UTAH DIVISION OF WATER RESOURCES

Volume III of III
Bear River Development Report Appendix

Consultant Job No. 233-18-01

October 2019

Prepared by:

BOWEN COLLINS & ASSOCIATES

In Association with:

HDR

BEAR RIVER DEVELOPMENT REPORT

VOLUME III OF III - APPENDIX

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VOLUME III OF III - APPENDIX
TABLE OF CONTENTS

CHAPTER 3 - BEAR RIVER AGREEMENTS

Bear River Compact

Bear River Development Act

PacifiCorp's Operations Agreement

Bear River System Agreement

Bear Lake Settlement Agreement

CHAPTER 7 - HDR DAM INVESTIGATION REPORT

State of Utah Comments on Gerhart Cole Dam Investigation Reports

Gerhart Cole Dam Investigation Reports

Cub River

Fieldling

South Willard Bay

Temple Fork

Whites Valley

Above Cutler

CHAPTER 9 - LITHOS TUNNELING INFORMATION

CHAPTER 10 - DETAILED COST ESTIMATES AND PIPELINE UNIT COSTS

CHAPTER 11 - DETAILED HYDRAULIC ANALYSIS

Agency Coordination Summary

CHAPTER 14 – WHITE PAPER ON GREAT SALT LAKE IMPACT FROM DEVELOPMENT

CHAPTER 3

BEAR RIVER AGREEMENTS

BEAR RIVER COMPACT

AS AMENDED

Amended Compact unanimously approved
December 22, 1978
by
the duly appointed Commissioners
from those states of Idaho, Utah and Wyoming

Ratified
by the Legislatures of all three states in 1979

Congressional Consent Public Law 96-189
February 8, 1980

TABLE OF CONTENTS

Compact			Page
Article I	—	Statement of Purpose	1
Article II	—	Definition of Terms	1
Article III	—	Bear River Commission	4
Article IV	—	Allocation of Direct Flow	5
Article V	—	Lower Division Allocation	7
Article VI	—	Allocation of Storage	8
Article VII	—	New Projects	10
Article VIII	—	Rights in Other Signatory States	10
Article IX	—	Conveyance of Stored Water between States	11
Article X	—	Rights in Interstate Canals	11
Article XI	—	Applications for Appropriation, Etc.	12
Article XII	—	Legal Actions and Proceedings	12
Article XIII	—	Existing Rights of United States	12
Article XIV	—	Review of Compact Provisions	12
Article XV	—	Termination	13
Article XVI	—	Severability	13
Article XVII	—	Ratification and Effective Date	13

Public Law 96-189
96th Congress

An Act

Feb 8, 1980
[H.R. 4320]

To consent to the amended Bear River Compact between the States of Utah, Idaho, and Wyoming.

Bear River Compact Congressional consent

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That the consent of Congress is given to the amended Bear River Compact between the States of Idaho, Utah, and Wyoming. Such compact reads as follows:

AMENDED BEAR RIVER COMPACT

Amended agreement by Idaho, Utah and Wyoming

The State of Idaho, the State of Utah and the State of Wyoming, acting through their respective Commissioners after negotiations participated in by a representative of the United States of America appointed by the President, have agreed to an Amended Bear River Compact as follows:

ARTICLE I

A. The major purposes of this Compact are to remove the causes of present and future controversy over the distribution and use of the waters of the Bear River; to provide for efficient use of water for multiple purposes; to permit additional development of the water resources of Bear River; to promote interstate comity; and to accomplish an equitable apportionment of the waters of the Bear River among the compacting States.

B. The physical and all other conditions peculiar to the Bear River constitute the basis for this Compact. No general principle or precedent with respect to any other interstate stream is intended to be established.

ARTICLE II

Definitions

As used in this Compact the term

1. "Bear River" means the Bear River and its tributaries from its source in the Uinta Mountains to its mouth in Great Salt Lake;
2. "Bear Lake" means Bear Lake and Mud Lake;
3. "Upper Division" means the portion of Bear River from its source in the Uinta Mountains to and including Pixley Dam, a diversion dam in the Southeast Quarter of Section 25, Township 23 North, Range 120 West, Sixth Principal Meridian, Wyoming;
4. "Central Division" means the portion of Bear River from Pixley Dam to and including Stewart Dam, a diversion dam in Section 34, Township 13 South, Range 44 East, Boise Base and Meridian, Idaho;
5. "Lower Division" means the portion of the Bear River between Stewart Dam and Great Salt Lake, including Bear Lake and its tributary drainage;
6. "Upper Utah Section Diversions" means the sum of all diversions in second-feet from the Bear River and the tributaries of the Bear River joining the Bear River

upstream from the point where the Bear River crosses the Utah-Wyoming State line above Evanston, Wyoming; excluding the diversions by the Hilliard East Fork Canal, Lannon Canal, Lone Mountain Ditch, and Hilliard West Side Canal;

7. "Upper Wyoming Section Diversions" means the sum of all diversions in second-feet from the Bear River main stem from the point where the Bear River crosses the Utah-Wyoming State line above Evanston, Wyoming, to the point where the Bear River crosses the Wyoming-Utah State line east of Woodruff, Utah, and including the diversions by the Hilliard East Fork Canal, Lannon Canal, Lone Mountain Ditch, and Hilliard West Side Canal;
8. "Lower Utah Section Diversions" means the sum of all diversions in second-feet from the Bear River main stem from the point where the Bear River crosses the Wyoming-Utah State line east of Woodruff, Utah, to the point where the Bear River crosses the Utah-Wyoming State line northeast of Randolph, Utah;
9. "Lower Wyoming Section Diversions" means the sum of all diversions in second-feet from the Bear River main stem from the point where the Bear River crosses the Utah-Wyoming State line northeast of Randolph to and including the diversion at Pixley Dam;
10. "Commission" means the Bear River Commission, organized pursuant to Article III of this Compact;
11. "Water user" means a person, corporation, or other entity having a right to divert water from the Bear River for beneficial use;
12. "Second-foot" means a flow of one cubic foot of water per second of time passing a given point;
13. "Acre-foot" means the quantity of water required to cover one acre to a depth of one foot, equivalent to 43,560 cubic feet;
14. "Biennium" means the 2-year period commencing on October 1 of the first odd-numbered year after the effective date of this Compact and each 2-year period thereafter;
15. "Water year" means the period beginning October 1 and ending September 30 of the following year;
16. "Direct flow" means all water flowing in a natural watercourse except water released from storage or imported from a source other than the Bear River watershed;
17. "Border Gaging Station" means the stream flow gaging station in Idaho on the Bear River above Thomas Fork near the Wyoming-Idaho boundary line in the Northeast Quarter of the Northeast Quarter of Section 15, Township 14 South, Range 46 East, Boise Base and Meridian, Idaho;
18. "Smiths Fork" means a Bear River tributary which rises in Lincoln County, Wyoming, and flows in a general southwesterly direction to its confluence with Bear River near Cokeville, Wyoming;
19. "Grade Creek" means a Smiths Fork tributary which rises in Lincoln County, Wyoming, and flows in a westerly direction and in its natural channel is tributary to Smiths Fork in Section 17, Township 25 North, Range 118 West, Sixth Principal Meridian, Wyoming;
20. "Pine Creek" means a Smiths Fork tributary which rises in Lincoln County, Wyoming, emerging from its mountain canyon in Section 34, Township 25 North, Range 118 West, Sixth Principal Meridian, Wyoming, and in its natural channel is tributary to Smiths Fork in Section 36, Township 25 North, Range 119 West, Sixth Principal Meridian, Wyoming;
21. "Bruner Creek" and "Pine Creek Springs" means Smiths Fork tributaries which rise

in Lincoln County, Wyoming, in Sections 31 and 32, Township 25 North, Range 118 West, Sixth Principal Meridian, and in their natural channels are tributary to Smiths Fork in Section 36, Township 25 North, Range 119 West, Sixth Principal Meridian, Wyoming;

22. "Spring Creek" means a Smiths Fork tributary which rises in Lincoln County, Wyoming, in Sections 1 and 2, Township 24, Range 119 West, Sixth Principal Meridian, Wyoming, and flows in a general westerly direction to its confluence with Smiths Fork in Section 4, Township 24 North, Range 119 West, Sixth Principal Meridian, Wyoming;
23. "Sublette Creek" means the Bear River tributary which rises in Lincoln County, Wyoming, and flows in a general westerly direction to its confluence with Bear River in Section 20, Township 24 North, Range 119 West, Sixth Principal Meridian, Wyoming;
24. "Hobble Creek" means the Smiths Fork tributary which rises in Lincoln County, Wyoming, and flows in a general southwesterly direction to its confluence with Smiths Fork in Section 35, Township 28 North, Range 118 West, Sixth Principal Meridian, Wyoming;
25. "Hilliard East Fork Canal" means that irrigation canal which diverts water from the right bank of the East Fork of Bear River in Summit County, Utah, at a point West 1,310 feet and North 330 feet from the Southeast corner of Section 16, Township 2 North, Range 10 East, Salt Lake Base and Meridian, Utah, and runs in a northerly direction crossing the Utah-Wyoming State line into the Southwest Quarter of Section 21, Township 12 North, Range 119 West, Sixth Principal Meridian, Wyoming;
26. "Lannon Canal" means that irrigation canal which diverts water from the right bank of the Bear River in Summit County, Utah, East 1,480 feet from the West Quarter corner of Section 19, Township 3 North, Range 10 East, Salt Lake Base and Meridian, Utah, and runs in a northerly direction crossing the Utah-Wyoming State line into the South Half of Section 20, Township 12 North, Range 119 West, Sixth Principal Meridian, Wyoming;
27. "Lone Mountain Ditch" means that irrigation canal which diverts water from the right bank of the Bear River in Summit County, Utah, North 1,535 feet and East 1,120 feet from the West Quarter corner of Section 19, Township 3 North, Range 10 East, Salt Lake Base and Meridian, Utah, and runs in a northerly direction crossing the Utah-Wyoming State line into the South Half of Section 20, Township 12 North, Range 119 West, Sixth Principal Meridian, Wyoming;
28. "Hilliard West Side Canal" means that irrigation canal which diverts water from the right bank of the Bear River in Summit County, Utah, at a point North 2,190 feet and East 1,450 feet from the South Quarter corner of Section 13, Township 3 North, Range 9 East, Salt Lake Base and Meridian, Utah, and runs in a northerly direction crossing the Utah-Wyoming State line into the South Half of Section 20, Township 12 North, Range 119 West, Sixth Principal Meridian, Wyoming;
29. "Francis Lee Canal" means that irrigation canal which diverts water from the left bank of the Bear River in Uinta County, Wyoming, in the Northeast Quarter corner of Section 30, Township 18 North, Range 120 West, Sixth Principal Meridian, Wyoming, and runs in a westerly direction across the Wyoming-Utah State line into Section 16, Township 9 North, Range 8 East, Salt Lake Base and Meridian, Utah;
30. "Chapman Canal" means that irrigation canal which diverts water from the left bank of the Bear River in Uinta County, Wyoming, in the Northeast Quarter of

Section 36, Township 16 North, Range 121 West, Sixth Principal Meridian, Wyoming, and runs in a northerly direction crossing over the low divided into the Saleratus drainage basin near the Southeast corner of Section 36, Township 17 North, Range 121 West, Sixth Principal Meridian, Wyoming, and then in a general westerly direction crossing the Wyoming-Utah State line;

31. "Neponset Reservoir" means that reservoir located principally in Sections 34 and 35, Township 8 North, Range 7 East, Salt Lake Base and Meridian, Utah, having a capacity of 6,900 acre-feet.

ARTICLE III

Bear River Commission, establishment and membership

A. There is hereby created an interstate administrative agency to be known as the "Bear River Commission" which is hereby constituted a legal entity and in such name shall exercise the powers hereinafter specified. The Commission shall be composed of nine Commissioners, three Commissioners representing each signatory State, and if appointed by the President, one additional Commissioner representing the United States of America who shall serve as chairman, without vote. Each Commissioner, except the chairman, shall have one vote. The State Commissioners shall be selected in accordance with State law. Six Commissioners who shall include two Commissioners from each State shall constitute a quorum. The vote of at least two-thirds of the Commissioners when a quorum is present shall be necessary for the action of the Commission.

Compensation and expenses

B. The compensation and expenses of each Commissioner and each adviser shall be paid by the government which he represents. All expenses incurred by the Commission in the administration of this Compact, except those paid by the United States of America, shall be paid by the signatory States on an equal basis.

Powers

C. The Commission shall have power to:
   1. Adopt bylaws, rules, and regulations not inconsistent with this Compact;
   2. Acquire, hold, convey or otherwise dispose of property;
   3. Employ such persons and contract for such services as may be necessary to carry out its duties under this Compact;
   4. Sue and be sued as a legal entity in any court of record of a signatory State, and in any court of the United States having jurisdiction of such action;
   5. Co-operate with State and Federal agencies in matters relating to water pollution of interstate significance;
   6. Perform all functions required of it by this Compact and do all things necessary, proper or convenient in the performance of its duties hereunder, independently or in co-operation with others, including State and Federal agencies.

D. The Commission shall:
   1. Enforce this Compact and its order made hereunder by suit or other appropriate action;

Report, transmittal to President and Governors

   2. Compile a report covering the work of the Commission and expenditures during the current biennium, and an estimate of expenditures for the following biennium and transmit it to the President of the United States and to the Governors of the signatory States on or before July 1 following each biennium.

ARTICLE IV

Water rights, limitations

Rights to direct flow water shall be administered in each signatory State under State law, with the following limitations:

A. When there is a water emergency, as hereinafter defined for each division, water shall be distributed therein as provided below.
   1. Upper Division
      a. When the divertible flow as defined below for the Upper Division is less than 1,250 second-feet, a water emergency shall be deemed to exist therein and such divertible flow is allocated for diversion in the river sections of the Division as follows:

Upper Utah Section Diversions	0.6 percent
Upper Wyoming Section Diversions	49.3 percent
Lower Utah Section Diversions	40.5 percent
Lower Wyoming Section Diversions	9.6 percent

         Such divertible flow shall be the total of the following five items:
         (1) Upper Utah Section Diversions in second-feet
         (2) Upper Wyoming Section Diversions in second-feet
         (3) Lower Utah Section Diversions in second-feet
         (4) Lower Wyoming Section Diversions in second-feet
         (5) The flow in second-feet passing Pixley Dam
      b. The Hilliard East Fork Canal, Lannon Canal, Lone Mountain Ditch, and Hilliard West Side Canal, which divert water in Utah to irrigate lands in Wyoming, shall be supplied from the divertible flow allocated to the Upper Wyoming Section Diversions.
      c. The Chapman, Bear River, and Francis Lee Canals, which divert water from the main stem of Bear River in Wyoming to irrigate lands in both Wyoming and Utah, shall be supplied from the divertible flow allocated to the Upper Wyoming Section Diversions.
      d. The Beckwith Quinn West Side Canal, which diverts water from the main stem of Bear River in Utah to irrigate lands in both Utah and Wyoming, shall be supplied from the divertible flow allocated to the Lower Utah Section Diversions.
      e. If for any reason the aggregate of all diversions in a river section of the Upper Division does not equal the allocation of water thereto, the unused portion of such allocation shall be available for use in the other river sections in the Upper Division in the following order: (1) In the other river section of the same State in which the unused allocation occurs; and (2) in the river sections of the other State. No permanent right of use shall be established by the distribution of water pursuant to this paragraph e.
      f. Water allocated to the several sections shall be distributed in each section in accordance with State law.
   2. Central Division
      a. When either the divertible flow as hereinafter defined for the Central Division is less than 870 second-feet, or the flow of the Bear River at Border Gaging Station is less than 350 second-feet, whichever shall first occur, a water emergency shall be deemed to exist in the Central Division and the total of all diversions in Wyoming from Grade Creek, Pine Creek, Bruner Creek and Pine Creek Springs, Spring Creek, Sublette Creek, Smiths

Fork, and all the tributaries of Smiths Fork above the mouth of Hobble Creek including Hobble Creek, and from the main stem of the Bear River between Pixley Dam and the point where the river crosses the Wyoming-Idaho State line near Border shall be limited for the benefit of the State of Idaho, to not exceed forty-three (43) percent of the divertible flow. The remaining fifty-seven (57) percent of the divertible flow shall be available for use in Idaho in the Central Division, but if any portion of such allocation is not used therein it shall be available for use in Idaho in the Lower Division.

The divertible flow for the Central Division shall be the total of the following three items:

(1) Diversions in second-feet in Wyoming consisting of the sum of all diversions from Grade Creek, Pine Creek, Bruner Creek and Pine Creek Springs, Spring Creek, Sublette Creek, and Smiths Fork and all the tributaries of Smiths Fork above the mouth of Hobble Creek including Hobble Creek, and the main stem of the Bear River between Pixley Dam and the point where the river crosses the Wyoming-Idaho State line near Border, Wyoming.

(2) Diversions in second-feet in Idaho from the Bear River main stem from the point where the river crosses the Wyoming-Idaho State line near Border to Stewart Dam including West Fork Canal which diverts at Stewart Dam.

(3) Flow in second-feet of the Rainbow Inlet Canal and of the Bear River passing downstream from Stewart Dam.

b. The Cook Canal, which diverts water from the main stem of the Bear River in Wyoming to irrigate lands in both Wyoming and Idaho, shall be considered a Wyoming diversion and shall be supplied from the divertible flow allocated to Wyoming.

c. Water allocated to each State shall be distributed in accordance with State law.

3. Lower Division

a. When the flow of water across the Idaho-Utah boundary line is insufficient to satisfy water rights in Utah, covering water applied to beneficial use prior to January 1, 1976, any water user in Utah may file a petition with the Commission alleging that by reason of diversions in Idaho he is being deprived of water to which he is justly entitled, and that by reason thereof, a water emergency exists, and requesting distribution of water under the direction of the Commission. If the Commission finds a water emergency exists, it shall put into effect water delivery schedules based on priority of rights and prepared by the Commission without regard to the boundary line for all or any part of the Division, and during such emergency, water shall be delivered in accordance with such schedules by the State official charged with the administration of public waters.

Emergency declaration authority

B. The Commission shall have authority upon its own motion (1) to declare a water emergency in any or all river divisions based upon its determination that there are diversions which violate this Compact and which encroach upon water rights in a lower State, (2) to make appropriate orders to prevent such encroachments, and (3) to enforce such orders by action before State administrative officials or by court proceedings.

User's water rights, petition filing

Water delivery schedules

Joint water commissioner

C. When the flow of water in an interstate tributary across a State boundary line is insufficient to satisfy water rights on such tributary in a lower State, any water user may file a petition with the Commission alleging that by reason of diversions in an upstream State he is being deprived of water to which he is justly entitled and that by reason thereof a water emergency exists, and requesting distribution of water under the direction of the Commission. If the Commission finds that a water emergency exists and that interstate control of water of such tributary is necessary, it shall put into effect water delivery schedules based on priority of rights and prepared without regard to the State boundary line. The State officials in charge of water distribution on interstate tributaries may appoint and fix the compensation and expenses of a joint water commissioner for each tributary. The proportion of the compensation and expenses to be paid by each State shall be determined by the ratio between the number of acres therein which are irrigated by diversions from such tributary, and the total number of acres irrigated from such tributary.

Interstate water delivery schedules, findings of fact

Prima facie evidence

D. In preparing interstate water delivery schedules the Commission, upon notice and after public hearings, shall make findings of fact as to the nature, priority, and extent of water rights, rates of flow, duty of water, irrigated acreages, types of crops, time of use, and related matters; provided that such schedules shall recognize and incorporate therein priority of water rights as adjudicated in each of the signatory States. Such findings of fact shall, in any court or before any tribunal, constitute prima facie evidence of the facts found.

Emergency termination

E. Water emergencies provided for herein shall terminate on September 30 of each year unless terminated sooner or extended by the Commission.

ARTICLE V

Lower Division water rights, Idaho and Utah

A. Water rights in the Lower Division acquired under the laws of Idaho and Utah covering water applied to beneficial use prior to January 1, 1976, are hereby recognized and shall be administered in accordance with State law based on priority of rights as provided in Article IV, paragraph A3. Rights to water first applied to beneficial use on or after January 1, 1976, shall be satisfied from the respective allocations made to Idaho and Utah in this paragraph and the water allocated to each State shall be administered in accordance with State law. Subject to the foregoing provisions, the remaining water in the Lower Division, including ground water tributary to the Bear River, is hereby apportioned for use in Idaho and Utah as follows:

(1) Idaho shall have the first right to the use of such remaining water resulting in an annual depletion of not more than 125,000 acre-feet.
(2) Utah shall have the second right to the use of such remaining water resulting in an annual depletion of not more than 275,000 acre-feet.
(3) Idaho and Utah shall each have an additional right to deplete annually on an equal basis, 75,000 acre-feet of the remaining water after the rights provided by subparagraphs (1) and (2) above have been satisfied.
(4) Any remaining water in the Lower Division after the allocations provided for in subparagraphs (1), (2), and (3) above have been satisfied shall be divided; thirty (30) percent to Idaho and seventy (70) percent to Utah.

Allocation charge

B. Water allocated under the above subparagraphs shall be charged against the State in which it is used regardless of the location of the point of diversion.

Depletions

C. Water depletions permitted under provisions of subparagraphs (1), (2), (3), and (4) above, shall be calculated and administered by a Commission-approved procedure.

ARTICLE VI

Reservoir storage rights

A. Existing storage rights in reservoirs constructed above Stewart Dam prior to February 4, 1955, are as follows:

Idaho ..... 324 acre-feet
Utah ..... 11,850 acre-feet
Wyoming ..... 2,150 acre-feet

Additional rights are hereby granted to store in any water year above Stewart Dam, 35,500 acre-feet of Bear River water and no more under this paragraph for use in Utah and Wyoming; and to store in any water year in Idaho or Wyoming on Thomas Fork 1,000 acre-feet of water for use in Idaho. Such additional storage rights shall be subordinate to, and shall not be exercised when the effect thereof will be to impair or interfere with (1) existing direct flow rights for consumptive use in any river division and (2) existing storage rights above Stewart Dam, but shall not be subordinate to any right to store water in Bear Lake or elsewhere below Stewart Dam. One-half of the 35,500 acre-feet of additional storage right above Stewart Dam so granted to Utah and Wyoming is hereby allocated to Utah, and the remaining one-half thereof is allocated to Wyoming.

Additional storage rights

B. In addition to the rights defined in Paragraph A of this Article, further storage entitlements above Stewart Dam are hereby granted. Wyoming and Utah are granted an additional right to store in any year 70,000 acre-feet of Bear River water for use in Utah and Wyoming to be divided equally; and Idaho is granted an additional right to store 4,500 acre-feet of Bear River water in Wyoming or Idaho for use in Idaho. Water rights granted under this paragraph and water appropriated, including ground water tributary to Bear River, which is applied to beneficial use on or after January 1, 1976, shall not result in an annual increase in depletion of the flow of the Bear River and its tributaries above Stewart Dam of more than 28,000 acre-feet in excess of the depletion as of January 1, 1976. Thirteen thousand (13,000) acre-feet of the additional depletion above Stewart Dam is allocated to each of Utah and Wyoming, and two thousand (2,000) acre-feet is allocated to Idaho.

Limitations

The additional storage rights provided for in this paragraph shall be subordinate to, and shall not be exercised when the effect thereof will be to impair or interfere with (1) existing direct flow rights for consumptive use in any river division and (2) existing storage rights above Stewart Dam, but shall not be subordinate to any right to store water in Bear Lake or elsewhere below Stewart Dam; provided, however, there shall be no diversion of water to storage above Stewart Dam under this Paragraph B when the water surface elevation of Bear Lake is below 5,911.00

feet, Utah Power & Light Company datum (the equivalent of elevation 5,913.75 feet based on the sea level datum of 1929 through the Pacific Northwest Supplementary Adjustment of 1947). Water depletions permitted under this Paragraph B shall be calculated and administered by a Commission-approved procedure.

C. In addition to the rights defined in Article VI, Paragraphs A and B, Idaho, Utah and Wyoming are granted the right to store and use water above Stewart Dam that otherwise would be bypassed or released from Bear Lake at times when all other direct flow and storage rights are satisfied. The availability of such water and the operation of reservoir space to store water above Bear Lake under this paragraph shall be determined by a Commission-approved procedure. The storage provided for in this paragraph shall be subordinate to all other storage and direct flow rights in the Bear River. Storage rights under this paragraph shall be exercised with equal priority on the following basis: six (6) percent thereof to Idaho; forty-seven (47) percent thereof to Utah; and forty-seven (47) percent thereof to Wyoming.

Irrigation reserve

D. The waters of Bear Lake below elevation 5,912.91 feet, Utah Power and Light Company Bear Lake datum (the equivalent of elevation 5,915.66 feet based on the sea level datum of 1929 through the Pacific Northwest Supplementary Adjustment of 1947) shall constitute a reserve for irrigation. The water of such reserve shall not be released solely for the generation of power, except in emergency, but after release for irrigation it may be used in generating power if not inconsistent with its use for irrigation. Any water in Bear Lake in excess of that constituting the irrigation reserve may be used for the generation of power or for other beneficial uses. As new reservoir capacity above the Stewart Dam is constructed to provide additional storage pursuant to Paragraph A of this Article, the Commission shall make a finding in writing as to the quantity of additional storage and shall thereupon make an order increasing the irrigation reserve in accordance with the following table:

Additional Storage (acre-feet)	Lake surface elevation Utah Power and Light Company Bear Lake datum
5,000	5,913.24
10,000	5,913.56
15,000	5,913.87
20,000	5,914.15
25,000	5,914.41
30,000	5,914.61
35,500	5,914.69
36,500	5,914.70

E. Subject to existing rights, each State shall have the use of water, including ground water, for ordinary domestic and stock watering purposes, as determined by State law and shall have the right to impound water for such proposes in reservoirs having storage capacities not in excess, in any case, of 20 acre-feet, without deduction from the allocation made by paragraphs A, B, and C of this Article.

F. The storage rights in Bear Lake are hereby recognized and confirmed subject only to the restrictions hereinbefore recited.

ARTICLE VII

Development projects

It is the policy of the signatory States to encourage additional projects for the development of the water resources of the Bear River to obtain the maximum beneficial use of water with a minimum of waste, and in furtherance of such policy, authority is granted within the limitations provided by this Compact to investigate, plan, construct, and operate such projects without regard to State boundaries, provided that water rights for each such project shall, except as provided in Article VI, paragraphs A and B, thereof, be subject to rights theretofore initiated and in good standing.

ARTICLE VIII

Water rights, acquisition

A. No State shall deny the right of the United States of America, and subject to the conditions hereinafter contained, no State shall deny the right of another signatory State, any person or entity of another signatory State, to acquire rights to the use of water or to construct or to participate in the construction and use of diversion works and storage reservoirs with appurtenant works, canals, and conduits in one State for use of water in another State, either directly or by exchange. Water rights acquired for out-of-state use shall be appropriated in the State where the point of diversion is located in the manner provided by law for appropriation of water for use within such State.

Property rights, acquisition

B. Any signatory State, any person or any entity of any signatory State, shall have the right to acquire in any other signatory State such property rights as are necessary to the use of water in conformity with this Compact by donation, purchase, or, as hereinafter provided through the exercise of the power of eminent domain in accordance with the law of the State in which such property is located. Any signatory State, upon the written request of the Governor of any other signatory State for the benefit of whose water users property is to be acquired in the State to which such written request is made, shall proceed expeditiously to acquire the desired property either by purchase at a price acceptable to the requesting Governor, or if such purchase cannot be made, then through the exercise of its power of eminent domain and shall convey such property to the requesting State or to the person or entity designated by its Governor, provided that all costs of acquisition and expenses of every kind and nature whatsoever incurred in obtaining such property shall be paid by the requesting State or the person or entity designated by its Governor.

Facilities, State authority

C. Should any facility be constructed in a signatory State by and for the benefit of another signatory State or persons or entities therein, as above provided, the construction, repair, replacement, maintenance and operation of such facility shall be subject to the laws of the State in which the facility is located.

Facilities, taxation

D. In the event lands or other taxable facilities are acquired by a signatory State in another signatory State for the use and benefit of the former, the users of the water made available by such facilities, as a condition precedent to the use thereof, shall pay to the political subdivisions of the State in which such facilities are located,

each and every year during which such rights are enjoyed for such proposes, a sum of money equivalent to the average of the amount of taxes annually levied and assessed against the land and improvements thereon during the ten years preceding the acquisition of such land. Said payments shall be in full reimbursement for the loss of taxes in such political subdivision of the State.

E. Rights to the use of water acquired under this Article shall in all respects be subject to this Compact.

ARTICLE IX

Water exchanges

Stored water, or water from another watershed may be turned into the channel of the Bear River in one State and a like quantity, with allowance for loss by evaporation, transpiration, and seepage, may be taken out of the Bear River in another State either above or below the point where the water is turned into the channel, but in making such exchange the replacement water shall not be inferior in quality for the purpose used or diminished in quantity. Exchanges shall not be permitted if the effect thereof is to impair vested rights or to cause damage for which no compensation is paid. Water from another watershed or source which enters the Bear River by actions within a State may be claimed exclusively by that State and use thereof by that State shall not be subject to the depletion limitations of Articles IV, V and VI. Proof of any claimed increase in flow shall be the burden of the State making such claim, and it shall be approved only by the unanimous vote of the Commission.

ARTICLE X

Interstate canals, water use

A. The following rights to the use of Bear River water carried in interstate canals are recognized and confirmed.

Name of Canal	Date of priority	Primary right second-feet	Lands irrigated	
			Acres	State
Hilliard East Fork	1914	28.00	2,644	Wyoming
Chapman	8-13-86	16.46	1,155	Wyoming
	8-13-86	98.46	6,892	Utah
	4-12-12	.57	40	Wyoming
	5- 3-12	4.07	285	Utah
	5-21-12	10.17	712	Utah
	2- 6-13	.79	55	Wyoming
	8-28-05	[1]134.00		
Francis Lee	1879	2.20	154	Wyoming
	1879	7.41	519	Utah

[1]Under the right as herein confirmed not to exceed 134 second-feet may be carried across the Wyoming-Utah State line in the Chapman Canal at any time for filling the Neponset Reservoir, for irrigation of land in Utah and for other purposes. The storage right in Neponset Reservoir is for 6,900 acre-feet, which is a component part of the irrigation right for the Utah lands listed above.

Administration

All other rights to the use of water carried in interstate canals and ditches, as adjudicated in the State in which the point of diversion is located, are recognized and confirmed.

B. All interstate rights shall be administered by the State in which the point of diversion is located and during times of water emergency, such rights shall be filled from the allocations specified in Article IV hereof for the Section in which the point of diversion is located, with the exception that the diversion of water into the Hilliard East Fork Canal, Lannon Canal, Lone Mountain Ditch, and Hilliard West Side Canal shall be under the administration of Wyoming. During times of water emergency these canals and the Lone Mountain Ditch shall be supplied from the allocation specified in Article IV for the Upper Wyoming Section Diversions.

ARTICLE XI

Applications

Applications for appropriation, for change of point of diversion, place and nature of use, and for exchange of Bear River water shall be considered and acted upon in accordance with the law of the State in which the point of diversion is located, but no such application shall be approved if the effect thereof will be to deprive any water user in another State of water to which he is entitled, nor shall any such application be approved if the effect thereof will be an increase in the depletion of the flow of the Bear River and its tributaries beyond the limits authorized in each State in Articles IV, V and VI of this Compact. The official of each State in charge of water administration shall, at intervals and in the format established by the Commission, report on the status of use of the respective allocations.

Allocation status report

ARTICLE XII

Nothing in this Compact shall be construed to prevent the United States, a signatory State or political subdivision thereof, person, corporation, or association, from instituting or maintaining any action or proceeding, legal or equitable, for the protection of any right under State or Federal law or under this Compact.

ARTICLE XIII

Nothing contained in this Compact shall be deemed:

1. To affect the obligations of the United States of America to the Indian tribes;
2. To impair, extend or otherwise affect any right or power of the United States, its agencies or instrumentalities involved herein; nor the capacity of the United States to hold or acquire additional rights to the use of the water of the Bear River;
3. To subject any property or rights of the United States to the laws of the States which were not subject thereto prior to the date of this Compact;
4. To subject any property of the United States to taxation by the States or any subdivision thereof, nor to obligate the United States to pay any State or subdivision thereof for loss of taxes.

ARTICLE XIV

Commission review and proposed amendments

At intervals not exceeding twenty years, the Commission shall review the provisions hereof, and after notice and public hearing, may propose amendments to any such provision, provided, however, that the provisions contained herein shall remain in full

force and effect until such proposed amendments have been ratified by the legislatures of the signatory States and consented to by Congress.

ARTICLE XV

Termination of Compact

This Compact may be terminated at any time by the unanimous agreement of the signatory States. In the event of such termination all rights established under it shall continue unimpaired.

ARTICLE XVI

Constitutionality of provision

Should a court of competent jurisdiction hold any part of this Compact to be contrary to the constitution of any signatory State or to the Constitution of the United States, all other severable provisions of this Compact shall continue in full force and effect.

ARTICLE XVII

Ratification and notice

This Compact shall be in effect when it shall have been ratified by the Legislature of each signatory State and consented to by the Congress of the United States of America. Notice of ratification by the legislatures of the signatory States shall be given by the Governor of each signatory State to the Governor of each of the other signatory States and to the President of the United States of America, and the President is hereby requested to give notice to the Governor of each of the signatory States of approval by the Congress of the United States of America.

IN WITNESS WHEREOF, the Commissioners and their advisers have executed this Compact in five originals, one of which shall be deposited with the General Services Administration of the United States of America, one of which shall be forwarded to the Governor of each of the signatory States, and one of which shall be made a part of the permanent records of the Bear River Commission.

Done at Salt Lake City, Utah, this 22nd day of December, 1978.
For the State of Idaho:
(s) Clifford J. Skinner
(s) J. Daniel Roberts
(s) Don W. Gilbert
For the State of Utah:
(s) S. Paul Holmgren
(s) Simeon Weston
(s) Daniel F. Lawrence
For the State of Wyoming:
(s) George L. Christopulos
(s) J. W. Myers
(s) John A. Teichert
Approved:
Wallace N. Jibson
Representative of the United States of America
Attest:
Daniel F. Lawrence
Secretary of the Bear River Commission

Approved February 8, 1980.

STATE AMENDING LEGISLATION

WYOMING: Enrolled Act No. 41
Amended W.S. 41-12-101
March 6, 1979

UTAH: Enrolled Copy S.B. No. 255
Amended Section 73-16-2, Ut. Code Annot. 1953
May 8, 1979

IDAHO: Senate Bill No. 1162
Amended Section 42-3402, Idaho Code
April 5, 1979

LEGISLATIVE HISTORY:

HOUSE REPORT No. 96-524 (Comm. on Interior and Insular Affairs).
SENATE REPORT No. 96-526 accompanying S. 1489 (Comm. on the Judiciary).
CONGRESSIONAL RECORD:
Vol. 125 (1979): Nov. 27, considered and passed House.
Dec. 20, S. 1489 considered and passed Senate.
Vol. 126 (1980): Jan. 23, considered and passed Senate.

LEGISLATIVE GENERAL COUNSEL
₵ Approved for Filing: E.R. Brown ₵
₵ 01-17-06 3:24 PM ₵

H.B. 45
1st Sub. (Buff)

Representative J. Stuart Adams proposes the following substitute bill:

BEAR RIVER DEVELOPMENT ACT

2006 GENERAL SESSION

STATE OF UTAH

Chief Sponsor: J. Stuart Adams

Senate Sponsor: Lyle W. Hillyard

LONG TITLE

General Description:

This bill amends the Bear River Development Act to allow funds to be spent on preconstruction activities even though certain construction funding requirements have not been met, to repeal construction funding prerequisites, and to make developed water available to Cache County.

Highlighted Provisions:

This bill:

- defines preconstruction costs;
- authorizes the expenditure of funds on preconstruction costs;
- repeals construction prerequisites that require the division to:
  - contract for the sale or lease of 70% of the developed water; and
  - obtain permits;
- authorizes water to be made available to Cache County;
- limits the amount of water made available to Cache County; and
- makes technical changes.

Monies Appropriated in this Bill:

None

Other Special Clauses:

26 None
27 **Utah Code Sections Affected:**
28 AMENDS:
29 **73-26-103**, as enacted by Chapter 251, Laws of Utah 1991
30 **73-26-104**, as last amended by Chapter 182, Laws of Utah 2002
31 **73-26-201**, as enacted by Chapter 251, Laws of Utah 1991
32 **73-26-202**, as enacted by Chapter 251, Laws of Utah 1991
33 **73-26-301**, as last amended by Chapter 182, Laws of Utah 2002
34 REPEALS:
35 **73-26-302**, as enacted by Chapter 251, Laws of Utah 1991
36

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37 *Be it enacted by the Legislature of the state of Utah:*
38 Section 1. Section **73-26-103** is amended to read:
39 **73-26-103. Definitions.**
40 As used in this chapter:
41 (1) "Board" means the Board of Water Resources.
42 (2) (a) "Construction costs" means all costs related to the development of a project,
43 except the costs of environmental mitigation.
44 (b) Construction costs include:
45 [~~(a)~~] (i) planning;
46 [~~(b)~~] (ii) engineering and legal work;
47 [~~(c)~~] (iii) permitting;
48 [~~(d)~~] (iv) acquisition of land and rights-of-way;
49 [~~(e)~~] (v) rebuilding and relocation of highways or other facilities affected by the
50 project;
51 [~~(f)~~] (vi) compensation for impairment of existing water rights;
52 [~~(g)~~] (vii) construction of the dam, reservoir, and associated facilities; and
53 [~~(h)~~] (viii) expenses of the division related to the project.
54 (3) "Developed waters" means surface water developed by projects authorized under
55 this chapter.
56 (4) "Division" means the Division of Water Resources.

57 (5) "Environmental mitigation costs" means costs that may be required by federal,
58 state, or local governmental agencies for project environmental permitting, including:
59 (a) planning;
60 (b) environmental and engineering studies;
61 (c) permitting;
62 (d) acquisition of land and rights-of-way; and
63 (e) operation, maintenance, and repair of facilities associated with project
64 environmental mitigation.
65 (6) "Preconstruction costs" means any of the following costs incurred before project
66 construction begins:
67 (a) planning;
68 (b) design;
69 (c) engineering studies;
70 (d) legal work;
71 (e) permitting;
72 (f) acquisition of land and rights-of-way;
73 (g) compensation for impairment of existing water rights;
74 (h) environmental studies; or
75 (i) any combination of Subsections (6)(a) through (h).
76 [~~(6)~~] (7) "Project costs" include preconstruction costs, construction costs,
77 environmental mitigation costs, and costs of operation, maintenance, repair, and replacement.
78 [~~(7) "Environmental mitigation team" means the team identified in the environmental~~
79 ~~impact statement (EIS) and chaired by the EIS lead agency.~~]
80 Section 2. Section **73-26-104** is amended to read:
81 **73-26-104. Bear River development projects.**
82 (1) The division shall:
83 (a) develop the surface waters of the Bear River and its tributaries through the planning
84 and construction of reservoirs and associated facilities as authorized and funded by the
85 Legislature;
86 (b) own and operate the facilities constructed; and
87 (c) market the developed waters.

88 (2) Potential projects include:
89 (a) Hyrum Dam;
90 (b) Avon;
91 (c) Mill Creek;
92 (d) Oneida Narrows;
93 (e) North Eden Creek; [~~and~~]
94 (f) Washakie[~~.~~]; and
95 (g) an interconnection from the Corinne area to Willard Reservoir.
96 (3) The division may develop sites other than those listed in Subsection (2) if those
97 projects are authorized and funded by the Legislature.
98 (4) The purchase of real property does not constitute water development.
99 Section 3. Section **73-26-201** is amended to read:
100 **73-26-201. Entities eligible to receive developed water -- Selling or leasing water**
101 **outside entity boundaries.**
102 (1) Water developed by projects authorized under this chapter, except water reserved
103 for wildlife or public recreation, shall be made available by contract exclusively to the
104 following entities:
105 (a) the Bear River Water Conservancy District;
106 (b) the Salt Lake County Water Conservancy District;
107 (c) the Weber Basin Water Conservancy District; and
108 (d) [~~municipalities, water companies,~~] Cache County and any water conservancy
109 district in Cache County.
110 (2) A county or conservancy district that purchases or leases developed water may
111 lease the water to any person.
112 [~~(3) A municipality that purchases or leases developed water may sell or lease the~~
113 ~~water to any person located:~~]
114 [~~(a) within the boundaries of the municipality; or~~]
115 [~~(b) outside the boundaries of the municipality:~~]
116 [~~(i) but within the county in which the municipality is located; or~~]
117 [~~(ii) into a state adjacent to the county in which the municipality is located, subject to~~
118 ~~state law and approval by the state engineer.~~]

119 [~~(4)~~] (3) A [~~municipality, water company,~~] county or conservancy district that
120 purchases or leases developed water may use the water directly or by exchange in accordance
121 with Section 73-3-20.
122 Section 4. Section **73-26-202** is amended to read:
123 **73-26-202. Limits on amount of water available to any entity or area -- Exception.**
124 (1) Except as provided in Subsection (2), the total amount of water from projects
125 authorized under this chapter that may be made available to any entity or area is limited as
126 follows:
127 (a) The Salt Lake County Water Conservancy District and Weber Basin Water
128 Conservancy District each may purchase or lease no more than 50,000 acre-feet a year.
129 (b) The Bear River Water Conservancy District may purchase or lease no more than
130 60,000 acre-feet a year.
131 (c) The total cumulative amount of developed waters purchased or leased by
132 [~~municipalities, water companies,~~] Cache County and any water conservancy [~~districts~~] district
133 in Cache County may not exceed 60,000 acre-feet a year.
134 (2) An entity or area may purchase or lease water in excess of the limits specified in
135 Subsection (1) on a temporary basis, if water is available from a project and no other entity
136 eligible to receive water has offered to purchase or lease it.
137 Section 5. Section **73-26-301** is amended to read:
138 **73-26-301. Authorized projects -- Work subject to legislative appropriations.**
139 (1) The division [~~is authorized to~~] may develop the potential projects listed under
140 Subsection 73-26-104(2) and associated works[~~, including an interconnection from the Corinne~~
141 ~~area to Willard Reservoir, and shall proceed with design work, environmental assessments,~~
142 ~~acquisition of land and rights-of-way, and construction, subject to:~~].
143 [~~(1) the appropriation of funds for those purposes by the Legislature; and~~]
144 [~~(2) fulfillment of the requirements specified in Section 73-26-302.~~]
145 (2) The division may make expenditures for preconstruction costs if monies are
146 expressly appropriated or earmarked by statute for that purpose by the Legislature.
147 Section 6. **Repealer.**
148 This bill repeals:
149 Section **73-26-302, Construction contingent upon sale or lease of water.**

150

OPERATIONS AGREEMENT

FOR PACIFICORP'S BEAR RIVER SYSTEM

This Agreement is made this 18th day of April, 2000 by and among PacifiCorp, an Oregon Corporation, the Idaho Department of Water Resources, the Utah Division of Water Resources, and the Wyoming State Engineer's Office. Collectively, Idaho, Utah and Wyoming are referred to as the "States." PacifiCorp, Idaho, Utah, and Wyoming are collectively referred to as the "Parties."

WHEREAS, the States executed the Bear River Compact in 1957, and the Amended Bear River Compact in 1978, to "remove the causes of present and future controversy over the distribution and use of the waters of Bear River; to provide for efficient use of water for multiple purposes; to permit additional development of the water resources of Bear River; to promote interstate comity; and to accomplish an equitable apportionment of the waters of Bear River among the compacting States," and

WHEREAS, PacifiCorp owns water rights to divert and store water in Bear Lake and water rights in the Bear River as decreed in the matter of *Utah Power & Light Company v. The Last Chance Canal Company, Limited, et al,* in Equity No. 203, July 14, 1920 (the "Dietrich Decree"), and *Utah Power & Light Company v. Richmond Irrigation Company, et al.,* February 21, 1922 (the "Kimball Decree"), as well as other water rights in the Bear River. PacifiCorp's water rights include the exclusive right to divert and store water in and release water from Bear Lake between elevations 5923.65 ft and 5902.00 ft MSL (UP&L Datum) ("Bear Lake Storage Water"). The Idaho Water Resource Board holds a license issued by the State of Idaho establishing a minimum Bear Lake elevation of 5902.00 ft; and

WHEREAS, PacifiCorp has entered into various contracts for the use and allocation of its Bear Lake Storage Water under certain terms and conditions; and

WHEREAS, PacifiCorp owns and operates six hydroelectric plants with a total capacity of 116 MW on the Bear River downstream from Bear Lake. Five of the plants are licensed by the Federal Energy Regulatory Commission ("FERC"); and

WHEREAS, FERC determined on February 12, 1998 that Bear Lake "is operated primarily to supply irrigation water to downstream users in accordance to the Bear River Compact, [and] does not provide energy generation benefits to licensed projects downstream;" and

WHEREAS, by "AGREEMENT Regarding the Bear River System" between the States, PacifiCorp, and ScottishPower dated October 5, 1999 (the "October 5, 1999 Agreement") relating to PacifiCorp's operation of Bear Lake and its hydroelectric plants downstream from Bear Lake, the Parties agreed "PacifiCorp's water rights are constrained by the historic practice of not making a delivery call for hydropower

generation;" and "Bear Lake is operated, consistent with long-standing historic practice and applicable laws, primarily as a storage reservoir to satisfy contracts for existing irrigation uses and flood control needs in the three States, with the use of water for hydropower generation being incidental to the other purposes for which the water is being released;" and

WHEREAS, the October 5, 1999 Agreement anticipated the Parties would enter into a subsequent agreement further describing PacifiCorp's operations, and the Parties have negotiated this Agreement in satisfaction of the October 5, 1999 Agreement.

NOW THEREFORE, for the mutual promises of the Parties, and for other good and valuable consideration, the Parties agree as follows:

1. Purpose of this Agreement.

A. The purpose of this Agreement is to satisfy the requirements of Paragraph 2 of the October 5, 1999 Agreement committing the parties to negotiate an enforceable Bear River System Operations Agreement that shall confirm and continue PacifiCorp's historic practice of utilizing its water rights primarily for existing irrigation uses and contractual obligations.

B. The Parties agree that Paragraph 1.a. of the October 5, 1999 Agreement describes PacifiCorp's use of its water rights in Bear River for hydropower generation. Further agreement on PacifiCorp's use of its water rights for hydropower generation is not described herein, and the scope of this Bear River Systems Operations Agreement is limited to PacifiCorp's operations at Bear Lake.

C. The Parties recognize that PacifiCorp's operations at Bear Lake and at its downstream hydroelectric power plants on Bear River are separate operations and are not related, other than water released from Bear Lake is used for hydropower generation incidental to the other purposes for which water is released.

D. The Parties do not intend by this Agreement to confirm or agree that any specific water management practice of PacifiCorp described, referred to, or implied in this Agreement, other than the limitations set forth in the October 5, 1999 Agreement, shall constitute a constraint or limitation on PacifiCorp's use of its water rights. PacifiCorp will consult with the States if it sees the need to deviate from the operation and practices outlined in this Agreement.

E. The Parties do not intend by this Agreement to set forth a detailed plan for day-to-day operations of Bear Lake, but rather to establish the framework within which PacifiCorp will develop and implement such a plan. Such plan will conform to the terms of this Agreement and the October 5, 1999 Agreement.

F. The Parties recognize that persons not party to this agreement have varying interests in the manner in which Bear Lake is managed and operated. This Agreement is not intended as a formal recognition or confirmation of the interests of persons not party to this Agreement.

G. The Parties agree that if any of the terms of this Agreement are found to be inconsistent with the terms of the October 5, 1999 Agreement, the October 5, 1999 Agreement is controlling.

2. PacifiCorp's Regulation of Bear Lake.

A. PacifiCorp agrees to continue to operate Bear Lake primarily for Bear Lake Storage Water delivery under its contracts, or for flood control, depending on the level of Bear Lake, the forecasted runoff, general water supply conditions, constraints of its contracts, its assessment of the hydrology and other conditions in the Bear River basin. Hydropower generation at its downstream hydroelectric plants shall continue to be an incidental use of Bear Lake Storage Water released primarily for contract deliveries or flood control.

B. PacifiCorp will not execute new Bear Lake Storage Water contracts which would result in delivery of a greater amount of Bear Lake Storage Water than the amount historically used. The extent of historical use is currently documented by interstate accounting models used by Idaho and Utah. Nothing herein will prevent the States, by agreement, from updating said models or adopting a different technical basis for determining historical use.

C. PacifiCorp's Bear Lake Target Elevation (the "PTE"). PacifiCorp has determined the PTE represents the elevation of Bear Lake to be achieved, if possible, on March 31st of each year. The PTE may range from as low as elevation 5916 ft during projected high runoff conditions to elevation 5920 ft during projected low runoff conditions. Under normal conditions, PacifiCorp sets the PTE at 5918 ft. PacifiCorp has established the PTE to best balance long term contract requirements for Bear Lake Storage Water during sustained drought periods with flood control operation during high runoff periods. Although this increase above the Bear River Compact Irrigation Reserve results in additional lost generation at the downstream hydroelectric plants during high runoff periods, it provides on average an additional 225,000 acre feet of Bear Lake Storage Water for contract deliveries in excess of the Bear River Compact Irrigation Reserve, enhanced recreational and aesthetic opportunities at Bear Lake, and maintenance of wildlife values, while still maintaining flood control capabilities.

i. Generally, PacifiCorp sets the PTE at the end of the irrigation season and updates the PTE each month during the period from the end of the irrigation season to March 31st of the following year. During extreme high runoff years, PacifiCorp may set the PTE as early as August 1st and may continue to update it into the following runoff season. Adjustments to the PTE are made to accommodate changing conditions, including weather forecasts, downstream constraints, uncertain irrigation demands, variations in runoff from month to month, and other operational constraints.

ii. Generally, if Bear Lake elevation is 5918 ft or higher at the end of the irrigation season, releases are scheduled to lower Bear Lake to elevation 5918 ft by March 31st of the following year. Conversely, if Bear Lake is below elevation 5918 ft at the end of the irrigation season, releases are curtailed until such time as the lake is predicted to reach elevation 5918 ft or until such time as high snowpack and runoff forecasts during the following winter months require PacifiCorp to make releases for flood control. At times during the period from the end of the irrigation season to March 31st of the following year, if snowpack and runoff forecasts indicate below average runoff, releases may be curtailed for the entire winter, even if the Bear Lake elevation is higher than 5918 ft. Except in emergencies, PacifiCorp will not release water from Bear Lake when the elevation is below the PTE unless consistent with flood control operation.

iii. Setting and adjusting the PTE is consistent with PacifiCorp's operation of Bear Lake since the early 1970s. In addition, the practice is consistent with PacifiCorp's FERC applications to relicense its Bear River hydroelectric facilities submitted to FERC on September 23, 1999. The FERC applications commit to continuation of historical operation. Refer to PacifiCorp's FERC applications for Soda (FERC #20) at FERC Application Exhibit B1-11 (September 1999), Grace/Cove (FERC #2401) at FERC Application Exhibit B1-14 (September 1999) and Oneida (FERC #472) at FERC Application Exhibit B1-13 (September 1999). The FERC applications do not provide for the release of Bear Lake storage water for hydro generation. From time to time, the elevation of Bear Lake may range from elevation 5902.00 ft to elevation 5923.65 ft. Nothing herein shall restrict PacifiCorp's right to store water in Bear Lake to elevation 5923.65 ft.

3. PacifiCorp's Hydroelectric Operations on Bear River

A. PacifiCorp owns and operates 6 hydroelectric plants on the Bear River downstream from Bear Lake which are listed in the table below.

Hydroelectric Project	FERC No.	Current Licensed Capacity
Soda	20	14.0 MW
Last Chance	4580	1.4 MW*
Grace	2401	33.0 MW
Cove	2401	7.5 MW
Oneida	472	30.0 MW
Cutler	2420	30.0 MW

(*FERC License Exemption)

PacifiCorp operates each hydroelectric plant with water rights granted by the state in which the hydroelectric plant is located. The Cutler hydroelectric plant operates with water rights recognized by both Utah and Idaho.

B. PacifiCorp agrees to continue its historic practice of regulating operation at its hydroelectric plants to meet existing downstream demands, some of which have water rights which are earlier in priority than PacifiCorp's hydro power water rights. Such historic operation is consistent with PacifiCorp's FERC licenses.

C. Nothing in this Agreement or the October 5, 1999 Agreement shall be interpreted as limiting PacifiCorp's right or ability to protest water right applications or filings in the Bear River Basin or from otherwise exercising and defending its water rights.

4. PacifiCorp regulates Bear Lake and operates its Bear River hydroelectric plants subject to various institutional, legal. and operational guidelines. The Parties recognize that said institutional guidelines may change due to conditions beyond the control of one or more of the Parties, and that such change may require adjustments in PacifiCorp's operations. If this occurs, PacifiCorp will advise the States and consult with them prior to changing its operations.

5. This Agreement is made in recognition of the existing rights and practices of the Parties.

6. This Agreement is intended to be a final and binding agreement in satisfaction of the commitment to negotiate a Bear River System Operations Agreement pursuant to Paragraph 2 of the October 5, 1999 Agreement between the States and PacifiCorp and inures to the benefit of, and is binding upon, the representatives, successors in interest, and assigns of each entity. No promise or inducement has been offered or made except as herein set forth, and this Agreement is executed without reliance upon any statement or representation by any other Party or its agent.

7. Nothing in this Agreement shall be interpreted to modify, limit or enhance any rights or obligations of the States under the laws of the States and the Amended Bear River Compact.

8. Consideration. The Parties acknowledge receiving sufficient consideration for the commitments contained in this Agreement and waive any argument that they might have in any judicial proceeding that no consideration exists to support this Agreement or that the consideration received is not sufficient.

9. Binding Effect of Agreement. This Agreement is intended to be a final and binding agreement between the States and PacifiCorp and inures to the benefit of, and is binding upon, the representatives, successors in interest, and assigns of each entity.

10. Sovereign Immunity. Each of the States and their various agencies do not waive their sovereign immunity by entering into this Agreement and fully retain all immunities and defenses provided by law with respect to any action based on or occurring as a result of this Agreement.

11. Capacity to Execute Agreement. The Parties warrant and represent that the person executing this Agreement is empowered to do so on behalf of such Party and thereby binds each entity by signing this Agreement.

12. Waivers. The failure to object to any breach of any term or condition in this Agreement shall not constitute a waiver and no failure to object shall be deemed a waiver of any prior or subsequent breach.

13. Modification. This Agreement may be amended or modified only by a written agreement signed by each of the Parties to this Agreement.

14. Execution of Multiple Originals. The Parties agree that this Agreement may be executed in four counterparts, each of which shall be an original.

15. Signatures. In witness whereof, the Parties to this Agreement through their duly authorized representatives have executed this Agreement and certify that they have read, understood, and agreed to the terms and conditions of this Agreement as set forth herein.

IN WITNESS WHEREOF, this Agreement is executed on the date first above written.

PACIFICORP

By: _____
Vice President Generation

STATE OF IDAHO

By: _____
Karl J. Dreher, Director
Department of Water Resources

STATE OF WYOMING

By: _____
Gordon W. Fassett
State Engineer

APPROVED AS TO FORM

By: _____
For Wyoming

STATE OF UTAH

By: _____
D. Larry Anderson, Director
Division of Water Resources

ACKNOWLEDGEMENTS

STATE OF Utah)
) ss.
COUNTY OF Salt Lake)

On the 5th day of April, 2000, before me, Jan S. Mahoney a notary public, personally appeared Barry G. Cunningham, a Vice President Generation of PacifiCorp, known or identified to me to be the person who executed the foregoing instrument on behalf of PacifiCorp, and he acknowledged to me that he executed the same.

NOTARY PUBLIC
JAN S. MA
201 South M
Salt Lake City
My Commission
August

Jan S. Mahoney
NOTARY PUBLIC

residing at:

STATE OF Utah)
) ss.
COUNTY OF Salt Lake)

On the 18th day of April, 2000, before me, Boyd E. Phillips a notary public, personally appeared Karl J. Dreher, Director, Idaho Department of Water Resources, known or identified to me to be the person who executed the foregoing instrument on behalf of the State of Idaho, and he acknowledged to me that he executed the same.

NOTARY PUBLIC
BOYD E. PHILLIPS
1636 West North Temple
Salt Lake City, Utah 84116
My Commission Expires
May 19, 2000
STATE OF UTAH

Boyd E. Phillips
NOTARY PUBLIC

residing at:

STATE OF Utah)
) ss.
COUNTY OF Salt Lake)

On the 18th day of April, 2000, before me, Boyd E. Phillips a notary public, personally appeared Gordon W. Fassett, Wyoming State Engineer, known or identified to me to be the person who executed the foregoing instrument on behalf of the State of Wyoming, and he acknowledged to me that he executed the same.

NOTARY PUBLIC
BOYD E. PHILLIPS
1636 West North Temple
Salt Lake City, Utah 84116
My Commission Expires
May 19, 2000
STATE OF UTAH

Boyd E. Phillips
NOTARY PUBLIC

residing at:

_____

_____

STATE OF Utah)
) ss.
COUNTY OF Salt Lake)

On the 18th day of April, 2000, before me, Boyd E. Phillips a notary public, personally appeared D. Larry Anderson, Director of the Utah Division of Water Resources, known or identified to me to be the person who executed the foregoing instrument on behalf of the State of Utah, and he acknowledged to me that he executed the same.

NOTARY PUBLIC
BOYD E. PHILLIPS
1636 West North Temple
Salt Lake City, Utah 84116
My Commission Expires
May 19, 2000
STATE OF UTAH

Boyd E. Phillips
NOTARY PUBLIC

residing at:

_____

_____

AGREEMENT
Regarding the Bear River System

This Agreement is entered into this 5th day of October, 1999, by and among PACIFICORP, an Oregon corporation ("PacifiCorp"); SCOTTISH POWER plc, a public limited company registered in Scotland ("ScottishPower"); the STATE OF IDAHO, by and through the Director of the Department of Water Resources ("Idaho"); the STATE OF UTAH, by and through the Director of the Division of Water Resources, ("Utah"); and the STATE OF WYOMING, by and through the State Engineer ("Wyoming"). PacifiCorp, ScottishPower, Idaho, Utah, and Wyoming are individually referred to as a "Party" and collectively as the "Parties."

RECITALS

A. PacifiCorp operates hydroelectric plants on the Bear River and holds water rights in the Bear River and Bear Lake (such hydroelectric plants and water rights referred to herein as "Bear River System"). PacifiCorp's water rights in the Bear River System are subject to the Amended Bear River Compact among the States of Idaho, Utah and Wyoming, as well as the laws of the three States, and other obligations.

B. PacifiCorp and ScottishPower are parties to a merger transaction that is currently the subject of approval proceedings before the public utility commissions in the States of Idaho, Utah and Wyoming.

C. The Parties recognize the need to assure the public utility commissions of the States of Idaho, Utah, and Wyoming, and the other public officials and water users of the three States that PacifiCorp's merger with ScottishPower will not affect the operation of the Bear River System or PacifiCorp's ownership or exercise of its Bear River water rights.

D. By this Agreement, PacifiCorp and ScottishPower intend to assure the States of Idaho, Utah and Wyoming that PacifiCorp or ScottishPower will not make any separate agreement with any State individually regarding PacifiCorp's or ScottishPower's water rights in the Bear River System.

NOW, THEREFORE, IT IS HEREBY AGREED BY THE PARTIES AS FOLLOWS:

1. Both ScottishPower and PacifiCorp agree that:

   a. PacifiCorp's water rights are constrained by the historic practice of not making a delivery call for hydropower generation; and

   b. Bear Lake is operated, consistent with long-standing historic practice and applicable laws, primarily as a storage reservoir to satisfy

contracts for existing irrigation uses and flood control needs in the three States, with the use of water for hydropower generation being incidental to the other purposes for which the water is being released.

2. The Parties agree to jointly negotiate an enforceable Bear River System Operations Agreement consistent with the provisions set forth in paragraph 1. With respect to the Bear River, the Operations Agreement shall confirm and continue PacifiCorp's historic practice of utilizing its water rights primarily for existing irrigation uses and contractual obligations. The Operations Agreement shall be made available for public review and comment in each of the three States.

3. This Agreement, the Operations Agreement, or any other agreement that may be entered into with PacifiCorp and/or ScottishPower concerning utilization of PacifiCorp's water rights in the Bear River System may be recorded in the County Recorders' Offices of the appropriate counties and shall be provided to the public utility commissions of the respective States within 10 days of execution of the document.

4. Approval and execution of the Operations Agreement by each of the States of Idaho, Utah, and Wyoming shall be required for the Operations Agreement to be effective.

5. The Parties commit to use their best efforts to complete negotiation, review, and execution of the Bear River System Operation Agreement within sixty (60) days of the execution of this Agreement.

6. No agreements between PacifiCorp and/or ScottishPower and one or more of the States concerning utilization of PacifiCorp's water rights in the Bear River System shall be effective unless jointly approved by all three States.

7. Nothing in this Agreement, nor in any Operations Agreement, shall be interpreted to modify, limit or enhance any rights or obligations of the three States under the laws of the States and the Amended Bear River Compact.

8. Consideration. ScottishPower and PacifiCorp acknowledge receiving sufficient consideration for the commitments contained in this Agreement and waive any argument that they might have in any judicial proceeding that no consideration exists to support this Agreement or that the consideration received is not sufficient.

9. Binding Effect of Agreement. This Agreement is intended to be a final and binding settlement agreement between the three States and ScottishPower and PacifiCorp, jointly and severally, and inures to the benefit of, and is binding upon, the representatives, successors in interest, and assigns of each entity.

10. Sovereign Immunity. Each of the three States and their various agencies do not waive their sovereign immunity by entering into this Agreement and fully retain all immunities and defenses provided by law with respect to any action based on or occurring as a result of this Agreement.

11. Capacity to Execute Agreement. ScottishPower and PacifiCorp each warrant and represent that the person executing this Agreement is empowered to do so on behalf of such company and thereby binds each entity by signing this Agreement.

12. Waivers. The failure to object to any breach of any term or condition in this Agreement shall not constitute a waiver and no failure to object shall be deemed a waiver of any prior or subsequent breach.

13. Entirety of Agreement. This Agreement represents the entire and integrated agreement between the Parties and supersedes all prior negotiations, representations and oral agreements. No promise or inducement has been offered or made except as herein set forth and this Agreement is executed without reliance upon any statement or representation by any other Party or their agent.

14. Modification. This Agreement may be amended or modified only by a written agreement signed by each of the Parties to this Agreement.

15. Execution of Agreement in Parts. Due to time constraints, the Parties acknowledge that it is not possible to have all Parties sign the same copy of this Agreement. Therefore, the Parties agree that this Agreement may be executed in any number of counterparts, each of which shall be deemed an original, but all of which together shall constitute one and the same instrument.

16. Signatures. In witness whereof, the Parties to this Agreement through their duly authorized representatives have executed this Agreement and certify that they have read, understood, and agreed to the terms and conditions of this Agreement as set forth herein.

IN WITNESS WHEREOF, the Parties have executed this Agreement the day and the year first above written.

PACIFICORP

By: _____
DENNIS P. STEINBERG
Senior Vice President of PacifiCorp

SCOTTISH POWER plc

By: _____
MATTHEW R. WRIGHT
Manager of Scottish Power plc

STATE OF IDAHO

By: _____
Karl J. Dreher, Director
Department of Water Resources

STATE OF UTAH

By: _____
Larry Anderson, Director
Division of Water Resources

STATE OF WYOMING

By: _____
Gordon W. Fassett
State Engineer

APPROVAL AS TO FORM:

By: _____
for Wyoming

ACKNOWLEDGMENTS

STATE OF Wyoming)
) ss.
COUNTY OF Laramie)

On this 5th day of October, 1999, before me, Diana M. Gorman, a notary public of the State of Wyoming, personally appeared DENNIS P. STEINBERG, a Senior Vice President of PacifiCorp, known or identified to me to be the person who executed the foregoing instrument on behalf of PacifiCorp, and he acknowledged to me that he executed the same.

DIANA M. GORMAN NOTARY PUBLIC LARAMIE COUNTY, WYOMING

Diana M. Gorman
NOTARY PUBLIC FOR WYOMING
residing at:
739 Cypress Lane
Cheyenne, WY 82009

My commission expires: 2/21/02

STATE OF Wyoming)
) ss.
COUNTY OF Laramie)

On this 5th day of October, 1999, before me, Diana M. Gorman, a notary public of the State of Wyoming, personally appeared MATTHEW R. WRIGHT, a Manager of Scottish Power plc, known or identified to me to be the person who executed the foregoing instrument on behalf of Scottish Power plc, and he acknowledged to me that he executed the same.

DIANA M. GORMAN NOTARY PUBLIC LARAMIE COUNTY, WYOMING

Diana M. Gorman
NOTARY PUBLIC FOR WYOMING
residing at:
739 Cypress Lane
Cheyenne, WY 82009

My commission expires: 2/21/02

AMENDED AND RESTATED
BEAR LAKE SETTLEMENT AGREEMENT

THIS AMENDED AND RESTATED BEAR LAKE SETTLEMENT AGREEMENT (the "Agreement") is made and entered into this 2nd day of July, 2004, by and between LAST CHANCE CANAL COMPANY, CUB RIVER IRRIGATION COMPANY, WEST CACHE IRRIGATION COMPANY, BEAR RIVER CANAL COMPANY, and THE BEAR RIVER WATER USERS ASSOCIATION, INC. (referred to collectively as the "Company Irrigators"); and BEAR LAKE WATCH, INC. in its own behalf and as successor in interest to JIM KIMBAL, EMERALD BEACH, INC., and BEAR LAKE EAST, INC. (referred to collectively as the "Bear Lake Group"); and PACIFICORP. The foregoing are sometimes referred to herein individually as a "Party" or collectively as the "Parties."

RECITALS

A. WHEREAS, PacifiCorp owns certain decreed rights under the Dietrich Decree in Idaho (*Utah Power & Light Company v. Last Chance Canal Company, Limited, et al.*, in Equity No. 203, July 14, 1920) and the Kimball Decree in Utah (*Utah Power & Light Company v. Richmond Irrigation Company, et al.*, February 21, 1922) to divert water from Bear River for storage in the top 21.65 feet of Bear Lake between elevations 5902 and 5923.65 and to operate, manage and release the same for irrigation in the Bear River Valley in Idaho and Utah; power generation incidental to releases for irrigation, stockwatering and flood control; and flood control and for other beneficial uses; and

B. WHEREAS, the Company Irrigators and certain individual small irrigators diverting water from Bear River under State granted water rights in the States of Idaho and Utah (the "Small Irrigators") hold contracts with PacifiCorp to receive Bear Lake storage water which has historically been applied to beneficial use for the supplemental irrigation of more than 157,000 acres in Idaho and Utah (the "Contracts"); and

C. WHEREAS, the Bear Lake Group represents the interests of its members who consist of property owners around Bear Lake, recreationalists and others who use waters of Bear Lake for recreation, aesthetic and other non-consumptive purposes; and

D. WHEREAS, the Parties have heretofore entered into that certain agreement entitled "Bear Lake Settlement Agreement," dated April 10, 1995 (the "Original Settlement Agreement"); and

E. WHEREAS, the signatories to the Original Settlement Agreement included two unincorporated associations of individual irrigators identified as the "Idaho Pumpers Association" and the "Utah Pumpers Association" (the "Associations"). The members of the Associations are referred to in this Agreement as the "Small Irrigators"; and

F. WHEREAS, as contemplated in the Original Settlement Agreement, the Parties have pursued with the states of Idaho, Utah and Wyoming the concept and implementation of a single interstate model and modeling process for the administration and distribution of water in

the Bear River System (the "Interstate Model"), including the delivery of supplemental irrigation storage water out of Bear Lake allocated by PacifiCorp among the Company Irrigators and Small Irrigators holding Contracts with PacifiCorp as set forth herein; and

G. WHEREAS, because the Interstate Model improved the accuracy of accounting for Bear River natural flow and Bear Lake storage water use, PacifiCorp and certain of the Company Irrigators and Small Irrigators amended their Contracts to adjust the amount of Bear Lake storage water releases to them, which Contracts specifically made reference to the Original Settlement Agreement; and

H. WHEREAS, subsequent to the Original Settlement Agreement, PacifiCorp entered into certain agreements referencing the Original Settlement Agreement, among them the October 5, 1999 and April 19, 2000 agreements with the States of Wyoming, Idaho and Utah; and

I. WHEREAS, as contemplated in the Original Settlement Agreement, the Parties have been able to resolve conflicts by pursuing means other than litigation, and appropriate changes to the "Irrigation Water Allocation Lake Recovery Proposal for Bear Lake" have been demonstrated; and

J. WHEREAS, certain provisions of the Original Settlement Agreement are no longer applicable; and

K. WHEREAS, the Parties desire to amend and restate in its entirety the Original Settlement Agreement to facilitate the changes set forth above in this Agreement.

AGREEMENT

NOW, THEREFORE, IT IS HEREBY MUTUALLY AGREED among the Parties as follows:

1. The Bear Lake Irrigation Water Allocation and Lake Recovery Table attached hereto as EXHIBIT "A" and incorporated by reference herein, is hereby approved by the Company Irrigators and Bear Lake Group, and adopted by PacifiCorp as established policy for the supplemental irrigation water delivery component of its operation and management of Bear Lake. The Bear Lake Irrigation Water Allocation and Lake Recovery Table attached as Exhibit "A" hereto replaces and supersedes the "Irrigation Water Allocation Lake Recovery Proposal for Bear Lake" table attached to the Original Settlement Agreement.

2. The Parties acknowledge and agree that PacifiCorp shall retain the authority and discretion to determine the "Estimated Lake Elevation" set forth in Column (A) of Exhibit "A;" adjust the "Estimated System Losses" set forth in Column (H) of Exhibit "A;" and make all decisions regarding the operation and maintenance of PacifiCorp's Bear River and Bear Lake system facilities. Under extreme conditions of unforeseen circumstances, and for good cause shown, PacifiCorp, after consultation with the Bear Lake Preservation Advisory Committee (the "Advisory Committee"), may adjust the Annual Allocation set forth in Column (E) of Exhibit "A."

3. The Advisory Committee shall remain in effect and consists of a representative of each of the Company Irrigators, representatives of the entity or entities comprising the Small Irrigators, each of the entities comprising the Bear Lake Group, representatives for PacifiCorp, and representatives from the Bear River Commission and the States of Idaho, Utah and Wyoming should they desire to participate, as well as other parties who have an interest in promoting the goals enumerated below. The purpose of the Advisory Committee will be to address and attempt to resolve through compromise and negotiations disagreements among the Parties and others concerning the use, operation and management of Bear Lake. Among other things, the purposes of the Advisory Committee will include the following;

a. to promote water conservation and efficient use practices;
b. to promote more reliable water supplies in Bear Lake and Bear River for all users;
c. to promote soil and energy conservation and improved water quality;
d. to pursue means other than litigation to resolve conflicts;
e. to continue to support the concept of a single accounting model for administration of water in the Bear Lake/Bear River System; and
f. to periodically review Exhibit "A" and recommend changes in that policy to PacifiCorp as may be appropriate.

4. PacifiCorp shall present its Estimated Annual Allocation to the Company Irrigators and Small Irrigators based upon the Estimated Lake Elevation of Bear Lake as set forth in Exhibit "A" or its anticipated flood control release projections at a meeting of the Advisory Committee. The Advisory Committee will meet at least annually as scheduled by the Advisory Committee or PacifiCorp.

5. The Company Irrigators shall be allocated 92.2% of the Estimated Annual Allocation to Irrigators as set forth in Column (E) of Exhibit "A." The 92.2% of the Estimated Annual Allocation to Irrigators shall be apportioned by the Company Irrigators among themselves according to a written apportionment schedule established by the Company Irrigators at their sole discretion and approved under the bylaws of the Bear River Water Users Association. The remaining 7.8% of the Estimated Annual Allocation to Irrigators shall be allocated by PacifiCorp to the Small Irrigators as follows: Idaho Small Irrigators 3.0% and Utah Small Irrigators 4.8%. The Idaho Small Irrigators and/or the Utah Small Irrigators may organize corporations or entities to which the individual Contracts of the Small Irrigators are assigned. The Parties do not object to such assignments so long as no more than 7.8% of the Estimated Annual Allocation to Irrigators is allocated to such corporations or entities. The Bear Lake Group does not agree or disagree with, or in any manner take part in, this provision of this Agreement.

6. The Parties provide and hereby intend that the Small Irrigators participate in this Agreement either as set forth in Paragraph 5 above, or as one or two representative organizations receiving allocations of the Estimated Annual Allocation as set forth in Paragraph 5 above. If the Small Irrigators participate as one organization, said organization shall include all of the Small Irrigators. If the Small Irrigators participate as two organizations, said organizations shall be organized by State and include all Idaho Small Irrigators in one organization and all Utah Small Irrigators in one organization. Subsequent to the execution of this Agreement, the Small

Irrigators' organization(s) may execute a counterpart to this Agreement stating the name of the representative organization, providing a statement of the individual Small Irrigators represented and proof of assignment of Contracts to the representative organization, and a statement of unconditional concurrence with the terms of this Agreement. Once the counterpart or counterparts to this Agreement are so executed and copies delivered to the original signatories, the organization(s) or entities shall be considered to be Parties to this Agreement. The Bear Lake Group does not agree or disagree with, or in any manner take part in, this provision of this Agreement.

7. The Parties acknowledge and agree that the Company Irrigators have entered into this Agreement voluntarily with the other Parties, for the purpose of allocating Bear Lake storage water for supplemental irrigation use in times of shortage, when nature does not otherwise provide a full supply. Nothing in this Agreement shall be construed as an abandonment or forfeiture of any appropriated or Contract rights of the Company Irrigators and Small Irrigators, or rights of Bear Lake Group under environmental laws, or other rights belonging to the Parties.

8. Subsequent to the implementation of the Interstate Model, certain of the Company Irrigators and Small Irrigators amended their Contracts with PacifiCorp. PacifiCorp entered into agreements with the States of Wyoming, Idaho and Utah dated October 5, 1999 and April 18, 2000 referencing PacifiCorp's operations at Bear Lake and in Bear River. Said Contracts and agreements made specific reference to the Original Settlement Agreement. By executing this Agreement, the Parties agree to the following:

a. all references to the Original Settlement Agreement in the November 16, 1999 "Last Chance Bear Lake Storage Water Agreement" shall be replaced with and refer to this Agreement; and
b. all references to the Original Settlement Agreement in the November 11, 1999 "West Cache Irrigation Company Amendatory Agreement" shall be replaced with and refer to this Agreement.
c. any and all references to the Original Settlement Agreement in the October 5, 1999 and April 18, 2000 agreements with the States of Wyoming, Idaho and Utah and PacifiCorp shall be replaced with and refer to this Agreement;

To the extent the Parties to this Agreement have any legal or equitable rights, duties, or obligations under any agreement or contract containing references to the Original Settlement Agreement, each Party agrees that said references to the Original Settlement Agreement shall be replaced with and refer to this Agreement.

9. Any Party shall be excused from performance under this Agreement buy only during and to the extent that it is unable to perform, or its performance is delayed or interrupted, for a cause beyond its reasonable control. Such causes may include lack of water, labor or material, fire, storm, flood, acts of God, war (whether or not declared), labor disputes or an order or necessity of any governmental authority so long as the cause is not a result of any negligence of the Party claiming inability to perform. In the event of a claim of inability to perform pursuant to this provision, then the Party making such claim shall give immediate written notice with explanation to the other Parties. Following such notice, the affected obligations of the Party

giving notice shall be suspended only during the continuance of the events giving rise to the cause, provided that the affected Party is acting with all reasonable speed and due diligence to remedy the events giving rise to the cause of its inability to perform.

10. Copies of this Agreement shall be provided to the U.S. Army Corps of Engineers, the Idaho Department of Lands, the Bear River Commission, the Idaho Department of Water Resources, the Utah Divisions of Water Resources and Water Rights, and the Wyoming State Engineer's Office.

11. With respect to the rights and obligations of the Parties, this Agreement shall replace and supersede the Original Settlement Agreement in its entirety.

12. General Provisions:

a. Each Party to this Agreement will bear its expenses incurred in connection with the preparation, execution and performance of this Agreement, including all fees and expenses of agents, representatives, counsel and accountants.

b. All notices, consents, waivers and other communications under this Agreement must be in writing and will be deemed to have been duly given when (i) delivered by hand (with written confirmation of receipt), or (ii) when received by the addressee, if sent by a nationally recognized overnight delivery service (receipt requested), in each case to the appropriate addressees set forth below (or to such other addresses and fax numbers as a party may designate by notice to the other Parties):

Last Chance Canal Company	P O Box 287 Grace, ID 83241 _____
Cub River Irrigation Company	P O Box 215 Lewiston UT 84320 _____
West Cache Irrigation Company	Trenton, UT 84338 _____ _____
Bear River Canal Company	275 North 1600 East Tremonton UT 84337 _____
The Bear River Water Users Association, Inc.	_____ _____ _____

Bear Lake Watch, Inc.	c/o David R. Cottle 3539 Brighton Point Dr. Salt Lake City UT 84121 (801) 733-5243
Emerald Beach, Inc.	c/o Don C. Riches 8626 Scottish Dr. Sandy UT 84093-2132 (801) 944-9019
Bear Lake East, Inc.	Bruce Passey 4326 Rupp Court Taylorsville UT (801) 969-7787
PacifiCorp	Connely Baldwin Hydro Resources Department 1407 West North Temple, Suite 330 Salt Lake City, UT 84116

c. The rights and remedies of the Parties to this Agreement are cumulative and not alternative. Neither the failure nor any delay by any Party in exercising any right, power or privilege under this Agreement or the documents referred to in this Agreement, nor the single or partial exercise of any such right, power or privilege, will operate as a waiver of such right, power or privilege. To the maximum extent permitted by applicable law, (i) no claim or right arising out of this Agreement or the documents referred to in this Agreement can be discharged by one Party, in whole or in part, by a waiver or renunciation of the claim or right unless in writing signed by the other Parties; (ii) no waiver that may be given by a Party will be applicable except in the specific instance for which it is given; and (iii) no notice to or demand on one party will be deemed to be a waiver of any obligation of such Party or of the right of the Party giving such notice or demand to take further action without notice or demand as provided in this Agreement or the documents referred to in this Agreement.

d. PacifiCorp may assign its interest in this Agreement to a successor without the prior consent of the other Parties so long as the successor assumes all of PacifiCorp's agreements, liabilities and obligations relating to Bear Lake. No other Party may assign this Agreement without the prior consent of each other Party. Subject to the preceding sentence, this Agreement will apply to, be binding in all respects upon, and inure to the benefit of the successors and permitted assigns of the Parties. Nothing expressed or referred to in this Agreement will be construed to give any person other than the Parties to this Agreement any legal or equitable right, remedy or claim under or with respect to this Agreement or any provision of this Agreement.

e. If any provision of this Agreement is held invalid or unenforceable by any court of competent jurisdiction, the other provisions of this Agreement will remain in full force and effect. Any provision of this Agreement held invalid or unenforceable only in part or degree will remain in full force and effect to the extent not held invalid or unenforceable.

f. The headings of sections in this Agreement are provided for convenience only and will not affect its construction or interpretation. With regard to all dates and time periods set forth or referred to in this Agreement, time is of the essence.

g. This Agreement will be governed by the laws of the State of Utah, without regard to its conflicts of laws principles.

h. This Agreement may be executed in one or more counterparts, each of which will be deemed to be an original copy of this Agreement and all of which, when taken together, will be deemed to constitute one and the same Agreement.

IN WITNESS WHEREOF, the Parties have executed this Agreement the day and the year first written above.

LAST CHANCE CANAL COMPANY

By: _____

CUB RIVER IRRIGATION COMPANY

By: _____

WEST CACHE IRRIGATION COMPANY

By: _____

BEAR RIVER CANAL COMPANY

By: _____

Signatures continue on the following page.

BEAR RIVER WATER USERS ASSOCIATION, INC.

By: _____

BEAR LAKE WATCH, INC., in its own behalf and as successor-in-interest Jim Kimbal

By: _____

EMERALD BEACH, INC.

By: _____

BEAR LAKE EAST, INC.

By: _____

PACIFICORP

By: _____

EXHIBIT "A"

(To Amended and Restated Bear Lake Settlement Agreement)

BEAR LAKE IRRIGATION WATER ALLOCATION AND LAKE RECOVERY TABLE

(Quantities Expressed in Acre-feet)

(A) Estimated Lake Elevation (in feet) (Footnote 1)	(B) Calculated Storage Content (Footnote 2)	(C) Estimated Lake Evaporation (Footnote 3)	(D) Estimated Net Storage Water Available (Footnote 4)	(E) Estimated Annual Allocation to Irrigators (Footnote 5)	(F) Decreed Transit Losses (Averaged) (Footnote 6)	(G) Estimated Head Gate Delivery to Irrigators (Footnote 7)	(H) Estimated System Losses (Averaged) (Footnote 8)	(I) Estimated Balance for Lake Recovery (Footnote 9)
5923.65 (Full)	1,421,000							
5914.7	801,000	125,000	676,000	230,000 (100%)	8,200	221,800	17,000	429,000
5914	754,000	125,000	629,000	225,000 (98%)	8,100	216,900	17,000	387,000
5913	688,000	125,000	563,000	220,000 (96%)	8,000	212,000	17,000	326,000
5912	622,000	125,000	496,000	215,000 (93%)	7,800	207,200	17,000	264,000
5911	557,000	125,000	432,000	210,000 (91%)	7,600	202,400	17,000	205,000
5910	492,000	125,000	372,000	205,000 (89%)	7,400	197,600	17,000	150,000
5909	428,000	125,000	303,000	181,000 (79%)	6,700	174,300	17,000	105,000
5908	365,000	125,000	240,000	168,000 (73%)	6,000	162,000	17,000	55,000
5907	303,000	125,000	177,000	141,000 (61%)	5,000	136,000	17,000	19,000
5906	241,000	125,000	115,000	104,000 (45%)	3,700	100,300	17,000	- 6,000
5905	180,000	125,000	55,000	55,000 (24%)	2,000	53,000	17,000	- 17,000
5904	119,000	125,000	0	0 (0%)	0 (0%)	0 (0%)	17,000	0
5903	59,000	125,000	0	0 (0%)	0 (0%)	0 (0%)	17,000	0
5902	0	125,000	0	0 (0%)	0 (0%)	0 (0%)	17,000	0

THE ACTUAL QUANTITY OF WATER TO BE RELEASED FROM BEAR LAKE EACH YEAR IS MEASURED AT THE OUTLET CANAL GAGE AND CALCULATED BY ADDING THE QUANTITY IN COLUMN E TO THE QUANTITY IN COLUMN H.

FOOTNOTES TO EXHIBIT "A"

1. The "Estimated Lake Elevation," Column A, represents PacifiCorp's estimated, maximum water level in Bear Lake, in any given year, calculated by adding the forecasted amount of storable spring runoff (i.e. the forecasted flow in the Bear River less the flow required to satisfy natural flow rights) to the actual quantity of water then in storage in Bear Lake on April 10 of said year.

2. The "Calculated Storage Content," Column B, is the calculated content according to PacifiCorp data at each projected lake elevation.

3. The "Estimated Evaporation," Column C, represents the estimated amount of water lost out of Bear Lake in any given year due to evaporation, according to PacifiCorp data.

4. The "Estimated Net Storage Water Available," Column D, is calculated by subtracting the Estimated Evaporation in Column C from the Calculated Storage Content in Column B.

5. The "Estimated Annual Allocation to Irrigators," Column E, represents the total, estimated quantity of supplemental irrigation storage water determined as of April 10 to be available for release by PacifiCorp to the BRWUA on behalf of the Company Irrigators and by PacifiCorp to the Small Irrigators from Bear Lake pursuant to the Contracts during those periods when the elevation of Bear Lake is within the Irrigation Reserve range between 5914.7 feet and 5902 feet, subject to the following:

   a. The Estimated Annual Allocation available at each estimated Bear Lake elevation is subject to the maximum flow rates deliverable through PacifiCorp facilities, PacifiCorp's historic Bear Lake operational practices, and other operating and legal constraints and subject to Contract limitations of each of the Company Irrigators and Small Irrigators.

   b. PacifiCorp shall send written notice of the Estimated Annual Allocation to Company Irrigators to the Bear River Water Users Association (BRWUA) on behalf of the Company Irrigators and to the Small Irrigators or their duly appointed representatives with a copy to the Bear River Commission Engineer-Manager. The BRWUA shall apportion 92.2% of the Estimated Annual Allocation to Irrigators among the Company Irrigators. Such apportionment shall not exceed the Contract limitations of each of the Irrigators. BRWUA shall send written notice of its apportionment to PacifiCorp and the Bear River Commission Engineer-Manager annually prior to the commencement of the irrigation season. The remaining 7.8% of the Estimated Annual Allocation to Irrigators shall be apportioned to the Small Irrigators as follows: Idaho Small Irrigators 3.0% and Utah Small Irrigators 4.8%.

   c. Unused water allocated to the BRWUA on behalf of the Company Irrigators or to the Small Irrigators under the Estimated Annual Allocation may not be accrued or carried over by the BRWUA or any Company Irrigator or Small Irrigator to any future year and will remain in Bear Lake for additional lake recovery.

d. PacifiCorp will not deliver storage water from Bear Lake to new contracts, or otherwise additionally encumber its Bear Lake storage water, over and above the water allocated to the BRWUA on behalf of the Company Irrigators and the Small Irrigators for their existing Contracts.

e. No allocation of Bear Lake storage water will be made to the BRWUA on behalf of the Company Irrigators and Small Irrigators if PacifiCorp calculates the Estimated Lake Elevation (Column A) to be 5904 feet or below. If, however, PacifiCorp calculates that the Estimated Lake Elevation will be higher than 5904 feet, PacifiCorp will pump, subject to operating and legal constraints, in order to release water from Bear Lake until such time as its operation, together with anticipated evaporation, is expected to result in a calculated Bear Lake elevation of 5902 feet after evaporation and releases.

f. The Estimated Annual Allocation to the BRWUA on behalf of the Company Irrigators and Small Irrigators will be refined by PacifiCorp by pro-rating between the nearest even foot elevations set forth in the table above and below the actual Bear Lake elevation projected on April 10, calculated in tenths of a foot.

g. PacifiCorp's historical maximum delivery of Bear Lake storage water to the Company Irrigators and the Small Irrigators for supplemental irrigation was 245,000 acre feet in 1961. Two hundred forty-five thousand acre feet shall be the maximum Estimated Annual Allocation to Irrigators at all Bear Lake elevations above 5914.7 feet. However, under extreme conditions, and only when elevations are above 5914.7 feet, delivery of Bear Lake storage water to the BRWUA may exceed 245,000 acre feet in order to satisfy the Company Irrigators' and Small Irrigators' Contracts.

6. The "Decreed Transit Losses (Averaged)," Column F, represents the transit losses calculated for the purpose of this Agreement using an average of 3.6% to cover all reaches of the Bear River. The Decreed Transit Losses are deducted from the "Estimated Annual Allocation to Irrigators" (Column E). The actual transit losses will be calculated pursuant to the Dietrich and Kimball Decrees and accounted for in the Interstate Model.

7. The "Estimated Head Gate Delivery," Column G, is the aggregate quantity of supplemental Bear Lake storage water allocated to BRWUA on behalf of the Company Irrigators and Small Irrigators by PacifiCorp to be diverted at the Company Irrigators' and the Small Irrigators' individual head gates on the Bear River, and is determined by subtracting the total Decreed Transit Losses in Column F from the total Estimated Annual Allocation in Column E. PacifiCorp will make said Bear Lake storage water available to the Bear River for subsequent diversion by the Company Irrigators and the Small Irrigators at their individual head gates as described in Footnote 5(b) above.

8. The "Estimated System Losses," Column H, represents the operating losses to the Bear River System measured at the stream gauging station below the Cutler hydroelectric plant and are accounted for under the Interstate Model as Bear Lake storage water. The actual system losses will be calculated each year by the Interstate Model and be accounted for

by PacifiCorp in determining the actual quantity of water to be preserved for Bear Lake Recovery under Column I.

9. The "Estimated Balance for Lake Recovery," Column I, is calculated by subtracting the Estimated Annual Allocation quantity in Column E and the Estimated System Losses quantity in Column H from the Estimated Net Storage Water Available quantity in Column D. Note that the actual amount preserved for Bear Lake recovery in any given year will be determined once the actual system losses have been determined each year. If actual system losses exceed the Estimated System Losses, PacifiCorp will provide notice to the Advisory Committee stating the reason, and then release additional storage water from Bear Lake to cover the increased amount of system losses. If actual system losses are less than Estimated System Losses, PacifiCorp will hold the remaining water allocated to Estimated System Losses in Bear Lake for lake recovery.

CHAPTER 7

HDR DAM INVESTIGATION REPORT

Bowen Collins & Associates, Inc.
CONSULTING ENGINEERS

HDR

Conceptual Engineering Analyses for Potential Dam Sites

- Above Cutler
- Cub River
- Fielding
- South Willard Bay
- Temple Fork
- Whites Valley

Bear River Project, Utah

April 5, 2016

DRAFT

Contents

1 Executive Summary 1
1.1 Soil Foundation Sites 1
1.2 Rock Foundation Sites 2
2 Introduction 3
3 Subsurface Conditions and Material Properties 5
3.1 Above Cutler 6
3.2 Cub River 7
3.3 Fielding 8
3.4 South Willard Bay 9
3.5 Temple Fork 10
3.6 Whites Valley 11
4 Methodology for the Conceptual Design and Analysis 12
4.1 Basic Dam Types and Configurations 13
4.2 Criteria for Analyzing the Stability of Embankment Dams 13
4.3 Earthquake Hazard Review 14
4.4 Seismic Tolerable-Deformation Scale 15
5 Results of the Analysis of Seepage, Stability, and Seismic Deformations 16
5.1 Results of the Slope Stability Analysis 17
5.2 Results of the Empirical Newmark Deformation Analysis 17
6 Conclusions 19
6.1 Overall Study Conclusions 19
6.2 Above Cutler 20
6.3 Cub River 21
6.4 Fielding 22
6.5 South Willard Bay 23
6.6 Temple Fork 23
6.7 Whites Valley 24
6.8 Summary of Dam Types and Configurations 25
7 References 26

Tables

Table 1. Above Cutler: Summary of Embankment and Foundation Material Properties 6
Table 2. Cub River: Summary of Embankment and Foundation Material Properties 7
Table 3. Fielding: Summary of Embankment and Foundation Material Properties 8
Table 4. South Willard Bay: Summary of Embankment and Foundation Material Properties 9
Table 5. Temple Fork: Summary of Dam and Foundation Material Properties 10
Table 6. Whites Valley: Summary of Embankment and Foundation Material Properties 11
Table 7. Estimated Earthquake Magnitude Values 14
Table 8. Estimated Peak Ground Acceleration Values 14
Table 9. Summary Results of Slope Stability Analysis 17
Table 10. Summary of Dam Types and Characteristics 25

Figures

Figure 1. Bear River Basin Map 4
Figure 2. Location Map of Proposed Sites 27
Figure 3. Above Cutler Site – Representative Maximum Cross-Section 28
Figure 4. Above Cutler Site – Seepage Analysis Results – Seepage Total Head Contours 29
Figure 5. Above Cutler Site – Steady-State Seepage Condition – Slope Stability Analysis Results 30
Figure 6. Above Cutler Site – Slope Stability Analysis Results – Post-seismic Factor of Safety 31
Figure 7. Above Cutler Site – Empirically Estimated Seismic Displacements 32
Figure 8. Cub River Site – Representative Maximum Cross-Section 33
Figure 9. Cub River Site – Seepage Analysis Results – Seepage Total Head Contours 34
Figure 10. Cub River Site – Steady-State Seepage Condition – Slope Stability Analysis Results 35
Figure 11. Cub River Site – Slope Stability Analysis Results – Post-seismic Factor of Safety 36
Figure 12. Cub River Site – Empirically Estimated Seismic Displacements 37
Figure 13. Fielding Site – Representative Maximum Cross-Section 38
Figure 14. Fielding Site – Seepage Analysis Results – Seepage Total Head Contours 39
Figure 15. Fielding Site – Steady-State Seepage Condition – Slope Stability Analysis Results 40
Figure 16. Fielding Site – Slope Stability Analysis Results – Post-seismic Factor of Safety 41
Figure 17. Fielding Site – Empirically Estimated Seismic Displacements 42
Figure 18. South Willard Bay Site – Representative Maximum Cross-Section 43
Figure 19. South Willard Bay Site – Seepage Analysis Results – Seepage Total Head Contours 44
Figure 20. South Willard Bay Site – Steady-State Seepage Condition – Slope Stability Analysis Results 45
Figure 21. South Willard Bay Site – Slope Stability Analysis Results – Post-seismic Factor of Safety 46
Figure 22. South Willard Bay Site – Estimated Seismic Displacements 47
Figure 23. Temple Fork Site – Representative Maximum Cross-Section 48
Figure 24. Whites Valley Site – Representative Maximum Cross-Section 49
Figure 25. Whites Valley Site – Seepage Analysis Results – Seepage Total Head Contours 50
Figure 26. Whites Valley Site – Steady-State Seepage Condition – Slope Stability Analysis Results 51
Figure 27. Whites Valley Site – Slope Stability Analysis Results for Steady-State Seepage Condition – Factor of Safety with Weak Sandstone Seam, $\phi = 25°$ 52
Figure 28. Whites Valley Site – Empirically Estimated Seismic Displacements 53

Terminology

2-D	two-dimensional
c	total stress cohesion
c'	effective stress cohesion
CFRD	concrete-faced rockfill dam
CH	high-plasticity clay
CL	low-plasticity clay
deg	degrees
DMM	deep mixing method
ECRD	earth-core rockfill dam
FERC	Federal Energy Regulatory Commission
FLAC	Fast Lagrangian Analysis of Continua
g	gravity
GM	silty gravel
GP	poorly graded gravel
H	horizontal
m/s	meters per second
ML	silt
PGA	peak ground acceleration
psf	pounds per square foot
RCC	roller-compacted concrete
Reclamation	Bureau of Reclamation
SC	clayey sand
SM	silty sand
SP	poorly graded sand
S_r/σ'_{vo}	shear strength/effective vertical stress ratio
S_u	undrained shear strength
SW	well-graded sand
USACE	U.S. Army Corps of Engineers
USGS	U.S. Geological Survey
V	vertical
V_{s30}	shear wave velocity at 30 meters' depth
ϕ	total stress friction angle
ϕ'	effective stress friction angle
γ_{moist}	moist unit weight

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1 Executive Summary

HDR performed conceptual-level engineering analyses on six potential dam sites (Above Cutler, Cub River, Fielding, South Willard Bay, Temple Fork, and Whites Valley) for the Bear River Project. HDR used these engineering analyses, along with the results of a site-characterization study, to select a preferred dam type for each site and develop a generalized dam cross-section that can be used for conceptual planning and cost estimating. This report presents the results of the dam conceptual engineering analyses including evaluations of material properties, seepage analyses, stability analyses, seismic deformation analyses, dam type selection, and general cross-section requirements.

In general, all six of the dam sites appear technically feasible for dam structures. The four sites where the dam would be built on a soil foundation (Above Cutler, Cub River, Fielding, and South Willard Bay) would have significant technical and construction challenges, and some would require more soil and site improvement work than others. The two sites where the dam would be built on a rock foundation (Temple Fork and Whites Valley) have potential challenges associated with local and regional lineament and/or faulting features. Overall, however, the two rock-foundation sites present fewer geologic and geotechnical challenges.

The site subsurface exploration and laboratory testing program provided a significant amount of technical information and insight into the geologic and related geotechnical design conditions present at each site and the challenges that need to be addressed. Further site characterization and design development will be needed to support further refinement of the designs, refinement of cost estimates, and identification of preferred alternatives for the project.

1.1 Soil Foundation Sites

At the earthfill dam sites (Above Cutler, Cub River, Fielding, and South Willard Bay), embankment borrow materials are generally available with the exception of (1) clean sand and gravel materials for filters and drains and (2) rock materials for riprap and slope protection. When constructing new dams or modifying existing dams, it is common to import the high-quality materials required for these important components of the dam.

The Above Cutler site has significant design and construction challenges associated with founding a dam on the very soft foundation soils. The need for a very high-capacity spillway at this site (and at Fielding) is a significant issue associated with these two sites on the Bear River. These challenges could make the Above Cutler site much less economically feasible than the other sites. Foundation improvement or treatment options might be available to optimize the design for this site, but some challenges would likely remain, and the costs to address them could be significant.

The Cub River site also has some challenges associated with soft soils, but our analyses indicate that a dam could be designed and constructed to perform well for normal operational and potential seismic loading conditions. At this site, there could be short-term issues with the low strength of foundation materials during construction and long-term concerns about settlement.

The Fielding site is geologically complex, with soft, weak soils in the foundation that would significantly hamper the ability to design simple stability berms to improve stability and seismic deformation performance. Similar to the Above Cutler site, the high-capacity spillway and the foundation improvements or treatments that would likely be needed at this site represent important technical, construction, and corresponding economic risks compared to several of the other sites. Because of the complex geologic and depositional environment at this site, the design requirements cannot be adequately understood without further site characterization.

The South Willard Bay site also has very soft foundation soils that would be problematic for stability, seismic deformation, and long-term settlement of a dam. A key focus of future site characterization work would be developing a better understanding of the variability of foundation soil properties over this large site.

Additional explorations, laboratory testing and analyses should be considered for each of the soil foundation sites to (1) further refine a geologic model of the sites, (2) update/verify the design configuration, and (3) reduce uncertainties related to design, construction and cost risks. Additional site characterization work will be necessary to develop designs to a full concept level and establish cost estimates suitable for evaluation of the alternatives and section of a preferred combination of projects to meet the overall water supply objectives.

1.2 Rock Foundation Sites

The Temple Fork site has bedrock near the surface that would provide a sound foundation for a roller-compacted concrete (RCC) dam. An RCC dam offers several advantages at this site, including the ability to position the overflow spillway on the dam and away from steep and challenging abutment terrain and the ability to incorporate a low-level outlet works through the base of the dam, thereby eliminating the need for tunnels in the lower abutment areas. RCC aggregate might be available in the area of the proposed reservoir basin, which would improve the economic feasibility of this dam at this site. Potentially active faults have been identified in the immediate vicinity and possibly under a portion of the site where a dam could be located. The RCC dam offers a minimal dam footprint that we believe can be located away from these fault features. Additional site characterization is needed to better define the fault locations and refine the location of the dam axis.

The Whites Valley dam site has several positive geologic and dam design attributes. The bedrock at the site would generally provide a sound foundation for an earth-core rockfill dam (ECRD). In addition, it is likely that most, if not all, borrow materials needed for construction could be developed from on-site sources. This type of dam, designed with a central impervious core and wide filters and drains and constructed with compacted rockfill shells, should perform well under all anticipated normal and seismic loading conditions. HDR has identified concerns in the left abutment of the dam footprint as well as in an area along the left reservoir rim upstream of the dam where the bedrock material is highly fractured and permeable. This bedrock condition might be associated with an old (paleo) fault and/or lineament feature. Such a feature would require remediation to limit reservoir seepage through the left abutment and rim area. Further investigation and study of this issue is recommended as the designs and cost estimate for this site are advanced.

2 Introduction

The Bear River Project is being proposed by the State of Utah to develop increased water supply in the Bear River Basin, which is shown on Figure 1 below. This supply would be used to provide municipal and industrial water to Cache County, the Bear River Water Conservancy District, the Weber Basin Water Conservancy District, and the Jordan Valley Water Conservancy District and would also provide environmental and recreational benefits to the region.

As part of the project, water would be diverted from the Bear River and seasonally stored in reservoirs for later use by the project stakeholders listed above. The water supply from this project can be effectively developed only through storage. Under the State's rights on the Bear River system, water is available for diversion primarily in the winter and spring. Very little flow is available for diversion during the summer, when the project stakeholders have their peak demands.

Preliminary hydrologic modeling conducted by the Utah Division of Water Resources shows that the project would require at least 250,000 acre-feet of storage in order to reliably deliver the full Bear River Project supply of 220,000 acre-feet per year. Because few sites in the Bear River Basin can store the full 250,000 acre-feet of water, it is necessary to evaluate combinations of several reservoirs.

Previous studies have identified six preferred dam site locations in the Bear River Basin to meet the storage and supply requirements described above. The general locations of these dam sites are shown on Figure 2 on page 27:

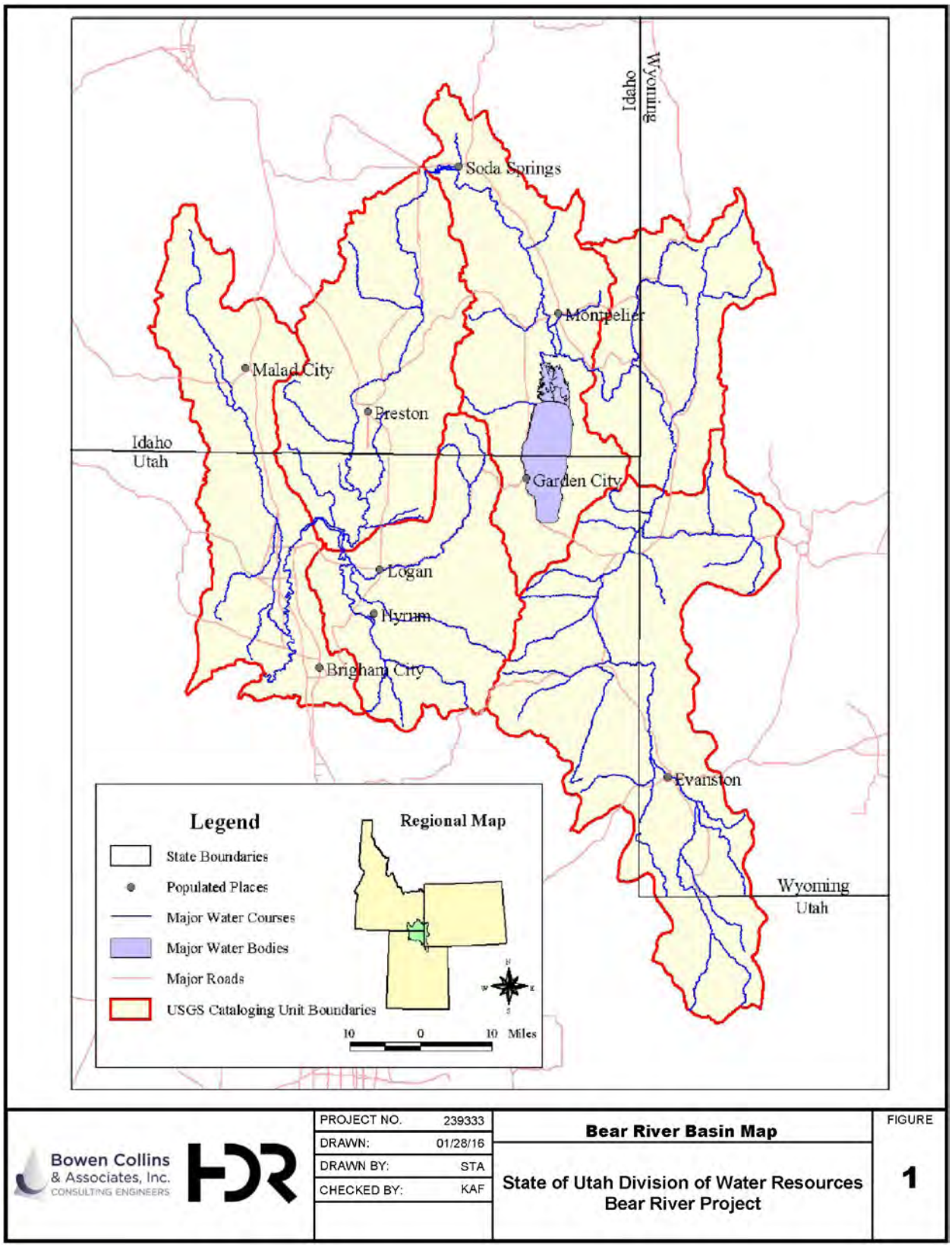
- Above Cutler
- Cub River
- Fielding
- South Willard Bay
- Temple Fork
- Whites Valley

Of the six sites evaluated in this study, only two (Temple Fork and Whites Valley) have bedrock close enough to the surface that a dam could be founded on rock. As described in more detail later in this report, the Temple Fork site is best suited for a roller-compacted concrete (RCC) dam because the high-quality rock can provide a solid foundation. The Whites Valley site is suitable for an earth-core rockfill dam (ECRD) or possibly a concrete-faced rockfill dam (CFRD) because both soil borrow for core material and rock borrow for rockfill are available. Dams at the other four sites (Above Cutler, Cub River, Fielding, and South Willard Bay) would need to be founded on deep soil deposits, so embankment dams would be best suited to those four sites.

The HDR team responsible for completing the study and preparing this report is:

Project manager	Steve Thurin, PE
Principal engineer	Keith Ferguson, PE
Senior geotechnical engineer	Dan Osmun, PE
Material properties	Gokhan Inci, PE, PhD
Geotechnical analyses	Scott Anderson, PE

Figure 1. Bear River Basin Map



3 Subsurface Conditions and Material Properties

In 2014, HDR developed a site-characterization program to be used for each of the six proposed dam sites. The Bowen-Collins/HDR team performed the site subsurface exploration and laboratory testing program (with some modifications) in 2014 and 2015. Our understanding of the general site and subsurface conditions for each dam site was obtained from site-specific geotechnical data reports prepared by Gerhart Cole, Inc. (2015). Each site report generally includes:

- Subsurface information (site conditions) obtained from subsurface exploration (drilling, sampling, and testing)
- Descriptions of the geologic setting, geologic deposits and formations, and geologic hazards
- Field and laboratory test results
- Groundwater information

The number of borings and the corresponding laboratory testing performed for each site was consistent with the general industry standard of care for early appraisal and/or feasibility-level evaluations. The initial site-characterization program gave HDR important insights into some of the key design and construction issues at each site and the basis for identifying the preferred dam type at each location. Additional site characterization will be needed to update the dam designs and refine costs in order to reduce risks and the uncertainties of the estimates. Refined cost estimates would then be suitable for evaluating the alternatives and selecting a preferred combination of reservoirs to meet the project's overall water-supply objectives.

For each dam site, HDR reviewed the available subsurface information and laboratory testing and made extensive use of published correlations and our general experience in similar geologic environments to evaluate the material properties for use in our engineering analyses. The Gerhart Cole geotechnical data reports included triaxial strength test results as well as index property test results for various foundation soil units. It is important to recognize that, for this level of study, strength tests from various depths representing each material type, and for each different loading condition and associated potential failure conditions, are not typically available. The HDR team applied engineering judgment and correlations using the field and laboratory information that was available. Therefore, this report does not contain a detailed evaluation of the basis for selecting each strength value. Rather, where direct testing was not available, general strength assignments are made so that the relative strength values for different materials under different loading conditions and the potential configurations of failure surfaces make sense.

Subsequent sections of this report provide justifications for selecting different dam types at the different sites. For ease of presentation, this report presents all material properties for each dam site in one section rather than having separate sections for dam (embankment or concrete) material properties and foundation material properties.

The assumed subsurface conditions and material properties for each dam site are described in the following sections.

3.1 Above Cutler

The simplified foundation stratigraphy model used at the Above Cutler site consists of an upper silty sand and poorly graded silty sand (SM and SP-SM) layer that is underlain by both a lean clay (CL) layer and a deeper fat clay (CH) layer. The lower limit of the model corresponds to where the boring for the maximum dam cross-section was terminated. The clay deposits were found to be soft with low strengths.

Table 1 summarizes the material properties assigned to the foundation layers as well as the embankment zones. Note that, for this study, embankment shells and core were judged to have the same strength properties because their likely borrow sources would not be substantially different. However, as part of design refinements and explorations of borrow areas, more-granular units might be identified for the embankment shells. Some of the shear strength values presented were not used in the analysis cases in this report but are presented for future reference when the analysis cases are expanded to address other loading conditions.

Table 1. Above Cutler: Summary of Embankment and Foundation Material Properties

Material Description	Unit Weight γ_{moist} (pcf)	Static Stability				Post Earthquake Stability	
		Effective (Drained) Shear Strength		Total (Undrained) Shear Strength			
		ϕ' (deg)	c' (psf)	ϕ (deg)	c (psf)	Liquefied Residual Strength S_r/σ'_{vo}	Undrained Shear Strength, S_u (psf)
Embankment shells and berms (SM, SC, CL)	120	30	50	14	500	—	3,000*
Filter and drain (SW)	125	35	0	—	—	—	
Core (SM, SC, CL, CH)	120	30	50	14	500	—	3,000*
Upper sand (SM, SP)	125	35	0	—	—	0.06	
Upper lean clay (CL)	115	19	250	9	250	—	250*
Lower fat clay (CH)	115	19	250	9	250	—	250*

* The undrained strengths for earthfills and for foundation CL and CH have been further reduced to 2,400 and 200 psf, respectively, for pseudostatic stability analysis.

3.2 Cub River

The Cub River site's stratigraphy model consists of a lean clay (CL) crust with slightly higher-strength soil underlain by silty sand and poorly graded silty sand (SM and SP-SM), which is underlain by a fat clay (CH) soil to the depths explored. At the proposed abutments, an upper fat clay (CH) soil is present that is not present at the valley section.

Table 2 summarizes the material properties assigned to the foundation layers as well as the embankment zones. Note that, for this study, embankment shells and core were judged to have the same strength properties because their likely borrow sources would not be substantially different. However, as part of design refinements and explorations of borrow areas, more-granular units might be identified for the embankment shells. Some of the shear strength values presented were not used in the analysis cases in this report but are presented for future reference when the analysis cases are expanded to address other loading conditions.

Table 2. Cub River: Summary of Embankment and Foundation Material Properties

Material Description	Unit Weight γ_{moist} (pcf)	Static Stability				Post Earthquake Stability	
		Effective (Drained) Shear Strength		Total (Undrained) Shear Strength			
		ϕ' (deg)	c' (psf)	ϕ (deg)	c (psf)	Liquefied Residual Strength S_r/σ'_{vo}	Undrained Shear Strength, S_u (psf)
Embankment (SM, SC, CL)	120	30	50	14	500	—	3,000*
Filter (SW)	125	35	0	—	—	—	—
Core (SM, SC, CL, CH)	120	30	50	14	500	—	3,000*
Upper CH (at abutments)	115	31	50	13	500	—	2,000*
CL layer	112	29	50	13	500		1,000*
Sand (SM, SP)	125	30	0	—	—	0.06	—
Lower CH	115	28	50	13	500	—	250*

* The undrained strengths for earthfills, upper CH, CL, and lower CH are reduced to 2,400, 1,600, 800, and 200 psf, respectively, for pseudostatic stability analysis.

3.3 Fielding

Site explorations at the Fielding site indicate a complex depositional environment with many soil units varying in gradation from gravels to clays. For analysis purposes, the foundation model was simplified into six units. The Fielding foundation model includes an upper lean clay (CL) soil underlain by a poorly graded, silty gravel (GP-GM) that is in turn underlain by a lower lean clay (CL) soil. The lower lean clay soil is followed with a silt (ML) layer and a silty sand (SM) layer, which is underlain by a fat clay (CH) soil that is followed with a lower silt soil. The lower silt is the deepest layer that was encountered in the boring performed near the maximum cross-section of the proposed dam. There is also an upper lean clay (CL) soil present at the proposed abutments that is above the upper lean clay found in the valley section.

Table 3 summarizes the material properties assigned to the foundation layers as well as the embankment zones. Note that, for this study, embankment shells and core were judged to have the same strength properties because their likely borrow sources would not be substantially different. However, as part of design refinements and explorations of borrow areas, more-granular units might be identified for the embankment shells, particularly since a gravel unit was encountered in explorations just below the surficial clay layer. Some of the shear strength values presented were not used in the analysis cases in this report but are presented for future reference when the analysis cases are expanded to address other loading conditions.

Table 3. Fielding: Summary of Embankment and Foundation Material Properties

Material Description	Unit Weight γ_{moist} (pcf)	Static Stability				Post Earthquake Stability	
		Effective (Drained) Shear Strength		Total (Undrained) Shear Strength			
		ϕ' (deg)	c' (psf)	ϕ (deg)	c (psf)	Liquefied Residual Strength S_r/σ'_{vo}	Undrained Shear Strength, S_u (psf)
Embankment (GM, SW, SP, SM, SC, ML, CL)	120	30	50	14	500	—	3,000*
Filter (SW)	125	35	0	—	——	—	—
Core (SM, SC, ML, CL, CH)	125	30	50	14	500	—	3,000*
Upper CL at abutments	123	28	500	15	1,000	—	1,000*
Upper CL	118	28	500	15	1,000	—	1,200*
Gravel (GP, GM)	130	34	0	—	—	0.06	—
Middle CL	123	32	500	17	1,000	—	750*
Sand/silt (SM, ML)	125	35	0	—	—	0.2	—
Lower CH	121	13	1,000	6	1,000	—	2,000*
Silt (ML)	115	33	0	—	—	—	—

* The undrained strengths for earthfills, upper CL at abutments, upper CL, middle CL, and lower CH are reduced to 2,400, 800, 960, 600, and 1,600 psf, respectively, for pseudostatic stability analysis.

3.4 South Willard Bay

The foundation soils at the South Willard Bay site consisted of fill and native silt (ML) soils underlain by lean clay (CL) soils. For evaluating the material properties, the clay unit was divided into three separate units. However, the foundation model was subsequently simplified with one clay unit in the analytical model.

Table 4 summarizes the material properties assigned to the foundation layers as well as the embankment zones. Some of the shear strength values presented were not used in the analysis cases in this report but are presented for future reference when the analysis cases are expanded to address other loading conditions.

Table 4. South Willard Bay: Summary of Embankment and Foundation Material Properties

Material Description	Unit Weight γ_{moist} (pcf)	Static Stability				Post Earthquake Stability	
		Effective (Drained) Shear Strength		Total (Undrained) Shear Strength			
		ϕ' (deg)	c' (psf)	ϕ (deg)	c (psf)	Liquefied Residual Strength S_r/σ'_{vo}	Undrained Shear Strength, S_u (psf)
Embankment (SM, SC, ML, CL)	115	30	50	14	500	—	3,000*
Filter (SW)	125	35	0	—	—	—	—
Silt (ML)	115	35	0	—	—	0.06	—
Upper clay (CL)	110	19	100	10	100	—	500*
Middle clay (CL)	110	19	100	10	100	—	500*
Lower clay (CL)	110	27	50	6	500	—	500*

* The undrained strengths for earthfills, upper CL, middle CL, and lower CL are reduced to 2,400, 400, 400, and 1,200 psf, respectively, for pseudostatic stability analysis.

3.5 Temple Fork

The Temple Fork site has limestone and siltstone bedrock beneath about 20 to 25 feet of silt (ML) and poorly graded silty gravel (GP-GM) overburden soils. The limestone was divided into upper, middle, and lower units with different strength and permeability properties. Upper and lower siltstone units separate the limestone units and were also assigned differing strength and permeability properties. The boring for the maximum cross-section was terminated in the lower limestone layer.

Table 5 summarizes the material properties assigned to the foundation units as well as the RCC. Note that a structural model of the proposed dam cross-section was not completed as part of the current study. The cross-section properties are based on our general experience with similar-height RCC dams in a moderate seismic environment. The properties in Table 5 will be augmented and used for 2-D finite element response spectrum and time history analyses.

Table 5. Temple Fork: Summary of Dam and Foundation Material Properties

Material Description	Unit Weight γ_{moist} (pcf)	Effective Shear Strength		Total Shear Strength	
		ϕ' (deg)	c' (psf)	ϕ (deg)	c (psf)
RCC	140	—	—	0*	360,000*
Backfill (ML, SM)	120	30	0	—	—
Silt (ML)	115	25	0	—	—
Sand (GP-GM)	130	35	0	—	—
Upper limestone	140	—	—	0	500,000
Upper siltstone	140	—	—	0	190,000
Middle limestone	140	—	—	0	500,000
Lower siltstone	160	—	—	0	190,000
Lower limestone	160	—	—	0	500,000

* For the RCC/limestone bedrock interface, friction is selected as 55 degrees with no adhesion.

3.6 Whites Valley

The Whites Valley site has calcareous sandstone bedrock beneath about 25 feet of silt, sand, and gravel overburden soils. The calcareous sandstone bedrock was encountered to the depths explored.

Table 6 summarizes the material properties assigned to the foundation units as well as the embankment materials. Note that, for this study, HDR assumed that a rockfill borrow source would be developed and made a generally conservative (low) assumption for rockfill strength. Well-built compacted rockfill dams are generally very strong and perform well under normal operations and under seismic loadings. HDR expects that, as part of design refinements and explorations of borrow areas, particularly explorations of rock borrow areas, more-site-specific information would provide justifications for higher strengths.

Table 6. Whites Valley: Summary of Embankment and Foundation Material Properties

Material Description	Unit Weight γ_{moist} (pcf)	Static Stability				Post Earthquake Stability	
		Effective (Drained) Shear Strength		Total (Undrained) Shear Strength			
		ϕ' (deg)	c' (psf)	ϕ (deg)	c (psf)	Liquefied Residual Strength S_r/σ'_{vo}	Undrained Shear Strength, S_u (psf)
Zone 3 rockfill	135	40	0	—	—	—	—
Zone 2 transition (GP, GW, SW, SP)	125	36	0	—	—	—	—
Filter (SW)	125	35	0	—	—	—	—
Core (SC, ML, CL, CH)	125	33	50	13	100	—	3,000*
Grout curtain	130	0	21,600	—	—	—	—
Backfill (ML, SM)	120	32	0	—	—	—	—
Silt (ML)	115	30	0	—	—	—	—
Sand (SM, GP-GM)	125	35	0	—	—	—	—
Calcareous sandstone	160	0	1,200,000	—	—	—	—

* The undrained strength for core is reduced to 2,400 psf for pseudostatic stability analysis.

4 Methodology for the Conceptual Design and Analysis

This section describes the methodology for the conceptual design and analysis that HDR followed to arrive at the dam configurations presented in this report. Our design process was iterative, with a goal of developing a dam configuration geometry that would satisfy standards-based design criteria and would perform well for a large range of seismic loadings. A simplified methodology is provided below:

1. Begin with a basic dam type and configuration for each site, given the site and subsurface conditions.
2. Evaluate the material properties for each site for various loading conditions.
3. Perform seepage and stability analyses for the long-term steady-state seepage case and the post-seismic case, assuming some strength loss from cyclic loading.
4. Review the stability results and compare them to the design criteria. Revise the cross-section geometry as needed to improve stability. Typically, this involved adding stability berms to improve stability for the post-seismic case.
5. Repeat steps 3 and 4, reanalyzing seepage and stability until the design criteria are satisfied.
6. Perform a pseudostatic stability analysis to estimate the yield acceleration (that is, the horizontal seismic acceleration that results in a factor of safety of 1.0). This is an iterative process in which the yield acceleration is continuously changed and critical failure surfaces are evaluated until the minimum computed factor of safety is 1.0.
7. Using several published empirical methods for estimating seismic deformation, use a range of earthquake return periods and corresponding loadings, along with the estimated yield accelerations from the pseudostatic analyses, to estimate possible seismic deformations.
8. Review deformation estimates and compare them to tolerable deformation criteria developed by HDR for this conceptual design project. Revise the cross-section geometry as needed to reduce deformation.
9. Repeat steps 6, 7, and 8 until the estimated deformations are judged to be tolerable or marginally tolerable.

The methodology described above is considered industry standard for dam design. Further details regarding the methodology used are not included in this conceptual analysis report. Higher-level analysis and design studies would typically include more-thorough descriptions of the methodology and procedures followed. Also, these steps generally apply to the five embankment dam sites but not the Temple Fork site, since the proposed RCC dam is a concrete gravity structure founded on rock.

4.1 Basic Dam Types and Configurations

At four sites (Above Cutler, Cub River, Fielding, and South Willard Bay), deep soil deposits preclude constructing a concrete dam, so HDR selected embankment dams for these sites. The Above Cutler, Cub River, and Fielding dams were configured as zoned earthfill dams with a central clay core, filter, and earthfill shells. For these sites, more-granular borrow areas (for example, sandy or gravelly materials) might be developed, resulting in different zoning in the earthfill dam. At South Willard Bay, given the geologic environment, it is unlikely that a significant granular borrow area could be developed, so the proposed dam is a homogeneous earthfill dam with an internal filter and drain system.

The Temple Fork site is probably best suited for an RCC dam because it has high-quality foundation rock that can provide a solid foundation. The RCC dam also has the advantage of economics associated with combining hydraulic structures (spillway and outlet works) as part of the structure and can most readily be adapted to avoid or mitigate any foundation faulting issues.

The Whites Valley site is unique among the six sites because it is likely the only site where both fine-grained and rockfill borrow sources could be easily developed and used, making an ECRD well suited for this site.

4.2 Criteria for Analyzing the Stability of Embankment Dams

The State of Utah, as well as federal agencies such as the Federal Energy Regulatory Commission (FERC), the U.S. Army Corps of Engineers (USACE), and the Bureau of Reclamation, provides criteria for analyzing the stability of a dam design in terms of minimum factors of safety. An excerpt from the State of Utah guidelines is provided below. The State of Utah guidelines are generally consistent with various federal guidelines.

R655-11-6A. Factors of Safety.
A. All dams should meet the following criteria for factors of safety under normal loading conditions.

TABLE

Condition	Minimum Factor of Safety
End of Construction Case--upstream and downstream slopes	1.3
Steady State Seepage--upstream and downstream slopes (full pool)	1.5
Instantaneous Drawdown--upstream slope	1.2
OR	
Actual Drawdown--upstream slope	1.5

Although HDR is aware of the minimum factor-of-safety criteria shown above, HDR's development of each dam's cross-section and zoning for the soil foundation sites was driven by the seismic response (deformations) of the structures. The tolerable and marginally tolerable deformation guidelines used in our evaluation (described in

Section 4.4) are based on our experience with similar evaluations in Utah and other regulatory environments (FERC, USACE, Reclamation, and programs in other states).

4.3 Earthquake Hazard Review

HDR used the U.S. Geological Survey's (USGS) website to evaluate the earthquake hazard for the six potential dam sites. Earthquake magnitude values and peak ground acceleration (PGA) values were estimated as summarized in Tables 7 and 8. A minimum magnitude of 6.5 was used as the random or background event, as discussed in the State of Utah's dam safety guidelines (document R655-11-5A). For this conceptual study, the maximum considered event (MCE) is taken as the event corresponding to a return period of 9,975 years.

Also, a V_{s30} shear wave velocity value of 760 meters per second (m/s) was assumed for estimating the PGA values. However, amplification effects could be associated with the deep soil-filled basins. More-site-specific seismic hazards would need to be developed in order to better understand the ground motions at each site. The values presented in Tables 7 and 8 were used in the empirical methods of analyzing seismic deformation to estimate the seismic deformation at each site.

Table 7. Estimated Earthquake Magnitude Values

Site	Magnitude for Return Period (mean/modal)				
	475 Years	975 Years	2,475 Years	4,975 Years	9,975 Years
Above Cutler	6.4 / 6.6	6.4 / 6.6	6.5 / 6.6	6.6 / 6.6	6.7 / 6.6
Cub River	6.3 / 6.6	6.4 / 6.6	6.6 / 6.6	6.7 / 6.6	6.8 / 7.2
Fielding	6.4 / 6.6	6.4 / 6.6	6.4 / 6.6	6.4 / 7.0	6.4 / 7.0
South Willard Bay	6.8 / 7.0	6.9 / 7.0	6.9 / 7.0	7.0 / 7.0	7.0 / 7.0
Temple Fork	6.3 / 7.2	6.3 / 7.2	6.4 / 7.2	6.4 / 7.2	6.4 / 7.2
Whites Valley	6.2 / 6.6	6.2 / 6.6	6.2 / 6.6	6.2 / 6.2	6.2 / 6.2

Source: USGS 2008

Table 8. Estimated Peak Ground Acceleration Values

Site	Peak Ground Acceleration (g) for Return Period				
	475 Years	975 Years	2,475 Years	4,975 Years	9,975 Years
Above Cutler	0.17	0.25	0.39	0.52	0.67
Cub River	0.17	0.25	0.41	0.55	0.72
Fielding	0.17	0.24	0.34	0.43	0.52
South Willard Bay	0.20	0.32	0.51	0.66	0.83
Temple Fork	0.16	0.22	0.32	0.41	0.52
Whites Valley	0.15	0.20	0.29	0.36	0.45

Source: USGS 2008

4.4 Seismic Tolerable-Deformation Scale

Critical potential failure modes for the embankment dams are related to seismic deformation. Earthquake shaking can reduce the strength of soft or loose materials, possibly resulting in instability, deformations, and cracks in the embankment. For higher-level studies, embankment dams are modeled using complex software programs (such as FLAC), and stresses and deformations are calculated and can be compared to the available freeboard to assess the potential for a dam to fail.

However, for this conceptual study, HDR used simple empirical methods to estimate deformations. HDR used a relatively simple tolerable-deformation scale as an initial criterion by which to assess adequate seismic performance for the embankment dams, all of which are assumed to have 10 feet of freeboard at the maximum height of the reservoir pool. The tolerable-deformation scale is summarized below:

- Tolerable displacement: less than 3 feet
- Marginally tolerable displacement: 3 to 5 feet
- Intolerable displacement: greater than 5 feet

It is important to note that this scale is only for these dams for this focused study. As more-site-specific seismic ground motions are developed and the project team better understands the seismic properties of the materials, the team can apply a greater degree of sophistication in its analysis and design in order to make appropriate judgments regarding the seismic performance of the dams.

5 Results of the Analysis of Seepage, Stability, and Seismic Deformations

To support developing dam configurations at each site, HDR performed a series of seepage and stability analyses, as described in Section 4. Using these results, HDR then used various empirical methods to estimate the potential for the dams to deform. Depending on the results of both the stability and deformation analyses, HDR's objective was to iteratively adjust the dam cross-section geometry until acceptable safety and performance were achieved.

Note that the configurations presented in this report are based on limited site-characterization information and simplified and conservative evaluation methods. HDR will be able to further refine and optimize the dam configurations as additional information is obtained and evaluated during future phases of the project.

HDR used seepage analyses to establish the potential seepage patterns and water pressures in the dams and foundations. These seepage analyses were performed with the estimated permeability parameters that produced the most-conservative estimates of the water pressures that could develop in the dams and foundations.

Two primary loading conditions were evaluated as part of this study.

- **Static stability analysis cases considering maximum pool steady-state seepage conditions using drained strength parameters (long-term conditions).** Both the upstream and downstream slopes of the dams were evaluated.
- **Post-earthquake stability using degraded or residual strengths.** This condition was evaluated and was generally found to control the cross-section requirements for the upstream and downstream slopes of each soil-foundation dam.

Based on our experience, we believe that, after satisfactory cross-section geometry is established for the two primary loading conditions above, the same geometry will be suitable for other loading conditions such as construction and rapid drawdown; although we did not perform analyses for those cases. As noted in Section 3, the earthfill embankment sites (Above Cutler, Fielding, South Willard Bay, and possibly Cub River) could require additional design and construction provisions to address construction-related pore water pressures that might develop in foundation clay layers. Additional construction-related evaluations will be needed during future design work to refine such project requirements.

5.1 Results of the Slope Stability Analysis

Table 9 summarizes the results of the static and post-earthquake slope stability analyses that HDR performed for both the upstream and downstream slopes of the maximum cross-section of each proposed embankment dam. The post-earthquake analyses for the upstream slopes were performed for normal maximum conditions in the reservoir pools. The minimum post-earthquake factor of safety values for the upstream slopes would approach those obtained for the downstream slopes as the reservoir water levels drop during certain times of the year. Hence, the dam cross-sections are generally symmetrical at this time. Future site characterization should provide information that is suitable to confirm and/or establish appropriate stratigraphy models and corresponding engineering properties for both the upstream and downstream parts of the embankments.

Table 9. Summary Results of Slope Stability Analysis

Slope and Analysis Case	Estimated Minimum Factor of Safety and Yield Acceleration				
	Above Cutler	Cub River	Fielding	South Willard Bay	Whites Valley
Downstream Slope					
Steady-state seepage (static)	2.54	1.81	2.55	3.19	1.81
Post-seismic	1.38	1.21	1.03	1.35	1.56
Yield acceleration	0.04g	0.05g	0.01g	0.04g	0.17g
Upstream Slope					
Steady-state seepage (static)	2.45	2.49	2.50	3.97	2.10
Post-seismic	2.48	2.20	2.25	2.10	1.67

5.2 Results of the Empirical Newmark Deformation Analysis

HDR estimated potential seismic deformations of the embankments using simplified (empirical) Newmark sliding block analyses for each of the embankment dam configurations. Rigid-block analysis, first developed by Newmark (1965), treats a mass block created by a slope failure as a rigid mass (no internal deformation) that slides in a perfectly plastic manner on an inclined plane. Thus, the mass experiences no permanent displacement until the base acceleration exceeds the critical (yield) of the block; when the base acceleration exceeds the critical acceleration, the block begins to move downslope.

HDR performed these analyses once a cross-section configuration with a post-seismic factor of safety of above 1.0 was established. The simplified methods included those developed by Ambraseys and Menu (1988), Jibson (2007), Saygili and Rathje (2008), and Rathje and Saygili (2009). These simplified methods require estimates of yield acceleration as well as one or both of the following variables: estimated PGA and earthquake magnitude (M). The yield acceleration is evaluated for cross-sections with

post-seismic factors of safety above 1.0 by increasing the seismic coefficient in the model until a minimum factor of safety value of 1.0 is obtained.

The empirical methods listed above use regression equations to estimate the amount of deformation that is expected for combinations of the two above-mentioned variables. Although these empirical methods are not as rigorous as analyses that use the actual ground motions, they provide a relative indication of the magnitude of deformation that can be expected based on the observed performance of similar dams subjected to significant earthquakes.

HDR considered both circular and nonlinear-shaped failure surfaces. Nonlinear surfaces based on both circular and wedge types of analyses produce the smallest yield coefficients. For the earthen embankments on soft foundations (Above Cutler, Cub River, Fielding, and South Willard Bay), the post-seismic failure surfaces are located within the layers having zero, or very low blow count, clay materials. Although adding berms both upstream and downstream of the main embankment cross-section produces post-seismic factor-of-safety values above 1.0, the yield acceleration coefficients for these cross-sections remained very low (< 0.05g). When cross-sections were analyzed using the simplified Newmark methods, displacement was relatively high, and some additional modifications to the cross-sections were needed to converge on a configuration that we believe is acceptable at this time from a planning standpoint.

HDR considers these estimates of displacements to be possible movement of the dam crest, and they likely include both vertical and horizontal components. Under full pool conditions, the displacements would occur in the downstream direction. The displacement-tolerance scale shown in Section 4.4 is based on the assumption that the estimated crest deformations are primarily vertical.

Although the proposed dam configurations currently include 10 feet of flood-routing freeboard, if total displacements are higher than about 5 feet, the dam would likely experience significant transverse cracking that could lead to potential failure of the dam. In such a situation, the dam would likely fail as a result of contact erosion through these cracks when the reservoir is at the maximum normal pool elevation.

Note that estimating embankment deformations as a result of earthquake loadings involves a high degree of uncertainty. At some sites, different empirical methods of estimating displacements indicate a wide range of values for the same return period. To illustrate this, HDR estimated and has provided a range of values.

In addition, large seismic deformations caused by soft soils can lead to other seepage-related safety issues such as excessive deformation of filter elements and chimney and blanket drains, or transverse or longitudinal cracking due to differential settling of the embankment.

6 Conclusions

6.1 Overall Study Conclusions

In general, all six of the dam sites appear technically feasible for dam structures, although some, particularly the four soil foundation sites, would require more soil and site improvement. Four of the six sites (Above Cutler, Cub River, Fielding, and South Willard Bay) would be suitable for earthfill embankment dams. The Temple Fork site is best suited for an RCC gravity dam. The Whites Valley site is suitable for an ECRD or possibly a CFRD. When completed, the feasibility of configuration of hydraulic structures at each site will be presented in a different report.

HDR developed the overall cross-section for each dam using the iterative design process described in Section 4. Each cross-section is based on our general understanding of the site's geology and stratigraphy, our initial assessment of the engineering properties of both the foundation and possible embankment materials, the anticipated loading conditions, and our experience with the design, construction, safety, and long-term performance of similar types of dams. These preliminary cross-sections were developed for each dam for the purposes of evaluating technical feasibility, developing cost estimates, and guiding alternatives evaluation and future studies. Summaries of the proposed dam types and configurations are provided in the site-specific sections below.

The site subsurface exploration and laboratory testing program provided a significant amount of technical information and insight into the geologic and geotechnical conditions present at each site and the challenges that need to be addressed. Further site characterization and design development will be needed in order to further refine and identify preferred alternatives and configurations at each site.

At the soil foundation sites where earthfill dams are proposed (Above Cutler, Cub River, Fielding, and South Willard Bay), embankment borrow materials are generally available with the exception of (1) clean sand and gravel materials for filters and drains and (2) rock materials for riprap and slope protection. When constructing new dams or modifying existing dams, it is common to import the high-quality materials needed for these important components of the dam.

At the four soil foundation sites (Above Cutler, Cub River, Fielding, and South Willard Bay), subsurface exploration, laboratory testing, and geotechnical analyses indicated significant challenges with regard to shear strength, seismic deformation, settlement, and seismic performance. The challenges at these sites are driven by foundation geology and our understanding based on limited borings and laboratory testing. More exploration and testing can better define these design concerns. However, the foundation geology would likely still present design challenges for foundation strength, static and seismic deformations, and seepage concerns.

Very large settlements that could take many years to fully manifest after construction would require significant crest overbuild and camber and could require additional future crest modifications. Liquefaction of silts and sands encountered at each of the soil foundation sites could also present seismic design challenges. Liquefaction evaluations would need to consider the density of the potentially liquefiable materials, the seismic

loading that would trigger liquefaction, and the lateral continuity of potentially liquefiable materials.

Significant pore water pressure development in soft, fine-grained foundation soils as a result of loads created by constructing the embankment could cause temporary instability. It might become necessary to consider staging construction and installing foundation treatments such as wick drains. Staged construction would most likely be required at the four soil foundation sites. Staged construction allows the soft materials to slowly consolidate and gain strength as the loading from the embankment is increased in stages. Installing wick drains would accelerate the rate of consolidation (settlement) and pore pressure dissipation required to provide adequate stability during and immediately after construction. The amount of anticipated strength gain could be evaluated through a well-planned geotechnical exploration and testing program.

In lieu of staged construction, the foundation could also be strengthened using a variety of methods such as (1) deep mixing method (DMM), (2) jet grouting, or (3) other ground-improvement methods. These methods would result in either a longer period for consolidation and construction or increased costs for ground improvement. If the foundation conditions are not improved, through either pre-loading (consolidation) or ground improvement (DMM and/or jet grouting), acceptable post-seismic factors of safety and estimated seismic deformations might not be achievable.

In addition to specialized considerations related to foundation strength, multiple lines of defense would also be needed for seepage control and safety against internal erosion. The overall filter and drainage design for each dam would need to consider positive seepage cutoffs to relatively impermeable units as well as toe drains and filters at seepage exits.

6.2 Above Cutler

An earthfill embankment dam at the Above Cutler site would have a central, relatively impervious core or zone tied into an impervious layer within the foundation. The core would be protected against cracking and possible internal erosion and/or other potential failure modes by a downstream filter and blanket drain system. Depending on the characteristics of the embankment materials used for the outer “shells” of the dam, other internal transition zones might be required in order to provide the dam with adequate internal stability under all possible loading conditions.

A generalized cross-section for an earthfill embankment dam at the Above Cutler site is shown on Figure 3. The results of the seepage analyses are shown on Figure 4, and the results of the steady-state seepage (static) stability analyses are shown on Figure 5. The results of the post-seismic stability analysis are shown on Figure 6. Estimated seismic deformations are shown on Figure 7 (pages 28–33).

The geotechnical exploration and laboratory testing program indicates that very soft soils that are problematic for stability and seismic deformation are prevalent in the area of the proposed dam foundation. In order to achieve reasonable post-seismic factors of safety, large upstream and downstream berms were added to the proposed embankment. Our initial assessment suggests that these berms would be about 200 feet long and 12 feet high. The embankment would slope from an elevation of 4,422 feet at the top of the

berms to the dam crest elevation of 4,442 feet at 4H:1V on both the upstream and downstream sides of the dam.

In addition, HDR performed a parameter study for the post-seismic stability condition to estimate how much the foundation strength would need to be improved in order to achieve various factors of safety with the berms in place. The results indicate that an estimated foundation residual strength of about 450 psf would provide a post-earthquake factor of safety of about 1.5. The estimated empirical seismic deformations would also be excessive if the foundation strength were not improved. With a residual strength of about 450 psf, estimated seismic deformations range from tolerable to marginally tolerable (depending on the earthquake return period and the empirical method used).

Based on these simplified analyses and HDR's current knowledge of the subsurface conditions, designing and constructing a 32-foot-high embankment at the Above Cutler site would likely require significant foundation improvements and large stability berms that would add significant costs to development of this site. Furthermore, the long-term performance is questionable because of the potential for significant settling of the foundation, which could result in cracks in the embankment and the need to raise the crest in the future to maintain operational freeboard.

Because of the significant geotechnical concerns identified at the Above Cutler site, the State of Utah should consider ranking this site relatively low compared to the other sites when selecting sites to be carried forward into subsequent studies.

6.3 Cub River

An earthfill embankment dam at the Cub River site would have a central, relatively impervious core or zone tied into an impervious layer within the foundation. The core would be protected against cracking and possible internal erosion and/or other potential failure modes by a downstream filter and blanket drain system. Depending on the characteristics of the embankment materials used for the outer "shells" of the dam, other internal transition zones might be required in order to provide the dam with adequate internal stability under all possible loading conditions.

The exterior upstream and downstream embankment slopes would be about 4H:1V from the ground surface at the toes to an elevation of 4,443 feet. Above this elevation, the upstream slope would continue to the dam crest at a slope of 3H:1V, while the downstream slope would continue at 2.5H:1V to the crest elevation of about 4,475 feet.

A generalized cross-section for an earthfill embankment dam at the Cub River site is shown on Figure 8. The results of the seepage analyses are shown on Figure 9, and the results of the steady-state seepage (static) stability analyses are shown on Figure 10. The results of the post-seismic stability analysis are shown on Figure 11. Estimated seismic deformations are shown on Figure 12 (pages 33–37).

The geotechnical exploration and laboratory testing program indicates that some soft soils are present in the area of the proposed dam foundation but with strengths greater than those at the Above Cutler site. Analyses indicate satisfactory stability and deformation estimates without the need for additional berms.

6.4 Fielding

The Fielding site is suitable for an earthfill embankment dam with a central, relatively impervious core or zone. The geology of this site is relatively complex with various layers of clays, silts, sands, and gravels. It would be necessary to achieve a positive cutoff of seepage between the central impermeable zone and a suitable, continuous impervious foundation layer. The depth to a suitable impervious foundation layer could be variable across the profile of the dam, and alternate methods for constructing an impermeable cutoff of seepage to and through the foundation, such as a deep vertical wall installed using slurry wall construction techniques, could be required.

The core would be protected against cracking and possible internal erosion and/or other potential failure modes by a downstream filter and blanket drain system. Depending on the characteristics of the embankment materials used for the outer “shells” of the dam, other internal transition zones might be required in order to provide the dam with adequate internal stability under all possible loading conditions. In addition, it might be necessary to construct a foundation toe drain system to provide adequate filtered drainage of foundation seepage that bypasses the primary seepage cutoff system.

A generalized cross-section for an earthfill embankment dam at the Fielding site is shown on Figure 13. The results of the seepage analyses are shown on Figure 14, and the results of the steady-state seepage (static) stability analyses are shown on Figure 15. The results of the post-seismic stability analysis are shown on Figure 16. Estimated seismic deformations are shown on Figure 17 (pages 38–42).

The geotechnical exploration and laboratory testing program indicates that low-strength soils that are problematic for stability and seismic deformation are prevalent in the area of the proposed dam foundation. In order to increase the post-seismic factors of safety, large upstream and downstream berms were added to the proposed embankment. Our initial assessment suggests that these berms would be about 150 feet long and 25 feet high. From the intersection of the berm and the upstream slope, the exterior slope would continue to the dam crest at 3H:1V, while the downstream slope would continue at 2.5H:1V to the dam crest at an elevation of 4,310 feet.

The estimated seismic displacements are large and greater than what is considered to be tolerable by current industry standards. Our efforts to reduce the estimated deformations by increasing the berm sizes were only marginally effective.

Based on these simplified analyses and HDR’s current knowledge of the subsurface conditions, designing and constructing a 67-foot-high embankment at the Fielding site would likely require significant foundation improvements such as enhanced foundation drainage with wick drains, installation of a shear key, larger stability berms, soil treatment through mixing or jet grouting, or a combination of these treatment methods. If the low strength of the foundation materials is confirmed, necessary foundation improvements would add significant costs to developing this site. Furthermore, the long-term performance is questionable because of the potential for significant settling of the foundation, which could result in cracks in the embankment and the need to raise the crest in the future to maintain operational freeboard.

Because of the significant geotechnical concerns identified at the Fielding site, the ranking for this site might be similar to but higher than that of the Above Cutler site.

Because of its favorable location, it is likely that this site will be carried forward into subsequent studies. Future studies will require highly technical site characterization and laboratory testing work that is very challenging. These programs will require careful design and execution.

6.5 South Willard Bay

An earthfill embankment dam at the South Willard Bay site would likely have a homogenous cross-section that incorporates an inclined filter and blanket drain system. Fill present at the site would need to be excavated so that the dam could be founded on native materials.

A generalized cross-section for an earthfill embankment dam at the South Willard Bay site is shown on Figure 18. The results of the seepage analyses are shown on Figure 19, and the results of the steady-state seepage (static) stability analyses are shown on Figure 20. The results of the post-seismic stability analysis are shown on Figure 21. Estimated seismic deformations are shown on Figure 22 (pages 43–47).

The geotechnical exploration and laboratory testing program indicates that very soft soils that are problematic for stability and seismic deformation are prevalent in the area of the proposed dam foundation. In order to achieve reasonable post-seismic factors of safety, large upstream and downstream berms were added to the proposed embankment. Our initial assessment suggests that these berms would be about 150 feet long and about 15 feet high. The upstream and downstream slopes of the embankment would be 4H:1V to the top of the berms.

Similar to the Above Cutler site, staged construction and drainage would likely be required in order to allow the foundation materials to gain strength. In addition to the cross-section needing to address post-seismic stability and deformation concerns, this site draws attention to long-term settlement issues that might need to be addressed at earthfill dam sites with soft foundations. The Bureau of Reclamation's experience with the AV Watkins dam suggests that settlements as high as 18 feet have occurred. Constructing a dam at the South Willard Bay site would likely require significant overbuild as part of the original construction as well as several supplemental construction efforts to restore the required dam crest elevation as long-term settlements continue. Future site characterization work is required to better understand the strength and settlement properties of the foundation's silt and clay materials and the variability of the properties across this large site.

6.6 Temple Fork

The bedrock at the Temple Fork site would provide a sound foundation for a concrete gravity dam or an ECRD. At this time, we believe that an RCC gravity dam is preferred, because both spillway and outlet works elements could be incorporated into the dam. There are some geologic fault concerns at the site. We believe that the footprint of an RCC dam can be established that would avoid or minimize concerns related to faulting and potential fault rupture in the vicinity of or under the dam. A CFRD is not as suitable for this site because of design issues associated with foundation faulting, the potential for fault rupture, and near-field seismic ground-motion hazards that could significantly crack the facing system and cause associated leakage from the dam.

The ECRD alternative is not as favorable as an RCC dam because the abutment conditions for a side channel spillway are moderately adverse and would add significant costs to the project. In addition, the outlet works for an ECRD would likely require an abutment tunnel configuration and would include at least one fault crossing. This tunnel, combined with the substantially longer total length of the outlet works, would increase the outlet works' cost relative to an RCC dam.

The RCC dam would be founded on sound limestone bedrock. The non-overflow section would have a 25-foot-wide dam crest at about elevation 6,177 feet. The upstream face of the dam would be about 0.15H:1V. The upper portion of the dam would include a "chimney" section that has a height of about 25 feet transitioning to a downstream slope of about 0.75H:1V. The spillway overflow section would be formed over the central portion of the structure and would consist of a formed and reinforced concrete Ogee overflow weir with a crest at elevation 6,167 feet that transitions to a stepped chute leading to a stilling basin structure at the downstream toe of the dam. The hydraulic parameters of the spillway have not been developed at this time. Up to 25 feet of surficial soils, including alluvial sands and gravels as well as weathered bedrock, would be removed to reach sound rock.

A generalized cross-section for an RCC dam at the Temple Fork site is shown on Figure 23 (page 48). Future studies for this alternative should include structural modeling of the dam, evaluation of pre- and post- earthquake sliding stability, and evaluation of potential sources of aggregate for constructing the RCC dam.

There are several important design considerations for this site, including karst and possible active faults in the bedrock near the area of the proposed dam foundation and in the area of the proposed reservoir basin upstream and downstream of the site. Near-field earthquake ground-motion hazards would be an important loading condition that would likely govern the cross-section requirements of the dam. Aggregate for an RCC dam is a major cost, but it might be available from suitable bedrock materials in the proposed reservoir basin. Further studies are needed to address these key issues and refine the concept for the dam and spillway.

An RCC dam offers several advantages at this site, including the ability to position the overflow spillway on the dam and away from steep and challenging abutment terrain and the ability to incorporate a low-level outlet works through the base of the dam, thereby eliminating the need for tunnels in the lower abutment areas.

6.7 Whites Valley

From geologic and dam-design perspectives, the Whites Valley site has many positive attributes. The bedrock at the site would provide a sound foundation for an ECRD. In addition, it is likely that most, if not all, borrow materials needed for construction could be developed from on-site sources. The dam would be founded on the underlying calcareous sandstone.

The recommended dam cross-section would consist of a central, low-permeability clay (earth) core with adjacent filters and drains, and transition zones (Zone 2), and rockfill shells (Zone 3). The exterior upstream slope would be about 2.5H:1V to an elevation of 5,160 feet and would continue to the dam crest at elevation of 5,270 feet at a slope of

about 2H:1V. The exterior downstream slope would be about 2H:1V from the ground surface to the crest of the dam.

A generalized cross-section for an ECRD at the Whites Valley site is shown on Figure 24. The results of the seepage analyses are shown on Figure 25, and the results of the steady-state seepage (static) stability analyses are shown on Figure 26. The results of stability analysis assuming a potential weak layer in the foundation are shown on Figure 27. Estimated seismic deformations are shown on Figure 28 (pages 49–53).

HDR has identified potentially significant issues with foundation seepage and treatment in the left abutment and in portions of the reservoir rim upstream of the left abutment. Further site characterization and evaluations are needed to identify the extent of the hazard and to identify appropriate foundation-treatment methods such as grouting, cutoff walls, and filter and drainage systems, and possible reservoir lining in limited areas upstream of the left abutment of the dam.

6.8 Summary of Dam Types and Configurations

Table 10 summarizes the preferred dam types and other information for each site.

Table 10. Summary of Dam Types and Characteristics

Dam	Preferred Dam Type	Dam Crest Elevation (feet)	Dam Crest Width (feet)	Dam Crest Length (feet)	Flood-Routing Freeboard (feet)	Comments
Above Cutler	Earthfill embankment	4,442	20	1,580	10	Stability berms required. Other significant settlement and construction issues to be assessed. Marginal site feasibility identified.
Cub River	Earthfill embankment	4,475	30	1,610	10	Significant settlement and other construction issues.
Fielding	Earthfill embankment	4,310	30	1,480	10	Stability berms required. Other significant seepage, settlement, and construction issues to be addressed.
South Willard Bay	Earthfill embankment	4,240	20	27,140	10	Stability berms required. Other significant seepage, settlement, and construction issues.
Temple Fork	Roller-compacted concrete (RCC) dam	6,177	25	1,020	10	Significant foundation faulting and hazards identified that require additional site characterization and modeling work to finalize the location of the dam axis and cross-section requirements.
Whites Valley	Earth-core rockfill dam (ECRD) or concrete-faced rockfill dam (CFRD)	5,270	40	1,410	10	Significant foundation seepage issues in left abutment and possible reservoir rim areas.

7 References

Ambraseys, N.N., and J.M. Menu

1988 Earthquake-induced ground displacements. *Earthquake Engineering and Structural Dynamics* 16: 985–1006.

Gerhart-Cole, Inc.

2015 Draft Geotechnical Data Reports for Cub River, Fielding, South Willard Bay, Temple Fork, and Whites Valley; Bear River Project Concept Study.

Jibson, R.W.

2007 Regression models for estimating coseismic landslide displacement. *Engineering Geology* 91: 209–218.

Rathje, E.M., and Gokhan Saygili

2009 Probabilistic assessment of earthquake-induced sliding displacements of natural slopes. *Bulletin of the New Zealand Society of Earthquake Engineering* 41: 18–27.

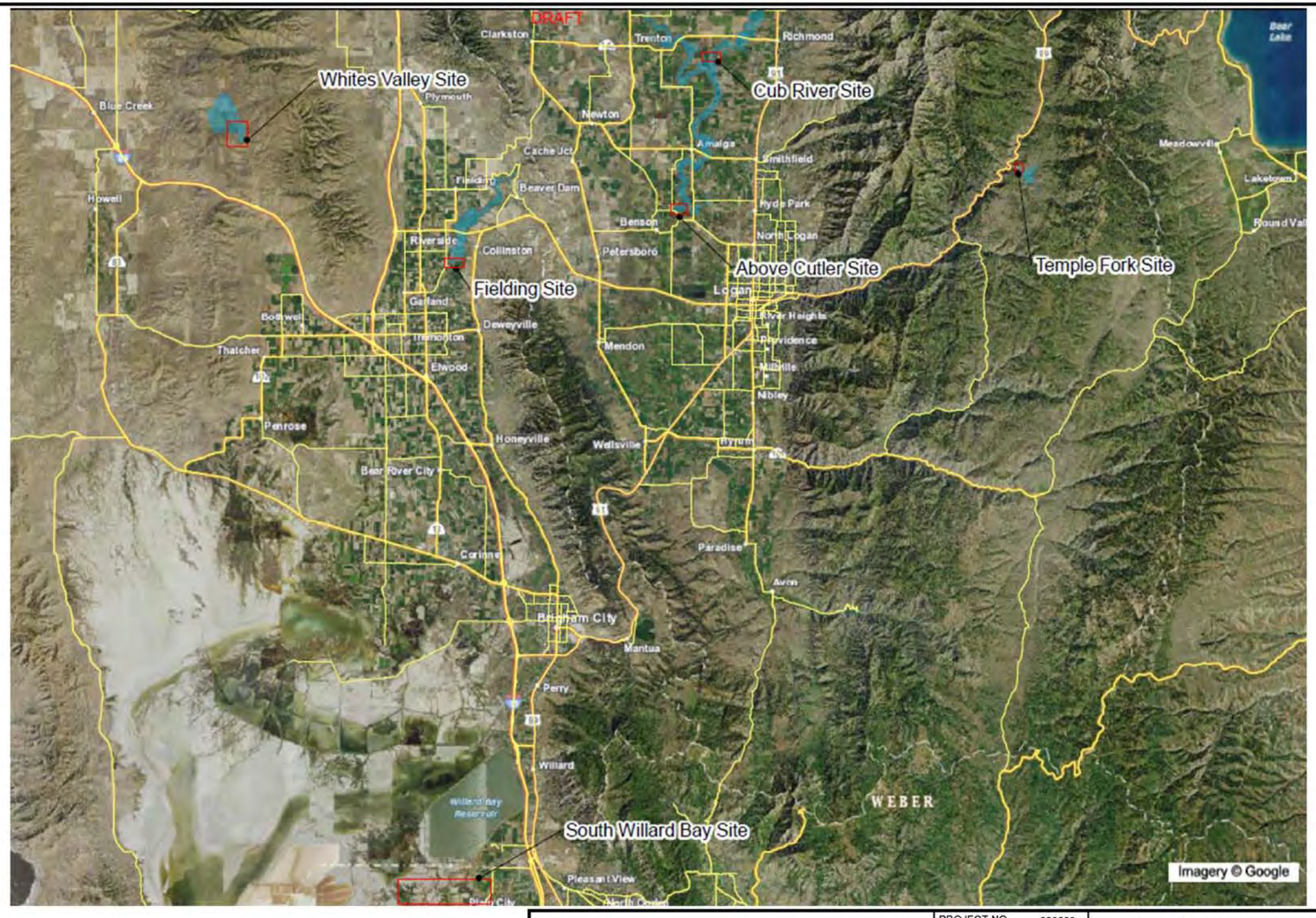
Saygili, Gokhan, and E.M. Rathje

2008 Empirical predictive models for earthquake-induced sliding displacements of slopes. *Journal of Geotechnical and Geoenvironmental Engineering* 134: 790–803.

[USGS] United States Geological Survey

2008 Earthquake Hazards website. http://geohazards.usgs.gov/deaggint/2008/.

Figure 2. Location Map of Proposed Sites



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CONSULTING ENGINEERS

HDR

PROJECT NO.	239333
DRAWN:	1/26/2016
DRAWN BY:	STA
CHECKED BY:	KAF

Location Map of Proposed Sites

State of Utah Division of Water Resources
Bear River Project

FIGURE
2

Figure 3. Above Cutler Site – Representative Maximum Cross-Section

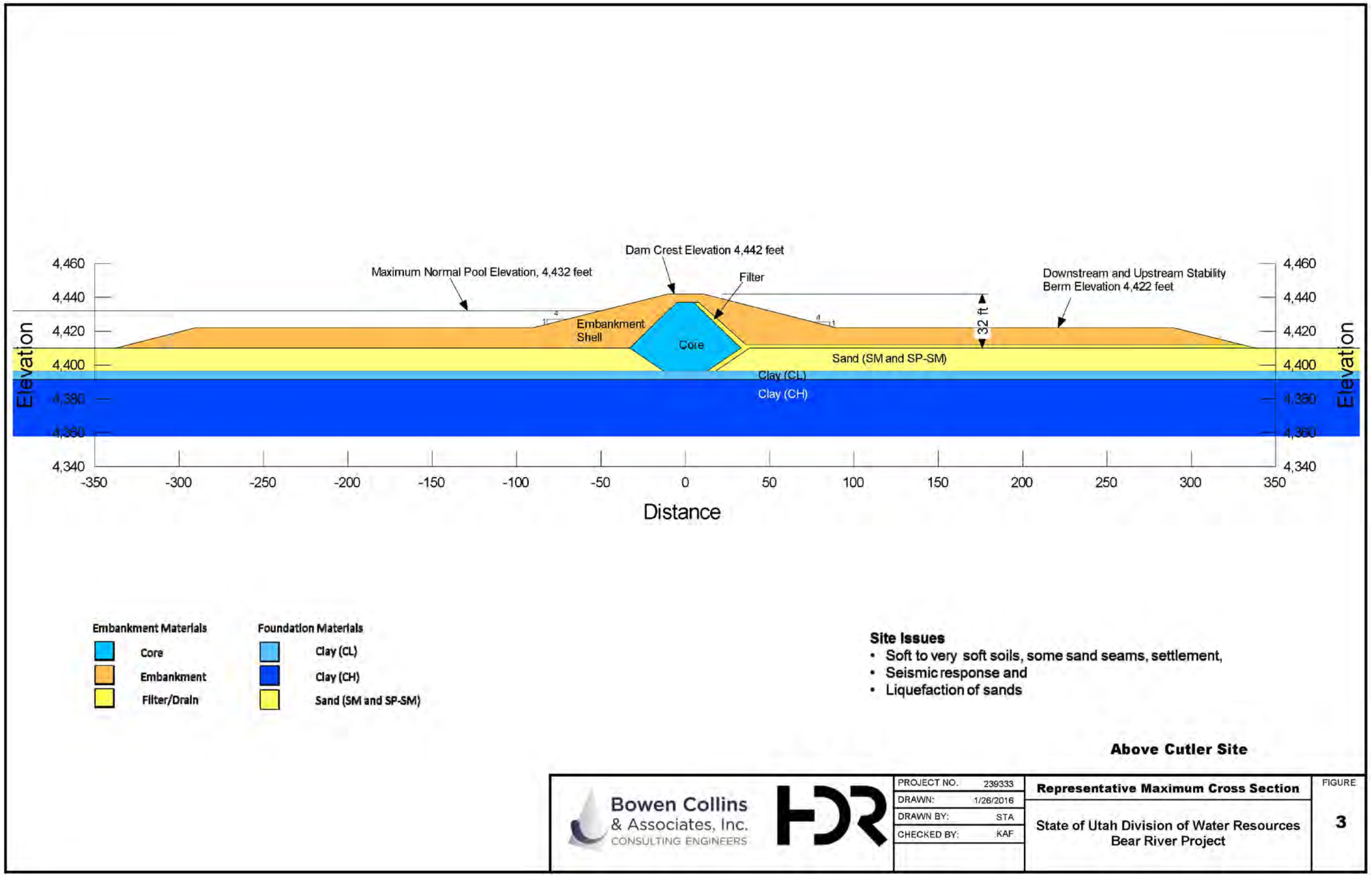
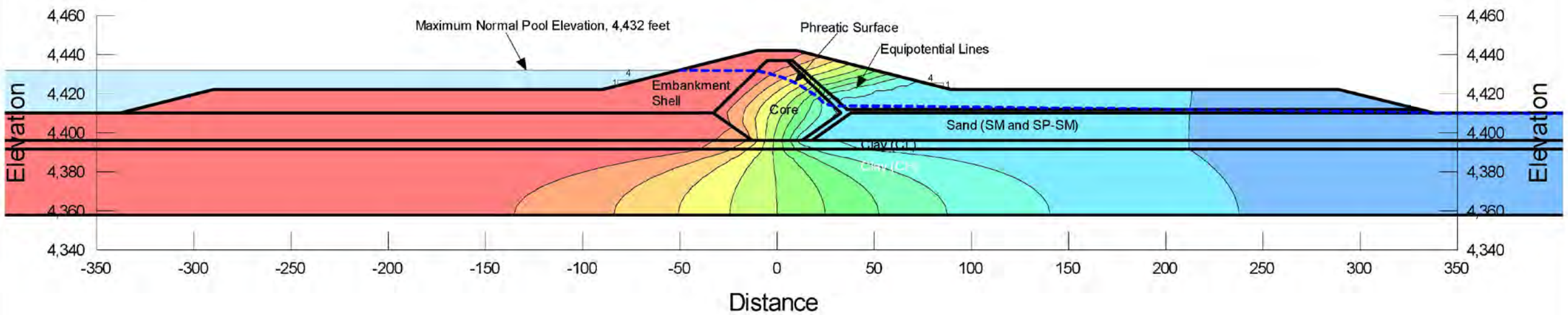


Figure 4. Above Cutler Site – Seepage Analysis Results – Seepage Total Head Contours



Above Cutler Site

Seepage Analysis Results

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CHECKED BY:	KAF

Seepage Total Head Contours

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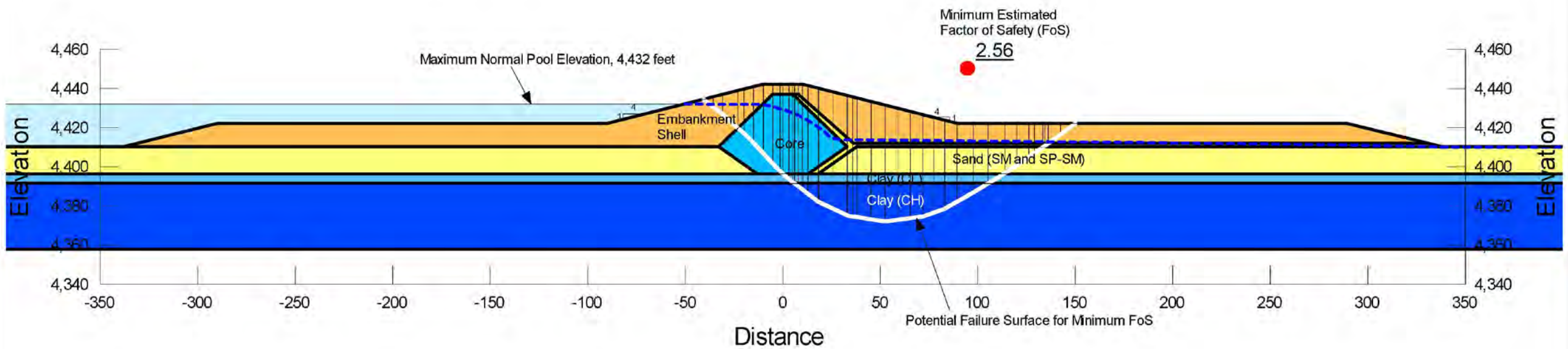
FIGURE

4

Figure 5. Above Cutler Site – Steady-State Seepage Condition – Slope Stability Analysis Results



Above Cutler Site
Steady State Seepage Condition

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Slope Stability Analysis Results

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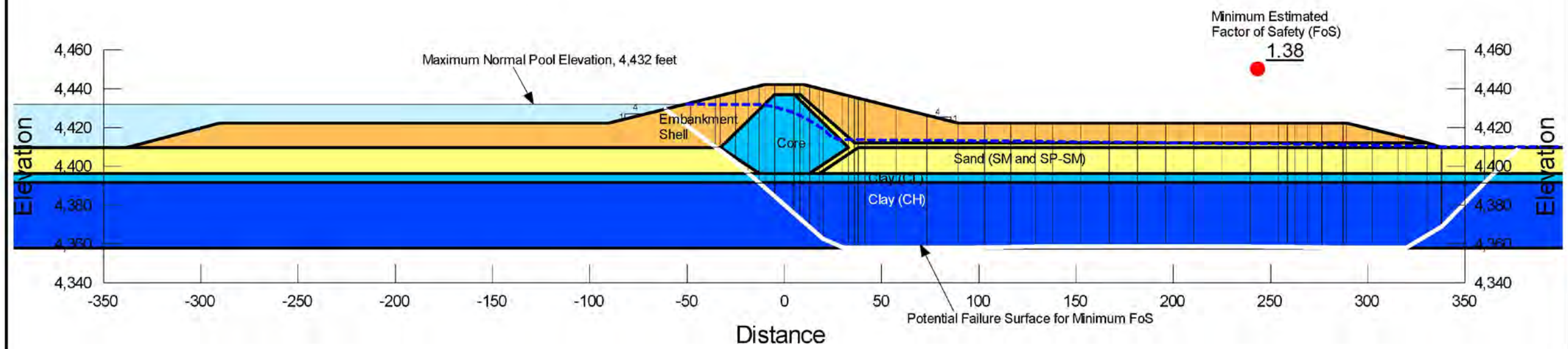
Bear River Project

FIGURE
5

Figure 6. Above Cutler Site – Slope Stability Analysis Results – Post-seismic Factor of Safety



Notes:
1. Strength used for CH Layer was 350 pounds per square foot to obtain the FoS shown

Above Cutler Site
Slope Stability Analysis Results

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Post-Seismic Factor of Safety

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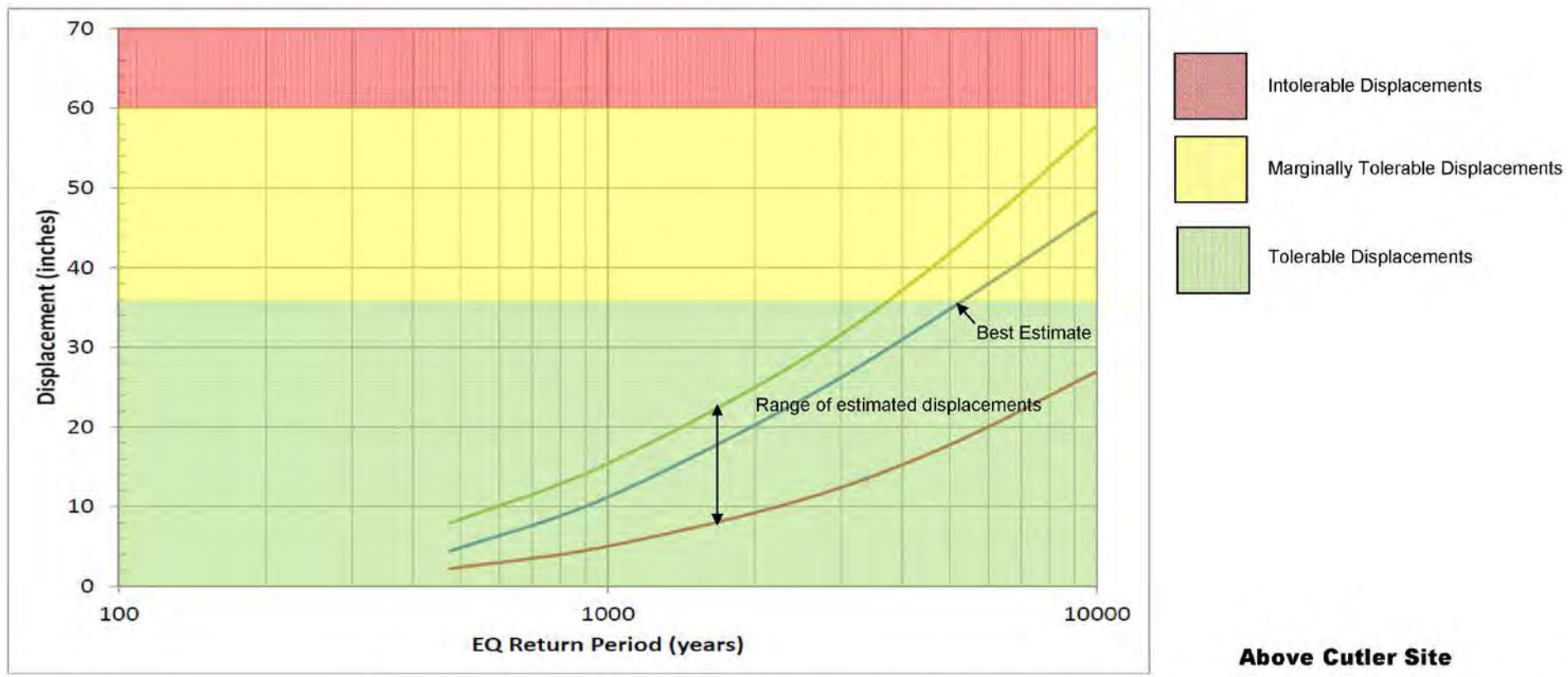
FIGURE
6

Figure 7. Above Cutler Site – Empirically Estimated Seismic Displacements

Site/Method	Estimated Displacement for EQ Return Interval (in.)				
Above Cutler (0.04g)	**475-yr**	**975-yr**	**2,475-yr**	**4,975-yr**	**9,950-yr**
Rathje and Saygili (2009)	4.4	10.9	23.3	34.7	47
Saygili and Rathje (2008)	5.2	12.6	26.5	39.3	53
Jibson (2007) Critical Acceleration Ratio	2.8	6.1	13.2	21.3	32.1
Jibson (2007) Critical Acceleration Ratio and Magnitude	2.2	4.9	10.8	17.7	26.9
Ambraseys and Menu (1998)	7.9	15.1	28.3	41.7	57.7



Above Cutler Site

Notes:
1. Displacements based on an increased shear strength of 350 psf, due to either ground improvement or consolidation

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Empirically Estimated Seismic Displacements

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Bear River Project

FIGURE 7

Figure 8. Cub River Site – Representative Maximum Cross-Section

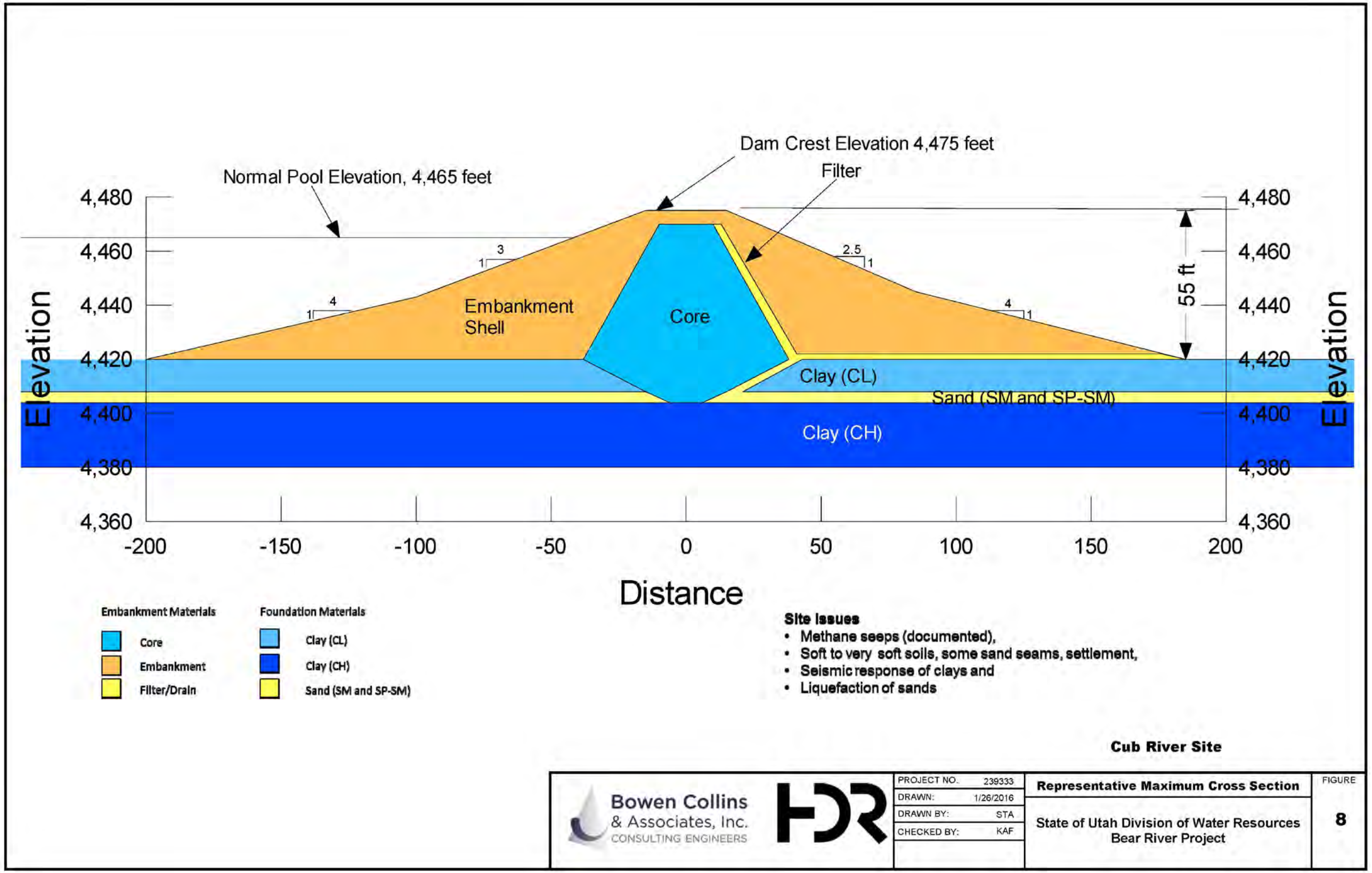
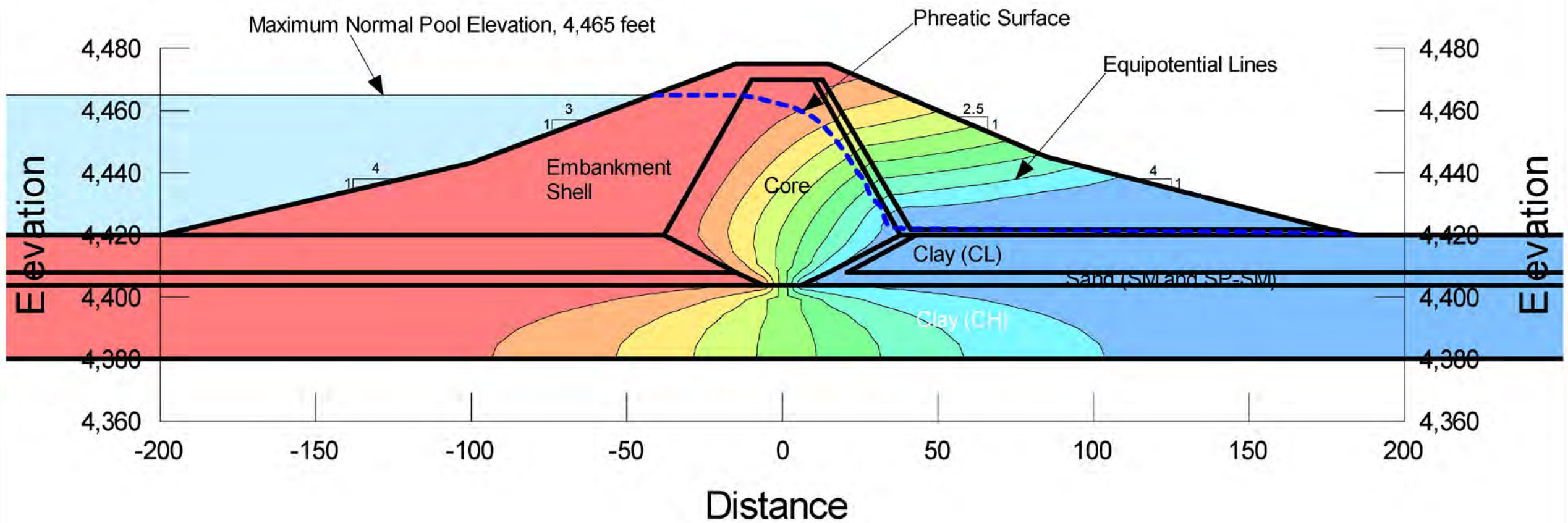


Figure 9. Cub River Site – Seepage Analysis Results – Seepage Total Head Contours



Cub River Site

Seepage Analysis Results

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Seepage Total Head Contours

State of Utah Division of Water Resources
Bear River Project

FIGURE
9

Figure 10. Cub River Site – Steady-State Seepage Condition – Slope Stability Analysis Results

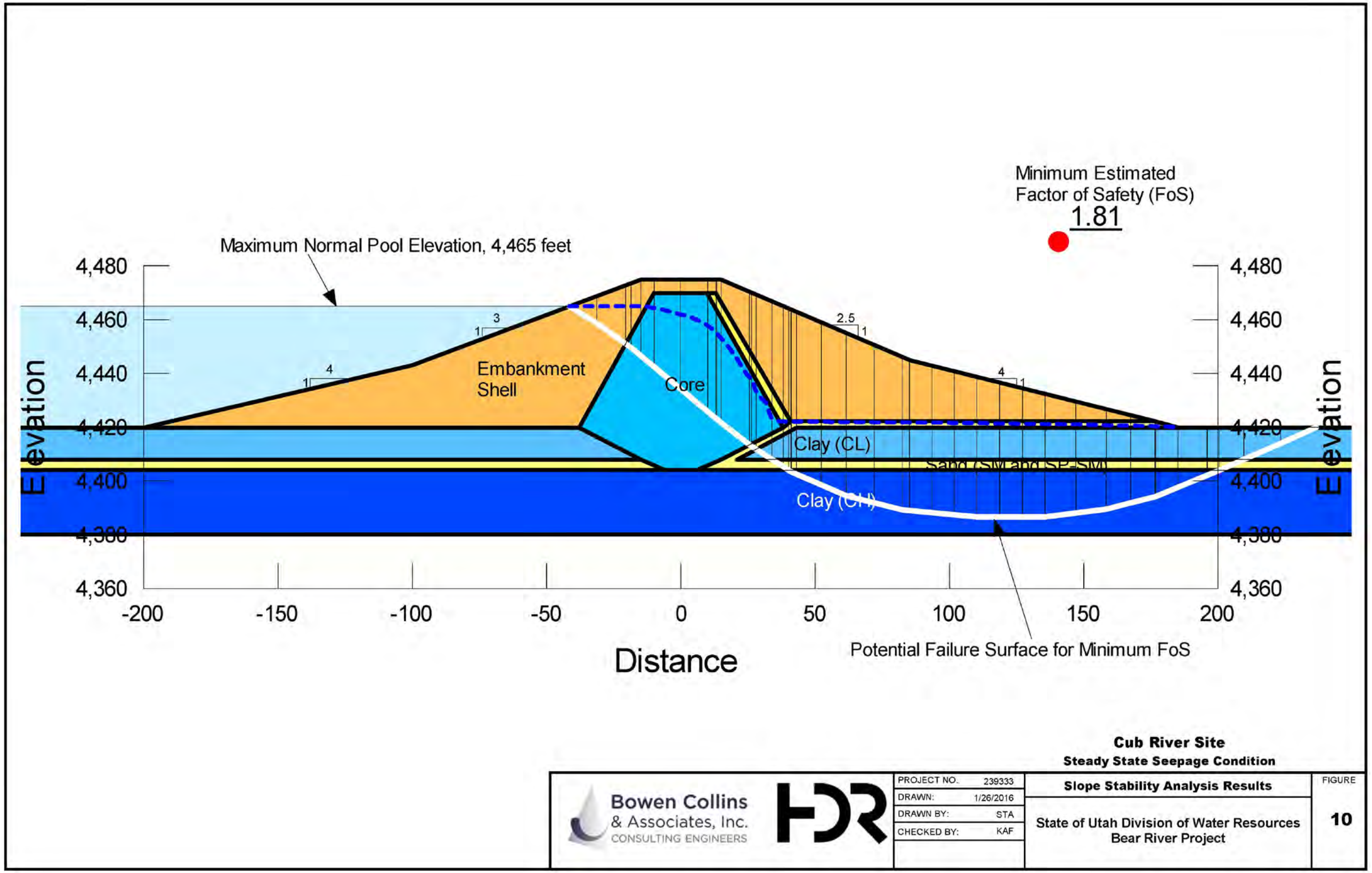
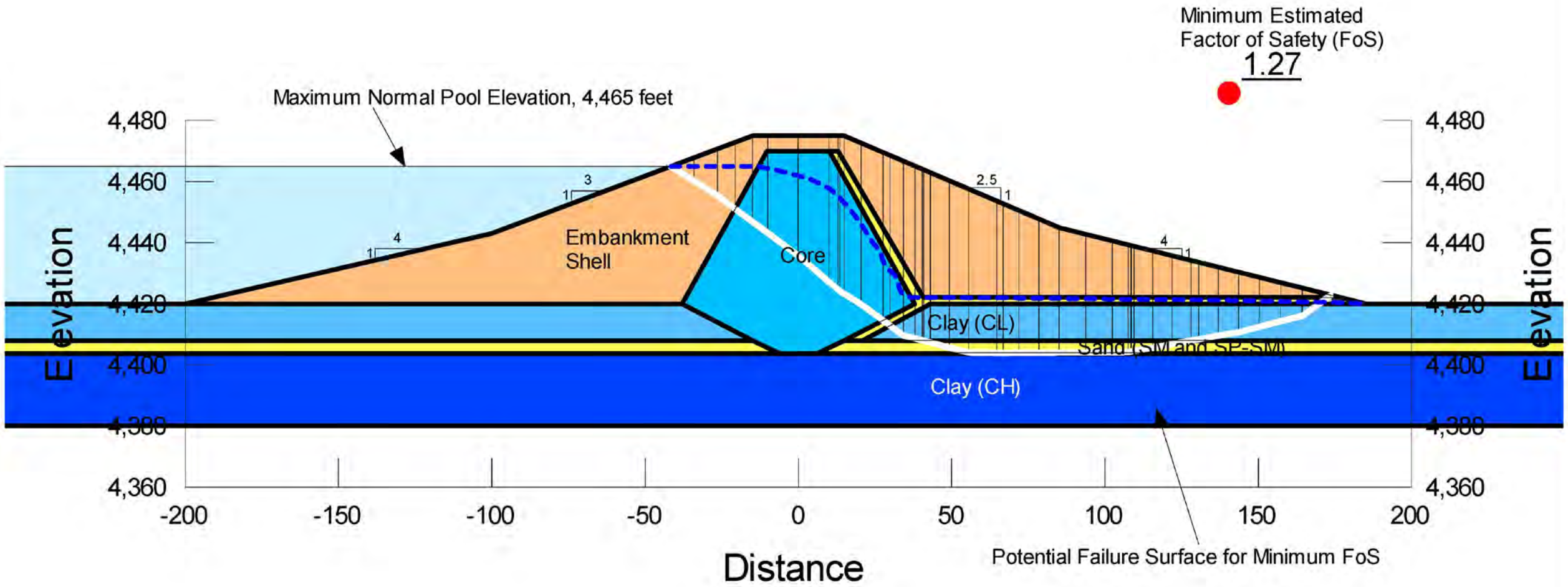


Figure 11. Cub River Site – Slope Stability Analysis Results – Post-seismic Factor of Safety



Cub River Site
Slope Stability Analysis Results

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Post-Seismic Factor of Safety

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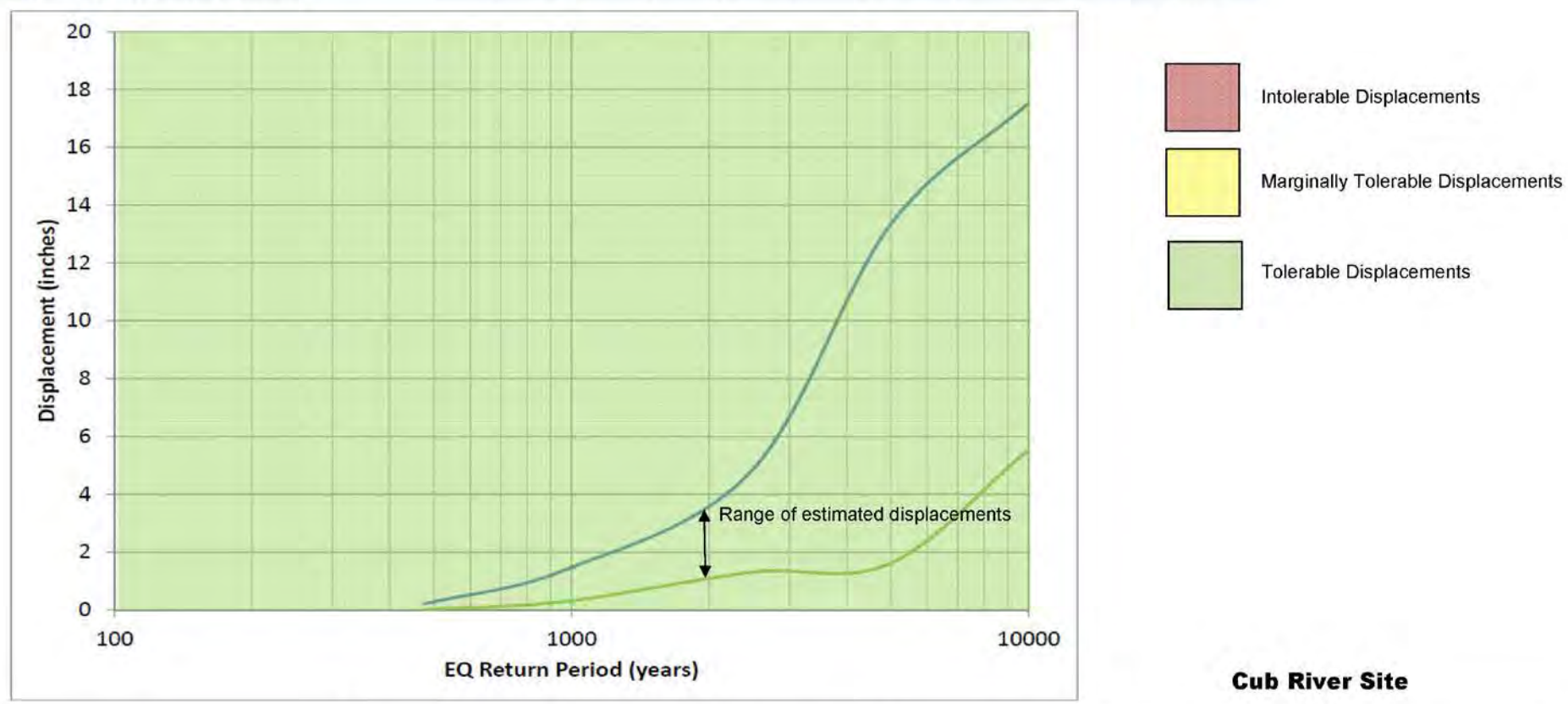
Bear River Project

FIGURE **11**

Figure 12. Cub River Site – Empirically Estimated Seismic Displacements

Site/Method	Estimated Displacement for EQ Return Interval (in.)				
Cub River (0.12g)	**475-yr**	**975-yr**	**2,475-yr**	**4,975-yr**	**9,950-yr**
Rathje and Saygili (2009)	0.1	0.9	4.8	11.5	37.5
Saygili and Rathje (2008)	0.1	1	5.6	13.3	24.8
Jibson (2007) Critical Acceleration Ratio	0.1	0.4	1.6	3.2	5.5
Jibson (2007) Critical Acceleration Ratio and Magnitude	0	0.3	1.3	2.6	8.8
Ambraseys and Menu (1998)	0.2	1.4	4.8	8.8	13.8



Cub River Site

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Empirically Estimated Seismic Displacements

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Bear River Project

FIGURE
12

Figure 13. Fielding Site – Representative Maximum Cross-Section

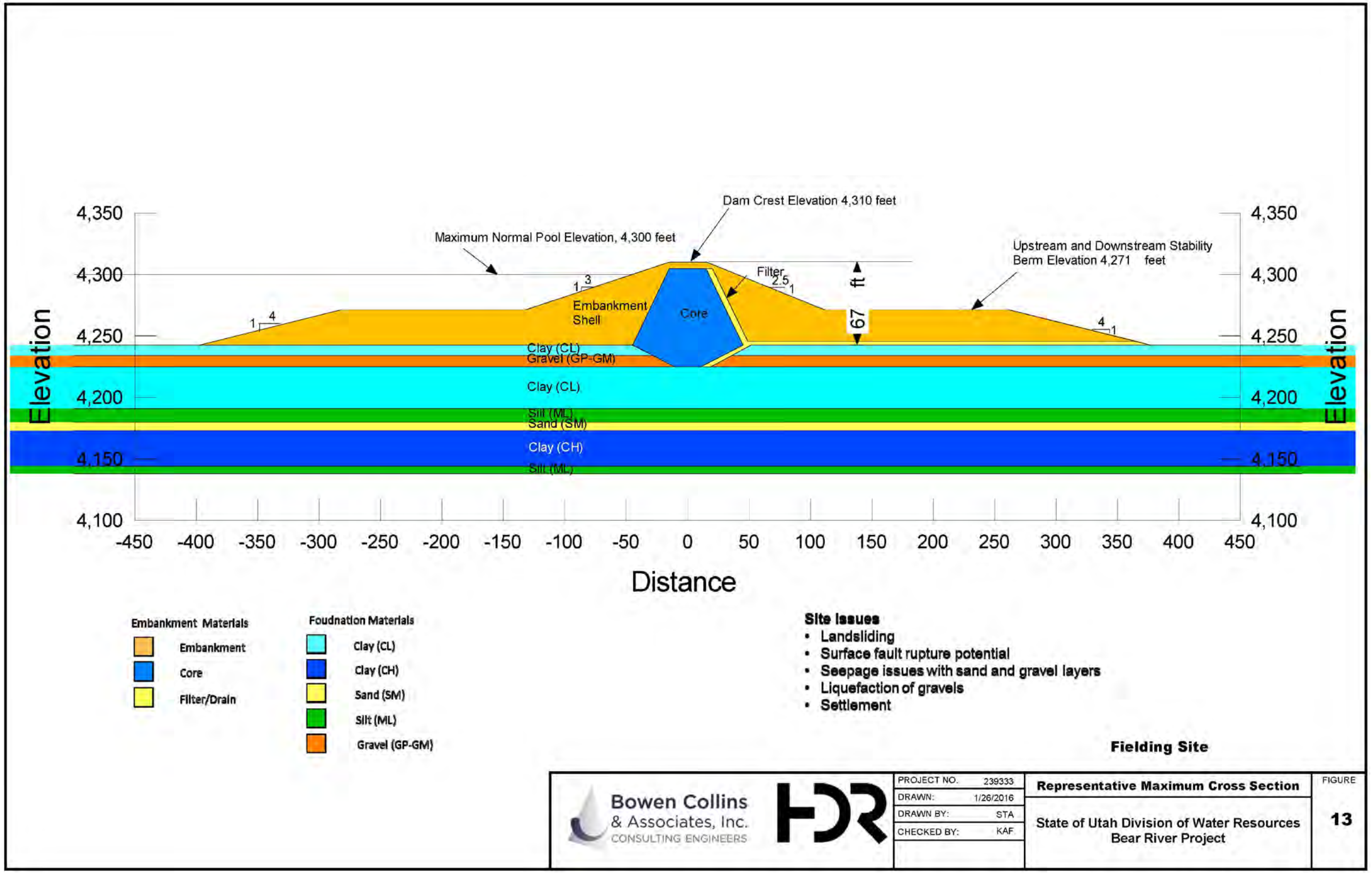
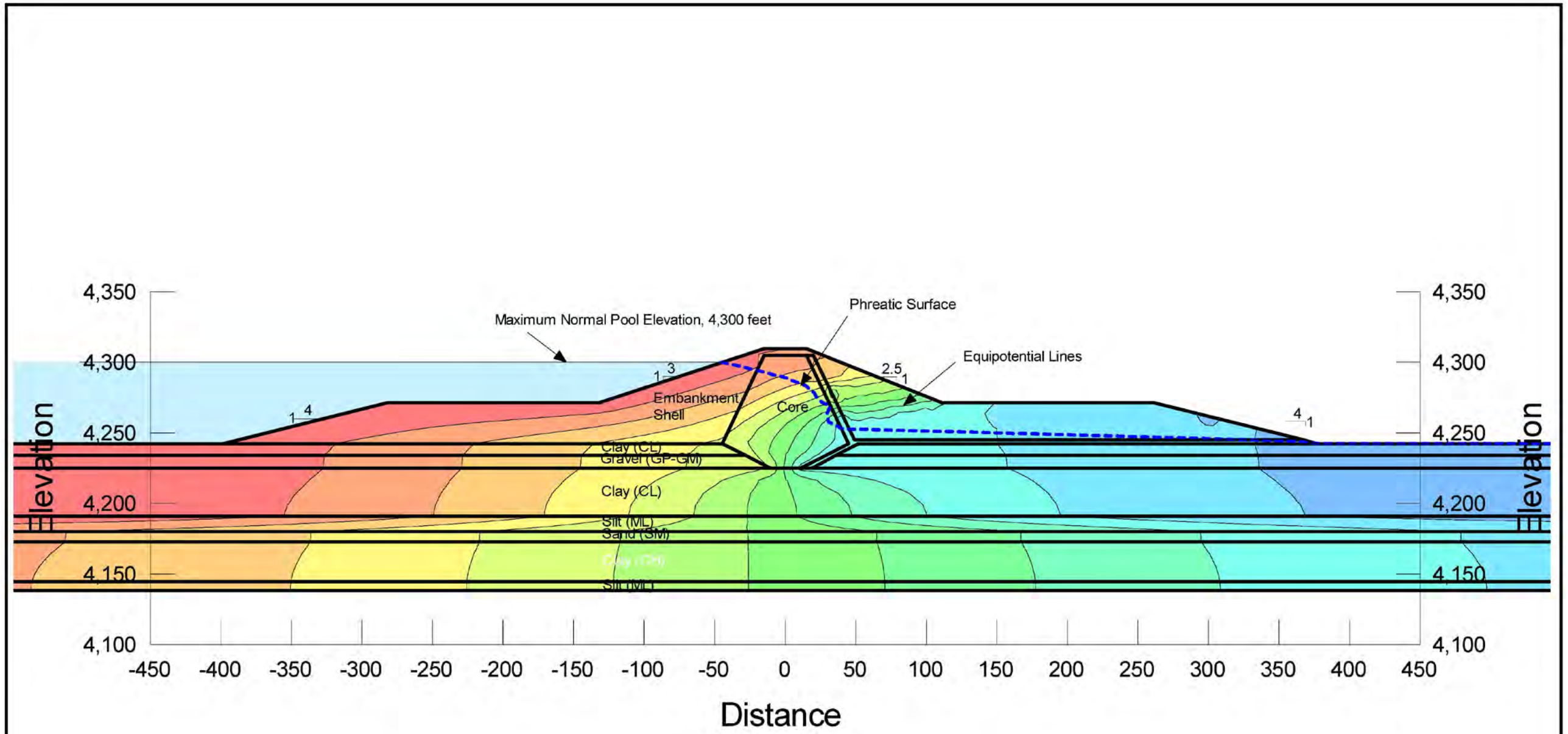


Figure 14. Fielding Site – Seepage Analysis Results – Seepage Total Head Contours



Fielding Site

Seepage Analysis Results

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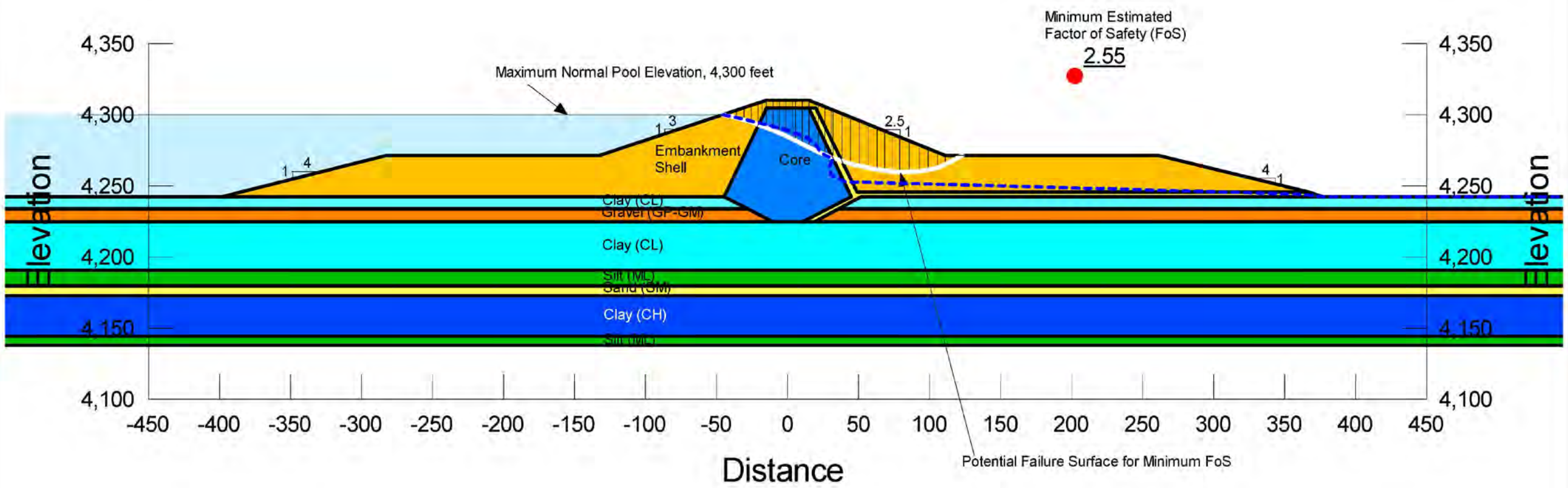
Seepage Total Head Contours

State of Utah Division of Water Resources
Bear River Project

FIGURE
14

Figure 15. Fielding Site – Steady-State Seepage Condition – Slope Stability Analysis Results



Fielding Site
Steady State Seepage Condition

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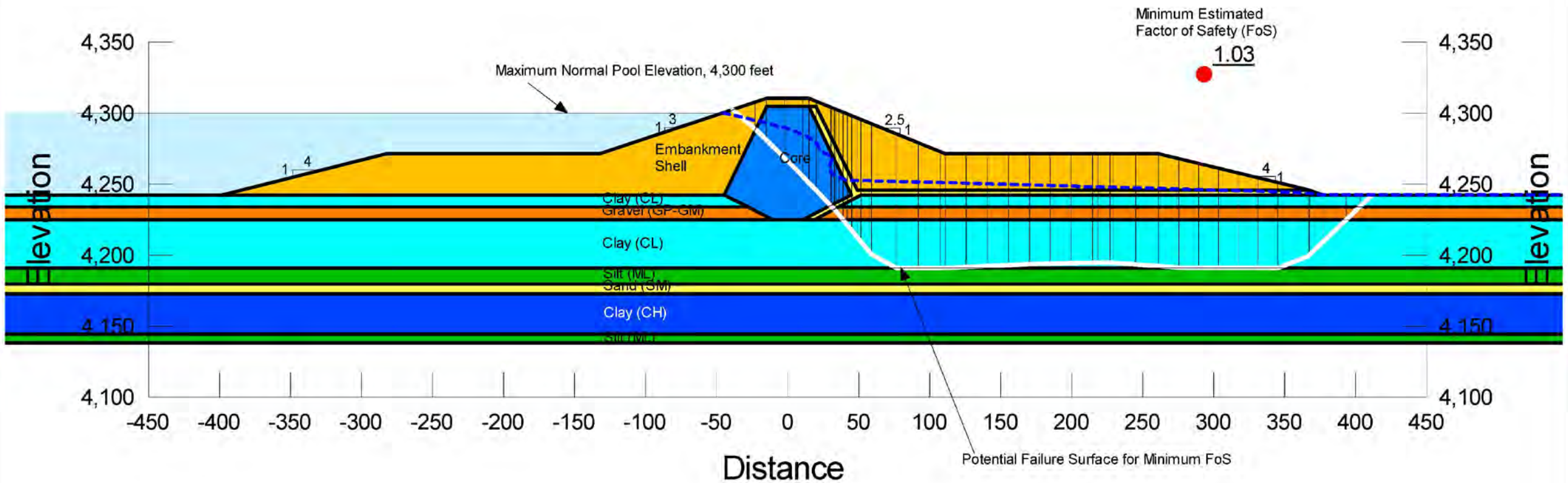
Slope Stability Analysis Results

State of Utah Division of Water Resources
Bear River Project

FIGURE
15

Figure 16. Fielding Site – Slope Stability Analysis Results – Post-seismic Factor of Safety



Notes:
1. FoS based on an increased shear strength of 950 psf, due to either ground improvement or consolidation

Fielding Site
Slope Stability Analysis Results

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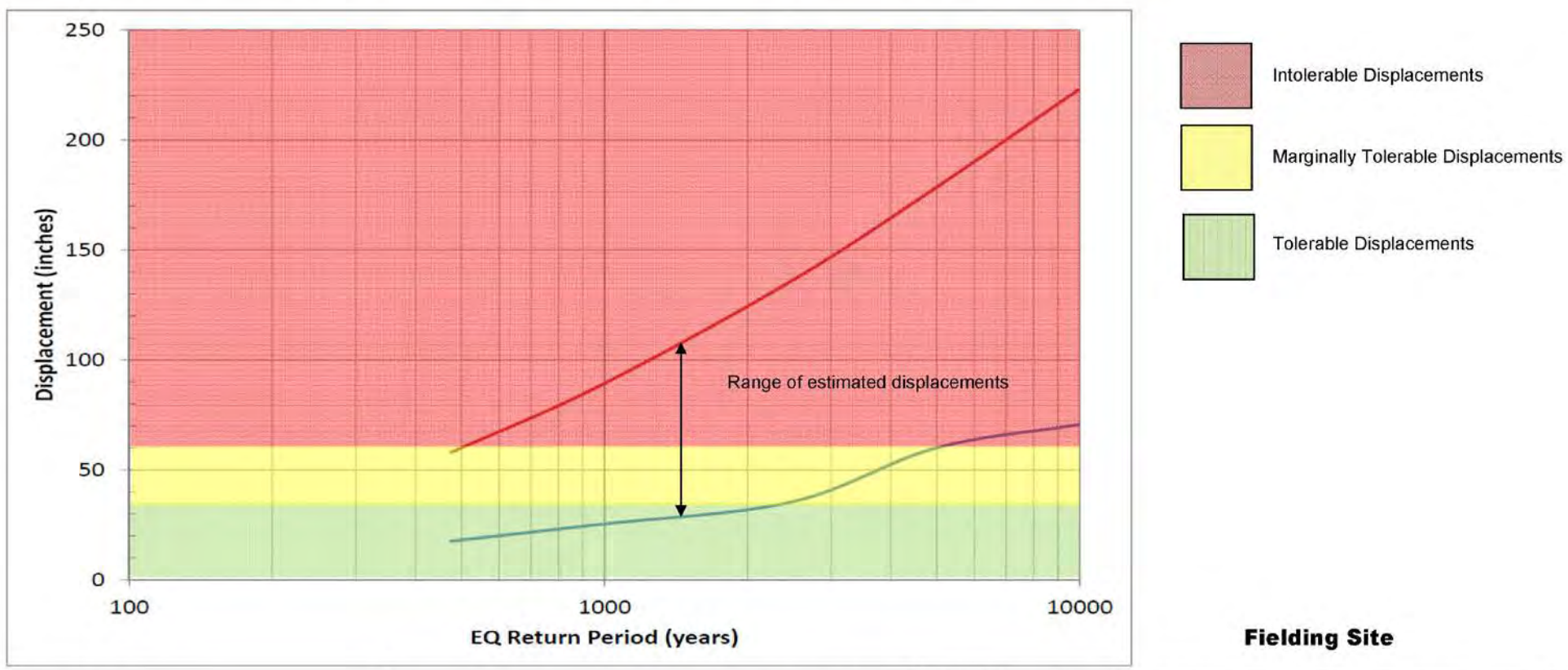
Post Seismic Factor of Safety

State of Utah Division of Water Resources
Bear River Project

FIGURE
16

Figure 17. Fielding Site – Empirically Estimated Seismic Displacements

Site/Method	Estimated Displacement for EQ Return Interval (in.)				
Fielding (0.01g)	**475-yr**	**975-yr**	**2,475-yr**	**4,975-yr**	**9,950-yr**
Rathje and Saygili (2009)	17.6	25.2	35.4	59.9	70.6
Saygili and Rathje (2008)	19.6	27.9	39.1	47.9	56.3
Jibson (2007) Critical Acceleration Ratio	32.3	55.2	96.4	137	183.3
Jibson (2007) Critical Acceleration Ratio and Magnitude	27.3	47.2	83.7	170.7	230.2
Ambraseys and Menu (1998)	57.9	88.1	135.9	178.2	222.9



Fielding Site

Notes:
1. Displacements based on an increased shear strength of 950 psf, due to either ground improvement or consolidation

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Empirically Estimated Seismic Displacements

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Bear River Project

FIGURE 17

Figure 18. South Willard Bay Site – Representative Maximum Cross-Section

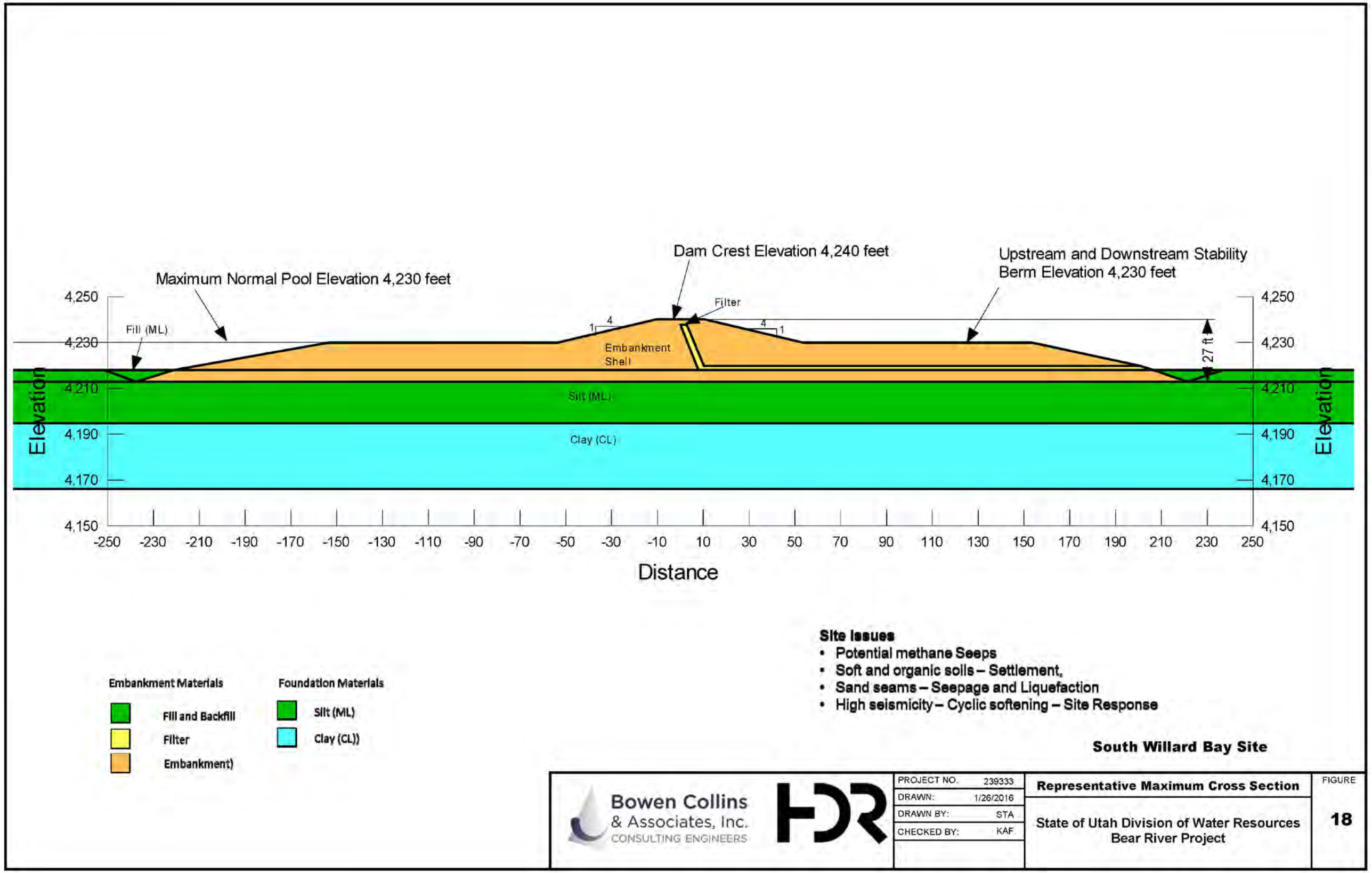
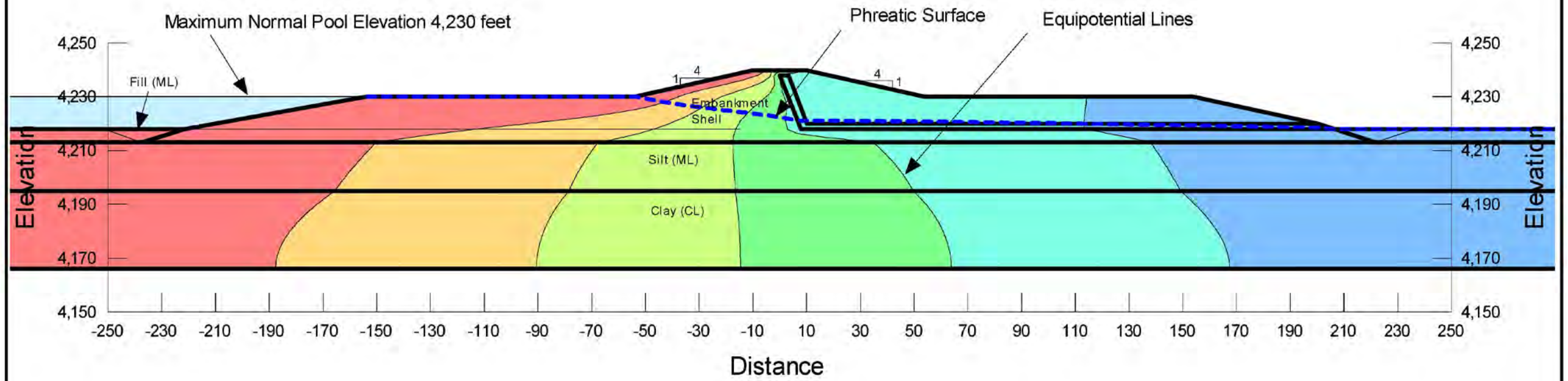


Figure 19. South Willard Bay Site – Seepage Analysis Results – Seepage Total Head Contours



South Willard Bay Site

Seepage Analysis Results

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Seepage Total Head Contours

State of Utah Division of Water Resources
Bear River Project

FIGURE **19**

Figure 20. South Willard Bay Site – Steady-State Seepage Condition – Slope Stability Analysis Results

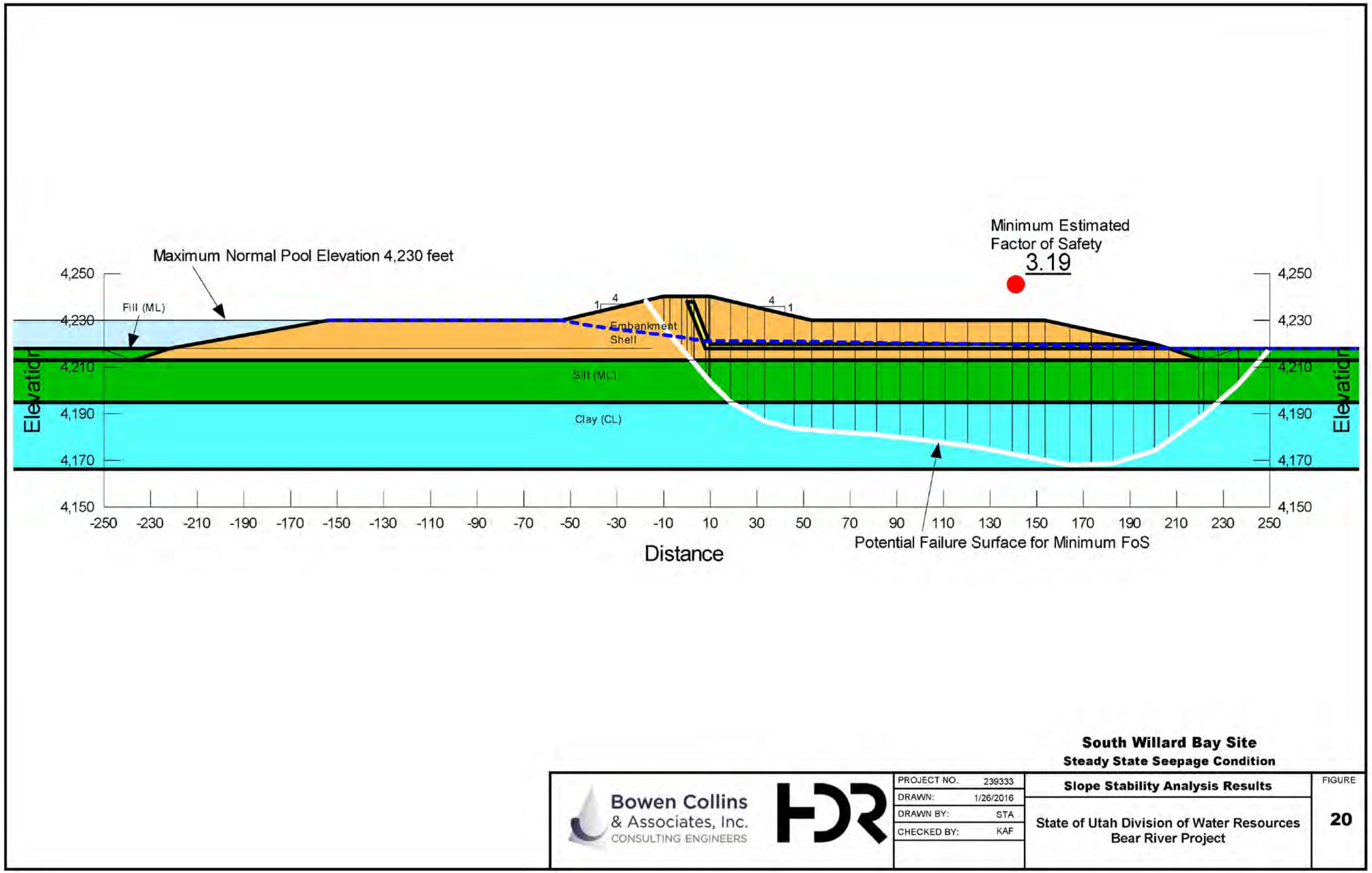
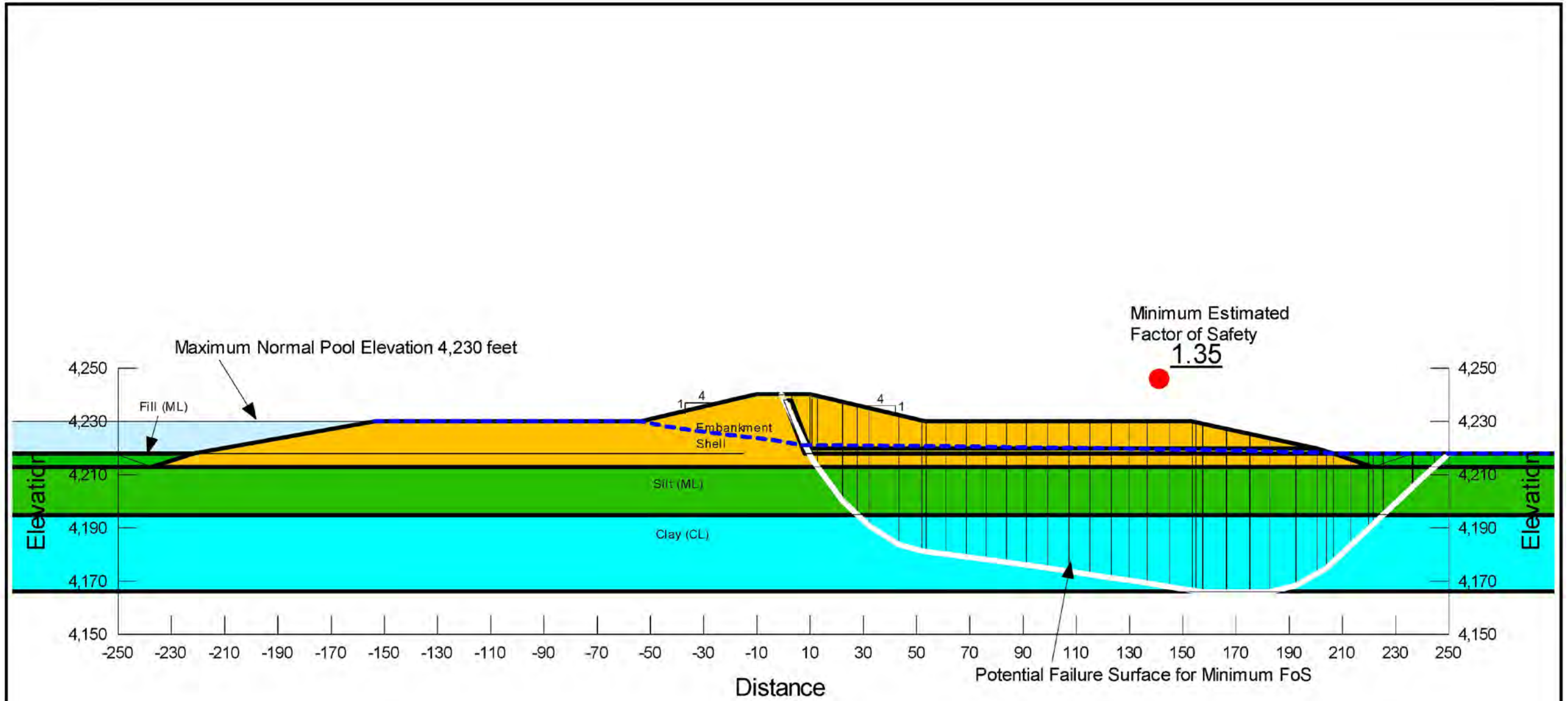


Figure 21. South Willard Bay Site – Slope Stability Analysis Results – Post-seismic Factor of Safety



South Willard Bay Site
Slope Stability Analysis Results

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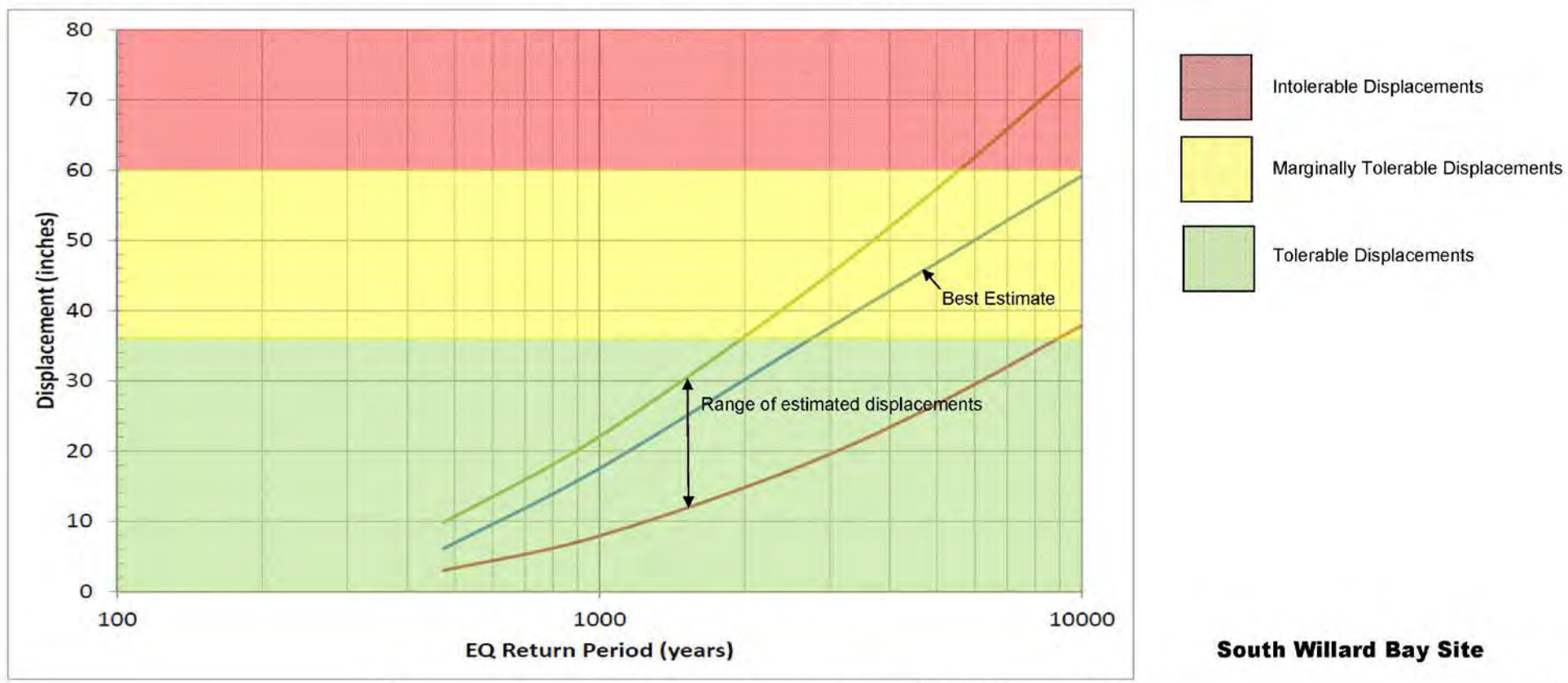
Post-Seismic Factor of Safety

State of Utah Division of Water Resources
Bear River Project

FIGURE
21

Figure 22. South Willard Bay Site – Estimated Seismic Displacements

Site/Method	Estimated Displacement for EQ Return Interval (in.)				
South Willard Bay (0.04g)	**475-yr**	**975-yr**	**2,475-yr**	**4,975-yr**	**9,950-yr**
Rathje and Saygili (2009)	6.1	17.1	34.1	46.7	59.1
Saygili and Rathje (2008)	7.1	19.6	38.6	52.6	66.3
Jibson (2007) Critical Acceleration Ratio	3.7	9.4	20.8	31.8	44.8
Jibson (2007) Critical Acceleration Ratio and Magnitude	3	7.7	17.2	26.6	37.8
Ambraseys and Menu (1998)	9.8	21.6	40.9	57.2	74.9



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Estimated Seismic Displacements

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FIGURE
22

Figure 23. Temple Fork Site – Representative Maximum Cross-Section

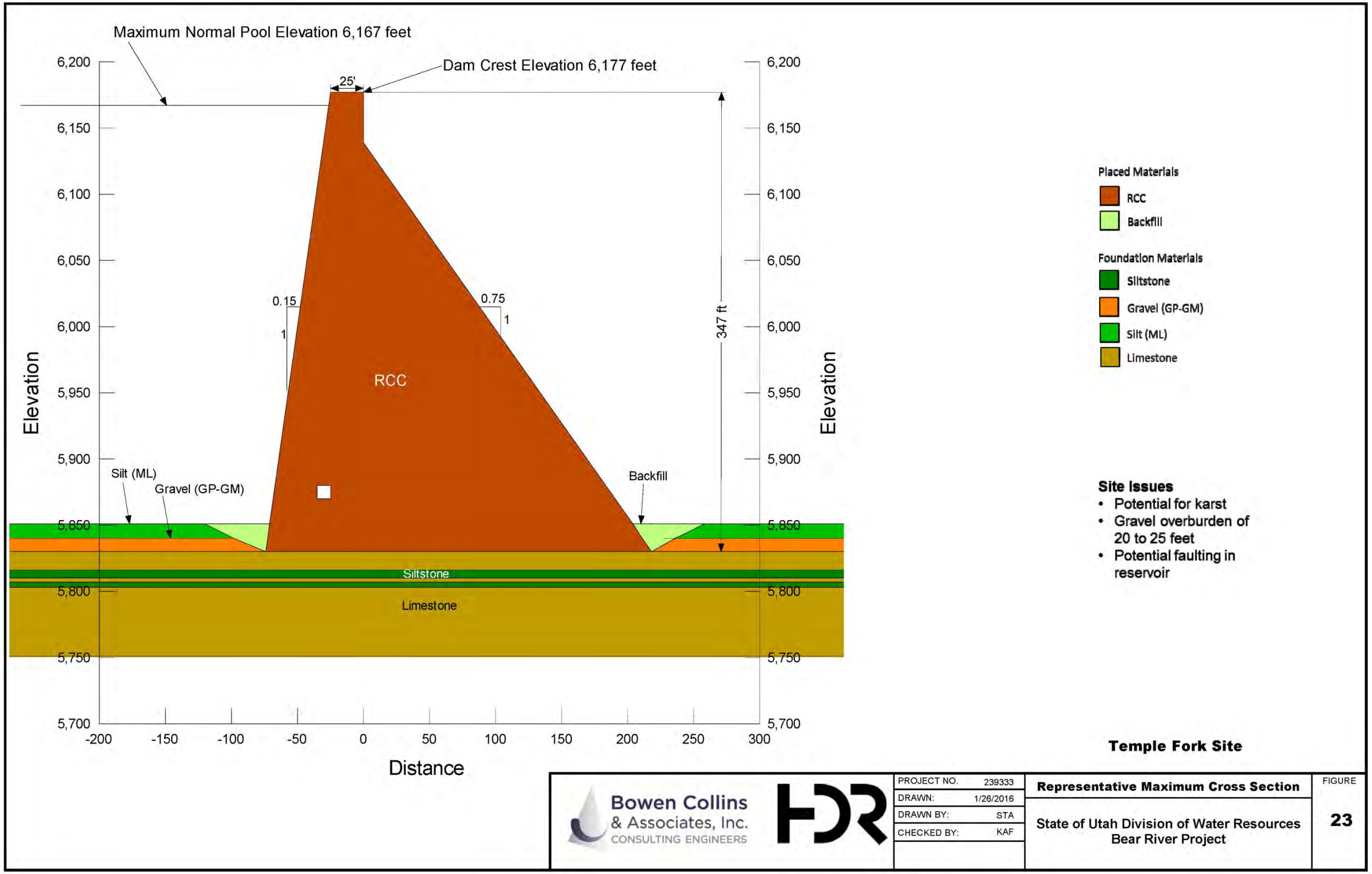


Figure 24. Whites Valley Site – Representative Maximum Cross-Section

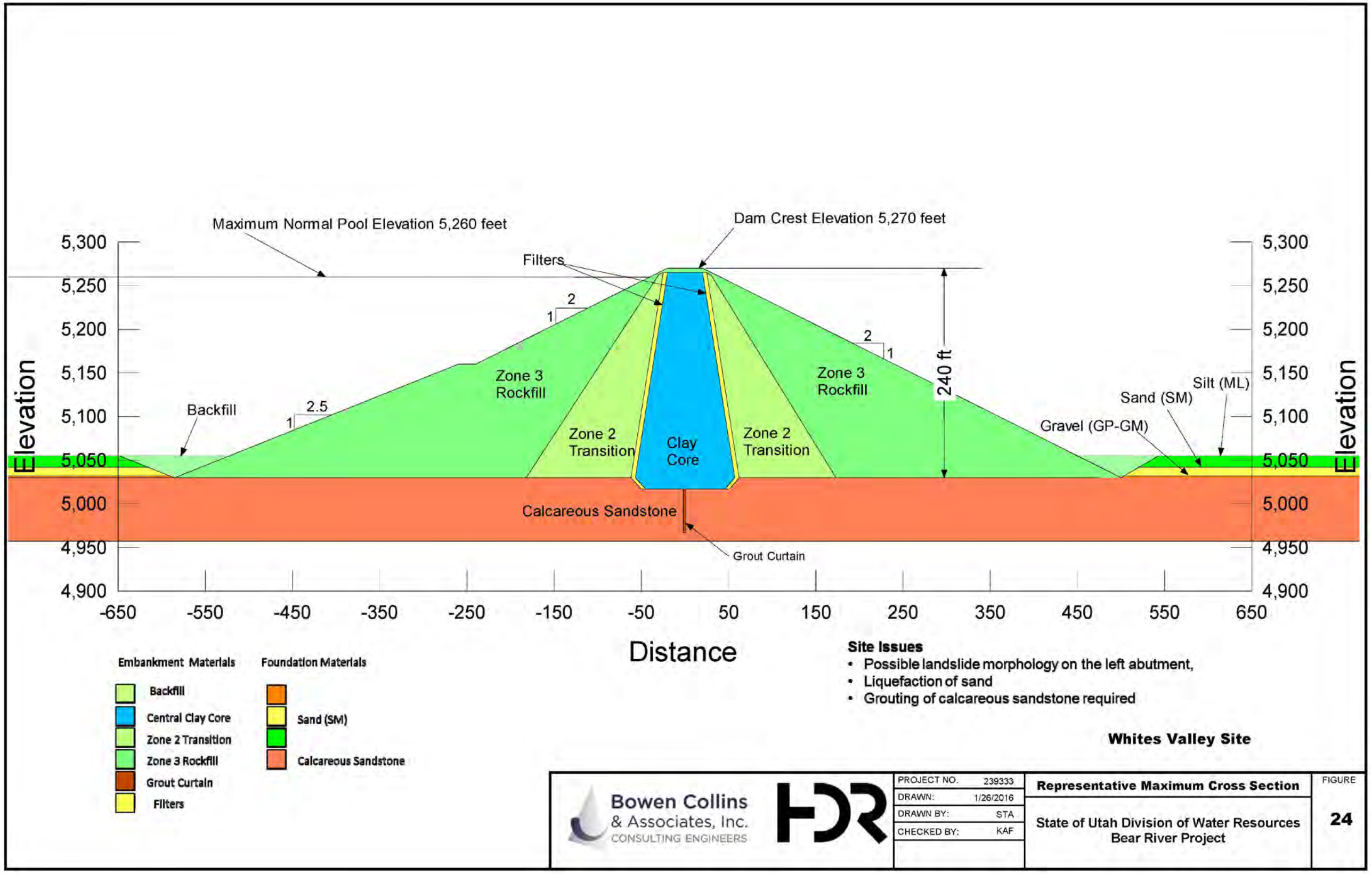
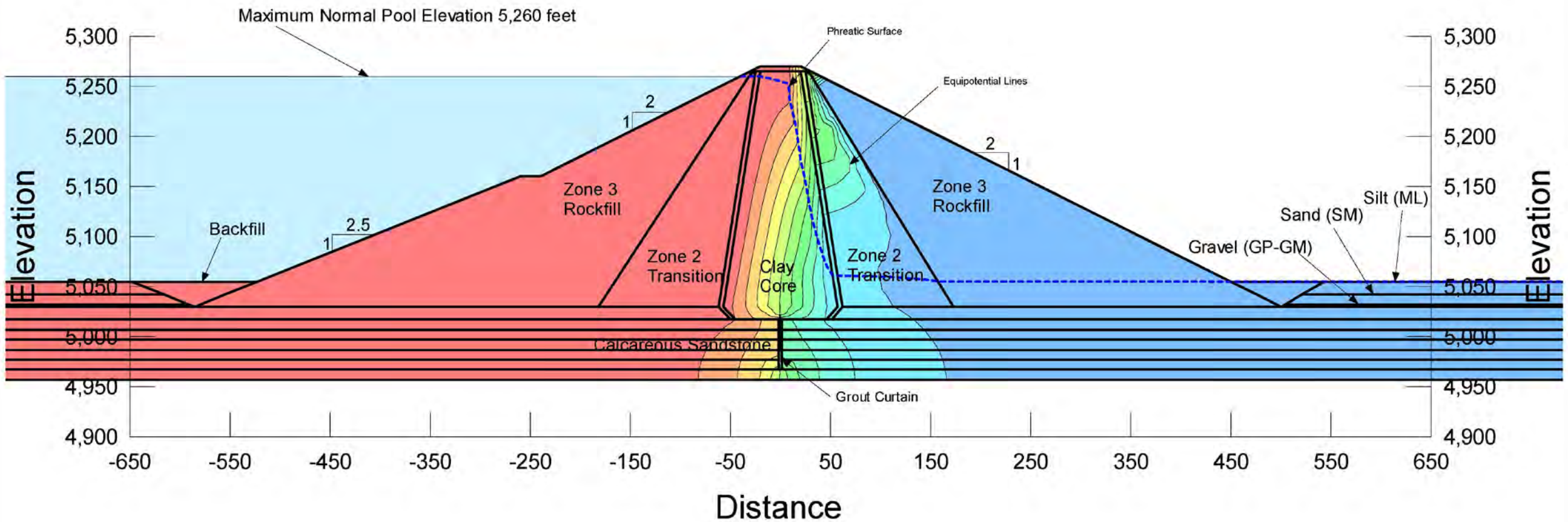


Figure 25. Whites Valley Site – Seepage Analysis Results – Seepage Total Head Contours



Whites Valley Site

Seepage Analysis Results

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Seepage Total Head Contours

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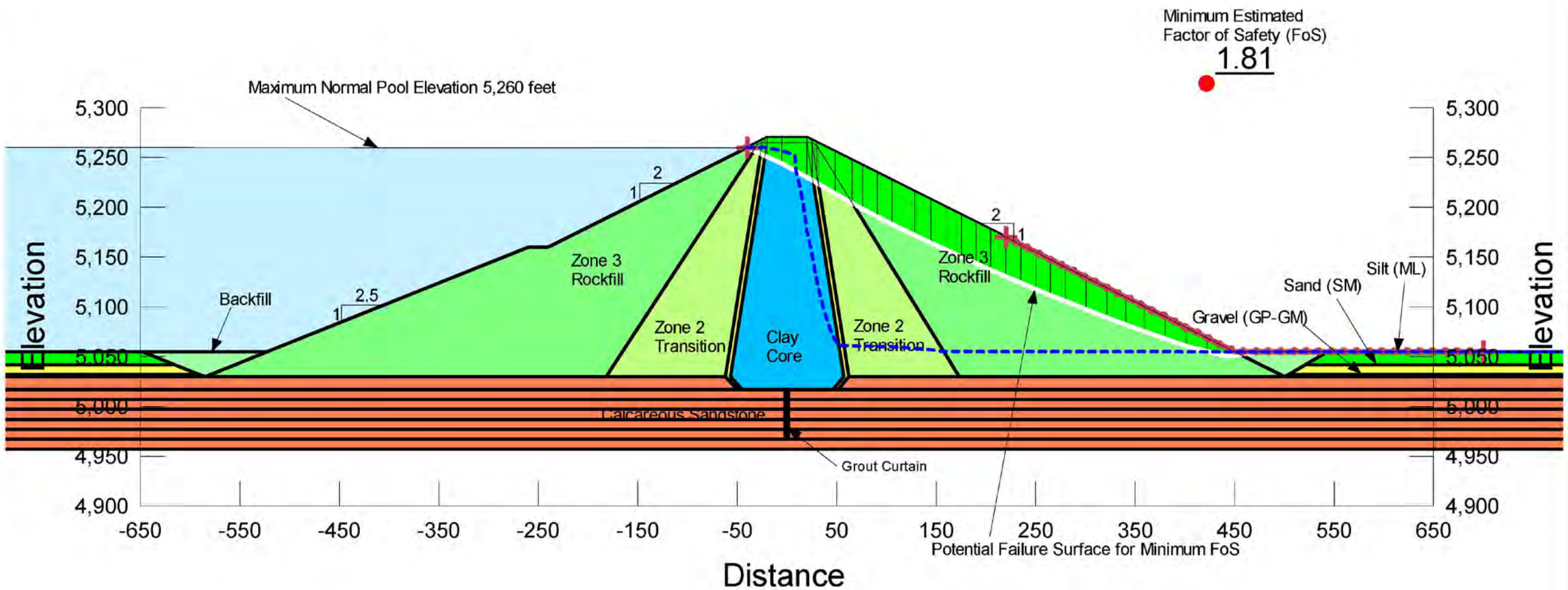
Bear River Project

FIGURE
25

Figure 26. Whites Valley Site – Steady-State Seepage Condition – Slope Stability Analysis Results



Whites Valley Site
Steady State Seepage Condition

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PROJECT NO. 239333	Slope Stability Analysis Results	FIGURE
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DRAWN BY: STA		
CHECKED BY: KAF		

Figure 27. Whites Valley Site – Slope Stability Analysis Results for Steady-State Seepage Condition – Factor of Safety with Weak Sandstone Seam, ϕ = 25°

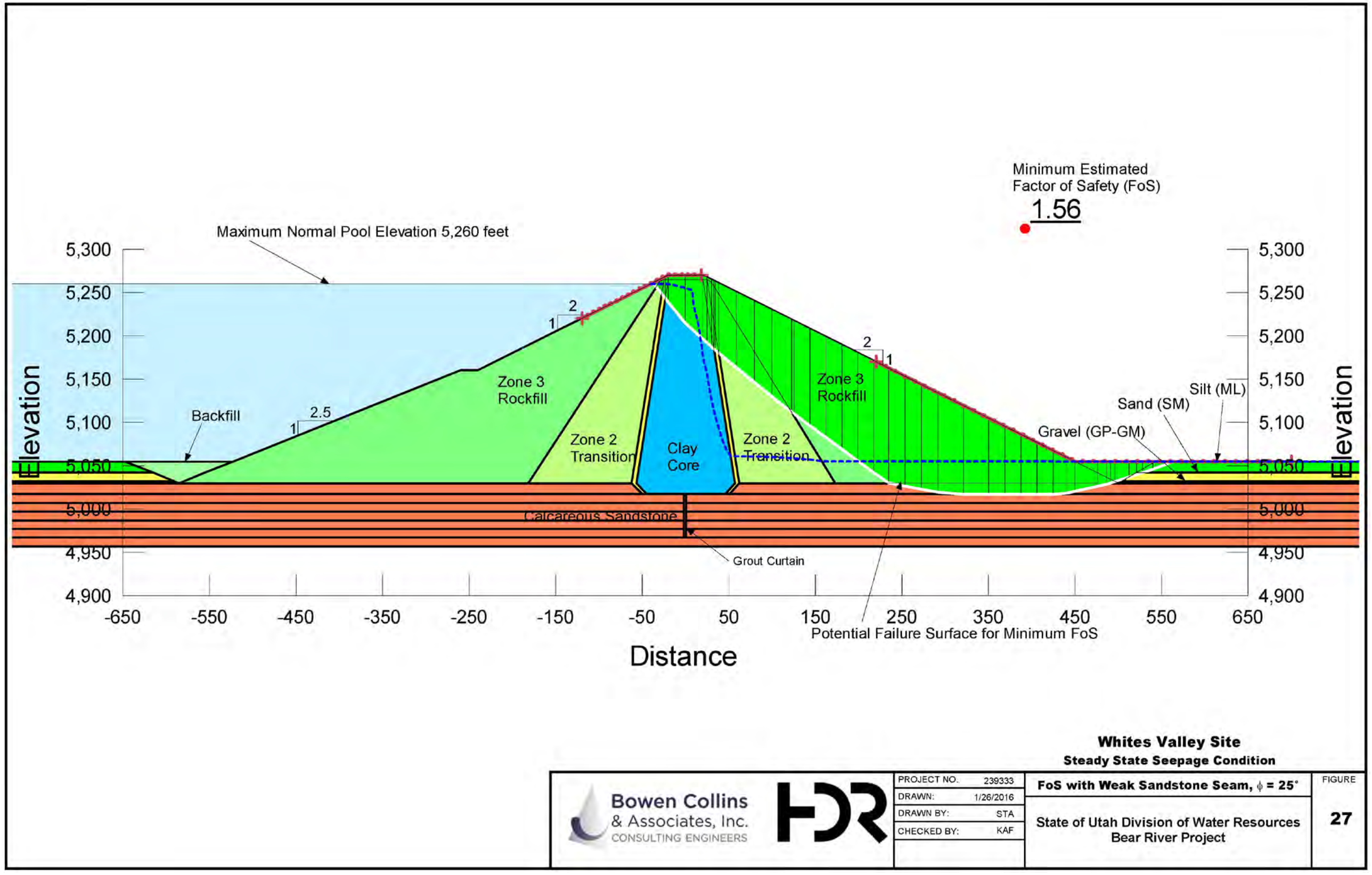
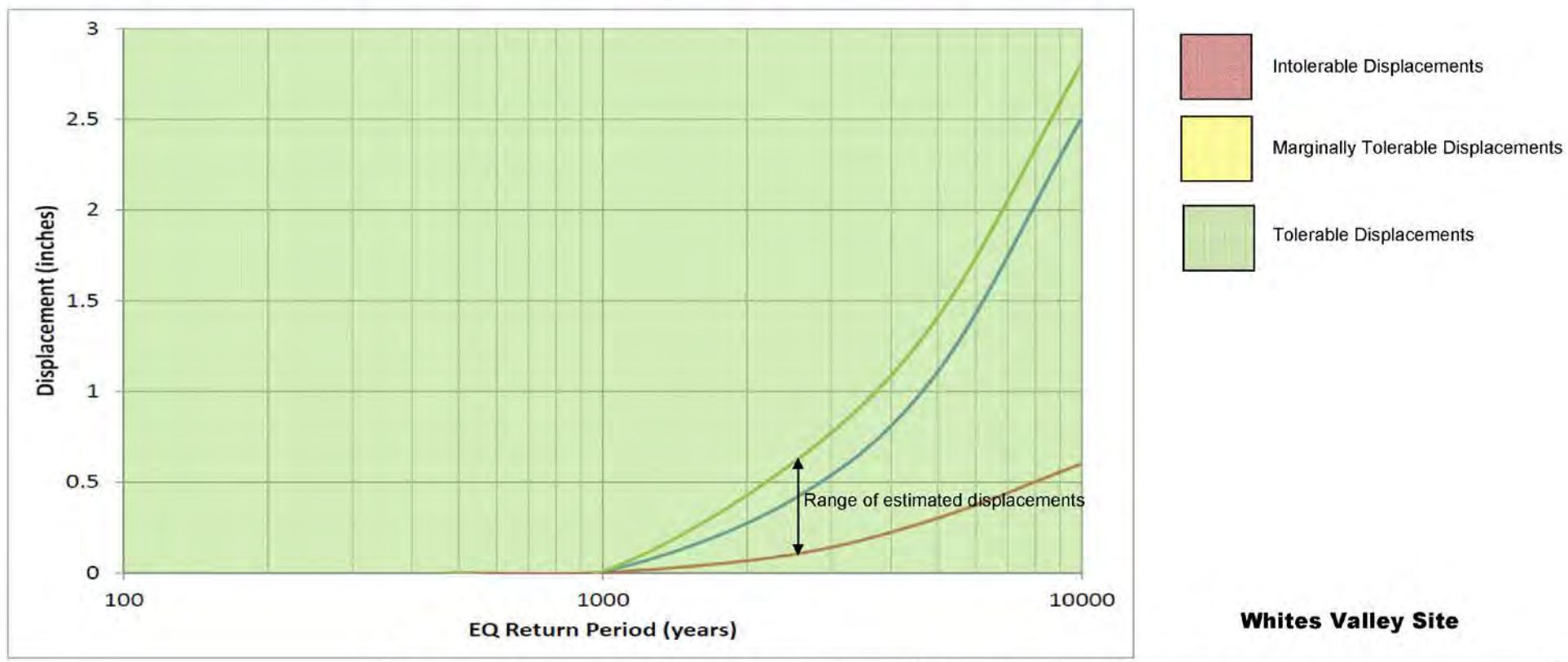


Figure 28. Whites Valley Site – Empirically Estimated Seismic Displacements

Site/Method	Estimated Displacement for EQ Return Interval (in.)				
Whites Valley (0.17g)	**475-yr**	**975-yr**	**2,475-yr**	**4,975-yr**	**9,950-yr**
Rathje and Saygili (2009)	0.0	0.0	0.4	1.1	2.5
Saygili and Rathje (2008)	0.0	0.0	0.4	1.3	3.1
Jibson (2007) Critical Acceleration Ratio	0.0	0.0	0.2	0.4	0.9
Jibson (2007) Critical Acceleration Ratio and Magnitude	0.0	0.0	0.1	0.3	0.6
Ambraseys and Menu (1998)	0.0	0.0	0.6	1.4	2.8



Whites Valley Site

Notes:
1. Estimated displacements from simplified empirical methods for cross section shown on Figure A-20

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Empirically Estimated Seismic Displacements

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FIGURE
28

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Comment Resolution Form

Disposition Codes	
A - Accept Comment	C - Delete Comment
B - Designer To Evaluate	D - IDT to Evaluate
E - So Noted	

Package No.		**Project Name**	Bear River Project - Temple Fork	**Submittal**	Temple Fork
Meeting Date		**Project No.**	13GCI329		

Item #	Sheet #	Reviewer/Date Received	Comment	Initial Disposition	Response / Clarification		Response By	Date	Verified By
1	Title Page	C. Ege	Name the study site of the report that is being presented, for example Temple Fork, South Willard Bay, Whites Valley, Fielding, or Cub River. This is a general comment that should apply to every geotechnical report associated with the Bear River Project	A	Will be added to report		R. Buhler	10/1/2018	R.Cole
2	Table of Contents	C. Ege	It would be nice to have an Executive Summary (Abstract) summarizing the highpoints of the report.	C	This is a data report intended as an appendix in the overall report. The main text, Bowen Collins report, summarizes each dam site.		R. Buhler	10/1/2018	R.Cole
3	Table of Contents	C. Ege	Also there should be a section entitled Conclusion and Recommendations (Section 4) that also serves the same purpose	C	This is a data report intended as an appendix in the overall report. The main text, Bowen Collins report, summarizes each dam site.		R. Buhler	10/1/2018	R.Cole
4	Overall Map	C. Ege	What is the purpose of this map? The map does not show all of the sites of the Bear River Project. Temple Fork is in the far left corner and is partially cut off. This map should either include all Bear River Project sites, thus covering a larger area or focus on the site that is currently being discussed in the report.	A	It appears you were provided a hard copy of our report and when they copied it they didn't copy the full 11x17 sheet. The original copy shows all locations and we will provide the full sheet in update report.		R. Buhler	10/1/2018	R.Cole
5	Figure 2.1	C. Ege	Include location of proposed dam alignment with dashed line. Map may need to cover a wider area to show the both abutments of the proposed dam alignment.	A	Will be included.		R. Buhler	10/1/2018	R.Cole
6	Site Specific Geology	C. Ege	If faults A and B are indeed active, they should be located on a map, showing where they project on the surface. Now to be the devil's advocate…Is there any evidence that these antithetic faults offset any Holocene material in the last 35,000 years? All that has been proven in this report is that these faults have offset the Garden City formation. A future fault trench study and more detailed geologic mapping of the site will need to be implemented to answer if these faults are indeed active.	A	Faults A and B have been added to Figure 2.1. As stated in Section 3.5.1 we consider these faults active according to the definition of UAC (R655-10-4) because they have a structural relationship to an active fault (the Temple Ridge fault). The following has been added to the text: "At this time, we do not have information on the displacement history of Faults A and B other than they offset beds within the Garden City formation. Additional studies might provide information on late-Pleistocene or Holocene surface rupture history."		E Lips	10/1/2018	R.Cole
7	Geolgic Hazards	C. Ege	Are there any other geologic hazards that could impact the site? May want to discuss possible solution cavities/karst issues with the Garden City limestone. This was already mentioned under the site-specific geology section and should be moved to the Geologic Hazards section. Another possible hazard that may need to be addressed is rock fall.	A	The section on solution cavities in the Garden City formation has been moved to a new section (3.5.3) in the Geologic Hazards part of the report. In addition a new section (3.5.4) has been added on rock-fall hazards.		E Lips	10/1/2018	R.Cole
8	Figure 3.1a and b	C. Ege	The geologic map needs several things: (1) to be consistent with other geologic maps, ie. Fielding and Cub River with caption and figure titles, (2) a north arrow, (3) a scale, (4) include geologic units that are not marked (see scan that is included). These missing units should also be included in the description of units (see scan that is included).	A	Will make adjustment		R. Buhler	10/1/2018	R.Cole
9	Figure 3.5	C. Ege	Needs a north arrow and scale.	A	Will include		R. Buhler	10/1/2018	R.Cole
10	Test Holes	C. Ege	Would be nice to have a list of acronyms that are listed on the test hole logs. Some of these acronyms can be found on the field discontinuity logs which are hidden within the report. Reader/Client may not be aware what these acronyms stand for.	A	Will include a description key		R. Buhler	10/1/2018	R.Cole
11	Test Holes	C. Ege	Also, include the approximate location of Fault A and B on the logs in the field notes section.	A	Will include		R. Buhler	10/1/2018	R.Cole

Comment Resolution Form

						Disposition Codes	
Package No.		**Project Name**	Bear River Project - Temple Fork	**Submittal**	Temple Fork	A - Accept Comment	C - Delete Comment
Meeting Date		**Project No.**	13GCI329			B - Designer To Evaluate	D - IDT to Evaluate
						E - So Noted	

Item #	Sheet #	Reviewer/Date Received	Comment	Initial Disposition	Response / Clarification		Response By	Date	Verified By
12	Miscellaneous Issues	C. Ege	These comments are common punctuation or spelling errors seen throughout the text of the report and the logs. See scan of report that follows this section for more information.	A	Will revise		R. Buhler	10/1/2018	R.Cole
13	Miscellaneous Issues	C. Ege	Seismic refraction was part of the scope associated with the site characterization plans. What was the reasoning that the survey was not included in part of the study? Forest Services Issues, etc?	A	The seismic refraction survey was intended to provide information on the depth to bedrock. However, after completing the field studies, it was determined that bedrock was near the surface at the abutments, and within 22 feet of the ground surface along Temple Fork Road (based on borings). Given this infomation, it was determined that little else on depth to bedrock would be gained from conducting seismic refraction surveys. In addition, there were limitations from the Forest Service.		E Lips	10/1/2018	R.Cole

Comment Resolution Form

Disposition Codes	
A - Accept Comment	C - Delete Comment
B - Designer To Evaluate	D - IDT to Evaluate
E - So Noted	

Package No.		**Project Name**	Bear River Project - Whites Valley	**Submittal**	Whites Valley
Meeting Date		**Project No.**	13GCI329		

Item #	Sheet #	Reviewer/Date Received	Comment	Initial Disposition	Response / Clarification		Response By	Date	Verified By
1	Title Page	C. Ege	Name the study site of the report that is being presented, for example Temple Fork, South Willard Bay, Whites Valley, Fielding, or Cub River. This is a general comment that should apply to every geotechnical report associated with the Bear River Project	A	Will be added to report		R. Buhler	10/7/2018	R.Cole
2	Table of Contents	C. Ege	It would be nice to have an Executive Summary (Abstract) summarizing the highpoints of the report.	A	This is a data report intended as an appendix in the overall report. The main text, Bowen Collins report, summarizes each dam site.		R. Buhler	10/7/2018	R.Cole
	Table of Contents	C. Ege	Additional Services should be in caps like other reports.	A	Will revise		R. Buhler	10/7/2018	R.Cole
3	Table of Contents	C. Ege	Also there should be a section entitled Conclusion and Recommendations (Section 4) that also serves the same purpose	A	Has been added		R. Buhler	10/7/2018	R.Cole
4	Overall Map	C. Ege	What is the purpose of this map? The map does not show all of the sites of the Bear River Project. Temple Fork is in the far left corner and is partially cut off. This map should either include all Bear River Project sites, thus covering a larger area or focus on the site that is currently being discussed in the report.	A	It appears you were provided a hard copy of our report and when they copied it they didn't copy the full 11x17 sheet. The original copy shows all locations and we will provide the full sheet in update report.		R. Buhler	10/7/2018	R.Cole
5	Figure 2.1	C. Ege	Include location of proposed dam alignment with dashed line. Map may need to cover a wider area to show the both abutments of the proposed dam alignment.	A	Will include		R. Buhler	10/7/2018	R.Cole
6	Figure 3.1a and b	C. Ege	The geologic map needs several things: (1) to be consistent with other geologic maps, ie. Fielding and Cub River with caption and figure titles, (2) a north arrow, (3) a scale, (4) include geologic units that are not marked (see scan that is included). These missing units should also be included in the description of units (see scan that is included).	A	Will make adjustment		R. Buhler	10/7/2018	R.Cole
7	Test Holes	C. Ege	Would be nice to have a list of acronyms that are listed on the test hole logs. Some of these acronyms can be found on the field discontinuity logs which are hidden within the report. Reader/Client may not be aware what these acronyms stand for.	A	Will include a description key		R. Buhler	10/7/2018	R.Cole
8	Miscellaneous Issues	C. Ege	These comments are common punctuation or spelling errors seen throughout the text of the report and the logs. See scan of report that follows this section for more information.	A	Will revise		R. Buhler	10/7/2018	R.Cole
9	Miscellaneous Issues	C. Ege	What happened to the series of 6 to 8 auger borings wihin the reservoir basin to depths of 20 to 25 feet were included as part of the site characterization plans? Does TH-WV-04 satisfy that need.	A	See new report with test pits throughout the valley.		R. Buhler		R.Cole

Comment Resolution Form

Disposition Codes	
A - Accept Comment	C - Delete Comment
B - Designer To Evaluate	D - IDT to Evaluate
E - So Noted	

Package No.		**Project Name**	Bear River Project - Cub River	**Submittal**	Cub River
Meeting Date		**Project No.**	13GCI329		

Item #	Sheet #	Reviewer/Date Received	Comment	Initial Disposition	Response / Clarification		Response By	Date	Verified By
1	Title Page	C. Ege	Name the study site of the report that is being presented, for example Temple Fork, South Willard Bay, Whites Valley, Fielding, or Cub River. This is a general comment that should apply to every geotechnical report associated with the Bear River Project	A	Will be added to report		R. Buhler	9/24/2018	R.Cole
2	Table of Contents	C. Ege	It would be nice to have an Executive Summary (Abstract) summarizing the highpoints of the report.	C	This is a data report intended as an appendix in the overall report. The main text, Bowen Collins report, summarizes each dam site.		R. Buhler	9/24/2018	R.Cole
3	Table of Contents	C. Ege	Also there should be a section entitled Conclusion and Recommendations (Section 4) that also serves the same purpose	C	It is a data report, conclusions and recommendations on design can be found in HDR's report		R. Buhler	9/24/2018	R.Cole
4	Table of Contents	C. Ege	The general in General setting should be capitalized.	A	Will revise		R. Buhler	9/24/2018	R.Cole
5	Overall Map	C. Ege	What is the purpose of this map? The map does not show all of the sites of the Bear River Project. Temple Fork is in the far left corner and is partially cut off. This map should either include all Bear River Project sites, thus covering a larger area or focus on the site that is currently being discussed in the report.	A	It appears you were provided a hard copy of our report and when they copied it they didn't copy the full 11x17 sheet. The original copy shows all locations and we will provide.		R. Buhler	9/24/2018	R.Cole
6	Figure 2.1	C. Ege	Include location of proposed dam alignment with dashed line. Map may need to cover a wider area to show the both abutments of the proposed dam alignment.	A	Will include		R. Buhler	9/24/2018	R.Cole
7	Geologic Hazards	C. Ege	Are there any other geologic hazards that could impact the site, such as liquefaction? A general liquefaction assessment would suffice at this stage of the process.	A	Our report is inteded as a data report. Liquefaction related risks are addressed by HDR.		R. Buhler	9/24/2018	R.Cole
8	Test Holes	C. Ege	Need to add water levels to TH-CUB-01 and TH-CUB-02 (see scans)	A	Will include		R. Buhler	9/24/2018	R.Cole
9	Test Holes	C. Ege	Some punctuation erros need to be corrected.	A	Will revise		R. Buhler	9/24/2018	R.Cole
10	Miscellaneous Issues	C. Ege	These comments are common punctuation or spelling errors seen throughout the text of the report and the logs. See scan of report that follows this section for more information.	A	Will revise		R. Buhler	9/24/2018	R.Cole
11	Miscellaneous Issues	C. Ege	Why no seismic refraction survey? A seismic refraction survewy was part of the site characterization plans.	A	The seismic refraction survey was intended to provide information on depth to bedrock. After conducting the initial geologic investigation, the design team determined that the depth to bedrock was likely beyond the limits of the shallow refraction surveys, and more importantly, the depth to bedrock would not influence the design of the dam.		E Lips	9/24/2018	R.Cole

Comment Resolution Form

						Disposition Codes	
Package No.		**Project Name**	Bear River Project - South Willard Bay	**Submittal**	South Willard Bay	A - Accept Comment	C - Delete Comment
Meeting Date		**Project No.**	13GCI329			B - Designer To Evaluate	D - IDT to Evaluate
						E - So Noted	

Item #	Sheet #	Reviewer/Date Received	Comment	Initial Disposition	Response / Clarification		Response By	Date	Verified By
1	Title Page	C. Ege	Name the study site of the report that is being presented, for example Temple Fork, South Willard Bay, Whites Valley, Fielding, or Cub River. This is a general comment that should apply to every geotechnical report associated with the Bear River Project	A	Will be added to report		R. Buhler	9/24/2018	R.Cole
2	Table of Contents	C. Ege	It would be nice to have an Executive Summary (Abstract) summarizing the highpoints of the report.	C	This is a data report intended as an appendix in the overall report. The main text, Bowen Collins report, summarizes each dam site.		R. Buhler	9/24/2018	R.Cole
3	Table of Contents	C. Ege	Also there should be a section entitled Conclusion and Recommendations (Section 4) that also serves the same purpose	C	It is a data report, conclusions and recommendations on design can be found in HDR's report		R. Buhler	9/24/2018	R.Cole
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5	Figure 2.1	C. Ege	Include location of proposed dam alignment with dashed line. Map may need to cover a wider area to show the both abutments of the proposed dam alignment.	A	Will include		R. Buhler	9/24/2018	R.Cole
6	Figure 3.1	C. Ege	The geologic map needs several things: (1) to be consistent with other geologic maps, ie. Fielding and Cub River with caption, figure title, and number, (2) a north arrow, (3) a scale, (4) approximate location of the proposed dam, (5) there is also a geologic unit (Qav) shown on the map that is not described (see scan that is included).	A	Will revise		R. Buhler	9/24/2018	R.Cole
7	Test Holes	C. Ege	The term “varved” is used in Test Hole TH-WB-01 and TH-WB-02. This term is generally used to describe deposits associated with glacial lakes. Another word should be used to describe the clay. See scan of logs for more details.	C	While the term "varved" is used to describe deposits associated with glacial lakes, it is also commonly used and accepted in the Lake Bonneville research community as describing laminations in lake bed deposits representing seasonal pairs, or couplets, of sediments.		R. Buhler / E. Lips	9/24/2018	R.Cole
8	Test Holes	C. Ege	Some punctuation errors need to be corrected.	A	Will revise		R. Buhler	9/24/2018	R.Cole
9	Miscellaneous Issues	C. Ege	These comments are common punctuation or spelling errors seen throughout the text of the report and the logs. See scan of report that follows this section for more information.	A	Will revise		R. Buhler	9/24/2018	R.Cole

Comment Resolution Form

						Disposition Codes	
Package No.		**Project Name**	Bear River Project - Fielding Site	**Submittal**	Fielding	A - Accept Comment	C - Delete Comment
Meeting Date		**Project No.**	13GCI329			B - Designer To Evaluate	D - IDT to Evaluate
						E - So Noted	

Item #	Sheet #	Reviewer/Date Received	Comment	Initial Disposition	Response / Clarification		Response By	Date	Verified By
1	Title Page	C. Ege	Name the study site of the report that is being presented, for example Temple Fork, South Willard Bay, Whites Valley, Fielding, or Cub River. This is a general comment that should apply to every geotechnical report associated with the Bear River Project	A	Will be added to report		R. Buhler	9/26/2018	R.Cole
2	Table of Contents	C. Ege	It would be nice to have an Executive Summary (Abstract) summarizing the highpoints of the report.	C	This is a data report intended as an appendix in the overall report. The main text, Bowen Collins report, summarizes each dam site.		R. Buhler	9/26/2018	R.Cole
3	Table of Contents	C. Ege	Surficial under section 3 Geology is spelled wrong.	A	Will revise		R. Buhler	9/26/2018	R.Cole
4	Table of Contents	C. Ege	Geologic under section 3 Geology is not capitalized.	A	Will revise		R. Buhler	9/26/2018	R.Cole
5	Table of Contents	C. Ege	Also there should be a section entitled Conclusion and Recommendations (Section 4) that also serves the same purpose	C	It is a data report, conclusions and recommendations on design can be found in HDR's report		R. Buhler	9/26/2018	R.Cole
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7	Figure 2.1	C. Ege	Include location of proposed dam alignment with dashed line. Map may need to center to show test holes better.	A	Will revise		R. Buhler	9/26/2018	R.Cole
8	Test Holes	C. Ege	The term “varved” is used in Test Hole TH-WB-01 and TH-WB-02. This term is generally used to describe deposits associated with glacial lakes. Another word should be used to describe the clay. See scan of logs for more details.	C	While the term "varved" is used to describe deposits associated with glacial lakes, it is also commonly used and accepted in the Lake Bonneville research community as describing laminations in lake bed deposits representing seasonal pairs, or couplets, of sediments.		R. Buhler / E. Lips	9/26/2018	R.Cole
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DRAFT Cub River - Geotechnical Data Report - Bear River Project Concept Study

Prepared for
Bowen Collins & Associates, Inc
October 2018

GCI project number: 13GCI329

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October 31, 2018

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Cub River Geotechnical Data Report
Bear River Project Concept Study
13GCI329

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TABLE OF CONTENTS

SECTION 1 Introduction 1-1

1.1 Project Description 1-1
1.2 Purpose, Authorization, and Work Scope 1-1

SECTION 2 Methods of Study and Findings 2-1

2.1 Cub River Site 2-1
2.1.1 Test Hole Drilling and Sampling 2-1
2.1.2 Laboratory Testing 2-2
2.1.3 Permeability Testing 2-2
2.1.4 Site Specific Conditions 2-2
2.1.5 Groundwater 2-3

SECTION 3 Geology 3-1

3.1 General setting 3-1
3.2 Lake Bonneville History 3-1
3.3 Surficial Deposits 3-2
3.4 Site-Specific Conditions 3-2
3.5 Geologic Hazards 3-3
3.5.1 Surface Fault Rupture 3-3
3.5.2 Landslides 3-3

SECTION 4 Conclusion 4-1

4.1 Additional Services 4-1
4.2 Limitations 4-1

SECTION 5 References 5-1

List of Tables

Table 2-1 Cub River – Laboratory Test Results

Table 2-2 Cub River – Constant Head Permeability Test Results

Table 2-3 Cub River - Groundwater Measurements

Table 3-1 Qualitative Landslide Rating

List of Figures

Figure 1.1 Vicinity Map

Figure 2.1 Cub River – Site and Exploration Map

Figure 3.1 Geologic Map (reference: Brummer and McCalpin, 1995)

TABLE OF CONTENTS

List of Appendices

Appendix A - Cub River - Test Hole Logs

Appendix B - Cub River - Interpretative Laboratory Test Results

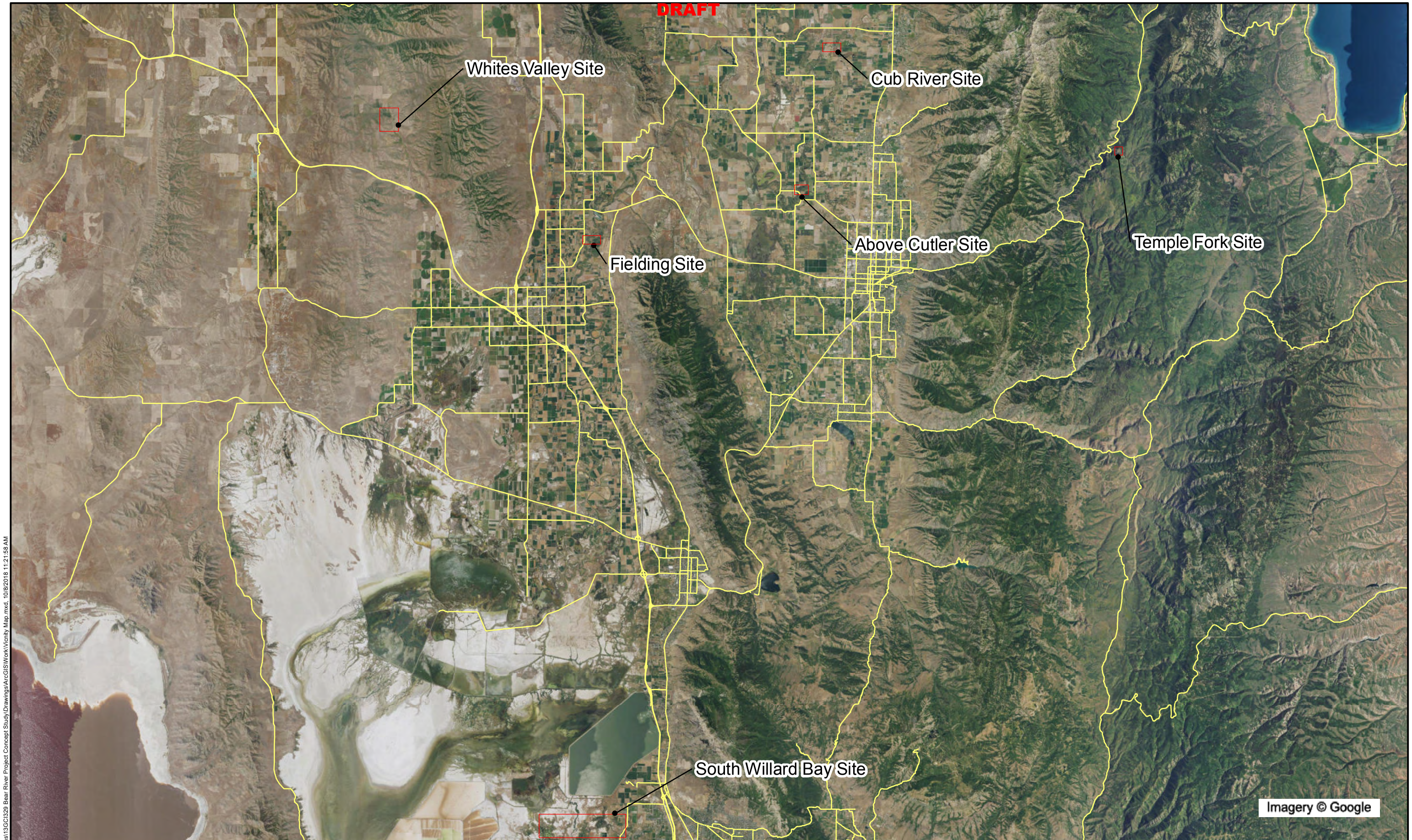
1.1 Project Description

The purpose of the Bear River Project is to develop Utah's unused water rights on the Bear River and deliver it to Box Elder, Cache, Weber, Davis, and Salt Lake Counties. The overall Project will consist of conveyance facilities and reservoir storage necessary to deliver water from the Bear River to the communities in the service areas of the Bear River Water Conservancy District (BRWCD), Cache County, the Weber Basin Water Conservancy District (WBWCD), and the Jordan Valley Water Conservancy District (JVWCD). The Utah Division of Water Resources (DWRe) has been working with Bowen Collins and Associates and HDR (Project Team) for several years to develop the overall Project.

1.2 Purpose, Authorization, and Work Scope

This report presents the results of geotechnical and geologic studies performed by Gerhart Cole Inc. (GCI) at Cub River in support of the project design team. The other project study areas that have had some studies completed are Fielding, Above Cutler, Temple Fork, South Willard Bay, and Whites Valley. The locations of these study sites are shown in Figure 1-1 along with the Cub River Site.

GCI scope of work included a preliminary site characterization of the site, including drilling 3 test holes, geologic study of the dam and reservoir site, and associated laboratory testing on select samples recovered from the test holes. This work was completed under GCI's existing cooperative reciprocal service agreement with BCA.



GERHART COLE

Bear River Project Concept Study

Vicinity Map

N

0 8,000 16,000 32,000 Feet

Figure 1-1

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2.1 CUB RIVER SITE

A field study was conducted at the Cub River site between September 4 and September 9, 2014. The study consisted of drilling and sampling three test holes (TH-CUB-01, TH-CUB-02, and TH-CUB-03). A site map showing test hole locations is presented as Figure 2-1. Test hole locations were: a) established by GCI based on accessibility and proximity to the proposed dam; and b) documented by using a hand-held, tablet-mounted GPS device. Test Hole elevations were estimated from auto-correlated 5 meter DEM data from the Utah GIS portal website with an elevation datum of NAVD88.

2.1.1 Test Hole Drilling and Sampling

Test holes were drilled on private property with the permission of the land owners, and advanced to depths between 40 and 80 feet. TH-CUB-01 was advanced near the proposed right abutment while TH-CUB-02 is on the east bank of the Cub River near the center of the proposed dam. TH-CUB-03 was drilled near the left abutment of the proposed dam. One-inch diameter open standpipe piezometers, to monitor groundwater levels, were installed in all three test holes.

The piezometer in TH-CUB-01 was screened from 57 to 62 feet, with a sand pack from 62 to 52 feet. TH-CUB-02 piezometer was screened from 42 to 37 feet, with a sand pack from 42 to 32 feet, and the piezometer in TH-CUB-03 was screened from 81.5 to 76.5 feet, with a sand pack from 81.5 to 71.5 feet. Remaining well intervals were sealed with bentonite chips.

Test holes were completed by advancing HW casing (4-inch I.D) and rotary wash drilling methods. Drilling was accomplished with a CME 75 truck-mounted drill rig operated by Bedke Geotechnical Field Services under subcontract to GCI.

Subsurface conditions were logged by a GCI field engineer at the time of drilling. Three sampling methods were used to obtain soil specimens for characterization and laboratory testing. Standard Penetration Test (SPT), Shelby Tube (ST) samples, and fixed piston Shelby Tube (ST-Piston) samples were obtained from the test holes. ST-Piston samplers were used in softer soil deposits when difficulty was experienced obtaining ST samples.

Sampling was performed at 2.5 or 5-foot intervals. Two and one half-foot intervals were generally performed in coarse-grained soil deposits, with 5-foot sample intervals performed in fine-grained soil deposits. SPT samples were obtained using an automatic hammer, the energy efficiency of which was recently measured at 77 percent. The number of hammer blows required to advance the sampler in 6-inch increments was recorded in the field, with the sum of the second and third 6-inch intervals constituting the SPT blowcount or “N-value.”

Logs of test holes are presented in Appendix A. Lines designating boundaries between different materials shown on the logs should be considered approximate, as transitions between subsurface materials may be gradual or occur between sampling depths. Relative density and consistency descriptions contained in a final test hole log may

deviate from field logs and/or criteria for a number of reasons, including; a) reliance on other test results, b) visual observation and/or manual manipulation of disturbed field samples, or c) the Engineer's judgment. For most engineering assessments involving cohesionless, non-gravelly soils, the SPT blowcount is usually adjusted for effective vertical pressure at the sampling depth, and for other sampling system parameters such as the efficiency of the sampling system and/or sampling techniques used.

2.1.2 Laboratory Testing

Laboratory testing was performed on selected soil specimens obtained during field studies to further classify them and evaluate their engineering properties. Laboratory testing included moisture content, Atterberg limits, grain size distribution, and pinhole dispersion tests. One dimensional (1-D) consolidation testing was performed on seven (7) samples. Shear strength testing was performed on three (3) samples by performing tri-axial, consolidated, undrained (with pore pressure measurements) (CUPP) tests. Laboratory test results are summarized in Table 2-1, with additional data and plots presented in Appendix B.

2.1.3 Permeability Testing

Field permeability tests were performed by drilling down to the bottom of the test zone, with the casing held at the top of the test zone and extending to the ground surface. The bit was then removed, leaving the casing in place creating a vertical cylindrical void within soil comprising the test region and a cased test hole down to the top of the test region. The void and casing were filled with water to the top of the casing and water was added as needed to keep the casing full for the duration of the test (typically 10 to 15 minutes). At the end of the test, the volume of water added and test duration were recorded. These results are presented in Table 2-2.

2.1.4 Site Specific Conditions

Soils found in the test holes generally consisted of high plasticity clay (CH) or medium plasticity clay (CL). Approximately 18 feet of medium stiff to stiff clay (CH) was found overlying 44 feet of very soft to medium stiff clay (CL) in TH-CUB-01. Field permeability testing suggested that sand seams are present in the profile between 20 to 30 feet.

Soft silty clay (CL-ML) was found from the ground surface to 12.5 feet in TH-CUB-02. Underlying the silty clay was 4.5 feet of loose silty sand (SM), then 2.5 feet of loose sand (SP) followed by 22 feet of very soft clay (CH) to a depth 41.5 feet, where the test hole was terminated.

Approximately 25 feet of soft to medium stiff clay (CH) was found in TH-CUB-03 that then transitioned to a soft to very soft clay (CH) to a depth of 30 feet. Between 30 and 43 feet, 4.5 feet of medium stiff to stiff clay (CL) was found, followed by 2 feet of soft silt (ML), and then approximately 6.5 feet of soft to medium stiff clay (CL). From a depth of approximately 43 feet to the bottom of the test hole at 81.5 feet, soils consisted of a soft to very soft clay (CH). See Appendix A for more information.

2.1.5 Groundwater

Groundwater levels were measured in piezometers, as summarized in Table 2-3. Artesian groundwater was found in TH-CUB-01, as indicated by a "+" in the groundwater measurement table. Measurements made during/after drilling may be less reliable than the later groundwater measurements due to drilling methods. Groundwater levels do fluctuate seasonally and may vary several feet in elevation.

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Table 2-1 - Laboratory Test Result Summary

Bear River Project Concept Study- Cub River

Test Hole	Depth (ft)	Moisture content (%)	Dry unit weight (pcf)	Moist / Sat. unit weight (pcf)	Atterberg Limits					Grain-Size			Grain-Size Analysis (Percent Finer)										Other Tests (Interpretative Data in Appendix)
					LL (%)	PL (%)	PI (%)	Cohesive Index, CI	Liquidity Index, LI	GRAVEL (No.4 - 3")	SAND (No.200-No.4)	FINES (<No.200)	1.5-in (37.5 mm)	3/4-in (19 mm)	3/8-in (9.5 mm)	No.4 (4.75 mm)	No.10 (2 mm)	No.20 (0.85 mm)	No.40 (0.425 mm)	No.60 (0.25 mm)	No.100 (0.15 mm)	No.200 (0.075 mm)	
TH-CUB-01	5-7	31			65	23	42	1.83	0.2														Proctor, Pinhole
TH-CUB-01	10-12	34			70	25	45	1.8	0.2														
TH-CUB-01	15-16.5	42.4	78	111	68	27	41	1.52	0.4														1D Consolidation
TH-CUB-01	25-26.5	31	91	119	42	22	20	0.91	0.4														1D Consolidation
TH-CUB-01	35-36.5	25	95	118	48	19	29	1.53	0.2														CU
TH-CUB-01	40-42	36			48	22	26	1.18	0.6														
TH-CUB-01	60-62	29	87	115	39	25	14	0.56	0.3	1	19	80	100	100	100	99	94	88	85	83	81	80	1D Consolidation
TH-CUB-02	5-7	27			26	21	5	0.24	1.1	0	24	75	100	100	100	100	100	100	100	99	94	75	Proctor, Pinhole
TH-CUB-02	14.3-15	26								0	83	17	100	100	100	100	99	98	94	71	31	17	
TH-CUB-02	15-17	31								0	80	20	100	100	100	100	97	87	71	51	27	20	
TH-CUB-02	17.5-19.5	23								0	93	6	100	100	100	100	96	76	37	19	10	6	
TH-CUB-02	20-21.5	31	89	117	48	22	26	1.18	0.4														CU
TH-CUB-02	25-27	57			72	29	43	1.48	0.6														
TH-CUB-02	35-37	56			73	29	44	1.52	0.6														
TH-CUB-02	40-41.5	56	66	102	74	30	44	1.47	0.6														1D Consolidation

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Table 2-1 - Laboratory Test Result Summary

Bear River Project Concept Study- Cub River

Test Hole	Depth (ft)	Moisture content (%)	Dry unit weight (pcf)	Moist / Sat. unit weight (pcf)	Atterberg Limits					Grain-Size			Grain-Size Analysis (Percent Finer)										Other Tests (Interpretative Data in Appendix)
					LL (%)	PL (%)	PI (%)	Cohesive Index, CI	Liquidity Index, LI	GRAVEL (No.4 - 3")	SAND (No.200-No.4)	FINES (<No.200)	1.5-in (37.5 mm)	3/4-in (19 mm)	3/8-in (9.5 mm)	No.4 (4.75 mm)	No.10 (2 mm)	No.20 (0.85 mm)	No.40 (0.425 mm)	No.60 (0.25 mm)	No.100 (0.15 mm)	No.200 (0.075 mm)	
TH-CUB-03	5-7	33.0			56	25	31	1.24	0.3													98	Proctor, Pinhole
TH-CUB-03	10-12	36.6			62	25	37	1.48	0.3														
TH-CUB-03	15-16.5	35.6	86	116	73	28	45	1.61	0.2														1D Consolidation, Proctor, Pinhole
TH-CUB-03	20-22	36.0			53	25	28	1.12	0.4														
TH-CUB-03	25-27	32.9	86	115	46	23	23	1	0.4														CU
TH-CUB-03	30-32	31.6			33	20	13	0.65	0.9	0	7	93	100	100	100	100	100	100	100	100	100	93	
TH-CUB-03	32.5-33.5	38.5			43	23	20	0.87	0.8														
TH-CUB-03	33.5-34.5	26.0			NP					0	24	76	100	100	100	100	100	100	100	100	100	76	Hydrometer
TH-CUB-03	35-36.5	31.9								0	4	96	100	100	100	100	100	100	100	100	100	96	Hydrometer
TH-CUB-03	36.5-37	35.7			47	23	24	1.04	0.5														
TH-CUB-03	40-41.5	39.9	80	112	48	23	25	1.09	0.7														1D Consolidation
TH-CUB-03	45-47	44.1			59	25	34	1.36	0.6														
TH-CUB-03	55-57	45.1			61	25	36	1.44	0.6														
TH-CUB-03	65-67	41			64	27	37	1.37	0.4														
TH-CUB-03	75-77	60			60	26	34	1.31	1.0														
TH-CUB-03	80-81.5				67	28	39	1.39															

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Table 2-2 - Cub River - Constant Head Permeability Testing Summary

Bear River Concept Study - Cub River

Location	Test Depth (ft)	Soil Type in Test Range	Ground Water Depth (ft)[a]	Flow, Q (gpm)	Hydraulic Conductivity (Lugeons)	Hydraulic Conductivity (cm/sec)	Comments
TH-CUB-01	9-20	CL/CH	10	0.20	7	9E-05	CL bounds top and CH bounds bottom of test zone
TH-CUB-01	19-30	CH	10	0.58	19	3E-04	Inordinantly high hydraulic conductivity -- sand seams or leakage possible.
TH-CUB-01	29-40	CH	10	0.00	0	2E-06	CH bounds bottom and top of test zone
TH-CUB-01	40-50	CH	10	0.00	0	2E-06	CH bounds bottom and top of test zone
TH-CUB-02	9-15	CL/ML/SM	10	1.28	69	9E-04	CL bounds top and sand bounds bottom of test zone
TH-CUB-02	19-25	CH	10	0.00	0	3E-06	CH bounds bottom and top of test zone
TH-CUB-02	25-40	CH	10	0.04	1	1E-05	CH bounds bottom and top of test zone
TH-CUB-03	9-20	CL	25	0.04	1	7E-06	CL bounds bottom and top of test zone
TH-CUB-03	20-30	CL/CH	25	0.00	0	9E-07	CL extends beyond limits of test in both directions.
TH-CUB-03	30-40	CL/CH/SM	25	0.01	0	1E-06	Clay on top and silt on bottom of test zone.
TH-CUB-03	9-60	CL/CH/SM	25	0.04	0	2E-06	Essentially no flow between 40 and 60 feet.
TH-CUB-03	60-80	CH	25	0.04	0	5E-06	CH bounds bottom and top of test zone

Notes: a. Depth to groundwater estimated from water level in river adjacent to test hole and by moisture profile.

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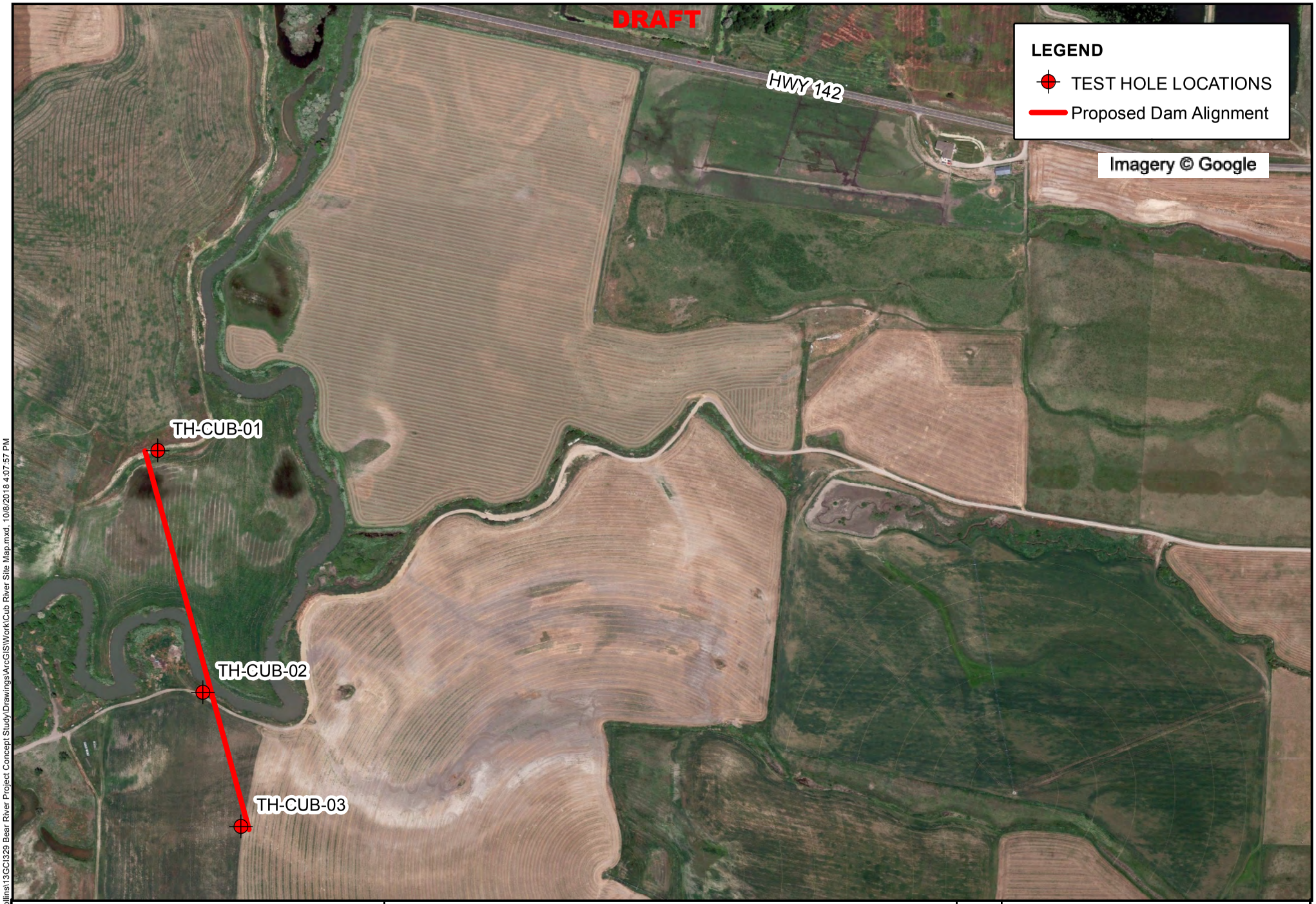
Table 2-3 - Cub River- Groundwater Measurements

Bear River Concept Study - Cub River

Date	Groundwater Depth in Piezometer (ft)		
	TH-CUB-01	TH-CUB-02	TH-CUB-03
September 5, 2014		+1.7	
September 8, 2014			20.6
September 9, 2014	+10		
June 16, 2015	+10.3	0	20.3
September 30, 2015	+8.1>	0	19.2



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Bear River Project Concept Study - Cub River

Cub River Site and Exploration Map

N

0 250 500 1,000 Feet

Figure 2-1

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3.1 GENERAL SETTING

The proposed site is located on the eastern side of Cache Valley, a north-trending, deep, sediment-filled structural basin bounded by the Bear River Range on the east and by Bergeson Hill, Pete McCombs Hill, and Little Mountain on the west. Cache Valley is located at the eastern margin of the Basin and Range Physiographic Province, a region characterized by a series of generally north-trending mountain ranges separated by similarly trending valleys, and the Middle Rocky Mountains Physiographic Province, an area characterized in this region by folded and faulted sedimentary rocks. The large-scale topographic features are a result of east-west crustal extension that began about 15 to 17 million years ago, and continues today (Hecker, 1993). The crustal extension has resulted in range front normal faults separating the mountains from valleys. Erosional processes have removed material from the mountains and partially filled the valley with alluvial and lacustrine (lake) sediments.

3.2 LAKE BONNEVILLE HISTORY

The near-surface geology of the proposed site is dominated by sediments deposited and/or reworked by Lake Bonneville, a large late-Pleistocene lake that covered much of northwestern Utah and adjacent parts of Idaho and Nevada. The lake began to rise above levels comparable to the Great Salt Lake about 28,000 years ago[1] and by approximately 16,000 ago, the lake reached its highest elevation – the Bonneville shoreline (Gilbert, 1890; Currey, 1990). Near the proposed site, the elevation of the Bonneville shoreline is at about 5,100 feet (Brummer and McCalpin, 1995).

Lake Bonneville remained at the elevation of the Bonneville shoreline until about 14,500 years ago when a catastrophic failure near Red Rock Pass caused a massive flooding of lake waters into the Snake River drainage. This event, called the Bonneville flood, caused a drop in lake level of about 340 feet, where the lake level restabilized and the Provo shoreline began to form. Near the proposed site, the elevation of the Provo shoreline is at about 4,800 feet (Brummer and McCalpin, 1995).

The lake oscillated at or near the level of the Provo shoreline until about 12,500 years ago when a change in climate conditions permanently drove the lake below the threshold at Red Rock Pass. By about 11,500 years ago, the lake had reached levels comparable to modern Great Salt Lake – about 4,200 feet (Godsey et. al., 2005).

The lake rose again briefly between about 11,000 and 10,000 years ago to form the Gilbert shoreline at approximately 4,240 to 4,250 feet, and then again declined (Oviatt et al., 2005). This marks the end of Lake Bonneville and the beginning of its successor, Great Salt Lake (Currey et al., 1984).

During the time Lake Bonneville existed in Cache Valley, coarse-grained sediments were deposited in the shore and nearshore environments creating beaches, deltas, spits, and bars. In deeper water, toward the center of the valley, deposits generally consist of finer grained sand, silt, clay, and marl (Oviatt and Miller, 1997).

[1] Unless otherwise noted, all ages are radiocarbon ages.

3.3 SURFICIAL DEPOSITS

The most detailed published geologic mapping completed in the vicinity of the proposed site is at a scale of 1:24,000 (Brummer and McCalpin, 1995). Brummer and McCalpin have mapped two surficial deposits in the vicinity of, and immediately upstream of the project site (Figure 3-1):

- Stream Alluvium (Qal_1) consisting of pebble to cobble gravel in sand and silt matrix deposited on modern flood plains and terraces (Holocene).
- Lacustrine fine-grained sediments (Qlf) consisting of silt and clay deposited as lake bottom sediments during the Bonneville lake cycle (upper Pleistocene).

3.4 SITE-SPECIFIC CONDITIONS

The proposed embankment site consists of relatively flat-lying benches at elevations of about 4,475 feet on both sides of the Cub River channel and modern flood plain. Brummer and McCalpin (1995) map the benches and slopes down to the flood plain as lacustrine silt and clay (Qlf on Figure 3-1) that were deposited during the time Lake Bonneville occupied the site. The Cub River has incised about 50 feet into, and exposed the lacustrine sediments; the elevation of the river at the proposed site is at about 4,425 feet; and the proposed height of the embankment is 45 feet.

Sediments recovered from the three test holes at the proposed site consisted primarily of clays, with minor layers of silt and sand seams. We interpret the silts and clays to have been deposited in deep water during the times that the site was occupied by Lake Bonneville. The predominance of the fine-grained sediments, along with our understanding of Lake Bonneville chronology and deposition, suggests that the clays are likely laterally extensive across the proposed site.

We interpret the silt layers and silt and sand seams to have been deposited by meandering or braided streams, or low-angle deltas in the shore and near shore environment of Lake Bonneville. The varying thickness of these deposits represents the amount of time that the lake was at this elevation – thicker deposits are associated with extended periods of shore or near zone deposition, thinner deposits are associated with deposition in a rapidly rising, or falling lake level.

We interpret the sand found between 13 and 20 feet in TH-CUB-02 to be associated with stream alluvium (Qal_1) mapped by Brummer and McCalpin (1995). Silty clay found in this test hole overlying the sand also represents stream deposition of reworked and deposited silt and clay lacustrine sediments derived from higher up in the drainage basin. These alluvial silty clays contain frequent sand seams and are oxidized to reddish brown to tan color.

On the flood plain of the Cub River near the proposed embankment are two areas that were reported by the property owner to be the sites of historic methane seeps (MS-1 and MS-2 on Figure 2-2). MS-1 was a slight depression in the ground about 10 feet in diameter in fine-grained alluvial deposits. On September 4, 2014, the ground was wet but there was no standing water; reeds were observed growing in the area. At the time of our visit, we did not observe methane bubbles or other evidence of methane seepage. MS-2 was a small depression in the ground about 10 feet by 20 feet in the

fine-grained alluvial deposits. On September 4, 2014, the ground was dry and no phreatophytic vegetation was observed growing in the area. At the time of our visit, we did not observe methane bubbles or other evidence of methane seepage. Methane bubbles were observed in the flowing artesian water in TH-CUB-01. We are uncertain of the source of the methane or how extensive it is, although it is likely related to decomposition of organic matter in the lacustrine and/or alluvial sediments.

3.5 GEOLOGIC HAZARDS

3.5.1 Surface Fault Rupture

The project site is located within the East Cache fault zone, a generally north-trending range-front fault that extends for about 75 miles along the base of the Bear River Range between about Preston, Idaho and Avon, Utah (Black, et. al., 2004). Surface features associated with faulting have created a zone of deformation characterized by roughly north-trending west-facing main fault scarps and smaller east-facing antithetic fault scarps. The East Cache fault has been divided into 3 sections based on fault zone complexity, tectonic geomorphology, and expressions of surface fault scarps, but the faulting history is not well enough constrained to define seismogenic segments which rupture independently (McCalpin, 1994).

The proposed site is near the northern section, a poorly exposed, approximately 20-mile long section of the East Cache fault (Black et. al., 2004). Brummer and McCalpin (1995) map four high-angle, west-dipping normal faults in a zone that is approximately 4 miles wide in the northern section of the East Cache fault; the closest fault (fault D) is approximately 1.5 miles east of the proposed site. Fault D is mapped as concealed by Bonneville lake cycle and younger sediments. Stanley (1972) inferred a west-dipping, down to the west, high-angle normal fault west of fault D from geophysical and well data. However, because these data poorly constrain the location of the fault, it might not be within the Richmond quadrangle of Brummer and McCalpin (1995).

There have been no paleoseismic investigations conducted along the northern section of the East Cache fault (Lund, 2005). As such, the age of most recent surface rupture is unknown, but McCalpin (1994) notes that there are no fault scarps on latest Quaternary surfaces and believes that the best estimate of the time of the last event is at least early Pleistocene. Based on displacement of pre-Bonneville surfaces at the southern end of the section, Black and others (2004) estimate the late Quaternary slip rate for the southern section to be less than 0.2 mm/yr. Lund (2005) notes that only the central section of the East Cache fault shows evidence for Holocene surface faulting, but the east-dipping West Cache fault on the opposite (west) side of Cache Valley is segmented and all three segments have experienced Holocene surface faulting. Lund recommends that additional paleoseismic investigations be conducted on the north section of the East Cache fault to assess its seismic potential.

3.5.2 Landslides

Slopes between the Cub River flood plain and the adjacent flat-lying benches are comprised of predominately fine-grained lacustrine sediments that are susceptible to

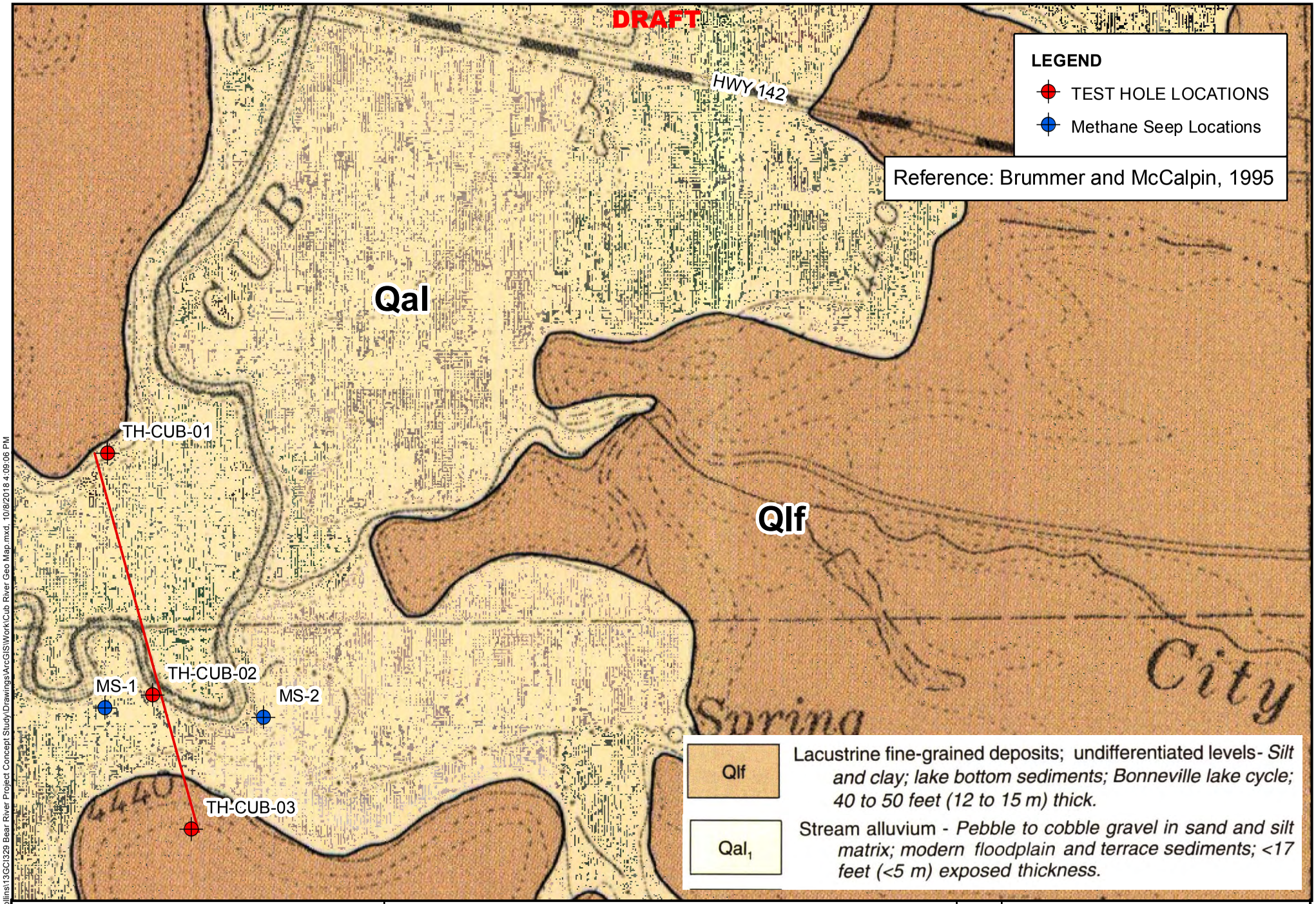
slope movement. Landslides have been documented in numerous locations along slopes adjacent to the Bear River where the river has cut into lacustrine sand, silt, and clay deposits of the old bed of Lake Bonneville (Oviatt, 1986a, 1986b). These landslides are common on the outsides of bends in the river, although we have observed several recent and active slides away from the active channel in similar geologic materials along the Bear River. The landslides are likely initiated as a result of over-steepened slopes and seeps associated with perched ground water table above clayey and silty clay layers in the lacustrine deposits (Ashland, 1997)

Brummer and McCalpin (1995) have not mapped scarps associated with landslides on the slopes adjacent to the flood plain within the reservoir basin and we observed only minor areas of landsliding near the active channel. However, the slopes that will be in contact with the proposed reservoir are potentially unstable, and could likely experience additional landsliding as a result of undercutting by wave action. Furthermore, fluctuating reservoir levels could create saturated zones in the fine-grained, slow-draining sediments adjacent to the reservoir and thereby reduce the slope stability.

In order to qualitatively assess the hazards of landslides in the reservoir basin we conducted reconnaissance-level observations of the slopes that would be in contact with the proposed reservoir. Our observations were limited to areas where access was available from public rights of way. In addition, we examined aerial imagery available from Google Earth for evidence of fresh landslide scarps. We developed a landslide hazard rating system based on the height and steepness of the slopes, and evidence for recent landslide activity and/or mapped landslide scarps (Table 3-1). Based on these criteria, we estimate that approximately 30 percent of the slopes that would be in contact with the proposed reservoir have a relatively moderate landslide hazard and 70 percent have a relatively low landslide hazard.

Table 3-1 Qualitative Landslide Rating

Landslide Hazard Rating	Steep and High Slopes	Evidence of Recent Landslides and/or Mapped Scarps
Low	No	No
Moderate	Yes	No
High	Yes	Yes



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Bear River Project Concept Study - Cub River

Cub River Geologic Map

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0 250 500 1,000 Feet

Figure 3-1

4.1 ADDITIONAL SERVICES

We understand that the studies to date have focused on providing the design team with preliminary information to study the feasibility of constructing a reservoir at Cub River. If this location is determined to be studied more additional geotechnical and geologic information will need to be gathered. A few of the items are as follows:

- Additional test holes will be required prior to moving to final design to study soil conditions and understand potential borrow sites,
- Additional study of Geologic Hazards.

This is not an extensive list but we can provide more information if needed.

4.2 LIMITATIONS

The assessments and recommendations presented in this document are based on limited field studies and laboratory testing, as well as our understanding of the project's design and manner of construction. If the project's design or manner of construction changes, or if conditions are found later that are different from those described, we should be notified immediately so that we can make revisions as necessary.

This document was prepared solely for the use of the addressee and may not contain sufficient information for other parties or uses.

We represent that our services are performed within the limitations prescribed by our Client, in a manner consistent with the level of care and skill ordinarily exercised by other professional consultants under similar circumstances. No other representation, expressed or implied, and no warranty or guarantee is included or intended. We do not assume responsibility for the accuracy of information provided by others.

Ashland, F.X., 1997, Reconnaissance of a landslide along the Bear River, Honeyville, Utah: Utah Geological Survey, Technical Report 97-07, 2 p.

Black, B.D., and Hylland, M.D., and Haller, K.M., and Hecker, S., compilers, 2004, Fault number 2352a, East Cache fault zone, northern section, in Quaternary fault and fold database of the United States: U.S. Geological Survey, accessed online http://earthquakes.usgs.gov/hazards/qfaults

Brummer, J. and McCalpin, 1995, Geologic map of the Richmond Quadrangle, Cache County, Utah and Franklin County, Idaho: Utah Geological Survey Miscellaneous Publication 95-3, 1:24,000.

Currey, D.R., 1990, Quaternary paleolakes in the evolution of semidesert basins, with special emphasis on Lake Bonneville and the Great Basin, U.S.A.: Paleogeography, Paleoclimatology, Paleoecology, v. 76, p. 189-214.

Currey, D.R., Atwood, G. and Mabey, D.R., 1984, Major levels of the Great Salt Lake and Lake Bonneville: Utah Geological and Mineral Survey Map 73.

Gilbert, G.K., 1890, Lake Bonneville: U.S. Geological Survey Monograph 1, 438 p.

Godsey, H.S., Currey, D.R., and Chan, M.A., 2005, New evidence for an extended occupation of the Provo shoreline and implications for regional climate change, Pleistocene Lake Bonneville, Utah: Quaternary Research v. 63, p. 212–223.

Hecker, S., 1993, Quaternary tectonics of Utah with emphasis on earthquake-induced characterization: Utah Geological Survey Bulletin 127, 157 p.

Lund, W.R., 2005, Consensus preferred recurrence-intervals and vertical slip-rate estimates, Review of Utah paleoseismic-trenching data by the Utah Quaternary Fault Parameters Working Group: Utah Geological Survey, Bulletin 134, 109 p.

McCalpin, J.P., 1994, Neotectonic deformation along the East Cache fault zone, Cache County, Utah: Utah Geological Survey, Special Study 83, 37 p.

Oviatt C.G, Miller, D.M. McGeehin, J.O., Zachary, C., Mahan, S., 2005. The younger dryas phase of great salt Lake, Utah, USA Palaeogeography, Palaeoclimatology, Palaeoecology 219, 263-284.

Oviatt, C.G., 1986a, Geologic map of the Cutler Dam Quadrangle, Cache and Box Elder Counties, Utah: Utah Geological and Mineral Survey, Map 91, 1:24,000.

Oviatt, C.G., 1986b, Geologic map of the Honeyville Quadrangle, Cache and Box Elder Counties, Utah: Utah Geological and Mineral Survey, Map 88, 1:24,000.

Oviatt, C.G., and Miller, D.M., 1997, New explorations along the northern shores of Lake Bonneville, *in* Link, P.K. and Kowallis, B.J., eds., Mesozoic to recent geology of Utah: Brigham Young Geology Studies v. 42, pt. II, p. 345-371.

Stanley, W.D., 1972, Geophysical study of unconsolidated sediments and basin structure in Cache Valley, Utah and Idaho: Geological Society of America Bulletin, v. 83, p. 1817-1830.

Appendix A

Test Hole Logs – Cub River

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Project: Bear River Project **Project Location:** Cub River **Project Number:** 13GCI329	**Log of Test Hole TH-CUB-01** Sheet 1 of 2

Date(s) Drilled	9/9/14	Logged By	D. Billings	Checked By	P. Gerhart
Drilling Method	Rotary wash with water	Drill Bit Size/Type	Drag bit with HW Casing	Total Depth Drilled (feet)	62.0 feet
Drill Rig Type	CME 75	Drilling Contractor	Bedke Geotechnical F.S.	Hammer Weight/ Drop(lbs/in.)	Automatic trip hammer
Apparent Groundwater Depth	10.3 feet above GS; 6/16/2015	Latitude / Longitude	41.91976, -111.85425	Ground Surface Elevation (feet)	4448.0
Comments		Test Hole Backfill	Piezometer Well	Elevation Datum	NAVD88

Elevation, feet	Depth, feet	SAMPLES Type	Number	Sampling Resistance	Recovery, inches	Graphic Log	MATERIAL DESCRIPTION	FIELD NOTES
	0						CLAY - medium stiff to stiff, occasional fine sand layers to 3-inch, mottled, high plasticity, moist, pinkish brown to dark brownish orange, (CH)	Water measured 10.3 feet above ground surface on 6/16/15
	5	X		3-6-7-5 [13]	15.0			
4440								
	10	X		2-2-3-4 [5]	24.0			
	15				20.0			
4430							CLAY - very soft to medium stiff, medium plasticity, wet, dark gray to black, (CL)	
	20	X		0-1-2-2 [3]	24.0			
	25				19.0			Field permeability testing suggests sand seams are present between 20 and 30 feet.
4420								
	30	X		0-0-0-3 [0]	24.0			
	35				21.0			
4410								
	40	X		0-1-4-4 [5]	24.0			
	45				24.0			
4400								
	50							

SOIL TEST HOLE TH_LOGS_#1_BEAR_RIVER.GPJ GERHART.GDT 6/25/18

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Project: Bear River Project
Project Location: Cub River
Project Number: 13GCI329

Log of Test Hole TH-CUB-01

Elevation, feet	Depth, feet	SAMPLES Type	SAMPLES Number	SAMPLES Sampling Resistance	SAMPLES Recovery, inches	Graphic Log	MATERIAL DESCRIPTION	FIELD NOTES
	50			0-1-3-4 [4]	24.0			
	55				24.0			
4390								
	60				23.0			Artesian pressure ~10 feet above the ground surface. Methane bubbles.
							CLAY, with sand, trace fine gravel - stiff, wet, light gray and black, (CL)	
							Bottom of Test Hole at 62.0 feet. Piezometer data Screen 57-62 ft 10-20 Sand 62-52 Bentonite Chips 52-0 ft	
	65							
4380								
	70							
	75							
4370								
	80							
	85							
4360								
	90							
	95							
4350								
	100							
	105							
4340								

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Project: Bear River Project **Project Location:** Cub River **Project Number:** 13GCI329	**Log of Test Hole TH-CUB-02** Sheet 1 of 1

Date(s) Drilled	9/4/14 - 9/5/14	Logged By	D. Billings	Checked By	P. Gerhart
Drilling Method	Rotary wash with water	Drill Bit Size/Type	Drag bit with HW Casing	Total Depth Drilled (feet)	41.5 feet
Drill Rig Type	CME 75	Drilling Contractor	Bedke Geotechnical F.S.	Hammer Weight/ Drop(lbs/in.)	Automatic trip hammer
Apparent Groundwater Depth	0; 6/16/2015	Latitude / Longitude	41.91704, -111.85353	Ground Surface Elevation (feet)	4421.0
Comments		Test Hole Backfill	Piezometer Well	Elevation Datum	NAVD88

Elevation, feet	Depth, feet	SAMPLES Type	Number	Sampling Resistance	Recovery, inches	Graphic Log	MATERIAL DESCRIPTION	FIELD NOTES
4420	0						CLAY, silty, with sand - soft, frequent sand seams, moist, reddish-brown to tan, (CL-ML)	
	5			1-2-2-3 [4]	18.0		- grades from dark reddish-brown to light brown	
4410	10				0.0			No recovery from Shelby tube. Drove spoon to recover some sample.
	15			0-1-3-5 [4]	24.0		SAND, silty - loose, fine to coarse-grained, wet, light brownish-gray to gray, (SM)	
				1-3-3-4 [6]	16.0			
				2-2-3-3 [5]	4.0		SAND, some silt - loose, medium to coarse-grained, wet, dark gray, (SP-SM)	
4400	20				24.0		CLAY - very soft, high plasticity, wet, dark gray and black, (CH)	
	25			0-0-0-2 [0]	24.0			
4390	30				22.0			
	35			0-0-0-0 [0]	24.0			
4380	40				24.0			
	45						Bottom of Test Hole at 41.5 feet. Piezometer data Screen 42-37 ft 10-20 Sand 42-32 Bentonite Chips 32-0 ft	
	50							

SOIL TEST HOLE TH_LOGS_#1_BEAR_RIVER.GPJ GERHART.GDT 6/25/18

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Project: Bear River Project **Project Location:** Cub River **Project Number:** 13GCI329	**Log of Test Hole TH-CUB-03** Sheet 1 of 2

Date(s) Drilled	9/5/14 - 9/8/14	Logged By	D. Billings	Checked By	P. Gerhart
Drilling Method	Rotary wash with water	Drill Bit Size/Type	Drag bit with HW Casing	Total Depth Drilled (feet)	81.5 feet
Drill Rig Type	CME 75	Drilling Contractor	Bedke Geotechnical F.S.	Hammer Weight/ Drop(lbs/in.)	Automatic trip hammer
Apparent Groundwater Depth	20.3 ft: 6/16/2015	Latitude / Longitude	41.91553, -111.85293	Ground Surface Elevation (feet)	4465.0
Comments		Test Hole Backfill	Piezometer Well	Elevation Datum	NAVD88

Elevation, feet	Depth, feet	SAMPLES Type	Number	Sampling Resistance	Recovery, inches	Graphic Log	MATERIAL DESCRIPTION	FIELD NOTES
	0						CLAY - soft to medium stiff, frequent sandy silt seams and layers stained with iron oxide, high plasticity, moist, orangish-brown to yellowish-brown, (CH)	
4460	5	X		4-4-4-5 [8]	17.0			
	10	X		2-3-4-4 [7]	19.0		- decreasing silt seams	
4450	15				20.0			
	20	X		2-2-2-3 [4]	24.0			
4440	25				23.0		CLAY - soft to very soft, high plasticity, wet, dark gray, (CH)	
	30	X		0-3-3-2 [6]	24.0		CLAY - medium stiff to stiff, frequent sand seams and layers, stratified, wet, dark gray, (CL)	
		X		0-5-6-5 [11]	19			
4430	35	X		4-2-2-2 [4]	24.0		SILT, some fine-grained sand, some clay - soft, frequent fine sand seams and layers, wet, very dark gray, (ML)	
							CLAY - soft to medium stiff, frequent sand seams and layers, stratified, wet, dark gray, (CL)	
	40				17.0		- decreasing sand seams	
							CLAY - soft to very soft, high plasticity, wet, dark gray to black, (CH)	
4420	45	X		0-0-0-2 [0]	24.0			
	50							

SOIL TEST HOLE TH_LOGS_#1_BEAR_RIVER.GPJ GERHART.GDT 6/25/18

GERHART COLE

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Project: Bear River Project
Project Location: Cub River
Project Number: 13GCI329

Log of Test Hole TH-CUB-03

Elevation, feet	Depth, feet	SAMPLES Type	Number	Sampling Resistance	Recovery, inches	Graphic Log	MATERIAL DESCRIPTION	FIELD NOTES
	50				24.0			
4410	55			0-0-1-3 [1]	24.0			
	60				25.0			
4400	65			0-0-0-3 [0]	24.0			
	70				21			
4390	75			0-0-3-3 [3]	24.0			
	80				6.0			Sample fell out of end of sampler.
4380	85						Bottom of Test Hole at 81.5 feet. Piezometer data Screen 81.5-76.5 ft 10-20 Sand 81.5-71.5 Bentonite Chips 71.5-0 ft	
	90							
4370	95							
	100							
4360	105							

GERHART COLE

Unified Soil Classification System (USCS)

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Material Types	Major Soil Divisions		Group Symbol and Legend	Typical Names
COARSE-GRAINED SOILS >50% retained on No. 200 sieve	GRAVELS >50% of coarse fraction retained on No. 4 Sieve	Clean GRAVELS (little or no fines)	GW	Well-Graded GRAVEL, GRAVEL-sand mixtures, few fines
			GP	Poorly-Graded GRAVEL, GRAVEL-sand mixtures, few fines
		GRAVELS with fines (appreciable amount of fines)	GM	Silty GRAVEL, GRAVEL-sand silt mixtures
			GC	Clayey GRAVEL, GRAVEL-sand clay mixtures
	SANDS >50% of coarse fraction passing the No. 4 sieve	Clean SANDS (little or no fines)	SW	Well-Graded SAND, SAND-gravel mixtures, few fines
			SP	Poorly-Graded SAND, SAND-gravel mixtures, few fines
		SANDS with fines (appreciable amount of fines)	SM	Silty SAND, SAND-silt mixtures
			SC	Clayey SAND, SAND-clay mixtures
FINE-GRAINED SOILS >50% Passing No. 200 Sieve	SILTS and CLAYS liquid limit < 50	Inorganic 1) CF > 30%: + Sandy/Gravelly 2) CF = 15-30% + with sand/gravel	CL	Lean CLAY, Gravelly/Sandy CLAY, low to med. plasticity
			ML	SILT, Gravelly/Sandy SILT, no to slight plasticity
		Organic	OL	Organic CLAY or SILT
	SILTS and CLAYS liquid limit < 50	Inorganic 1) CF > 30%: + Sandy/Gravelly 2) CF = 15-30% + with sand/gravel	CH	Fat CLAY, Gravelly/Sandy Fat CLAY, high plasticity
			MH	Elastic SILT, Gravelly/Sandy Elastic SILT, low to high plasticity
		Organic	OH	Organic CLAY or SILT
Highly orgainc soils		Primarily Organic Matter; Organic Odor	PT	PEAT
Boulders / Cobbles		> 50% (by volume) particles > 3"	COBBLES BOULDERS	Boulders (>12"); Cobbles (>3" and <12")

Other Material Symbols

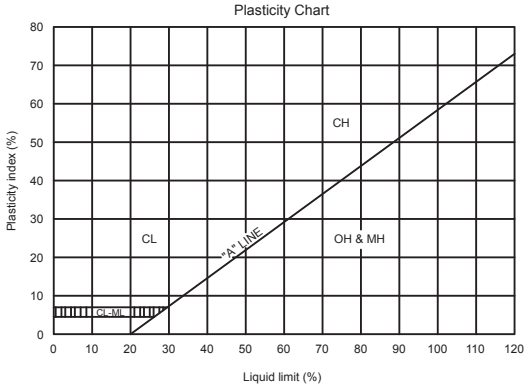
- Bedrock
- Asphalt
- Concrete
- Topsoil
- Fill

Sample Types

- Auger Cuttings
- Continuous sampler
- Grab Sample
- No Recovery
- Shelby Tube
- Standard Penetration Test (SPT)
- California Sampler
- Rock Core
- Modified California Sampler
- Other (see remarks)
- Piston Sampler (Shelby Tube)
- Split Spoon
- Vane Shear

Apparent water level

Measured water level



Descriptors for Coarse Grained Soils

Apparent Density	Dr (%)	SPT	MC	CAL
very loose	0-15	<4	<6	<8
loose	15-35	4-10	6-15	8-20
med. dense	35-65	10-30	15-42	20-56
dense	65-85	30-50	42-72	56-96
very dense	85-100	>50	>72	>96

Descriptors for Fine Grained Soils

Consistency	Su (psf)	SPT	MC	CAL
very soft	< 250	<2	<2	<2
soft	250-500	2-4	2-4	2-5
med. stiff	500-1000	4-8	4-10	5-11
stiff	1000-2000	8-15	10-19	11-22
very stiff	2000-4000	15-30	19-37	22-45
hard	>4000	>30	>37	>45

SPT - Standard split spoon (SPT): 2" OD, 1.375" ID
MC - Modified California: 2.5" OD, 1.875" ID
CAL - California: 3" OD, 2.375" ID

Stratification

Description	Criteria
Seam	1/16" to 1/2"
Layer	1/2" to 12"
Occasional	<= 1 per ft. thickness
Frequent	> 1 per ft. thickness

Modifiers

Description	Est. (%)
Trace	<5
Some	5-12
With	>12

Descriptors for Moisture

Description	Criteria
Dry	Absence of moisture, dusty, dry to the touch
Moist	Damp but no visible water
Wet	Visible free water, usually soil is below water table

Descriptors for Particle Size

Description	Criteria
Boulder	>12" : larger than a basketball
Cobble	3-12" : larger than a grapefruit
Coarse Gravel	3/4-3" : larger than a grape
Fine Gravel	No.4-3/4" : larger than a pea
Coarse Sand	No.10-4 : larger than rock salt grain
Medium Sand	No.40-4 : larger than window screen opening
Fine Sand	No.200-40 : larger than a sugar grain

Descriptios for Particle Angularity

Description	Criteria
Angular	Sharp edges, rel. plane sides, unpolished surface
Subangular	Similar to angular, but with rounded edges
Subrounded	Nearly plane sides, well-rounded corners & edges
Rounded	Smoothly curved sides and no edges

Abbreviated Soil Classification Symbols (after ASTM D2488 X.5)

Prefix	Suffix
s = sandy	s = with sand
g = gravelly	g = with gravel
	c = with cobbles
	b = with boulders

Abbreviated system for supplementary presentations when complete description is referenced. Examples:

Group Symbol and Full Name	Abbreviated
Sandy Lean CLAY (CL)	s(CL)
Poorly Graded SAND with silt and gravel	(SP-SM)g
Poorly Graded GRAVEL with sand, cobbles, and boulders (GP)	(GP)scb
Gravelly SILT with sand and cobbles (ML)	g(ML)sc

General Notes:
1) Strata graphic lines on the logs represent approximate boundaries.
2) No warranty is provided as to the continuity of soil conditions between points explored and sample locations.
3) Logs represent soil conditions observed at the point of exploration on the date indicated.
4) Visual methods were used to classify the materials in general accordance with the Unified Soils Classification Systems; actual designations based on laboratory methods may vary.

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Legend to Soil Descriptions

Appendix B Interpretative Laboratory Test Results – Cub River

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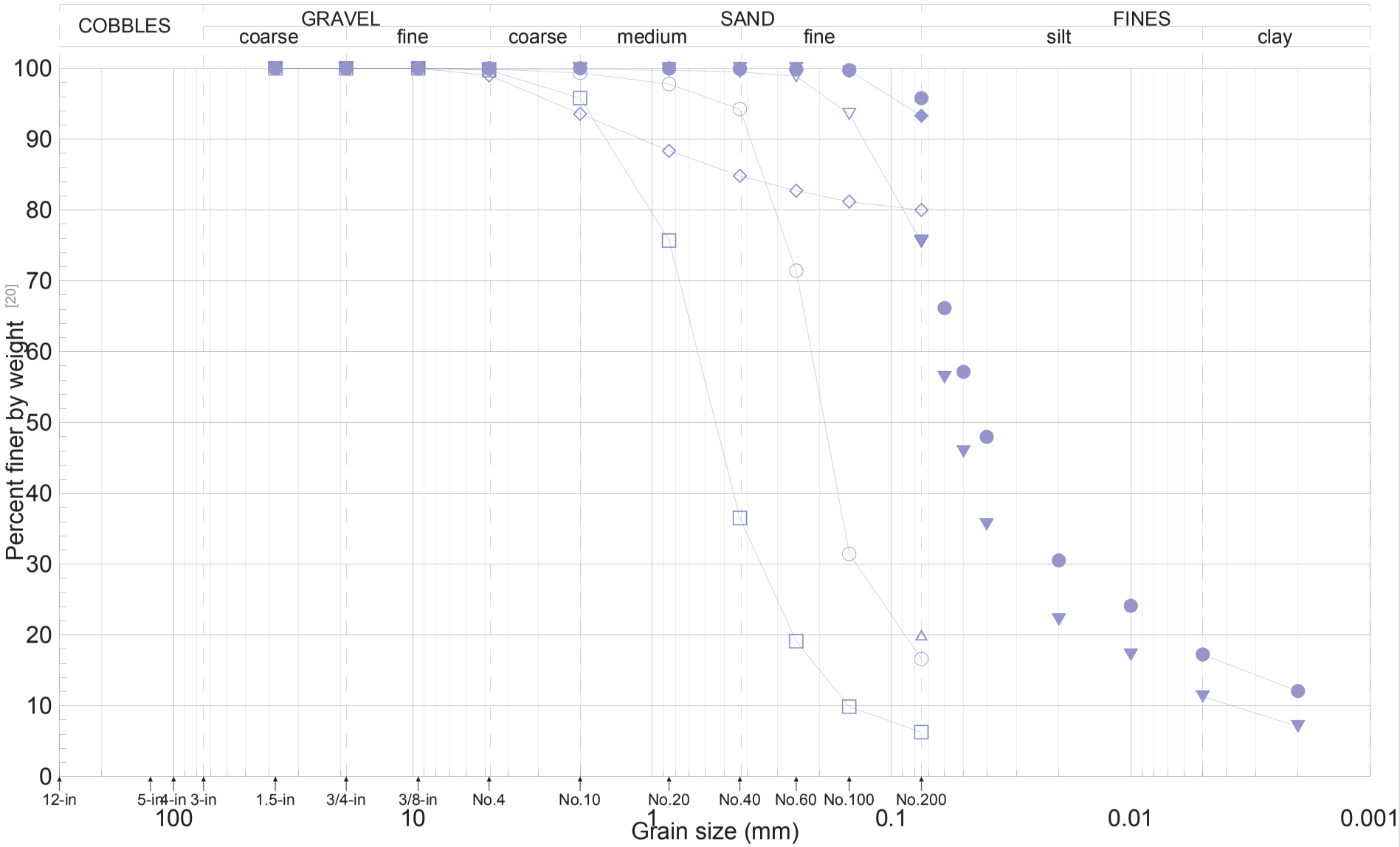

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Grain-Size Analysis

Bear River Project Concept Study- Cub River (13GCI329)

Figure B-1

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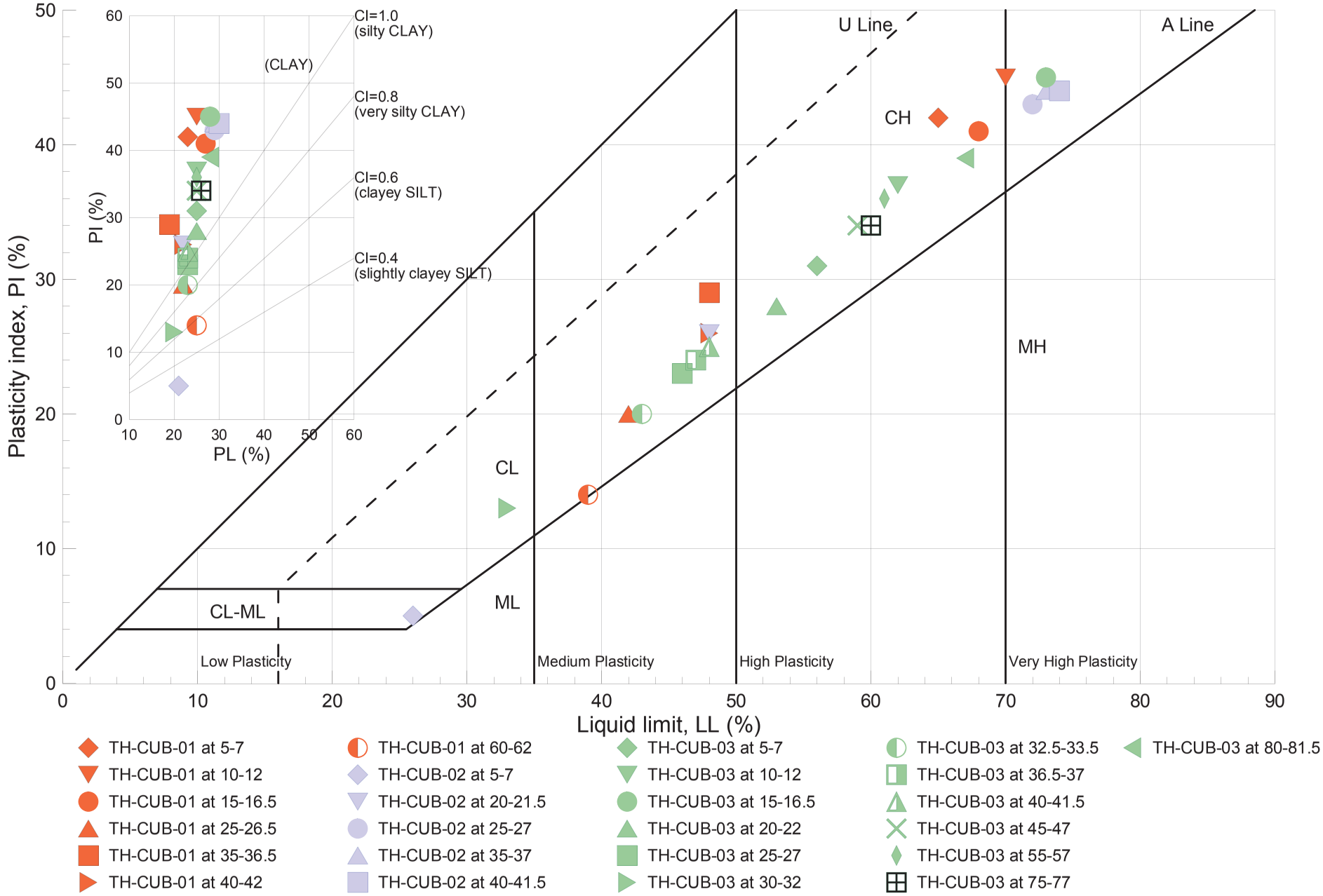

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Casagrande's Plasticity Chart (Atterberg Limits)

Bear River Project Concept Study- Cub River (13GCI329)

Figure B-2

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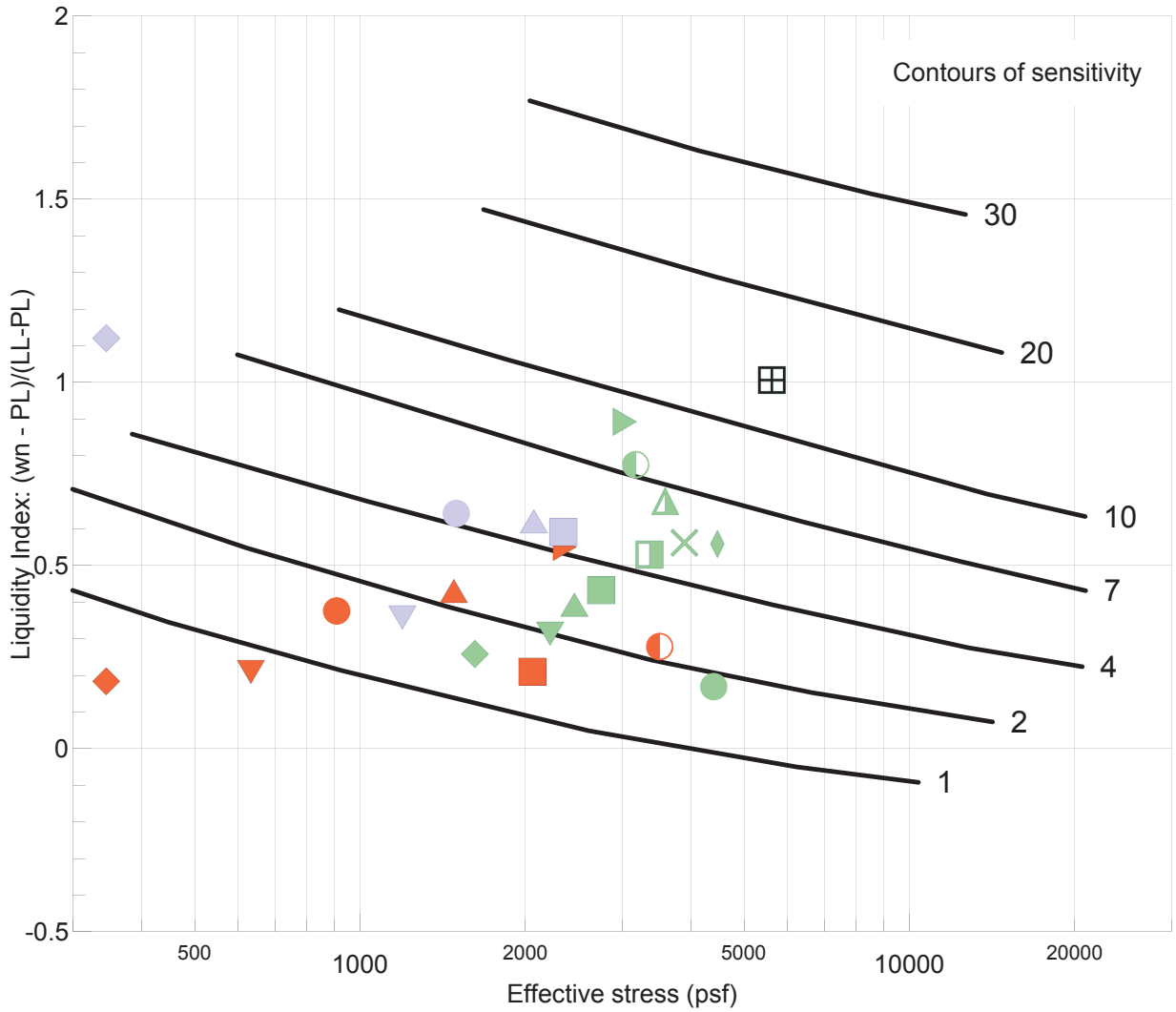

- TH-CUB-01 at 5-7
- TH-CUB-01 at 10-12
- TH-CUB-01 at 15-16.5
- TH-CUB-01 at 25-26.5
- TH-CUB-01 at 35-36.5
- TH-CUB-01 at 40-42
- TH-CUB-01 at 60-62
- TH-CUB-02 at 5-7
- TH-CUB-02 at 20-21.5
- TH-CUB-02 at 25-27
- TH-CUB-02 at 35-37
- TH-CUB-02 at 40-41.5
- TH-CUB-03 at 5-7
- TH-CUB-03 at 10-12
- TH-CUB-03 at 15-16.5
- TH-CUB-03 at 20-22
- TH-CUB-03 at 25-27
- TH-CUB-03 at 30-32
- TH-CUB-03 at 32.5-33.5
- TH-CUB-03 at 36.5-37
- TH-CUB-03 at 40-41.5
- TH-CUB-03 at 45-47
- TH-CUB-03 at 55-57
- TH-CUB-03 at 75-77

GERHART COLE	Sensitivity, LI, and Effective Stress Relationships (Mitchell,1993)	
	Cub River (13GCI329)	Figure B-3

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One-Dimensional Consolidation Properties of Soils
After ASTM D2435 and USBR 5700

GERHART COLE

Project:	**Bear River**	**TH/TP/Sample:**	**TH-CUB-01**
No:	**13GCI329**	**Depth:**	**15-16.5 (16.5)**
Location:	Cache County, Utah	Sample description:	orange brown clay
Date:	22-Sep-14	USCS classification:	not requested
Tested by:	zg	Sample type:	Rel. undisturbed, Shelby Tube
Reduced by:	zg	Inundation stress (psf):	100, beginning
Checked by:	dab	Swell pressure (psf):	308
Comments:		Test method:	B
		Preparation procedure:	trimmed

Phase Relationships

	Initial	Final
Height, H (in)	1.0000	0.8673
Height, H (cm)	2.540	2.203
Dia., D (in)	2.500	2.500
Dia., D (cm)	6.350	6.350
Wt. rings + wet soil (g)	357.85	349.04
Wt. rings (g)	214.39	214.39
Wet soil + tare (g)	286.51	
Dry soil + tare (g)	244.27	
Tare (g)	144.68	
Moisture cont., w (%)	42.4	33.7
Gs, assumed	2.75	2.75
Mass total (g)	143.5	134.7
Mass of solids (g)	100.7	100.7
Volume (cm^3)	80.4	69.8
Vol. of water (cm^3)	42.7	33.9
Vol. of solids (cm^3)	36.6	36.6
Vol. of voids (cm^3)	43.8	33.1
Vol. of air (cm^3)	1.1	-0.8
Area, A (cm^2)	31.7	31.7
Ht. solids, Hs (cm)	1.157	1.157
Void ratio, e	1.196	0.905
Porosity, n	0.545	0.475
Vol.moisture, T	0.531	0.486
Saturation, S (%)	98	102
Dry density (gm/cm^3)	1.252	1.444
Wet unit wt., gm (pcf)	111.3	120.5
Dry unit wt., gd (pcf)	78.2	90.1

Vertical Stress - Deformation Results

Vert. stress (psf)	Corr. Dial, dfc [a] (in)	Hc [b] (in)	Vert. strain, ev	Load duration (min)	t-90 (min)	Hdr (in)	Cv (ft^2/day)
Seating	0.0000	1.0000	0.0000	0			
100	0.0001	0.9999	0.0001	100			
800	0.0037	0.9963	0.0037	55			
1,600	0.0095	0.9905	0.0095	40			
3,200	0.0183	0.9817	0.0183	40	7.9	0.49306	0.26
6,400	0.0351	0.9649	0.0351	42	15.8	0.48666	0.12
12,800	0.0829	0.9171	0.0829	95	39.8	0.47051	0.05
25,600	0.1468	0.8532	0.1468	63	50.1	0.44257	0.03
51,200	0.2172	0.7828	0.2172	134	50.1	0.40899	0.03
25,600	0.2109	0.7891	0.2109	60			
6,400	0.1882	0.8118	0.1882	60			
1,600	0.1694	0.8306	0.1694	52			
400	0.1327	0.8673	0.1327	240			

Data Interpretation Summary

Preconsolidation stress, s'p (psf)	---	
Compression ratio, CR	---	To be determined by the Geotechnical Engineer
Recompression ratio, RR	---	

Notes:
[a] Dfc = end of increment deformation corrected for machine, porous stone, and filter paper deformation
[b] Hc = height at end of consolidation of each vert. stress
[c] Hdr = height at 50 consolidation computed from D90 using sq-root time method
[d] Cv computed from Taylor (1948) aquare root of time method (note 1 in^2/min = 10 ft^2/day)

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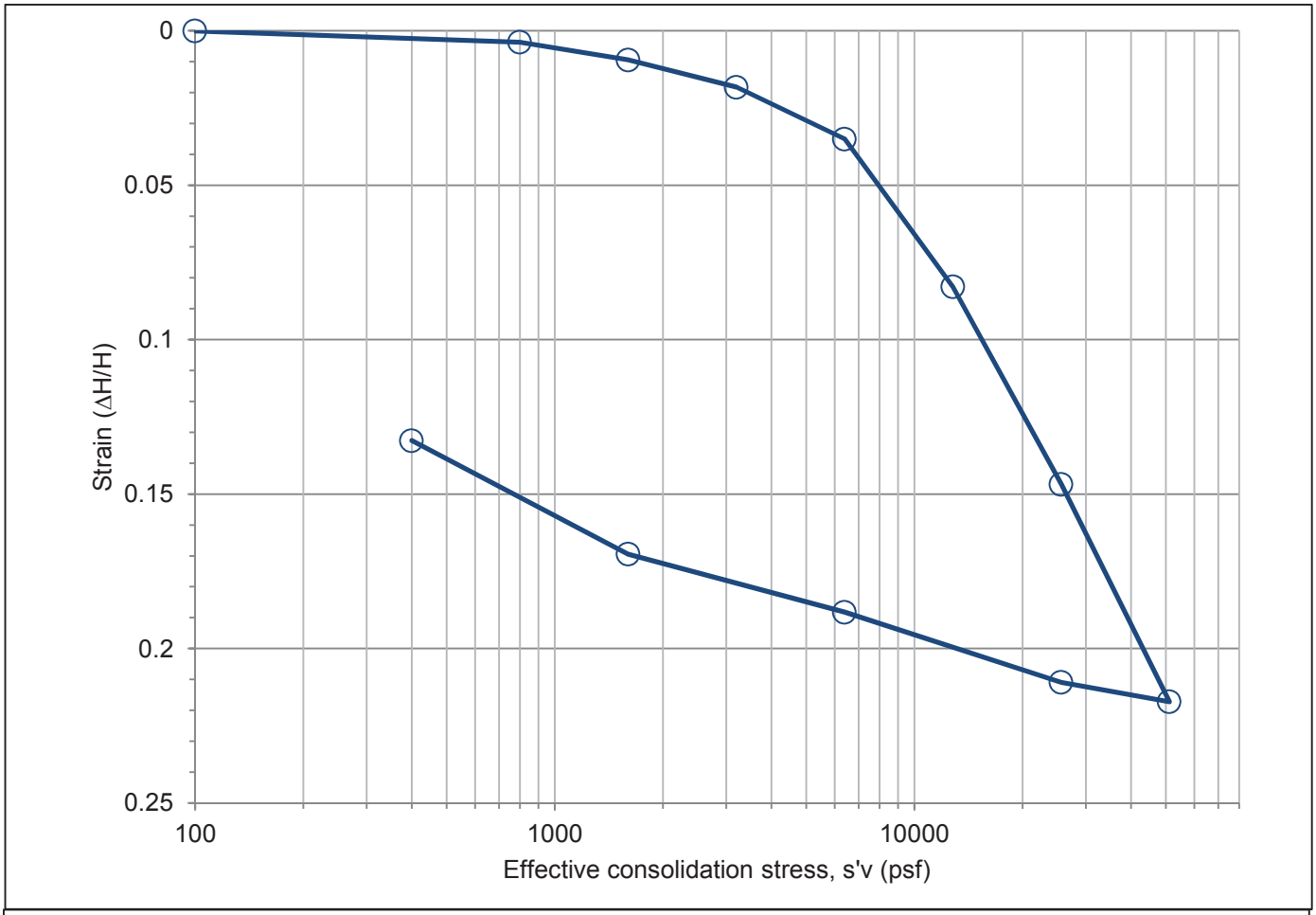
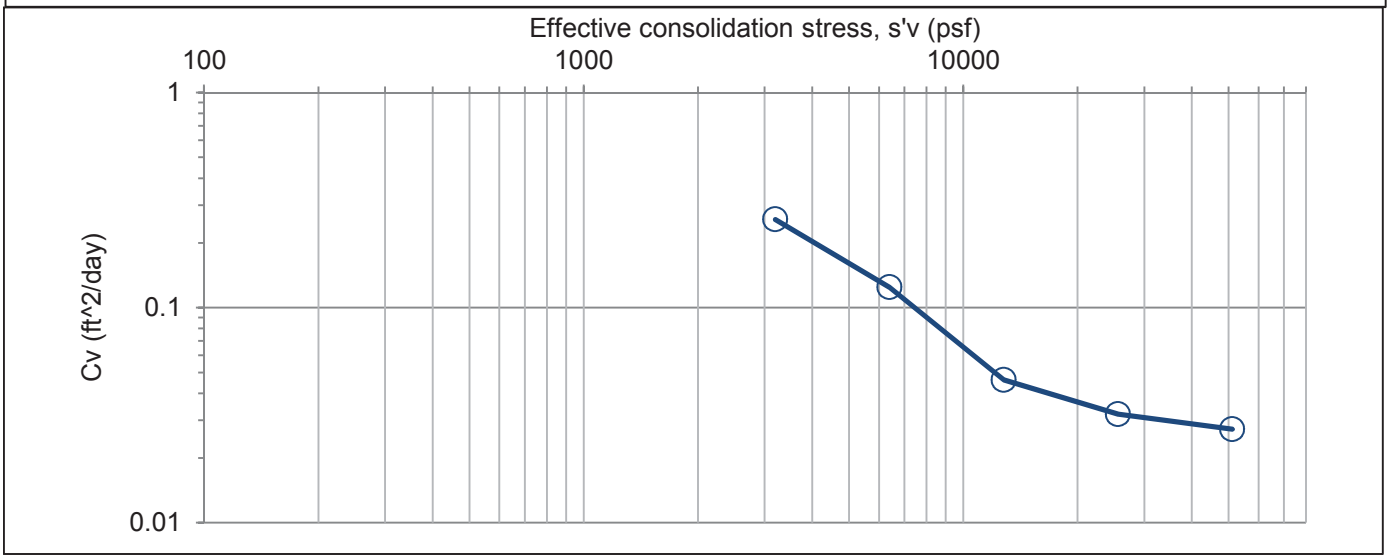
One-Dimensional Consolidation Properties of Soils
After ASTM D2435 and USBR 5700

GERHART COLE

Project: Bear River
No: 13GCI329

TH/TP/Sample: TH-CUB-01
Depth: 15-16.5 (16.5)





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One-Dimensional Consolidation Properties of Soils
After ASTM D2435 and USBR 5700

GERHART COLE

Project:	**Bear River**	**TH/TP/Sample:**	**TH-CUB-01**
No:	**13GCI329**	**Depth:**	**25-26.5 (26.5)**
Location:	Cache County, Utah	Sample description:	dark purpleish brown clay
Date:	23-Sep-14	USCS classification:	not requested
Tested by:	zg	Sample type:	Rel. undisturbed, Shelby Tube
Reduced by:	zg	Inundation stress (psf):	100, beginning
Checked by:	dab	Swell pressure (psf):	308
Comments:		Test method:	B
		Preparation procedure:	trimmed

Phase Relationships

	Initial	Final
Height, H (in)	1.0000	0.8766
Height, H (cm)	2.540	2.227
Dia., D (in)	2.500	2.500
Dia., D (cm)	6.350	6.350
Wt. rings + wet soil (g)	367.32	360.02
Wt. rings (g)	214.39	214.39
Wet soil + tare (g)	353.65	
Dry soil + tare (g)	311.33	
Tare (g)	173.00	
Moisture cont., w (%)	30.6	24.4
Gs, assumed	2.75	2.75
Mass total (g)	152.9	145.6
Mass of solids (g)	117.1	117.1
Volume (cm^3)	80.4	70.5
Vol. of water (cm^3)	35.8	28.5
Vol. of solids (cm^3)	42.6	42.6
Vol. of voids (cm^3)	37.9	27.9
Vol. of air (cm^3)	2.0	-0.6
Area, A (cm^2)	31.7	31.7
Ht. solids, Hs (cm)	1.345	1.345
Void ratio, e	0.889	0.656
Porosity, n	0.471	0.396
Vol.moisture, T	0.445	0.405
Saturation, S (%)	95	102
Dry density (gm/cm^3)	1.456	1.661
Wet unit wt., gm (pcf)	118.7	128.9
Dry unit wt., gd (pcf)	90.9	103.7

Vertical Stress - Deformation Results

Vert. stress (psf)	Corr. Dial, dfc [a] (in)	Hc [b] (in)	Vert. strain, ev	Load duration (min)	t-90 (min)	Hdr (in)	Cv (ft^2/day)
Seating	0.0000	1.0000	0.0000	0			
100	0.0007	0.9993	0.0007	32			
400	0.0036	0.9964	0.0036	52			
800	0.0092	0.9908	0.0092	50	15.8	0.4968	0.13
1,600	0.0188	0.9812	0.0188	52	19.9	0.493	0.10
3,200	0.0334	0.9666	0.0334	161	12.6	0.48695	0.16
6,400	0.0514	0.9486	0.0514	72	15.8	0.47879	0.12
12,800	0.0806	0.9194	0.0806	113	15.8	0.467	0.11
25,600	0.1171	0.8829	0.1171	82	12.6	0.45057	0.13
51,200	0.1575	0.8425	0.1575	90			
25,600	0.1539	0.8461	0.1539	60			
6,400	0.1415	0.8585	0.1415	60			
1,600	0.1234	0.8766	0.1234	120			
400	0.1039	0.8961	0.1039	240			

Data Interpretation Summary

Preconsolidation stress, s'p (psf)	---	
Compression ratio, CR	---	To be determined by the Geotechnical Engineer
Recompression ratio, RR	---	

Notes:
[a] Dfc = end of increment deformation corrected for machine, porous stone, and filter paper deformation
[b] Hc = height at end of consolidation of each vert. stress
[c] Hdr = height at 50 consolidation computed from D90 using sq-root time method
[d] Cv computed from Taylor (1948) aquare root of time method (note 1 in^2/min = 10 ft^2/day)

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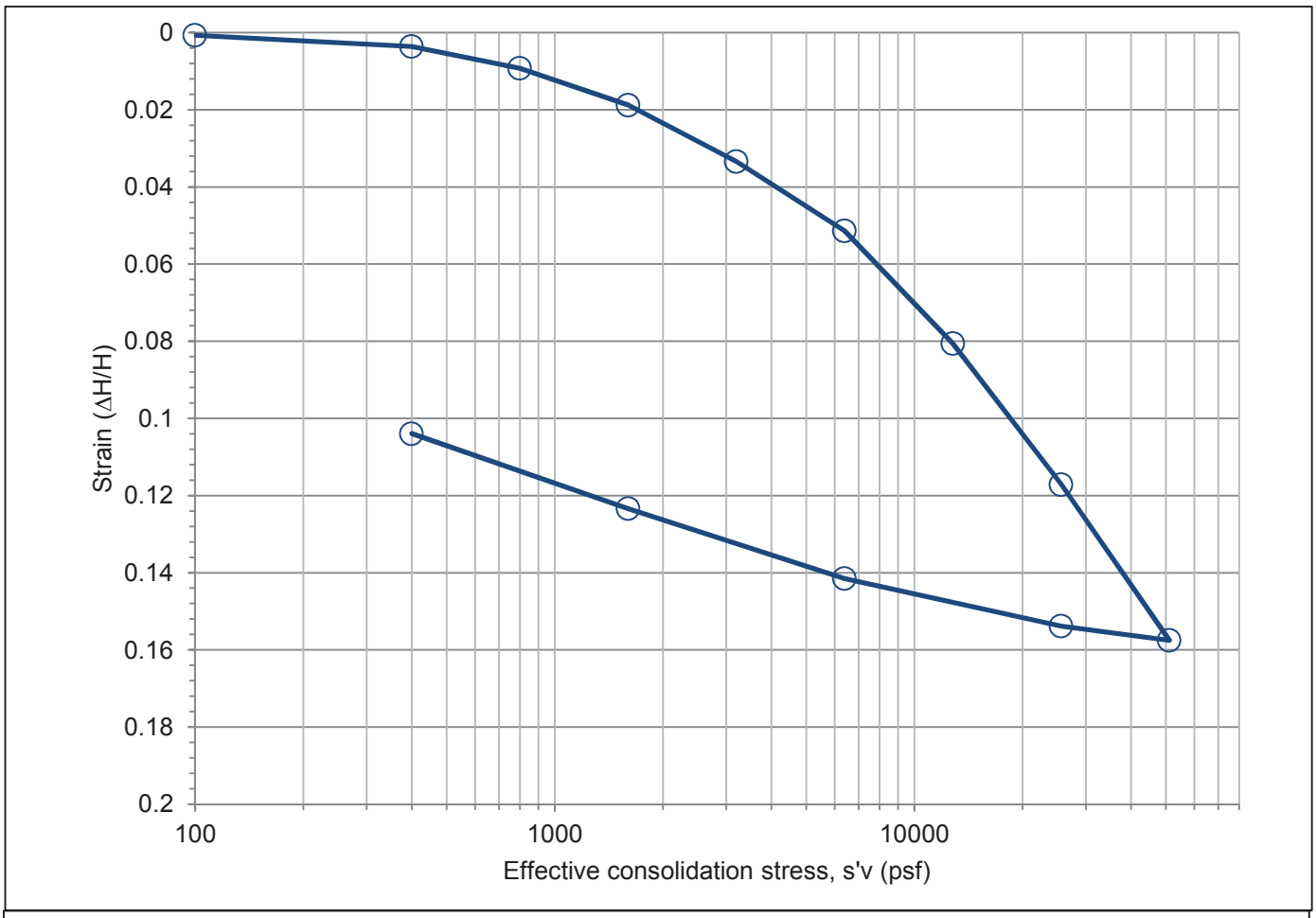
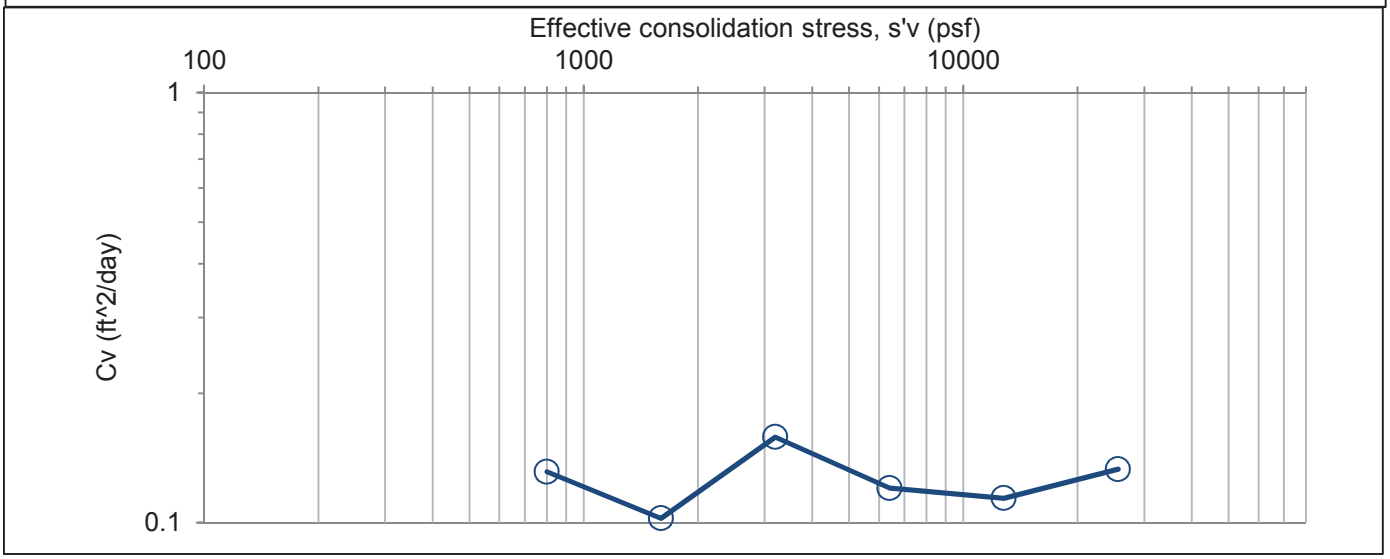
One-Dimensional Consolidation Properties of Soils
After ASTM D2435 and USBR 5700

GERHART COLE

Project: Bear River
No: 13GCI329

TH/TP/Sample: TH-CUB-01
Depth: 25-26.5 (26.5)





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One-Dimensional Consolidation Properties of Soils

After ASTM D2435 and USBR 5700

GERHART COLE

Project:	**Bear River**	**TH/TP/Sample:**	**TH-CUB-01**
No:	**13GCI329**	**Depth:**	**60-62 (62)**
Location:	Cache County, Utah	Sample description:	light gray to gray clay
Date:	19-Sep-14	USCS classification:	not requested
Tested by:	zg	Sample type:	Rel. undisturbed, Shelby Tube
Reduced by:	zg	Inundation stress (psf):	100, beginning
Checked by:	dab	Swell pressure (psf):	< 100
Comments:		Test method:	B
		Preparation procedure:	trimmed

Phase Relationships

	Initial	Final
Height, H (in)	1.0000	0.8859
Height, H (cm)	2.540	2.250
Dia., D (in)	2.500	2.500
Dia., D (cm)	6.350	6.350
Wt. rings + wet soil (g)	362.29	355.93
Wt. rings (g)	214.41	214.41
Wet soil + tare (g)	293.96	
Dry soil + tare (g)	258.17	
Tare (g)	145.14	
Moisture cont., w (%)	31.7	26.0
Gs, assumed	2.75	2.75
Mass total (g)	147.9	141.5
Mass of solids (g)	112.3	112.3
Volume (cm^3)	80.4	71.3
Vol. of water (cm^3)	35.6	29.2
Vol. of solids (cm^3)	40.8	40.8
Vol. of voids (cm^3)	39.6	30.4
Vol. of air (cm^3)	4.0	1.2
Area, A (cm^2)	31.7	31.7
Ht. solids, Hs (cm)	1.290	1.290
Void ratio, e	0.970	0.745
Porosity, n	0.492	0.427
Vol.moisture, T	0.442	0.410
Saturation, S (%)	90	96
Dry density (gm/cm^3)	1.396	1.576
Wet unit wt., gm (pcf)	114.8	124.0
Dry unit wt., gd (pcf)	87.2	98.4

Vertical Stress - Deformation Results

Vert. stress (psf)	Corr. Dial, dfc [a] (in)	Hc [b] (in)	Vert. strain, ev	Load duration (min)	t-90 (min)	Hdr (in)	Cv (ft^2/day)
Seating	0.0000	1.0000	0.0000	0			
100	0.0000	1.0000	0.0000	25			
200	0.0028	0.9972	0.0028	120			
400	0.0069	0.9931	0.0069	120			
800	0.0105	0.9895	0.0105	107	0.5	0.49565	4.61
1,600	0.0175	0.9825	0.0175	70	0.3	0.493	5.85
3,200	0.0300	0.9700	0.0300	180	0.4	0.48813	4.62
6,400	0.0488	0.9512	0.0488	180	0.3	0.4803	5.81
12,800	0.0743	0.9257	0.0743	79	0.3	0.46921	5.54
25,600	0.1075	0.8925	0.1075	123	1.5	0.45454	1.11
51,200	0.1426	0.8574	0.1426	61	1.5	0.43747	1.01
25,600	0.1411	0.8589	0.1411	16			
6,400	0.1352	0.8648	0.1352	25			
1,600	0.1141	0.8859	0.1141	272			

Data Interpretation Summary

Preconsolidation stress, s'p (psf)	---	
Compression ratio, CR	---	To be determined by the Geotechnical Engineer
Recompression ratio, RR	---	

Notes:
[a] Dfc = end of increment deformation corrected for machine, porous stone, and filter paper deformation
[b] Hc = height at end of consolidation of each vert. stress
[c] Hdr = height at 50 consolidation computed from D90 using sq-root time method
[d] Cv computed from Taylor (1948) aquare root of time method (note 1 in^2/min = 10 ft^2/day)

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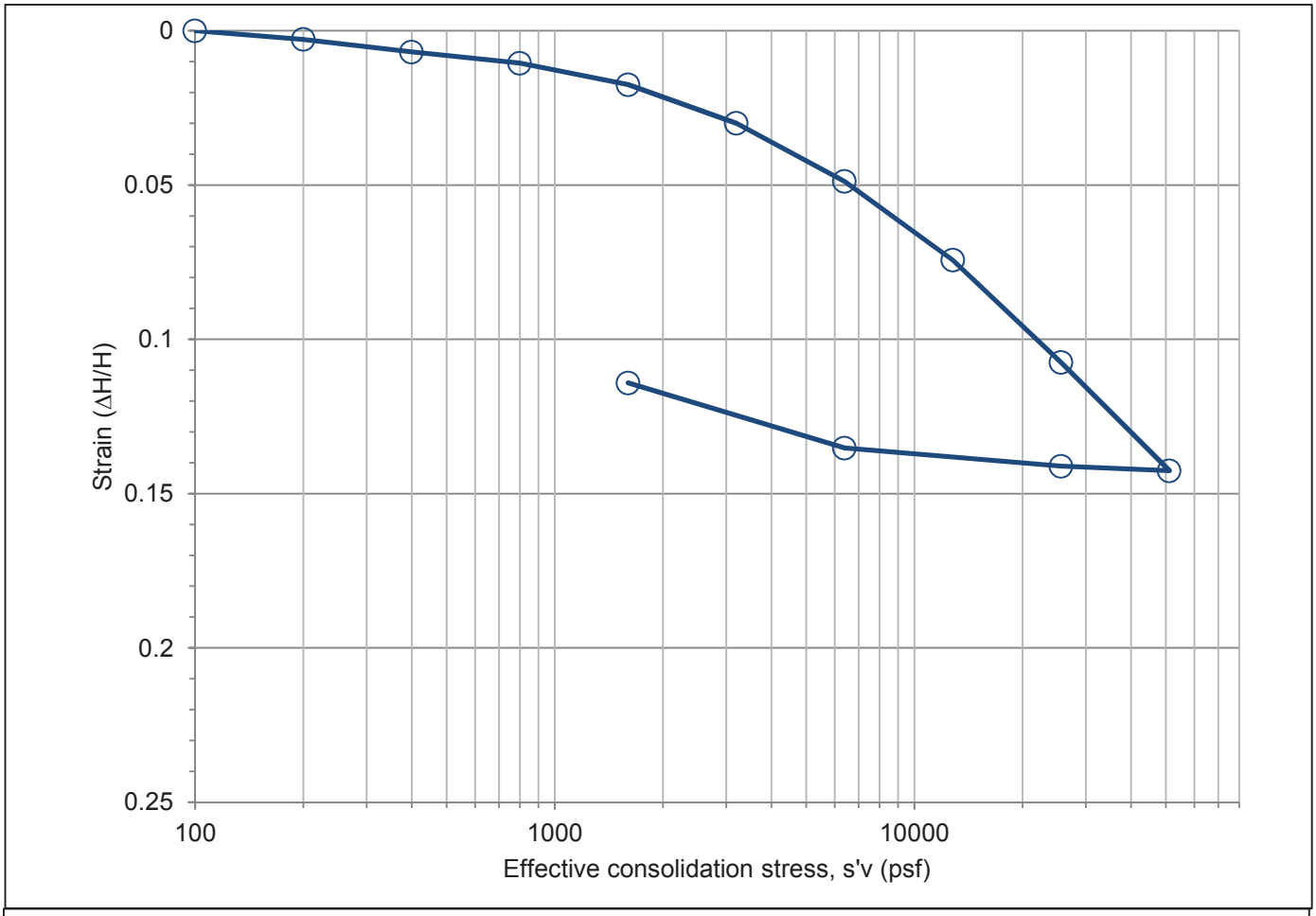
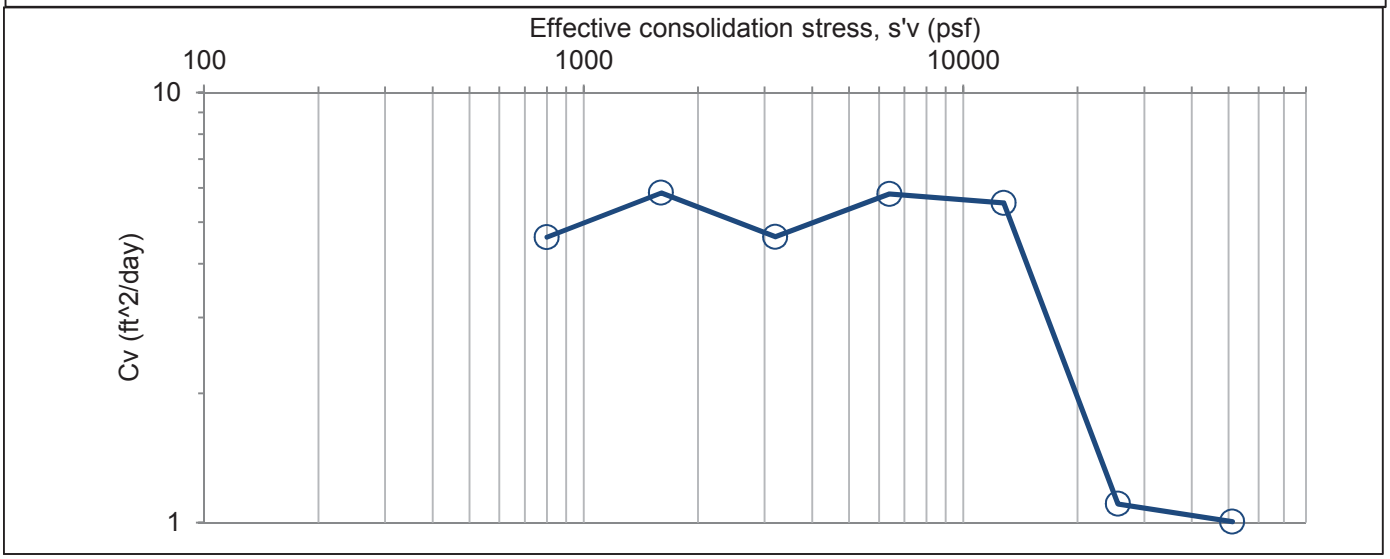
One-Dimensional Consolidation Properties of Soils
After ASTM D2435 and USBR 5700

GERHART COLE

Project: Bear River
No: 13GCI329

TH/TP/Sample: TH-CUB-01
Depth: 60-62 (62)





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One-Dimensional Consolidation Properties of Soils
After ASTM D2435 and USBR 5700

GERHART COLE

Project:	**Bear River**	**TH/TP/Sample:**	**TH-CUB-02**
No:	**13GCI329**	**Depth:**	**40-41.5 (41.5)**
Location:	Cache County, Utah	Sample description:	dark gray to black clay
Date:	18-Sep-14	USCS classification:	not requested
Tested by:	zg	Sample type:	Rel. undisturbed, Shelby Tube
Reduced by:	zg	Inundation stress (psf):	100, beginning
Checked by:	dab	Swell pressure (psf):	194
Comments:		Test method:	B
		Preparation procedure:	trimmed

Phase Relationships

	Initial	Final
Height, H (in)	1.0000	0.7509
Height, H (cm)	2.540	1.907
Dia., D (in)	2.500	2.500
Dia., D (cm)	6.350	6.350
Wt. rings + wet soil (g)	346.20	327.89
Wt. rings (g)	214.40	214.40
Wet soil + tare (g)	312.01	
Dry soil + tare (g)	252.02	
Tare (g)	144.95	
Moisture cont., w (%)	56.0	34.4
Gs, assumed	2.75	2.75
Mass total (g)	131.8	113.5
Mass of solids (g)	84.5	84.5
Volume (cm^3)	80.4	60.4
Vol. of water (cm^3)	47.3	29.0
Vol. of solids (cm^3)	30.7	30.7
Vol. of voids (cm^3)	49.7	29.7
Vol. of air (cm^3)	2.4	0.7
Area, A (cm^2)	31.7	31.7
Ht. solids, Hs (cm)	0.970	0.970
Void ratio, e	1.619	0.966
Porosity, n	0.618	0.491
Vol.moisture, T	0.588	0.480
Saturation, S (%)	95	98
Dry density (gm/cm^3)	1.050	1.398
Wet unit wt., gm (pcf)	102.3	117.3
Dry unit wt., gd (pcf)	65.6	87.3

Vertical Stress - Deformation Results

Vert. stress (psf)	Corr. Dial, dfc [a] (in)	Hc [b] (in)	Vert. strain, ev	Load duration (min)	t-90 (min)	Hdr (in)	Cv (ft^2/day)
Seating	0.0000	1.0000	0.0000	0			
100	0.0002	0.9998	0.0002	100			
400	0.0043	0.9957	0.0043	25			
800	0.0100	0.9900	0.0100	32			
1,600	0.0221	0.9779	0.0221	131	25.1	0.49198	0.08
3,200	0.0409	0.9591	0.0409	105	31.6	0.48424	0.06
6,400	0.0873	0.9127	0.0873	132	79.4	0.46794	0.02
12,800	0.1841	0.8159	0.1841	240	158.5	0.43214	0.01
25,600	0.2622	0.7378	0.2622	203	125.9	0.38843	0.01
51,200	0.3271	0.6729	0.3271	251	125.9	0.35269	0.01
25,600	0.3208	0.6792	0.3208	32			
6,400	0.3018	0.6982	0.3018	40			
1,600	0.2792	0.7208	0.2792	63			
400	0.2491	0.7509	0.2491	126			

Data Interpretation Summary

Preconsolidation stress, s'p (psf)	---	
Compression ratio, CR	---	To be determined by the Geotechnical Engineer
Recompression ratio, RR	---	

Notes:
[a] Dfc = end of increment deformation corrected for machine, porous stone, and filter paper deformation
[b] Hc = height at end of consolidation of each vert. stress
[c] Hdr = height at 50 consolidation computed from D90 using sq-root time method
[d] Cv computed from Taylor (1948) aquare root of time method (note 1 in^2/min = 10 ft^2/day)

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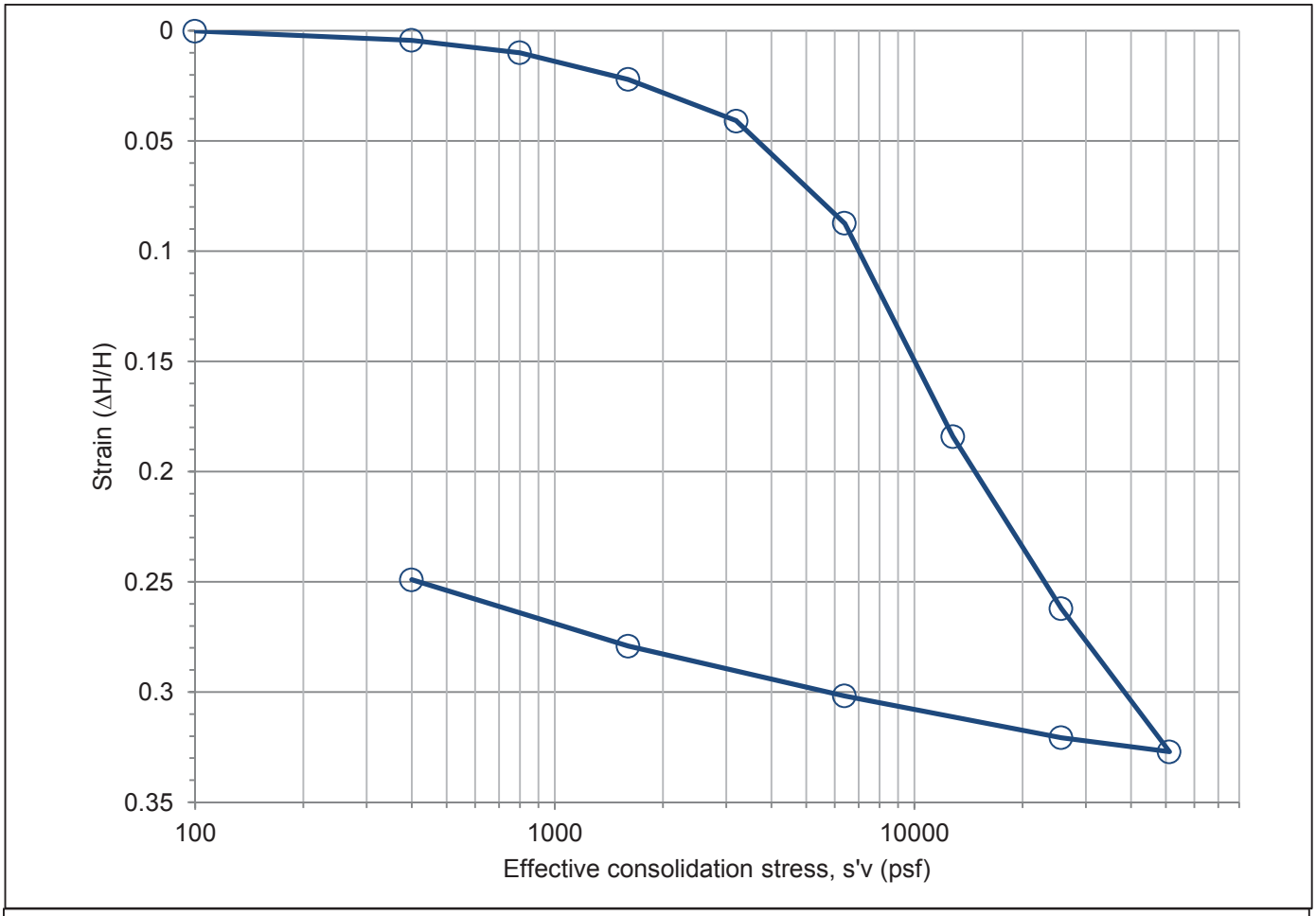
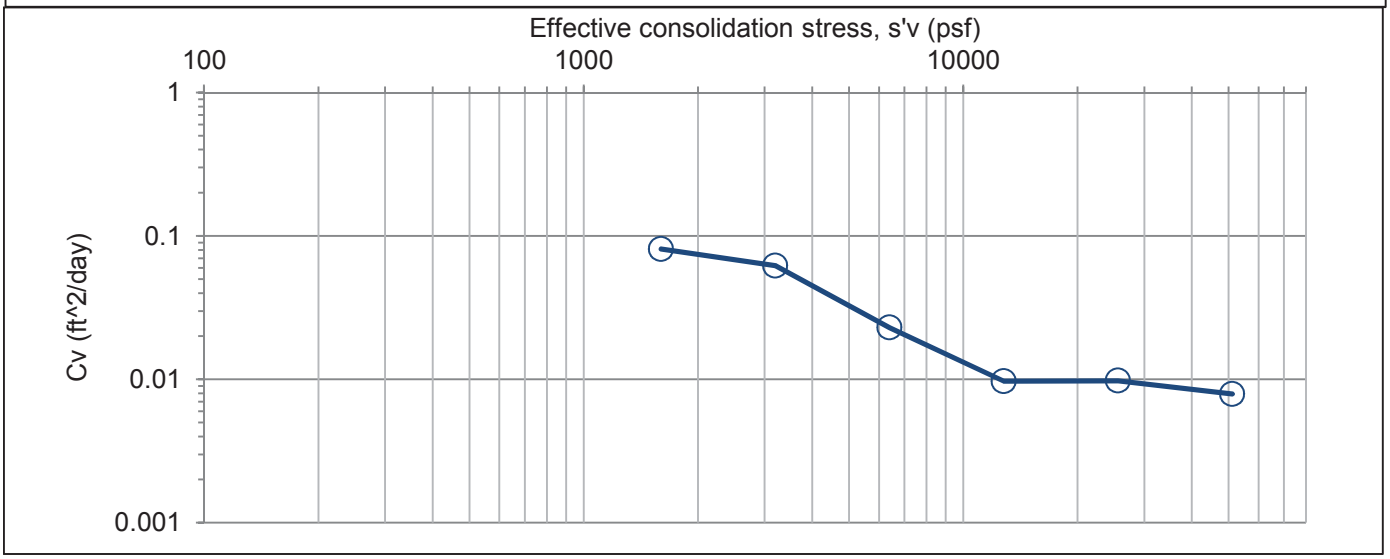
One-Dimensional Consolidation Properties of Soils
After ASTM D2435 and USBR 5700

GERHART COLE

Project: Bear River
No: 13GCI329

TH/TP/Sample: TH-CUB-02
Depth: 40-41.5 (41.5)





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One-Dimensional Consolidation Properties of Soils
After ASTM D2435 and USBR 5700

GERHART COLE

Project:	**Bear River**	**TH/TP/Sample:**	**TH-CUB-03**
No:	**13GCI329**	**Depth:**	**15-16.5 (15.5)**
Location:	Logan Ut	Sample description:	orange brown to gray brown
Date:	15-Sep-14	USCS classification:	not requested
Tested by:	zg	Sample type:	Rel. undisturbed, Shelby Tube
Reduced by:	zg	Inundation stress (psf):	100, beginning
Checked by:	dab	Swell pressure (psf):	769
Comments:	Some disturbance observed in the tube.	Test method:	B
		Preparation procedure:	trimmed

Phase Relationships

	Initial	Final
Height, H (in)	1.0000	0.9402
Height, H (cm)	2.540	2.388
Dia., D (in)	2.500	2.500
Dia., D (cm)	6.350	6.350
Wt. rings + wet soil (g)	363.93	360.57
Wt. rings (g)	214.41	214.41
Wet soil + tare (g)	301.42	
Dry soil + tare (g)	260.43	
Tare (g)	144.50	
Moisture cont., w (%)	35.4	32.3
Gs, assumed	2.75	2.75
Mass total (g)	149.5	146.2
Mass of solids (g)	110.5	110.5
Volume (cm^3)	80.4	75.6
Vol. of water (cm^3)	39.1	35.7
Vol. of solids (cm^3)	40.2	40.2
Vol. of voids (cm^3)	40.3	35.5
Vol. of air (cm^3)	1.2	-0.2
Area, A (cm^2)	31.7	31.7
Ht. solids, Hs (cm)	1.268	1.268
Void ratio, e	1.003	0.883
Porosity, n	0.501	0.469
Vol.moisture, T	0.486	0.472
Saturation, S (%)	97	101
Dry density (gm/cm^3)	1.373	1.461
Wet unit wt., gm (pcf)	116.0	120.6
Dry unit wt., gd (pcf)	85.7	91.2

Vertical Stress - Deformation Results

Vert. stress (psf)	Corr. Dial, dfc [a] (in)	Hc [b] (in)	Vert. strain, ev	Load duration (min)	t-90 (min)	Hdr (in)	Cv (ft^2/day)
Seating	0.0000	1.0000	0.0000	0			
100	0.0004	0.9996	0.0004	60			
1,600	0.0041	0.9959	0.0041	65	39.8	0.49887	0.05
3,200	0.0119	0.9881	0.0119	63	19.9	0.496	0.10
6,400	0.0261	0.9739	0.0261	86	50.1	0.4905	0.04
12,800	0.0521	0.9479	0.0521	159	63.1	0.48044	0.03
25,600	0.0901	0.9099	0.0901	240	100.0	0.46445	0.02
51,200	0.1405	0.8595	0.1405	300	125.9	0.44235	0.01
25,600	0.1338	0.8662	0.1338	60			
6,400	0.1156	0.8844	0.1156	50			
1,600	0.0893	0.9107	0.0893	120			
400	0.0598	0.9402	0.0598	240			

Data Interpretation Summary

Preconsolidation stress, s'p (psf)	---	
Compression ratio, CR	---	To be determined by the Geotechnical Engineer
Recompression ratio, RR	---	

Notes:
[a] Dfc = end of increment deformation corrected for machine, porous stone, and filter paper deformation
[b] Hc = height at end of consolidation of each vert. stress
[c] Hdr = height at 50 consolidation computed from D90 using sq-root time method
[d] Cv computed from Taylor (1948) aquare root of time method (note 1 in^2/min = 10 ft^2/day)

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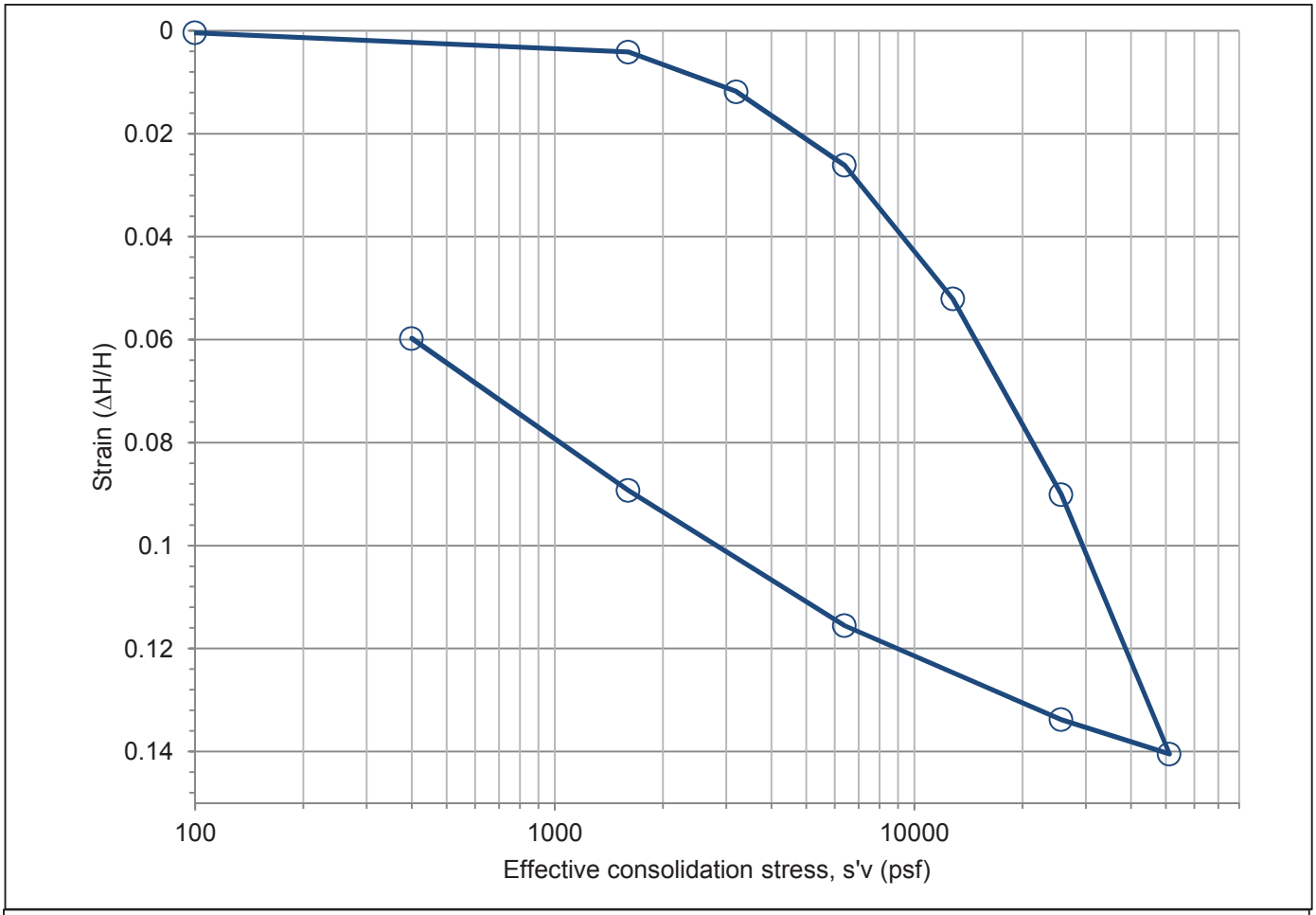
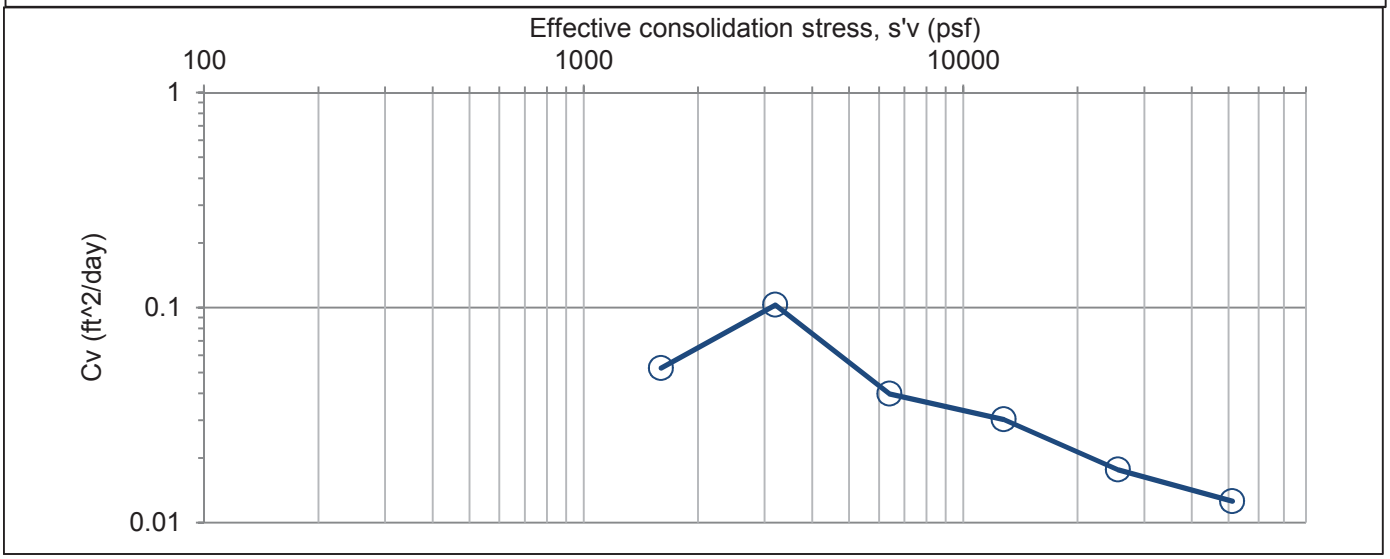
One-Dimensional Consolidation Properties of Soils
After ASTM D2435 and USBR 5700

GERHART COLE

Project: Bear River
No: 13GCI329

TH/TP/Sample: TH-CUB-03
Depth: 15-16.5 (15.5)





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One-Dimensional Consolidation Properties of Soils

After ASTM D2435 and USBR 5700

GERHART COLE

Project:	**Bear River**	**TH/TP/Sample:**	**TH-CUB-03**
No:	**13GCI329**	**Depth:**	**15-16.5 (15.25)**
Location:	Cache County, Utah	Sample description:	orange brown to gray brown
Date:	26-Sep-14	USCS classification:	not requested
Tested by:	zg	Sample type:	Rel. undisturbed, Shelby Tube
Reduced by:	zg	Inundation stress (psf):	100, beginning
Checked by:	dab	Swell pressure (psf):	782
Comments:		Test method:	B
measured swell pressure for 12 hours		Preparation procedure:	trimmed

Phase Relationships

	Initial	Final
Height, H (in)	1.0000	0.9340
Height, H (cm)	2.540	2.372
Dia., D (in)	2.500	2.500
Dia., D (cm)	6.350	6.350
Wt. rings + wet soil (g)	364.06	362.24
Wt. rings (g)	214.41	214.41
Wet soil + tare (g)	302.72	
Dry soil + tare (g)	261.33	
Tare (g)	145.16	
Moisture cont., w (%)	35.6	34.0
Gs, assumed	2.75	2.75
Mass total (g)	149.7	147.8
Mass of solids (g)	110.3	110.3
Volume (cm^3)	80.4	75.1
Vol. of water (cm^3)	39.3	37.5
Vol. of solids (cm^3)	40.1	40.1
Vol. of voids (cm^3)	40.3	35.0
Vol. of air (cm^3)	1.0	-2.5
Area, A (cm^2)	31.7	31.7
Ht. solids, Hs (cm)	1.267	1.267
Void ratio, e	1.005	0.872
Porosity, n	0.501	0.466
Vol.moisture, T	0.489	0.499
Saturation, S (%)	98	107
Dry density (gm/cm^3)	1.372	1.469
Wet unit wt., gm (pcf)	116.1	122.8
Dry unit wt., gd (pcf)	85.6	91.7

Vertical Stress - Deformation Results

Vert. stress (psf)	Corr. Dial, dfc [a] (in)	Hc [b] (in)	Vert. strain, ev	Load duration (min)	t-90 (min)	Hdr (in)	Cv (ft^2/day)
Seating	0.0000	1.0000	0.0000	0			
100	0.0010	0.9990	0.0010	732			
1,600	0.0041	0.9959	0.0041	240			
3,200	0.0161	0.9839	0.0161	240	25.1	0.49495	0.08
6,400	0.0321	0.9679	0.0321	240	50.1	0.48795	0.04
12,800	0.0572	0.9428	0.0572	240	63.1	0.47768	0.03
25,600	0.0944	0.9056	0.0944	240	100.0	0.46211	0.02
51,200	0.1435	0.8565	0.1435	240	125.9	0.44054	0.01
25,600	0.1367	0.8633	0.1367	60			
6,400	0.1171	0.8829	0.1171	60			
1,600	0.1053	0.8947	0.1053	34			
400	0.0660	0.9340	0.0660	240			

Data Interpretation Summary

Casagrande (1936)

Preconsolidation stress, s'p (psf) -

Compression ratio, CR by the Geotechnical Engineer

Recompression ratio, RR 0.00

Strain Energy Method (after Becker et al. 1987)

Preconsolidation stress, s'p (psf) 11,400

Notes:

[a] Dfc = end of increment deformation corrected for machine, porous stone, and filter paper deformation

[b] Hc = height at end of consolidation of each vert. stress

[c] Hdr = height at 50 consolidation computed from D90 using sq-root time method

[d] Cv computed from Taylor (1948) aquare root of time method (note 1 in^2/min = 10 ft^2/day)

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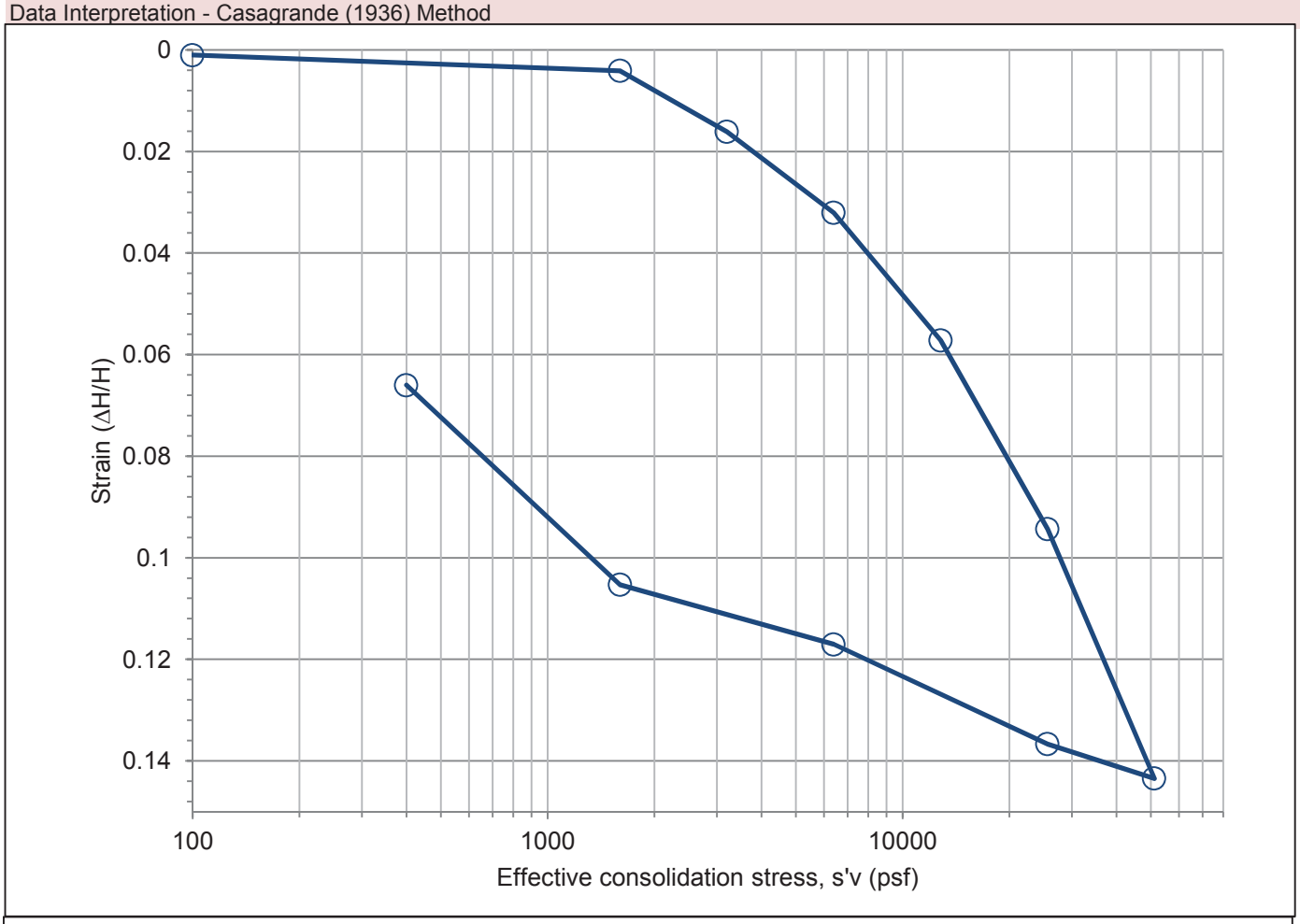
One-Dimensional Consolidation Properties of Soils
After ASTM D2435 and USBR 5700

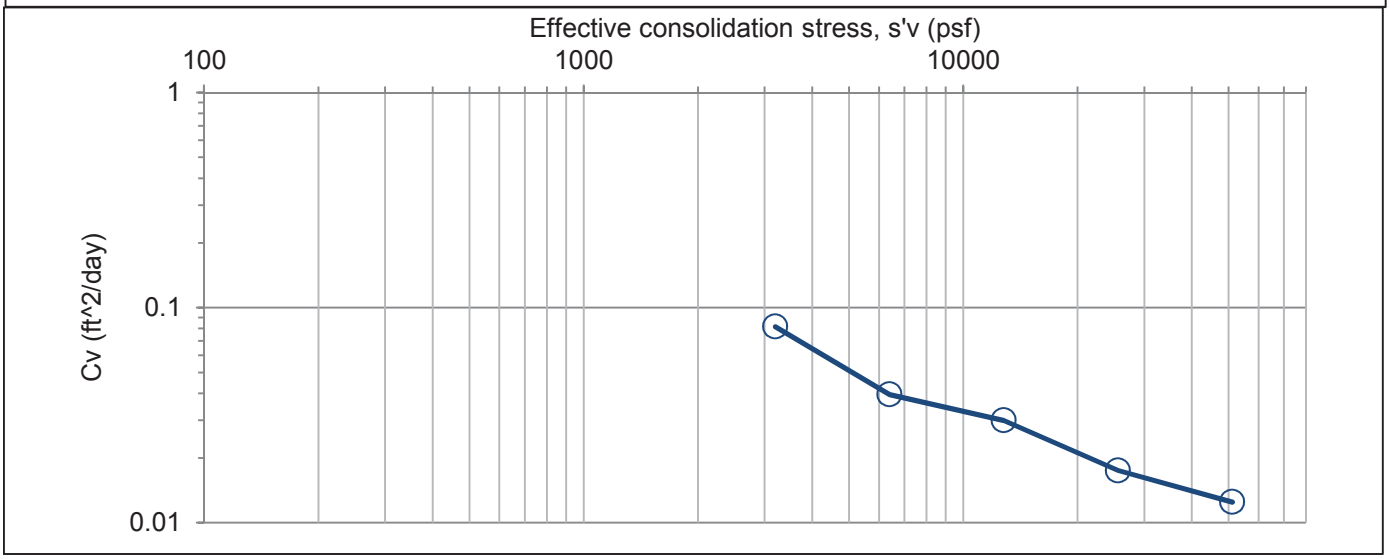
GERHART COLE

Project: Bear River
No: 13GCI329

TH/TP/Sample: TH-CUB-03
Depth: 15-16.5 (15.25)

Data Interpretation - Casagrande (1936) Method





Preconsolidation stress, s'p (psf)	---	
Compression ratio, CR	---	To be determined by the Geotechnical Engineer
Recompression ratio, RR	---	

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One-Dimensional Consolidation Properties of Soils
After ASTM D2435 and USBR 5700

GERHART COLE

Project:	**Bear River**	**TH/TP/Sample:**	**TH-CUB-03**
No:	**13GCI329**	**Depth:**	**40-41.5 (41.5)**
Location:	Cache County, Utah	Sample description:	dark gray to purpulish gray
Date:	12-Sep-14	USCS classification:	not requested
Tested by:	zg	Sample type:	Rel. undisturbed, Shelby Tube
Reduced by:	zg	Inundation stress (psf):	100, beginning
Checked by:	dab	Swell pressure (psf):	310
Comments:		Test method:	B
		Preparation procedure:	trimmed

Phase Relationships

	Initial	Final
Height, H (in)	1.0000	0.8412
Height, H (cm)	2.540	2.137
Dia., D (in)	2.500	2.500
Dia., D (cm)	6.350	6.350
Wt. rings + wet soil (g)	358.19	347.71
Wt. rings (g)	214.41	214.41
Wet soil + tare (g)	317.47	
Dry soil + tare (g)	268.22	
Tare (g)	144.91	
Moisture cont., w (%)	39.9	29.7
Gs, assumed	2.75	2.75
Mass total (g)	143.8	133.3
Mass of solids (g)	102.7	102.7
Volume (cm^3)	80.4	67.7
Vol. of water (cm^3)	41.0	30.6
Vol. of solids (cm^3)	37.4	37.4
Vol. of voids (cm^3)	43.1	30.3
Vol. of air (cm^3)	2.0	-0.2
Area, A (cm^2)	31.7	31.7
Ht. solids, Hs (cm)	1.180	1.180
Void ratio, e	1.153	0.811
Porosity, n	0.536	0.448
Vol.moisture, T	0.510	0.452
Saturation, S (%)	95	101
Dry density (gm/cm^3)	1.277	1.518
Wet unit wt., gm (pcf)	111.6	123.0
Dry unit wt., gd (pcf)	79.7	94.8

Vertical Stress - Deformation Results

Vert. stress (psf)	Corr. Dial, dfc [a] (in)	Hc [b] (in)	Vert. strain, ev	Load duration (min)	t-90 (min)	Hdr (in)	Cv (ft^2/day)
Seating	0.0000	1.0000	0.0000	0			
100	0.0000	1.0000	0.0000	60			
800	0.0053	0.9947	0.0053	65			
1,600	0.0141	0.9859	0.0141	135	15.8	0.49514	0.13
3,200	0.0265	0.9735	0.0265	135	10.0	0.48985	0.20
6,400	0.0619	0.9381	0.0619	240	25.1	0.47789	0.08
12,800	0.1309	0.8691	0.1309	172	63.1	0.45178	0.03
25,600	0.1910	0.8090	0.1910	240	50.1	0.41952	0.03
51,200	0.2421	0.7579	0.2421	240	39.8	0.39172	0.03
25,600	0.2369	0.7631	0.2369	60			
6,400	0.2171	0.7829	0.2171	60			
1,600	0.1907	0.8093	0.1907	120			
400	0.1588	0.8412	0.1588	240			

Data Interpretation Summary

Preconsolidation stress, s'p (psf)	---	
Compression ratio, CR	---	To be determined by the Geotechnical Engineer
Recompression ratio, RR	---	

Notes:
[a] Dfc = end of increment deformation corrected for machine, porous stone, and filter paper deformation
[b] Hc = height at end of consolidation of each vert. stress
[c] Hdr = height at 50 consolidation computed from D90 using sq-root time method
[d] Cv computed from Taylor (1948) aquare root of time method (note 1 in^2/min = 10 ft^2/day)

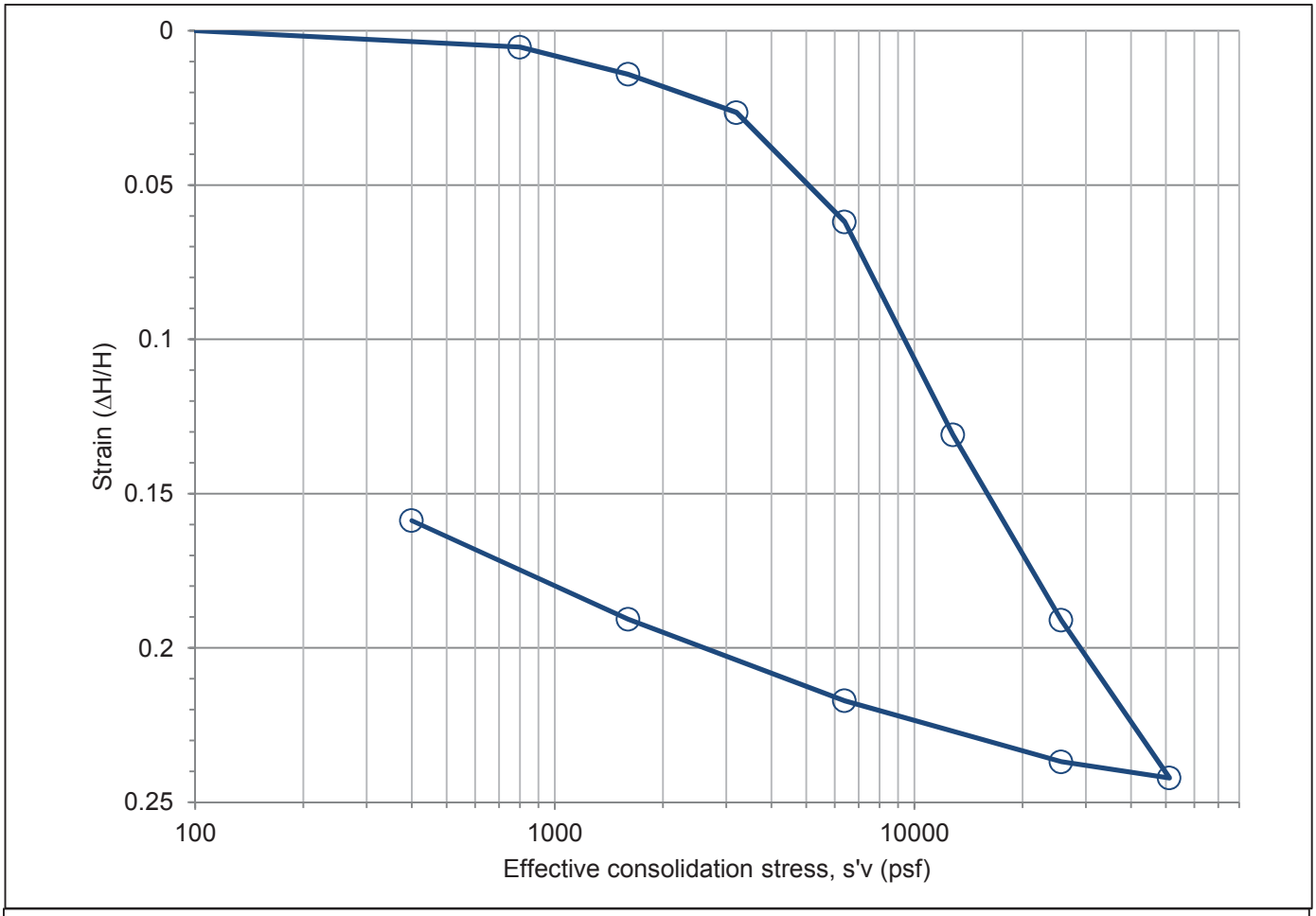
DRAFT

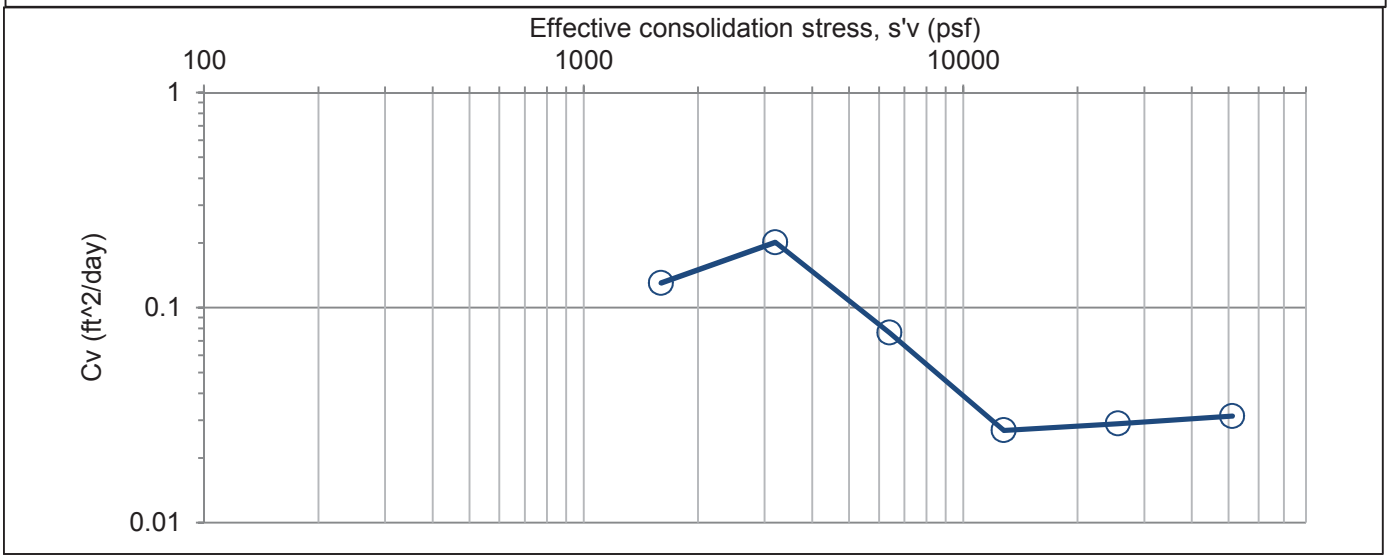
One-Dimensional Consolidation Properties of Soils
After ASTM D2435 and USBR 5700

GERHART COLE

Project: Bear River
No: 13GCI329

TH/TP/Sample: TH-CUB-03
Depth: 40-41.5 (41.5)





DRAFT

Triaxial Test - Isotropic Consolidated Sheared Undrained Measuring Pore Pressure (CIU-PP) - *After ASTM D4767 and USBR 5750*

GERHART COLE

Project:	**Bear River - Cub River**	**TH/TP/Sample:**	**TH-CUB-02**
No:	**13GCI329**	**Depth:**	**20-22**
Location:	Cache County Utah	Sample description:	purplish gray clay
Date:	17-Aug-15	USCS classification:	CL
Tested by:	zmg	Sample type:	undisturbed
Reduced by:	zmg	Notes:	
Checked by:	rrb		

	Test Number	S1	50 psi	S2	20 psi	S3	10 psi
		Initial	Bef. Shr. MethodB [e]	Initial			Bef. Shr. MethodB [e]
Unit weight data	Sample ht., H (in) 0°	5.777		5.753			
	Sample ht., H (in) 120°	5.774		5.755			
	Sample ht., H (in) 240°	5.773		5.756			
	Avg. height, Havg (in)	5.775	5.675	5.755			5.471
	Avg. height, Havg (cm)	14.668	14.414	14.617			13.896
	ΔHsc (in) [a]		0.10				0.03
	Sample dia., D (in) top	2.776		2.835			
	Sample dia., D (in) mid	2.714		2.836			
	Sample dia., D (in) bot	2.845		2.834			
	Avg. dia., Davg (in)	2.762	2.623	2.835			2.886
	Avg. dia., Davg (cm)	7.016	6.662	7.202			7.329
	Avg. area, Aavg (in^2)	5.993	5.403	6.314			6.540
	Avg. area, Aavg (cm^2)	38.662	34.861	40.732			42.191
	Wt. rings + wet soil (g)	1011.31	969.81	1166.00			1144.72
	Wt. rings (g)	0.00	0.00	0.00			0.00
	Volume, Vo (in^3)	34.6	30.7	36.3			35.8
	Vo (cm^3)	567.1	502.5	595.4			586.3
	Vo (ft^3)	0.0200	0.0177	0.0210			0.0207
Moisture	Wet soil + tare (g)	207.02	1142.37	227.00			1534.30
	Dry soil + tare (g)	184.89	926.26	208.51			1286.47
	Tare (g)	119.21	173.00	144.37			389.69
	Moisture content, w (%)	33.7	28.7	28.8			27.6
Phase Relationships	Gs, assumed	2.65	2.65	2.65			2.65
	Mass total (g)	1011.3	973.5	1166.0			1144.7
	Mass of solids (g)	756.4	756.4	905.1			896.9
	Volume (cm^3)	567.1	502.5	595.4			586.3
	Volume of water (cm^3)	254.9	217.0	260.9			247.9
	Volume of solids (cm^3)	285.4	285.4	341.5			338.4
	Volume of voids (cm^3)	281.6	217.0	253.8			247.9
	Volume of air (cm^3)	26.8	0.0	-7.1			0.0
	Void ratio, e	0.987	0.760	0.743			0.732
	Porosity, n	0.497	0.432	0.426			0.423
	Volumetric moisture, T	0.449	0.432	0.438			0.423
	Saturation, S (%) [c]	90.50	100.00	102.79			100.00
	Dry density (gm/cm^3)	1.334	1.505	1.520			1.530
	Wet unit wt., gm (pcf)	111.3	120.9	122.3			121.9
	Dry unit wt., gd (pcf)	83.3	94.0	94.9			95.5

Staged Test

Notes:

[a] ΔHsc (in) = change in height during saturation and consolidation

[b] ΔVs = change in volume during saturation, ΔVc = change in volume during consolidation

[c] Saturation before shear set to 100% for phase calculations

[d] Before shear Aavg using method A; where Ac (Method A) = (Vo-DVs - DVc)/(Ho-DHsc)

[e] Before shear Aavg using method B; where Ac (Method B) = (Vwf + Vs)/Hc

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DRAFT

Triaxial Test - Isotropic Consolidated Sheared Undrained
Measuring Pore Pressure (CIU-PP) *- After ASTM D4767 and USBR 5750*

GERHART COLE

Project:	**Bear River - Cub River**	**TH/TP/Sample:**	**TH-CUB-02**
No:	**13GCI329**	**Depth:**	**20-22**
Location:	Cache County Utah	Sample description:	purplish gray clay
Date:	17-Aug-15	USCS classification:	CL
Tested by:	zmg	Sample type:	undisturbed

X:\PROJECTS\13GCI329 Bear River Project Concept Study\Bear River\[TX_CU3pts_TH-CUB-02_20-22ft-v02.xlsx]SUM

	Test Number	S1 at 50 psi	S2 at 20 psi	S3 at 10 psi
Test information	Total backpressure (psi)	40.0	40.0	40.0
	Skempton B	0.96	0.95	0.95
	t-90 (min)	270.1	240.2	115.2
	t-100 (min)	420.2	390.2	170.2
	t-50 (min)	63.1	56.1	26.9
	Strain rate (%/hr)	0.60	0.90	0.90
	Strain rate (%/min)	0.010	0.015	0.015
	Membrane correction	Yes	Yes	Yes
	Filter paper correction	No filter paper	No filter paper	No filter paper
Max principal stress ratio (s1/s3), failure criteria	Strain at failure, ef (%)	6.85	5.27	4.16
	Time to failure, tf (min)	685.4	351.0	277.5
	Obliquity, s'1/s'3	2.731	2.960	2.940
	Excess pore pressure, u (psi)	27.96	7.54	3.53
	q = q' = (s1+s3)/2 (psi)	19.08	12.21	6.28
	p' = (s'1+s'3)/2 (psi)	41.12	24.68	12.76
	p = (s1+s3)/2 (psi)	69.08	32.21	16.28
	Effective major principal stress, s'1 (psi)	60.19	36.89	19.04
	Effective minor principal stress, s'3 (psi)	22.04	12.46	6.47
	Total major pincipal stress, s1 (psi)	88.15	44.43	22.56
	Total minor pincipal stress, s3 (psi)	50.00	20.00	10.00
	Skemption A at failure, Af	0.73	0.31	0.28
	Secant friction angle, phi-s (deg)	27.6	29.7	29.5
		Effective stress	Total stress	
	Friction angle, phi (deg)	26.7	13.4	
	Cohesion intercept, c (psi)	0.9	3.5	
Peak deviator stress (s1-s3), failure criteria	Strain at failure, ef (%)	6.85	7.03	4.16
	Time to failure, tf (min)	685.4	468.5	277.5
	Deviator stress, s1-s3 (psi)	38.15	24.97	12.56
	Excess pore pressure, u (psi)	27.96	6.99	3.53
	q = q' = (s1+s3)/2 (psi)	19.08	12.49	6.28
	p' = (s'1+s'3)/2 (psi)	41.12	25.49	12.76
	p = (s1+s3)/2 (psi)	69.08	32.49	16.28
	Effective major principal stress, s'1 (psi)	60.19	37.98	19.04
	Effective minor principal stress, s'3 (psi)	22.04	13.01	6.47
	Total major pincipal stress, s1 (psi)	88.15	44.97	22.56
	Total minor pincipal stress, s3 (psi)	50.00	20.00	10.00
	Skemption A at failure, Af	0.73	0.28	0.28
	Secant friction angle, phi-s (deg)	27.6	29.3	29.5
		Effective stress	Total stress	
	Friction angle, phi (deg)	26.8	13.4	
	Cohesion intercept, c (psi)	0.8	3.6	

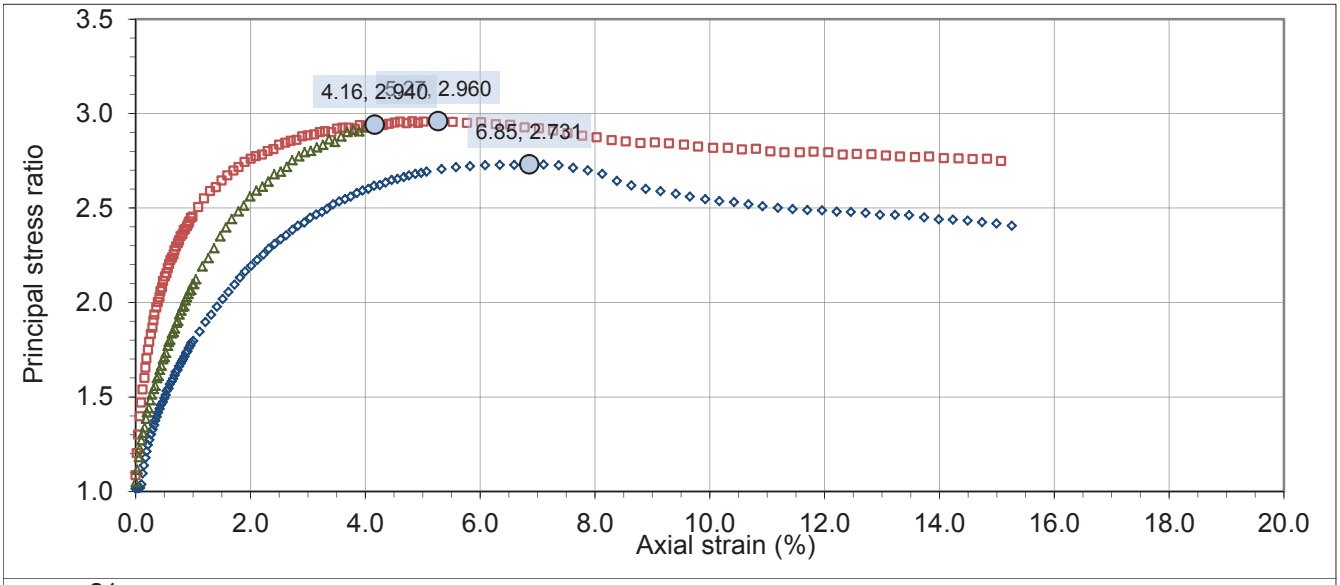
Comments:

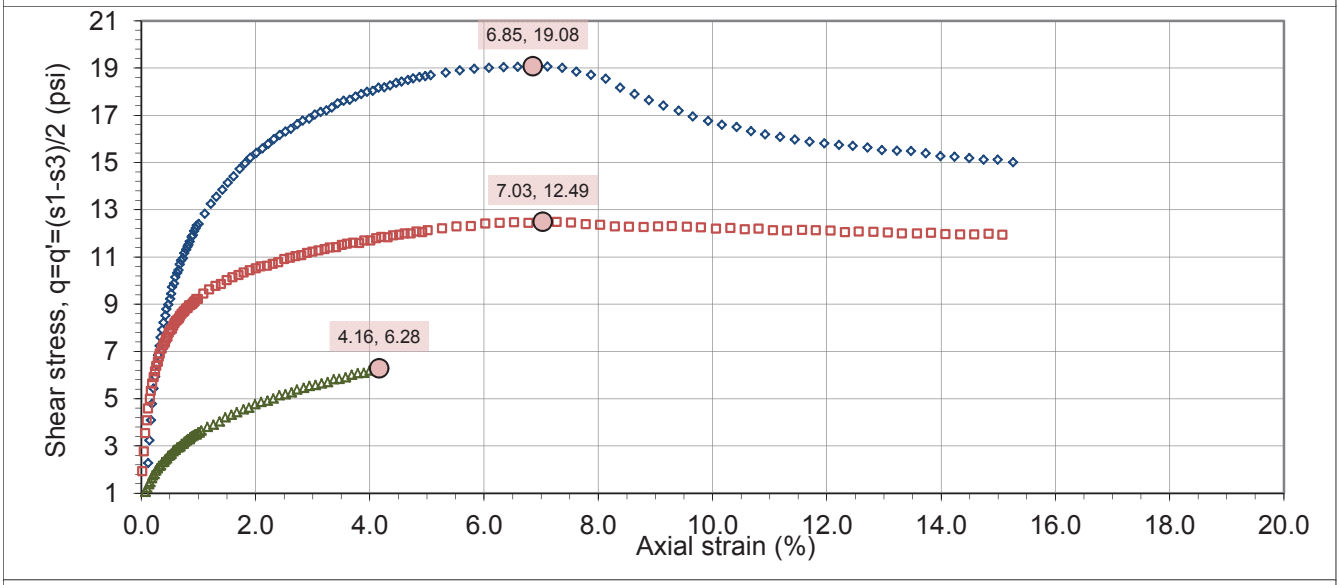
DRAFT

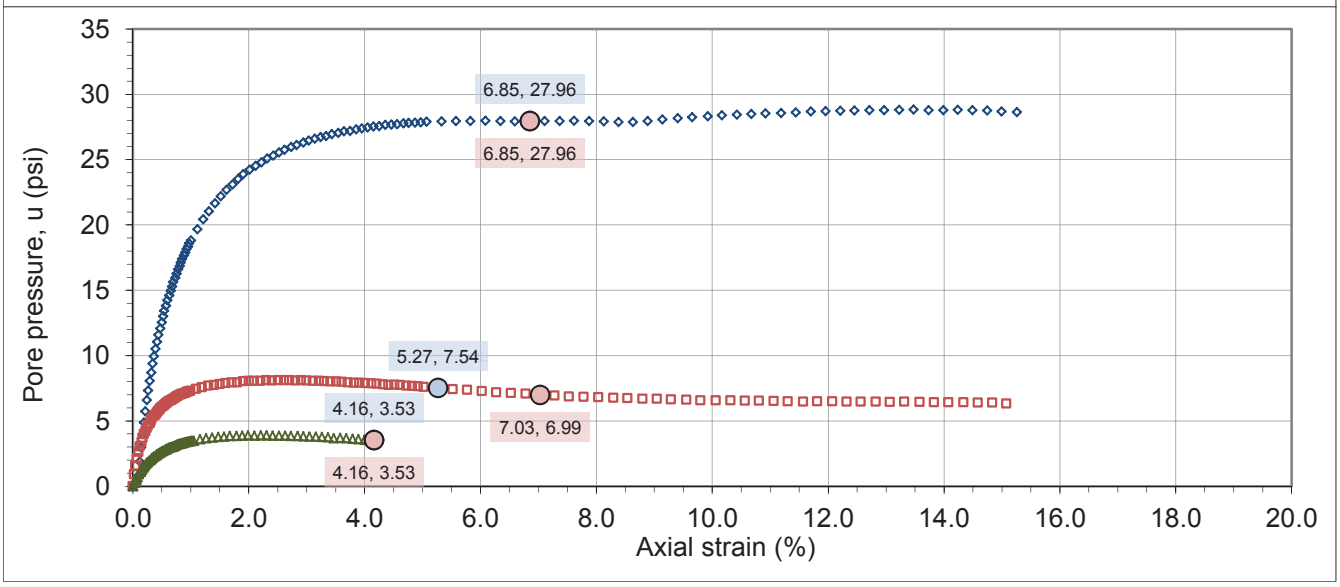
Triaxial Test - Isotropic Consolidated Sheared Undrained
Measuring Pore Pressure (CIU-PP) *- After ASTM D4767 and USBR 5750*

GERHART COLE

Project: Bear River - Cub River **TH/TP/Sample:** TH-CUB-02
No: 13GCI329 **Depth:** 20-22







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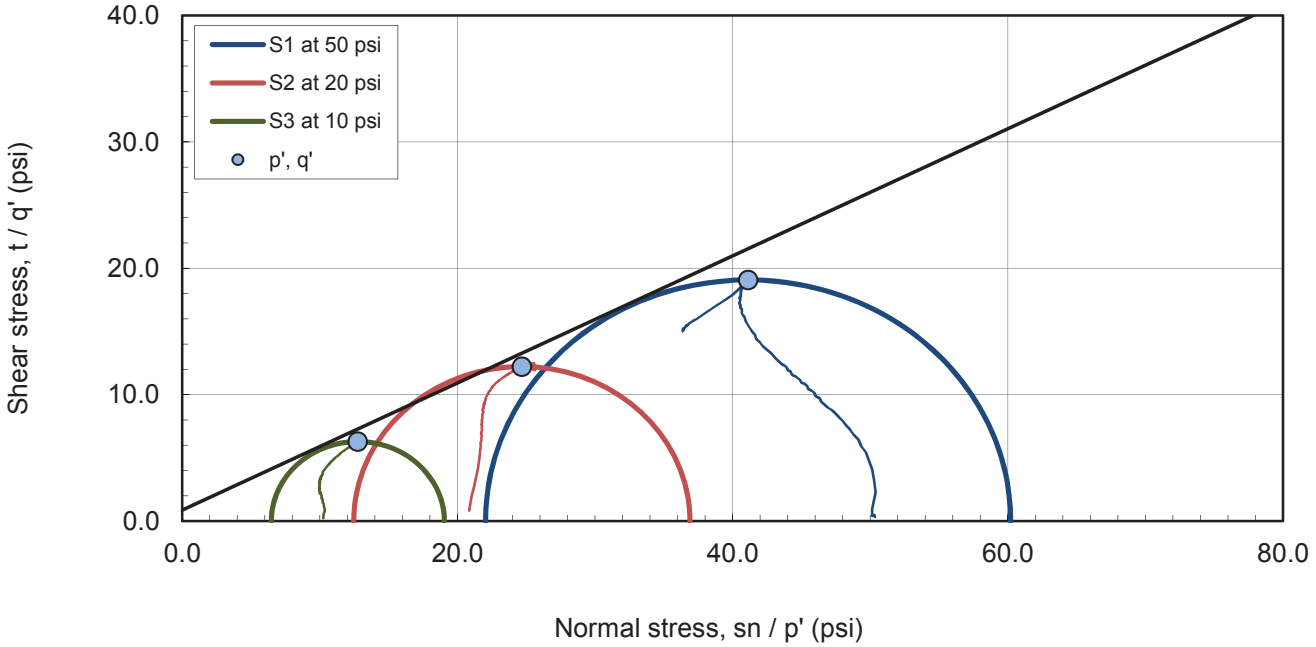
Triaxial Test - Isotropic Consolidated Sheared Undrained
Measuring Pore Pressure (CIU-PP) *- After ASTM D4767 and USBR 5750*

GERHART COLE

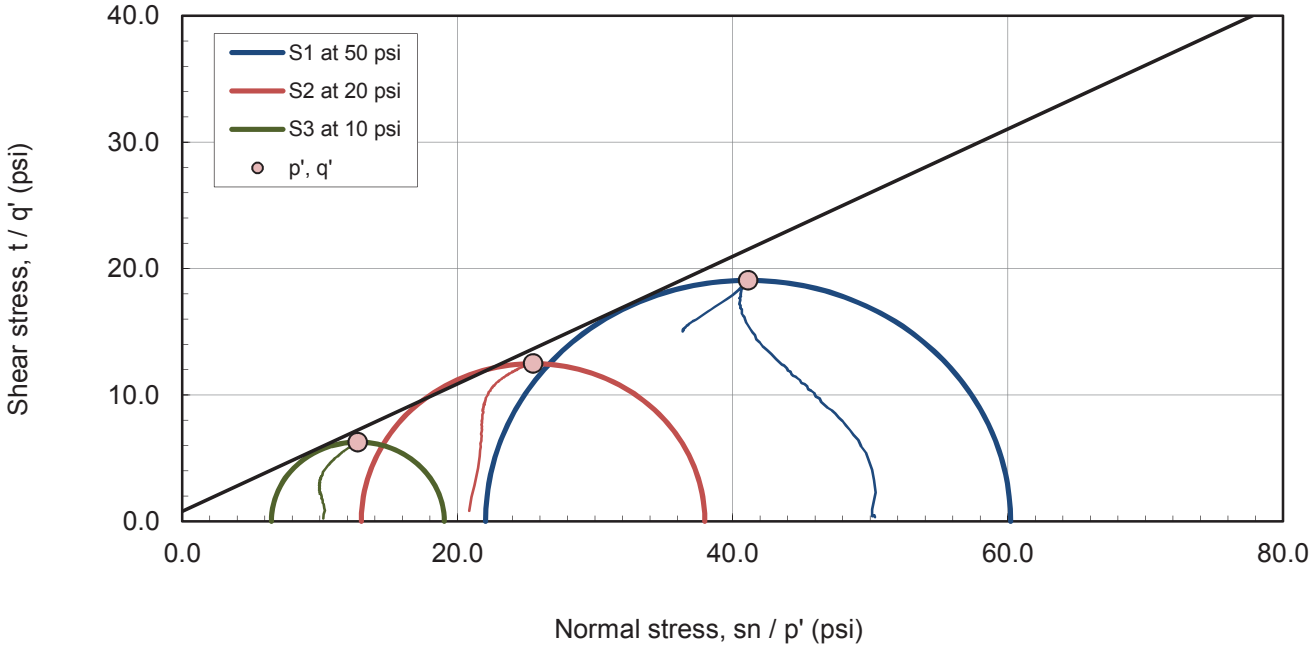
Project: Bear River - Cub River **TH/TP/Sample:** TH-CUB-02
No: 13GCI329 **Depth:** 20-22

Effective stress results



Max principal stress ratio (s'1/s'3), failure criteria Mohr and p' - q' space plots

Effective stress results



Peak deviator stress (s1-s3), failure criteria Mohr and p' - q' space plots

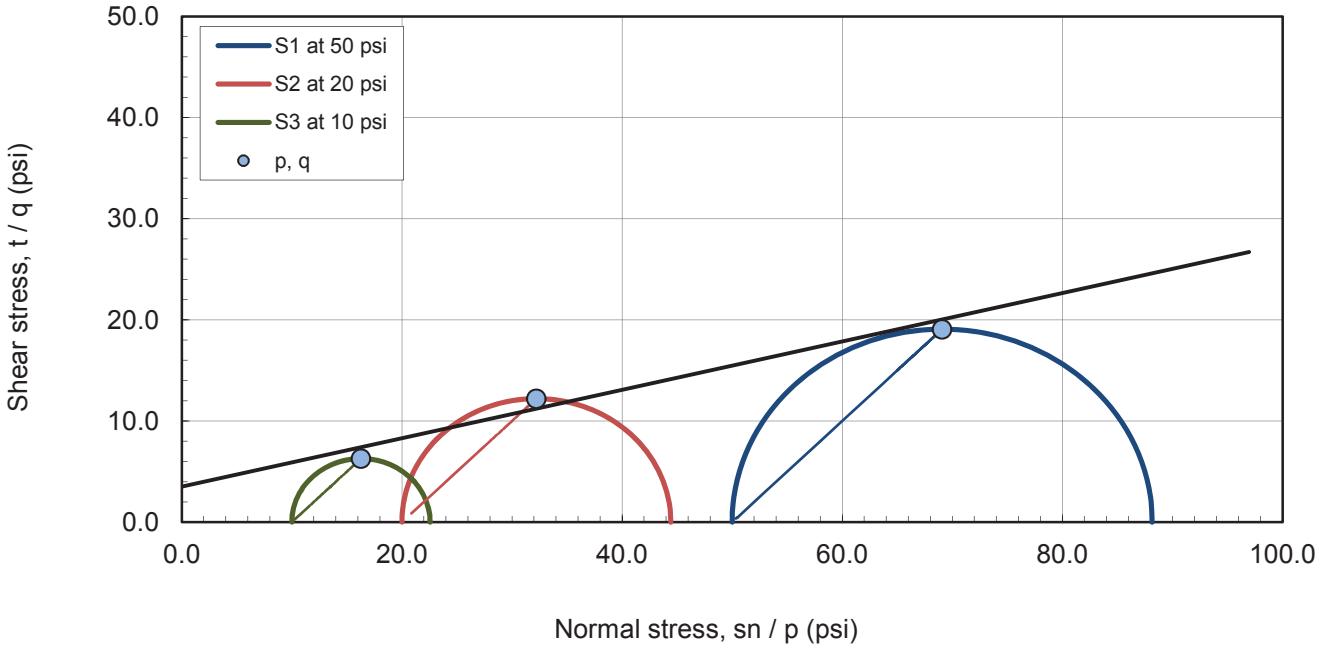
DRAFT

Triaxial Test - Isotropic Consolidated Sheared Undrained
Measuring Pore Pressure (CIU-PP) *- After ASTM D4767 and USBR 5750*

GERHART COLE

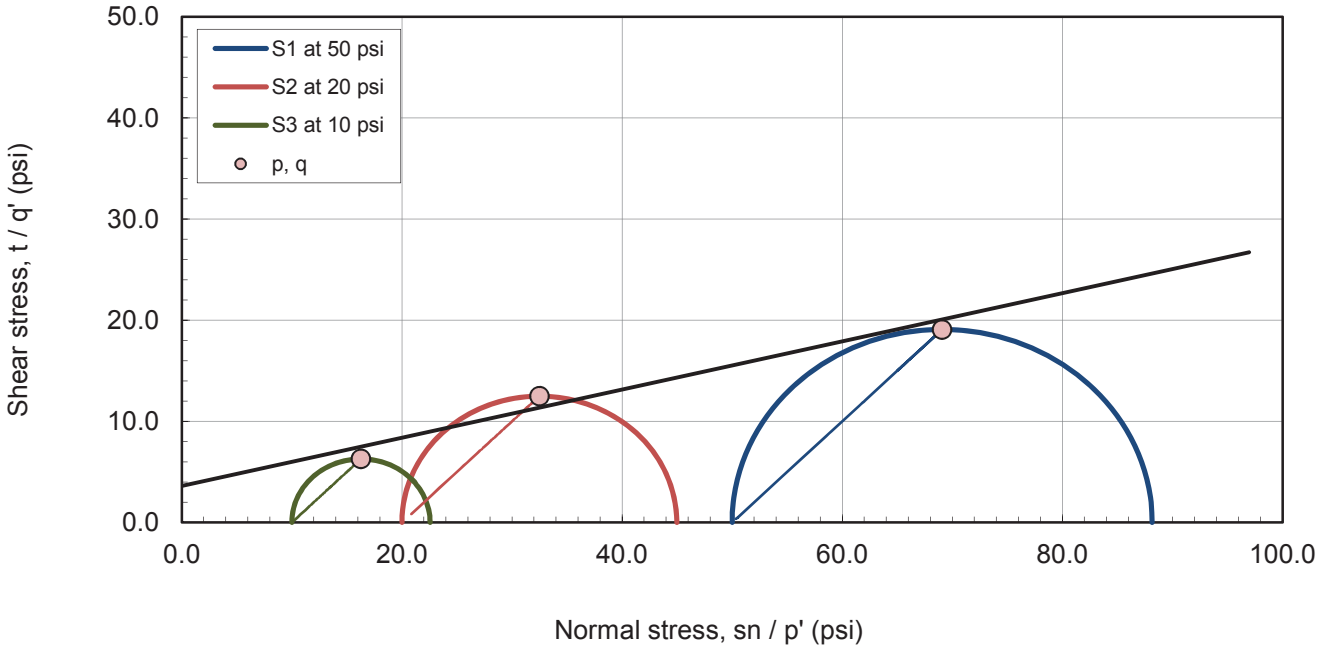
Project: Bear River - Cub River | **TH/TP/Sample:** TH-CUB-02
No: 13GCI329 | **Depth:** 20-22

Total stress results



Max principal stress ratio (s1/s3), failure criteria Mohr and p - q space plots - effective stress results

Total stress results



Peak deviator stress (s1-s3), failure criteria Mohr and p - q space plots

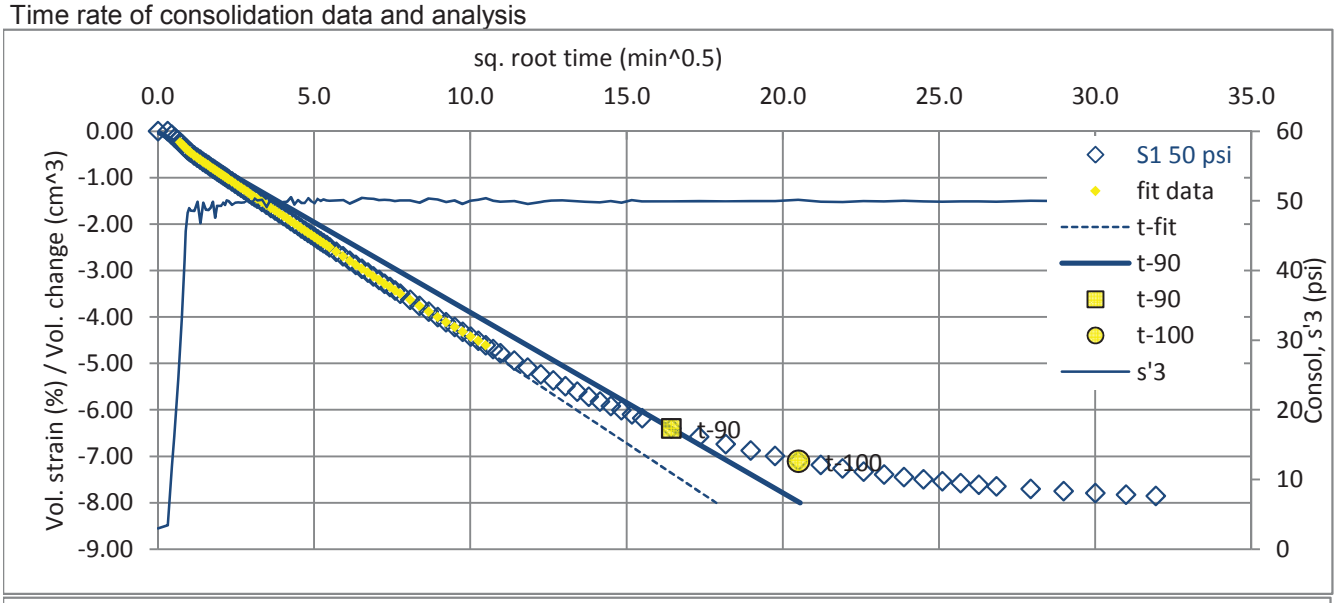
DRAFT

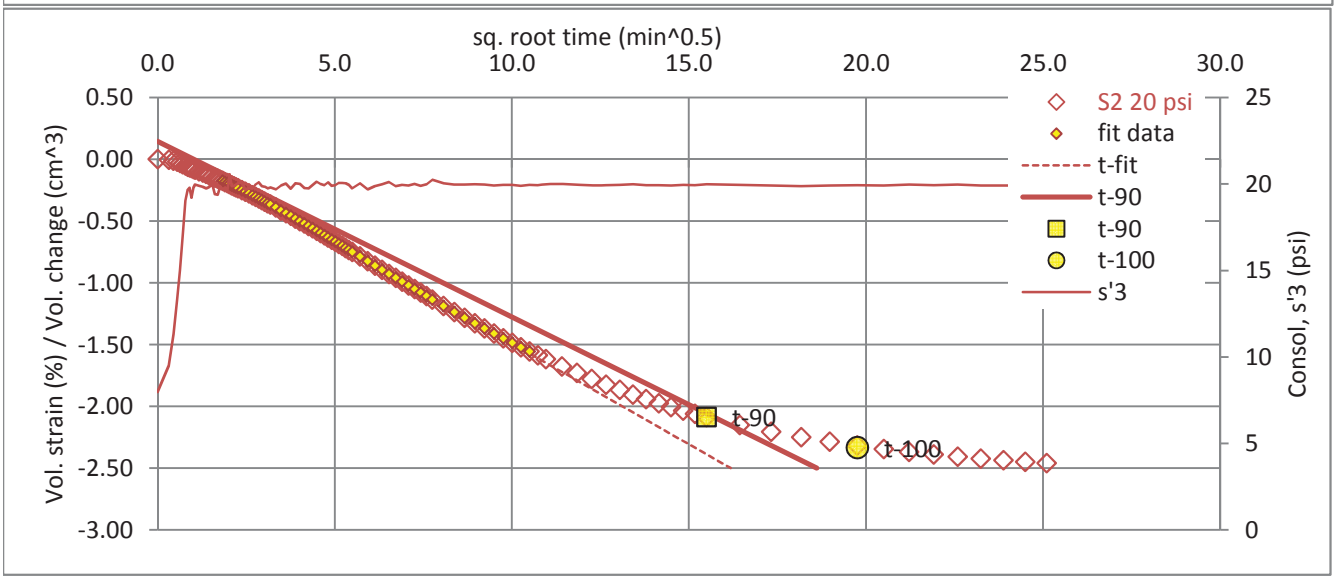
Triaxial Test - Isotropic Consolidated Sheared Undrained
Measuring Pore Pressure (CIU-PP) *- After ASTM D4767 and USBR 5750*

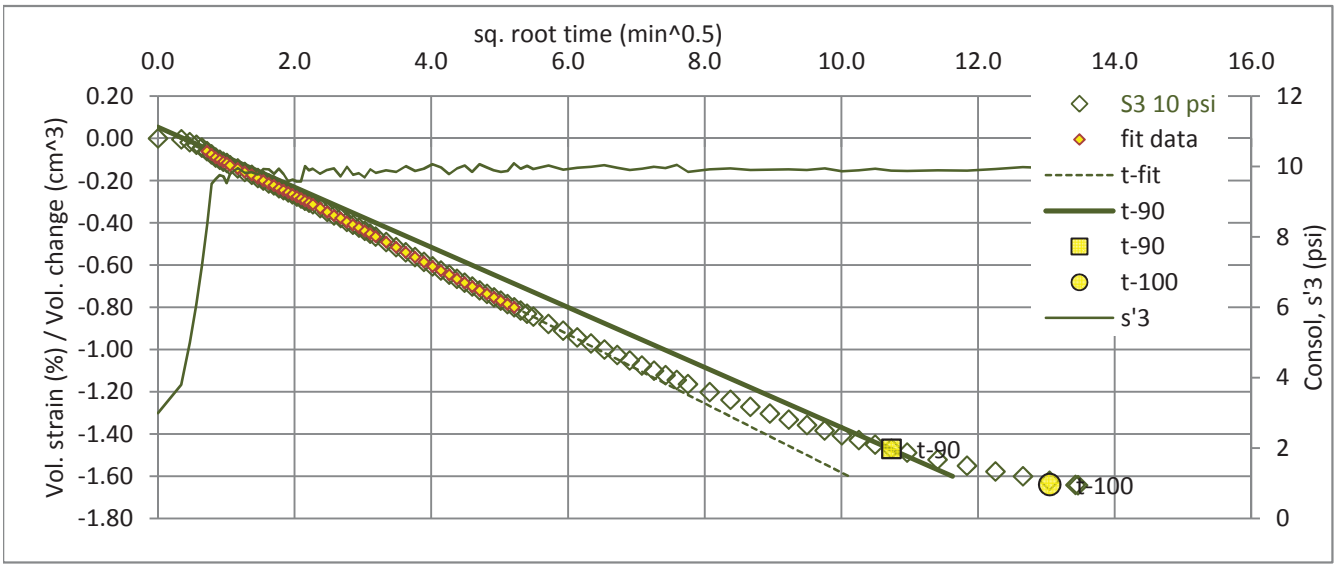
GERHART COLE

Project: Bear River - Cub River **TH/TP/Sample: TH-CUB-02**
No: 13GCI329 **Depth: 20-22**

Time rate of consolidation data and analysis







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Triaxial Test - Isotropic Consolidated Sheared Undrained Measuring Pore Pressure (CIU-PP) - *After ASTM D4767 and USBR 5750*

GERHART COLE

Project:	**Bear River - Cub River**	**TH/TP/Sample:**	**TH-CUB-03**
No:	**13GCI329**	**Depth:**	**25-27**
Location:	Cache County Utah	Sample description:	gray clay
Date:	19-Aug-15	USCS classification:	CL
Tested by:	zmg	Sample type:	undisturbed
Reduced by:	zmg	Notes:	
Checked by:	rrb		

	Test Number	S1	50 psi	S2	25 psi	S3	15 psi
		Initial	Bef. Shr. MethodB [e]	Initial	Bef. Shr. MethodB [e]	Initial	Bef. Shr. MethodB [e]
Unit weight data	Sample ht., H (in) 0°	5.758		5.765		5.736	
	120°	5.754		5.757		5.714	
	240°	5.754		5.779		5.726	
	Avg. height, Havg (in)	5.755	5.635	5.767	5.717	5.725	5.645
	Avg. height, Havg (cm)	14.619	14.314	14.648	14.521	14.542	14.339
	ΔHsc (in) [a]		0.12		0.05		0.08
	Sample dia., D (in) top	2.849		2.813		2.809	
	mid	2.785		2.660		2.840	
	bot	2.818		2.818		2.828	
	Avg. dia., Davg (in)	2.809	2.604	2.738	2.694	2.829	2.799
	Avg. dia., Davg (cm)	7.135	6.615	6.954	6.844	7.186	7.111
	Avg. area, Aavg (in^2)	6.198	5.327	5.887	5.702	6.287	6.155
	Avg. area, Aavg (cm^2)	39.989	34.369	37.979	36.786	40.560	39.712
	Wt. rings + wet soil (g)	987.45	946.31	1045.02	1022.65	1148.51	1124.54
	Wt. rings (g)	0.00	0.00	0.00	0.00	0.00	0.00
	Volume, Vo (in^3)	35.7	30.0	33.9	32.6	36.0	34.7
	Vo (cm^3)	584.6	492.0	556.3	534.2	589.8	569.4
	Vo (ft^3)	0.0206	0.0174	0.0196	0.0189	0.0208	0.0201
Moisture	Wet soil + tare (g)	203.63	1091.22	251.70	1142.27	278.90	1268.85
	Dry soil + tare (g)	185.13	885.16	219.66	906.69	237.94	1015.64
	Tare (g)	126.69	145.43	120.77	119.91	120.05	144.61
	Moisture content, w (%)	31.7	27.9	32.4	29.9	34.7	29.1
Phase Relationships	Gs, assumed	2.65	2.65	2.65	2.65	2.65	2.65
	Mass total (g)	987.5	958.9	1045.0	1025.6	1148.5	1100.1
	Mass of solids (g)	750.0	750.0	789.3	789.3	852.4	852.4
	Volume (cm^3)	584.6	492.0	556.3	534.2	589.8	569.4
	Volume of water (cm^3)	237.4	208.9	255.7	236.3	296.1	247.8
	Volume of solids (cm^3)	283.0	283.0	297.8	297.8	321.6	321.6
	Volume of voids (cm^3)	301.6	208.9	258.5	236.3	268.2	247.8
	Volume of air (cm^3)	64.1	0.0	2.8	0.0	-28.0	0.0
	Void ratio, e	1.065	0.738	0.868	0.793	0.834	0.770
	Porosity, n	0.516	0.425	0.465	0.442	0.455	0.435
	Volumetric moisture, T	0.406	0.425	0.460	0.442	0.502	0.435
	Saturation, S (%) [c]	78.74	100.00	98.94	100.00	110.42	100.00
	Dry density (gm/cm^3)	1.283	1.525	1.419	1.478	1.445	1.497
	Wet unit wt., gm (pcf)	105.5	121.7	117.3	119.9	121.6	120.6
	Dry unit wt., gd (pcf)	80.1	95.2	88.6	92.2	90.2	93.4

Notes:

[a] ΔHsc (in) = change in height during saturation and consolidation

[b] ΔVs = change in volume during saturation, ΔVc = change in volume during consolidation

[c] Saturation before shear set to 100% for phase calculations

[d] Before shear Aavg using method A; where Ac (Method A) = (Vo-DVs - DVc)/(Ho-DHsc)

[e] Before shear Aavg using method B; where Ac (Method B) = (Vwf + Vs)/Hc

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DRAFT

Triaxial Test - Isotropic Consolidated Sheared Undrained
Measuring Pore Pressure (CIU-PP) *- After ASTM D4767 and USBR 5750*

GERHART COLE

Project:	**Bear River - Cub River**	**TH/TP/Sample:**	**TH-CUB-03**
No:	**13GCI329**	**Depth:**	**25-27**
Location:	Cache County Utah	Sample description:	gray clay
Date:	19-Aug-15	USCS classification:	CL
Tested by:	zmg	Sample type:	undisturbed

X:\PROJECTS\13GCI329 Bear River Project Concept Study\Bear River\[TX_CU3pts_TH-CUB-03_25-27ft-v02.xlsx]SUM

	Test Number	S1 at 50 psi	S2 at 25 psi	S3 at 15 psi
Test information	Total backpressure (psi)	29.0	40.0	14.0
	Skempton B	0.97	0.95	0.98
	t-90 (min)	150.0	200.2	120.0
	t-100 (min)	210.0	330.2	150.0
	t-50 (min)	35.0	46.8	28.0
	Strain rate (%/hr)	0.60	0.90	0.90
	Strain rate (%/min)	0.010	0.015	0.015
	Membrane correction	Yes	Yes	Yes
	Filter paper correction	No filter paper	No filter paper	No filter paper
Max principal stress ratio (s1/s3), failure criteria	Strain at failure, ef (%)	9.69	6.79	8.86
	Time to failure, tf (min)	968.9	452.6	590.6
	Obliquity, s'1/s'3	3.242	3.317	3.022
	Excess pore pressure, u (psi)	32.41	14.94	6.39
	q = q' = (s1+s3)/2 (psi)	19.72	11.65	8.70
	p' = (s'1+s'3)/2 (psi)	37.30	21.71	17.31
	p = (s1+s3)/2 (psi)	69.72	36.65	23.70
	Effective major principal stress, s'1 (psi)	57.02	33.36	26.01
	Effective minor principal stress, s'3 (psi)	17.59	10.06	8.61
	Total major pincipal stress, s1 (psi)	89.43	48.31	32.41
	Total minor pincipal stress, s3 (psi)	50.00	25.00	15.00
	Skemption A at failure, Af	0.82	0.64	0.37
	Secant friction angle, phi-s (deg)	31.9	32.5	30.2
		Effective stress	Total stress	
	Friction angle, phi (deg)	31.8	13.9	
	Cohesion intercept, c (psi)	0.0	3.0	
Peak deviator stress (s1-s3), failure criteria	Strain at failure, ef (%)	8.92	10.57	15.21
	Time to failure, tf (min)	891.6	704.5	1014.0
	Deviator stress, s1-s3 (psi)	39.44	23.81	20.36
	Excess pore pressure, u (psi)	32.40	14.60	4.48
	q = q' = (s1+s3)/2 (psi)	19.72	11.90	10.18
	p' = (s'1+s'3)/2 (psi)	37.32	22.30	20.70
	p = (s1+s3)/2 (psi)	69.72	36.90	25.18
	Effective major principal stress, s'1 (psi)	57.04	34.20	30.88
	Effective minor principal stress, s'3 (psi)	17.60	10.40	10.52
	Total major pincipal stress, s1 (psi)	89.44	48.81	35.36
	Total minor pincipal stress, s3 (psi)	50.00	25.00	15.00
	Skemption A at failure, Af	0.82	0.61	0.22
	Secant friction angle, phi-s (deg)	31.9	32.3	29.5
		Effective stress	Total stress	
	Friction angle, phi (deg)	31.5	12.7	
	Cohesion intercept, c (psi)	0.0	4.4	

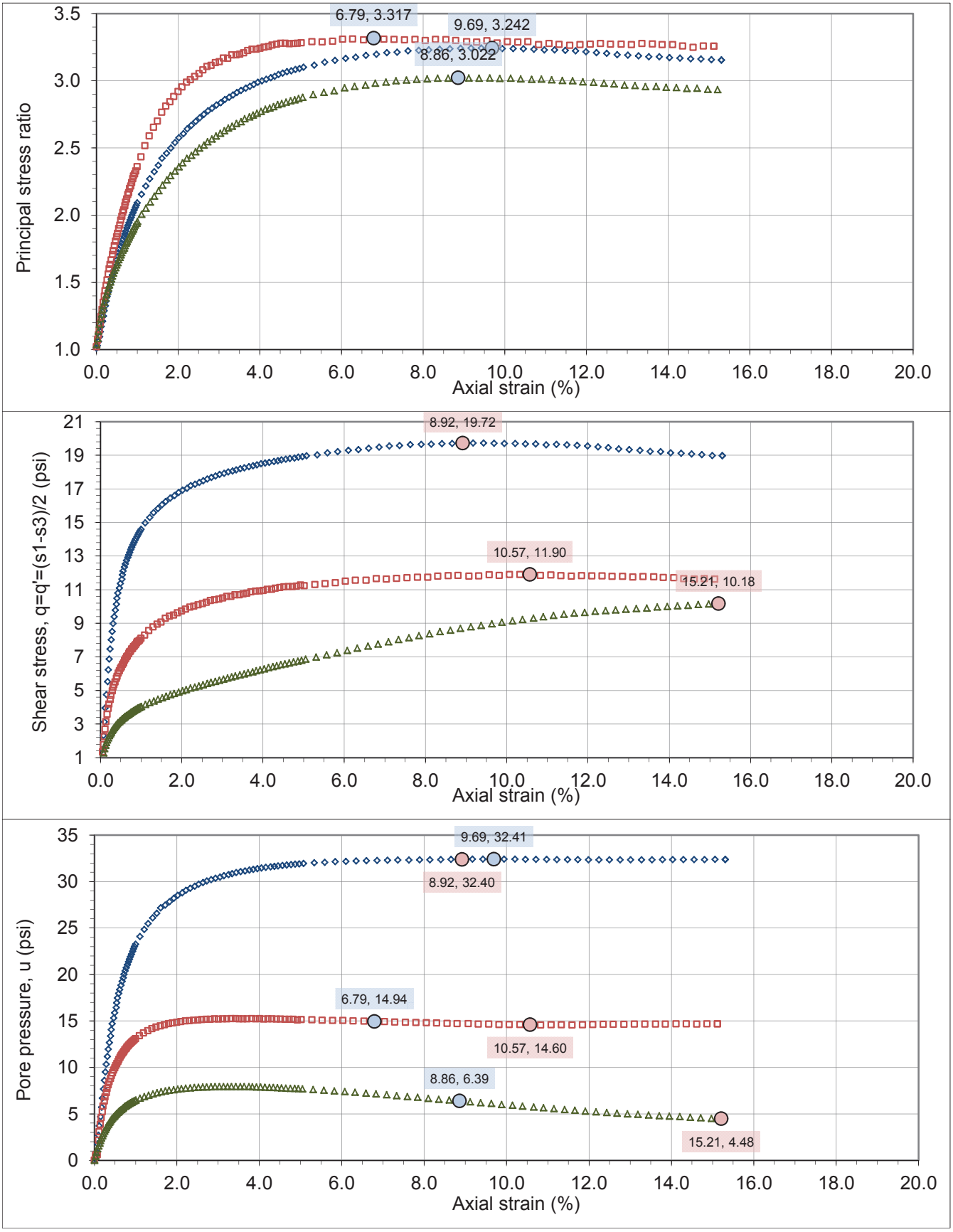
Comments:

DRAFT

Triaxial Test - Isotropic Consolidated Sheared Undrained
Measuring Pore Pressure (CIU-PP) *- After ASTM D4767 and USBR 5750*

GERHART COLE

Project: Bear River - Cub River **TH/TP/Sample: TH-CUB-03**
No: 13GCI329 **Depth: 25-27**



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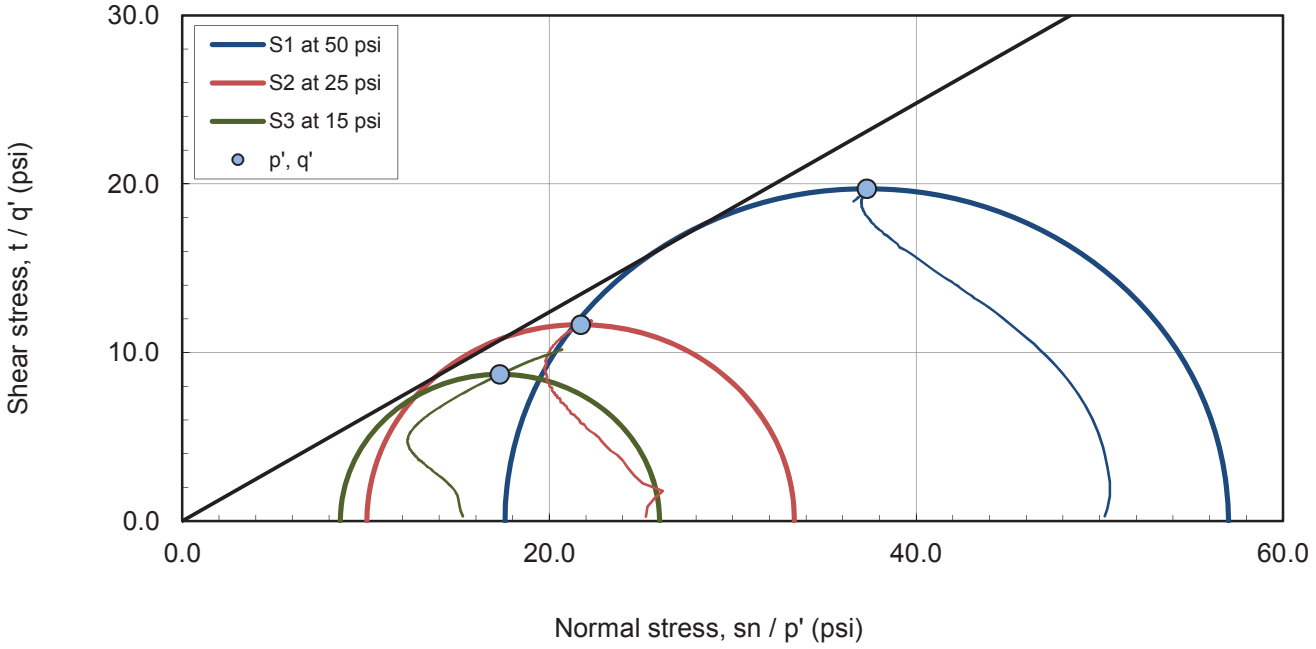
Triaxial Test - Isotropic Consolidated Sheared Undrained
Measuring Pore Pressure (CIU-PP) *- After ASTM D4767 and USBR 5750*

GERHART COLE

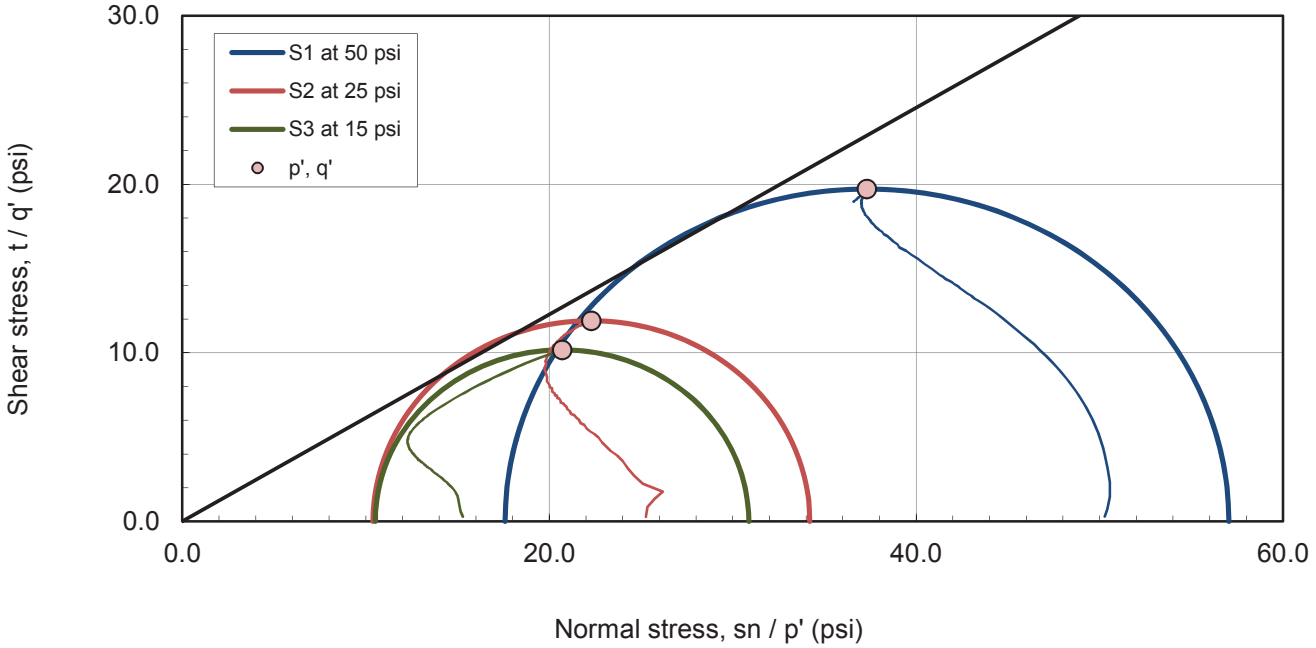
Project: **Bear River - Cub River** **TH/TP/Sample:** **TH-CUB-03**
No: **13GCI329** **Depth:** **25-27**

Effective stress results



Max principal stress ratio (s'1/s'3), failure criteria Mohr and p' - q' space plots

Effective stress results



Peak deviator stress (s1-s3), failure criteria Mohr and p' - q' space plots

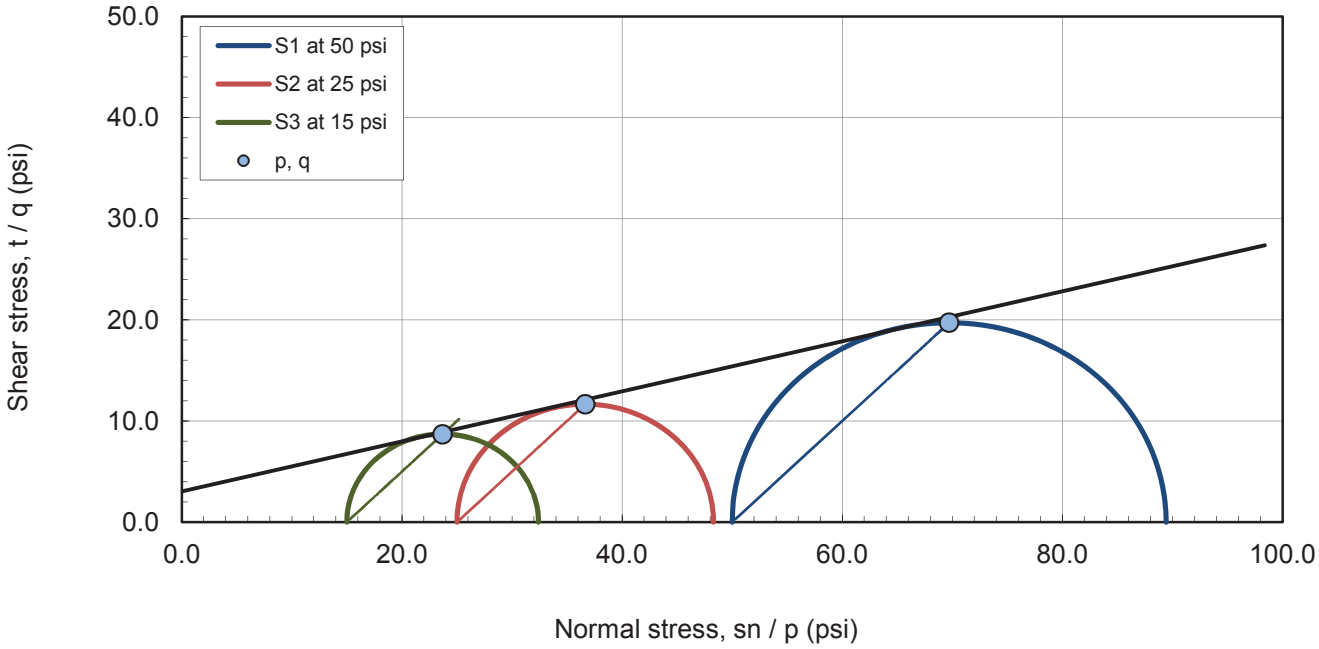
DRAFT

Triaxial Test - Isotropic Consolidated Sheared Undrained
Measuring Pore Pressure (CIU-PP) *- After ASTM D4767 and USBR 5750*

GERHART COLE

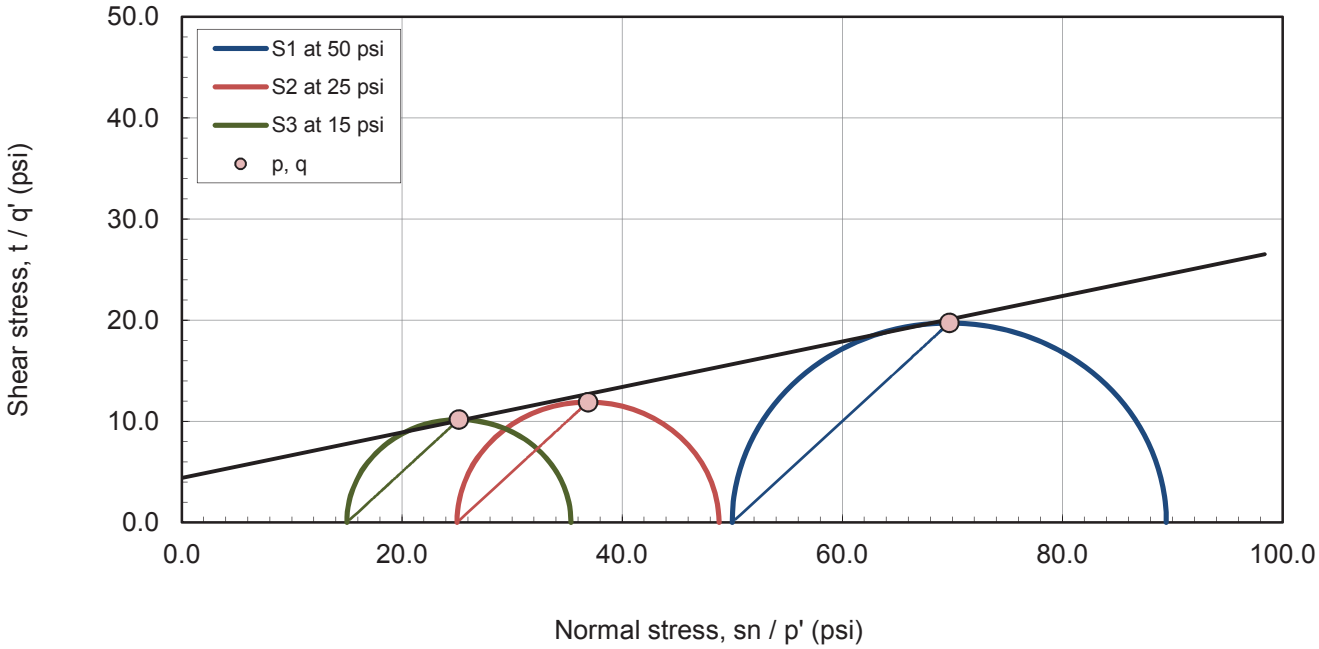
Project: Bear River - Cub River | **TH/TP/Sample:** TH-CUB-03
No: 13GCI329 | **Depth:** 25-27

Total stress results



Max principal stress ratio (s1/s3), failure criteria Mohr and p - q space plots - effective stress results

Total stress results



Peak deviator stress (s1-s3), failure criteria Mohr and p - q space plots

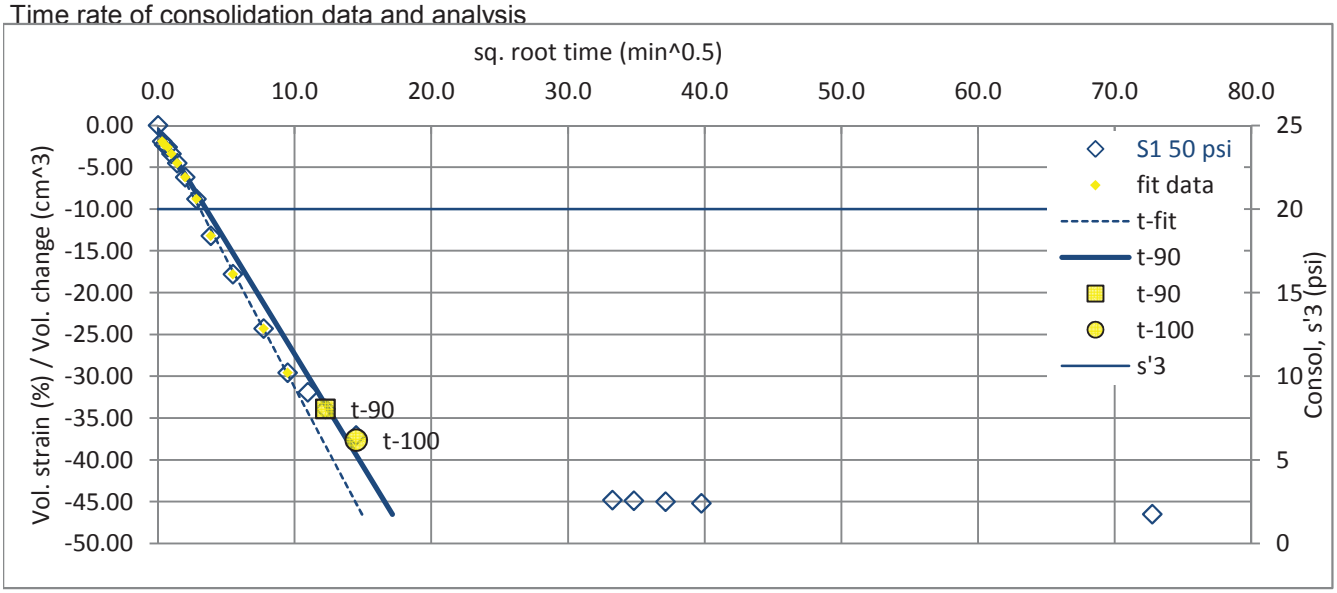
DRAFT

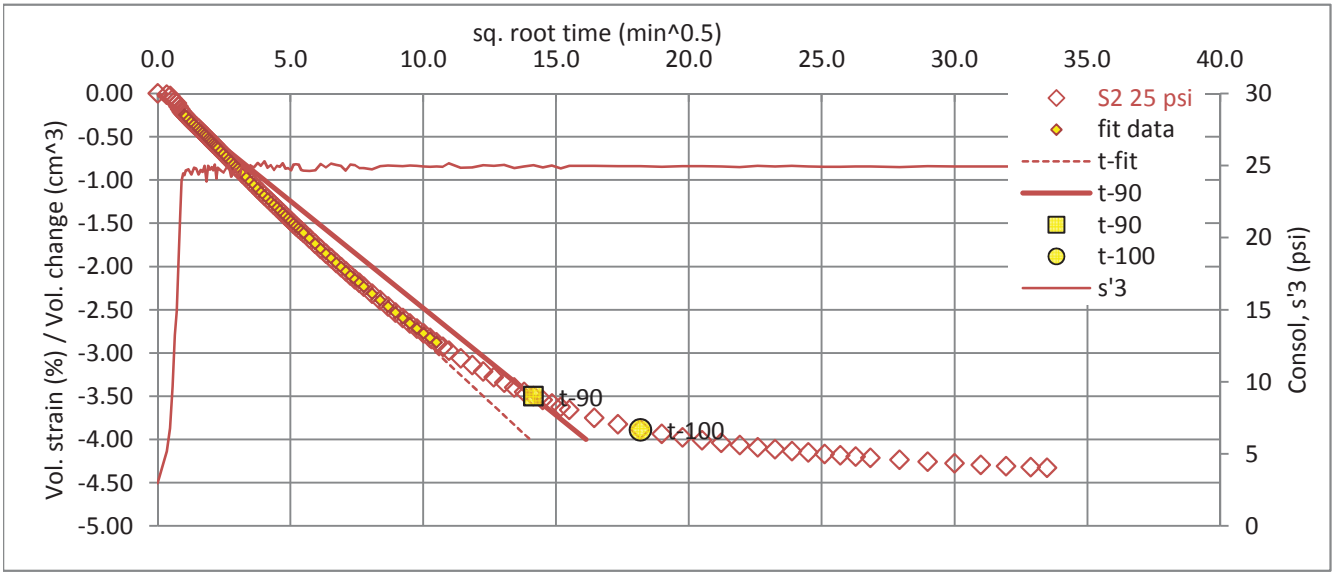
Triaxial Test - Isotropic Consolidated Sheared Undrained
Measuring Pore Pressure (CIU-PP) *- After ASTM D4767 and USBR 5750*

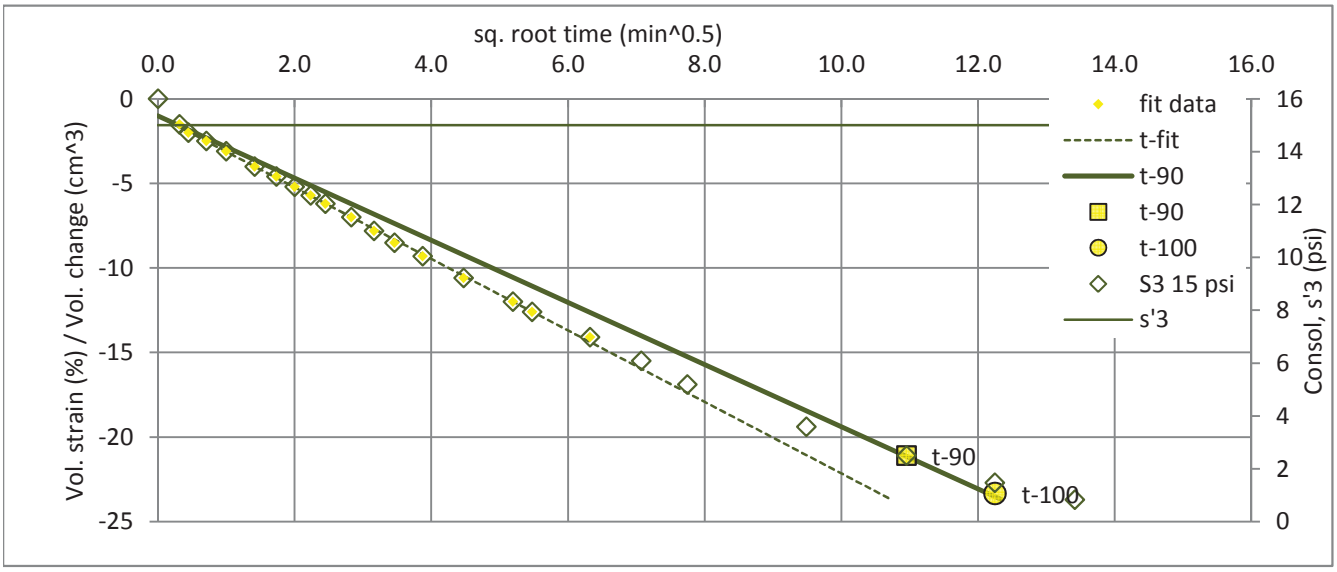
GERHART COLE

Project: Bear River - Cub River **TH/TP/Sample: TH-CUB-03**
No: 13GCI329 **Depth: 25-27**

Time rate of consolidation data and analysis







DRAFT

Pinhole Dispersion Test

After ASTM D4647 and USBR 5410

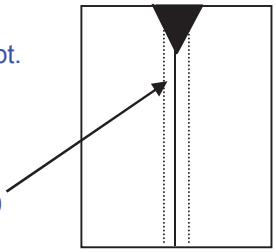
GERHART COLE

Project: Bear River
No: 13GCI329
Location: Cache County, Utah
Date: 17-Oct-14
Tested by: zg
Reduced by: zg
Checked by: dab

TH/TP/Sample: TH-CUB-03
Depth: 15-16.5
Sample description: light brown clay
USCS classification: CH

Test type / method: A
Sample type: remolded
Moisture content (%): 31.2
Dry unit weight (pcf): 82.6

Compaction specifications: 95% of opt.
Target moisture content (%): 32
Target dry unit weight (pcf): 82
Specimen After Test
Final Hole (mm): >2.0



Dispersive Classification: ND3 - Moderately to Slightly Dispersive

Clock Time	Head (in)	Flow			Turbidity From Side						Completely Clear From Top	Particles Falling			Remarks
		ml	sec	Rate (ml/sec)	Very Dark	Dark	Moderately Dark	Slightly Dark	Barely Visible	Completely Clear		None	Few	Heavy	
15:11	2	9.0	60	0.2				X				X			
	2	15.0	60	0.3				X				X			
	2	20.0	60	0.3				X				X			
	2	23.0	60	0.4				X				X			
	2	24.0	60	0.4				X				X			
15:19	7	74.0	60	1.2				X					X		
	7	79.0	60	1.3				X					X		
	7	81.0	60	1.4				X				X			
	7	80.0	60	1.3				X				X			
15:27	15	97.0	45	2.2			X						X		
	15	95.0	45	2.1			X						X		
	15	96.0	45	2.1			X						X		
	15	97.0	45	2.2			X						X		
15:35	40	85.0	20	4.3		X							X		
	40	88.0	20	4.4			X						X		
	40	89.0	20	4.5			X						X		
	40	88.0	20	4.4			X						X		
	40	88.0	20	4.4			X						X		

DRAFT

Pinhole Dispersion Test

After ASTM D4647 and USBR 5410

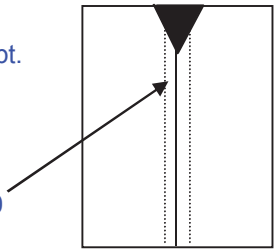
GERHART COLE

Project: **Bear River**
No: **13GCI329**
Location: Cache County, Utah
Date: 17-Oct-14
Tested by: zg
Reduced by: zg
Checked by: dab

TH/TP/Sample: **TH-CUB-03**
Depth: **5-7**
Sample description: brown clay
USCS classification: CH

Test type / method: A
Sample type: remolded
Moisture content (%): 27.6
Dry unit weight (pcf): 89

Compaction specifications: 95% of opt.
Target moisture content (%): 27
Target dry unit weight (pcf): 89
Specimen After Test
Final Hole (mm): >2.0



Dispersive Classification: **ND3 - Moderately to Slightly Dispersive**

Clock Time	Head (in)	Flow			Turbidity From Side						Completely Clear From Top	Particles Falling			Remarks
		ml	sec	Rate (ml/sec)	Very Dark	Dark	Moderately Dark	Slightly Dark	Barely Visible	Completely Clear		None	Few	Heavy	
13:55	2	11.0	60	0.2				X				X			
	2	15.0	60	0.3				X				X			
	2	20.0	60	0.3				X				X			
	2	22.0	60	0.4				X				X			
	2	22.0	60	0.4				X				X			
14:07	7	68.0	60	1.1				X				X			
	7	70.0	60	1.2				X				X			
	7	72.0	60	1.2				X				X			
	7	73.0	60	1.2				X				X			
	7	72.0	60	1.2				X				X			
14:15	15	94.0	45	2.1				X					X		
	15	94.0	45	2.1				X				X			
	15	92.0	45	2.0				X				X			
	15	94.0	45	2.1				X				X			
14:25	40	90.0	20	4.5			X						X		
	40	85.0	20	4.3			X						X		
	40	86.0	20	4.3			X						X		
	40	89.0	20	4.5			X						X		
	40	90.0	20	4.5			X						X		
	40	89.0	20	4.5			X						X		

DRAFT

Pinhole Dispersion Test

After ASTM D4647 and USBR 5410

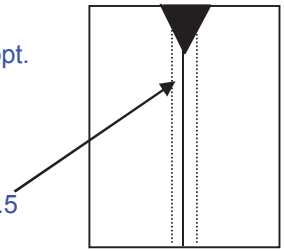
GERHART COLE

Project: **Bear River**
No: **13GCI329**
Location: Cache County, Utah
Date: 10-Oct-14
Tested by: zg
Reduced by: zg
Checked by: dab

TH/TP/Sample: **TH-CUB-01**
Depth: **5-7**
Sample description: red clay
USCS classification: CH

Test type / method: A
Sample type: remolded
Moisture content (%): 27.5
Dry unit weight (pcf): 90.1

Compaction specifications: 95% of opt.
Target moisture content (%): 27
Target dry unit weight (pcf): 90
Specimen After Test
Final Hole (mm): <=1.5



Dispersive Classification: **ND2 - Nondispersive**

Clock Time	Head (in)	Flow			Turbidity From Side						Completely Clear From Top	Particles Falling			Remarks
		ml	sec	Rate (ml/sec)	Very Dark	Dark	Moderately Dark	Slightly Dark	Barely Visible	Completely Clear		None	Few	Heavy	
10:00	2	10.0	100	0.1				X				X			
	2	10.0	71	0.1				X				X			
	2	10.0	50	0.2				X				X			
	2	10.0	51	0.2				X				X			
	2	25.0	95	0.3				X				X			
	2	25.0	81	0.3				X				X			
10:17	7	10.0	17	0.6				X				X			
	7	60.0	60	1.0				X				X			
	7	39.0	60	0.7				X				X			
	7	47.0	60	0.8				X				X			
	7	46.0	60	0.8				X				X			
10:28	15	69.0	60	1.2			X					X			
	15	55.0	60	0.9			X					X			
	15	52.0	60	0.9			X					X			
	15	50.0	60	0.8			X					X			
	15	41.0	60	0.7				X					X		
10:42	40	78.0	60	1.3			X					X			
	40	56.0	60	0.9			X					X			
	40	64.0	60	1.1			X					X			
	40	59.0	60	1.0			X					X			
	40	58.0	60	1.0			X					X			

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Pinhole Dispersion Test

After ASTM D4647 and USBR 5410

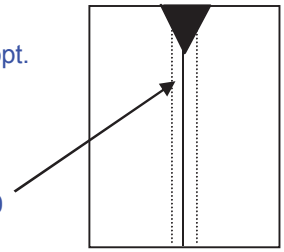
GERHART COLE

Project: Bear River
No: 13GCI329
Location: Cache County, Utah
Date: 10-Oct-14
Tested by: zg
Reduced by: zg
Checked by: dab

TH/TP/Sample: TH-CUB-02
Depth: 5-7
Sample description: brown silt
USCS classification: CL-ML

Test type / method: A
Sample type: remolded
Moisture content (%): 18.6
Dry unit weight (pcf): 102.3

Compaction specifications: 95% of opt.
Target moisture content (%): 20
Target dry unit weight (pcf): 101
Specimen After Test
Final Hole (mm): 1.0



Dispersive Classification: ND2 - Nondispersive

Clock Time	Head (in)	Flow			Turbidity From Side						Completely Clear From Top	Particles Falling			Remarks
		ml	sec	Rate (ml/sec)	Very Dark	Dark	Moderately Dark	Slightly Dark	Barely Visible	Completely Clear		None	Few	Heavy	
11:40	2	19.0	60	0.3				X				X			
	2	23.0	60	0.4				X				X			
	2	50.0	126	0.4				X				X			
	2	50.0	127	0.4				X				X			
	2	50.0	128	0.4				X				X			
11:52	7	73.0	60	1.2				X					X		
	7	70.0	60	1.2				X				X			
	7	68.0	60	1.1				X				X			
	7	67.0	60	1.1				X				X			
	7	69.0	60	1.2				X				X			
12:03	15	100.0	50	2.0				X					X		
	15	100.0	51	2.0				X					X		
	15	100.0	50	2.0				X					X		
12:12	40	100.0	57	1.8				X					X		
	40	110.0	32	3.4				X					X		
	40	100.0	25	4.0				X					X		
	40	100.0	26	3.8				X					X		
	40	100.0	25	4.0				X					X		

DRAFT

Laboratory Compaction Characteristics of Soil

(ASTM D698 / D1557)

GERHART COLE

Project: Bear River
No: 13GCI329
Date: 30-Sep-14
Tested by: zg
Reduced by: zg
Reviewed by: dab

TH/TP/Sample: TH-CUB-01
Depth: 5-7
Location: **Cache County, UT**
Comments: Used Harvard mini compaction device. Spring = 20 lb, 4 layers, 25 blows per layer.

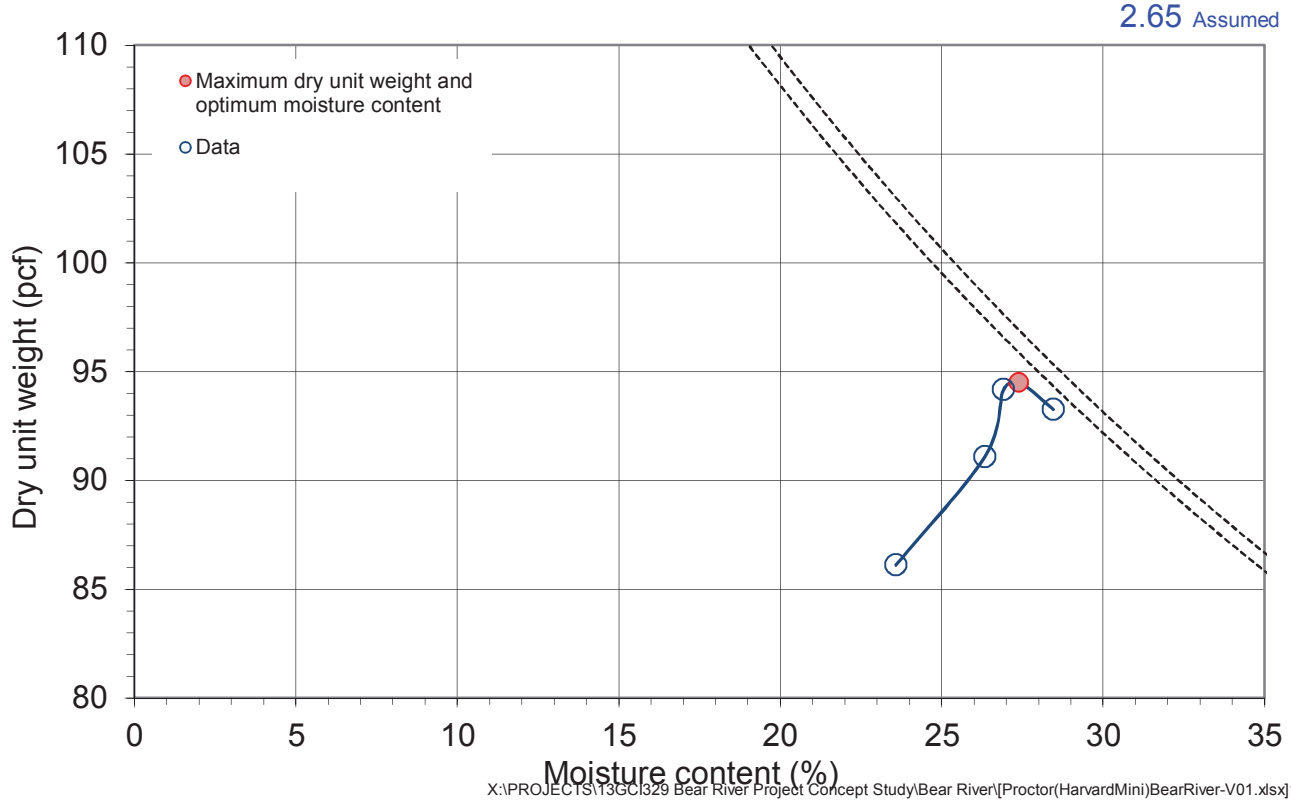
Test Summary

Method: Harvard Mini
Mold volume (ft^3): 0.0022

Optimum moisture content (%): 27.4
Maximum dry unit weight (pcf): 94.5

Sample Description: clay
Engineering Classification: CL
As-received moisture content (%): Not requested
Preparation method: Moist
Rammer: Manual
Rock Correction: No

Point Number	26%	28%	30	32
Wt. mold + wet soil (g)	525.4	534.1	538.5	538.8
Wt. mold (g)	419.08	419.08	419.08	419.08
Moist unit wt., gd (pcf)	106.4	115.1	119.5	119.8
Wet soil + tare (g)	224.25	42.78	30.23	23.91
Dry soil + tare (g)	209.18	36.85	26.86	21.73
Tare (g)	145.28	14.34	14.34	14.07
Moisture content, w (%)	23.6	26.3	26.9	28.5
Dry unit wt., gd (pcf)	86.1	91.1	94.2	93.2



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DRAFT

Laboratory Compaction Characteristics of Soil

(ASTM D698 / D1557)

GERHART COLE

Project: Bear River
No: 13GCI329
Date: 30-Sep-14
Tested by: zg
Reduced by: zg
Reviewed by: dab

TH/TP/Sample: TH-CUB-02
Depth: 5-7
Location: Cache County, UT
Comments: Used Harvard mini compaction device. Spring = 20 lb, 4 layers, 25 blows per layer.

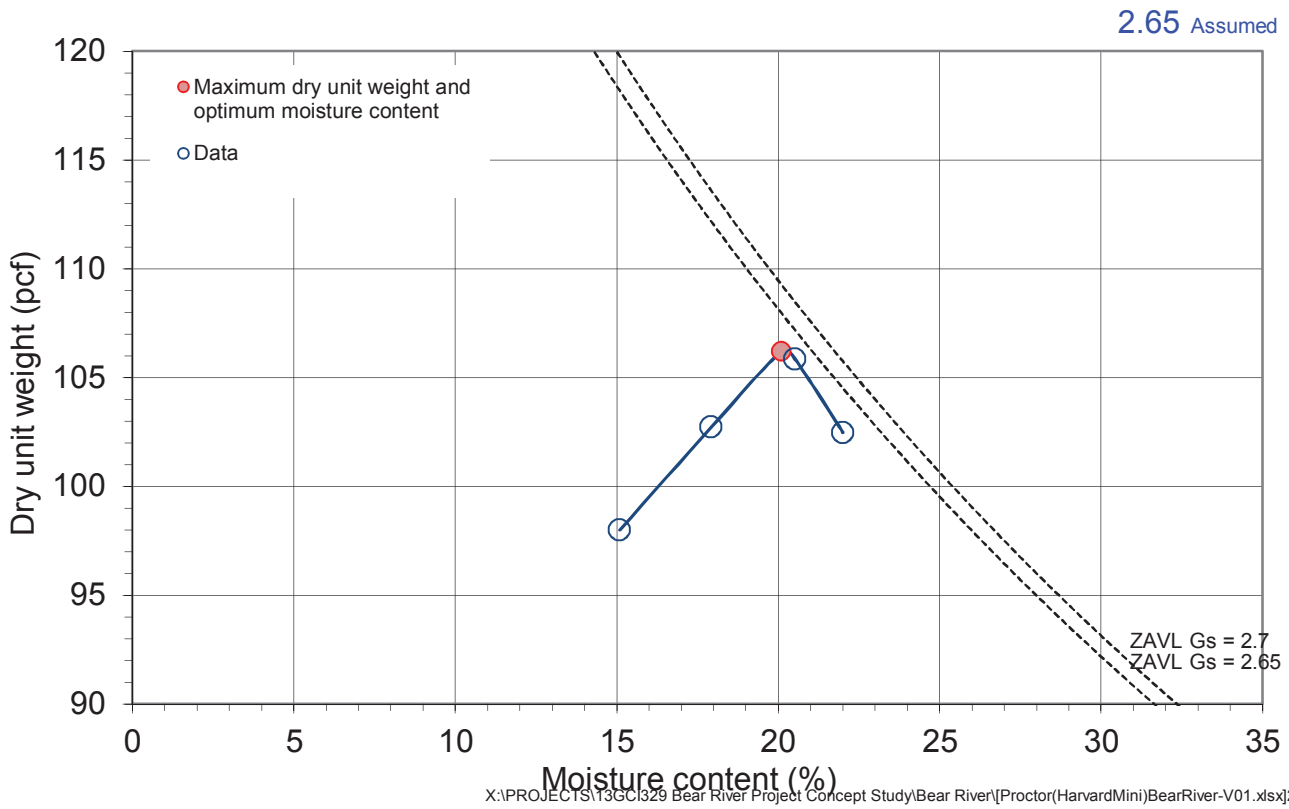
Test Summary

Method: Harvard Mini
Mold volume (ft^3): 0.0022

Optimum moisture content (%): 20.1
Maximum dry unit weight (pcf): 106.2

Sample Description: clay
Engineering Classification: CL
As-received moisture content (%): Not requested
Preparation method: Moist
Rammer: Manual
Rock Correction: No

Point Number	19%	17%	21%	15%
Wt. mold + wet soil (g)	546.5	540.1	544.0	531.8
Wt. mold (g)	419.08	419.08	419.08	419.08
Moist unit wt., gd (pcf)	127.6	121.1	125.0	112.8
Wet soil + tare (g)	232.08	208.02	38.71	32.03
Dry soil + tare (g)	217.2	198.48	34.3	29.7
Tare (g)	144.68	145.27	14.26	14.26
Moisture content, w (%)	20.5	17.9	22.0	15.1
Dry unit wt., gd (pcf)	105.8	102.7	102.5	98.0



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Laboratory Compaction Characteristics of Soil

(ASTM D698 / D1557)

GERHART COLE

Project: Bear River
No: 13GCI329
Date: 30-Sep-14
Tested by: zg
Reduced by: zg
Reviewed by: dab

TH/TP/Sample: TH-CUB-03
Depth: 5-7
Location: **Cache County, UT**
Comments: Used Harvard mini compaction device. Spring = 20 lb, 4 layers, 25 blows per layer.

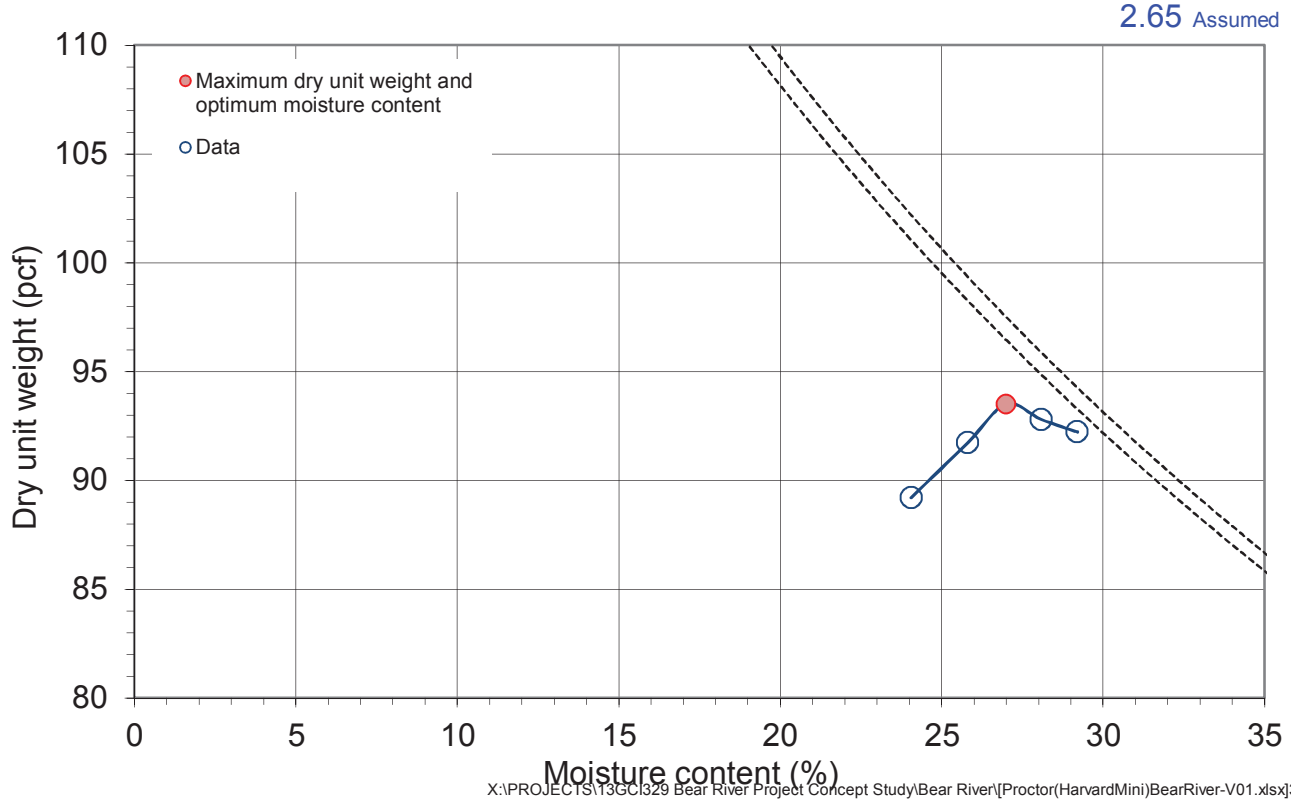
Test Summary

Method: Harvard Mini
Mold volume (ft^3): 0.0022

Optimum moisture content (%): 27
Maximum dry unit weight (pcf): 93.5

Sample Description: --
Engineering Classification: CL
As-received moisture content (%): Not requested
Preparation method: Moist
Rammer: Manual
Rock Correction: No

Point Number	26%	28%	30	32
Wt. mold + wet soil (g)	529.6	534.4	537.8	538.1
Wt. mold (g)	419.08	419.08	419.08	419.08
Moist unit wt., gd (pcf)	110.6	115.4	118.8	119.1
Wet soil + tare (g)	33.21	38.1	21.09	54.29
Dry soil + tare (g)	29.45	33.12	19.54	45.23
Tare (g)	13.82	13.82	14.02	14.21
Moisture content, w (%)	24.1	25.8	28.1	29.2
Dry unit wt., gd (pcf)	89.2	91.7	92.8	92.2



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DRAFT

Laboratory Compaction Characteristics of Soil

(ASTM D698 / D1557)

GERHART COLE

Project: Bear River
No: 13GCI329
Date: 30-Sep-14
Tested by: zg
Reduced by: zg
Reviewed by: dab

TH/TP/Sample: TH-CUB-03
Depth: 15-16.5
Location: **Cache County, UT**
Comments: Used Harvard mini compaction device. Spring = 20 lb, 4 layers, 25 blows per layer.

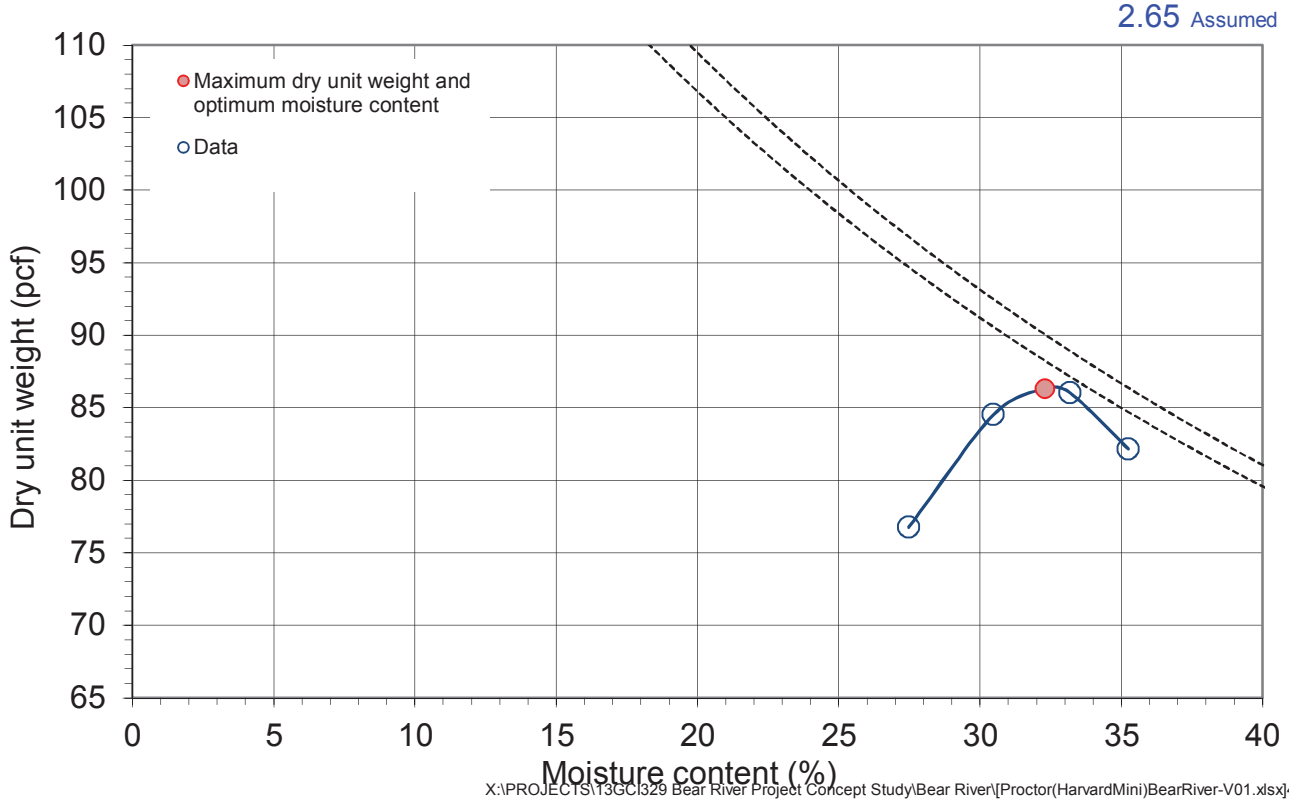
Test Summary

Method: Harvard Mini
Mold volume (ft^3): 0.0022

Optimum moisture content (%): 32.3
Maximum dry unit weight (pcf): 86.3

Sample Description: --
Engineering Classification: CL
As-received moisture content (%): Not requested
Preparation method: Moist
Rammer: Manual
Rock Correction: No

Point Number	26%	32	34	36
Wt. mold + wet soil (g)	516.8	529.3	533.6	530.1
Wt. mold (g)	419.08	419.08	419.08	419.08
Moist unit wt., gd (pcf)	97.8	110.3	114.6	111.1
Wet soil + tare (g)	216.7	27.54	34.29	52.08
Dry soil + tare (g)	195.67	24.44	29.23	42.21
Tare (g)	119.14	14.27	13.98	14.21
Moisture content, w (%)	27.5	30.5	33.2	35.3
Dry unit wt., gd (pcf)	76.7	84.5	86.0	82.2



DRAFT Fielding - Geotechnical Data Report - Bear River Project Concept Study

Prepared for
Bowen Collins & Associates, Inc
October 2018

GCI project number: 13GCI329

GERHART COLE

DRAFT

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October 31, 2018

Prepared for:

Mike Collins
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754 East 14000 South
Draper, Utah 84020

Fielding - Geotechnical Data Report
Bear River Project Concept Study
13GCI329

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TABLE OF CONTENTS

SECTION 1 Introduction 1-1

1.1 Project Description 1-1
1.2 Purpose, Authorization, and Work Scope 1-1

SECTION 2 Methods of Study and Findings 2-1

2.1 Fielding Site 2-1
2.1.1 Test Hole Drilling and Sampling 2-1
2.1.2 Laboratory Testing 2-2
2.1.3 Permeability Testing 2-2
2.1.4 Site Specific Conditions 2-2
2.1.5 Groundwater 2-3

SECTION 3 GEOLOGY 3-1

3.1 General setting 3-1
3.2 Lake bonnevile history 3-1
3.3 Surficial deposits 3-2
3.4 Site specific conditions 3-2
3.5 Geologic hazards 3-4
3.5.1 Surface Fault Rupture 3-4

SECTION 4 Conclusion 4-1

4.1 LIMITATIONS 4-1

SECTION 5 References 5-1

List of Tables

Table 2-1 Fielding - Laboratory Test Results

Table 2-2 Fielding – Constant Head Permeability Test Results

Table 2-3 Fielding – Pressure Permeability Test Results

Table 2-4 Fielding Groundwater Measurements

Table 3-1 Qualitative Landslide Rating

List of Figures

Figure 1-1 Vicinity Map

Figure 2-1 Fielding – Site and Exploration Map

Figure 3.1 Geologic Map (reference Oviatt, 1986a)

TABLE OF CONTENTS

List of Appendices

Appendix A - Fielding - Test Hole Logs

Appendix B - Fielding - Interpretative Laboratory Test Results

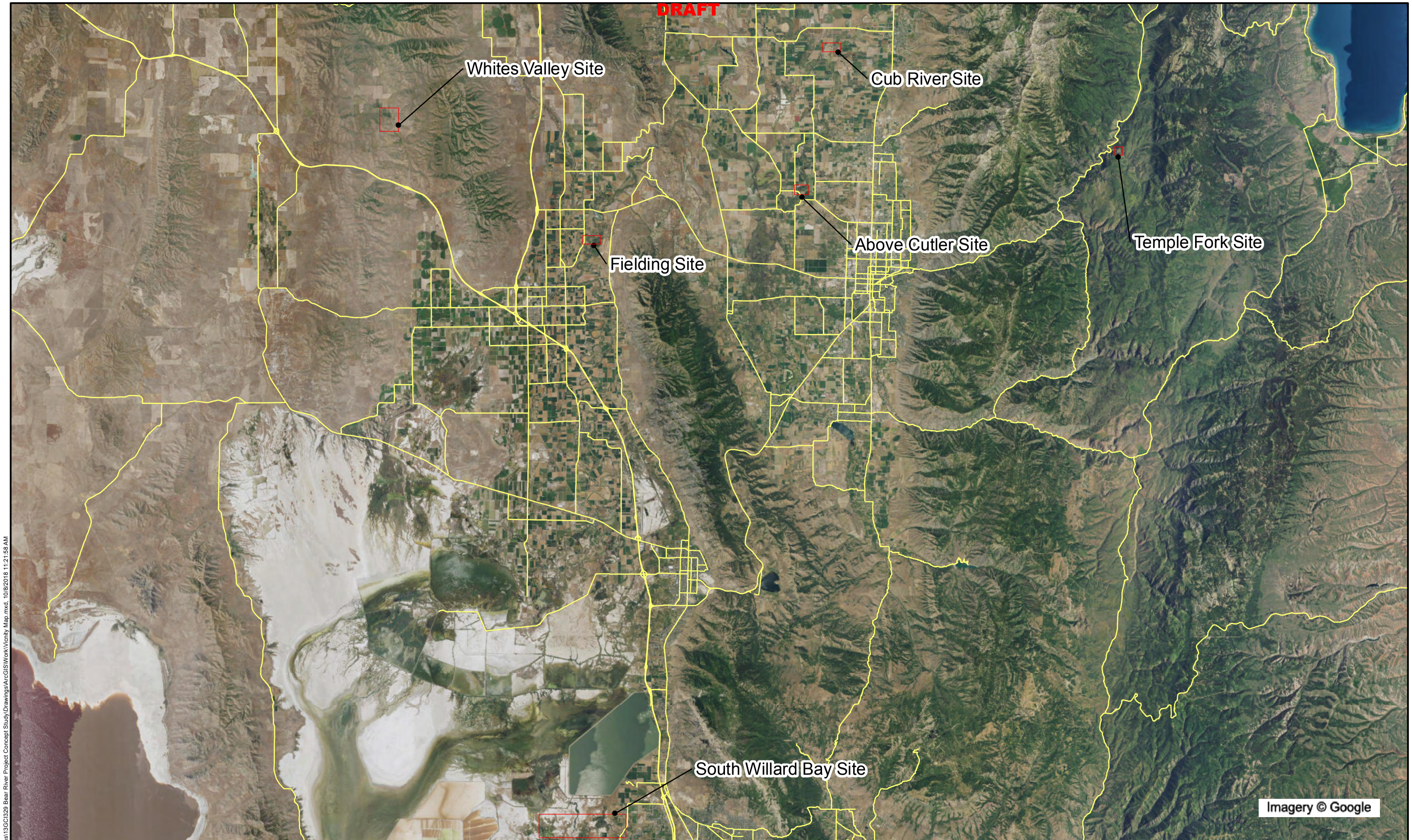
1.1 Project Description

The purpose of the Bear River Project is to develop Utah's unused water rights on the Bear River and deliver it to Box Elder, Cache, Weber, Davis, and Salt Lake Counties. The overall Project will consist of conveyance facilities and reservoir storage necessary to deliver water from the Bear River to the communities in the service areas of the Bear River Water Conservancy District (BRWCD), Cache County, the Weber Basin Water Conservancy District (WBWCD), and the Jordan Valley Water Conservancy District (JVWCD). The Utah Division of Water Resources (DWRe) has been working with Bowen Collins and Associates and HDR (Project Team) for several years to develop the overall Project.

1.2 Purpose, Authorization, and Work Scope

This report presents the results of geotechnical and geologic studies performed by Gerhart Cole Inc. (GCI) at Fielding in support of the project design team. The other project study areas that have had some studies completed are Cub River, Above Cutler, Temple Fork, South Willard Bay, and Whites Valley. The locations of these study sites are shown in Figure 1.1 along with the Fielding Site.

GCI scope of work included a preliminary site characterization of the site, including drilling 3 test holes, geologic study of the dam and reservoir site, and associated laboratory testing on select samples recovered from the test holes. This work was completed under GCI's existing cooperative reciprocal service agreement with BCA.



GERHART COLE

Bear River Project Concept Study

Vicinity Map

N

0 8,000 16,000 32,000 Feet

Figure 1-1

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2.1 FIELDING SITE

A field study was conducted at the Fielding site between June 29 and July 27, 2015. The study consisted of drilling and sampling three test holes (TH-FD-01, TH-FD-02, and TH-FD-03). A site map showing test hole locations is presented as Figure 2.1. Test hole locations were established by GCI based on accessibility and proximity to the proposed dam. Test hole locations were documented using a hand-held, tablet-mounted GPS device, with elevations taken from LiDAR data associated with the Utah GIS portal website with an elevation datum of NAVD88.

2.1.1 Test Hole Drilling and Sampling

Test holes were drilled on private property with permission of the land owners. TH-FD-01, TH-FD-02 and TH-FD-03 were advanced to depths of 100 feet, 105 feet and 86.5 feet, respectively. TH-FD-01 was advanced near the proposed right abutment while TH-FD-02 was drilled near the center of the dam and TH-FD-03 in the left abutment. TH-FD-02 was terminated early due to the presence of high artesian groundwater pressures. One-inch diameter open standpipe piezometers, to monitor groundwater levels, were installed in TH-FD-01 and TH-FD-03. TH-FD-02 was plugged with a bentonite/barite/cement grout mix to terminate artesian flows.

Two nested piezometers were installed in TH-01. The deeper piezometer was screened from 101.5 to 96.5 feet, with a sand pack from 101.5 to 73 feet. The shallower piezometer was screened from 40.2 to 36.2 feet, with a sand pack from 40.2 to 31.2 feet, and the remaining interval sealed with bentonite chips. In TH-FD-03, the piezometer was screened from 87 to 82 feet, with a sand pack from 87 to 36 feet, and the remaining interval sealed with bentonite chips.

Test holes were completed by advancing HW casing (4-inch I.D) and rotary wash drilling methods. Casing was hydraulically pushed in 5 to 10 foot increments to a maximum depth of 75 feet in all three test holes, beyond which open hole drilling was completed. Drilling was accomplished with a CME 75 truck-mounted drill rig operated by Bedke Geotechnical Field Services under subcontract to GCI.

Subsurface conditions were logged by a GCI field engineer at the time of drilling. Three sampling methods were used to obtain soil specimens for characterization and laboratory testing: a) Standard Penetration Test (SPT), b) Shelby Tube (ST) samples, and c) fixed piston Shelby Tube (ST-Piston). ST-Piston sampling procedures were used in softer soil deposits, when difficulty was experienced obtaining ST samples.

Sampling was performed at 2.5 or 5-foot intervals. Two and one half-foot sampling intervals were generally used in coarse-grained soil deposits, with 5-foot sampling intervals being used in fine-grained soil deposits. SPT samples were obtained using an automatic hammer, the energy efficiency of which was recently measured at 77 percent. The number of hammer blows required to advance the sampler in 6-inch increments was recorded in the field, with the sum of the second and third 6-inch intervals constituting the SPT blowcount or “N-value.”

Logs of test holes are presented in Appendix A. Lines designating boundaries between different materials shown on the logs should be considered approximate, as transitions between subsurface materials may be gradual or occur between sampling depths. Relative density and consistency descriptions contained in a final test hole log may deviate from field logs and/or criteria for a number of reasons, including; a) reliance on other test results, b) visual observation and/or manual manipulation of disturbed field samples, or c) the Engineer's judgment. For most engineering assessments involving cohesionless, non-gravelly soils, the SPT blowcount is usually adjusted for effective vertical pressure at the sampling depth, and for other sampling system parameters such as the efficiency of the sampling system and/or sampling techniques used.

2.1.2 Laboratory Testing

Laboratory testing was performed on select soil specimens obtained during field studies to further classify them and evaluate their engineering properties. Laboratory testing included moisture content, Atterberg limits, grain size distribution, and pinhole dispersion tests. One dimensional (1-D) consolidation testing was performed on 10 samples. Shear strength testing was performed on 7 samples by performing tri-axial, consolidated, undrained (with pore pressure measurement - CUPP) tests. Laboratory test results are summarized in Table 2-1, with additional data and plots presented in Appendix B.

2.1.3 Permeability Testing

Two different methods of Field permeability tests were performed for the Fielding Site. The first being constant head permeability tests, which were performed by drilling down to the bottom of the test zone, with the casing held at the top of the test zone and extending to the ground surface. The bit was then removed, leaving the casing in place creating a vertical cylindrical void within soil comprising the test region and a cased test hole down to the top of the test region. The void and casing were filled with water to the top of the casing and water was added as needed to keep the casing full for the duration of the test (typically 10 to 15 minutes). At the end of the test, the volume of water added and test duration were recorded. These results are presented in Table 2-2.

Pressure testing was performed in zones where flowing (artesian) groundwater was found (TH-FD-01 and TH-FD-02). The test was set up similar to that described for constant head permeability testing, except that the top of the casing was capped and then water was pumped into the test zone. Water pumping pressure, time interval of test (typically 5 to 10 minutes), and amount of water pumped into the casing was then recorded. These results are presented in Table 2-3.

2.1.4 Site Specific Conditions

Soils in TH-FD-01 generally consisted of approximately 7 feet of silty sand overlying 6 feet of silt, and then a 35 foot layer of clay (grading to sandy clay at a depth of approximately 37 feet) with interbedded seams of silt to a depth of 48 feet; followed from 48 to 57 feet by silty sands and then by alternating layers of clay, fat clay and silts

to a depth of 84 feet. The bottom 18 feet of this test hole consisted of fat clays. Based on SPT blowcounts, sands and silts from the ground surface to a depth of 15 feet are considered to be generally loose to very soft. Clays and silts below 15 feet are considered to be generally stiff to very stiff with the sand layer at a depth of 48 feet considered to be medium dense to dense. The Shelby tube sample obtained at a depth of 15 feet showed seams of sands and silts dipping at an angle of 70 degrees. Photographs of these seams are presented in Appendix B.

Approximately 7 feet of soft lean clay was found below the ground surface in TH-FD-02, followed by a 10 foot thick layer of medium dense to loose gravel with sand to a depth of approximately 17 feet, and then an approximately 35 foot thick layer of medium stiff to stiff clay with a few sand and silt seams to a depth of 52 feet. Underlying the clay between depths of 52 feet and 63 feet the soil consisted of stiff sandy silt followed by a 7 foot thick layer of medium dense silty sand to a depth of approximately 70 feet. Alternating layers of stiff to very stiff clays were then found from 70 to 98 feet with layer thicknesses ranging between 5 and 16 feet thick. TH-FD-02 terminated in very stiff silt with sand at a depth of 105 feet.

Soils found in TH-FD-03 included silts and clays varying from medium stiff to very stiff based on SPT blow counts. Stratigraphically, the profile consisted of 12 feet of medium stiff silt with gravel and sand, overlying 35 feet of stiff clay to a depth of approximately 47 feet; followed by stiff to very stiff silt between 47 and 52 feet and then a 22 foot layer of stiff clay to a depth of 74 feet. Stiff fat clay was found between 74 and 86.5 feet and the test hole was terminated in these soils.

2.1.5 Groundwater

Flowing (artesian) groundwater was found in TH-FD-01 and TH-FD-02. Flowing groundwater water in TH-FD-01 was found between depths of 30 and 40 feet, with pressures, measured at the ground surface, between 1 to 1.5 psi. At a depth of 45 feet, the groundwater was flowing, but no pressure was measured with the pressure gauge.

Flowing (artesian) groundwater in TH-FD-02 was found between depths of 55 to 75 feet and 95 to 105 feet. Pressures measured at the ground surface ranged between 1 to 3 psi at depths of 55 to 75 feet, 3 psi at 95 feet and 20 to 23 psi at a depth of 105 feet.

Groundwater levels were measured in the piezometers, and are summarized in Table 2-4 Measurements made after drilling may be less reliable than the later groundwater measurements due to drilling methods. Groundwater levels do fluctuate seasonally and may vary several feet in elevation.

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Table 2-1 Laboratory Test Result Summary

Bear River Project Concept Study- Fielding

GERHART COLE

Test Hole	Depth (ft)	Moisture content (%)	Dry unit weight (pcf)	Moist / Sat. unit weight (pcf)	Atterberg Limits					Grain-Size			Grain-Size Analysis (Percent Finer)										Other Tests (Interpretative Data in Appendix)
					LL (%)	PL (%)	PI (%)	Cohesive Index, CI	Liquidity Index, LI	GRAVEL (No.4 - 3")	SAND (No.200-No.4)	FINES (<No.200)	1.5-in (37.5 mm)	3/4-in (19 mm)	3/8-in (9.5 mm)	No.4 (4.75 mm)	No.10 (2 mm)	No.20 (0.85 mm)	No.40 (0.425 mm)	No.60 (0.25 mm)	No.100 (0.15 mm)	No.200 (0.075 mm)	
TH-FD-01	15-17	30	92	120	44	20	24	1.2	0.4														CU, 1D Consolidation
TH-FD-01	22.5-24.5	27								0	9	91	100	100	100	100	100	100	100	99	97	91	
TH-FD-01	27.5-29.25	29			38	18	20	1.11	0.5	0	18	82	100	100	100	100	100	98	97	96	91	82	
TH-FD-01	32.5-34.5	26			33	18	15	0.83	0.5	0	30	70	100	100	100	100	100	99	97	94	84	70	
TH-FD-01	40-42	24								0	35	65	100	100	100	100	100	98	95	91	80	65	
TH-FD-01	45-47	22			30	18	12	0.67	0.4													85	
TH-FD-01	55-56.5	27								0	78	22	100	100	100	100	100	99	97	95	54	22	
TH-FD-01	60-62	27	95	120	38	18	20	1.11	0.4														1D Consolidation
TH-FD-01	70.8-72.8	23			31	18	13	0.72	0.4														
TH-FD-01	90-91.5	28	96	122	46	20	26	1.3	0.3														CU
TH-FD-01	100-101.7	35	86	116	68	22	46	2.09	0.3														1D Consolidation
TH-FD-02	10-17	14.4								63	27	10	100	58	49	37	25	20	17	14	12	10	
TH-FD-02	17.5-19.5	32.5			55	24	31	1.29	0.3														
TH-FD-02	20-22	29.3	97	126	48	22	26	1.18	0.3														Pinhole
TH-FD-02	25-27	32.0	91	120	39	20	19	0.95	0.6														1D Consolidation, CU
TH-FD-02	30-32	28.4			34	18	16	0.89	0.7													61	
TH-FD-02	40-42	29.4	94	121	39	19	20	1.05	0.5														1D Consolidation
TH-FD-02	40-42 sluff	44.3			46	20	26	1.3	0.9														
TH-FD-02	50-52	23.2	105	129																			CU
TH-FD-02	55-56	24.4								0	39	61	100	100	100	100	100	100	100	98	78	61	
TH-FD-02	56-57	26.0			NP																	81	
TH-FD-02	60-62	21.1								0	38	62	100	100	100	100	100	100	99	98	80	62	
TH-FD-02	75-77	29	96	124	58	25	33	1.32	0.1														1D Consolidation, CU
TH-FD-02	100-102	32			29	22	7	0.32	1.4													78	

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Table 2-1 Laboratory Test Result Summary

Bear River Project Concept Study- Fielding

GERHART COLE

Test Hole	Depth (ft)	Moisture content (%)	Dry unit weight (pcf)	Moist / Sat. unit weight (pcf)	Atterberg Limits					Grain-Size			Grain-Size Analysis (Percent Finer)										Other Tests (Interpretative Data in Appendix)
					LL (%)	PL (%)	PI (%)	Cohesive Index, CI	Liquidity Index, LI	GRAVEL (No.4 - 3")	SAND (No.200-No.4)	FINES (<No.200)	1.5-in (37.5 mm)	3/4-in (19 mm)	3/8-in (9.5 mm)	No.4 (4.75 mm)	No.10 (2 mm)	No.20 (0.85 mm)	No.40 (0.425 mm)	No.60 (0.25 mm)	No.100 (0.15 mm)	No.200 (0.075 mm)	
TH-FD-03	5-6.5	17								19	23	57	100	100	86	81	76	74	74	72	68	57	
TH-FD-03	10-11.5	23																				78	
TH-FD-03	15-16.5	25	100	125	33	19	14	0.74	0.5														CU
TH-FD-03	25-26.75	22	101	123	27	24	3	0.13	-0.7														1D Consolidation
TH-FD-03	35-36.5	24	99	122																			1D Consolidation
TH-FD-03	40-42	29			32	22	10	0.45	0.7													87	
TH-FD-03	47.5-49.5	26								0	23	77	100	100	100	100	100	100	100	99	98	77	
TH-FD-03	50-52	31			NP					0	15	85	100	100	100	100	100	100	100	99	98	85	
TH-FD-03	55-57	31			31	20	11	0.55	1.0													81	
TH-FD-03	60-61.7	27	97	123	38	22	16	0.73	0.3														CU
TH-FD-03	65-67	33			37	18	19	1.06	0.8														
TH-FD-03	70-71.5	34	88	118	39	22	17	0.77	0.7														1D Consolidation
TH-FD-03	80-81.5	32	89	117	48	21	27	1.29	0.4														1D Consolidation

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Table 2-2 - Fielding - Constant Head Permeability Testing Summary

Bear River Concept Study - Fielding

Location	Test Depth (ft)	Soil Type in Test Range	Ground Water Depth (ft)[a]	Flow, Q (gpm)	Hydraulic Conductivity (Lugeons)	Hydraulic Conductivity (cm/sec)	Comments
TH-FD-02	0-5	CL	12	0.18	10	1E-04	CL bounds top and CH bounds bottom of test zone
TH-FD-02	10-13	GP-GM	12	1.25	96	1E-03	GP-GM bounds top and bottom of test zone
TH-FD-02	17.5-20	CL	12	0.00	0	3E-06	CL bounds bottom of test zone, essentially no flow
TH-FD-02	20-25	CL	12	0.00	0	2E-06	CL bounds bottom and top of test zone, essentially no flow
TH-FD-02	25-30	CL	12	0.00	0	3E-06	CL bounds top and bottom of test zone, essentially no flow
TH-FD-02	30-35	CL	12	0.19	10	1E-04	Thin clayey sand seam encountered in run.
TH-FD-02	35-40	CL	12	0.00	0	9E-07	CL bounds top and CH bounds bottom of test zone, essentially no flow
TH-FD-02	40-45	CL	12	0.00	0	2E-06	CL bounds top and bottom of test zone, essentially no flow
Due to artesian flows pressure tests performed from depths of 45 to 100 ft.							
TH-FD-01	0-5	SM	15	0.48	22	3E-04	SM bound top and bottom of test zone
TH-FD-01	0-10	SM/ML	15	1.32	33	4E-04	SM bound top and ML bounds bottom of test zone
TH-FD-01	15-20	CL	15	0.02	1	1E-05	CL bounds top and bottom of test zone
TH-FD-01	20-25	ML	15	0.15	6	8E-05	ML bounds top and bottom of test zone
Due to artesian flows pressure tests performed from depths of 25 to 45 ft.							
TH-FD-01	45-50	ML	15	0.47	20	3E-04	CL bounds top and SM bounds bottom of test zone
TH-FD-01	50-55	SM	15	0.80	34	4E-04	SM bounds top and bottom of test zone
TH-FD-01	55-60	SM/CL	15	0.45	19	2E-04	SM bounds top and CL bounds bottom of test zone
TH-FD-01	60-65	CL/CH	15	0.01	1	8E-06	CL bounds top and CH bounds bottom of test zone
TH-FD-01	60-70	CH/CL	15	1.37	34	4E-04	CH bounds top and CH and CL bound bottom of test zone
TH-FD-01	60-75	CL	15	0.02	0	4E-06	CL and CH bound test zone; results are suspect due to less flow
TH-FD-01	75-80	CL/ML	15	0.06	2	3E-05	CL and ML bound test zone
TH-FD-01	80-85	CL/CH	20	0.05	0	3E-06	CL and CH bound test zone
TH-FD-01	85-90	CH	20	0.00	0	3E-06	CH bound test zone
TH-FD-01	90-95	CH	20	0.01	0	3E-06	CH bound test zone
TH-FD-01	95-100	CH	20	0.01	0	3E-06	CH bound test zone

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Table 2-2 - Fielding - Constant Head Permeability Testing Summary

Bear River Concept Study - Fielding

Location	Test Depth (ft)	Soil Type in Test Range	Ground Water Depth (ft)[a]	Flow, Q (gpm)	Hydraulic Conductivity (Lugeons)	Hydraulic Conductivity (cm/sec)	Comments
TH-FD-03	0-5	ML	30	0.08	2	2E-05	ML bounds test zone
TH-FD-03	0-10	ML	30	0.07	1	1E-05	ML bounds test zone
TH-FD-03	10-15	ML/CL	30	1.21	28	4E-04	Leakage around casing - results not valid
TH-FD-03	15-20	CL	30	0.26	6	7E-05	CL bounds test zone
TH-FD-03	20-25	CL	30	0.21	5	6E-05	CL bounds test zone with layers of ML
TH-FD-03	25-30	CL	30	0.41	9	1E-04	CL bounds test zone
TH-FD-03	30-35	CL	30	0.20	4	6E-05	CL bounds test zone
TH-FD-03	35-40	CL/ML	30	0.90	19	3E-04	CL bounds top and CL/ML bounds bottom of test zone
TH-FD-03	40-45	ML	30	1.01	22	3E-04	CL/ML bounds top and ML with sand seams bounds bottom of test zone
TH-FD-03	45-50	ML/SM	30	1.08	23	3E-04	ML and SM bound test zone
TH-FD-03	50-55	SM/ML	30	1.05	23	3E-04	SM and ML bound test zone
TH-FD-03	55-60	CL	30	1.27	27	4E-04	CL bounds test zone
TH-FD-03	60-65	CL	30	1.09	24	3E-04	CL bounds test zone but sand seams possible
TH-FD-03	65-70	CL	30	1.12	24	3E-04	CL bounds test zone but sand seams possible
TH-FD-03	70-75	CL	30	1.05	23	3E-04	CL bounds test zone but sand seams possible
TH-FD-03	75-80	CH	30	0.89	19	3E-04	CH bounds test zone but sand seams possible
TH-FD-03	80-85	CH	30	0.84	9	1E-04	CH bounds test zone

Notes: a. Depth to groundwater measured in test hole at completion of well installation.

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Table 2-3 - Fielding Pressure Permeability Test Results
Fielding Site - Bear River Project TH-FD-01

Project Name	Bear River		Inclination (degrees)	0	Tested by	R. Buhler
Project Location	Fielding		Distance to Water (ft)	12	Date	7/20 and 7/21/2015
Project Number	13GCI329		Vertical Depth to Water (ft)	18.0	Reviewed by	P. Gerhart
Test Hole No.	TH-FD-02	Sheet 1 of 1	Hole Diameter = 2*r (in)	4	Date	Nov-15

Notes:

Test #,	Testing Interbal		Test Length	Total Applied Pressure	Pressure Losses	Adjusted Applied Pressure	Applied Pressure Head	Gravity Head	Total Head	Water Take	Shape Factor	Hydraulic Conductivity			Comments
	Start	End	(ft)	(psi)	(psi)	(psi)	(ft)	(ft)	(ft)	(gpm)		(ft/yr)	(cm/s)	(Lugeon)	
a	b	c	L	pgage	ploss	pactual	hp	hg	htotal	Q	Cp	k	km	kL	
1, (CL) w/SM	20	30	10	2.5	2	0.50	1.2	25.0	26.2	0.3	4582	45	4.3E-05	3	Static artesian pressure ~ 1 psi
	20	30	10	3.4	2	1.40	3.2	25.0	28.2	0.4	4582	62	6.0E-05	5	
2, (CL) w/SM	30	35	5	2.2	2	0.20	0.5	32.5	33.0	0.02	7612	5	4.9E-06	0	Static artesian pressure ~ 1.5 psi
	30	35	5	3.2	2	1.20	2.8	32.5	35.3	0.6	7612	129	1.3E-04	10	
3, (CL) w/SM	30	40	10	2.2	2	0.20	0.5	35.0	35.5	0.46	4582	59	5.7E-05	4	Static artesian pressure ~ 1.5 psi
	30	40	10	3.4	2	1.40	3.2	35.0	38.2	1.7	4582	204	2.0E-04	15	
4, (CL) w/SM	40	45	5	2.2	2	0.20	0.5	42.5	43.0	0.92	7612	163	1.6E-04	12	No artesian pressures
	40	45	5	3.3	2	1.30	3.0	42.5	45.5	1.3	7612	211	2.0E-04	16	

a = Test #, Material

b = Btm of Casing

c = Bottom of test hole

L = c-b

p_{gage} = Pressure gage

p_{loss} = Pressure losses from calibration in field

$p_{actual} = p_{gage} - p_{loss}$

$h_p = p_{actual}*2.31$

h_g = Mid Interval depth

$h_{total} = h_p + h_g$

If L >= 10r, $C_p = 1/(2\pi L)*\ln(L/r)*70309$

If r<L<10r, $C_p = 1/(2\pi L)*\sinh^{-1}(L/2r)*70309$

70309 is unit conversion from gpm/ft^2 to ft/yr

$k = C_p*Q/h_{total}$

$k_m = k*9.6651E-7$

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Table 2-3 - Fielding Pressure Permeability Test Results
Fielding Site - Bear River Project TH-FD-02

Project Name	Bear River	Inclination (degrees)	0	Tested by	R. Buhler
Project Location	Fielding	Distance to Water (ft)	12	Date	7/2/2015 through 7/6/2015
Project Number	13GCI329	Vertical Depth to Water (ft)	12.0	Reviewed by	P. Gerhart
Test Hole No.	TH-FD-02 Sheet 1 of 1	Hole Diameter = 2*r (in)	4	Date	Nov-15

Notes:

Test #,	Testing Interbal		Test Length	Total Applied Pressure	Pressure Losses	Adjusted Applied Pressure	Applied Pressure Head	Gravity Head	Total Head	Water Take	Shape Factor	Hydraulic Conductivity			Comments
	Start	End	(ft)	(psi)	(psi)	(psi)	(ft)	(ft)	(ft)	(gpm)		(ft/yr)	(cm/s)	(Lugeon)	
a	b	c	L	pgage	ploss	pactual	hp	hg	htotal	Q	Cp	k	km	kL	
1, CL	45	55	10	4	2	2.00	4.6	50.0	54.6	0.1	4582	11	1.1E-05	1	Static artesian pressure ~ 3 psi
	45	55	10	6	2	4.00	9.2	50.0	59.2	0.3	4582	24	2.3E-05	2	
2, (ML,SM)	55	65	10	4.5	2	2.50	5.8	60.0	65.8	0.5	4582	33	3.2E-05	2	Static artesian pressure ~ 1 psi
	55	65	10	6	2	4.00	9.2	60.0	69.2	0.7	4582	46	4.5E-05	3	
3 (SM, CH)	65	75	10	5	2	3.00	6.9	70.0	76.9	0.02	4582	1	1.2E-06	0	Static artesian pressure ~ 1.5 psi
	65	75	10	6	2	4.00	9.2	70.0	79.2	0.1	4582	5	5.3E-06	0	
	65	75	10	8	2	6.00	13.9	70.0	83.9	0.2	4582	13	1.3E-05	1	
4, (CH, CL)	75	85	10	4.5	2	2.50	5.8	80.0	85.8	0.2	4582	11	1.0E-05	1	No artesian pressures
	75	85	10	6	2	4.00	9.2	80.0	89.2	0.3	4582	16	1.5E-05	1	
5, (CL, CH)	75	95	20	11	2	9.00	20.8	85.0	105.8	0.01	2679	0	1.3E-07	0	Static artesian pressure ~ 3 psi

a = Test #, Material

b = Btm of Casing

c = Bottom of test hole

L = c-b

p_{gage} = Pressure gage

p_{loss} = Pressure losses from calibration in field

$p_{actual} = p_{gage} - p_{loss}$

$h_p = p_{actual}*2.31$

h_g = Mid Interval depth

$h_{total} = h_p + h_g$

If L >= 10r, $C_p = 1/(2\pi L)*\ln(L/r)*70309$

If r<L<10r, $C_p = 1/(2\pi L)*\sinh^{-1}(L/2r)*70309$

70309 is unit conversion from gpm/ft^2 to ft/yr

$k = C_p*Q/h_{total}$

$k_m = k*9.6651E-7$

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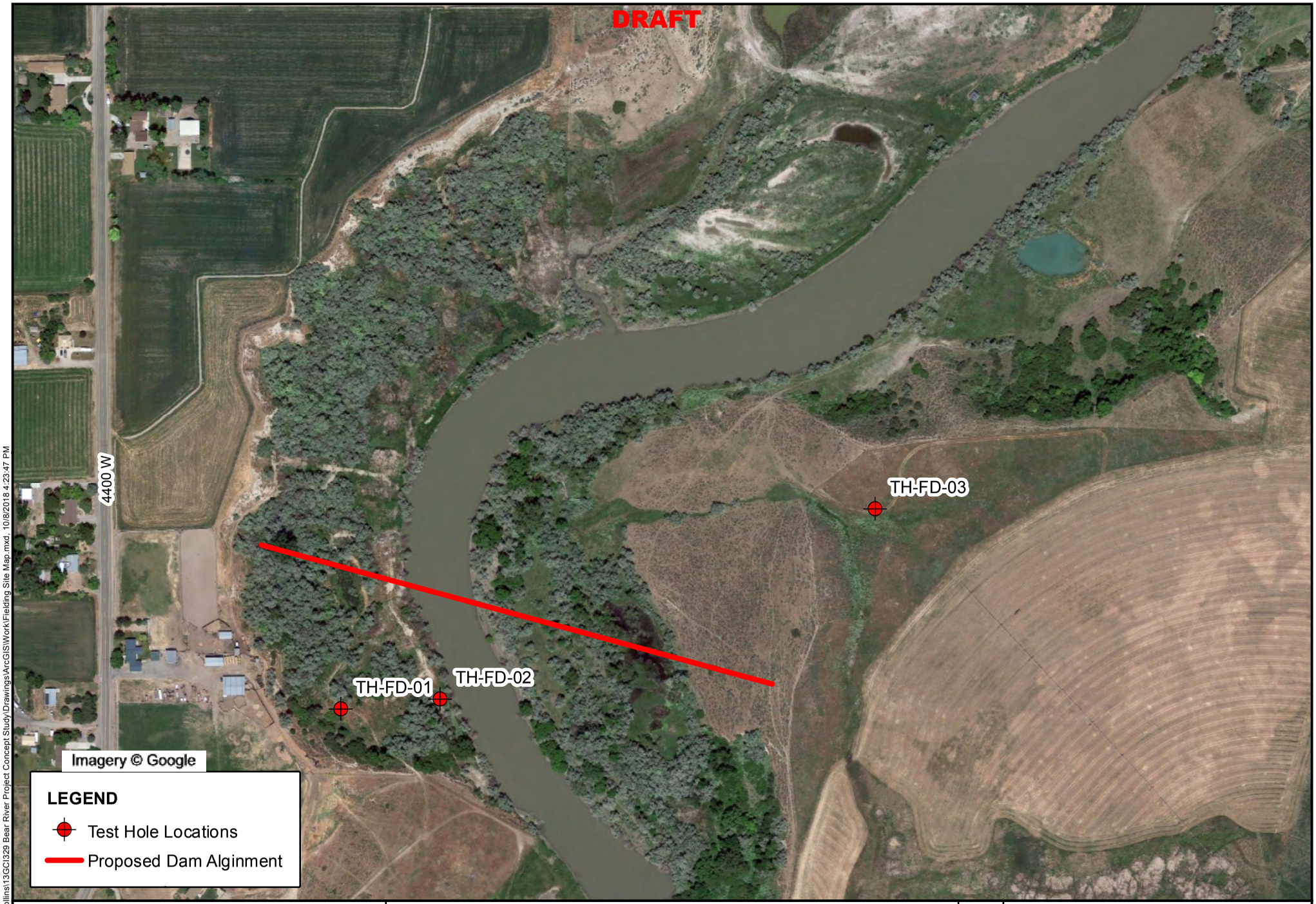
Table 2-4 - Fielding - Groundwater Measurements

Bear River Concept Study (13GCI329)

Date	Groundwater Depth in Piezometer (ft)		
	TH-FD-01 (Deep)	TH-FD-01 (Shallow)	TH-FD-03
July 22, 2015	23		
July 23, 2015	17	+4.2	
July 27, 2015	17	+4	
July 30, 2015			29.9
September 30, 2015	16.8	+5.4	31.3



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Bear River Project Concept Study - Fielding

Fielding Site and Exploration Map

N

0 170 340 680 Feet

Figure 2-1

J:\PROJECTS\Bowen Collins\13GCI329 Bear River Project Concept Study\Drawings\ArcGIS\Work\Fielding Site Map.mxd, 10/8/2018 4:23:47 PM

3.1 GENERAL SETTING

The proposed site is located in Bear River Valley, a north-trending, deep, sediment-filled structural basin bounded by the Wellsville Mountains on the east and the Point Lookout Mountains on the west. Bear River Valley is located at the eastern margin of the Basin and Range Physiographic Province, a region characterized by a series of generally north-trending mountain ranges separated by similarly trending valleys. The large-scale topographic features are a result of east-west crustal extension that began about 15 to 17 million years ago, and continues today (Hecker, 1993). The crustal extension has resulted in range front normal faults separating the mountains from valleys. Erosional processes have removed materials from the mountains and partially filled the valley with alluvial and lacustrine (lake) sediments.

3.2 LAKE BONNEVILE HISTORY

The near-surface geology of the proposed site is dominated by sediments deposited and/or reworked by Lake Bonneville, a large late-Pleistocene lake that covered much of northwestern Utah and adjacent parts of Idaho and Nevada. The lake began to rise above levels comparable to the Great Salt Lake about 28,000 years ago[1] and by approximately 16,000 ago, the lake reached its highest elevation – the Bonneville shoreline (Gilbert, 1890; Currey, 1990). Near the proposed site, the elevation of the Bonneville shoreline varies between 5,170 and 5,180 feet (Oviatt, 1986a).

Lake Bonneville remained at the elevation of the Bonneville shoreline until about 14,500 years ago when a catastrophic failure near Red Rock Pass caused a massive flooding of lake waters into the Snake River drainage. This event, called the Bonneville flood, caused a drop in lake level of about 340 feet where the lake level restabilized and the Provo shoreline began to form. Near the proposed site, the elevation of the Provo shoreline varies between 4,780 and 4,790 feet (Oviatt, 1986a).

The lake oscillated at or near the level of the Provo shoreline until about 12,500 years ago when a change in climate conditions permanently drove the lake below the threshold at Red Rock Pass. By about 11,500 years ago, the lake had reached levels comparable to modern Great Salt Lake – about 4,200 feet (Godsey et. al., 2005).

The lake rose again briefly between about 11,000 and 10,000 years ago to form the Gilbert shoreline at approximately 4,240 to 4,250 feet, and then again declined (Oviatt et al., 2005). This marks the end of Lake Bonneville and the beginning of its successor, Great Salt Lake (Currey et al., 1984).

During the time Lake Bonneville existed in the Bear River Valley, coarse-grained sediments were deposited in the shore and nearshore environments creating beaches, deltas, spits, and bars. In deeper water, toward the center of the valley, deposits generally consist of finer grained sand, silt, clay, and marl (Oviatt and Miller, 1997)

[1] Unless otherwise noted, all ages are radiocarbon ages.

3.3 SURFICIAL DEPOSITS

The most detailed published geologic mapping completed in the vicinity of the proposed site is at a scale of 1:24,000 (Oviatt, 1986a). Oviatt has mapped six surficial deposits in the vicinity of, and immediately upstream of the project site (Figure 3-1):

- Alluvium (Qal) consisting of fine-grained to gravelly material deposited on flood plains and channels (Holocene).
- Oxbow lake deposits (Qab) consisting of fine grained organic rich sediments (Holocene).
- Alluvial gravels (Qag) associated with the Bear River and deposited in paleochannels within unit Qls_2 (upper Pleistocene).
- Lacustrine sediments (Qls_1) consisting of sand, silt, and clay deposited during the Gilbert Stage of Lake Bonneville (upper Pleistocene).
- Lacustrine sediments (Qls_2) consisting of sand, silt, and clay deposited during Bonneville and pre-Bonneville ages (upper Pleistocene).
- Thin lacustrine deposits overlying lateral-spread deposits (Qlu/Qml) (upper Pleistocene).

3.4 SITE SPECIFIC CONDITIONS

The proposed embankment site consists of relatively flat-lying benches at elevations between about 4,340 and 4,350 feet on both sides the Bear River channel and modern flood plain. Oviatt (1986a) maps the benches and slopes down to the flood plain as lacustrine sand, silt, and clay (Qls_2 on Figure 3-1) that were deposited during the time Lake Bonneville and precursor lakes occupied the site. The Bear River has incised about 100 feet into, and exposed the lacustrine sediments; the elevation of the river at the proposed site is at about 4,240 feet; and the proposed height of the embankment is 70 feet.

Sediments recovered from three test holes at the proposed site consisted primarily of silts and clays, with minor layers of sand and gravel. We interpret the silts and clays to have been deposited in deep water during the times that the site was occupied by Lake Bonneville and prior late-Pleistocene lakes. We do not have sufficient information to delineate Lake Bonneville sediments from those of previous lake cycles. The predominance of fine-grained sediments, along with our understanding of Lake Bonneville chronology and deposition, suggests that the silts and clays are likely laterally extensive across the proposed site.

We interpret the sands and silty sands to have been deposited by meandering or braided streams, low-angle deltas, beaches, and/or spits in the shore and near shore environment of the late Pleistocene lakes. Varying thickness of these coarser grained deposits represent the amount of time that the lakes were at this elevation – thicker deposits are associated with extended periods of shore zone deposition, thinner deposits are associated with deposition in a rapidly rising, or falling lake level. It is also possible that some of the sandy layers found in deeper portions of the test holes represent subaerial deposition occurring between lake cycles, although we have insufficient data to confirm this.

Oviatt (1986a) maps the head scarp of a slump or slide near the break in slope on the right abutment (Figure 3-1). We confirmed that this is an active slide, with movement occurring in historic time based on displaced fences at the scarp. The morphology of the slope between the scarp and the Bear River suggests that this slide extends to the river. Test hole TH-FD-01 contained seams of sand and silt dipping at 70 degrees at a depth of 15-17 feet. This indicates that these sediments are part of the slide and not in place soils. In test hole TH-FD-02, we interpret the clay found to a depth of 7 feet to be part of the slide that is overlying gravels and sand that are likely related to the channel of the modern Bear River.

At the site of the proposed embankment, the incised river and floodplain are fairly narrow and Oviatt (1986a) has only mapped the lacustrine sediments. However, immediately upstream and downstream of the proposed site, Oviatt has mapped alluvial deposits consisting of fine-grained to gravelly sediments (Qal on Figure 3.1). Although not mapped, we believe that sands and gravels are also present at the proposed site, but may be restricted to the channel or small flood plain deposits.

Upstream of the embankment site, Oviatt (1986a) has mapped fine-grained, organic-rich sediments deposited in ox-bow lakes on the flood plain of the Bear River (Qab on Figure 3-1). We observed these oxbow lakes, and similar smaller ones elsewhere on the flood plain where it widens north of the proposed embankment site. It is possible that small deposits of fine-grained, organic-rich sediments are present near the proposed embankment site, but are buried by more recent alluvial deposits, or slide deposits.

Upstream, and downstream of the proposed embankment site, Oviatt (1986a) has mapped lacustrine sand, silt, and clay deposited during the Gilbert stage of Lake Bonneville (Qls_1 on Figure 3.1). These deposits are only distinguished from the other lacustrine deposits in the vicinity of the proposed site, and discussed above, by their age.

On the bench, immediately east of the left abutment, Oviatt (1986a) has mapped alluvial gravels of the late Pleistocene Bear River that fill channels cut into the lacustrine deposits (Qag on Figure 3.1). We did not find deposits in our test holes that we believe are gravelly or sandy channel fills. However, we note that these deposits are aligned parallel with the river and because of their coarse-grained nature are likely to have high permeabilities and could provide conduits for seepage from the reservoir around the left abutment.

Also on the bench, in the vicinity of the left abutment, Oviatt (1986a) has mapped lateral spread deposits that are covered with a thin layer of lacustrine deposits (Qlu/Qml on Figure 3.1). Given that these lateral spread deposits are overlain by lacustrine sediments, they are at least late Pleistocene in age.

3.5 GEOLOGIC HAZARDS

3.5.1 Surface Fault Rupture

The project site is located within the Wasatch fault zone, one of the longest and most tectonically active faults in North America (Black, et. al., 2004). The Wasatch fault extends for about 213 miles along the base of the Wasatch Range between Malad City, Idaho and Fayette, Utah (Machette et. al., 1992) and marks the eastern boundary of the Basin and Range in northern Utah. Surface features associated with faulting have created a zone of deformation characterized by roughly north-trending west-facing main fault scarps and smaller east-facing antithetic fault scarps. The Wasatch fault has been divided into 10 sections, which rupture independently and are capable of generating large-magnitude surface-rupturing earthquakes (Machette et. al., 1992).

The proposed site is near the northern end of the Colliston section, a poorly constrained, approximately 20-mile long section of the Wasatch fault (Black et. al., 2004). Oviatt (1986a) maps the Colliston section of the Wasatch fault approximately 1.5 miles east of the proposed site (Figure 3-1). The fault is mapped as concealed by lacustrine sand and gravel deposited in the shore zone of Lake Bonneville (Qlg) near the base of the Wellsville Mountains.

There have been no paleoseismic investigations conducted along the Colliston section of the Wasatch fault (Lund, 2005). As such, the reliability of the location is poor, and the age of most recent surface rupture is estimated to be within the past 130,000 years, but the section shows no evidence of Holocene (past 10,000 years) faulting (Black, et. al., 2004). Based on displacement of alluvium and soil-profile development at the southern end of the section, Black and others (2004) estimate the slip rate for the Colliston section to be less than 0.2 mm/yr. Lund (2005) recommends additional fieldwork be conducted in order to determine if evidence exists for Holocene or late Pleistocene surface faulting, and if so that the section is trenched to determine earthquake timing, recurrence intervals, and vertical slip rates.

3.1.1 Landslides

Slopes between the Bear River flood plain and adjacent flat-lying benches are comprised of predominately fine-grained lacustrine sediments that are susceptible to slope movement. Landslides have been documented in numerous locations along slopes adjacent to the Bear River where the river has cut into lacustrine sand, silt, and clay deposits of the old bed of Lake Bonneville (Oviatt, 1986a, 1986b). These landslides are common on the outsides of bends in the river, although we have observed several recent and active slides away from the active channel. The landslides are likely initiated as a result of over-steepened slopes and seeps associated with perched ground water above clayey and silty clay layers in the lacustrine deposits (Ashland, 1997)

In addition to the landslide scarp mapped at the proposed abutment site, Oviatt (1986a) maps several within the reservoir basin. One area of recent landslide activity is the slope adjacent to the East Garland Cemetery. At this location, portions of the fence have been displaced downslope by recent movement, and because Oviatt did not map this area as a landslide in 1986, we believe that at least portions of the landslide have

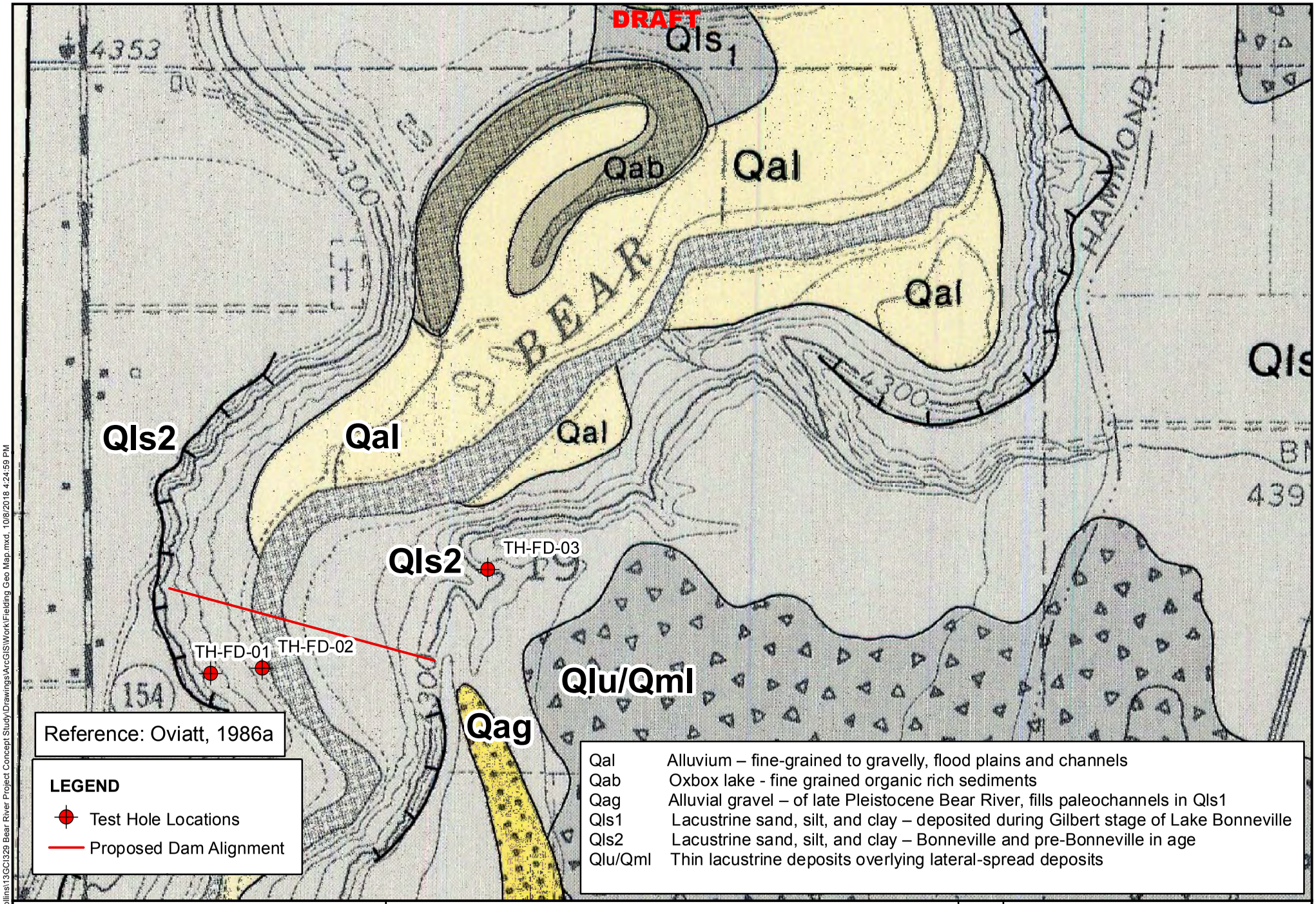
been active within the past 30 years. Similarly, we observed several landslide features near the proposed embankment site and within the reservoir basin that indicate recent movement. Based on observations of fresh, steep, and unvegetated scarps; irregular and hummocky topography; and displaced and tilted vegetation, we believe that significant portions of the reservoir basin have experienced landsliding within the past few decades.

The slopes that will be in contact with the proposed reservoir are inherently unstable, and could likely experience additional landsliding as a result of undercutting by wave action. Furthermore, fluctuating reservoir levels could create saturated zones in the fine-grained, slow-draining sediments adjacent to the reservoir and thereby reduce the slope stability.

In order to qualitatively assess the hazards of landslides in the reservoir basin we conducted reconnaissance-level observations of the slopes that would be in contact with the proposed reservoir. Our observations were limited to areas where access was available from public rights of way. In addition, we examined aerial imagery available from Google Earth for evidence of fresh landslide scarps. We developed a landslide hazard rating system based on the height and steepness of the slopes, and evidence for recent landslide activity and/or mapped landslide scarps (Table 3-1). Based on these criteria, we estimate that approximately 40 percent of the slopes that would be in contact with the proposed reservoir have a relatively high landslide hazard, 40 percent have a relatively moderate landslide hazard, and 20 percent have a relatively low landslide hazard.

Table 3-1 Qualitative Landslide Rating

Landslide Hazard Rating	Steep and High Slopes	Evidence of Recent Landslides and/or Mapped Scarps
Low	No	No
Medium	Yes	No
High	Yes	Yes



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Bear River Project Concept Study - Fielding

Fielding Geologic Map

N

0 330 660 1,320 Feet

Figure 3-1

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4.1 LIMITATIONS

The assessments and recommendations presented in this document are based on limited field studies and laboratory testing, as well as our understanding of the project's design and manner of construction. If the project's design or manner of construction changes, or if conditions are found later that are different from those described, we should be notified immediately so that we can make revisions as necessary.

This document was prepared solely for the use of the addressee and may not contain sufficient information for other parties or uses.

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Ashland, F.X., 1997, Reconnaissance of a landslide along the Bear River, Honeyville, Utah: Utah Geological Survey, Technical Report 97-07, 2p.

Black, B.D., DuRoss, C.B., Hylland, M.D., McDonald, G.N., and Hecker, S., compilers, 2004, Fault number 2351c, Wasatch fault zone, Colliston section, in Quaternary fault and fold database of the United States: U.S. Geological Survey, accessed online http://earthquakes.usgs.gov/hazards/qfaults

Currey, D.R., 1990, Quaternary palaeolakes in the evolution of semidesert basins, with special emphasis on Lake Bonneville and the Great Basin, U.S.A.: Palaeogeography, Palaeoclimatology, Palaeoecology, v. 76, p. 189-214.

Currey, D.R., Atwood, G. and Mabey, D.R., 1984, Major levels of the Great Salt Lake and Lake Bonneville: Utah Geological and Mineral Survey Map 73.

Gilbert, G.K., 1890, Lake Bonneville: U.S. Geological Survey Monograph 1, 438 p.

Godsey, H.S., Currey, D.R., and Chan, M.A., 2005, New evidence for an extended occupation of the Provo shoreline and implications for regional climate change, Pleistocene Lake Bonneville, Utah: Quaternary Research v. 63, p. 212– 223.

Hecker, S., 1993, Quaternary tectonics of Utah with emphasis on earthquake-induced characterization: Utah Geological Survey Bulletin 127, 157p.

Lund, W.R., 2005, Consensus preferred recurrence-intervals and vertical slip-rate estimates, Review of Utah paleoseismic-trenching data by the Utah Quaternary Fault Parameters Working Group: Utah Geological Survey, Bulletin 134, 109 p.

Machette, M. N., 1992, Surficial geologic map of the Wasatch fault zone, eastern part of Utah valley, Utah County and parts of Salt Lake and Juab Counties, Utah: U.S. Geological Survey Miscellaneous Investigation Series Map I-2095, scale 1:50,000, 26 p.

Oviatt, C.G., 1986a, Geologic map of the Cutler Dam Quadrangle, Cache and Box Elder Counties, Utah: Utah Geological and Mineral Survey, Map 91, 1:24,000.

Oviatt, C.G., 1986b, Geologic map of the Honeyville Quadrangle, Cache and Box Elder Counties, Utah: Utah Geological and Mineral Survey, Map 88, 1:24,000.

Oviatt, C.G., and Miller, D.M., 1997, New explorations along the northern shores of Lake Bonneville, in Link, P.K. and Kowallis, B.J., eds., Mesozoic to recent geology of Utah: Brigham Young Geology Studies v. 42, pt. II, p. 345-371.

Oviatt C.G, Miller, D.M. McGeehin, J.O., Zachary, C., Mahan, S., 2005. The younger dryas phase of great salt Lake, Utah, USA Palaeogeography, Palaeoclimatology, Palaeoecology 219, 263-284.

Appendix A Test Hole Logs – Fielding

DRAFT

Project: Bear River Project **Project Location:** Fielding **Project Number:** 13GCI329	**Log of Test Hole TH-FD-01** Sheet 1 of 2

Date(s) Drilled	7/20/15 - 7/22/15	Logged By	R. Buhler	Checked By	P. Gerhart
Drilling Method	Rotary wash with water	Drill Bit Size/Type	Drag bit with HW Casing	Total Depth Drilled (feet)	101.8 feet
Drill Rig Type	CME 75	Drilling Contractor	Bedke Geotechnical F.S.	Hammer Weight/ Drop(lbs/in.)	Automatic trip hammer
Apparent Groundwater Depth	See Table 2.4 Two Piezos Installed	Latitude / Longitude	41.76182, -112.12203	Ground Surface Elevation (feet)	4280.0
Comments		Test Hole Backfill	Piezometer Well	Elevation Datum	NAVD88

Elevation, feet	Depth, feet	SAMPLES Type	Number	Sampling Resistance	Recovery, inches	Graphic Log	MATERIAL DESCRIPTION	FIELD NOTES
4280	0						SAND, silty, some gravel - loose, moist, light brown, fine to coarse-grained sand, fine-grained subrounded gravel, (SM)	
		SPT	01	3-3-4-4 [7]	12.0			
							SILT, some sand - very soft, light brown, wet, low plasticity, (ML)	
	10	SPT	02	2-1-1-1 [2]	12.0			
							CLAY, trace sand - stiff to very stiff, light brown, wet, medium plasticity, (CL)	
		SH	03		24.0		▽	
4260	20	SPT	04	3-3-6-10 [9]	24.0			
		SPT	05	3-3-7-6 [10]	24.0			
		SPT	06	2-3-4-9 [7]	18.0		Frequent Interbeds of SILT with sand seams	
		SPT	07	4-9-12-10 [21]	21.0			
	30	SPT	08	3-8-10 [18]	18.0		Interbeds of gray SILT seams	Pressure head measured at 1 psi with btm of hole at 30 ft.
		SPT	09	6-11-12 -17 [23]	24.0			
		SPT	10	9-13-12 -18 [25]	20.0		Interbeds of gray SILT seams	Pressure head measured at 1.5 psi with btm of hole at 35 ft.
		SPT	11	7-12-19 -26 [31]	18.0		CLAY, sandy - stiff, blueish gray, wet, frequent interbedded layers of tan silt with iron oxide staining, (CL) Silty SAND seams	
4240	40	SPT	12	6-14-14 -14 [28]	18.0			Pressure head measured at 1.5 psi with btm of hole at 40 ft.
		SPT	13	6-11-14 -20 [25]	24.0			
		SPT	14	5-9-15-25 [24]	17.0			No pressure head measured but water flowing overtop of casing
							SAND, silty - medium dense to dense, gray, wet (SM)	
	50	SPT SH	16 15	0-1-1 [2]	18 0.0			No recovery with shelby followed with spoon. Measured water at 12.8 ft when returned to drillijg on 7/21/15
		SPT	17	8-11-15 -32 [26]	20.0		Interbedded layers of silt and clay at 52.5 ft	

SOIL TEST HOLE TH_LOGS_#1_BEAR_RIVER.GPJ GERHART.GDT 6/25/18

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Project: Bear River Project
Project Location: Fielding
Project Number: 13GCI329

Log of Test Hole TH-FD-01

Elevation, feet	Depth, feet	Type	Number	Sampling Resistance	Recovery, inches	Graphic Log	MATERIAL DESCRIPTION	FIELD NOTES
		SPT	18	13-19-30 [49]	18.0			
		SPT	19	4-9-14-12 [23]	24.0		CLAY, some silt, trace sand - very stiff light bluish-gray, wet, medium plasticity, (CL)	
4220	60	SH	20		24.0			
							CLAY, trace sand - stiff - bluish-gray, wet, high plasticity (CH)	
		SPT	21	3-6-8-9 [14]	24.0			
	70						CLAY, with sand - stiff, light bluish-gray, wet, medium plasticity, (CL) Interbedded layers of sand at 70 ft	
		SPT / SH	23 / 22	1-6-10-11 [16]	24.0 / 8.0			
		SH	24		8.0		SILT, sandy - very stiff, bluish-gray, wet, low plasticity (ML)	
		SPT	25	14-16-20 -18 [36]	24.0			
4200	80	P	26		20.0		CLAY, some sand - stiff, light bluish-gray, wet, (CL)	
							CLAY, trace sand - stiff, bluish-gray, wet, high plasticity, (CH)	
		SPT	27	5-8-11-12 [19]	24.0			
	90	P	28		20.0			Measured water at 15 ft when returned to drillijg on 7/22/15
		SPT	29	5-6-9-10 [15]	24.0			
4180	100	P	30		21.0			
							Bottom of Test Hole at 101.8 feet. Deeper Piezometer Screen 101.5-96.5 ft 10-20 Sand 101.5-73 ft Bentonite Chips 73 - 40.2 ft Shallow Piezometer Screen 40.2 - 36.2 ft 10-20 Sand 40.2 - 31.2 ft Bentonite Chips 31.2-0 ft	
	110							

SOIL TEST HOLE TH_LOGS_#1_BEAR_RIVER.GPJ GERHART.GDT 6/25/18

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Project: Bear River Project
Project Location: Fielding
Project Number: 13GCI329

Log of Test Hole TH-FD-02

Date(s) Drilled	6/29/15 - 7/7/15	Logged By	R. Buhler	Checked By	P. Gerhart
Drilling Method	Rotary wash with water	Drill Bit Size/Type	Drag bit with HW Casing	Total Depth Drilled (feet)	105.0 feet
Drill Rig Type	CME 75	Drilling Contractor	Bedke Geotechnical F.S.	Hammer Weight/ Drop(lbs/in.)	Automatic trip hammer
Apparent Groundwater Depth	Not Measured	Latitude / Longitude	41.76191, -112.12101	Ground Surface Elevation (feet)	4242.5
Comments		Test Hole Backfill	Cement-Bentonite Grout	Elevation Datum	NAVD88

Elevation, feet	Depth, feet	SAMPLES Type	Number	Sampling Resistance	Recovery, inches	Graphic Log	MATERIAL DESCRIPTION	FIELD NOTES
	0						CLAY, some sand - soft, wet, brown, medium plasticity, (CL)	
4240								
	5		SH-01		22.0			Tube had small dent at bottom
							GRAVEL, with sand, some silt - medium dense to loose, wet, gray, fine to coarse gravel, subrounded gravel, (GP-GM)	
	10		SPT-02	4-7-5 [12]	3.0			Gravel stuck in spt shoe
4230			SPT-03	2-2-2-3 [4]	4.0			Switched to 2.75 inch diameter tricone bit at 13 ft
	15		SPT-04	6-9-10-14 [19]	2.0			
			SPT-05	2-2-3-4 [5]	24.0		CLAY, trace fine sand - medium stiff, wet, dark bluish gray, medium plasticity, (CL)	
	20		SH-06		0		Thin seams of fine silt	Driller switched to 3.5 inch diameter drag bit at 20 ft No recovery from Shelby tube. Drove spoon to recover some sample.
4220								
	25		SH-08		25.0			
	30		SPT-09	4-4-10-9 [14]	24.0		Increasing silt content and organics at 30 ft	
4210							Thin layer of sandy CLAY (CL) from 31 to 32 ft.	
	35		SH-10		15.0			
			SPT-11	4-9-14-14 [23]	24		SAND, silty - medium dense, wet, bluish gray, (SM) CLAY - stiff, wet, light bluish gray, medium plasticity, (CL)	
	40		SH-12		24.0			
4200								
	45		SPT-13	3-5-7-9 [12]	24.0		1-inch seam of sand at 46 ft	Artesian groundwater flow from casing when returned 7/6/15. Water level was at ~12 ft on 7/2/15. Pressure head measured at 3 psi with btm of hole at 55 ft. Casing
	50							

SOIL TEST HOLE TH_LOGS_#1_BEAR_RIVER.GPJ GERHART.GDT 6/25/18

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Project: Bear River Project
Project Location: Fielding
Project Number: 13GCI329

Log of Test Hole TH-FD-02

Elevation, feet	Depth, feet	Type	Number	Sampling Resistance	Recovery, inches	Graphic Log	MATERIAL DESCRIPTION	FIELD NOTES
	50		SH-14		24.0			was pushed hydraulically to 55 ft.
4190							SILT, sandy - stiff, wet, light bluish gray, numerous thin interbedded layers of fine sand, nonplastic, (ML)	
	55		SPT-15	6-11-19 -20 [30]	24.0			Pressure head measured at 1 psi with btm of hole at 65 ft. Casing was pushed hydraulically to 65 ft.
	60		SPT-16	7-13-16 -15 [29]	24.0			
4180							SAND, silty- medium dense, gray, wet, thin interbeds of silt, (SM)	
	65		SH-17		24.0			Pressure head measured at 1.5 psi with btm of hole at 75 ft. Casing was pushed hydraulically to 75 ft. Refusal shelby push after 12 inches
	70		SPT-18	5-8-10-10 [18]	24.0		CLAY - stiff, wet, dark bluish gray, varved, medium to high plasticity, (CH)	
4170								
	75		SH-19		24.0			
	80		SPT-20	4-6-10-11 [16]	24.0			
4160								
	85		SH-21		7		Btm tube has clay (CL), some silt, micaceous	Pressure head measured at 3 psi with btm of hole at 95 ft.
							CLAY, some silty sand - very stiff, wet, bluish gray, medium plasticity, numerous very thin interbeds of silty sand to sandy silt, (CL)	
	90		SPT-22	5-7-13-12 [20]	24.0			
4150							CLAY - stiff, wet, dark bluish gray, varved, medium to high plasticity, (CH)	
	95		SH-23		20.0			Casing has been advanced to 75 ft. Driller tried to advance casing to 95 ft to cut off artesian pressure with hammer but casing was not advancing. Driller decided to drill ahead of casing.
							SILT, with sand - very stiff, wet, light bluish gray, numerous thin interbeds of silty sand, (ML).	
	100		SPT-24	7-9-14-16 [23]	24.0			Pressure head measured at 20 psi with btm of hole at 105 ft. Hole was terminated at 105 ft due to high artesian pressures.
4140								
	105						Bottom of Test Hole at 105.0 feet.	Pressure head measured at 23 psi with btm of hole at 105 ft when returned to grout hole on 7/16/15.

SOIL TEST HOLE TH_LOGS_#1_BEAR_RIVER.GPJ GERHART.GDT 6/25/18

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Project: Bear River Project **Project Location:** Fielding **Project Number:** 13GCI329	**Log of Test Hole TH-FD-03** Sheet 1 of 2

Date(s) Drilled	7/23/15, 7/27/15	Logged By	R. Buhler	Checked By	P. Gerhart
Drilling Method	Rotary wash with water	Drill Bit Size/Type	Drag bit with HW Casing	Total Depth Drilled (feet)	86.5 feet
Drill Rig Type	CME 75	Drilling Contractor	Bedke Geotechnical F.S.	Hammer Weight/ Drop(lbs/in.)	Automatic trip hammer
Apparent Groundwater Depth	31.3 feet; 9/30/2015	Latitude / Longitude	41.76341, -112.11659	Ground Surface Elevation (feet)	4309.0
Comments		Test Hole Backfill	Piezometer Well	Elevation Datum	NAVD88

Elevation, feet	Depth, feet	SAMPLES Type	Number	Sampling Resistance	Recovery, inches	Graphic Log	MATERIAL DESCRIPTION	FIELD NOTES
	0						SILT, with gravel, with sand - medium stiff, light brown to brown, moist, low plasticity (ML)	
	5	SPT	01	4-5-4-4 [9]	14.0			
4300	10	SPT	02	3-2-3-3 [5]	18.0		SILT with sand layer	
							CLAY, trace sand - stiff, trace sand, medium plasticity, light brown, orange mottling, (CL)	
	15	SH	03		21.0			
4290	20	SPT	04	4-6-8-7 [14]	24.0			
	25	SH	05		21.0		micaceous	
4280	30	SPT	06	4-4-7-9 [11]	24.0		▽	
	35	SH	07		18.0			
4270	40	SPT	08	7-7-9-13 [16]	24.0			
	45	SH	09		0.0			No recovery from Shelby tube. Drove spoon to recover some sample.
4260	50	SPT	11	11-16-21 -16 [37]	24.0		SILT, with sand - stiff to very stiff, gray, wet, low plasticity, interbedded layers of sandy silt to silty sand, (ML) Interbedded layers of Sandy SILT	

SOIL TEST HOLE TH_LOGS_#1_BEAR_RIVER.GPJ GERHART.GDT 6/25/18

GERHART COLE

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Project: Bear River Project
Project Location: Fielding
Project Number: 13GCI329

Log of Test Hole TH-FD-03

Elevation, feet	Depth, feet	Type	Number	Sampling Resistance	Recovery, inches	Graphic Log	MATERIAL DESCRIPTION	FIELD NOTES
	50	SAMPLES	SPT-12	5-7-14-17 [21]	24.0			
			SPT-13	9-6-10-14 [16]	20.0		CLAY, with sand - stiff, light bluish gray, wet, medium plasticity, numerous thin interbedded lenses of silty SAND, (CL)	
	55		SPT-14	4-6-20-19 [26]	24			
4250								
	60		P-15		20.0			
	65		SPT-16	4-7-7-11 [14]	24.0			
4240								
	70		P-17		17.0		Sand layer at 71.3 ft	
	75		SPT-18	1-4-5-7 [9]	24.0		CLAY, trace sand, - stiff, bluish gray, wet, high plasticity, (CH)	
4230								
	80		P-19		18			
	85		P-20		18			
4220	90						Bottom of Test Hole at 86.8 feet. Piezometer Data Screen 87 - 82 10-20 Sand 87 - 36 Bentonite Chips 36-0 ft	
	95							
4210	100							
	105							

SOIL TEST HOLE TH_LOGS_#1_BEAR_RIVER.GPJ GERHART.GDT 6/25/18

GERHART COLE

Unified Soil Classification System (USCS)

DRAFT

Material Types	Major Soil Divisions		Group Symbol and Legend	Typical Names
COARSE-GRAINED SOILS >50% retained on No. 200 sieve	GRAVELS >50% of coarse fraction retained on No. 4 Sieve	Clean GRAVELS (little or no fines)	GW	Well-Graded GRAVEL, GRAVEL-sand mixtures, few fines
			GP	Poorly-Graded GRAVEL, GRAVEL-sand mixtures, few fines
		GRAVELS with fines (appreciable amount of fines)	GM	Silty GRAVEL, GRAVEL-sand silt mixtures
			GC	Clayey GRAVEL, GRAVEL-sand clay mixtures
	SANDS >50% of coarse fraction passing the No. 4 sieve	Clean SANDS (little or no fines)	SW	Well-Graded SAND, SAND-gravel mixtures, few fines
			SP	Poorly-Graded SAND, SAND-gravel mixtures, few fines
		SANDS with fines (appreciable amount of fines)	SM	Silty SAND, SAND-silt mixtures
			SC	Clayey SAND, SAND-clay mixtures
FINE-GRAINED SOILS >50% Passing No. 200 Sieve	SILTS and CLAYS liquid limit < 50	Inorganic 1) CF > 30%: + Sandy/Gravelly 2) CF = 15-30% + with sand/gravel	CL	Lean CLAY, Gravelly/Sandy CLAY, low to med. plasticity
			ML	SILT, Gravelly/Sandy SILT, no to slight plasticity
		Organic	OL	Organic CLAY or SILT
	SILTS and CLAYS liquid limit < 50	Inorganic 1) CF > 30%: + Sandy/Gravelly 2) CF = 15-30% + with sand/gravel	CH	Fat CLAY, Gravelly/Sandy Fat CLAY, high plasticity
			MH	Elastic SILT, Gravelly/Sandy Elastic SILT, low to high plasticity
		Organic	OH	Organic CLAY or SILT
Highly orgainc soils		Primarily Organic Matter; Organic Odor	PT	PEAT
Boulders / Cobbles		> 50% (by volume) particles > 3"	COBBLES BOULDERS	Boulders (>12"); Cobbles (>3" and <12")

Other Material Symbols

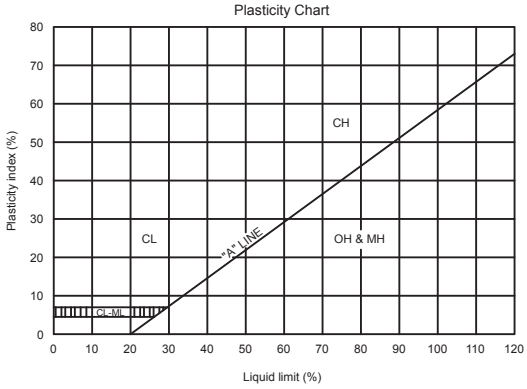
- Bedrock
- Asphalt
- Concrete
- Topsoil
- Fill

Sample Types

- Auger Cuttings
- Continuous sampler
- Grab Sample
- No Recovery
- Shelby Tube
- Standard Penetration Test (SPT)
- California Sampler
- Rock Core
- Modified California Sampler
- Other (see remarks)
- Piston Sampler (Shelby Tube)
- Split Spoon
- Vane Shear

Apparent water level

Measured water level



Descriptors for Coarse Grained Soils

Apparent Density	Dr (%)	SPT	MC	CAL
very loose	0-15	<4	<6	<8
loose	15-35	4-10	6-15	8-20
med. dense	35-65	10-30	15-42	20-56
dense	65-85	30-50	42-72	56-96
very dense	85-100	>50	>72	>96

Descriptors for Fine Grained Soils

Consistency	Su (psf)	SPT	MC	CAL
very soft	< 250	<2	<2	<2
soft	250-500	2-4	2-4	2-5
med. stiff	500-1000	4-8	4-10	5-11
stiff	1000-2000	8-15	10-19	11-22
very stiff	2000-4000	15-30	19-37	22-45
hard	>4000	>30	>37	>45

SPT - Standard split spoon (SPT): 2" OD, 1.375" ID
MC - Modified California: 2.5" OD, 1.875" ID
CAL - California: 3" OD, 2.375" ID

Stratification

Description	Criteria
Seam	1/16" to 1/2"
Layer	1/2" to 12"
Occasional	<= 1 per ft. thickness
Frequent	> 1 per ft. thickness

Modifiers

Description	Est. (%)
Trace	<5
Some	5-12
With	>12

Descriptors for Moisture

Description	Criteria
Dry	Absence of moisture, dusty, dry to the touch
Moist	Damp but no visible water
Wet	Visible free water, usually soil is below water table

Descriptors for Particle Size

Description	Criteria
Boulder	>12" : larger than a basketball
Cobble	3-12" : larger than a grapefruit
Coarse Gravel	3/4-3" : larger than a grape
Fine Gravel	No.4-3/4" : larger than a pea
Coarse Sand	No.10-4 : larger than rock salt grain
Medium Sand	No.40-4 : larger than window screen opening
Fine Sand	No.200-40 : larger than a sugar grain

Descriptios for Particle Angularity

Description	Criteria
Angular	Sharp edges, rel. plane sides, unpolished surface
Subangular	Similar to angular, but with rounded edges
Subrounded	Nearly plane sides, well-rounded corners & edges
Rounded	Smoothly curved sides and no edges

Abbreviated Soil Classification Symbols (after ASTM D2488 X.5)

Prefix	Suffix
s = sandy	s = with sand
g = gravelly	g = with gravel
	c = with cobbles
	b = with boulders

Abbreviated system for supplementary presentations when complete description is referenced. Examples:

Group Symbol and Full Name	Abbreviated
Sandy Lean CLAY (CL)	s(CL)
Poorly Graded SAND with silt and gravel	(SP-SM)g
Poorly Graded GRAVEL with sand, cobbles, and boulders (GP)	(GP)scb
Gravelly SILT with sand and cobbles (ML)	g(ML)sc

General Notes:
1) Strata graphic lines on the logs represent approximate boundaries.
2) No warranty is provided as to the continuity of soil conditions between points explored and sample locations.
3) Logs represent soil conditions observed at the point of exploration on the date indicated.
4) Visual methods were used to classify the materials in general accordance with the Unified Soils Classification Systems; actual designations based on laboratory methods may vary.

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Legend to Soil Descriptions

Appendix B Interpretative Laboratory Test Results – Fielding

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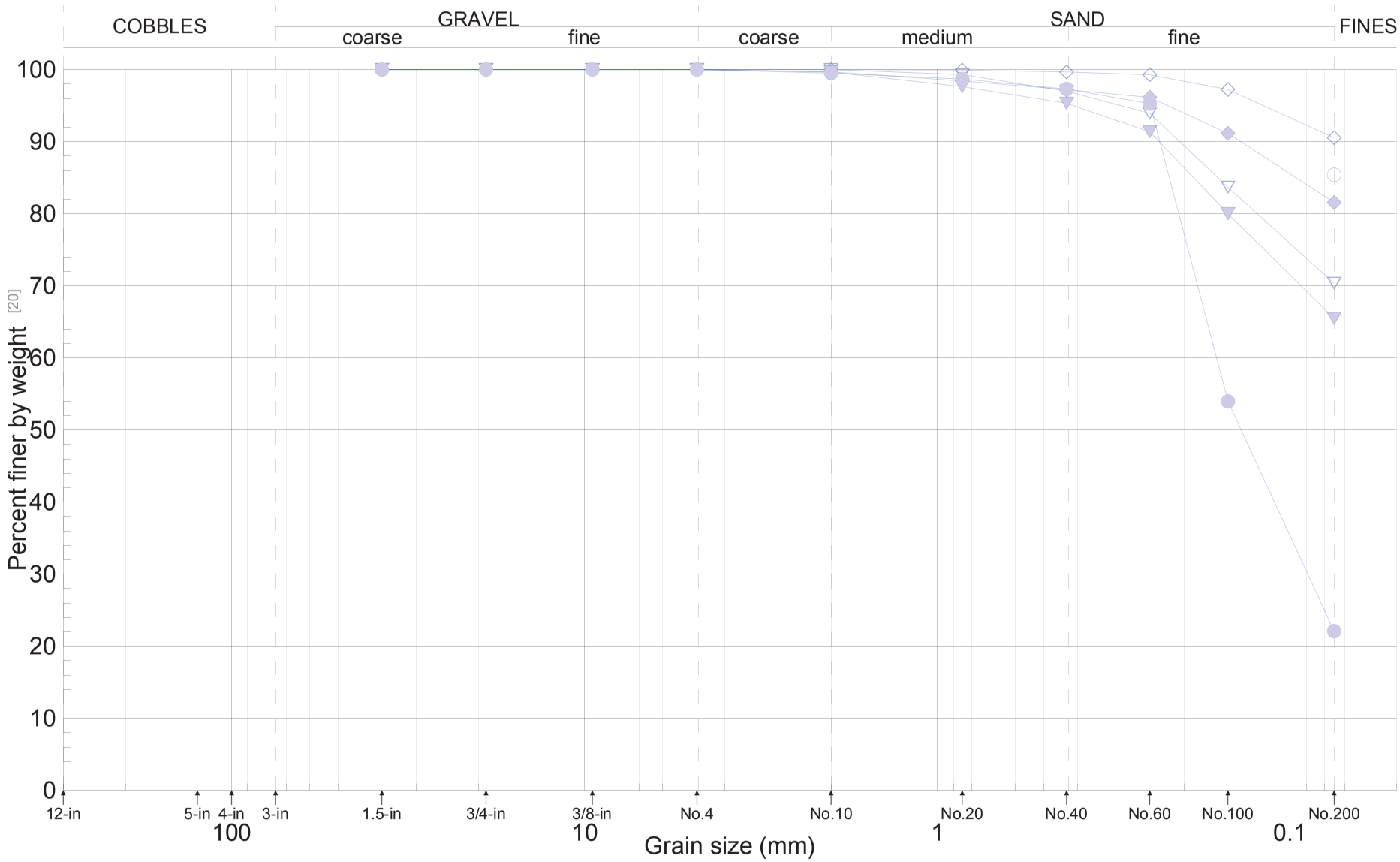

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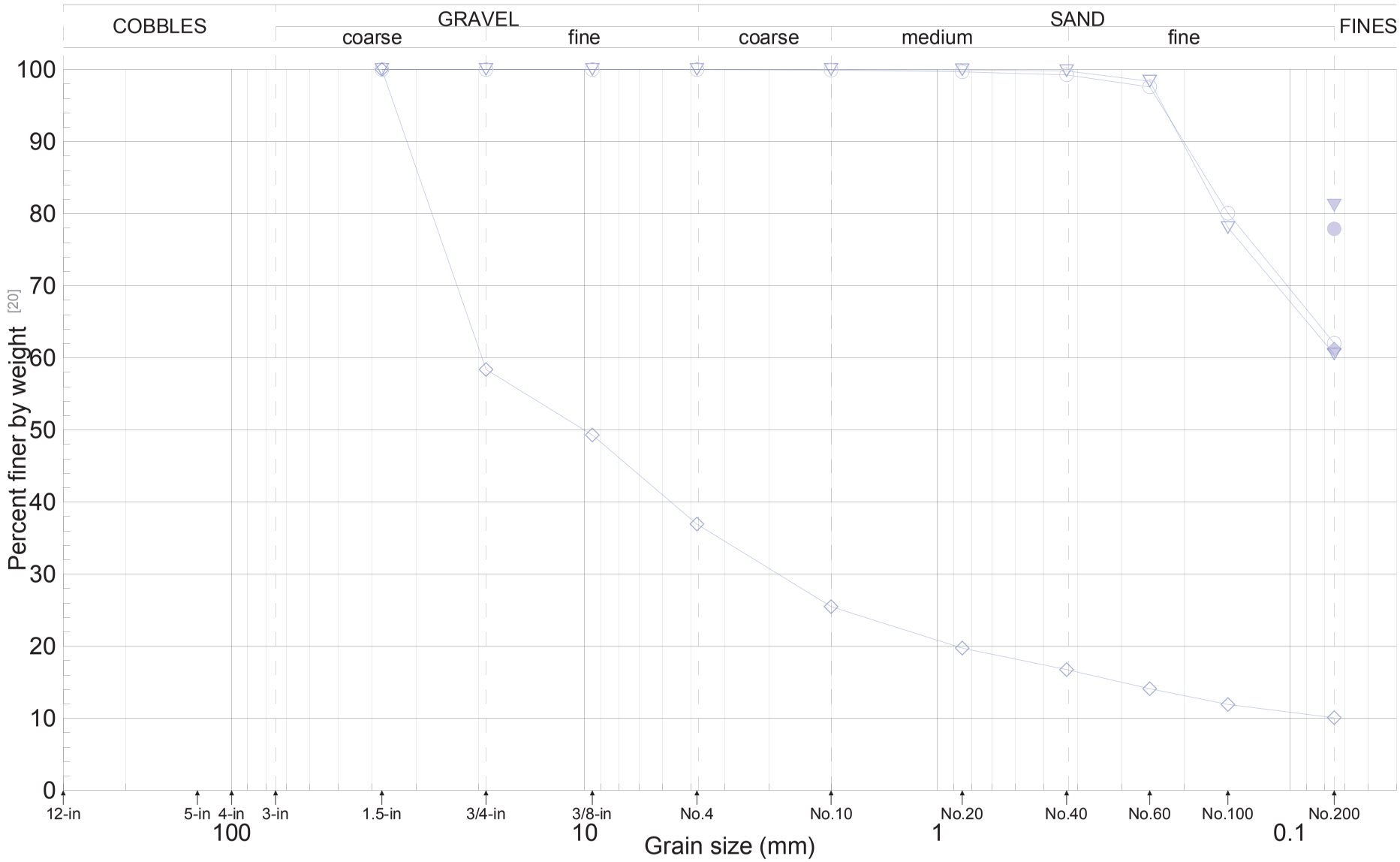
Grain-Size Analysis -TH-FD-01

Bear River Project Concept Study- Fielding (13GCI329)

Figure B-1a

DRAFT



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Grain-Size Analysis

Bear River Project Concept Study- Fielding (13GCI329)

Figure B-1b

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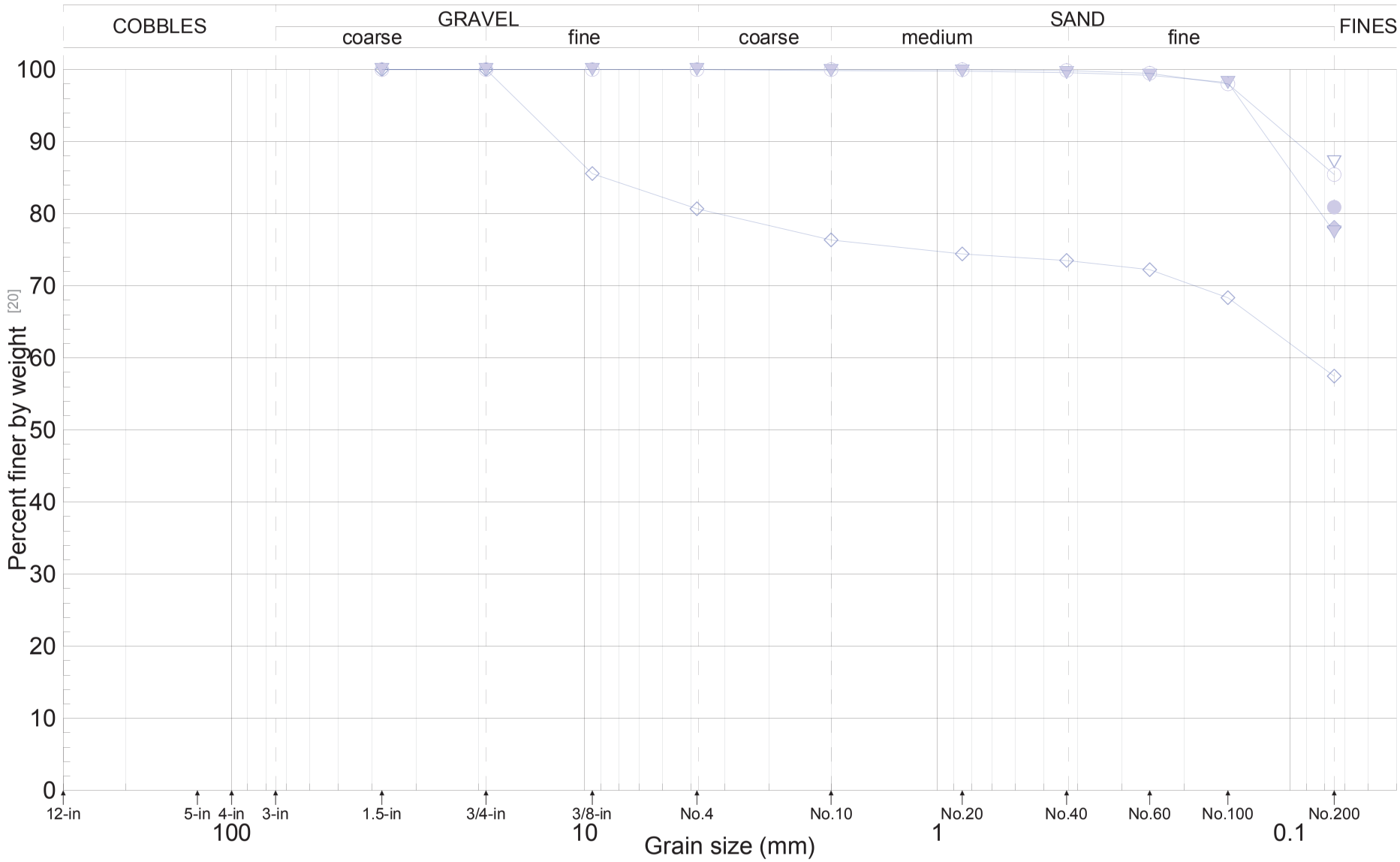


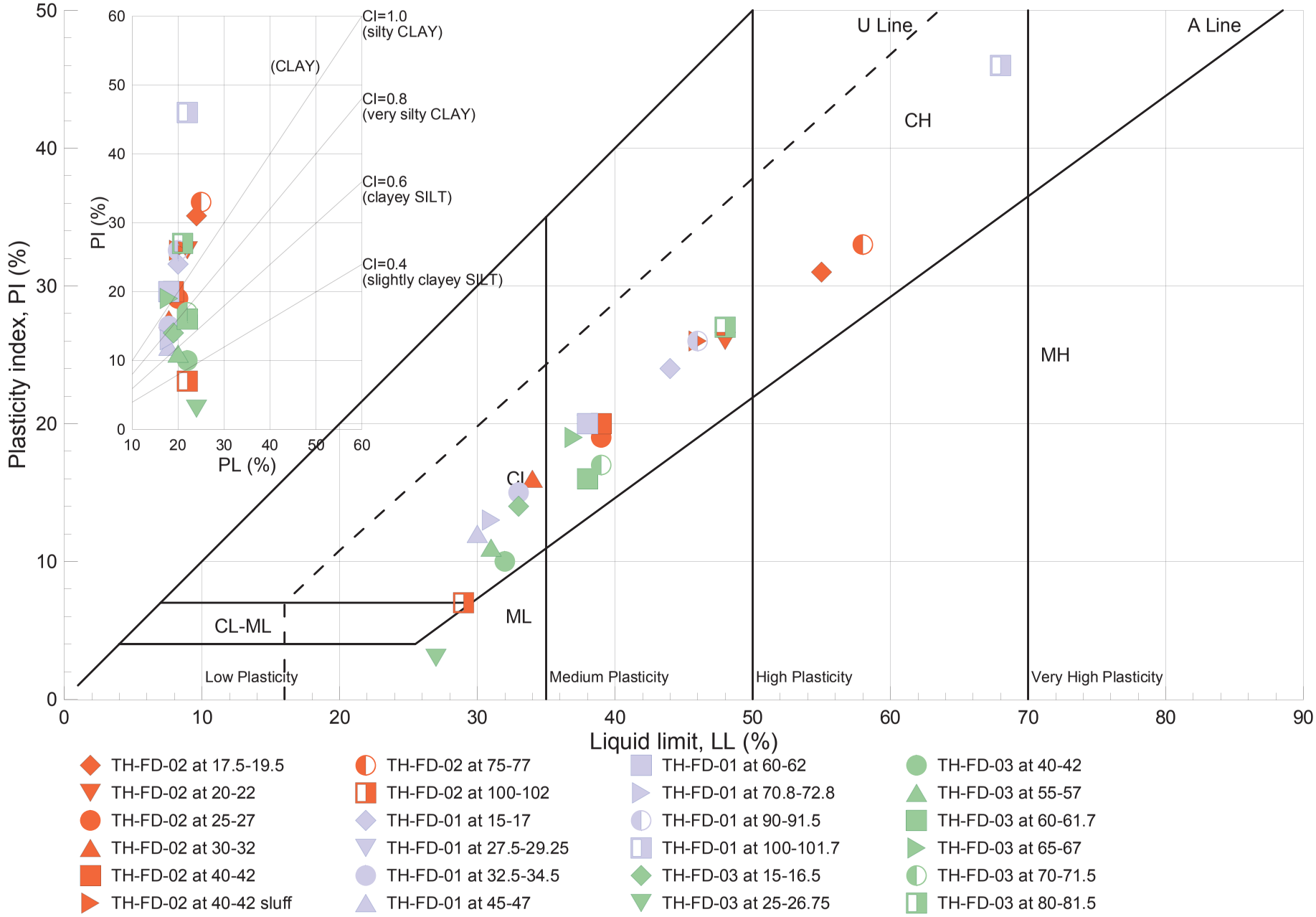
GERHART COLE

Grain-Size Analysis -TH-FD-03

Bear River Project Concept Study- Fielding (13GCI329)

Figure B-1c

DRAFT



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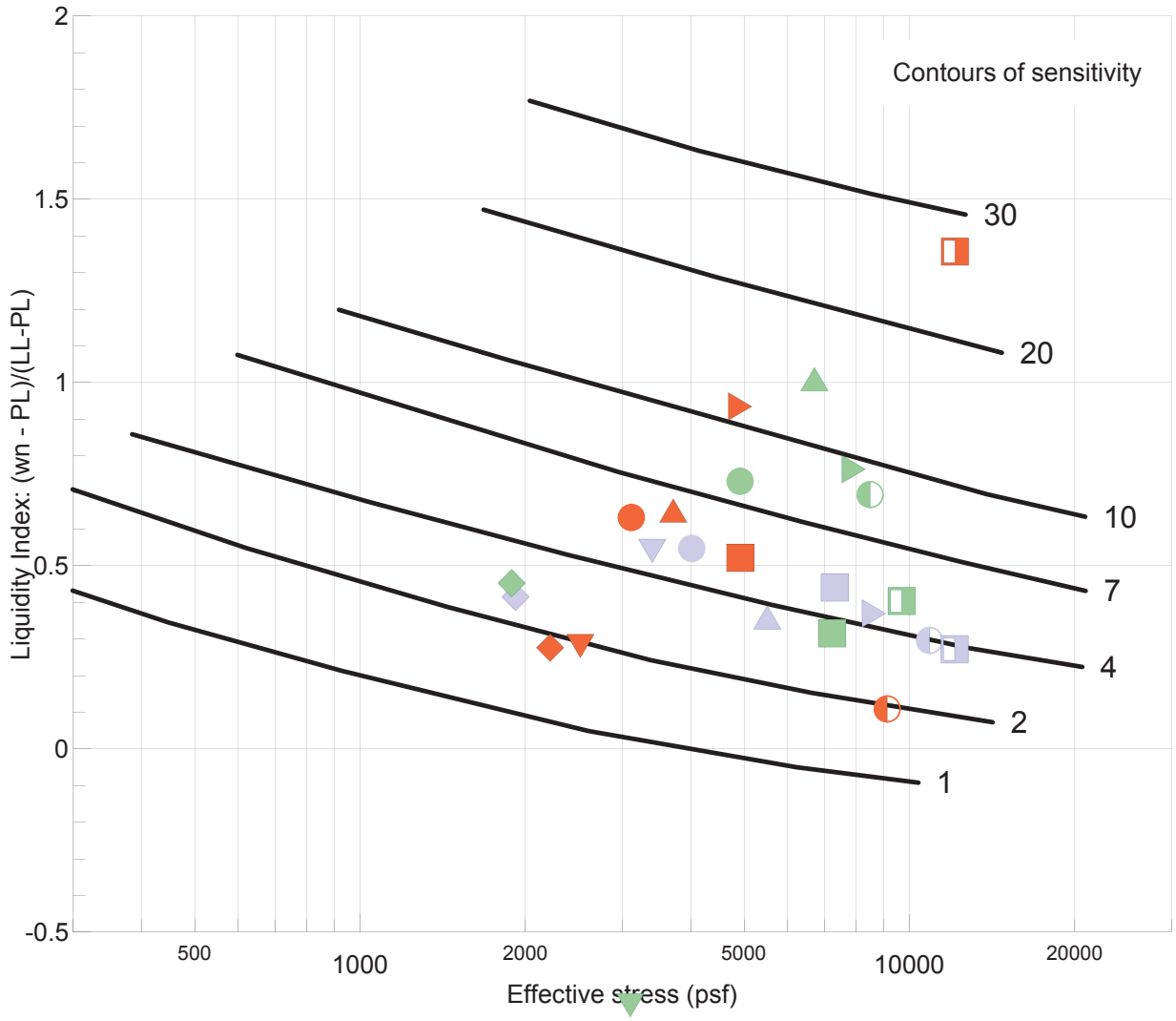
Casagrande's Plasticity Chart (Atterberg Limits)

Bear River Project Concept Study- Fielding (13GCI329)

Figure B-2

DRAFT



- TH-FD-02 at 17.5-19.5
- TH-FD-02 at 20-22
- TH-FD-02 at 25-27
- TH-FD-02 at 30-32
- TH-FD-02 at 40-42
- TH-FD-02 at 40-42 sluff
- TH-FD-02 at 75-77
- TH-FD-02 at 100-102
- TH-FD-01 at 15-17
- TH-FD-01 at 27.5-29.25
- TH-FD-01 at 32.5-34.5
- TH-FD-01 at 45-47
- TH-FD-01 at 60-62
- TH-FD-01 at 70.8-72.8
- TH-FD-01 at 90-91.5
- TH-FD-01 at 100-101.7
- TH-FD-03 at 15-16.5
- TH-FD-03 at 25-26.75
- TH-FD-03 at 40-42
- TH-FD-03 at 55-57
- TH-FD-03 at 60-61.7
- TH-FD-03 at 65-67
- TH-FD-03 at 70-71.5
- TH-FD-03 at 80-81.5

GERHART COLE	Sensitivity, LI, and Effective Stress Relationships (Mitchell,1993)	
	Fielding (13GCI329)	Figure B-3

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One-Dimensional Consolidation Properties of Soils
After ASTM D2435 and USBR 5700

GERHART COLE

Project:	**Bear River - Fielding**	**TH/TP/Sample:**	**TH-FD-03**
No:	**13GCI329**	**Depth:**	**80-81.5 (81.25)**
Location:	Box Elder County, Utah	Sample description:	dark bluish gray clay
Date:	31-Jul-15	USCS classification:	CL
Tested by:	zmg	Sample type:	Rel. undisturbed, Shelby Tube
Reduced by:	zmg	Inundation stress (psf):	100, completion
Checked by:	bjb	Swell pressure (psf):	284.385
Comments:		Test method:	B
		Preparation procedure:	trimmed

Phase Relationships

	Initial	Final
Height, H (in)	1.0000	0.8704
Height, H (cm)	2.540	2.211
Dia., D (in)	2.500	2.500
Dia., D (cm)	6.350	6.350
Wt. rings + wet soil (g)	366.04	358.24
Wt. rings (g)	214.85	214.85
Wet soil + tare (g)	378.32	288.30
Dry soil + tare (g)	315.62	257.30
Tare (g)	119.02	145.97
Moisture cont., w (%)	31.9	27.8
Gs, assumed	2.75	2.75
Mass total (g)	151.2	143.4
Mass of solids (g)	114.6	114.6
Volume (cm^3)	80.4	70.0
Vol. of water (cm^3)	36.6	28.8
Vol. of solids (cm^3)	41.7	41.7
Vol. of voids (cm^3)	38.8	28.3
Vol. of air (cm^3)	2.2	-0.4
Area, A (cm^2)	31.7	31.7
Ht. solids, Hs (cm)	1.316	1.316
Void ratio, e	0.930	0.680
Porosity, n	0.482	0.405
Vol.moisture, T	0.454	0.411
Saturation, S (%)	94	102
Dry density (gm/cm^3)	1.425	1.637
Wet unit wt., gm (pcf)	117.3	130.7
Dry unit wt., gd (pcf)	89.0	102.2

Vertical Stress - Deformation Results

Vert. stress (psf)	Corr. Dial, dfc [a] (in)	Hc [b] (in)	Vert. strain, ev	Load duration (min)	t-90 (min)	Hdr (in)	Cv (ft^2/day)
Seating	0.0000	1.0000	0.0000	0			
100	0.0002	0.9998	0.0002	240			
800	0.0051	0.9949	0.0051	180			
1,600	0.0122	0.9878	0.0122	240			
3,200	0.0215	0.9785	0.0215	240	19.9	0.49157	0.10
6,400	0.0356	0.9644	0.0356	240	19.9	0.48572	0.10
12,800	0.0585	0.9415	0.0585	240	19.9	0.47647	0.09
25,600	0.1093	0.8907	0.1093	300	39.8	0.45804	0.04
51,200	0.1655	0.8345	0.1655	300	50.1	0.43129	0.03
102,400	0.2167	0.7833	0.2167	300	50.1	0.40444	0.03
51,200	0.2122	0.7878	0.2122	120			
12,800	0.1933	0.8067	0.1933	120			
3,200	0.1723	0.8277	0.1723	120			
800	0.1520	0.8480	0.1520	120			
200	0.1296	0.8704	0.1296	240			

Data Interpretation Summary

Preconsolidation stress, s'p (psf)	---	
Compression ratio, CR	---	To be determined by the Geotechnical Engineer
Recompression ratio, RR	---	

Notes:
[a] Dfc = end of increment deformation corrected for machine, porous stone, and filter paper deformation
[b] Hc = height at end of consolidation of each vert. stress
[c] Hdr = height at 50 consolidation computed from D90 using sq-root time method
[d] Cv computed from Taylor (1948) aquare root of time method (note 1 in^2/min = 10 ft^2/day)

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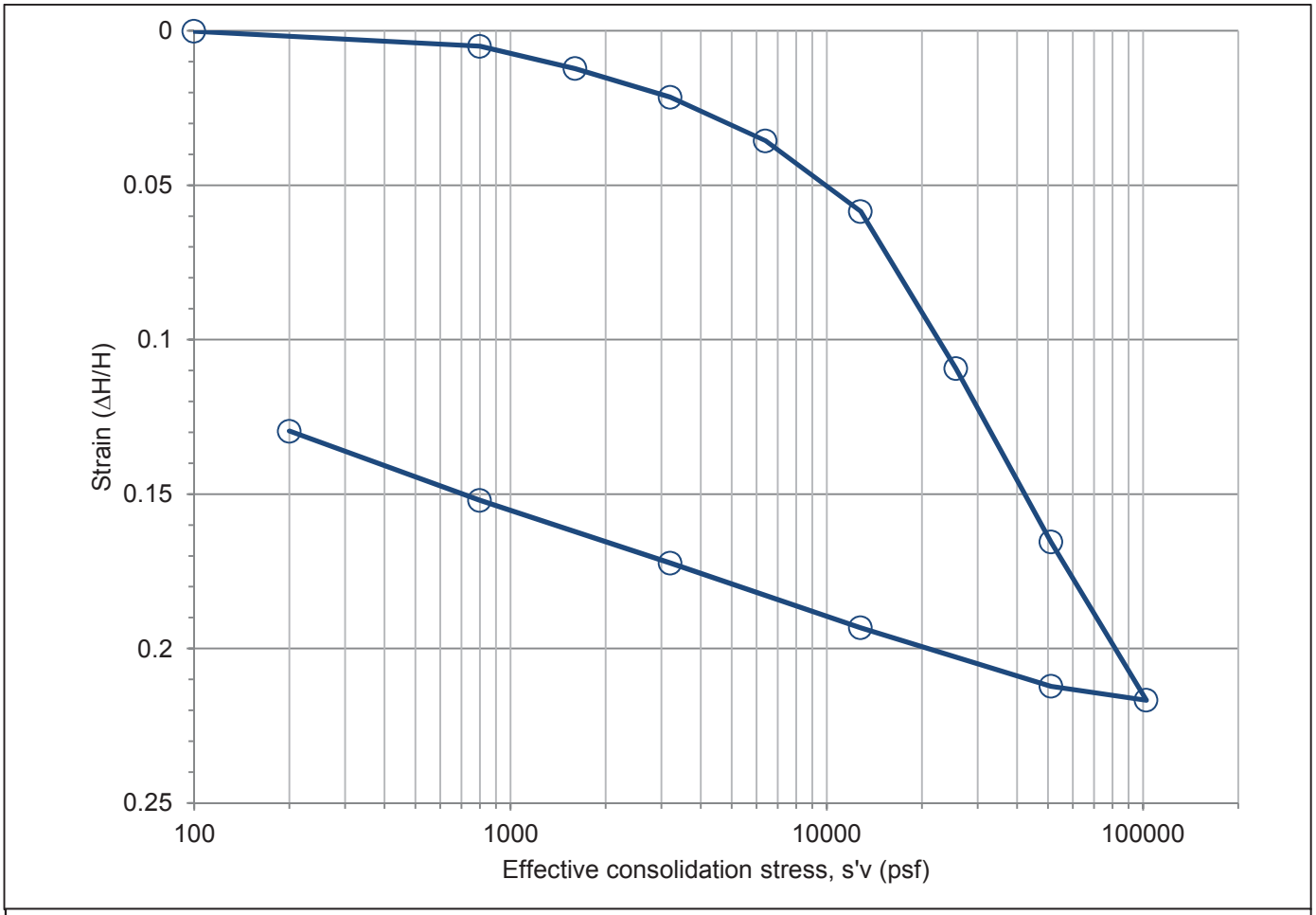
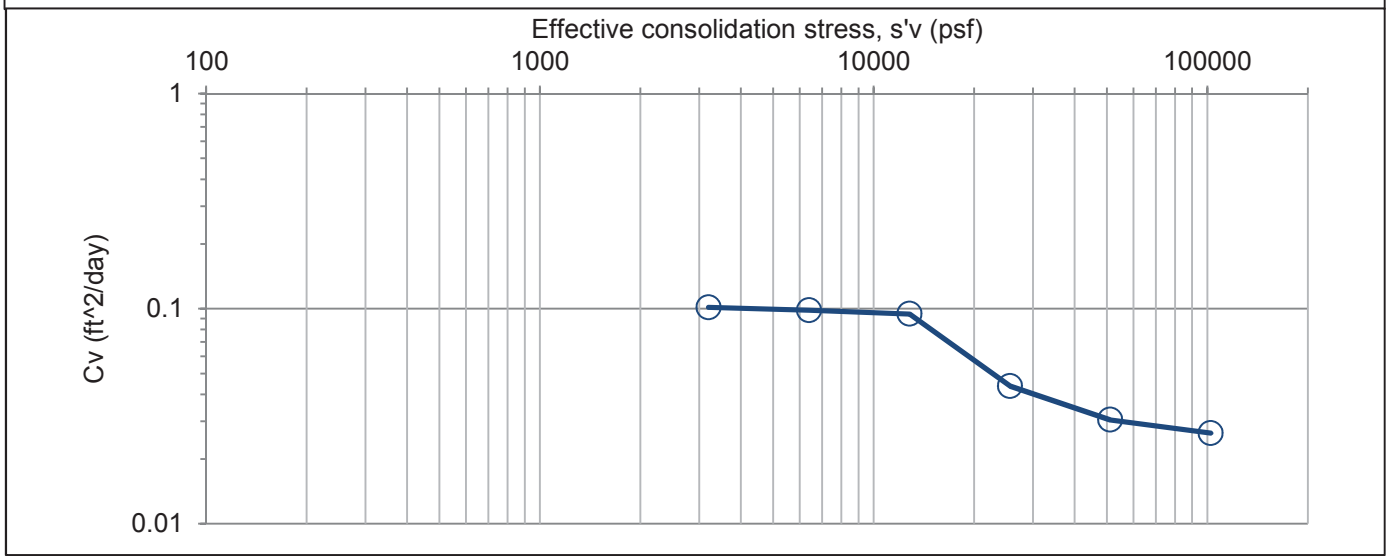
One-Dimensional Consolidation Properties of Soils
After ASTM D2435 and USBR 5700

GERHART COLE

Project: Bear River - Fielding
No: 13GCI329

TH/TP/Sample: TH-FD-03
Depth: 80-81.5 (81.25)





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One-Dimensional Consolidation Properties of Soils
After ASTM D2435 and USBR 5700

GERHART COLE

Project:	**Bear River - Fielding**	**TH/TP/Sample:**	**TH-FD-03**
No:	**13GCI329**	**Depth:**	**70-71.5 (71)**
Location:	Box Elder County, Utah	Sample description:	greenish gray clay
Date:	03-Aug-15	USCS classification:	CL
Tested by:	zmg	Sample type:	Rel. undisturbed, Shelby Tube
Reduced by:	zmg	Inundation stress (psf):	100, completion
Checked by:	bjb	Swell pressure (psf):	146.868
Comments:		Test method:	B
		Preparation procedure:	trimmed

Phase Relationships

	Initial	Final
Height, H (in)	1.0000	0.9004
Height, H (cm)	2.540	2.287
Dia., D (in)	2.500	2.500
Dia., D (cm)	6.350	6.350
Wt. rings + wet soil (g)	366.61	360.71
Wt. rings (g)	214.83	214.83
Wet soil + tare (g)	262.20	272.25
Dry soil + tare (g)	228.09	239.90
Tare (g)	127.26	126.69
Moisture cont., w (%)	33.8	28.6
Gs, assumed	2.75	2.75
Mass total (g)	151.8	145.9
Mass of solids (g)	113.4	113.4
Volume (cm^3)	80.4	72.4
Vol. of water (cm^3)	38.4	32.5
Vol. of solids (cm^3)	41.2	41.2
Vol. of voids (cm^3)	39.2	31.2
Vol. of air (cm^3)	0.8	-1.3
Area, A (cm^2)	31.7	31.7
Ht. solids, Hs (cm)	1.302	1.302
Void ratio, e	0.950	0.756
Porosity, n	0.487	0.431
Vol.moisture, T	0.477	0.448
Saturation, S (%)	98	104
Dry density (gm/cm^3)	1.410	1.566
Wet unit wt., gm (pcf)	117.8	125.7
Dry unit wt., gd (pcf)	88.0	97.8

Vertical Stress - Deformation Results

Vert. stress (psf)	Corr. Dial, dfc [a] (in)	Hc [b] (in)	Vert. strain, ev	Load duration (min)	t-90 (min)	Hdr (in)	Cv (ft^2/day)
Seating	0.0000	1.0000	0.0000	0			
100	0.0003	0.9997	0.0003	187			
400	0.0026	0.9974	0.0026	32			
800	0.0054	0.9946	0.0054	37			
1,600	0.0115	0.9885	0.0115	96	6.5	0.49576	0.32
3,200	0.0165	0.9835	0.0165	137	6.5	0.49299	0.32
6,400	0.0254	0.9746	0.0254	240	4.1	0.48953	0.49
12,800	0.0443	0.9557	0.0443	240	6.4	0.48258	0.30
25,600	0.1043	0.8957	0.1043	240	25.3	0.46285	0.07
51,200	0.1614	0.8386	0.1614	172	20.1	0.43359	0.08
25,600	0.1574	0.8426	0.1574	16			
6,400	0.1404	0.8596	0.1404	54			
1,600	0.1240	0.8760	0.1240	40			
400	0.0996	0.9004	0.0996	126			

Data Interpretation Summary

Preconsolidation stress, s'p (psf)	---	
Compression ratio, CR	---	To be determined by the Geotechnical Engineer
Recompression ratio, RR	---	

Notes:
[a] Dfc = end of increment deformation corrected for machine, porous stone, and filter paper deformation
[b] Hc = height at end of consolidation of each vert. stress
[c] Hdr = height at 50 consolidation computed from D90 using sq-root time method
[d] Cv computed from Taylor (1948) aquare root of time method (note 1 in^2/min = 10 ft^2/day)

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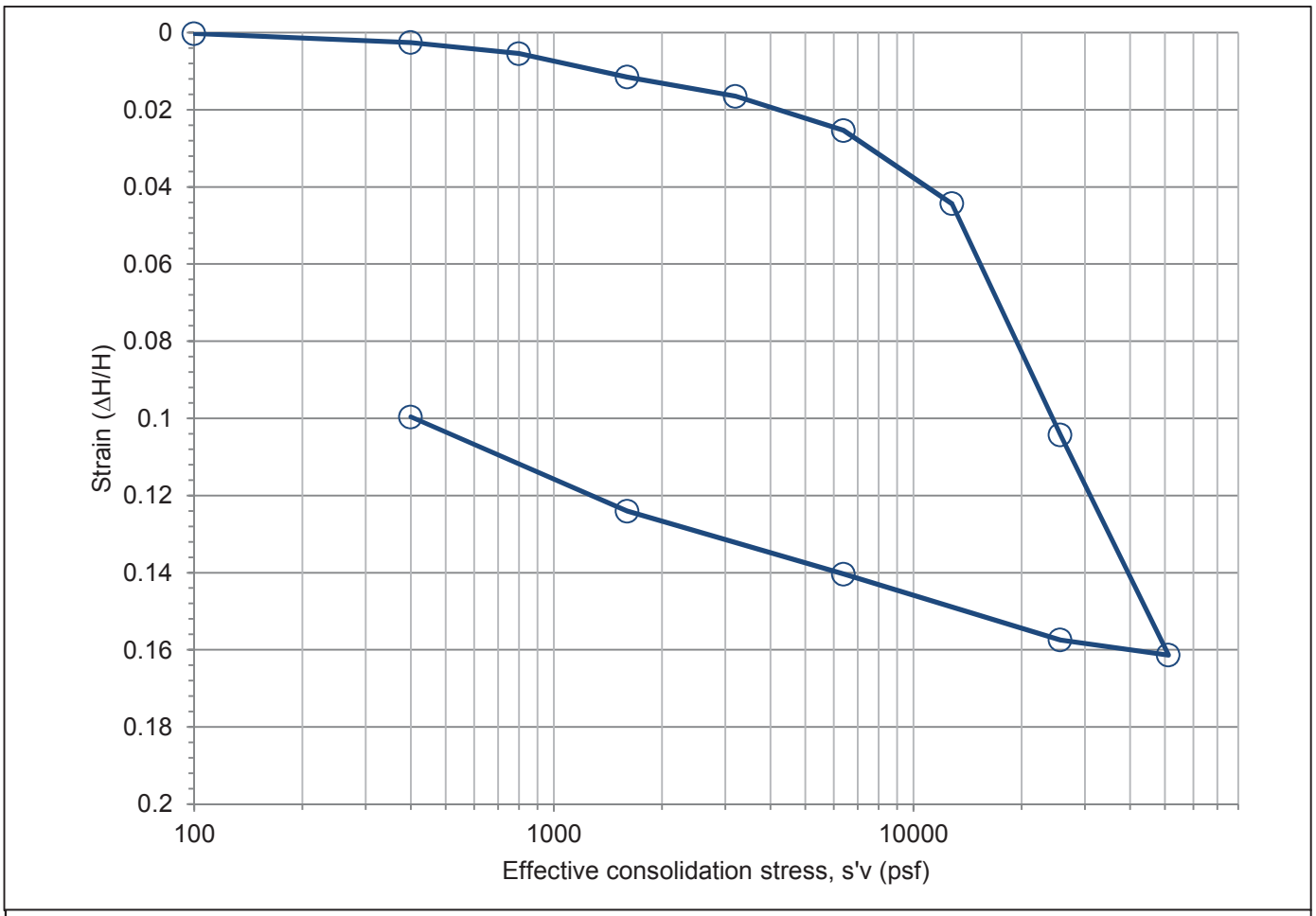
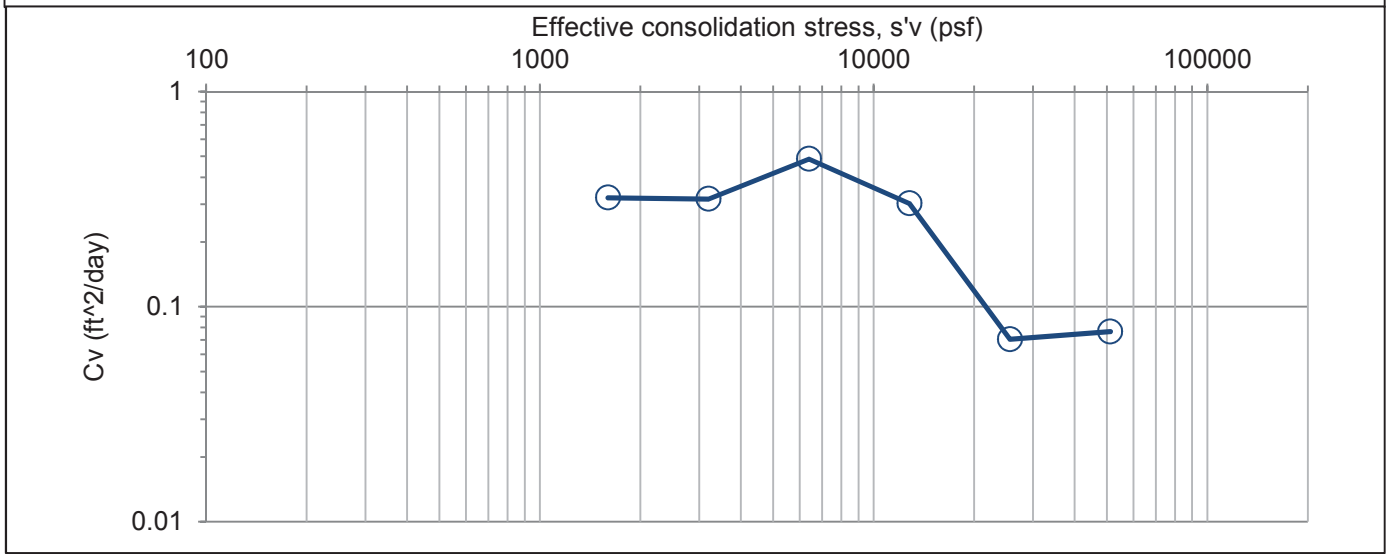
One-Dimensional Consolidation Properties of Soils
After ASTM D2435 and USBR 5700

GERHART COLE

Project: Bear River - Fielding
No: 13GCI329

TH/TP/Sample: TH-FD-03
Depth: 70-71.5 (71)





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One-Dimensional Consolidation Properties of Soils
After ASTM D2435 and USBR 5700

GERHART COLE

Project:	**Bear River - Fielding**	**TH/TP/Sample:**	**TH-FD-03**
No:	**13GCI329**	**Depth:**	**35-36.5 (36.25)**
Location:	Box Elder County, Utah	Sample description:	olive brown silt
Date:	31-Jul-15	USCS classification:	not requested
Tested by:	zmg	Sample type:	Rel. undisturbed, Shelby Tube
Reduced by:	zmg	Inundation stress (psf):	100, beginning
Checked by:	bjb	Swell pressure (psf):	< 100
Comments:		Test method:	B
		Preparation procedure:	trimmed

Phase Relationships

	Initial	Final
Height, H (in)	1.0000	0.8909
Height, H (cm)	2.540	2.263
Dia., D (in)	2.500	2.500
Dia., D (cm)	6.350	6.350
Wt. rings + wet soil (g)	372.12	365.15
Wt. rings (g)	214.52	214.52
Wet soil + tare (g)	227.16	277.50
Dry soil + tare (g)	206.60	251.01
Tare (g)	120.72	127.24
Moisture cont., w (%)	23.9	21.4
Gs, assumed	2.75	2.75
Mass total (g)	157.6	150.6
Mass of solids (g)	127.2	127.2
Volume (cm^3)	80.4	71.7
Vol. of water (cm^3)	30.4	23.5
Vol. of solids (cm^3)	46.2	46.2
Vol. of voids (cm^3)	34.2	25.4
Vol. of air (cm^3)	3.8	2.0
Area, A (cm^2)	31.7	31.7
Ht. solids, Hs (cm)	1.460	1.460
Void ratio, e	0.740	0.550
Porosity, n	0.425	0.355
Vol.moisture, T	0.378	0.328
Saturation, S (%)	89	92
Dry density (gm/cm^3)	1.581	1.774
Wet unit wt., gm (pcf)	122.3	134.5
Dry unit wt., gd (pcf)	98.7	110.8

Vertical Stress - Deformation Results

Vert. stress (psf)	Corr. Dial, dfc [a] (in)	Hc [b] (in)	Vert. strain, ev	Load duration (min)	t-90 (min)	Hdr (in)	Cv (ft^2/day)
Seating	0.0000	1.0000	0.0000	0			
100	-0.0003	1.0003	-0.0003	120			
200	0.0079	0.9921	0.0079	120			
400	0.0137	0.9863	0.0137	120			
800	0.0219	0.9781	0.0219	240	2.6	0.49108	0.78
1,600	0.0320	0.9680	0.0320	240	5.1	0.48652	0.39
3,200	0.0425	0.9575	0.0425	240	2.6	0.48138	0.74
6,400	0.0580	0.9420	0.0580	240	2.6	0.47487	0.72
12,800	0.0780	0.9220	0.0780	240	1.7	0.46599	1.06
25,600	0.1033	0.8967	0.1033	240	2.6	0.45466	0.65
51,200	0.1336	0.8664	0.1336	240	2.1	0.44077	0.75
25,600	0.1318	0.8682	0.1318	60			
6,400	0.1264	0.8736	0.1264	60			
1,600	0.1171	0.8829	0.1171	120			
400	0.1091	0.8909	0.1091	44			

Data Interpretation Summary

Preconsolidation stress, s'p (psf)	---	
Compression ratio, CR	---	To be determined by the Geotechnical Engineer
Recompression ratio, RR	---	

Notes:
[a] Dfc = end of increment deformation corrected for machine, porous stone, and filter paper deformation
[b] Hc = height at end of consolidation of each vert. stress
[c] Hdr = height at 50 consolidation computed from D90 using sq-root time method
[d] Cv computed from Taylor (1948) aquare root of time method (note 1 in^2/min = 10 ft^2/day)

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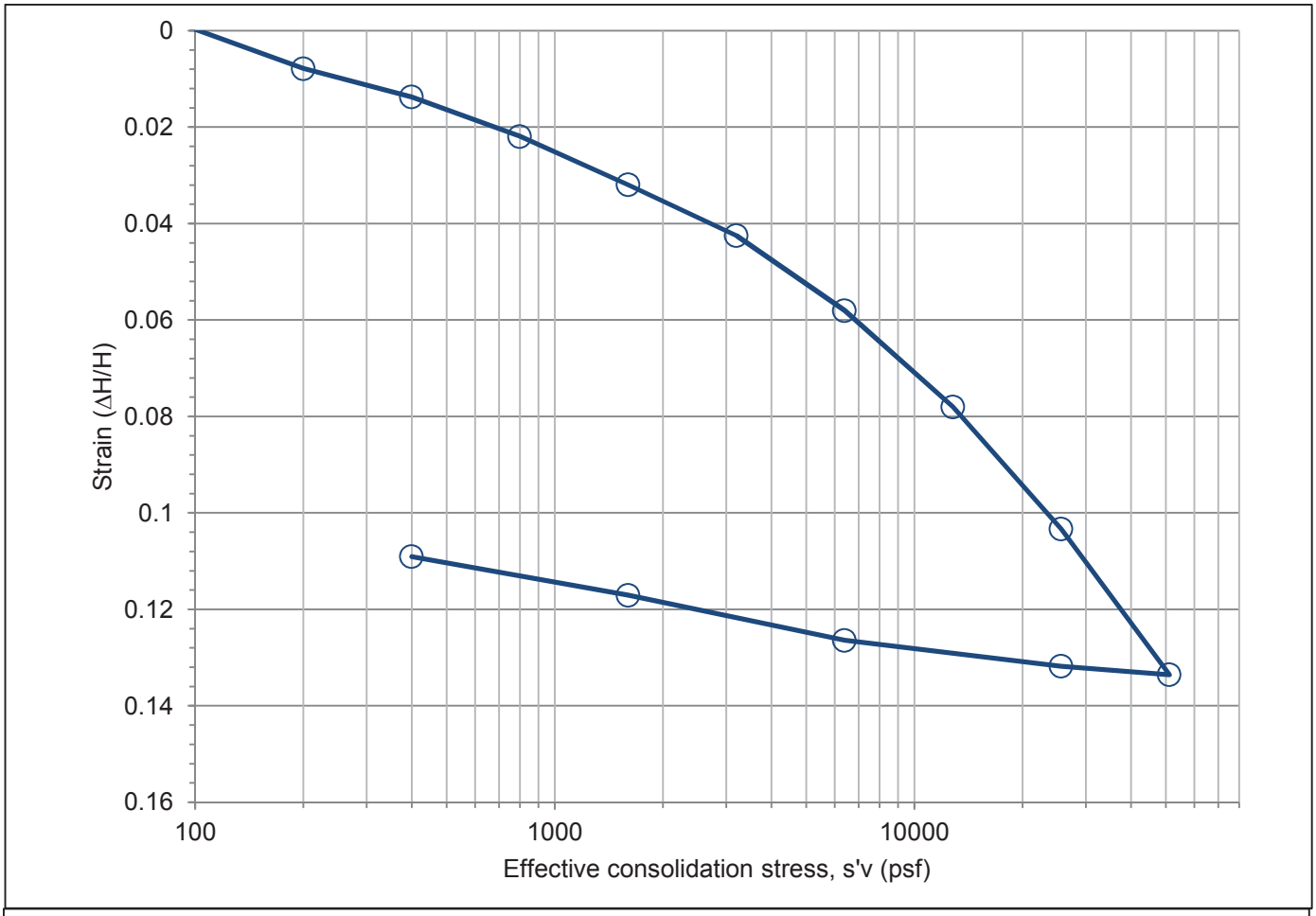
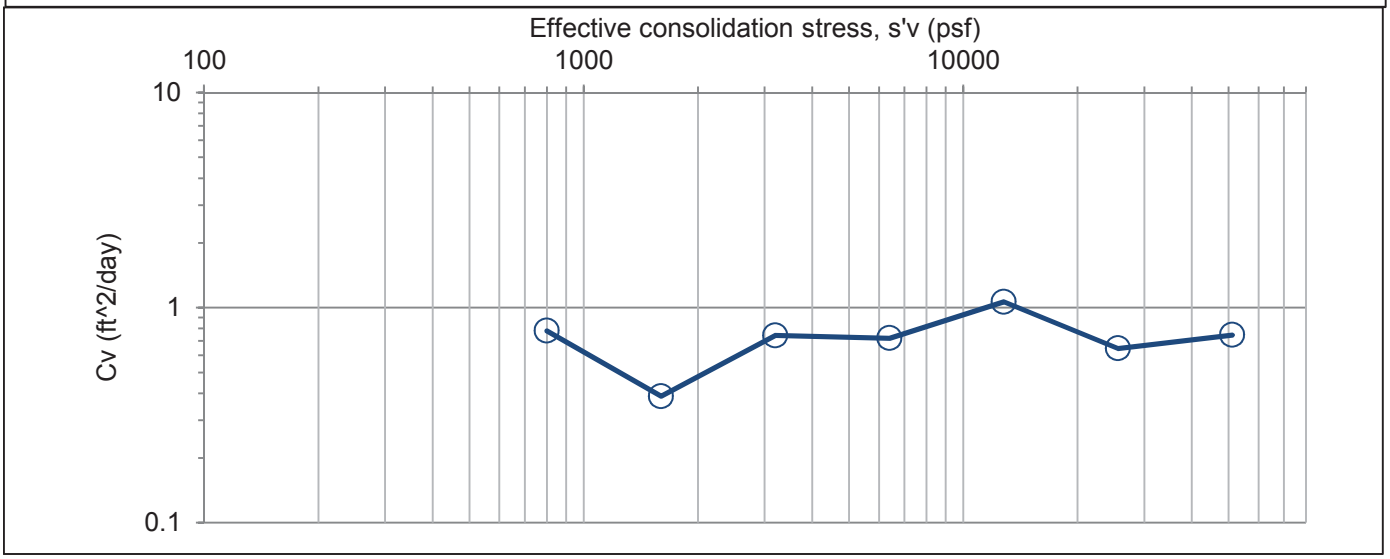
One-Dimensional Consolidation Properties of Soils
After ASTM D2435 and USBR 5700

GERHART COLE

Project: Bear River - Fielding
No: 13GCI329

TH/TP/Sample: TH-FD-03
Depth: 35-36.5 (36.25)





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One-Dimensional Consolidation Properties of Soils
After ASTM D2435 and USBR 5700

GERHART COLE

Project:	**Bear River - Fielding**	**TH/TP/Sample:**	**TH-FD-03**
No:	**13GCI329**	**Depth:**	**25-26.75**
Location:	Box Elder County, Utah	Sample description:	olive brown sandy silt
Date:	31-Jul-15	USCS classification:	ML
Tested by:	zmg	Sample type:	Rel. undisturbed, Shelby Tube
Reduced by:	zmg	Inundation stress (psf):	100, completion
Checked by:	bjb	Swell pressure (psf):	< 100
Comments:		Test method:	B
		Preparation procedure:	trimmed

Phase Relationships

	Initial	Final
Height, H (in)	1.0000	0.9494
Height, H (cm)	2.540	2.412
Dia., D (in)	2.500	2.500
Dia., D (cm)	6.350	6.350
Wt. rings + wet soil (g)	373.09	372.33
Wt. rings (g)	214.52	214.52
Wet soil + tare (g)	242.48	276.56
Dry soil + tare (g)	221.66	247.20
Tare (g)	126.72	119.24
Moisture cont., w (%)	21.9	22.9
Gs, assumed	2.75	2.75
Mass total (g)	158.6	157.8
Mass of solids (g)	130.1	130.1
Volume (cm^3)	80.4	76.4
Vol. of water (cm^3)	28.5	27.8
Vol. of solids (cm^3)	47.3	47.3
Vol. of voids (cm^3)	33.1	29.1
Vol. of air (cm^3)	4.6	1.3
Area, A (cm^2)	31.7	31.7
Ht. solids, Hs (cm)	1.493	1.493
Void ratio, e	0.701	0.615
Porosity, n	0.412	0.381
Vol.moisture, T	0.355	0.363
Saturation, S (%)	86	95
Dry density (gm/cm^3)	1.617	1.703
Wet unit wt., gm (pcf)	123.1	130.7
Dry unit wt., gd (pcf)	100.9	106.3

Vertical Stress - Deformation Results

Vert. stress (psf)	Corr. Dial, dfc [a] (in)	Hc [b] (in)	Vert. strain, ev	Load duration (min)	t-90 (min)	Hdr (in)	Cv (ft^2/day)
Seating	0.0000	1.0000	0.0000	0			
100	0.0000	1.0000	0.0000	32			
200	0.0043	0.9957	0.0043	34			
400	0.0080	0.9920	0.0080	10			
800	0.0119	0.9881	0.0119	33	5.1	0.49501	0.40
1,600	0.0163	0.9837	0.0163	10	1.4	0.49294	1.49
3,200	0.0213	0.9787	0.0213	8	2.1	0.49061	0.95
6,400	0.0279	0.9721	0.0279	12	8.1	0.4877	0.24
12,800	0.0346	0.9654	0.0346	24	10.1	0.48437	0.19
25,600	0.0454	0.9546	0.0454	51	3.3	0.48	0.57
51,200	0.0638	0.9362	0.0638	32	12.7	0.47269	0.14
25,600	0.0627	0.9373	0.0627	3			
6,400	0.0598	0.9402	0.0598	4			
1,600	0.0556	0.9444	0.0556	4			
400	0.0506	0.9494	0.0506	4			

Data Interpretation Summary

Preconsolidation stress, s'p (psf)	---	
Compression ratio, CR	---	To be determined by the Geotechnical Engineer
Recompression ratio, RR	---	

Notes:
[a] Dfc = end of increment deformation corrected for machine, porous stone, and filter paper deformation
[b] Hc = height at end of consolidation of each vert. stress
[c] Hdr = height at 50 consolidation computed from D90 using sq-root time method
[d] Cv computed from Taylor (1948) aquare root of time method (note 1 in^2/min = 10 ft^2/day)

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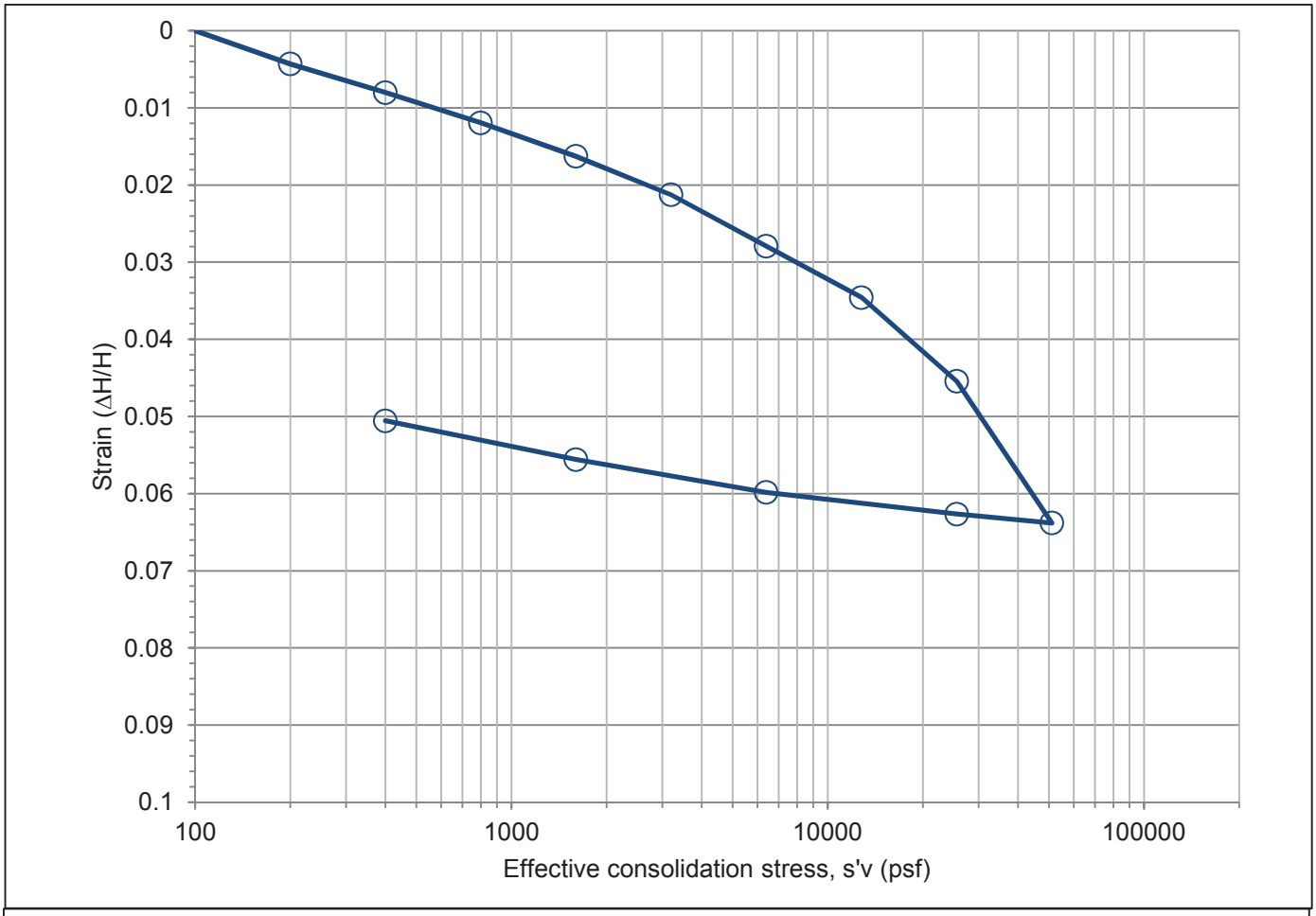
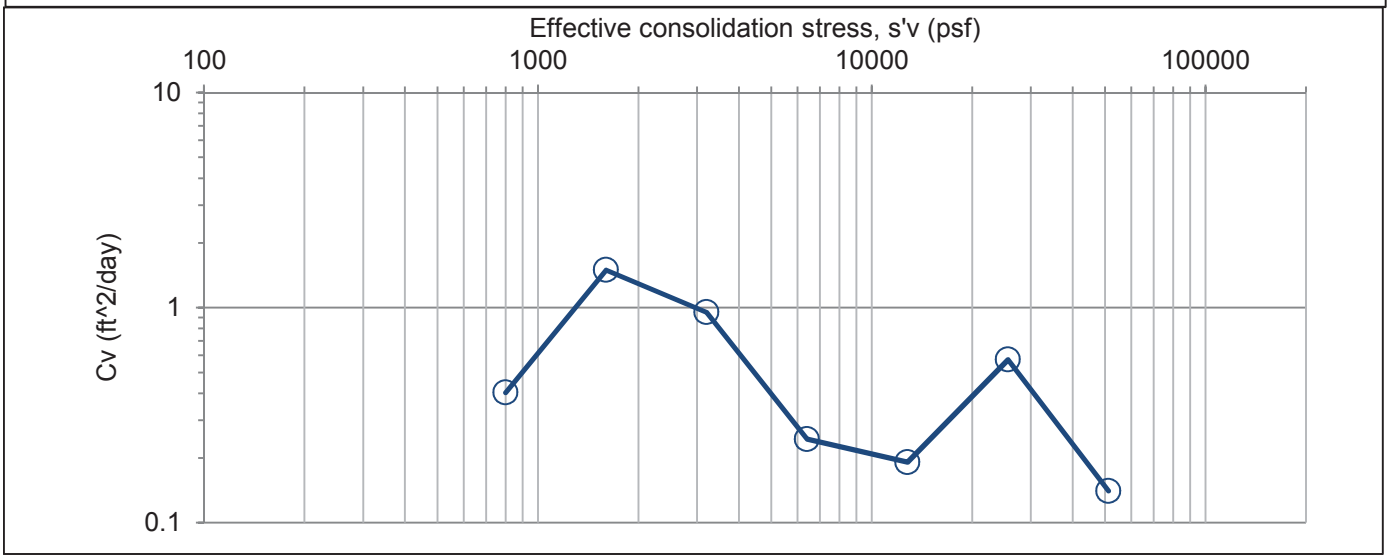
One-Dimensional Consolidation Properties of Soils
After ASTM D2435 and USBR 5700

GERHART COLE

Project: Bear River - Fielding
No: 13GCI329

TH/TP/Sample: TH-FD-03
Depth: 25-26.75





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One-Dimensional Consolidation Properties of Soils
After ASTM D2435 and USBR 5700

GERHART COLE

Project:	**Bear River - Fielding**	**TH/TP/Sample:**	**TH-FD-02**
No:	**13GCI329**	**Depth:**	**75-77 (75.5)**
Location:	Box Elder County, Utah	Sample description:	gray clay
Date:	29-Jul-15	USCS classification:	CH
Tested by:	zmg	Sample type:	Rel. undisturbed, Shelby Tube
Reduced by:	zmg	Inundation stress (psf):	100, completion
Checked by:	bjb	Swell pressure (psf):	233.484
Comments:		Test method:	B
		Preparation procedure:	trimmed

Phase Relationships

	Initial	Final
Height, H (in)	1.0000	0.8622
Height, H (cm)	2.540	2.190
Dia., D (in)	2.500	2.500
Dia., D (cm)	6.350	6.350
Wt. rings + wet soil (g)	371.82	367.16
Wt. rings (g)	214.85	214.85
Wet soil + tare (g)	274.17	298.33
Dry soil + tare (g)	240.05	268.87
Tare (g)	120.71	146.37
Moisture cont., w (%)	28.6	24.8
Gs, assumed	2.75	2.75
Mass total (g)	157.0	152.3
Mass of solids (g)	122.1	122.1
Volume (cm^3)	80.4	69.4
Vol. of water (cm^3)	34.9	30.2
Vol. of solids (cm^3)	44.4	44.4
Vol. of voids (cm^3)	36.1	25.0
Vol. of air (cm^3)	1.2	-5.3
Area, A (cm^2)	31.7	31.7
Ht. solids, Hs (cm)	1.402	1.402
Void ratio, e	0.812	0.563
Porosity, n	0.448	0.360
Vol.moisture, T	0.434	0.436
Saturation, S (%)	97	121
Dry density (gm/cm^3)	1.518	1.760
Wet unit wt., gm (pcf)	121.8	137.1
Dry unit wt., gd (pcf)	94.7	109.9

Vertical Stress - Deformation Results

Vert. stress (psf)	Corr. Dial, dfc [a] (in)	Hc [b] (in)	Vert. strain, ev	Load duration (min)	t-90 (min)	Hdr (in)	Cv (ft^2/day)
Seating	0.0000	1.0000	0.0000	0			
100	0.0004	0.9996	0.0004	180			
400	0.0011	0.9989	0.0011	33			
800	0.0049	0.9951	0.0049	46	25.1	0.49849	0.08
1,600	0.0099	0.9901	0.0099	51	19.9	0.49629	0.10
3,200	0.0148	0.9852	0.0148	55	25.1	0.49383	0.08
6,400	0.0218	0.9782	0.0218	56	19.9	0.49087	0.10
12,800	0.0295	0.9705	0.0295	71	19.9	0.48718	0.10
25,600	0.0487	0.9513	0.0487	96	15.8	0.48044	0.12
51,200	0.0908	0.9092	0.0908	93	31.6	0.46511	0.06
102,400	0.1416	0.8584	0.1416	120	39.8	0.4419	0.04
51,200	0.1378	0.8622	0.1378	60			
12,800	0.1248	0.8752	0.1248	120			
3,200	0.1079	0.8921	0.1079	120			
800	0.0911	0.9089	0.0911	120			
200	0.0783	0.9217	0.0783	126			

Data Interpretation Summary

Casagrande (1936)		Strain Energy Method (after Becker et al. 1987)	
Preconsolidation stress, s'p (psf)	23,900	Preconsolidation stress, s'p (psf)	27,000
Compression ratio, CR	0.17		
Recompression ratio, RR	0.03		

Notes:
[a] Dfc = end of increment deformation corrected for machine, porous stone, and filter paper deformation
[b] Hc = height at end of consolidation of each vert. stress
[c] Hdr = height at 50 consolidation computed from D90 using sq-root time method
[d] Cv computed from Taylor (1948) aquare root of time method (note 1 in^2/min = 10 ft^2/day)

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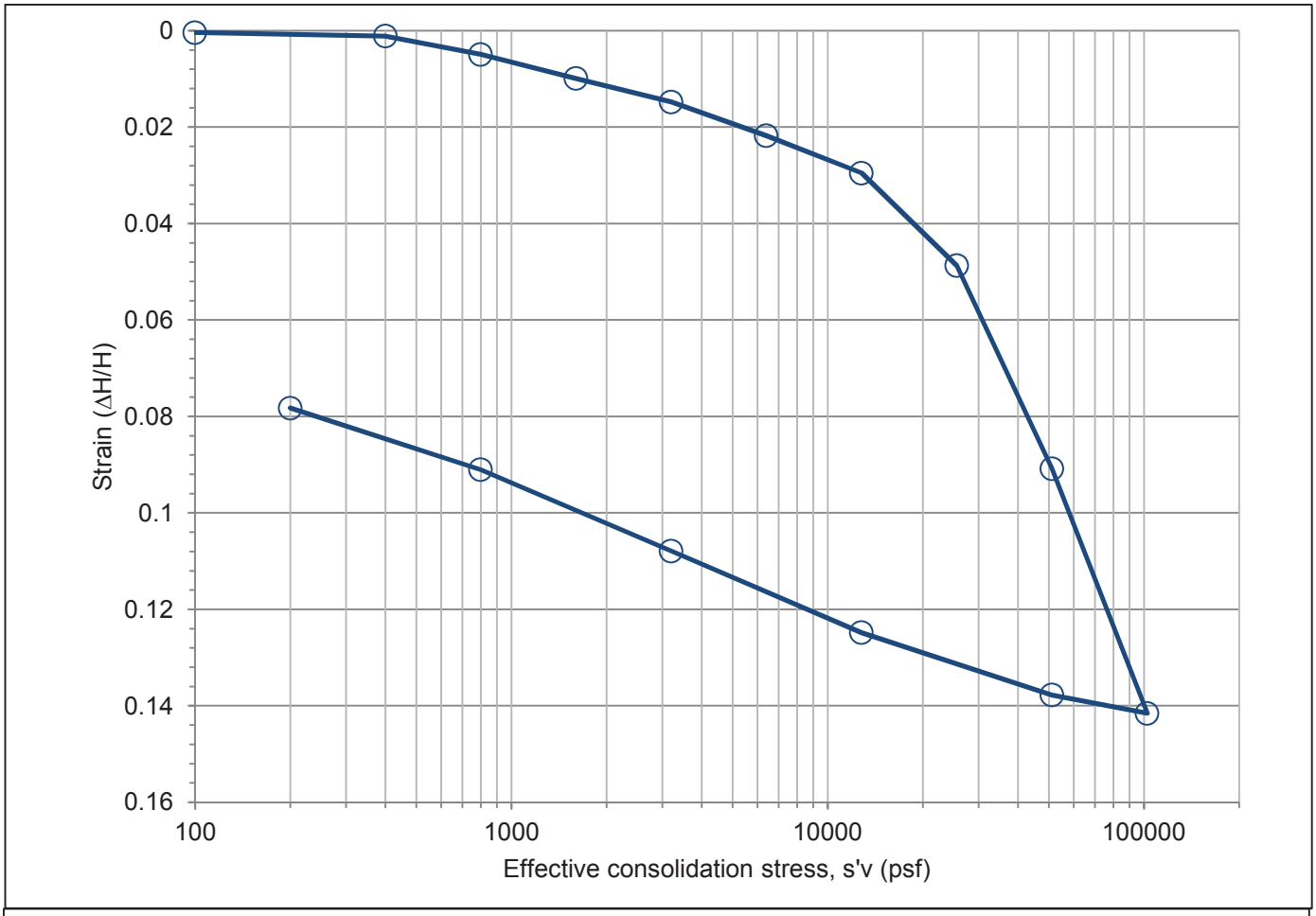
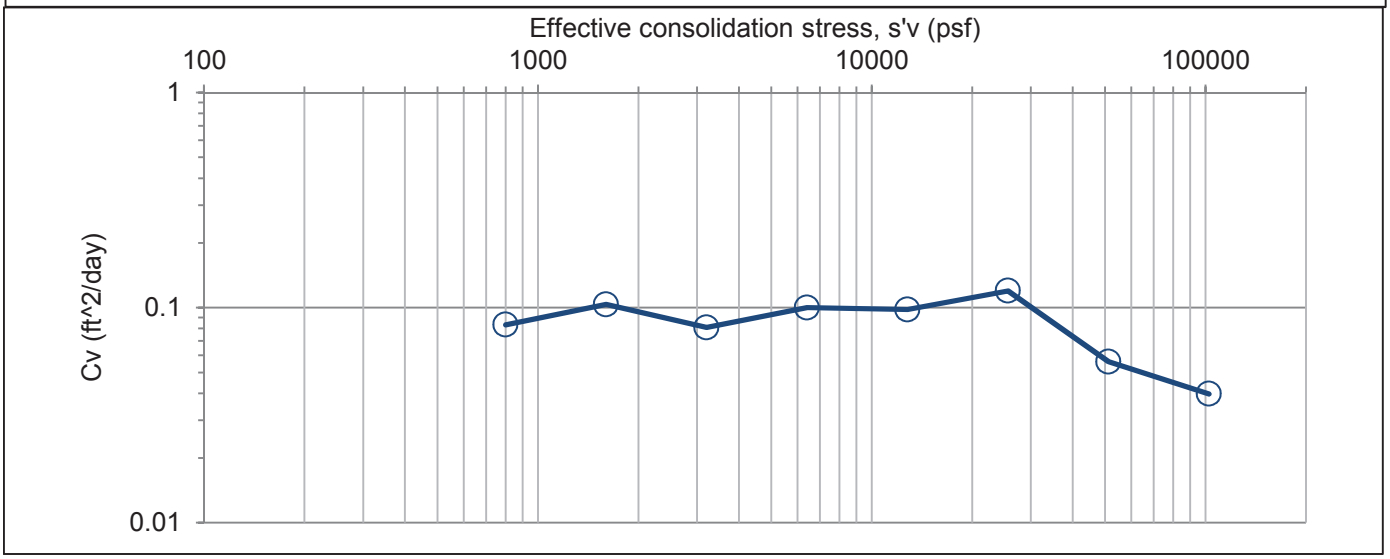
One-Dimensional Consolidation Properties of Soils
After ASTM D2435 and USBR 5700

GERHART COLE

Project: Bear River - Fielding
No: 13GCI329

TH/TP/Sample: TH-FD-02
Depth: 75-77 (75.5)





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One-Dimensional Consolidation Properties of Soils
After ASTM D2435 and USBR 5700

GERHART COLE

Project:	**Bear River - Fielding**	**TH/TP/Sample:**	**TH-FD-02**
No:	**13GCI329**	**Depth:**	**40-42 (41.25)**
Location:	Box Elder County, Utah	Sample description:	gray clay
Date:	10-Jul-15	USCS classification:	CL
Tested by:	zmg	Sample type:	Rel. undisturbed, Shelby Tube
Reduced by:	zmg	Inundation stress (psf):	100, completion
Checked by:	bjb	Swell pressure (psf):	193.272
Comments:		Test method:	B
		Preparation procedure:	trimmed

Phase Relationships

	Initial	Final
Height, H (in)	1.0000	0.9323
Height, H (cm)	2.540	2.368
Dia., D (in)	2.500	2.500
Dia., D (cm)	6.350	6.350
Wt. rings + wet soil (g)	370.77	367.54
Wt. rings (g)	214.52	214.52
Wet soil + tare (g)	405.99	297.42
Dry soil + tare (g)	352.75	266.96
Tare (g)	173.39	144.97
Moisture cont., w (%)	29.7	25.0
Gs, assumed	2.75	2.75
Mass total (g)	156.3	153.0
Mass of solids (g)	120.5	120.5
Volume (cm^3)	80.4	75.0
Vol. of water (cm^3)	35.8	32.5
Vol. of solids (cm^3)	43.8	43.8
Vol. of voids (cm^3)	36.6	31.2
Vol. of air (cm^3)	0.9	-1.4
Area, A (cm^2)	31.7	31.7
Ht. solids, Hs (cm)	1.383	1.383
Void ratio, e	0.836	0.712
Porosity, n	0.455	0.416
Vol.moisture, T	0.445	0.434
Saturation, S (%)	98	104
Dry density (gm/cm^3)	1.498	1.607
Wet unit wt., gm (pcf)	121.3	125.3
Dry unit wt., gd (pcf)	93.5	100.3

Vertical Stress - Deformation Results

Vert. stress (psf)	Corr. Dial, dfc [a] (in)	Hc [b] (in)	Vert. strain, ev	Load duration (min)	t-90 (min)	Hdr (in)	Cv (ft^2/day)
Seating	0.0000	1.0000	0.0000	0			
100	0.0002	0.9998	0.0002	56			
400	0.0019	0.9981	0.0019	60			
800	0.0058	0.9942	0.0058	77			
1,600	0.0109	0.9891	0.0109	101			
3,200	0.0182	0.9818	0.0182	103	4.1	0.49272	0.49
6,400	0.0254	0.9746	0.0254	180	3.3	0.48908	0.61
12,800	0.0354	0.9646	0.0354	180	2.1	0.48479	0.92
25,600	0.0623	0.9377	0.0623	150	8.1	0.47558	0.23
51,200	0.1090	0.8910	0.1090	146	12.7	0.45718	0.13
25,600	0.1056	0.8944	0.1056	18			
6,400	0.0949	0.9051	0.0949	29			
1,600	0.0814	0.9186	0.0814	60			
400	0.0677	0.9323	0.0677	100			

Data Interpretation Summary

Preconsolidation stress, s'p (psf)	---	
Compression ratio, CR	---	To be determined by the Geotechnical Engineer
Recompression ratio, RR	---	

Notes:
[a] Dfc = end of increment deformation corrected for machine, porous stone, and filter paper deformation
[b] Hc = height at end of consolidation of each vert. stress
[c] Hdr = height at 50 consolidation computed from D90 using sq-root time method
[d] Cv computed from Taylor (1948) aquare root of time method (note 1 in^2/min = 10 ft^2/day)

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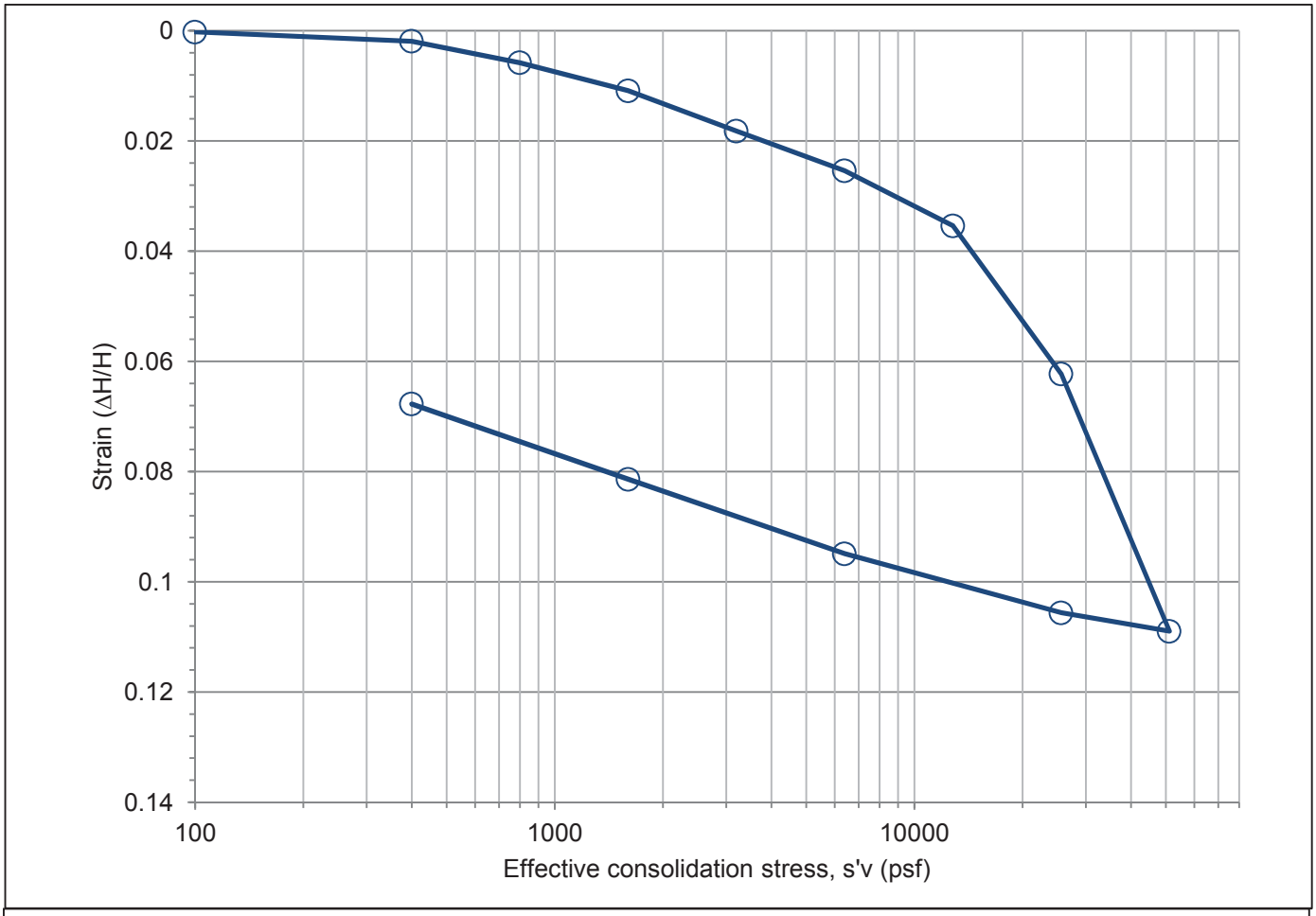
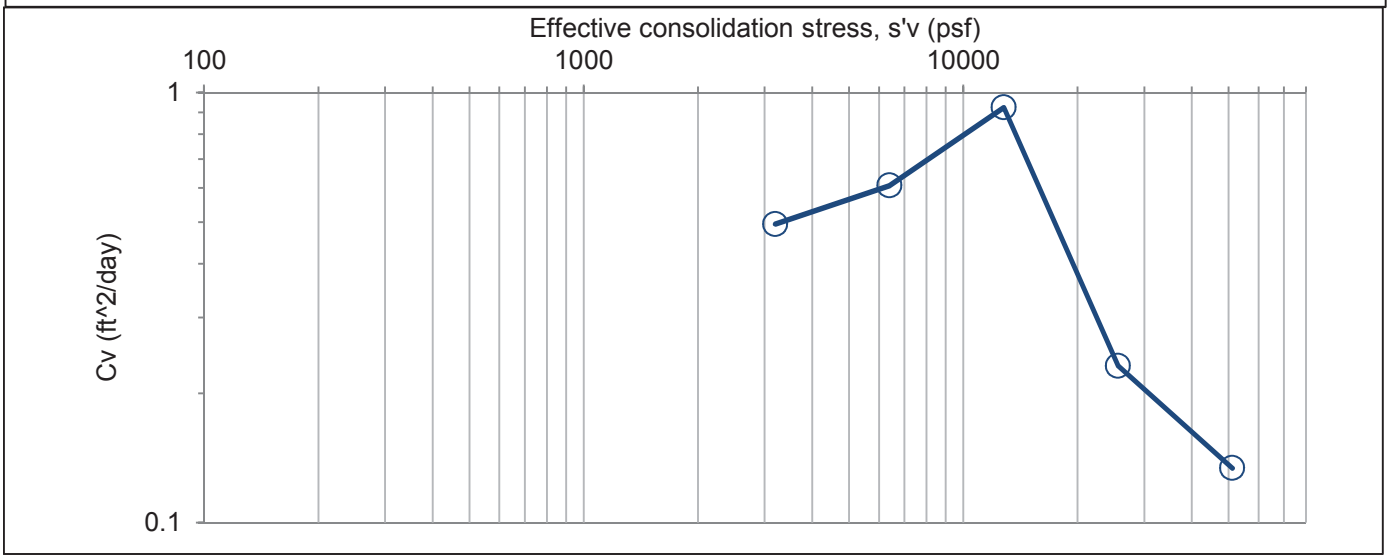
One-Dimensional Consolidation Properties of Soils
After ASTM D2435 and USBR 5700

GERHART COLE

Project: Bear River - Fielding
No: 13GCI329

TH/TP/Sample: TH-FD-02
Depth: 40-42 (41.25)





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One-Dimensional Consolidation Properties of Soils
After ASTM D2435 and USBR 5700

GERHART COLE

Project:	**Bear River - Fielding**	**TH/TP/Sample:**	**TH-FD-02**
No:	**13GCI329**	**Depth:**	**25-27 (27)**
Location:	Box Elder County, Utah	Sample description:	gray clay
Date:	09-Jul-15	USCS classification:	CL
Tested by:	zmg	Sample type:	Rel. undisturbed, Shelby Tube
Reduced by:	zmg	Inundation stress (psf):	100, beginning
Checked by:	bjb	Swell pressure (psf):	136.189
Comments:		Test method:	B
		Preparation procedure:	trimmed

Phase Relationships

	Initial	Final
Height, H (in)	1.0000	0.9088
Height, H (cm)	2.540	2.308
Dia., D (in)	2.500	2.500
Dia., D (cm)	6.350	6.350
Wt. rings + wet soil (g)	366.24	360.80
Wt. rings (g)	214.84	214.84
Wet soil + tare (g)	258.54	264.40
Dry soil + tare (g)	229.96	232.36
Tare (g)	144.29	119.01
Moisture cont., w (%)	33.4	28.3
Gs, assumed	2.75	2.75
Mass total (g)	151.4	146.0
Mass of solids (g)	113.5	113.5
Volume (cm^3)	80.4	73.1
Vol. of water (cm^3)	37.9	32.4
Vol. of solids (cm^3)	41.3	41.3
Vol. of voids (cm^3)	39.2	31.8
Vol. of air (cm^3)	1.3	-0.6
Area, A (cm^2)	31.7	31.7
Ht. solids, Hs (cm)	1.304	1.304
Void ratio, e	0.949	0.771
Porosity, n	0.487	0.435
Vol.moisture, T	0.471	0.444
Saturation, S (%)	97	102
Dry density (gm/cm^3)	1.411	1.553
Wet unit wt., gm (pcf)	117.5	124.4
Dry unit wt., gd (pcf)	88.1	97.0

Vertical Stress - Deformation Results

Vert. stress (psf)	Corr. Dial, dfc [a] (in)	Hc [b] (in)	Vert. strain, ev	Load duration (min)	t-90 (min)	Hdr (in)	Cv (ft^2/day)
Seating	0.0000	1.0000	0.0000	0			
100	0.0007	0.9993	0.0007	120			
400	0.0054	0.9946	0.0054	120			
800	0.0111	0.9889	0.0111	79			
1,600	0.0175	0.9825	0.0175	240			
3,200	0.0237	0.9763	0.0237	105	4.1	0.48968	0.49
6,400	0.0316	0.9684	0.0316	175	5.1	0.48617	0.38
12,800	0.0419	0.9581	0.0419	83	5.1	0.48163	0.37
25,600	0.0794	0.9206	0.0794	63	10.1	0.46967	0.18
51,200	0.1451	0.8549	0.1451	63	12.7	0.44387	0.13
25,600	0.1417	0.8583	0.1417	30			
6,400	0.1279	0.8721	0.1279	53			
1,600	0.1099	0.8901	0.1099	68			
400	0.0912	0.9088	0.0912	126			

Data Interpretation Summary

Preconsolidation stress, s'p (psf)	---	
Compression ratio, CR	---	To be determined by the Geotechnical Engineer
Recompression ratio, RR	---	

Notes:
[a] Dfc = end of increment deformation corrected for machine, porous stone, and filter paper deformation
[b] Hc = height at end of consolidation of each vert. stress
[c] Hdr = height at 50 consolidation computed from D90 using sq-root time method
[d] Cv computed from Taylor (1948) aquare root of time method (note 1 in^2/min = 10 ft^2/day)

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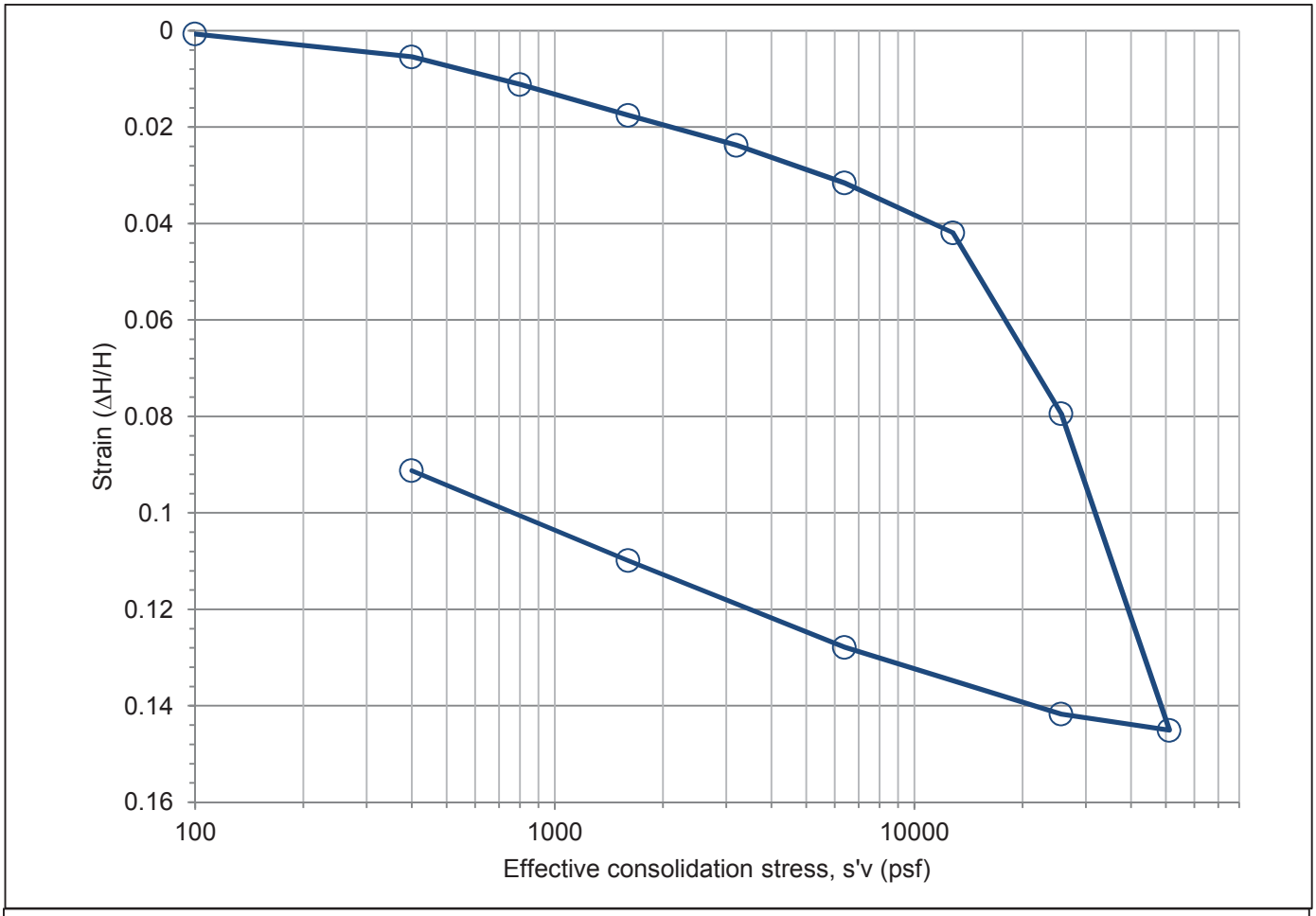
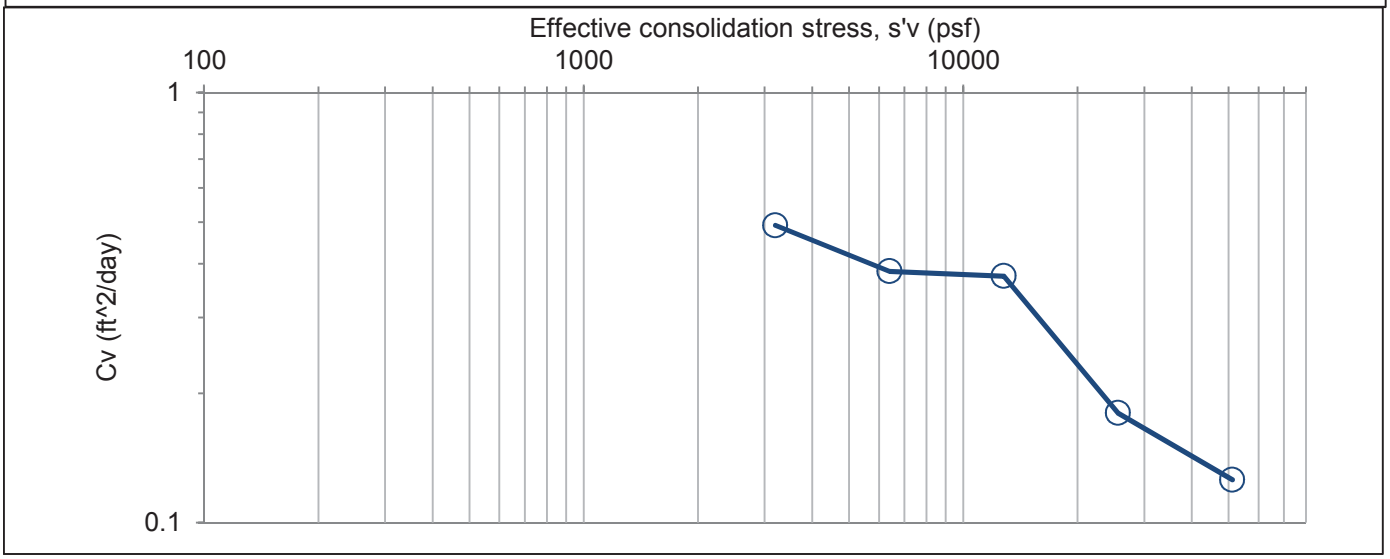
One-Dimensional Consolidation Properties of Soils
After ASTM D2435 and USBR 5700

GERHART COLE

Project: Bear River - Fielding
No: 13GCI329

TH/TP/Sample: TH-FD-02
Depth: 25-27 (27)





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One-Dimensional Consolidation Properties of Soils
After ASTM D2435 and USBR 5700

GERHART COLE

Project:	**Bear River - Fielding**	**TH/TP/Sample:**	**TH-FD-01**
No:	**13GCI329**	**Depth:**	**100-101.7 (101.5)**
Location:	Logan Utah	Sample description:	dark blueish gray clay
Date:	30-Jul-15	USCS classification:	CH
Tested by:	zmg	Sample type:	Rel. undisturbed, Shelby Tube
Reduced by:	zmg	Inundation stress (psf):	100,completion
Checked by:	bjb	Swell pressure (psf):	1704.51
Comments:		Test method:	B
		Preparation procedure:	trimmed

Phase Relationships

	Initial	Final
Height, H (in)	1.0000	0.8859
Height, H (cm)	2.540	2.250
Dia., D (in)	2.500	2.500
Dia., D (cm)	6.350	6.350
Wt. rings + wet soil (g)	363.73	357.42
Wt. rings (g)	214.89	214.89
Wet soil + tare (g)	420.06	287.15
Dry soil + tare (g)	343.02	255.37
Tare (g)	119.89	145.02
Moisture cont., w (%)	34.5	28.8
Gs, assumed	2.75	2.75
Mass total (g)	148.8	142.5
Mass of solids (g)	110.6	110.6
Volume (cm^3)	80.4	71.3
Vol. of water (cm^3)	38.2	31.9
Vol. of solids (cm^3)	40.2	40.2
Vol. of voids (cm^3)	40.2	31.0
Vol. of air (cm^3)	2.0	-0.9
Area, A (cm^2)	31.7	31.7
Ht. solids, Hs (cm)	1.270	1.270
Void ratio, e	0.999	0.771
Porosity, n	0.500	0.435
Vol.moisture, T	0.475	0.447
Saturation, S (%)	95	103
Dry density (gm/cm^3)	1.375	1.553
Wet unit wt., gm (pcf)	115.5	124.8
Dry unit wt., gd (pcf)	85.9	96.9

Vertical Stress - Deformation Results

Vert. stress (psf)	Corr. Dial, dfc [a] (in)	Hc [b] (in)	Vert. strain, ev	Load duration (min)	t-90 (min)	Hdr (in)	Cv (ft^2/day)
Seating	0.0000	1.0000	0.0000	0			
100	0.0002	0.9998	0.0002	159			
3,200	0.0054	0.9946	0.0054	116	63.1	0.4986	0.03
6,400	0.0186	0.9814	0.0186	102	50.1	0.494	0.04
12,800	0.0387	0.9613	0.0387	135	63.1	0.48568	0.03
25,600	0.0795	0.9205	0.0795	240	125.9	0.47044	0.01
51,200	0.1342	0.8658	0.1342	240	125.9	0.44657	0.01
102,400	0.1895	0.8105	0.1895	240	125.9	0.41909	0.01
51,200	0.1838	0.8162	0.1838	60			
12,800	0.1707	0.8293	0.1707	28			
3,200	0.1518	0.8482	0.1518	60			
800	0.1356	0.8644	0.1356	60			
200	0.1141	0.8859	0.1141	120			

Data Interpretation Summary

Preconsolidation stress, s'p (psf)	---	
Compression ratio, CR	---	To be determined by the Geotechnical Engineer
Recompression ratio, RR	---	

Notes:
[a] Dfc = end of increment deformation corrected for machine, porous stone, and filter paper deformation
[b] Hc = height at end of consolidation of each vert. stress
[c] Hdr = height at 50 consolidation computed from D90 using sq-root time method
[d] Cv computed from Taylor (1948) aquare root of time method (note 1 in^2/min = 10 ft^2/day)

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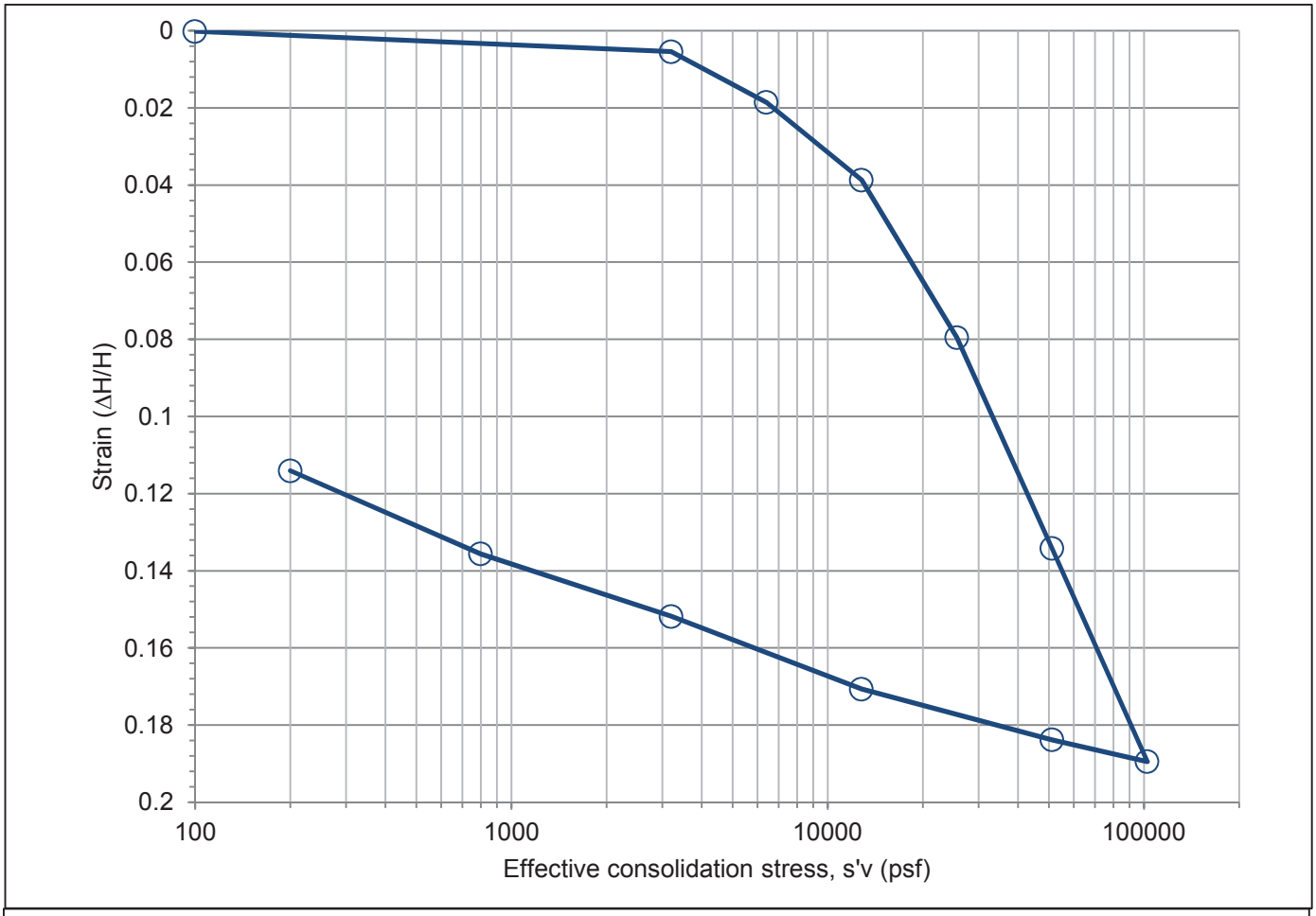
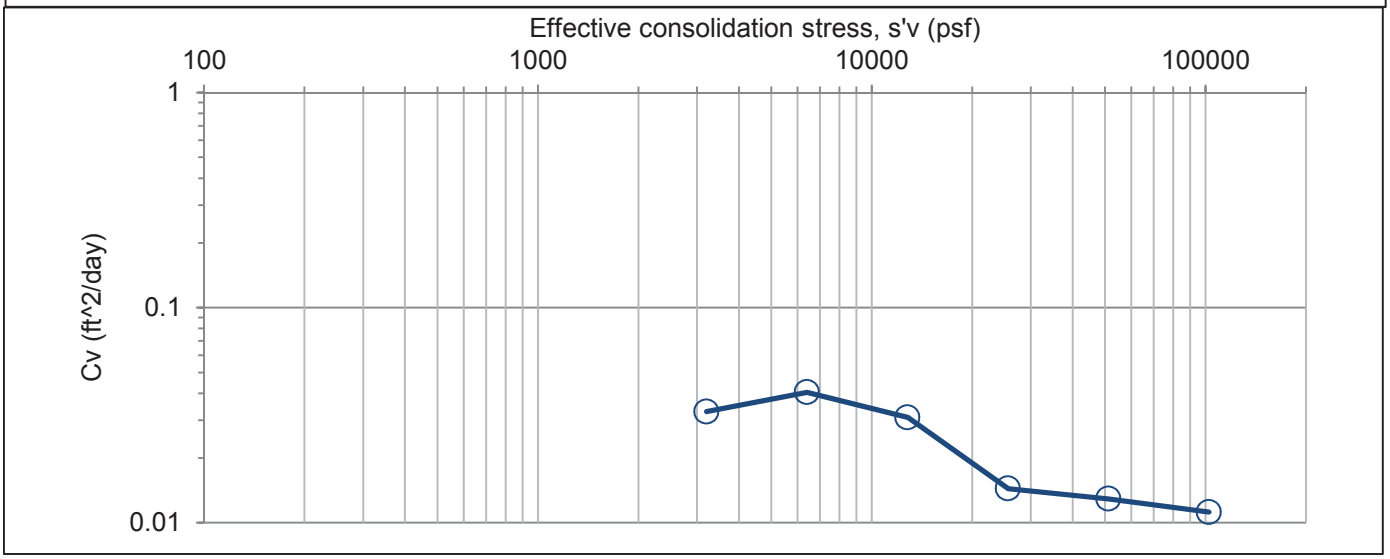
One-Dimensional Consolidation Properties of Soils
After ASTM D2435 and USBR 5700

GERHART COLE

Project: Bear River - Fielding
No: 13GCI329

TH/TP/Sample: TH-FD-01
Depth: 100-101.7 (101.5)





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One-Dimensional Consolidation Properties of Soils
After ASTM D2435 and USBR 5700

GERHART COLE

Project:	**Bear River - Fielding**	**TH/TP/Sample:**	**TH-FD-01**
No:	**13GCI329**	**Depth:**	**60-62 (61.75)**
Location:	Box Elder County, Utah	Sample description:	greenish gray clay
Date:	30-Jul-15	USCS classification:	CL
Tested by:	zmg	Sample type:	Rel. undisturbed, Shelby Tube
Reduced by:	zmg	Inundation stress (psf):	100, completion
Checked by:	bjb	Swell pressure (psf):	195.322
Comments:		Test method:	B
		Preparation procedure:	trimmed

Phase Relationships

	Initial	Final
Height, H (in)	1.0000	0.9300
Height, H (cm)	2.540	2.362
Dia., D (in)	2.500	2.500
Dia., D (cm)	6.350	6.350
Wt. rings + wet soil (g)	369.20	365.27
Wt. rings (g)	214.53	214.53
Wet soil + tare (g)	441.20	290.64
Dry soil + tare (g)	378.59	259.63
Tare (g)	144.96	140.30
Moisture cont., w (%)	26.8	26.0
Gs, assumed	2.75	2.75
Mass total (g)	154.7	150.7
Mass of solids (g)	122.0	122.0
Volume (cm^3)	80.4	74.8
Vol. of water (cm^3)	32.7	28.8
Vol. of solids (cm^3)	44.4	44.4
Vol. of voids (cm^3)	36.1	30.5
Vol. of air (cm^3)	3.4	1.7
Area, A (cm^2)	31.7	31.7
Ht. solids, Hs (cm)	1.401	1.401
Void ratio, e	0.813	0.687
Porosity, n	0.449	0.407
Vol.moisture, T	0.406	0.384
Saturation, S (%)	91	94
Dry density (gm/cm^3)	1.516	1.631
Wet unit wt., gm (pcf)	120.0	128.2
Dry unit wt., gd (pcf)	94.7	101.8

Vertical Stress - Deformation Results

Vert. stress (psf)	Corr. Dial, dfc [a] (in)	Hc [b] (in)	Vert. strain, ev	Load duration (min)	t-90 (min)	Hdr (in)	Cv (ft^2/day)
Seating	0.0000	1.0000	0.0000	0			
100	0.0000	1.0000	0.0000	120			
400	0.0012	0.9988	0.0012	17			
800	0.0052	0.9948	0.0052	63	4.1	0.4984	0.51
1,600	0.0089	0.9911	0.0089	37	4.1	0.49648	0.50
3,200	0.0134	0.9866	0.0134	120	3.3	0.49442	0.62
6,400	0.0206	0.9794	0.0206	167	2.6	0.49149	0.77
12,800	0.0317	0.9683	0.0317	120	5.1	0.48692	0.38
25,600	0.0581	0.9419	0.0581	180	8.1	0.47755	0.23
51,200	0.1102	0.8898	0.1102	225	10.1	0.45792	0.17
25,600	0.1065	0.8935	0.1065	60			
6,400	0.0972	0.9028	0.0972	60			
1,600	0.0838	0.9162	0.0838	69			
400	0.0700	0.9300	0.0700	100			

Data Interpretation Summary

Preconsolidation stress, s'p (psf)	---	
Compression ratio, CR	---	To be determined by the Geotechnical Engineer
Recompression ratio, RR	---	

Notes:
[a] Dfc = end of increment deformation corrected for machine, porous stone, and filter paper deformation
[b] Hc = height at end of consolidation of each vert. stress
[c] Hdr = height at 50 consolidation computed from D90 using sq-root time method
[d] Cv computed from Taylor (1948) aquare root of time method (note 1 in^2/min = 10 ft^2/day)

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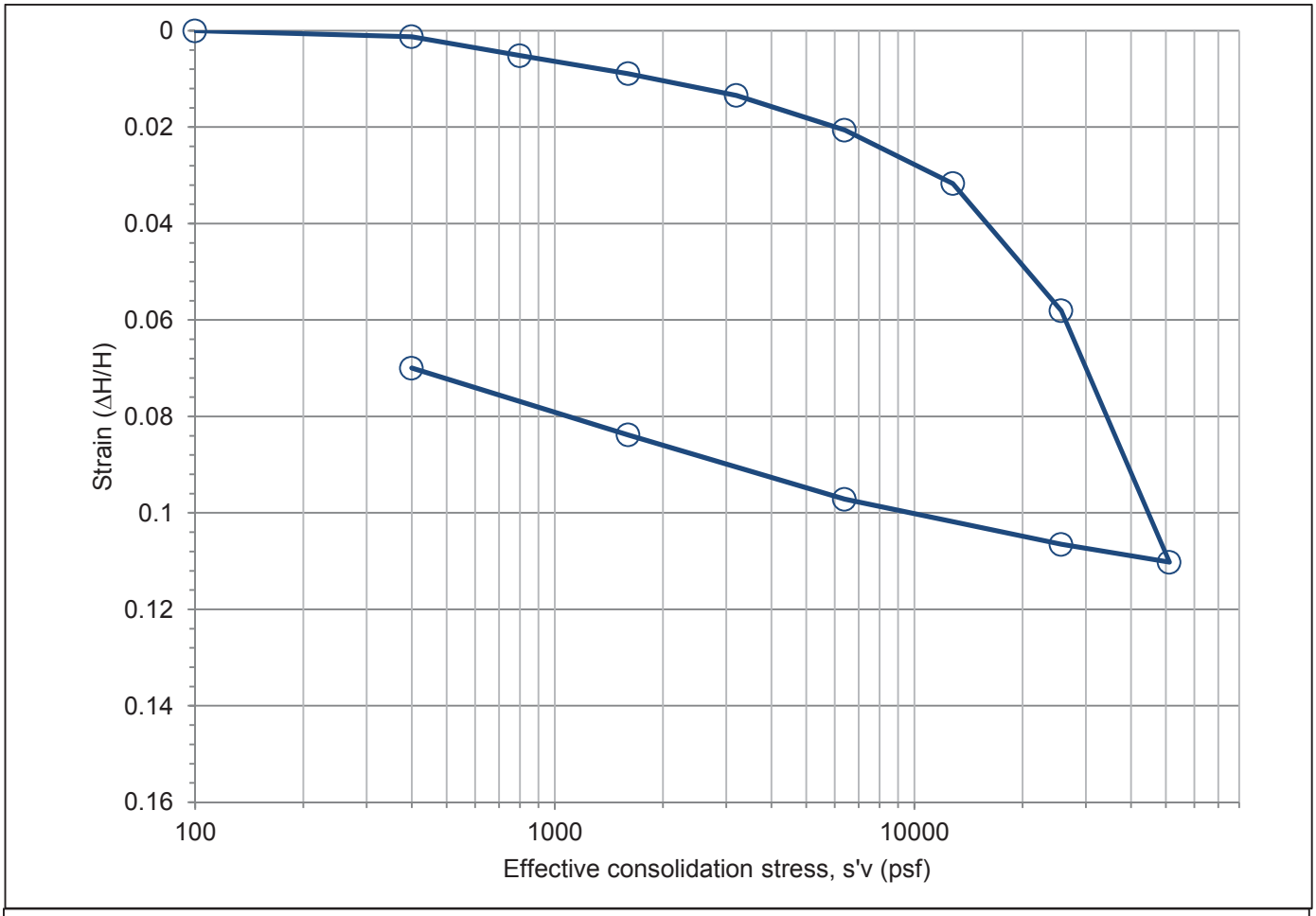
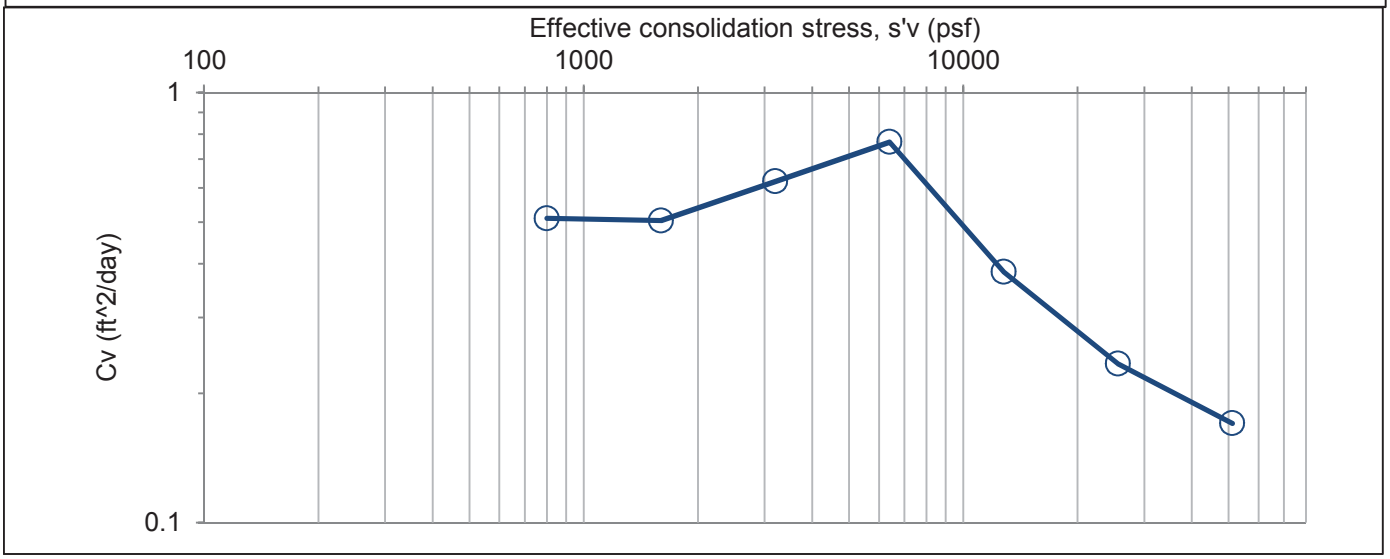
One-Dimensional Consolidation Properties of Soils
After ASTM D2435 and USBR 5700

GERHART COLE

Project: Bear River - Fielding
No: 13GCI329

TH/TP/Sample: TH-FD-01
Depth: 60-62 (61.75)





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One-Dimensional Consolidation Properties of Soils
After ASTM D2435 and USBR 5700

GERHART COLE

Project:	**Bear River - Fielding**	**TH/TP/Sample:**	**TH-FD-01**
No:	**13GCI329**	**Depth:**	**15-17 (16.75)**
Location:	Box Elder County, Utah	Sample description:	light olive brown clay
Date:	29-Jul-15	USCS classification:	CL
Tested by:	zmg	Sample type:	Rel. undisturbed, Shelby Tube
Reduced by:	zmg	Inundation stress (psf):	100, beginning
Checked by:	bjb	Swell pressure (psf):	103.596
Comments:		Test method:	B
		Preparation procedure:	trimmed

Phase Relationships

	Initial	Final
Height, H (in)	1.0000	0.9066
Height, H (cm)	2.540	2.303
Dia., D (in)	2.500	2.500
Dia., D (cm)	6.350	6.350
Wt. rings + wet soil (g)	366.11	360.75
Wt. rings (g)	214.52	214.52
Wet soil + tare (g)	310.38	265.75
Dry soil + tare (g)	263.24	234.81
Tare (g)	119.02	120.05
Moisture cont., w (%)	32.7	27.0
Gs, assumed	2.75	2.75
Mass total (g)	151.6	146.2
Mass of solids (g)	114.2	114.2
Volume (cm^3)	80.4	72.9
Vol. of water (cm^3)	37.3	32.0
Vol. of solids (cm^3)	41.5	41.5
Vol. of voids (cm^3)	38.9	31.4
Vol. of air (cm^3)	1.6	-0.6
Area, A (cm^2)	31.7	31.7
Ht. solids, Hs (cm)	1.312	1.312
Void ratio, e	0.936	0.755
Porosity, n	0.484	0.430
Vol.moisture, T	0.464	0.439
Saturation, S (%)	96	102
Dry density (gm/cm^3)	1.420	1.567
Wet unit wt., gm (pcf)	117.7	124.2
Dry unit wt., gd (pcf)	88.7	97.8

Vertical Stress - Deformation Results

Vert. stress (psf)	Corr. Dial, dfc [a] (in)	Hc [b] (in)	Vert. strain, ev	Load duration (min)	t-90 (min)	Hdr (in)	Cv (ft^2/day)
Seating	0.0000	1.0000	0.0000	0			
100	0.0000	1.0000	0.0000	82			
200	0.0015	0.9985	0.0015	96			
400	0.0047	0.9953	0.0047	93	4.1	0.49845	0.51
800	0.0108	0.9892	0.0108	58	3.3	0.49613	0.63
1,600	0.0196	0.9804	0.0196	120	2.6	0.49239	0.78
3,200	0.0314	0.9686	0.0314	120	4.1	0.48724	0.48
6,400	0.0450	0.9550	0.0450	120	3.3	0.48091	0.59
12,800	0.0684	0.9316	0.0684	120	3.3	0.47167	0.56
25,600	0.1027	0.8973	0.1027	120	6.4	0.45722	0.27
51,200	0.1455	0.8545	0.1455	56	5.1	0.43794	0.30
25,600	0.1426	0.8574	0.1426	11			
6,400	0.1306	0.8694	0.1306	60			
1,600	0.1139	0.8861	0.1139	28			
400	0.0934	0.9066	0.0934	100			

Data Interpretation Summary

Preconsolidation stress, s'p (psf)	---	
Compression ratio, CR	---	To be determined by the Geotechnical Engineer
Recompression ratio, RR	---	

Notes:
[a] Dfc = end of increment deformation corrected for machine, porous stone, and filter paper deformation
[b] Hc = height at end of consolidation of each vert. stress
[c] Hdr = height at 50 consolidation computed from D90 using sq-root time method
[d] Cv computed from Taylor (1948) aquare root of time method (note 1 in^2/min = 10 ft^2/day)

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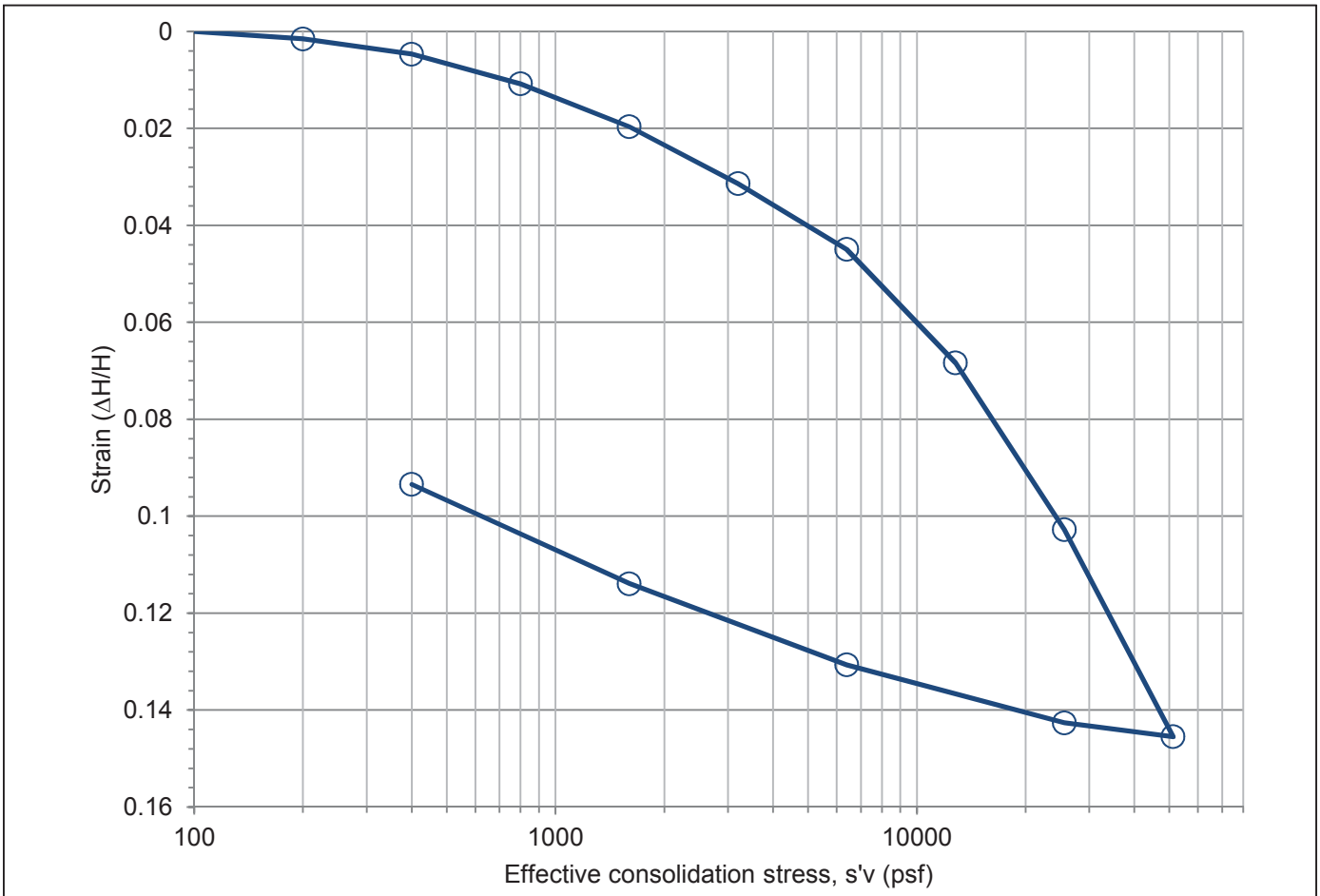
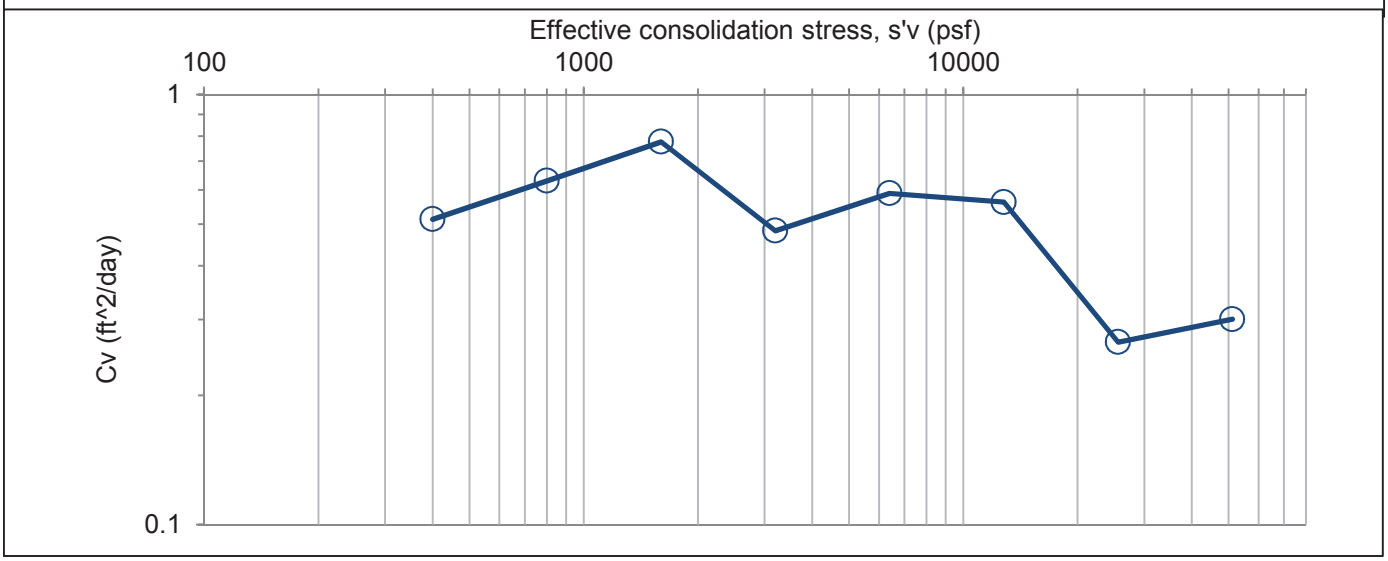
One-Dimensional Consolidation Properties of Soils
After ASTM D2435 and USBR 5700

GERHART COLE

Project: Bear River - Fielding
No: 13GCI329

TH/TP/Sample: TH-FD-01
Depth: 15-17 (16.75)





DRAFT

Triaxial Test - Isotropic Consolidated Sheared Undrained Measuring Pore Pressure (CIU-PP) - *After ASTM D4767 and USBR 5750*

GERHART COLE

Project: Bear River - Fielding
No: 13GCI329
Location: Box Elder County Utah
Date: 10-Aug-15
Tested by: zmg
Reduced by: zmg
Checked by: dab

TH/TP/Sample: TH-FD-01
Depth: 15-17
Sample description: light olive brown clay
USCS classification: CL
Sample type: undisturbed
Notes:

	Test Number	S1	50 psi	S2	20 psi	S3	10 psi
		Initial	Bef. Shr. MethodB [e]	Initial	Bef. Shr. MethodB [e]	Initial	Bef. Shr. MethodB [e]
Unit weight data	Sample ht., H (in) 0°	5.746		5.749		5.722	
	120°	5.748		5.749		5.720	
	240°	5.746		5.746		5.723	
	Avg. height, Havg (in)	5.747	5.667	5.748	5.718	5.722	5.682
	Avg. height, Havg (cm)	14.597	14.393	14.600	14.524	14.533	14.431
	ΔHsc (in) [a]		0.08		0.03		0.04
	Sample dia., D (in) top	2.846		2.847		2.824	
	mid	2.849		2.846		2.866	
	bot	2.845		2.865		2.851	
	Avg. dia., Davg (in)	2.847	2.851	2.851	2.860	2.852	2.806
	Avg. dia., Davg (cm)	7.232	7.242	7.242	7.264	7.243	7.127
	Avg. area, Aavg (in^2)	6.367	6.384	6.384	6.423	6.387	6.183
	Avg. area, Aavg (cm^2)	41.078	41.189	41.186	41.442	41.208	39.890
	Wt. rings + wet soil (g)	1152.33	1137.49	1132.87	1129.71	1182.34	1165.39
	Wt. rings (g)	0.00	0.00	0.00	0.00	0.00	0.00
	Volume, Vo (in^3)	36.6	36.2	36.7	36.7	36.5	35.1
	Vo (cm^3)	599.6	592.8	601.3	601.9	598.9	575.7
	Vo (ft^3)	0.0212	0.0209	0.0212	0.0213	0.0211	0.0203
Moisture	Wet soil + tare (g)	247.26	679.60	212.43	667.18	245.19	783.67
	Dry soil + tare (g)	223.76	559.44	192.13	544.99	223.86	655.33
	Tare (g)	144.41	144.35	120.71	144.30	150.64	144.76
	Moisture content, w (%)	29.6	28.9	28.4	30.5	29.1	25.1
Phase Relationships	Gs, assumed	2.65	2.65	2.65	2.65	2.65	2.65
	Mass total (g)	1152.3	1146.4	1132.9	1151.1	1182.3	1145.8
	Mass of solids (g)	889.0	889.0	882.1	882.1	915.6	915.6
	Volume (cm^3)	599.6	592.8	601.3	601.9	598.9	575.7
	Volume of water (cm^3)	263.3	257.4	250.7	269.0	266.7	230.2
	Volume of solids (cm^3)	335.5	335.5	332.9	332.9	345.5	345.5
	Volume of voids (cm^3)	264.1	257.4	268.4	269.0	253.4	230.2
	Volume of air (cm^3)	0.8	0.0	17.7	0.0	-13.4	0.0
	Void ratio, e	0.787	0.767	0.806	0.808	0.733	0.666
	Porosity, n	0.440	0.434	0.446	0.447	0.423	0.400
	Volumetric moisture, T	0.439	0.434	0.417	0.447	0.445	0.400
	Saturation, S (%) [c]	99.69	100.00	93.41	100.00	105.28	100.00
	Dry density (gm/cm^3)	1.483	1.500	1.467	1.466	1.529	1.591
	Wet unit wt., gm (pcf)	120.0	120.7	117.6	119.4	123.3	124.3
	Dry unit wt., gd (pcf)	92.6	93.6	91.6	91.5	95.4	99.3

Notes:

[a] ΔHsc (in) = change in height during saturation and consolidation

[b] ΔVs = change in volume during saturation, ΔVc = change in volume during consolidation

[c] Saturation before shear set to 100% for phase calculations

[d] Before shear Aavg using method A; where Ac (Method A) = (Vo-DVs - DVc)/(Ho-DHsc)

[e] Before shear Aavg using method B; where Ac (Method B) = (Vwf + Vs)/Hc

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DRAFT

Triaxial Test - Isotropic Consolidated Sheared Undrained
Measuring Pore Pressure (CIU-PP) *- After ASTM D4767 and USBR 5750*

GERHART COLE

Project:	**Bear River - Fielding**	**TH/TP/Sample:**	**TH-FD-01**
No:	**13GCI329**	**Depth:**	**15-17**
Location:	Box Elder County Utah	Sample description:	light olive brown clay
Date:	10-Aug-15	USCS classification:	CL
Tested by:	zmg	Sample type:	undisturbed

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	Test Number	S1 at 50 psi	S2 at 20 psi	S3 at 10 psi
Test information	Total backpressure (psi)	37.0	24.0	24.0
	Skempton B	0.95	0.98	0.96
	t-90 (min)	8.1	3.0	4.0
	t-100 (min)	13.2	6.0	5.0
	t-50 (min)	1.9	0.7	0.9
	Strain rate (%/hr)	1.20	1.20	1.20
	Strain rate (%/min)	0.020	0.020	0.020
	Membrane correction	Yes	Yes	Yes
	Filter paper correction	No filter paper	No filter paper	No filter paper
Max principal stress ratio (s1/s3), failure criteria	Strain at failure, ef (%)	4.85	3.90	5.76
	Time to failure, tf (min)	242.3	194.9	287.9
	Obliquity, s'1/s'3	2.891	3.442	2.955
	Excess pore pressure, u (psi)	27.52	8.29	3.59
	q = q' = (s1+s3)/2 (psi)	21.25	14.30	6.27
	p' = (s'1+s'3)/2 (psi)	43.72	26.01	12.68
	p = (s1+s3)/2 (psi)	71.25	34.30	16.27
	Effective major principal stress, s'1 (psi)	64.97	40.30	18.94
	Effective minor principal stress, s'3 (psi)	22.48	11.71	6.41
	Total major pincipal stress, s1 (psi)	92.50	48.59	22.53
	Total minor pincipal stress, s3 (psi)	50.00	20.00	10.00
	Skemption A at failure, Af	0.65	0.29	0.29
	Secant friction angle, phi-s (deg)	29.1	33.3	29.6
		Effective stress	Total stress	
	Friction angle, phi (deg)	28.5	15.1	
	Cohesion intercept, c (psi)	0.9	3.5	
Peak deviator stress (s1-s3), failure criteria	Strain at failure, ef (%)	4.85	6.25	14.84
	Time to failure, tf (min)	242.3	312.5	741.9
	Deviator stress, s1-s3 (psi)	42.50	31.77	15.26
	Excess pore pressure, u (psi)	27.52	6.31	1.46
	q = q' = (s1+s3)/2 (psi)	21.25	15.89	7.63
	p' = (s'1+s'3)/2 (psi)	43.72	29.58	16.17
	p = (s1+s3)/2 (psi)	71.25	35.89	17.63
	Effective major principal stress, s'1 (psi)	64.97	45.47	23.80
	Effective minor principal stress, s'3 (psi)	22.48	13.69	8.54
	Total major pincipal stress, s1 (psi)	92.50	51.77	25.26
	Total minor pincipal stress, s3 (psi)	50.00	20.00	10.00
	Skemption A at failure, Af	0.65	0.20	0.10
	Secant friction angle, phi-s (deg)	29.1	32.5	28.1
		Effective stress	Total stress	
	Friction angle, phi (deg)	29.6	13.9	
	Cohesion intercept, c (psi)	0.2	5.1	

Comments:

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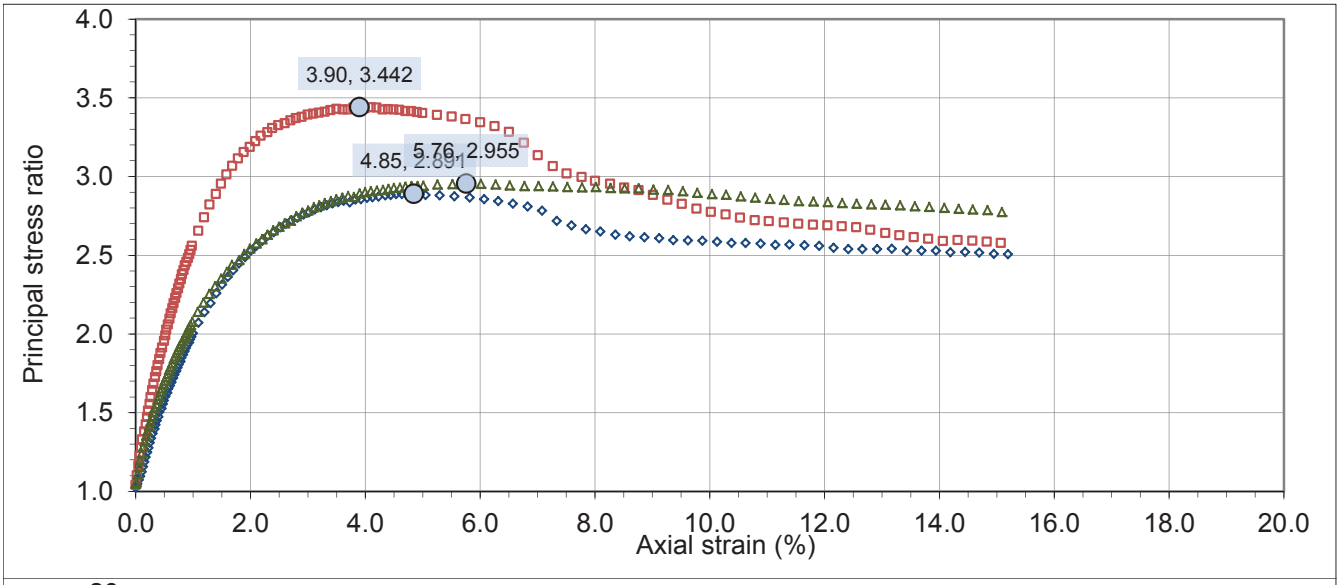
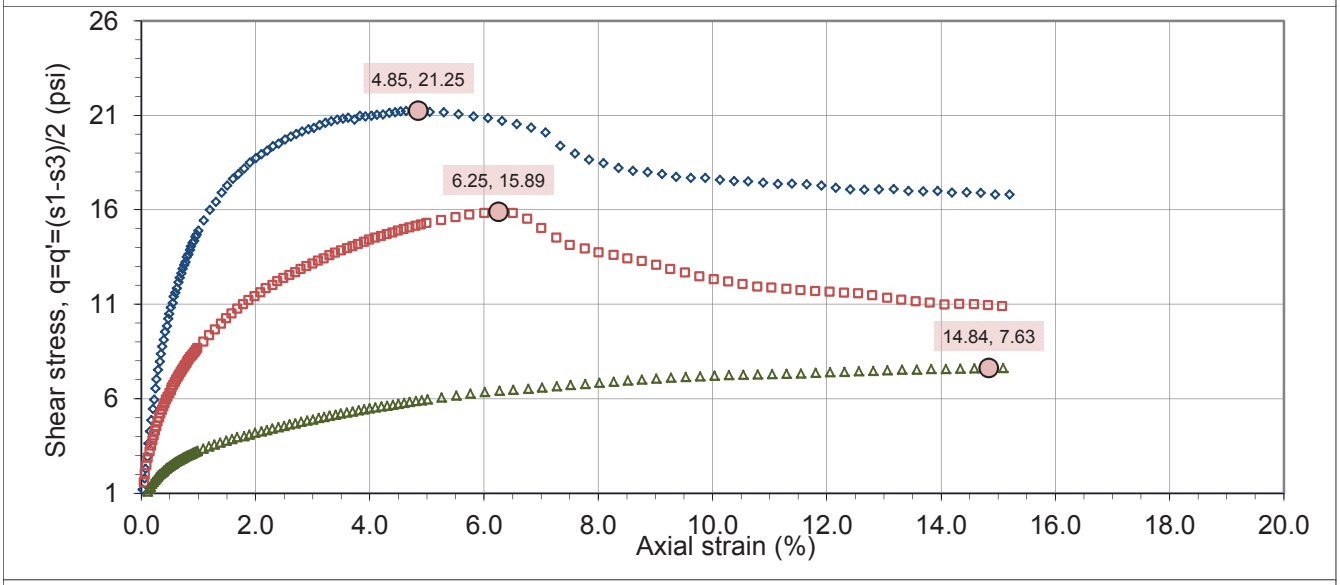
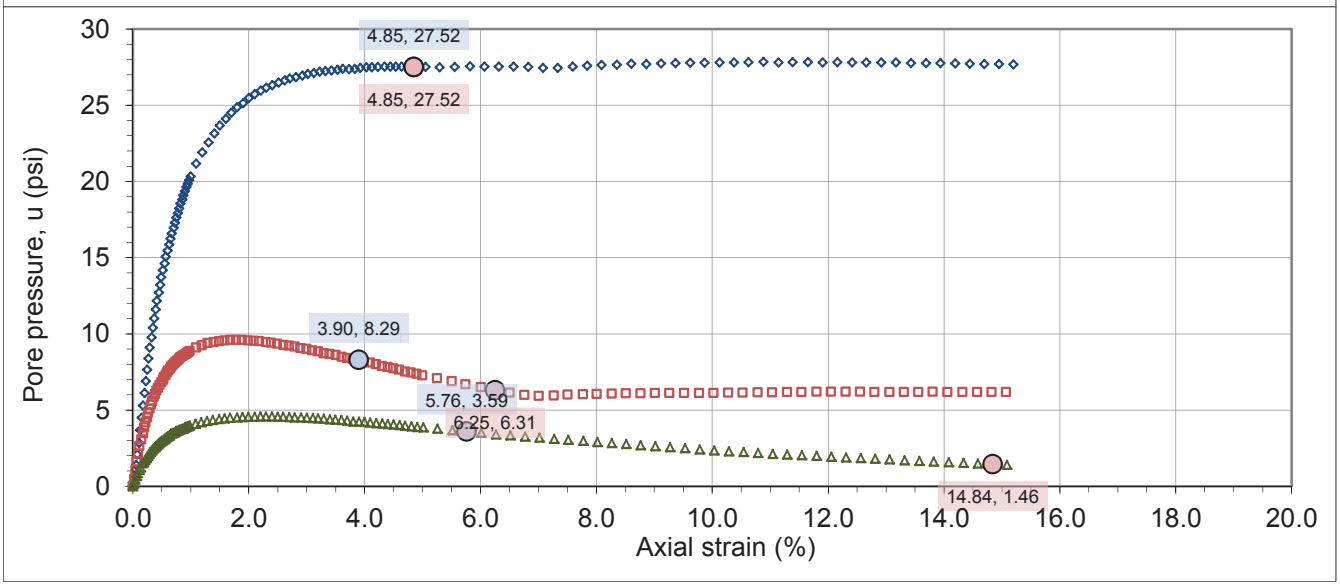
Triaxial Test - Isotropic Consolidated Sheared Undrained
Measuring Pore Pressure (CIU-PP) *- After ASTM D4767 and USBR 5750*

GERHART COLE

Project: Bear River - Fielding **TH/TP/Sample: TH-FD-01**
No: 13GCI329 **Depth: 15-17**







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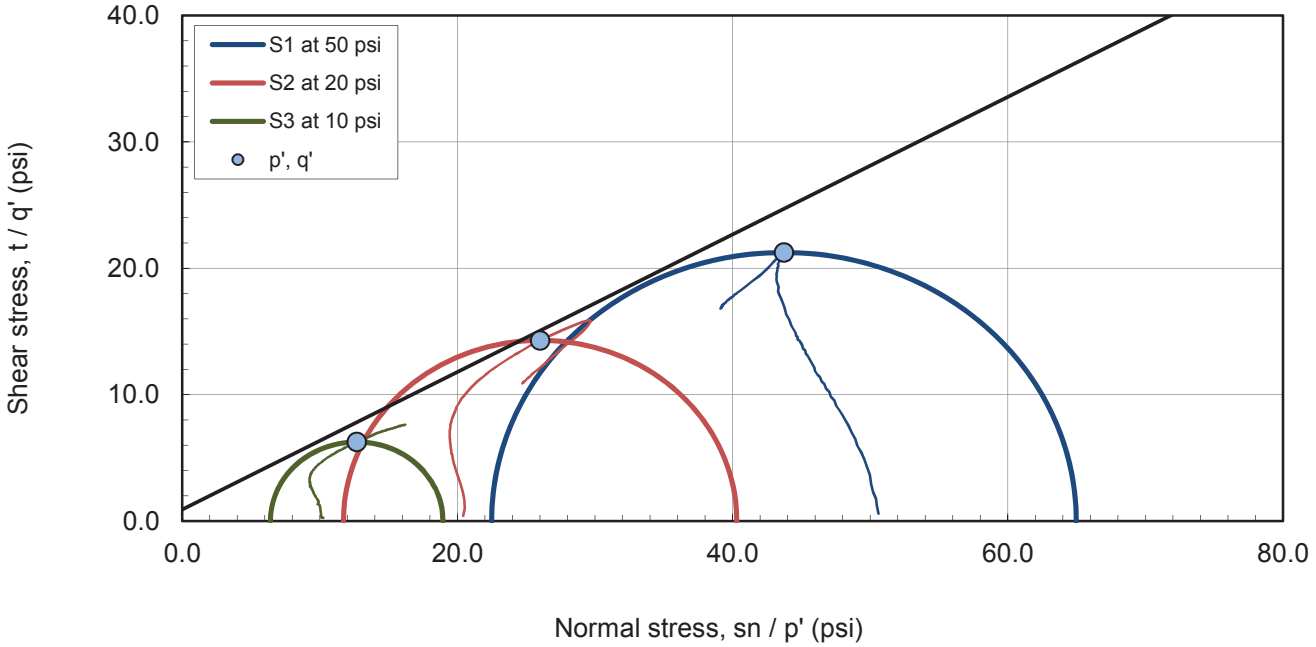
Triaxial Test - Isotropic Consolidated Sheared Undrained
Measuring Pore Pressure (CIU-PP) *- After ASTM D4767 and USBR 5750*

GERHART COLE

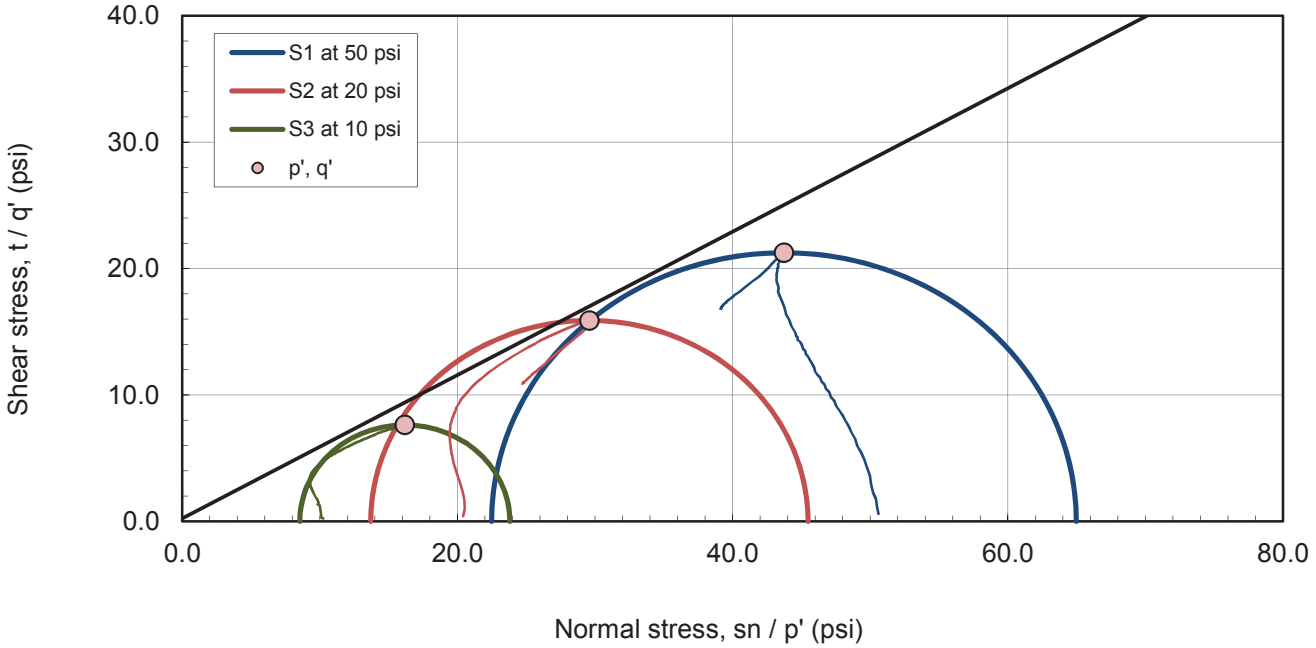
Project: **Bear River - Fielding** **TH/TP/Sample:** **TH-FD-01**
No: **13GCI329** **Depth:** **15-17**

Effective stress results



Max principal stress ratio (s'1/s'3), failure criteria Mohr and p' - q' space plots

Effective stress results



Peak deviator stress (s1-s3), failure criteria Mohr and p' - q' space plots

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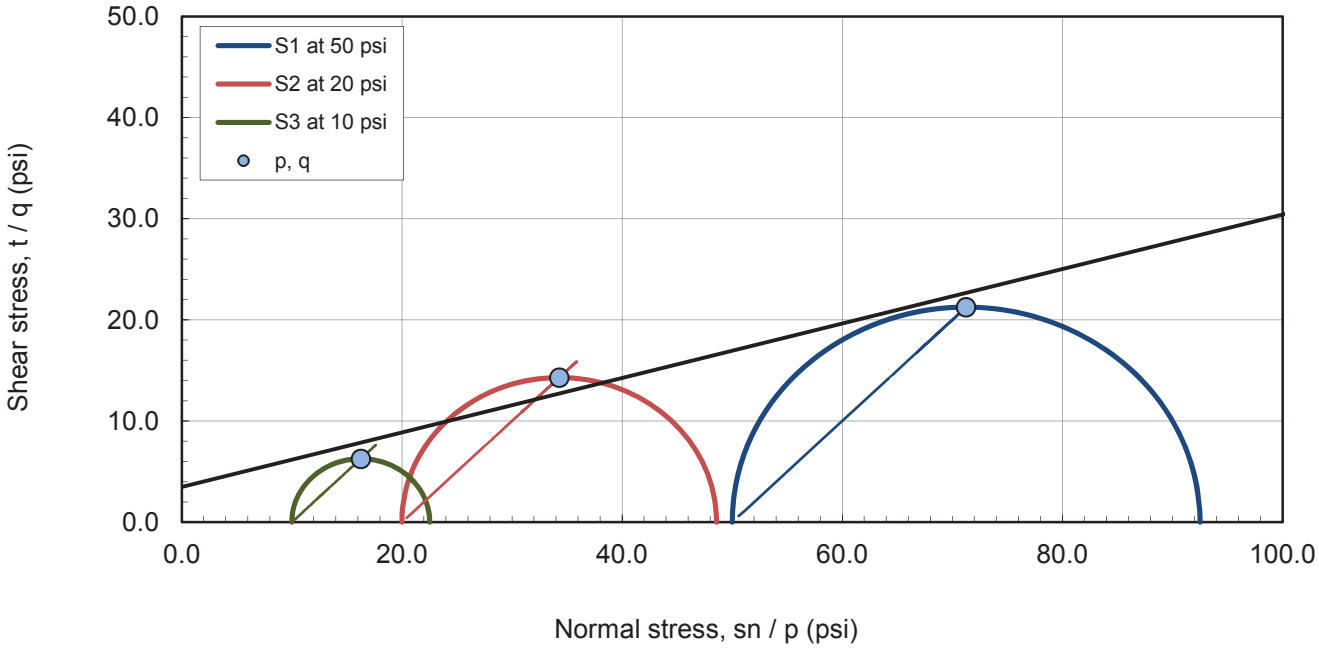
Triaxial Test - Isotropic Consolidated Sheared Undrained
Measuring Pore Pressure (CIU-PP) *- After ASTM D4767 and USBR 5750*

GERHART COLE

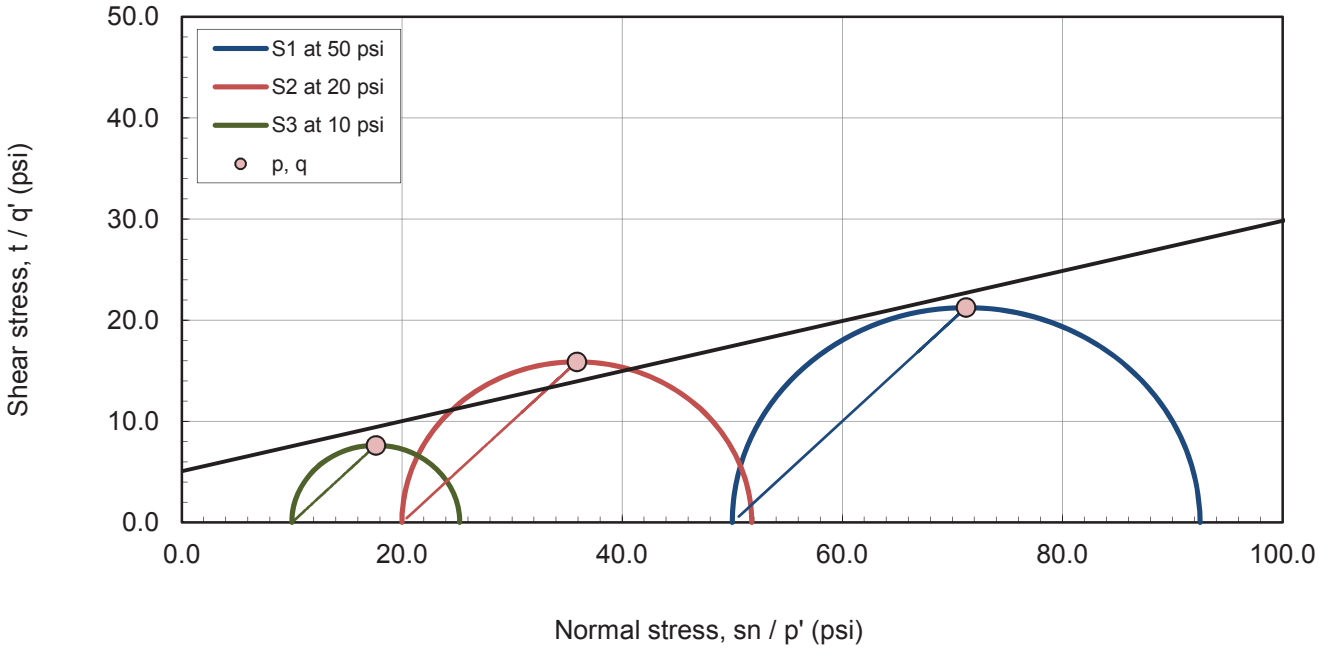
Project: Bear River - Fielding | **TH/TP/Sample:** TH-FD-01
No: 13GCI329 | **Depth:** 15-17

Total stress results



Max principal stress ratio (s1/s3), failure criteria Mohr and p - q space plots - effective stress results

Total stress results



Peak deviator stress (s1-s3), failure criteria Mohr and p - q space plots

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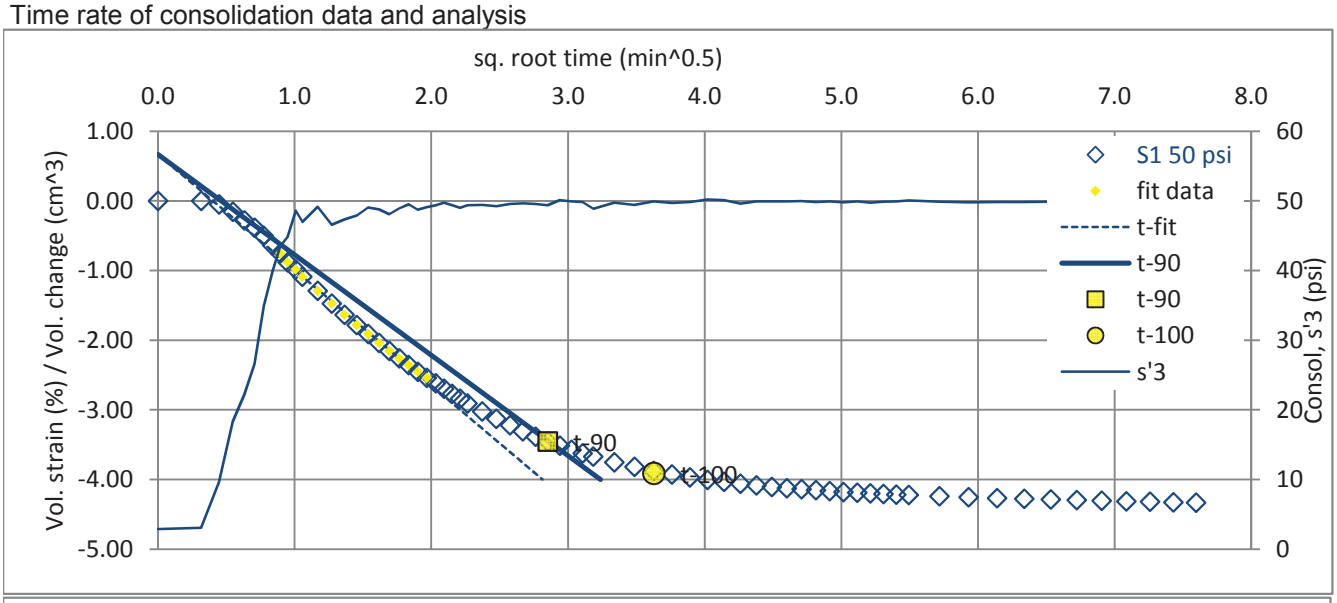
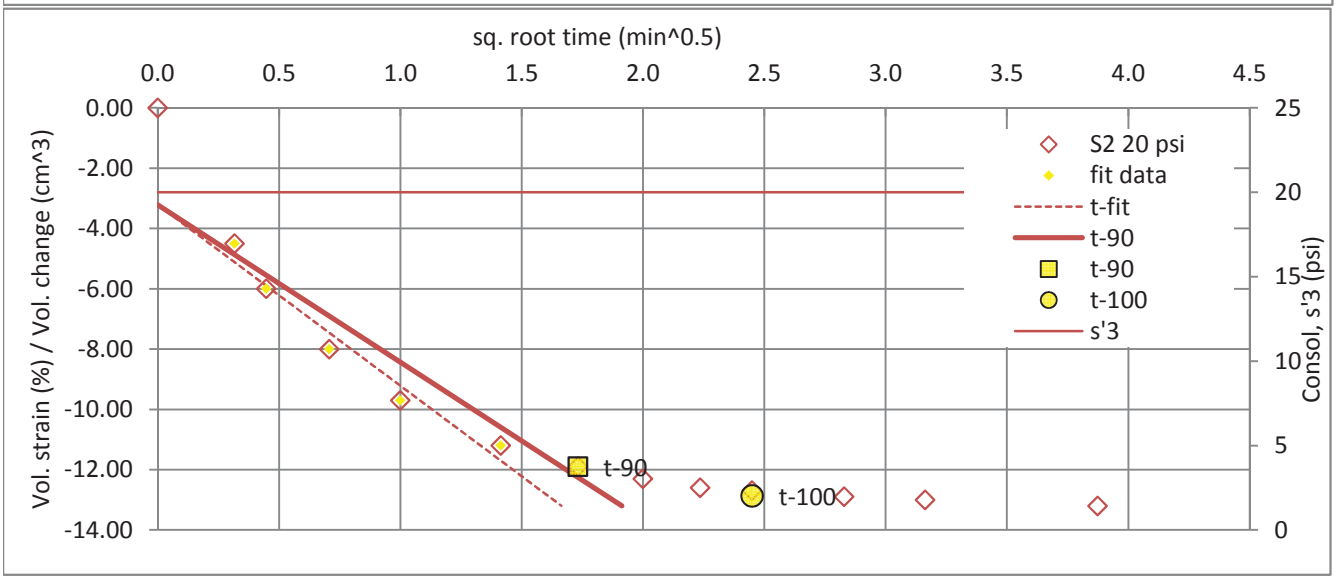
Triaxial Test - Isotropic Consolidated Sheared Undrained
Measuring Pore Pressure (CIU-PP) *- After ASTM D4767 and USBR 5750*

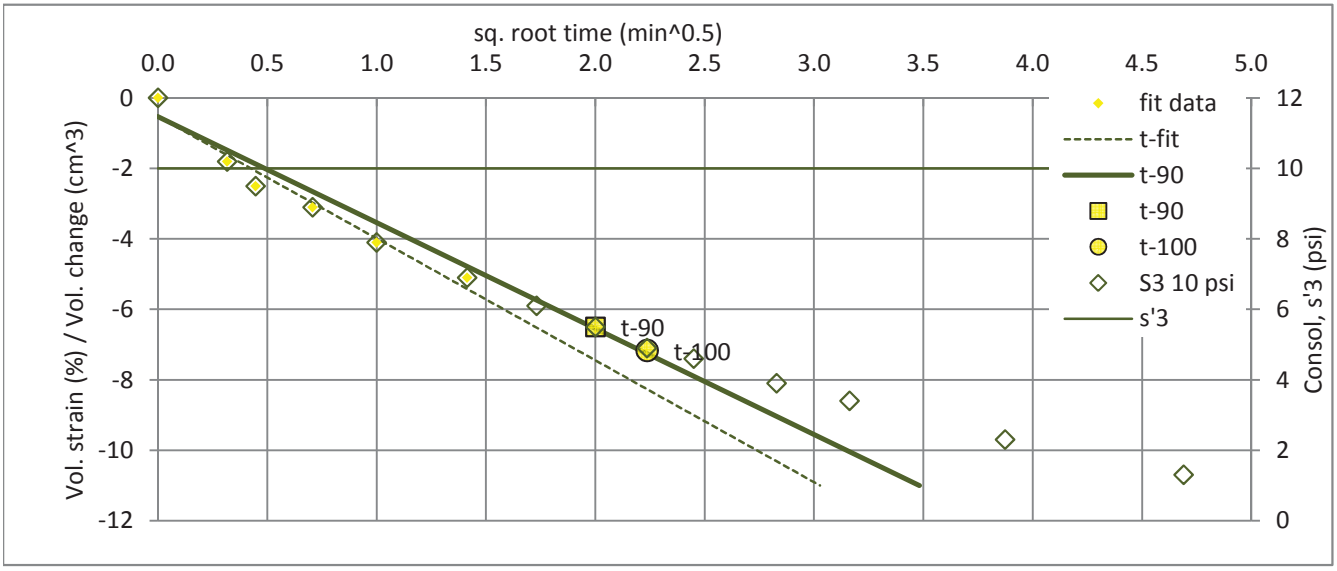
GERHART COLE

Project: Bear River - Fielding **TH/TP/Sample: TH-FD-01**
No: 13GCI329 **Depth: 15-17**

Time rate of consolidation data and analysis







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GERHART COLE

PHOTOGRAPHIC SUMMARY

FIELDING – BEAR RIVER PROJECT

SUMMARY OF LABORATORY TEST PHOTOS

Project No. 13GCI329

Photo Identification:
TH-FD -01;
15-17 ft

Date Taken: 08/10/2015

Description:
Soil Picture of dipping sand seams from Shelby tube sample before shearing

Photo Identification:
TH-FD -01;
15-17 ft

Date Taken: 08/19/2015

Description:
Soil Picture of dipping sand seams from Shelby tube sample after shearing

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Triaxial Test - Isotropic Consolidated Sheared Undrained Measuring Pore Pressure (CIU-PP) - *After ASTM D4767 and USBR 5750*

GERHART COLE

Project: Bear River - Fielding
No: 13GCI329
Location: Box Elder County Utah
Date: 06-Aug-15
Tested by: zmg
Reduced by: zmg
Checked by: dab

TH/TP/Sample: TH-FD-01
Depth: 90-91.7
Sample description: dark gray clay
USCS classification: CL
Sample type: undisturbed
Notes:

	Test Number	S1	90 psi	S2	60 psi	S3	30 psi
		Initial	Bef. Shr. MethodB [e]	Initial	Bef. Shr. MethodB [e]	Initial	Bef. Shr. MethodB [e]
Unit weight data	Sample ht., H (in) 0°	5.752		5.743		5.752	
	120°	5.758		5.748		5.757	
	240°	5.746		5.746		5.741	
	Avg. height, Havg (in)	5.752	5.632	5.746	5.696	5.750	5.680
	Avg. height, Havg (cm)	14.610	14.305	14.594	14.467	14.605	14.427
	ΔHsc (in) [a]		0.12		0.05		0.07
	Sample dia., D (in) top	2.826		2.832		2.853	
	mid	2.820		2.841		2.848	
	bot	2.827		2.838		2.849	
	Avg. dia., Davg (in)	2.823	2.831	2.838	2.829	2.850	2.870
	Avg. dia., Davg (cm)	7.171	7.190	7.209	7.186	7.238	7.289
	Avg. area, Aavg (in^2)	6.260	6.293	6.326	6.286	6.377	6.468
	Avg. area, Aavg (cm^2)	40.388	40.600	40.811	40.555	41.143	41.728
	Wt. rings + wet soil (g)	1137.99	1114.97	1180.88	1171.99	1184.06	1181.01
	Wt. rings (g)	0.00	0.00	0.00	0.00	0.00	0.00
	Volume, Vo (in^3)	36.0	35.4	36.3	35.8	36.7	36.7
	Vo (cm^3)	590.1	580.8	595.6	586.7	600.9	602.0
	Vo (ft^3)	0.0208	0.0205	0.0210	0.0207	0.0212	0.0213
Moisture	Wet soil + tare (g)	162.08	1258.66	245.19	1344.82	299.62	1299.70
	Dry soil + tare (g)	153.37	1022.33	223.86	1099.96	266.38	1048.65
	Tare (g)	120.71	144.15	150.64	173.24	144.77	119.02
	Moisture content, w (%)	26.7	26.9	29.1	26.4	27.3	27.0
Phase Relationships	Gs, assumed	2.65	2.65	2.65	2.65	2.65	2.65
	Mass total (g)	1138.0	1140.2	1180.9	1156.1	1184.1	1181.0
	Mass of solids (g)	898.4	898.4	914.5	914.5	929.9	929.9
	Volume (cm^3)	590.1	580.8	595.6	586.7	600.9	602.0
	Volume of water (cm^3)	239.6	241.8	266.4	241.6	254.2	251.1
	Volume of solids (cm^3)	339.0	339.0	345.1	345.1	350.9	350.9
	Volume of voids (cm^3)	251.1	241.8	250.5	241.6	250.0	251.1
	Volume of air (cm^3)	11.5	0.0	-15.9	0.0	-4.2	0.0
	Void ratio, e	0.741	0.713	0.726	0.700	0.712	0.716
	Porosity, n	0.425	0.416	0.421	0.412	0.416	0.417
	Volumetric moisture, T	0.406	0.416	0.447	0.412	0.423	0.417
	Saturation, S (%) [c]	95.43	100.00	106.34	100.00	101.67	100.00
	Dry density (gm/cm^3)	1.523	1.547	1.535	1.559	1.548	1.545
	Wet unit wt., gm (pcf)	120.4	122.6	123.8	123.0	123.0	122.5
	Dry unit wt., gd (pcf)	95.1	96.6	95.9	97.3	96.6	96.4

Notes:

[a] ΔHsc (in) = change in height during saturation and consolidation

[b] ΔVs = change in volume during saturation, ΔVc = change in volume during consolidation

[c] Saturation before shear set to 100% for phase calculations

[d] Before shear Aavg using method A; where Ac (Method A) = (Vo-DVs - DVc)/(Ho-DHsc)

[e] Before shear Aavg using method B; where Ac (Method B) = (Vwf + Vs)/Hc

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Triaxial Test - Isotropic Consolidated Sheared Undrained
Measuring Pore Pressure (CIU-PP) *- After ASTM D4767 and USBR 5750*

GERHART COLE

Project:	**Bear River - Fielding**	**TH/TP/Sample:**	**TH-FD-01**
No:	**13GCI329**	**Depth:**	**90-91.7**
Location:	Box Elder County Utah	Sample description:	dark gray clay
Date:	8/6/2015	USCS classification:	CL
Tested by:	zmg	Sample type:	undisturbed

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	Test Number	S1 at 90 psi	S2 at 60 psi	S3 at 30 psi
Test information	Total backpressure (psi)	60.0	44.0	40.0
	Skempton B	0.95	0.96	0.95
	t-90 (min)	690.2	780.0	300.2
	t-100 (min)	1140.2	1050.0	480.2
	t-50 (min)	161.3	182.2	70.1
	Strain rate (%/hr)	0.40	0.40	0.40
	Strain rate (%/min)	0.007	0.007	0.007
	Membrane correction	Yes	Yes	Yes
	Filter paper correction	No filter paper	No filter paper	No filter paper
Max principal stress ratio (s1/s3), failure criteria	Strain at failure, ef (%)	5.56	3.09	2.29
	Time to failure, tf (min)	833.3	464.0	344.0
	Obliquity, s'1/s'3	2.826	3.196	4.062
	Excess pore pressure, u (psi)	49.02	27.41	11.60
	q = q' = (s1+s3)/2 (psi)	37.41	35.78	28.17
	p' = (s'1+s'3)/2 (psi)	78.39	68.37	46.57
	p = (s1+s3)/2 (psi)	127.41	95.78	58.17
	Effective major principal stress, s'1 (psi)	115.80	104.15	74.74
	Effective minor principal stress, s'3 (psi)	40.98	32.59	18.40
	Total major pincipal stress, s1 (psi)	164.82	131.56	86.34
	Total minor pincipal stress, s3 (psi)	90.00	60.00	30.00
	Skemption A at failure, Af	0.66	0.38	0.21
	Secant friction angle, phi-s (deg)	28.5	31.6	37.2
		Effective stress	Total stress	
	Friction angle, phi (deg)	17.4	7.8	
	Cohesion intercept, c (psi)	15.2	21.3	
Peak deviator stress (s1-s3), failure criteria	Strain at failure, ef (%)	5.56	3.91	4.71
	Time to failure, tf (min)	833.3	587.0	707.2
	Deviator stress, s1-s3 (psi)	74.82	72.37	65.44
	Excess pore pressure, u (psi)	49.02	26.68	5.89
	q = q' = (s1+s3)/2 (psi)	37.41	36.19	32.72
	p' = (s'1+s'3)/2 (psi)	78.39	69.51	56.83
	p = (s1+s3)/2 (psi)	127.41	96.19	62.72
	Effective major principal stress, s'1 (psi)	115.80	105.69	89.55
	Effective minor principal stress, s'3 (psi)	40.98	33.32	24.11
	Total major pincipal stress, s1 (psi)	164.82	132.37	95.44
	Total minor pincipal stress, s3 (psi)	90.00	60.00	30.00
	Skemption A at failure, Af	0.66	0.37	0.09
	Secant friction angle, phi-s (deg)	28.5	31.4	35.1
		Effective stress	Total stress	
	Friction angle, phi (deg)	12.8	4.2	
	Cohesion intercept, c (psi)	20.8	28.6	

Comments:

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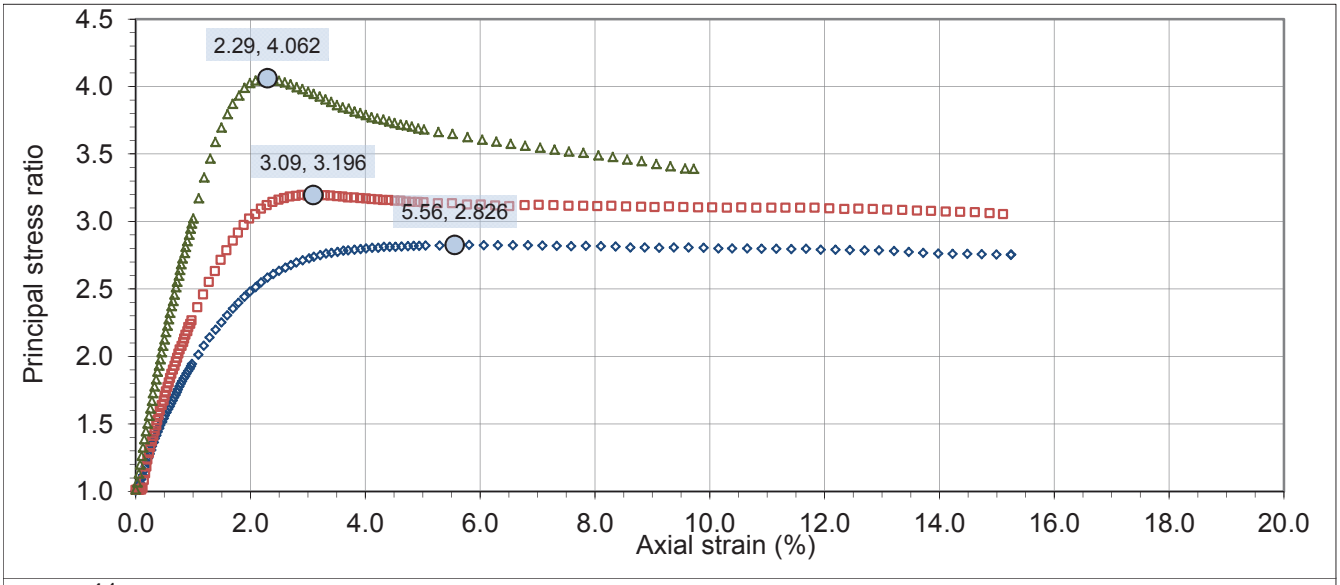
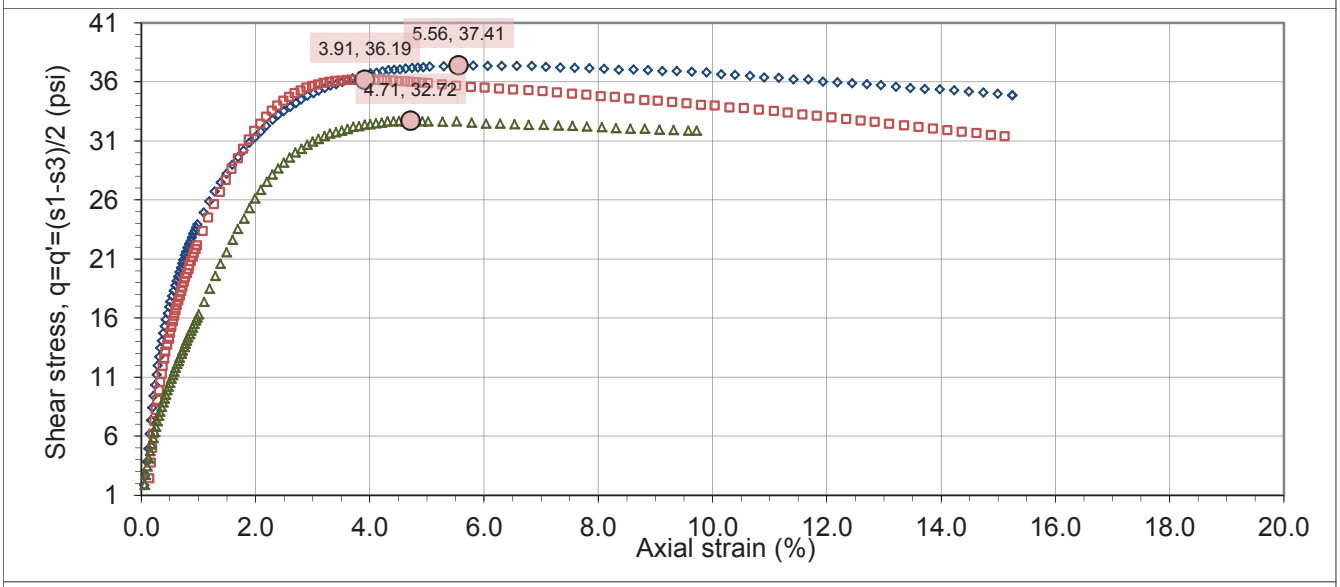
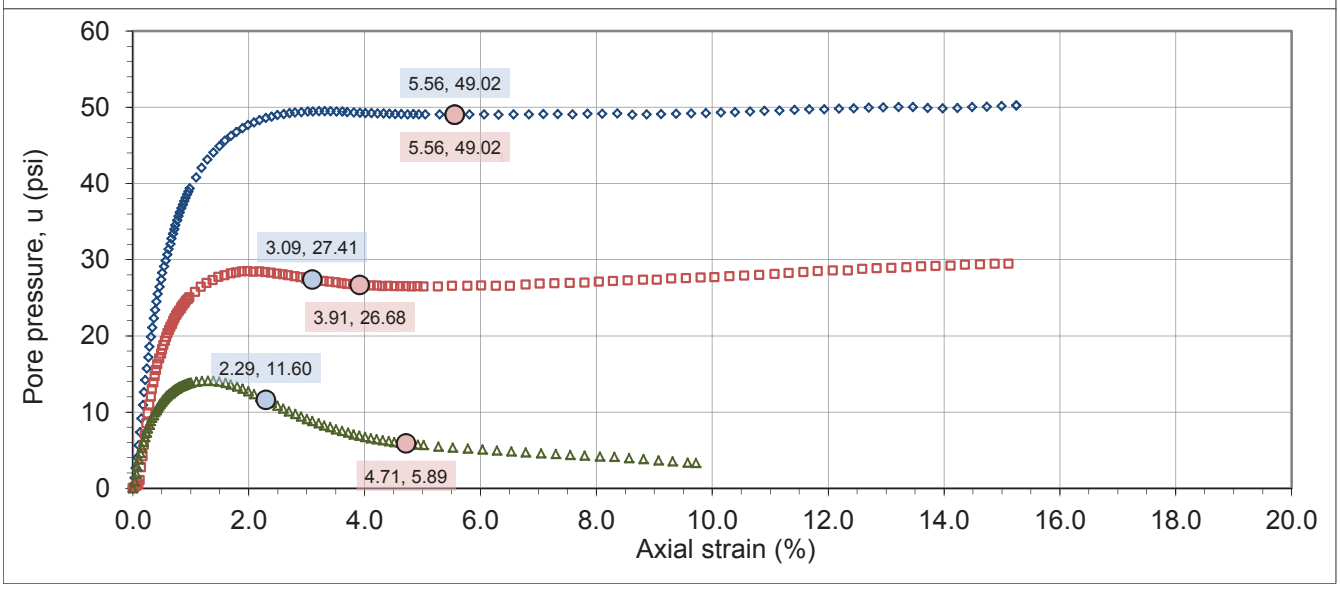
Triaxial Test - Isotropic Consolidated Sheared Undrained
Measuring Pore Pressure (CIU-PP) *- After ASTM D4767 and USBR 5750*

GERHART COLE

Project: Bear River - Fielding **TH/TP/Sample: TH-FD-01**
No: 13GCI329 **Depth: 90-91.7**







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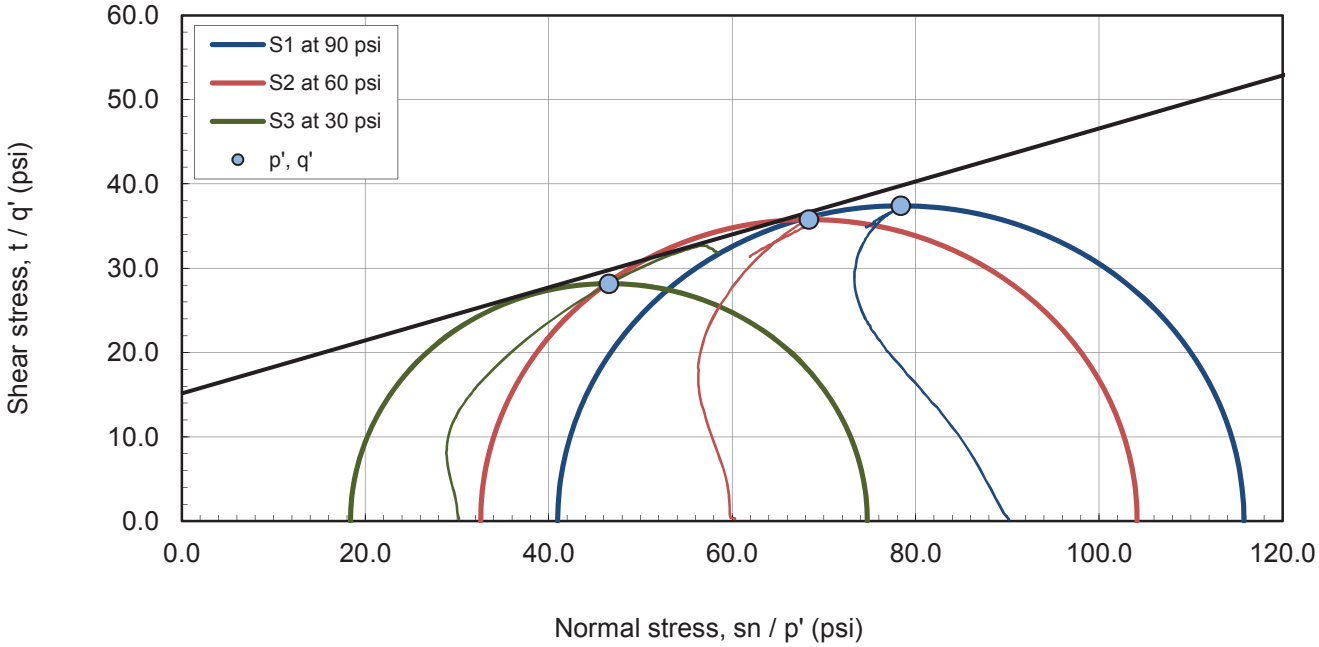
Triaxial Test - Isotropic Consolidated Sheared Undrained
Measuring Pore Pressure (CIU-PP) *- After ASTM D4767 and USBR 5750*

GERHART COLE

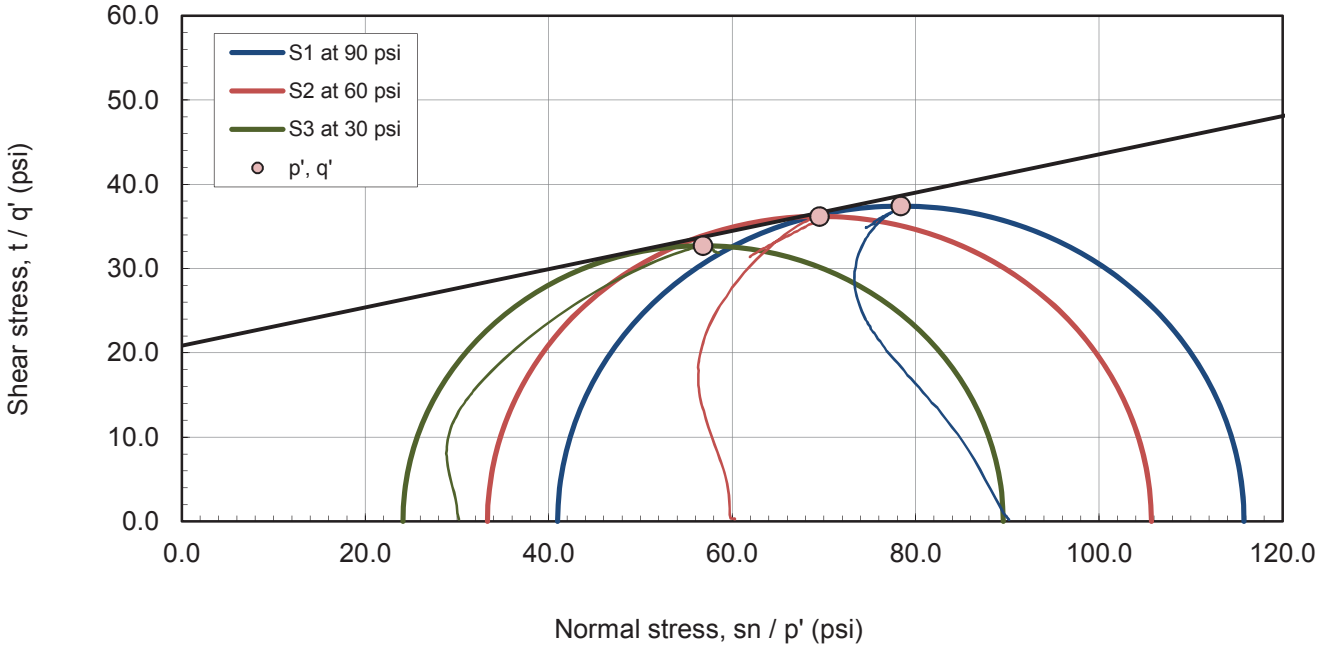
Project: **Bear River - Fielding** **TH/TP/Sample:** **TH-FD-01**
No: **13GCI329** **Depth:** **90-91.7**

Effective stress results



Max principal stress ratio (s'1/s'3), failure criteria Mohr and p' - q' space plots

Effective stress results



Peak deviator stress (s1-s3), failure criteria Mohr and p' - q' space plots

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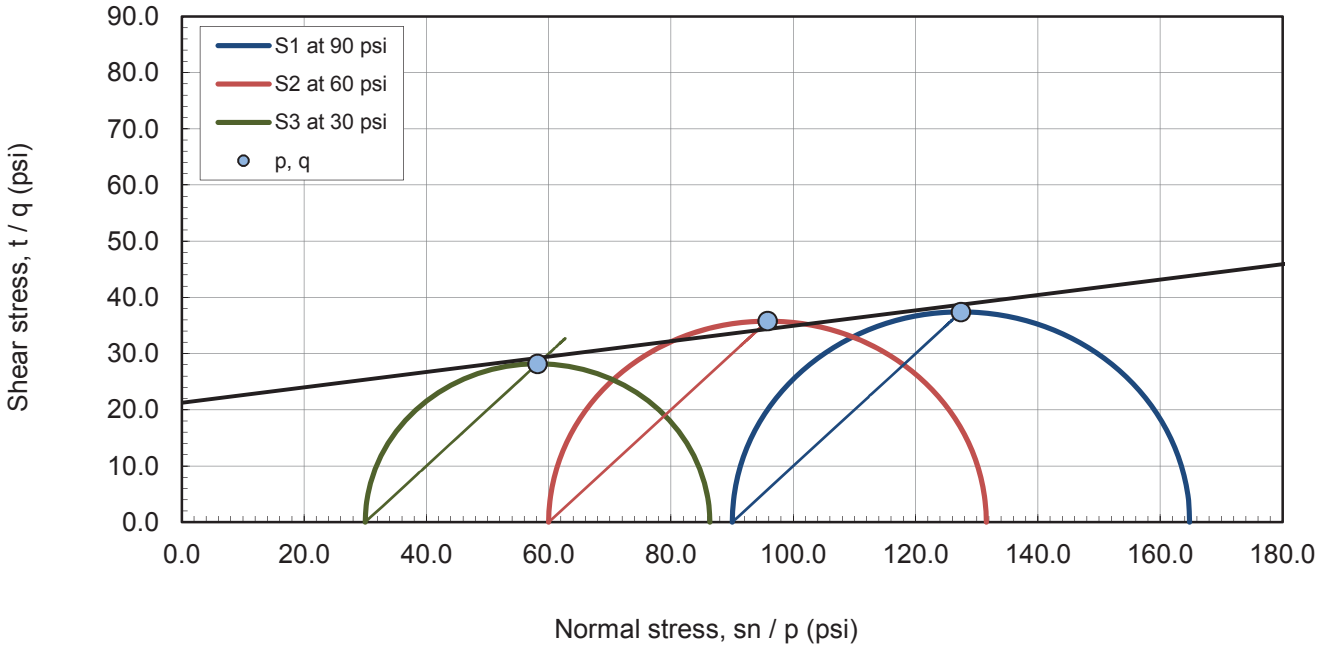
Triaxial Test - Isotropic Consolidated Sheared Undrained
Measuring Pore Pressure (CIU-PP) *- After ASTM D4767 and USBR 5750*

GERHART COLE

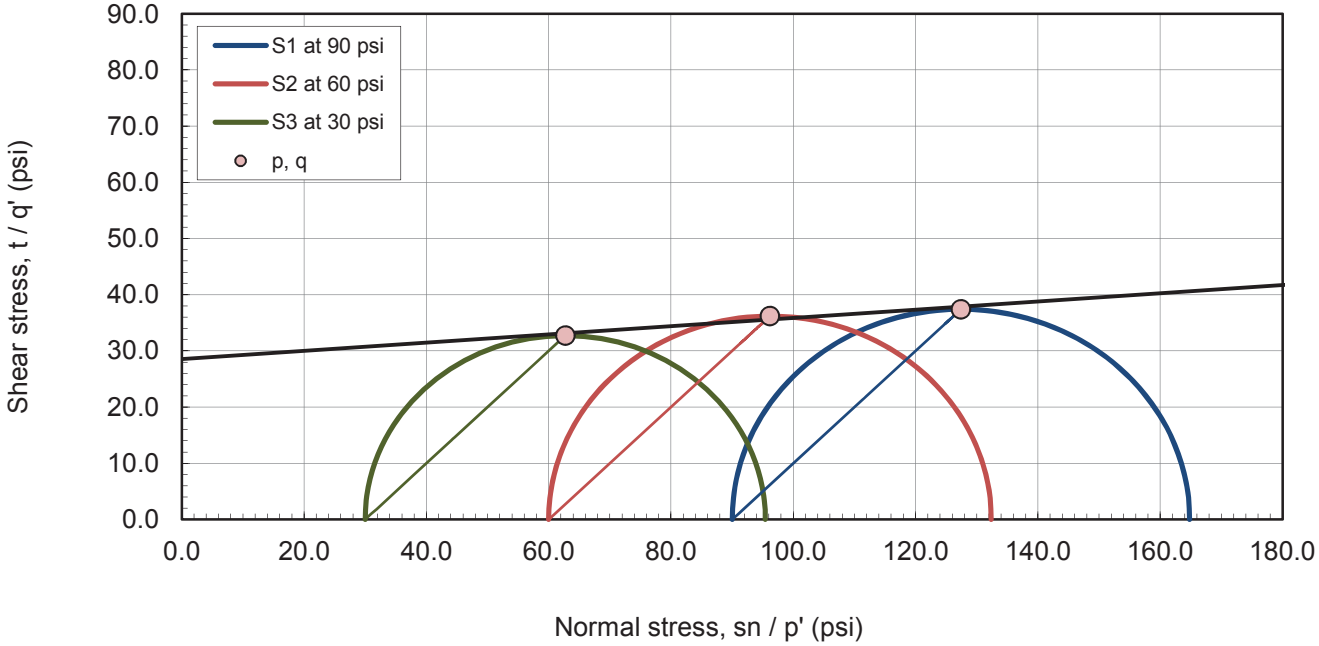
Project: **Bear River - Fielding** **TH/TP/Sample:** **TH-FD-01**
No: **13GCI329** **Depth:** **90-91.7**

Total stress results



Max principal stress ratio (s1/s3), failure criteria Mohr and p - q space plots - effective stress results

Total stress results



Peak deviator stress (s1-s3), failure criteria Mohr and p - q space plots

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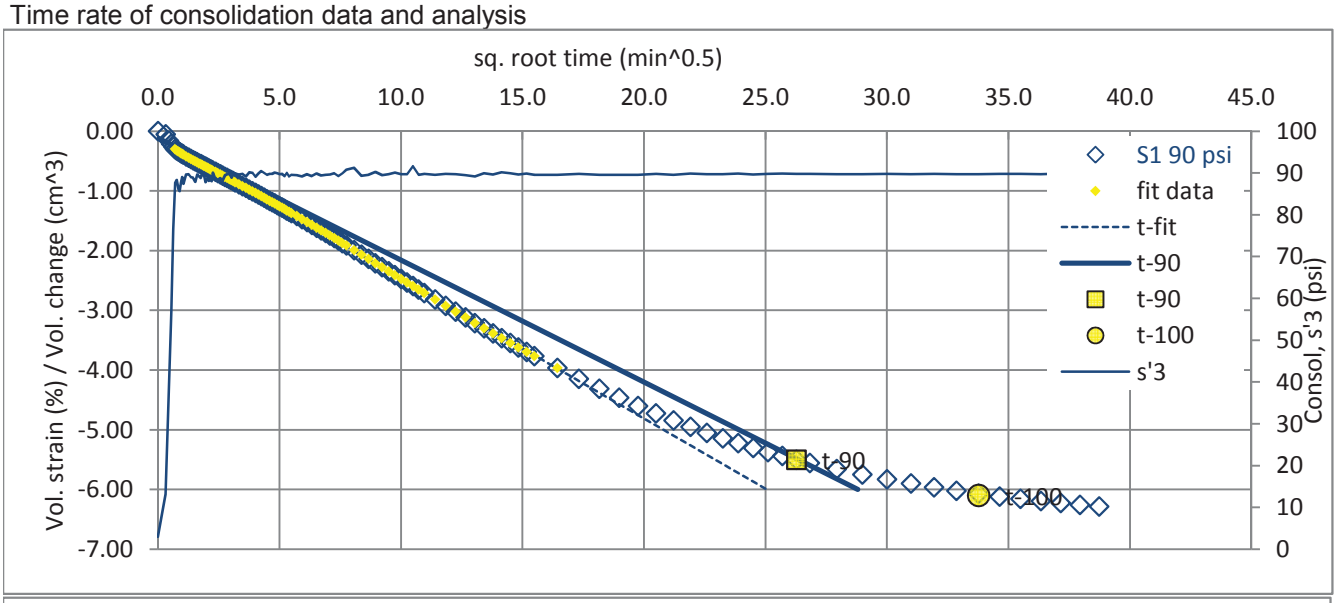
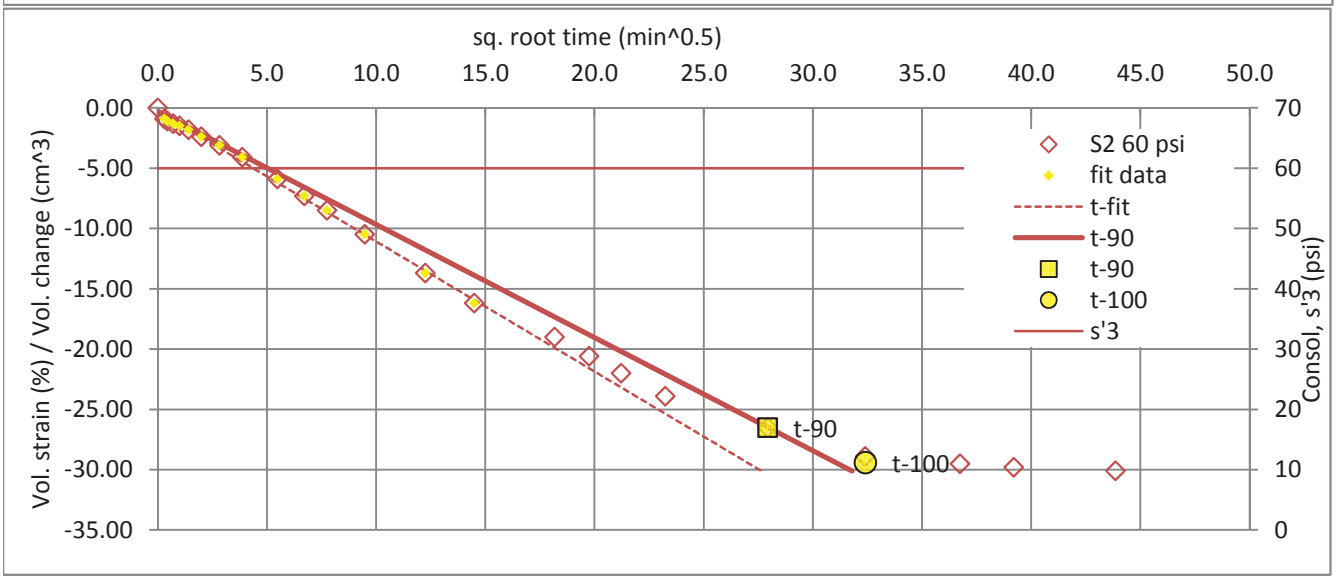
Triaxial Test - Isotropic Consolidated Sheared Undrained
Measuring Pore Pressure (CIU-PP) *- After ASTM D4767 and USBR 5750*

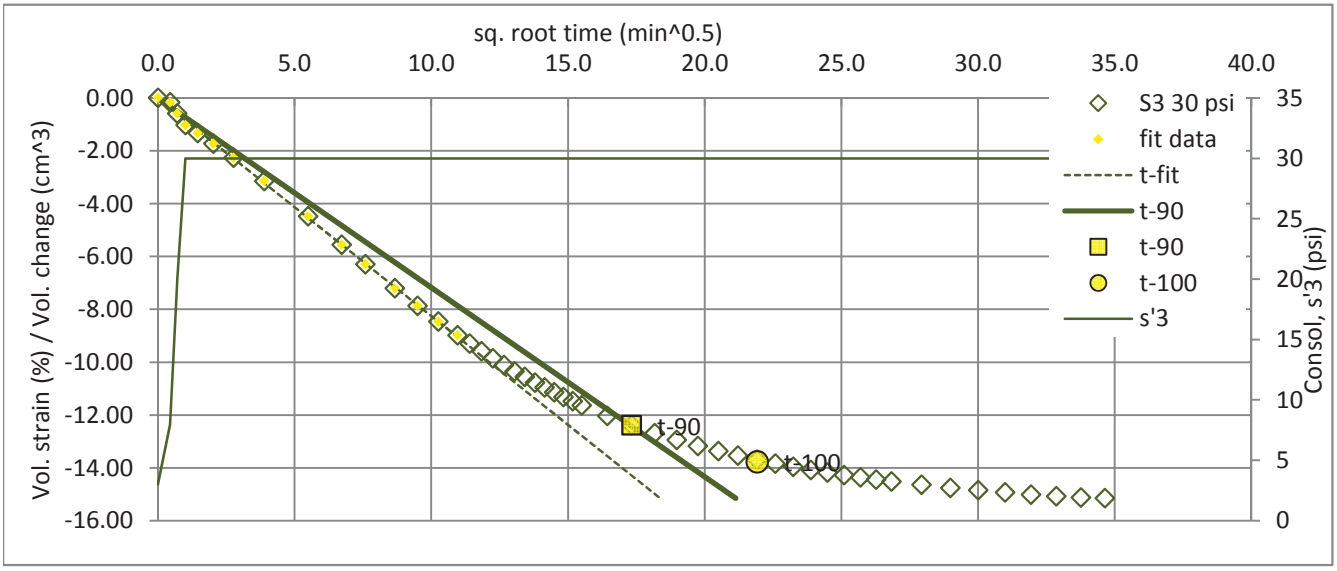
GERHART COLE

Project: Bear River - Fielding **TH/TP/Sample: TH-FD-01**
No: 13GCI329 **Depth: 90-91.7**

Time rate of consolidation data and analysis







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Triaxial Test - Isotropic Consolidated Sheared Undrained Measuring Pore Pressure (CIU-PP) - *After ASTM D4767 and USBR 5750*

GERHART COLE

Project:	**Bear River - Fielding**	**TH/TP/Sample:**	**TH-FD-02**
No:	**13GCI329**	**Depth:**	**25-27**
Location:	Box Elder County Utah	Sample description:	dark gray clay
Date:	22-Jul-15	USCS classification:	CL
Tested by:	zmg	Sample type:	undisturbed
Reduced by:	zmg	Notes:	
Checked by:	bjb		

	Test Number	S1	120 psi	S2	50 psi	S3	20 psi
		Initial	Bef. Shr. MethodB [e]	Initial	Bef. Shr. MethodB [e]	Initial	Bef. Shr. MethodB [e]
Unit weight data	Sample ht., H (in) 0°	5.655		5.758		5.888	
	120°	5.640		5.749		5.896	
	240°	5.625		5.761		5.893	
	Avg. height, Havg (in)	5.640	5.510	5.756	5.686	5.892	5.802
	Avg. height, Havg (cm)	14.326	13.995	14.620	14.442	14.967	14.738
	ΔHsc (in) [a]		0.13		0.07		0.09
	Sample dia., D (in) top	2.816		2.820		2.855	
	mid	2.819		2.834		2.851	
	bot	2.817		2.816		2.853	
	Avg. dia., Davg (in)	2.818	2.748	2.826	2.930	2.853	2.824
	Avg. dia., Davg (cm)	7.157	6.980	7.178	7.443	7.245	7.173
	Avg. area, Aavg (in^2)	6.236	5.932	6.272	6.744	6.391	6.264
	Avg. area, Aavg (cm^2)	40.231	38.270	40.467	43.509	41.230	40.415
	Wt. rings + wet soil (g)	1121.64	1103.25	1466.31	1143.69	1186.26	1170.01
	Wt. rings (g)	0.00	0.00	305.54	0.00	0.00	0.00
	Volume, Vo (in^3)	35.2	32.7	36.1	38.3	37.7	36.3
	Vo (cm^3)	576.3	535.6	591.6	628.4	617.1	595.6
	Vo (ft^3)	0.0204	0.0189	0.0209	0.0222	0.0218	0.0210
Moisture	Wet soil + tare (g)	258.54	1247.57	205.15	1288.53	221.85	1289.81
	Dry soil + tare (g)	229.96	1020.43	193.93	1032.32	201.48	1008.90
	Tare (g)	144.29	144.98	145.29	145.37	148.01	120.05
	Moisture content, w (%)	33.4	25.9	23.1	28.9	38.1	31.6
Phase Relationships	Gs, assumed	2.65	2.65	2.65	2.65	2.65	2.65
	Mass total (g)	1121.6	1059.3	1160.8	1215.7	1186.3	1130.5
	Mass of solids (g)	841.1	841.1	943.2	943.2	859.0	859.0
	Volume (cm^3)	576.3	535.6	591.6	628.4	617.1	595.6
	Volume of water (cm^3)	280.6	218.2	217.6	272.5	327.2	271.5
	Volume of solids (cm^3)	317.4	317.4	355.9	355.9	324.2	324.2
	Volume of voids (cm^3)	259.0	218.2	235.7	272.5	292.9	271.5
	Volume of air (cm^3)	-21.6	0.0	18.1	0.0	-34.3	0.0
	Void ratio, e	0.816	0.688	0.662	0.765	0.904	0.837
	Porosity, n	0.449	0.407	0.398	0.434	0.475	0.456
	Volumetric moisture, T	0.487	0.407	0.368	0.434	0.530	0.456
	Saturation, S (%) [c]	108.35	100.00	92.30	100.00	111.72	100.00
	Dry density (gm/cm^3)	1.459	1.570	1.594	1.501	1.392	1.442
	Wet unit wt., gm (pcf)	121.5	123.5	122.5	120.8	120.0	118.5
	Dry unit wt., gd (pcf)	91.1	98.0	99.5	93.7	86.9	90.0

Notes:

[a] ΔHsc (in) = change in height during saturation and consolidation

[b] ΔVs = change in volume during saturation, ΔVc = change in volume during consolidation

[c] Saturation before shear set to 100% for phase calculations

[d] Before shear Aavg using method A; where Ac (Method A) = (Vo-DVs - DVc)/(Ho-DHsc)

[e] Before shear Aavg using method B; where Ac (Method B) = (Vwf + Vs)/Hc

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Triaxial Test - Isotropic Consolidated Sheared Undrained
Measuring Pore Pressure (CIU-PP) *- After ASTM D4767 and USBR 5750*

GERHART COLE

Project:	**Bear River - Fielding**	**TH/TP/Sample:**	**TH-FD-02**
No:	**13GCI329**	**Depth:**	**25-27**
Location:	Box Elder County Utah	Sample description:	dark gray clay
Date:	7/22/2015	USCS classification:	CL
Tested by:	zmg	Sample type:	undisturbed

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	Test Number	S1 at 120 psi	S2 at 50 psi	S3 at 20 psi
Test information	Total backpressure (psi)	50.0	34.0	24.0
	Skempton B	0.98	0.96	0.98
	t-90 (min)	5.6	150.0	330.0
	t-100 (min)	8.1	210.0	420.0
	t-50 (min)	1.3	35.0	77.1
	Strain rate (%/hr)	1.20	1.20	1.20
	Strain rate (%/min)	0.020	0.020	0.020
	Membrane correction	Yes	Yes	Yes
	Filter paper correction	No filter paper	No filter paper	No filter paper
Max principal stress ratio (s1/s3), failure criteria	Strain at failure, ef (%)	7.35	3.62	3.11
	Time to failure, tf (min)	367.5	180.9	155.5
	Obliquity, s'1/s'3	3.298	9.242	4.058
	Excess pore pressure, u (psi)	78.85	43.98	11.99
	q = q' = (s1+s3)/2 (psi)	47.28	24.80	12.25
	p' = (s'1+s'3)/2 (psi)	88.44	30.82	20.27
	p = (s1+s3)/2 (psi)	167.28	74.80	32.25
	Effective major principal stress, s'1 (psi)	135.72	55.62	32.52
	Effective minor principal stress, s'3 (psi)	41.15	6.02	8.01
	Total major pincipal stress, s1 (psi)	214.57	99.60	44.51
	Total minor pincipal stress, s3 (psi)	120.00	50.00	20.00
	Skemption A at failure, Af	0.83	0.89	0.49
	Secant friction angle, phi-s (deg)	32.3	53.6	37.2
		Effective stress	Total stress	
	Friction angle, phi (deg)	28.2	14.9	
	Cohesion intercept, c (psi)	7.0	4.8	
Peak deviator stress (s1-s3), failure criteria	Strain at failure, ef (%)	7.35	6.82	15.21
	Time to failure, tf (min)	367.5	341.1	760.4
	Deviator stress, s1-s3 (psi)	94.57	51.20	29.14
	Excess pore pressure, u (psi)	78.85	43.37	6.81
	q = q' = (s1+s3)/2 (psi)	47.28	25.60	14.57
	p' = (s'1+s'3)/2 (psi)	88.44	32.23	27.76
	p = (s1+s3)/2 (psi)	167.28	75.60	34.57
	Effective major principal stress, s'1 (psi)	135.72	57.83	42.33
	Effective minor principal stress, s'3 (psi)	41.15	6.63	13.19
	Total major pincipal stress, s1 (psi)	214.57	101.20	49.14
	Total minor pincipal stress, s3 (psi)	120.00	50.00	20.00
	Skemption A at failure, Af	0.83	0.85	0.23
	Secant friction angle, phi-s (deg)	32.3	52.6	31.7
		Effective stress	Total stress	
	Friction angle, phi (deg)	28.3	14.2	
	Cohesion intercept, c (psi)	6.5	6.7	

Comments:

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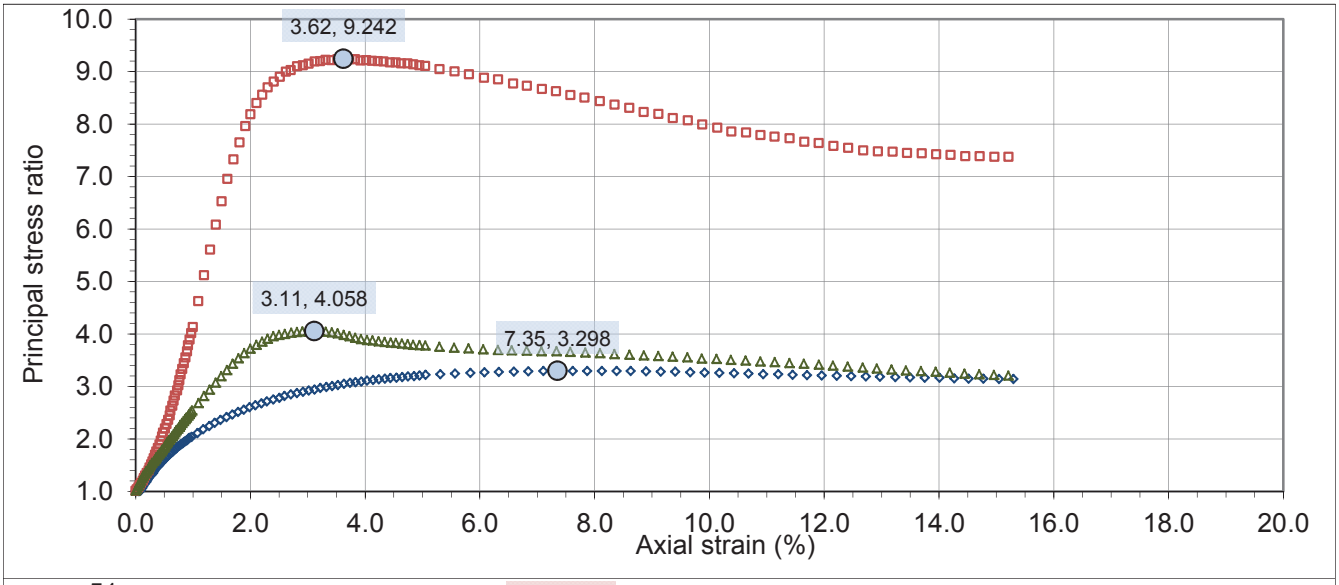
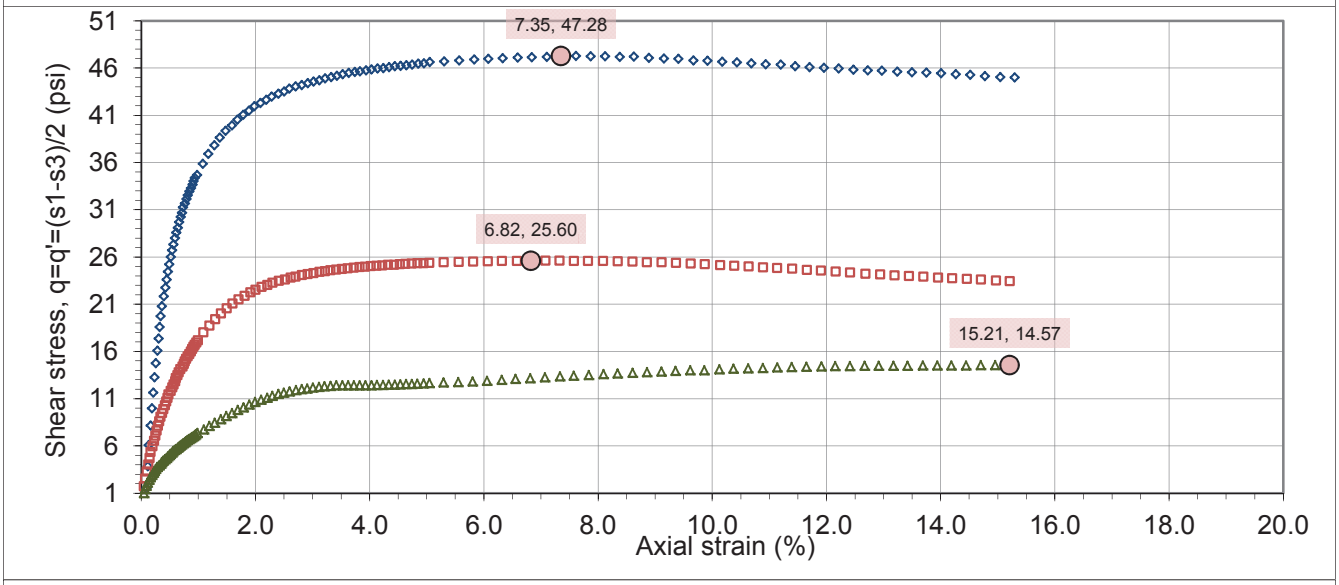
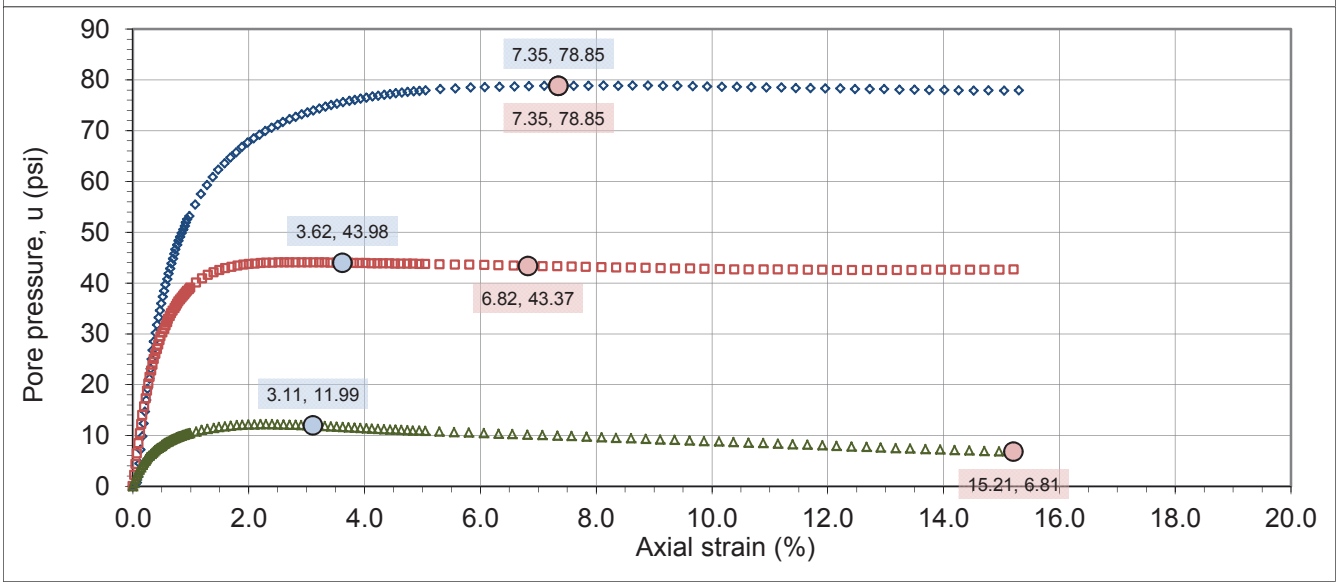
Triaxial Test - Isotropic Consolidated Sheared Undrained
Measuring Pore Pressure (CIU-PP) *- After ASTM D4767 and USBR 5750*

GERHART COLE

Project: Bear River - Fielding **TH/TP/Sample:** TH-FD-02
No: 13GCI329 **Depth:** 25-27







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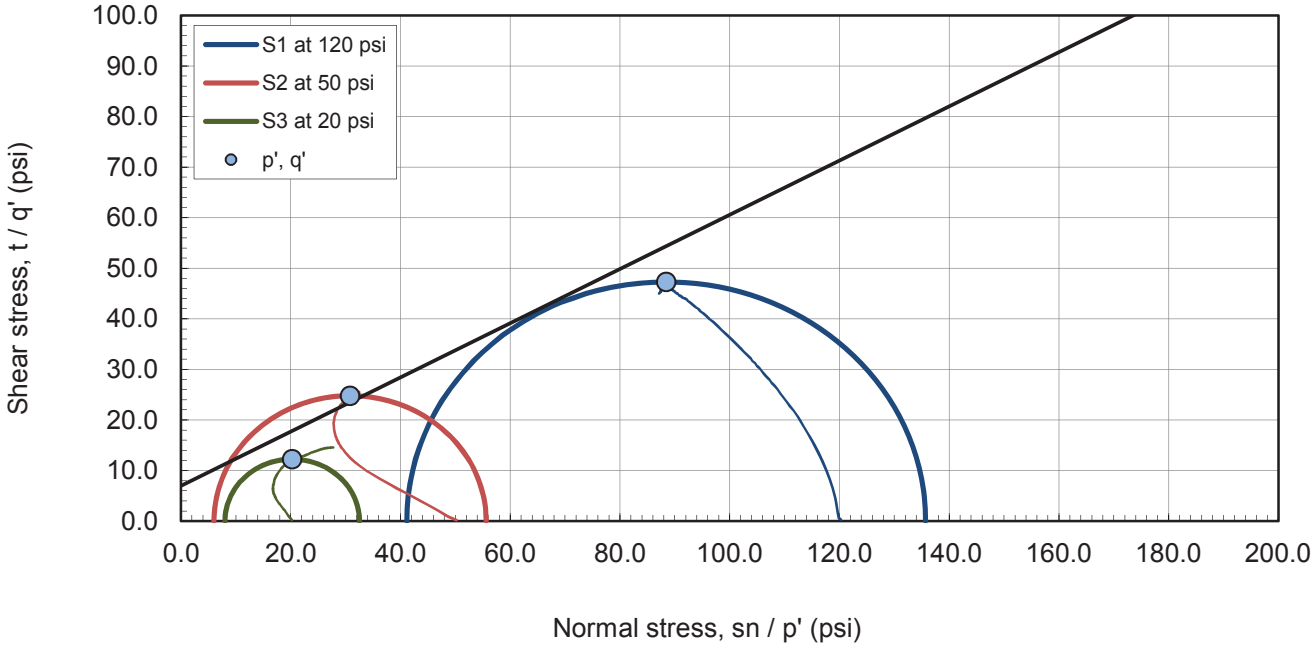
Triaxial Test - Isotropic Consolidated Sheared Undrained
Measuring Pore Pressure (CIU-PP) *- After ASTM D4767 and USBR 5750*

GERHART COLE

Project: Bear River - Fielding
No: 13GCI329

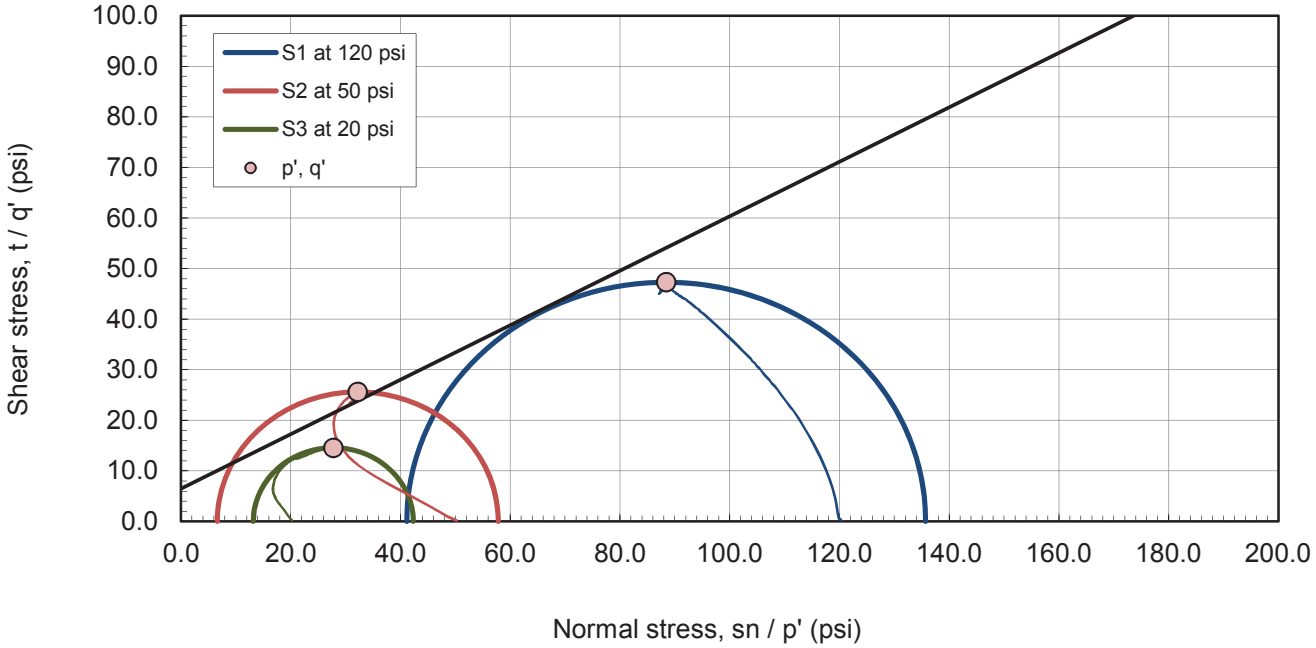
TH/TP/Sample: TH-FD-02
Depth: 25-27

Effective stress results



Max principal stress ratio (s'1/s'3), failure criteria Mohr and p' - q' space plots

Effective stress results



Peak deviator stress (s1-s3), failure criteria Mohr and p' - q' space plots

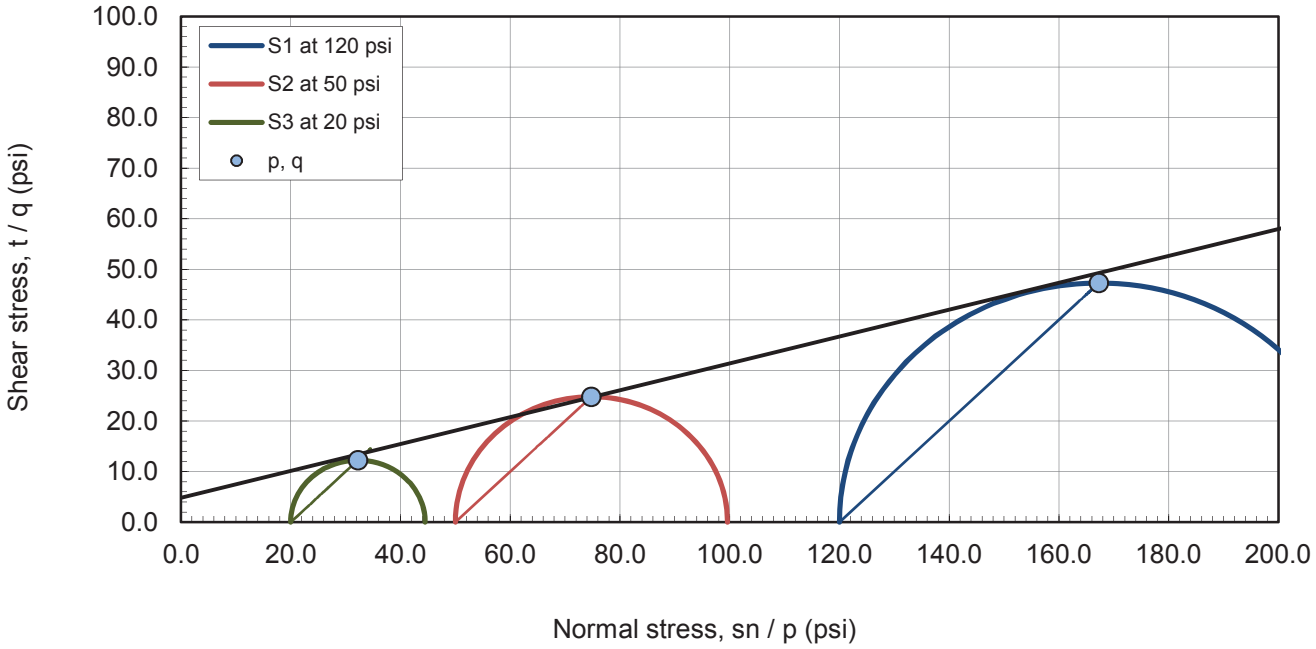
DRAFT

Triaxial Test - Isotropic Consolidated Sheared Undrained
Measuring Pore Pressure (CIU-PP) *- After ASTM D4767 and USBR 5750*

GERHART COLE

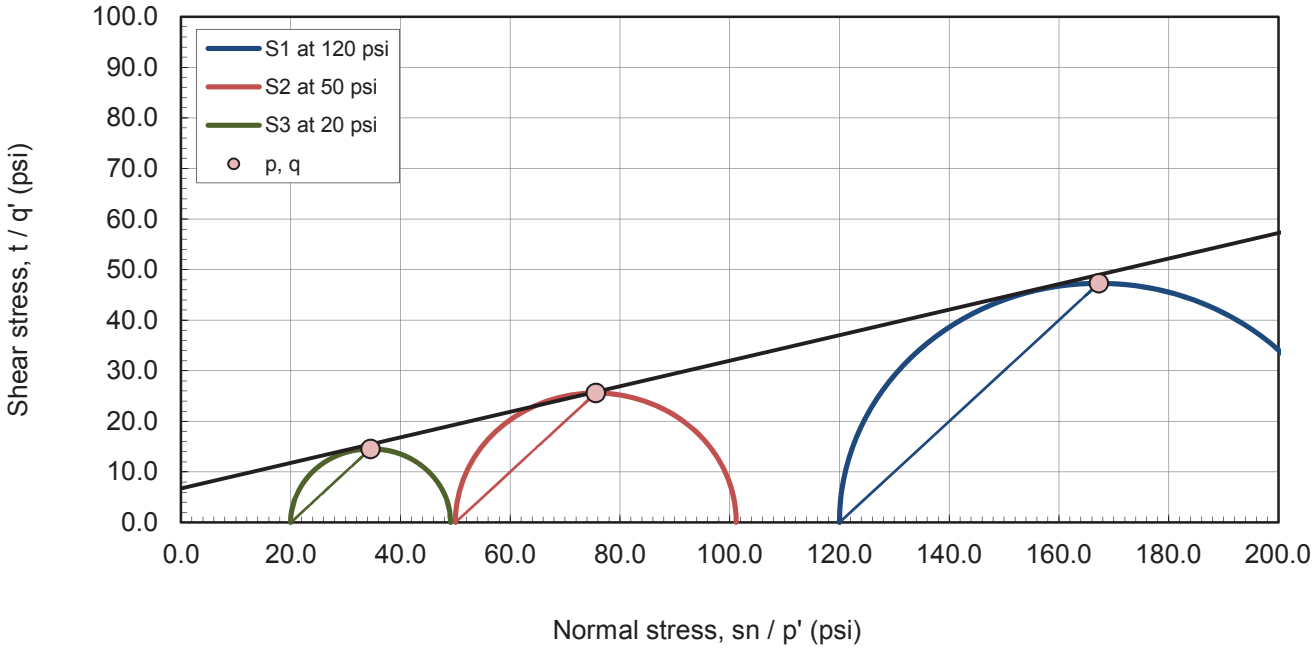
Project: Bear River - Fielding | **TH/TP/Sample:** TH-FD-02
No: 13GCI329 | **Depth:** 25-27

Total stress results



Max principal stress ratio (s1/s3), failure criteria Mohr and p - q space plots - effective stress results

Total stress results



Peak deviator stress (s1-s3), failure criteria Mohr and p - q space plots

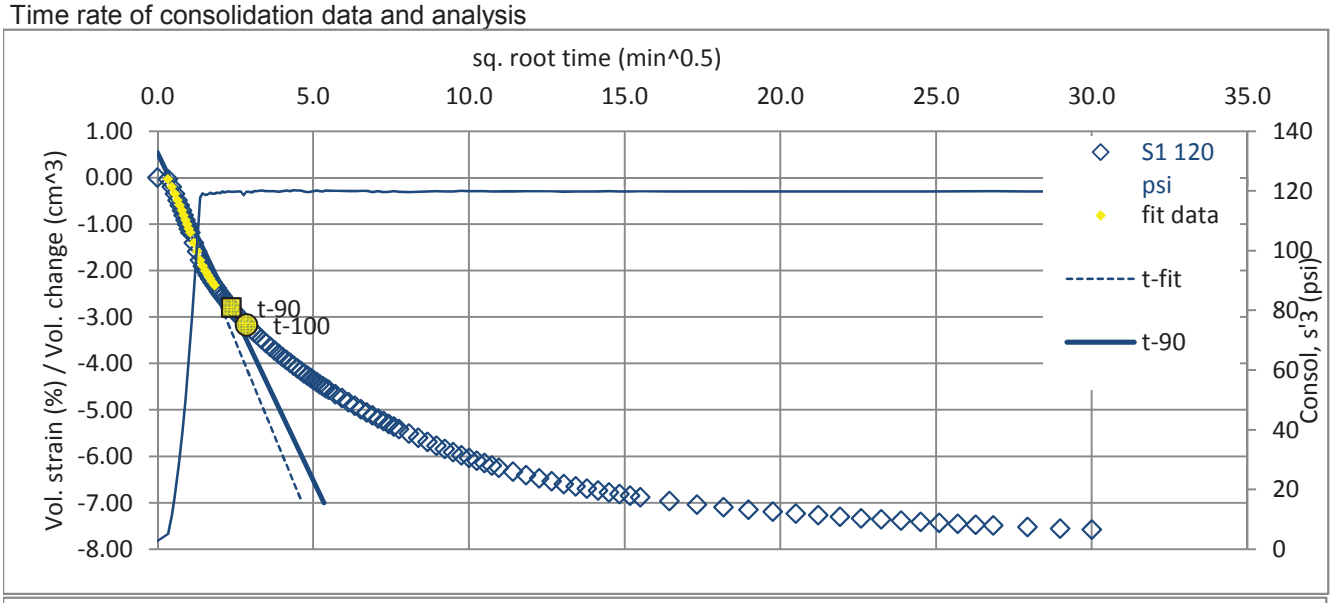
DRAFT

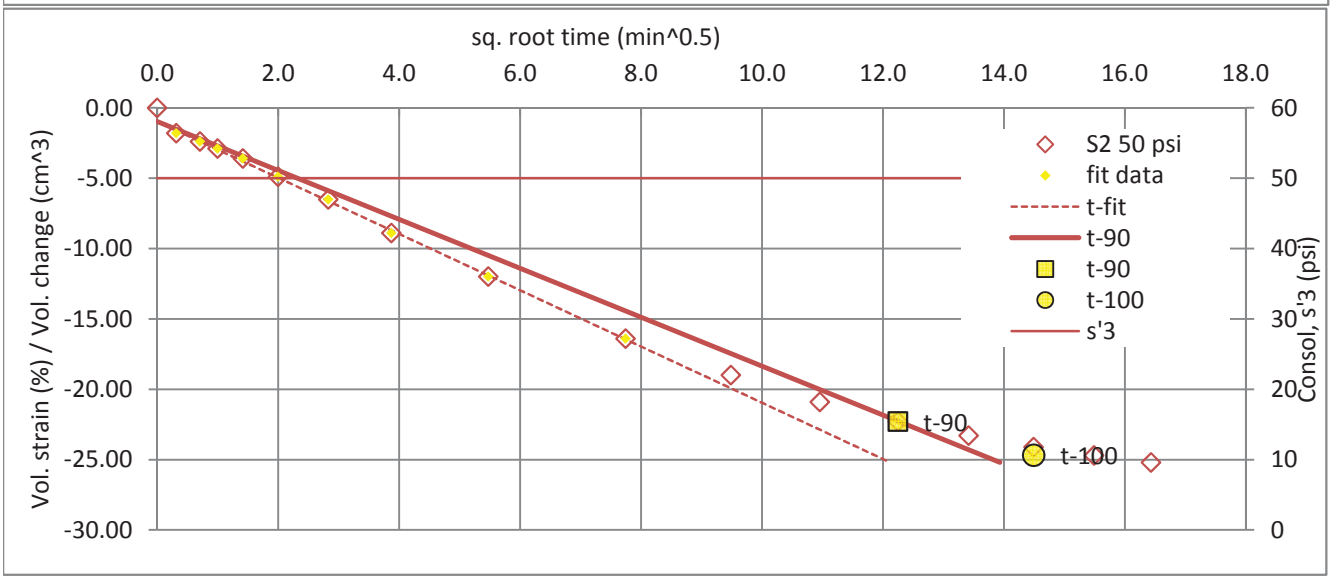
Triaxial Test - Isotropic Consolidated Sheared Undrained
Measuring Pore Pressure (CIU-PP) *- After ASTM D4767 and USBR 5750*

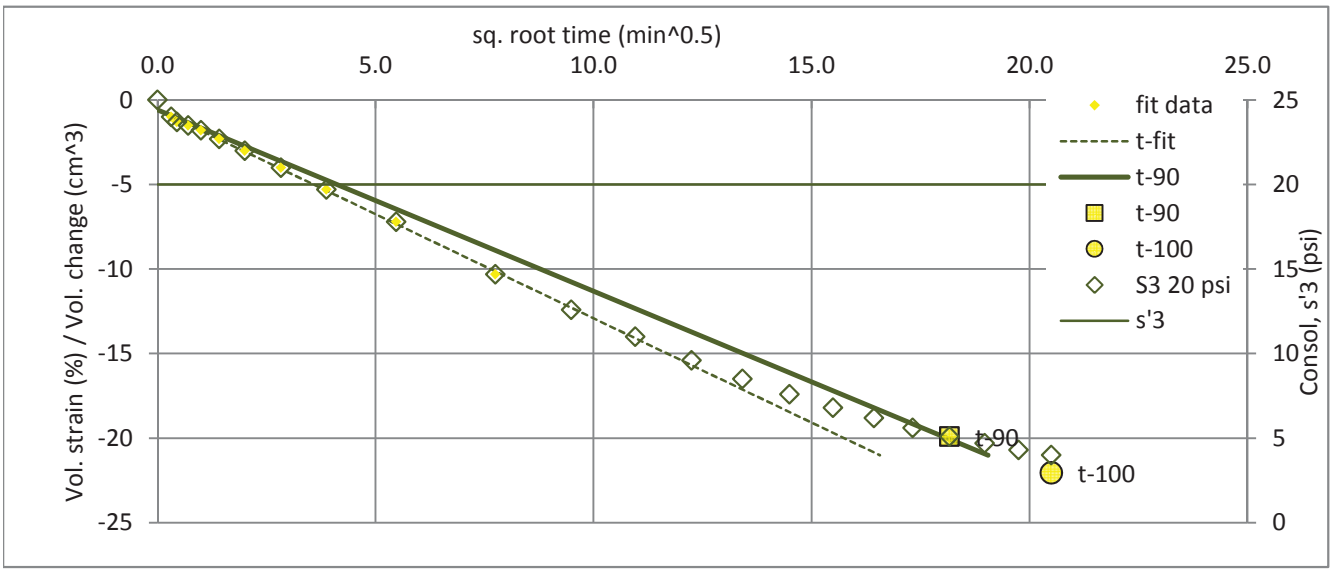
GERHART COLE

Project: Bear River - Fielding **TH/TP/Sample: TH-FD-02**
No: 13GCI329 **Depth: 25-27**

Time rate of consolidation data and analysis







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Triaxial Test - Isotropic Consolidated Sheared Undrained Measuring Pore Pressure (CIU-PP) - *After ASTM D4767 and USBR 5750*

GERHART COLE

Project: Bear River - Fielding
No: 13GCI329
Location: Box Elder County Utah
Date: 20-Jul-15
Tested by: zmg
Reduced by: zmg
Checked by: bjb

TH/TP/Sample: TH-FD-02
Depth: 50-52
Sample description: light blueish gray clay
USCS classification: not requested
Sample type: undisturbed
Notes:

	Test Number	S1	120 psi	S2	55 psi	S3	25 psi
		Initial	Bef. Shr. MethodB [e]	Initial	Bef. Shr. MethodB [e]	Initial	Bef. Shr. MethodB [e]
Unit weight data	Sample ht., H (in) 0°	5.755		5.737		5.728	
	120°	5.732		5.740		5.720	
	240°	5.760		5.745		5.707	
	Avg. height, Havg (in)	5.749	5.669	5.741	5.681	5.718	5.678
	Avg. height, Havg (cm)	14.602	14.399	14.581	14.429	14.525	14.423
	ΔHsc (in) [a]		0.08		0.06		0.04
	Sample dia., D (in) top	2.823		2.848		2.836	
	mid	2.832		2.829		2.830	
	bot	2.821		2.822		2.833	
	Avg. dia., Davg (in)	2.827	2.797	2.832	2.867	2.832	2.835
	Avg. dia., Davg (cm)	7.181	7.104	7.193	7.282	7.194	7.201
	Avg. area, Aavg (in^2)	6.277	6.144	6.299	6.455	6.300	6.312
	Avg. area, Aavg (cm^2)	40.496	39.638	40.639	41.647	40.646	40.722
	Wt. rings + wet soil (g)	1221.20	1215.97	1246.87	1244.40	1197.53	1193.22
	Wt. rings (g)	0.00	0.00	0.00	0.00	0.00	0.00
	Volume, Vo (in^3)	36.1	34.8	36.2	36.7	36.0	35.8
	Vo (cm^3)	591.3	570.8	592.6	600.9	590.4	587.3
	Vo (ft^3)	0.0209	0.0202	0.0209	0.0212	0.0208	0.0207
Moisture	Wet soil + tare (g)	282.96	1366.26	199.23	1363.58	226.99	1336.82
	Dry soil + tare (g)	262.43	1165.94	185.56	1151.79	206.59	1106.61
	Tare (g)	173.00	150.68	120.08	119.67	127.25	144.17
	Moisture content, w (%)	23.0	19.7	20.9	20.5	25.7	23.9
Phase Relationships	Gs, assumed	2.65	2.65	2.65	2.65	2.65	2.65
	Mass total (g)	1221.2	1189.2	1246.9	1243.2	1197.5	1180.5
	Mass of solids (g)	993.2	993.2	1031.5	1031.5	952.6	952.6
	Volume (cm^3)	591.3	570.8	592.6	600.9	590.4	587.3
	Volume of water (cm^3)	228.0	196.0	215.3	211.7	244.9	227.9
	Volume of solids (cm^3)	374.8	374.8	389.3	389.3	359.5	359.5
	Volume of voids (cm^3)	216.5	196.0	203.3	211.7	230.9	227.9
	Volume of air (cm^3)	-11.5	0.0	-12.0	0.0	-14.0	0.0
	Void ratio, e	0.578	0.523	0.522	0.544	0.642	0.634
	Porosity, n	0.366	0.343	0.343	0.352	0.391	0.388
	Volumetric moisture, T	0.386	0.343	0.363	0.352	0.415	0.388
	Saturation, S (%) [c]	105.29	100.00	105.92	100.00	106.08	100.00
	Dry density (gm/cm^3)	1.680	1.740	1.741	1.717	1.614	1.622
	Wet unit wt., gm (pcf)	128.9	130.1	131.4	129.2	126.6	125.5
	Dry unit wt., gd (pcf)	104.9	108.6	108.7	107.2	100.7	101.3

Notes:

[a] ΔHsc (in) = change in height during saturation and consolidation

[b] ΔVs = change in volume during saturation, ΔVc = change in volume during consolidation

[c] Saturation before shear set to 100% for phase calculations

[d] Before shear Aavg using method A; where Ac (Method A) = (Vo-DVs - DVc)/(Ho-DHsc)

[e] Before shear Aavg using method B; where Ac (Method B) = (Vwf + Vs)/Hc

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Triaxial Test - Isotropic Consolidated Sheared Undrained
Measuring Pore Pressure (CIU-PP) *- After ASTM D4767 and USBR 5750*

GERHART COLE

Project:	**Bear River - Fielding**	**TH/TP/Sample:**	**TH-FD-02**
No:	**13GCI329**	**Depth:**	**50-52**
Location:	Box Elder County Utah	Sample description:	light blueish gray clay
Date:	7/20/2015	USCS classification:	not requested
Tested by:	zmg	Sample type:	undisturbed

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	Test Number	S1 at 120 psi	S2 at 55 psi	S3 at 25 psi
Test information	Total backpressure (psi)	55.0	29.0	24.0
	Skempton B	0.95	0.96	0.98
	t-90 (min)	3.6	8.0	2.0
	t-100 (min)	6.6	15.0	5.0
	t-50 (min)	0.8	1.9	0.5
	Strain rate (%/hr)	1.20	1.20	1.20
	Strain rate (%/min)	0.020	0.020	0.020
	Membrane correction	Yes	Yes	Yes
	Filter paper correction	No filter paper	No filter paper	No filter paper
Max principal stress ratio (s1/s3), failure criteria	Strain at failure, ef (%)	6.25	4.91	4.99
	Time to failure, tf (min)	312.3	245.3	249.3
	Obliquity, s'1/s'3	3.846	4.141	4.247
	Excess pore pressure, u (psi)	63.62	21.01	3.05
	q = q' = (s1+s3)/2 (psi)	80.24	53.37	35.64
	p' = (s'1+s'3)/2 (psi)	136.62	87.36	57.59
	p = (s1+s3)/2 (psi)	200.24	108.37	60.64
	Effective major principal stress, s'1 (psi)	216.86	140.74	93.23
	Effective minor principal stress, s'3 (psi)	56.38	33.99	21.95
	Total major pincipal stress, s1 (psi)	280.48	161.75	96.28
	Total minor pincipal stress, s3 (psi)	120.00	55.00	25.00
	Skemption A at failure, Af	0.40	0.20	0.04
	Secant friction angle, phi-s (deg)	36.0	37.7	38.2
		Effective stress	Total stress	
	Friction angle, phi (deg)	34.2	18.4	
	Cohesion intercept, c (psi)	4.4	18.5	
Peak deviator stress (s1-s3), failure criteria	Strain at failure, ef (%)	15.08	13.35	15.04
	Time to failure, tf (min)	754.2	667.6	752.2
	Deviator stress, s1-s3 (psi)	196.51	152.55	131.78
	Excess pore pressure, u (psi)	46.89	-0.07	-21.91
	q = q' = (s1+s3)/2 (psi)	98.25	76.28	65.89
	p' = (s'1+s'3)/2 (psi)	171.36	131.35	112.80
	p = (s1+s3)/2 (psi)	218.25	131.28	90.89
	Effective major principal stress, s'1 (psi)	269.61	207.63	178.69
	Effective minor principal stress, s'3 (psi)	73.11	55.07	46.91
	Total major pincipal stress, s1 (psi)	316.51	207.55	156.78
	Total minor pincipal stress, s3 (psi)	120.00	55.00	25.00
	Skemption A at failure, Af	0.24	0.00	-0.17
	Secant friction angle, phi-s (deg)	35.0	35.5	35.7
		Effective stress	Total stress	
	Friction angle, phi (deg)	33.5	14.7	
	Cohesion intercept, c (psi)	4.4	44.3	

Comments:

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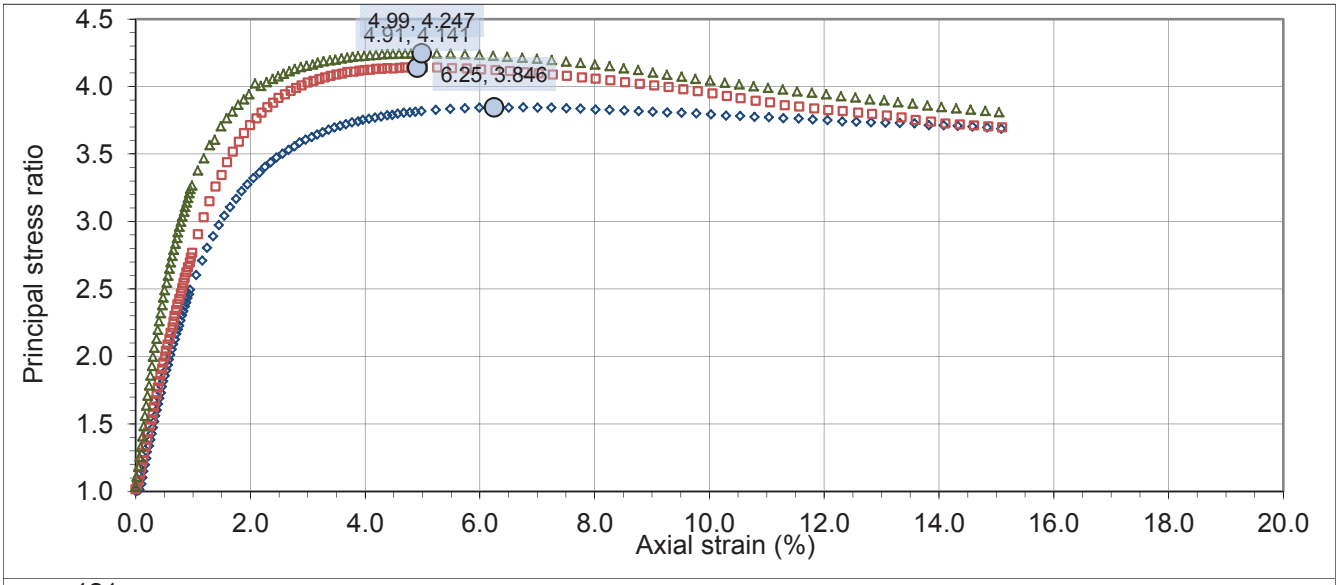
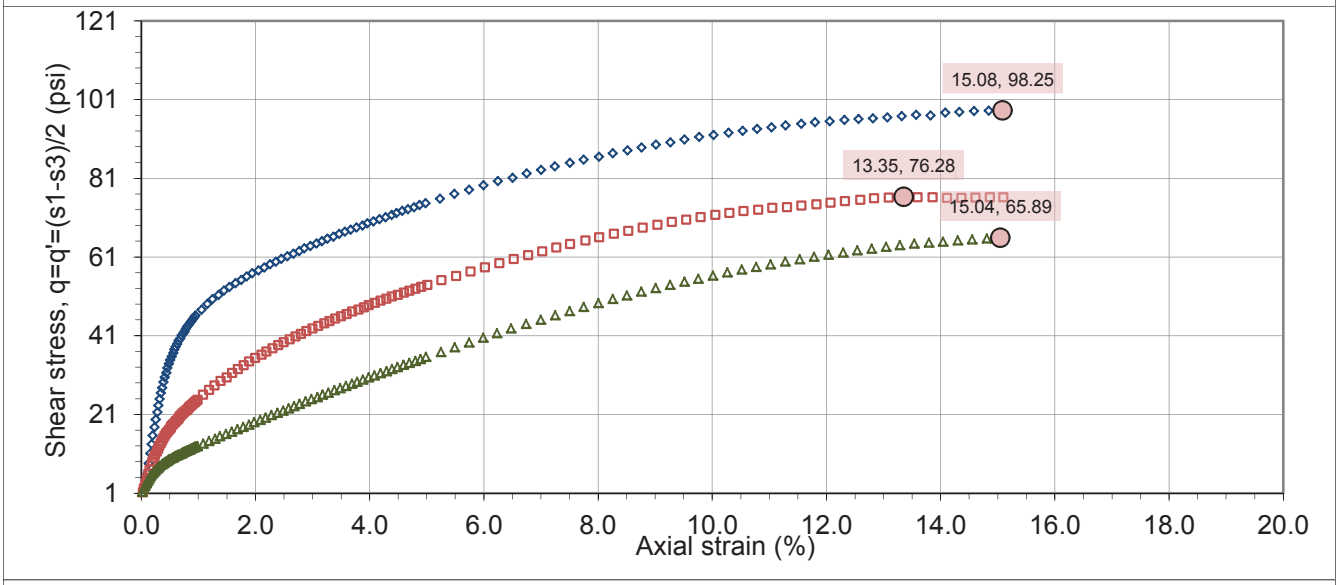
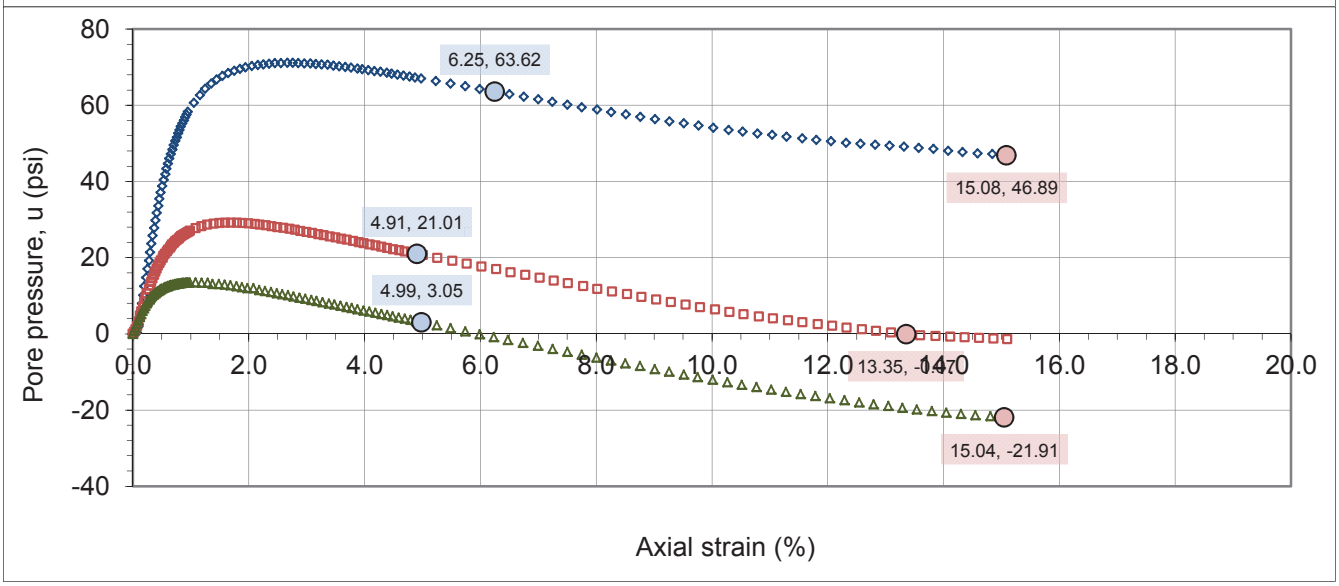
Triaxial Test - Isotropic Consolidated Sheared Undrained
Measuring Pore Pressure (CIU-PP) *- After ASTM D4767 and USBR 5750*

GERHART COLE

Project: Bear River - Fielding | **TH/TP/Sample:** TH-FD-02
No: 13GCI329 | **Depth:** 50-52







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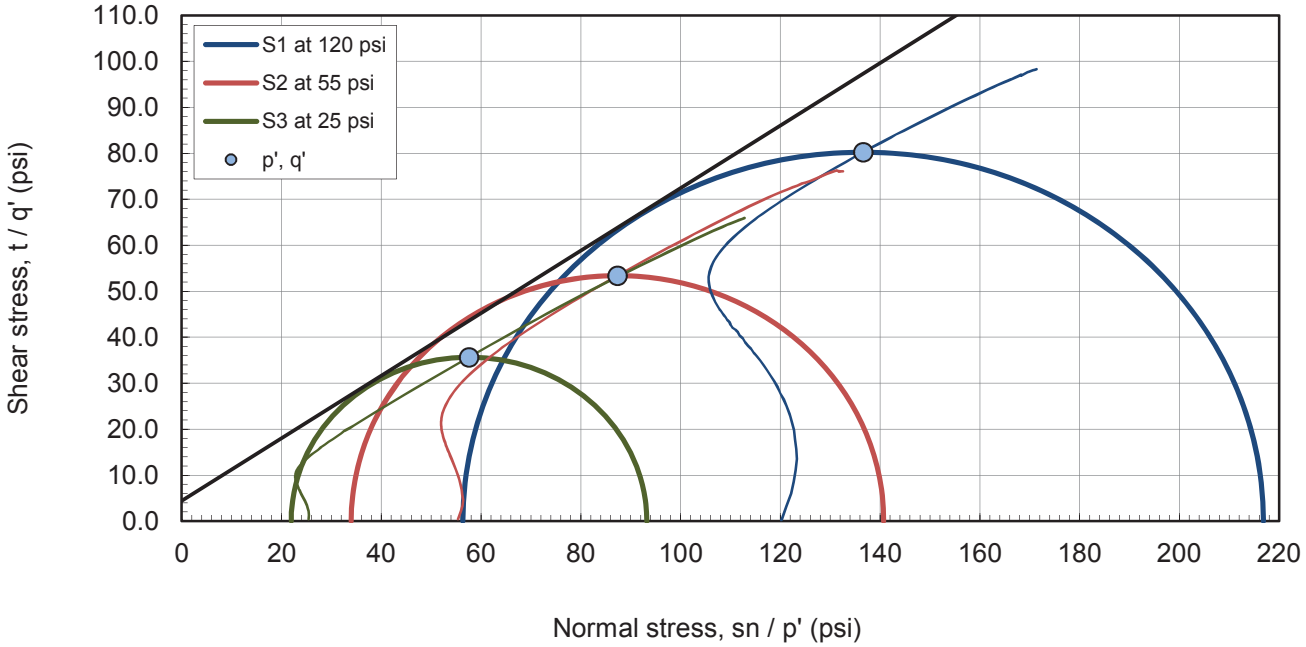
Triaxial Test - Isotropic Consolidated Sheared Undrained
Measuring Pore Pressure (CIU-PP) *- After ASTM D4767 and USBR 5750*

GERHART COLE

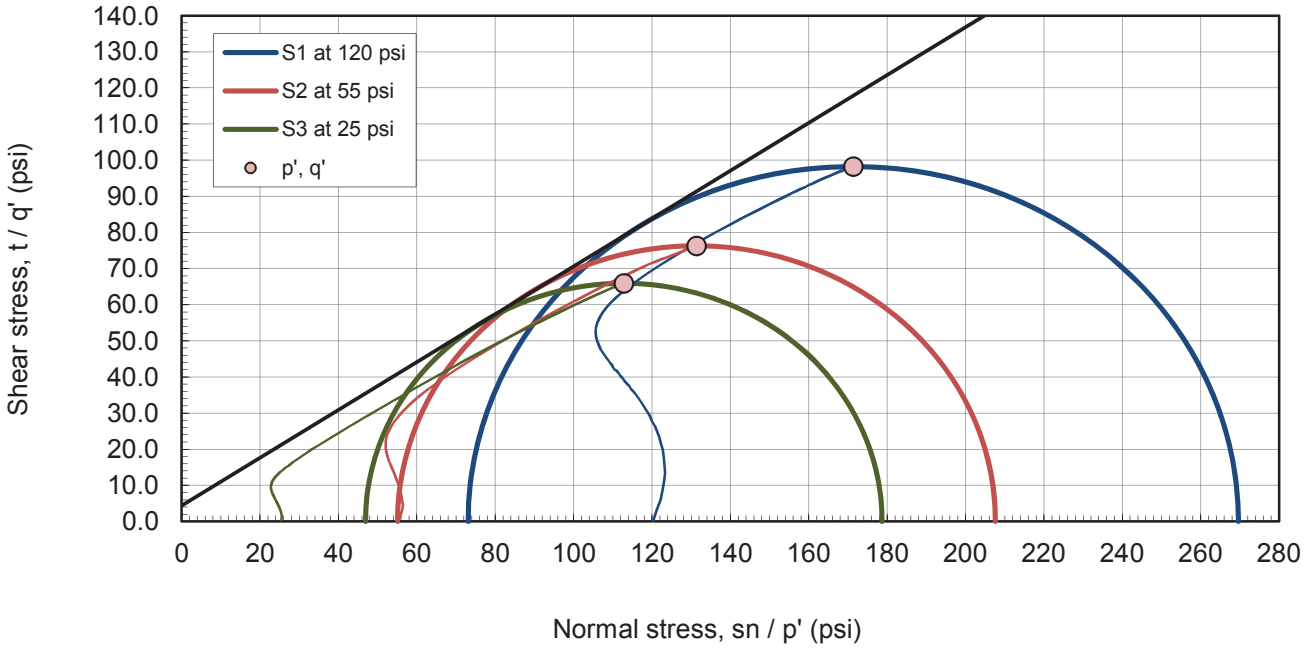
Project: **Bear River - Fielding** **TH/TP/Sample:** **TH-FD-02**
No: **13GCI329** **Depth:** **50-52**

Effective stress results



Max principal stress ratio (s'1/s'3), failure criteria Mohr and p' - q' space plots

Effective stress results



Peak deviator stress (s1-s3), failure criteria Mohr and p' - q' space plots

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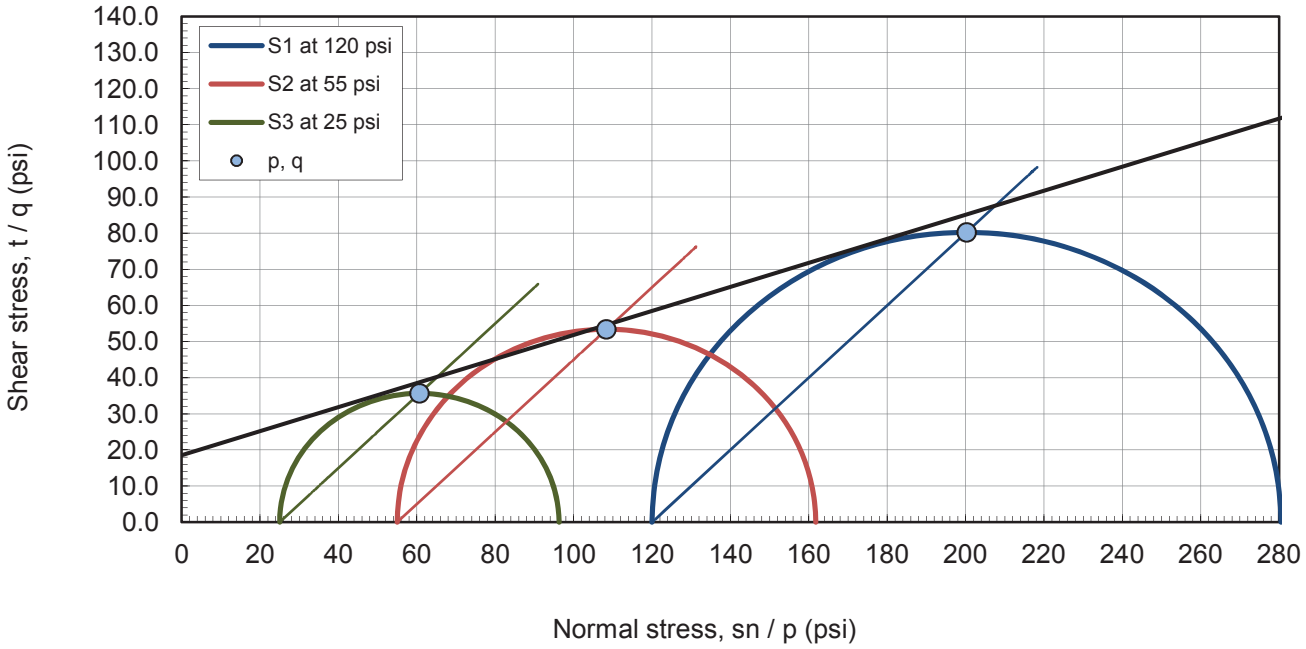
Triaxial Test - Isotropic Consolidated Sheared Undrained
Measuring Pore Pressure (CIU-PP) *- After ASTM D4767 and USBR 5750*

GERHART COLE

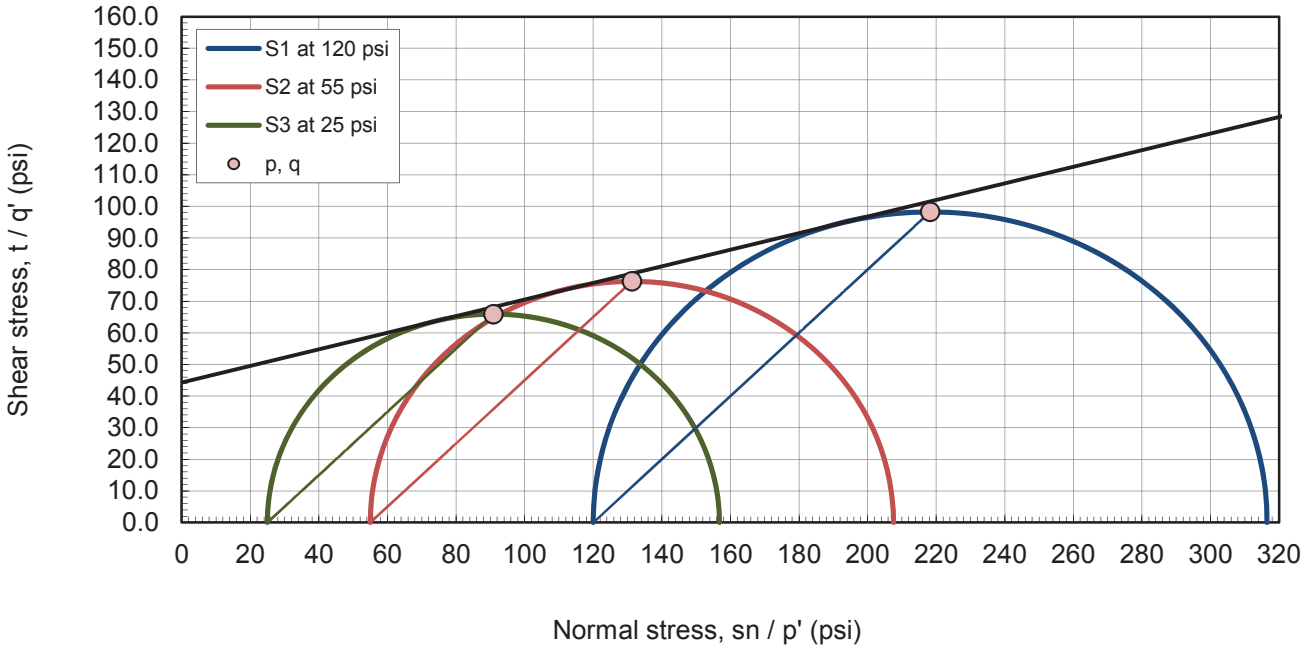
Project: Bear River - Fielding | **TH/TP/Sample:** TH-FD-02
No: 13GCI329 | **Depth:** 50-52

Total stress results



Max principal stress ratio (s1/s3), failure criteria Mohr and p - q space plots - effective stress results

Total stress results



Peak deviator stress (s1-s3), failure criteria Mohr and p - q space plots

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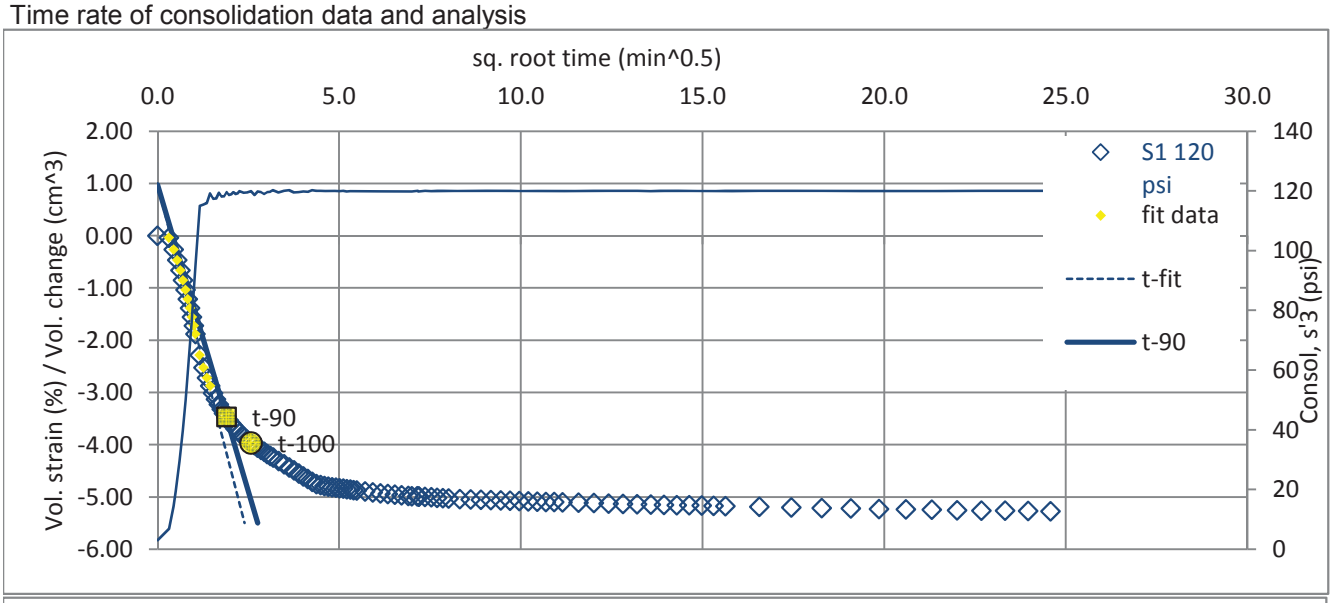
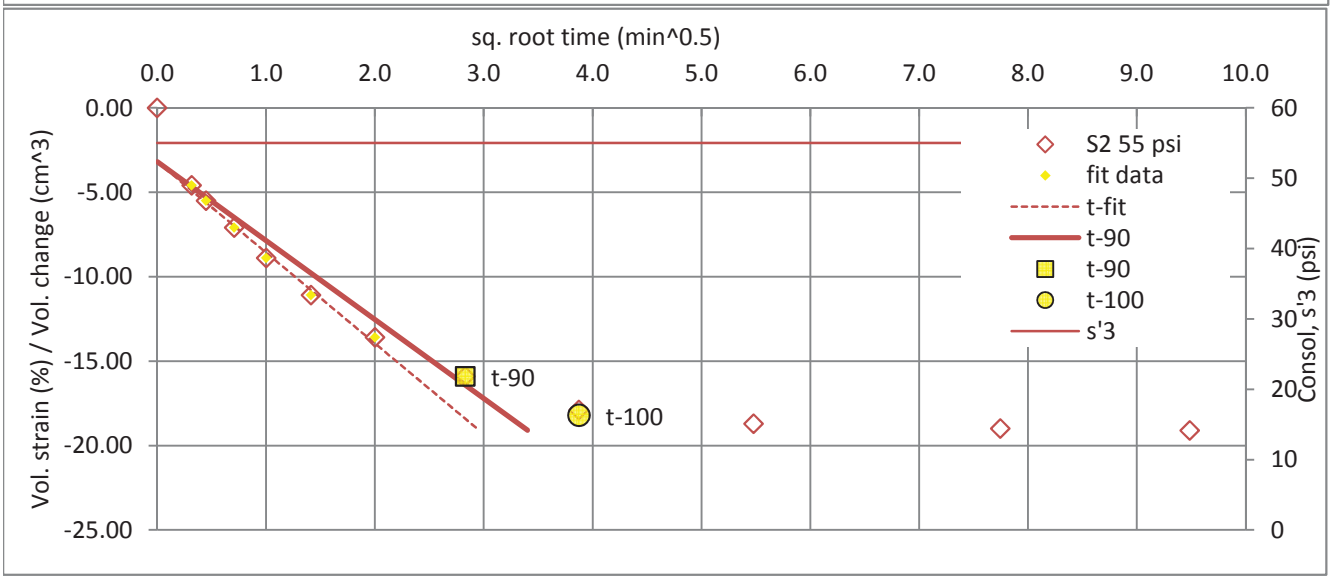
Triaxial Test - Isotropic Consolidated Sheared Undrained
Measuring Pore Pressure (CIU-PP) *- After ASTM D4767 and USBR 5750*

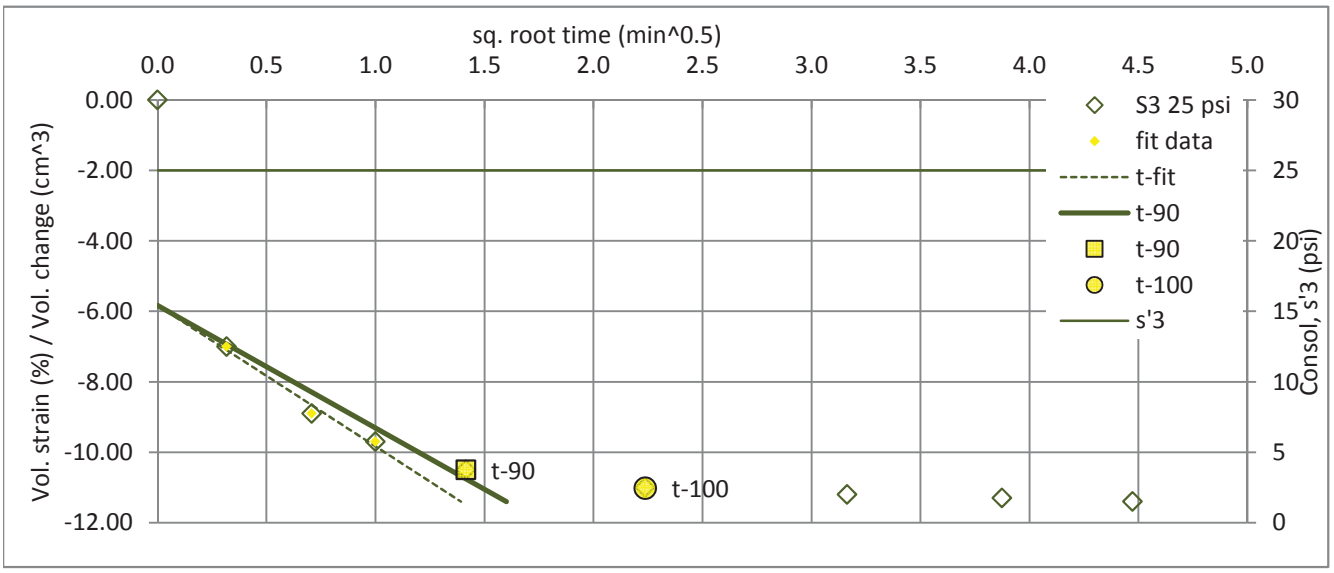
GERHART COLE

Project: Bear River - Fielding **TH/TP/Sample: TH-FD-02**
No: 13GCI329 **Depth: 50-52**

Time rate of consolidation data and analysis







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Triaxial Test - Isotropic Consolidated Sheared Undrained Measuring Pore Pressure (CIU-PP) - *After ASTM D4767 and USBR 5750*

GERHART COLE

Project:	**Bear River - Fielding**	**TH/TP/Sample:**	**TH-FD-02**
No:	**13GCI329**	**Depth:**	**75-77**
Location:	Box Elder County Utah	Sample description:	dark gray clay
Date:	13-Jul-15	USCS classification:	CH
Tested by:	zmg	Sample type:	undisturbed
Reduced by:	zmg	Notes:	
Checked by:	bjb		

	Test Number	S1	125 psi	S2	35 psi	S3	70 psi
		Initial	Bef. Shr. MethodB [e]	Initial			Bef. Shr. MethodB [e]
Unit weight data	Sample ht., H (in) 0°	5.903		5.830			
	Sample ht., H (in) 120°	5.904		5.826			
	Sample ht., H (in) 240°	5.901		5.825			
	Avg. height, Havg (in)	5.903	5.823	5.827			5.641
	Avg. height, Havg (cm)	14.993	14.790	14.801			14.328
	ΔHsc (in) [a]		0.08				0.02
	Sample dia., D (in) top	2.811		2.836			
	Sample dia., D (in) mid	2.824		2.832			
	Sample dia., D (in) bot	2.819		2.831			
	Avg. dia., Davg (in)	2.820	2.817	2.833			2.897
	Avg. dia., Davg (cm)	7.162	7.156	7.195			7.358
	Avg. area, Aavg (in^2)	6.244	6.234	6.302			6.592
	Avg. area, Aavg (cm^2)	40.281	40.221	40.661			42.527
	Wt. rings + wet soil (g)	1197.39	1180.84	1211.80			1202.90
	Wt. rings (g)	0.00	0.00	0.00			0.00
	Volume, Vo (in^3)	36.9	36.3	36.7			37.2
	Vo (cm^3)	603.9	594.9	601.8			609.3
	Vo (ft^3)	0.0213	0.0210	0.0213			0.0215
Moisture	Wet soil + tare (g)	221.01	1306.99	166.69			1341.91
	Dry soil + tare (g)	197.66	1056.80	158.17			1088.59
	Tare (g)	120.10	126.71	126.75			140.32
	Moisture content, w (%)	30.1	26.9	27.1			26.7
Phase Relationships	Gs, assumed	2.65	2.65	2.65			2.65
	Mass total (g)	1197.4	1167.9	1211.8			1202.9
	Mass of solids (g)	920.3	920.3	953.3			953.3
	Volume (cm^3)	603.9	594.9	601.8			609.3
	Volume of water (cm^3)	277.1	247.6	258.5			249.6
	Volume of solids (cm^3)	347.3	347.3	359.7			359.7
	Volume of voids (cm^3)	256.6	247.6	242.1			249.6
	Volume of air (cm^3)	-20.4	0.0	-16.4			0.0
	Void ratio, e	0.739	0.713	0.673			0.694
	Porosity, n	0.425	0.416	0.402			0.410
	Volumetric moisture, T	0.459	0.416	0.430			0.410
	Saturation, S (%) [c]	107.96	100.00	106.79			100.00
	Dry density (gm/cm^3)	1.524	1.547	1.584			1.564
	Wet unit wt., gm (pcf)	123.8	122.6	125.7			123.8
	Dry unit wt., gd (pcf)	95.1	96.6	98.9			97.7

Staged Test

Notes:

[a] ΔHsc (in) = change in height during saturation and consolidation

[b] ΔVs = change in volume during saturation, ΔVc = change in volume during consolidation

[c] Saturation before shear set to 100% for phase calculations

[d] Before shear Aavg using method A; where Ac (Method A) = (Vo-DVs - DVc)/(Ho-DHsc)

[e] Before shear Aavg using method B; where Ac (Method B) = (Vwf + Vs)/Hc

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Triaxial Test - Isotropic Consolidated Sheared Undrained
Measuring Pore Pressure (CIU-PP) *- After ASTM D4767 and USBR 5750*

GERHART COLE

Project:	**Bear River - Fielding**	**TH/TP/Sample:**	**TH-FD-02**
No:	**13GCI329**	**Depth:**	**75-77**
Location:	Box Elder County Utah	Sample description:	dark gray clay
Date:	7/13/2015	USCS classification:	CH
Tested by:	zmg	Sample type:	undisturbed

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	Test Number	S1 at 125 psi	S2 at 35 psi	S3 at 70 psi
Test information	Total backpressure (psi)	65.0	39.0	39.0
	Skempton B	0.95	0.98	0.98
	t-90 (min)	840.3	330.0	556.0
	t-100 (min)	1440.3	570.0	1492.0
	t-50 (min)	196.3	77.1	129.9
	Strain rate (%/hr)	0.12	1.20	0.60
	Strain rate (%/min)	0.002	0.020	0.010
	Membrane correction	Yes	Yes	Yes
	Filter paper correction	No filter paper	No filter paper	No filter paper
Max principal stress ratio (s1/s3), failure criteria	Strain at failure, ef (%)	2.88	1.78	3.37
	Time to failure, tf (min)	1439.6	88.8	337.0
	Obliquity, s'1/s'3	2.300	4.539	3.465
	Excess pore pressure, u (psi)	63.88	18.23	34.78
	q = q' = (s1+s3)/2 (psi)	39.72	29.68	43.41
	p' = (s'1+s'3)/2 (psi)	100.85	46.45	78.63
	p = (s1+s3)/2 (psi)	164.72	64.68	113.41
	Effective major principal stress, s'1 (psi)	140.57	76.14	122.04
	Effective minor principal stress, s'3 (psi)	61.12	16.77	35.22
	Total major pincipal stress, s1 (psi)	204.45	94.36	156.83
	Total minor pincipal stress, s3 (psi)	125.00	35.00	70.00
	Skemption A at failure, Af	0.80	0.31	0.40
	Secant friction angle, phi-s (deg)	23.2	39.7	33.5
		Effective stress	Total stress	
	Friction angle, phi (deg)	11.6	5.7	
	Cohesion intercept, c (psi)	22.9	26.4	
Peak deviator stress (s1-s3), failure criteria	Strain at failure, ef (%)	2.98	2.06	3.67
	Time to failure, tf (min)	1489.6	103.0	367.2
	Deviator stress, s1-s3 (psi)	79.45	62.16	86.94
	Excess pore pressure, u (psi)	63.73	16.95	34.73
	q = q' = (s1+s3)/2 (psi)	39.73	31.08	43.47
	p' = (s'1+s'3)/2 (psi)	101.00	49.14	78.75
	p = (s1+s3)/2 (psi)	164.73	66.08	113.47
	Effective major principal stress, s'1 (psi)	140.72	80.22	122.22
	Effective minor principal stress, s'3 (psi)	61.27	18.05	35.27
	Total major pincipal stress, s1 (psi)	204.45	97.16	156.94
	Total minor pincipal stress, s3 (psi)	125.00	35.00	70.00
	Skemption A at failure, Af	0.80	0.27	0.40
	Secant friction angle, phi-s (deg)	23.2	39.2	33.5
		Effective stress	Total stress	
	Friction angle, phi (deg)	10.4	4.9	
	Cohesion intercept, c (psi)	24.8	28.4	

Comments:

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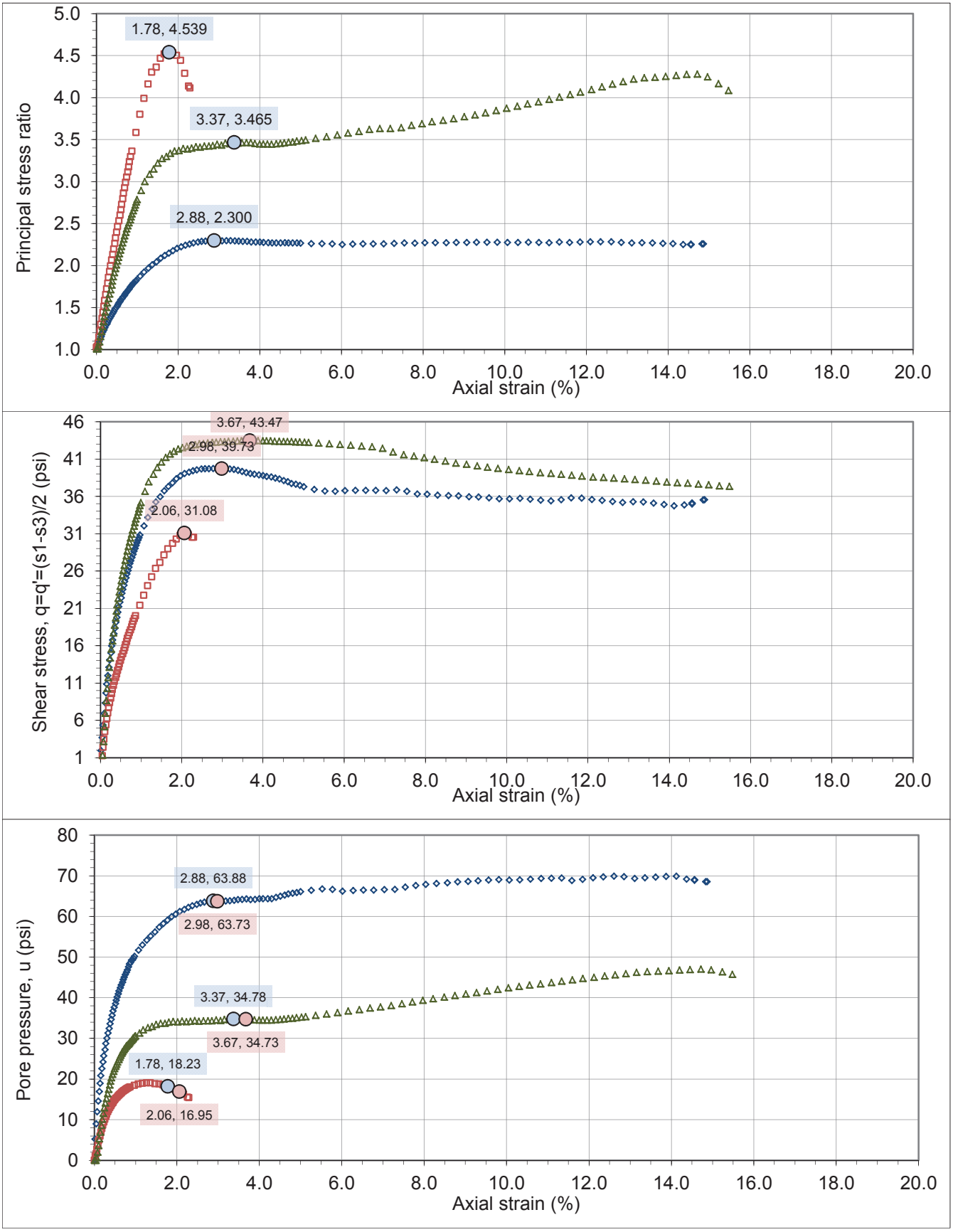
Triaxial Test - Isotropic Consolidated Sheared Undrained
Measuring Pore Pressure (CIU-PP) *- After ASTM D4767 and USBR 5750*

GERHART COLE

Project: Bear River - Fielding
No: 13GCI329

TH/TP/Sample: TH-FD-02
Depth: 75-77



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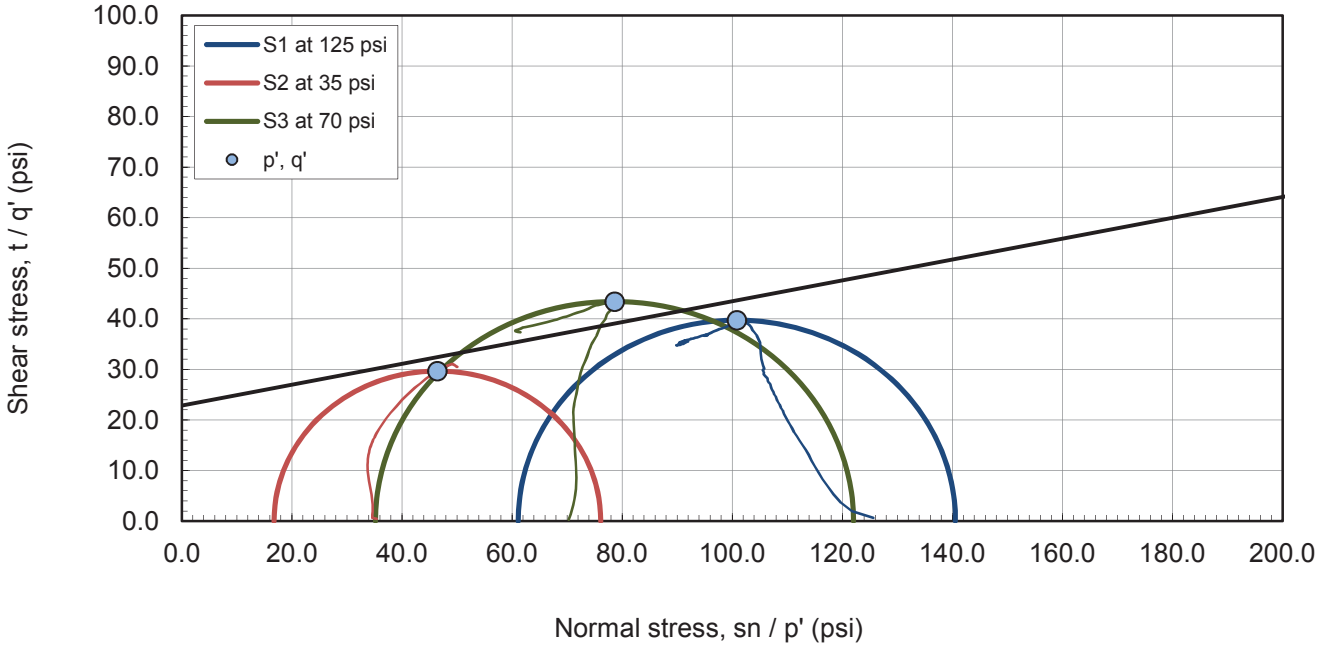
Triaxial Test - Isotropic Consolidated Sheared Undrained
Measuring Pore Pressure (CIU-PP) *- After ASTM D4767 and USBR 5750*

GERHART COLE

Project: Bear River - Fielding
No: 13GCI329

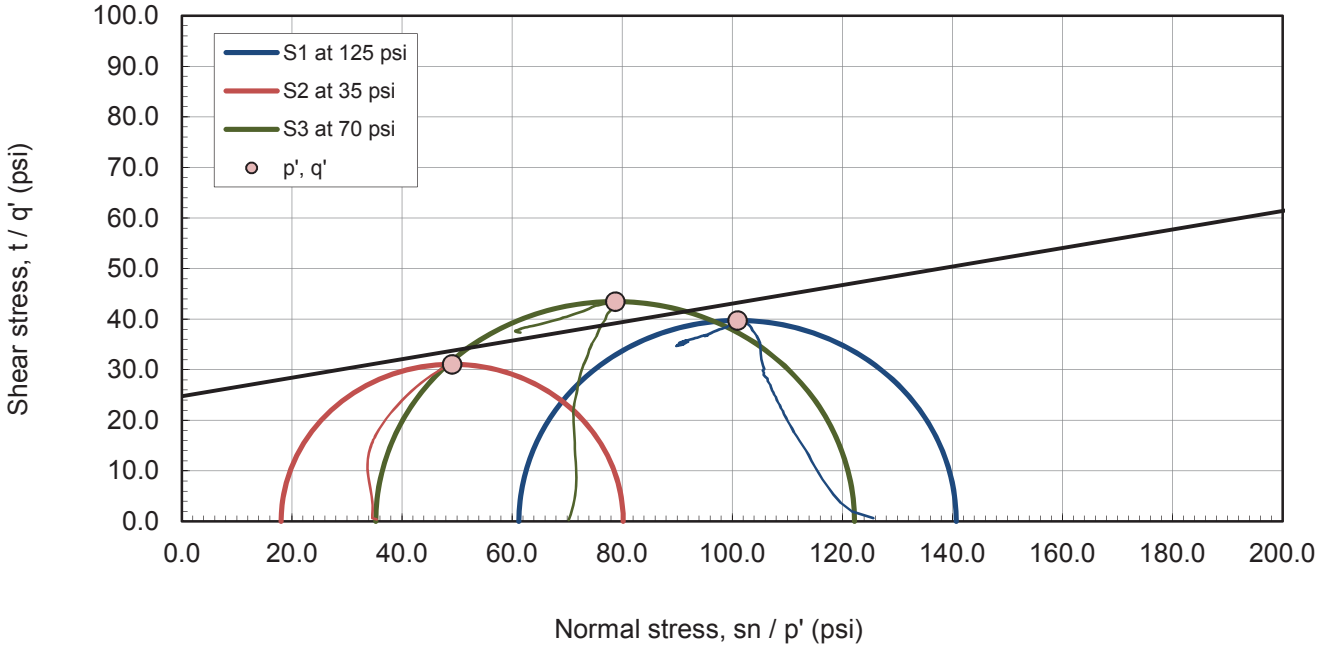
TH/TP/Sample: TH-FD-02
Depth: 75-77

Effective stress results



Max principal stress ratio (s'1/s'3), failure criteria Mohr and p' - q' space plots

Effective stress results



Peak deviator stress (s1-s3), failure criteria Mohr and p' - q' space plots

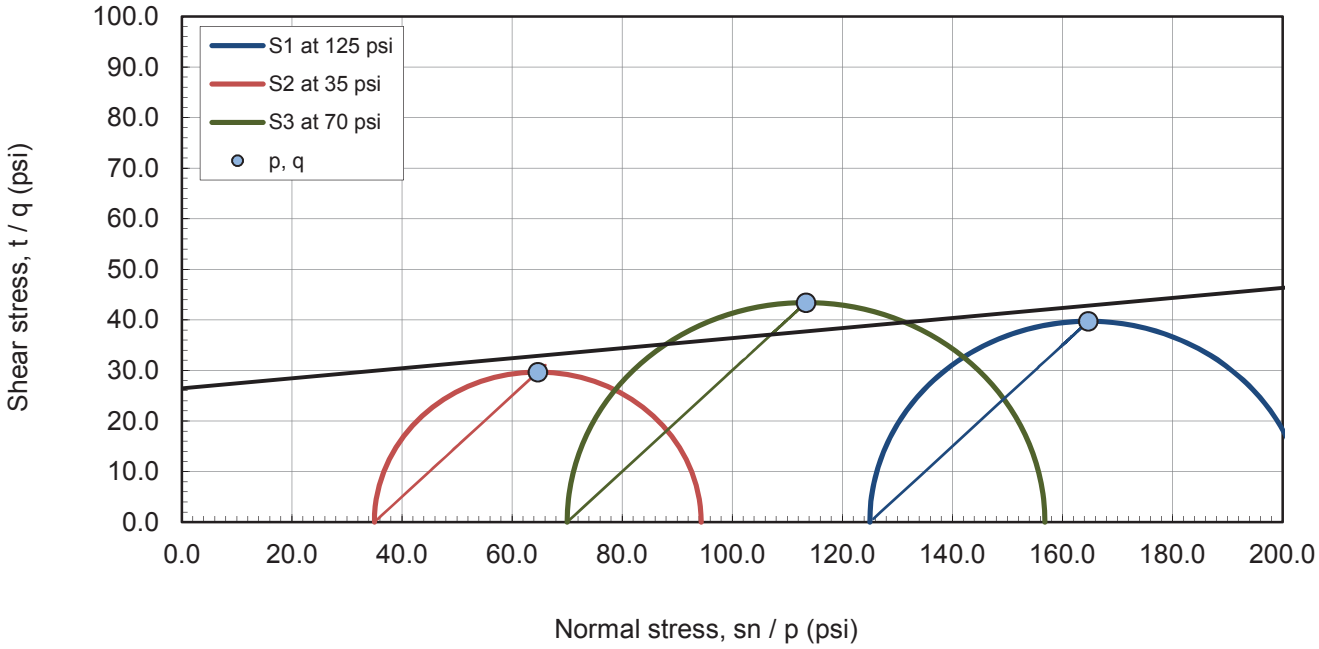
DRAFT

Triaxial Test - Isotropic Consolidated Sheared Undrained
Measuring Pore Pressure (CIU-PP) *- After ASTM D4767 and USBR 5750*

GERHART COLE

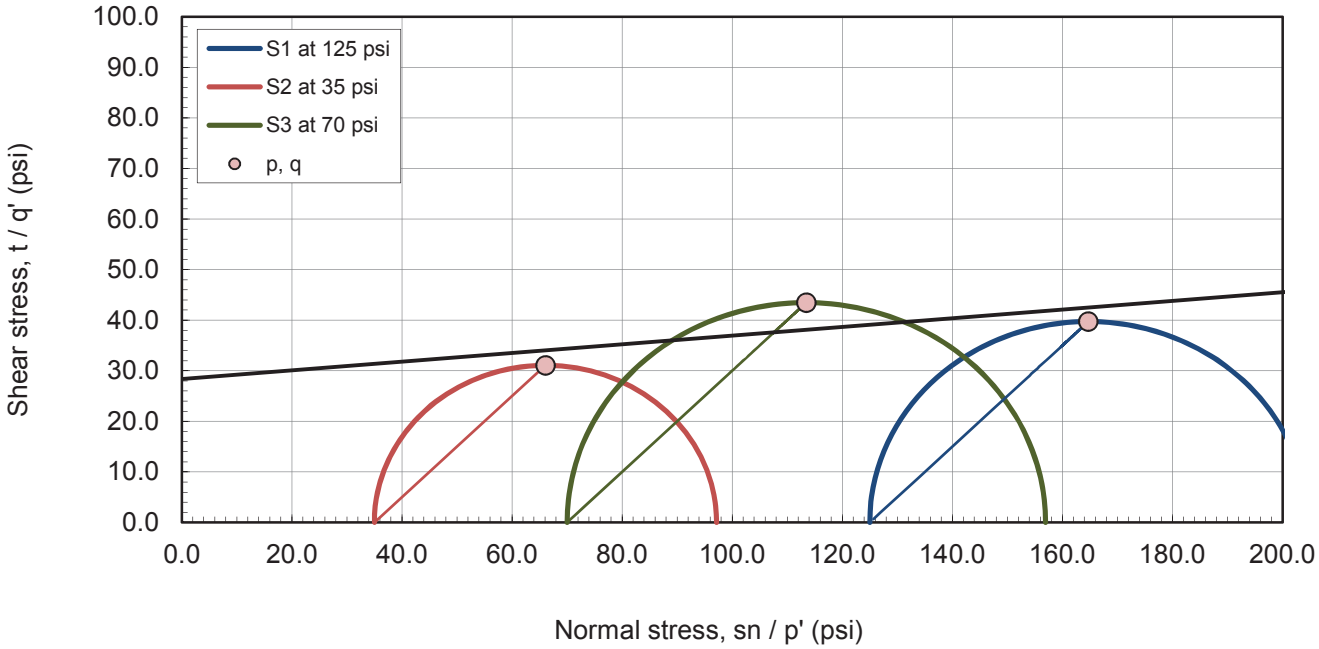
Project: Bear River - Fielding | **TH/TP/Sample:** TH-FD-02
No: 13GCI329 | **Depth:** 75-77

Total stress results



Max principal stress ratio (s1/s3), failure criteria Mohr and p - q space plots - effective stress results

Total stress results



Peak deviator stress (s1-s3), failure criteria Mohr and p - q space plots

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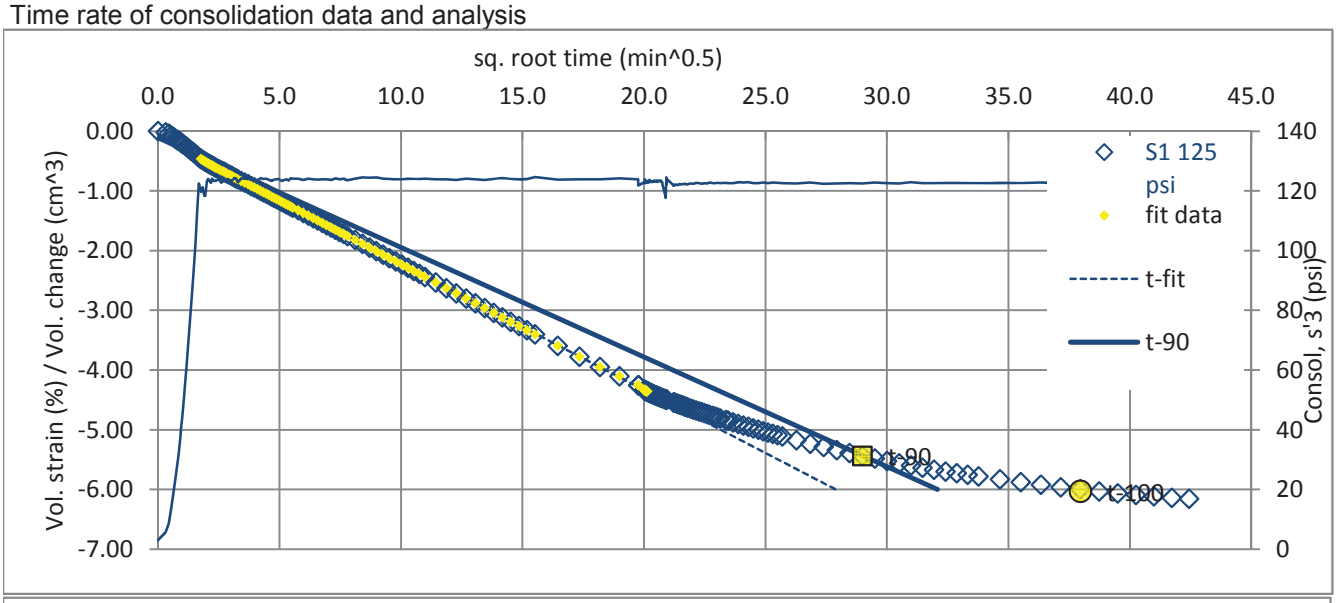
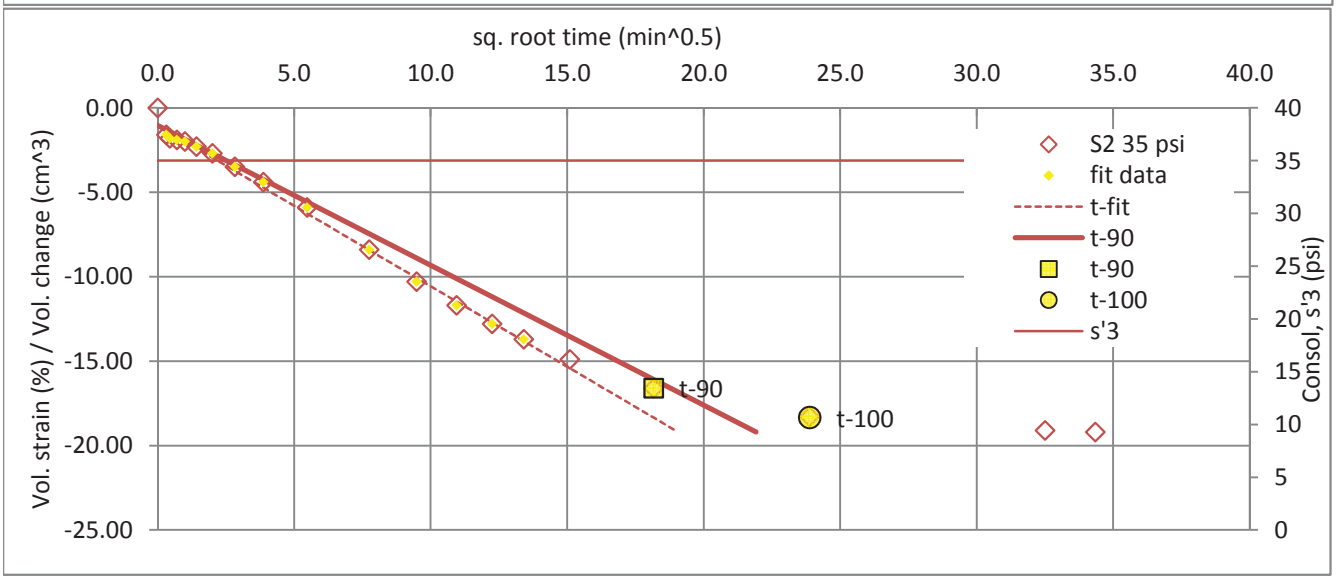
Triaxial Test - Isotropic Consolidated Sheared Undrained
Measuring Pore Pressure (CIU-PP) *- After ASTM D4767 and USBR 5750*

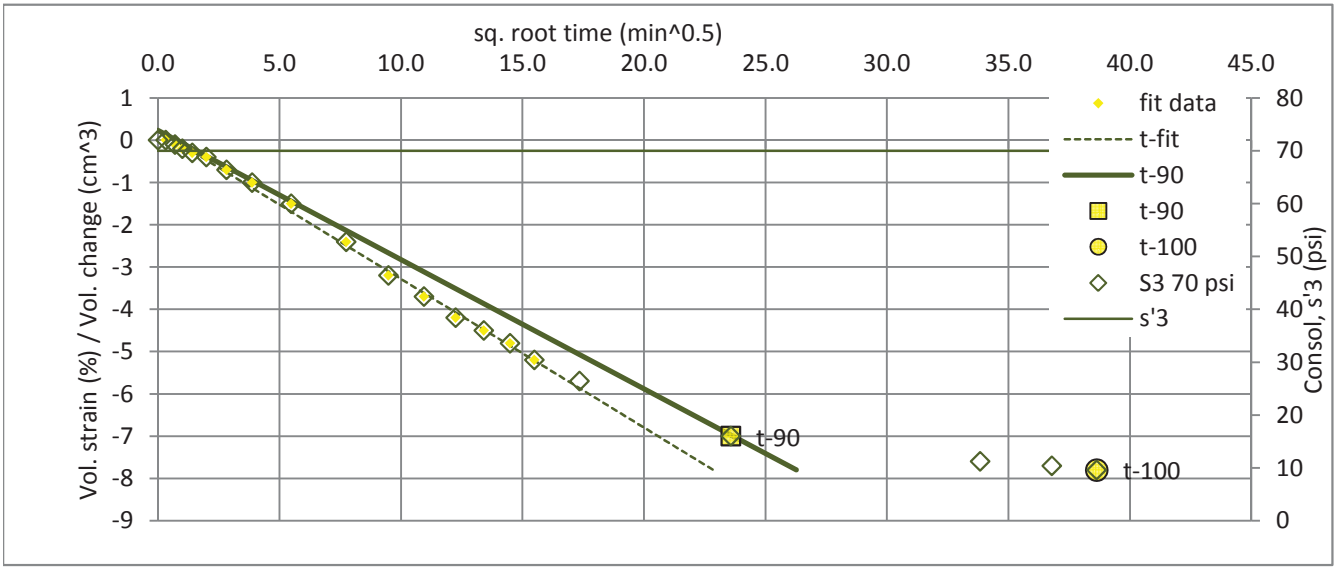
GERHART COLE

Project: Bear River - Fielding **TH/TP/Sample: TH-FD-02**
No: 13GCI329 **Depth: 75-77**

Time rate of consolidation data and analysis







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Triaxial Test - Isotropic Consolidated Sheared Undrained Measuring Pore Pressure (CIU-PP) - *After ASTM D4767 and USBR 5750*

GERHART COLE

Project:	**Bear River - Fielding**	**TH/TP/Sample:**	**TH-FD-03**
No:	**13GCI329**	**Depth:**	**15-16.75**
Location:	Box Elder County Utah	Sample description:	olive brown clay
Date:	05-Aug-15	USCS classification:	CL
Tested by:	zmg	Sample type:	undisturbed
Reduced by:	zmg	Notes:	
Checked by:	bjb		

	Test Number	S1	45 psi	S2	20 psi	S3	10 psi
		Initial	Bef. Shr. MethodB [e]	Initial	Bef. Shr. MethodB [e]	Initial	Bef. Shr. MethodB [e]
Unit weight data	Sample ht., H (in) 0°	5.745		5.742		5.735	
	120°	5.740		5.744		5.716	
	240°	5.742		5.749		5.728	
	Avg. height, Havg (in)	5.742	5.702	5.745	5.715	5.726	5.706
	Avg. height, Havg (cm)	14.586	14.484	14.592	14.516	14.545	14.494
	ΔHsc (in) [a]		0.04		0.03		0.02
	Sample dia., D (in) top	2.835		2.857		2.858	
	mid	2.834		2.835		2.859	
	bot	2.832		2.827		2.858	
	Avg. dia., Davg (in)	2.834	2.850	2.839	2.870	2.859	2.872
	Avg. dia., Davg (cm)	7.198	7.238	7.210	7.290	7.261	7.295
	Avg. area, Aavg (in^2)	6.307	6.378	6.328	6.469	6.418	6.478
	Avg. area, Aavg (cm^2)	40.689	41.149	40.826	41.736	41.403	41.796
	Wt. rings + wet soil (g)	1175.54	1166.06	1197.82	1195.59	1208.81	1200.02
	Wt. rings (g)	0.00	0.00	0.00	0.00	0.00	0.00
	Volume, Vo (in^3)	36.2	36.4	36.4	37.0	36.7	37.0
	Vo (cm^3)	593.5	596.0	595.7	605.9	602.2	605.8
	Vo (ft^3)	0.0210	0.0210	0.0210	0.0214	0.0213	0.0214
Moisture	Wet soil + tare (g)	192.58	1339.13	220.87	1104.82	164.65	1318.80
	Dry soil + tare (g)	180.20	1107.86	201.38	905.74	156.50	1073.83
	Tare (g)	126.94	173.39	127.29	144.41	125.75	119.23
	Moisture content, w (%)	23.2	24.7	26.3	26.1	26.5	25.7
Phase Relationships	Gs, assumed	2.65	2.65	2.65	2.65	2.65	2.65
	Mass total (g)	1175.5	1189.9	1197.8	1196.3	1208.8	1200.8
	Mass of solids (g)	953.8	953.8	948.3	948.3	955.6	955.6
	Volume (cm^3)	593.5	596.0	595.7	605.9	602.2	605.8
	Volume of water (cm^3)	221.7	236.1	249.5	248.0	253.3	245.2
	Volume of solids (cm^3)	359.9	359.9	357.9	357.9	360.6	360.6
	Volume of voids (cm^3)	233.5	236.1	237.9	248.0	241.6	245.2
	Volume of air (cm^3)	11.8	0.0	-11.6	0.0	-11.6	0.0
	Void ratio, e	0.649	0.656	0.665	0.693	0.670	0.680
	Porosity, n	0.394	0.396	0.399	0.409	0.401	0.405
	Volumetric moisture, T	0.374	0.396	0.419	0.409	0.421	0.405
	Saturation, S (%) [c]	94.94	100.00	104.87	100.00	104.82	100.00
	Dry density (gm/cm^3)	1.607	1.600	1.592	1.565	1.587	1.577
	Wet unit wt., gm (pcf)	123.7	124.6	125.5	123.3	125.3	123.7
	Dry unit wt., gd (pcf)	100.3	99.9	99.4	97.7	99.1	98.5

Notes:

[a] ΔHsc (in) = change in height during saturation and consolidation

[b] ΔVs = change in volume during saturation, ΔVc = change in volume during consolidation

[c] Saturation before shear set to 100% for phase calculations

[d] Before shear Aavg using method A; where Ac (Method A) = (Vo-DVs - DVc)/(Ho-DHsc)

[e] Before shear Aavg using method B; where Ac (Method B) = (Vwf + Vs)/Hc

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Triaxial Test - Isotropic Consolidated Sheared Undrained
Measuring Pore Pressure (CIU-PP) *- After ASTM D4767 and USBR 5750*

GERHART COLE

Project:	**Bear River - Fielding**	**TH/TP/Sample:**	**TH-FD-03**
No:	**13GCI329**	**Depth:**	**15-16.75**
Location:	Box Elder County Utah	Sample description:	olive brown clay
Date:	8/5/2015	USCS classification:	CL
Tested by:	zmg	Sample type:	undisturbed

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Test Number		S1 at 45 psi	S2 at 20 psi	S3 at 10 psi
Test information	Total backpressure (psi)	25.0	19.0	24.0
	Skempton B	0.95	0.98	0.98
	t-90 (min)	1.9	2.0	4.0
	t-100 (min)	3.6	6.0	6.0
	t-50 (min)	0.4	0.5	0.9
	Strain rate (%/hr)	2.40	2.40	2.40
	Strain rate (%/min)	0.040	0.040	0.040
	Membrane correction	Yes	Yes	Yes
	Filter paper correction	No filter paper	No filter paper	No filter paper
Max principal stress ratio (s1/s3), failure criteria	Strain at failure, ef (%)	1.78	1.19	1.90
	Time to failure, tf (min)	44.4	29.6	47.4
	Obliquity, s'1/s'3	3.362	4.106	5.228
	Excess pore pressure, u (psi)	22.73	8.65	3.56
	q = q' = (s1+s3)/2 (psi)	26.30	17.63	13.62
	p' = (s'1+s'3)/2 (psi)	48.58	28.98	20.06
	p = (s1+s3)/2 (psi)	71.30	37.63	23.62
	Effective major principal stress, s'1 (psi)	74.88	46.61	33.67
	Effective minor principal stress, s'3 (psi)	22.27	11.35	6.44
	Total major pincipal stress, s1 (psi)	97.61	55.26	37.23
	Total minor pincipal stress, s3 (psi)	45.00	20.00	10.00
	Skemption A at failure, Af	0.43	0.25	0.13
	Secant friction angle, phi-s (deg)	32.8	37.5	42.8
		Effective stress	Total stress	
	Friction angle, phi (deg)	26.4	15.3	
	Cohesion intercept, c (psi)	5.3	7.8	
Peak deviator stress (s1-s3), failure criteria	Strain at failure, ef (%)	1.78	13.31	15.04
	Time to failure, tf (min)	44.4	332.7	376.0
	Deviator stress, s1-s3 (psi)	52.61	37.16	40.33
	Excess pore pressure, u (psi)	22.73	4.59	-5.97
	q = q' = (s1+s3)/2 (psi)	26.30	18.58	20.16
	p' = (s'1+s'3)/2 (psi)	48.58	33.99	36.13
	p = (s1+s3)/2 (psi)	71.30	38.58	30.16
	Effective major principal stress, s'1 (psi)	74.88	52.57	56.30
	Effective minor principal stress, s'3 (psi)	22.27	15.41	15.97
	Total major pincipal stress, s1 (psi)	97.61	57.16	50.33
	Total minor pincipal stress, s3 (psi)	45.00	20.00	10.00
	Skemption A at failure, Af	0.43	0.12	-0.15
	Secant friction angle, phi-s (deg)	32.8	33.1	33.9
		Effective stress	Total stress	
	Friction angle, phi (deg)	31.1	10.0	
	Cohesion intercept, c (psi)	1.4	13.8	

Comments:

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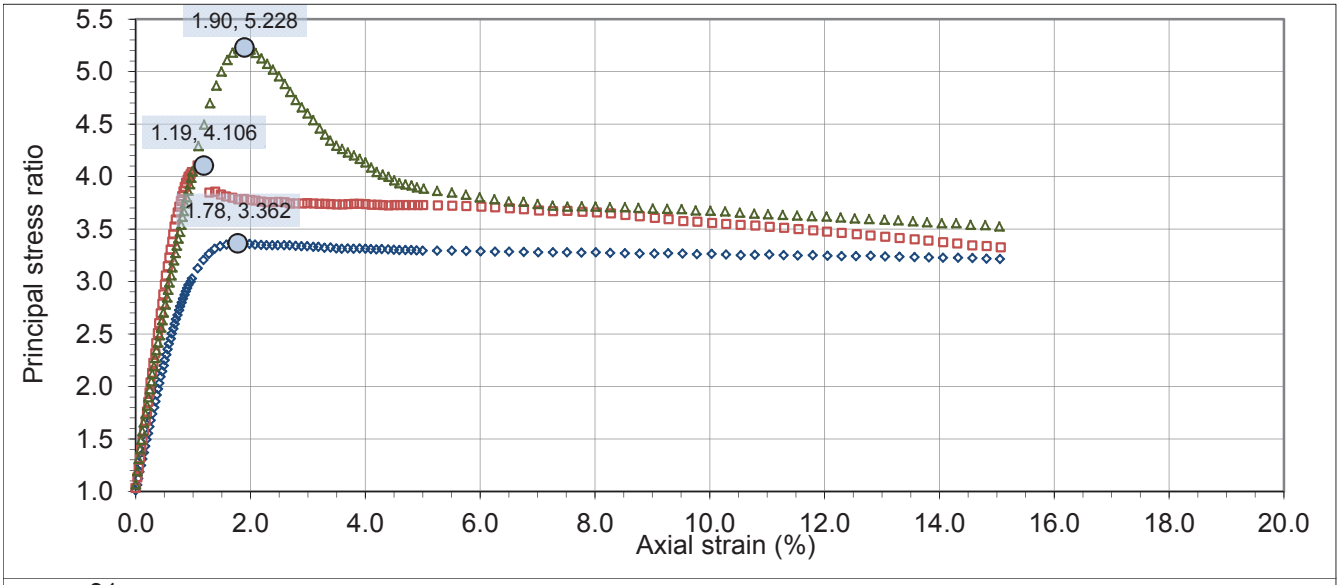
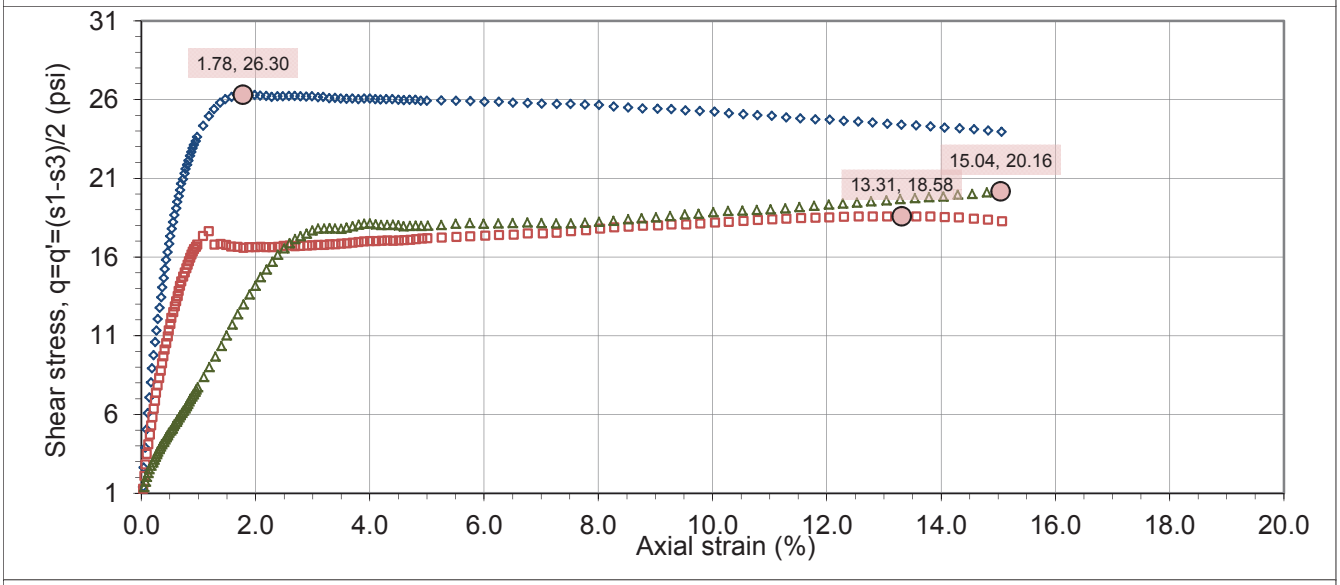
Triaxial Test - Isotropic Consolidated Sheared Undrained
Measuring Pore Pressure (CIU-PP) *- After ASTM D4767 and USBR 5750*

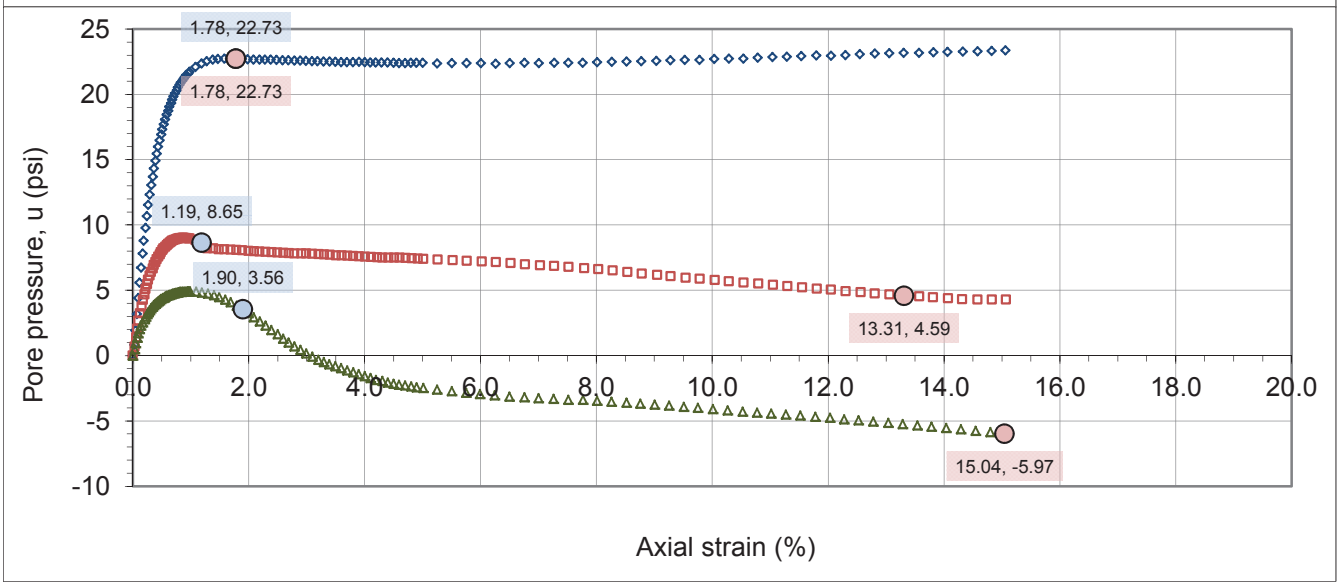
GERHART COLE

Project: Bear River - Fielding
No: 13GCI329

TH/TP/Sample: TH-FD-03
Depth: 15-16.75







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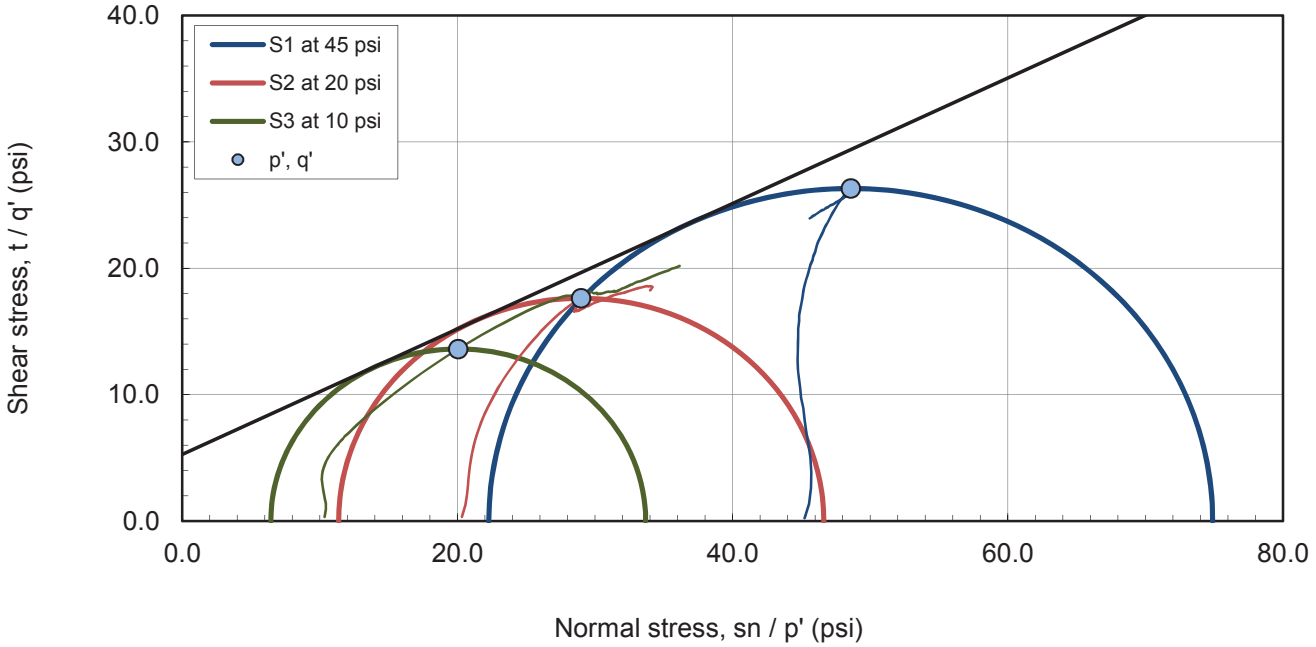
Triaxial Test - Isotropic Consolidated Sheared Undrained
Measuring Pore Pressure (CIU-PP) *- After ASTM D4767 and USBR 5750*

GERHART COLE

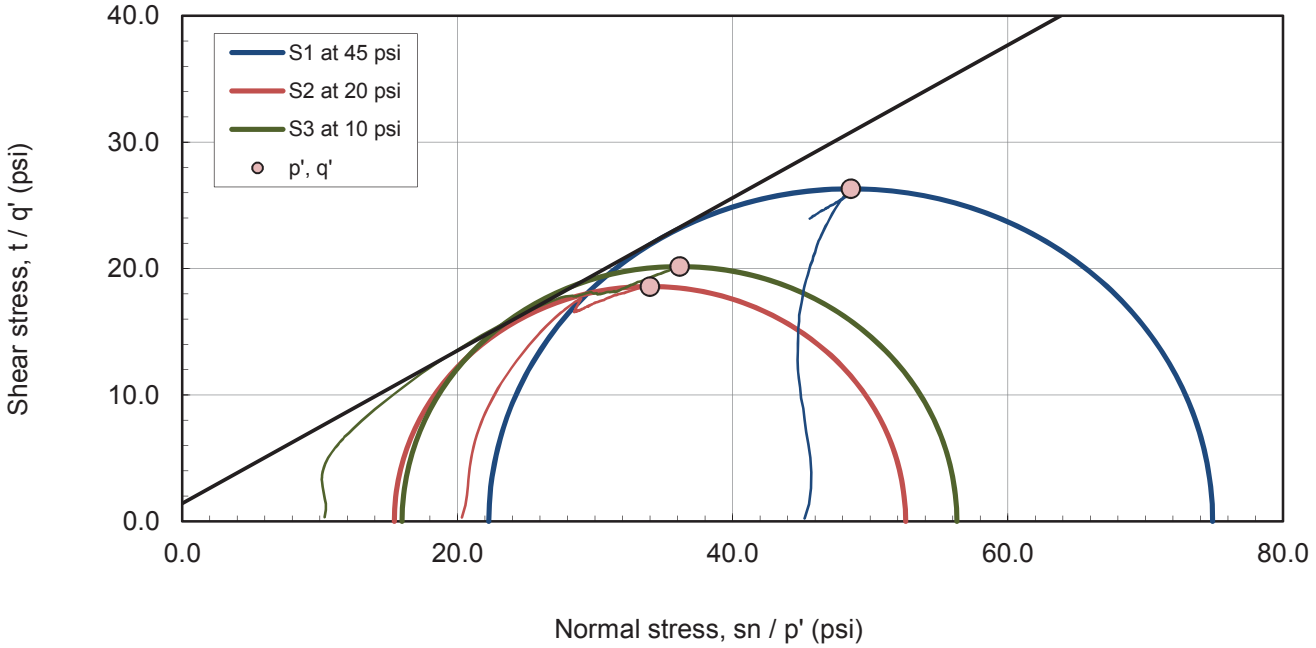
Project: **Bear River - Fielding** **TH/TP/Sample:** **TH-FD-03**
No: **13GCI329** **Depth:** **15-16.75**

Effective stress results



Max principal stress ratio (s'1/s'3), failure criteria Mohr and p' - q' space plots

Effective stress results



Peak deviator stress (s1-s3), failure criteria Mohr and p' - q' space plots

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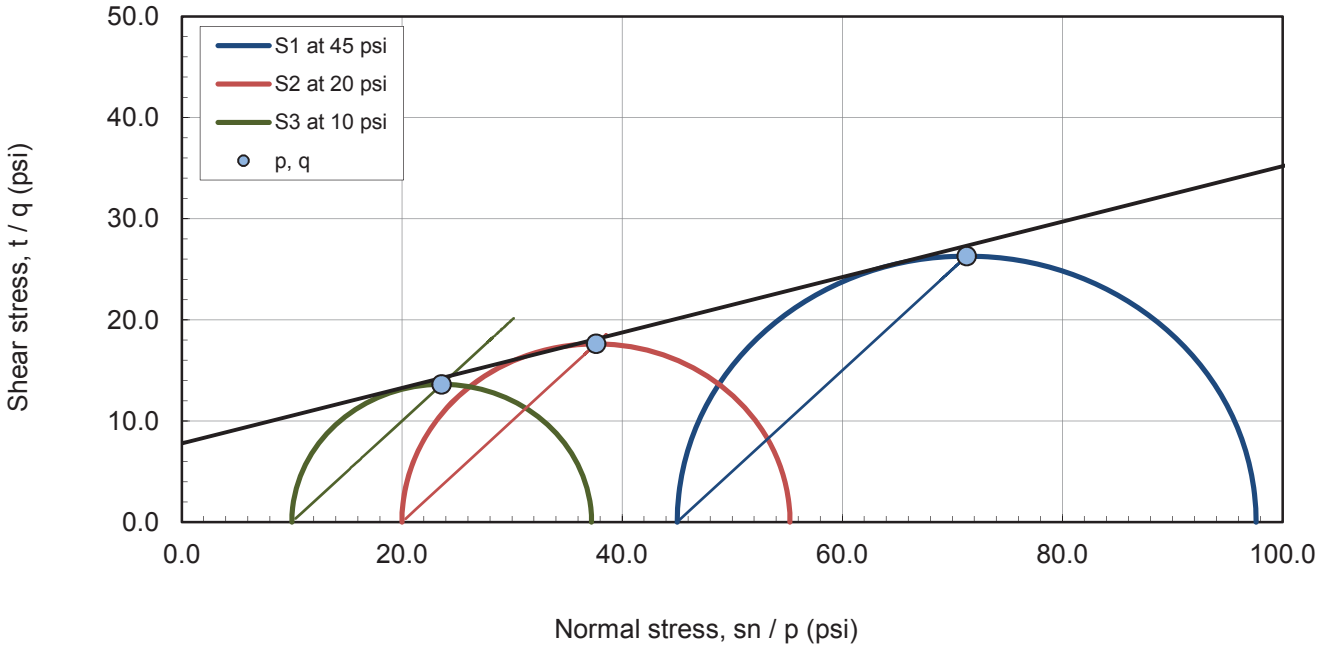
Triaxial Test - Isotropic Consolidated Sheared Undrained
Measuring Pore Pressure (CIU-PP) *- After ASTM D4767 and USBR 5750*

GERHART COLE

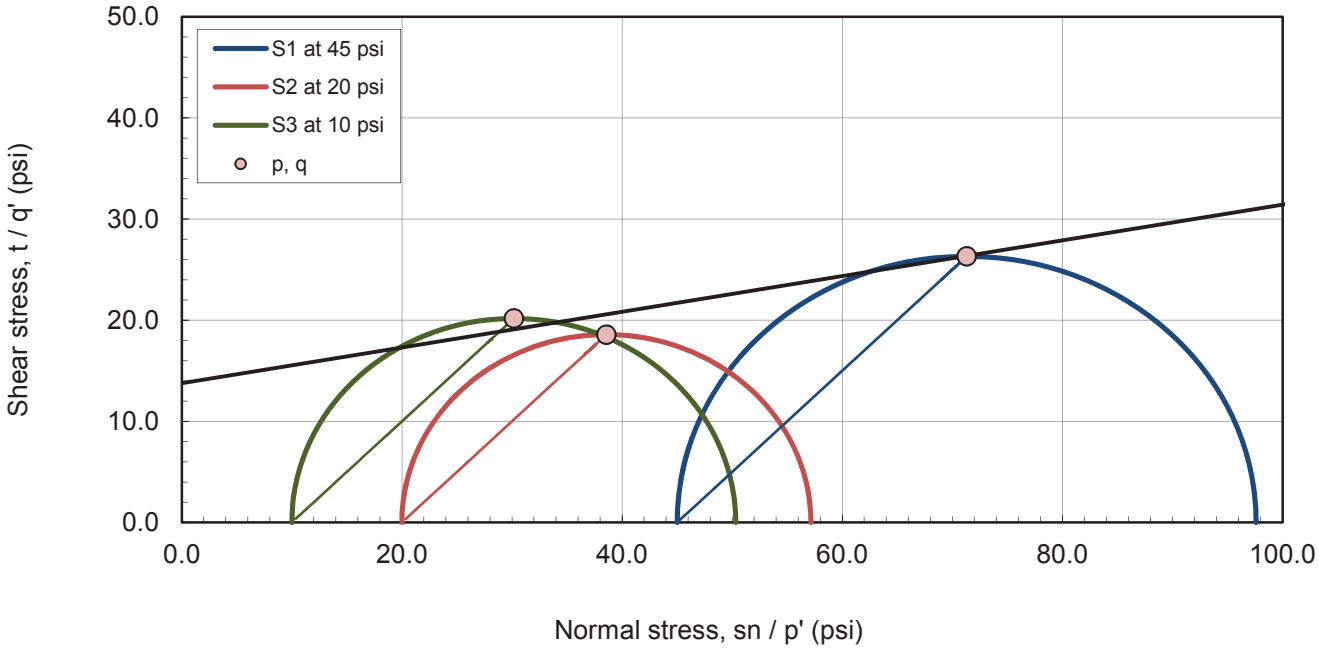
Project: Bear River - Fielding | **TH/TP/Sample:** TH-FD-03
No: 13GCI329 | **Depth:** 15-16.75

Total stress results



Max principal stress ratio (s1/s3), failure criteria Mohr and p - q space plots - effective stress results

Total stress results



Peak deviator stress (s1-s3), failure criteria Mohr and p - q space plots

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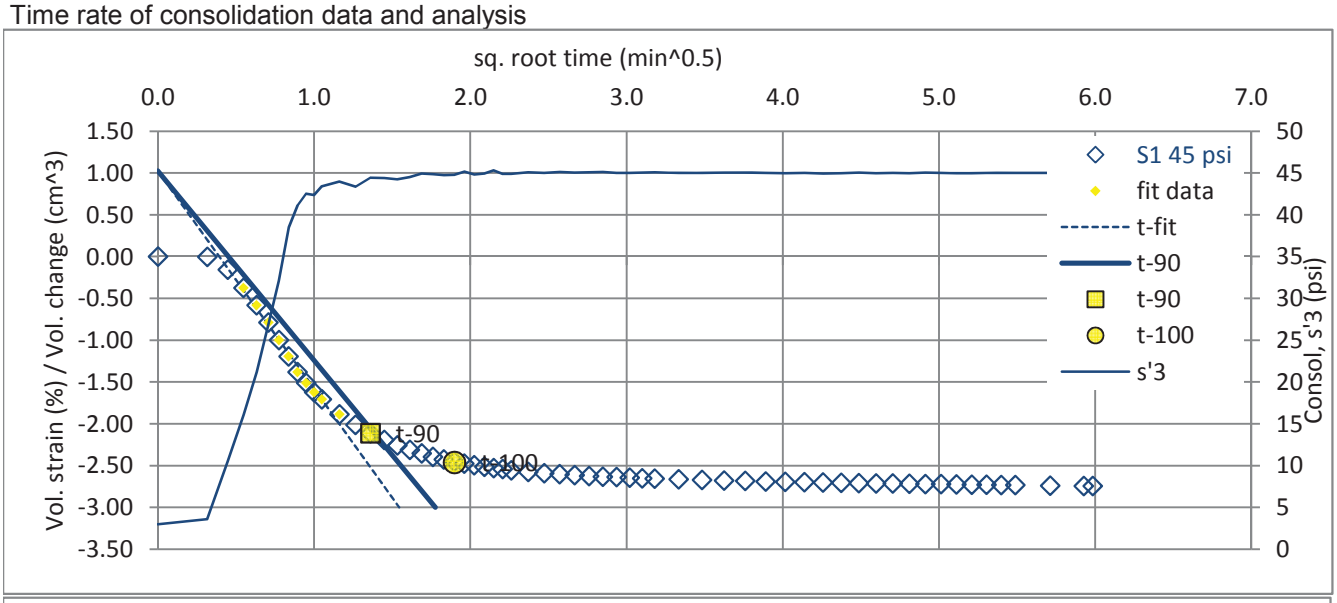
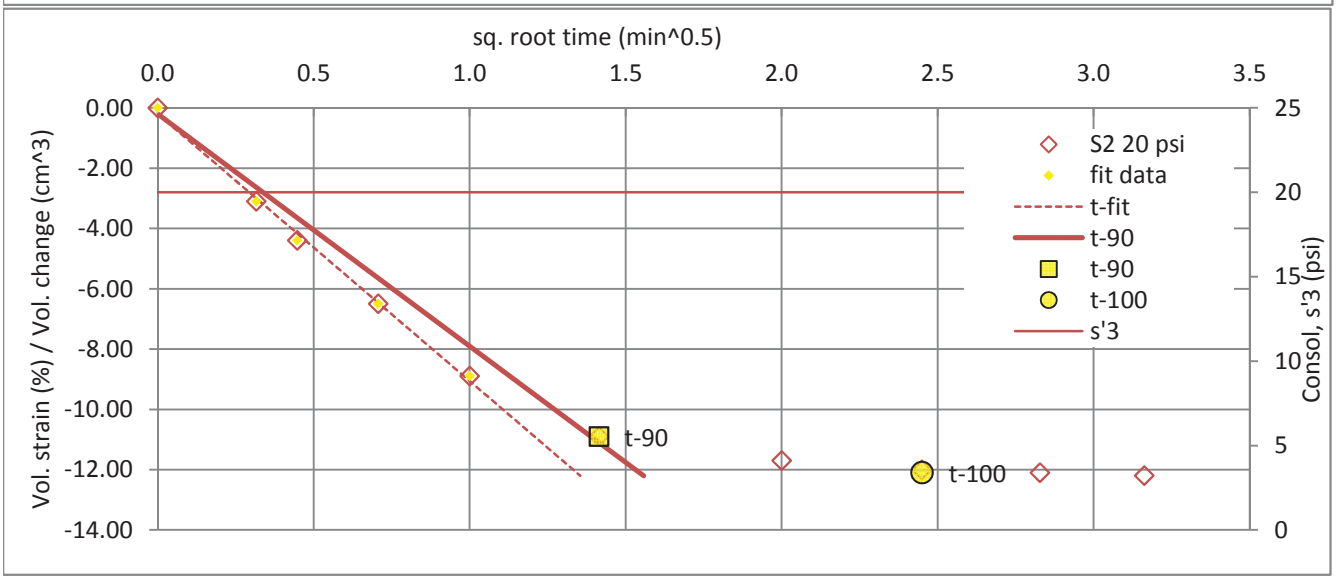
Triaxial Test - Isotropic Consolidated Sheared Undrained
Measuring Pore Pressure (CIU-PP) *- After ASTM D4767 and USBR 5750*

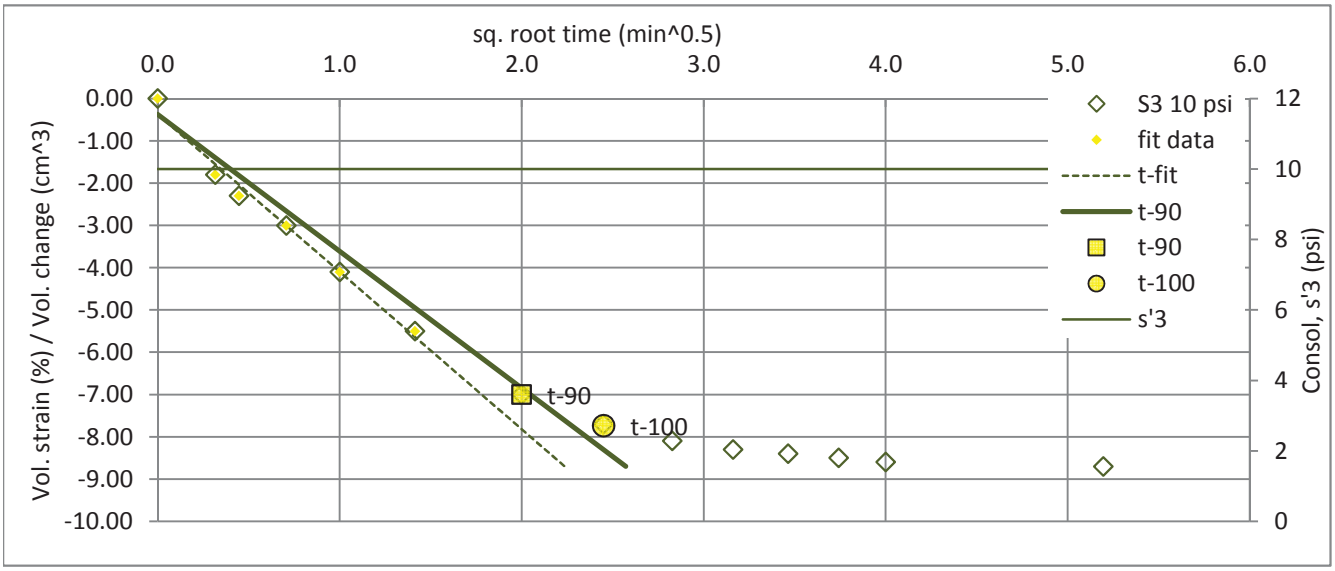
GERHART COLE

Project: Bear River - Fielding **TH/TP/Sample: TH-FD-03**
No: 13GCI329 **Depth: 15-16.75**

Time rate of consolidation data and analysis







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Triaxial Test - Isotropic Consolidated Sheared Undrained Measuring Pore Pressure (CIU-PP) - *After ASTM D4767 and USBR 5750*

GERHART COLE

Project: Bear River - Fielding
No: 13GCI329
Location: Box Elder County Utah
Date: 03-Aug-15
Tested by: zmg
Reduced by: zmg
Checked by: bjb

TH/TP/Sample: TH-FD-03
Depth: 60-61.7
Sample description: greenish gray clay
USCS classification: CL
Sample type: undisturbed
Notes:

	Test Number	S1	65 psi	S2	40 psi	S3	20 psi
		Initial	Bef. Shr. MethodB [e]	Initial	Bef. Shr. MethodB [e]	Initial	Bef. Shr. MethodB [e]
Unit weight data	Sample ht., H (in) 0°	5.735		5.745		5.738	
	120°	5.738		5.747		5.742	
	240°	5.748		5.746		5.742	
	Avg. height, Havg (in)	5.740	5.700	5.746	5.716	5.741	5.701
	Avg. height, Havg (cm)	14.580	14.479	14.595	14.519	14.581	14.480
	ΔHsc (in) [a]		0.04		0.03		0.04
	Sample dia., D (in) top	2.844		2.852		2.853	
	mid	2.840		2.852		2.856	
	bot	2.850		2.852		2.854	
	Avg. dia., Davg (in)	2.844	2.847	2.852	2.884	2.855	2.859
	Avg. dia., Davg (cm)	7.222	7.232	7.244	7.326	7.251	7.262
	Avg. area, Aavg (in^2)	6.350	6.367	6.388	6.533	6.401	6.420
	Avg. area, Aavg (cm^2)	40.970	41.074	41.215	42.149	41.295	41.417
	Wt. rings + wet soil (g)	1188.82	1182.57	1187.98	1184.42	1161.40	1168.43
	Wt. rings (g)	0.00	0.00	0.00	0.00	0.00	0.00
	Volume, Vo (in^3)	36.5	36.3	36.7	37.3	36.7	36.6
	Vo (cm^3)	597.4	594.7	601.5	611.9	602.1	599.7
	Vo (ft^3)	0.0211	0.0210	0.0212	0.0216	0.0213	0.0212
Moisture	Wet soil + tare (g)	178.20	1326.99	204.38	1309.70	289.94	1287.10
	Dry soil + tare (g)	167.51	1089.83	192.15	1055.01	257.47	1025.58
	Tare (g)	125.75	144.79	145.94	125.76	145.35	119.22
	Moisture content, w (%)	25.6	25.1	26.5	27.4	29.0	28.9
Phase Relationships	Gs, assumed	2.65	2.65	2.65	2.65	2.65	2.65
	Mass total (g)	1188.8	1184.1	1188.0	1196.8	1161.4	1160.4
	Mass of solids (g)	946.5	946.5	939.4	939.4	900.6	900.6
	Volume (cm^3)	597.4	594.7	601.5	611.9	602.1	599.7
	Volume of water (cm^3)	242.3	237.5	248.6	257.5	260.8	259.9
	Volume of solids (cm^3)	357.2	357.2	354.5	354.5	339.8	339.8
	Volume of voids (cm^3)	240.2	237.5	247.1	257.5	262.3	259.9
	Volume of air (cm^3)	-2.1	0.0	-1.6	0.0	1.5	0.0
	Void ratio, e	0.672	0.665	0.697	0.726	0.772	0.765
	Porosity, n	0.402	0.399	0.411	0.421	0.436	0.433
	Volumetric moisture, T	0.406	0.399	0.413	0.421	0.433	0.433
	Saturation, S (%) [c]	100.88	100.00	100.63	100.00	99.44	100.00
	Dry density (gm/cm^3)	1.585	1.592	1.562	1.535	1.496	1.502
	Wet unit wt., gm (pcf)	124.2	124.3	123.3	122.1	120.4	120.8
	Dry unit wt., gd (pcf)	98.9	99.4	97.5	95.8	93.4	93.8

Notes:

[a] ΔHsc (in) = change in height during saturation and consolidation

[b] ΔVs = change in volume during saturation, ΔVc = change in volume during consolidation

[c] Saturation before shear set to 100% for phase calculations

[d] Before shear Aavg using method A; where Ac (Method A) = (Vo-DVs - DVc)/(Ho-DHsc)

[e] Before shear Aavg using method B; where Ac (Method B) = (Vwf + Vs)/Hc

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DRAFT

Triaxial Test - Isotropic Consolidated Sheared Undrained
Measuring Pore Pressure (CIU-PP) *- After ASTM D4767 and USBR 5750*

GERHART COLE

Project:	**Bear River - Fielding**	**TH/TP/Sample:**	**TH-FD-03**
No:	**13GCI329**	**Depth:**	**60-61.7**
Location:	Box Elder County Utah	Sample description:	greenish gray clay
Date:	8/3/2015	USCS classification:	CL
Tested by:	zmg	Sample type:	undisturbed

X:\PROJECTS\13GCI329 Bear River Project Concept Study\Fielding\[TX_CU3pts_TH-FD-03_60-61-7ft-v02.xlsx]SUM

	Test Number	S1 at 65 psi	S2 at 40 psi	S3 at 20 psi
Test information	Total backpressure (psi)	45.0	24.0	60.0
	Skempton B	0.95	0.96	0.95
	t-90 (min)	3.1	8.0	13.1
	t-100 (min)	6.6	10.0	19.1
	t-50 (min)	0.7	1.9	3.1
	Strain rate (%/hr)	2.40	2.40	2.40
	Strain rate (%/min)	0.040	0.040	0.040
	Membrane correction	Yes	Yes	Yes
	Filter paper correction	No filter paper	No filter paper	No filter paper
Max principal stress ratio (s1/s3), failure criteria	Strain at failure, ef (%)	5.98	6.77	2.99
	Time to failure, tf (min)	149.6	169.2	74.8
	Obliquity, s'1/s'3	3.814	3.353	4.302
	Excess pore pressure, u (psi)	37.08	18.04	9.09
	q = q' = (s1+s3)/2 (psi)	39.29	25.84	18.01
	p' = (s'1+s'3)/2 (psi)	67.20	47.80	28.92
	p = (s1+s3)/2 (psi)	104.29	65.84	38.01
	Effective major principal stress, s'1 (psi)	106.49	73.64	46.93
	Effective minor principal stress, s'3 (psi)	27.92	21.96	10.91
	Total major pincipal stress, s1 (psi)	143.57	91.68	56.02
	Total minor pincipal stress, s3 (psi)	65.00	40.00	20.00
	Skemption A at failure, Af	0.47	0.35	0.25
	Secant friction angle, phi-s (deg)	35.8	32.7	38.5
		Effective stress	Total stress	
	Friction angle, phi (deg)	33.8	18.8	
	Cohesion intercept, c (psi)	1.2	5.6	
Peak deviator stress (s1-s3), failure criteria	Strain at failure, ef (%)	10.26	10.28	9.02
	Time to failure, tf (min)	256.5	257.1	225.5
	Deviator stress, s1-s3 (psi)	85.81	52.53	44.27
	Excess pore pressure, u (psi)	33.53	17.41	4.28
	q = q' = (s1+s3)/2 (psi)	42.90	26.27	22.14
	p' = (s'1+s'3)/2 (psi)	74.38	48.86	37.85
	p = (s1+s3)/2 (psi)	107.90	66.27	42.14
	Effective major principal stress, s'1 (psi)	117.28	75.12	59.99
	Effective minor principal stress, s'3 (psi)	31.47	22.59	15.72
	Total major pincipal stress, s1 (psi)	150.81	92.53	64.27
	Total minor pincipal stress, s3 (psi)	65.00	40.00	20.00
	Skemption A at failure, Af	0.39	0.33	0.10
	Secant friction angle, phi-s (deg)	35.2	32.5	35.8
		Effective stress	Total stress	
	Friction angle, phi (deg)	34.6	19.0	
	Cohesion intercept, c (psi)	0.0	7.4	

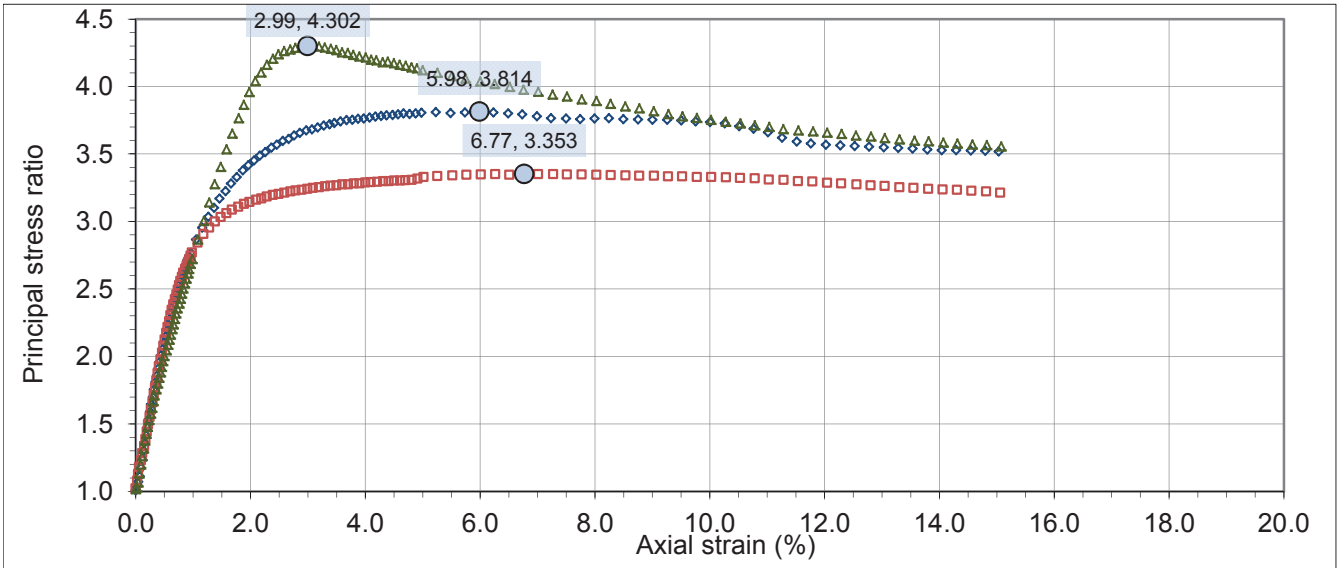
Comments:

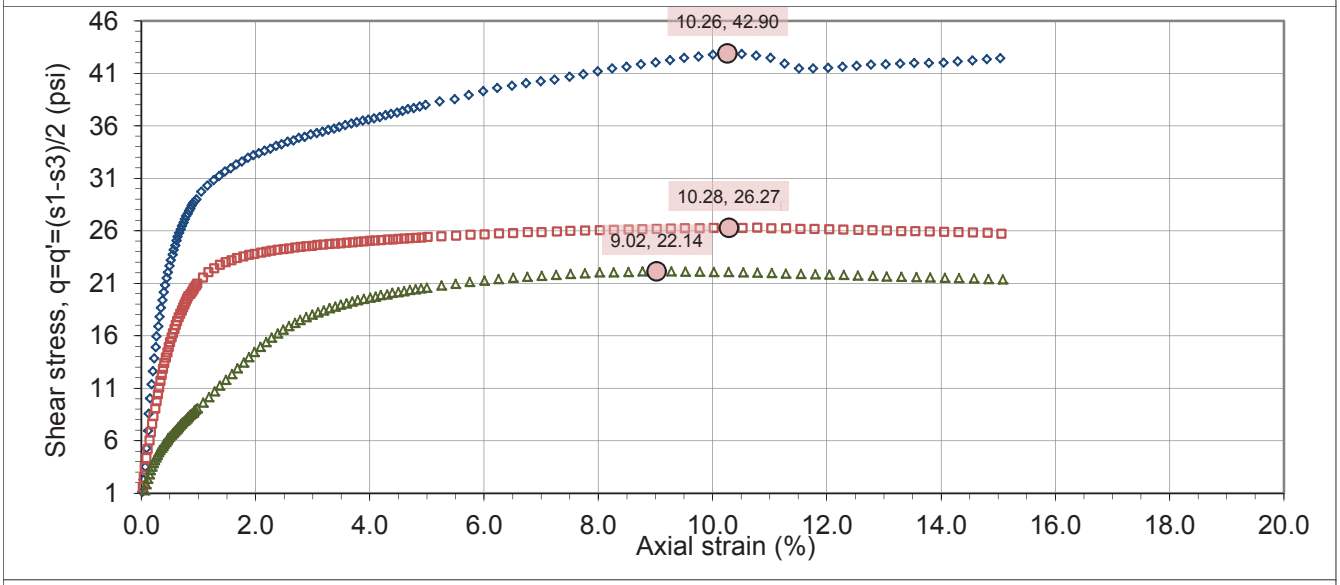
DRAFT

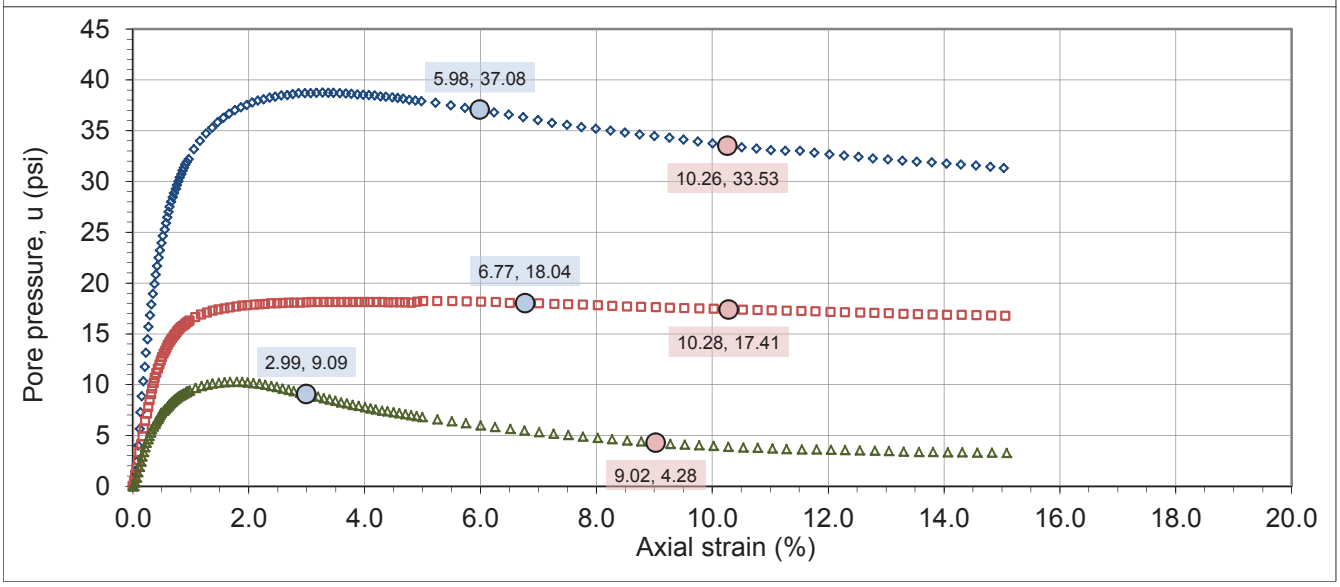
Triaxial Test - Isotropic Consolidated Sheared Undrained
Measuring Pore Pressure (CIU-PP) *- After ASTM D4767 and USBR 5750*

GERHART COLE

Project: Bear River - Fielding **TH/TP/Sample:** TH-FD-03
No: 13GCI329 **Depth:** 60-61.7







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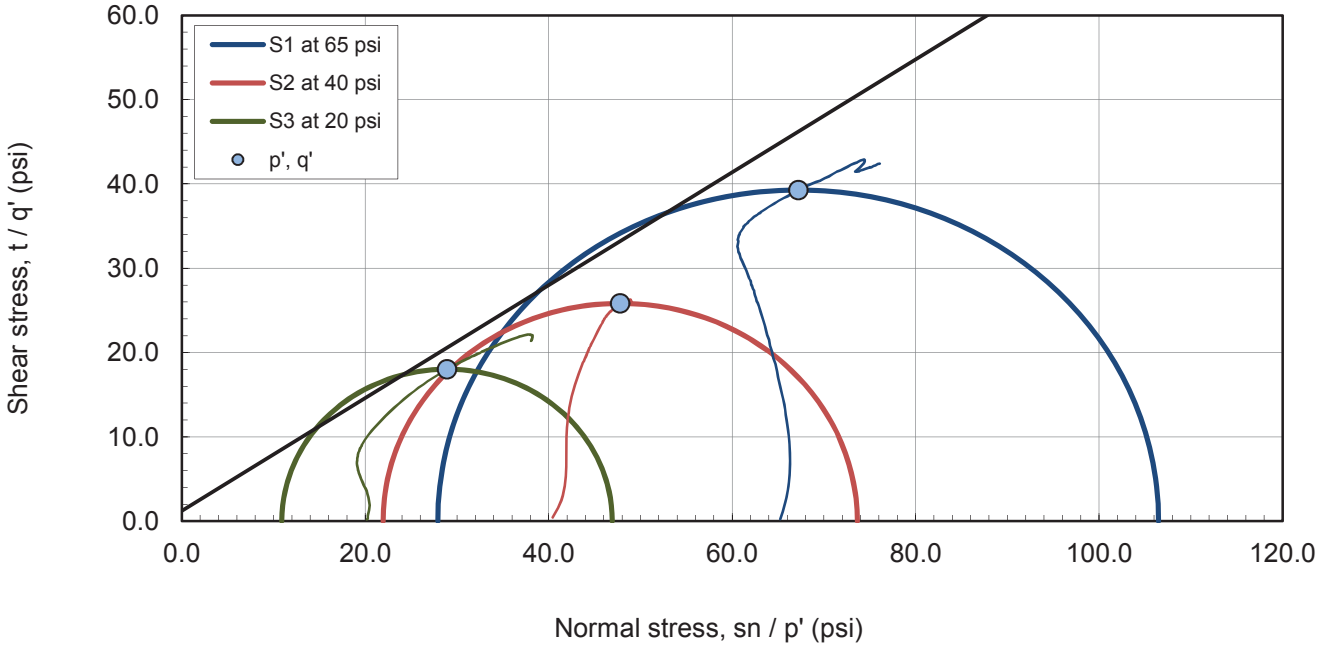
Triaxial Test - Isotropic Consolidated Sheared Undrained
Measuring Pore Pressure (CIU-PP) *- After ASTM D4767 and USBR 5750*

GERHART COLE

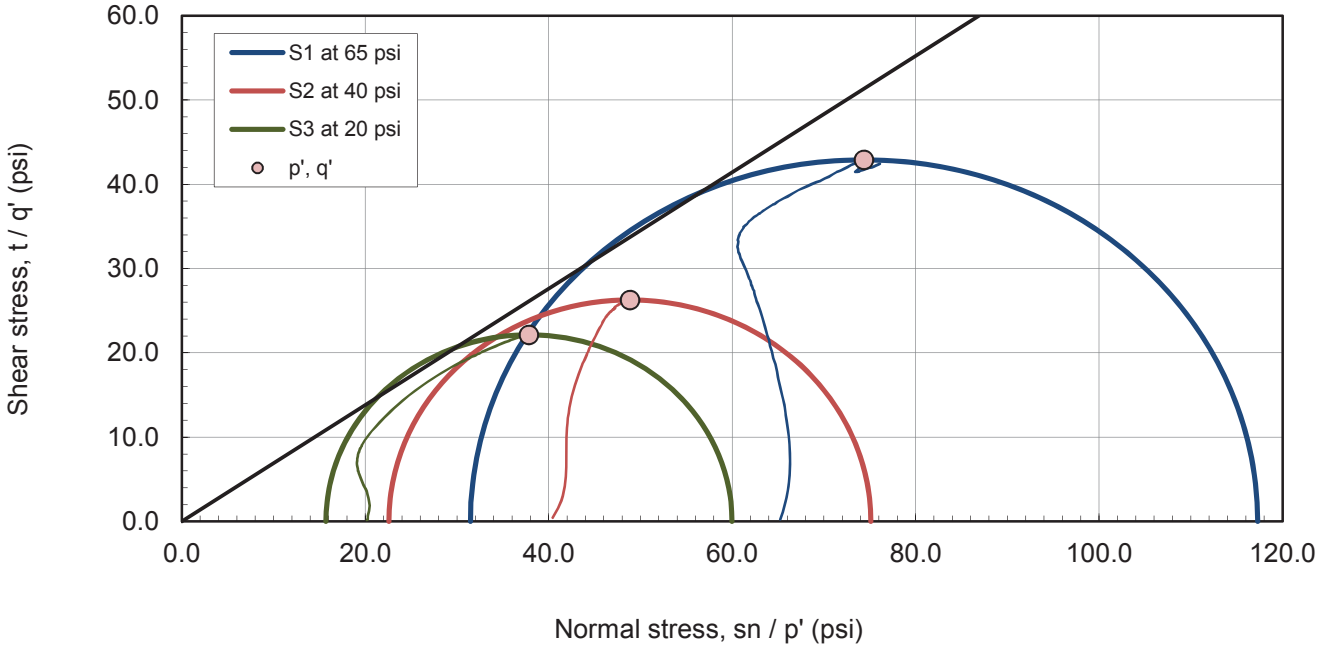
Project: **Bear River - Fielding** **TH/TP/Sample:** **TH-FD-03**
No: **13GCI329** **Depth:** **60-61.7**

Effective stress results



Max principal stress ratio (s'1/s'3), failure criteria Mohr and p' - q' space plots

Effective stress results



Peak deviator stress (s1-s3), failure criteria Mohr and p' - q' space plots

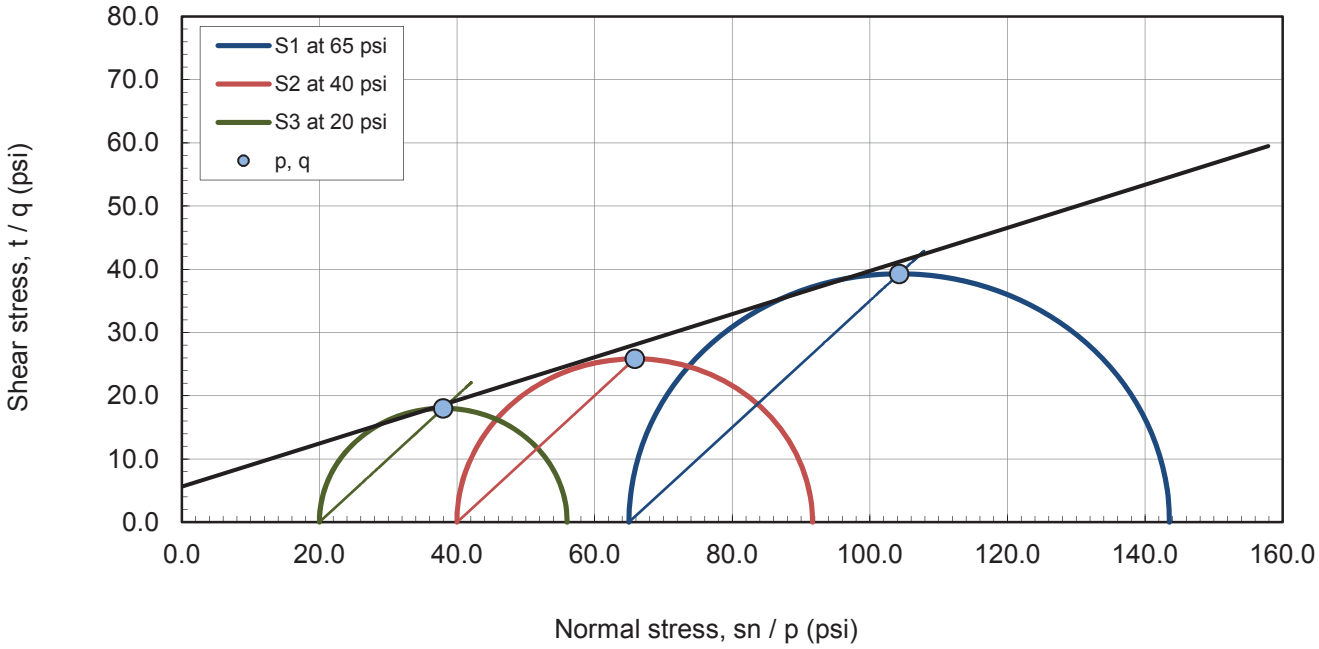
DRAFT

Triaxial Test - Isotropic Consolidated Sheared Undrained
Measuring Pore Pressure (CIU-PP) *- After ASTM D4767 and USBR 5750*

GERHART COLE

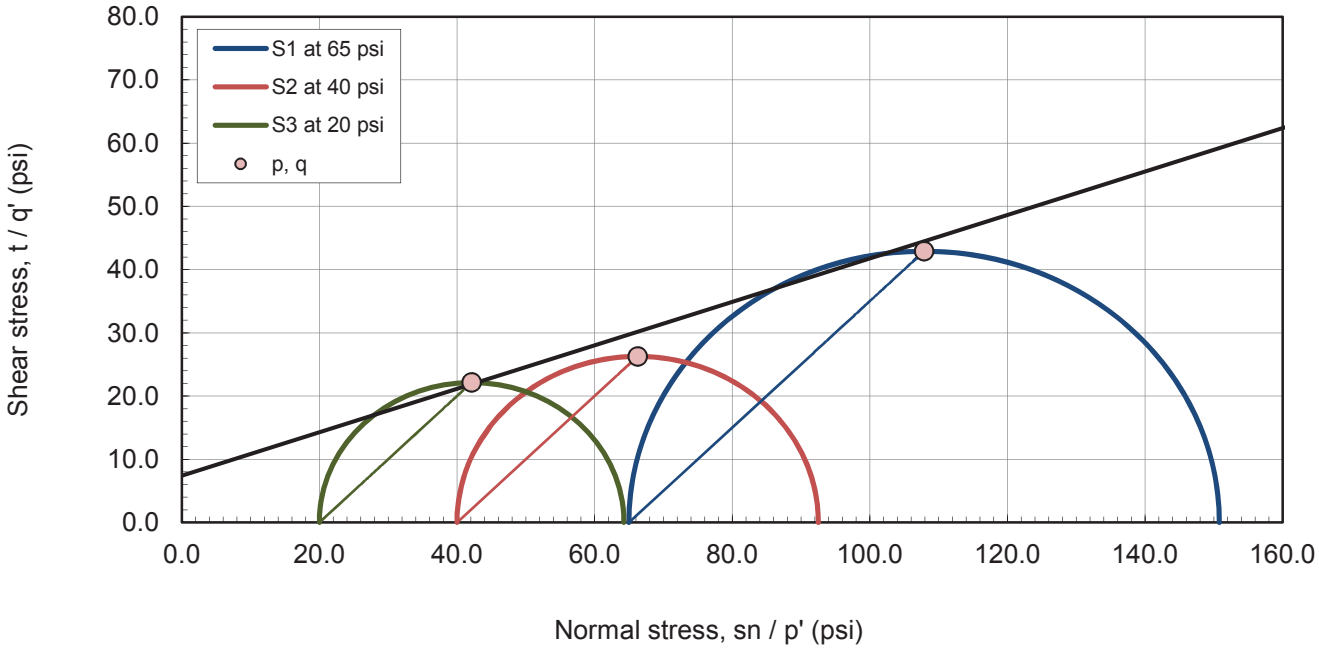
Project: Bear River - Fielding | **TH/TP/Sample:** TH-FD-03
No: 13GCI329 | **Depth:** 60-61.7

Total stress results



Max principal stress ratio (s1/s3), failure criteria Mohr and p - q space plots - effective stress results

Total stress results



Peak deviator stress (s1-s3), failure criteria Mohr and p - q space plots

DRAFT

Triaxial Test - Isotropic Consolidated Sheared Undrained
Measuring Pore Pressure (CIU-PP) *- After ASTM D4767 and USBR 5750*

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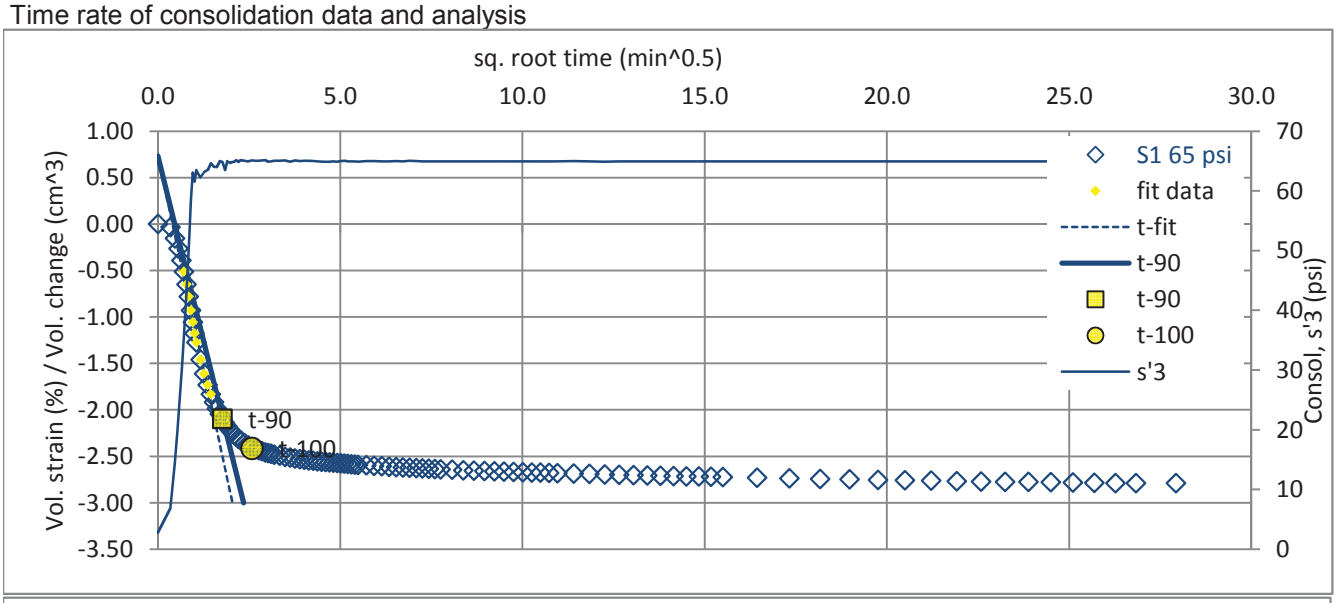
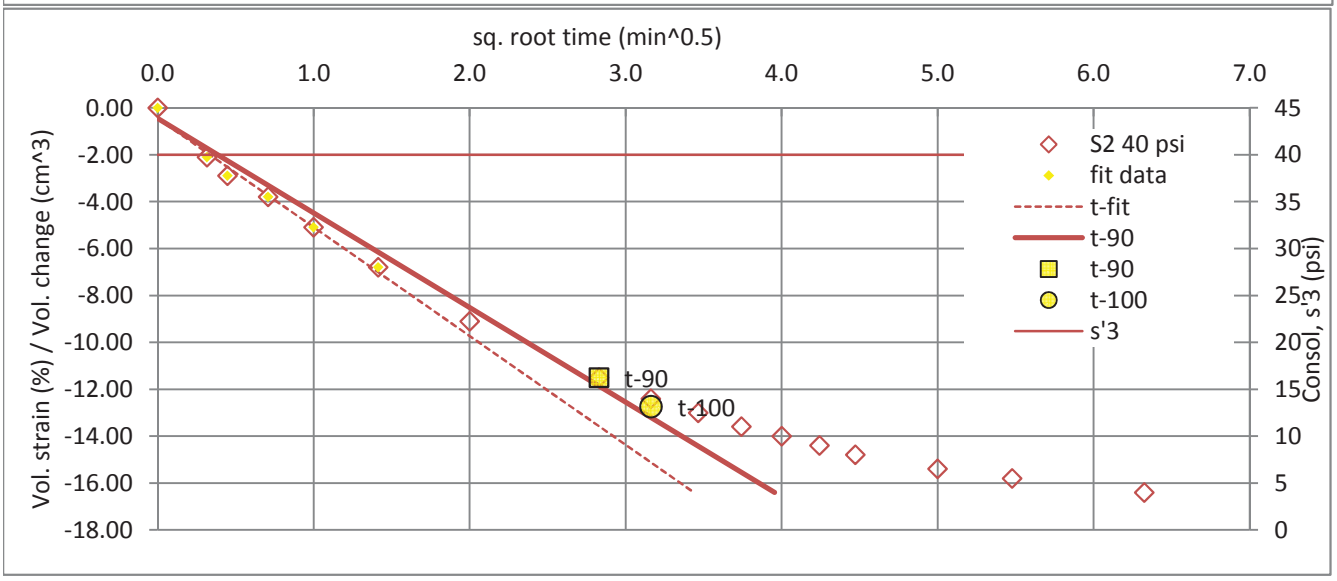
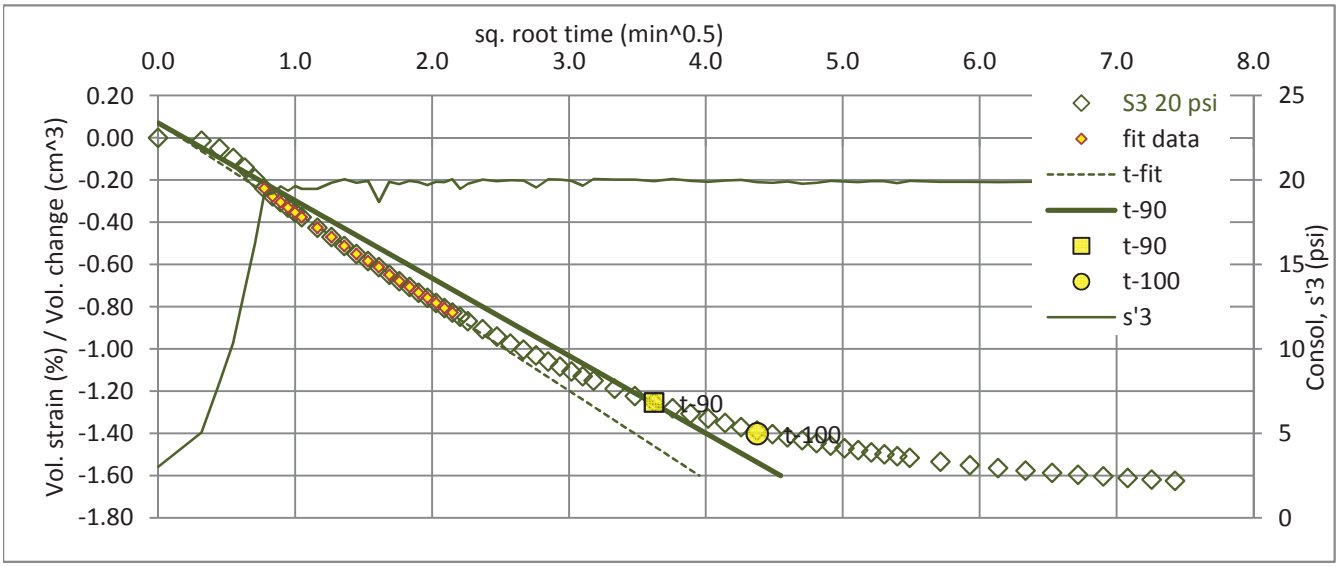
Project: Bear River - Fielding **TH/TP/Sample: TH-FD-03**
No: 13GCI329 **Depth: 60-61.7**

Time rate of consolidation data and analysis







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One-Dimensional Collapse / Swell Properties of Soils

After ASTM D4647 and USBR 5410

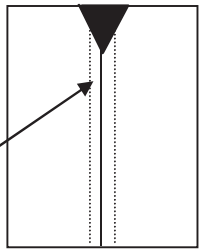
GERHART COLE

Project: **Bear River - Fielding**
No: **13GCI329**
Location: Box Elder County, Utah
Date: 29-Jul-15
Tested by: zmg
Reduced by: zmg
Checked by: bjb

TH/TP/Sample: **TH-FD-02**
Depth: **20-22**
Sample description: gray clay
Visual description: gray clay
USCS classification: CL

Test type / method: A
Sample type: Undisturbed
Moisture content (%): 29.3
Dry unit weight (pcf): 97.5

Compaction specifications: in situ
Target moisture content (%): -
Target dry unit weight (pcf): -
Specimen After Test
Final Hole (mm): 1.0



Dispersive Classification: **ND1 - Nondisperisve**

Clock Time	Head (in)	Flow			Turbidity From Side						Completely Clear From Top	Particles Falling			Remarks
		ml	sec	Rate (ml/sec)	Very Dark	Dark	Moderately Dark	Slightly Dark	Barely Visible	Completely Clear		None	Few	Heavy	
14:00	2	12.0	60	0.2					X			X			
	2	12.0	60	0.2					X			X			
	2	16.0	60	0.3					X			X			
	2	15.0	60	0.3					X			X			
	2	15.0	60	0.3					X			X			
	7	36.0	60	0.6					X			X			
	7	35.0	60	0.6					X			X			
	7	36.0	60	0.6					X			X			
	7	39.0	60	0.7					X			X			
	7	37.0	60	0.6					X			X			
	15	60.0	60	1.0					X			X			
	15	60.0	60	1.0					X			X			
	15	61.0	60	1.0					X			X			
	15	61.0	60	1.0					X			X			
	15	61.0	60	1.0					X			X			
	40	97.0	44	2.2				X					X		
	40	108.0	44	2.5				X					X		
	40	76.0	30	2.5				X					X		
	40	75.0	30	2.5				X					X		
	40	76.0	30	2.5				X					X		

DRAFT – South Willard Bay Geotechnical Data Report Bear River Project Concept Study

Prepared for
Bowen Collins & Associates, Inc
October, 2018

GCI project number: 13GCI329

GERHART COLE

DRAFT

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October, 31 2018

Prepared for:

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Draper, Utah 84020

South Willard Bay - Geotechnical Data Report
Bear River Project Concept Study
13GCI329

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TABLE OF CONTENTS

SECTION 1 Introduction 1-1

1.1 Project Description 1-1
1.2 Purpose, Authorization, and Work Scope 1-1

SECTION 2 Methods of Study and Findings 2-1

2.1 South Willard Bay Site 2-1
2.1.1 Test Hole Drilling and Sampling 2-1
2.1.2 Laboratory Testing 2-2
2.1.3 Permeability Testing 2-2
2.1.4 Site Specific Conditions 2-2
2.1.5 Groundwater 2-3

SECTION 3 Geology 3-1

3.1 General Setting 3-1
3.2 Lake Bonneville History 3-1
3.3 Surficial Deposits 3-2
3.4 Site-Specific Conditions 3-2
3.5 Geologic Hazards 3-3
3.5.1 Surface Fault Rupture 3-3
3.5.2 Landslides 3-4

SECTION 4 Conclusion 4-1

4.1 Additional Services 4-1
4.2 Limitations 4-1

SECTION 5 References 5-1

List of Tables

Table 2-1 South Willard Bay – Laboratory Test Results

Table 2-2 South Willard Bay – Constant Head Permeability Test Results

Table 2-3 South Willard Bay Groundwater Measurements

List of Figures

Figure 1.1 Vicinity Map

Figure 2-1 South Willard Bay – Site and Exploration Map

Figure 3.1a Geologic Map (Reference: Harty and others, 2012)

TABLE OF CONTENTS

List of Appendices

Appendix A - South Willard Bay - Test Hole Logs

Appendix B - South Willard Bay - Interpretative Laboratory Test Results

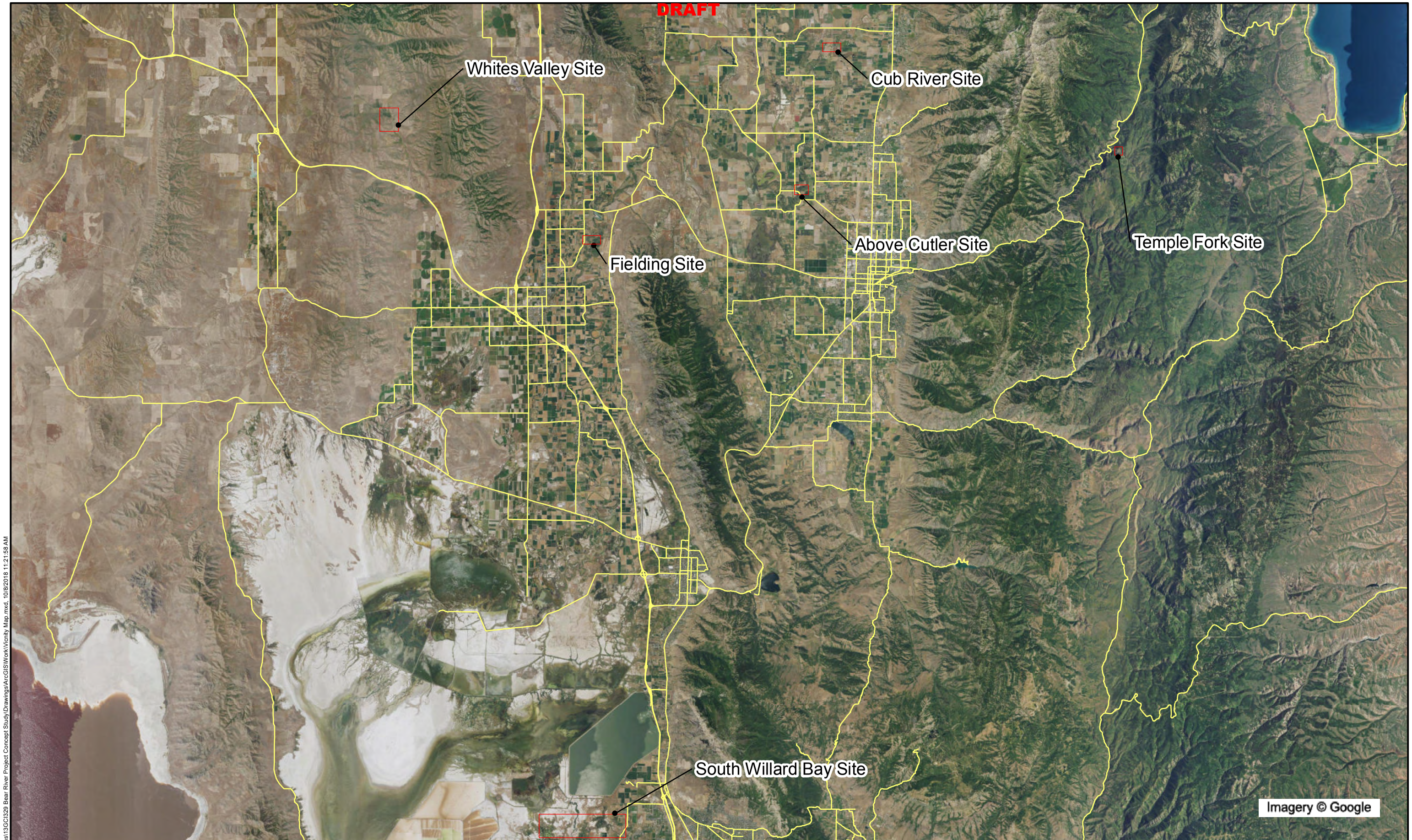
1.1 Project Description

The purpose of the Bear River Project is to develop Utah's unused water rights on the Bear River and deliver it to Box Elder, Cache, Weber, Davis, and Salt Lake Counties. The overall Project will consist of conveyance facilities and reservoir storage necessary to deliver water from the Bear River to the communities in the service areas of the Bear River Water Conservancy District (BRWCD), Cache County, the Weber Basin Water Conservancy District (WBWCD), and the Jordan Valley Water Conservancy District (JVWCD). The Utah Division of Water Resources (DWRe) has been working with Bowen Collins and Associates and HDR (Project Team) for several years to develop the overall Project.

1.2 Purpose, Authorization, and Work Scope

This report presents the results of geotechnical and geologic studies performed by Gerhart Cole Inc. (GCI) at South Willard Bay in support of the project design team. The other project study areas that have had some studies completed are Cub River, Above Cutler, Fielding, Temple Fork, and Whites Valley. The locations of these study sites are shown in Figure 1-1 along with the South Willard Bay Site.

GCI scope of work included a preliminary site characterization of the site, including drilling 2 test holes, geologic study of the dam and reservoir site, and associated laboratory testing on select samples recovered from the test holes. This work was completed under GCI's existing cooperative reciprocal service agreement with BCA.



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Bear River Project Concept Study

Vicinity Map

N

0 8,000 16,000 32,000 Feet

Figure 1-1

J:\PROJECTS\Bowen Collins\13GC\328 Bear River Project Concept Study\Drawings\ArcGIS\Work\Vicinity Map.mxd, 10/8/2018 11:21:58 AM

2.1 SOUTH WILLARD BAY SITE

A field study was conducted at the South Willard Bay site between September 8 and September 10, 2015. The study consisted of drilling and sampling two test holes (TH-WB-01, TH-WB-02). A site map showing test hole locations is presented as Figure 2-1. Test hole locations were established by GCI based on accessibility and proximity to the proposed dam. Test hole locations were documented by using a hand-held, tablet-mounted GPS device, with elevations taken from LiDAR data from the Utah GIS portal website with an elevation datum of NAVD88.

2.1.1 Test Hole Drilling and Sampling

Test holes were drilled on the Little Mountain Rail Trail in Plain City, Utah. Weber Pathways and the landowners provided permission to drill on the trail. TH-WB-01 and TH-WB-02 were advanced to depths of 52 feet and 62 feet, respectively. One-inch diameter open standpipe piezometers, to monitor groundwater levels, were installed in both test holes.

The piezometer installed in TH-WB-01 was screened from 52 to 47 feet, with a sand pack from 52 to 38 feet, and the remaining interval sealed with bentonite chips. In TH-WB-02 the piezometer was screened from 56 to 51 feet, with a sand pack from 56 to 36 feet, and the remaining interval was sealed with bentonite chips. The screen in TH-WB-02 was not placed at the bottom of the test hole due to the bottom 6 feet of hole collapsing before the piezometer could be placed.

Test holes were completed by advancing HW casing (4-inch I.D) and rotary wash drilling methods. The driller would advance the holes in 5 ft increments, a water test would be performed, soil sampled, and then casing would be hydraulically pushed to the bottom of the increment. In TH-WB-02 the hole was advanced to 60 feet to investigate the bottom depth of the soft clays, but the casing was only set to a depth of 45 feet. Drilling was accomplished with a CME 75 truck-mounted drill rig operated by Bedke Geotechnical Field Services under subcontract to GCI.

Subsurface conditions were logged by a GCI field engineer at the time of drilling. Three sampling methods were used to obtain soil specimens for characterization and laboratory testing: a) Standard Penetration Test (SPT), b) Shelby Tube (ST) samples, and c) fixed piston Shelby Tube (ST-Piston). ST-Piston sampling procedures were used in softer soil deposits, when difficulty was experienced obtaining ST samples.

Sampling was performed at 2.5 or 5-foot intervals. Two and one half-foot sampling intervals were generally used in coarse grained soil deposits, with 5-foot sampling intervals being used in fine grained soil deposits. SPT samples were obtained using an automatic hammer, the energy efficiency of which was recently measured at 77 percent. The number of hammer blows required to advance the sampler in 6-inch increments was recorded in the field, with the sum of the second and third 6-inch intervals constituting the SPT blowcount or “N-value.”

Logs of test holes are presented in Appendix A. Lines designating boundaries between different materials shown on the logs should be considered approximate, as transitions between subsurface materials may be gradual or occur between sampling depths. Relative density and consistency descriptions contained in a final test hole log may deviate from field logs and/or criteria for a number of reasons, including; a) reliance on other test results, b) visual observation and/or manual manipulation of disturbed field samples, or c) the Engineer's judgment. For most engineering assessments involving cohesionless, non-gravelly soils, the SPT blowcount is usually adjusted for effective vertical pressure at the sampling depth, and for other sampling system parameters such as the efficiency of the sampling system and/or sampling techniques used.

2.1.2 Laboratory Testing

Laboratory testing was performed on select soil specimens obtained during field studies to further classify them and evaluate their engineering properties. Laboratory testing for South Willard included moisture content, Atterberg limits, grain size distribution tests, and organic content tests. One dimensional (1-D) consolidation testing was performed on 4 samples. Shear strength testing was performed on 2 samples by performing tri-axial, consolidated, undrained (with pore pressure measurement - CUPP) tests. Laboratory test results are summarized in Table 2-1, with additional data and plots presented in Appendix B.

2.1.3 Permeability Testing

Constant head permeability tests were performed by drilling down to the bottom of the test zone, with the casing held at the top of the test zone and extending to the ground surface. The bit was then removed, leaving the casing in place creating a vertical cylindrical void within soil comprising the test region and a cased test hole down to the top of the test region. The void and casing were filled with water to the top of the casing and water was added as needed to keep the casing full for the duration of the test (typically 10 to 15 minutes). At the end of the test, the volume of water added and test duration were recorded. These results are presented in Table 2-2.

2.1.4 Site Specific Conditions

Soils generally consisted of fill, medium plastic clay (CL) and silt (ML) in both test holes. Fill, presumably from the old railroad grade that now constitutes Little Mountain Rail Trail, was found from the ground surface to depths of 3 to 5 feet. Below the fill, results of drilling and sampling in TH-WB-01 showed medium stiff to stiff sandy silt (ML) to a depth of 23 feet, followed by from 23 to 43 feet of black to dark gray very soft clay (CL) with some organics, and then the soils consisting of a very soft bluish gray clay (CL) from 43 feet to the bottom of the hole. Field permeability testing suggests sand or silt seams between depths of 15 to 40 feet are present in TH-WB-01.

Stiff silt was found below the fill to a depth of 14 feet in TH-WB-02 followed by from 14 to 25 feet of very soft dark gray clay with some organics to a depth of 25 feet, with a thin layer of 10-inch layer of sand at approximately 15.5 feet; and then 25 to 27 feet of soft sandy silt and very soft bluish gray clay from 27 to 61 feet. The test hole was

terminated in a medium dense sand (SP-SM) layer at 62 feet. Field permeability testing suggests sand or silt seams between depths of 10 to 30 feet in TH-WB-02.

2.1.5 Groundwater

Groundwater levels were measured in the piezometers, as summarized in Table 2-3. Measurements made after drilling and before the piezometer installation may be less reliable than later groundwater measurements.

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Table 2-1 Laboratory Test Result Summary

Bear River Project Concept Study- South Willard Bay (13GCI329)

Test Hole	Depth (ft)	Moisture content (%)	Dry unit weight (pcf)	Moist / Sat. unit weight (pcf)	Atterberg Limits					Grain-Size			Grain-Size Analysis (Percent Finer)										Organic content (%)	Other Tests (Interpretative Data in Appendix)
					LL (%)	PL (%)	PI (%)	Cohesive Index, CI	Liquidity Index, LI	GRAVEL (No.4 - 3")	SAND (No.200-No.4)	FINES (<No.200)	1.5-in (37.5 mm)	3/4-in (19 mm)	3/8-in (9.5 mm)	No.4 (4.75 mm)	No.10 (2 mm)	No.20 (0.85 mm)	No.40 (0.425 mm)	No.60 (0.25 mm)	No.100 (0.15 mm)	No.200 (0.075 mm)		
TH-WB-01	15-17	26								0	40	60	100	100	100	100	100	100	100	100	97	60		
TH-WB-01	23.5-25																						3.6	
TH-WB-01	25-26.5	41	74	104	34	21	13	0.62	1.6															1D Consolidation
TH-WB-01	30-31.5	39	81	112	40	25	15	0.6	0.9															CU
TH-WB-01	35-37																						3.2	
TH-WB-01	45-47	40	78	109	48	23	25	1.09	0.7															1D Consolidation
TH-WB-02	5-7	14								0	28	72	100	100	100	100	100	100	99	99	98	72		
TH-WB-02	15-17	41	79	111	40	23	17	0.74	1.1															1D Consolidation
TH-WB-02	20-22																						2.3	
TH-WB-02	25-26.5	29										60										60		
TH-WB-02	40-42	54	66	102	48	27	21	0.78	1.3															CU
TH-WB-02	45-47	33	85	113	41	23	18	0.78	0.6															1D Consolidation
TH-WB-02	61-62	28								0	88	12	100	100	100	100	100	100	100	98	71	12		

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Table 2-2 - South Willard Bay - Constant Head Permeability Testing Summary

Bear River Concept Study - South Willard Bay

Location	Test Depth (ft)	Soil Type in Test Range	Ground Water Depth (ft)[a]	Flow, Q (gpm)	Hydraulic Conductivity (Lugeon)	Hydraulic Conductivity (cm/sec)	Comments
TH-WB-01	0-10	ML	3	0.04	5	7E-05	ML bounds bottom and top of test zone
TH-WB-01	10-15	ML	3	0.16	32	4E-04	ML bounds bottom and top of test zone
TH-WB-01	15-20	ML	3	0.34	63	8E-04	ML bounds bottom and top of test zone, Sand seams or leakage possible.
TH-WB-01	20-25	ML/CL	3	0.37	63	8E-04	ML bounds top of test zone and CL bounds btm of test zone; Sand seams or leakage possible.
TH-WB-01	25-30	CL	3	0.42	72	9E-04	CL bounds bottom and top of test zone, Sand seams or leakage possible.
TH-WB-01	30-35	CL	3	0.50	85	1E-03	CL bounds bottom and top of test zone, Sand seams or leakage possible.
TH-WB-01	35-40	CL	3	0.38	65	8E-04	CL bounds bottom and top of test zone, Sand seams or leakage possible.
TH-WB-01	40-45	CL	3	0.02	4	5E-05	CL bounds bottom and top of test zone
TH-WB-01	45-50	CL	3	0.01	2	3E-05	CL bounds bottom and top of test zone
TH-WB-02	0-5	GP-GM/ML	3	0.21	48	6E-04	GP-GM bounds top of test and ML bounds btm of test zone
TH-WB-02	0-10	ML	3	0.24	32	4E-04	ML bounds bottom and top of test zone
TH-WB-02	10-15	ML/CL	3	0.20	33	4E-04	ML bounds bottom and top of test zone, Sand seams or leakage possible.
TH-WB-02	15-20	CL	3	0.16	27	4E-04	CL bounds bottom and top of test zone with a sand seam
TH-WB-02	20-25	CL	3	0.20	33	4E-04	CL bounds bottom and top of test zone with a sand seam
TH-WB-02	25-30	MH	3	0.45	76	1E-03	ML bounds top of test zone and CL bounds btm of test zone; Sand seams or leakage possible.
TH-WB-02	35-40	CH	3	0.00	0	1E-06	CL bounds bottom and top of test zone
TH-WB-02	40-45	CH	3	0.01	1	1E-05	CL bounds bottom and top of test zone
TH-WB-02	45-50	CH	3	0.01	1	2E-05	CL bounds bottom and top of test zone

Notes: a. Depth to groundwater estimated from water content in soil

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Table 2-3 - Cub River- Groundwater Measurements

Bear River Concept Study - Cub River

Date	Groundwater Depth in Piezometer (ft)		
	TH-CUB-01	TH-CUB-02	TH-CUB-03
September 5, 2014		+1.7	
September 8, 2014			20.6
September 9, 2014	+10		
June 16, 2015	+10.3	0	20.3
September 30, 2015	+8.1>	0	19.2

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Bear River Project Concept Study - South Willard Bay

South Willard Bay - Site and Exploration Map

N

0 950 1,900 3,800 Feet

Figure 2-1

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3.1 GENERAL SETTING

The proposed site is located in Great Salt Lake Valley, a north-trending, deep, sediment-filled structural basin bounded by the Wasatch Mountains on the east and by the Promontory Mountains on the west. Great Salt Lake Valley is located at the eastern margin of the Basin and Range Physiographic Province, a region characterized by a series of generally north-trending mountain ranges separated by similarly trending valleys. The large-scale topographic features are a result of east-west crustal extension that began about 15 to 17 million years ago, and continues today (Hecker, 1993). Crustal extension has resulted in range front normal faults separating the mountains from valleys. Erosional processes have removed material from the mountains and partially filled the valley with alluvial and lacustrine (lake) sediments.

3.2 LAKE BONNEVILLE HISTORY

The near-surface geology of the proposed site is dominated by sediments deposited and/or reworked by the Great Salt Lake and Lake Bonneville, a large late-Pleistocene lake that covered much of northwestern Utah and adjacent parts of Idaho and Nevada. The lake began to rise above levels comparable to the Great Salt Lake about 28,000 years ago[1] and by approximately 16,000 ago, the lake reached its highest elevation – the Bonneville shoreline (Gilbert, 1890; Currey, 1990). Near the proposed site, the elevation of the Bonneville shoreline is at about 5,200 and 5,180 feet (Harty, et. al., 2012).

Lake Bonneville remained at the elevation of the Bonneville shoreline until about 14,500 years ago when a catastrophic failure near Red Rock Pass caused a massive flooding of lake waters into the Snake River drainage. This event, called the Bonneville flood, caused a drop in lake level of about 340 feet where the lake level restabilized and the Provo shoreline began to form. Near the proposed site, the elevation of the Provo shoreline varies between about 4,800 and 4,830 feet (Harty, et. al., 2012).

The lake oscillated at or near the level of the Provo shoreline until about 12,500 years ago when a change in climate conditions permanently drove the lake below the threshold at Red Rock Pass. By about 11,500 years ago, the lake had reached levels comparable to modern Great Salt Lake – about 4,200 feet (Godsey et. al., 2005).

The lake rose again briefly between about 11,000 and 10,000 years ago to form the Gilbert shoreline at approximately 4,240 feet, and then again declined (Oviatt et al., 2005). This marks the end of Lake Bonneville and the beginning of its successor, Great Salt Lake (Currey et al., 1984). In the vicinity of the proposed embankment, Holocene high stands of Great Salt Lake have been about 4,221 and 4,240 (Harty, et. al., 2012).

During the time Lake Bonneville existed in the Great Salt Lake Valley, coarse-grained sediments were deposited in the shore and nearshore environments creating beaches, deltas, spits, and bars. In deeper water, toward the center of the valley, deposits generally consist of finer grained sand, silt, clay, and marl (Oviatt and Miller, 1997).

[1] Unless otherwise noted, all ages are radiocarbon ages.

3.3 SURFICIAL DEPOSITS

The most detailed published geologic mapping completed in the vicinity of the proposed site is at a scale of 1:24,000 (Harty, et. al., 2012). Harty and others have mapped six surficial deposits in the vicinity of the project site (Figure 3-1):

- Younger stream alluvium (Qal_1) consisting of well to poorly sorted silt, sand, and gravel deposited on active flood plains and channels (Holocene).
- Older stream alluvium (Qal_2) consisting of well to poorly sorted silt, sand, and gravel deposited on inactive flood plains and channels (Holocene).
- Marsh deposits (Qsm) wet, fine-grained, organic rich sediment associated with springs and seeps (Holocene).
- Delta deposits (Qd_2) consisting of sand, silt, and clay deposited in a platform-like topographic form (lower Holocene).
- Mixed lacustrine, alluvial, and marsh deposits (Qlam) consisting of sand, silt, and clay deposited by low-gradient streams and in marshes (Holocene to Pleistocene).
- Lacustrine fine-grained deposits (Qlf) consisting of intervals of mixed clay and silt and intervals of rhythmically interbedded fine to medium-grained sand deposited in offshore environments of Great Salt Lake and Lake Bonneville (Holocene to upper Pleistocene).

3.4 SITE-SPECIFIC CONDITIONS

The proposed embankment site consists of relatively flat-lying topography at elevations between about 4,210 and 4,250 feet. A majority of the site has been mapped by Harty and others (2012) as marsh deposits; mixed lacustrine, alluvial, and marsh deposits; and lacustrine fine-grained deposits (Figure 3-1). Small portions of the embankment, on the eastern extent, will rest on delta deposits, and the embankments will cross several narrow deposits of stream alluvium. It is important to note that because of the elevation of the site, most of the deposits mapped at the surface are likely to be discontinuous in the subsurface. This area is within the elevation of numerous late Pleistocene and Holocene lake fluctuations, and as such the shore zone was constantly shifting both in elevation and laterally. Thus any given location in the area has experienced a complex history of subaqueous depositional, and subaerial depositional and erosional processes.

Test hole TH-WB-01 was drilled in the unit described by Harty and others (2012) as mixed lacustrine, alluvial, and marsh deposits (Qlam); TH-WB-02 was drilled near the boundary of younger alluvial deposits (Qal_1) and fine-grained lacustrine deposits (Qlf).

Sediments recovered from the two test holes at the proposed site consisted primarily of silts and clays, with minor layers of sand. We interpret the silts and clays to have been deposited in deep water during times that the site was occupied by the Great Salt Lake and/or Lake Bonneville. We do not have sufficient information to delineate Great Salt Lake sediments from Lake Bonneville sediments. The predominance of fine-grained sediments at this elevation, along with our understanding of Lake Bonneville and Great Salt Lake chronology and deposition, suggests that the silts and clays are likely laterally

extensive across the proposed site, however there are likely interbeds of sandy materials as well.

We interpret the sands and silty sands to have been deposited by meandering or braided streams, low-angle deltas, beaches, and/or spits in the shore and near shore environment of the Great Salt Lake. It is likely that some of the sandy layers found in TH-WB-02 represent subaerial deposition occurring during low stands of the Great Salt Lake. We expect that similar deposits are present elsewhere across the site, and at varying depths.

The dark gray to black clays with organic organics and organic odor found in the test holes likely represent deposition in a marsh environment. Again, given the elevation of the site, we expect that these deposits are present elsewhere across the site, and at varying depths. Although we do not have details, we understand that methane seeps have been observed in the vicinity, and that methane from one of these seeps was used in a residential home. Harty and others (2012) map several marsh deposits, and it is likely that the methane seeps are originating in one of these deposits, or similar deposits at depth.

3.5 GEOLOGIC HAZARDS

3.5.1 Surface Fault Rupture

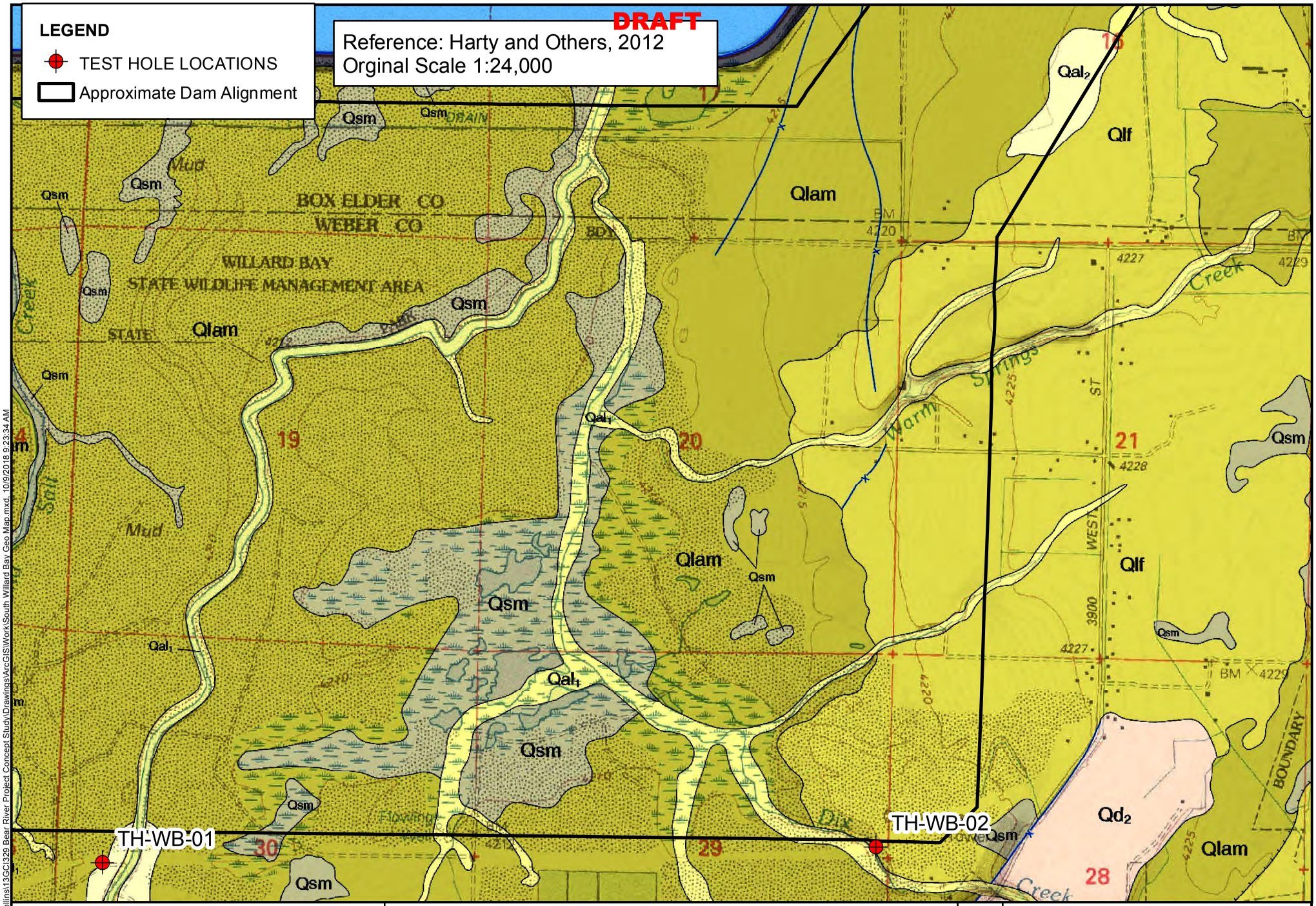
The project site is located within the Wasatch fault zone, one of the longest and most tectonically active faults in North America (Black, et. al., 2004). The Wasatch fault extends for about 213 miles along the base of the Wasatch Range between Malad City, Idaho and Fayette, Utah (Machette et. al., 1992) and marks the eastern boundary of the Basin and Range in northern Utah. Surface features associated with faulting have created a zone of deformation characterized by roughly north-trending west-facing main fault scarps and smaller east-facing antithetic fault scarps. The Wasatch fault has been divided into 10 sections, which rupture independently and are capable of generating large-magnitude surface-rupturing earthquakes (Machette et. al., 1992).

The proposed site is near the southern end of the Brigham City section, a well constrained, approximately 23-mile long section of the Wasatch fault (Black et. al., 2004). Harty and others (2012) map a western splay of the Brigham City section of the Wasatch fault approximately 3.5 miles east of the proposed site. The fault is mapped as concealed by Holocene to upper Pleistocene lacustrine fine-grained sediments, Holocene to Pleistocene mixed lacustrine, alluvial, and marsh deposits, and Holocene alluvial fans.

The paleoseismic history of this splay is not reported; however the U.S. Geological Survey and the Utah Geological Survey have conducted paleoseismic investigations of the Brigham City section of the Wasatch fault in a trench near Brigham City and at 14 trenches near Box Elder Canyon (summarized in Black et. al., 2004). Results of these investigations indicate that: 1) surface-rupturing earthquakes have a recurrence interval of about 1,300 years, 2) the most recent earthquake was about 2,100 years ago, and 3) the vertical slip rate is between 1.0 and 5.0 mm/year.

3.5.2 Landslides

The gradient across the proposed site is low enough that landslides are unlikely. However, Harty and others (2012) map a large liquefaction-induced landslide deposit consisting of silt, fine sand, and minor gravel redeposited in flow slides and lateral spreads. This landslide complex of 25 square miles is mapped in the eastern portion of the Plain City Quadrangle, approximately 3 miles southeast of the proposed site. In addition, Harty and others (2012) have mapped (queried) a liquefaction-induced landslide deposit in the vicinity of the South Marina campground near Willard Bay reservoir.



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Bear River Project Concept Study - South Willard Bay

South Willard Bay Geologic Map

N

0 750 1,500 3,000 Feet

Figure 3-1a

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DESCRIPTION OF MAP UNITS

Qlf — **Lacustrine fine-grained deposits, Holocene to upper Pleistocene** – Intervals of mixed fine-grained sediment, clay to silt, and intervals of rhythmically interbedded fine to medium sand; commonly calcareous; typically laminated or thin bedded; deposited in low-energy, generally offshore environments at elevations below the Provo shoreline; thickness typically less than 5 meters (15 ft).

Qd_2 — **Delta deposits, lower Holocene** – Silt, fine sand, and clay deposited in a platform-like topographic form with an upper-surface elevation of about 1292 meters (4240 ft) (about 8 meters [25 feet] above modern Weber River flood plain); scattered pebble gravel covers the surface of the platform in some areas; deposited during transgression of the post-Gilbert Great Salt Lake shoreline between about 9.7 and 9.4 ka (Murchison, 1989; Sack, 2005); relates to the lower Holocene high water level; northwestern boundary of Qd_2 at Plain City is cut by a well-defined, sublinear upper Holocene shoreline at 1287 meters (4221 ft), and traceable for about 4.8 kilometers (3.0 mi) along the ground surface; formed between 2.5 and 2.0 ka, remnants of this shoreline are exposed elsewhere in the Lake Bonneville basin and are considered to mark Great Salt Lake's upper Holocene high water level (Sack, 2005); Qd_2 is dissected by and thus predates Qal_2 deposits; total thickness about 3 to 6 meters (10–20 ft).

Qal_1 — **Younger stream alluvium, Holocene** – Well to poorly sorted silt, sand, and gravel deposited along modern channels and flood plains; clasts subrounded to rounded; mapped where fluvial processes are currently or episodically active; thickness generally less than 3 meters (10 ft).

Qal_2 — **Older stream alluvium, Holocene** – Well to poorly sorted silt, sand, and gravel deposited along inactive flood plains 1 to 3 meters (3–10 ft) above modern stream level; mapped where fluvial processes are generally no longer active; thickness generally less than 3 meters (10 ft).

Qsm — **Marsh deposits, Holocene** – Wet, fine-grained, organic-rich sediment associated with springs and seeps; thickness probably less than 1 meter (3 ft) in most areas.

Qlam — **Mixed lacustrine, alluvial, and marsh deposits, Holocene to Pleistocene** – Predominantly fine-grained sediment (sand, silt, and clay) deposited by low-gradient streams and in marshes, and mixed with Lake Bonneville and Great Salt Lake sediment; mapped south and west of the Pleasant View salient; total thickness typically less than 6 meters (20 ft).

Qfd — **Fill and disturbed land, historical** – Land disturbed and excavated during aggregate (sand and gravel) operations; fill in Interstate highways, highway interchanges, Willard Bay dikes, and major canal embankments; mapped where major excavations, grading, road building or fill obscure underlying deposits or bedrock geology; large, active aggregate operations on and north of the Pleasant View salient are taken from aerial photographs (2006), unmapped fill exists in developed areas; variable thickness 0 to 15 meters (0–50 ft).

EXPLANATION OF GEOLOGIC SYMBOLS

Regressive shoreline

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4.1 ADDITIONAL SERVICES

We understand that the studies to date have focused on providing the design team with preliminary information to study the feasibility of constructing a reservoir at South Willard Bay. If this location is determined to be studied more additional geotechnical and geologic information will need to be gathered. A few of the items are as follows:

- Additional test holes will be required prior to moving to final design to study soil conditions and understand potential borrow sites,
- Additional study of Geologic Hazards.

This is not an extensive list but we can provide more information if needed.

4.2 LIMITATIONS

The assessments and recommendations presented in this document are based on limited field studies and laboratory testing, as well as our understanding of the project's design and manner of construction. If the project's design or manner of construction changes, or if conditions are found later that are different from those described, we should be notified immediately so that we can make revisions as necessary.

This document was prepared solely for the use of the addressee and may not contain sufficient information for other parties or uses.

We represent that our services are performed within the limitations prescribed by our Client, in a manner consistent with the level of care and skill ordinarily exercised by other professional consultants under similar circumstances. No other representation, expressed or implied, and no warranty or guarantee is included or intended. We do not assume responsibility for the accuracy of information provided by others.

Black, B.D., DuRoss, C.B., Hylland, M.D., McDonald, G.N., and Hecker, S., compilers, 2004, Fault number 2351d, Wasatch fault zone, Brigham City section, in Quaternary fault and fold database of the United States: U.S. Geological Survey, accessed online http://earthquakes.usgs.gov/hazards/qfaults

Currey, D.R., 1990, Quaternary paleolakes in the evolution of semidesert basins, with special emphasis on Lake Bonneville and the Great Basin, U.S.A.: Palaeogeography, Palaeoclimatology, Palaeoecology, v. 76, p. 189-214.

Currey, D.R., Atwood, G. and Mabey, D.R., 1984, Major levels of the Great Salt Lake and Lake Bonneville: Utah Geological and Mineral Survey Map 73.

Gilbert, G.K., 1890, Lake Bonneville: U.S. Geological Survey Monograph 1, 438 p.

Godsey, H.S., Currey, D.R., and Chan, M.A., 2005, New evidence for an extended occupation of the Provo shoreline and implications for regional climate change, Pleistocene Lake Bonneville, Utah: Quaternary Research v. 63, p. 212– 223.

Harty, K.M., Lowe, M., and Kirby, S.M., 2012, Geologic map of the Plain City Quadrangle, Weber and Box Elder Counties, Utah: Utah Geological and Mineral Survey, Map 253DM, 1:24,000.

Hecker, S., 1993, Quaternary tectonics of Utah with emphasis on earthquake-induced characterization: Utah Geological Survey Bulletin 127, 157p.

Machette, M. N., 1992, Surficial geologic map of the Wasatch fault zone, eastern part of Utah valley, Utah County and parts of Salt Lake and Juab Counties, Utah: U.S. Geological Survey Miscellaneous Investigation Series Map I-2095, scale 1:50,000, 26 p.

Oviatt, C.G., and Miller, D.M., 1997, New explorations along the northern shores of Lake Bonneville, in Link, P.K. and Kowallis, B.J., eds., Mesozoic to recent geology of Utah: Brigham Young Geology Studies v. 42, pt. II, 34 p.

Appendix A Test Hole Logs – South Willard Bay

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Project: Bear River Project **Project Location:** South Willard Bay **Project Number:** 13GCI329	**Log of Test Hole TH-WB-01** Sheet 1 of 2

Date(s) Drilled	**9/8/15 - 9/9/15**	Logged By	**R. Buhler**	Checked By	**P. Gerhart**
Drilling Method	**Rotary wash with water**	Drill Bit Size/Type	**Mud Rotary with HW**	Total Depth Drilled (feet)	**52.0 feet**
Drill Rig Type	**CME 75**	Drilling Contractor	**Bedke Geotechnical F.S.**	Hammer Weight/ Drop(lbs/in.)	**Automatic trip hammer**
Apparent Groundwater Depth	**1 ft; 9/10/2015**	Latitude / Longitude	**41.31390, -112.11996**	Ground Surface Elevation (feet)	**4218.0**
Comments		Test Hole Backfill	**Piezometer Well**	Elevation Datum	**NAVD88**

Elevation, feet	Depth, feet	SAMPLES Type	Number	Sampling Resistance	Recovery, inches	Graphic Log	MATERIAL DESCRIPTION	FIELD NOTES
	0						SILT, some sand, - soft, low plasticity, fine to medium sand, wet, brown to reddish-brown, (ML) FILL	
	5		SPT-01	3-3-3-2 [6]	16.0		SILT, sandy, - medium stiff to stiff, low plasticity, fine to medium sand, wet, dark brown to reddish-brown, (ML)	
4210								
	10		P-02		18.0			
							Grades to bluish-gray sandy SILT	
	15		SH-03		0			No recovery from Shelby tube. Drove spoon to recover some sample.
4200			SPT-04	4-6-4-5 [10]	18.0			
	20		P-05		18.0			
			SPT-06	0-0-0 [0]	18.0		CLAY - very soft, medium plastic, some organics, organic odor, wet, black to dark gray, (CL)	
	25		P-06		20.0			
4190								
	30		P-07		24			
	35		SPT-09	0-0-0-0 [0]	24.0			
4180								
	40							

SOIL TEST HOLE TH_LOGS_#1_BEAR_RIVER.GPJ GERHART.GDT 6/25/18

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Project: Bear River Project
Project Location: South Willard Bay
Project Number: 13GCI329

Log of Test Hole TH-WB-01

Elevation, feet	Depth, feet	SAMPLES Type	Number	Sampling Resistance	Recovery, inches	Graphic Log	MATERIAL DESCRIPTION	FIELD NOTES
	40		P-10		24.0			
							CLAY, some sand - very soft, medium plasticity, wet, bluish gray, varved clay with thin seams of sandy silt to sandy clay, (CL)	
	45		P-11		24			
							Bluish-gray Silty Sand layer at 46.5 ft.	
4170								
	50		SPT-12	0-0-1-1 [1]	24.0			
							Bottom of Test Hole at 52.0 feet. Piezometer Data Screen 52 - 47 10-20 Sand 52 - 38 Bentonite Chips 38-0 ft	
	55							
4160								
	60							
	65							
4150								
	70							
	75							
4140								
	80							
	85							

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Project: Bear River Project
Project Location: South Willard Bay
Project Number: 13GCI329

Log of Test Hole TH-WB-02

Date(s) Drilled	9/9/15 - 9/10/15	Logged By	R. Buhler	Checked By	P. Gerhart
Drilling Method	Rotary wash with water	Drill Bit Size/Type	Mud Rotary with HW	Total Depth Drilled (feet)	62.0 feet
Drill Rig Type	CME 75	Drilling Contractor	Bedke Geotechnical F.S.	Hammer Weight/ Drop(lbs/in.)	Automatic trip hammer
Apparent Groundwater Depth	0.8 ft; 9/10/2015	Latitude / Longitude	41.31480, -112.08394	Ground Surface Elevation (feet)	4217.5
Comments		Test Hole Backfill	Piezometer Well	Elevation Datum	NAVD88

Elevation, feet	Depth, feet	SAMPLES Type	Number	Sampling Resistance	Recovery, inches	Graphic Log	MATERIAL DESCRIPTION	FIELD NOTES
	0						GRAVEL, some sand and some silt - medium dense, subangular fine to coarse gravel, moist, light brown, (GP-GM), FILL	
							SILT, with sand - stiff, nonplastic, moist, brown, (SM)	
	5	SPT	01	4-6-6-9 [12]	18.0			
4210		SPT	02	4-6-6-5 [12]	12.0			
	10	P	03		0.0		Grades to dark gray SILT some sand @ 10 ft with some organics	No recovery from Shelby tube. Drove spoon to recover some sample.
							CLAY - very soft, medium plastic, some organics, organic odor, wet, dark gray, (CL)	
	15	P	04		24.0		SAND, some silt - loose, fine sand, wet, dark gray, (SM)	
4200							CLAY - very soft, medium plastic, some organics, organic odor, wet, dark gray, (CL)	
	20	SPT	05	0-0-1-3 [1]	24.0		Thin silty sand seam at 20 ft	
	25	P	06		17		SILT, sandy - very soft, fine sand, nonplastic to low plasticity, wet, dark gray, (ML)	Last 6 inches were a harder push
4190							CLAY - very soft, medium plastic, wet, bluish gray, varved clay, (CL)	
	30	P	07		5			
	35	SPT	08	0-0-2-2 [2]	18.0			
4180								Casing fell under own weight from 30 to 35 ft. Hydraucially pushing casing
	40							

SOIL TEST HOLE TH_LOGS_#1_BEAR_RIVER.GPJ GERHART.GDT 6/25/18

GERHART COLE

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Project: Bear River Project
Project Location: South Willard Bay
Project Number: 13GCI329

Log of Test Hole TH-WB-02

Elevation, feet	Depth, feet	SAMPLES Type	Number	Sampling Resistance	Recovery, inches	Graphic Log	MATERIAL DESCRIPTION	FIELD NOTES
	40		P-09		24.0			
	45		P-10		24.0			
4170							1/4 - inch seam of gray SILT at 46.8 ft	
	50		SPT-11	2-0-0-1 [0]	24.0		Thin seam of clayey sand	
	55		P-12		24.0			
4160								
	60		SPT-13	0-0-11-8 [11]	24.0		Grades to sandy silt to silty sand at 60 ft SAND, some silt - medium dense, wet, dark bluish gray, (SP-SM)	
							Bottom of Test Hole at 62.0 feet. Piezometer Data Screen 56 - 51 10-20 Sand 56 - 36 Bentonite Chips 36-0 ft	
	65							
4150								
	70							
	75							
4140								
	80							
	85							

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Unified Soil Classification System (USCS)

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Material Types	Major Soil Divisions		Group Symbol and Legend	Typical Names
COARSE-GRAINED SOILS >50% retained on No. 200 sieve	GRAVELS >50% of coarse fraction retained on No. 4 Sieve	Clean GRAVELS (little or no fines)	GW	Well-Graded GRAVEL, GRAVEL-sand mixtures, few fines
			GP	Poorly-Graded GRAVEL, GRAVEL-sand mixtures, few fines
		GRAVELS with fines (appreciable amount of fines)	GM	Silty GRAVEL, GRAVEL-sand silt mixtures
			GC	Clayey GRAVEL, GRAVEL-sand clay mixtures
	SANDS >50% of coarse fraction passing the No. 4 sieve	Clean SANDS (little or no fines)	SW	Well-Graded SAND, SAND-gravel mixtures, few fines
			SP	Poorly-Graded SAND, SAND-gravel mixtures, few fines
		SANDS with fines (appreciable amount of fines)	SM	Silty SAND, SAND-silt mixtures
			SC	Clayey SAND, SAND-clay mixtures
FINE-GRAINED SOILS >50% Passing No. 200 Sieve	SILTS and CLAYS liquid limit < 50	Inorganic 1) CF > 30%: + Sandy/Gravelly 2) CF = 15-30% + with sand/gravel	CL	Lean CLAY, Gravelly/Sandy CLAY, low to med. plasticity
			ML	SILT, Gravelly/Sandy SILT, no to slight plasticity
		Organic	OL	Organic CLAY or SILT
	SILTS and CLAYS liquid limit < 50	Inorganic 1) CF > 30%: + Sandy/Gravelly 2) CF = 15-30% + with sand/gravel	CH	Fat CLAY, Gravelly/Sandy Fat CLAY, high plasticity
			MH	Elastic SILT, Gravelly/Sandy Elastic SILT, low to high plasticity
		Organic	OH	Organic CLAY or SILT
Highly orgainc soils		Primarily Organic Matter; Organic Odor	PT	PEAT
Boulders / Cobbles		> 50% (by volume) particles > 3"	COBBLES BOULDERS	Boulders (>12"); Cobbles (>3" and <12")

Other Material Symbols

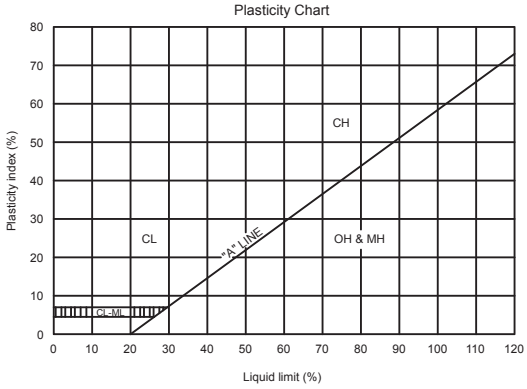
- Bedrock
- Asphalt
- Concrete
- Topsoil
- Fill

Sample Types

- Auger Cuttings
- Continuous sampler
- Grab Sample
- No Recovery
- Shelby Tube
- Standard Penetration Test (SPT)
- California Sampler
- Rock Core
- Modified California Sampler
- Other (see remarks)
- Piston Sampler (Shelby Tube)
- Split Spoon
- Vane Shear

Apparent water level

Measured water level



Descriptors for Coarse Grained Soils

Apparent Density	Dr (%)	SPT	MC	CAL
very loose	0-15	<4	<6	<8
loose	15-35	4-10	6-15	8-20
med. dense	35-65	10-30	15-42	20-56
dense	65-85	30-50	42-72	56-96
very dense	85-100	>50	>72	>96

Descriptors for Fine Grained Soils

Consistency	Su (psf)	SPT	MC	CAL
very soft	< 250	<2	<2	<2
soft	250-500	2-4	2-4	2-5
med. stiff	500-1000	4-8	4-10	5-11
stiff	1000-2000	8-15	10-19	11-22
very stiff	2000-4000	15-30	19-37	22-45
hard	>4000	>30	>37	>45

SPT - Standard split spoon (SPT): 2" OD, 1.375" ID
MC - Modified California: 2.5" OD, 1.875" ID
CAL - California: 3" OD, 2.375" ID

Stratification

Description	Criteria
Seam	1/16" to 1/2"
Layer	1/2" to 12"
Occasional	<= 1 per ft. thickness
Frequent	> 1 per ft. thickness

Modifiers

Description	Est. (%)
Trace	<5
Some	5-12
With	>12

Descriptors for Moisture

Description	Criteria
Dry	Absence of moisture, dusty, dry to the touch
Moist	Damp but no visible water
Wet	Visible free water, usually soil is below water table

Descriptors for Particle Size

Description	Criteria
Boulder	>12" : larger than a basketball
Cobble	3-12" : larger than a grapefruit
Coarse Gravel	3/4-3" : larger than a grape
Fine Gravel	No.4-3/4" : larger than a pea
Coarse Sand	No.10-4 : larger than rock salt grain
Medium Sand	No.40-4 : larger than window screen opening
Fine Sand	No.200-40 : larger than a sugar grain

Descriptios for Particle Angularity

Description	Criteria
Angular	Sharp edges, rel. plane sides, unpolished surface
Subangular	Similar to angular, but with rounded edges
Subrounded	Nearly plane sides, well-rounded corners & edges
Rounded	Smoothly curved sides and no edges

Abbreviated Soil Classification Symbols (after ASTM D2488 X.5)

Prefix	Suffix
s = sandy	s = with sand
g = gravelly	g = with gravel
	c = with cobbles
	b = with boulders

Abbreviated system for supplementary presentations when complete description is referenced. Examples:

Group Symbol and Full Name	Abbreviated
Sandy Lean CLAY (CL)	s(CL)
Poorly Graded SAND with silt and gravel	(SP-SM)g
Poorly Graded GRAVEL with sand, cobbles, and boulders (GP)	(GP)scb
Gravelly SILT with sand and cobbles (ML)	g(ML)sc

General Notes:
1) Strata graphic lines on the logs represent approximate boundaries.
2) No warranty is provided as to the continuity of soil conditions between points explored and sample locations.
3) Logs represent soil conditions observed at the point of exploration on the date indicated.
4) Visual methods were used to classify the materials in general accordance with the Unified Soils Classification Systems; actual designations based on laboratory methods may vary.

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Legend to Soil Descriptions

Appendix B

Interpretative Laboratory Test Results – South Willard Bay

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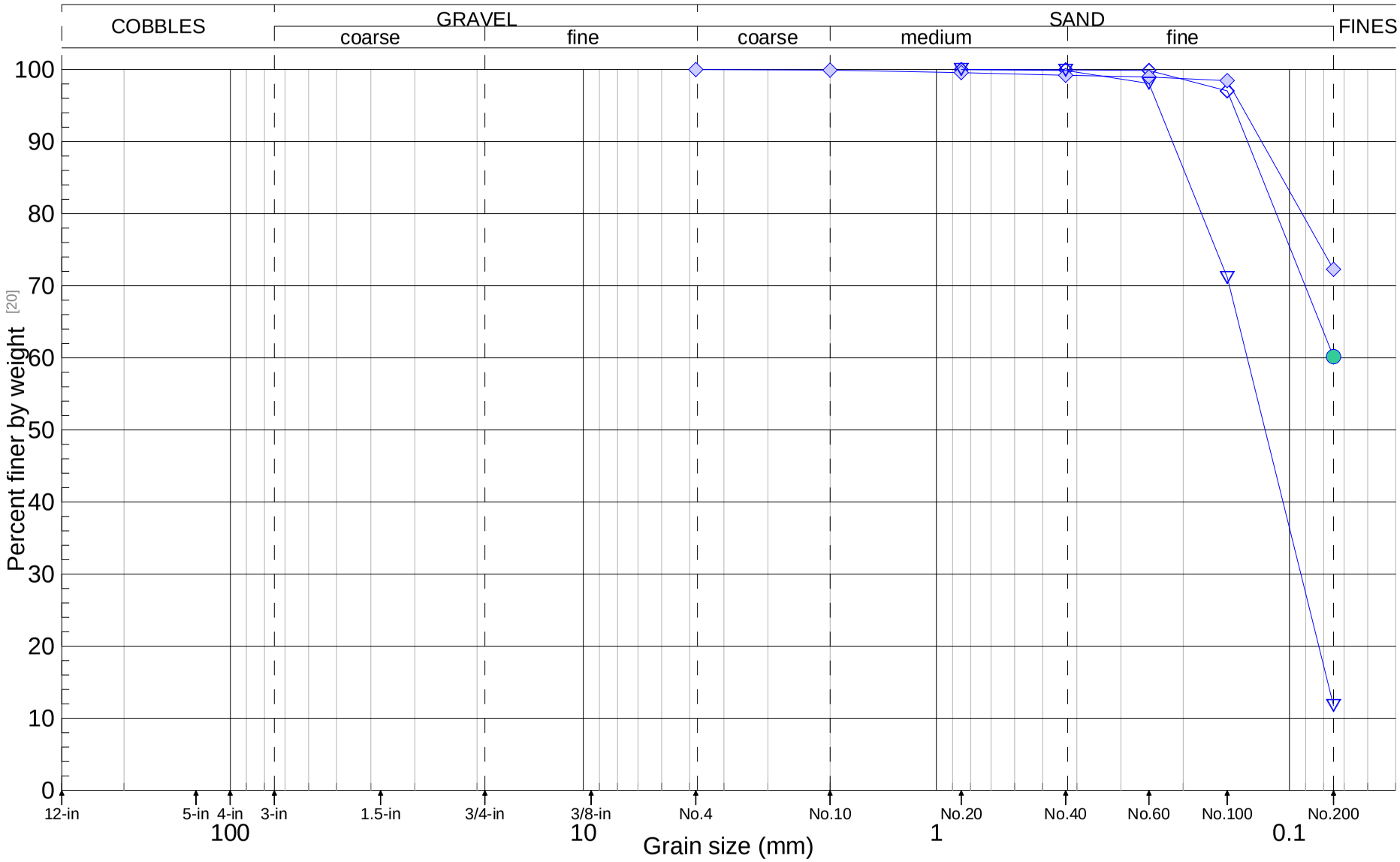

◇TH-WB-01 at 15-17
◆TH-WB-02 at 5-7
▽TH-WB-02 at 61-62
●TH-WB-02 at 25-26.5

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Grain-Size Analysis

Bear River Project Concept Study- South Willard Bay

Figure B-1

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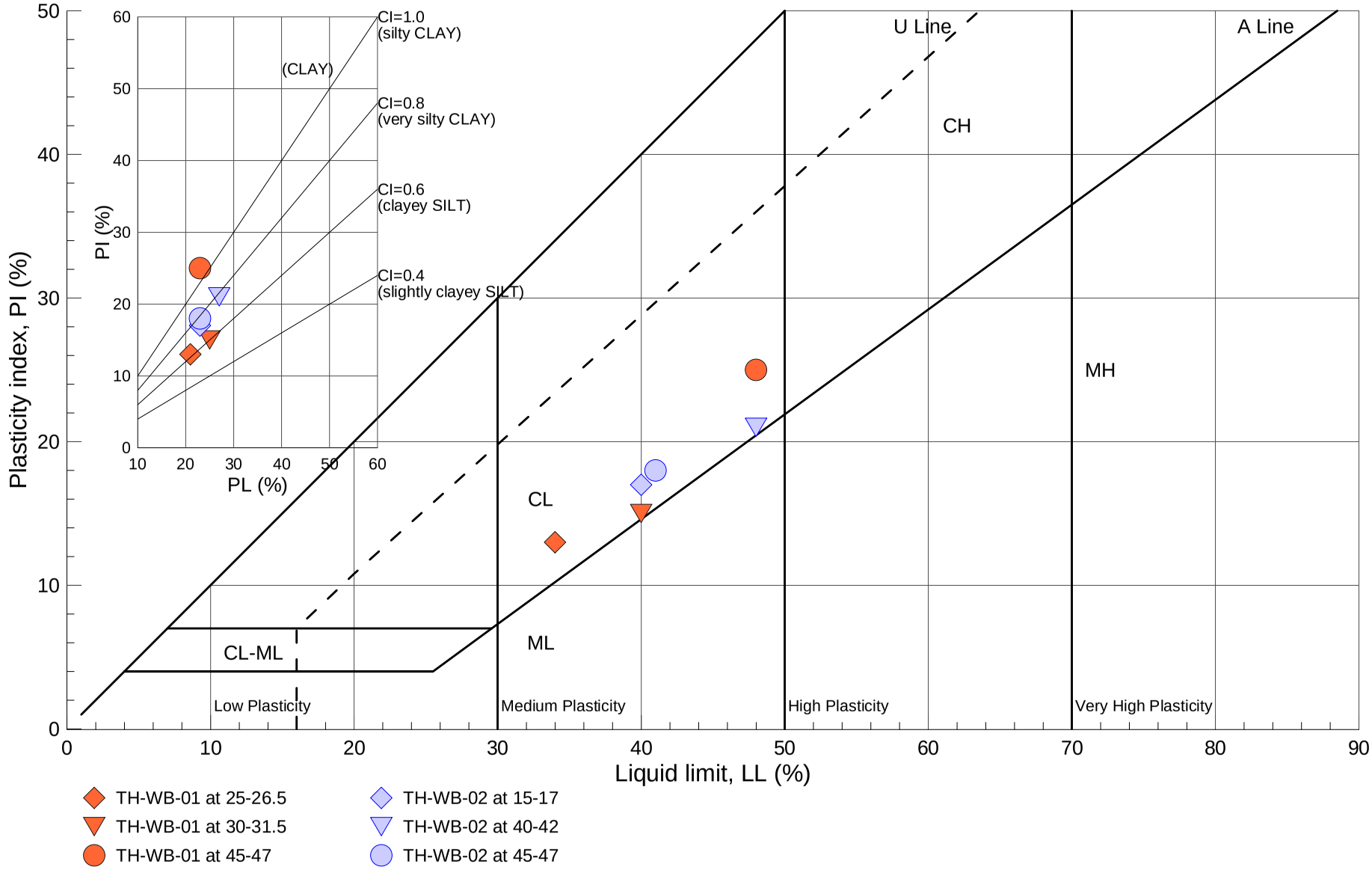

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Casagrande's Plasticity Chart (Atterberg Limits)

Bear River Project Concept Study- South Willard Bay

Figure B-2

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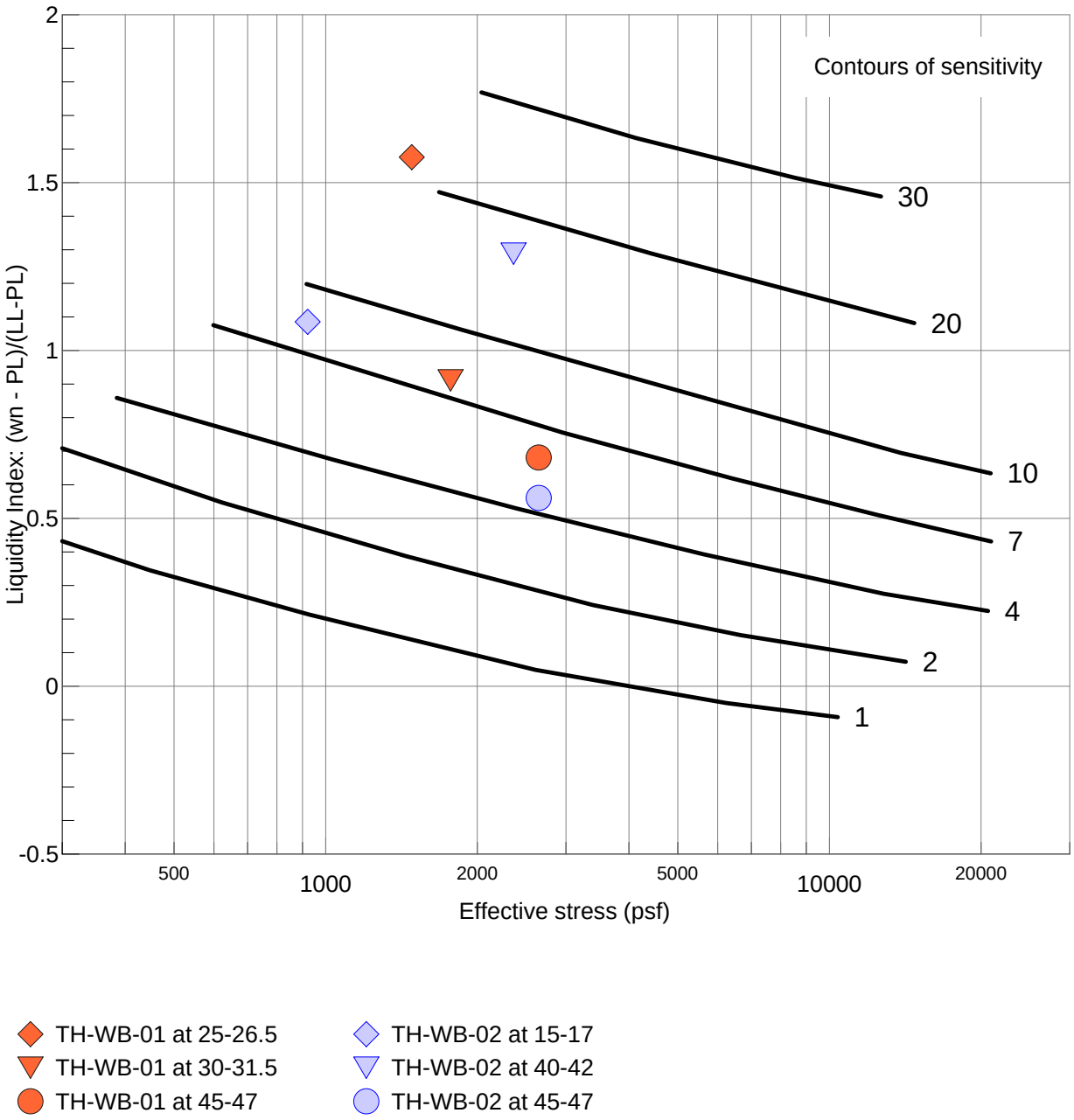

GERHART COLE	Sensitivity, LI, and Effective Stress Relationships (Mitchell,1993)	
	Bear River Project Concept Study- South Willard Bay	Figure B-3

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One-Dimensional Consolidation Properties of Soils
After ASTM D2435 and USBR 5700

GERHART COLE

Project:	**Bear River - South Willard Bay**	**TH/TP/Sample:**	**TH-WB-01**
No:	**13GCI329**	**Depth:**	**25-26.5 (25.75)**
Location:	Weber County	Sample description:	black clay
Date:	17-Sep-15	USCS classification:	CL
Tested by:	zmg	Sample type:	Rel. undisturbed, Shelby Tube
Reduced by:	zmg	Inundation stress (psf):	100, beginning
Checked by:	rrb	Swell pressure (psf):	< 100
Comments:		Test method:	B
		Preparation procedure:	trimmed

Phase Relationships

	Initial	Final
Height, H (in)	1.0000	0.7435
Height, H (cm)	2.540	1.889
Dia., D (in)	2.500	2.500
Dia., D (cm)	6.350	6.350
Wt. rings + wet soil (g)	349.49	332.41
Wt. rings (g)	214.85	214.85
Wet soil + tare (g)	324.52	235.28
Dry soil + tare (g)	264.52	208.70
Tare (g)	119.87	119.08
Moisture cont., w (%)	41.5	29.7
Gs, assumed	2.75	2.75
Mass total (g)	134.6	117.6
Mass of solids (g)	95.2	95.2
Volume (cm^3)	80.4	59.8
Vol. of water (cm^3)	39.5	22.4
Vol. of solids (cm^3)	34.6	34.6
Vol. of voids (cm^3)	45.8	25.2
Vol. of air (cm^3)	6.4	2.8
Area, A (cm^2)	31.7	31.7
Ht. solids, Hs (cm)	1.093	1.093
Void ratio, e	1.324	0.728
Porosity, n	0.570	0.421
Vol.moisture, T	0.491	0.374
Saturation, S (%)	86	89
Dry density (gm/cm^3)	1.183	1.591
Wet unit wt., gm (pcf)	104.5	128.8
Dry unit wt., gd (pcf)	73.9	99.3

Vertical Stress - Deformation Results

Vert. stress (psf)	Corr. Dial, dfc [a] (in)	Hc [b] (in)	Vert. strain, ev	Load duration (min)	t-90 (min)	Hdr (in)	Cv (ft^2/day)
Seating	0.0000	1.0000	0.0000	0			
100	0.0001	0.9999	0.0001	22			
200	0.0198	0.9802	0.0198	43			
400	0.0326	0.9674	0.0326	60			
800	0.0495	0.9505	0.0495	43			
1,600	0.0695	0.9305	0.0695	180			
3,200	0.0950	0.9050	0.0950	37	25.1	0.45887	0.07
6,400	0.1858	0.8142	0.1858	85	25.1	0.42978	0.06
12,800	0.2273	0.7727	0.2273	60	20.0	0.39671	0.07
25,600	0.2721	0.7279	0.2721	180	19.9	0.37514	0.06
51,200	0.3133	0.6867	0.3133	180	15.8	0.35364	0.06
25,600	0.3105	0.6895	0.3105	60			
6,400	0.2981	0.7019	0.2981	60			
1,600	0.2823	0.7177	0.2823	60			
400	0.2565	0.7435	0.2565	240			

Data Interpretation Summary

Preconsolidation stress, s'p (psf)	---	
Compression ratio, CR	---	To be determined by the Geotechnical Engineer
Recompression ratio, RR	---	

Notes:
[a] Dfc = end of increment deformation corrected for machine, porous stone, and filter paper deformation
[b] Hc = height at end of consolidation of each vert. stress
[c] Hdr = height at 50 consolidation computed from D90 using sq-root time method
[d] Cv computed from Taylor (1948) aquare root of time method (note 1 in^2/min = 10 ft^2/day)

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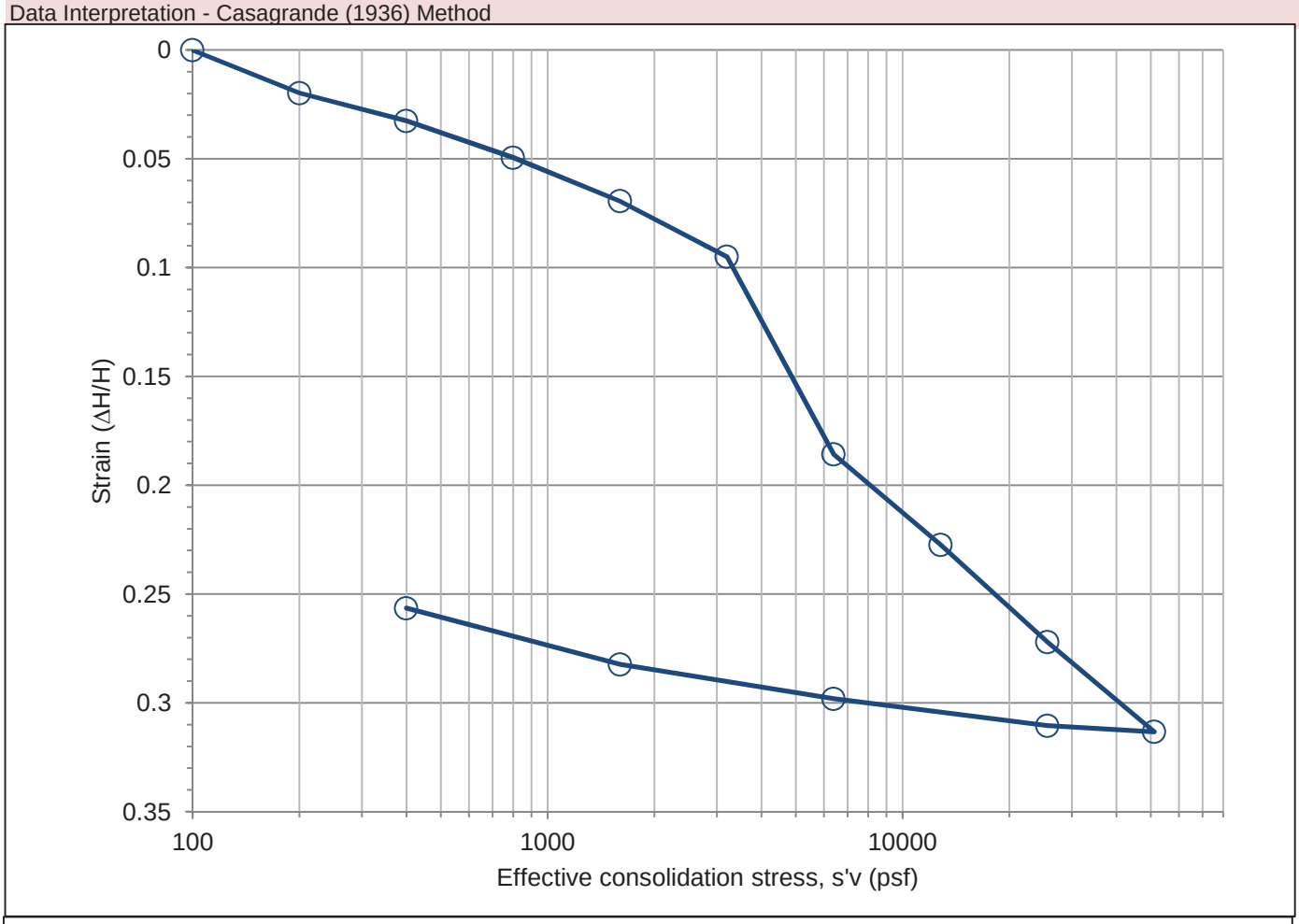
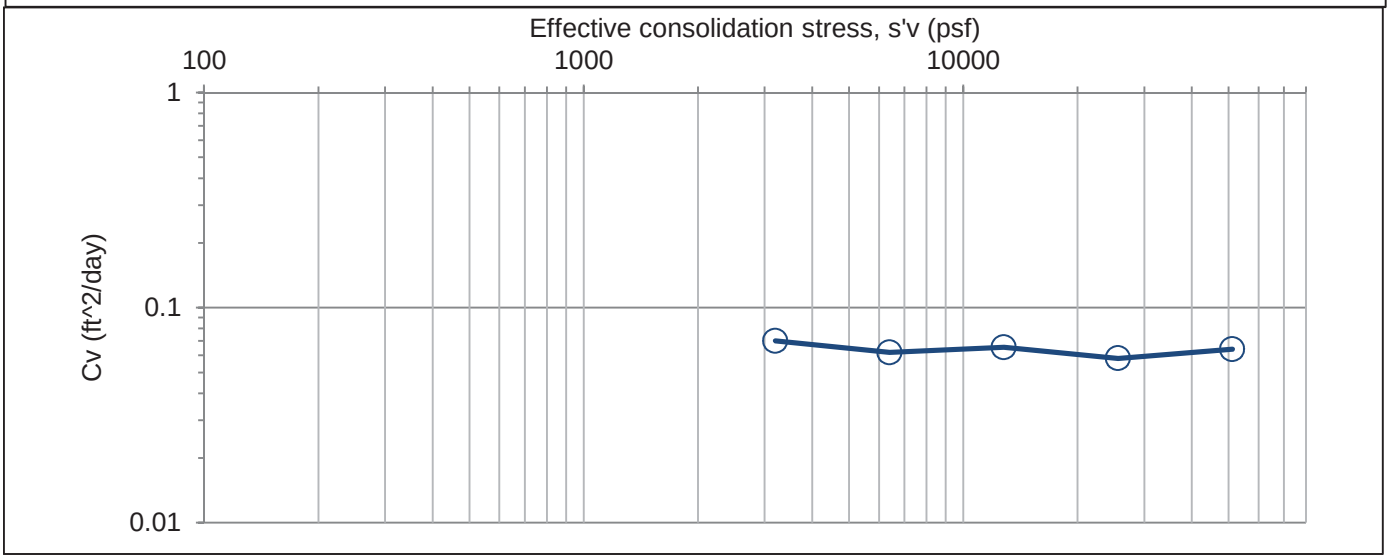
One-Dimensional Consolidation Properties of Soils
After ASTM D2435 and USBR 5700

GERHART COLE

Project: Bear River - South Willard Bay
No: 13GCI329
TH/TP/Sample: TH-WB-01
Depth: 25-26.5 (25.75)

Data Interpretation - Casagrande (1936) Method





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One-Dimensional Consolidation Properties of Soils
After ASTM D2435 and USBR 5700

GERHART COLE

Project:	**Bear River - South Willard Bay**	**TH/TP/Sample:**	**TH-WB-01**
No:	**13GCI329**	**Depth:**	**45-46.5 (46)**
Location:	Weber County	Sample description:	dark gray clay
Date:	14-Sep-15	USCS classification:	CL
Tested by:	zmg	Sample type:	Rel. undisturbed, Shelby Tube
Reduced by:	zmg	Inundation stress (psf):	100, beginning
Checked by:	rrb	Swell pressure (psf):	138.234
Comments:		Test method:	B
		Preparation procedure:	trimmed

Phase Relationships

	Initial	Final
Height, H (in)	1.0000	0.7959
Height, H (cm)	2.540	2.021
Dia., D (in)	2.500	2.500
Dia., D (cm)	6.350	6.350
Wt. rings + wet soil (g)	355.42	340.60
Wt. rings (g)	214.86	214.86
Wet soil + tare (g)	255.63	244.40
Dry soil + tare (g)	216.58	214.79
Tare (g)	119.01	119.23
Moisture cont., w (%)	40.0	31.0
Gs, assumed	2.75	2.75
Mass total (g)	140.6	125.7
Mass of solids (g)	100.4	100.4
Volume (cm^3)	80.4	64.0
Vol. of water (cm^3)	40.2	25.4
Vol. of solids (cm^3)	36.5	36.5
Vol. of voids (cm^3)	43.9	27.5
Vol. of air (cm^3)	3.8	2.2
Area, A (cm^2)	31.7	31.7
Ht. solids, Hs (cm)	1.153	1.153
Void ratio, e	1.204	0.754
Porosity, n	0.546	0.430
Vol.moisture, T	0.499	0.396
Saturation, S (%)	91	92
Dry density (gm/cm^3)	1.248	1.568
Wet unit wt., gm (pcf)	109.1	128.2
Dry unit wt., gd (pcf)	77.9	97.9

Vertical Stress - Deformation Results

Vert. stress (psf)	Corr. Dial, dfc [a] (in)	Hc [b] (in)	Vert. strain, ev	Load duration (min)	t-90 (min)	Hdr (in)	Cv (ft^2/day)
Seating	0.0000	1.0000	0.0000	0			
100	0.0002	0.9998	0.0002	123			
400	0.0113	0.9887	0.0113	29			
800	0.0227	0.9773	0.0227	100	31.6	0.49149	0.06
1,600	0.0387	0.9613	0.0387	312	25.1	0.48466	0.08
3,200	0.0675	0.9325	0.0675	126	31.6	0.47347	0.06
6,400	0.1189	0.8811	0.1189	119	39.8	0.45341	0.04
12,800	0.1769	0.8231	0.1769	338	31.6	0.42604	0.05
25,600	0.2234	0.7766	0.2234	147	19.9	0.39991	0.07
51,200	0.2677	0.7323	0.2677	79	19.9	0.37721	0.06
25,600	0.2641	0.7359	0.2641	21			
6,400	0.2477	0.7523	0.2477	40			
1,600	0.2247	0.7753	0.2247	76			
400	0.2041	0.7959	0.2041	79			

Data Interpretation Summary

Preconsolidation stress, s'p (psf)	---	
Compression ratio, CR	---	To be determined by the Geotechnical Engineer
Recompression ratio, RR	---	

Notes:
[a] Dfc = end of increment deformation corrected for machine, porous stone, and filter paper deformation
[b] Hc = height at end of consolidation of each vert. stress
[c] Hdr = height at 50 consolidation computed from D90 using sq-root time method
[d] Cv computed from Taylor (1948) aquare root of time method (note 1 in^2/min = 10 ft^2/day)

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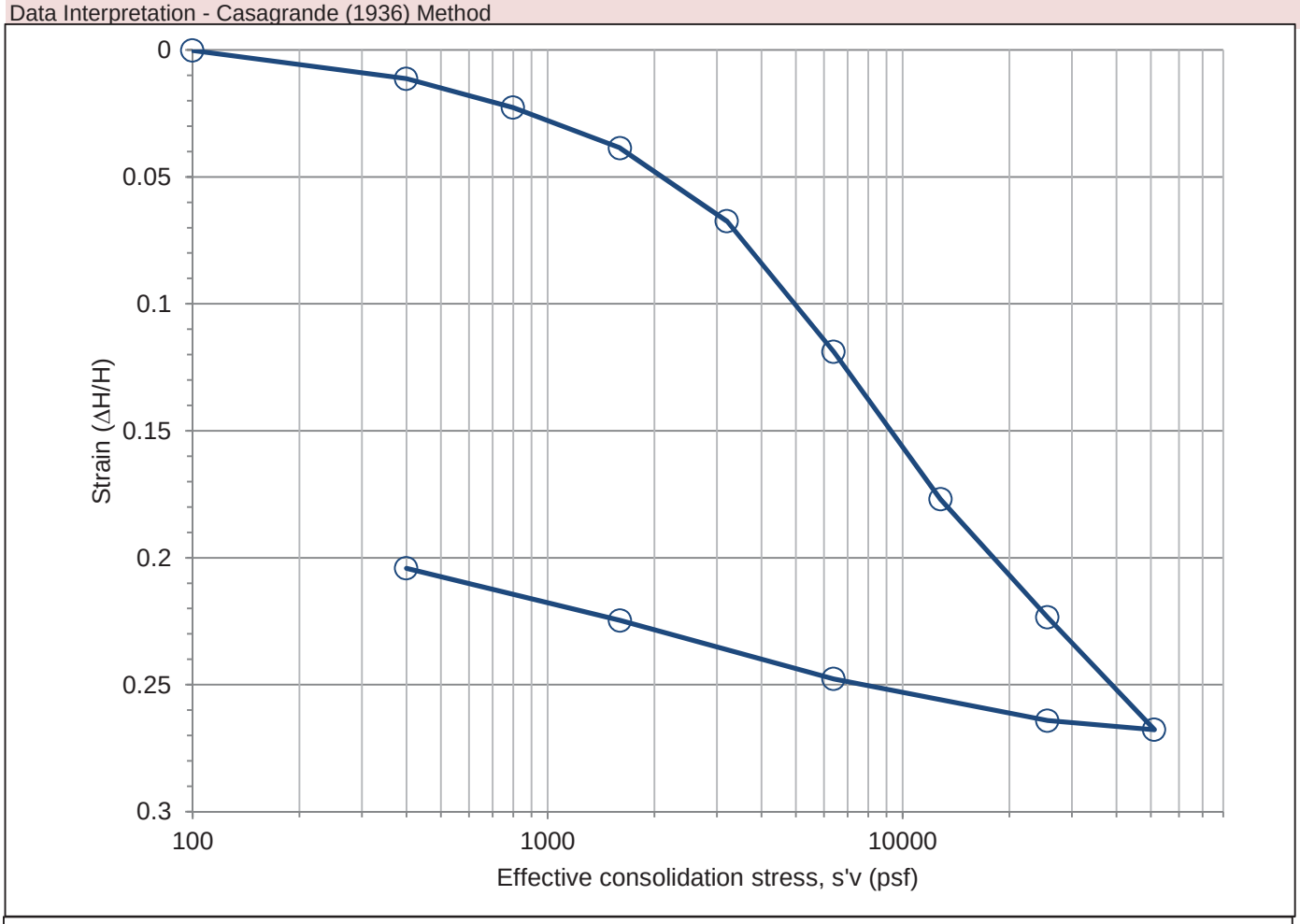
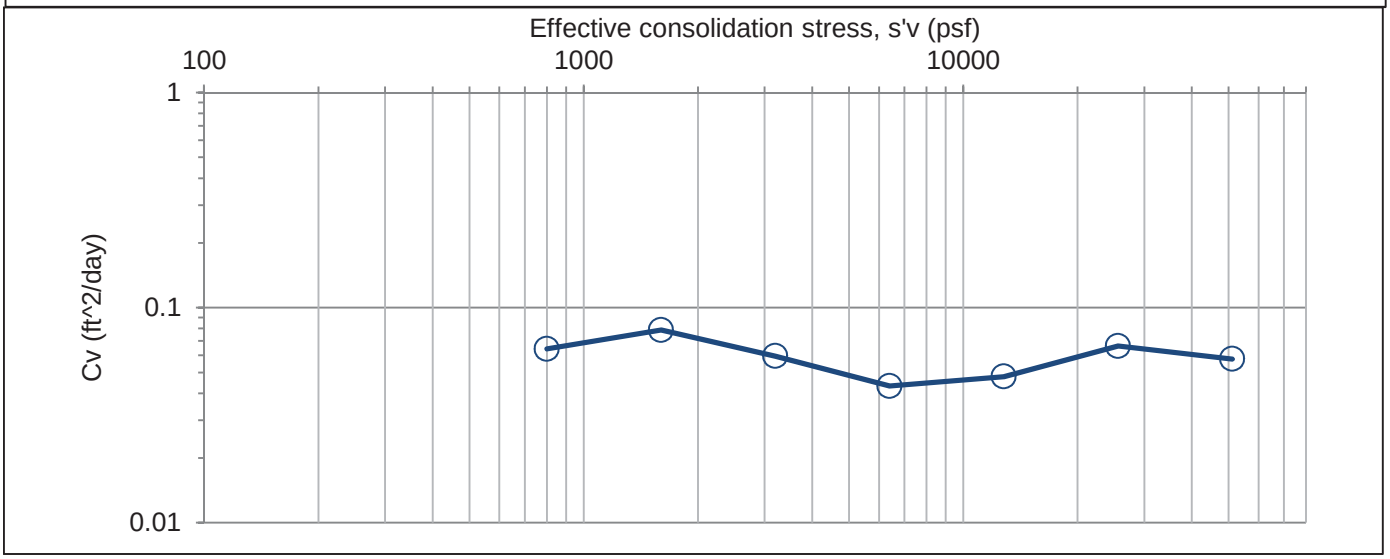
One-Dimensional Consolidation Properties of Soils
After ASTM D2435 and USBR 5700

GERHART COLE

Project: Bear River - South Willard Bay
No: 13GCI329
TH/TP/Sample: TH-WB-01
Depth: 45-46.5 (46)

Data Interpretation - Casagrande (1936) Method





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One-Dimensional Consolidation Properties of Soils
After ASTM D2435 and USBR 5700

GERHART COLE

Project:	**Bear River - South Willard Bay**	**TH/TP/Sample:**	**TH-WB-02**
No:	**13GCI329**	**Depth:**	**15-16.5 (15.25)**
Location:	Weber County	Sample description:	dark gray clay
Date:	15-Sep-15	USCS classification:	CL
Tested by:	zmg	Sample type:	Rel. undisturbed, Shelby Tube
Reduced by:	zmg	Inundation stress (psf):	100, beginning
Checked by:	rrb	Swell pressure (psf):	< 100
Comments:		Test method:	B
		Preparation procedure:	trimmed

Phase Relationships

	Initial	Final
Height, H (in)	1.0000	0.8124
Height, H (cm)	2.540	2.063
Dia., D (in)	2.500	2.500
Dia., D (cm)	6.350	6.350
Wt. rings + wet soil (g)	357.97	345.08
Wt. rings (g)	214.82	214.82
Wet soil + tare (g)	363.31	248.92
Dry soil + tare (g)	299.36	221.56
Tare (g)	145.06	119.00
Moisture cont., w (%)	41.4	26.7
Gs, assumed	2.75	2.75
Mass total (g)	143.2	130.3
Mass of solids (g)	101.2	101.2
Volume (cm^3)	80.4	65.3
Vol. of water (cm^3)	41.9	29.1
Vol. of solids (cm^3)	36.8	36.8
Vol. of voids (cm^3)	43.6	28.5
Vol. of air (cm^3)	1.7	-0.5
Area, A (cm^2)	31.7	31.7
Ht. solids, Hs (cm)	1.162	1.162
Void ratio, e	1.186	0.776
Porosity, n	0.542	0.437
Vol.moisture, T	0.521	0.445
Saturation, S (%)	96	102
Dry density (gm/cm^3)	1.258	1.549
Wet unit wt., gm (pcf)	111.1	122.5
Dry unit wt., gd (pcf)	78.5	96.7

Vertical Stress - Deformation Results

Vert. stress (psf)	Corr. Dial, dfc [a] (in)	Hc [b] (in)	Vert. strain, ev	Load duration (min)	t-90 (min)	Hdr (in)	Cv (ft^2/day)
Seating	0.0000	1.0000	0.0000	0			
100	-0.0001	1.0001	-0.0001	60			
200	0.0121	0.9879	0.0121	170			
400	0.0199	0.9801	0.0199	122			
800	0.0265	0.9735	0.0265	360			
1,600	0.0386	0.9614	0.0386	281	1.2	0.48372	1.64
3,200	0.0569	0.9431	0.0569	70	1.5	0.4761	1.22
6,400	0.1083	0.8917	0.1083	40	3.1	0.4587	0.56
12,800	0.1433	0.8567	0.1433	23	0.9	0.43712	1.68
25,600	0.1801	0.8199	0.1801	35	0.7	0.41915	1.93
51,200	0.2176	0.7824	0.2176	21			
25,600	0.2163	0.7837	0.2163	20			
6,400	0.2099	0.7901	0.2099	14			
1,600	0.2021	0.7979	0.2021	23			
400	0.1876	0.8124	0.1876	158			

Data Interpretation Summary

Preconsolidation stress, s'p (psf)	---	
Compression ratio, CR	---	To be determined by the Geotechnical Engineer
Recompression ratio, RR	---	

Notes:
[a] Dfc = end of increment deformation corrected for machine, porous stone, and filter paper deformation
[b] Hc = height at end of consolidation of each vert. stress
[c] Hdr = height at 50 consolidation computed from D90 using sq-root time method
[d] Cv computed from Taylor (1948) aquare root of time method (note 1 in^2/min = 10 ft^2/day)

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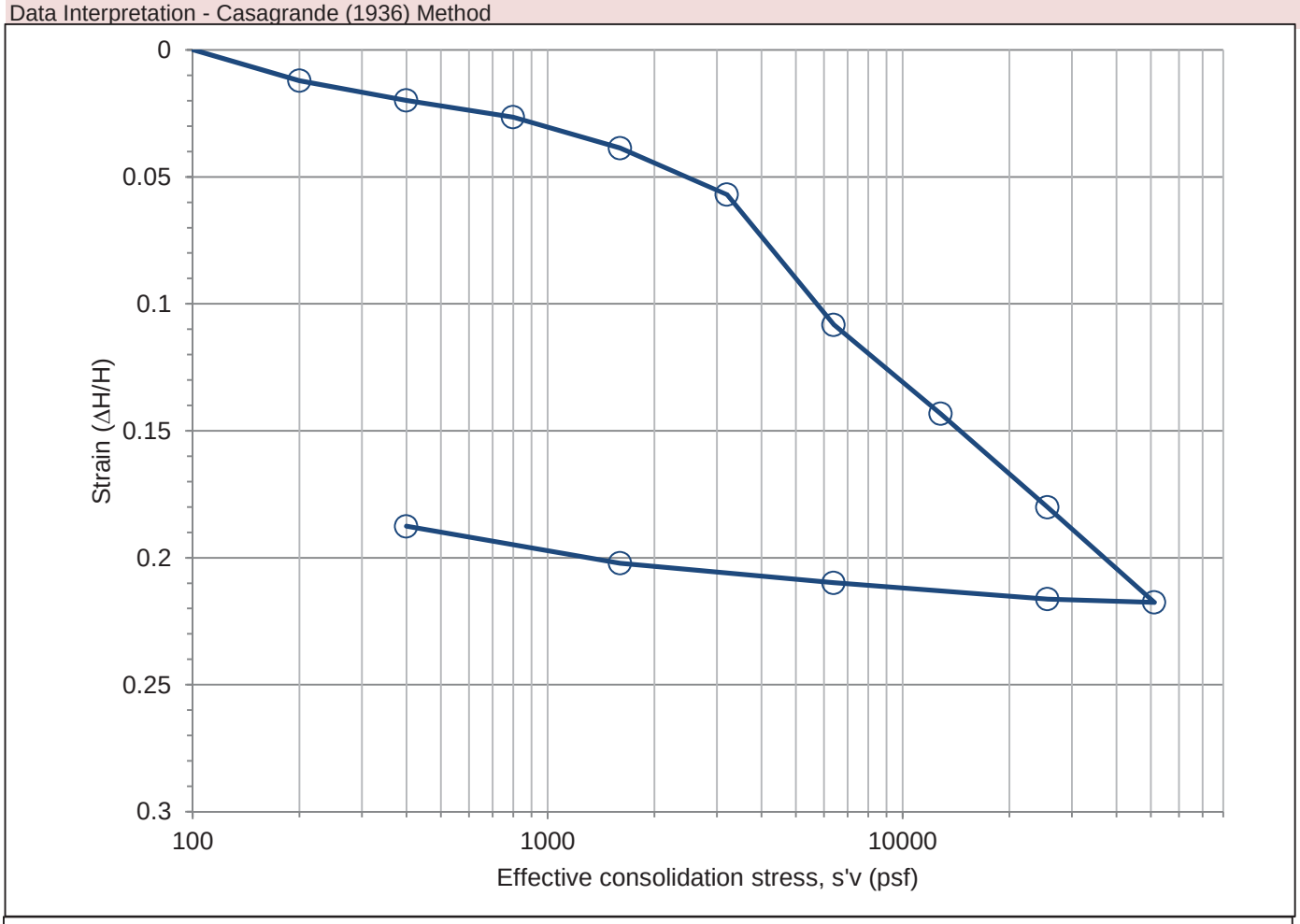
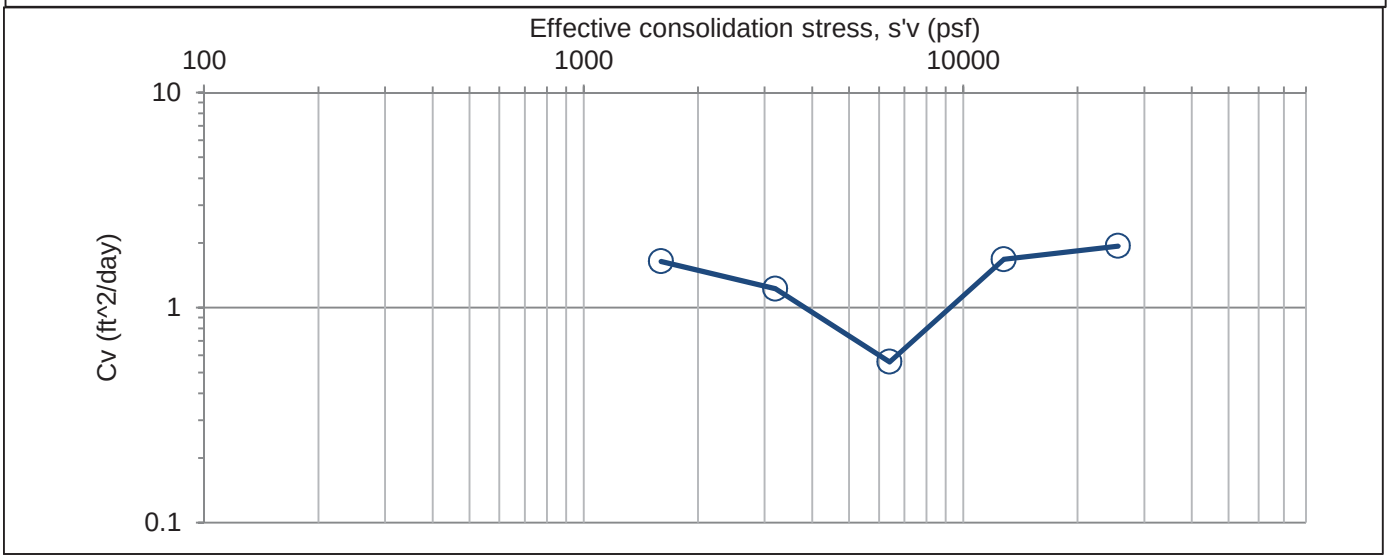
One-Dimensional Consolidation Properties of Soils
After ASTM D2435 and USBR 5700

GERHART COLE

Project: Bear River - South Willard Bay
No: 13GCI329
TH/TP/Sample: TH-WB-02
Depth: 15-16.5 (15.25)

Data Interpretation - Casagrande (1936) Method





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One-Dimensional Consolidation Properties of Soils
After ASTM D2435 and USBR 5700

GERHART COLE

Project:	**Bear River - South Willard Bay**	**TH/TP/Sample:**	**TH-WB-02**
No:	**13GCI329**	**Depth:**	**45-47 (46.75)**
Location:	Weber County	Sample description:	dark gray clay
Date:	16-Sep-15	USCS classification:	CL
Tested by:	zmg	Sample type:	Rel. undisturbed, Shelby Tube
Reduced by:	zmg	Inundation stress (psf):	100, beginning
Checked by:	rrb	Swell pressure (psf):	< 100
Comments:		Test method:	B
		Preparation procedure:	trimmed

Phase Relationships

	Initial	Final
Height, H (in)	1.0000	0.8231
Height, H (cm)	2.540	2.091
Dia., D (in)	2.500	2.500
Dia., D (cm)	6.350	6.350
Wt. rings + wet soil (g)	359.87	346.85
Wt. rings (g)	214.83	214.83
Wet soil + tare (g)	397.21	276.94
Dry soil + tare (g)	329.95	248.33
Tare (g)	126.68	145.44
Moisture cont., w (%)	33.1	27.8
Gs, assumed	2.75	2.75
Mass total (g)	145.0	132.0
Mass of solids (g)	109.0	109.0
Volume (cm^3)	80.4	66.2
Vol. of water (cm^3)	36.1	23.0
Vol. of solids (cm^3)	39.6	39.6
Vol. of voids (cm^3)	40.8	26.6
Vol. of air (cm^3)	4.8	3.5
Area, A (cm^2)	31.7	31.7
Ht. solids, Hs (cm)	1.251	1.251
Void ratio, e	1.030	0.671
Porosity, n	0.507	0.401
Vol.moisture, T	0.448	0.348
Saturation, S (%)	88	87
Dry density (gm/cm^3)	1.355	1.646
Wet unit wt., gm (pcf)	112.6	131.3
Dry unit wt., gd (pcf)	84.6	102.8

Vertical Stress - Deformation Results

Vert. stress (psf)	Corr. Dial, dfc [a] (in)	Hc [b] (in)	Vert. strain, ev	Load duration (min)	t-90 (min)	Hdr (in)	Cv (ft^2/day)
Seating	0.0000	1.0000	0.0000	0			
100	0.0001	0.9999	0.0001	35			
200	0.0022	0.9978	0.0022	16			
400	0.0064	0.9936	0.0064	67			
800	0.0135	0.9865	0.0135	175			
1,600	0.0231	0.9769	0.0231	160			
3,200	0.0412	0.9588	0.0412	360			
6,400	0.0819	0.9181	0.0819	82	19.9	0.46922	0.09
12,800	0.1385	0.8615	0.1385	81	15.8	0.4449	0.10
25,600	0.1890	0.8110	0.1890	84	12.6	0.41813	0.12
51,200	0.2364	0.7636	0.2364	80	12.6	0.39366	0.10
25,600	0.2333	0.7667	0.2333	18			
6,400	0.2202	0.7798	0.2202	35			
1,600	0.2029	0.7971	0.2029	42			
400	0.1769	0.8231	0.1769	200			

Data Interpretation Summary

Preconsolidation stress, s'p (psf)	---	
Compression ratio, CR	---	To be determined by the Geotechnical Engineer
Recompression ratio, RR	---	

Notes:
[a] Dfc = end of increment deformation corrected for machine, porous stone, and filter paper deformation
[b] Hc = height at end of consolidation of each vert. stress
[c] Hdr = height at 50 consolidation computed from D90 using sq-root time method
[d] Cv computed from Taylor (1948) aquare root of time method (note 1 in^2/min = 10 ft^2/day)

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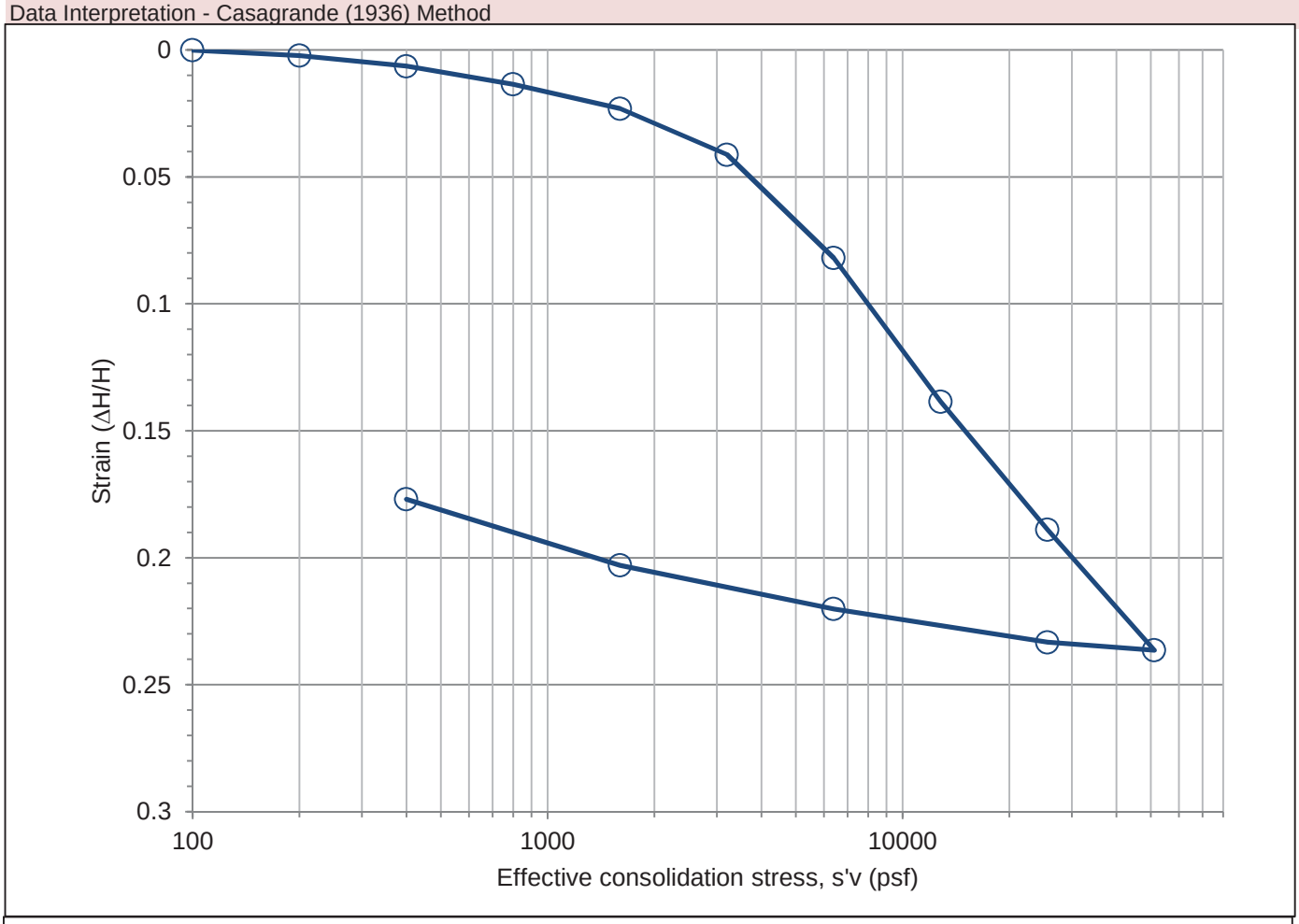
One-Dimensional Consolidation Properties of Soils
After ASTM D2435 and USBR 5700

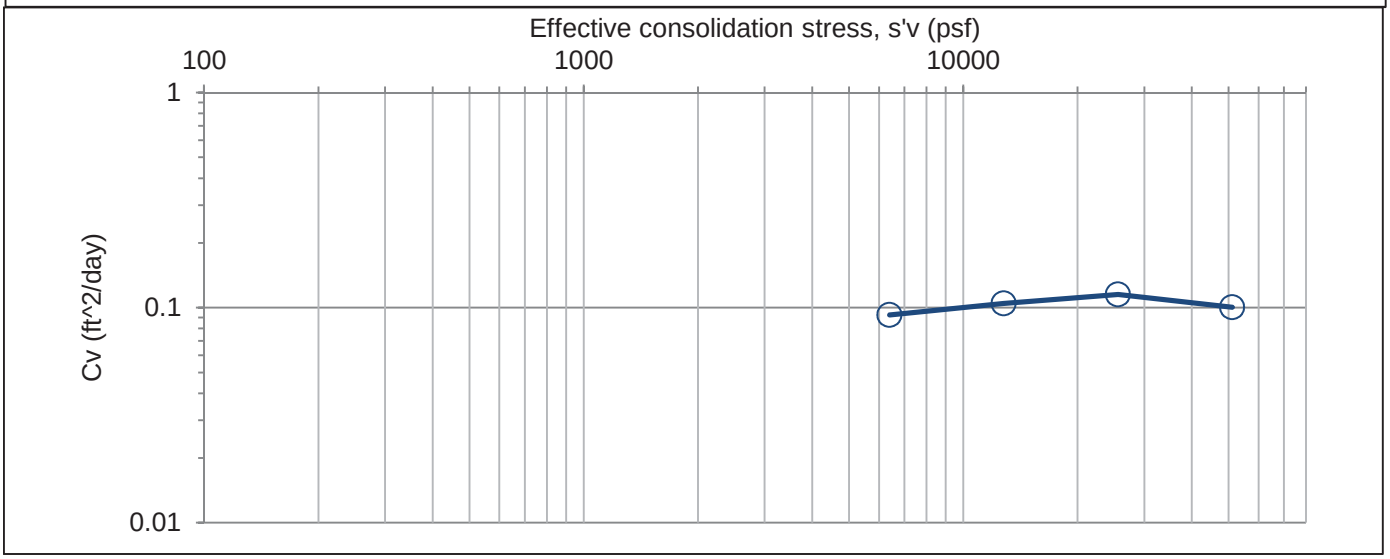
GERHART COLE

Project: Bear River - South Willard Bay
No: 13GCI329

TH/TP/Sample: TH-WB-02
Depth: 45-47 (46.75)

Data Interpretation - Casagrande (1936) Method





DRAFT

Triaxial Test - Isotropic Consolidated Sheared Undrained Measuring Pore Pressure (CIU-PP) - *After ASTM D4767 and USBR 5750*

GERHART COLE

Project:	**Bear River - Cub River**	**TH/TP/Sample:**	**TH-WB-01**
No:	**13GCI329**	**Depth:**	**30-31.5**
Location:	Weber County	Sample description:	dark gray clay
Date:	14-Sep-15	USCS classification:	CL
Tested by:	zmg	Sample type:	undisturbed
Reduced by:	zmg	Notes:	
Checked by:	rrb		

	Test Number	S1	35 psi	S2	10 psi
		Initial	Bef. Shr. MethodB [e]	Initial	Bef. Shr. MethodB [e]
Unit weight data	Sample ht., H (in) 0°	5.750		5.752	
	120°	5.749		5.747	
	240°	5.752		5.751	
	Avg. height, Havg (in)	5.750	5.470	5.750	5.610
	Avg. height, Havg (cm)	14.606	13.895	14.605	14.249
	ΔHsc (in) [a]		0.28		0.14
	Sample dia., D (in) top	2.830		2.847	
	mid	2.844		2.847	
	bot	2.825		2.843	
	Avg. dia., Davg (in)	2.836	2.796	2.846	2.859
	Avg. dia., Davg (cm)	7.203	7.102	7.229	7.262
	Avg. area, Aavg (in^2)	6.316	6.140	6.362	6.420
	Avg. area, Aavg (cm^2)	40.747	39.614	41.042	41.418
	Wt. rings + wet soil (g)	1359.39	984.69	1380.94	1055.58
	Wt. rings (g)	305.52	0.00	305.52	0.00
	Volume, Vo (in^3)	36.3	33.6	36.6	36.0
	Vo (cm^3)	595.1	550.4	599.4	590.2
	Vo (ft^3)	0.0210	0.0194	0.0212	0.0208
Moisture	Wet soil + tare (g)	270.99	1111.84	223.47	1181.99
	Dry soil + tare (g)	229.09	859.33	194.01	886.18
	Tare (g)	119.70	127.38	119.87	126.72
	Moisture content, w (%)	38.3	34.5	39.7	39.0
Phase Relationships	Gs, assumed	2.65	2.65	2.65	2.65
	Mass total (g)	1053.9	1024.9	1075.4	1069.4
	Mass of solids (g)	762.0	762.0	769.6	769.6
	Volume (cm^3)	595.1	550.4	599.4	590.2
	Volume of water (cm^3)	291.9	262.9	305.8	299.8
	Volume of solids (cm^3)	287.5	287.5	290.4	290.4
	Volume of voids (cm^3)	307.6	262.9	309.0	299.8
	Volume of air (cm^3)	15.7	0.0	3.2	0.0
	Void ratio, e	1.070	0.914	1.064	1.032
	Porosity, n	0.517	0.478	0.515	0.508
	Volumetric moisture, T	0.490	0.478	0.510	0.508
	Saturation, S (%) [c]	94.89	100.00	98.97	100.00
	Dry density (gm/cm^3)	1.280	1.384	1.284	1.304
	Wet unit wt., gm (pcf)	110.6	116.2	112.0	113.1
	Dry unit wt., gd (pcf)	79.9	86.4	80.2	81.4

Notes:

[a] ΔHsc (in) = change in height during saturation and consolidation

[b] ΔVs = change in volume during saturation, ΔVc = change in volume during consolidation

[c] Saturation before shear set to 100% for phase calculations

[d] Before shear Aavg using method A; where Ac (Method A) = (Vo-DVs - DVc)/(Ho-DHsc)

[e] Before shear Aavg using method B; where Ac (Method B) = (Vwf + Vs)/Hc

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Triaxial Test - Isotropic Consolidated Sheared Undrained
Measuring Pore Pressure (CIU-PP) *- After ASTM D4767 and USBR 5750*

GERHART COLE

Project:	**Bear River - Cub River**	**TH/TP/Sample:**	**TH-WB-01**
No:	**13GCI329**	**Depth:**	**30-31.5**
Location:	Weber County	Sample description:	dark gray clay
Date:	14-Sep-15	USCS classification:	CL
Tested by:	zmg	Sample type:	undisturbed

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Test Number		S1 at 35 psi	S2 at 10 psi
Test information	Total backpressure (psi)	50.0	39.0
	Skempton B	0.95	0.96
	t-90 (min)	330.2	210.2
	t-100 (min)	536.8	330.2
	t-50 (min)	77.1	49.1
	Strain rate (%/hr)	0.60	0.60
	Strain rate (%/min)	0.010	0.010
	Membrane correction	Yes	Yes
	Filter paper correction	No filter paper	No filter paper
Max principal stress ratio (s1/s3), failure criteria	Strain at failure, ef (%)	11.82	14.83
	Time to failure, tf (min)	1181.8	1483.3
	Obliquity, s'1/s'3	2.588	7.259
	Excess pore pressure, u (psi)	23.58	8.74
	q = q' = (s1+s3)/2 (psi)	9.07	3.93
	p' = (s'1+s'3)/2 (psi)	20.49	5.19
	p = (s1+s3)/2 (psi)	44.07	13.93
	Effective major principal stress, s'1 (psi)	29.56	9.12
	Effective minor principal stress, s'3 (psi)	11.42	1.26
	Total major pincipal stress, s1 (psi)	53.14	17.87
	Total minor pincipal stress, s3 (psi)	35.00	10.00
	Skemption A at failure, Af	1.30	1.11
	Secant friction angle, phi-s (deg)	26.3	49.3
		Effective stress	Total stress
	Friction angle, phi (deg)	19.6	9.8
	Cohesion intercept, c (psi)	2.3	1.6
Peak deviator stress (s1-s3), failure criteria	Strain at failure, ef (%)	6.31	3.47
	Time to failure, tf (min)	630.5	347.1
	Deviator stress, s1-s3 (psi)	18.36	8.96
	Excess pore pressure, u (psi)	22.34	7.78
	q = q' = (s1+s3)/2 (psi)	9.18	4.48
	p' = (s'1+s'3)/2 (psi)	21.84	6.70
	p = (s1+s3)/2 (psi)	44.18	14.48
	Effective major principal stress, s'1 (psi)	31.02	11.18
	Effective minor principal stress, s'3 (psi)	12.66	2.22
	Total major pincipal stress, s1 (psi)	53.36	18.96
	Total minor pincipal stress, s3 (psi)	35.00	10.00
	Skemption A at failure, Af	1.22	0.87
	Secant friction angle, phi-s (deg)	24.9	42.0
		Effective stress	Total stress
	Friction angle, phi (deg)	18.1	9.1
	Cohesion intercept, c (psi)	2.5	2.2

Comments:

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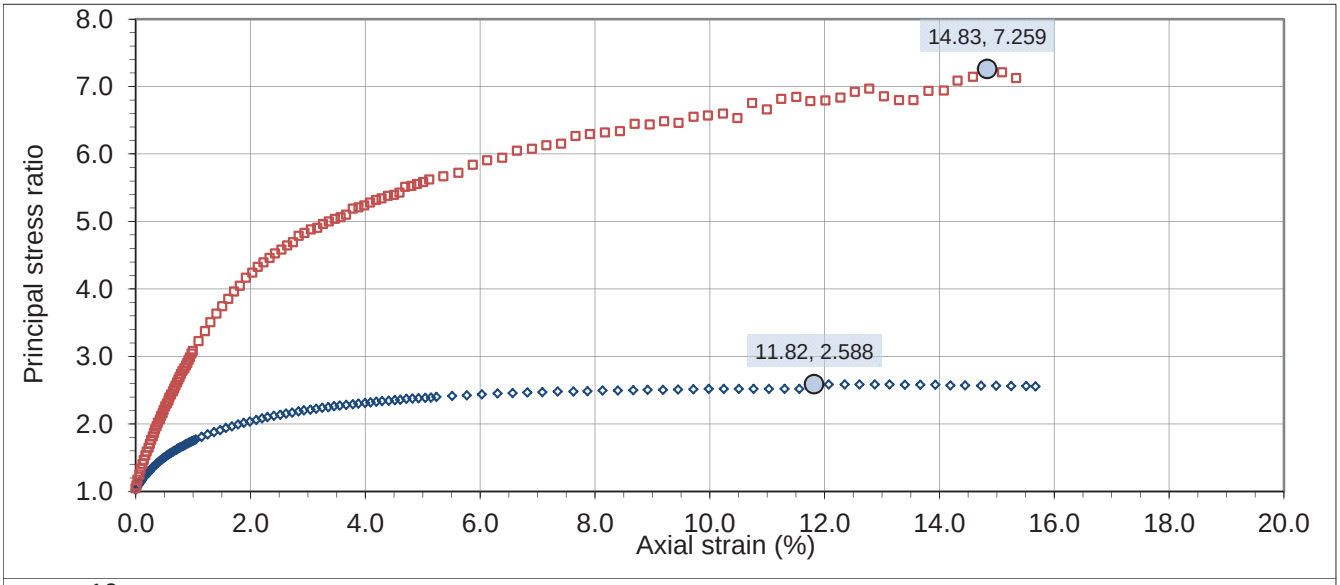
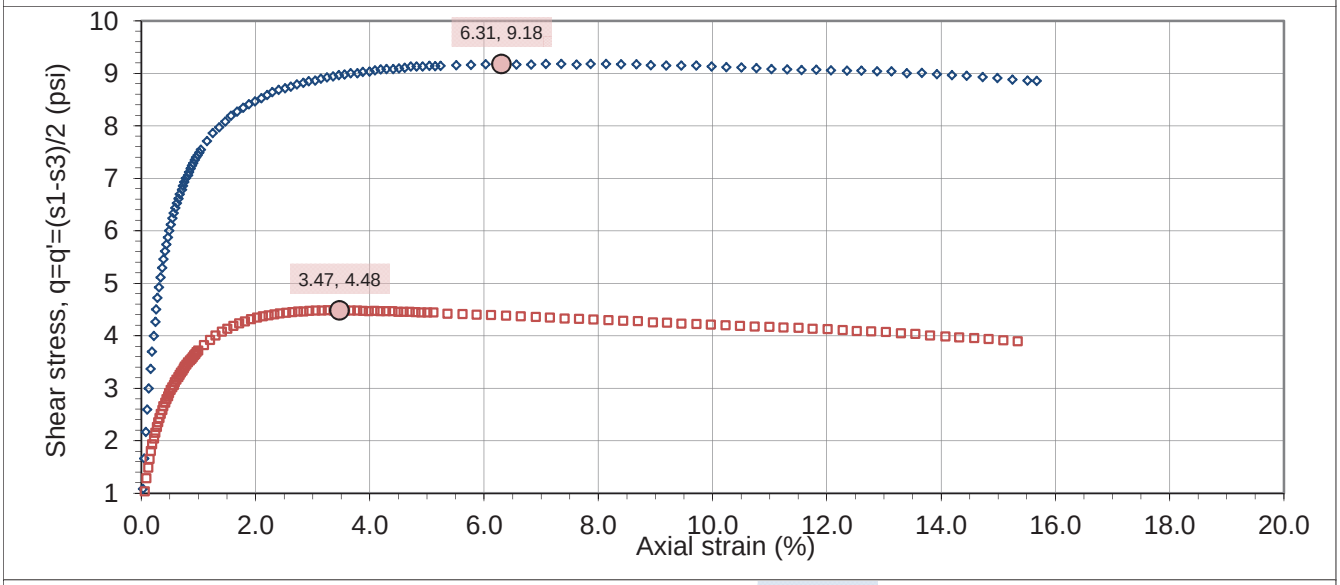
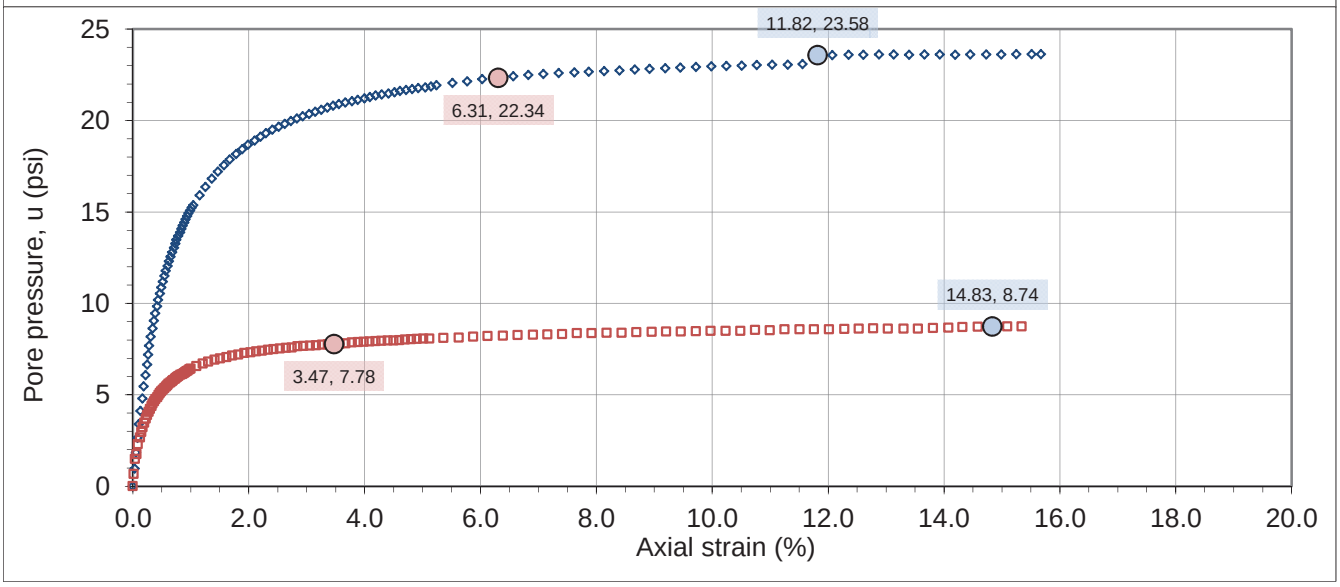
Triaxial Test - Isotropic Consolidated Sheared Undrained
Measuring Pore Pressure (CIU-PP) *- After ASTM D4767 and USBR 5750*

GERHART COLE

Project: Bear River - Cub River **TH/TP/Sample: TH-WB-01**
No: 13GCI329 **Depth: 30-31.5**







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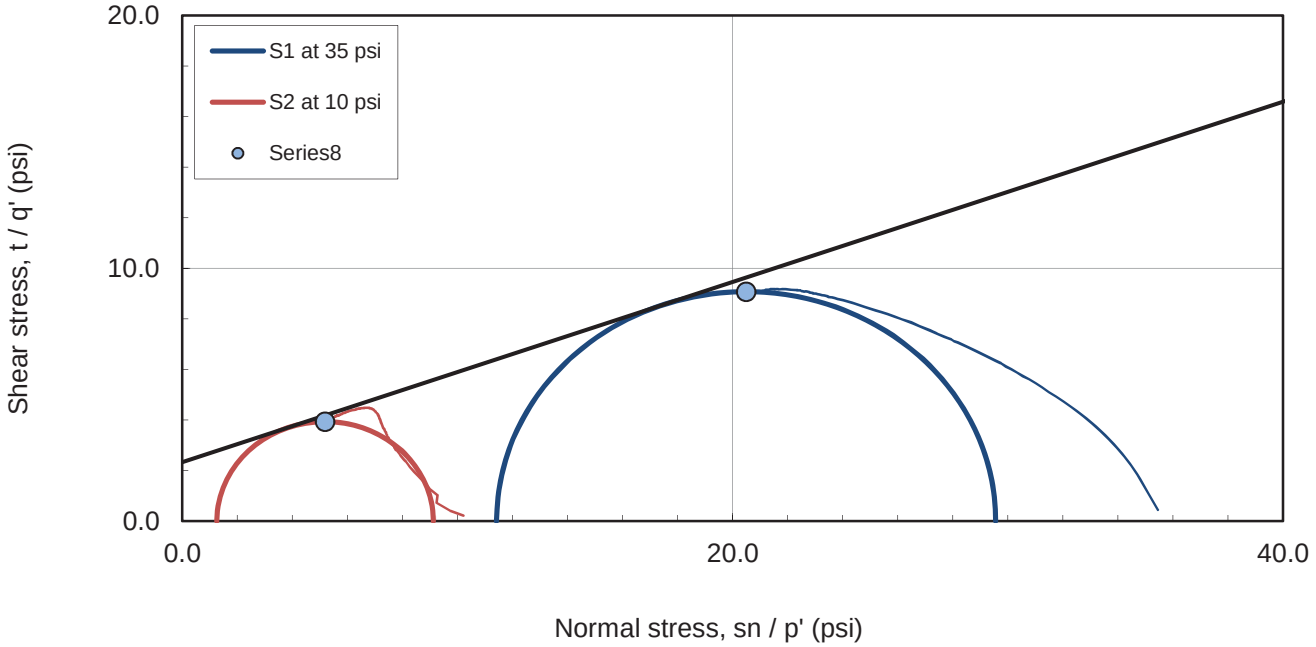
Triaxial Test - Isotropic Consolidated Sheared Undrained
Measuring Pore Pressure (CIU-PP) *- After ASTM D4767 and USBR 5750*

GERHART COLE

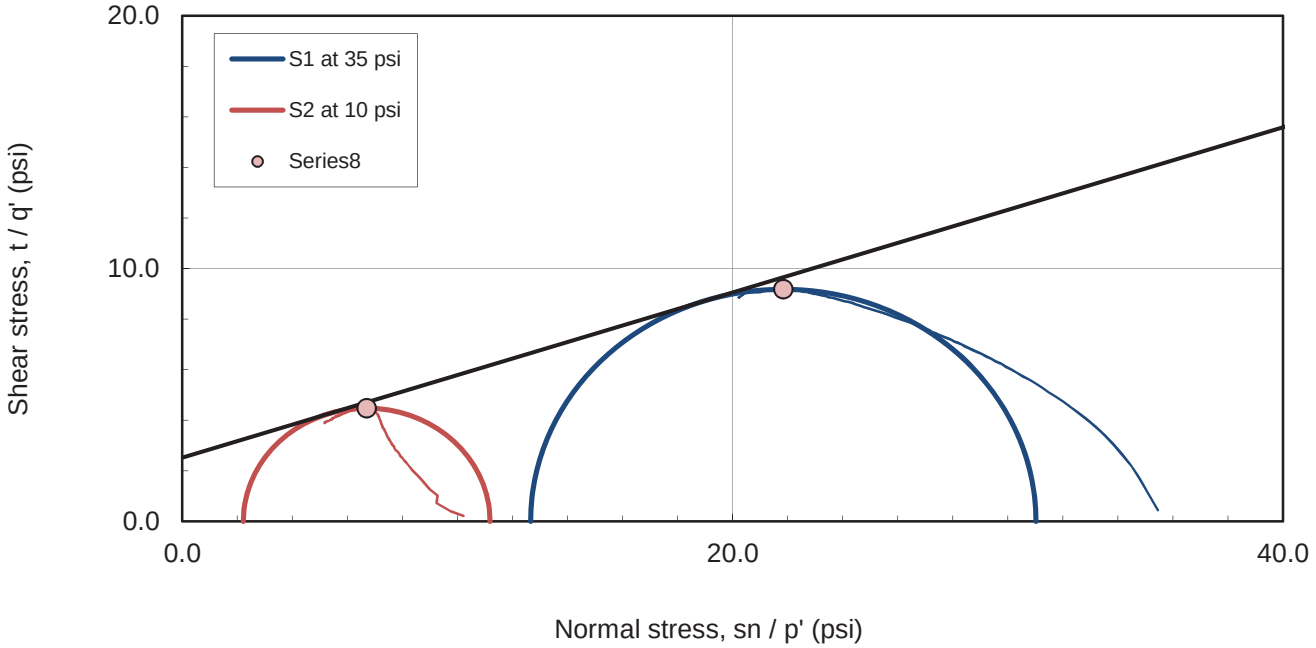
Project: **Bear River - Cub River** **TH/TP/Sample:** **TH-WB-01**
No: **13GCI329** **Depth:** **30-31.5**

Effective stress results



Max principal stress ratio (s'1/s'3), failure criteria Mohr and p' - q' space plots

Effective stress results



Peak deviator stress (s1-s3), failure criteria Mohr and p' - q' space plots

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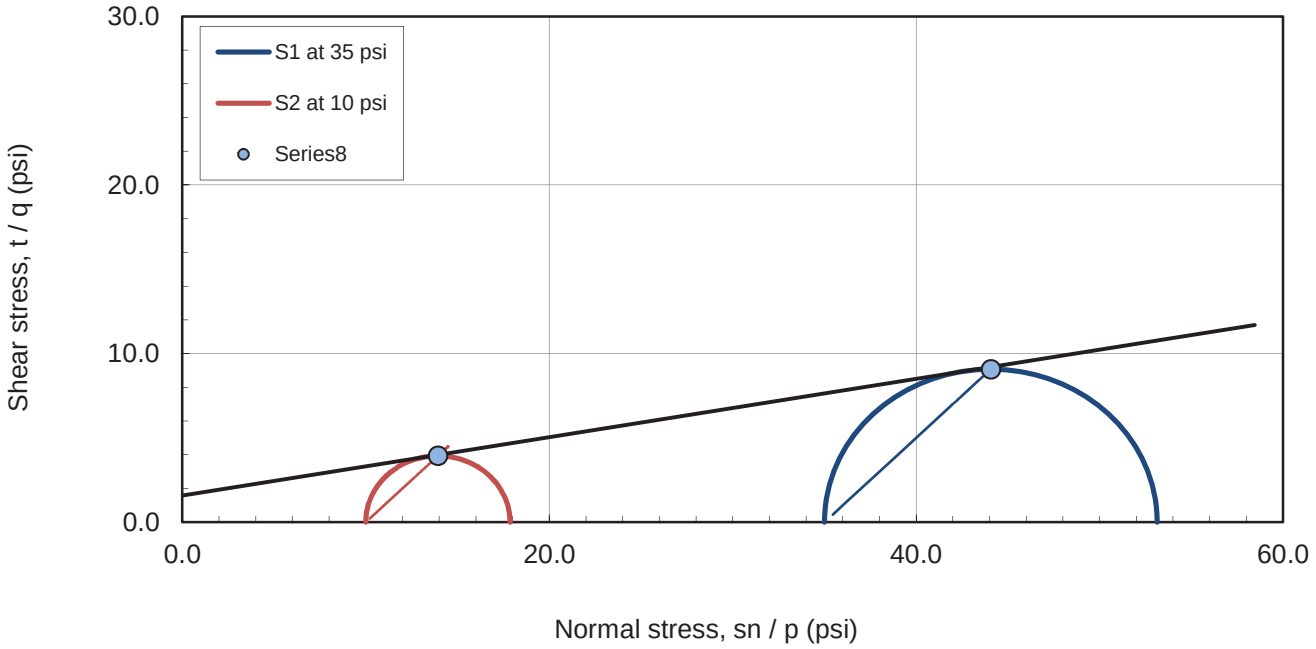
Triaxial Test - Isotropic Consolidated Sheared Undrained
Measuring Pore Pressure (CIU-PP) *- After ASTM D4767 and USBR 5750*

GERHART COLE

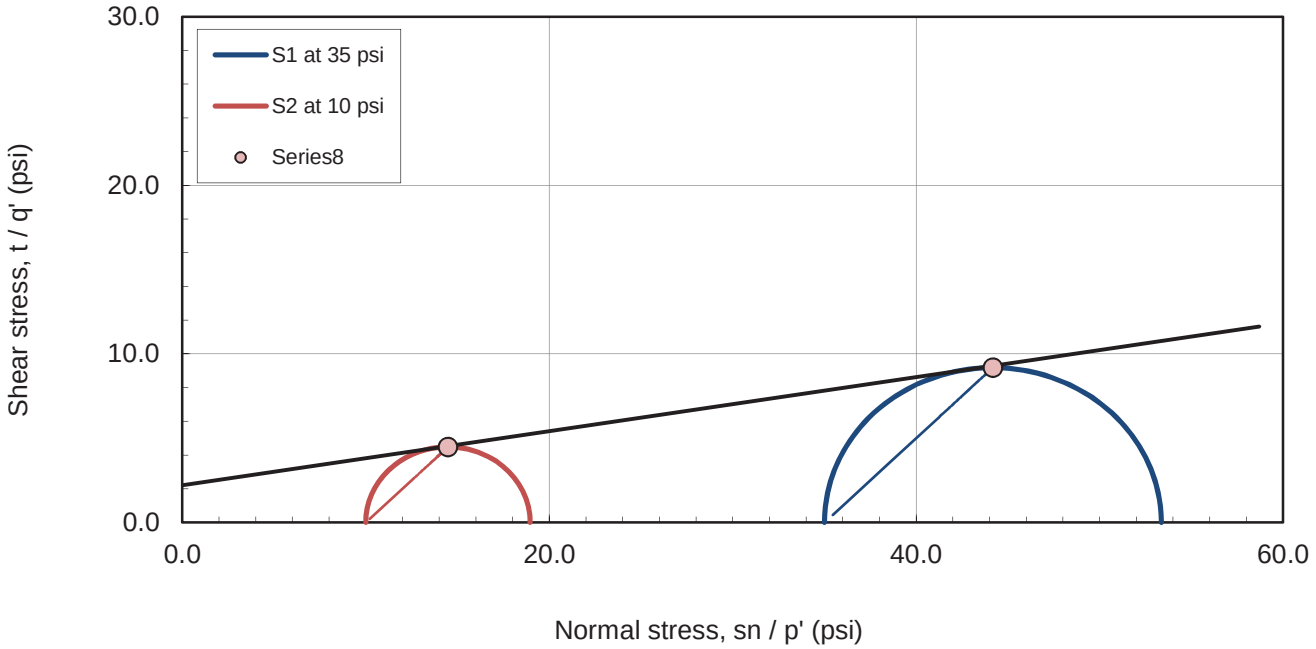
Project: **Bear River - Cub River** **TH/TP/Sample:** **TH-WB-01**
No: **13GCI329** **Depth:** **30-31.5**

Total stress results



Max principal stress ratio (s1/s3), failure criteria Mohr and p - q space plots - effective stress results

Total stress results



Peak deviator stress (s1-s3), failure criteria Mohr and p - q space plots

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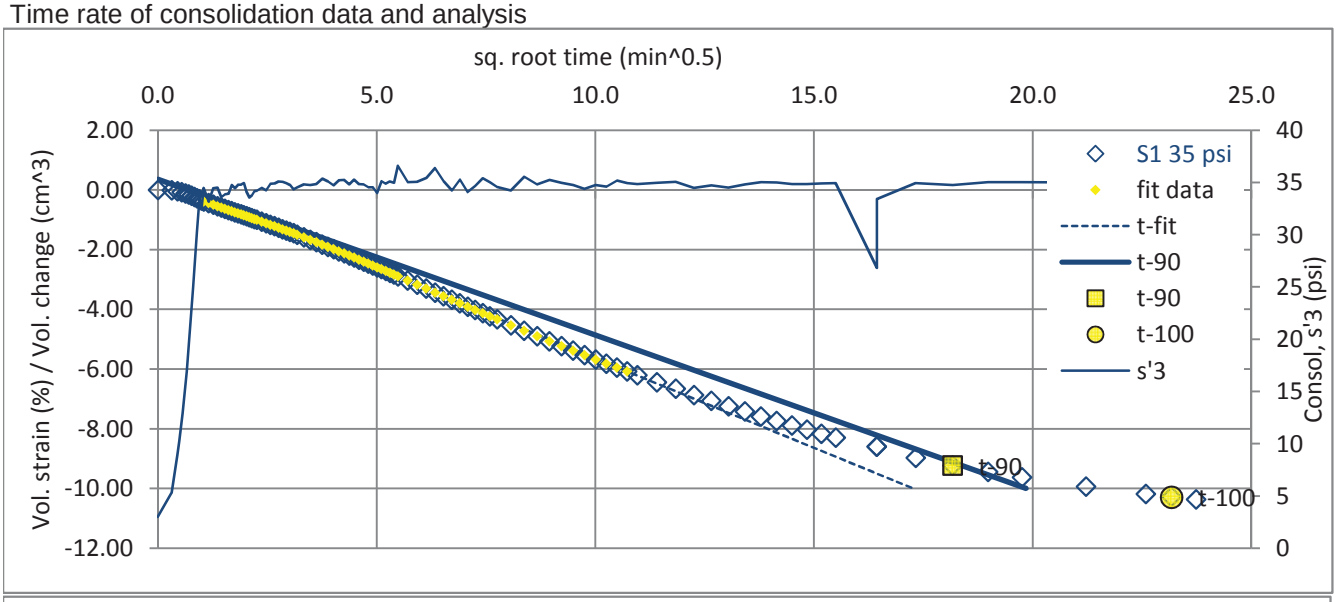
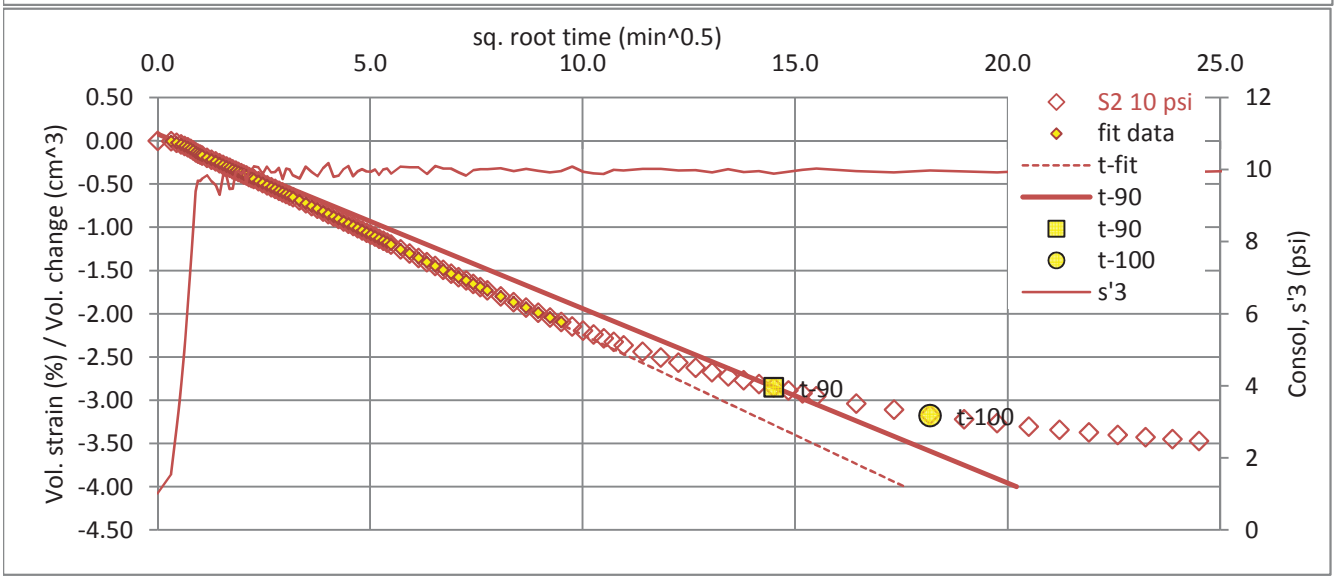
Triaxial Test - Isotropic Consolidated Sheared Undrained
Measuring Pore Pressure (CIU-PP) *- After ASTM D4767 and USBR 5750*

GERHART COLE

Project: **Bear River - Cub River** **TH/TP/Sample:** **TH-WB-01**
No: **13GCI329** **Depth:** **30-31.5**

Time rate of consolidation data and analysis





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Triaxial Test - Isotropic Consolidated Sheared Undrained Measuring Pore Pressure (CIU-PP) - *After ASTM D4767 and USBR 5750*

GERHART COLE

Project:	**Bear River - Cub River**	**TH/TP/Sample:**	**TH-WB-02**
No:	**13GCI329**	**Depth:**	**40-42**
Location:	Weber County	Sample description:	dark gray clay
Date:	17-Sep-15	USCS classification:	CL
Tested by:	zmg	Sample type:	undisturbed
Reduced by:	zmg	Notes:	
Checked by:	rrb		

	Test Number	S1	40 psi	S2	25 psi	S3	15 psi
		Initial	Bef. Shr. MethodB [e]	Initial	Bef. Shr. MethodB [e]	Initial	Bef. Shr. MethodB [e]
Unit weight data	Sample ht., H (in) 0°	5.756		5.751		5.749	
	120°	5.759		5.744		5.759	
	240°	5.754		5.749		5.758	
	Avg. height, Havg (in)	5.756	5.506	5.748	5.528	5.755	5.635
	Avg. height, Havg (cm)	14.621	13.986	14.600	14.041	14.619	14.314
	ΔHsc (in) [a]		0.25		0.22		0.12
	Sample dia., D (in) top	2.843		2.815		2.816	
	mid	2.845		2.817		2.801	
	bot	2.822		2.814		2.813	
	Avg. dia., Davg (in)	2.839	2.776	2.816	2.815	2.808	2.815
	Avg. dia., Davg (cm)	7.210	7.051	7.152	7.150	7.132	7.150
	Avg. area, Aavg (in^2)	6.329	6.052	6.227	6.223	6.192	6.224
	Avg. area, Aavg (cm^2)	40.833	39.047	40.174	40.149	39.946	40.152
	Wt. rings + wet soil (g)	956.03	862.41	994.97	933.46	927.77	899.50
	Wt. rings (g)	0.00	0.00	0.00	0.00	0.00	0.00
	Volume, Vo (in^3)	36.4	33.3	35.8	34.4	35.6	35.1
	Vo (cm^3)	597.0	546.1	586.5	563.7	584.0	574.7
	Vo (ft^3)	0.0211	0.0193	0.0207	0.0199	0.0206	0.0203
Moisture	Wet soil + tare (g)	232.42	981.10	215.18	1081.20	252.18	1018.22
	Dry soil + tare (g)	200.27	684.43	192.73	789.59	214.18	681.81
	Tare (g)	144.76	119.04	144.78	148.00	148.00	119.07
	Moisture content, w (%)	57.9	52.5	46.8	45.5	57.4	59.8
Phase Relationships	Gs, assumed	2.65	2.65	2.65	2.65	2.65	2.65
	Mass total (g)	956.0	923.1	995.0	985.7	927.8	941.7
	Mass of solids (g)	605.4	605.4	677.7	677.7	589.4	589.4
	Volume (cm^3)	597.0	546.1	586.5	563.7	584.0	574.7
	Volume of water (cm^3)	350.6	317.7	317.3	308.0	338.4	352.3
	Volume of solids (cm^3)	228.5	228.5	255.7	255.7	222.4	222.4
	Volume of voids (cm^3)	368.6	317.7	330.8	308.0	361.6	352.3
	Volume of air (cm^3)	17.9	0.0	13.5	0.0	23.1	0.0
	Void ratio, e	1.613	1.391	1.294	1.204	1.626	1.584
	Porosity, n	0.617	0.582	0.564	0.546	0.619	0.613
	Volumetric moisture, T	0.587	0.582	0.541	0.546	0.580	0.613
	Saturation, S (%) [c]	95.13	100.00	95.91	100.00	93.60	100.00
	Dry density (gm/cm^3)	1.014	1.109	1.155	1.202	1.009	1.025
	Wet unit wt., gm (pcf)	100.0	105.5	105.9	109.2	99.2	102.3
	Dry unit wt., gd (pcf)	63.3	69.2	72.1	75.0	63.0	64.0

Notes:

[a] ΔHsc (in) = change in height during saturation and consolidation

[b] ΔVs = change in volume during saturation, ΔVc = change in volume during consolidation

[c] Saturation before shear set to 100% for phase calculations

[d] Before shear Aavg using method A; where Ac (Method A) = (Vo-DVs - DVc)/(Ho-DHsc)

[e] Before shear Aavg using method B; where Ac (Method B) = (Vwf + Vs)/Hc

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Triaxial Test - Isotropic Consolidated Sheared Undrained
Measuring Pore Pressure (CIU-PP) *- After ASTM D4767 and USBR 5750*

GERHART COLE

Project:	**Bear River - Cub River**	**TH/TP/Sample:**	**TH-WB-02**
No:	**13GCI329**	**Depth:**	**40-42**
Location:	Weber County	Sample description:	dark gray clay
Date:	17-Sep-15	USCS classification:	CL
Tested by:	zmg	Sample type:	undisturbed

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	Test Number	S1 at 40 psi	S2 at 25 psi	S3 at 15 psi
Test information	Total backpressure (psi)	30.0	50.0	14.0
	Skempton B	0.95	0.95	0.96
	t-90 (min)	470.2	450.2	200.4
	t-100 (min)	650.2	630.2	270.3
	t-50 (min)	109.9	105.2	46.8
	Strain rate (%/hr)	0.50	0.50	0.70
	Strain rate (%/min)	0.008	0.008	0.012
	Membrane correction	Yes	Yes	Yes
	Filter paper correction	No filter paper	No filter paper	No filter paper
Max principal stress ratio (s1/s3), failure criteria	Strain at failure, ef (%)	12.54	5.69	6.64
	Time to failure, tf (min)	1504.6	682.9	569.2
	Obliquity, s'1/s'3	2.879	2.831	2.961
	Excess pore pressure, u (psi)	30.66	16.27	9.37
	q = q' = (s1+s3)/2 (psi)	8.78	7.99	5.52
	p' = (s'1+s'3)/2 (psi)	18.12	16.72	11.15
	p = (s1+s3)/2 (psi)	48.78	32.99	20.52
	Effective major principal stress, s'1 (psi)	26.89	24.72	16.67
	Effective minor principal stress, s'3 (psi)	9.34	8.73	5.63
	Total major pincipal stress, s1 (psi)	57.55	40.99	26.04
	Total minor pincipal stress, s3 (psi)	40.00	25.00	15.00
	Skemption A at failure, Af	1.75	1.02	0.85
	Secant friction angle, phi-s (deg)	29.0	28.5	29.7
		Effective stress	Total stress	
	Friction angle, phi (deg)	27.4	6.5	
	Cohesion intercept, c (psi)	0.4	3.6	
Peak deviator stress (s1-s3), failure criteria	Strain at failure, ef (%)	4.79	4.34	4.49
	Time to failure, tf (min)	574.3	520.7	385.1
	Deviator stress, s1-s3 (psi)	19.01	16.07	11.25
	Excess pore pressure, u (psi)	28.03	15.73	9.11
	q = q' = (s1+s3)/2 (psi)	9.51	8.04	5.63
	p' = (s'1+s'3)/2 (psi)	21.48	17.31	11.51
	p = (s1+s3)/2 (psi)	49.51	33.04	20.63
	Effective major principal stress, s'1 (psi)	30.99	25.35	17.14
	Effective minor principal stress, s'3 (psi)	11.97	9.27	5.89
	Total major pincipal stress, s1 (psi)	59.01	41.07	26.25
	Total minor pincipal stress, s3 (psi)	40.00	25.00	15.00
	Skemption A at failure, Af	1.47	0.98	0.81
	Secant friction angle, phi-s (deg)	26.3	27.7	29.3
		Effective stress	Total stress	
	Friction angle, phi (deg)	23.0	7.6	
	Cohesion intercept, c (psi)	1.3	3.2	

Comments:

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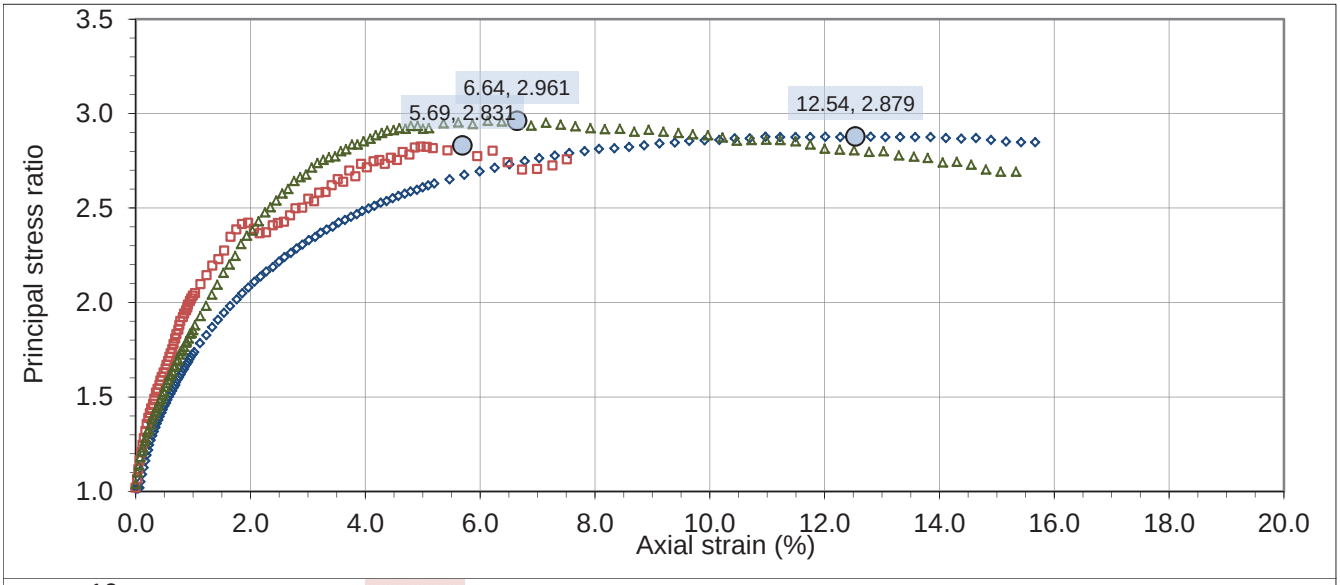
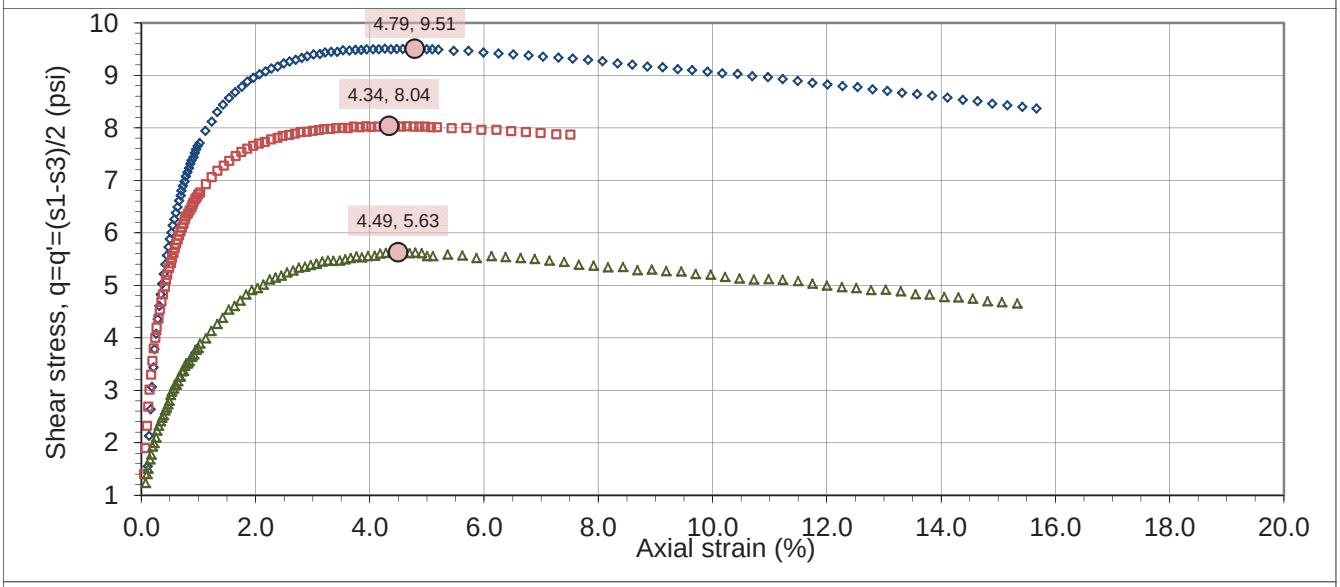
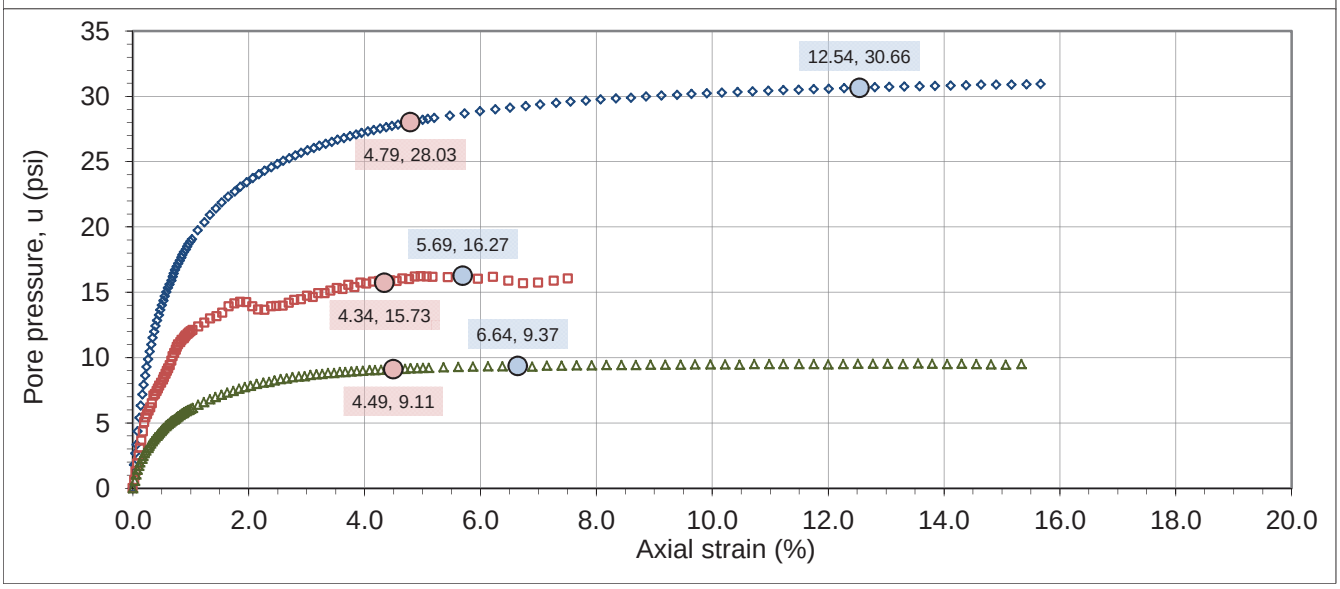
Triaxial Test - Isotropic Consolidated Sheared Undrained
Measuring Pore Pressure (CIU-PP) *- After ASTM D4767 and USBR 5750*

GERHART COLE

Project: Bear River - Cub River **TH/TP/Sample: TH-WB-02**
No: 13GCI329 **Depth: 40-42**







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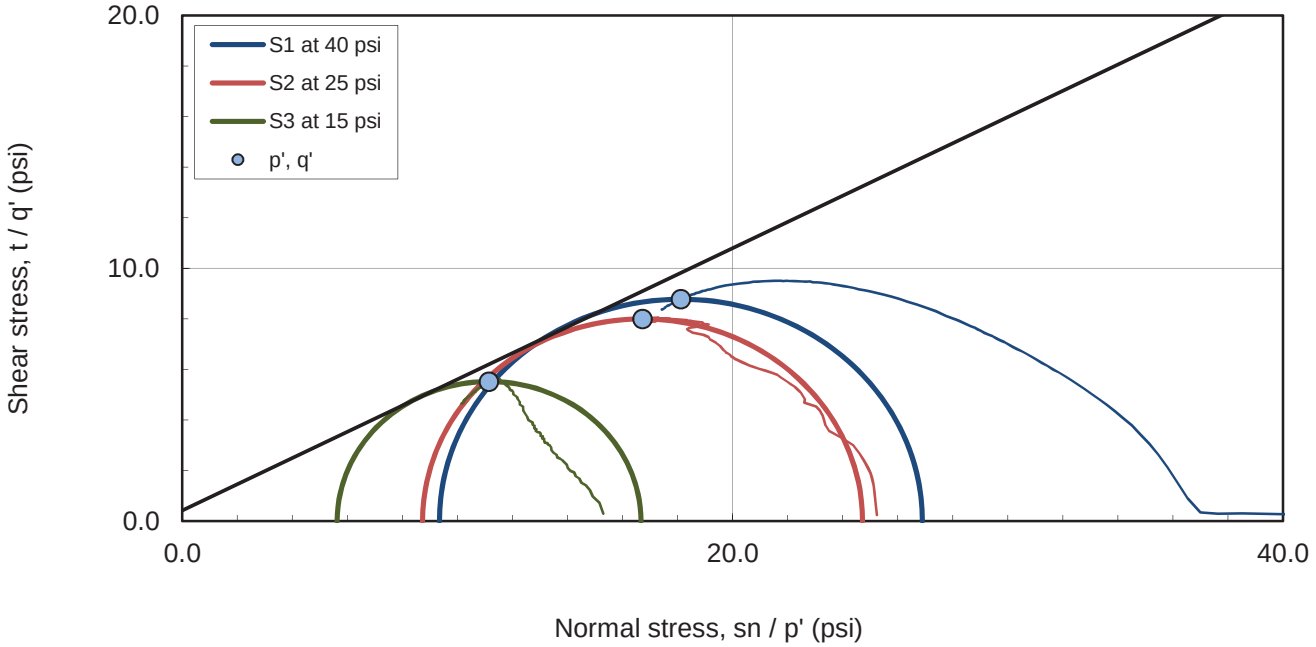
Triaxial Test - Isotropic Consolidated Sheared Undrained
Measuring Pore Pressure (CIU-PP) *- After ASTM D4767 and USBR 5750*

GERHART COLE

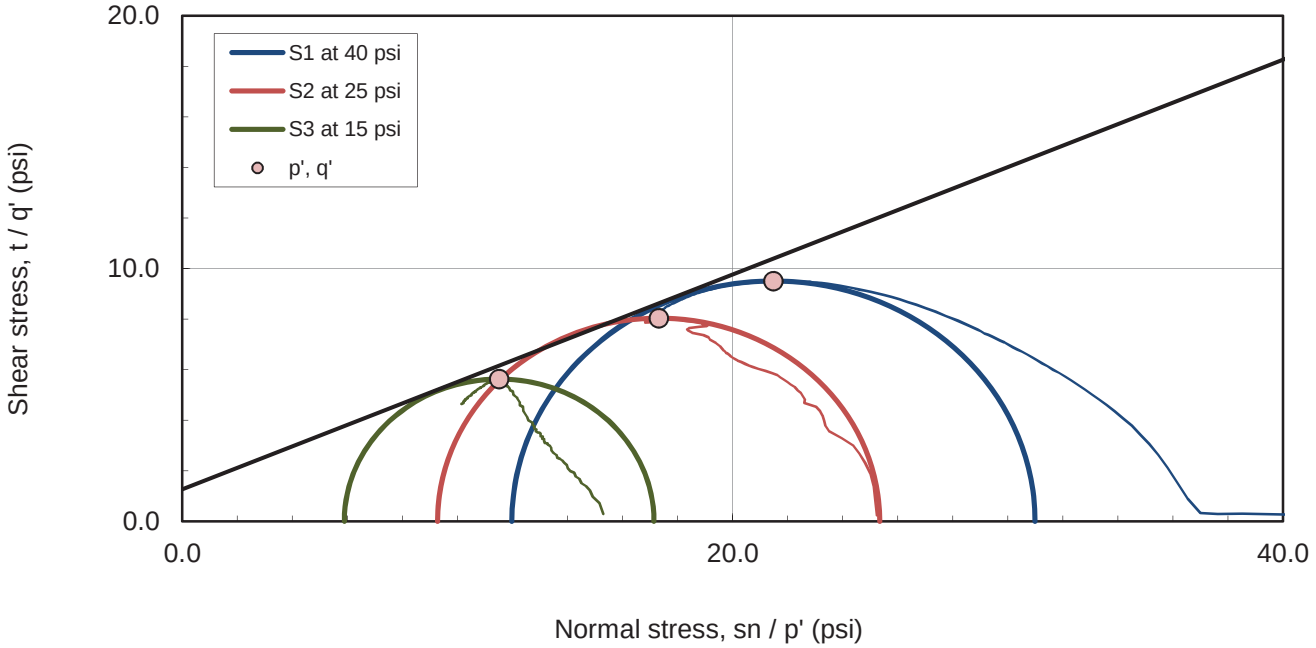
Project: **Bear River - Cub River** **TH/TP/Sample:** **TH-WB-02**
No: **13GCI329** **Depth:** **40-42**

Effective stress results



Max principal stress ratio (s'1/s'3), failure criteria Mohr and p' - q' space plots

Effective stress results



Peak deviator stress (s1-s3), failure criteria Mohr and p' - q' space plots

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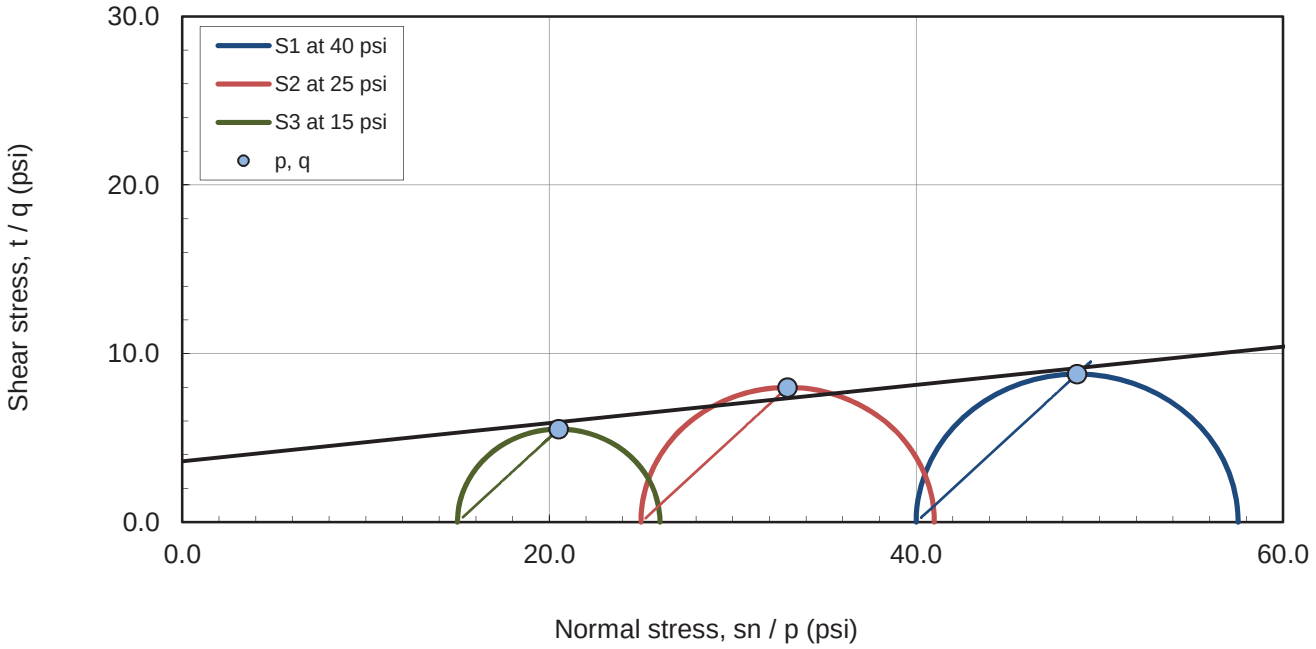
Triaxial Test - Isotropic Consolidated Sheared Undrained
Measuring Pore Pressure (CIU-PP) *- After ASTM D4767 and USBR 5750*

GERHART COLE

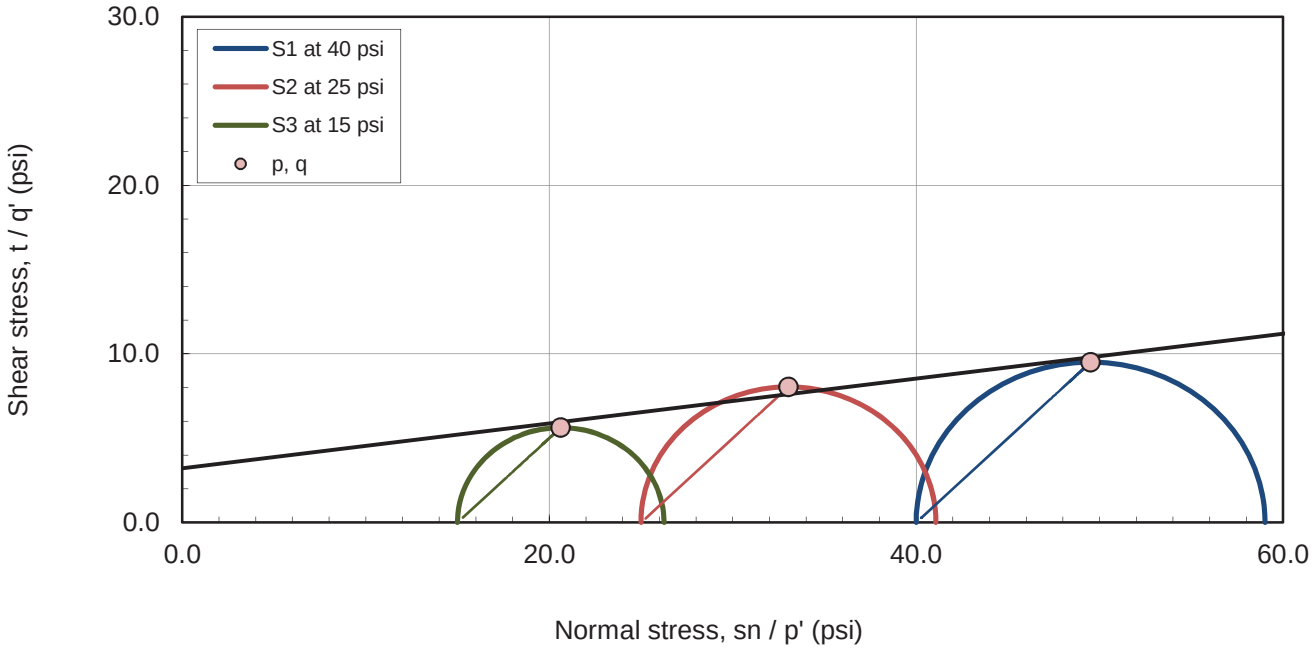
Project: Bear River - Cub River **TH/TP/Sample: TH-WB-02**
No: 13GCI329 **Depth: 40-42**

Total stress results



Max principal stress ratio (s1/s3), failure criteria Mohr and p - q space plots - effective stress results

Total stress results



Peak deviator stress (s1-s3), failure criteria Mohr and p - q space plots

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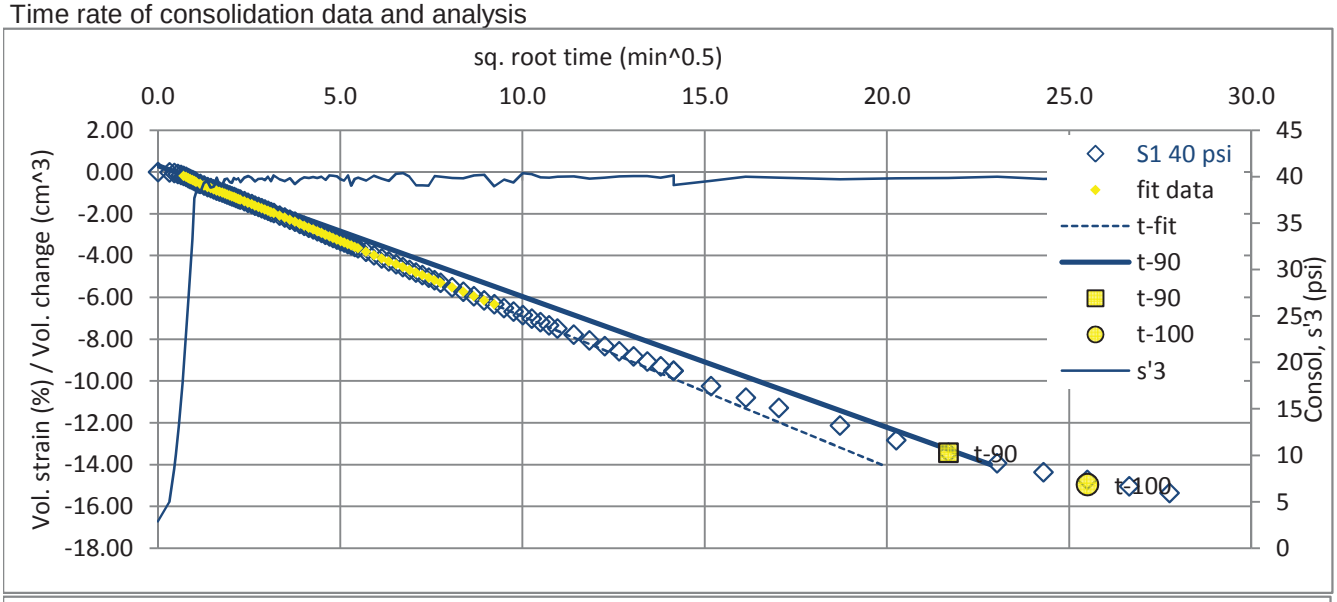
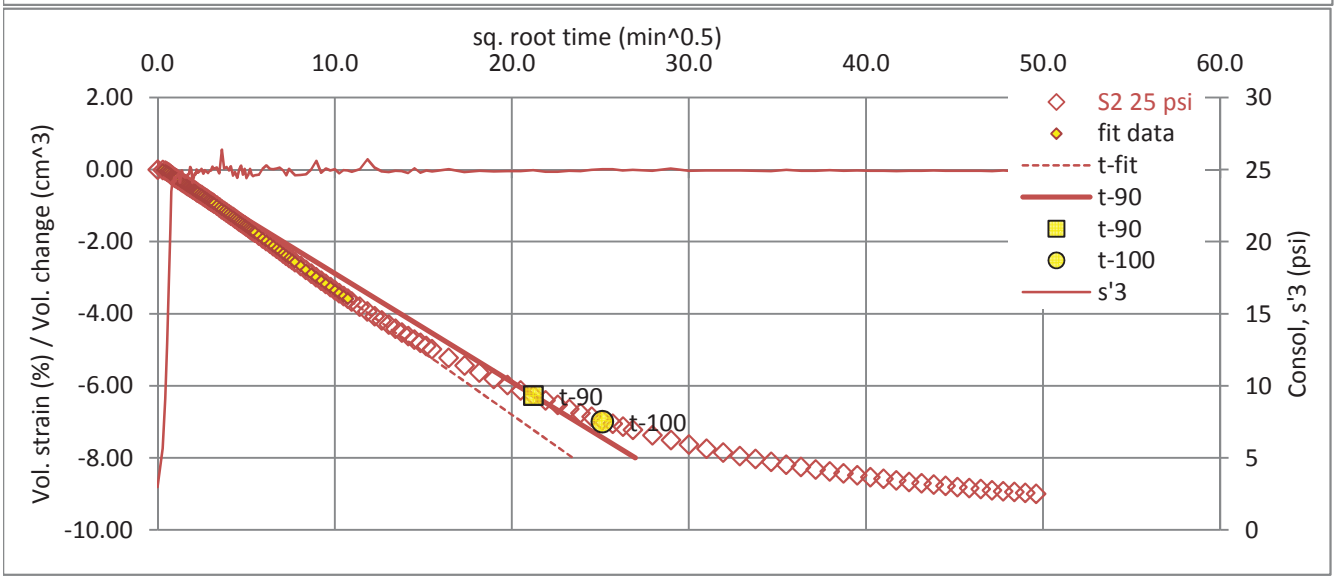
Triaxial Test - Isotropic Consolidated Sheared Undrained
Measuring Pore Pressure (CIU-PP) *- After ASTM D4767 and USBR 5750*

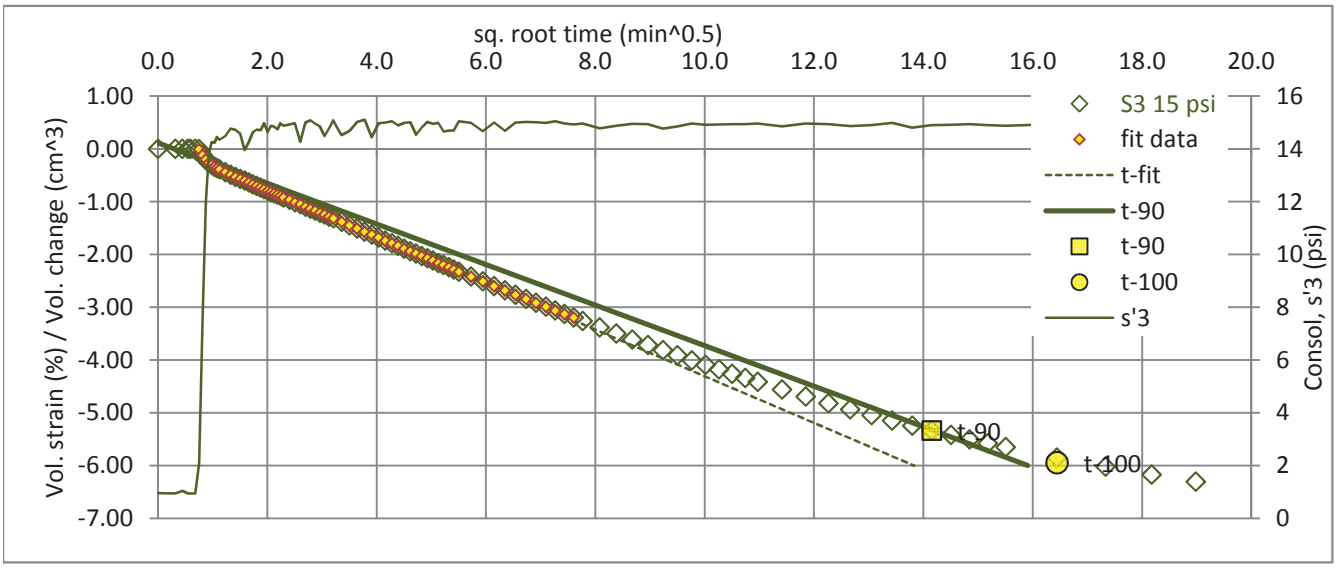
GERHART COLE

Project: Bear River - Cub River **TH/TP/Sample: TH-WB-02**
No: 13GCI329 **Depth: 40-42**

Time rate of consolidation data and analysis







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DRAFT Temple Fork Geotechnical Data Report Bear River Project Concept Study

Prepared for

Bowen Collins & Associates, Inc

October 2018

GCI project number: 13GCI329

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Temple Fork - Geotechnical Data Report
Bear River Project Concept Study
13GCI329

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TABLE OF CONTENTS

SECTION 1 Introduction 1-1

1.1 Project Description 1-1
1.2 Purpose, Authorization, And Work Scope 1-1

SECTION 2 Methods of Study and Findings 2-1

2.1 Temple Fork Site 2-1
2.1.1 Test Hole Drilling and Sampling 2-1
2.1.2 Laboratory Study 2-2
2.1.3 Permeability Testing 2-2
2.1.4 Groundwater 2-3

SECTION 3 Geology 3-1

3.1 General Setting 3-1
3.2 Bedrock Stratigraphy 3-1
3.3 Geologic Structure 3-1
3.4 Site-Specific Geology 3-2
3.5 Geologic Hazards 3-4
3.5.1 Surface Fault Rupture 3-4
3.5.2 Landslides 3-4
3.5.3 Solution Cavities 3-5
3.5.4 Rock Falls 3-5

SECTION 4 Conclusion 4-1

4.1 Recommendations for additional Studies 4-1
4.2 Limitations 4-1

SECTION 5 References 5-1

List of Tables

Table 2-1 Temple Fork – Laboratory Test Results
Table 2-2 Temple Fork – Packer Permeability Test Results
Table 2-3 Temple Fork Groundwater Measurements

List of Figures

Figure 1-1 Vicinity Map
Figure 2-1 Temple Fork – Site and Exploration Map
Figure 3-1a Geologic Map (Modified from: Dover, 1995)
Figure 3-1b Geologic Map Descriptions

TABLE OF CONTENTS

Figure 3-2 Geologic Cross-section (Reference: Dover, 1995)

Figure 3-3 Stereonet Plot of Measured Discontinuities (major planes and poles; lower hemisphere, equal area), Right Abutment

Figure 3-4a Temple Fork Landslide Map (Mod. from Elliott and Harty, 2010)

Figure 3-4b Landslide Map Descriptions

List of Appendices

Appendix A - Temple Fork - Test Hole Logs and Core Photographs

Appendix B - Temple Fork - Interpretative Laboratory Test Results

Appendix C - Temple Fork – Discontinuity Data

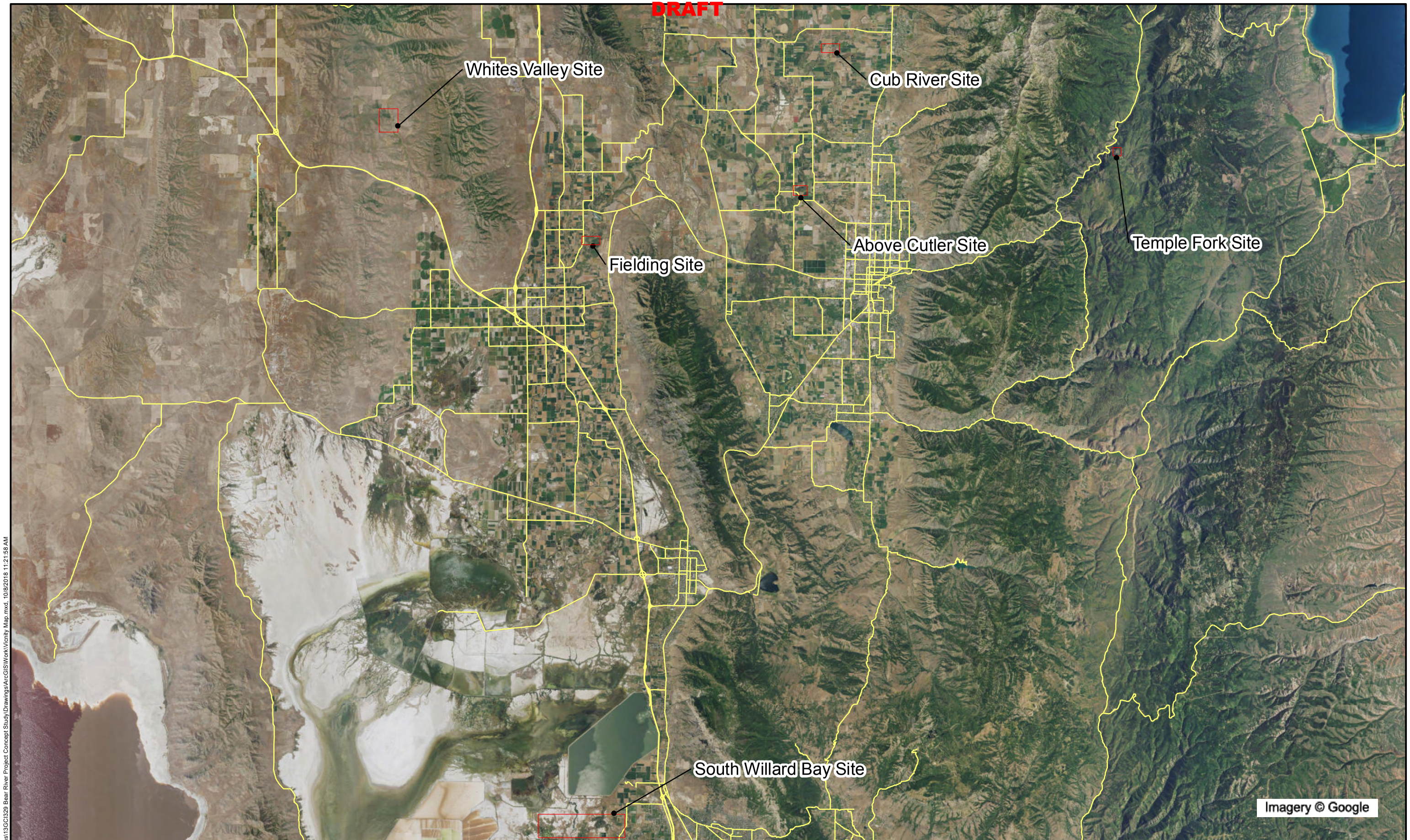
1.1 Project Description

The purpose of the Bear River Project is to develop Utah's unused water rights on the Bear River and deliver it to Box Elder, Cache, Weber, Davis, and Salt Lake Counties. The overall Project will consist of conveyance facilities and reservoir storage necessary to deliver water from the Bear River to the communities in the service areas of the Bear River Water Conservancy District (BRWCD), Cache County, the Weber Basin Water Conservancy District (WBWCD), and the Jordan Valley Water Conservancy District (JVWCD). The Utah Division of Water Resources (DWRe) has been working with Bowen Collins and Associates and HDR (Project Team) for several years to develop the overall Project.

1.2 Purpose, Authorization, And Work Scope

This report presents the results of geotechnical and geologic studies performed by Gerhart Cole Inc. (GCI) at Temple Fork in support of the project design team. The other project study areas that have had some studies completed are Cub River, Above Cutler, Fielding, South Willard Bay, and Whites Valley. The locations of these study sites are shown in Figure 1-1 along with the Temple Fork Site.

GCI scope of work included a preliminary site characterization of the site, including drilling 2 test holes, geologic study of the dam and reservoir site, and associated laboratory testing on select samples recovered from the test holes. This work was completed under GCI's existing cooperative reciprocal service agreement with BCA.



GERHART COLE

Bear River Project Concept Study

Vicinity Map

N

0 8,000 16,000 32,000 Feet

Figure 1-1

J:\PROJECTS\Bowen Collins\13GC\328 Bear River Project Concept Study\Drawings\ArcGIS\Work\Vicinity Map.mxd, 10/8/2018 11:21:58 AM

2.1 TEMPLE FORK SITE

A field study was conducted at the site between May 7 and May 29, 2015. The study consisted of drilling and sampling three (3) test holes, and performing a LiDAR scan of the site. A site map showing test hole locations is presented as Figure 2-1. Test hole locations were established by GCI based on accessibility and proximity to the proposed dam. Test hole locations were documented by using a hand-held, tablet-mounted GPS device. Test hole elevations were estimated from the LiDAR survey, which was performed by Horrocks Engineers/Aerographics under subcontract to GCI.

2.1.1 Test Hole Drilling and Sampling

Test holes were advanced using rotary wash with HW casing and rock coring with a truck-mounted CME 75. This equipment and associated drilling services were provided by Bedke Geotechnical Field Services under subcontract to GCI. Three test holes were drilled on the United States Forest Service (USFS) Temple Fork Road near the proposed dam site (TH-TF-01, TH-TF-02, and TH-TF-03). TH-TF-01 was drilled vertical while TH-TF-02 and TH-TF-03 were drilled at a 30 degree angle with an azimuth of 270 degrees. Test holes locations are shown in Figure 2-1.

Approximately 20 to 25 feet of HW casing was set in each test hole, through soils overlying bedrock, to allow return/circulation of drilling fluids. Rock coring was accomplished using a HQ size (3.83 inch diameter) triple-tube core barrel with a wire-line setup for core retrieval. Drilling was performed using a CME 75 truck-mounted drill rig operated by Bedke Geotechnical Field Services under subcontract to GCI.

Coring was generally accomplished in 5-foot runs unless blockage necessitated premature termination of a run. Clear water (no additives) was used as a circulation fluid. It was necessary to “grout-out” sections of the hole through more fractured limestones to stabilize test hole walls and prevent further accumulations of sand (“sanding”) around the drill bit. Grouted sections were then re-drilled and holes extended to their design depths. Due to the HQ casing breakage in TH-TF-02, the hole had to be abandoned at 55.8 feet, and TH-TF-03 was drilled approximately 15 feet east of TH-TF-02 to the target depth of 150 feet. TH-TF-01 was drilled to 100.5 feet and met the target depth.

Core samples were collected and boxed after recording pertinent information such as length of recovered core, percent RQD (rock quality designation), fracture density and general lithologic information. Logging was performed by a licensed professional engineer and reviewed by a licensed geologist. Standard Penetration Testing (SPT) with a standard split-spoon sampler and thin-walled Shelby tube (ST) samplers were obtained in the soil overlying the bedrock in TH-TF-01. The number of hammer blows required to advance the sampler in 6-inch increments was recorded in the field, with the sum of the second and third 6-inch intervals constituting the SPT “N-value.”

Following test hole completion, a piezometer was installed in TH-TF-01 for ground water monitoring. The piezometer was screened from 100.5 to 90.5 feet, sand packed from 100.5 to 65 feet, and sealed with bentonite chips from 65 feet to the ground surface.

Upon completion, TH-TF-02 and TH-TF-03 were grouted to the surface using a cement/bentonite grout mix.

Logs of the test holes are presented in Appendix A, along with rock core photos. Lines designating boundaries between different materials shown on the logs should be considered approximate; transitions between subsurface materials may be gradual or occur between sampling depths. Relative density and consistency descriptions used on a final test hole log may deviate from field logs and/or criteria for a number of reasons, including; a) reliance on other test results, b) visual observation and/or manual manipulation of disturbed field samples, or c) the engineer's judgment. For most engineering assessments involving cohesionless, non-gravelly soils, the SPT blowcount is usually adjusted for the effective vertical pressure at the sampling depth, and for other sampling system parameters such as the efficiency of the sampling system and/or sampling techniques used.

2.1.2 Laboratory Study

Laboratory testing was performed on select rock core specimens obtained during field studies in order to further classify and characterize the rock. Laboratory testing included moisture content, Atterberg limits, grain size distribution, and point load testing. Laboratory test results are summarized in Table 2-1, with additional data and plots presented in Appendix B.

2.1.3 Permeability Testing

To evaluate rock permeability, testing was performed in each of the three core holes described above using packer test methods. Testing in intervals of 10 feet was commenced in each of the holes at about 25 to 35 feet below grade using a 10 foot long packer assembly suspended by a cable and compressed gas (nitrogen) line. The packer was equipped with a transducer to provide continuous indication of head pressure at the packer. In addition, an in-line pressure gauge was placed within the line at the top of the casing to provide a back-up reading of down-hole pressure at the packer. For each test, the packer was inflated under sufficient air pressure to seal off the bottom of the hole and allow testing at required head pressures. Head pressures were calculated in advance of each test so that the pressure at the packer could be appropriately regulated. Tests were run in three to four steps of generally 5 minutes per step. Under the initial step test, head pressure was maintained at levels less than 1 psi per foot of depth and was generally equivalent to a column of water equal to the mid-depth of the tested interval. Flow measurements for each minute of the test were recorded. During the second step test, applied pressure was increased from the first test and again water intake recorded in gallons per minute. The third test applied pressure was increased to maximum pressure, and for the final step test, the head pressure was reduced back to the level of the second step test to see if there was any change in flow. A large increase would indicate hydraulic fracturing of the rock during the third step test. Once field data were obtained, permeability estimates for each 10 foot increment of the bedrock in each hole were calculated both in centimeters per second, feet per year, and Lugeons. Results are presented on Table 2-2

2.1.4 Groundwater

Groundwater levels were measured in the piezometer at TH-TF-01, as summarized in Table 2-3. Measurements made directly after drilling may be less reliable than those obtained later, due to drilling methods and effects. Groundwater levels do fluctuate seasonally and may vary several feet in elevation.

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Table 2-1 Laboratory Test Result Summary

Bear River Project Concept Study- Temple Fork (13GCI329)

Test Hole	Depth (ft)	Moisture content (%)	Dry unit weight (pcf)	Moist / Sat. unit weight (pcf)	Atterberg Limits					Grain-Size			Grain-Size Analysis (Percent Finer)										Other Tests (Interpretative Data in Appendix)
					LL (%)	PL (%)	PI (%)	Cohesive Index, CI	Liquidity Index, LI	GRAVEL (No.4 - 3")	SAND (No.200-No.4)	FINES (<No.200)	1.5-in (37.5 mm)	3/4-in (19 mm)	3/8-in (9.5 mm)	No.4 (4.75 mm)	No.10 (2 mm)	No.20 (0.85 mm)	No.40 (0.425 mm)	No.60 (0.25 mm)	No.100 (0.15 mm)	No.200 (0.075 mm)	
TH-TF-01	5-6.5	23.4			41	23	18	0.78	0.0	27	20	53	100	100	80	73	69	65	61	59	56	53	
TH-TF-01	11-12.5	5.4								76	18	6	100	75	43	24	13	9	8	7	7	6	
TH-TF-01	15-17	9.4								50	22	28	100	72	58	50	41	34	32	30	29	28	
TH-TF-01	23-24																						Point Load Test = 1195 psi
TH-TF-01	40-41																						Point Load Test = 563 psi
TH-TF-01	72-73																						Point Load Test = 566 psi
TH-TF-01	92-93																						Point Load Test = 708 psi
TH-TF-02	26-27																						Point Load Test = 516 psi
TH-TF-02	46-47																						Point Load Test = 879 psi
TH-TF-03	32-33																						Point Load Test = 444 psi
TH-TF-03	54-55																						Point Load Test = 2306 psi
TH-TF-03	72-73																						Point Load Test = 995 psi
TH-TF-03	97-98																						Point Load Test = 957 psi
TH-TF-03	120-121																						Point Load Test = 1239 psi
TH-TF-03	148-149																						Point Load Test = 1096 psi

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Table 2-2 - Core Hole Packer Permeability Test Results
Temple Fork Site TH-TF-01

Project Name	Bear River	Inclination (degrees)	0	Tested by	R. Buhler
Project Location	Temple Fork	Distance to Water (ft)	5	Date	May-15
Project Number	13GCI329	Vertical Depth to Water (ft)	5.0	Reviewed by	P. Gerhart
Test Hole No.	TH-TF-01 Sheet 1 of 1	Hole Diameter = 2*r (in)	3.83	Date	Nov-15

Notes: Test #3 through #6 the pressures were measured with the vibrating wire pressure tranducer in the test zone
Test #3 step 2 and Test #5 step 2 water flowing around packer.

Test #, Packer Pressure, Material	Inclined Packer Test Interval (ft)		Vertical Packer Test Interval (ft)		Packer Test Length, inclined	Total Applied Pressure	Pressure Losses	Adjusted Applied Pressure	Applied Pressure Head	Gravity Head	Total Head	Water Take	Shape Factor	Hydraulic Conductivity		
	Start	End	Start	End	(ft)	(psi)	(psi)	(psi)	(ft)	(ft)	(ft)	(gpm)		(ft/yr)	(cm/s)	Lugeon
a	b	c	d	e	L	pgage or pvw	ploss	pactual	hp	hg	htotal	Q	Cp	k	km	kL
1	28	38	28.0	38.0	10	16	3.5	12.50	28.9	5.0	33.9	7.6	4630	1033	9.99E-04	77
280 psi	28	38	28.0	38.0	10	32	8.5	23.50	54.3	5.0	59.3	18.8	4630	1468	1.42E-03	109
Limestone	28	38	38.0	48.0	10	16	4.5	11.50	26.6	5.0	31.6	9.8	4630	1432	1.38E-03	106
2	38	48	38.0	48.0	10	22	3.3	18.70	43.2	5.0	48.2	3.2	4630	309	2.99E-04	23
290 psi	38	48	38.0	48.0	10	34	3.3	30.70	70.9	5.0	75.9	4.2	4630	256	2.48E-04	19
Limestone	38	48	38.0	48.0	10	48	3.3	44.70	103.3	5.0	108.3	5.3	4630	227	2.19E-04	17
	38	48	38.0	48.0	10	32	3.3	28.70	66.3	5.0	71.3	3.2	4630	210	2.03E-04	16
	38	48	38.0	48.0	10	20	3.3	16.70	38.6	5.0	43.6	2.4	4630	259	2.51E-04	19
3	48	58	48.0	58.0	10	25		25.11	58.0		58.0	9.3	4630	742	7.18E-04	55
300 psi	48	58	48.0	58.0	10	62		62.47	144.3		144.3	20.0	4630	642	6.20E-04	48
Limestone	48	58	48.0	58.0	10	14		13.85	32.0		32.0	4.9	4630	706	6.82E-04	52
4	58	68	58.0	68.0	10	56		55.84	129.0		129.0	7.4	4630	266	2.57E-04	20
300 psi	58	68	58.0	68.0	10	76		76.19	176.0		176.0	4.9	4630	128	1.24E-04	10
Limestone	58	68	58.0	68.0	10	88		87.88	203.0		203.0	14.5	4630	331	3.20E-04	25
	58	68	58.0	68.0	10	45		45.02	104.0		104.0	5.8	4630	258	2.50E-04	19

Table 2-2 - Core Hole Packer Permeability Test Results
Temple Fork Site TH-TF-01

Project Name	Bear River	Inclination (degrees)	0	Tested by	R. Buhler
Project Location	Temple Fork	Distance to Water (ft)	5	Date	May-15
Project Number	13GCI329	Vertical Depth to Water (ft)	5.0	Reviewed by	P. Gerhart
Test Hole No.	TH-TF-01 Sheet 1 of 1	Hole Diameter = 2*r (in)	3.83	Date	Nov-15

Notes: Test #3 through #6 the pressures were measured with the vibrating wire pressure tranducer in the test zone
Test #3 step 2 and Test #5 step 2 water flowing around packer.

Test #, Packer Pressure, Material	Inclined Packer Test Interval (ft)		Vertical Packer Test Interval (ft)		Packer Test Length, inclined	Total Applied Pressure	Pressure Losses	Adjusted Applied Pressure	Applied Pressure Head	Gravity Head	Total Head	Water Take	Shape Factor	Hydraulic Conductivity		
	Start	End	Start	End	(ft)	(psi)	(psi)	(psi)	(ft)	(ft)	(ft)	(gpm)		(ft/yr)	(cm/s)	Lugeon
a	b	c	d	e	L	pgage or pvw	ploss	pactual	hp	hg	htotal	Q	Cp	k	km	kL
5	68	78	68.0	78.0	10	35		34.63	80.0		80.0	18.6	4630	1077	1.04E-03	80
300 psi	68	78	68.0	78.0	10	39		38.96	90.0		90.0	29.6	4630	1523	1.47E-03	113
Limestone	68	78	68.0	78.0	10	35		34.63	80.0		80.0	20.1	4630	1163	1.12E-03	86
6	78	88	78.0	88.0	10	41		41.13	95.0		95.0	2.0	4630	97	9.42E-05	7
300 psi	78	88	78.0	88.0	10	64		64.07	148.0		148.0	7.8	4630	245	2.37E-04	18
Limestone	78	88	78.0	88.0	10	73		72.73	168.0		168.0	16.8	4630	463	4.48E-04	34
	78	88	78.0	88.0	10	44		43.72	101.0		101.0	3.6	4630	163	1.58E-04	12
7	88	100	88.0	100.0	12	63		63.20	146.0		146.0	1.6	4028	44	4.27E-05	3
300 psi	88	100	88.0	100.0	12	77		77.49	179.0		179.0	2.3	4028	53	5.09E-05	4
Limestone	88	100	88.0	100.0	12	95		95.24	220.0		220.0	3.9	4028	71	6.90E-05	5
	88	100	88.0	100.0	12	68		68.40	158.0		158.0	2.3	4028	58	5.57E-05	4

a = Test #, Packer pressure, Material
b = Packer tip
c = Bottom of test hole
d = b*cos(inclination)
e = c*cos(inclination)
L = c-b

p_{gage} = Pressure gage
p_{loss} = Pressure losses from charts
$p_{actual} = p_{gage} - p_{loss}$
$h_p = p_{actual}*2.31$
h_g = Smaller of water depth or mid-packer
$h_{total} = h_p + h_g$

If L >= 10r, $C_p = 1/(2\pi L)*\ln(L/r)*70309$
If r<L<10r, $C_p = 1/(2\pi L)*\sinh^{-1}(L/2r)*70309$
70309 is unit conversion from gpm/ft² to ft/yr
$k = C_p*Q/h_{total}$
$k_m = k*9.6651E-7$

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Table 2-2 Core Hole Packer Permeability Test Results
Temple Fork Site TH-TF-02

Project Name	Bear River	Inclination (degrees)	30	Tested by	R. Buhler
Project Location	Temple Fork	Distance to Water (ft)	10	Date	May-15
Project Number	13GCI329	Vertical Depth to Water (ft)	8.7	Reviewed by	P. Gerhart
Test Hole No.	TH-TF-02 Sheet 1 of 1	Hole Diameter = 2*r (in)	3.83	Date	Nov-15

Notes: All tests the pressures were measured with the vibrating wire pressure tranducer in the test zone

Test #, Packer Pressure, Material	Inclined Packer Test Interval (ft)		Vertical Packer Test Interval (ft)		Packer Test Length, inclined	Total Applied Pressure	Adjusted Applied Pressure	Applied Pressure Head	Total Head	Water Take	Shape Factor	Hydraulic Conductivity		
	Start	End	Start	End	(ft)	(psi)	(psi)	(ft)	(ft)	(gpm)		(ft/yr)	(cm/s)	(Lugeon)
a	b	c	d	e	L	pgage	pactual	hp	htotal	Q	Cp	k	km	kL
1	35.8	45.8	31.0	39.7	10	24.24242	24.2	56.0	56.0	1.2	4630	101	9.75E-05	7
350 psi	35.8	45.8	31.0	39.7	10	29.43723	29.4	68.0	68.0	1.4	4630	94	9.08E-05	7
Limestone	35.8	45.8	38.0	48.0	10	39.82684	39.8	92.0	92.0	1.8	4630	91	8.76E-05	7
	35.8	45.8	38.0	48.0	10	29.43723	29.4	68.0	68.0	1.4	4630	98	9.48E-05	7
2	45.8	55.8	39.7	48.3	10	25.10823	25.1	58.0	58.0	4.4	4630	348	3.36E-04	26
340 psi	45.8	55.8	39.7	48.3	10	33.76623	33.8	78.0	78.0	7.2	4630	426	4.12E-04	32
Limestone	45.8	55.8	38.0	48.0	10	45.02165	45.0	104.0	104.0	10.4	4630	462	4.47E-04	34
	45.8	55.8	38.0	48.0	10	29.43723	29.4	68.0	68.0	6.9	4630	470	4.54E-04	35

a = Test #, Packer pressure, Material

b = Packer tip

c = Bottom of test hole

d = b*cos(inclination)

e = c*cos(inclination)

L = c-b

p_{vw} = Pressure head in vibrating wire piezometer

$p_{actual} = p_{vw}$

$h_p = p_{actual}*2.31$

$h_{total} = h_p$

L = c-b

$h_{total} = h_p + h_g$

If L >= 10r, $C_p = 1/(2\pi L)*\ln(L/r)*70309$

If r<L<10r, $C_p = 1/(2\pi L)*\sinh^{-1}(L/2r)*70309$

70309 is unit conversion from gpm/ft^2 to ft/yr

$k = C_p*Q/h_{total}$

$k_m = k*9.6651E-7$

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Table 2-2 - Core Hole Packer Permeability Test Results
Temple Fork Site TH-TF-03

Project Name	Bear River	Inclination (degrees)	30	Tested by	R. Buhler
Project Location	Temple Fork	Distance to Water (ft)	10	Date	May-15
Project Number	13GCI329	Vertical Depth to Water (ft)	8.7	Reviewed by	P. Gerhart
Test Hole No.	TH-TF-03 Sheet 1 of 1	Hole Diameter = 2*r (in)	3.83	Date	Nov-15

Notes: All tests the pressures were measured with the vibrating wire pressure tranducer in the test zone

Test #, Packer Pressure, Material	Inclined Packer Test Interval (ft)		Vertical Packer Test Interval (ft)		Packer Test Length, inclined	Total Applied Pressure	Adjusted Applied Pressure	Applied Pressure Head	Total Head	Water Take	Shape Factor	Hydraulic Conductivity		
	Start	End	Start	End	(ft)	(psi)	(psi)	(ft)	(ft)	(gpm)		(ft/yr)	(cm/s)	(Lugeon)
a	b	c	d	e	L	p_{vw}	pactual	hp	htotal	Q	Cp	k	km	kL
1	35.8	45.8	31.0	39.7	10	17.74892	17.7	41.0	41.0	8.8	4630	989	9.56E-04	74
350 psi	35.8	45.8	31.0	39.7	10	25.10823	25.1	58.0	58.0	10.1	4630	806	7.79E-04	60
Limestone	35.8	45.8	38.0	48.0	10	32.25108	32.3	74.5	74.5	12.1	4630	752	7.27E-04	56
	35.8	45.8	38.0	48.0	10	21.64502	21.6	50.0	50.0	6.6	4630	611	5.91E-04	45
2	55.8	65.8	48.3	57.0	10	32.90043	32.9	76.0	76.0	0.6	4630	34	3.30E-05	3
350 psi	55.8	65.8	48.3	57.0	10	43.07359	43.1	99.5	99.5	0.7	4630	32	3.06E-05	2
Limestone	55.8	65.8	38.0	48.0	10	56.27706	56.3	130.0	130.0	1.2	4630	43	4.13E-05	3
	55.8	65.8	38.0	48.0	10	40.04329	40.0	92.5	92.5	1.1	4630	53	5.13E-05	4
3	65.8	75.8	57.0	65.6	10	38.7	38.7	89.3	89.3	0.5	4630	27	2.61E-05	2
350 psi	65.8	75.8	57.0	65.6	10	48.7	48.7	112.5	112.5	0.7	4630	29	2.78E-05	2
Limestone	65.8	75.8	57.0	65.6	10	64.3	64.3	148.5	148.5	0.9	4630	29	2.77E-05	2
	65.8	75.8	48.0	58.0	10	47.8	47.8	110.5	110.5	0.6	4630	23	2.27E-05	2
4	75.8	85.8	65.6	74.3	10	45.3	45.3	104.6	104.6	4.2	4630	186	1.80E-04	14
350 psi	75.8	85.8	65.6	74.3	10	60.2	60.2	139.0	139	6.0	4630	199	1.93E-04	15
Limestone	75.8	85.8	58.0	68.0	10	71.0	71.0	164.0	164	7.0	4630	198	1.91E-04	15
	75.8	85.8	58.0	68.0	10	53.7	53.7	124.0	124	4.6	4630	172	1.66E-04	13
5	85.8	95.8	74.3	83.0	10	51.9	51.9	120.0	120	1.9	4630	73	7.09E-05	5
350 psi	85.8	95.8	74.3	83.0	10	66.5	66.5	153.7	153.7	2.9	4630	87	8.44E-05	6
Limestone	85.8	95.8	74.3	83.0	10	76.4	76.4	176.5	176.5	3.5	4630	93	8.98E-05	7
	85.8	95.8	68.0	78.0	10	62.3	62.3	144.0	144	2.7	4630	86	8.27E-05	6

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Table 2-2 - Core Hole Packer Permeability Test Results
Temple Fork Site TH-TF-03

Project Name	Bear River	Inclination (degrees)	30	Tested by	R. Buhler
Project Location	Temple Fork	Distance to Water (ft)	10	Date	May-15
Project Number	13GCI329	Vertical Depth to Water (ft)	8.7	Reviewed by	P. Gerhart
Test Hole No.	TH-TF-03 Sheet 1 of 1	Hole Diameter = 2*r (in)	3.83	Date	Nov-15

Notes: All tests the pressures were measured with the vibrating wire pressure tranducer in the test zone

Test #, Packer Pressure, Material	Inclined Packer Test Interval (ft)		Vertical Packer Test Interval (ft)		Packer Test Length, inclined	Total Applied Pressure	Adjusted Applied Pressure	Applied Pressure Head	Total Head	Water Take	Shape Factor	Hydraulic Conductivity		
	Start	End	Start	End	(ft)	(psi)	(psi)	(ft)	(ft)	(gpm)		(ft/yr)	(cm/s)	(Lugeon)
a	b	c	d	e	L	p_{vw}	pactual	hp	htotal	Q	Cp	k	km	kL
6	95.8	105.8	83.0	91.6	10	49.8	49.8	115.0	115	6.5	4630	262	2.53E-04	19
350 psi	95.8	105.8	83.0	91.6	10	58.1	58.1	134.2	134.2	7.0	4630	240	2.32E-04	18
Limestone	95.8	105.8	78.0	88.0	10	67.1	67.1	154.9	154.9	8.7	4630	261	2.53E-04	19
	95.8	105.8	78.0	88.0	10	57.8	57.8	133.5	133.5	6.0	4630	208	2.01E-04	15
7	105.8	115.8	88.0	100.0	10	44.2	44.2	102.0	102	0.1	4630	5	4.39E-06	0
350 psi	105.8	115.8	88.0	100.0	10	73.6	73.6	170.0	170	0.2	4630	6	5.79E-06	0
Limestone	105.8	115.8	88.0	100.0	10	89.2	89.2	206.0	206	0.4	4630	9	8.69E-06	1
	105.8	115.8	88.0	100.0	10	74.0	74.0	171.0	171	0.3	4630	9	8.37E-06	1
8	115.8	125.8	88.0	100.0	10	60.6	60.6	140.0	140	1.6	4630	53	5.11E-05	4
350 psi	115.8	125.8	88.0	100.0	10	77.9	77.9	180.0	180	2.5	4630	65	6.27E-05	5
Limestone	115.8	125.8	88.0	100.0	10	98.7	98.7	228.0	228	3.3	4630	66	6.40E-05	5
	115.8	125.8	88.0	100.0	10	79.7	79.7	184.0	184	2.5	4630	62	6.03E-05	5
9	125.8	135.8	88.0	100.0	10	56.7	56.7	131.0	131	1.5	4630	54	5.26E-05	4
350 psi	125.8	135.8	88.0	100.0	10	77.9	77.9	180.0	180	2.0	4630	50	4.87E-05	4
Limestone	125.8	135.8	88.0	100.0	10	96.5	96.5	223.0	223	2.6	4630	54	5.22E-05	4
	125.8	135.8	88.0	100.0	10	77.9	77.9	180.0	180	2.1	4630	54	5.17E-05	4
10	135.8	150.3	88.0	100.0	14.5	46.3	46.3	107.0	107	16.9	3480	550	5.31E-04	41
400 psi	135.8	150.3	88.0	100.0	14.5	73.6	73.6	170.0	170	25.3	3480	518	5.01E-04	39
Limestone	135.8	150.3	88.0	100.0	14.5	52.8	52.8	122.0	122	9.4	3480	268	2.59E-04	20

a = Test #, Packer pressure, Material

b = Packer tip

c = Bottom of test hole

d = b*cos(inclination)

e = c*cos(inclination)

p_{vw} = Pressure head in vibrating wire piezometer

$p_{actual} = p_{vw}$

$h_p = p_{actual}*2.31$

$h_{total} = h_p$

L = c-b

If L >= 10r, $C_p = 1/(2\pi L)*\ln(L/r)*70309$

If r<L<10r, $C_p = 1/(2\pi L)*\sinh^{-1}(L/2r)*70309$

70309 is unit conversion from gpm/ft^2 to ft/yr

$k = C_p*Q/h_{total}$

$k_m = k*9.6651E-7$

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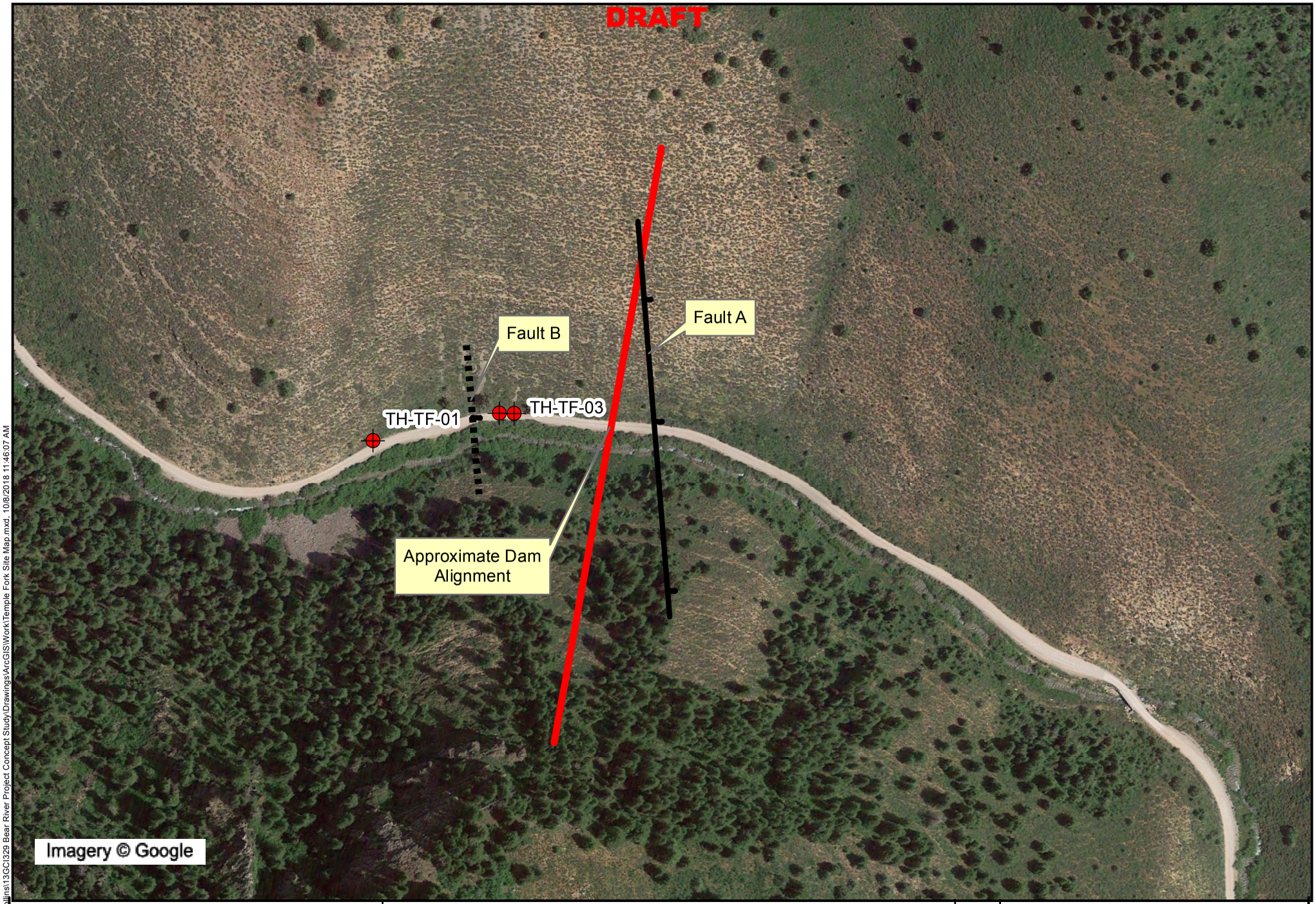
Table 2-3 - Temple Fork - Groundwater Measurements

Bear River Concept Study - Temple Fork

Date	Groundwater Depth in Piezometer (ft)
	TH-TF-01
May 27, 2015	4.8
June 19, 2015	5.8
October 1, 2015	6.8



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Bear River Project Concept Study - Temple Fork

Temple Fork - Site and Exploration Map

N

0 100 200 400 Feet

Figure 2-1

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3.1 GENERAL SETTING

The proposed site is located in the Bear River Range at the eastern margin of the Basin and Range Physiographic Province, a region characterized by a series of generally north-trending mountain ranges separated by similarly trending valleys, and the Middle Rocky Mountains Physiographic Province, an area characterized in this region by folded and faulted Precambrian- to Tertiary-age sedimentary rocks. Bear River Range contains small- to moderate-sized back valleys that formed by movement along north-striking normal faults (Gilbert, 1928). Large-scale topographic features are a result of east-west crustal extension and normal faulting that began about 15 to 17 million years ago, and continues today (Hecker, 1993).

3.2 BEDROCK STRATIGRAPHY

The most detailed published geologic mapping completed in the vicinity of the proposed site is at a scale of 1:100,000 (Dover, 1995). Bedrock at the proposed site has been mapped by Dover as Middle and Lower Ordovician Garden City Formation (Og), consisting of gray, thin-bedded, slabby limestone and argillaceous limestone characterized by intraformational limestone conglomerate and breccia (Figure 3-1a). The Garden City formation varies in thickness from about 1,200 to 1,700 feet.

In addition to the Garden City Formation, Dover (1995) has mapped the following surficial and bedrock units within the reservoir basin (Figure 3-1a):

- Stream alluvium and fan deposits consisting of unconsolidated, crudely stratified, clay- to boulder-size material deposited in tributary stream channels and alluvial fans; includes terrace deposits colluvium, talus, or lake deposits (Holocene and Pleistocene).
- Paleozoic rocks, undivided (Pzu), mapped by Dover; not examined in the field, but near and on trend with known Paleozoic rocks. Likely the Fish Haven Dolomite, Swan Peak Quartzite, Garden City Formation and/or the St. Charles Formation (Silurian to Ordovician).
- Wasatch Formation (Tw) consisting of reddish, crudely stratified, poorly sorted, conglomerate and siltstone, with interbeds of limestone and marl (Tertiary).
- Fish Haven Dolomite (SOf) consisting of dark gray, medium-bedded, medium-grained bioclastic dolostone (Lower Silurian and Upper Ordovician).
- Swan Peak Quartzite (Os) consisting of white to tan, fine- to medium-grained, well sorted, fucoidal quartzite or quartz sandstone, with a lower unit consisting of black shale and thin quartzite and limestone interbeds (Ordovician).

3.3 GEOLOGIC STRUCTURE

Geologic structure of the Bear River Range in the vicinity of the proposed site is related to two regional tectonic events: 1) thrust faulting and folding associated with compressional tectonics related to the Sevier orogeny, and 2) later normal faulting associated with Basin and Range extensional tectonics (Brummer and McCalpin, 1995). During the Cretaceous-age Sevier orogeny, Precambrian and Paleozoic rocks, now exposed in the Bear River Range, were folded and thrust eastward approximately 65

miles from their original deposition site (Levy and Christie-Blick, 1989). In the vicinity of the proposed site, these rocks are in the hanging wall (upper block) of the low-angle Paris thrust sheet (Figure 3-2).

Beginning in the Tertiary, and continuing today, the area is experiencing basin-and-range-style extensional tectonism. As a result of this extensional tectonics, the area is characterized by numerous high-angle normal faults with down-to-the-west displacement, and corresponding high-angle, normal, down-to-the east displacement antithetic faults.

The proposed site is located on the western flank of the Temple Fork Graben (Figures 3-1a and 3-2). Dover (1995) maps the Temple Fork Graben as bounded on the east by the north-trending, down-to-the west, normal Temple Ridge fault, and on the west by two to three, generally north-trending unnamed down-to-the-east, normal faults that are antithetic to the Temple Ridge fault. In the central part of the Bear River Range (near the proposed site), the Temple Ridge fault is approximately 12 miles long and consists of a single strand (Evans, 1991). Displacement along the fault is approximately 2,460 feet, and the fault dips 75^0 to 80^0 to the west at the surface (Evans and Oaks, 1990).

3.4 SITE-SPECIFIC GEOLOGY

Surficial materials at the toe of the slope on the right abutment were obtained from TH-TF-01. These materials consisted of soft, low plasticity, gravelly and sandy silt, and medium dense to loose, sandy and silty gravel (Appendix A). The thickness of the unconsolidated materials overlying bedrock was approximately 21 to 22 feet at the location of the Temple Fork Road.

The slopes of both abutments at the proposed site consist of steep-to-vertical slopes of the Garden City Formation with intermittent cover of colluvium and talus. Vertical cliffs of limestone range from a few feet to approximately 10 feet in height on both abutments.

Bedrock consisted of slabby, gray, very thickly to thinly bedded, slightly weathered to fresh, hard limestone with a few interbeds of gray, very thinly bedded, slightly weathered to fresh, silty and clayey limestone and occasional intraformational limestone conglomerate/breccia. The orientation of the bedding was measured at seven locations; dip azimuth averages 248 degrees, and dip magnitude averages 9 degrees.

Additional characterization of the bedrock on the right abutment was conducted in order to gather data relevant to rock strength and stability. Data on 77 individual discontinuities were collected along two transects (100 feet and 130 feet in length) following the methodology of the U.S. Bureau of Reclamation (2001). Orientations, spacing, roughness, condition/alteration, aperture, and infill material were recorded for each discontinuity (Appendix C) Stereonet plots of measured discontinuities and bedding planes showing major planes and poles (lower hemisphere, equal area) were prepared with RocScience Dips 7.0 (Figures 3.3).

Preliminary analysis of the discontinuity data indicates that there are two prominent joint sets. The joints are generally continuous over lengths of 3.0 to 10.0 feet, however, because the outcrop was generally less than 10 feet, no ends or only one end were visible. Joint surfaces are planar and generally moderately to slightly rough; dry with no

visible evidence of water; hard; moderately to slightly weathered; moderately open to open (< 3/8 inch); and have moderately thin to thin (< 3/8 inch) filling.

Joint sets JS1 and JS2 are nearly orthogonal to the orientation of the bedding fractures (Figure 3.3). This produces a blocky structure of interlocked, partially disturbed mass of angular blocks.

Bedrock recovered from test holes consisted of predominantly gray, thinly to very thinly bedded, limestone and silty limestone, with interbeds of reddish brown calcareous siltstone and beds of reddish brown to gray, thinly to very thinly bedded, calcareous siltstone of the Garden City Formation. Recovery in TH-TF-01, was between 95 and 100 percent; RQD was generally between 68 and 100 percent, with two runs of 43 and 50 percent; bedrock was generally between slightly fractured and moderately fractured, with a few zones intensely fractured; fresh; and moderately hard. Recovery In TH-TF-02, was between 95 and 100 percent; RQD was generally between 78 and 100 percent, with two runs of 0 and 56 percent; bedrock was generally between slightly fractured and moderately fractured, with one zone very intensely fractured; fresh, and one zone moderately weathered; and moderately hard. Recovery in TH-TF-03, was generally between 90 and 100 percent, with two runs of 50 and 58 percent; RQD was generally between 65 and 100 percent, with two runs of 18 and 20 percent; bedrock was generally between slightly fractured and moderately fractured, with two zones very intensely fractured; fresh, with one zone moderately weathered; and moderately hard.

One fault (Fault A on Figure 2-1) is present near the axis of the original dam location. Fault A offsets a prominent bed on the Garden City Formation on both abutments. Preliminary mapping indicates that the fault trends N10^{0}W and has approximately 20 feet of normal down-to-the-east displacement on the right abutment and approximately 10 feet of normal, down-to-the-east displacement on the left abutment. Fault A is located about 1,000 feet west of the unnamed east-dipping normal fault mapped by Dover (1995) on the west side of the Temple Fork Graben. We believe that Fault A, which is north trending and east dipping, is a previously unmapped normal fault on the western margin of the Temple Fork Graben.

A second fault (Fault B on Figure 2-1) has been tentatively recognized in the angle test holes. In TH-TF-02 at a depth of 52.5 to 53.0 feet is a zone of intensely fractured limestone with light brown to yellowish gray clay and iron oxides that we interpret to be fault gouge. In addition, one piece of the fractured core recovered in this interval contained slickensides. RQD in this interval was 0 percent. In TH-TF-03 at a depth 78.5 to 79.5 is a zone of intensely fractured limestone with light brown to yellowish gray, thinly bedded, clay and iron oxides. Recovery in this interval was 58 percent and the RQD was 18 percent. Given the location and orientation of the angle holes, and the depths of the fault zones, Fault B is dipping between about 70 and 75 degrees to the east. Although we do not know the sense of displacement, given this steep angle, it is likely a normal fault, and related to the nearby east-dipping normal faults on the west margin of the Temple Fork Graben.

3.5 GEOLOGIC HAZARDS

3.5.1 Surface Fault Rupture

The project site is located immediately west of the Temple Fork Graben, which is bounded on the east by the Temple Ridge fault (Dover, 1995). Black and Hecker (1999) report that faults in the Bear River Range are poorly understood, Quaternary faults and that the Temple Ridge fault is the likely source for the 1962 Ms 5.7 Cache Valley (Logan or Richmond) earthquake.

There have been no paleoseismic investigations conducted along the Bear River Range faults (Lund, 2005). As such, the age of most recent surface rupture is unknown. Black and Hecker (1999) estimate the late Quaternary slip rate to be less than 0.2 mm/yr.

The Utah Administrative Code (R655-10-4) defines an "ACTIVE FAULT is a fault that has exhibited one or more of the following characteristics:

(a) movement at or near the ground surface at least once in the last 35,000 years;

(b) instrumentally determined seismicity that demonstrates a causal relationship with the fault;

(c) structural relationship to an active fault such that movement on one fault could be expected to cause movement on the other."

Based on the available information provided by Westaway and Smith (1989), Evans (1991), Dover (1995), and Black and Hecker (1999), we consider the Temple Ridge fault as the likely source of the 1962 Cache Valley earthquake and therefore active. Because of the structural relationship between the Temple Ridge fault and the antithetic faults on the east margin of the Temple Fork Graben, we consider the antithetic faults – those mapped by Dover (1995) and Faults A and B identified at the proposed dam sites – active as well.

At this time, we do not have information on the displacement history of Faults A and B other than they offset beds within the Garden City formation. Additional studies might provide information on late-Pleistocene or Holocene surface rupture history.

3.5.2 Landslides

We observed that no evidence exists for landslides (scarps, displaced material, hummocky topography, internal drainage) at the abutments for the proposed dam sites. However, within the reservoir basin, Elliott and Harty (2010) have mapped five deep or unclassified landslides that would be in contact with the reservoir (red areas on Figure 3-4). These landslides are described as generally 10 feet or more in thickness, show characteristic landslide morphology, and include areas of complex or composite landsliding. In addition, significant portions of the hill slopes within the reservoir basin are mapped as landslide undifferentiated from talus, colluvial, rock-fall, glacial, and soil creep deposits (brown areas on Figure 3-5).

The existing landsides and slopes that will be in contact with the proposed reservoir are potentially unstable, and could likely experience additional landsliding as a result of undercutting by wave action. Furthermore, fluctuating reservoir levels could create saturated zones in the landslide and/or unconsolidated materials adjacent to the reservoir and thereby reduce the slope stability.

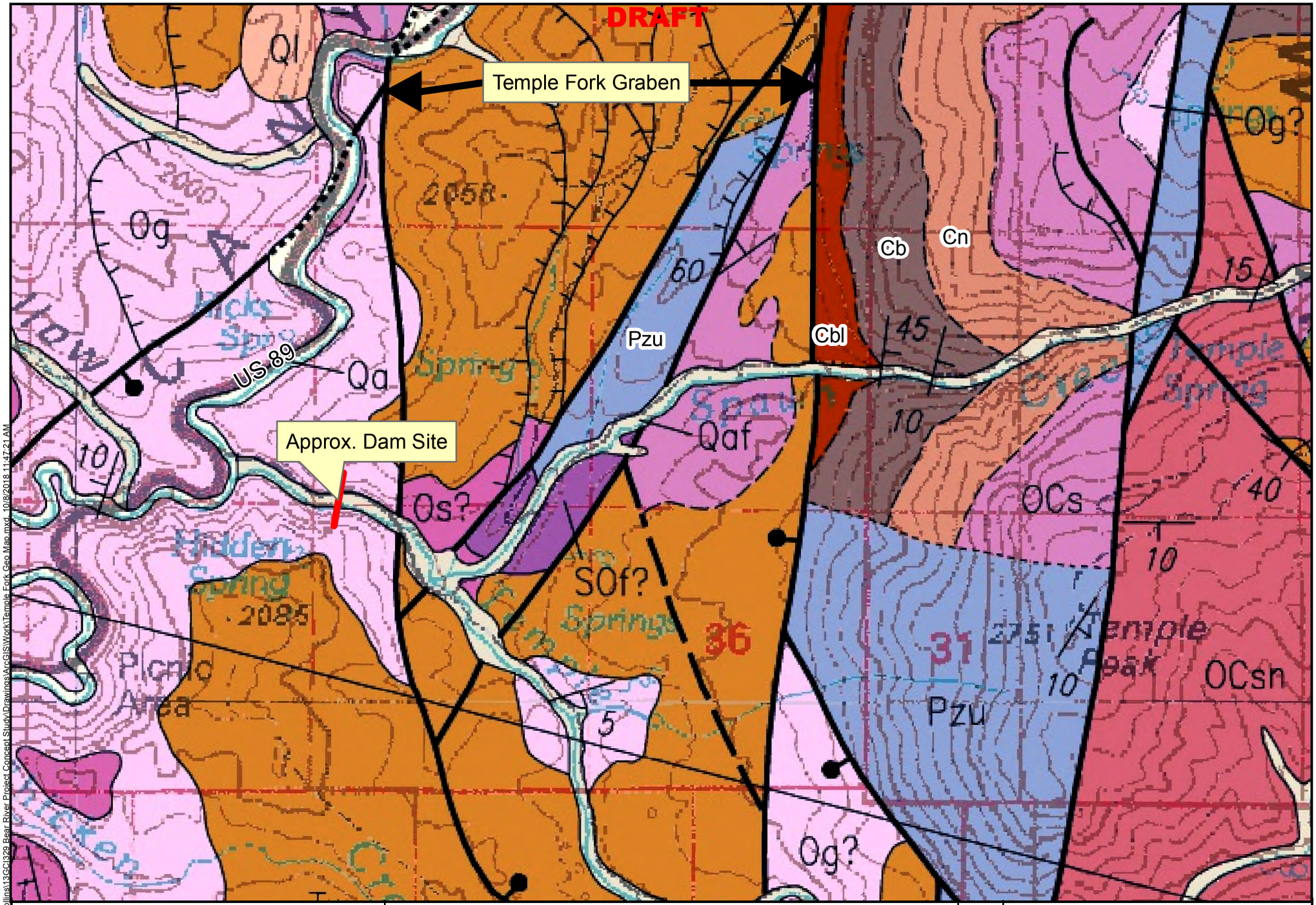
3.5.3 Solution Cavities

The Garden City Formation and other carbonate rocks in the Logan Canyon area of the Bear River Range are known to contain karst features such as springs, losing streams, caves and pits, solution caverns, blind valleys, and sinkholes (Spangler, 2001). We did not observe karst features in the Garden City Formation near the proposed site, but much of the surface is covered with colluvium. We examined the Garden City Formation outcrops further to the west in Logan Canyon and did observe a few caves and possible solution features related to karst processes. South and west of the proposed site, on the west side of Logan Canyon, Spangler (2001) documents discharge from springs in the lower Paleozoic carbonate rocks (including the Garden City Formation) ranging between about 1 to 75 cubic feet per second. Two large springs discharge from caves developed in joints and faults within the Garden City Formation.

Solution cavities, if present, could pose a potential hazard to foundation the dam. Further investigations of the dam site are necessary to determine if solution cavities are present and what measures could be taken to mitigate the impact on the dam.

3.5.4 Rock Falls

The slopes of the abutments and immediately upstream of the dam site are steep with interspersed vertical faces of fractured bedrock. These slopes are potential sources for rock falls that could pose a hazard during construction and along any roads constructed around the reservoir. In addition, depending on the size of the rock fall, there could be a hazard from rocks falling into the reservoir and displacing water of significant enough volume that waves impact the dam.



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Bear River Project Concept Study - Temple Fork

Temple Fork Geologic Map (Modified from: Dover, 1995)
Orginal Scale 1:100,000

N

0 1,150 2,300 4,600 Feet

Figure 3-1a

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Qa — **Main-stream alluvium (Holocene)**—Unconsolidated, crudely stratified, clay- to boulder-size material deposited in channels and flood plains of major streams, including Bear, Little Bear, and Logan Rivers, and Blacksmith Fork; locally includes alluvial-fan and terrace deposits, colluvium, talus, or lake deposits. Contacts with side-stream alluvium (unit Qaf) are gradational and arbitrarily drawn in places. Thickness generally a few meters or less

Tw — **Wasatch Formation (middle and lower Eocene)**—Red, pale-red, and reddish-buff, crudely stratified, poorly sorted grit, conglomerate, and siltstone; locally includes interbeds of lacustrine pisolitic limestone and marl. Some interbeds of conglomerate are gray and contain mainly well-rounded pebbles and cobbles of Paleozoic carbonate rocks. Characterized by abrupt facies changes and interfingering of lithic types. Maximum thickness is a few hundred meters in areas east of Bear Lake and west of Randolph, Utah

SOf — **Fish Haven Dolomite (Lower Silurian and Upper Ordovician)**—Dark-gray, medium-bedded, medium-grained, bioclastic dolostone. Thickness 60–75 m

Ob — **Bighorn Dolomite (Upper and Middle Ordovician)**—Light-gray, generally massive, sugary-textured dolostone and dolomitic limestone. Thickness 236 m of equivalent rocks in Crawford Mountains (Ott, 1980)

Os — **Swan Peak Quartzite (Middle Ordovician)**—Mainly white to pale-reddish-tan, fine- to medium-grained, well-sorted, fucoidal quartzite or quartz sandstone having well-rounded grains; lower unit of black shale has thin quartzite and sandy limestone interbeds present locally. Thickness varies from 0 to 150 m (Oaks and others, 1977); unit thins southeastward across Bear River Range and is generally absent in southeast half of map area

Og — **Garden City Formation (Middle and Lower Ordovician)**—Mainly gray, thin-bedded, slabby limestone and argillaceous limestone characterized by intraformational limestone conglomerate and breccia; upper 70 m typically dolomitic and cherty (shown by dotted line on map). Thickness 370–520 m (Ross, 1951)

OCs — **St. Charles Formation (Lower Ordovician and Upper Cambrian)**—Gray to dark-gray, mottled, thin-bedded to massive, algal-mat dolostone, dolomitic limestone, and limestone in upper member; basal Worm Creek Quartzite Member mapped separately in most places. Estimated thickness 300–400 m

Csw — **Worm Creek Quartzite Member(Upper Cambrian)**—Gray to tan, medium-bedded, fine- to medium-grained quartzite and quartz sandstone; poorly exposed in most places.Thickness 2–125 m (Williams, 1948)

OCn — **St. Charles Formation (Lower Ordovician and Upper Cambrian) and Nounan Dolomite (Upper and Middle Cambrian), undivided**

Pzu — **Paleozoic rocks, undivided**—Mapped in central and southwestern parts of map area; not examined in the field, but near and on trend with known Paleozoic rocks

Cb — **Bloomington Formation (Middle Cambrian)**—Interbedded gray, thin-bedded limestone and olive-tan shale and siltstone. Minimum thickness 300 m; deformation and solution collapse complicate thickness estimates in places

Cbl — **Blacksmith Dolomite (Middle Cambrian)**—Gray, cliff-forming, thick-bedded, fine-grained, locally oolitic dolostone and subordinate silty dolostone, dolomitic limestone, and limestone. Thickness 100–215 m (Williams, 1948)

Cu — **Ute Formation (Middle Cambrian)**—Interbedded gray, thin-bedded, typically oolitic, silty limestone and limestone breccia and citrine shale. Thickness 200–300 m

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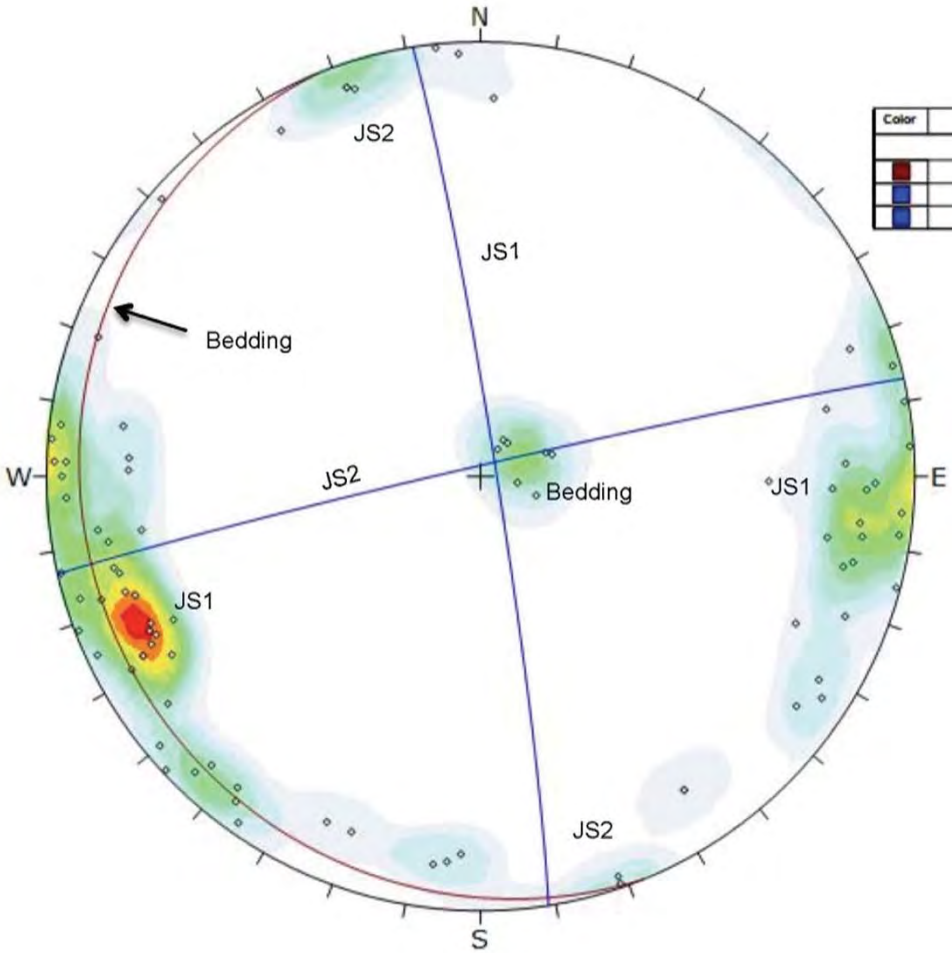

Color	Dip	Dip Direction	Label
Mean Set Planes			
	9	248	Bedding
	87	81	JS1
	88	347	JS2

Stereonet Plot of Measured (major planes and poles; lower hemisphere, equal area), Right Abutment

Bear River Project Concept Study
Temple Fork

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Figure 3-3

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Table 2-1 Laboratory Test Result Summary

Bear River Project Concept Study- Temple Fork (13GCI329)

Test Hole	Depth (ft)	Moisture content (%)	Dry unit weight (pcf)	Moist / Sat. unit weight (pcf)	Atterberg Limits					Grain-Size			Grain-Size Analysis (Percent Finer)										Other Tests (Interpretative Data in Appendix)
					LL (%)	PL (%)	PI (%)	Cohesive Index, CI	Liquidity Index, LI	GRAVEL (No.4 - 3")	SAND (No.200-No.4)	FINES (<No.200)	1.5-in (37.5 mm)	3/4-in (19 mm)	3/8-in (9.5 mm)	No.4 (4.75 mm)	No.10 (2 mm)	No.20 (0.85 mm)	No.40 (0.425 mm)	No.60 (0.25 mm)	No.100 (0.15 mm)	No.200 (0.075 mm)	
TH-TF-01	5-6.5	23.4			41	23	18	0.78	0.0	27	20	53	100	100	80	73	69	65	61	59	56	53	
TH-TF-01	11-12.5	5.4								76	18	6	100	75	43	24	13	9	8	7	7	6	
TH-TF-01	15-17	9.4								50	22	28	100	72	58	50	41	34	32	30	29	28	
TH-TF-01	23-24																						Point Load Test = 1195 psi
TH-TF-01	40-41																						Point Load Test = 563 psi
TH-TF-01	72-73																						Point Load Test = 566 psi
TH-TF-01	92-93																						Point Load Test = 708 psi
TH-TF-02	26-27																						Point Load Test = 516 psi
TH-TF-02	46-47																						Point Load Test = 879 psi
TH-TF-03	32-33																						Point Load Test = 444 psi
TH-TF-03	54-55																						Point Load Test = 2306 psi
TH-TF-03	72-73																						Point Load Test = 995 psi
TH-TF-03	97-98																						Point Load Test = 957 psi
TH-TF-03	120-121																						Point Load Test = 1239 psi
TH-TF-03	148-149																						Point Load Test = 1096 psi

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Table 2-2 - Core Hole Packer Permeability Test Results
Temple Fork Site TH-TF-01

Project Name	Bear River	Inclination (degrees)	0	Tested by	R. Buhler
Project Location	Temple Fork	Distance to Water (ft)	5	Date	May-15
Project Number	13GCI329	Vertical Depth to Water (ft)	5.0	Reviewed by	P. Gerhart
Test Hole No.	TH-TF-01 Sheet 1 of 1	Hole Diameter = 2*r (in)	3.83	Date	Nov-15

Notes: Test #3 through #6 the pressures were measured with the vibrating wire pressure tranducer in the test zone
Test #3 step 2 and Test #5 step 2 water flowing around packer.

Test #, Packer Pressure, Material	Inclined Packer Test Interval (ft)		Vertical Packer Test Interval (ft)		Packer Test Length, inclined	Total Applied Pressure	Pressure Losses	Adjusted Applied Pressure	Applied Pressure Head	Gravity Head	Total Head	Water Take	Shape Factor	Hydraulic Conductivity		
	Start	End	Start	End	(ft)	(psi)	(psi)	(psi)	(ft)	(ft)	(ft)	(gpm)		(ft/yr)	(cm/s)	Lugeon
a	b	c	d	e	L	pgage or pvw	ploss	pactual	hp	hg	htotal	Q	Cp	k	km	kL
1	28	38	28.0	38.0	10	16	3.5	12.50	28.9	5.0	33.9	7.6	4630	1033	9.99E-04	77
280 psi	28	38	28.0	38.0	10	32	8.5	23.50	54.3	5.0	59.3	18.8	4630	1468	1.42E-03	109
Limestone	28	38	38.0	48.0	10	16	4.5	11.50	26.6	5.0	31.6	9.8	4630	1432	1.38E-03	106
2	38	48	38.0	48.0	10	22	3.3	18.70	43.2	5.0	48.2	3.2	4630	309	2.99E-04	23
290 psi	38	48	38.0	48.0	10	34	3.3	30.70	70.9	5.0	75.9	4.2	4630	256	2.48E-04	19
Limestone	38	48	38.0	48.0	10	48	3.3	44.70	103.3	5.0	108.3	5.3	4630	227	2.19E-04	17
	38	48	38.0	48.0	10	32	3.3	28.70	66.3	5.0	71.3	3.2	4630	210	2.03E-04	16
	38	48	38.0	48.0	10	20	3.3	16.70	38.6	5.0	43.6	2.4	4630	259	2.51E-04	19
3	48	58	48.0	58.0	10	25		25.11	58.0		58.0	9.3	4630	742	7.18E-04	55
300 psi	48	58	48.0	58.0	10	62		62.47	144.3		144.3	20.0	4630	642	6.20E-04	48
Limestone	48	58	48.0	58.0	10	14		13.85	32.0		32.0	4.9	4630	706	6.82E-04	52
4	58	68	58.0	68.0	10	56		55.84	129.0		129.0	7.4	4630	266	2.57E-04	20
300 psi	58	68	58.0	68.0	10	76		76.19	176.0		176.0	4.9	4630	128	1.24E-04	10
Limestone	58	68	58.0	68.0	10	88		87.88	203.0		203.0	14.5	4630	331	3.20E-04	25
	58	68	58.0	68.0	10	45		45.02	104.0		104.0	5.8	4630	258	2.50E-04	19

Table 2-2 - Core Hole Packer Permeability Test Results
Temple Fork Site TH-TF-01

Project Name	Bear River	Inclination (degrees)	0	Tested by	R. Buhler
Project Location	Temple Fork	Distance to Water (ft)	5	Date	May-15
Project Number	13GCI329	Vertical Depth to Water (ft)	5.0	Reviewed by	P. Gerhart
Test Hole No.	TH-TF-01 Sheet 1 of 1	Hole Diameter = 2*r (in)	3.83	Date	Nov-15

Notes: Test #3 through #6 the pressures were measured with the vibrating wire pressure tranducer in the test zone
Test #3 step 2 and Test #5 step 2 water flowing around packer.

Test #, Packer Pressure, Material	Inclined Packer Test Interval (ft)		Vertical Packer Test Interval (ft)		Packer Test Length, inclined	Total Applied Pressure	Pressure Losses	Adjusted Applied Pressure	Applied Pressure Head	Gravity Head	Total Head	Water Take	Shape Factor	Hydraulic Conductivity		
	Start	End	Start	End	(ft)	(psi)	(psi)	(psi)	(ft)	(ft)	(ft)	(gpm)		(ft/yr)	(cm/s)	Lugeon
a	b	c	d	e	L	pgage or pvw	ploss	pactual	hp	hg	htotal	Q	Cp	k	km	kL
5	68	78	68.0	78.0	10	35		34.63	80.0		80.0	18.6	4630	1077	1.04E-03	80
300 psi	68	78	68.0	78.0	10	39		38.96	90.0		90.0	29.6	4630	1523	1.47E-03	113
Limestone	68	78	68.0	78.0	10	35		34.63	80.0		80.0	20.1	4630	1163	1.12E-03	86
6	78	88	78.0	88.0	10	41		41.13	95.0		95.0	2.0	4630	97	9.42E-05	7
300 psi	78	88	78.0	88.0	10	64		64.07	148.0		148.0	7.8	4630	245	2.37E-04	18
Limestone	78	88	78.0	88.0	10	73		72.73	168.0		168.0	16.8	4630	463	4.48E-04	34
	78	88	78.0	88.0	10	44		43.72	101.0		101.0	3.6	4630	163	1.58E-04	12
7	88	100	88.0	100.0	12	63		63.20	146.0		146.0	1.6	4028	44	4.27E-05	3
300 psi	88	100	88.0	100.0	12	77		77.49	179.0		179.0	2.3	4028	53	5.09E-05	4
Limestone	88	100	88.0	100.0	12	95		95.24	220.0		220.0	3.9	4028	71	6.90E-05	5
	88	100	88.0	100.0	12	68		68.40	158.0		158.0	2.3	4028	58	5.57E-05	4

a = Test #, Packer pressure, Material
b = Packer tip
c = Bottom of test hole
d = b*cos(inclination)
e = c*cos(inclination)
L = c-b

p_{gage} = Pressure gage
p_{loss} = Pressure losses from charts
$p_{actual} = p_{gage} - p_{loss}$
$h_p = p_{actual}*2.31$
h_g = Smaller of water depth or mid-packer
$h_{total} = h_p + h_g$

If L >= 10r, $C_p = 1/(2\pi L)*\ln(L/r)*70309$
If r<L<10r, $C_p = 1/(2\pi L)*\sinh^{-1}(L/2r)*70309$
70309 is unit conversion from gpm/ft² to ft/yr
$k = C_p*Q/h_{total}$
$k_m = k*9.6651E-7$

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Table 2-2 Core Hole Packer Permeability Test Results
Temple Fork Site TH-TF-02

Project Name	Bear River	Inclination (degrees)	30	Tested by	R. Buhler
Project Location	Temple Fork	Distance to Water (ft)	10	Date	May-15
Project Number	13GCI329	Vertical Depth to Water (ft)	8.7	Reviewed by	P. Gerhart
Test Hole No.	TH-TF-02 Sheet 1 of 1	Hole Diameter = 2*r (in)	3.83	Date	Nov-15

Notes: All tests the pressures were measured with the vibrating wire pressure tranducer in the test zone

Test #, Packer Pressure, Material	Inclined Packer Test Interval (ft)		Vertical Packer Test Interval (ft)		Packer Test Length, inclined	Total Applied Pressure	Adjusted Applied Pressure	Applied Pressure Head	Total Head	Water Take	Shape Factor	Hydraulic Conductivity		
	Start	End	Start	End	(ft)	(psi)	(psi)	(ft)	(ft)	(gpm)		(ft/yr)	(cm/s)	(Lugeon)
a	b	c	d	e	L	pgage	pactual	hp	htotal	Q	Cp	k	km	kL
1	35.8	45.8	31.0	39.7	10	24.24242	24.2	56.0	56.0	1.2	4630	101	9.75E-05	7
350 psi	35.8	45.8	31.0	39.7	10	29.43723	29.4	68.0	68.0	1.4	4630	94	9.08E-05	7
Limestone	35.8	45.8	38.0	48.0	10	39.82684	39.8	92.0	92.0	1.8	4630	91	8.76E-05	7
	35.8	45.8	38.0	48.0	10	29.43723	29.4	68.0	68.0	1.4	4630	98	9.48E-05	7
2	45.8	55.8	39.7	48.3	10	25.10823	25.1	58.0	58.0	4.4	4630	348	3.36E-04	26
340 psi	45.8	55.8	39.7	48.3	10	33.76623	33.8	78.0	78.0	7.2	4630	426	4.12E-04	32
Limestone	45.8	55.8	38.0	48.0	10	45.02165	45.0	104.0	104.0	10.4	4630	462	4.47E-04	34
	45.8	55.8	38.0	48.0	10	29.43723	29.4	68.0	68.0	6.9	4630	470	4.54E-04	35

a = Test #, Packer pressure, Material

b = Packer tip

c = Bottom of test hole

d = b*cos(inclination)

e = c*cos(inclination)

L = c-b

p_{vw} = Pressure head in vibrating wire piezometer

$p_{actual} = p_{vw}$

$h_p = p_{actual}*2.31$

$h_{total} = h_p$

L = c-b

$h_{total} = h_p + h_g$

If L >= 10r, $C_p = 1/(2\pi L)*\ln(L/r)*70309$

If r<L<10r, $C_p = 1/(2\pi L)*\sinh^{-1}(L/2r)*70309$

70309 is unit conversion from gpm/ft^2 to ft/yr

$k = C_p*Q/h_{total}$

$k_m = k*9.6651E-7$

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Table 2-2 - Core Hole Packer Permeability Test Results
Temple Fork Site TH-TF-03

Project Name	Bear River	Inclination (degrees)	30	Tested by	R. Buhler
Project Location	Temple Fork	Distance to Water (ft)	10	Date	May-15
Project Number	13GCI329	Vertical Depth to Water (ft)	8.7	Reviewed by	P. Gerhart
Test Hole No.	TH-TF-03 Sheet 1 of 1	Hole Diameter = 2*r (in)	3.83	Date	Nov-15

Notes: All tests the pressures were measured with the vibrating wire pressure tranducer in the test zone

Test #, Packer Pressure, Material	Inclined Packer Test Interval (ft)		Vertical Packer Test Interval (ft)		Packer Test Length, inclined	Total Applied Pressure	Adjusted Applied Pressure	Applied Pressure Head	Total Head	Water Take	Shape Factor	Hydraulic Conductivity		
	Start	End	Start	End	(ft)	(psi)	(psi)	(ft)	(ft)	(gpm)		(ft/yr)	(cm/s)	(Lugeon)
a	b	c	d	e	L	p_{vw}	pactual	hp	htotal	Q	Cp	k	km	kL
1	35.8	45.8	31.0	39.7	10	17.74892	17.7	41.0	41.0	8.8	4630	989	9.56E-04	74
350 psi	35.8	45.8	31.0	39.7	10	25.10823	25.1	58.0	58.0	10.1	4630	806	7.79E-04	60
Limestone	35.8	45.8	38.0	48.0	10	32.25108	32.3	74.5	74.5	12.1	4630	752	7.27E-04	56
	35.8	45.8	38.0	48.0	10	21.64502	21.6	50.0	50.0	6.6	4630	611	5.91E-04	45
2	55.8	65.8	48.3	57.0	10	32.90043	32.9	76.0	76.0	0.6	4630	34	3.30E-05	3
350 psi	55.8	65.8	48.3	57.0	10	43.07359	43.1	99.5	99.5	0.7	4630	32	3.06E-05	2
Limestone	55.8	65.8	38.0	48.0	10	56.27706	56.3	130.0	130.0	1.2	4630	43	4.13E-05	3
	55.8	65.8	38.0	48.0	10	40.04329	40.0	92.5	92.5	1.1	4630	53	5.13E-05	4
3	65.8	75.8	57.0	65.6	10	38.7	38.7	89.3	89.3	0.5	4630	27	2.61E-05	2
350 psi	65.8	75.8	57.0	65.6	10	48.7	48.7	112.5	112.5	0.7	4630	29	2.78E-05	2
Limestone	65.8	75.8	57.0	65.6	10	64.3	64.3	148.5	148.5	0.9	4630	29	2.77E-05	2
	65.8	75.8	48.0	58.0	10	47.8	47.8	110.5	110.5	0.6	4630	23	2.27E-05	2
4	75.8	85.8	65.6	74.3	10	45.3	45.3	104.6	104.6	4.2	4630	186	1.80E-04	14
350 psi	75.8	85.8	65.6	74.3	10	60.2	60.2	139.0	139	6.0	4630	199	1.93E-04	15
Limestone	75.8	85.8	58.0	68.0	10	71.0	71.0	164.0	164	7.0	4630	198	1.91E-04	15
	75.8	85.8	58.0	68.0	10	53.7	53.7	124.0	124	4.6	4630	172	1.66E-04	13
5	85.8	95.8	74.3	83.0	10	51.9	51.9	120.0	120	1.9	4630	73	7.09E-05	5
350 psi	85.8	95.8	74.3	83.0	10	66.5	66.5	153.7	153.7	2.9	4630	87	8.44E-05	6
Limestone	85.8	95.8	74.3	83.0	10	76.4	76.4	176.5	176.5	3.5	4630	93	8.98E-05	7
	85.8	95.8	68.0	78.0	10	62.3	62.3	144.0	144	2.7	4630	86	8.27E-05	6

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Table 2-2 - Core Hole Packer Permeability Test Results
Temple Fork Site TH-TF-03

Project Name	Bear River	Inclination (degrees)	30	Tested by	R. Buhler
Project Location	Temple Fork	Distance to Water (ft)	10	Date	May-15
Project Number	13GCI329	Vertical Depth to Water (ft)	8.7	Reviewed by	P. Gerhart
Test Hole No.	TH-TF-03 Sheet 1 of 1	Hole Diameter = 2*r (in)	3.83	Date	Nov-15

Notes: All tests the pressures were measured with the vibrating wire pressure tranducer in the test zone

Test #, Packer Pressure, Material	Inclined Packer Test Interval (ft)		Vertical Packer Test Interval (ft)		Packer Test Length, inclined	Total Applied Pressure	Adjusted Applied Pressure	Applied Pressure Head	Total Head	Water Take	Shape Factor	Hydraulic Conductivity		
	Start	End	Start	End	(ft)	(psi)	(psi)	(ft)	(ft)	(gpm)		(ft/yr)	(cm/s)	(Lugeon)
a	b	c	d	e	L	p_{vw}	pactual	hp	htotal	Q	Cp	k	km	kL
6	95.8	105.8	83.0	91.6	10	49.8	49.8	115.0	115	6.5	4630	262	2.53E-04	19
350 psi	95.8	105.8	83.0	91.6	10	58.1	58.1	134.2	134.2	7.0	4630	240	2.32E-04	18
Limestone	95.8	105.8	78.0	88.0	10	67.1	67.1	154.9	154.9	8.7	4630	261	2.53E-04	19
	95.8	105.8	78.0	88.0	10	57.8	57.8	133.5	133.5	6.0	4630	208	2.01E-04	15
7	105.8	115.8	88.0	100.0	10	44.2	44.2	102.0	102	0.1	4630	5	4.39E-06	0
350 psi	105.8	115.8	88.0	100.0	10	73.6	73.6	170.0	170	0.2	4630	6	5.79E-06	0
Limestone	105.8	115.8	88.0	100.0	10	89.2	89.2	206.0	206	0.4	4630	9	8.69E-06	1
	105.8	115.8	88.0	100.0	10	74.0	74.0	171.0	171	0.3	4630	9	8.37E-06	1
8	115.8	125.8	88.0	100.0	10	60.6	60.6	140.0	140	1.6	4630	53	5.11E-05	4
350 psi	115.8	125.8	88.0	100.0	10	77.9	77.9	180.0	180	2.5	4630	65	6.27E-05	5
Limestone	115.8	125.8	88.0	100.0	10	98.7	98.7	228.0	228	3.3	4630	66	6.40E-05	5
	115.8	125.8	88.0	100.0	10	79.7	79.7	184.0	184	2.5	4630	62	6.03E-05	5
9	125.8	135.8	88.0	100.0	10	56.7	56.7	131.0	131	1.5	4630	54	5.26E-05	4
350 psi	125.8	135.8	88.0	100.0	10	77.9	77.9	180.0	180	2.0	4630	50	4.87E-05	4
Limestone	125.8	135.8	88.0	100.0	10	96.5	96.5	223.0	223	2.6	4630	54	5.22E-05	4
	125.8	135.8	88.0	100.0	10	77.9	77.9	180.0	180	2.1	4630	54	5.17E-05	4
10	135.8	150.3	88.0	100.0	14.5	46.3	46.3	107.0	107	16.9	3480	550	5.31E-04	41
400 psi	135.8	150.3	88.0	100.0	14.5	73.6	73.6	170.0	170	25.3	3480	518	5.01E-04	39
Limestone	135.8	150.3	88.0	100.0	14.5	52.8	52.8	122.0	122	9.4	3480	268	2.59E-04	20

a = Test #, Packer pressure, Material

b = Packer tip

c = Bottom of test hole

d = b*cos(inclination)

e = c*cos(inclination)

p_{vw} = Pressure head in vibrating wire piezometer

$p_{actual} = p_{vw}$

$h_p = p_{actual}*2.31$

$h_{total} = h_p$

L = c-b

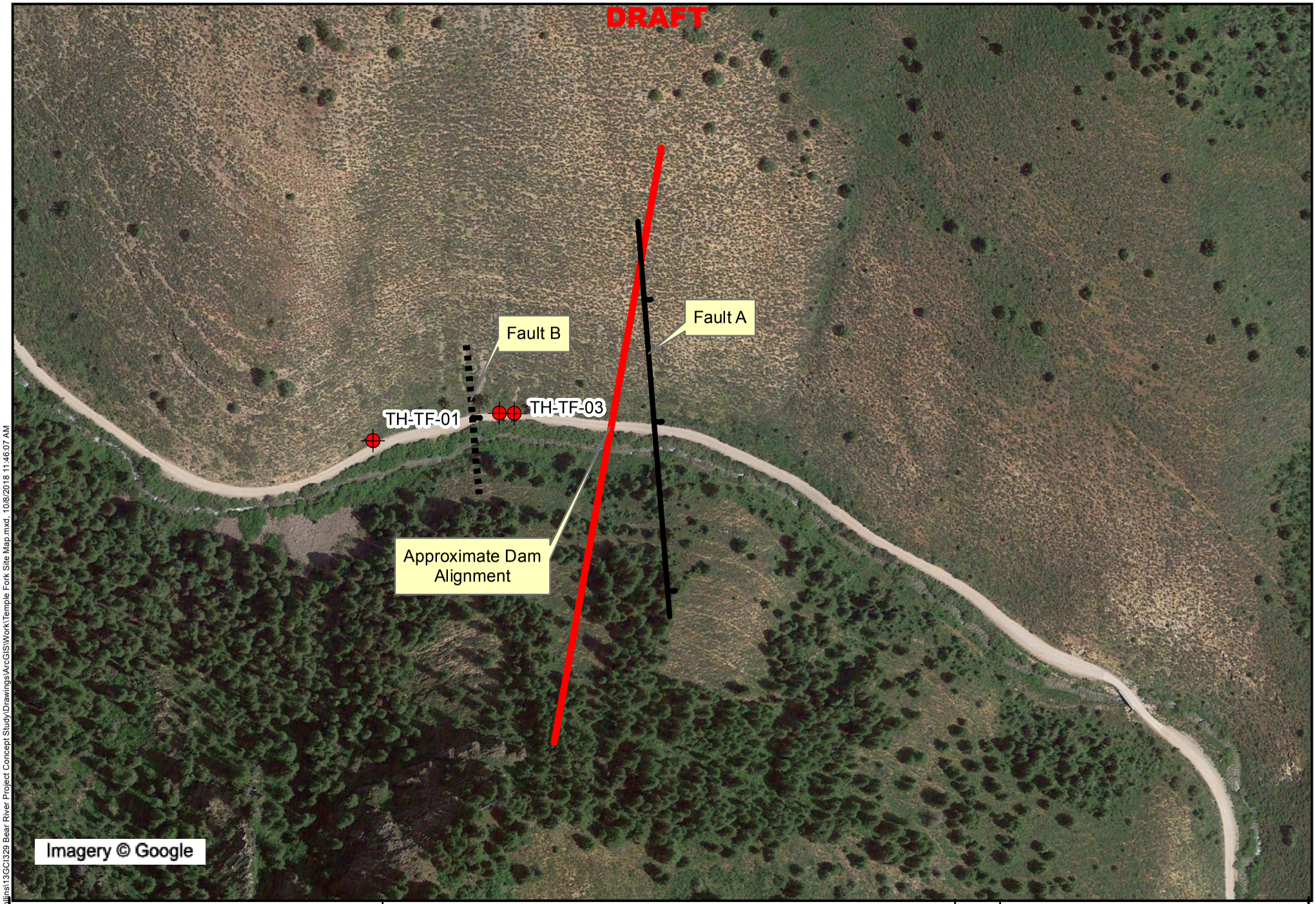
If L >= 10r, $C_p = 1/(2\pi L)*\ln(L/r)*70309$

If r<L<10r, $C_p = 1/(2\pi L)*\sinh^{-1}(L/2r)*70309$

70309 is unit conversion from gpm/ft^2 to ft/yr

$k = C_p*Q/h_{total}$

$k_m = k*9.6651E-7$



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Bear River Project Concept Study - Temple Fork

Temple Fork - Site and Exploration Map

N

0 100 200 400 Feet

Figure 2-1

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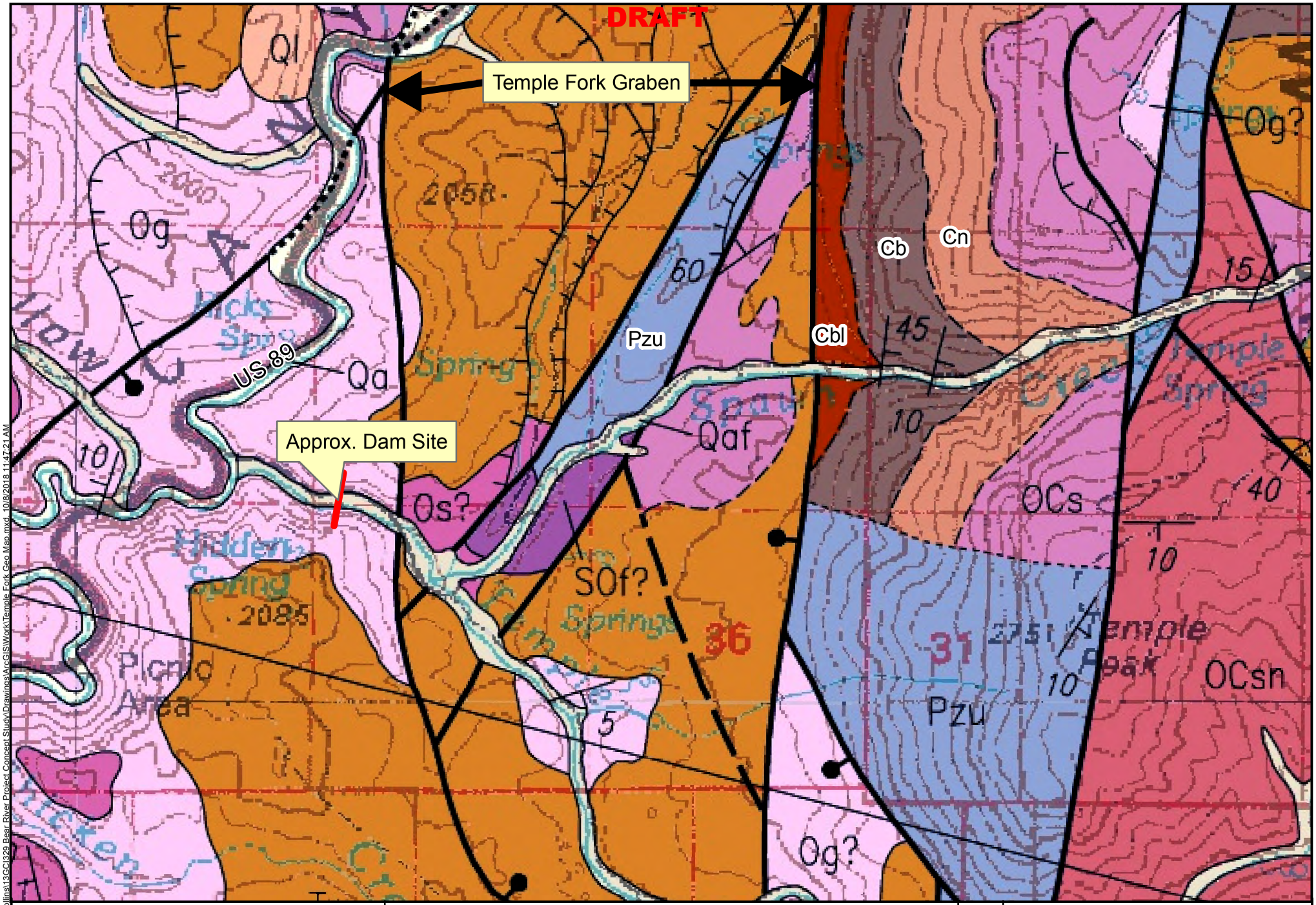

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Bear River Project Concept Study - Temple Fork

Temple Fork Geologic Map (Modified from: Dover, 1995)
Orginal Scale 1:100,000

N

0 1,150 2,300 4,600 Feet

Figure 3-1a

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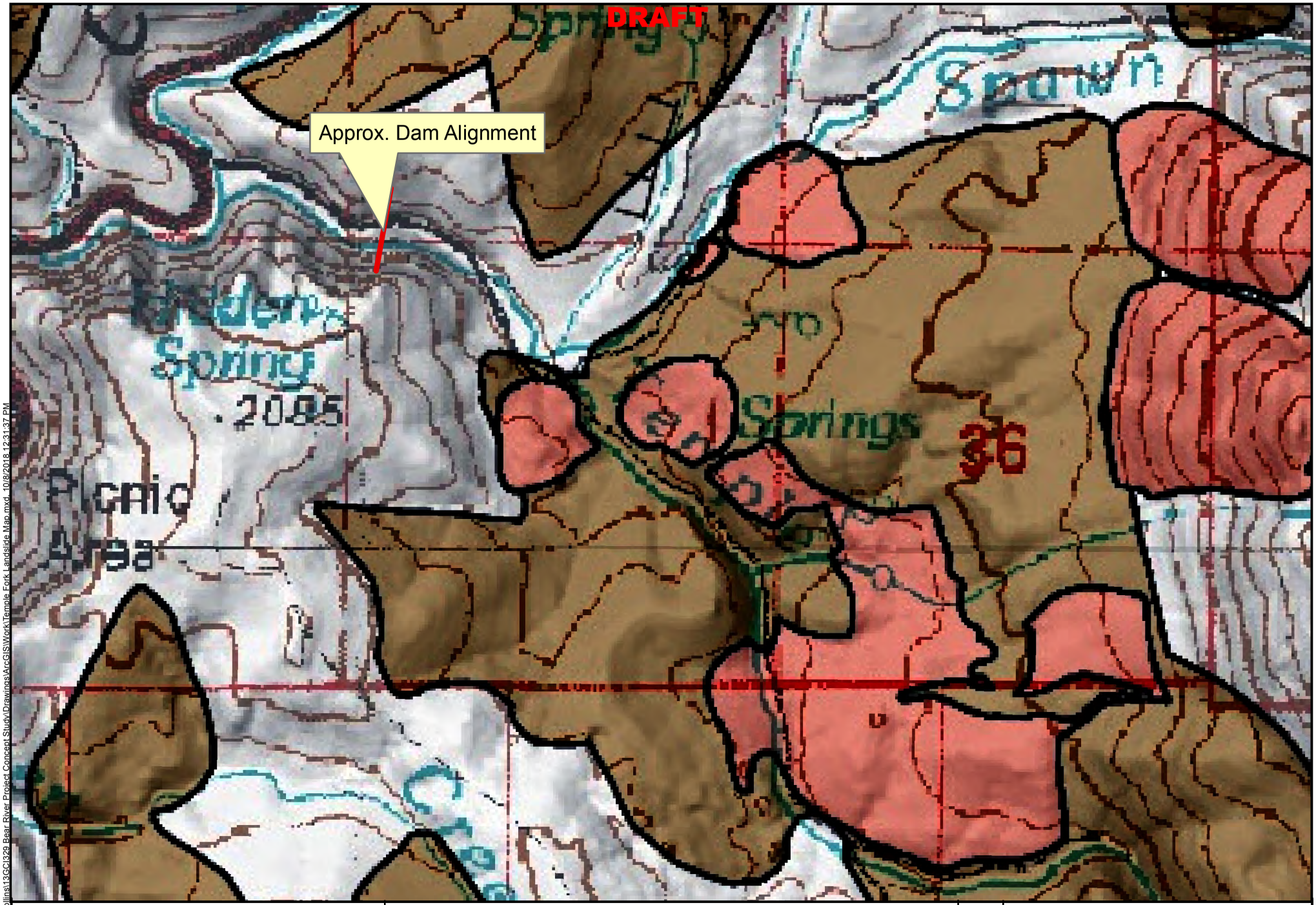

GERHART COLE

Bear River Project Concept Study - Temple Fork

Temple Fork Landslide Map
(Mod. from: Elliott and Harty 2010); Orginal Scale 1:100,000

N

0 700 1,400 2,800 Feet

Figure 3-4a

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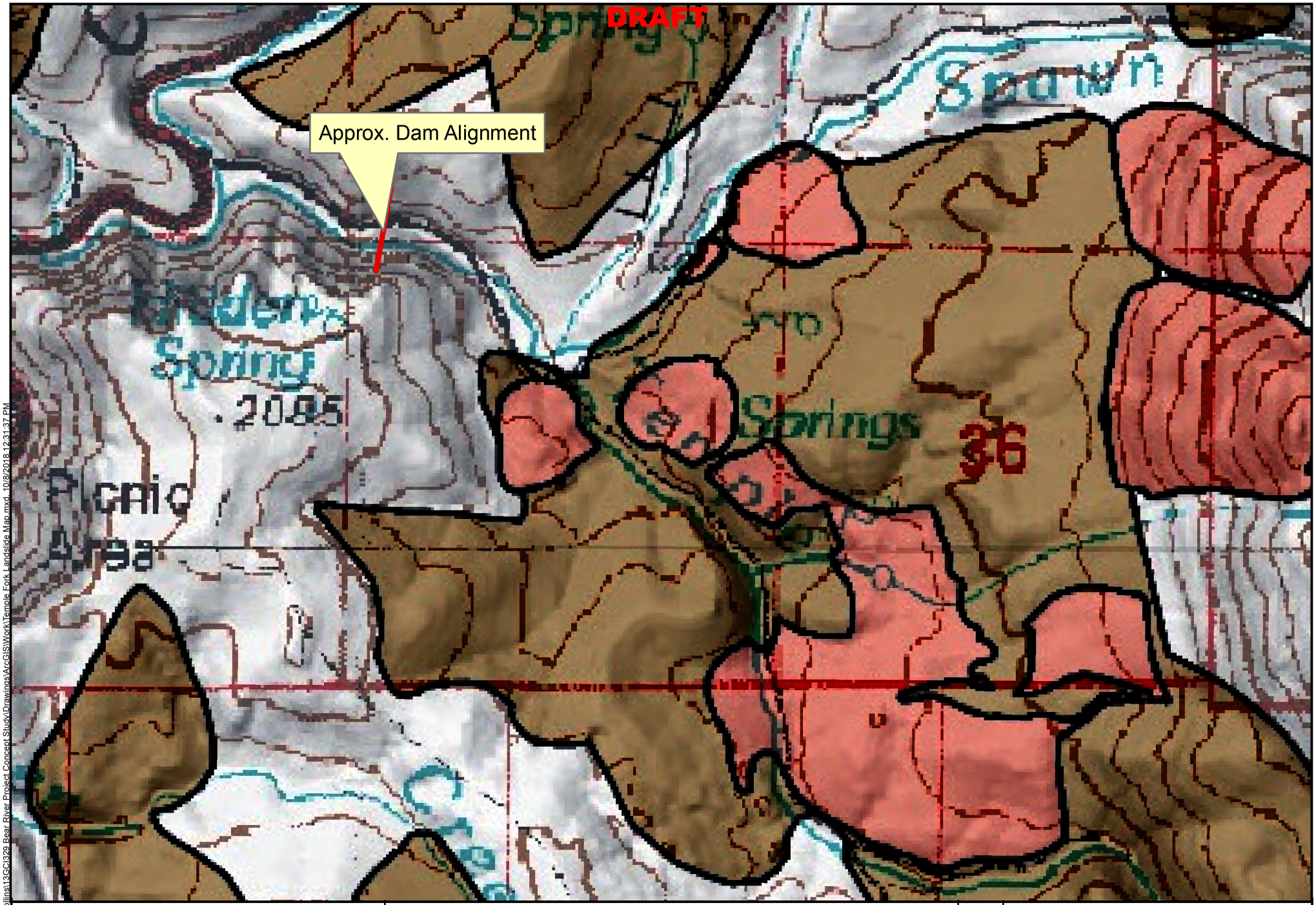

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Bear River Project Concept Study - Temple Fork

Temple Fork Landslide Map
(Mod. from: Elliott and Harty 2010); Orginal Scale 1:100,000

N

0 700 1,400 2,800 Feet

Figure 3-4a

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Deep or unclassified landslide - Generally 10 feet (3 m) thick or more and shows characteristic landslide morphology. May include areas of complex or composite landsliding where landslide density is too great to show individual landslides separately. Also includes unclassified landslides (original source was not specific about landslide type).

Shallow landslide - Generally less than 10 feet (3 m) thick and shows characteristic landslide morphology. Includes mainly debris slides and debris flows. May include some composite landslides.

Lateral spread and/or flow failure - Liquefaction-induced landslides typically associated with earthquakes; generally occur on very gentle slopes or flat terrain.

Landslide undifferentiated from talus and/or colluvial deposits - May include deep or shallow landslides mapped with talus and/or colluvial deposits.

Landslide and/or landslide undifferentiated from talus, colluvial, rock-fall, glacial, and soil-creep deposits - May include deep or shallow landslides mapped with talus, colluvial, rock-fall, glacial, and/or soil-creep deposits; primarily mapped and compiled by Roger B. Colton, U.S. Geological Survey.

Not classified - Includes areas not mapped in the original studies compiled for this map, as well as mapped areas with no identified landsliding.

Landslide scarp - Landslide feature found near the head. Identified as the area where landslide material has moved downslope and away from the undisturbed ground. Hachures on down-dropped side.

Debris-flow travel path - Identifies the path of a debris flow (shallow landslide).

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4.1 RECOMMENDATIONS FOR ADDITIONAL STUDIES

We understand that the studies to date have focused on providing the design team with preliminary information to study the feasibility of constructing a reservoir at Temple Fork. If this location is determined to be studied more additional geotechnical and geologic information will need to be gathered. A few of the items are as follows:

- Additional fault studies are needed at the proposed dam site.
- Additional rock coring and test holes will be required prior to moving to final design,
- Additional studies of landslides, solution cavities, and rock falls.

This is not an extensive list but we can provide more information if needed.

4.2 LIMITATIONS

The assessments and recommendations presented in this document are based on limited field studies and laboratory testing, as well as our understanding of the project's design and manner of construction. If the project's design or manner of construction changes, or if conditions are found later that are different from those described, we should be notified immediately so that we can make revisions as necessary.

This document was prepared solely for the use of the addressee and may not contain sufficient information for other parties or uses.

We represent that our services are performed within the limitations prescribed by our Client, in a manner consistent with the level of care and skill ordinarily exercised by other professional consultants under similar circumstances. No other representation, expressed or implied, and no warranty or guarantee is included or intended. We do not assume responsibility for the accuracy of information provided by others.

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Black, B.D., and Hecker, S., compilers, 1999, Fault number 2410, Bear River Range faults, in Quaternary fault and fold database of the United States: U.S. Geological Survey, accessed online http://earthquakes.usgs.gov/hazards/qfaults

Brummer, J. and McCalpin, 1995, Geologic map of the Richmond Quadrangle, Cache County, Utah and Franklin County, Idaho: Utah Geological Survey Miscellaneous Publication 95-3, 1:24,000.

Dover, J.H., 1995, Geologic map of the Logan 30'x60' Quadrangle, Cache and Rich Counties, Utah and Lincoln and Uinta Counties, Wyoming: U.S. Geological Survey Miscellaneous Investigations Series Map I-2210, 1:100,000.

Elliott, A.H., and Harty, K.M., 2010, Landslide maps of Utah, Logan 30'x60' Quadrangle: Utah Geological Survey Map 246DM, 1:100,000.

Evans, J.P., 1991, Structural setting of seismicity in northern Utah: Utah Geological Survey, Contract Report 91-15, 37 p.

Evans, J.P., and Oaks, R.Q., Jr., 1990, Geometry of Tertiary extension in the northeastern Basin and Range province superimposed on the Sevier fold and thrust belt, Utah, Idaho, and Wyoming: Geological Society of America Abstracts with Programs, v. 22, no. 6, 10 p.

Gilbert, G.K., 1928, Studies of basin-range structure: U.S. Geological Survey Professional Paper 153, 89 p.

Hecker, S., 1993, Quaternary tectonics of Utah with emphasis on earthquake-induced characterization: Utah Geological Survey Bulletin 127, 157 p.

Levy, M., and Christie-Blick, N., 1989, Pre-Mesozoic palinspastic reconstruction of the eastern Great Basin (western United States): Science, v. 245, p. 1454-1462.

Lund, W.R., 2005, Consensus preferred recurrence-intervals and vertical slip-rate estimates, Review of Utah paleoseismic-trenching data by the Utah Quaternary Fault Parameters Working Group: Utah Geological Survey, Bulletin 134, 109 p.

Spangler, L.E., 2001, Delineation of recharge areas for karst springs in Logan Canyon, Bear River Range, northern Utah, in Kuniansky, E.L. ed., U.S. Geological Survey Karst Interest Group Proceedings: Water Resources Investigations Report 01-4011, p. 186-193.

U.S. Bureau of Reclamation, 2001, Engineering Geology Field Manual, Second Edition, Volume 1: Technical Service Center, Bureau of Reclamation, U.S. Department of the Interior, accessed online http://www.usbr.gov/pmts/geology/geoman.html

Westaway, R., and Smith, R.B., 1989, Source parameters of the Cache Valley (Logan), Utah earthquake of 30 August 1962: Bulletin of the Seismological Society of America, v. 79, no. 5, p. 1410-1425.

Appendix A Test Hole Logs Temple Fork

DRAFT

Project: Bear River Project Concept Study **Project Location:** Temple Fork **Project Number:** 13GCI329	**Log of Test Hole TH-TF-01** Sheet 1 of 5

Date(s) Drilled	5/7/15 - 5/12/15	Logged By	R. Buhler	Checked By	P. Gerhart
Drilling Method	Rotary Wash/HQ3	Drill Bit Size/Type	3.83" HQ-3 6FM	Total Depth Drilled (feet)	100.5
Drill Rig Type	CME 75	Drilling Contractor	Bedke Geotechnical F.S.	Hammer Weight/ Drop(lbs/in.)	Automatic Trip Hammer
Apparent Groundwater Depth	4.8; 5/27/2015	Latitude / Longitude	41.83284, -111.58562	Ground Surface Elevation (feet)	5851.0
Test Hole Backfill	Piezometer Well	Comments		Elevation Datum	NAVD 88

Depth (feet)	ROCK CORE: Run No.	Recovery,%	R Q D, %	Fracture Density	Weathering	Hardness	Lithology	MATERIAL DESCRIPTION	Discontinuity Drawing	Discontinuity Type	DISCONTINUITY DESCRIPTION	Point Load Test Results (psi)	Packer Test Intervals	SOIL SAMPLES: Type	Number	Sampling Resistance	FIELD NOTES
0								GRAVEL, ROAD									
1								SILT, gravelly, some sand - very soft, low plasticity, angular fine gravel, brown, wet. (ML)									
2																	
3																	
4																	
5																	
6														SPT-01		1-1-1 [2]	
7																	
8																	
9																	
10																	
11								GRAVEL, some sand, some silt - medium dense to loose, fine to coarse gravel, fine to coarse sand, limestone gravel, wet. (GP-GM)						SH-02			
12														SPT-03		6-10-6 [16]	
13																	
14																	
15																	
16														SPT-04		2-5-3-8 [8]	
17																	
18																	
19																	
20																	

NEW ROCK CORE LOG TH_LOGS_#2_BEAR_RIVER.GPJ GERHART.GDT 9/23/15

GERHART COLE

DRAFT

Project: Bear River Project Concept Study
Project Location: Temple Fork
Project Number: 13GCI329

Log of Test Hole TH-TF-01

Depth (feet)	ROCK CORE Run No.	Recovery, %	R Q D, %	Fracture Density	Weathering	Hardness	Lithology	MATERIAL DESCRIPTION	Discontinuity Drawing	Discontinuity Type	DISCONTINUITY DESCRIPTION	Point Load Test Results (psi)	Packer Test Intervals	SOIL SAMPLES Type	Number	Sampling Resistance	FIELD NOTES
20																	
21										JO	70°, WA, R2, CA, CL			X	SPT-05	3-25-50/1" [R]	
				FD4				LIMESTONE, silty, with limestone and silt inclusions(<1 inch), gray, thinly to very thinly bedded, with a few interbeds of light reddish brown calcareous siltstone, (GARDEN CITY FORMATION, Og)		JO	15°, WA, R2, CA						
22	1	100	88		W1	H4				JO	16°, WA, R3, CA						
				FD3						JO	0°, WA, R3						
23										JO	0°, ST, R2, FE						
				FD4						JO	80°, PL, O1, T1, CA	8369					
24										JO	11°, WA, R3, CL						
				FD4						JO	75°, WA, T2, O2, CA						
25										JO	8°, WA, R3, CL						
	2	100	83	FD4	W1	H4				JO	4°, WA, R4, O1, T1, CL,						
26										ME	FE,						
				FD4						JO	0°, WA, R3, CA, CL, FE						
27																	
				FD3													
28																	
				FD4						JO	9°, WA, R3, O1, T1, FE						
29																	
				FD6													
30																	
	3	100	68	FD7	W1	H4				JO	40°, ST, R3, T2, FE, CA						
31										JO	3°, WA, R3, T1, FE, CA						
				FD4						JO	0°, WA, R3, T2. CL, FE						
32																	
				FD4						JO	3°, WA, R3, FE, CL						
33										JO	10°, WA, R3, T1, FE, CA						
				FD5						JO	10°, WA, R3, T1, FE, CA						
34										JO	10°, WA, R4, T1, FE, CL						
										JO	0°, WA, R3, T1, CL, FE						
				FD5						ME							
35										JO	0°, PL, R3, T1, CA, CL						
	4	100	70	FD5	W1	H4		SILTSTONE, calcareous, light reddish brown to gray, thinly to very thinly bedded, (Og)		JO	0°, PL, R3, T1, CL, FE						
36										JO	15°, ST, R3, CL, FE						
				FD5						JO	5°, WA, R3, CL, FE						
37																	
				FD5						ME							
38										JO	80°, WA, O1, T1, CA						
				FD3						JO	6°, WA, T1, O1						
39																	
				FD3						JO	85°, WA, O1, T1, CA						
40										JO	Highly fractured from 40.2 to 41 ft						
	5	95	85	FD7	W1	H4						2682					
41										JO	65°, WA, O1, T1, CL						
				FD3				LIMESTONE, silty, with limestone and silt inclusions(<1 inch), gray, thinly to very thinly bedded, with a few interbeds of light reddish brown calcareous siltstone, GARDEN CITY FORMATION, (Og)									
42										JO	0°, WA, R4, O1, T1,, CL,						
				FD3						JO	FE						
											0°, WA, R4, O1, T1, CL, FE						
43																	
				FD5						JO	4°, ST, R4, FE, CL						
	6	100	68		W1	H4				ME							
44										ME							
								SILTSTONE, calcareous,									

NEW ROCK CORE LOG TH_LOGS #2 BEAR_RIVER.GPJ GERHART.GDT 9/23/15

GERHART COLE

DRAFT

Project: Bear River Project Concept Study
Project Location: Temple Fork
Project Number: 13GCI329

Log of Test Hole TH-TF-01

Depth (feet)	ROCK CORE Run No.	Recovery,%	R Q D, %	Fracture Density	Weathering	Hardness	Lithology	MATERIAL DESCRIPTION	Discontinuity Drawing	Discontinuity Type	DISCONTINUITY DESCRIPTION	Point Load Test Results (psi)	Packer Test Intervals	SOIL SAMPLES Type	Number	Sampling Resistance	FIELD NOTES
45				FD5				light reddish brown to gray, thinly to very thinly bedded, (Og)		JO	5°, ST, R3, O1, T1, CL, FE						
										JO	5°, ST, R3, O1, T1, CL, FE						
				FD5						JO	4°, WA, R3, CL, FE						
46										JO	11°, ST, R5, O1, T1, CL, FE						
	6	100	68	FD5	W1	H4		LIMESTONE, silty, with limestone and silt inclusions(<1 inch), gray, thinly to very thinly bedded, with a few interbeds of light reddish brown calcareous siltstone, GARDEN CITY FORMATION, (Og)		JO	6°, WA, R3, FE						
										JO	90°, WA, O1, T1, CA						
47										JO	5°, WA, R4, FE						
				FD5						JO	5°, WA, R4, FE						
										JO	5°, WA, R4, FE						
48										JO	5°, WA, R4, FE						
				FD5						JO	5°, WA, R3, T1, FE						
										JO	5°, WA, R3, T1, FE						
49										JO	80-90°, WA, T1, R4, FE						
				FD5						JO	25°, ST, R3, FE						
50								SILTSTONE, calcareous, light reddish brown to gray, thinly to very thinly bedded, (Og)		JO	7°, WA, R3, FE						
										JO	7°, WA, R3, FE						
	7	100	43	FD6	W1	H4				JO	80°, WA, R3						
										JO	5°, ST, R3, FE						
51										JO	20°, WA, R3, FE						
				FD6				LIMESTONE, silty, with limestone and silt inclusions(<1 inch), gray, thinly to very thinly bedded, with a few interbeds of light reddish brown calcareous siltstone, GARDEN CITY FORMATION, (Og)									
52										JO	80°, WA, R4, T1, CA, FE						
				FD5						JO	6°, WA, R3						
53										JO	6°, WA, R3						
				FD3													
54								@ 51.5 ft, LIMESTONE chips in reddish brown calcite iron oxides and clay matrix (up to 1" thick).									
				FD4						JO	18°-60°. ST. R4, FE						
55										JO	30°, PL, R4, FE						
										JO	0°, WA, R4, FE						
	8	100	82	FD6	W1	H4		LIMESTONE, gray to greenish gray, thinly bedded to very thinly bedded from 51.7 to 61 ft.		JO	12°, WA, R4, FE						
56										JO	2°, WA, R5, FE						
				FD5													
57										ME							
				FD5													
58										JO	60°, PL, O1, T1, CA						
				FD3						JO	60°, PL, O1, T1, CA						
59																	
				FD3													
60										JO	0°, PL						
										JO	0°, PL						
	9	100	88	FD5	W1	H4				JO	40°, PL, R4, CA						
61										JO	20°, WA, R3, CL, CA						
				FD3				LIMESTONE, gray, thinly bedded from 61 to 61.5 ft.		BE	20°, WA, O0						
62								LIMESTONE, gray, thinly bedded to very thinly bedded from 61.5 to 64 ft.									
				FD3													
63										BE	8°, WA, O0						
										BE	10°, WA, O0						
				FD3						JO	70°, PL, O1, T1, CA						
64										BE	10°, WA, O0						
				FD3				LIMESTONE, gray, thinly bedded from 64 to 64.5 ft.		BE	5°, WA, O0						
65								LIMESTONE, gray, thinly bedded to very thinly bedded from 64.5 to 65.5 ft.									
	10	100	80	FD3	W1	H4				JO	3°, WA, R3, O1, T1						
66								LIMESTONE, gray, thinly bedded from 65.5 to 66.4 ft.		JO	2°, PL, R3, FE						
				FD5						JO	2°, PL, R3, FE						
										JO	85°, WA, R2, CA						
67								LIMESTONE, gray, thinly bedded to very thinly bedded from 66.4 to 71.4 ft.		JO	22°, WA, R3, FE, CA						
				FD5						JO	2°, WA, R3						
68										ME	6°, WA, R3						
										JO							
	11	100	100	FD5	W1	H4											
69										JO	10°, WA, R4						

GERHART COLE

DRAFT

Project: Bear River Project Concept Study
Project Location: Temple Fork
Project Number: 13GCI329

Log of Test Hole TH-TF-01

Depth (feet)	Run No.	Recovery,%	R Q D, %	Fracture Density	Weathering	Hardness	Lithology	MATERIAL DESCRIPTION	Discontinuity Drawing	Discontinuity Type	DISCONTINUITY DESCRIPTION	Point Load Test Results (psi)	Packer Test Intervals	SOIL SAMPLES Type	Number	Sampling Resistance	FIELD NOTES
				FD3													
70				— —				(CONT.)									
				FD5				LIMESTONE, silty, with limestone and silt inclusions(<1 inch), gray, thinly to very thinly bedded, with a few interbeds of light reddish brown calcareous siltstone, GARDEN CITY FORMATION, (Og)		ME							
71	11	100	100	— —	W1	H4				ME							
										JO	7°, WA, R4, FE						
				FD3						JO	9°, PL, R5, O1, T1, FE						
72				— —													
				FD3								3964					
73				— —													
				FD6				LIMESTONE, gray, thinly bedded from 71.4 to 71.6 ft.		JO	85°, PL, O3, T2, CA, FE						
74				— —				LIMESTONE, gray, thinly bedded to very thinly bedded from 71.6 to 78 ft.		JO	50°, WA, R2, O1, T1, FE, CA						
				FD6						JO	5°, WA, R3, O1, T1, FE						
75				— —						JO	0°, WA, R3, O1, T1, FE						
	12	98	50	FD7	W1	H4				JO	75-85°, WA, ST, R3, O1, T1,						
										JO							
76				— —						ME	3°, WA, R3, O1, T1, FE, CA Intensely Fractured 75.4 TO 76 FT, T4, CA, FE, CL						
				FD6						JO							
										JO	1°, WA, R3, O1, T1, FE						
77				— —						ME	60°, WA, R3, O1, T1, FE, CA						
				FD6						JO							
										JO	16°, WA, R3, O1, T1, FE						
78				— —						JO	10°, WA, R3, O2, T1, FE						
											75°, WA, R2, O1, T1, FE						
				FD5				LIMESTONE, gray, thinly bedded from 78 to 79.9 ft.									
79				— —						JO	2°, Disturbed by Barrel						
										JO	2°, Disturbed by Barrel						
				FD5													
80				— —						JO	70°, WA, R3, O1, T1, FE						
										JO	0°, WA, R3, O1, T1, FE, CA						
	13	95	77	FD5	W1	H4		LIMESTONE, gray, thinly bedded to very thinly bedded from 79.9 to 81.1 ft.									
81				— —						ME							
				FD5				LIMESTONE, gray, thinly bedded from 81.1 to 82.7 ft.		JO	5°, WA, R3, O1, T2, FE, CL						
82				— —													
				FD6						JO	50°, WA, R3, O2, T2, CA						
										JO	1°, WA, R3, O1, T1, FE						
83				— —				LIMESTONE, gray, thinly bedded to very thinly bedded from 82.7 to 86.5 ft.		JO	12°, WA, R3, O1, T1, FE						
				FD3						JO	70°, PL, O2, T2, CA						
84				— —						JO	85°, WA, R3, O1, T1, FE						
				FD3													
85				— —						JO	5°, WA, R3, O1, T1, CA						
	14	100	98	FD5	W1	H4											
86				— —						JO	3°, WA, R3, O1, T1, CA						
				FD3													
87				— —				LIMESTONE, gray, thinly bedded from 86.5 to 87 ft.		JO	75°, PL, O1, T1, CA						
				FD3				LIMESTONE, gray, thinly bedded to very thinly bedded from 87 to 95 ft.		JO	4°, WA, R3, O1, T1, CA						
88				— —													
				FD5													
89				— —						JO	0°, WA, R4, O1, T1, CA						
				FD5						JO	80°, WA, O1, T1, CA						
90				— —						JO	10°, WA, R4, O1, T1, FE, CA						
	15	100	100	FD5	W1	H4											
91				— —						JO	0°, ST, R3, O1, T1, FE, CA						
				FD5						JO	5°, WA, R3, O1, T1, CA						
92				— —						JO	11°, ST, R3, O1, T1, FE, CA						
				FD5								4958					
93				— —													
	16	100	83	FD6	W1	H4				JO	80°, WA, O1, T1, CA						

GERHART COLE

DRAFT

Project: Bear River Project Concept Study
Project Location: Temple Fork
Project Number: 13GCI329

Log of Test Hole TH-TF-01

Depth (feet)	ROCK CORE Run No.	Recovery,%	R Q D, %	Fracture Density	Weathering	Hardness	Lithology	MATERIAL DESCRIPTION	Discontinuity Drawing	Discontinuity Type	DISCONTINUITY DESCRIPTION	Point Load Test Results (psi)	Packer Test Intervals	SOIL SAMPLES Type	Number	Sampling Resistance	FIELD NOTES
94				FD5				(CONT.) LIMESTONE, silty, with limestone and silt inclusions(<1 inch), gray, thinly to very thinly bedded, with a few interbeds of light reddish brown calcareous siltstone, GARDEN CITY FORMATION, (Og)		JO JO	75°, WA, R3, O1, T1, FE 10°, PL, R4, O1, T1, CA						
95				FD5						JO JO JO	0°, WA, R4, O1, T1, FE, CL 10°, ST, R3, O1, T1 10°, ST, R3, O1, T1						
96	16	100	83	FD6	W1	H4				JO JO JO JO	10°, WA, R3, T1, CA 75°, WA, R3 70°, PL, O4, T4, CA 80°, WA, O1, T1, CA						
97				FD5				LIMESTONE, gray, thinly bedded from 95 to 96.8 ft. LIMESTONE, gray to grennish gray, thinly bedded to very thinly bedded from 96.8 to 100.5 ft.		JO JO JO JO JO	0-15°, WA, R3, O1, T1, FE, CA 70°, WA, O2, T2, CA 0°, WA, R3, T1, FE 80°, WA, R3, O1, T1, FE, CA 5°, WA, R4, O1, T1, FE 80°, WA, O0-O1, T0-T1, CA						
98				FD5													
99	17	100	100	FD7	W1	H4											
100				FD5													
101								Bottom of Test Hole at 100.5 feet.									
102																	
103																	
104																	
105																	
106																	
107																	
108																	
109																	
110																	
111																	
112																	
113																	
114																	
115																	
116																	
117																	
118																	

GERHART COLE

DRAFT

Project: Bear River Project Concept Study **Project Location:** Temple Fork **Project Number:** 13GCI329	**Log of Test Hole TH-TF-02** Sheet 1 of 3

Date(s) Drilled	5/13/15-5/14/15	Logged By	R. Buhler	Checked By	P. Gerhart
Drilling Method	Rotary Wash/HQ3	Drill Bit Size/Type	3.83" HQ-3 6FM	Total Depth Drilled (feet)	55.8
Drill Rig Type	CME 75	Drilling Contractor	Bedke Geotechnical F.S.	Hammer Weight/ Drop(lbs/in.)	
Apparent Groundwater Depth		Latitude / Longitude	41.83297, -111.58484	Ground Surface Elevation (feet)	5857.0
Test Hole Backfill	Benonite Grout/ Chips	Comments	Angled Hole at 30 degrees from Vertical; Azimuth 270°	Elevation Datum	NAVD 88

Depth (feet)	ROCK CORE: Run No.	Recovery,%	R Q D, %	Fracture Density	Weathering	Hardness	Lithology	MATERIAL DESCRIPTION	Discontinuity Drawing	Discontinuity Type	DISCONTINUITY DESCRIPTION	Point Load Test Results (psi)	Packer Test Intervals	SOIL SAMPLES: Type	Number	Sampling Resistance	FIELD NOTES
0								DRILLED THROUGH OVERBURDEN -									
1								See TH-TF-01 for general description of overburden									
2																	
3																	
4																	
5																	
6																	Drilled through overbured to 24 feet and then installed casing to 24.5 feet and began coring.
7																	
8																	
9																	
10																	
11																	
12																	
13																	
14																	
15																	
16																	
17																	
18																	
19																	
20																	

GERHART COLE

DRAFT

Project: Bear River Project Concept Study
Project Location: Temple Fork
Project Number: 13GCI329

Log of Test Hole TH-TF-02

Depth (feet)	ROCK CORE Run No.	Recovery, %	R Q D, %	Fracture Density	Weathering	Hardness	Lithology	MATERIAL DESCRIPTION	Discontinuity Drawing	Discontinuity Type	DISCONTINUITY DESCRIPTION	Point Load Test Results (psi)	Packer Test Intervals	SOIL SAMPLES Type	Number	Sampling Resistance	FIELD NOTES
20																	
21																	
22																	
23																	
24																	
25	1	33	27		W1	H4		GRAVEL, (LIMESTONE) - subrounded and subangular medium gravel, gray, wet. (GP-GM)									
26					W1	H4				ME							
				FD5				LIMESTONE, silty, with limestone and silt inclusions (< 1 inch), gray to greenish gray, thinly bedded, (GARDEN CITY FORMATION, Og)		ME		3614					
27										ME							
				FD5													
28	2	95	87														
				FD5						JO	15°, WA, R4, O1, T1						
29																	
				FD5						JO	33°, PL, R4, O1, T1, FE						
30										JO	25°, PL, O1, T1						
				FD5						JO	15°, PL, R4, O1, T1, FE						
					W1	H4				JO	5°, WA, R3, O1, T1						
31																	
				FD5						ME							
32																	
				FD6						JO	60°, WA, R3, FE, CA						
										JO	60°, WA, R3, FE, CA						
33	3	95	83							ME	30°, WA, R3, O1, T1, FE, CA						
										JO							
				FD3						ME							
34																	
				FD2						ME							
										ME							
35																	
				FD3													
36					W1	H4				JO	25°, WA, R3, O1, T1, FE						
				FD3						JO	30°, WA, R3, FE						
37																	
				FD3													
38																	
	4	100	100	FD3						JO	83°, WA, R3, O2, T2, CA						
39										JO	28°, WA, R3, FE, CA						
				FD3													
40										JO	27°, WA, O1, T1, FE						
				FD5													
41					W1	H4				JO	25°, PL, R4, O1, T1, FE,						
				FD6						JO	CA, CL						
42								LIMESTONE, gray, thinly bedded from 41.5 ft to 43.2 ft.		ME	20°, WA, R3, O1, T1, CA						
										JO	35°, PL, R4, T1, FE						
				FD3						JO	35°, PL, R4, T1, FE						
	5	100	78							JO	65°, WA, R3, O1, T1, FE						
43																	
				FD3				LIMESTONE, greenish gray, thinly bedded to very thinly bedded from 43.2 ft to 46 ft.									
44										JO	90°, PL, T1, O1, CA						
										ME	65°, ST, R3, O1, T1, FE						
										JO							

NEW ROCK CORE LOG TH_LOGS #2_BEAR_RIVER.GPJ GERHART.GDT 9/23/15

GERHART COLE

DRAFT

Project: Bear River Project Concept Study
Project Location: Temple Fork
Project Number: 13GCI329

Log of Test Hole TH-TF-02

Depth (feet)	ROCK CORE Run No.	Recovery, %	R Q D, %	Fracture Density	Weathering	Hardness	Lithology	MATERIAL DESCRIPTION	Discontinuity Drawing	Discontinuity Type	DISCONTINUITY DESCRIPTION	Point Load Test Results (psi)	Packer Test Intervals	SOIL SAMPLES Type	Number	Sampling Resistance	FIELD NOTES
45	5	100	78	FD3						ME							
				FD5						ME							
46					W1	H4		LIMESTONE, gray, thinly bedded from 46 ft to 46.5 ft.				6156					
				FD5													
47								LIMESTONE, greenish gray, thinly bedded to very thinly bedded from 46.5 ft to 48 ft.		ME JO	35°, WA, R3, FE, CL						
				FD5													
48	6	100	80					LIMESTONE, gray, thinly bedded from 48 ft to 52.5 ft.		ME JO JO	45°, WA, R4, O1, T1, FE 35°, PL, R3, O1, T1, FE						
				FD5													
49										JO	55°, PL, O2, T2, FE, CA						
				FD5						ME							
50										JO	55°, WA, O1, T1, CA						
				FD5	W5	H4				JO	45°, R3						
51						H5				JO	FRACTURED FROM 50.6 TO 53 FEET						
				FD8													
52	7	100	0														
				FD9	W1	H4											~Fault B
53								LIMESTONE gray, very intensely fractured, light brown to yellowish gray clay and iron oxides, gouge (?), slickensides on one piece of core, from 52.5 ft to 53.5 ft.		JO	70°, WA, R3, FE, CL						
				FD5						ME							
54	8	100	56							JO JO JO	20°, WA, R3, FE, CA, CL 70°, WA, R3, O1, T1, FE, CA						HQ casing broke while coring between 55.8 and 60.8 feet at a depth of 20 feet and hole was abandoned.
				FD5													
55								LIMESTONE, gray, thinly bedded from 53 ft to 55.8 ft.		JO JO JO	60°, WA, R3, O1, T1, FE, CA 20-35°, WA, R3, O1, T1, FE, CA						
				FD5													
56								Bottom of Test Hole at 55.8 feet, hole abandoned due to lose of core barrel and casing.			~~20°, WA, R3, O1, T1, FE, CA~~ 75°, WA, R2, FE, CA						
57																	
58																	
59																	
60																	
61																	
62																	
63																	
64																	
65																	
66																	
67																	
68																	
69																	

NEW ROCK CORE LOG TH_LOGS_#2_BEAR_RIVER.GPJ GERHART.GDT 9/23/15

GERHART COLE

DRAFT

Project: Bear River Project Concept Study **Project Location:** Temple Fork **Project Number:** 13GCI329	**Log of Test Hole TH-TF-03** Sheet 1 of 7

Date(s) Drilled	5/15/15 -5/28/15	Logged By	R. Buhler	Checked By	P. Gerhart
Drilling Method	Rotary Wash/HQ3	Drill Bit Size/Type	3.83" HQ-3 6FM	Total Depth Drilled (feet)	150.3
Drill Rig Type	CME 75	Drilling Contractor	Bedke Geotechnical F.S.	Hammer Weight/ Drop(lbs/in.)	
Apparent Groundwater Depth	10 ft; 5/28/2015	Latitude / Longitude	41.83297, -111.58475	Ground Surface Elevation (feet)	5858.0
Test Hole Backfill	Benonite Grout/ Chips	Comments	Angled Hole at 30 degrees from Vertical; Azimuth 270°	Elevation Datum	NAVD 88

Depth (feet)	ROCK CORE: Run No.	Recovery,%	R Q D, %	Fracture Density	Weathering	Hardness	Lithology	MATERIAL DESCRIPTION	Discontinuity Drawing	Discontinuity Type	DISCONTINUITY DESCRIPTION	Point Load Test Results (psi)	Packer Test Intervals	SOIL SAMPLES: Type	Number	Sampling Resistance	FIELD NOTES
0								DRILLED THROUGH OVERBURDEN -									
1								See TH-TF-01 for general description of overburden									
2																	
3																	
4																	
5																	Drilled through overbured to 23.5 feet and then installed casing to 24.3 feet and began coring.
6																	
7																	
8																	
9																	
10																	
11																	
12																	
13																	
14																	
15																	
16																	
17																	
18																	
19																	
20																	

GERHART COLE

DRAFT

Project: Bear River Project Concept Study
Project Location: Whites Valley
Project Number: 13GCI329

Log of Test Hole TH-TF-03

Depth (feet)	ROCK CORE: Run No.	Recovery,%	R Q D, %	Fracture Density	Weathering	Hardness	Lithology	MATERIAL DESCRIPTION	Discontinuity Drawing	Discontinuity Type	DISCONTINUITY DESCRIPTION	Point Load Test Results (psi)	Packer Test Intervals	SOIL SAMPLES: Type	Number	Sampling Resistance	FIELD NOTES
20																	
21																	
22																	
23																	
24																	
25	1	43	0	FD8	W1	H4		LIMESTONE, silty, with limestone and silt inclusions(<1 inch), gray to greenish gray, thinly to very thinly bedded, (GARDEN CITY FORMATION, Og)			HIGHLY FRACTURED FROM 24.4 TO 25.8 FT						
26	2	100	100	FD5	W1	H4											
27				FD6						JO	25°, WA, R3, CA						
28	3	95	95	FD4	W1	H4				ME ME ME							
29				FD5						JO	20°, WA, R3, O1, T1, FE						
30				FD7				LIMESTONE, gray to greenish gray, thinly bedded from 29.5 to 29.7 ft.		JO ME	30°, WA, R3, O1, T1, CA 20°, PL, R3, O1, T1, FE 70°, WA, R2, FE, CA						
31				FD3				LIMESTONE, gray, thinly bedded to very thinly bedded from 29.7 to 39.8 ft.		JO ME							
32				FD3								3236					
33	4	90	74	FD3	W1	H4				JO	30°, PL, R3, O1, T1, FE						
34				FD5						ME JO JO	35°, WA, R3, CA 30°, WA, R3, CA						
35				FD3						ME JO	80°, WA, O1, T1, CA						
36				FD6						JO	80°, ST, R4, CL						
37				FD5						JO ME ME	75°, WA, R3, CA, FE, CL						
38	5	100	73	FD3	W1	H4				JO	70°, WA, O1, T1, CA						
39				FD3						ME ME							
40				FD3				LIMESTONE, few inclusions, gray, thinly bedded from 39.8 to 50.8 ft.		JO ME	70°, R3, WA, CA						
41	6	50	20	FD8	W1	H4					INTENSELY FRACTURED FROM 41 TO 41.5 FT						
42										JO ME	90°, WA, R4, FE, CA						
43										ME							
44	7	7	0														

NEW ROCK CORE LOG TH_LOGS #2_BEAR_RIVER.GPJ GERHART.GDT 9/24/15

GERHART COLE

DRAFT

Project: Bear River Project Concept Study
Project Location: Whites Valley
Project Number: 13GCI329

Log of Test Hole TH-TF-03

Depth (feet)	Run No.	Recovery, %	R Q D, %	Fracture Density	Weathering	Hardness	Lithology	MATERIAL DESCRIPTION	Discontinuity Drawing	Discontinuity Type	DISCONTINUITY DESCRIPTION	Point Load Test Results (psi)	Packer Test Intervals	SOIL SAMPLES Type	Number	Sampling Resistance	FIELD NOTES
45	7	7	0					(CONT.) LIMESTONE, silty, with limestone and silt inclusions(<1 inch), gray to greenish gray, thinly to very thinly bedded, (GARDEN CITY FORMATION, Og)									
46																	Run #8, the core fell out of the inner tube and was caught in the core barrel. HQ casing was tripped out and the core was emptied from core barrel.
47																	
48	8	100	38		W1	H4											
49																	
50																	
51				FD5				LIMESTONE, with inclusions, gray to greenish gray, thinly to very thinly bedded from 50.8 to 58.3 ft.		JO	25°, PL, R4, O1, T1						
52				FD5						JO	55°, P1, O1, T1, CA						
53	9	100	86	FD5	W1	H4				JO	30°, PL, R4, FE						
54				FD5						JO	30°, PL, R4, FE						
55				FD5						ME		17468					
56				FD5						JO	20°, WA, R3, CA, FE						
57				FD5						ME							
58	10	100	78	FD5	W1	H4		LIMESTONE, gray to dark gray, thinly bedded to very thinly bedded from 58.3 to 60.5 ft.		JO	25°, PL, R3, O1, T1, FE						
59				FD4						JO	70°, WA, R4, FE						
60				FD4						JO	70°, WA, R4, FE, CA						
61				FD5				LIMESTONE, gray, thinly bedded from 60.5 to 78.6 ft.		ME	25°, PL, R3, O1, T1, FE						
62				FD2						JO	70°, WA, O2, T2, CA						
63	11	100	100	FD2	W1	H4				JO	25°, PL, R3, O1, T1, FE						
64				FD2						JO	25°, PL, R3, O1, T1, FE						
65				FD5						JO	25°, PL, R3, O1, T1, FE						
66				FD5						JO	30°, PL, R4, O1, T1						
67	12	100	94	FD5	W1	H4				JO	30°, PL, R3, O1, T1, FE						
68				FD3						JO	60-80°, WA, O1, T1, CA						
69										JO	80°, WA, O1, T1, CA						
										JO	30°, WA, R3, CL, CA						
										JO	20°, PL, O2, T2, CL						
										ME	30°, WA, R3, CA, FE						
										JO							
										JO	42°, WA, O1, T1, FE						

NEW ROCK CORE LOG TH_LOGS_#2_BEAR_RIVER.GPJ GERHART.GDT 9/24/15

GERHART COLE

DRAFT

Project: Bear River Project Concept Study
Project Location: Whites Valley
Project Number: 13GCI329

Log of Test Hole TH-TF-03

Depth (feet)	Run No.	Recovery, %	R Q D, %	Fracture Density	Weathering	Hardness	Lithology	MATERIAL DESCRIPTION	Discontinuity Type	DISCONTINUITY DESCRIPTION	Point Load Test Results (psi)	Packer Test Intervals	SOIL SAMPLES Type	Number	Sampling Resistance	FIELD NOTES
70	12	100	94	FD3	W1	H4		(CONT.) LIMESTONE, silty, with limestone and silt inclusions(<1 inch), gray to greenish gray, thinly to very thinly bedded, (GARDEN CITY FORMATION, Og)	JO	75°, PL, O1, T1 CA						
71				FD4					JO	40°, WA, O1, T1, FE						
72				FD5					JO ME	30°, PL, R4, O1, T1	7822					
73	13	100	86	FD4	W1	H4										
74				FD5					JO JO ME	35°, PL, R4, O1, T1 70-90°, WA, O1, T1, CA 40°, PL, O1, T1, CA						
75				FD6					JO JO JO ME ME	70°, PL, R4, O1, T1, FE, CA 90°, WA, O1, T1, CA						
76																
77																
78	14	58	18		W1	H4			ME							
79				FD5 FD8 FD9	W5	H4-H5		LIMESTONE, very intensely fractured, light brown to yellowish gray, thinly bedded, clay, and iron oxides, from 78.6 to 79.5 ft.	ME	VERY INTENSELY FRACTURED 78.6 TO 79.5 FT						~Fault B
80				F7	W1	H4			JO	30°, PL, R3 FRACTURED ZONE 80.2 TO 80.6 FT						
81				FD7	W1	H4		LIMESTONE, gray, thinly bedded from 79.5 to 150.3 ft.	JO JO JO	40°, WA, R3, FE, CL 65°, WA, R2, CA, CL 30°, PL, R4, O2, T2, CL, FE						
82	15	100	65	FD6												
83				FD5					JO JO JO JO ME	25°, WA, O1, T1, FE 70°, WA, O1, T1, CA 45°, WA, O1, T1, FE 45°, WA, O1, T1, FE						
84				FD5					JO JO	55°, WA, R3, FE, CL 60°, WA, R3, FE, CL						
85	16	100	100	FD6					JO	70°, PL, O1, T1, CA						
86				FD5					JO	30°, WA, R3, FE, CA						
87				FD6					JO	50°, WA, O1, T1, CA						
88	17	100	87	FD3	W1	H4			JO JO	90°, Wa, O1, T1, CA 10°, WA, R2, O1, T1, FE						
89				FD3					JO	55°, PL, O1, T1, CA						
90				FD5					JO ME	20°, PL, R4, O1, T1, FE, CA, CL						
91	18	100	100	FD3	W1	H4			ME							
92				FD8					JO JO JO JO	55°, WA, O1, T1, CA 90°, WA, O1, T1, CA 60°, PL, R4, CA, FE 35°, PL, R4, O1, T1, CA, FE						
93	19	96	88	FD3	W1	H4			JO	80-90°, WA, O1-O2, T2,						

NEW ROCK CORE LOG TH LOGS #2 BEAR RIVER.GPJ GERHART.GDT 9/24/15

GERHART COLE

DRAFT

Project: Bear River Project Concept Study
Project Location: Whites Valley
Project Number: 13GCI329

Log of Test Hole TH-TF-03

Depth (feet)	Run No.	Recovery,%	R Q D, %	Fracture Density	Weathering	Hardness	Lithology	MATERIAL DESCRIPTION	Discontinuity Drawing	Discontinuity Type	DISCONTINUITY DESCRIPTION	Point Load Test Results (psi)	Packer Test Intervals	SOIL SAMPLES Type	Number	Sampling Resistance	FIELD NOTES
94								(CONT.) LIMESTONE, silty, with limestone and silt inclusions(<1 inch), gray to greenish gray, thinly to very thinly bedded, (GARDEN CITY FORMATION, Og)		ME	FE, CA						
				FD3						JO	35°, WA, R2, O1, T1, FE, CA						
95	19	96	88		W1	H4											
				FD3						JO	35°, PL, R3, O1, T1, FE						
										ME							
96										JO	30°, PL, O2, T2, CA						
				FD3													
97																	
	20	100	91	FD3	W1	H4						7796					
98																	
				FD3						JO	80°, WA, R3, O1, T1, FE, CA						
										JO	35°, PL, R3, O1, T1, FE						
99																	
				FD5						ME							
100																	
				FD4						JO	30°, PL, R3, O1, T1, FE, CA						
101	21	100	100	FD3	W1	H4											
102																	
				FD3						JO	25°, R4, PL, O1, T1, FE						
103																	
				FD3													
104																	
	22	100	100	FD3	W1	H4											
105										JO	80°, WA, O0-O1, T0-T1, CA						
				FD3													
106										JO	50°, PL, O1, T1, CA						
				FD3													
107										JO	30°, PL, O1, T1, CA, R4						
				FD3													
108																	
	23	100	100	FD3	W1	H4				JO	50°, WA, O2, T2, CA						
109																	
				FD3													
110										ME							
				FD3													
111																	
				FD0													
112																	
				FD0													
113																	
	24	100	100	FD0	W1	H4				JO	85°, WA, O1, T1, CA						
114																	
				FD0													
115																	
				FD0													
116																	
				FD5						JO	45°, PL, R4, O1, T1, FE, CA						
										JO	20°, PL, R4, O1, T1, FE						
117	25	100	100		W1	H4											
				FD3													
118										JO	75°, WA, O1, T1, CA						
										JO	20°, WA, O1, T1, CA						

NEW ROCK CORE LOG TH_LOGS #2_BEAR_RIVER.GPJ GERHART.GDT 9/24/15

GERHART COLE

DRAFT

Project: Bear River Project Concept Study
Project Location: Whites Valley
Project Number: 13GCI329

Log of Test Hole TH-TF-03

Depth (feet)	Run No.	Recovery,%	R Q D, %	Fracture Density	Weathering	Hardness	Lithology	MATERIAL DESCRIPTION	Discontinuity Drawing	Discontinuity Type	DISCONTINUITY DESCRIPTION	Point Load Test Results (psi)	Packer Test Intervals	SOIL SAMPLES Type	Number	Sampling Resistance	FIELD NOTES
119				FD3				(CONT.) LIMESTONE, silty, with limestone and silt inclusions(<1 inch), gray to greenish gray, thinly to very thinly bedded, (GARDEN CITY FORMATION, Og)		ME							
	25	100	100	FD3	W1	H4				JO	40°, PL, T4, O1, T1, CA						
120				FD3						ME		10448					
121				FD5						JO	40°, PL, R3, O1, T1, FE						
122				FD6						JO JO JO	30°, WA, R3, FE, CA 30°, WA, R3, FE, CA 90°, WA, O1, T1, FE						
123	26	100	100	FD5	W1	H4				JO ME ME	30°, WA, R3, O1, T1, FE, CA						
124				FD3						JO JO	60°, WA, R4, FE, CL 70-80°, WA, O1, T1, FE						
125				FD3													
126				FD3						ME							
127				FD3													
128	27	100	100	FD3	W1	H4				JO	20°, WA, R3, CA, FE						
129				FD3													
130				FD3						JO JO ME	25°, PL, R3, O1, T1, FE, CA 70-90°, WA, O1, T1, CA, FE						
131				FD2						JO	50-70°, PL, O1, T1, CA						
132				FD2						JO	40°, PL, O1, T1, CA						
133	28	100	100	FD2	W1	H4				JO JO JO	50°, PL, O1, T1, CA 50°, PL, O1, T1, CA 50°, PL, O1, T1, CA						
134				FD2/FD3						ME	25°, PL, O1, T1, CA						
135				FD3						JO JO	40°, WA, R4, O1, T1, FE, CA						
136				FD5/FD3						ME JO JO	45°, WA, O2, T2, CA 45°, PL, R4, FE, CA						
137				FD3						ME ME							
138	29	100	94	FD3	W1	H4				JO	80°, WA, O1, T1, CA						
139				FD3													
140				FD3						JO JO JO JO JO	40°, PL, R3, O1, T1, CA, CL 45-90°, WA, O1, T1, CA 25°, PL, R4, O1, T1, CL 40°, PL, R4, O1, T1, CL 55°, WA, O1, T1, CA						
141				FD3													
142	30	100	100	FD3	W1	H4				ME							
143																	

NEW ROCK CORE LOG TH_LOGS #2_BEAR_RIVER.GPJ GERHART.GDT 9/24/15

GERHART COLE

DRAFT

Project: Bear River Project Concept Study
Project Location: Whites Valley
Project Number: 13GCI329

Log of Test Hole TH-TF-03

Depth (feet)	ROCK CORE: Run No.	Recovery,%	R Q D, %	Fracture Density	Weathering	Hardness	Lithology	MATERIAL DESCRIPTION	Discontinuity Drawing	Discontinuity Type	DISCONTINUITY DESCRIPTION	Point Load Test Results (psi)	Packer Test Intervals	SOIL SAMPLES: Type	Number	Sampling Resistance	FIELD NOTES
144				FD3				(CONT.) LIMESTONE, silty, with limestone and silt inclusions(<1 inch), gray to greenish gray, thinly to very thinly bedded, (GARDEN CITY FORMATION, Og)		JO	35°, PL, R3, O1, T1, CA, FE						
145	30	100	100	FD3	W1	H4											
146				FD3													
147				FD0													
148	31	100	100	FD0	W1	H4											
149				FD0								9555					
150				FD0						JO	25°, PL, R4, T1, CA, CL						
151								Bottom of Test Hole at 150.3 feet.									
152																	
153																	
154																	
155																	
156																	
157																	
158																	
159																	
160																	
161																	
162																	
163																	
164																	
165																	
166																	
167																	

GERHART COLE

Unified Soil Classification System (USCS)

DRAFT

Material Types	Major Soil Divisions		Group Symbol and Legend	Typical Names
COARSE-GRAINED SOILS >50% retained on No. 200 sieve	GRAVELS >50% of coarse fraction retained on No. 4 Sieve	Clean GRAVELS (little or no fines)	GW	Well-Graded GRAVEL, GRAVEL-sand mixtures, few fines
			GP	Poorly-Graded GRAVEL, GRAVEL-sand mixtures, few fines
		GRAVELS with fines (appreciable amount of fines)	GM	Silty GRAVEL, GRAVEL-sand silt mixtures
			GC	Clayey GRAVEL, GRAVEL-sand clay mixtures
	SANDS >50% of coarse fraction passing the No. 4 sieve	Clean SANDS (little or no fines)	SW	Well-Graded SAND, SAND-gravel mixtures, few fines
			SP	Poorly-Graded SAND, SAND-gravel mixtures, few fines
		SANDS with fines (appreciable amount of fines)	SM	Silty SAND, SAND-silt mixtures
			SC	Clayey SAND, SAND-clay mixtures
FINE-GRAINED SOILS >50% Passing No. 200 Sieve	SILTS and CLAYS liquid limit < 50	Inorganic 1) CF > 30%: + Sandy/Gravelly 2) CF = 15-30% + with sand/gravel	CL	Lean CLAY, Gravelly/Sandy CLAY, low to med. plasticity
			ML	SILT, Gravelly/Sandy SILT, no to slight plasticity
		Organic	OL	Organic CLAY or SILT
	SILTS and CLAYS liquid limit < 50	Inorganic 1) CF > 30%: + Sandy/Gravelly 2) CF = 15-30% + with sand/gravel	CH	Fat CLAY, Gravelly/Sandy Fat CLAY, high plasticity
			MH	Elastic SILT, Gravelly/Sandy Elastic SILT, low to high plasticity
		Organic	OH	Organic CLAY or SILT
Highly orgainc soils		Primarily Organic Matter; Organic Odor	PT	PEAT
Boulders / Cobbles		> 50% (by volume) particles > 3"	COBBLES BOULDERS	Boulders (>12"); Cobbles (>3" and <12")

Other Material Symbols

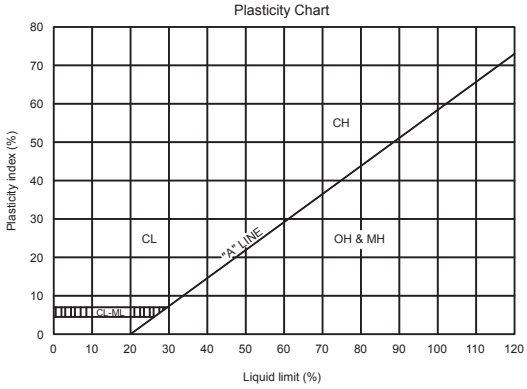
- Bedrock
- Asphalt
- Concrete
- Topsoil
- Fill

Sample Types

- Auger Cuttings
- Continuous sampler
- Grab Sample
- No Recovery
- Shelby Tube
- Standard Penetration Test (SPT)
- California Sampler
- Rock Core
- Modified California Sampler
- Other (see remarks)
- Piston Sampler (Shelby Tube)
- Split Spoon
- Vane Shear

Apparent water level

Measured water level



Descriptors for Coarse Grained Soils

Apparent Density	Dr (%)	SPT	MC	CAL
very loose	0-15	<4	<6	<8
loose	15-35	4-10	6-15	8-20
med. dense	35-65	10-30	15-42	20-56
dense	65-85	30-50	42-72	56-96
very dense	85-100	>50	>72	>96

Descriptors for Fine Grained Soils

Consistency	Su (psf)	SPT	MC	CAL
very soft	< 250	<2	<2	<2
soft	250-500	2-4	2-4	2-5
med. stiff	500-1000	4-8	4-10	5-11
stiff	1000-2000	8-15	10-19	11-22
very stiff	2000-4000	15-30	19-37	22-45
hard	>4000	>30	>37	>45

SPT - Standard split spoon (SPT): 2" OD, 1.375" ID
MC - Modified California: 2.5" OD, 1.875" ID
CAL - California: 3" OD, 2.375" ID

Stratification

Description	Criteria
Seam	1/16" to 1/2"
Layer	1/2" to 12"
Occasional	<= 1 per ft. thickness
Frequent	> 1 per ft. thickness

Modifiers

Description	Est. (%)
Trace	<5
Some	5-12
With	>12

Descriptors for Moisture

Description	Criteria
Dry	Absence of moisture, dusty, dry to the touch
Moist	Damp but no visible water
Wet	Visible free water, usually soil is below water table

Descriptors for Particle Size

Description	Criteria
Boulder	>12" : larger than a basketball
Cobble	3-12" : larger than a grapefruit
Coarse Gravel	3/4-3" : larger than a grape
Fine Gravel	No.4-3/4" : larger than a pea
Coarse Sand	No.10-4 : larger than rock salt grain
Medium Sand	No.40-4 : larger than window screen opening
Fine Sand	No.200-40 : larger than a sugar grain

Descriptios for Particle Angularity

Description	Criteria
Angular	Sharp edges, rel. plane sides, unpolished surface
Subangular	Similar to angular, but with rounded edges
Subrounded	Nearly plane sides, well-rounded corners & edges
Rounded	Smoothly curved sides and no edges

Abbreviated Soil Classification Symbols (after ASTM D2488 X.5)

Prefix	Suffix
s = sandy	s = with sand
g = gravelly	g = with gravel
	c = with cobbles
	b = with boulders

Abbreviated system for supplementary presentations when complete description is referenced. Examples:

Group Symbol and Full Name	Abbreviated
Sandy Lean CLAY (CL)	s(CL)
Poorly Graded SAND with silt and gravel	(SP-SM)g
Poorly Graded GRAVEL with sand, cobbles, and boulders (GP)	(GP)scb
Gravelly SILT with sand and cobbles (ML)	g(ML)sc

General Notes:
1) Strata graphic lines on the logs represent approximate boundaries.
2) No warranty is provided as to the continuity of soil conditions between points explored and sample locations.
3) Logs represent soil conditions observed at the point of exploration on the date indicated.
4) Visual methods were used to classify the materials in general accordance with the Unified Soils Classification Systems; actual designations based on laboratory methods may vary.

GERHART COLE

Legend to Soil Descriptions

DRAFT

KEY TO SOIL AND ROCK CORE LOG

Depth, feet	ROCK CORE						Lithology	MATERIAL DESCRIPTION	Discontinuity Drawing	Discontinuity Type	DISCONTINUITY DESCRIPTION	Point Load Test Results (psi)	Packer Test Intervals	SOIL SAMPLES		FIELD NOTES
	Run No.	Recovery, %	RQD, %	Fractures Density	Weathering	Hardness								Type Number	Sampling Resistance	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17

COLUMN DESCRIPTIONS

1 DEPTH: Distance (in feet) below the collar of the borehole.

2 RUN NO.: Number of the individual coring interval.

3 RECOVERY: Rock Coring: Amount (in percent) of core recovered from the coring interval; calculated as length of core recovered divided by length of run. Actual soil recovery in driven sampler as a percentage of the sampler penetration.

Soil/Rock Sampling: Ratio of sample length to recovered sample amount.

4 RQD: (Rock Quality Designation) Amount (in percent) of intact core (pieces of sound core greater than 4 inches in length) in each coring interval; calculated as the sum of lengths of intact core divided by length of core run. RQD of moderately weathered / altered rock does not meet soundness requirements, but provides some indication of rock quality with respect to the degree of fracturing.

5 FRACTURES DENSITY: (Fracture Frequency) The density of naturally occurring fractures in each foot of core; does not include mechanical breaks (induced by drilling) or healed fractures. See Sheet 2 for explaination and additional information. "NA" indicates not applicable due to lack of core recovery.

6 WEATHERING: The process of chemical or mechanical degradation of rock. See Sheet 2 for additional information.

7 HARDNESS: See Sheet 2 for explanation and additional information.

8 LITHOLOGY: A graphic log of material encountered using symbols to represent differing soil and types; graphic symbols are explained below.

9 DESCRIPTION: Rock: Lithologic description in this order: rock type, grain size, texture, color, strength, and other features; descriptive terms are defined on the attached sheets and tables. A detailed description of overburden material is not necessarily provided.

Soil or weathered rock: See sheet 2 for explanation and additional information.

10 DISCONTINUITY DRAWING: Sketch of the naturally occurring fractures and mechanical breaks, showing the angle of the fractures relative to the cross-sectional axis of the core. Intensely fractured material are not included in fractured drawings (see core photos, if available). "NR" indicates no recovery.

11 DISCONTINUITY TYPE: See Sheet 2 for explanation and additional Information

12 DISCONTINUITY DESCRIPTION: Orientation, Surface Shape, Roughness, Aperture, Filling Thickness, Filling Type, See Sheet 2 for explanation and additional Information

13 POINT LOAD TEST RESULTS: The testing results from point load tests.

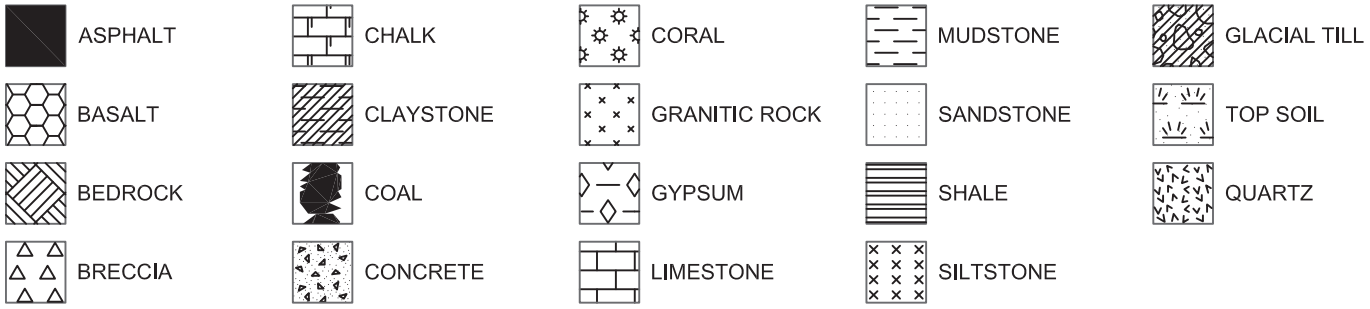
14 PACKER TEST INTERVALS: Testing permeability and water sampling in different regions of test hole by isolation of depths using inflatable packers or bladders.

15 SAMPLE TYPE \ NUMBER: Type of soil sample collected at depth interval shown; sampler symbols are explained below. Sample identification number.

16 SAMPLING RESISTANCE.: Number of blows to advance driven sampler each 6-inch drive interval, or distance noted, using a 140-lb hammer with a 30-inch drop (unless otherwise noted).

17 FIELD NOTES: Comments an observation regarding drilling or sampling made by driller or field personnel.

TYPICAL MATERIAL GRAPHIC SYMBOLS FOR ROCK



GERHART COLE

LEGEND TO
SOIL & ROCK DESCRIPTIONS
SHEET 1 OF 2

DRAFT

KEY TO SOIL AND ROCK CORE LOG

ROCK WEATHERING / ALTERATION

Weathering descriptors (Extracted from USBR, 2001)

Descriptors		Diagnostic features					
		Chemical weathering - Discoloration and/or oxidation		Mechanical weathering Grain boundary conditions (disaggregation) primarily for granitics and some coarse grained sediments	Texture and solutioning		
Alpha numeric descriptor	Descriptive term	Body of rock	Fracture surfaces[2]		Texture	Solutioning	General characteristics (strength, excavation, etc.)[3]
W1	Fresh	No discoloration, not oxidized	No discoloration or oxidation	No separation, intact (tight)	No change	No solutioning	Hammer rings when crystalline rocks are struck. Almost always rock excavation except for naturally weak or weakly cemented rocks such as siltstones or shale.
W2	Slightly Weathered to Fresh[1]						
W3	Slightly Weathered	Discoloration or oxidation is limited to surface of, or short distance from fractures; some feldspar crystals are dull.	Minor to complete discoloration or oxidation of most surfaces.	No visible separation, intact (tight).	Preserved.	Minor leaching of some soluble minerals may be noted.	Hammer rings when crystalline rocks are struck. Body of rock not weakened. With few exceptions, such as siltstones or shales, classifies as rock excavation.
W4	Moderately to Slightly Weathered[1]						
W5	Moderately Weathered	Discoloration or oxidation extends from fractures, usually throughout; Fe-Mg minerals are "rusty," feldspar crystals are "cloudy."	All fracture surfaces are discolored or oxidized.	Partial separation of boundaries visible.	Generally preserved.	Soluble minerals may be mostly leached.	Hammer does not ring when rock is struck. Body of rock is slightly weakened. Depending on fracturing, usually is rock excavation except in naturally weak rocks such as siltstone or shales.
W6	Intensely to Moderately Weathered[1]						
W7	Intensely Weathered	Discoloration or oxidation throughout; all feldspars and Fe-Mg minerals are altered to clay to some extent; or chemical alteration produces in situ disaggregation, see grain boundary conditions	All fracture surfaces are discolored or oxidized, surfaces friable.	Partial separation, rock is friable; in semiarid conditions granitica are disaggregated.	Texture alerted by chemical disintegration (hydration, argillation).	Leaching of soluble minerals may be complete.	Dull sound when struck with hammer; usually can be broken with moderate to heavy manual pressure or by light hammer blow without reference to planes of weakness such as incipient or hairline fractures, or veinlets. Rock is significantly weakened. Usually common excavation.
W8	Very Intensely Weathered						
W9	Decomposed	Discolored or oxidized throughout, but resistant minerals such as quartz may be unaltered; all feldspar and FE-Mg minerals		Complete separation of grain boundaries (disaggregated).	Resembles a soil, partial or complete remnant rock structure may be preserved; leaching of soluble minerals usually complete.		Can be granulated by hand. Always common excavation. Resistant minerals such as quartz may be present as "stringers" or "dikes."

Note: This chart and its horizontal categories are more readily applied to rocks with feldspars and mafic minerals. Weathering in various sedimentary rocks, particularly limestones and poorly indurated sediments, will not always fit the categories established. This chart and weathering categories may have to be modified for particular site conditions or alteration such as hydrothermal effects; however, the basic framework and similar descriptors are to be used.

1) Combination descriptors are permissible where equal distribution of both weathering characteristics are present over significant intervals or where characteristics present are "in between" the diagnostic feature. However, dual descriptors should not be used where significant, identifiable zones can be delineated. When given as a range, only two adjacent terms may be combined (i.e., decomposed to lightly weathered or moderately weathered to fresh) are not acceptable.

2) Does not include directional weathering along shears or faults and their associated features. For example, a shear zone that carried weathering to great depths into a fresh rock mass would not require the rock mass to be classified as weathered.

3) These are generalization and should not be used as diagnostic features for weathering or excavation classification. These characteristics vary to a large extent based on naturally weak materials or cementation and type of excavation.

ROCK HARDNESS

Rock Hardness/strength descriptors (Extracted from USBR, 2001)

Alpha numeric descriptor	Descriptor	Criteria
H1	Extremely hard	Core, fragment, or exposure cannot be scratched with knife or sharp pick; can only be chipped with repeated heavy hammer blows.
H2	Very hard	Cannot be scratched with knife or sharp pick. Core or fragment breaks with repeated heavy hammer blows.
H3	Hard	Can be scratched with knife or sharp pick with difficulty (heavy pressure). Heavy hammer blow required to break specimen.
H4	Moderately hard	Can be scratched with knife or sharp pick with light or moderate pressure. Core or fragment breaks with moderate hammer blow
H5	Moderately soft	Can be grooved 1/16 inch (2 mm) deep by knife or sharp pick with moderate or heavy pressure. Core or fragment breaks with light hammer blow or heavy manual pressure.
H6	Soft	Can be grooved or gouged easily by knife or sharp pick with light pressure, can be scratched with fingernail. Breaks with light to moderate manual pressure.
H7	Very soft	Can be readily indented, grooved or gouged with fingernail, or carved with a knife. Breaks with light manual pressure.
Any bedrock unit softer than H7, is to be described using USBR 5000 consistency descriptors		

Note: Although "sharp pick" is included in these definitions, descriptions of ability to be scratched, grooved, or gouged by a knife is the preferred criteria.

11 Discontinuity Type:

Fa - Fault
Jo - Joint
Sh - Shear
Fo - Foliation
V - Vein
Be - Bedding
Me - Mechanical break

12 DISCONTINUITY DESCRIPTIONS

a Orientation, Angle perpendicular to core

b Surface Shape of Joint:

Pl - Planer
Wa - Wavy
St - Stepped
Ir - Irregular

c Roughness of Surface:

Fracture roughness descriptors (Extracted from USBR, 2001)

Alpha numeric descriptor	Descriptor	Criteria
R1	Stepped	Near-normal steps and ridges occur on the fracture surface
R2	Rough	Large angualr asperities can be seen.
R3	Moderately rough	Asperities are clearly visible and fracture surface feels abrasive.
R4	Slightly rough	Small asperities on the fracture surface are visible and can be felt
R5	Smooth	No asperities, smooth to the touch
R6	Polished	Extremely smooth and shiny.

d Aperture:

Fracture openness descriptors (Extracted from USBR, 2001)

Alpha numeric descriptor	Descriptor	Criteria
O0	Tight	No visible separation
O1	Slightly open	Less than 0.003 ft [1/32 inch (in)] (<1 mm)
O2	Moderately open	0.003 to 0.01 ft [1/32 in to 1/8 in] (1 to 3 mm)
O3	Open	0.01 to 0.03 ft [1/8 to 3/8 in] (3 to 10 mm)
O4	Moderately wide	0.03 ft [3/8' to 0.1 ft (10 to 30 mm)
O5	Wide	Greater than 0.1 ft (>30 mm) (record actual openness)

e Filling Thickness:

Fracture filing thickness (Extracted from USBR, 2001)

Alpha numeric descriptor	Descriptor	Criteria
T0	Clean	No film coating
T1	Very thin	Less than 0.003 ft [1/32 in] (<1 mm)
T2	Moderately thin	0.003 to 0.01 ft [1/32 to 1/8 in] (1 to 3
T3	Thin	0.01 to 0.03 ft [1/8 to 3/8 in] (3 to 10
T4	Moderately thick	0.03 ft [3/8 in] to 0.1 ft (10 to 30 mm)
T5	Thick	Greater than 0.1 ft (>30 mm) (record actual thickness)

f Filling Type:

Ca - Clay
Ca - Calcite
Fe - Iron Oxide
Gy - Gypsum

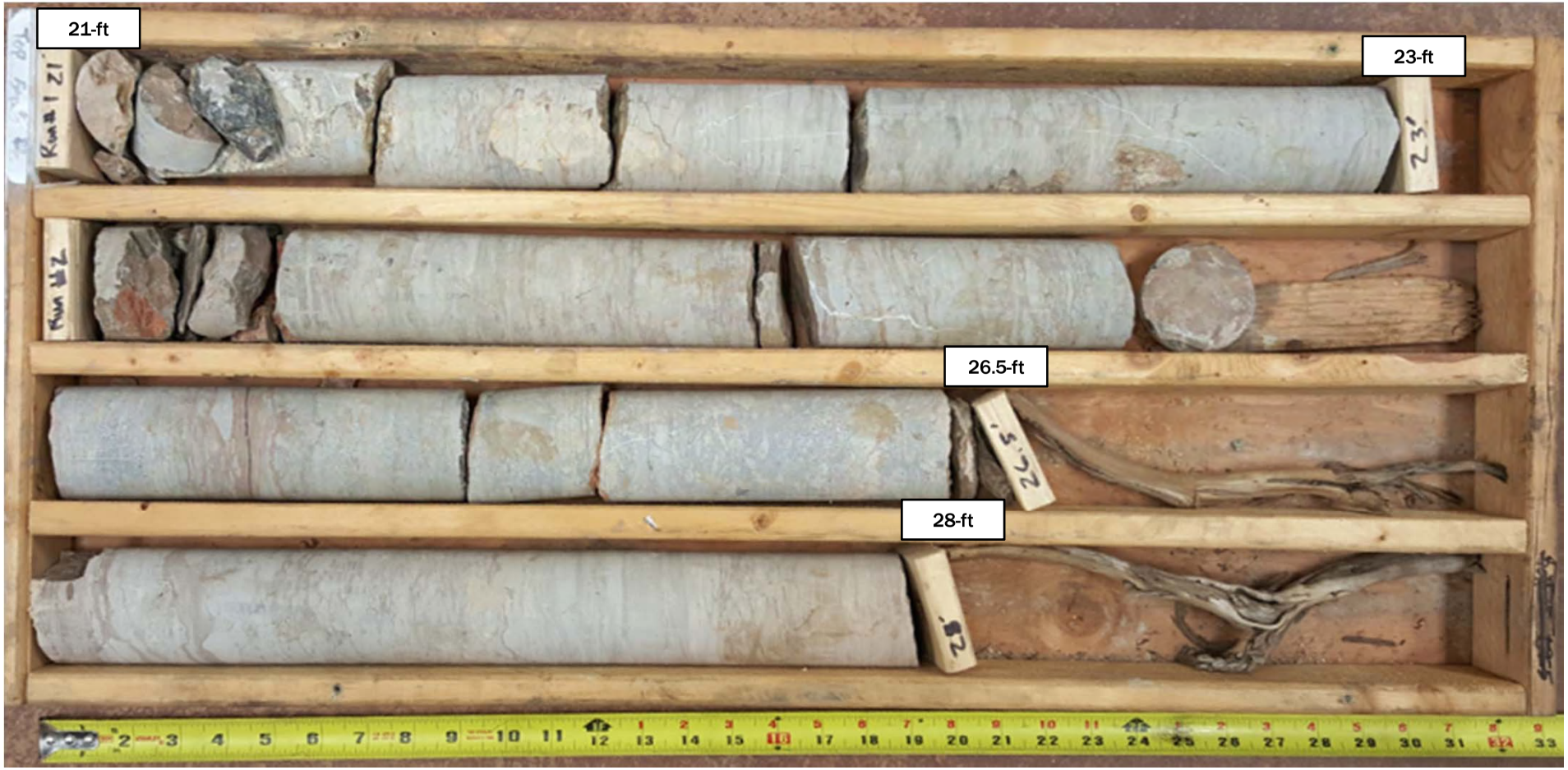
U.S. Bureau of Reclamation, 2001, Engineering Geology Field Manual, Second Edition, Volume 1: Technical Service Center, Bureau of Reclamation, U.S. Department of the Interior.

GERHART COLE

LEGEND TO
SOIL & ROCK DESCRIPTIONS
SHEET 2 OF 2

DRAFT

Location:	TH-TF-01	Box Number:	1	Run(s):	1,2	Depth(ft):	21-28



Notes:

1. This photo log is for information purposes only. It is intended to assist in showing features discussed in the attached field logs.

Reference: Log of Referenced Test Hole

PHOTOGRAPHIC SUMMARY OF ROCK CORE

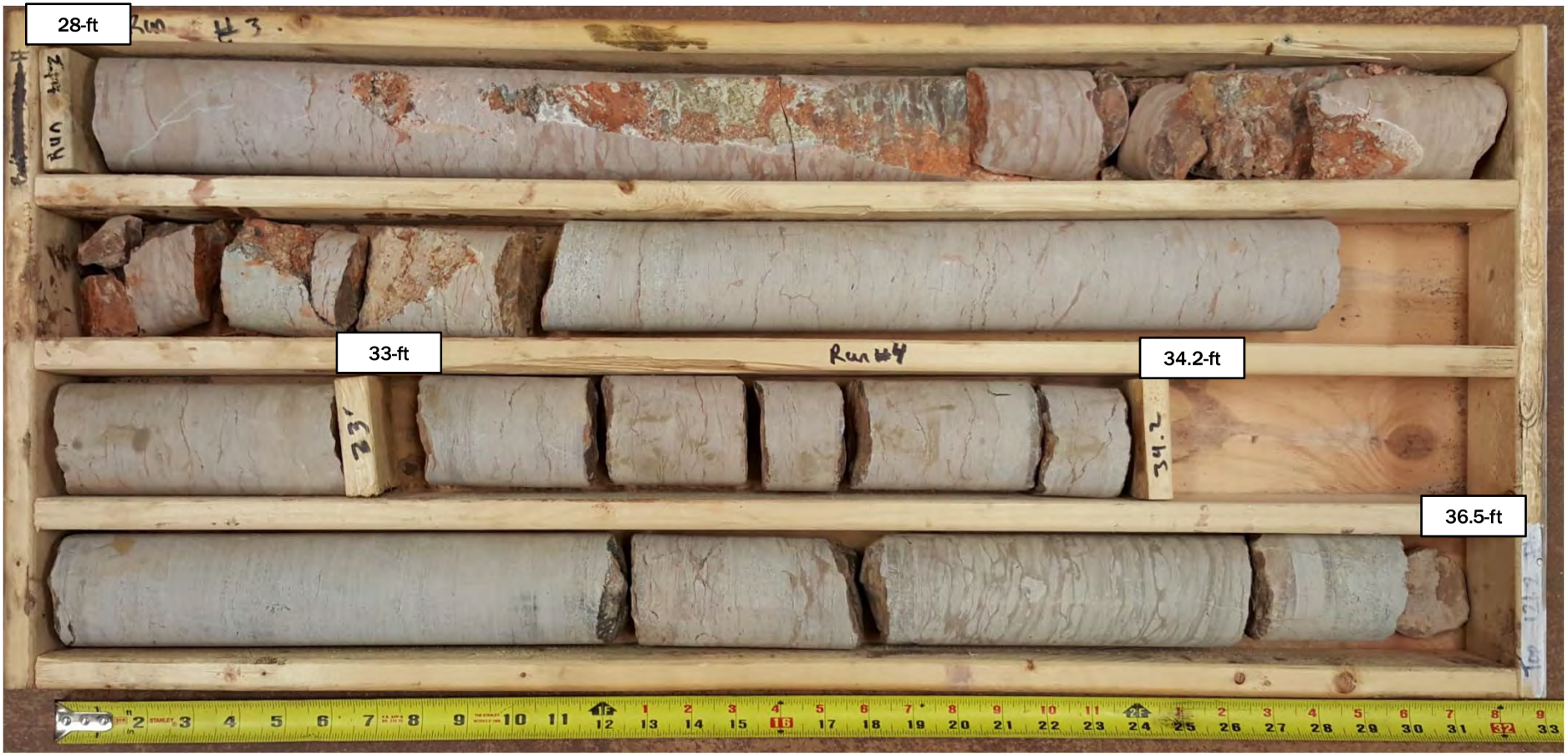
Bear River Project Concept Study
Temple Fork

GERHART COLE

Figure: 1

DRAFT

Location:	TH-TF-01	Box Number:	2	Run(s):	3,4	Depth(ft):	28-36.5



Notes:

1. This photo log is for information purposes only. It is intended to assist in showing features discussed in the attached field logs.

Reference: Log of Referenced Test Hole

PHOTOGRAPHIC SUMMARY OF ROCK CORE

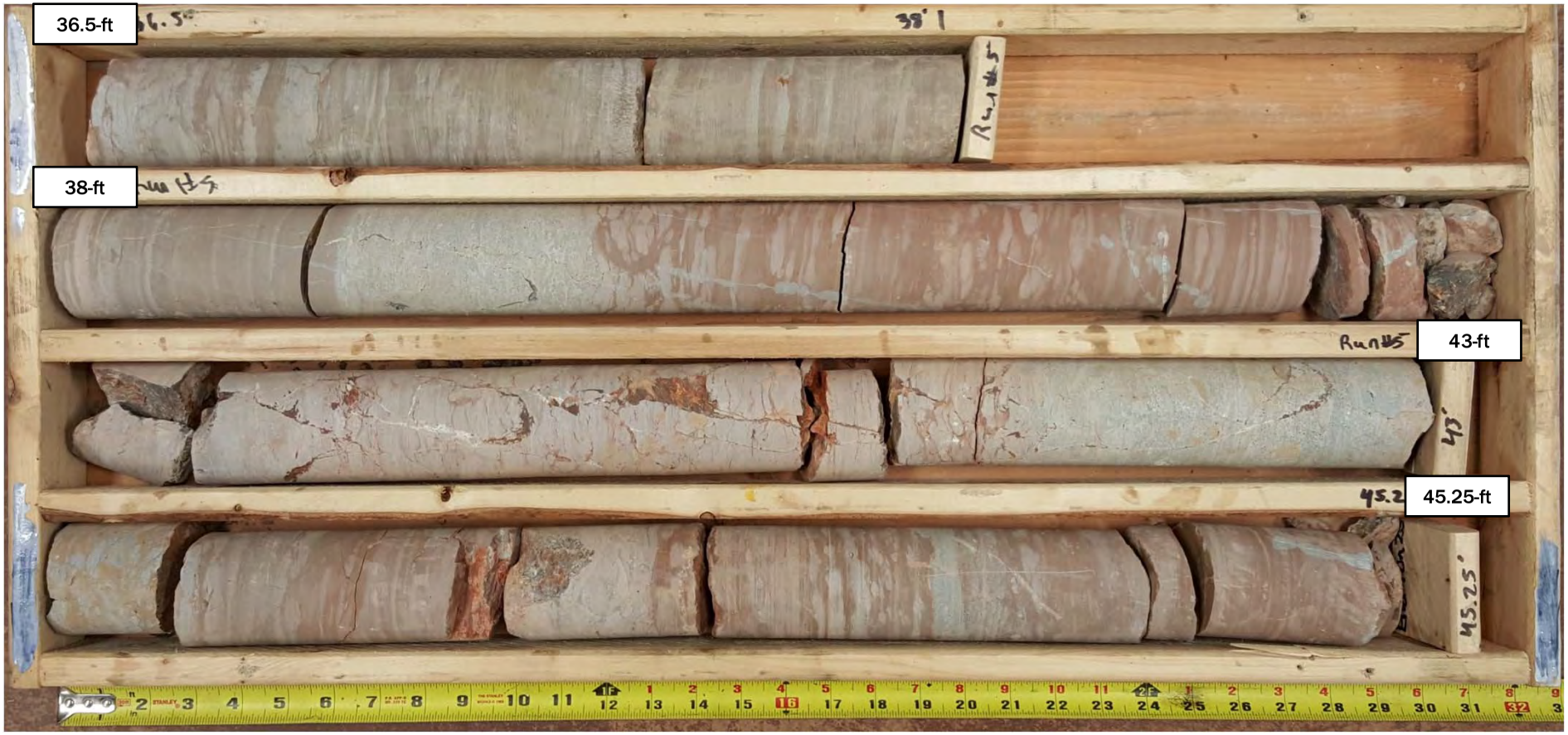
Bear River Project Concept Study
Temple Fork

GERHART COLE

Figure: 2

DRAFT

Location:	TH-TF-01	Box Number:	3	Run(s):	4,5,6	Depth(ft):	36.5-45.25



Notes:

1. This photo log is for information purposes only. It is intended to assist in showing features discussed in the attached field logs.

Reference: Log of Referenced Test Hole

PHOTOGRAPHIC SUMMARY OF ROCK CORE

Bear River Project Concept Study
Temple Fork

GERHART COLE

Figure: 3

DRAFT

Location:	TH-TF-01	Box Number:	4	Run(s):	6,7	Depth(ft):	45.25-53

Notes:

1. This photo log is for information purposes only. It is intended to assist in showing features discussed in the attached field logs.

Reference: Log of Referenced Test Hole

PHOTOGRAPHIC SUMMARY OF ROCK CORE

Bear River Project Concept Study
Temple Fork

GERHART COLE

Figure: 4

DRAFT

Location:	TH-TF-01	Box Number:	5	Run(s):	8,9	Depth(ft):	53-61

Notes:

1. This photo log is for information purposes only. It is intended to assist in showing features discussed in the attached field logs.

Reference: Log of Referenced Test Hole

PHOTOGRAPHIC SUMMARY OF ROCK CORE

Bear River Project Concept Study
Temple Fork

GERHART COLE

Figure: 5

DRAFT

Location:	TH-TF-01	Box Number:	6	Run(s):	9,10,11	Depth(ft):	61-70.25

Notes:

1. This photo log is for information purposes only. It is intended to assist in showing features discussed in the attached field logs.

Reference: Log of Referenced Test Hole

PHOTOGRAPHIC SUMMARY OF ROCK CORE

Bear River Project Concept Study
Temple Fork

GERHART COLE

Figure: 6

DRAFT

Location:	TH-TF-01	Box Number:	7	Run(s):	11,12	Depth(ft):	70.25-78

Notes:

1. This photo log is for information purposes only. It is intended to assist in showing features discussed in the attached field logs.

Reference: Log of Referenced Test Hole

PHOTOGRAPHIC SUMMARY OF ROCK CORE

Bear River Project Concept Study
Temple Fork

GERHART COLE

Figure: 7

DRAFT

Location:	TH-TF-01	Box Number:	8	Run(s):	13,14	Depth(ft):	78-85.2

Notes:

1. This photo log is for information purposes only. It is intended to assist in showing features discussed in the attached field logs.

Reference: Log of Referenced Test Hole

PHOTOGRAPHIC SUMMARY OF ROCK CORE

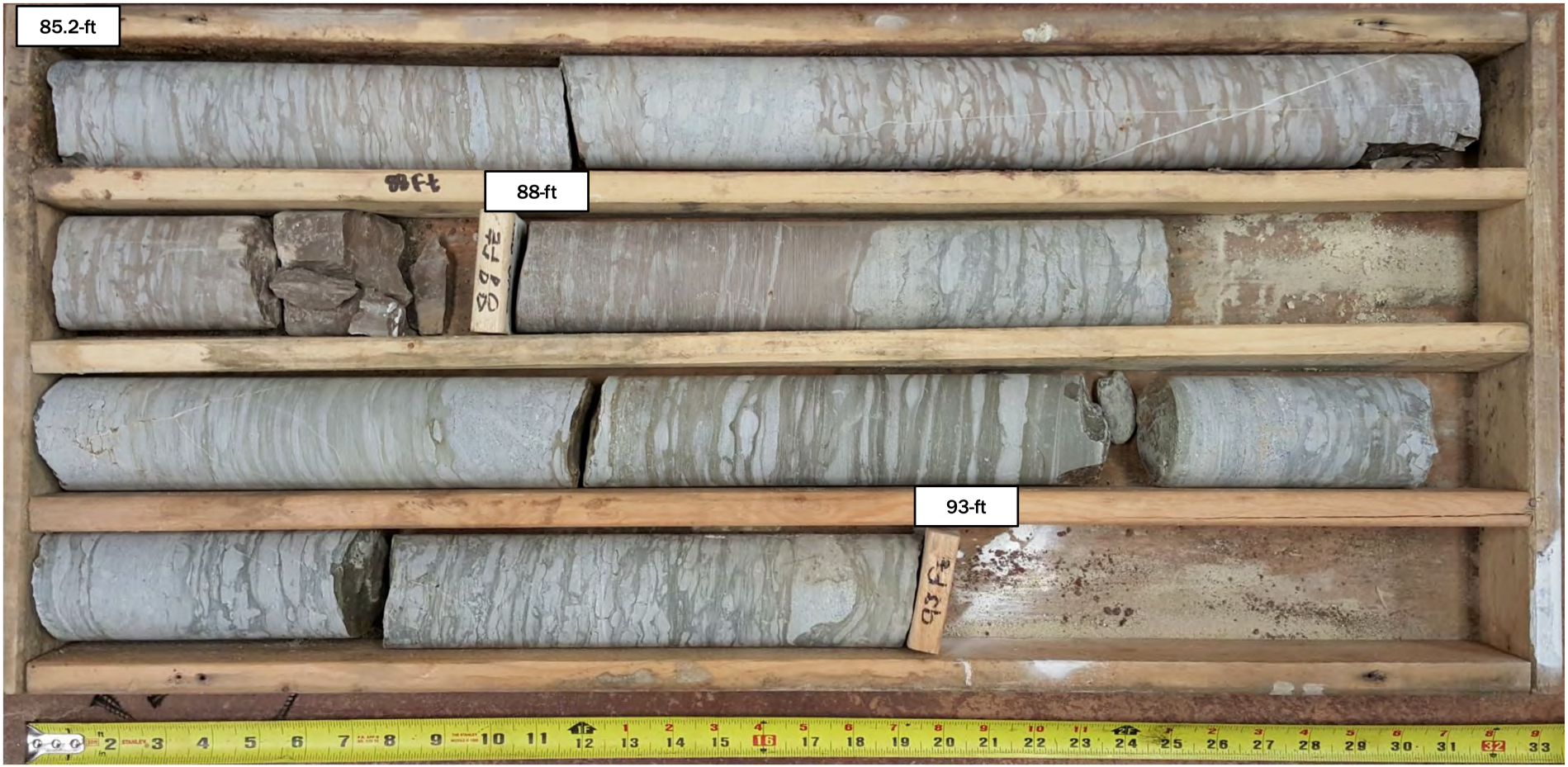
Bear River Project Concept Study
Temple Fork

GERHART COLE

Figure: 8

DRAFT

Location:	TH-TF-01	Box Number:	9	Run(s):	14,15	Depth(ft):	85.2-93



Notes:

1. This photo log is for information purposes only. It is intended to assist in showing features discussed in the attached field logs.

Reference: Log of Referenced Test Hole

PHOTOGRAPHIC SUMMARY OF ROCK CORE

Bear River Project Concept Study
Temple Fork

GERHART COLE

Figure: 9

DRAFT

Location:	TH-TF-01	Box Number:	10	Run(s):	16,17	Depth(ft):	93-100.5

Notes:

1. This photo log is for information purposes only. It is intended to assist in showing features discussed in the attached field logs.

Reference: Log of Referenced Test Hole

PHOTOGRAPHIC SUMMARY OF ROCK CORE

Bear River Project Concept Study
Temple Fork

GERHART COLE

Figure: 10

DRAFT

Location:	TH-TF-02	Box Number:	1	Run(s):	1,2,3	Depth(ft):	24.5-33.7

Notes:

1. This photo log is for information purposes only. It is intended to assist in showing features discussed in the attached field logs.

Reference: Log of Referenced Test Hole

PHOTOGRAPHIC SUMMARY OF ROCK CORE

Bear River Project Concept Study
Temple Fork

GERHART COLE

Figure: 11

DRAFT

Location:	TH-TF-02	Box Number:	2	Run(s):	3,4,5	Depth(ft):	33.7-42.6

Notes:

1. This photo log is for information purposes only. It is intended to assist in showing features discussed in the attached field logs.

Reference: Log of Referenced Test Hole

PHOTOGRAPHIC SUMMARY OF ROCK CORE

Bear River Project Concept Study
Temple Fork

GERHART COLE

Figure: 12

DRAFT

Location:	TH-TF-02	Box Number:	3	Run(s):	5,6	Depth(ft):	42.6-50.8

Notes:

1. This photo log is for information purposes only. It is intended to assist in showing features discussed in the attached field logs.

Reference: Log of Referenced Test Hole

PHOTOGRAPHIC SUMMARY OF ROCK CORE

Bear River Project Concept Study
Temple Fork

GERHART COLE

Figure: 13

DRAFT

Location:	TH-TF-02	Box Number:	4	Run(s):	7,8	Depth(ft):	50.8-55.8

Notes:

1. This photo log is for information purposes only. It is intended to assist in showing features discussed in the attached field logs.

Reference: Log of Referenced Test Hole

PHOTOGRAPHIC SUMMARY OF ROCK CORE

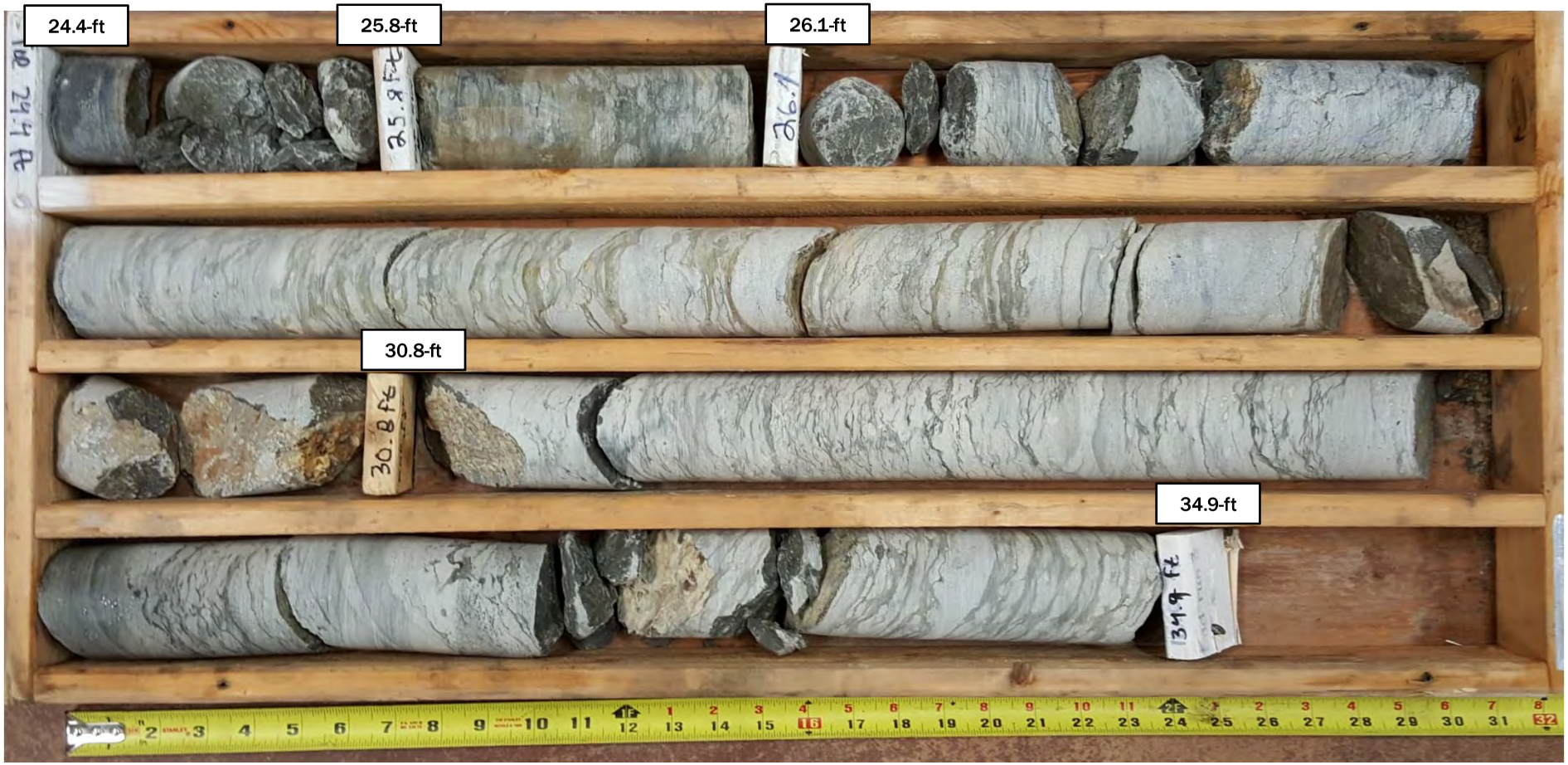
Bear River Project Concept Study
Temple Fork

GERHART COLE

Figure: 14

DRAFT

Location:	TH-TF-03	Box Number:	1	Run(s):	1,2,3,4	Depth(ft):	24.4-34.9



Notes:

1. This photo log is for information purposes only. It is intended to assist in showing features discussed in the attached field logs.

Reference: Log of Referenced Test Hole

PHOTOGRAPHIC SUMMARY OF ROCK CORE

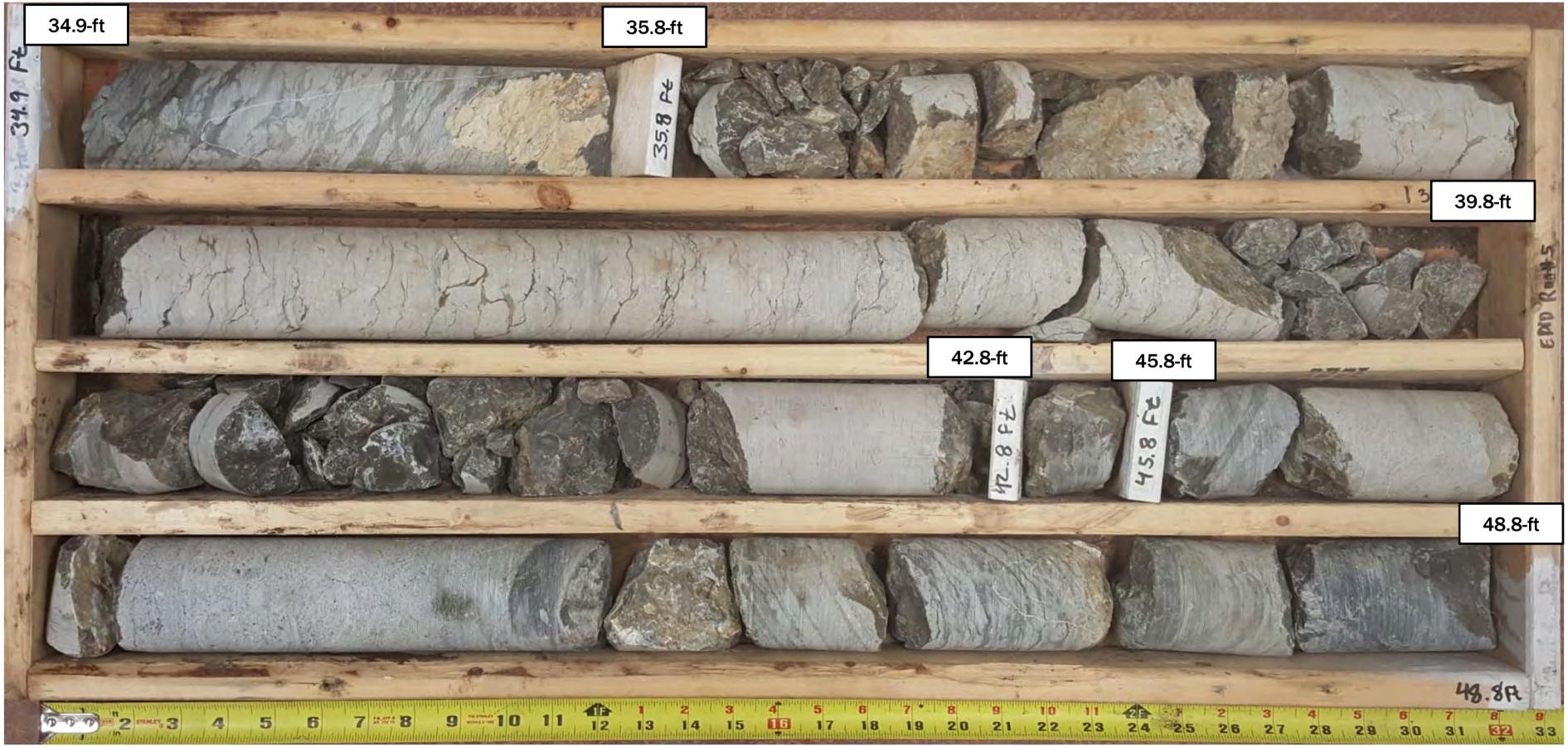
Bear River Project Concept Study
Temple Fork

GERHART COLE

Figure: 15

DRAFT

Location:	TH-TF-03	Box Number:	2	Run(s):	4,5,6,7,8	Depth(ft):	34.9-48.8



Notes:

1. This photo log is for information purposes only. It is intended to assist in showing features discussed in the attached field logs.

Reference: Log of Referenced Test Hole

PHOTOGRAPHIC SUMMARY OF ROCK CORE

Bear River Project Concept Study
Temple Fork

GERHART COLE

Figure: 16

DRAFT

Location:	TH-TF-03	Box Number:	3	Run(s):	8,9,10	Depth(ft):	48.8-58.3

Notes:

1. This photo log is for information purposes only. It is intended to assist in showing features discussed in the attached field logs.

Reference: Log of Referenced Test Hole

PHOTOGRAPHIC SUMMARY OF ROCK CORE

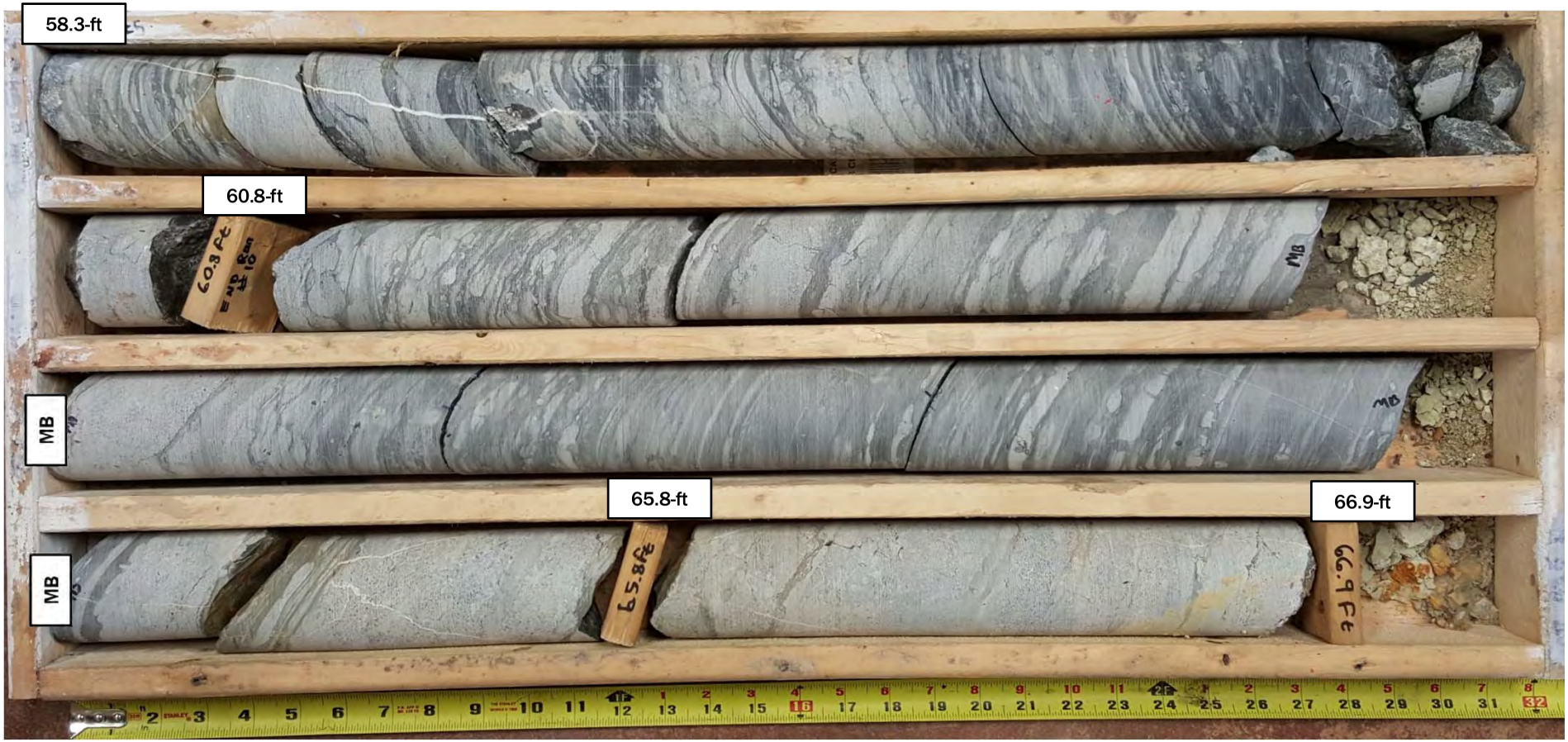
Bear River Project Concept Study
Temple Fork

GERHART COLE

Figure: 17

DRAFT

Location:	TH-TF-03	Box Number:	4	Run(s):	10,11,12	Depth(ft):	58.3-66.9



Notes:

1. This photo log is for information purposes only. It is intended to assist in showing features discussed in the attached field logs.

Reference: Log of Referenced Test Hole

PHOTOGRAPHIC SUMMARY OF ROCK CORE

Bear River Project Concept Study
Temple Fork

GERHART COLE

Figure: 18

DRAFT

Location:	TH-TF-03	Box Number:	5	Run(s):	12,13	Depth(ft):	66.9-75

Notes:

1. This photo log is for information purposes only. It is intended to assist in showing features discussed in the attached field logs.

Reference: Log of Referenced Test Hole

PHOTOGRAPHIC SUMMARY OF ROCK CORE

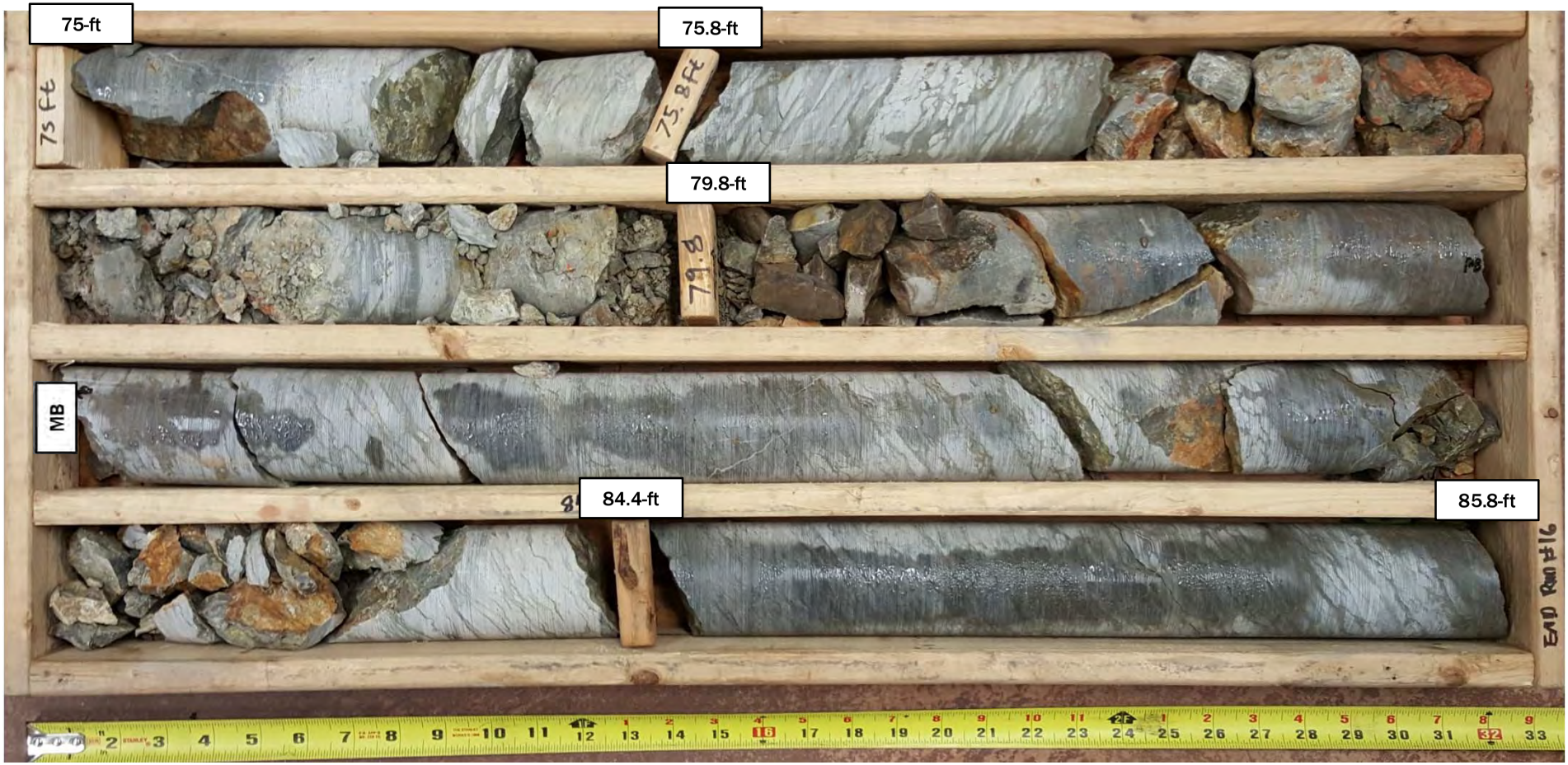
Bear River Project Concept Study
Temple Fork

GERHART COLE

Figure: 19

DRAFT

Location:	TH-TF-03	Box Number:	6	Run(s):	13,14,15,16	Depth(ft):	75-85.8



Notes:

1. This photo log is for information purposes only. It is intended to assist in showing features discussed in the attached field logs.

Reference: Log of Referenced Test Hole

PHOTOGRAPHIC SUMMARY OF ROCK CORE

Bear River Project Concept Study
Temple Fork

GERHART COLE

Figure: 20

DRAFT

Location:	TH-TF-03	Box Number:	7	Run(s):	17,18,19	Depth(ft):	85.8-94.7

Notes:

1. This photo log is for information purposes only. It is intended to assist in showing features discussed in the attached field logs.

Reference: Log of Referenced Test Hole

PHOTOGRAPHIC SUMMARY OF ROCK CORE

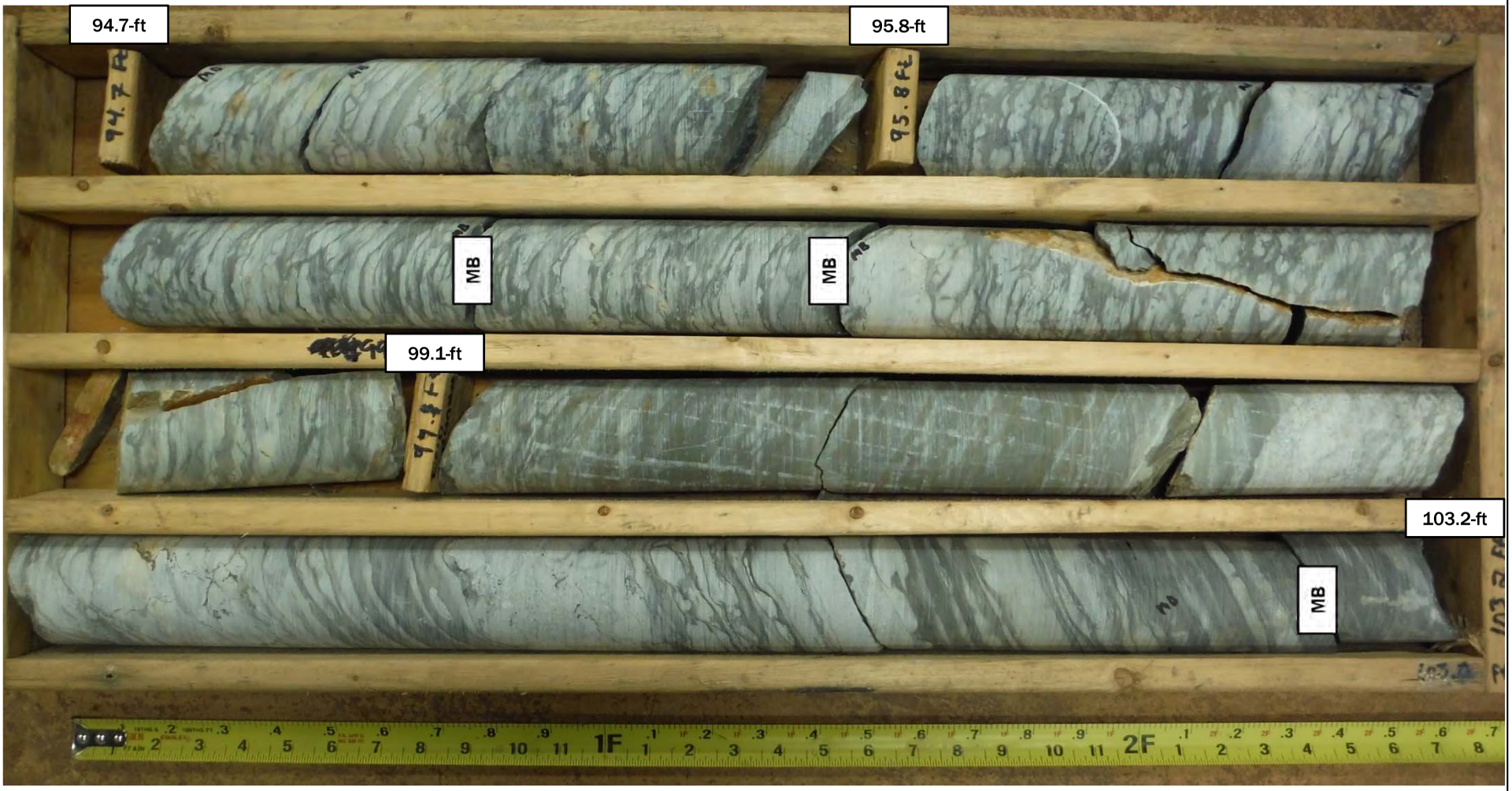
Bear River Project Concept Study
Temple Fork

GERHART COLE

Figure: 21

DRAFT

Location:	TH-TF-03	Box Number:	8	Run(s):	19,20,21	Depth(ft):	94.7-103.2



Notes:

1. This photo log is for information purposes only. It is intended to assist in showing features discussed in the attached field logs.

Reference: Log of Referenced Test Hole

PHOTOGRAPHIC SUMMARY OF ROCK CORE

Bear River Project Concept Study
Temple Fork

GERHART COLE

Figure: 22

DRAFT

Location:	TH-TF-03	Box Number:	9	Run(s):	21,22,23,24	Depth(ft):	103.2-112.1

Notes:

1. This photo log is for information purposes only. It is intended to assist in showing features discussed in the attached field logs.

Reference: Log of Referenced Test Hole

PHOTOGRAPHIC SUMMARY OF ROCK CORE

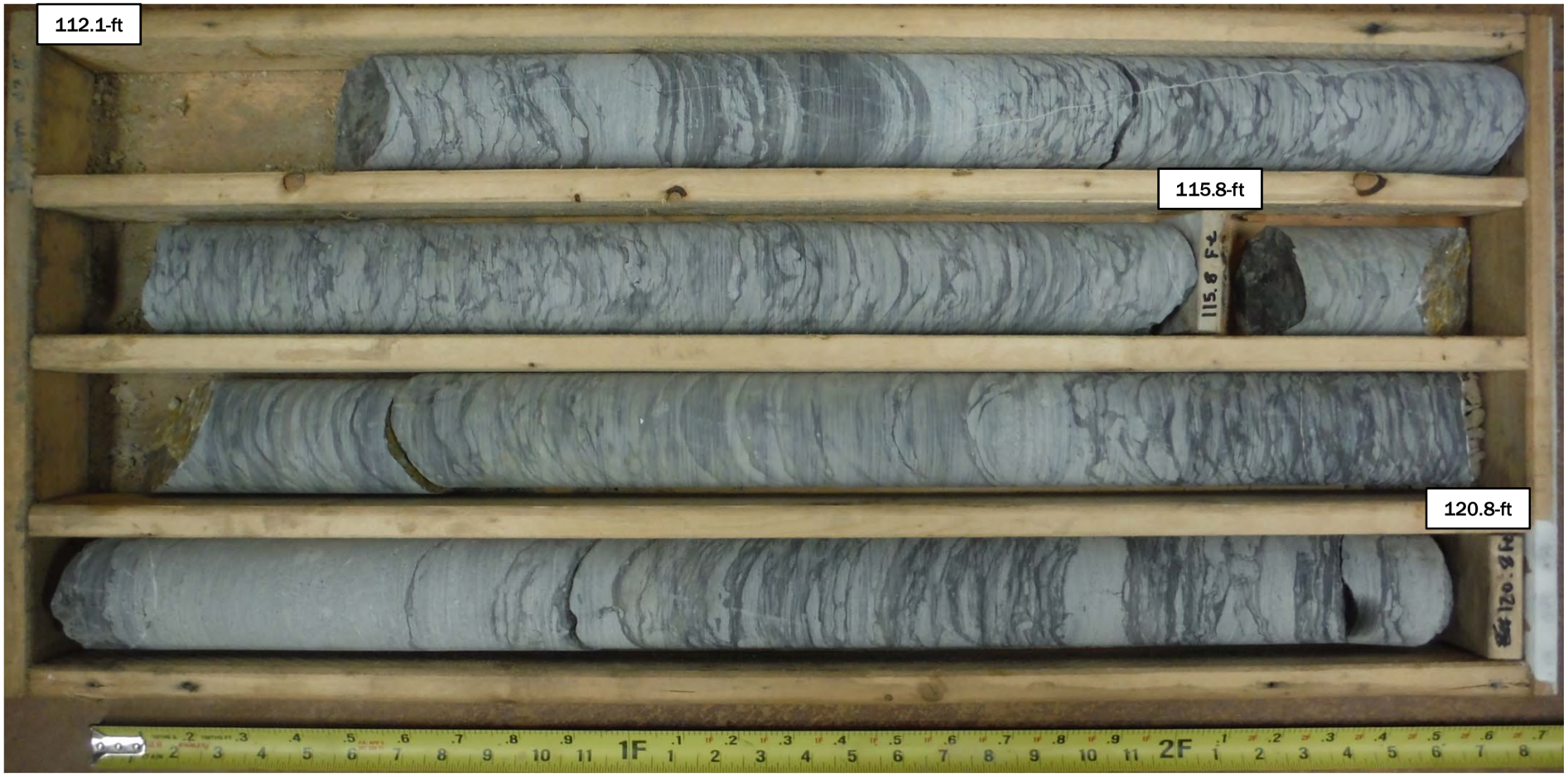
Bear River Project Concept Study
Temple Fork

GERHART COLE

Figure: 23

DRAFT

Location:	TH-TF-03	Box Number:	10	Run(s):	24,25	Depth(ft):	112.1-120.8



Notes:

1. This photo log is for information purposes only. It is intended to assist in showing features discussed in the attached field logs.

Reference: Log of Referenced Test Hole

PHOTOGRAPHIC SUMMARY OF ROCK CORE

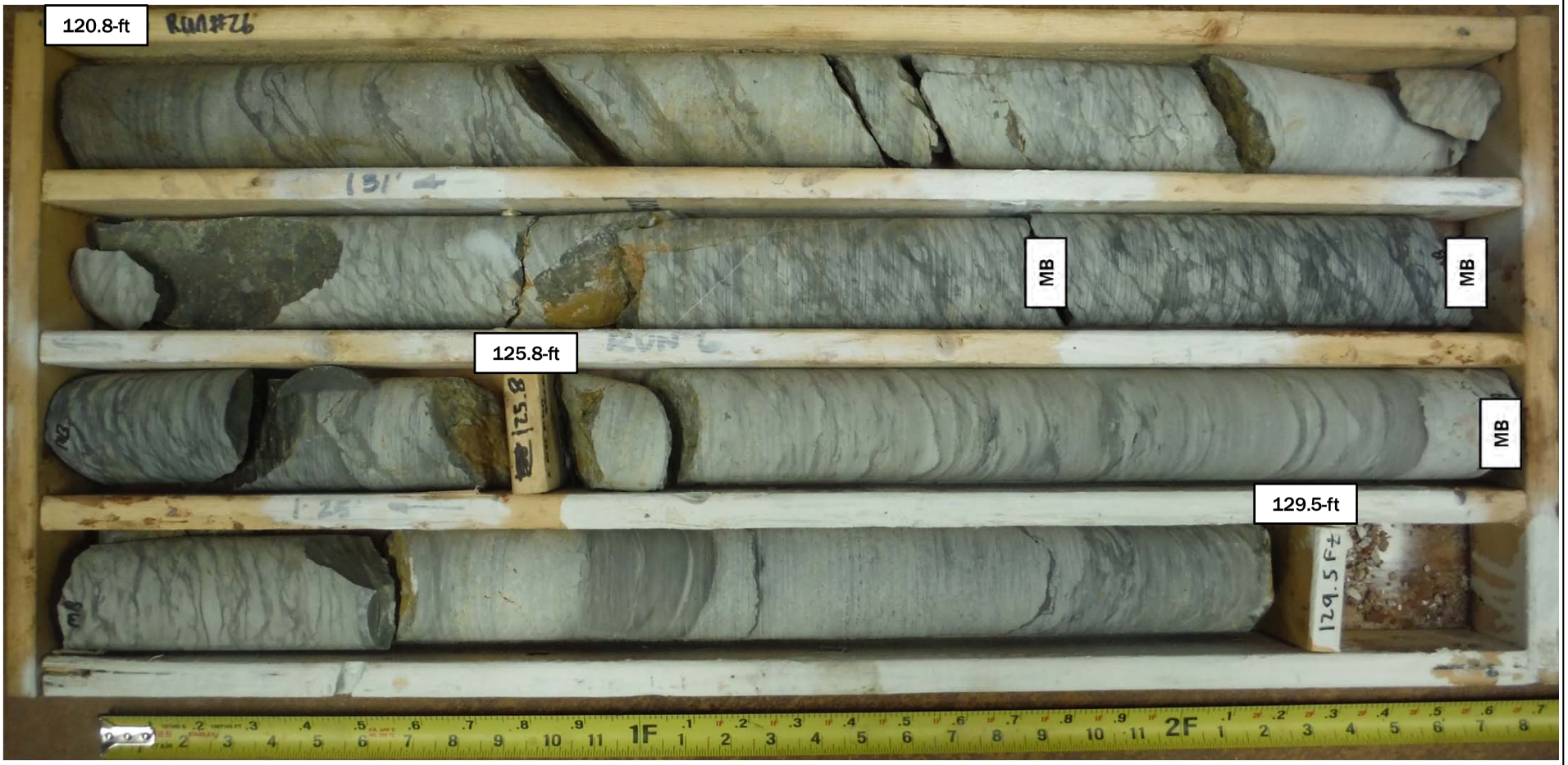
Bear River Project Concept Study
Temple Fork

GERHART COLE

Figure: 24

DRAFT

Location:	TH-TF-03	Box Number:	11	Run(s):	26,27	Depth(ft):	120.8-129.5



Notes:

1. This photo log is for information purposes only. It is intended to assist in showing features discussed in the attached field logs.

Reference: Log of Referenced Test Hole

PHOTOGRAPHIC SUMMARY OF ROCK CORE

Bear River Project Concept Study
Temple Fork

GERHART COLE

Figure: 25

DRAFT

Location:	TH-TF-03	Box Number:	12	Run(s):	27,28,29	Depth(ft):	129.5-138.4

Notes:

1. This photo log is for information purposes only. It is intended to assist in showing features discussed in the attached field logs.

Reference: Log of Referenced Test Hole

PHOTOGRAPHIC SUMMARY OF ROCK CORE

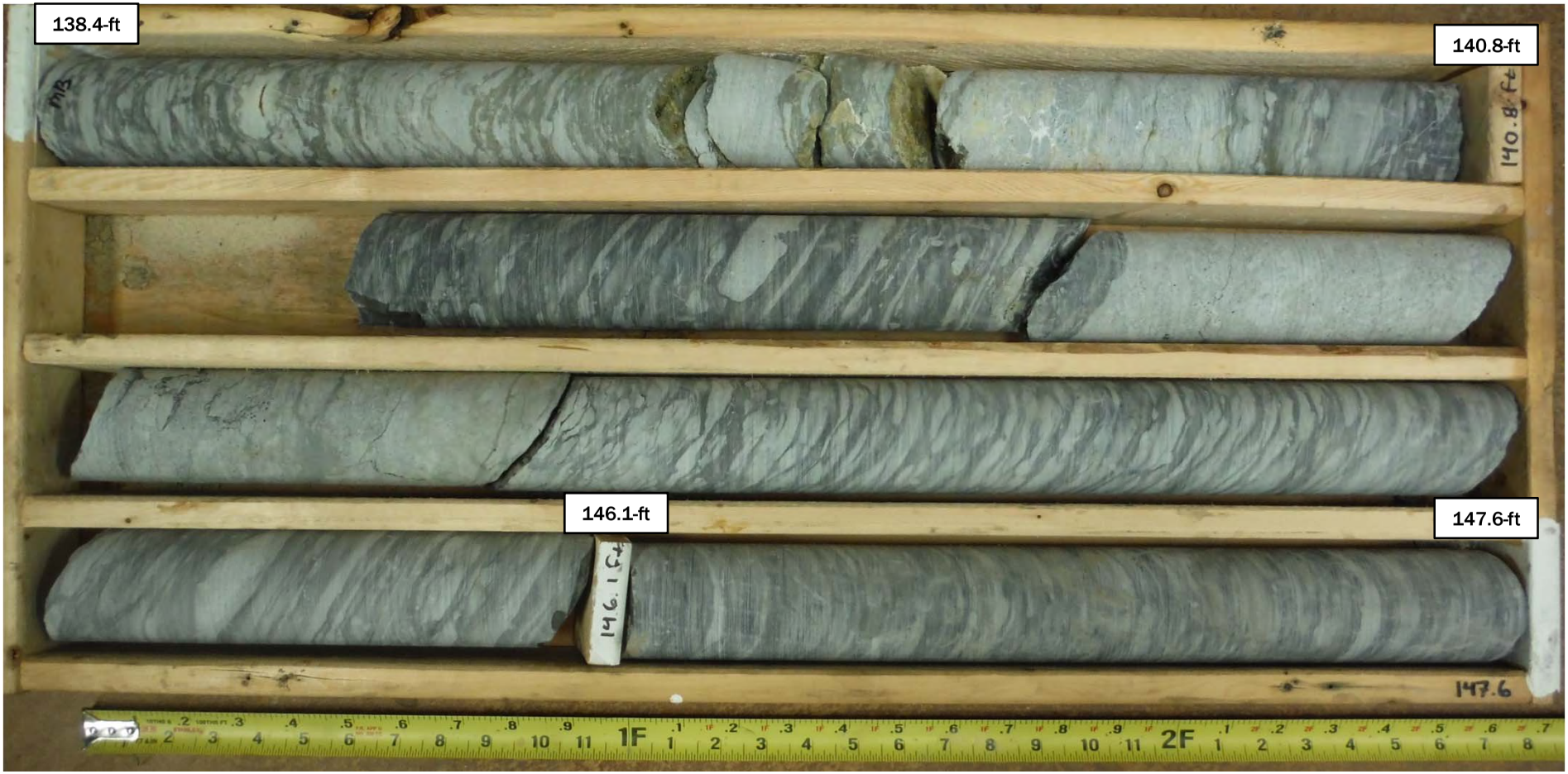
Bear River Project Concept Study
Temple Fork

GERHART COLE

Figure: 26

DRAFT

Location:	TH-TF-03	Box Number:	13	Run(s):	29,30,31	Depth(ft):	138.4-147.6



Notes:

1. This photo log is for information purposes only. It is intended to assist in showing features discussed in the attached field logs.

Reference: Log of Referenced Test Hole

PHOTOGRAPHIC SUMMARY OF ROCK CORE

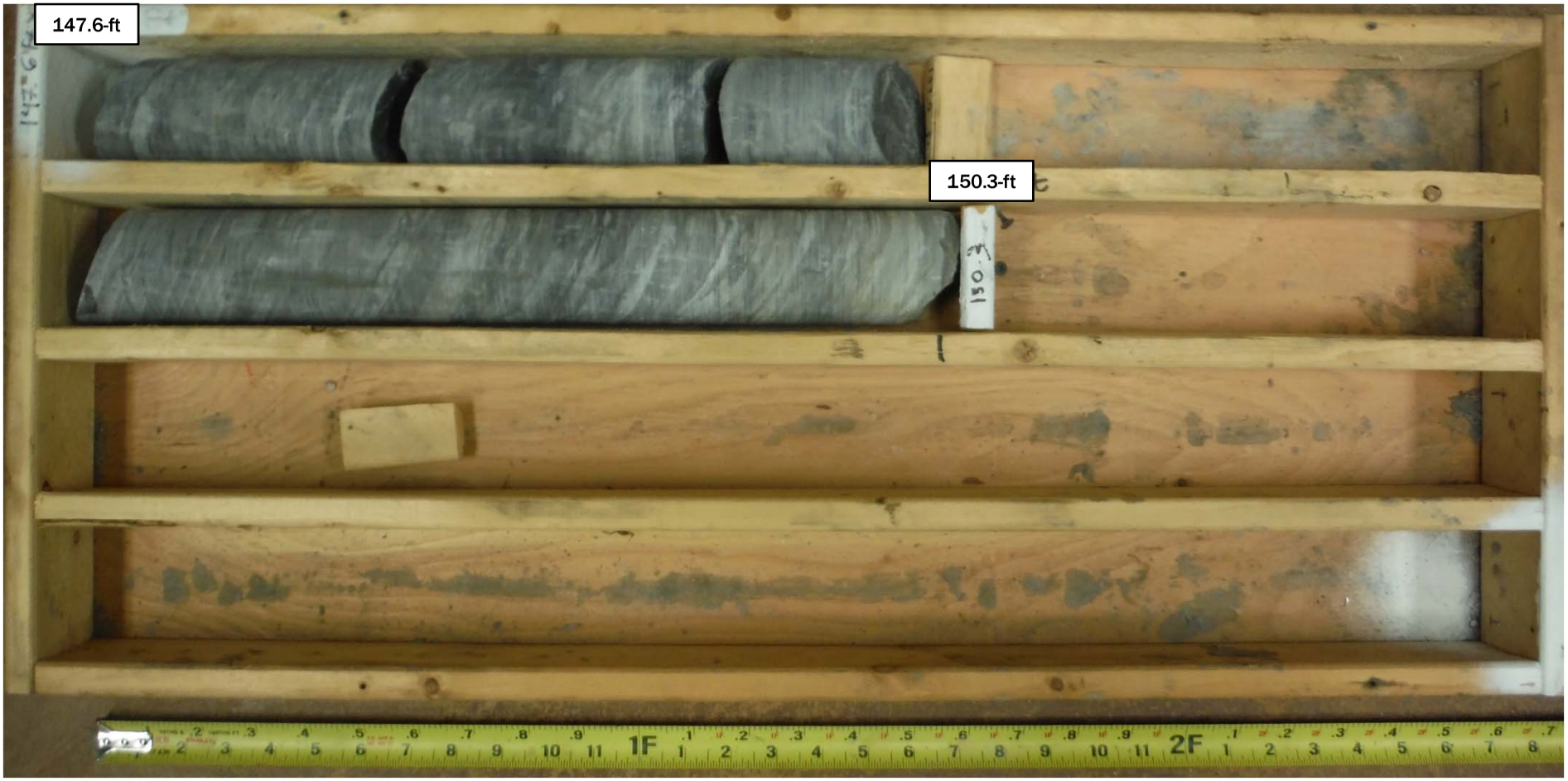
Bear River Project Concept Study
Temple Fork

GERHART COLE

Figure: 27

DRAFT

Location:	TH-TF-03	Box Number:	14	Run(s):	31	Depth(ft):	147.6-150.3



Notes:

1. This photo log is for information purposes only. It is intended to assist in showing features discussed in the attached field logs.

Reference: Log of Referenced Test Hole

PHOTOGRAPHIC SUMMARY OF ROCK CORE

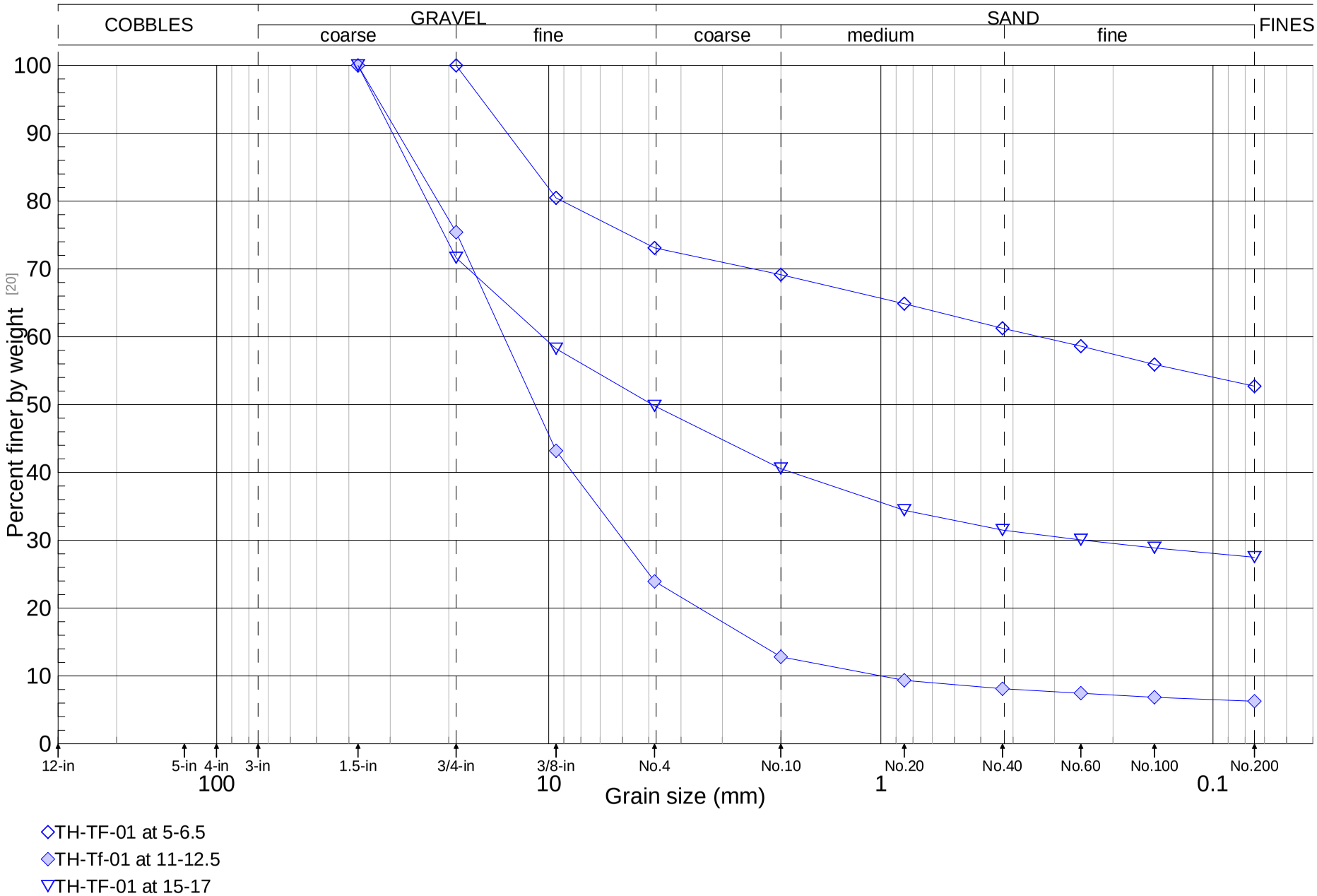
Bear River Project Concept Study
Temple Fork

GERHART COLE

Figure: 28

Appendix B Interpretative Laboratory Test Results – Temple Fork

DRAFT



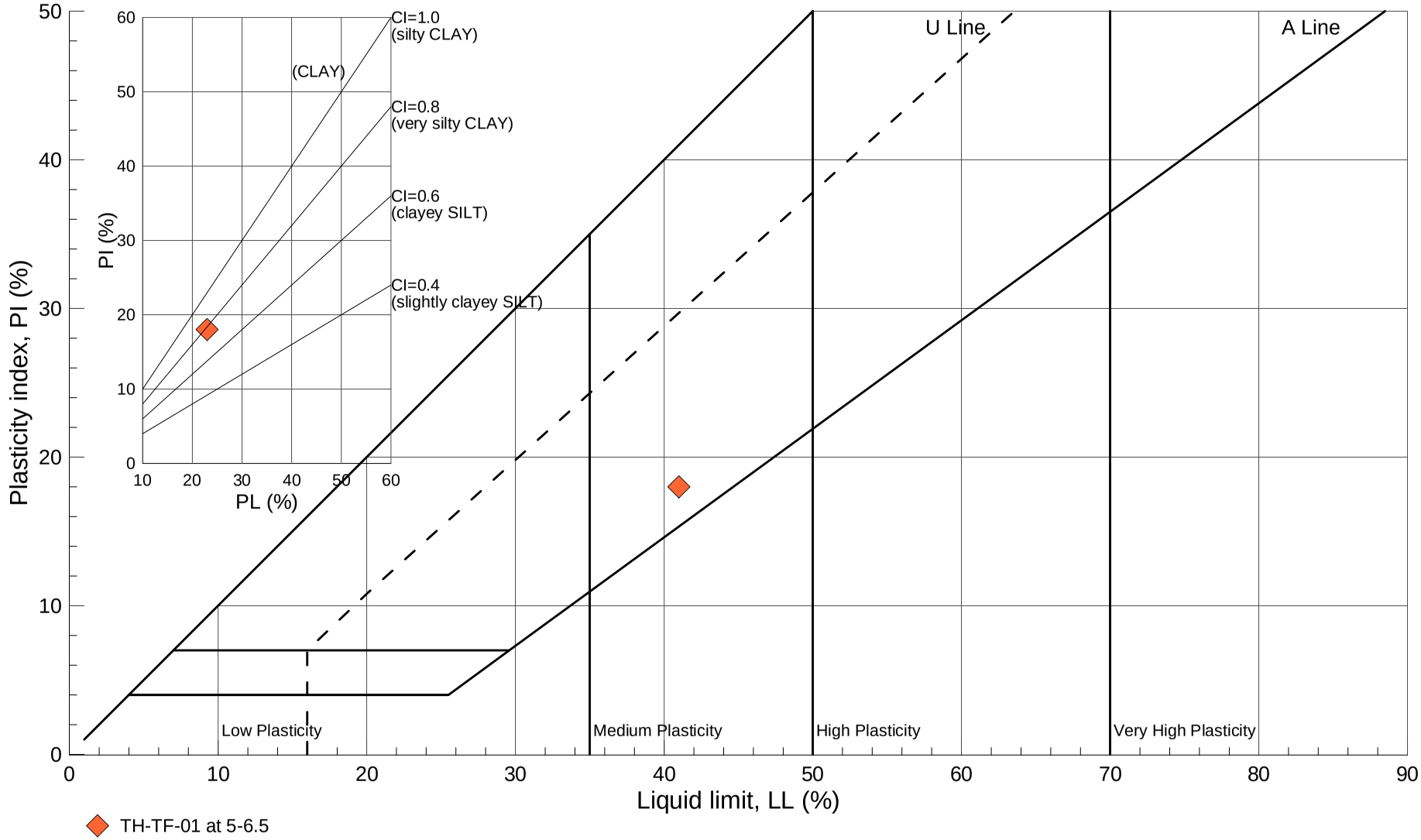
GERHART COLE

Grain-Size Analysis

Bear River Project Concept Study- Temple Fork (13GCI329)

Figure B-1

DRAFT



GERHART COLE	Casagrande's Plasticity Chart (Atterberg Limits)	
	Bear River Project Concept Study- Temple Fork (13GCI329)	Figure B-2

DRAFT

Determination of the Point Load Strength Index of Rock

After ASTM D 5731

GERHART COLE

Project: Temple Fork/Bear River

No: 13GCI329

Location: Logan Ut

Date: 10-Jun-15

Tested By: zmg Reduced by: zmg Reviewed by:

Sample Info.	Test Hole/Pit:	TH-TF-01	TH-TF-01	TH-TF-01	TH-TF-01
	Sample:				
	Depth:	23-24	40-41	72-73	92-93
	Date Sampled:	7-May-15	8-May-15	9-May-15	10-May-15
	Sample type	Core	Core	Core	Core
	Moisture condition:	Laboratory air dry	Laboratory air dry	Laboratory air dry	Laboratory air dry
Test Data	Distance between platen points, D (in.):	2.4	2.4	2.4	2.4
	D (mm):	60.0	60.0	60.0	60.0
	Smallest specimen width, W (in.):	1.6	1.6	2.8	2.0
	W (mm):	40.6	40.6	71.1	50.8
	Equivalent core area, D_e^2 (mm^2):	3600.0	3600.0	3600.0	3600.0
	Failure Pressure P_f, (psi):	1195	383	566	708
	Effective area of jack piston A_e, (cm^2):	9.48	9.48	9.48	9.48
	Effective area of jack piston A_e, (in^2):	1.47	1.47	1.47	1.47
	Failure load, P (lbf):	1756	563	832	1040
	P (N):	7811	2503	3700	4628
Test Results	Point load strength index, I_s (MPa):	2.17	0.70	1.03	1.29
	Size correction factor, F:	1.086	1.086	1.086	1.086
	PLSI 50mm equivalent, $I_{s(50)}$ (MPa):	2.36	0.75	1.12	1.40
	Correlation factor, C:	24.5	24.5	24.5	24.5
	Uniaxial compressive strength, d_{uc} (MPa):	57.70	18.49	27.33	34.19
	Uniaxial compressive strength, d_{uc} (psi):	8369	2682	3964	4958
	Break type:	Perpendicular	Parallel to planes of weakness	Parallel to planes of weakness	Perpendicular
	Photo before break:				
	Photo after break:				

Notes:

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DRAFT

Determination of the Point Load Strength Index of Rock

After ASTM D 5731

GERHART COLE

Project: Temple Fork/Bear River

No: 13GCI329

Location: Logan Ut

Date: 10-Jun-15

Tested By: zmg Reduced by: zmg Reviewed by:

Sample Info.	Test Hole/Pit:	TH-TF-02	TH-TF-02	TH-TF-03	TH-TF-03
	Sample:				
	Depth:	26-27	46-47	32-33	54-55
	Date Sampled:	13-May-15	14-May-15	15-May-15	15-May-15
	Sample type	Core	Core	Core	Core
	Moisture condition:	Laboratory air dry	Laboratory air dry	Laboratory air dry	Laboratory air dry
Test Data	Distance between platen points, D (in.):	2.4	2.4	2.4	2.4
	D (mm):	60.0	60.0	60.0	60.0
	Smallest specimen width, W (in.):	2.5	2.2	1.7	2.6
	W (mm):	63.5	55.9	43.2	66.0
	Equivalent core area, D_e^2 (mm^2):	3600.0	3600.0	3600.0	3600.0
	Failure Pressure L, (psi):	516	879	444	2306
	Effective area of jack piston A_e, (cm^2):	9.48	9.48	9.48	9.48
	Effective area of jack piston A_e, (in^2):	1.47	1.47	1.47	1.47
	Failure load, P (lbf):	758	1292	652	3388
	P (N):	3373	5745	2902	15073
Test Results	Point load strength index, I_s (MPa):	0.94	1.60	0.81	4.19
	Size correction factor, F:	1.086	1.086	1.086	1.086
	PLSI 50mm equivalent, $I_{s(50)}$ (MPa):	1.02	1.73	0.88	4.54
	Correlation factor, C:	24.5	24.5	25.5	26.5
	Uniaxial compressive strength, d_{uc} (MPa):	24.92	42.44	22.31	120.44
	Uniaxial compressive strength, d_{uc} (psi):	3614	6156	3236	17468
	Break type:	Parallel to planes of weakness	Parallel to planes of weakness	Parallel to planes of weakness	Perpendicular
	Photo before break:				
	Photo after break:				

Notes:

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DRAFT

Determination of the Point Load Strength Index of Rock

After ASTM D 5731

GERHART COLE

Project: Temple Fork/Bear River

No: 13GCI329

Location: Cache County, Utah

Date: 10-Jun-15

Tested By: zmg | Reduced by: zmg | Reviewed by:

Sample Info.	Test Hole/Pit:	TH-TF-03	TH-TF-03	TH-TF-03	TH-TF-03
	Sample:				
	Depth:	72-73	97-98	120-121	148-149
	Date Sampled:	15-May-15	15-May-15	15-May-15	15-May-15
	Sample type	Core	Core	Core	Core
	Moisture condition:	Laboratory air dry	Laboratory air dry	Laboratory air dry	Laboratory air dry
Test Data	Distance between platen points, D (in.):	2.4	2.4	2.4	2.4
	D (mm):	60.0	60.0	60.0	60.0
	Smallest specimen width, W (in.):	2.0	2.8	7.6	2.4
	W (mm):	50.8	71.1	193.0	61.0
	Equivalent core area, D_e^2 (mm^2):	3600.0	3600.0	3600.0	3600.0
	Failure Pressure L, (psi):	995	957	1239	1096
	Effective area of jack piston A_e, (cm^2):	9.48	9.48	9.48	9.48
	Effective area of jack piston A_e, (in^2):	1.47	1.47	1.47	1.47
	Failure load, P (lbf):	1462	1406	1821	1610
	P (N):	6504	6255	8098	7164
Test Results	Point load strength index, I_s (MPa):	1.81	1.74	2.25	1.99
	Size correction factor, F:	1.086	1.086	1.086	1.086
	PLSI 50mm equivalent, $I_{s(50)}$ (MPa):	1.96	1.89	2.44	2.16
	Correlation factor, C:	27.5	28.5	29.5	30.5
	Uniaxial compressive strength, d_{uc} (MPa):	53.93	53.75	72.04	65.88
	Uniaxial compressive strength, d_{uc} (psi):	7822	7796	10448	9555
	Break type:	Perpendicular	Parallel to planes of weakness	Perpendicular	Perpendicular
	Photo before break:				
	Photo after break:				

Notes:

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DRAFT

Determination of the Point Load Strength Index of Rock

After ASTM D 5731

GERHART COLE

Project: Temple Fork/Bear River

No: 13GCI329

Location: Logan Ut

Date: 10-Jun-15

Tested By: zmg Reduced by: zmg Reviewed by:

Sample Info.	Test Hole/Pit:	TH-TF-01	TH-TF-01	TH-TF-01	TH-TF-01
	Sample:				
	Depth:	23-24	40-41	72-73	92-93
	Date Sampled:	7-May-15	8-May-15	9-May-15	10-May-15
	Sample type	Core	Core	Core	Core
	Moisture condition:	Laboratory air dry	Laboratory air dry	Laboratory air dry	Laboratory air dry
Test Data	Distance between platen points, D (in.):	2.4	2.4	2.4	2.4
	D (mm):	60.0	60.0	60.0	60.0
	Smallest specimen width, W (in.):	1.6	1.6	2.8	2.0
	W (mm):	40.6	40.6	71.1	50.8
	Equivalent core area, D_e^2 (mm^2):	3600.0	3600.0	3600.0	3600.0
	Failure Pressure P_f, (psi):	1195	383	566	708
	Effective area of jack piston A_e, (cm^2):	9.48	9.48	9.48	9.48
	Effective area of jack piston A_e, (in^2):	1.47	1.47	1.47	1.47
	Failure load, P (lbf):	1756	563	832	1040
	P (N):	7811	2503	3700	4628
Test Results	Point load strength index, I_s (MPa):	2.17	0.70	1.03	1.29
	Size correction factor, F:	1.086	1.086	1.086	1.086
	PLSI 50mm equivalent, $I_{s(50)}$ (MPa):	2.36	0.75	1.12	1.40
	Correlation factor, C:	24.5	24.5	24.5	24.5
	Uniaxial compressive strength, d_{uc} (MPa):	57.70	18.49	27.33	34.19
	Uniaxial compressive strength, d_{uc} (psi):	8369	2682	3964	4958
	Break type:	Perpendicular	Parallel to planes of weakness	Parallel to planes of weakness	Perpendicular
	Photo before break:				
	Photo after break:				

Notes:

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Determination of the Point Load Strength Index of Rock

After ASTM D 5731

GERHART COLE

Project: Temple Fork/Bear River

No: 13GCI329

Location: Logan Ut

Date: 10-Jun-15

Tested By: zmg Reduced by: zmg Reviewed by:

Sample Info.	Test Hole/Pit:	TH-TF-02	TH-TF-02	TH-TF-03	TH-TF-03
	Sample:				
	Depth:	26-27	46-47	32-33	54-55
	Date Sampled:	13-May-15	14-May-15	15-May-15	15-May-15
	Sample type	Core	Core	Core	Core
	Moisture condition:	Laboratory air dry	Laboratory air dry	Laboratory air dry	Laboratory air dry
Test Data	Distance between platen points, D (in.):	2.4	2.4	2.4	2.4
	D (mm):	60.0	60.0	60.0	60.0
	Smallest specimen width, W (in.):	2.5	2.2	1.7	2.6
	W (mm):	63.5	55.9	43.2	66.0
	Equivalent core area, D_e^2 (mm^2):	3600.0	3600.0	3600.0	3600.0
	Failure Pressure L, (psi):	516	879	444	2306
	Effective area of jack piston A_e, (cm^2):	9.48	9.48	9.48	9.48
	Effective area of jack piston A_e, (in^2):	1.47	1.47	1.47	1.47
	Failure load, P (lbf):	758	1292	652	3388
	P (N):	3373	5745	2902	15073
Test Results	Point load strength index, I_s (MPa):	0.94	1.60	0.81	4.19
	Size correction factor, F:	1.086	1.086	1.086	1.086
	PLSI 50mm equivalent, $I_{s(50)}$ (MPa):	1.02	1.73	0.88	4.54
	Correlation factor, C:	24.5	24.5	25.5	26.5
	Uniaxial compressive strength, d_{uc} (MPa):	24.92	42.44	22.31	120.44
	Uniaxial compressive strength, d_{uc} (psi):	3614	6156	3236	17468
	Break type:	Parallel to planes of weakness	Parallel to planes of weakness	Parallel to planes of weakness	Perpendicular
	Photo before break:				
	Photo after break:				

Notes:

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DRAFT

Determination of the Point Load Strength Index of Rock

After ASTM D 5731

GERHART COLE

Project: Temple Fork/Bear River

No: 13GCI329

Location: Cache County, Utah

Date: 10-Jun-15

Tested By: zmg Reduced by: zmg Reviewed by:

Sample Info.	Test Hole/Pit:	TH-TF-03	TH-TF-03	TH-TF-03	TH-TF-03
	Sample:				
	Depth:	72-73	97-98	120-121	148-149
	Date Sampled:	15-May-15	15-May-15	15-May-15	15-May-15
	Sample type	Core	Core	Core	Core
	Moisture condition:	Laboratory air dry	Laboratory air dry	Laboratory air dry	Laboratory air dry
Test Data	Distance between platen points, D (in.):	2.4	2.4	2.4	2.4
	D (mm):	60.0	60.0	60.0	60.0
	Smallest specimen width, W (in.):	2.0	2.8	7.6	2.4
	W (mm):	50.8	71.1	193.0	61.0
	Equivalent core area, D_e^2 (mm^2):	3600.0	3600.0	3600.0	3600.0
	Failure Pressure L, (psi):	995	957	1239	1096
	Effective area of jack piston A_e, (cm^2):	9.48	9.48	9.48	9.48
	Effective area of jack piston A_e, (in^2):	1.47	1.47	1.47	1.47
	Failure load, P (lbf):	1462	1406	1821	1610
	P (N):	6504	6255	8098	7164
Test Results	Point load strength index, I_s (MPa):	1.81	1.74	2.25	1.99
	Size correction factor, F:	1.086	1.086	1.086	1.086
	PLSI 50mm equivalent, $I_{s(50)}$ (MPa):	1.96	1.89	2.44	2.16
	Correlation factor, C:	27.5	28.5	29.5	30.5
	Uniaxial compressive strength, d_{uc} (MPa):	53.93	53.75	72.04	65.88
	Uniaxial compressive strength, d_{uc} (psi):	7822	7796	10448	9555
	Break type:	Perpendicular	Parallel to planes of weakness	Perpendicular	Perpendicular
	Photo before break:				
	Photo after break:				

Notes:

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Appendix C

Discontinuity Data – Temple Fork

DRAFT

Project: Bear River Dams

Feature: Temple Fork Dam

DISCONTINUITY LOG

Location: Rt Abutment

Sheet 1 of 3
Date: 9/9/14
Recorded by: EL/JC

Traverse Id.	Northing (start)	Easting (start)	Elevation (start)	Trend	Plunge	Traverse Length	Tl. No. Obs.
001	41.83341	-111.58431		95°	-6°	102	37

Recording Method:
☐ Strike Azimuth and Dip Magnitude *
☒ Dip Azimuth and Dip Magnitude
☒ Feet ☐ Meters

Number	Distance	Rock	Azimuth	Dip	C	E	R	M	H	W	O	T	HL	Notes and Comments
1	1.2'		268	73	1	0	–	–	–	–	–	–	–	ROUGHNESS IS BASED ON A WEATHERED SURFACE
2	2.1		280	70	1	0	–	–	–	–	–	–	–	
3	5.8		037	83	1	1	3	–	3	4	2	2	3	CONTINUITY ≥ 3FT, HEALING WAS IN FILL
4	6.3		072	81	1	1	1	–	3		3	3	5	
5	7.7	LS	301	80	2	0								
6	8.4		277	77	2	0	4				2			OUTCROP IS 6-8 FT. THICK
7	10.0	LS	295	69	1	0	3				2	0	0	
8	15		090	86	1	1	4		3	4	2	0	0	
9	13.7		270	56	2	1	4		3	4	1	0	0	
10	15.3		279	78	2	0	–		3	4	2	2	2	
11	18.1		303	83	2	0	4		3	4	2	–	–	
12	23.0		109	83	2	0	3		3	4	2	2	2	CONTINUES TO EXTENT OF 5' OUTCROP
13	28.0		272	70	2	1	3		3	4	2	1	2	
14	30.7		061	81	2	0	4		3	4	1	1	2	— ANOTHER SPACED @ 0.5'
15	32.0		283	77	2	0	3		3	4	2	2	2	
16	36.3		035	87	2	0	–		3	4	1-2	2	2	

Continuity
- C1 <3 ft. (<1 m)
- C2 3-10 ft (1-3 m)
- C3 10-30 ft (3-10 m)
- C4 30-100 ft (10-30 m)
- C5 >100 ft (>30 m)

Ends
- E0 No ends visible
- E1 One end visible
- E2 Both ends visible

Roughness
- R1 Stepped
- R2 Rough
- R3 Moderately rough
- R4 Slightly rough
- R5 Smooth
- R6 Polished

Moisture
- M1 Dry, not possible
- M2 Dry, no evidence
- M3 Dry, some evidence
- M4 Damp, no free water
- M5 Wet, some drops
- M6 Cont. flow, low pres.
- M7 Cont. flow, high pres.

Wall Hardness
- H1 Extremely hard
- H2 Very hard
- H3 Hard
- H4 Moderately hard
- H5 Moderately soft
- H6 Soft
- H7 Very soft

Wall Weathering
- W1 Fresh
- W2 Slightly weathered to fresh
- W3 Slightly weathered
- W4 Moderately to slightly weathered
- W5 Moderately weathered
- W6 Intensely to moderately weathered
- W7 Intense. weathered
- W8 Very intensely weathered
- W9 Decomposed

Openness
- O0 Tight
- O1 <0.003 ft (<1 mm)
- O2 0.003-0.01 ft (1-3 mm)
- O3 0.01-0.03 ft (3-10 mm)
- O4 0.03-0.1 ft (10-30 mm)
- O5 >0.1 ft (>30 mm)

Thickness
- T0 None
- T1 <0.003 ft (<1 mm)
- T2 0.003-0.01 ft (1-3 mm)
- T3 0.01-0.03 ft (3-10 mm)
- T4 0.03-0.1 ft (10-30 mm)
- T5 >0.1 ft (>30 mm)

Healing
- HL0 completely, to strength of wall rock
- HL2 >50%, or weaker than wall rock
- HL3 <50%
- HL5 No induration

* Dip magnitude follows right-hand rule

Discontinuity Log 14HL
Version 1.0

DRAFT

Project: Bear River Dams

Feature: Temple Fork

DISCONTINUITY LOG

Location: Temple Fork

Sheet 2 of ___
Date: 9-9-14
Recorded by: JEC

Traverse Id.	Northing (start)	Easting (start)	Elevation (start)	Trend	Plunge	Traverse Length	Tl. No. Obs.
001							

Recording Method:
- [ ] Strike Azimuth and Dip Magnitude *
- [x] Dip Azimuth and Dip Magnitude
- [x] Feet [ ] Meters

Number	Distance	Rock	Azimuth	Dip	C	E	R	M	H	W	O	T	HL	Notes and Comments
17	36.3	L5	291	79	2	0	3	–	3	4	0-1	–	–	Set of 3, spaced 0.1-0.5 ft., becomes tight with depth
18	37.3		284	75	2	0	–	–	3	4	2	2	2	
19	41.4		259	70	–	–	–	–	–	–	–	–		
20	49.0		076	76	2	0	–	–	3	4	2			CANT OBSERVE HEALING
21	46.5		024	76	2	0	–	–	3	4	2	2	2	SET OF 5 SPACED 0.2-0.6, PARALLEL TO TRAVERSE, SO LOCATION RECORDED WHERE MEASURED.
22	47		007	79	2	0					3	3	2	
23	55.5		326	75	2	0	–	–	3	4	2	2	2	
24	61.0		271	80	2	0	–		3	4	–	–	–	
25	65.4		044	84	2	0			3	4	1	1	2	SET OF 4 SPACED 0.6-0.8 FE
26	66.3		069	89	2	1	–		3	4	0-1	0-1	2	
27	65.0		327	75	2	1	4		3	4	2	2	–	
28	69.5		266	90	2	0	4		–	–	–	–	–	
29	71.2		277	78	2	0	1,4		3	4	0-1	–	–	
30	74		020	77	–	–					2			PARALLEL TO TRANSECT, DISC. FILLING
31	83.8		275	88	2	0	–		3	4	3	–	–	
32	89.3		073	86	2	0	2		3	4	0-1	–	–	
33	90.5		285	89	2	0	4		3	4	1	1	2	
34	92.4		097	87	2	0	2		3	4	–	–	–	

Continuity
- C1 <3 ft. (<1 m)
- C2 3-10 ft (1-3 m)
- C3 10-30 ft (3-10 m)
- C4 30-100 ft (10-30 m)
- C5 >100 ft (>30 m)

Ends
- E0 No ends visible
- E1 One end visible
- E2 Both ends visible

Roughness
- R1 Stepped
- R2 Rough
- R3 Moderately rough
- R4 Slightly rough
- R5 Smooth
- R6 Polished

Moisture
- M1 Dry, not possible
- M2 Dry, no evidence
- M3 Dry, some evidence
- M4 Damp, no free water
- M5 Wet, some drops
- M6 Cont. flow, low pres.
- M7 Cont. flow, high pres.

Wall Hardness
- H1 Extremely hard
- H2 Very hard
- H3 Hard
- H4 Moderately hard
- H5 Moderately soft
- H6 Soft
- H7 Very soft

Wall Weathering
- W1 Fresh
- W2 Slightly weathered to fresh
- W3 Slightly weathered
- W4 Moderately to slightly weathered
- W5 Moderately weathered
- W6 Intensely to moderately weathered
- W7 Intense. weathered
- W8 Very intensely weathered
- W9 Decomposed

Openness
- O0 Tight
- O1 <0.003 ft (<1 mm)
- O2 0.003-0.01 ft (1-3 mm)
- O3 0.01-0.03 ft (3-10 mm)
- O4 0.03-0.1 ft (10-30 mm)
- O5 >0.1 ft (>30 mm)

Thickness
- T0 None
- T1 <0.003 ft (<1 mm)
- T2 0.003-0.01 ft (1-3 mm)
- T3 0.01-0.03 ft (3-10 mm)
- T4 0.03-0.1 ft (10-30 mm)
- T5 >0.1 ft (>30 mm)

Healing
- HL0 completely, to strength of wall rock
- HL2 >50%, or weaker than wall rock
- HL3 <50%
- HL5 No induration

* Dip magnitude follows right-hand rule

Discontinuity Log 14HL
Version 1.0

DRAFT

Project: BEAR RIVER DAMS

Feature: TEMPLE FORK

DISCONTINUITY LOG

Location: TEMPLE FORK

Sheet 3 of 3
Date: 9/9/14
Recorded by: JGC

Traverse Id.	Northing (start)	Easting (start)	Elevation (start)	Trend	Plunge	Traverse Length	Tl. No. Obs.
001							

Recording Method:
[ ] Strike Azimuth and Dip Magnitude *
[X] Dip Azimuth and Dip Magnitude
[X] Feet [ ] Meters

Number	Distance	Rock	Azimuth	Dip	C	E	R	M	H	W	O	T	HL	Notes and Comments
35	97.0	LS	278	87	2	0	2-3	-	3	4	3	–	–	
36	98.3		077	89							–			
37	102		306	80	2	0	2		3	4	3	3	2	

Continuity
- C1 <3 ft. (<1 m)
- C2 3-10 ft (1-3 m)
- C3 10-30 ft (3-10 m)
- C4 30-100 ft (10-30 m)
- C5 >100 ft (>30 m)

Ends
- E0 No ends visible
- E1 One end visible
- E2 Both ends visible

Roughness
- R1 Stepped
- R2 Rough
- R3 Moderately rough
- R4 Slightly rough
- R5 Smooth
- R6 Polished

Moisture
- M1 Dry, not possible
- M2 Dry, no evidence
- M3 Dry, some evidence
- M4 Damp, no free water
- M5 Wet, some drops
- M6 Cont. flow, low pres.
- M7 Cont. flow, high pres.

Wall Hardness
- H1 Extremely hard
- H2 Very hard
- H3 Hard
- H4 Moderately hard
- H5 Moderately soft
- H6 Soft
- H7 Very soft

Wall Weathering
- W1 Fresh
- W2 Slightly weathered to fresh
- W3 Slightly weathered
- W4 Moderately to slightly weathered
- W5 Moderately weathered
- W6 Intensely to moderately weathered
- W7 Intense. weathered
- W8 Very intensely weathered
- W9 Decomposed

Openness
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- HL5 No induration

* Dip magnitude follows right-hand rule

Discontinuity Log 14HL
Version 1.0

DRAFT

Project: BEAR RIVER DAMS

DISCONTINUITY LOG

Sheet 1 of 3
Date: 9/9/14
Recorded by: EC/JC

Feature: TEMPLE FORK

Location: RIGHT ABUTMENT DS of CL

Traverse Id.	Northing (start)	Easting (start)	Elevation (start)	Trend	Plunge	Traverse Length	Tl. No. Obs.
002	41.83337	-111.58.546		230	-5°	130.5	40

Recording Method:
☐ Strike Azimuth and Dip Magnitude *
☒ Dip Azimuth and Dip Magnitude
☒ Feet ☐ Meters

Number	Distance	Rock	Azimuth	Dip	C	E	R	M	H	W	O	T	HL	Notes and Comments
1	9.2	Og	091	88	1	0	2				2			
2	10.1		062	77	2	0	5			5	3	3	2	
3	14.2		174	89	2	0	3				3	-	-	no filling observed
3	16.7		182	76	1	0	3				3			
4	22.6		082	79	1	0	3				3			no filling observed
5	23.1		177	87	2	0	3							only one wall
6	24.7		341	89	1	0	2				3	2	3	
7	26.4		070	73	1	0	3				4			no filling observed
8	33.0		062	77	1	0	3							
9	33.1		098	72	1	0	2				3	3	3	
10	37.0		150	81	3	0	3				2	2	2	Parallel to tape
11	45.7		038	80	3	0	3				2		3	discontinuous filling
12	49.9		080	76	3	0	3				2			

Continuity
- C1 <3 ft. (<1 m)
- C2 3-10 ft (1-3 m)
- C3 10-30 ft (3-10 m)
- C4 30-100 ft (10-30 m)
- C5 >100 ft (>30 m)

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- HL5 No induration

* Dip magnitude follows right-hand rule

Discontinuity Log 14HL
Version 1.0

DRAFT

Project: _____

DISCONTINUITY LOG

Sheet 2 of 3
Date: 9/9/14
Recorded by: EC/JC

Feature: _____ Location: _____

Traverse Id.	Northing (start)	Easting (start)	Elevation (start)	Trend	Plunge	Traverse Length	Tl. No. Obs.
002							

Recording Method:
☐ Strike Azimuth and Dip Magnitude *
☒ Dip Azimuth and Dip Magnitude
☒ Feet ☐ Meters

Number	Distance	Rock	Azimuth	Dip	C	E	R	M	H	W	O	T	HL	Notes and Comments
13	51.6		060	71	2	0					3	3	2	
14	53.0		131	87	3	1	5							Parallel to tape. only one wall visable
15	59.7		065	87	1	1	4				2	2		second one 2' away
16	64.7		005	78	2		3							
17	70.8		063	74	2	0	3				3			Merge to one discontinuity
18	70.8		095	89	2	0	4				2	1	3	
19	73.4		091	71	2	0					0			
20	75.8		087	85	1	1	4				2			set of 3 w/i 1.5 ft
21	83.2		050	86	2	0	3							only one wall
22	83.8		042	80	2	0	3				1			no filling observed
23	86.6		047	89	2	0	4				1			
24	90.2		093	70	2	0	3				2	2	2	
25	88.6		065	67	2	0	4							
26	96.4		251	79	1	1	3				0			

Continuity
- C1 <3 ft. (<1 m)
- C2 3-10 ft (1-3 m)
- C3 10-30 ft (3-10 m)
- C4 30-100 ft (10-30 m)
- C5 >100 ft (>30 m)

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- T3 0.01-0.03 ft (3-10 mm)
- T4 0.03-0.1 ft (10-30 mm)
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Healing
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- HL2 >50%, or weaker than wall rock
- HL3 <50%
- HL5 No induration

* Dip magnitude follows right-hand rule

Discontinuity Log 14HL
Version 1.0

DRAFT

Project: Ben' River Dams

Feature: Temple Fork

DISCONTINUITY LOG

Location: RA DS of ℄'

Sheet 3 of 3
Date: 9/5/14
Recorded by: EL/JC

Traverse Id.	Northing (start)	Easting (start)	Elevation (start)	Trend	Plunge	Traverse Length	Tl. No. Obs.
002							

Recording Method:
- [ ] Strike Azimuth and Dip Magnitude *
- [x] Dip Azimuth and Dip Magnitude
- [x] Feet [ ] Meters

Number	Distance	Rock	Azimuth	Dip	C	E	R	M	H	W	O	T	HL	Notes and Comments
27	97.1		066	72	2	0	4				2	2		Merges w/28
28	97.1		255	88	2	0	4				3			loose filling
29	114.0		162	83	3	0	4				0			near parallel to tape
30	111.7		064	72	3	0	4				0			
31	119		341	87	3	0	3				0			near parallel to tape
32	119.3		065	73	2	0	3				3			no filling
33	122.1		260	89	2	0	3				1	1	3	
34	121.6		054	78	2	0					2	2	2	
35	125.6		072	75	2	0	2							only one wall
36	127.0		161	84	2	0	3							near parallel to tape
37	128.2		081	68	2	0	3							
38	128.2		075	75	2	0	4				2	2	2	
39	128.3		003	76	2	0								only one wall
40	130.5		091	85	2	0	4				2	2	2	

Continuity
- C1 <3 ft. (<1 m)
- C2 3-10 ft (1-3 m)
- C3 10-30 ft (3-10 m)
- C4 30-100 ft (10-30 m)
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- O3 0.01-0.03 ft (3-10 mm)
- O4 0.03-0.1 ft (10-30 mm)
- O5 >0.1 ft (>30 mm)

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- T1 <0.003 ft (<1 mm)
- T2 0.003-0.01 ft (1-3 mm)
- T3 0.01-0.03 ft (3-10 mm)
- T4 0.03-0.1 ft (10-30 mm)
- T5 >0.1 ft (>30 mm)

Healing
- HL0 completely, to strength of wall rock
- HL2 >50%, or weaker than wall rock
- HL3 <50%
- HL5 No induration

* Dip magnitude follows right-hand rule

Discontinuity Log 14HL
Version 1.0

DRAFT

DRAFT Whites Valley Geotechnical Data and Fault Study Bear River Project Concept Study

Prepared for
Bowen Collins & Associates
October, 2018

GCI project number: 13GCI329

GERHART COLE

DRAFT

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October 31 2018

Prepared for:

Mike Collins
Bowen Collins & Associates (BCA)
754 East 14000 South
Draper, Utah 84020

Whites Valley - Geotechnical and Data and Fault Study Report
Bear River Project Concept Study
13GCI329

Prepared by:

Ryan Cole, PhD, PE
Principal

Richard Buhler, PE
Project Engineer

Phil C. Gerhart, PE
Principal

Elliott W. Lips, PG
Senior Engineering Geologist

TABLE OF CONTENTS

SECTION 1 Introduction 1-1

1.1 Project Description 1-1
1.2 Purpose, Authorization, And Work Scope 1-1

SECTION 2 Methods of Study 2-1

2.1 Whites Valley Studies 2-1
2.1.1 Test Hole Drilling and Sampling 2-1
2.1.2 Test Pits 2-3
2.1.3 Cone Penetration Test 2-3
2.1.4 Seismic Refraction Surveys 2-3
2.1.5 Trench Excavation 2-4
2.1.6 Laboratory Study 2-6
2.1.7 Permeability Testing 2-6
2.1.8 Groundwater 2-7

SECTION 3 Geology 3-1

3.1 General Setting 3-1
3.2 Bedrock Stratigraphy 3-1
3.3 Geologic Structure 3-1
3.4 Site-Specific Geology 3-2
3.4.1 Surficial Geology 3-2
3.4.2 Bedrock Geology 3-3
3.4.2.1 Lithology 3-3
3.4.2.2 Discontinuities 3-4
3.5 Geologic Hazards 3-5
3.5.1 Surface Fault Rupture 3-5
3.5.1.1 Previous Mapping 3-6
3.5.1.2 Aerial Photographic and Topographic Interpretation 3-6
3.5.1.3 LiDAR Imagery Interpretation 3-7
3.5.1.4 Seismic Refraction Survey 3-7
3.5.1.5 CPT Profile 3-8
3.5.1.6 Trench Exposure 3-8
3.5.1.7 Summary 3-9
3.5.2 Landslides 3-10
3.6 Reservoir Seepage Study 3-10
3.6.1 Reservoir Basin Subsurface Conditions 3-10
3.6.2 Estimated Hydraulic Conductivity in Reservoir Basin 3-11

SECTION 4 Conclusion 4-1

4.1 Recommendations for Additional Studies 4-1
4.2 LIMITATIONS 4-1

TABLE OF CONTENTS

SECTION 5 References 5-1

List of Tables

Table 2-1 Whites Valley – Field Studies Data
Table 2-2 Radiocarbon Test Results from Trench 16-TR-02
Table 2-3 Whites Valley – Laboratory Test Results
Table 2-4 Whites Valley – Laboratory Test Results of Coarse Grained Material
Table 2-5 Whites Valley – Packer Permeability Test Results
Table 2-6 Whites Valley – Constant Head Permeability Test Results
Table 2-7 Whites Valley – Falling Head Permeability Test Result – 10-20 ft
Table 2-8 Whites Valley – Falling Head Permeability Test Result – 20-24 ft
Table 2-9 Whites Valley – Falling Head Permeability Test Result at 98 ft
Table 2-10 Whites Valley – Falling Head Permeability Test Result at 108 ft
Table 2-11 Whites Valley – Falling Head Permeability Test Result at 115.5 ft
Table 3-1 Hydraulic Conductivity Values used for Soil found in Test Pits (After Powers, 2007)
Table 3-2 Legend for Figure 3-11 and Figure 3-12

List of Figures

Figure 1-1 Vicinity Map
Figure 2-1 Whites Valley – Overall Site Map
Figure 2-2 Whites Valley Dam Site Studies Map
Figure 2-3a Whites Valley Test Pit Location Map (Sheet 1 of 3)
Figure 2-3b Whites Valley Test Pit Location Map (Sheet 2 of 3)
Figure 2-3c Whites Valley Test Pit Location Map (Sheet 3 of 3)
Figure 2-4 CPT Cross Section
Figure 2-5 Whites Valley compression wave velocity profile (Vp) – 2015-SR-01
Figure 2-6 Whites Valley compression wave velocity profile (Vp) – 2016-SR-01
Figure 2-7 Whites Valley compression wave velocity profile (Vp) – 2016-SR-02
Figure 2-8 Whites Valley compression wave velocity profile (Vp) – 2016-SR-03
Figure 2-9 Whites Valley compression wave velocity profile (Vp) – 2016-SR-04
Figure 2-10 Whites Valley compression wave velocity profile (Vp) – 2016-SR-05
Figure 2-11 Whites Valley Fault Trench Log – 16-TR-01

TABLE OF CONTENTS

Figure 2-12 Whites Valley Fault Trench Log – 16-TR-02

Figure 2-13 Whites Valley Fault Trench Log – 18-TR-01

Figure 2-14 Whites Valley Fault Trench Log – 18-TR-02

Figure 3-1 Geologic Map - Stokes (1962) original scale 1:250,000

Figure 3-2 Geologic Map – Beus (1963) original scale 1:48,000

Figure 3-3 Geologic Map – Doelling (1980) original scale 1:125,000

Figure 3-4 Geologic Map – Murphy, et.al. (1985) original scale 1:24,000

Figure 3-5 Stereonet Plot of Measured Discontinuities, Left Abutment, near 15-TH-WV-01

Figure 3-6 Stereonet Plot of Measured Discontinuities, Left Abutment, Trench 18-TR-02.

Figure 3-7 Stereonet Plot of Measured Discontinuities, Right Abutment.

Figure 3-8 LiDAR Slope Shade Image – Whites Valley

Figure 3-9 LiDAR Slope Shade Image – Whites Valley in Vicinity of Bues's Inferred Fault.

Figure 3-10 LiDAR Slope Shade Image – Proposed Dam Site

Figure 3-11 Whites Valley – Weighted Average of Vertical Hydraulic Permeability at Test Pit Locations

Figure 3-12 Whites Valley – Weighted Average of Horizontal Hydraulic Permeability at Test Pit Locations

List of Appendices

Appendix A – Whites Valley – Test Hole Logs and Core Photographs

Appendix B – Whites Valley – Test Pit Logs and Photographs

Appendix C – Whites Valley – Cone Penetration Test

Appendix D – Whites Valley – Seismic Refraction Survey

Appendix E – Whites Valley – Interpretative Laboratory Test Results

Appendix F – Whites Valley – Discontinuity Data

1.1 PROJECT DESCRIPTION

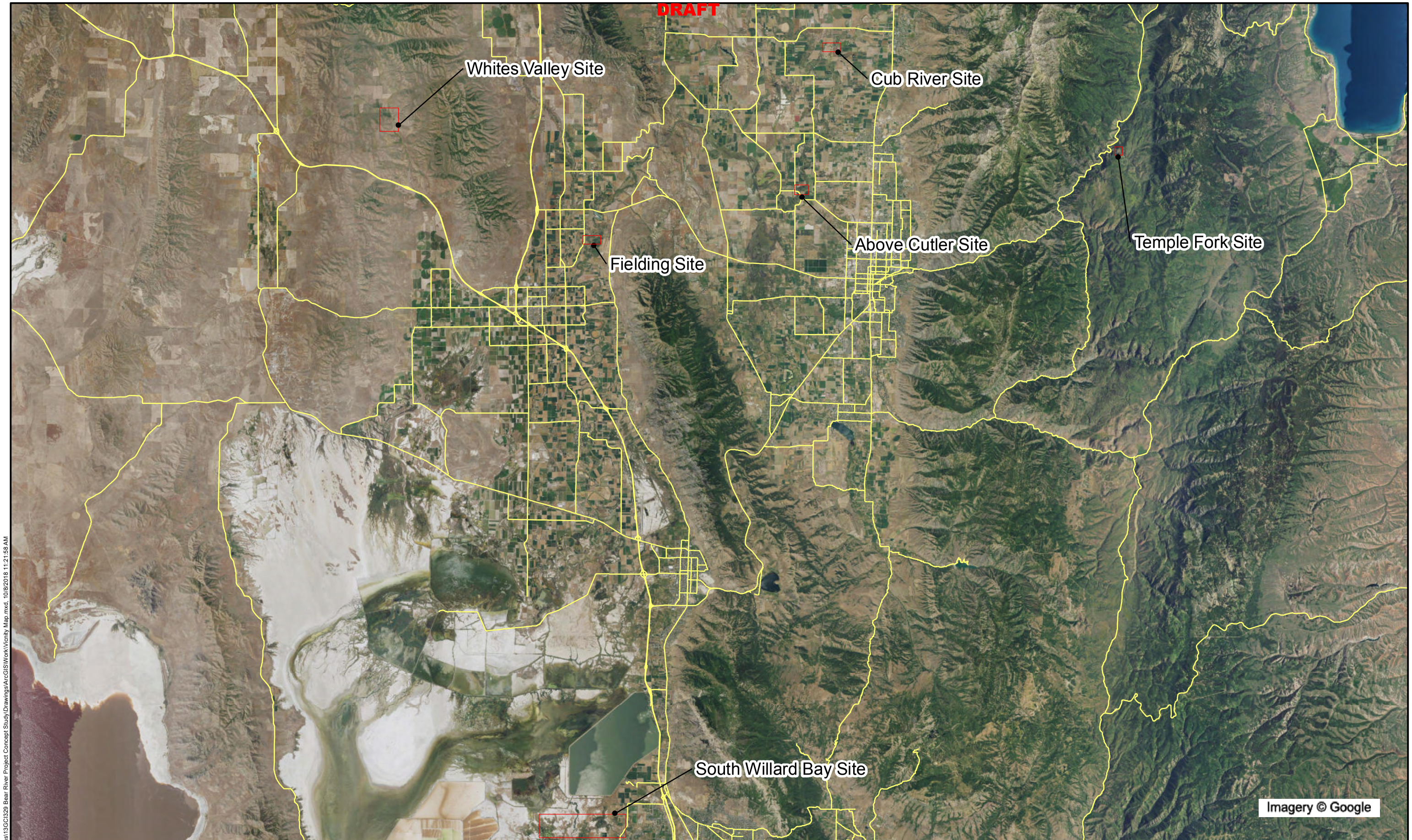
The purpose of the Bear River Project is to develop Utah's unused water rights on the Bear River and deliver it to Box Elder, Cache, Weber, Davis, and Salt Lake Counties. The overall Project will consist of conveyance facilities and reservoir storage necessary to deliver water from the Bear River to the communities in the service areas of the Bear River Water Conservancy District (BRWCD), Cache County, the Weber Basin Water Conservancy District (WBWCD), and the Jordan Valley Water Conservancy District (JVWCD). The Utah Division of Water Resources (DWRe) has been working with Bowen Collins and Associates and HDR (Project Team) for several years to develop the overall Project.

1.2 PURPOSE, AUTHORIZATION, AND WORK SCOPE

This report presents the results of geotechnical and geologic studies performed by Gerhart Cole Inc. (GCI) at Whites Valley in support of the project design team. The other project study areas that have had some studies completed are Cub River, Above Cutler, Temple Fork, Fielding, and South Willard Bay. The locations of these study sites are shown in Figure 1-1 along with the Whites Valley Site.

GCI completed the initial study of the proposed dam site between the fall 2014 and summer of 2015. The initial study of Whites Valley consisted of 4 test holes, geologic study of the dam and reservoir site, and associated laboratory testing on select samples recovered from the test holes. GCI provided the design team with a data report in October of 2015 summarizing these studies. In the fall of 2016, GCI conducted an initial fault study at the dam site and also complete a preliminary seepage study for the reservoir basin. In 2018, GCI excavated two additional trenches and examined LiDAR imagery as part of the fault study. The results from the fault study and seepage study have been added to the Whites Valley report issued in October of 2015 and are found in this revised report.

This work was completed under GCI's existing cooperative reciprocal service agreement with BCA, dated August 16, 2016. Additional details related to our scope of work are summarized in our proposal dated May 9, 2016 and February 9, 2018.



GERHART COLE

Bear River Project Concept Study

Vicinity Map

N

0 8,000 16,000 32,000 Feet

Figure 1-1

J:\PROJECTS\Bowen Collins\13GC\328 Bear River Project Concept Study\Drawings\ArcGIS\Work\Vicinity Map.mxd, 10/8/2018 11:21:58 AM

2.1 WHITES VALLEY STUDIES

Multiple field studies have been completed at the Whites Valley site. The initial drilling program occurred over the following dates; November 5 to 26, 2014, June 8 to 19, 2015, and August 10, 2015 to August 24, 2015, and consisted of drilling and sampling four (4) test holes (15-TH-WV-01, 14-TH-WV-02, 15-TH-WV-03 and 14-TH-WV-04). Two phases of seismic refraction surveys have completed at the dam site; the first in September 2015 and the second on October 31, 2016. Sage Earth Science completed these refraction surveys. Initial geologic studies were conducted in 2014 and 2015 and consisted of review of existing geologic maps, examination of aerial photographs, conducting site reconnaissance and data collection from outcrops, and review of drill hole data.

A fault study was conducted at the proposed dam site from September 19 to 30, 2016, and from March 26 to April 10, 2018, and included excavating four trenches (16-TR-01, 16-TR-02, 18-TR-01, and 18-TR-02) and pushing 10 cone penetration test (CPT) soundings (16-CPT-01 to 16-CPT-10); additional information on this fault study can be found in section 3.5. A preliminary study to assess qualitative seepage losses in the reservoir basin was completed from September 21 to October 6, 2016 and included excavating 48 test pits along various areas in the proposed reservoir basin. A site map showing the test hole, seismic refraction lines, fault trenches, and test pit locations are included in Figure 2-1 through Figure 2-3c. This data is also summarized along with other information in Table 2-1. Test hole, trenches, test pits, CPT, and seismic line locations were established by GCI based on accessibility and proximity to the proposed dam. The locations were documented by using a hand-held, GPS device. The test hole, CPT, test pit, and 2016 fault trenches elevations were estimated from the 2018 LiDAR survey based on the GPS locations. The seismic line elevations shown on Figures 2-5 through 2-10 were obtained from Google Earth by Sage Earth Science before the LiDAR was completed. Table 2-1 shows the approximate elevations of each end of the survey lines based on the LiDAR.

2.1.1 Test Hole Drilling and Sampling

Test hole 15-TH-WV-01 was advanced using TUBEX, rotary wash, and rock coring methods. Test holes 14-TH-WV-02 and 15-TH-WV-03 were advanced using rotary wash with HW casing and rock coring. Hollow stem auger drilling was used to complete test hole 14-TH-WV-04. All test holes were drilled using with a truck-mounted CME 75 drill rig provided by Bedke Geotechnical Field Services under subcontract to GCI. Additional information on test holes is provided in Table 2-1.

Test holes 15-TH-WV-01, 14-TH-WV-02, and 15-TH-WV-03 were drilled near the proposed dam site while 14-TH-WV-04 was drilled at a potential borrow site approximately 0.8 miles northwest of the dam site. All holes were drilled on private property with permission from the land owners. Test hole 15-TH-WV-03 was drilled at a 20-degree angle (off vertical) oriented at 296 degrees.

Approximately 20 to 25 feet of HW casing was set in 14-TH-WV-02 and 15-TH-WV-03, through soils overlying bedrock, to allow return/circulation of drilling fluids. Rock coring was accomplished using a HQ size (3.83 inch diameter) triple-tube core barrel with a wire-line setup for core retrieval.

Coring was generally accomplished in 5-foot runs unless blockage necessitated premature termination of a run. Clear water (no additives) was used as the drilling/circulation fluid. It was necessary to "grout-out" sections of the hole through more fractured limestone to stabilize test hole walls and prevent further accumulations of sand ("sanding") around the drill bit. Grouted sections were then re-drilled and test holes extended. Test hole 14-TH-WV-02 was drilled to 98 feet and met the target depth.

Due to minimal drilling/circulation fluid returns at 87 feet in 15-TH-WV-03, the hole was terminated and grouted to the top of bedrock. The test hole was then re-drilled with a NQ size triple-tube core barrel. At about 66 feet, rock retrieval was re-established, but circulation was still minimal below 87 feet and the hole was abandoned at a depth of 95 feet.

The top 25 feet of 15-TH-WV-01 was drilled utilizing TUBEX drilling methods, but due to weathered rock and accumulating fines, air circulation ceased, and the casing could not be advanced further. Drilling methods were then switched to rotary wash with a tri-cone bit from 25 to 65 feet. Between 60 to 65 feet, the drilling became very slow; therefore, HQ coring was attempted. At a depth of 85 feet, due to core blockage and circulation loss, grout was pumped into the hole in an attempt to stabilize it. The hole was then re-drilled to 85 feet and continued to 115.5 feet where the hole was abandoned due to lost circulation and core blockage.

Core samples were collected and boxed after recording pertinent information such as length of recovered core, percent RQD (rock quality designation), fracture density, and general lithologic information. Logging was performed by a licensed professional engineer (PE) and reviewed by a licensed professional geologist (PG). Standard Penetration Testing (SPT) with a standard split-spoon sampler was used to collect soil samples in 14-TH-WV-02 and 14-TH-WV-04. SPT tests were performed in 15-TH-WV-01 while the hole was advanced with either TUBEX or rotary wash drilling methods. The number of hammer blows required to advance the sampler in 6-inch increments was recorded in the field, with the sum of the second and third 6-inch intervals constituting the SPT "N-value." Bulk samples were also collected with hollow stem auger tool in 14-TH-WV-04 for classification and testing purposes.

Following completion in 15-TH-WV-01 and 15-TH-WV-03, a cement/bentonite grout mix was used to seal the holes. A piezometer was installed in 14-TH-WV-02 for ground water monitoring. The piezometer was screened from 98 to 88 feet, and sand packed from 98 to 41 feet, bentonite chips were placed from 41 feet to the 7 feet and then a concrete seal placed from 7 feet to the ground surface. In 14-TH-WV-04, bentonite chips were used to seal the entire hole.

Logs of the test holes are presented in Appendix A, along with rock core photos. Lines designating boundaries between different materials shown on the logs should be

considered approximate; transitions between subsurface materials may be gradual or occur between sampling depths. Relative density and consistency descriptions used on a final test hole log may deviate from field logs and/or criteria for a number of reasons, including; a) reliance on other test results, b) visual observation and/or manual manipulation of disturbed field samples, and/or c) the engineer's judgment. For most engineering assessments involving cohesionless, non-gravelly soils, the SPT blow count is usually adjusted for the effective vertical pressure at the sampling depth, and for other sampling system parameters such as the efficiency of the sampling system and/or sampling techniques used.

2.1.2 Test Pits

Test pits provided observation of surficial soils, collection of samples for soil classification testing as part of the preliminary seepage study. Western Pipe Fabrication Inc. (WPFI), under subcontract to GCI, excavated all test pits using a CAT 316E excavator. Test pit depths ranged from 2 to 13 feet. A GCI field engineer logged the test pits and estimated the material densities and stiffness based on field observations of the excavated material and observed equipment excavation effort. Test pit locations are plotted on Figure 2-3, summary information is included in Table 2-1, and associated test pit logs and photos are included in Appendix B.

2.1.3 Cone Penetration Test

Ten cone penetration test (CPT) soundings were advanced using truck-mounted equipment with a 15-cm^2 piezocone (tip net area ratio of 0.80) as part of the fault study. ConeTec of Salt Lake City, Utah, under subcontract to GCI, provided the equipment and associated operating services. The depths of the soundings ranged from 22 to 51 feet. Additional information regarding the location of the CPT sounding is presented in Table 2-1.

A cross section showing the CPT tip resistance (qt) versus depth is shown on Figure 2-4. The complete CPT sounding logs together with supporting data are presented in Appendix C. When interpreting soil type from CPT results, it is important to recognize that the soil behavior type (SBT) index shown on the logs is determined by correlation, and actual soil types may vary. Soil behavior type index is not the same as soil type.

2.1.4 Seismic Refraction Surveys

Sage Earth Science, under contract to GCI, completed two seismic refraction surveys at the site. The first survey (15-SR-01) was completed in September 2015 and one P-wave velocity profile was generated along the axis of the proposed embankment (Appendix D). The objective of the first survey was to assess the P-wave velocity profile of the shallow subsurface (0-150 feet) for the purpose of determining the depth to rock and the seismic velocity of the rock and overlying materials. This survey was based on correlation with the subsurface information obtained from the test holes. Three general velocity zones were delineated in 15-SR-01. The first zone consists of low-density materials exhibiting a velocity, Vp, of less than 3,000 feet per second (fps). This material is composed of unconsolidated to poorly consolidated sediments. The second

zone is characterized by a mid-range velocity from 3,000 to 6,000 fps. Based on correlation with the test hole logs and observations of outcrops exposed in road cuts (discussed below), this material is likely low-density rock that is significantly fractured and weathered. The third zone is characterized by a high velocity greater than 6,000 fps and is likely more dense rock than the overlying material and with a lesser degree of fracturing. The corresponding seismic profile is plotted in Figure 2-5.

The second survey occurred in October 2016 in order to locate, if possible, any discontinuities in the soil/bedrock interface and achieve better resolution in the near surface materials. To achieve better resolution near the surface, a closer geophone spacing was used which limits the depth of profiling to 40 or 50 feet. Five velocity profiles were conducted near the location of the proposed embankment. Three profiles were completed on the left abutment and two on the right abutment (16-SR-01 through 16-SR-05, Figure 2-2 and Figure 2-6 through Figure 2-10). See Appendix D for Sage Earth Sciences Seismic Refraction Survey Reports for additional information on details of the surveys.

2.1.5 Trench Excavation

In order to evaluate the subsurface geologic conditions and assess the surface-fault-rupture hazard, four trenches were excavated near the alignment of the dam; two in 2016 and two in 2018. The location of the trenches in relation to the proposed dam site is shown in Figure 2-2.

Following excavation, the sidewalls were scraped clean of material that was disturbed and spread along the trench walls by the excavating equipment. Once the geologic materials were exposed for examination, one of the trench walls was selected for detailed observation and logging. While both trench walls were examined, instability of the trench walls dictated that the wall with the most vertical, stable face was logged.

In order to provide safe working conditions to personnel conducting geologic observations of the subsurface materials, the trenches were excavated in lifts of about 5 feet in height, with a bench of about five feet wide between the lifts. The locations of the beginning and ending locations of the logged wall were determined with a hand-held GPS receiver. Horizontal control was established with a tape measure and control points set every five feet. Vertical control was established with level lines set on each lift. All measurements and geologic features were logged relative to the horizontal and vertical control at a scale of 1 inch equals 5 feet.

Subsurface materials exposed in the trenches were observed and graphically logged by an experienced engineering geologist having a State of Utah professional geologist license, following methodologies in McCalpin (2009) and in general accordance with the Utah Geological Survey's Guidelines for Evaluating Surface Fault Rupture Hazards in Utah (Lund, et. al., 2016). Graphic logs of the geologic materials exposed in the trenches are presented in Figure 2-11 through Figure 2-14. Discussions of the geologic materials exposed in the trenches are presented in Section 3.4 of this report.

The purpose of excavating the 2016 trenches was to identify the presence or absence of a previously mapped inferred normal fault shown to trend towards the dam site. The

trenches were oriented roughly in an east-west direction in order to intercept generally north trending Basin and Range extensional tectonics related normal faults that have been previously identified and mapped in the vicinity of the site.

The trenches were excavated with a track-mounted hydraulic excavator (CAT 316) between September 19 and 21, and between September 27 and 29, 2016. Trench 16-TR-01 was 195 feet in length; Trench 16-TR-02 was 165 feet in length. The trenches extended to a maximum depth ranging between 8.0 and 11.0 feet below the ground surface.

The purpose of excavating the 2018 trenches was to expose additional sediments at depths greater than the sediments that were exposed in the 2016 trenches and to examine additional exposure of bedrock near the toe of the slope. The goal of examining sediments at greater depths was to identify the presence or absence of faults in older sedimentary deposits. Similarly, additional bedrock was exposed in order to assess whether or not features identified in the seismic refraction profiles were related to faulting.

The trenches were excavated with two track-mounted hydraulic excavators (Volvo EC480DL) between March 29, 2018 and April 10, 2018. Trench 18-TR-01 was 162 feet in length; Trench 18-TR-02 was 145 feet in length. The trenches extended to a maximum depth ranging between 20.0 and 22.0 feet below the ground surface.

Following completion of excavating and logging, the trenches were backfilled. However, the backfilled material was not placed in uniform lifts or compacted to a specific density. Consequently, settlement of the backfill with time and saturation is likely to occur.

Four sediment samples were collected from Trench 16-TR-02 in order to assess the age of the sediments. Samples for radiocarbon dating were processed for pollen extraction at the University of Utah RED Lab. Standard palynological methods reported in Faegri et al. (1989), with the exception that acetolysis was replaced by a 2-minute treatment using Schulze's reagent (HNO_3 and $KClO_3$). This method concentrates pollen, providing a good source of organic material for radiocarbon dating in the absence of other terrestrial or aquatic macrofossils. Sample sizes were increased from the standard 2 cubic centimeters to 6 cubic centimeters to ensure sufficient pollen residuals for dating.

Radiocarbon analysis was performed at the University of Georgia Center for Applied Isotopic Studies (CAIS). Radiocarbon ages were calibrated using the CALIB 7.1 (Stuiver, et. al., 2017). Median calibrated calendar years before present (cal yr BP) for the samples are presented in Table 2-2.

Three samples were collected from sediments exposed near the bottom of Trench 18-TR-02. The samples were processed at the University of Utah RED Lab for pollen following the same procedures that were used in the samples from Trench 16-TR-02. Initial radiocarbon analysis of these samples returned dates that were too young to be consistent with the stratigraphy. Based on discussions with other researchers experiencing similar problems with radiocarbon dates from older Lake Bonneville sediments, and discussions with CAIS, we hypothesized that the samples from TR-18-

02 were contaminated with microbial spores utilizing modern carbon dioxide; and thus returning dates that are too young. In an effort to remove modern microbial spores, splits of the three samples were processed with hexane to dissolve the cell walls of microbial populations, followed by driving the hexane off in a drying oven. These hexane treated samples were then analyzed for radiocarbon following standard procedures. Unfortunately, the results of the additional radiocarbon dating were inconclusive. The samples treated with hexane were older than those not treated with hexane, however the dates are still too young to be consistent with the site stratigraphy. At this time, we still do not fully understand why the samples from TR-18-02 are dating too young. Because we do not have confidence that the radiocarbon dates reported by the laboratory are accurate or reliable, we do not include them in this report or rely upon them for our interpretation of the geologic history of the site.

2.1.6 Laboratory Study

Laboratory testing was performed on select rock core and soil specimens obtained during the drilling and seepage field studies to further classify and characterize the rock and soil. Laboratory testing included moisture content, Atterberg limits, grain size distribution, bulk sieves, shear strength testing, and point load testing on the rock cores. Laboratory test results are summarized in Table 2-3. Table 2-4 lists grain-size results of coarse-grained material from the bulk sieves collected during the seepage study, where cobble and boulder sized materials were estimated by volume in the field. Additional data and laboratory plots are included in Appendix E.

2.1.7 Permeability Testing

In order to evaluate rock permeability, testing was performed in each of the three core holes. Packer testing was completed in 14-TH-WV-02 and 15-TH-WV-03 at 10 foot intervals, and was commenced in each of the holes at about 25 to 40 feet below grade using a 10-foot long packer assembly suspended by a cable and compressed gas (nitrogen) line. The packer was equipped with a transducer to provide continuous indication of head pressure at the packer. In addition, an in-line pressure gauge was placed within the line at the top of the casing to provide a back-up reading of down-hole pressure at the packer. For each test, the packer was inflated under sufficient gas pressure to seal off the bottom of the hole and allow testing at required head pressures. Head pressures were calculated in advance of each test so that the pressure at the packer could be appropriately regulated. Tests were run in three to four steps of generally 5 minutes each. A few steps were stopped early due to the packer not sealing or due to significant loss of water through the formation. Under the initial step test, head pressure was maintained at levels less than 1 psi per foot of depth and was generally equivalent to a column of water equal to the mid-depth of the tested interval. Flow measurements for each minute of the test were recorded. During the second step test, applied pressure was increased from the first test and again water intake recorded in gallons per minute (gpm). The third test applied maximum pressure, and for the final step test, the head pressure was reduced back to the level of the second step test to see if there was any change in flow. A large increase would indicate hydraulic fracturing of the rock during the third step test. Once field data were obtained, permeability

estimates for each 10-foot increment of the bedrock in each hole were calculated both in centimeters per second, feet per year, and Lugeons; results are presented in Table 2-5 for 14-TH-WV-02 and 15-TH-WV-03.

Due to utilizing TUBEX and rotary wash drilling for 15-TH-WV-01, falling and constant head permeability tests were conducted. Constant head permeability tests were performed by drilling down to the bottom of the test zone, with the casing held at the top of the test zone and extending to the ground surface. The bit was then removed, leaving the casing in place, creating a vertical cylindrical void within soil comprising the test region and a cased test hole down to the top of the test region. The void and casing were filled with water to the top of the casing and water was added as needed to keep the casing full for the duration of the test (typically 10 to 15 minutes). At the end of the test, the volume of water added and test duration were recorded. These results are presented in Table 2-6.

Below a depth of 30 feet, casing could not be advanced due to bedrock hardness; therefore, constant head tests were completed with increasing open-hole lengths. The permeability for each test zone was calculated using an equivalent hydraulic conductivity method for each test layer. Table 2-6 presents the results of these tests and the calculated stratified hydraulic conductivity. Tests results between 30-40 feet and 30-88 feet seem to be suspect due to decreased water loss as opposed to the proceeding interval. We interpret the decreased water losses to be the result of drill cuttings/drill fluid plugging rock fractures as the test hole is deepened.

Two falling head tests were also conducted between 10 and 24 feet with the remainder performed in deeper portions of the test hole. Tests between 10 and 24 feet were setup and conducted in the same manner as constant head tests, except a vibrating wire piezometer was placed in the bottom of the hole and then water was added. The vibrating wire piezometer recorded water levels as they fell over time. Tests at depths of 98, 108, and 115.5 feet were tested in an “open end” condition (i.e. HQ casing not retracted due to unstable test hole conditions, and the vibrating wire piezometer placed inside the HQ casing at the bottom of the hole). Falling head test duration varied between 10 minutes to 24 hours with the majority of the tests lasting between 30 minutes to 1 hour. The test at a depth of 115.5 feet was at the end of the day; therefore, it was allowed to run until the drillers returned the next day. Table 2-7 through Table 2-11 present results of these falling head permeability tests.

2.1.8 Groundwater

Groundwater levels were measured in the piezometer in 14-TH-WV-02, on June 11, 2015 and September 23, 2016 and no water was observed in the hole. Groundwater was measured in 14-TH-WV-04 at about 28 feet at the time of drilling. Test hole 14-TH-WV-04 was drilled adjacent to the Whites Valley well. In the Utah Well Drilling Database the documentation on the well says it is 100 feet deep and it has the static water level at 20 feet. It also states it is used to fill water trucks and spray off equipment and is an “Awesome Well” (Utah DWRe, 2017).

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Table 2-1 Whites Valley - Field Studies Data

Bear River Project Concept Study; Whites Valley

Study Location Point Identification[a]	Date	Latitude [b]	Longitude [b]	Ground Surface Elev. (ft)[b]	Total depth (ft)	Water depth [c] (ft)	Drilling/Test Pit Method	Subcontractor	Comments
15-TH-WV-01	8/10 to 8/24/15	41.84604	-112.31765	5191.7	115.5	NM	Rock Coring (CME 75) HQ3 Triple Core Barrel Rotary Wash (Water)	Bedke Geotechnical Field Services	
14-TH-WV-02	11/5 to 11/7, 11/18 to 11/21/14	41.84597	-112.31896	5046.8	98	NF	Rock Coring (CME 75) HQ3 Triple Core Barrel Rotary Wash (Water)	Bedke Geotechnical Field Services	
15-TH-WV-03	6/8 to 6/19/2016	41.84607	-112.32051	5048.1	95	NM	Rock Coring (CME 75) HQ3 Triple Core Barrel Rotary Wash (Water)	Bedke Geotechnical Field Services	
14-TH-WV-04	11/26/2014	41.85641	-112.32608	5097.3	52	28	8 -in OD Hollow Stem Auger; 4.25 ID	Bedke Geotechnical Field Services	
16-TP-WV-01	9/21/2016	41.84776	-112.31264	5212.4	6	NF	Excavator (CAT 316E)	WPFI	
16-TP-WV-02	9/21/2016	41.84728	-112.31174	5226.5	6	NF	Excavator (CAT 316E)	WPFI	
16-TP-WV-03	9/21/2016	41.84720	-112.31100	5256.8	5	NF	Excavator (CAT 316E)	WPFI	
16-TP-WV-04	9/21/2016	41.84910	-112.31405	5200.8	6	NF	Excavator (CAT 316E)	WPFI	
16-TP-WV-05	9/21/2016	41.84888	-112.31445	5170.3	10	NF	Excavator (CAT 316E)	WPFI	
16-TP-WV-06	9/21/2016	41.85256	-112.31603	5210.7	3	NF	Excavator (CAT 316E)	WPFI	
16-TP-WV-07	9/21/2016	41.85252	-112.31655	5166.0	4.1	NF	Excavator (CAT 316E)	WPFI	
16-TP-WV-08	9/21/2016	41.85254	-112.31690	5136.9	10	NF	Excavator (CAT 316E)	WPFI	
16-TP-WV-09	9/21/2016	41.85598	-112.31429	5241.9	10	NF	Excavator (CAT 316E)	WPFI	
16-TP-WV-10	9/21/2016	41.85566	-112.31522	5220.3	10	NF	Excavator (CAT 316E)	WPFI	
16-TP-WV-11	9/22/2016	41.85512	-112.31696	5203.3	13	NF	Excavator (CAT 316E)	WPFI	
16-TP-WV-12	9/23/2016	41.85262	-112.33205	5236.5	11	NF	Excavator (CAT 316E)	WPFI	
16-TP-WV-13	9/23/2016	41.85316	-112.33244	5222.6	3.5	NF	Excavator (CAT 316E)	WPFI	
16-TP-WV-14	9/23/2016	41.85320	-112.33266	5201.5	5	NF	Excavator (CAT 316E)	WPFI	
16-TP-WV-15	9/26/2016	41.85194	-112.32953	5168.8	11	NF	Excavator (CAT 316E)	WPFI	
16-TP-WV-16	9/26/2016	41.85259	-112.32970	5149.9	10.5	NF	Excavator (CAT 316E)	WPFI	
16-TP-WV-17	9/26/2016	41.85281	-112.32939	5132.3	12	NF	Excavator (CAT 316E)	WPFI	
16-TP-WV-18	9/26/2016	41.85223	-112.32348	5143.1	6	NF	Excavator (CAT 316E)	WPFI	
16-TP-WV-19	9/26/2016	41.85242	-112.32335	5107.3	7.5	NF	Excavator (CAT 316E)	WPFI	
16-TP-WV-20	9/26/2016	41.85281	-112.32368	5093.3	10	NF	Excavator (CAT 316E)	WPFI	
16-TP-WV-21	9/26/2016	41.84905	-112.32359	5110.1	9	NF	Excavator (CAT 316E)	WPFI	
16-TP-WV-22	9/26/2016	41.84916	-112.32308	5090.5	7	NF	Excavator (CAT 316E)	WPFI	
16-TP-WV-23	9/26/2016	41.84887	-112.32141	5075.7	10.5	NF	Excavator (CAT 316E)	WPFI	
16-TP-WV-24	9/23/2016	41.85257	-112.33784	5260.8	10	NF	Excavator (CAT 316E)	WPFI	
16-TP-WV-25	9/23/2016	41.85275	-112.33788	5241.0	10	NF	Excavator (CAT 316E)	WPFI	

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Table 2-1 Whites Valley - Field Studies Data

Bear River Project Concept Study; Whites Valley

Study Location Point Identification[a]	Date	Latitude [b]	Longitude [b]	Ground Surface Elev. (ft)[b]	Total depth (ft)	Water depth [c] (ft)	Drilling/Test Pit Method	Subcontractor	Comments
16-TP-WV-26	9/23/2016	41.85299	-112.33788	5224.0	9.5	NF	Excavator (CAT 316E)	WPFI	
16-TP-WV-27	9/23/2016	41.85249	-112.34391	5222.9	10.5	NF	Excavator (CAT 316E)	WPFI	
16-TP-WV-28	9/23/2016	41.85373	-112.34309	5202.3	11.5	NF	Excavator (CAT 316E)	WPFI	
16-TP-WV-29	9/21/2016	41.84759	-112.31277	5230.0	10	NF	Excavator (CAT 316E)	WPFI	
16-TP-WV-30	9/21/2016	41.84742	-112.31298	5254.0	6	NF	Excavator (CAT 316E)	WPFI	
16-TP-WV-31	9/22/2016	41.87846	-112.34028	5221.3	9	NF	Excavator (CAT 316E)	WPFI	
16-TP-WV-32	9/22/2016	41.87627	-112.34010	5192.3	9	NF	Excavator (CAT 316E)	WPFI	
16-TP-WV-33	9/22/2016	41.87052	-112.31857	5241.4	10	NF	Excavator (CAT 316E)	WPFI	
16-TP-WV-34	9/22/2016	41.86940	-112.32077	5220.0	10	NF	Excavator (CAT 316E)	WPFI	
16-TP-WV-35	9/22/2016	41.86689	-112.32264	5216.9	10	NF	Excavator (CAT 316E)	WPFI	
16-TP-WV-36	9/22/2016	41.85792	-112.33023	5098.0	11	NF	Excavator (CAT 316E)	WPFI	
16-TP-WV-37	9/22/2016	41.86337	-112.33084	5122.9	11	NF	Excavator (CAT 316E)	WPFI	
16-TP-WV-38	9/22/2016	41.86680	-112.33159	5153.3	10	NF	Excavator (CAT 316E)	WPFI	
16-TP-WV-39	9/22/2016	41.86686	-112.33603	5117.3	10	NF	Excavator (CAT 316E)	WPFI	
16-TP-WV-40	9/23/2016	41.85471	-112.33273	5142.2	9	NF	Excavator (CAT 316E)	WPFI	
16-TP-WV-41	9/21/2016	41.84851	-112.31517	5181.7	8	NF	Excavator (CAT 316E)	WPFI	
16-TP-WV-42	9/21/2016	41.84840	-112.31551	5184.3	10	NF	Excavator (CAT 316E)	WPFI	
16-TP-WV-43	10/6/2016	41.84815	-112.31702	5164.6	4.5	NF	Excavator (CAT 316E)	WPFI	
16-TP-WV-44	10/6/2016	41.84793	-112.31650	5195.3	10	NF	Excavator (CAT 316E)	WPFI	
16-TP-WV-45	10/6/2016	41.84822	-112.31620	5183.7	8	NF	Excavator (CAT 316E)	WPFI	
16-TP-WV-46	10/6/2016	41.84835	-112.31820	5095.9	10	NF	Excavator (CAT 316E)	WPFI	
16-TP-WV-47	10/6/2016	41.84841	-112.32255	5170.4	5	NF	Excavator (CAT 316E)	WPFI	
16-TP-WV-48	10/6/2016	41.84927	-112.32249	5121.5	2	NF	Excavator (CAT 316E)	WPFI	
16-CPT-01	10/11/2016	41.84635	-112.31890	5047.7	31.5	NM	25 Ton CPT Truck Rig	ConeTec	
16-CPT-02	10/11/2016	41.84638	-112.31907	5047.6	39.04	NM	25 Ton CPT Truck Rig	ConeTec	
16-CPT-03	10/11/2016	41.84642	-112.31928	5047.7	41.67	NM	25 Ton CPT Truck Rig	ConeTec	
16-CPT-04	10/11/2016	41.84641	-112.31945	5045.6	39.7	NM	25 Ton CPT Truck Rig	ConeTec	
16-CPT-05	10/11/2016	41.84639	-112.31961	5046.4	40.52	NM	25 Ton CPT Truck Rig	ConeTec	
16-CPT-06	10/11/2016	41.84643	-112.31975	5045.8	40.35	NM	25 Ton CPT Truck Rig	ConeTec	
16-CPT-07	10/11/2016	41.84642	-112.31995	5046.0	35.76	NM	25 Ton CPT Truck Rig	ConeTec	
16-CPT-08	10/11/2016	41.84643	-112.32020	5047.2	34.61	NM	25 Ton CPT Truck Rig	ConeTec	
16-CPT-09	10/11/2016	41.84638	-112.31899	5047.6	34.45	NM	25 Ton CPT Truck Rig	ConeTec	
16-CPT-10	10/11/2016	41.84638	-112.31882	5049.2	22.15	NM	25 Ton CPT Truck Rig	ConeTec	
16-TR-01	9/19 to 9/21/2016	41.84608	-112.31996	5047.5	See Report			WPFI	
		41.84614	-112.32065	5082.0					
16-TR-02	9/27 to 9/30/2016	41.84693	-112.31904	5048.4	See Report			WPFI	
		41.84688	-112.31845	5066.5					
18-TR-01	3/29 to 4/10/2018	41.84623	-112.32032	5044.7	See Report			Whitaker Const.	
		41.84625	-112.32093	5054.7					
18-TR-02	3/29 to 4/10/2018	41.84667	-112.31908	5048.5	See Report			Whitaker Const.	
		41.84663	-112.31851	5065.2					

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Table 2-1 Whites Valley - Field Studies Data

Bear River Project Concept Study; Whites Valley

Study Location Point Identification[a]	Date	Latitude [b]	Longitude [b]	Ground Surface Elev. (ft)[b]	Total depth (ft)	Water depth [c] (ft)	Drilling/Test Pit Method	Subcontractor	Comments
15-SR-01	9/18/2015	41.84624	-112.32208	5253.5	See Appendix D			Sage Earth Science	
		41.84584	-112.31727	5247.8					
16-SR-01	10/31/2016	41.84605	-112.31897	5046.0	See Apendix D			Sage Earth Science	
		41.84601	-112.31841	5096.6					
16-SR-02	10/31/2016	41.84638	-112.31900	5047.5	See Appendix D			Sage Earth Science	
		41.84631	-112.31846	5076.7					
16-SR-03	10/31/2016	41.84688	-112.31912	5049.3	See Appendix D			Sage Earth Science	
		41.84665	-112.31813	5110.4					
16-SR-04	10/31/2016	41.84599	-112.32019	5045.9	See Appendix D			Sage Earth Science	
		41.84609	-112.32120	5119.3					
16-SR-05	10/31/2016	41.84645	-112.32018	5047.4	See Appendix D			Sage Earth Science	
		41.84651	-112.32118	5120.2					

Notes

a TH - Test Hole (drilled), TP= Test Pit (excavator), CPT=Cone Penetration Test, and SR - Sesimic Refraction Surveys

b Study Locations were surveyed with a handheld GPS, (NAD1983); Elevations estimated from 2018 Lidar Survey completed at site (NAVD88).

c Groundwater depth could not be measured (NM) due to drilling fluid or not found (NF)

Table 2-2 Radiocarbon Test Results from Trench 16-TR-02

Sample ID	UGAMS #	□^{13}C corrected Radiocarbon Age (YBP) ±	**Calib 7.1 Median Age (cal yr BP)**
16-TR-02-2-1	A27487	8,427±25	**9,463**
16-TR-02-3-1	A27488	9,116±31	**10,240**
16-TR-02-3-2	A27489	14,341±40	**17,445**
16-TR-02-7-1	A27490	24,190±73	**28,177**

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Table 2-3 Laboratory Test Result Summary
Bear River Project Concept Study - Whites Valley

GERHART COLE

Test Hole	Depth (ft)	Moisture content (%)	Atterberg Limits					Grain-Size					Grain-Size Analysis (Percent Finer)											Maximum dry unit weight, $g_{d\text{-}max}$ (pcf)	Optimum moisture content, w_{opt} (%)	Other Tests (Interpretative Data in Appendix)
			LL (%)	PL (%)	PI (%)	Cohesive Index, CI	Liquidity Index, LI	GRAVEL (No.4 - 3")	SAND (No.200-No.4)	FINES (<No.200)	silt (0.005-0.075	clay (<0.005 mm)	3-in (75 mm)	1.5-in (37.5 mm)	3/4-in (19 mm)	3/8-in (9.5 mm)	No.4 (4.75 mm)	No.10 (2 mm)	No.20 (0.85 mm)	No.40 (0.425 mm)	No.60 (0.25 mm)	No.100 (0.15 mm)	No.200 (0.075 mm)			
14-TH-WV-04	0-5	9.2	36	24	12	0.5	-1.2	2	11	86	63.2	23.2	100	100	100	99	98	95	94	93	92	91	86			
14-TH-WV-04	5-10	20.1	32	21	11	0.52	-0.1	0	4	96			100	100	100	100	100	100	100	100	99	99	96			
14-TH-WV-04	10-15	27.6	33	23	10	0.43	0.5	0	3	97	63.5	33.5	100	100	100	100	100	100	100	99	99	98	97			
14-TH-WV-04	15-20	33.0	30	25	5	0.2	1.6	0	11	89			100	100	100	100	100	100	99	97	95	92	89			
14-TH-WV-04	20-25	30.9	33	21	12	0.57	0.8	0	6	94	62.6	31.4	100	100	100	100	100	100	100	100	99	98	94			
14-TH-WV-04	25-30	30.9	32	21	11	0.52	0.9	1	6	93			100	100	100	99	99	99	99	98	98	97	93			
14-TH-WV-04	30-35	29.6	33	17	16	0.94	0.8	4	11	84	58.8	25.5	100	100	100	98	96	93	92	92	91	90	84			
14-TH-WV-04	35-40	33.3	40	21	19	0.9	0.6	0	6	94			100	100	100	100	100	100	100	100	99	98	94			
14-TH-WV-04	40-45	29.0	35	23	12	0.52	0.5	0	8	92	66.1	26.0	100	100	100	100	100	100	99	99	97	96	92			
14-TH-WV-04	0-15																							100.7	21.3	Pinhole, Permeability, CU
14-TH-WV-04	15-30																							110.0	18.0	Pinhole, Permeability, CU
14-TH-WV-04	30-45																							108.5	18.6	Pinhole
16-TP-WV-01	3 ft	18.5	38	19	19	1	0.0	5	7	89	52	36	100	100	97	96	95	95	94	94	94	93	89			
16-TP-WV-02	3-4 ft	13.9						67	15	17			100	86	65	42	33	26	23	21	20	19	17			
16-TP-WV-03	4-5 ft	16.3	34	19	15	0.79	-0.2	0	7	92	56	36	100	100	100	100	100	99	99	98	97	96	92			
16-TP-WV-08	9-10 ft	11.3	34	19	15	0.79	-0.5	42	11	47	26	21	100	100	69	63	58	55	53	52	50	49	47			
16-TP-WV-10	9-10 ft	36.7	42	26	16	0.62	0.7	0	5	95			100	100	100	100	100	99	98	97	97	96	95			
16-TP-WV-24	10 ft	15.1						25	34	41			100	100	84	80	75	70	62	55	51	47	41			
16-TP-WV-27	10 ft	16.3	56	18	38	2.11	0.0	13	14	73	34	39	100	100	100	90	87	85	83	82	81	79	73			
16-TP-WV-28	11 ft	15.6	37	20	17	0.85	-0.3	4	13	83			100	100	100	98	96	93	91	90	90	89	83			

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Table 2-3 Laboratory Test Result Summary

Bear River Project Concept Study - Whites Valley

GERHART COLE

Test Hole	Depth (ft)	Moisture content (%)	Atterberg Limits					Grain-Size					Grain-Size Analysis (Percent Finer)											Maximum dry unit weight, $g_{d\text{-}max}$ (pcf)	Optimum moisture content, w_{opt} (%)	Other Tests (Interpretative Data in Appendix)
			LL (%)	PL (%)	PI (%)	Cohesive Index, CI	Liquidity Index, LI	GRAVEL (No.4 - 3")	SAND (No.200-No.4)	FINES (<No.200)	silt (0.005-0.075	clay (<0.005 mm)	3-in (75 mm)	1.5-in (37.5 mm)	3/4-in (19 mm)	3/8-in (9.5 mm)	No.4 (4.75 mm)	No.10 (2 mm)	No.20 (0.85 mm)	No.40 (0.425 mm)	No.60 (0.25 mm)	No.100 (0.15 mm)	No.200 (0.075 mm)			
16-TP-WV-29	5-6 ft	11.3	39	18	21	1.17	-0.3	9	10	82			100	100	98	95	91	89	89	88	88	87	82			
16-TP-WV-30	3-4 ft	11.7	39	20	19	0.95	-0.4	10	6	84	49	35	100	100	93	91	90	88	88	87	87	86	84			
16-TP-WV-30	5-6 ft	20.6	51	22	29	1.32	0.0	21	11	68			100	94	84	82	79	77	75	75	74	73	68			
16-TP-WV-31	3-4 ft	15.0	62	22	40	1.82	-0.2	0	11	89			100	100	100	100	100	100	100	99	98	95	89			
16-TP-WV-33	3-5 ft	9.0	33	17	16	0.94	-0.5	8	12	80			100	100	100	95	92	90	89	88	87	86	80			
16-TP-WV-34	2-4 ft	5.7						63	25	13			100	100	97	81	37	22	16	15	14	14	13			
16-TP-WV-37	2-4 ft	12.0	45	19	26	1.37	-0.3	4	18	77	42	35	100	100	100	99	96	92	91	89	89	86	77			
16-TP-WV-41	5-6 ft	17.3						6	26	68			100	100	100	97	94	89	82	77	75	72	68			
16-TP-WV-42	9-10 ft	17.4	38	24	14	0.58	-0.5	28	21	51			100	89	80	75	72	69	65	61	58	55	51			
16-TP-WV-43	1-2 ft	7.8						60	16	23			100	94	78	55	40	32	28	26	25	25	23			
16-TP-WV-44	1.25-4 ft	13.3	44	28	15	0.54	-0.9	31	13	55			100	84	77	71	69	66	64	62	60	58	55			
16-TP-WV-45	7-8 ft	17.0	39	34	16	0.47	-3.4	32	29	40			100	100	81	74	68	63	58	52	48	44	40			
16-TH-WV-46	1-3 ft		43	23	17	0.74																				

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Table 2-4 Laboratory Test Results of Coarse Grained Material

GERHART COLE

Project: Bear River Project Concept Study **Location: Whites Valley**

Number: 13GCI329

J:\PROJECTS\Bowen Collins\13GCI329 Bear River Project Concept Study\Data\LabData\Whites Valley\Seepage Study\[BulkSievesWV.xls]Summary

Test Hole	Depth (ft)	Natural moisture content (%)	Grain-Size Distribution by Weight (%)										Soil Classification and [comments]
			BOULDERS (>300 mm) / (>12") [a]	COBBLES (75-300 mm) / (3"-12") [a]	GRAVEL (4.75-75 mm) / (No.4-3")	coarse gravel (19-75 mm) / (3/4-3")	fine gravel (4.75-19 mm) / (No.4-3/4")	SAND (0.075-4.75 mm) / (No.200-No. 4)	coarse sand (2-4.75 mm) / (No.10-No. 4)	medium sand (0.425-2.0 mm) / (No.40-No.10)	fine sand (0.075-0.425 mm) / (No.200-No.40)	FINES (<0.075 mm) / (<No.200)	
16-TP-WV-07	2-3	5	2-3	9-16	49-44	34-31	15-14	13-12	6-6	4-4	3-3	27-24	
16-TP-WV-11	4-6	4	2-3	5-10	60-56	27-25	34-31	19-18	9-8	6-6	4-4	14-13	
16-TP-WV-43	1-2	8	-	8-14	55-52	20-19	36-34	15-14	7-7	5-5	3-2	21-20	
16-TP-WV-44	1.25-4	13	-	15-26	27-23	20-17	7-6	11-10	2-2	4-3	6-5	47-41	
16-TP-WV-45	7-8	17	-	10-20	31-31	20-22	11-9	24-20	4-4	10-8	10-9	34-28	
16-TP-WV-46	9-10	19	-	6-10	27-26	18-17	8-8	14-14	4-4	4-4	6-6	53-51	
16-TP-WV-47	4-4.5	17	-	20-31	42-37	31-27	11-10	16-14	3-3	4-4	8-7	22-19	
16-TP-WV-48	1-2	16	-	29-40	39-33	20-17	19-16	20-17	6-5	7-6	7-6	12-10	

[a] Boulders and Cobbles (materials > 3") were screened and measured in the field. Mass determination based on measured volume and upper and lower bound estimates of the unit weight. Material <3" was tested in the laboratory

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Table 2-5 - Core Hole Packer Permeability Test Results
Whites Valley Site 14-TH-WV-02

Project Name	Bear River Project Concept Study	Inclination (degrees)	0	Tested by	R. Buhler
Project Location	Whites Valley	Distance to Water (ft)	None Observed	Date	Nov-14
Project Number	13GCI329	Vertical Depth to Water (ft)	None Observed	Reviewed by	P. Gerhart
Test Hole No.	14-TH-WV-02 Sheet 1 of 1	Hole Diameter = 2*r (in)	3.83	Date	Nov-15

Notes: All tests the pressures were measured with the vibrating wire pressure tranducer in the test zone

Test #, Packer Pressure, Material	Inclined Packer Test Interval (ft)		Vertical Packer Test Interval (ft)		Packer Test Length, inclined	Total Applied Pressure	Adjusted Applied Pressure	Applied Pressure Head	Total Head	Water Take	Shape Factor	Hydraulic Conductivity		
	Start	End	Start	End	(ft)	(psi)	(psi)	(ft)	(ft)	(gpm)		(ft/yr)	(cm/s)	(Lugeon)
a	b	c	d	e	L	p_{vw}	pactual	hp	htotal	Q	Cp	k	km	kL
1 No Seal	26	38	26.0	38.0	12	24.00	15.50	35.8	35.8	15.5	4028	1744	1.7E-03	130
2, (290 psi)	38	48	38.0	48.0	10	24.24	24.2	56.0	56.0	5.7	4630	471	4.6E-04	35
	38	48	38.0	48.0	10	24.68	24.7	57.0	57.0	5.9	4630	479	4.6E-04	36
	38	48	38.0	48.0	10	29.00	29.0	67.0	67.0	10.9	4630	753	7.3E-04	56
	38	48	38.0	48.0	10	15.58	15.6	36.0	36.0	5.9	4630	759	7.3E-04	56
	38	48	38.0	48.0	10	6.93	6.9	16.0	16.0	2.3	4630	666	6.4E-04	49
3 (290 psi)	48	58	48.0	58.0	10	22.51	22.51	52.0	52.0	20.9	4630	1861	1.8E-03	138
4, (300 psi)	58	68	58.0	68.0	10	13.85	13.85	32.0	32.0	26	4630	3762	3.6E-03	280
5, (310 psi)	68	78	68.0	78.0	10	17.32	17.32	40.0	40.0	27.7	4630	3203	3.1E-03	238
6, (310 psi)	78	88	78.0	88.0	10	35.15	35.15	81.2	81.20	14.1	4630	804	7.8E-04	60
	78	88	78.0	88.0	10	41.21	41.21	95.2	95.20	22.9	4630	1114	1.1E-03	83
7, (310 psi)	88	98	88.0	98.0	10	45.24	45.24	104.5	104.50	15.4	4630	682	6.6E-04	51
	88	98	88.0	98.0	10	41.21	41.21	95.2	95.20	21.2	4630	1031	1.0E-03	77

a = Test #, Packer pressure, Material

b = Packer tip

c = Bottom of test hole

d = b*cos(inclination)

e = c*cos(inclination)

p_{vw} = Pressure head in vibrating wire piezometer

$p_{actual} = p_{vw}$

$h_p = p_{actual}*2.31$

$h_{total} = h_p$

L = c-b

If L >= 10r, $C_p = 1/(2\pi L)*\ln(L/r)*70309$

If r<L<10r, $C_p = 1/(2\pi L)*\sinh^{-1}(L/2r)*70309$

70309 is unit conversion from gpm/ft^2 to ft/yr

$k = C_p*Q/h_{total}$

$k_m = k*9.6651E-7$

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Table 2-5 - Core Hole Packer Permeability Test Results
Whites Valley Site 15-TH-WV-03

Project Name	Bear River Project Concept Study	Inclination (degrees)	20	Tested by	R. Buhler
Project Location	Whites Valley	Distance to Water (ft)	None Observed	Date	Jun-15
Project Number	13GCI329	Vertical Depth to Water (ft)	None Observed	Reviewed by	P. Gerhart
Test Hole No.	15-TH-WV-03 Sheet 1 of 1	Hole Diameter = 2*r (in)	3.83	Date	Nov-15

Notes: All tests the pressures were measured with the vibrating wire pressure tranducer in the test zone

Test #, Packer Pressure, Material	Inclined Packer Test Interval (ft)		Vertical Packer Test Interval (ft)		Packer Test Length, inclined	Total Applied Pressure	Adjusted Applied Pressure	Applied Pressure Head	Total Head	Water Take	Shape Factor	Hydraulic Conductivity		
	Start	End	Start	End	(ft)	(psi)	(psi)	(ft)	(ft)	(gpm)		(ft/yr)	(cm/s)	(Lugeon)
a	b	c	d	e	L	p_{vw}	pactual	hp	htotal	Q	Cp	k	km	kL
1	37	47	34.8	44.2	10	14.29	14.29	33.0	33.0	12.4	4630	1740	1.68E-03	129
No Seal	37	47	34.8	44.2	10	14.72	14.72	34.0	34.0	15.8	4630	2152	2.08E-03	160
	37	47	38.0	48.0	10	13.42	13.42	31.0	31.0	10.0	4630	1494	1.44E-03	111
2, No Seal	47	57	44.2	53.6	10	0.00	0.00	0.0	0.0	0	4630	--	--	--
3	57	67	53.6	63.0	10	25.97	25.97	60.0	60.0	9.9	4630	761	7.35E-04	57
350 psi	57	67	53.6	63.0	10	34.59	34.59	79.9	79.9	13.9	4630	806	7.79E-04	60
	57	67	53.6	63.0	10	45.02	45.02	104.0	104.0	22.5	4630	1002	9.68E-04	74
	57	67	48.0	58.0	10	32.03	32.03	74.0	74.0	19.2	4630	1201	1.16E-03	89
4	67	77	63.0	72.4	10	46.75	46.75	108.0	108.0	11.4	4630	489	4.72E-04	36
350 psi	67	77	63.0	72.4	10	53.25	53.25	123.0	123.0	11.8	4630	444	4.29E-04	33
	67	77	58.0	68.0	10	72.73	72.73	168.0	168.0	15.8	4630	435	4.21E-04	32
	67	77	58.0	68.0	10	53.68	53.68	124.0	124.0	11.2	4630	418	4.04E-04	31
5	77	87	72.4	81.8	10	36.75	36.75	84.9	84.9	3.2	4630	175	1.69E-04	13
350 psi	77	87	72.4	81.8	10	45.11	45.11	104.2	104.2	4.2	4630	185	1.79E-04	14
	77	87	72.4	81.8	10	63.20	63.20	146.0	146.0	5.1	4630	163	1.58E-04	12
	77	87	72.4	81.8	10	45.89	45.89	106.0	106.0	3.9	4630	169	1.63E-04	13

a = Test #, Packer pressure, Material

b = Packer tip

c = Bottom of test hole

d = b*cos(inclination)

e = c*cos(inclination)

p_{vw} = Pressure head in vibrating wire piezometer

$p_{actual} = p_{vw}$

$h_p = p_{actual}*2.31$

$h_{total} = h_p$

L = c-b

If L >= 10r, $C_p = 1/(2\pi L)*\ln(L/r)*70309$

If r<L<10r, $C_p = 1/(2\pi L)*\sinh^{-1}(L/2r)*70309$

70309 is unit conversion from gpm/ft^2 to ft/yr

$k = C_p*Q/h_{total}$

$k_m = k*9.6651E-7$

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GERHART COLE

Table 2-6 - Whites Valley - Constant Head Permeability Testing Summary

Bear River Concept Study; Whites Valley

Location	Test Section (ft)	Ground Water Depth (ft)[a]	Total Flow, Q (gpm) in Test Section	Stratified Layer (ft)	Soil Type in Stratified Layer	Hydraulic Conductivity (Lugeon)[b]	Hydraulic Conductivity (cm/sec)[b]	Comments
15-TH-WV-01	0-10	10	0.05	0-10	W SS	2	2E-05	Test Section in Weathered Sandstone and Limestone Material
15-TH-WV-01	25-30	30	0.52	25-30	W SS	10	1E-04	Test Section in Weathered Sandstone and Limestone Material
15-TH-WV-01	30-35	35	0.24	30-35	W SS	4	5E-05	Test Section in Weathered Sandstone and Limestone Material
15-TH-WV-01	30-40	40	0.23	30-40	W SS	2	2E-05	Results suspect due to less flow in interval than test section 30-35; Possible plugging of formation
15-TH-WV-01	30-45	45	0.29	40-45	W SS	1	1E-05	Test Section in Weathered Sandstone and Limestone Material
15-TH-WV-01	30-50	50	0.41	45-50	W SS	2	2E-05	Test Section in Weathered Sandstone and Limestone Material
15-TH-WV-01	30-55	55	0.68	50-55	W SS	4	5E-05	Test Section in Weathered Sandstone and Limestone Material
15-TH-WV-01	30-60	60	0.97	55-60	W SS	4	5E-05	Test Section in Weathered Sandstone and Limestone Material
15-TH-WV-01	30-65	65	1.64	60-65	LMS/SS	8	1E-04	Test Section in Weathered Sandstone and Limestone Material
15-TH-WV-01	30-78	78	8.24	65-78	LMS/SS	63	8E-04	Test Section in Weathered Sandstone and Limestone Material
15-TH-WV-01	30-88	88	7.28	78-88	LMS/SS	66	9E-04	Results suspect due to less total flow than test section 30-78; Possible plugging of formation

Notes:

a. Groundwater not encountered. Assummed water depth at bottom of test section.

b. Equivalent hydraulic condicutivity calculated assuming stratified layers.

W SS - Weathered Sandstone; LMS/SS - Limestone Sandstone

Table 2-7 - Falling Head Permeability Test Result - 10-20 ft

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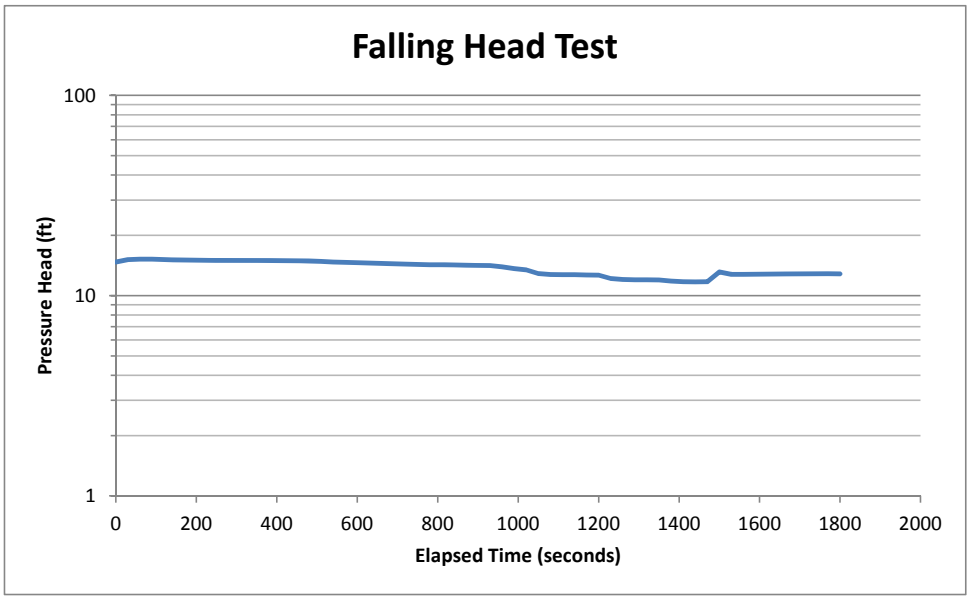
GERHART COLE

Test Hole	15-TH-WV-01	
Test Date	8/11/2015	
Casing	0-10	ft
Open Hole	10-20	ft
Hole Diameter	5	inches
Piezometer Depth	20	ft

Time	Pressure Head (ft)	Time	Pressure Head (ft)	Time	Pressure Head (ft)	Time	Pressure Head (ft)
10:42	14.70	10:50	14.89	10:58	13.93	11:06	11.72
10:43	15.12	10:51	14.82	10:59	13.65	11:07	11.73
10:43	15.21	10:51	14.72	10:59	13.44	11:07	13.13
10:44	15.20	10:52	14.65	11:00	12.88	11:08	12.76
10:44	15.14	10:52	14.60	11:00	12.74	11:08	12.78
10:45	15.09	10:53	14.53	11:01	12.72	11:09	12.80
10:45	15.04	10:53	14.48	11:01	12.71	11:09	12.82
10:46	15.03	10:54	14.43	11:02	12.68	11:10	12.82
10:46	14.99	10:54	14.36	11:02	12.66	11:10	12.83
10:47	14.96	10:55	14.31	11:03	12.17	11:11	12.84
10:47	14.96	10:55	14.27	11:03	12.03	11:11	12.84
10:48	14.99	10:56	14.25	11:04	11.99	11:12	12.86
10:48	14.99	10:56	14.23	11:04	11.98	11:12	12.85
10:49	14.97	10:57	14.19	11:05	11.97		
10:49	14.95	10:57	14.16	11:05	11.81		
10:50	14.93	10:58	14.13	11:06	11.73		



Time		Test Section (ft)		Initial	Final (H_2)	L (cm)	D (cm)	m	kh	Lugeon
Initial (sec)	Final (sec)	Top	Btm	(H_1)	(cm)				(cm/s)	(kL)
30	500	10	20	460.88	453.96	304.80	12.4	1	7.9E-06	1
500	900	10	20	453.96	431.59	304.80	12.4	1	3.1E-05	2
900	1200	10	20	431.59	385.73	304.80	12.4	1	9.2E-05	7
1200	1470	10	20	385.73	357.43	304.80	12.4	1	6.9E-05	5
								Avg	3.9E-05	4

1)Reference: Construction Dewatering and Groundwater Control, Powers, et al., 2007, p. 169-172

Table 2-8 - Falling Head Permeability Test Result - 20-24 ft

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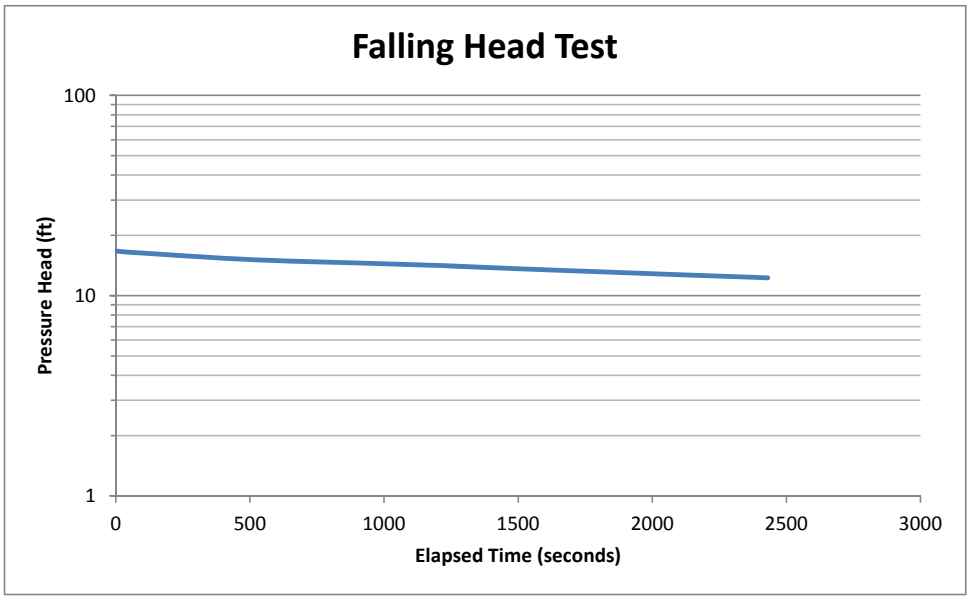
GERHART COLE

Test Hole	15-TH-WV-01	
Test Date	8/11/2015	
Casing	0-20	ft
Open Hole	20-24	ft
Hole Diameter	5	inches
Piezometer Depth	24	ft

1 ft of sluff on btm of hole

Time	Pressure Head (ft)	Time	Pressure Head (ft)	Time	Pressure Head (ft)	Time	Pressure Head (ft)
14:07	16.70	14:17	14.91	14:28	14.03	14:38	13.03
14:07	16.55	14:18	14.85	14:28	13.98	14:39	12.97
14:08	16.43	14:18	14.83	14:29	13.95	14:39	12.93
14:08	16.33	14:19	14.79	14:29	13.90	14:40	12.91
14:09	16.24	14:19	14.75	14:30	13.85	14:40	12.86
14:09	16.15	14:20	14.70	14:30	13.79	14:41	12.81
14:10	16.05	14:20	14.68	14:31	13.74	14:41	12.77
14:10	15.96	14:21	14.61	14:31	13.67	14:42	12.73
14:11	15.84	14:21	14.59	14:32	13.65	14:42	12.69
14:11	15.76	14:22	14.55	14:32	13.59	14:43	12.62
14:12	15.65	14:22	14.51	14:33	13.54	14:43	12.60
14:12	15.58	14:23	14.48	14:33	13.47	14:44	12.55
14:13	15.50	14:23	14.43	14:34	13.43	14:44	12.51
14:13	15.40	14:24	14.41	14:34	13.37	14:45	12.48
14:14	15.32	14:24	14.36	14:35	13.30	14:45	12.43
14:14	15.23	14:25	14.32	14:35	13.27	14:46	12.38
14:15	15.18	14:25	14.27	14:36	13.22	14:46	12.35
14:15	15.12	14:26	14.23	14:36	13.17	14:47	12.30
14:16	15.05	14:26	14.18	14:37	13.12	14:47	12.27
14:16	15.01	14:27	14.14	14:37	13.08		
14:17	14.96	14:27	14.09	14:38	13.05		



Time		Test Section (ft)		Initial	Final (H_2)	L (cm)	D (cm)	m	kh	Lugeon
Initial (sec)	Final (sec)	Top	Btm	(H_1)	(cm)				(cm/s)	(kL)
0	500	20	24	509.08	462.74	121.92	12.4	1	9.0E-05	7
500	1000	20	24	462.74	439.88	121.92	12.4	1	4.8E-05	4
1000	1500	20	24	439.88	416.79	121.92	12.4	1	5.1E-05	4
1500	2000	20	24	416.79	393.37	121.92	12.4	1	5.4E-05	4
2000	2430	20	24	393.37	373.85	121.92	12.4	1	5.6E-05	4
								Avg	6.0E-05	5

1)Reference: Construction Dewatering and Groundwater Control, Powers, et al., 2007, p. 169-172

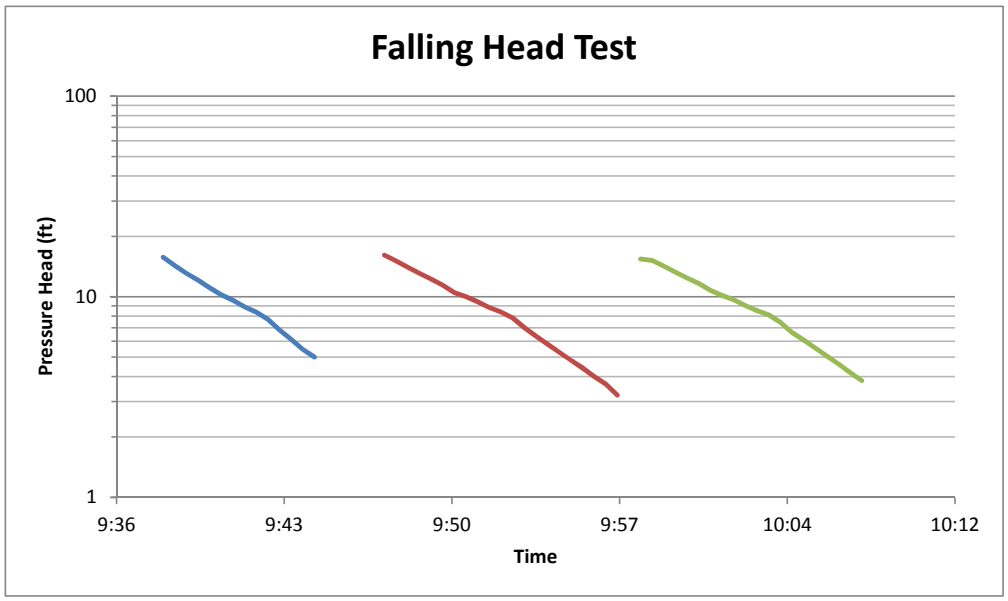
Table 2-9 - Falling Head Permeability Test Result - at 98 ft

DRAFT

GERHART COLE

Test Hole	15-TH-WV-01	
Test Date	8/24/2015	
Casing	0-98	ft
Hole Diameter	3	inches
Piezometer Depth	98	ft

Time	Pressure Head (ft)	Time	Pressure Head (ft)	Time	Pressure Head (ft)
9:38	15.74	9:47	16.13	9:58	15.44
9:38	14.30	9:48	15.10	9:59	15.19
9:39	13.07	9:48	14.04	9:59	14.19
9:39	12.11	9:49	13.10	10:00	13.24
9:40	11.09	9:49	12.25	10:00	12.40
9:40	10.22	9:50	11.43	10:01	11.65
9:41	9.61	9:50	10.50	10:01	10.76
9:41	8.91	9:51	10.01	10:02	10.15
9:42	8.38	9:51	9.45	10:02	9.65
9:42	7.72	9:52	8.84	10:03	9.04
9:43	6.83	9:52	8.40	10:03	8.53
9:43	6.12	9:53	7.84	10:04	8.13
9:44	5.47	9:53	7.03	10:04	7.45
9:44	5.00	9:54	6.37	10:05	6.64
		9:54	5.81	10:05	6.08
		9:55	5.28	10:06	5.56
		9:55	4.83	10:06	5.06
		9:56	4.44	10:07	4.62
		9:56	4.01	10:07	4.19
		9:57	3.67	10:08	3.82
		9:57	3.23		



Time		Initial (H_1)	Final (H_2)	D (cm)	Km	km
Initial (sec)	Final (sec)	(cm)	(cm)		(Lugeon	(cm/s)
0	390	479.8	152.5	7.4	481	6.2E-03
0	600	491.7	98.6	7.4	438	5.7E-03
0	570	470.6	116.4	7.4	401	5.2E-03
				Avg	440	5.7E-03

1)Reference: Construction Dewatering and Groundwater Control, Powers, et al., 2007, p. 169-172

2) Km = Mean Coefficient of Permeability

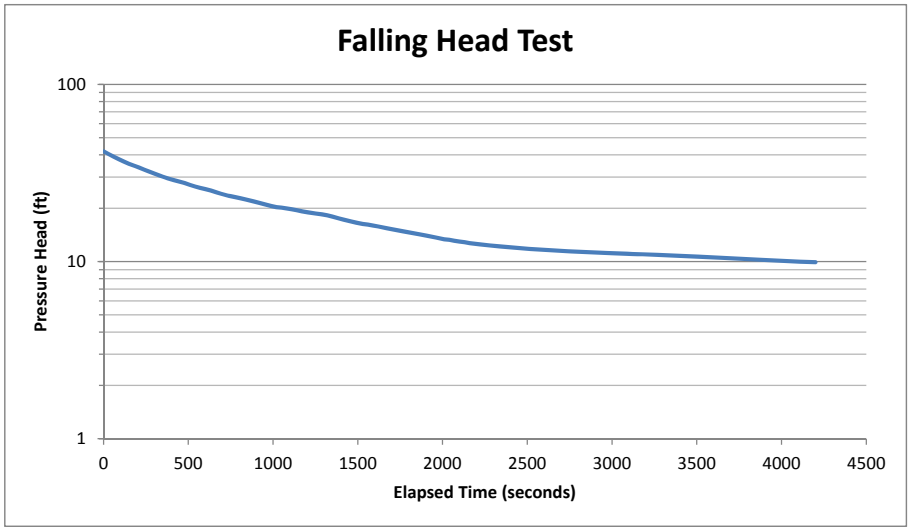
Table 2-10 - Falling Head Permeability Test Result - at 108 ft

DRAFT

GERHART COLE

Test Hole	15-TH-WV-01	
Test Date	8/24/2015	
Casing	0-108	ft
Hole Diameter	3	inches
Piezometer Depth	108	ft

Time	Pressure Head (ft)	Time	Pressure Head (ft)	Time	Pressure Head (ft)	Time	Pressure Head (ft)	Time	Pressure Head (ft)
11:19	41.88	11:35	20.92	11:51	13.96	12:07	11.29	12:23	10.28
11:19	40.46	11:35	20.57	11:51	13.79	12:07	11.24	12:23	10.24
11:20	39.05	11:36	20.30	11:52	13.53	12:08	11.22	12:24	10.20
11:20	37.82	11:36	20.17	11:52	13.36	12:08	11.19	12:24	10.18
11:21	36.65	11:37	19.93	11:53	13.26	12:09	11.15	12:25	10.15
11:21	35.60	11:37	19.74	11:53	13.10	12:09	11.13	12:25	10.13
11:22	34.71	11:38	19.50	11:54	12.97	12:10	11.09	12:26	10.09
11:22	33.94	11:38	19.22	11:54	12.87	12:10	11.06	12:26	10.05
11:23	32.98	11:39	19.02	11:55	12.71	12:11	11.03	12:27	10.01
11:23	32.15	11:39	18.79	11:55	12.57	12:11	11.01	12:27	9.98
11:24	31.35	11:40	18.61	11:56	12.47	12:12	11.00	12:28	9.96
11:24	30.59	11:40	18.46	11:56	12.42	12:12	10.99	12:28	9.93
11:25	29.91	11:41	18.24	11:57	12.33	12:13	10.96	12:29	9.92
11:25	29.26	11:41	17.95	11:57	12.25	12:13	10.93		
11:26	28.68	11:42	17.60	11:58	12.20	12:14	10.90		
11:26	28.23	11:42	17.29	11:58	12.14	12:14	10.85		
11:27	27.72	11:43	17.01	11:59	12.07	12:15	10.82		
11:27	27.05	11:43	16.75	11:59	11.97	12:15	10.79		
11:28	26.53	11:44	16.51	12:00	11.89	12:16	10.78		
11:28	26.02	11:44	16.32	12:00	11.82	12:16	10.74		
11:29	25.63	11:45	16.15	12:01	11.74	12:17	10.66		
11:29	25.21	11:45	15.96	12:01	11.71	12:17	10.63		
11:30	24.64	11:46	15.79	12:02	11.66	12:18	10.61		
11:30	24.21	11:46	15.60	12:02	11.61	12:18	10.57		
11:31	23.70	11:47	15.38	12:03	11.57	12:19	10.55		
11:31	23.43	11:47	15.18	12:03	11.53	12:19	10.52		
11:32	23.05	11:48	14.97	12:04	11.48	12:20	10.48		
11:32	22.75	11:48	14.79	12:04	11.45	12:20	10.45		
11:33	22.38	11:49	14.59	12:05	11.41	12:21	10.41		
11:33	22.03	11:49	14.43	12:05	11.38	12:21	10.39		
11:34	21.69	11:50	14.27	12:06	11.34	12:22	10.34		
11:34	21.25	11:50	14.10	12:06	11.30	12:22	10.30		



Time		Initial (H_1)	Final	D (cm)	Km	km (cm/s)
Initial (sec)	Final (sec)	(cm)	(H_2)		(Lugeon)	
0	500	1276.65	845.01	7.4	135	1.8E-03
500	1000	845.01	626.93	7.4	98	1.3E-03
1000	2000	626.93	412.28	7.4	69	8.9E-04
2000	3000	412.28	339.79	7.4	32	4.1E-04
3000	4200	339.79	302.21	7.4	16	2.1E-04
				Avg	70	9.1E-04

1)Reference: Construction Dewatering and Groundwater Control, Powers, et al., 2007, p. 169-172

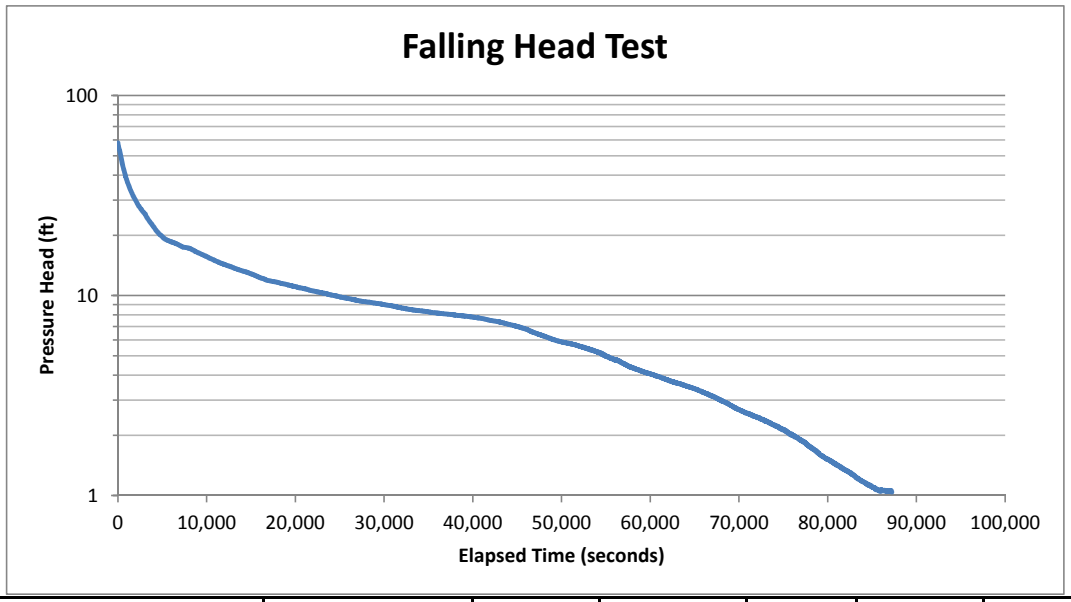
2) Km = Mean Coefficient of Permeability

Table 2-11 - Falling Head Permeability Test Result - at 115.5 ft

DRAFT

GERHART COLE

Test Hole	15-TH-WV-01	
Test Date	8/24/2015-8/25/2015	
Casing	0-115.5	ft
Hole Diameter	3	inches
Piezometer Depth	115.5	ft



Time		Test Section (ft)		Initial (H_1) (cm)	Final (H_2) (cm)	D (cm)	Km (Lugeon)	km (cm/s)
Initial (sec)	Final (sec)	Top	Btm					
0	3600	57	115.5	1769.06	713.09	7.44	41	5.4E-04
3600	7200	92	115.5	713.09	535.40	7.44	13	1.7E-04
7200	14400	98	115.5	535.40	400.79	7.44	7	8.5E-05
14400	28800	102	115.5	400.79	280.26	7.44	4	5.3E-05
28800	57600	106	115.5	280.26	134.93	7.44	4	5.4E-05
57600	87240	111	115.5	134.93	31.69	7.44	8	1.0E-04
						Avg	13	1.7E-04

1)Reference: Construction Dewatering and Groundwater Control, Powers, et al., 2007, p. 169-172

2) Km = Mean Coefficient of Permeability

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Figure 2-3c;Test Pit Location Map (3 of 3)

Figure 2-3b;Test Pit Location Map (2 of 3)

Figure 2-3a;Test Pit Location Map (1 of 3)

Figure 2-2; Dam Site Studies Map

Imagery © Google

GERHART COLE

Bear River Project Concept Study

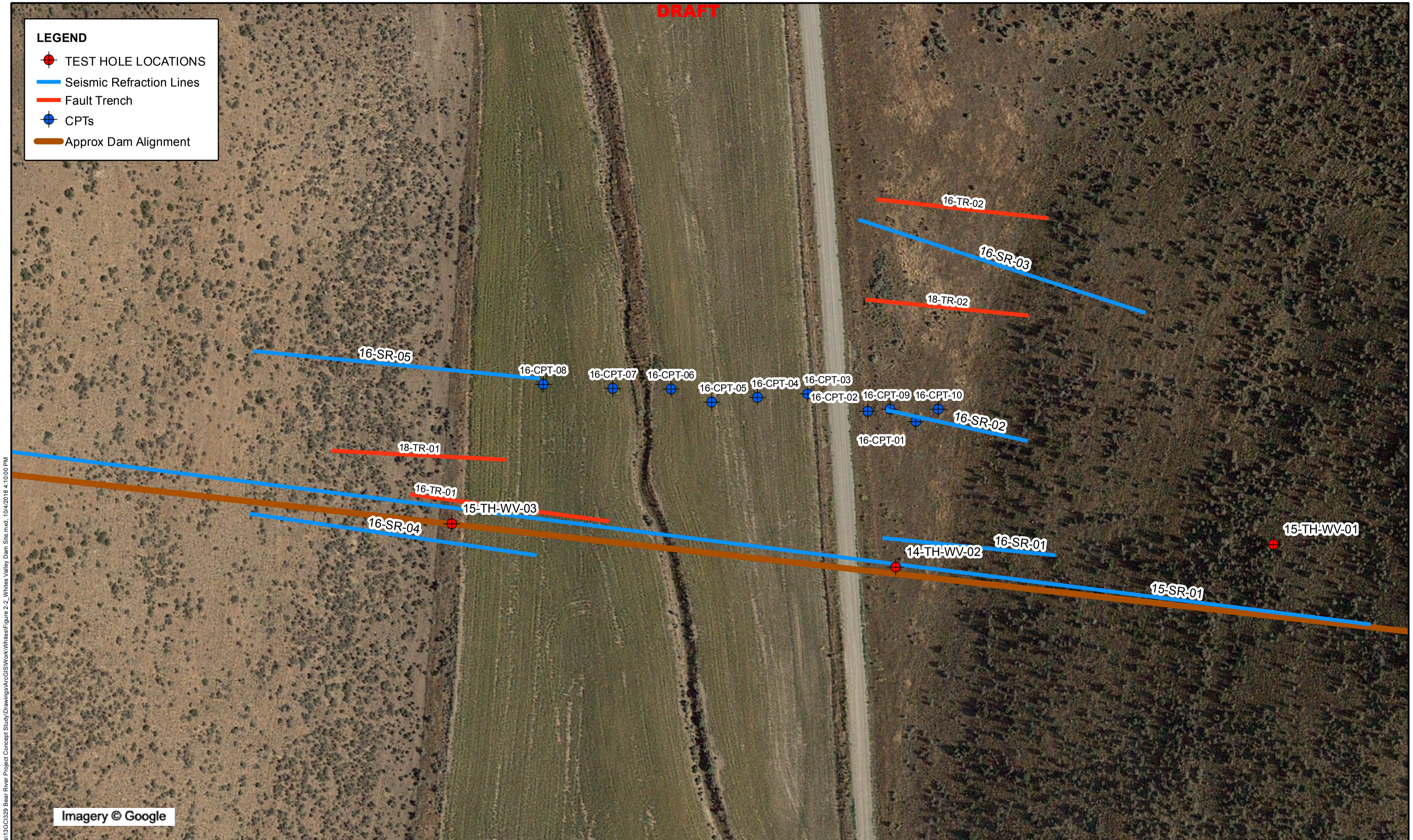
Whites Valley - Overall Site Map

N

0 550 1,100 2,200 Feet

Figure 2-1

J:\PROJECTS\Bowen Collins\13GCI329 Bear River Project Concept Study\Drawings\ArcGIS\Work\Whites\Figure 2-1_Whites Valley Overall Site Map.mxd, 10/4/2018 4:23:46 PM



GERHART COLE

Bear River Project Concept Study

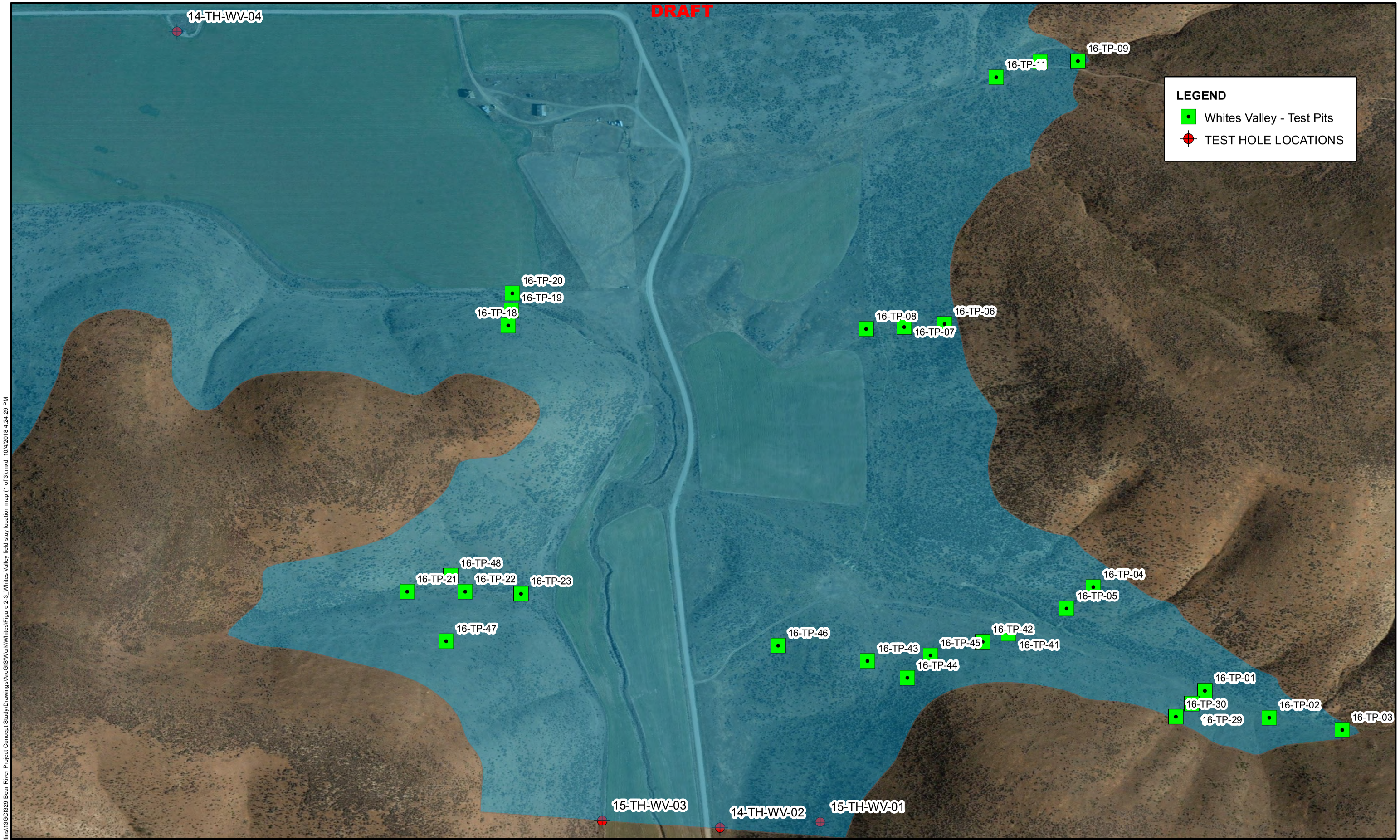
Whites Valley - Dam Site Studies Map

N

0 25 50 100 Feet

Figure 2-2

J:\PROJECTS\Bowen Collins\13GC\329 Bear River Project Concept Study\Drawings\ArcGIS\Work\Whites\Figure 2-2_Whites Valley Dam Site.mxd, 10/4/2018 4:10:00 PM



J:\PROJECTS\Bowen Collins\13GCI329 Bear River Project Concept Study\Drawings\ArcGIS\Work\Whites\Figure 2-3_Whites Valley field stuy location map (1 of 3).mxd, 10/4/2018 4:24:29 PM

GERHART COLE

Bear River Project Concept Study

Whites Valley - Test Pit Locations Map (1 of 3)

N

0 140 280 560 Feet

Figure 2-3a

GERHART COLE

Bear River Project Concept Study

Whites Valley - Test Pit Locations Map (2 of 3)

N

0 165 330 660 Feet

Figure 2-3b

J:\PROJECTS\Bowen Collins\13GC329 Bear River Project Concept Study\Drawings\ArcGIS\Work\Whites\Figure 2-3_Whites Valley field stuy location map (2 of 3).mxd, 10/4/2018 4:25:03 PM

GERHART COLE

Bear River Project Concept Study

Whites Valley - Test Pit Location Map (3 of 3)

N

0 210 420 840 Feet

Figure 2-3c

J:\PROJECTS\Bowen Collins\13GC\329 Bear River Project Concept Study\Drawings\ArcGIS\Work\Whites\Figure 2-3_Whites Valley field stuy location map (3 of 3).mxd, 10/4/2018 4:25:44 PM

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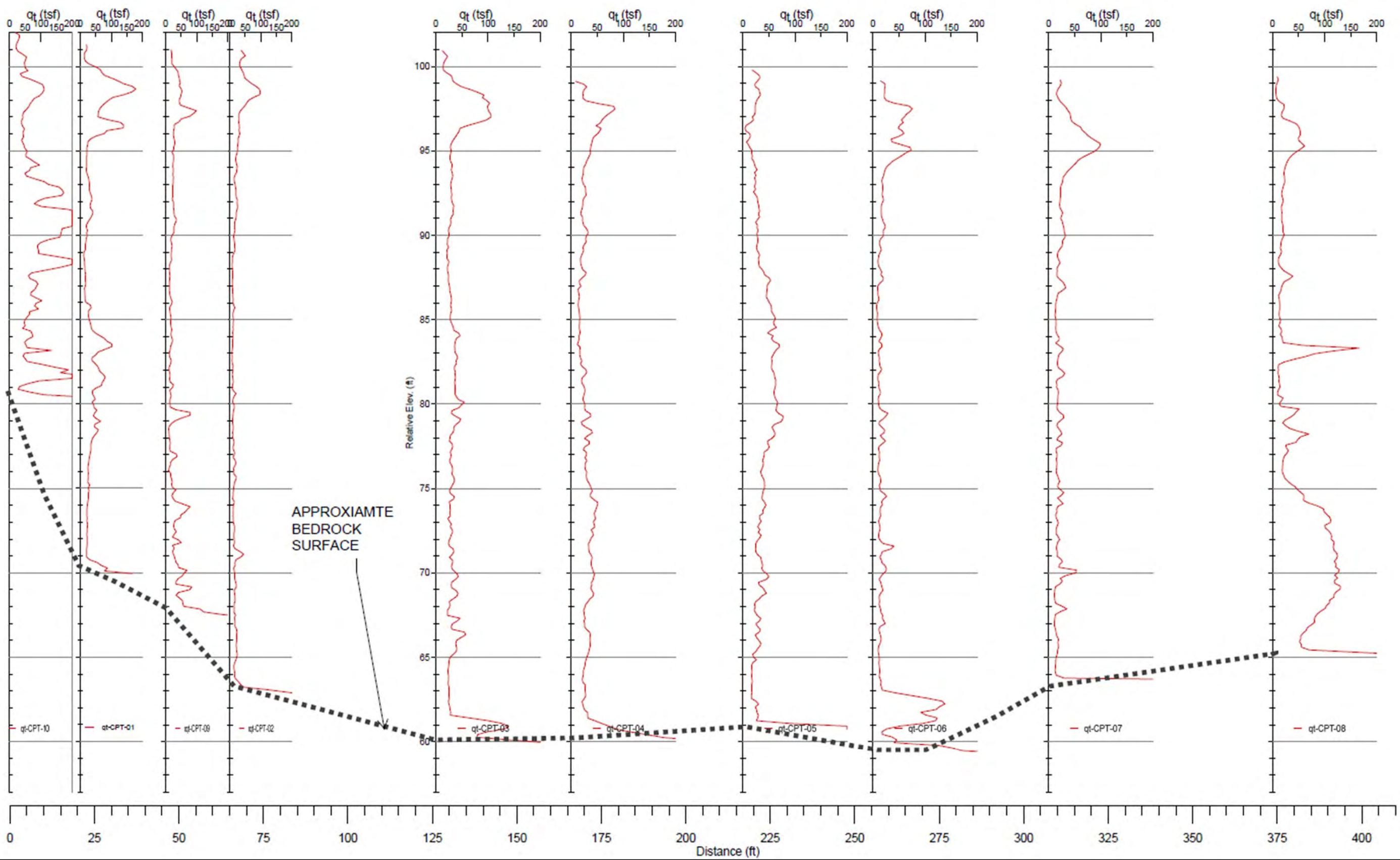

CPT CROSS SECTION

GERHART COLE	BEAR RIVER PROJECT – WHITES VALLEY	Figure 2-4

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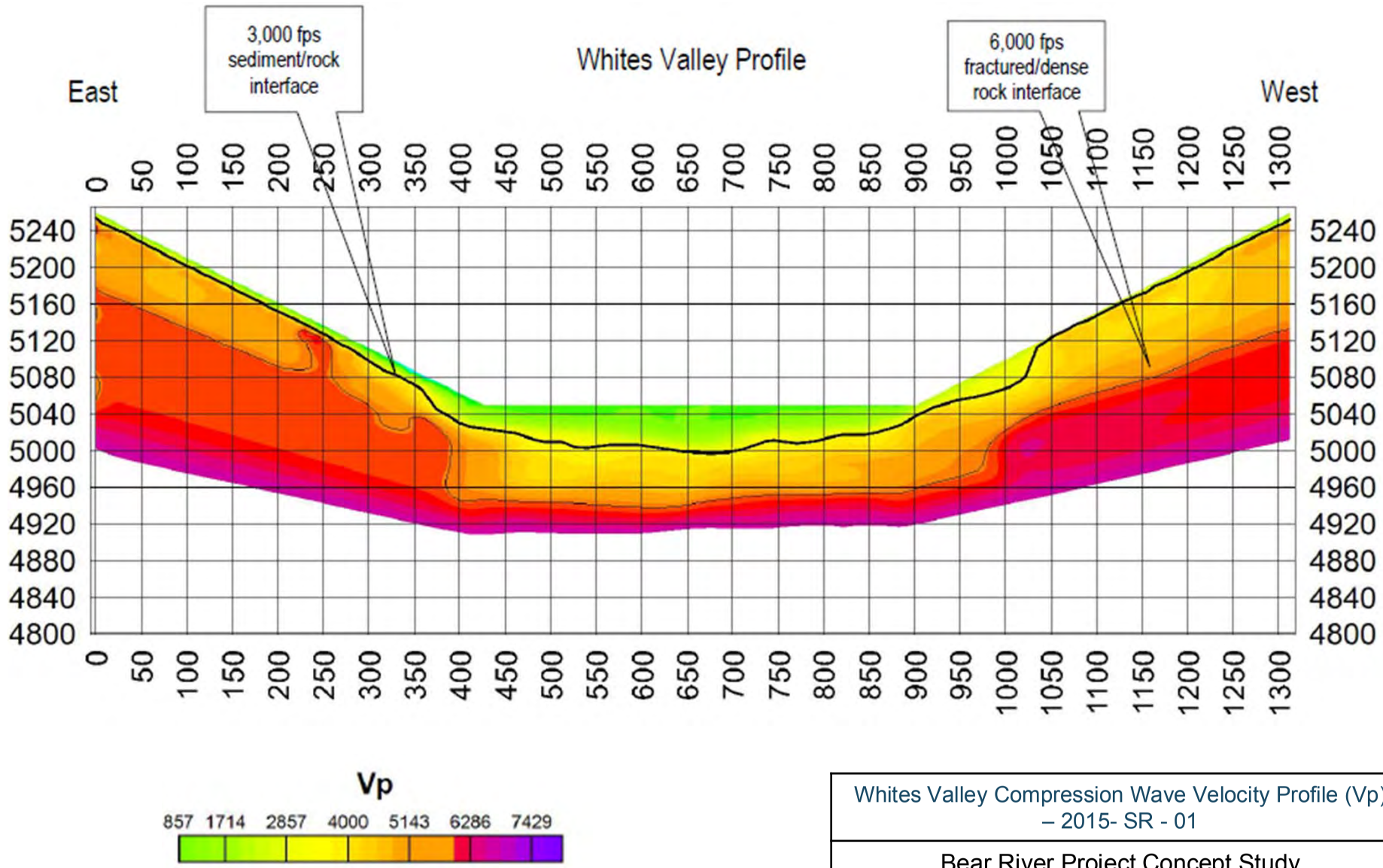

Note: Elevations obtained from Google Earth, Table 2-1 shows elevations of ends of Seismic lines based on LiDAR flown in 2018.

Whites Valley Compression Wave Velocity Profile (Vp) – 2015- SR - 01	
Bear River Project Concept Study Whites Valley	
GERHART COLE	Figure 2-5

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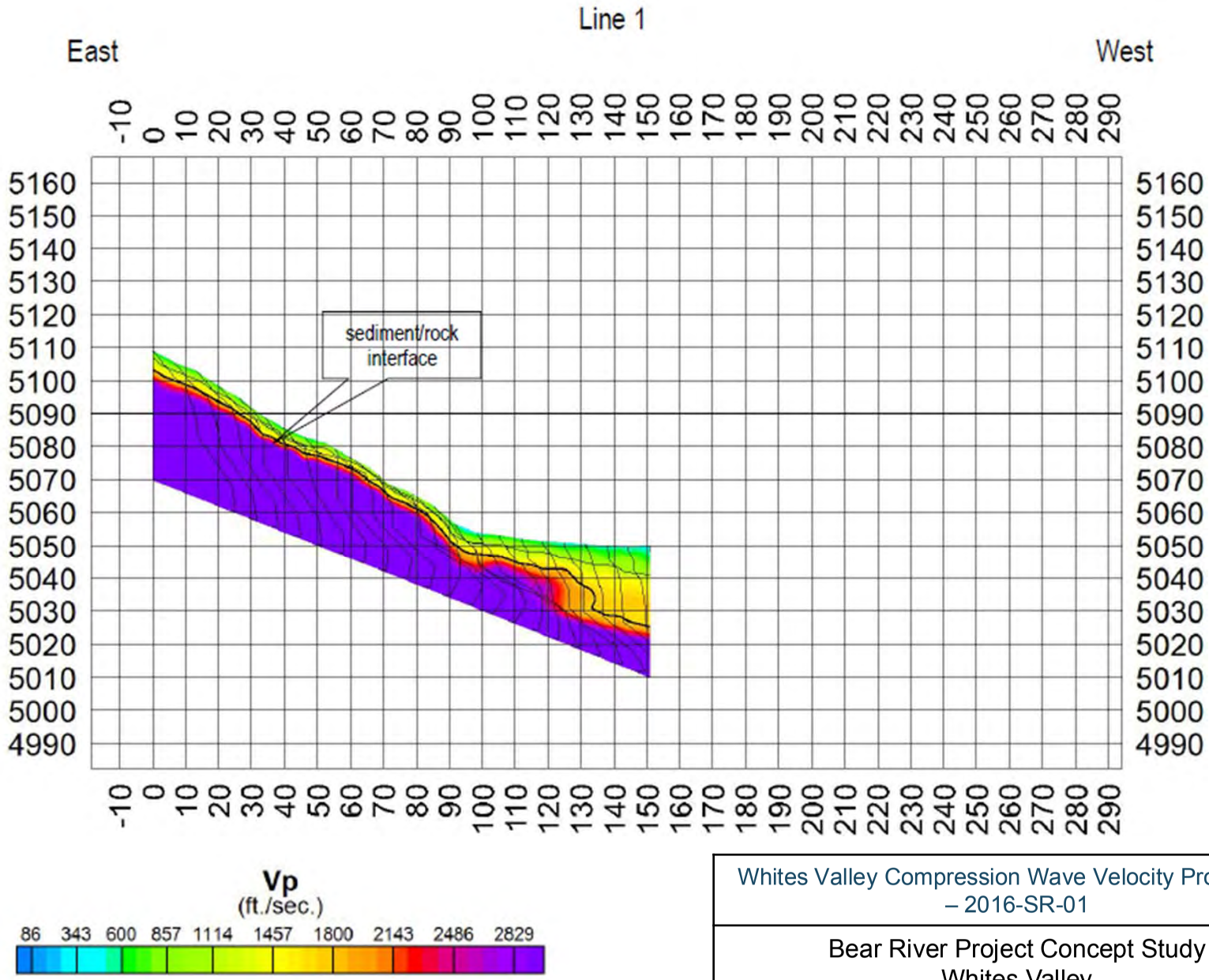

Note: Elevations obtained from Google Earth, Table 2-1 shows elevations of ends of Seismic lines based on LiDAR flown in 2018.

Whites Valley Compression Wave Velocity Profile (Vp) – 2016-SR-01

Bear River Project Concept Study
Whites Valley

GERHART COLE

Figure 2-6

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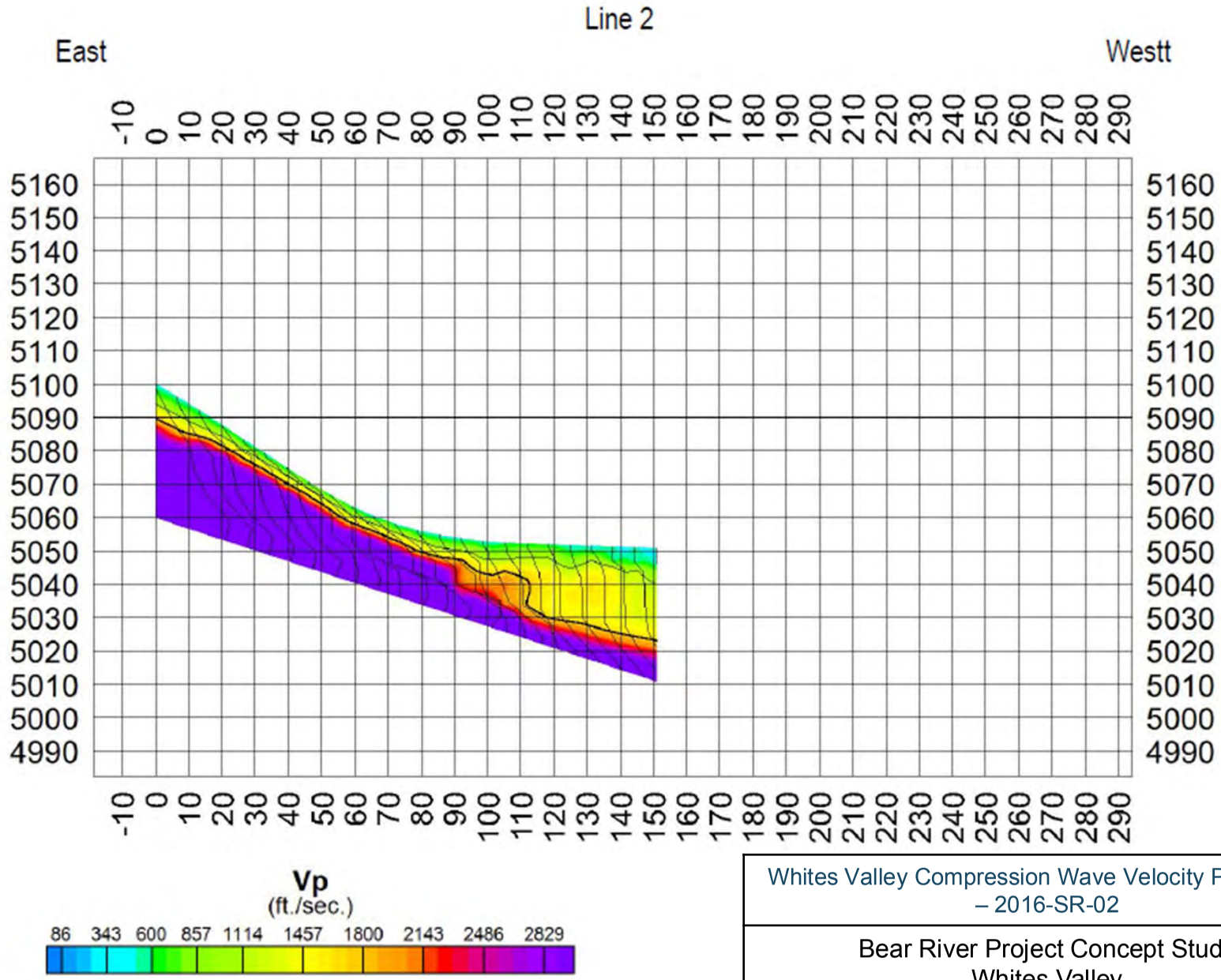

Note: Elevations obtained from Google Earth, Table 2-1 shows elevations of ends of Seismic lines based on LiDAR flown in 2018.

Whites Valley Compression Wave Velocity Profile (Vp) – 2016-SR-02

Bear River Project Concept Study
Whites Valley

GERHART COLE

Figure 2-7

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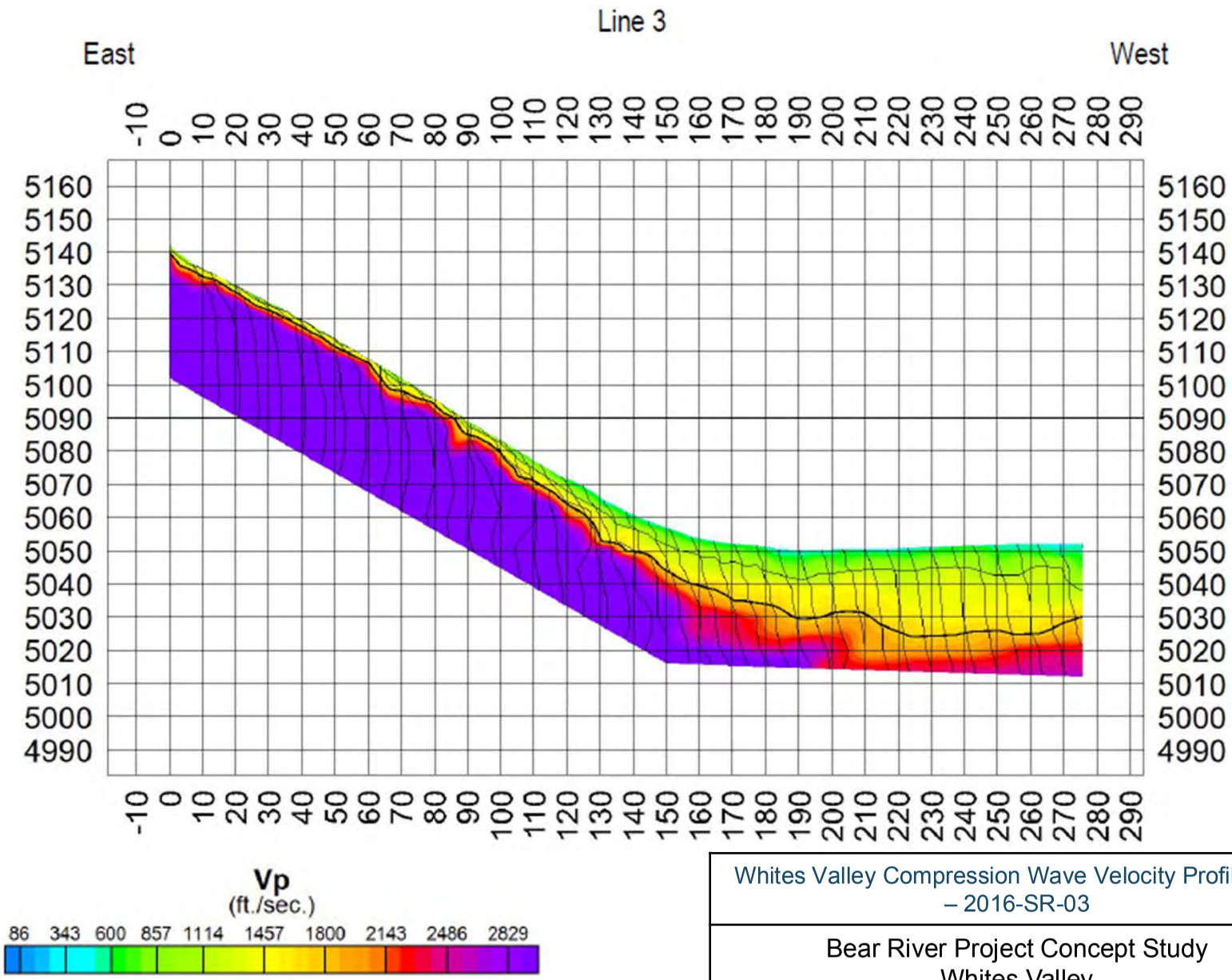

Note: Elevations obtained from Google Earth, Table 2-1 shows elevations of ends of Seismic lines based on LiDAR flown in 2018.

Whites Valley Compression Wave Velocity Profile (Vp) – 2016-SR-03

Bear River Project Concept Study
Whites Valley

GERHART COLE

Figure 2-8

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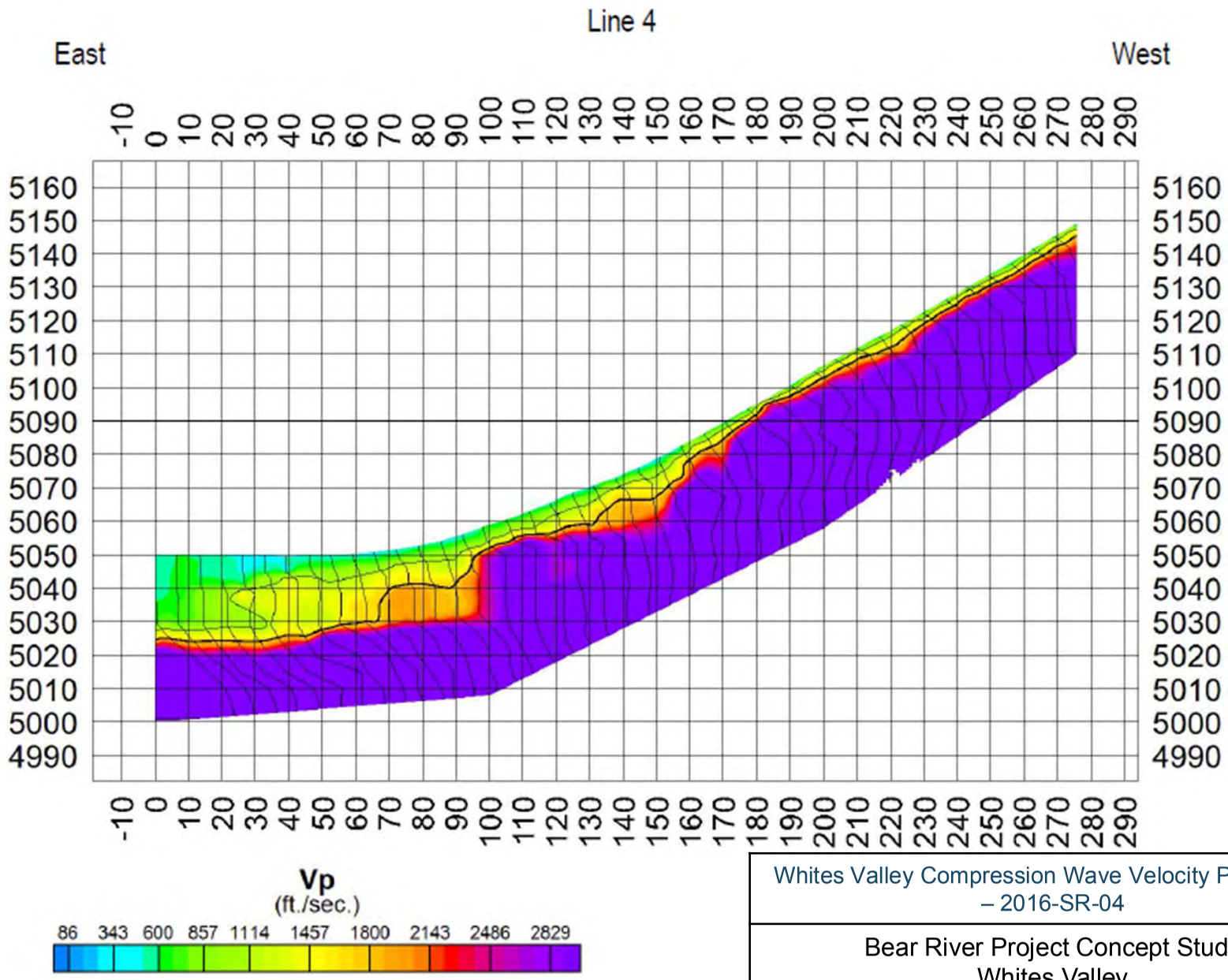

Note: Elevations obtained from Google Earth, Table 2-1 shows elevations of ends of Seismic lines based on LiDAR flown in 2018.

Whites Valley Compression Wave Velocity Profile (Vp) – 2016-SR-04

Bear River Project Concept Study
Whites Valley

GERHART COLE

Figure 2-9

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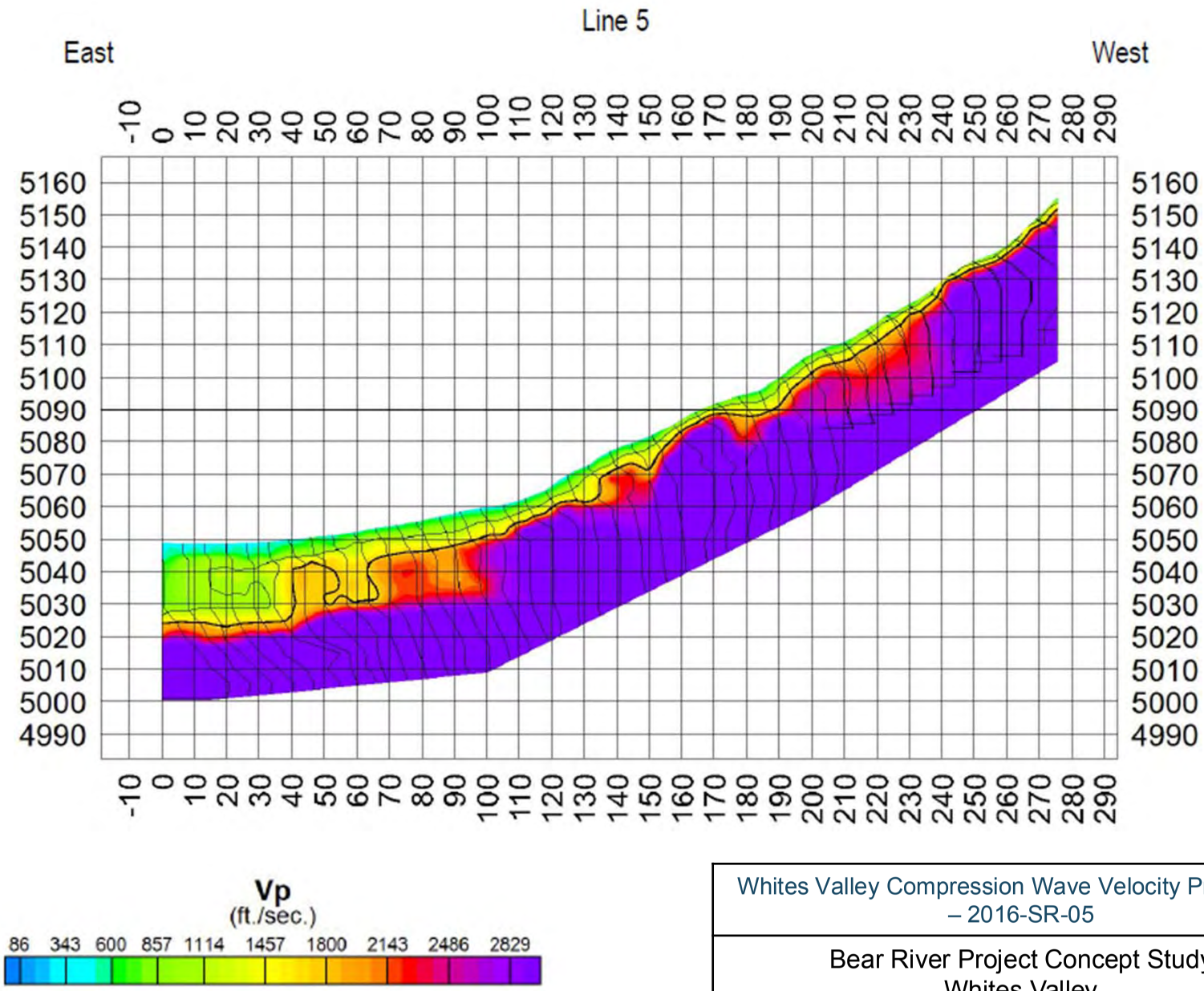

Note: Elevations obtained from Google Earth, Table 2-1 shows elevations of ends of Seismic lines based on LiDAR flown in 2018.

Whites Valley Compression Wave Velocity Profile (Vp) – 2016-SR-05

Bear River Project Concept Study
Whites Valley

GERHART COLE

Figure 2-10

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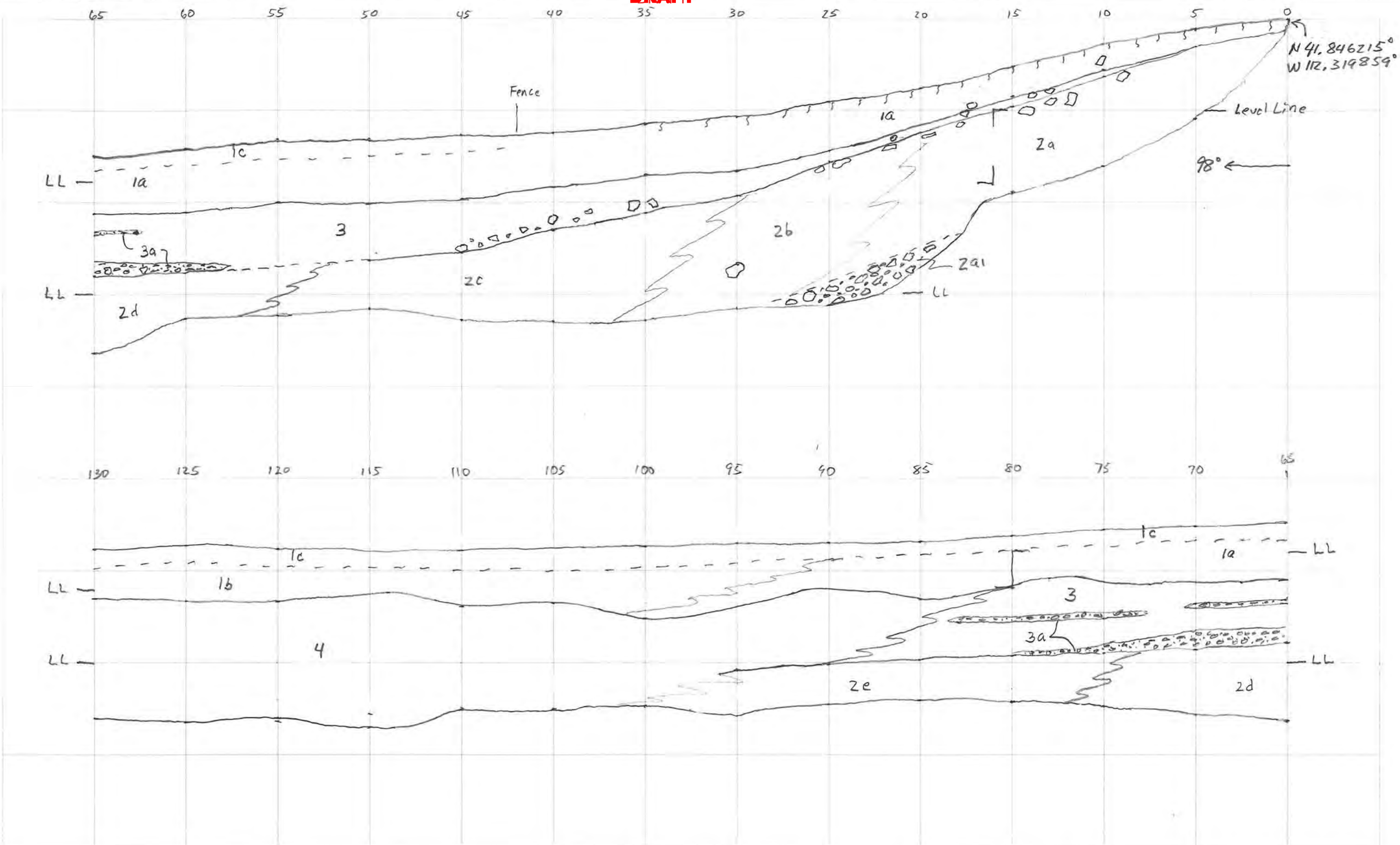
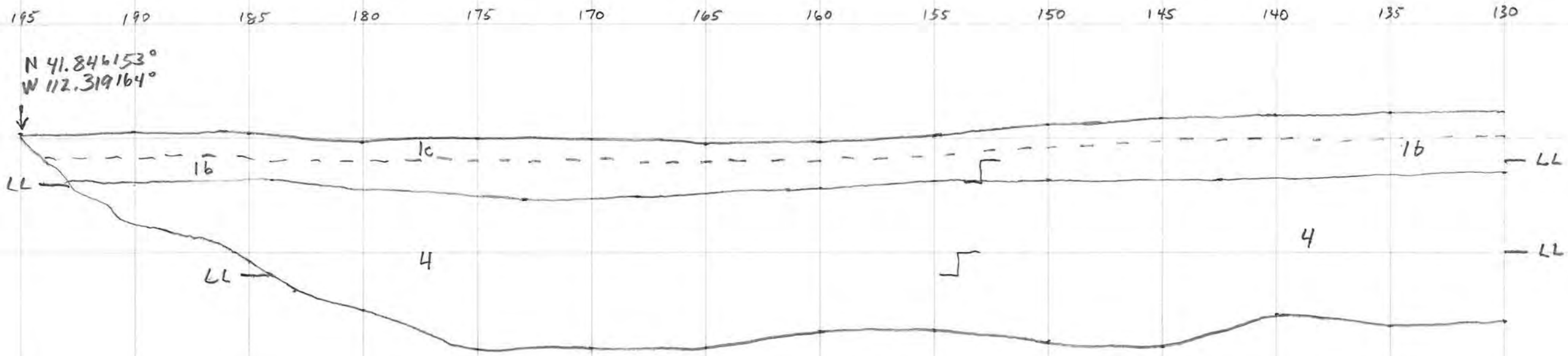


GERHART COLE	TRENCH LOG	PROJECT NAME: BEAR RIVER PROJECT CONCEPT STUDY - WHITES VALLEY	PROJECT NO.: 13GCI329	SCALE: 1 INCH = 5 FEET	DATE: 9/19 - 9/21/16	PAGE NO.: 1 OF 2
		TRENCH NO.: 16-TR-01	LOGGED BY: EWL/TLR	EQUIPMENT / COMMENTS: Cat 316 / Log of South Wall		Figure 2-11

DRAFT



Unit	Description
1a	Silt, sandy, with clay, few gravels, medium stiff, dry, dark grayish brown (10YR 4/2), fine to medium sand, gravels to 1.5 inches, trace cobble to 5 inches (Sta. 0-20), massive, some fine roots, occasional medium roots, no HCl reaction, weak modern A soil horizon < 6 inches Sta. 0 to ≈ 45 (near fence), gradational lower contact to Unit 3 [Lacustrine and Colluvial].
1b	Silt and clay, with sand, medium stiff, dry, brown (7.5YR 4/2) to dark grayish brown (10YR 4/2), very fine sand, massive, some fine roots, abundant pin holes, sharp to gradational lower contact to Unit 4 [Lacustrine and Colluvial].
1c	Unit 1b disturbed by modern vegetation/tilling.
2a	Silt and clay, sandy, with gravel and cobbles, very stiff, dry, light brown (7.5YR 6/3 - 6/4), gravel and angular cobbles to 9 inches, massive with weak stone lines of angular cobbles, no roots, abundant carbonate stringers and carbonate coating (< 1 mm) on gravels and cobbles (90 to 100%), sharp upper contact with Units 1 and 3, facies change to Unit 2b [Lacustrine and Colluvial].
2a1	As Unit 2a with 40 to 45% clasts > ¾ inch.
2b	Silt and clay, with sand, gravel, and cobbles, very stiff, dry, light brown (7.5YR 6/4) to brown (7.5YR 5/4), fine sand, 15 to 25% angular gravel and cobbles to 10 inches massive, no roots, abundant carbonate stringers and coating (< 1 mm) on clasts, sharp upper contact to Unit 3, facies change to Unit 2c [Lacustrine and Colluvial].
2c	Silt and clay with sand, some gravel and cobbles, stiff to medium stiff, dry, light brown (7.5YR 6/4) to brown (7.5YR 5/4), fine sand, 5 to 10% angular gravel and cobbles to 6 inches, massive, no roots, very few carbonate stringers, some carbonate coating on clasts, gradational upper contact to Unit 3, facies change to Unit 2d [Lacustrine and Colluvial].
2d	Silt and clay, sandy, some gravel and cobbles, stiff, slightly moist, brown (7.5YR 4/4) to dark yellowish brown (10YR 4/4), fine sand, 3 to 7% angular gravel and cobbles to 7 inches, massive, no roots, some carbonate stringers and coating on clasts, gradational upper contact to Unit 3, facies change to Unit 2e [Lacustrine and Colluvial].
2e	Silt and clay, sandy, trace gravel and cobbles, medium stiff, slightly moist, dark yellowish brown (10YR 4/4), fine sand, 0 to 1% angular gravel to 3 inches, massive, no roots, trace carbonate stringers and some coating on clasts, gradational upper contact to Unit 3, gradational horizontal contact to Unit 4 [Lacustrine and Colluvial].
3	Silt and clay, with sand and gravel, stiff, dry, brown (7.5YR 5/2), very fine to fine sand, 20 to 25% angular gravel to 2 inches, massive to weak sub-horizontal to horizontal bedding less than 1 foot thick, some carbonate stringers, carbonate coating on gravels < 1 mm, gravel percentage and size decrease to east, gradational (< 6 inches) upper contact to Unit 1, gradational horizontal contact to Unit 4 [Lacustrine and Colluvial].
3a	Gravel, sandy with silt and clay, medium dense to loose, gravel to 9 inches (3 to 6 inches average), weak imbrication of flat gravel. Beds in Unit 3 2 to 12 inches thick, only shown on log where continuous over several feet [Alluvial]
4	Silt and clay, with sand, trace gravel, medium stiff to stiff, dry to slightly moist, brown (7.5YR 4/4) to strong brown (7.5YR 4/6), medium plasticity, massive, trace fine roots in upper 1 to 2 feet, no roots at depth, abundant carbonate stringers, grades at depth to silt and clay, sandy, medium stiff, slightly moist, dark yellowish brown (10YR 4/4), some carbonate stringers [Lacustrine].

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TRENCH LOG

PROJECT NAME: BEAR RIVER PROJECT CONCEPT STUDY - WHITES VALLEY	PROJECT NO.: 13GCI329	SCALE: 1 INCH = 5 FEET	DATE: 9/19 - 9/21/16	PAGE NO.: 2 OF 2
TRENCH NO.: 16-TR-01	LOGGED BY: EWL/TLR	EQUIPMENT / COMMENTS: Cat 316/ Log of South Wall		

Figure 2-11

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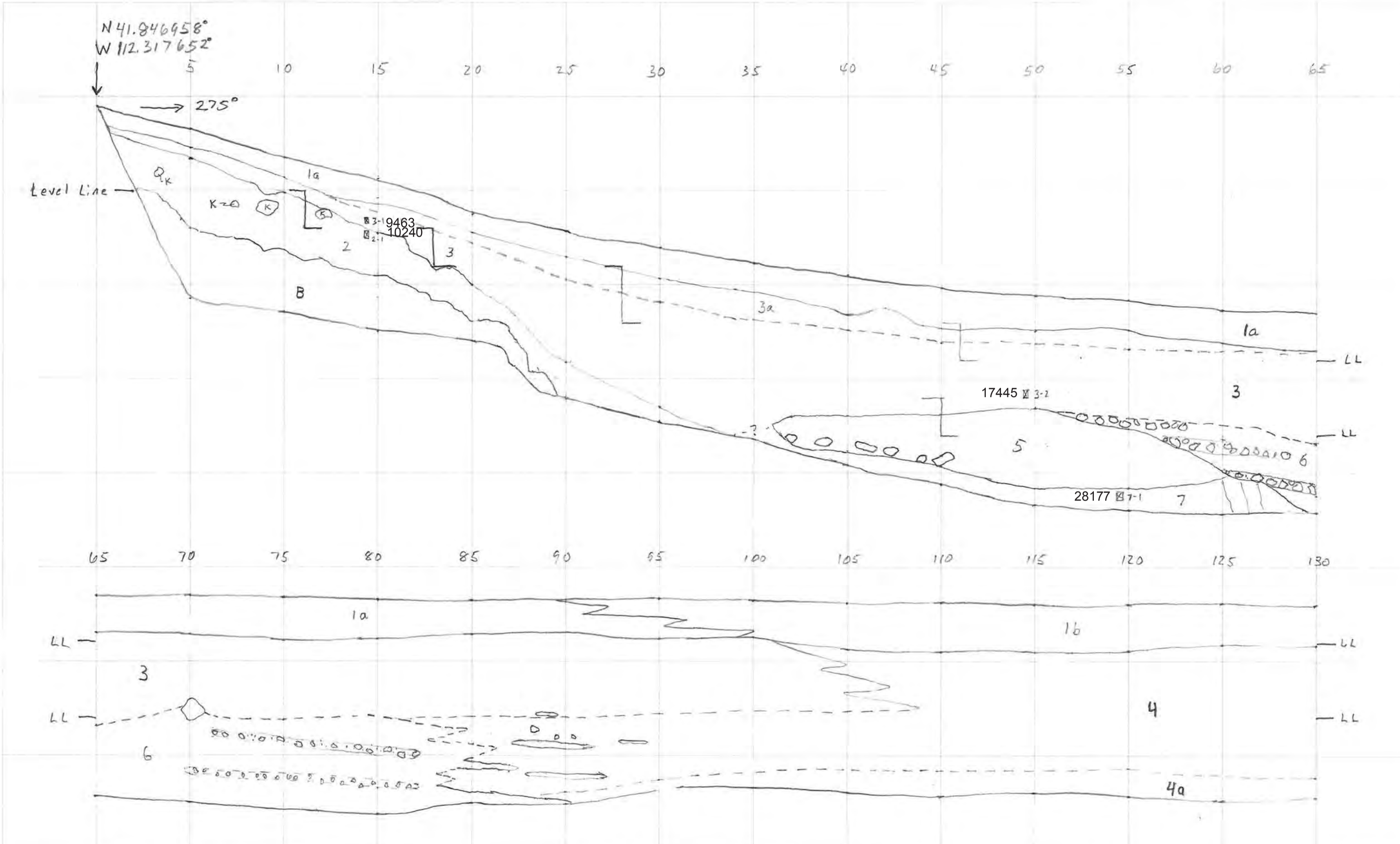

GERHART COLE	TRENCH LOG	PROJECT NAME: BEAR RIVER PROJECT CONCEPT STUDY - WHITES VALLEY	PROJECT NO.: 13GCI329	SCALE: 1 INCH = 5 FEET	DATE: 9/27 - 9/29/16	PAGE NO.: 1 OF 2
		TRENCH NO.: 16-TR-02	LOGGED BY: EWC/TLR	EQUIPMENT / COMMENTS: Cat 316 / Log of South Wall		Figure 2-12

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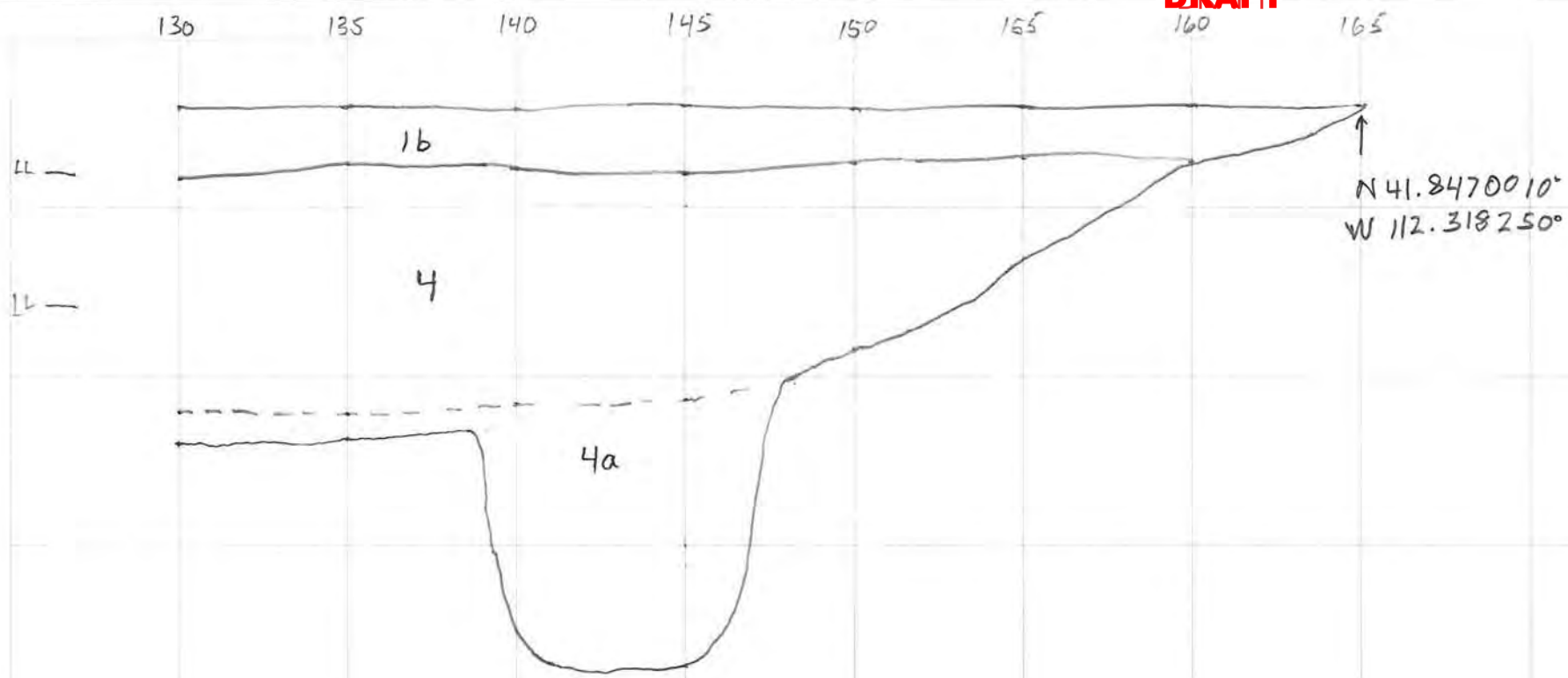

Unit	Description
1a	Silt, sandy, with gravels, soft to medium stiff, moist upper 1 foot, dry below 1 foot, brown (7.5YR 4/2), fine to coarse sand, gravels to 3 inches < 15% angular, massive, abundant fine roots, slight HCl reaction, gradational lower contact to Units 3 and 3a [Lacustrine and Colluvial].
1b	As Unit 1a, trace gravels.
2	Silt, sandy, with gravel and cobbles, stiff, dry, white (10YR 8/1) to very pale brown (10YR 8/2), gravel and angular cobbles to 5 inches, massive with localized thin bedding parallel to slope, trace fine roots, carbonate coating (< 1 mm) on all gravels and cobbles, violent HCl reaction, irregular sharp lower contact with bedrock (B) [Lacustrine and Colluvial].
3	Silt and clay, sandy, with gravel and cobbles, stiff, dry, light brown (7.5YR 6/4), gravel and angular cobbles to 5 inches (few subangular), massive with random cobbles and possible weak stone lines and thin (< 1 foot) layers of gravels and cobbles, abundant carbonate stringers and thin carbonate coating (< 1 mm) on gravels and cobbles, moderate HCl reaction, lower contact gradational, horizontal facies change to Unit 4 [Lacustrine and Colluvial].
3a	As Unit 3, dark brownish gray (10YR 4/2), medium stiff, abundant fine to medium roots.
4	Silt and clay, sandy, trace gravel and cobbles, medium stiff, dry to moist, brown (10YR 4/3), very fine to fine sand, massive, abundant carbonate stringers, strong HCl reaction, abundant pinholes, gradational lower contact to Unit 4a [Lacustrine].
4a	Silt, sandy, with clay, medium stiff, dry to moist, yellowish brown (10YR 5/4), very fine to fine sand, massive, no carbonate stringers, no pinholes [Lacustrine].
5	Multiple stream-flow and debris-flow deposits. Stream-flow deposits: Gravel, sandy, with cobbles, loose, dry, light brown (7.5YR 6/4) to brown (7.5YR 5/4), medium to coarse sand, cobbles to 6 inches, few well-graded clast-supported layers 1 to 12 inches thick, horizontal to eastward dipping at 10 to 15 degrees. Debris-flow deposits: Silt and clay, sandy, with gravel and cobbles, medium stiff, dark yellowish brown (10YR 4/4), medium to coarse sand, cobbles to 12 inches, subangular to subrounded mostly limestone some sandstone, massive matrix-supported deposits 1 to 2 feet thick. Sharp upper and lower contact with Units 3 and 7, gradational contact to Unit 6 [Fluvial/Alluvial].
6	Silt and clay, sandy, with gravels and cobbles, medium stiff, dark yellowish brown (10YR 4/4), medium to coarse sand, cobbles to 6 inches (one to 12 inches), subangular mostly limestone some sandstone, massive, matrix-supported, few layers 6 inches to 1 foot thick (shown on log where laterally continuous), trace carbonate stringers and carbonate coating on clasts, gradational horizontal contact to Unit 4. [Fluvial/Alluvial].
7	Silt and clay, with sand, trace gravels, medium stiff, dry to moist, dark yellowish brown (10YR 4/4), very fine sand, gravels to 1.5 inches, angular to subangular, percent gravels decrease towards west, massive, moderate to abundant carbonate stringers, 3 distinct carbonate stringers 1 to 2 mm thick at Sta. 60 to 62, sharp upper contact with Units 5 and 6, gradational or non-existent contact with Unit 3 [Lacustrine].
B	Oquirrh Group, calcareous siltstone and sandstone, and silty limestone, fine grained, dark gray, thinly bedded, slightly weathered to fresh, hard, (75 to 80%) with interbeds of siltstone, tan, thinly to very thinly bedded, slightly weathered to fresh, soft (20 to 25%). [Bedrock]
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GERHART COLE	TRENCH LOG	PROJECT NAME: BEAR RIVER PROJECT CONCEPT STUDY - WHITES VALLEY	PROJECT NO.: 13GCI329	SCALE: 1 INCH = 5 FEET	DATE: 9/27 - 9/29/16	PAGE NO.: 2 OF 2
		TRENCH NO.: 16-TR-02	LOGGED BY: EWL/TLR	EQUIPMENT / COMMENTS: Cat 316 / Log of South Wall		Figure 2-12

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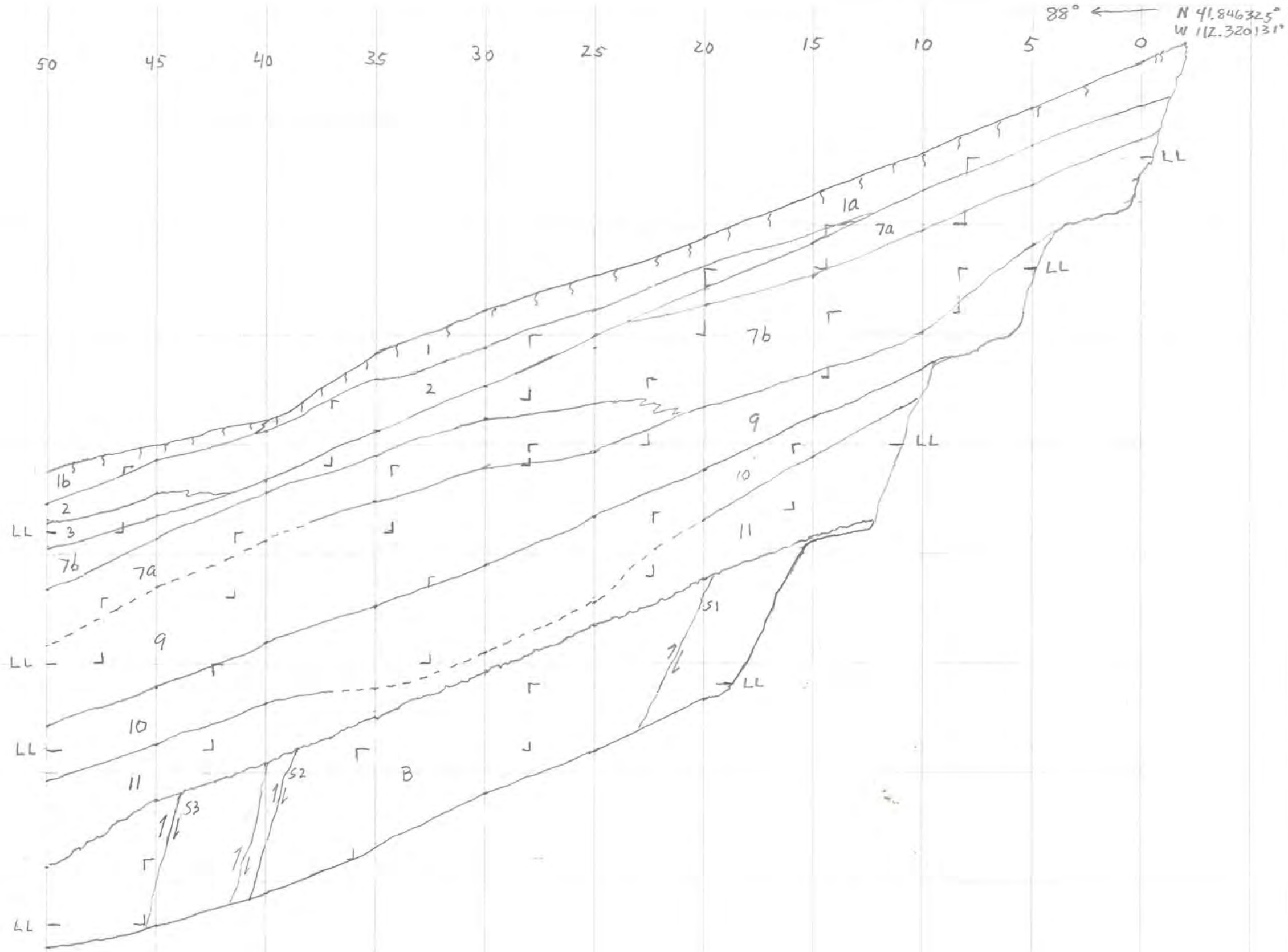

GERHART COLE 668 E. 12225 S., SUITE 203 Draper, Utah (801)849-0055	TRENCH LOG	PROJECT NAME: BEAR RIVER PROJECT - WHITES VALLEY	PROJECT NO.: 13GCI329	SCALE: 1 INCH = 5 FEET	DATE: 3/29 - 4/10/18	PAGE NO.: 1 OF 3
		TRENCH NO.: 18-TR-01	LOGGED BY: EWL	EQUIPMENT / COMMENTS: Volvo EC480DL	Log of South Wall	Figure 2-13

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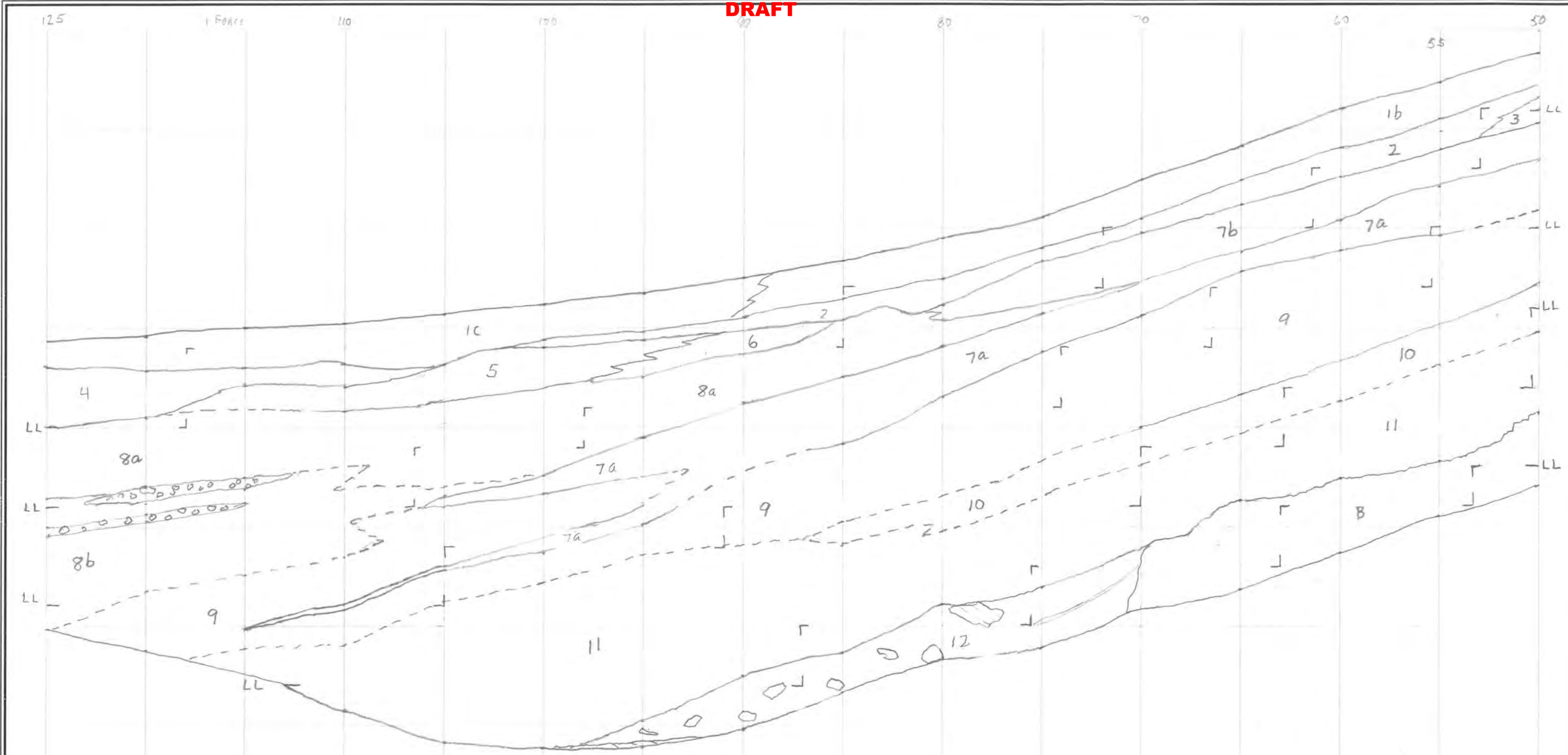

GERHART COLE 668 E. 12225 S., SUITE 203 Draper, Utah (801)849-0055	TRENCH LOG	PROJECT NAME: BEAR RIVER PROJECT - WHITES VALLEY	PROJECT NO.: 13GCI329	SCALE: 1 INCH = 5 FEET	DATE: 3/29 - 4/10/18	PAGE NO.: 2 OF 3
		TRENCH NO.: 18-TR-01	LOGGED BY: EWL	EQUIPMENT / COMMENTS: Volvo EC480DL Log of South Wall		

Figure 2-13

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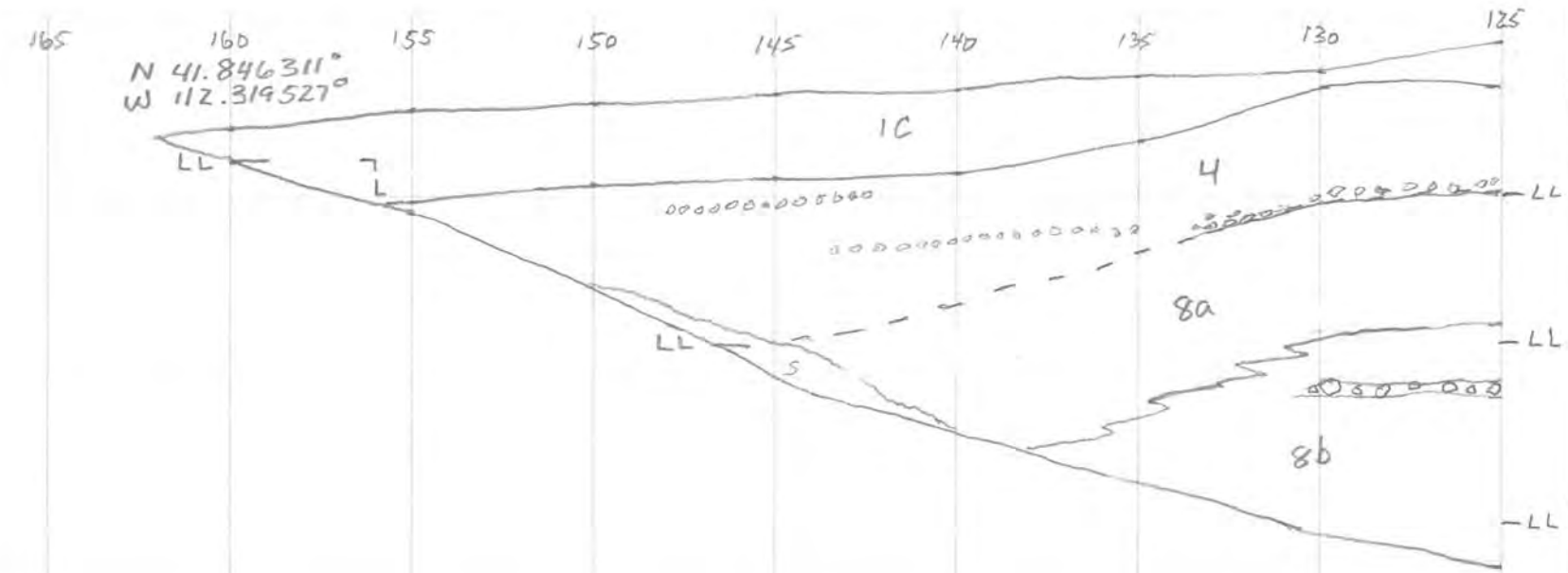

Unit	Description
1a	Silt, with clay, with sand, some gravels, with gravel, medium stiff, dry to moist, dark grayish brown (10YR 4/2), fine sand, angular gravels and cobbles to 6 inches, massive, abundant roots, none to weak HCl reaction, weak modern A soil horizon < 6 inches, gradational sharp lower contact to Units 2 and 7a [Lacustrine and Colluvial].
1b	As Unit 1a, some angular cobbles to 4 inches, sharp lower contact to Unit 2.
1c	As Unit 1a, with angular fine to coarse gravel, no cobbles, sharp lower contact to Units 2, 4, and 5.
2	Silt and clay, with sand, with gravel, trace cobbles, stiff, dry to moist, brown (7.5YR 5/4), fine to coarse sand, angular gravel and cobbles to 4 inches, massive, trace fine roots, frequent pin holes, none to weak HCl reaction, sharp lower contact to Units 3, 5, 6, and 7b [Lacustrine and Colluvial].
3	Silt and clay, with sand, some gravel, trace cobbles, stiff, dry to moist, yellowish brown (10YR 5/4) to brown (10YR 4/3), fine to medium sand, angular gravel and cobbles to 4 inches, massive, some carbonate mottling, frequent pin holes, strong to violent HCl reaction, sharp lower contact to Unit 7b [Lacustrine and Colluvial].
4	Silt and clay, some sand, some gravel, stiff, dry to moist, grayish brown (10YR 4/2) to brown (7.5 YR 4/3), fine to coarse sand, subangular gravel to 2 inches, massive, occasional fine roots, few pin holes, abundant carbonate stringers, strong HCl reaction, gradational to sharp lower contact to Units 5 and 8a [Lacustrine and Colluvial].
5	Silt and clay, trace sand, some gravel, stiff, dry to moist, brown (10YR 5/3), very fine sand, subangular gravel to 1 inch, massive, abundant carbonate stringers, violent HCl reaction, sharp lower contact to Unit 8a [Lacustrine and Colluvial].
6	Silt and clay, trace sand, with gravel and cobbles, medium stiff, dry to moist, light gray (10YR 7/2) to very pale brown (10YR 7/3), subangular coarse gravel and cobbles to 5 inches, massive, few pin holes, carbonate coating on clasts < 1 mm, violent HCl reaction, gradational lower contact to Unit 8a [Lacustrine and Colluvial].
7a	Silt and clay, trace sand, some gravel and cobbles, stiff, dry to moist, pale brown (10YR 6/3) to very pale brown (10YR 7/3), subangular gravel and cobbles to 7 inches, weak downslope imbrication of cobbles, massive, frequent pin holes, carbonate coating on clasts to 2 mm and silty carbonate (marl) between clasts to 2 cm, violent HCl reaction, gradational lower contact to Units 7b, and 9 [Lacustrine and Colluvial].
7b	Silt and clay, trace sand, some gravel and cobbles, medium stiff, dry to moist, brown (7.5YR 4/3), very fine sand, subangular gravel and cobbles to 4 inches, massive, few pin holes, carbonate coating on clasts 1 to 2 mm and stringers silty carbonate (marl), violent HCl reaction, sharp lower contact to Units 7a, 8a, and 9 [Lacustrine and Colluvial].
8a	Clay and silt, trace sand, trace gravel, medium stiff, dry to moist, yellowish brown (10YR 5/4) to dark yellowish brown (10YR 4/4), subangular fine to coarse gravel, massive, abundant pin holes, few carbonate coating stringers, weak to strong HCl reaction, sharp lower contact to Unit 7a, gradational lower contact to Unit 8b [Lacustrine and Colluvial].
8b	Silt and clay, some sand, stiff, dry to moist, yellowish brown (10YR 5/4) to dark yellowish brown (10YR 4/4), fine to medium sand, massive, frequent pin holes, weak HCl reaction, contains discontinuous lenses of angular gravel and cobbles to 5 inches, gradational lower contact to Unit 9 [Lacustrine and Colluvial].
9	Silt and clay, some sand, some gravel and cobbles, stiff, dry to moist, yellowish brown (10YR 5/4), fine to medium sand, angular to subangular gravel and cobbles to 6 inches, massive, frequent to abundant pin holes, some carbonate stringers, trace carbonate mottling, weak to strong HCl reaction, sharp lower contact to Unit 10 gradational lower contact to Unit 11 [Lacustrine and Colluvial].
10	Silt and clay, trace sand, with gravel and cobbles, medium stiff, dry to moist, very pale brown (10YR 7/3), carbonaceous, angular gravel and cobbles to 5 inches, massive, abundant pin holes, carbonate coating on clasts to 2 mm and silty carbonate (marl) between clasts to 2 cm pinkish white (7.5YR 8/1), violent HCl reaction, sharp lower contact to Unit 11 [Lacustrine and Colluvial].
11	Silt and clay, with sand, some gravel and cobbles, medium stiff to soft, dry to moist, yellowish brown (10YR 5/4), fine to coarse sand, angular gravel and cobbles to 5 inches, massive, abundant pin holes, carbonate coating on clasts to 1 mm and weak carbonate mottling, weak to strong HCl reaction, sharp lower contact to Unit 12 and B [Lacustrine and Colluvial].
12	Sandy silt and clay, some gravel and cobbles, very stiff, dry to moist, pale yellow (2.5YR 8/2) to brown (10YR 5/3), fine to coarse sand, angular gravel and cobbles to 6 inches, massive, with very pale brown (10YR 8/2) clayey shear zones, violent HCl reaction, sharp contact to B [Landslide].
B	Oquirrh Group, interbedded silty sandstone, fine sand, well sorted, grayish orange (10YR7/4) and siltstone with trace very fine sand, pale orange (10yr 8/2) to grayish orange (10YR 7/4), thinly bedded, soft, sharp contact between interbeds, one (partly exposed) bed of limestone, dark gray, hard. Shear zones of breccia and clay gouge, brown clay, with oxides of Mg and Mn, very soft, partially healed.

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TRENCH LOG

PROJECT NAME:	PROJECT NO.:	SCALE:	DATE:	PAGE NO.:
BEAR RIVER PROJECT - WHITES VALLEY	13GCI329	1 INCH = 5 FEET	3/26 - 4/10/18	3 OF 3
TRENCH NO.: 18-TR-01	LOGGED BY: EWL	EQUIPMENT / COMMENTS: Volvo EC480DL Log of South Wall		

Figure 2-13

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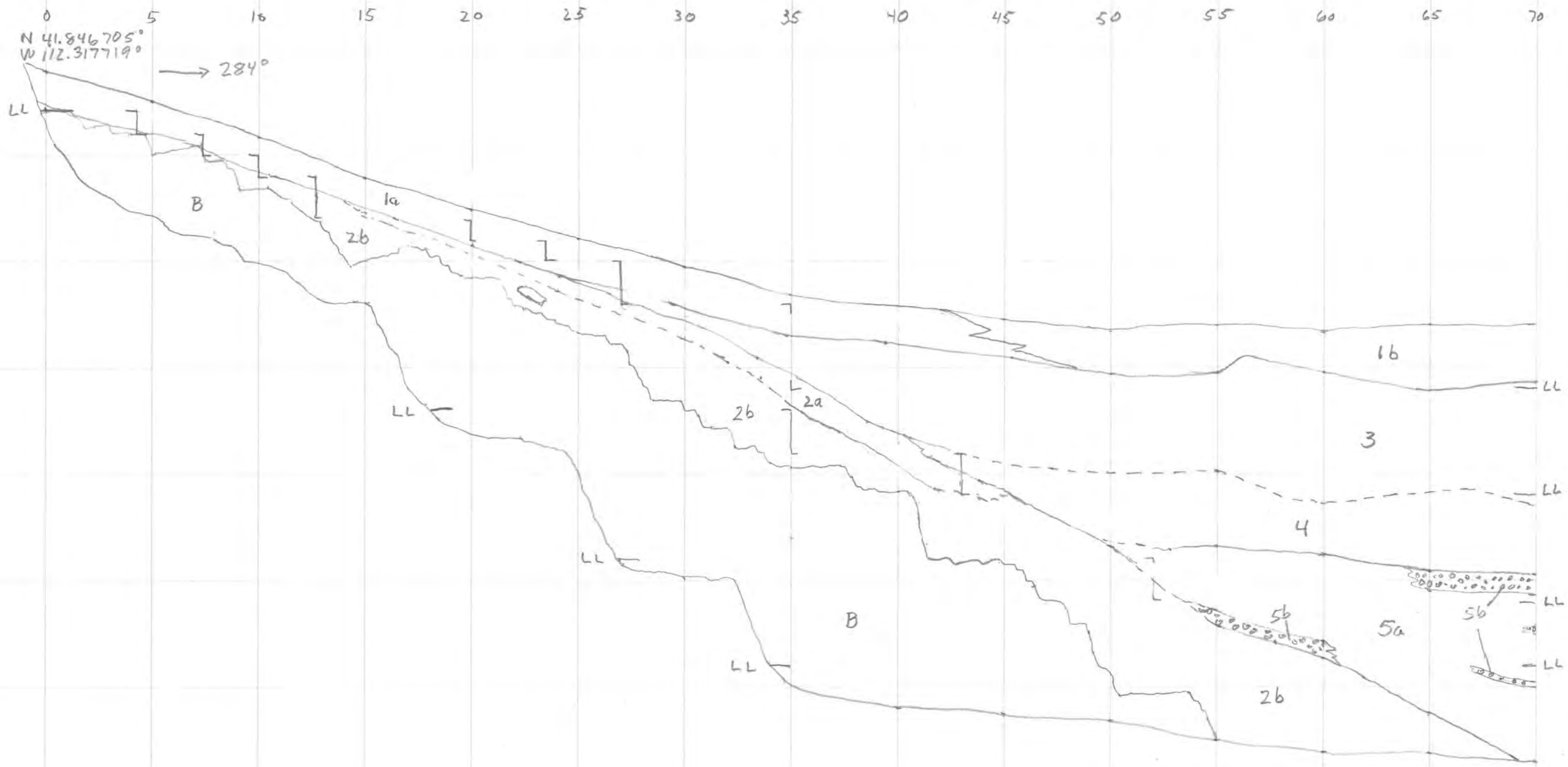

GERHART COLE 668 E. 12225 S., SUITE 203 Draper, Utah (801)849-0055	TRENCH LOG	PROJECT NAME: BEAR RIVER PROJECT - WHITES VALLEY	PROJECT NO.: 13GCI329	SCALE: 1 INCH = 5 FEET	DATE: 3/29 - 4/10/18	PAGE NO.: 1 OF 2
		TRENCH NO.: 18-TR-02	LOGGED BY: EWL	EQUIPMENT / COMMENTS: Volvo EC480DL Log of South Wall		

Figure 2-14

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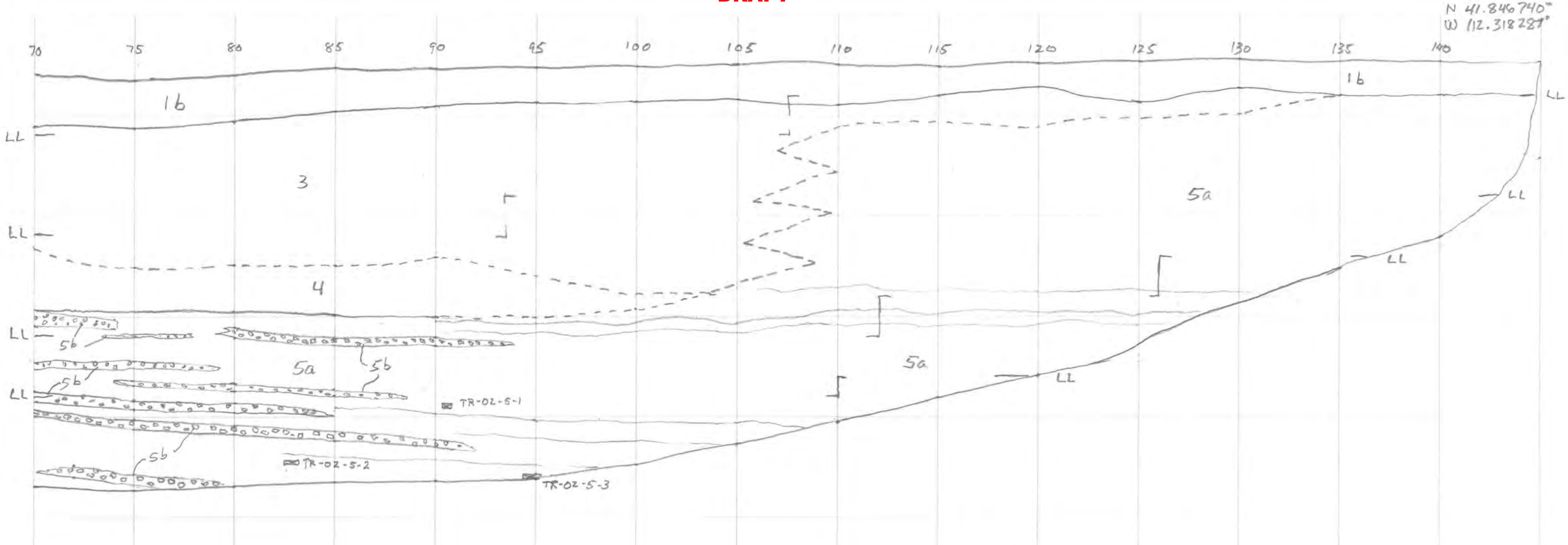

Unit	Description
1a	Silt, clayey, with sand, some gravels, trace cobbles, medium stiff to stiff, dry to moist, dark brown (7.5YR 3/2), fine to medium sand, fine to coarse gravels, angular cobbles to 5 inches, massive, abundant fine roots, weak to some HCl reaction, gradational lower contact to Units and 3 [Lacustrine and Colluvial].
1b	As Unit 1a, trace gravels, gradational lower contact to Units 3 and 5a.
2a	Silt and clay, sandy, with gravel, trace cobbles, very stiff, dry to moist, light brown (7.5YR 6/3), fine to medium sand, fine to coarse angular gravel and angular cobbles to 6 inches, massive with weak imbrication in direction of slope, few pin holes, strong to violent HCl reaction, carbonate coating on clasts (< 1 mm) and carbonate stringers in matrix, gradational lower contact with Unit 2b [Colluvial and Lacustrine].
2b	Silt and clay, sandy, with gravel and cobbles, very stiff, dry to moist, strong brown (7.5YR 5/4 - 4/4), fine to coarse sand, angular gravel cobbles to 10 inches, massive with weak imbrication in direction of slope, some pin holes, weak HCl reaction, weak carbonate coating on clasts and few carbonate stringers in matrix, sharp irregular lower contact Bedrock [Colluvial and Lacustrine].
3	Silt and clay, sandy, trace gravel, very stiff, dry to moist, light brownish gray (10YR 6/2), fine sand, angular gravel to 2 inches, massive, numerous pin holes, carbonate mottling in matrix, violent HCl reaction, lower contact gradational to Unit 4, horizontal facies change to Unit 5a [Lacustrine].
4	Sandy silt, stiff, dry to moist, light yellowish brown (10YR 6/4) to yellowish brown (10YR 5/4), fine to medium sand, massive, occasional pin holes, weak carbonate mottling, strong HCl reaction, gradational lower contact to Unit 5a and 5b [Lacustrine].
5a	Silt and clay, sandy, very stiff, dry to moist, grayish brown (10YR 5/2) to brown (10YR 5/3), fine sand, moderately to thinly bedded w/stringers of more carbonate approx. 1 inch thick (shown graphically on log), numerous pin holes, carbonate mottling, weak to strong HCl reaction, sharp contact to Units 2b and 5b. [Lacustrine].
5b	Gravelly silt, with sand, stiff with loose gravelly layers, dry to moist, brown (7.5YR 5/3), fine to coarse sand, angular to angular gravels to 2 inches, no bedding within unit, massive, strong to violent HCl reaction, sharp contact with Units 2b and 5a [Colluvial].
B	Oquirrh Group, silty limestone, medium dark gray, thinly to moderately bedded, slightly weathered to fresh, hard [Bedrock].

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TRENCH LOG

PROJECT NAME:	PROJECT NO.:	SCALE:	DATE:	PAGE NO.:
BEAR RIVER PROJECT - WHITES VALLEY	13GCI329	1 INCH = 5 FEET	3/29 - 4/10/18	2 OF 2
TRENCH NO.: 18-TR-02	LOGGED BY: EWL	EQUIPMENT / COMMENTS: Volvo EC480DL	Log of South Wall	

Figure 2-14

3.1 GENERAL SETTING

The proposed site is located in the central portion of the West Hills, near the eastern margin of the Basin and Range Physiographic Province, a region characterized by a series of generally north-trending mountain ranges separated by similarly trending valleys. The large-scale topographic features are a result of east-west crustal extension and normal faulting that began about 15 to 17 million years ago, and continues today (Hecker, 1993).

3.2 BEDROCK STRATIGRAPHY

Detailed geologic maps have not been published for the area at the proposed dam site. Bedrock at the proposed site has been mapped at a scale of 1:250,000 by Stokes (1962) as the Lower Permian and Pennsylvanian Oquirrh Formation consisting of quartzite, limestone, dolomite, sandstone, and shale (Figure 3-1). Beus (1963) maps the bedrock in the vicinity of the dam site as the upper part of the Oquirrh Formation (Figure 3-2). Doelling (1980) has mapped the geology of Box Elder County at a scale of 1:125,000 but does not differentiate between the Pennsylvanian and Permian units in the West Hills (Figure 3-3). Murphy and others (1985) have mapped the geology in the Limekiln Knoll Quadrangle, immediately north of the proposed dam site at a scale of 1:24,000 (Figure 3-4). They describe the Oquirrh Formation as Pennsylvanian-Permian in age and consisting of seven units; the upper three would likely extend to the south towards the proposed dam site. These units consist of: interbedded cherty gray limestone and tan to red quartzose sandstone; ledgy limestone, calcareous sandstone, and cherty siltstone; and finely laminated siltstone.

3.3 GEOLOGIC STRUCTURE

The geologic structure of the West Hills near the proposed site is poorly documented, but is likely related to similar structures in the western portion of the West Hills and the Blue Spring Hills located to the south. Immediately west of Whites Valley, in the western portion of the West Hills, Jordan and others (1988a) map tightly folded, and overturned Paleozoic sedimentary rocks displaced along generally north-trending thrust faults. Similar structures are mapped north of the proposed site by Murphy and others (1985) and south of the proposed site by Jordan and others (1988b) in the Blue Spring Hills. As described elsewhere in northern Utah, the thrust faulting and folding are associated with compressional tectonics related to the Sevier orogeny.

In addition to the deformed bedding and thrust faulting, Jordan and others (1988a, 1988b) and Murphy and others (1985) map several north trending normal faults that are associated with Basin and Range extensional tectonics. Beginning in the Tertiary, and continuing today, the area is experiencing Basin-and-Range-style extensional tectonism. As a result of this extensional tectonics, the area is characterized by numerous normal faults with down-to-the-west displacement, and corresponding, normal, down-to-the east displacement on antithetic faults.

The proposed dam site is located immediately south of Whites Valley, which is nearly in the middle of the north-trending West Hills. Murphy and others (1985) map a south-plunging anticline trending through the northern portions of Whites Valley, and three

down-to-the-west normal faults in the bedrock just east of the valley. It is uncertain if, or where these normal faults project in the vicinity of the proposed dam. Beus (1963) maps an inferred fault on the eastern margin of Whites Valley, which would project near the proposed dam site. This fault is mapped as a normal fault, but the sense of displacement is not indicated on Beus's map.

3.4 SITE-SPECIFIC GEOLOGY

3.4.1 Surficial Geology

Unconsolidated materials were found in test holes 14-TH-WV-04, in the reservoir basin, 14-TH-WV-02 near the left abutment, and in 15-TH-WV-03 near the right abutment. In 14-TH-WV-04, the soil generally consisted of soft, sandy and clayey silt, and very soft silty clay with sand lenses. One 2-foot layer of clayey sand with gravel was found at 30 feet, and one 8-foot layer of medium dense silty gravel with sand was found at a depth of 44 feet. Test hole 14-TH-WV-04 was advanced to a total depth of 52 feet and bedrock was not found. The near-surface geology and seepage potential within the reservoir basin are further discussed below in Section 3.6.

In test hole 14-TH-WV-02, approximately 25 feet of unconsolidated material are present overlying the bedrock. The soil consisted of approximately 13 feet of medium to soft sandy silt with trace gravel, 10 feet of loose silty and gravelly sand, and 2 feet of medium dense silty gravel with sand.

In test hole 15-TH-WV-03, approximately 27 feet of unconsolidated materials were present overlying the bedrock. This portion of the test hole was advanced with rotary wash drilling and no samples were collected.

Sediments exposed in four trenches (16-TR-01, 16-TR-02, 18-TR-01, and 18-TR-02) consisted primarily of silts and clays with sand, gravel, and cobbles. Distinct layers were observable and documented based on the percentages of coarse-grained material, color, and amount of calcium carbonate either in the matrix, or coating clasts. In general, the percentage of coarse-grained sediments decreased towards the valley center – away from the hill slopes. We interpret the origin of the fine-grained sediments to be deposited in a shallow lake, and the coarse-grained sediment to have been derived from colluvial processes.

The valley at the proposed dam site is at an elevation of approximately 5,050 feet; about 130 feet below the elevation of the highstand of Lake Bonneville, as mapped by Murphy and others (1985). We observed no deposits at the surface that appeared to be related to deposition in the shore zone of the lake (e.g. clean sand and gravel). However, the Bonneville shoreline is visible on the abutments in LiDAR imagery.

Radiocarbon analyses of pollen in the lacustrine sediments in Trench 16-TR-02 indicate that lacustrine sediments have been accumulating at the site intermittently, or continuously between about 28,000 and 10,000 cal yr BP. This time period is in good agreement with the ages for the cold and/or wet climate associated with the Bonneville and Gilbert lake cycles (approximately 30,000 to 11,000 cal yr BP) as reported by Oviatt (2014, 2015). The presence of a lake in the vicinity of the dam (herein named Lake

Safflower) likely resulted from the increased runoff related to the changes in climate, and a small topographic basin created by alluvial fans creating a pinch-point and/or dam approximately one mile down valley of the dam site. Fine-grained lacustrine sediments exposed in Trench 18-TR-02 extended to a depth of at least 20 feet below the ground surface. It is extremely unlikely that this thickness of fine-grained sediments could have accumulated in the short time that Lake Bonneville proper existed at this elevation. Rather, it is more likely that Lake Safflower existed in the vicinity of the dam prior to the rise, and following the drop of Lake Bonneville below the elevation of the dam site.

3.4.2 Bedrock Geology

The slopes of both abutments are nearly completely covered with colluvial material and talus. However, bedrock was exposed in five near-surface locations during the site investigations, and recovered in cores of the test holes.

3.4.2.1 Lithology

On the left abutment, bedrock was exposed in three near-surface locations: adjacent to test hole15-TH-WV-01, in the upper portions of Trench 16-TR-02, and in the upper portions of Trench 18-TR-02.

Bedrock was exposed along a road that was cut into the hill slope to provide access for the drill rig to 15-TH-WV-01. At this location, bedrock consisted of calcareous sandstone, light brown to light gray, fine-grained to very fine-grained, well sorted, thinly bedded to moderately bedded, slightly weathered, moderately hard to hard, with sharp contacts.

Bedrock exposed in the upper portions of Trench 16-TR-02 consisted of calcareous siltstone and sandstone to silty limestone, dark gray, fine-grained, thinly bedded, slightly weathered to fresh, hard, interbedded with siltstone and shale, tan, very thinly bedded, slightly weathered to fresh, soft.

Bedrock exposed in the upper portions of Trench 18-TR-02 consisted of silty limestone, medium dark gray, thinly to moderately bedded, slightly weathered to fresh, hard, with sharp contacts.

Bedrock was exposed on the right abutment in a test pit excavated on the hill slope approximately 50 feet up slope from test hole 15-TH-WV-03, and in the upper portions of Trench 18-TR-01.

In the test pit, the subsurface profile consisted of 1-2 feet of brown colluvial soils, 2-3 feet of carbonate-rich, white to light tan colluvial soils, and 0-1 feet of weathered bedrock. Bedrock consisted of calcareous sandstone, gray to tan, fine-grained to very fine-grained, well sorted, thinly bedded to moderately bedded, slightly weathered, moderately hard to hard with very thin beds of shale, tan, silty and sandy, and weathered to clay at the surface.

Bedrock exposed in the upper portions of Trench 18-TR-01 consisted of interbedded silty sandstone, fine sand, well sorted, grayish orange, and siltstone with trace very fine sand, pale orange to grayish orange, thinly bedded, soft, sharp contact between interbeds, one (partly exposed) bed of limestone, dark gray, hard.

Bedrock recovered from the test holes consisted of predominantly gray, fine-grained calcareous sandstone and siltstone, and silty limestone similar to the bedrock observed in near-surface exposures on the abutments. Low recoveries (discussed below), and drilling problems from clay are likely associated with the siltstone and/or shale interbeds.

3.4.2.2 Discontinuities

Additional characterization of the bedrock was conducted at three locations in order to gather data relevant to rock strength and stability. Orientations, spacing, roughness, condition/alteration, aperture, and infill material were recorded for discontinuities following the methodology of the U.S. Bureau of Reclamation (2001). Stereonet plots of measured discontinuities showing major planes and poles (lower hemisphere, equal area) were prepared with RocScience Dips 7.0 (Figures 3-5 through 3-7). Discontinuity data are presented in Appendix F.

On the left abutment, near test hole 15-TH-WV-01, data were collected on 36 individual discontinuities along a transect 87 feet in length. Preliminary analysis of the discontinuity data indicates that there are two prominent joint sets in addition to the bedding plane fractures (Figure 3-5). The joints and bedding plane fractures are moderately to widely spaced (0.3 to 3.0 feet) and generally continuous over lengths of 3.0 to 10.0 feet; however, because the outcrop was generally less than 10 feet in height, no ends or only one end were visible. Joint surfaces are planar and slightly rough to smooth; dry with no visible evidence of water; hard; slightly weathered to fresh; moderately open to open (< 3/8 inch); and have moderately thin to thin (< 3/8 inch) filling of mostly calcium carbonate. The maximum width on the bedding fractures was about 1.5 inches, with the entire fracture filled with calcium carbonate. The joint sets are nearly orthogonal to the orientation of the bedding fractures resulting in a blocky structure of well-interlocked, undisturbed rock mass of cuboidal blocks.

Also on the left abutment, data were collected on 31 individual discontinuities from bedrock exposed in Trench 16-TR-02, and on 73 discontinuities exposed in Trench 18-TR-02. Calibration errors in the data collection equipment preclude a quantitative analysis of the joint set data from Trench 16-TR-02; however, preliminary analysis of the discontinuity data from Trench 18-TR-02 indicate that there are three prominent joint sets in addition to the bedding plane fractures (Figure 3-6). The joints and bedding plane fractures are widely spaced (1 to 3 feet) and generally continuous over lengths of 3.0 to 30.0 feet; however, because the outcrop exposure in the trenches was generally less than 30 feet, no ends or only one end were visible. Joint surfaces are planar and slightly rough to smooth; moist to dry with some evidence of water; hard; slightly weathered; slightly open (< 1/32 inch) to wide (> 0.1 foot); and have very thin to thick filling of mostly soft to very soft calcium carbonate, clay, and iron oxides. The joint sets are nearly orthogonal to the orientation of the bedding fractures resulting in a very blocky structure of interlocked, partially disturbed rock mass of multi-faceted angular blocks.

On the right abutment, data were collected on 69 individual discontinuities from bedrock exposed in a test pit and Trench 18-TR-01. Preliminary analysis of the discontinuity data indicates that there are two prominent joint sets in addition to the bedding plane fractures (Figure 3.7). The joints and bedding plane fractures are widely spaced (1 to 3 feet) and generally continuous over lengths of 1.0 to 30.0; feet; however, because the outcrop exposure in the trenches was generally less than 30 feet, no ends or only one end were visible. Joint surfaces are planar to wavey and slightly rough to smooth; moist to dry with no visible evidence of water; hard; slightly weathered to fresh; slightly open to moderately open (< 1/8 inch) with a few wide (< 2 inches); and have very thin to moderately thin, with a few thick filling of mostly very soft calcium carbonate, clay, and oxides of manganese and iron. The joint sets are nearly orthogonal to the orientation of the bedding fractures resulting in a blocky structure of well-interlocked, undisturbed rock mass of cuboidal blocks.

In test hole 15-TH-WV-01, recovery was between 69 and 100 percent; RQD was generally between 0 and 30 percent, with one run of 39 percent; the rocks were generally very intensely to intensely fractured; fresh; and hard to moderately hard. In test hole 14-TH-WV-02, recovery was between 72 and 100 percent; RQD was generally between 10 and 74 percent, with one run of 82 percent; the rocks were generally moderately to slightly fractured, with a few zones that were intensely fractured; fresh; and hard to moderately hard. In test hole 15-TH-WV-03, recovery was generally between 40 and 100 percent, with one run of 14 percent and two runs of 0 percent; RQD was generally between 0 and 49 percent, with one run of 64 percent; the rocks were generally intensely to very intensely fractured; slightly weathered to fresh; and hard to moderately hard.

Discontinuities observed in the vertical test holes (15-TH-WV-01 and 14 TH-WV-02) generally fall into two groups based on the magnitude of the discontinuity dip. We interpret the discontinuities with dip magnitudes generally less than about 20 degrees to be bedding fractures, and those with dip magnitudes between 75 and 90 degrees to be joint sets. Because the cores were not oriented, it is not possible to delineate whether or not the steeply dipping joints are representative of one or two joints, however, based on observations in outcrop discussed above, we believe that two joint sets are likely present.

The low angle joint set (bedding plane discontinuities) is generally planar, moderately rough to slightly rough, slightly open to moderately open (1/32 to 1/8 inch) and filled with calcium carbonate and clay. The near-vertical joint set is generally planar to stepped, slightly rough to smooth, tight to moderately open (< 1/8 inch) and filled with calcium carbonate and clay.

3.5 GEOLOGIC HAZARDS

3.5.1 Surface Fault Rupture

The surface-fault-rupture hazard at the proposed dam site has been evaluated by reviewing previous geologic mapping, examining aerial photographic, conducting on-the-ground reconnaissance surveys of topographic features, examining LiDAR imagery,

reviewing seismic refraction surveys and CPT profiles, and examining subsurface sediments and bedrock exposed in four trenches.

3.5.1.1 Previous Mapping

The U.S. Geological Survey Quaternary Fault and Fold Database of the United States shows no faults with Quaternary aged displacement in Whites Valley, or at the proposed dam site (U.S.G.S., 2016). However, several north trending normal faults that are associated with Basin and Range extensional tectonics have been mapped near the proposed site - on the western flank of the West Hills by Jordan and others (1988a), in the Blue Spring Hills by Jordan and others (1988b) and by Miller and others (1991), in the West Hills by Murphy and others (1985) and in the Samaria Mountains by McCalpin and others (1992).

The closest fault that could project to the dam site is an inferred fault mapped by Beus (1963) in the northwest portion of Whites Valley, about two miles north of the proposed dam site (Figure 3-2). This fault is mapped as a normal fault, but the sense of displacement is not indicated on Beus's map. Subsequent geologic maps do not show this fault, particularly the 1:24,000 scale geologic map of Murphy and others (1985). It is worth noting that Beus was the second author of the Murphy and others (1985) geologic map and that the fault that he inferred in his 1963 map is not shown on the 1985 map.

3.5.1.2 Aerial Photographic and Topographic Interpretation

Stereo pairs of high-resolution black and white aerial photographs were obtained from the U.S. Department of Agriculture (AAH-5W, exposures 103-107, 146-151, 1959; A40 4903, exposures 141-144, 1974). The photographs were obtained in 10-inch by 10-inch prints and examined with the aid of a Lietz/Sokkisha MS-27 mirror stereoscope.

The photographs were examined for evidence of fault-related topography, contrasts, or lineaments possibly associated with ground-surface displacement. We observed no lineaments or topographic expression representative of fault scarps at the dam site either in the aerial photographs or from on-site surveys. In the vicinity of the inferred fault mapped by Beus in Whites Valley, we observed a topographic break in slope between the bedrock and the alluvial materials in the valley. This feature has a trend in general agreement with the fault mapped by Beus; however, there are no surface features associated with faulting. Agricultural activity has disturbed the ground surface in about half of the length of the fault mapped by Beus, such that any fault scarp could have been regraded.

On-site examination of the ground surface along the southern half of the inferred fault mapped by Beus revealed a generally even sloping ground surface with no noticeable topographic features likely associated with fault scarps. Our on-site examination took place within a few months of a fire that had removed the vegetation from the slopes in the vicinity of Beus's inferred fault. Thus, we were able to examine the ground surface unhindered by vegetation that could have covered topographic features related to surface faulting.

3.5.1.3 LiDAR Imagery Interpretation

In the spring of 2017, the State of Utah acquired LiDAR data for Whites Valley and the site of the proposed dam. The data consists of 8 points per meter Quality Level 1 LiDAR with a resolution of 0.5 meters. The bare earth DEM, with a 10.0 cm vertical RMSE accuracy, was obtained from Utah Automated Geographic Reference Center (AGRC); slope shade images were generated from the DEMs with Global Mapper.

The LiDAR slope shade images for Whites Valley and the proposed dam site are shown in Figures 3-8 through 3-10. Darker tones in the LiDAR imagery represent steeper slopes. The area of Beus's inferred fault in the northeastern portion of Whites Valley is shown in detail in Figure 3-9. Careful examination of this portion of Whites Valley indicates that there are no topographic features associated with fault scarps present. The only noticeable northwest-trending feature is the break in slope that represents the contact between the bedrock and alluvial/colluvial deposits. However, this is a geologic contact and there is no displacement of the ground surface that would be attributable to surface-fault ground rupture.

The area of the proposed dam site is shown in detail in Figure 3-10. There are no features in the vicinity of the dam site that show displacement of the ground surface that would be indicative of surface-fault ground rupture. The linear break in slope at the margins of the valley in this location represents the contact between the bedrock and colluvial/lacustrine sediments on the valley floor. There are no abrupt changes in the ground surface elevation along the valley margins and no other indications of ground-surface displacement.

3.5.1.4 Seismic Refraction Survey

The seismic refraction P-wave velocity profiles were conducted along, and near the axis of the proposed embankment in order to evaluate the configuration of the top of the bedrock. Specifically, we examined the profile of the sediment/fractured bedrock interface for abrupt changes in depth that could be associated with faulting.

The profile spanning the entire valley and adjacent abutments (15-SR-01, Figure 2-5) shows the following with regard to the depth to bedrock: 1) on the abutments, bedrock is shallow (less than about 5 feet); 2) in the central portion of the valley, the depth to bedrock is fairly consistent and about 40 feet below the ground surface; 3) the transition from the hill slopes to the valley on both abutments is punctuated by "steps" where the depth to bedrock increases abruptly over short distances. These steps over which bedrock deepens abruptly on the flanks of the valley could be associated with stratigraphic and/or structural changes in the rock, erosion of the valley by stream processes, or from displacement along a normal and antithetic fault that bound the valley.

In order to examine the bedrock steps on the flanks of the valley in more detail, five higher resolution (shorter geophone spacing) seismic refraction surveys were conducted (Figure 2-2). On the left abutment, bedrock steps are observable in 16-SR-01 (Figure 2-6) between about Station 85 and 95, and between Station 125 and 135; in 16-SR-02 (Figure 2-7) between about Station 110 and 115; and in 16-SR-03 (Figure 2-8) between about Station 125 and 135. On the right abutment, bedrock steps are

observable in 16-SR-04 (Figure 2-9) at about Stations 65, 95, 135, and 160; and in 16-SR-05 (Figure 2-10) at about Stations 40 and 135. Each of these steps represents an abrupt increase in the depth to bedrock of between 5 and 10 feet.

3.5.1.5 CPT Profile

The CPT profile was conducted across the valley near the axis of the proposed dam in order to identify continuity of discreet sedimentary layers and to identify the depth to bedrock. Due to the presence of colluvial cobbles near the valley margins, the CPTs were only pushed in the central portion of the valley. The logs of tip resistance (Figure 2-4) showed little variability in the upper portions of the profile, consistent with the general uniformity of the sediments observed in the trench excavations. Refusal is interpreted as representing the contact of the fractured bedrock.

In the central portion of the valley (between 16-CPT-02 and 16-CPT-08), the bedrock surface is generally uniform at a depth of about 40 feet, consistent with the depth observed in seismic refraction profiles. This indicates that the bedrock has likely not been displaced vertically along faults. On the left abutment, there are abrupt drops in the top of the bedrock surface between 16-CPT-10 and 16-CPT-01, and between 16-CPT-09 and 16-CPT-02. These steps are similar to those observed in the seismic refraction profiles, although as discussed above, their origin can not be determined from the CPT profiles alone.

3.5.1.6 Trench Exposure

The majority of the materials exposed in the trenches consisted of fine-grained lacustrine sediments with colluvial gravels and cobbles near the valley margins (Figures 2-11 through 2-14). We observed that no faults were present in the lacustrine/colluvial sediments in any of the four trenches, or in the stream and debris-flow deposits exposed in Trench 16-TR-02. Although the lacustrine sediments are generally massive, we examined distinct layers for evidence of displacement associated with faulting. We observed that there are no fractures, offset sediments, shear zones, colluvial wedges, or other features that would indicate movement along a fault. Where possible, we made observations of overlapping distinct layers in order to confirm that there was no displacement of the sediments.

Bedrock was exposed in the upper portions of Trenches 16-TR-02, 18-TR-01, and 18-TR-02. Small steps were observed in the contact between the bedrock and unconsolidated sediments in Trench 16-TR-02; however, there was insufficient exposure in the underlying bedrock to determine if the steps were related displacement along faults.

In Trench 18-TR-02, up to 11 feet of bedrock was exposed below the contact between bedrock and unconsolidated sediments. Thus, we able to examine the steps at this contact and assess their origin. At most steps, there were joints that extended into bedrock below the contact, but there was no shearing or displacement along opposite sides of the joints. We observed that the steps appeared to be where blocks of bedrock had been displaced and moved down slope likely due to colluvial processes. The steps occur where bedrock joints have fractured the rock allowing the blocks to move. It is also possible that lacustrine shore zone processes aided in the removal and/or breaking

up of bedrock once the blocks became dislodged. The steps are the remnants of portions of the bedrock hill slope where rock that was less fractured remained on the slope or shore zone.

The lacustrine sediments observed overlying the bedrock steps in Trenches 16-TR-02 and 18-TR-02 are continuous and unfaulted.

The contact between the bedrock and unconsolidated sediments exposed in the upper portions of Trench 18-TR-01 is uniform and lacks the steps observed in the trenches on the left abutment. This could be due to the differences in the lithology, orientation of bedding planes, and/or fracture density. We did observe a large offset in the depth of bedrock (at least 3 feet) near station 70 where a buried and ancient landslide deposit was noted. This step likely represents the head scarp of a landslide that existed prior to this area being inundated by Lake Safflower and the accumulation of the lacustrine and colluvial sediments. It is likely that this contact between the landslide materials and bedrock was initially interpreted as a “step” in the seismic refraction surveys. We also observed three shear zones in the bedrock along reverse faults with displacements ranging between 4 and 9 inches. There was no displacement of the contact between the bedrock and unconsolidated sediments. Given the sense of displacement, we interpret these shear zones to be associated with Laramide-age compressional tectonics and that they are not currently active.

3.5.1.7 Summary

The proposed dam site is in a region characterized by numerous normal faults associated with active Basin and Range extensional tectonics. In addition, Beus (1963) maps an inferred fault on the eastern flank of Whites Valley that trends towards the site; however, this fault was removed from a subsequent geologic map co-authored by Beus (Murphy and others, 1985).

Examination of vertical aerial photographs, LiDAR imagery, and on-site observations in Whites Valley and at the site of the proposed dam reveal a lack of surface features typically associated with normal faults. Specifically, we observed that there are no linear, north- to northwest-trending abrupt changes in the ground surface elevation that would be indicative of surface rupture along faults.

An abrupt change in the elevation of the sediment/bedrock contact (bedrock steps) along the flanks of the valley is observed in the seismic refraction and CPT profiles, and was exposed in the trenches on the left abutment. Based on detailed examination of the bedrock below the steps, we conclude that they are the result of downslope movement of more-or-less intact blocks that were created by joints in the bedrock. We noted that where the joints extended into the underlying bedrock there are is no shearing or other evidence of displacement along the joint planes. Thus, we conclude that the bedrock steps are not the result of surface-fault rupture. In addition, we note that the lacustrine and colluvial sediments overlying the steps are continuous and unfaulted.

The majority of the materials exposed in the trenches consisted of fine-grained lacustrine sediments with colluvial gravels and cobbles near the valley margins. We observed that no faults were present in any of the unconsolidated sediments.

Specifically we observed that the sediments were continuous and that there are no fractures, offset sediments, shear zones, colluvial wedges, or other features that would indicate movement along a fault.

The trenches exposed unfaulted lacustrine and colluvial sediments to depths of 22 and 20 feet on the right and left abutments, respectively. Given the thickness of the fine-grained lacustrine sediments, we conclude that the valley at the location of the proposed dam site was occupied by a lake for an extensive period of time in the latest Pleistocene, and is coeval with Lake Bonneville. Based on research in other parts of the Bonneville Basin, it is believed that lakes began to accumulate in the basin in response to colder and/or wetter climate conditions beginning about 30,000 years ago Miller and Phillips, 2016).

Based on the multiple lines of investigation discussed above, we find evidence for no faulting in Whites Valley or at the site of the proposed dam within the past 30,000 years.

3.5.2 Landslides

We observed that no evidence exists for landslides (scarps, displaced material, hummocky topography, and internal drainage) within the reservoir basin. Furthermore, Elliott and Harty (2010) have not mapped any landslides in the reservoir basin, or at the abutments.

We did observe that the hill slope on the left abutment, immediately north of the proposed embankment, appears to have landslide morphology, although it is less distinct in the LiDAR imagery. There are no fresh landslide features, and we believe that this may be a relict landslide, with movement associated with the time that Lake Bonneville occupied the lower portions of the slope. Although this area appears stable at present, the hill slope could be destabilized as a result of undercutting by wave action when the reservoir levels are low. Furthermore, fluctuating reservoir levels could create saturated zones in the materials adjacent to the reservoir and thereby reduce the slope stability.

3.6 RESERVOIR SEEPAGE STUDY

3.6.1 Reservoir Basin Subsurface Conditions

Forty-eight test pits were excavated in the reservoir basin in the fall of 2016, along with one test hole (14-TH-WV-04) that was advanced in the fall of 2014. Discussions of the test pits and test hole are discussed in Section 2.1.2 and Section 2.1.1. Unconsolidated materials were found in the majority of the test pits. The test pits excavated at the base of the slopes or in the valley generally exposed of fine-grained material consisting of silts and clays. Test pits excavated higher on the slopes exposed some coarse-grained material; however, fine-grained material was also found (i.e, 16-TP-WV-4, 5, 15, 16, 17, 24, 25, 26, 29, 30, 41, 42, 46). Bedrock was exposed in test pits 16-TP-WV-06, 07, 12, 13, 14, 18, 22, 43, 47 and 48. The bedrock was fractured and similar to what was observed on the abutments of proposed embankment and as discussed in Section 3.4.2.

3.6.2 Estimated Hydraulic Conductivity in Reservoir Basin

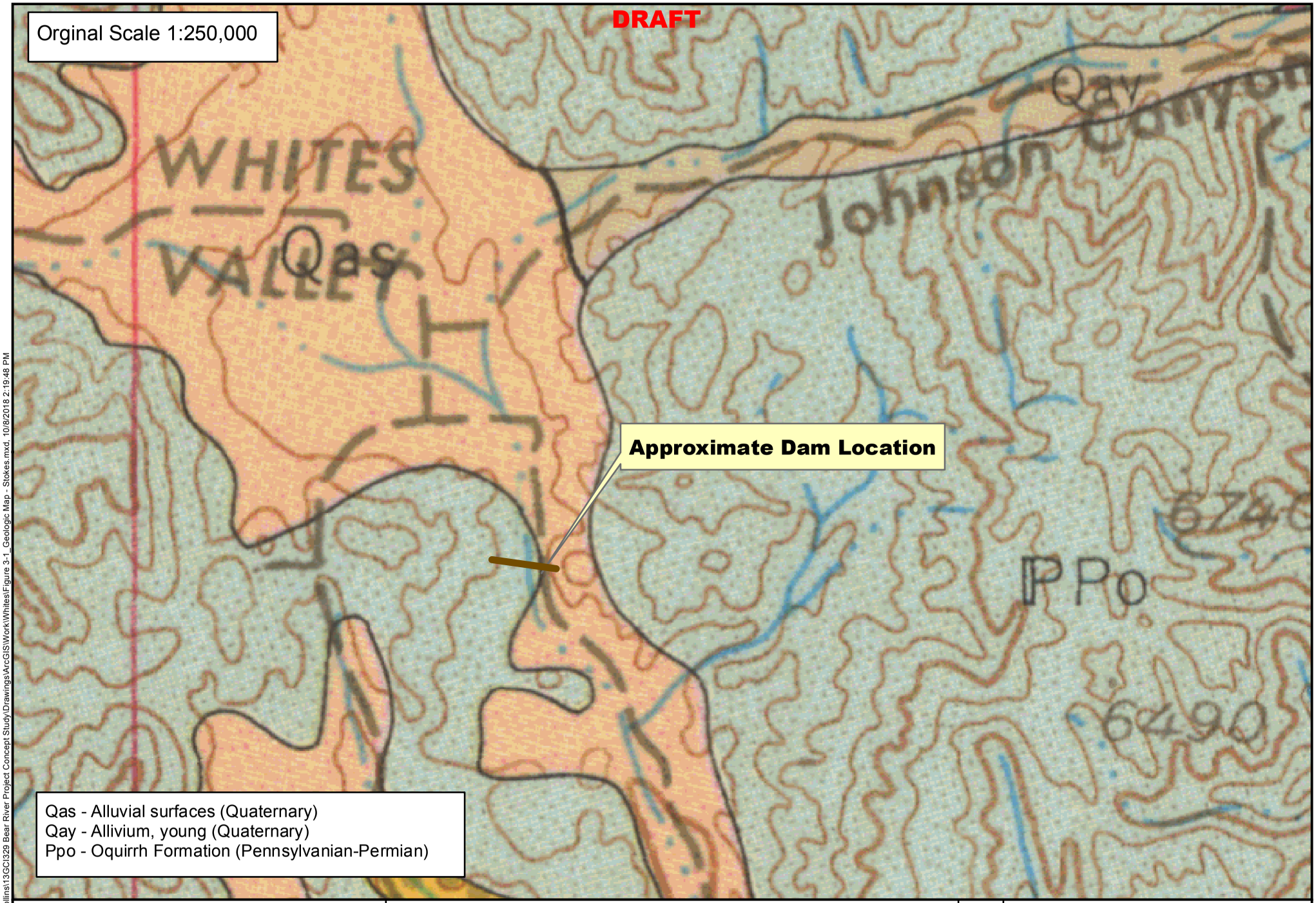
A weighted hydraulic conductivity was estimated for each test pit based on the soil found in the test pit. The process to estimate the hydraulic conductivity for each soil type was based on the calculated hydraulic conductivity values using Hazen Williams equation from the lab results on the material obtained from the test pits. The hydraulic conductivity calculated using Hazen Williams equation were compared with the Range of Hydraulic Conductivity of Natural Soils shown (Powers, 2007) and corresponded fairly well for the fine-grained soils. The values in Powers were used for the coarse-grained soils because the lab results did not meet the limitations of the Hazen Williams equation (Powers, 2007). The hydraulic conductivity used for each soil type is shown in Table 3-1. The bedrock value was based on results from the packer and permeability tests completed during the field studies in 2015. The weighted hydraulic conductivity values for the vertical and horizontal directions each test pit were plotted on Figure 3-11 and Figure 3-12; Table 3-2 shows the hydraulic conductivity range of values that correspond to the legend shown in the figures.

Table 3-1 Hydraulic Conductivity Values used for Soil found in Test Pits (After Powers, 2007)

Soil Type	Hydraulic Conductivity (ft/day)
Gravel	5 x 10^02
Silty Sandy (SM)	9 x 10^0
Silt (ML)	3 x 10^-01
Clay (CL)	1 x 10^-02
Limestone Bedrock	3 x 10^03

Table 3-2 Legend for Figure 3-11 and Figure 3-12

Hydraulic Conductivity Range (ft/day)	Permeability Description
< 3 x10^-02	Very Low to Practically Impermeable
3 x10^-02 to 1	Very Low to Low
1 - 300	Low to Moderate
300 - 900	Moderate to High
> 900	High to Very High



GERHART COLE

Bear River Project Concept Study - Whites Valley

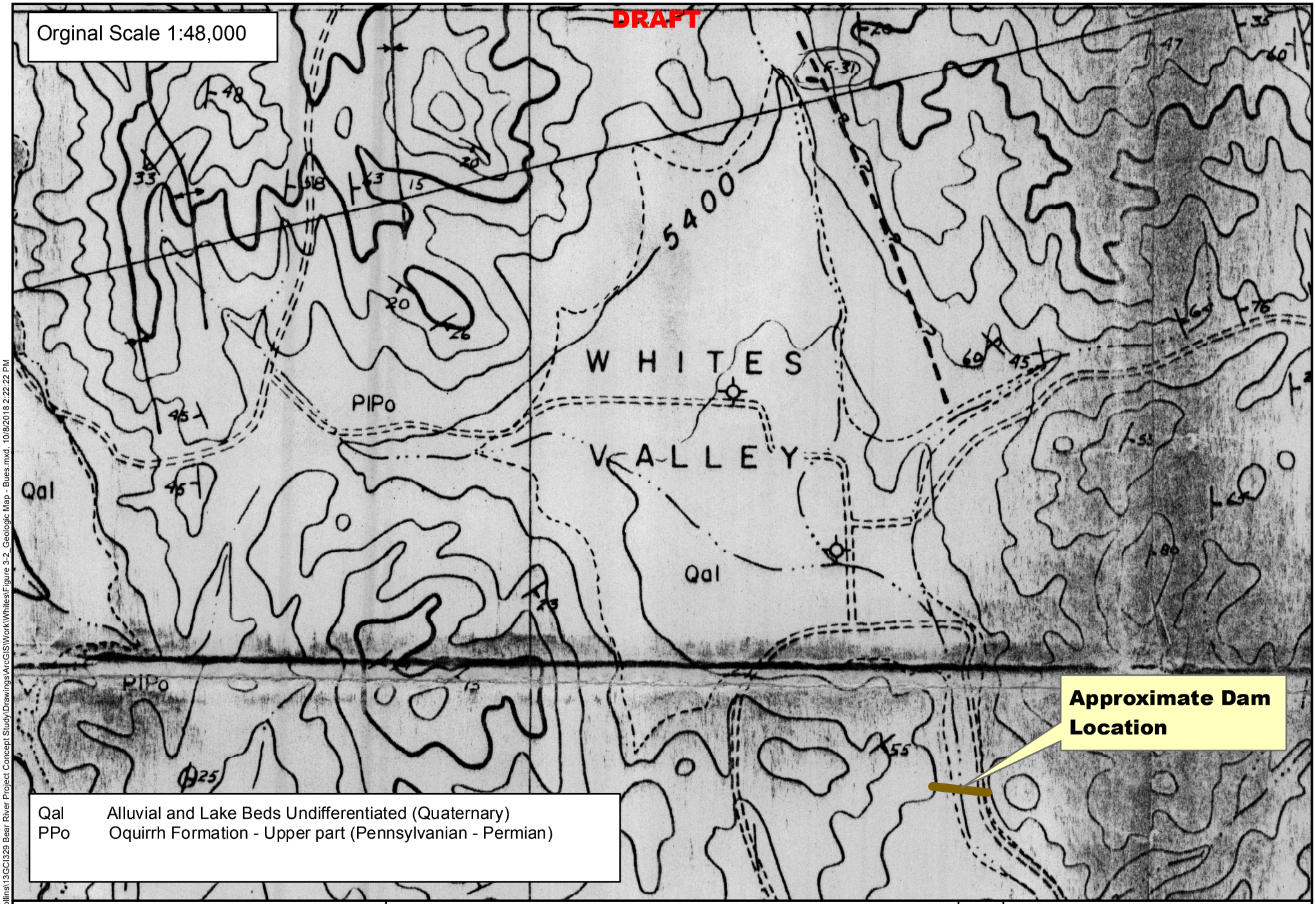
Geologic Map - Stokes (1962)

N

0 1,650 3,300 6,600 Feet

Figure 3-1

J:\PROJECTS\Bowen Collins\13GCI329 Bear River Project Concept Study\Drawings\ArcGIS\Work\Whites\Figure 3-1_Geologic Map - Stokes.mxd, 10/8/2018 2:19:48 PM



GERHART COLE

Bear River Project Concept Study - Whites Valley

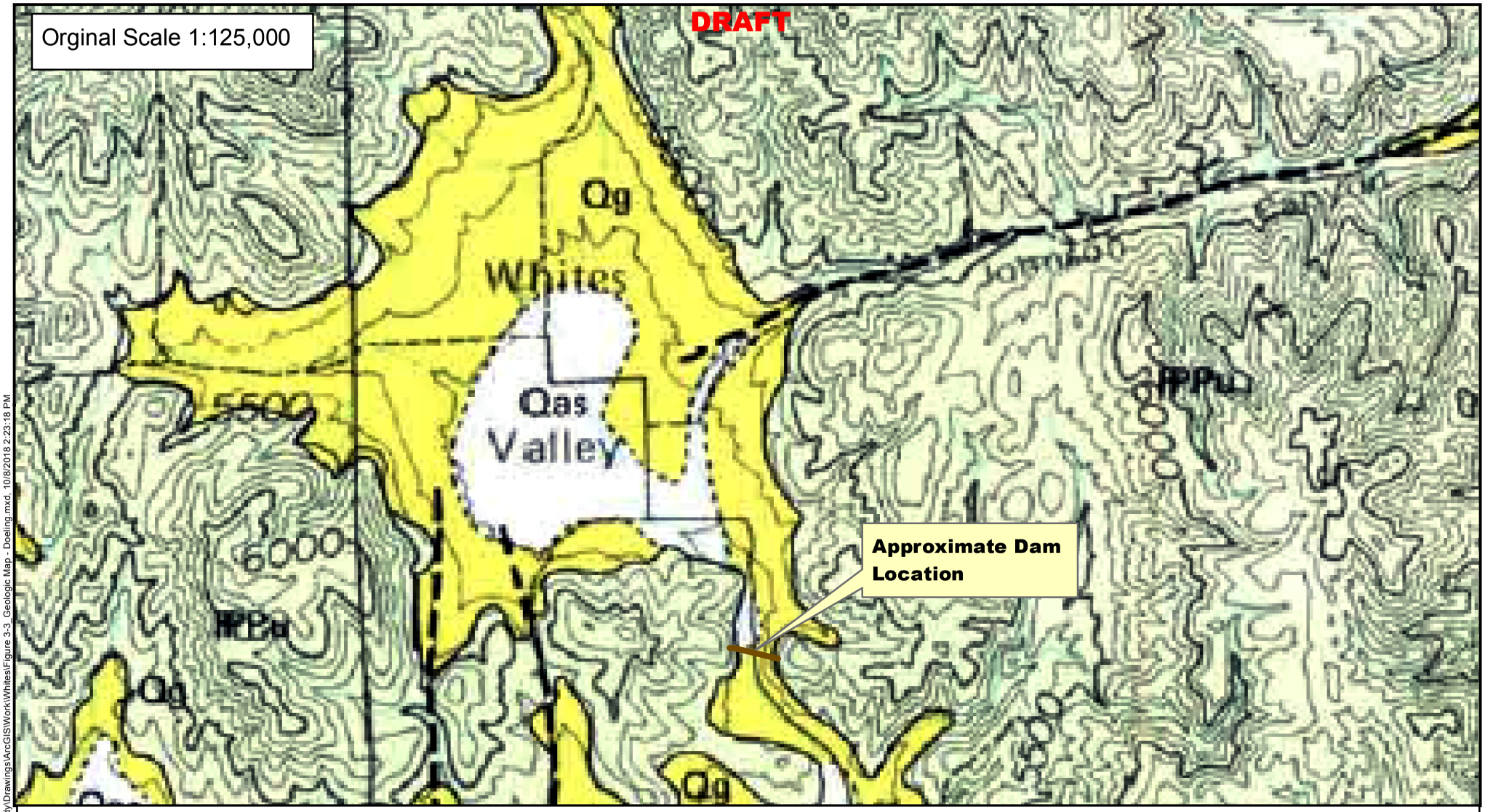
Geologic Map - Bues 1963

N

0 1,550 3,100 6,200 Feet

Figure 3-2

J:\PROJECTS\Bowen Collins\13GCI329 Bear River Project Concept Study\Drawings\ArcGIS\Work\Whites\Figure 3-2_Geologic Map - Bues.mxd, 10/8/2018 2:22:22 PM



Qg Gravel Quaternary
Qas Alluvial Soils (Quaternary)
PPu Pennsylvanian-Perminan Undifferentitated

GERHART COLE

Bear River Project Concept Study - Whites Valley

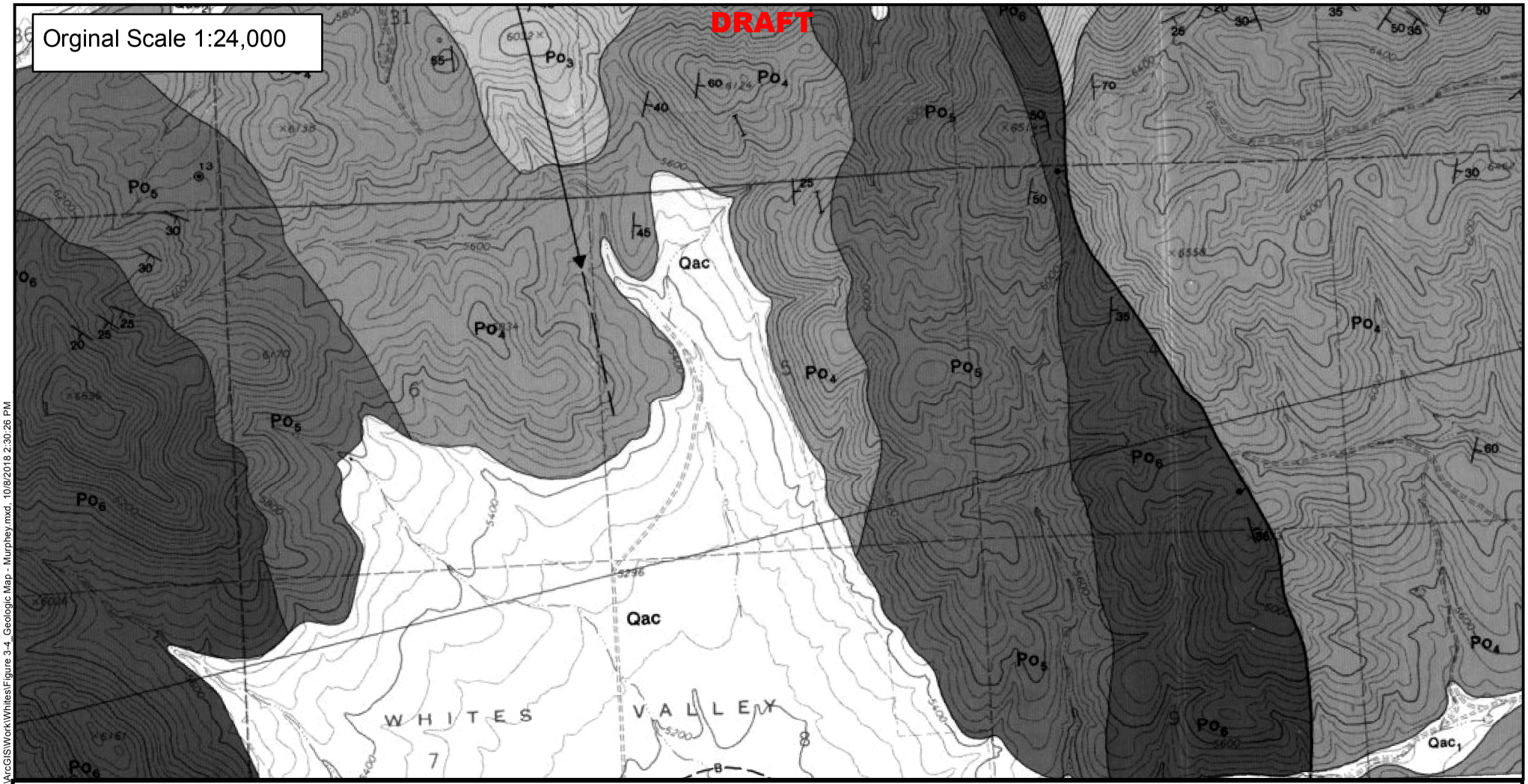
Geologic Map - Doeling 1980

N

Not to Scale

Figure 3-3

J:\PROJECTS\Bowen Collins\13GCI329 Bear River Project Concept Study\Drawings\ArcGIS\Work\Whites\Figure 3-3_Geologic Map - Doeling.mxd, 10/8/2018 2:23:18 PM



Qac - Stream alluvium and slope wash (Quaternary)
Po6 - Oquirrh Formation – Interbedded cherty gray limestone and tan to red quartzose sandstone (Pennsylvanian-Permian)
Po5 - Oquirrh Formation – Interbedded ledgy limestone, soft calcareous sandstone and cherty siltstone (Pennsylvanian-Permian)
Po4 - Oquirrh Formation – Cherty brown, finely laminated siltstone (Pennsylvanian-Permian)
Po3 - Oquirrh Formation – Thick-bedded brown quartzose to subarkosic sandstone and medium- to thick-bedded silty and bioclastic limestone (Interbedded chertygray limestone and tan to red quartzose sandstone (Pennsylvanian-Permian)

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Bear River Project Concept Study - Whites Valley

Geologic Map - Murphey et. al. (1985)

N

0 1,000 2,000 4,000 Feet

Figure 3-4

J:\PROJECTS\Bowen Collins\13GCI329 Bear River Project Concept Study\Drawings\ArcGIS\Work\Whites\Figure 3-4_Geologic Map - Murphey.mxd, 10/8/2018 2:30:26 PM

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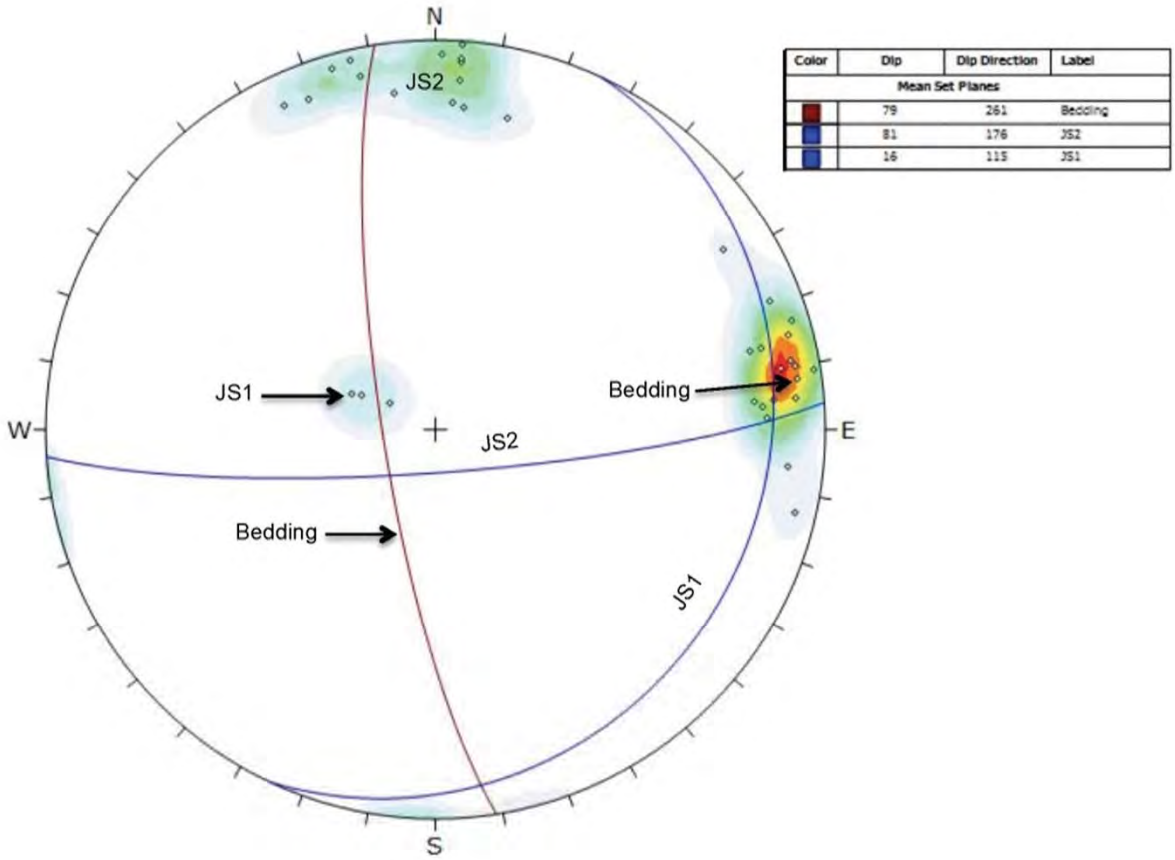

Figure 3-5 Stereonet Plot of Measured Discontinuities, Left Abutment, near 15-TH-WV-01 (major planes and poles; lower hemisphere, equal area).

Stereonet Plot of Measured Discontinuities, Left Abutment, near 15-TH-WV-01 (major planes and poles; lower hemisphere, equal area).
Bear River Project Concept Study Whites Valley
GERHART COLE — Figure 3-5

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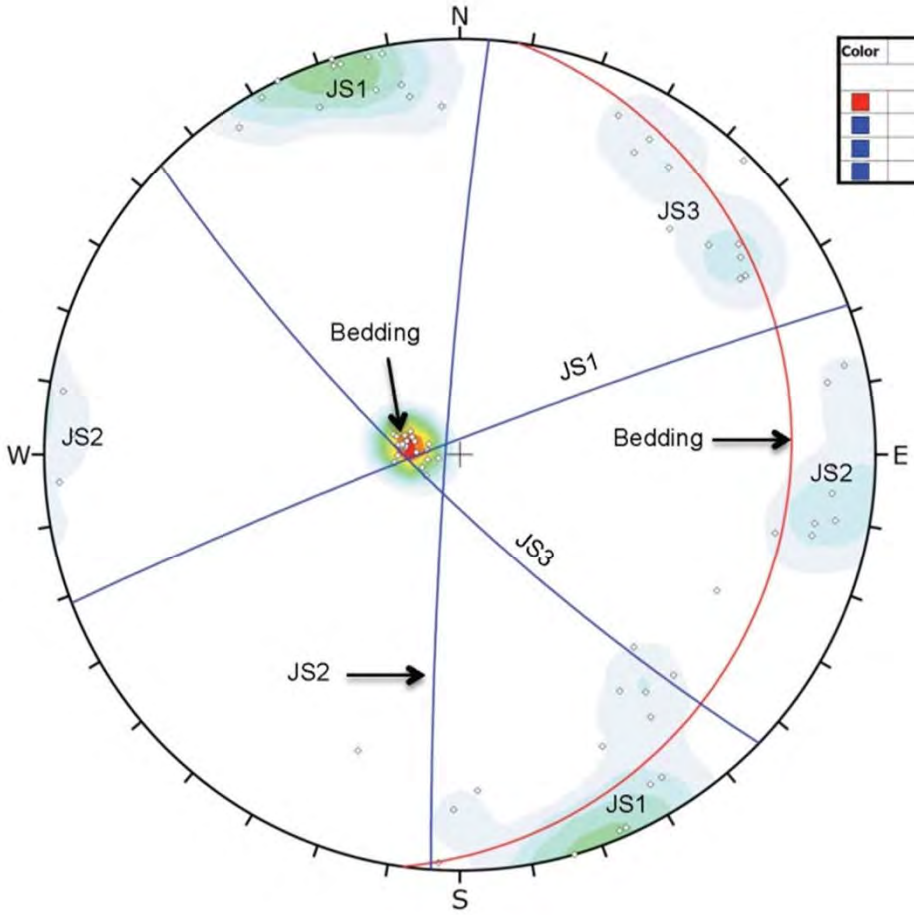

Color	Dip	Dip Direction	Label
Mean Set Planes			
	13	98	Bedding
	86	339	JS1
	86	274	JS2
	79	224	JS3

Stereonet Plot of Measured Discontinuities, Left Abutment, Trench 18-TR-02 (major planes and poles; lower hemisphere, equal area).

Bear River Project Concept Study
Whites Valley

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Figure 3-6

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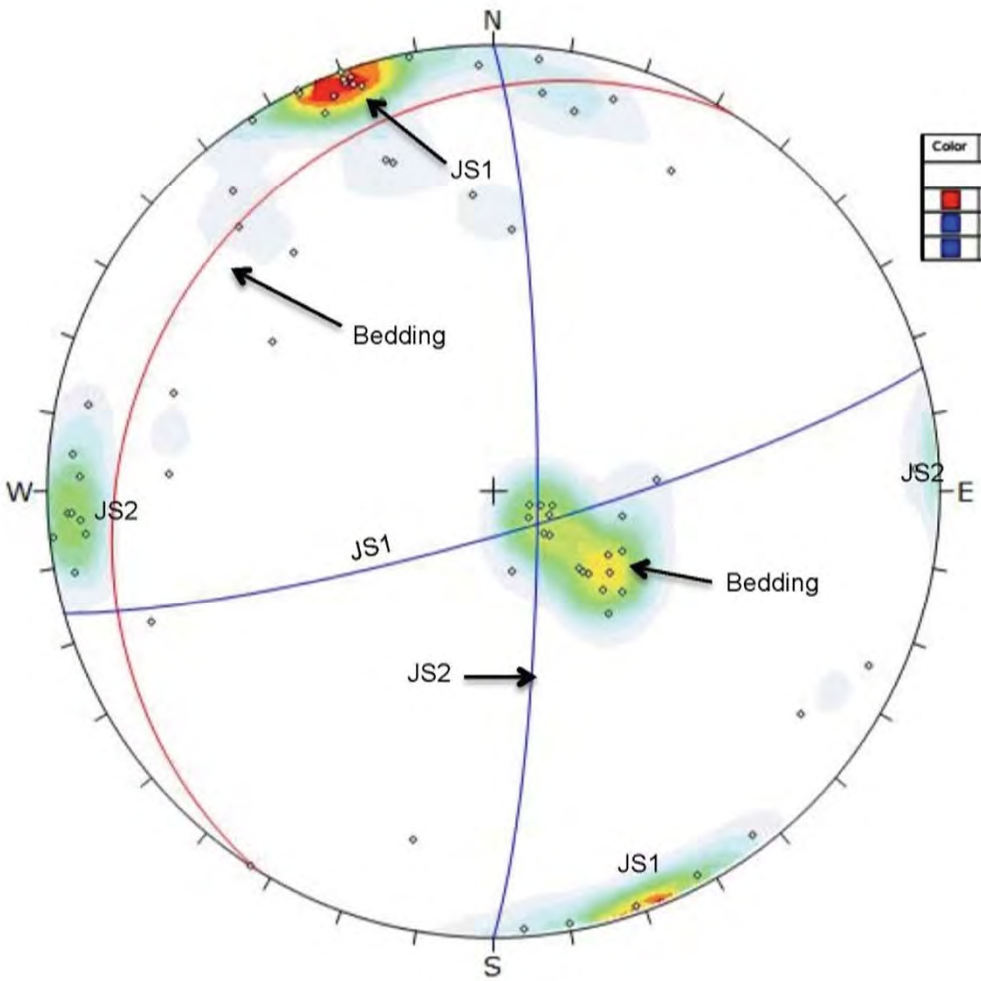

Color	Dip	Dip Direction	Label
Mean Set Planes			
	19	302	Bedding
	82	164	JS1
	82	90	JS2

Stereonet Plot of Measured Discontinuities, Right Abutment, (major planes and poles; lower hemisphere, equal area).

Bear River Project Concept Study
Whites Valley

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Figure 3-7

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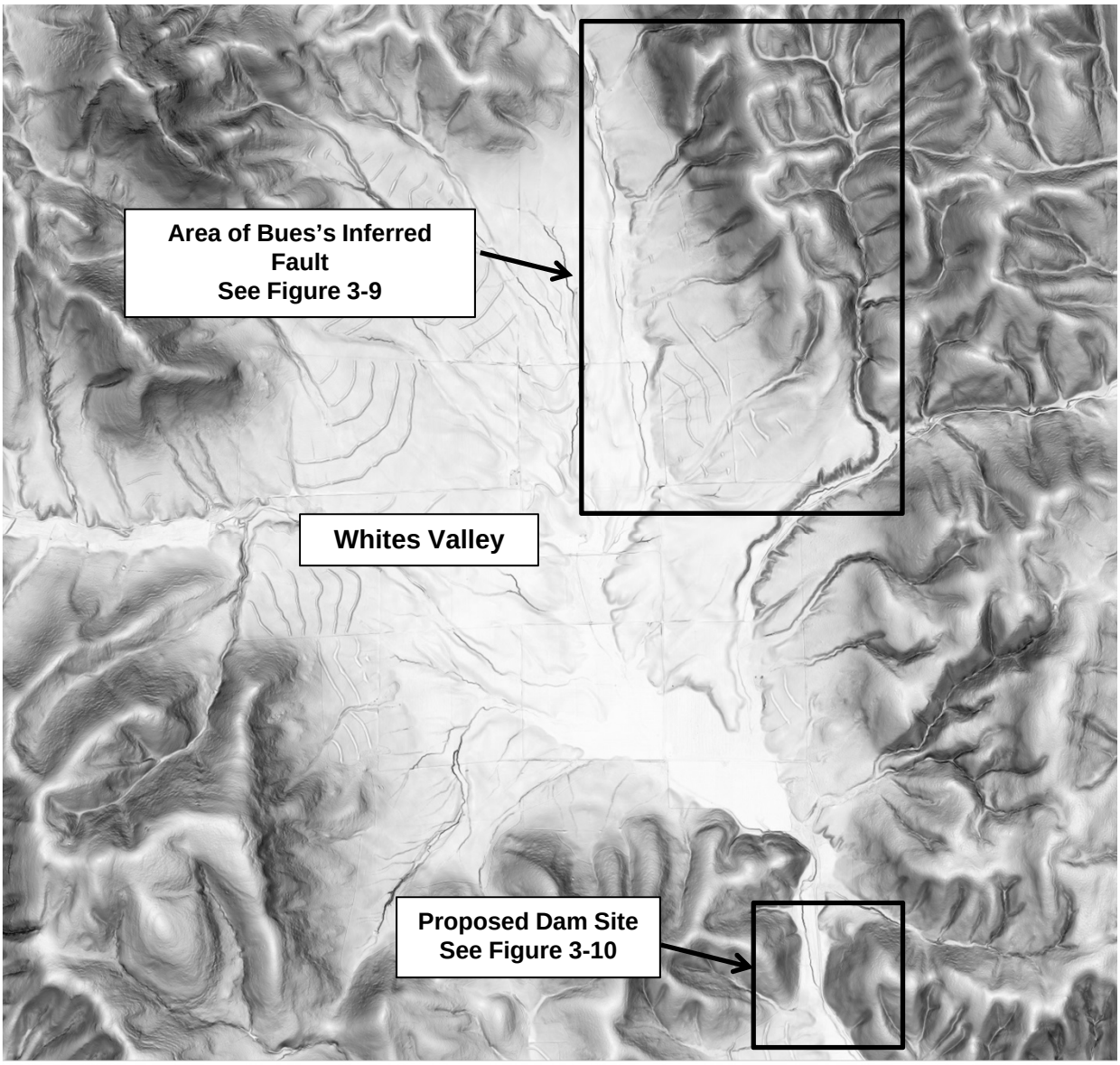

Approximate Scale 1 inch = 3000 feet

N

LiDAR Slope Shade Image
Whites Valley

Bear River Project Concept Study
Whites Valley

GERHART COLE

Figure 3-8

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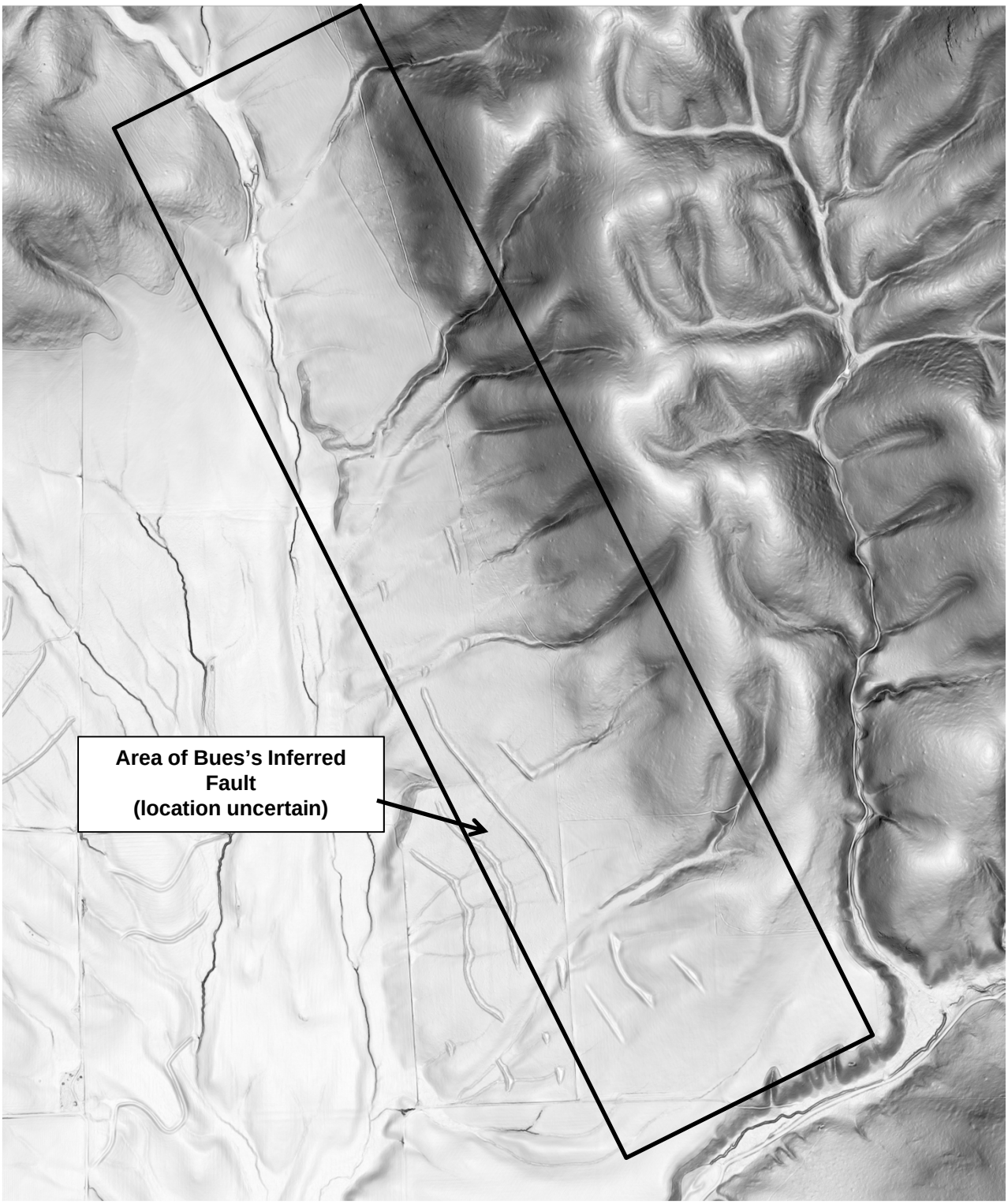

Approximate Scale 1 inch = 1,250 feet

N

LiDAR Slope Shade Image
Whites Valley in Vicinity of Bues's Inferred Fault

Bear River Project Concept Study
Whites Valley

GERHART COLE

Figure 3-9

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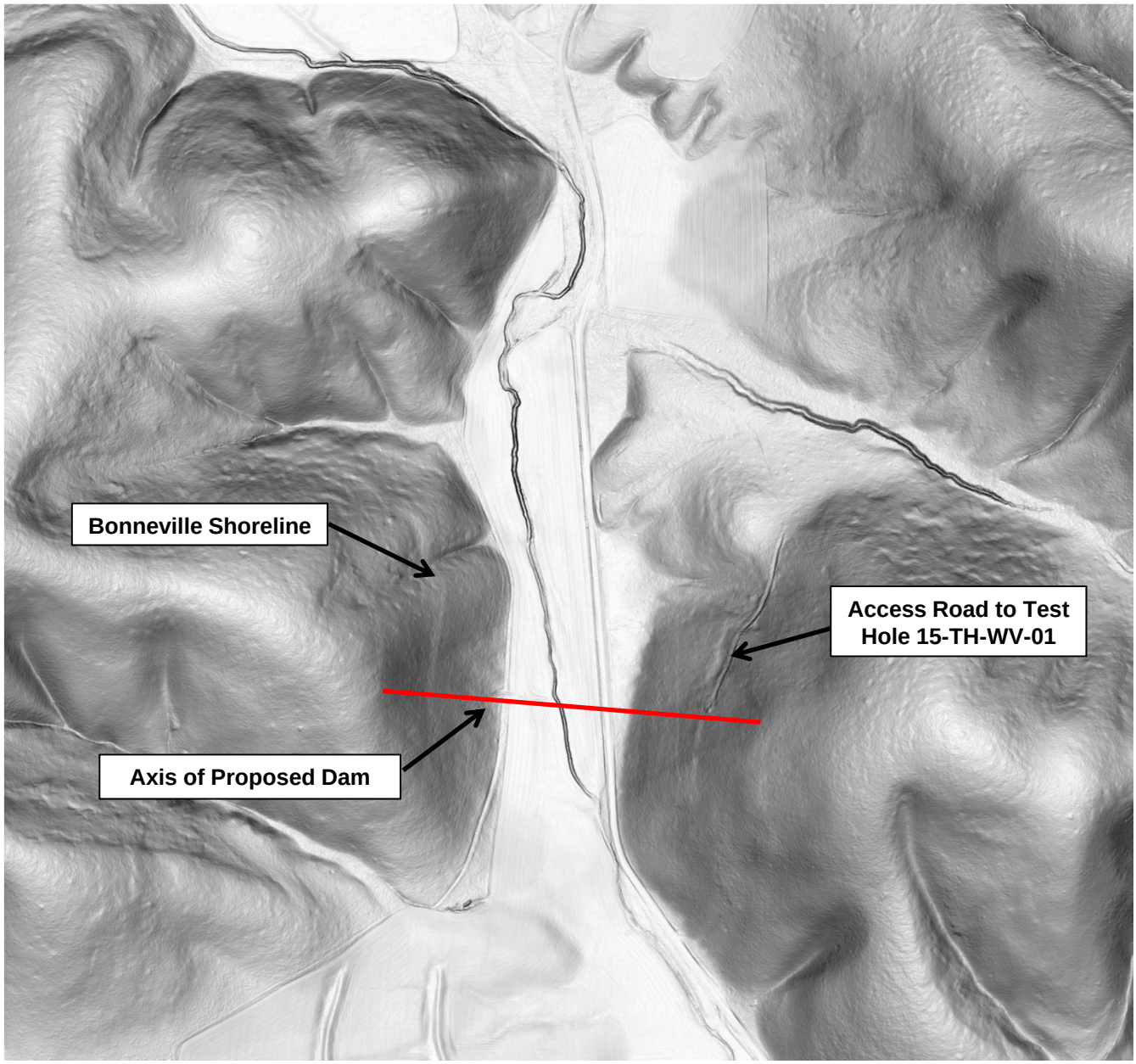

Approximate Scale 1 inch = 650 feet

N

LiDAR Slope Shade Image
Proposed Dam Site

Bear River Project Concept Study
Whites Valley

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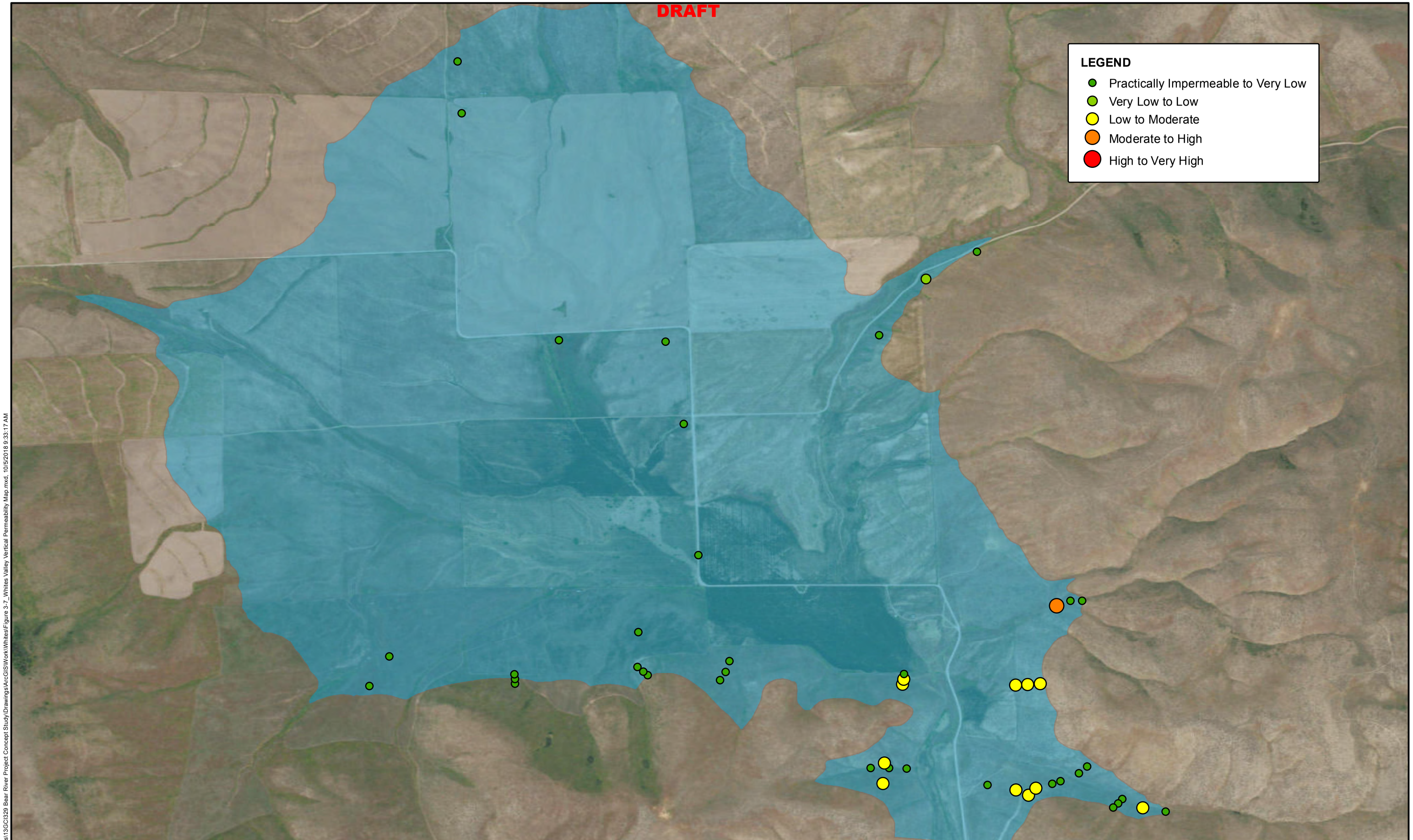
Figure 3-10



GERHART COLE

Bear River Project Concept Study

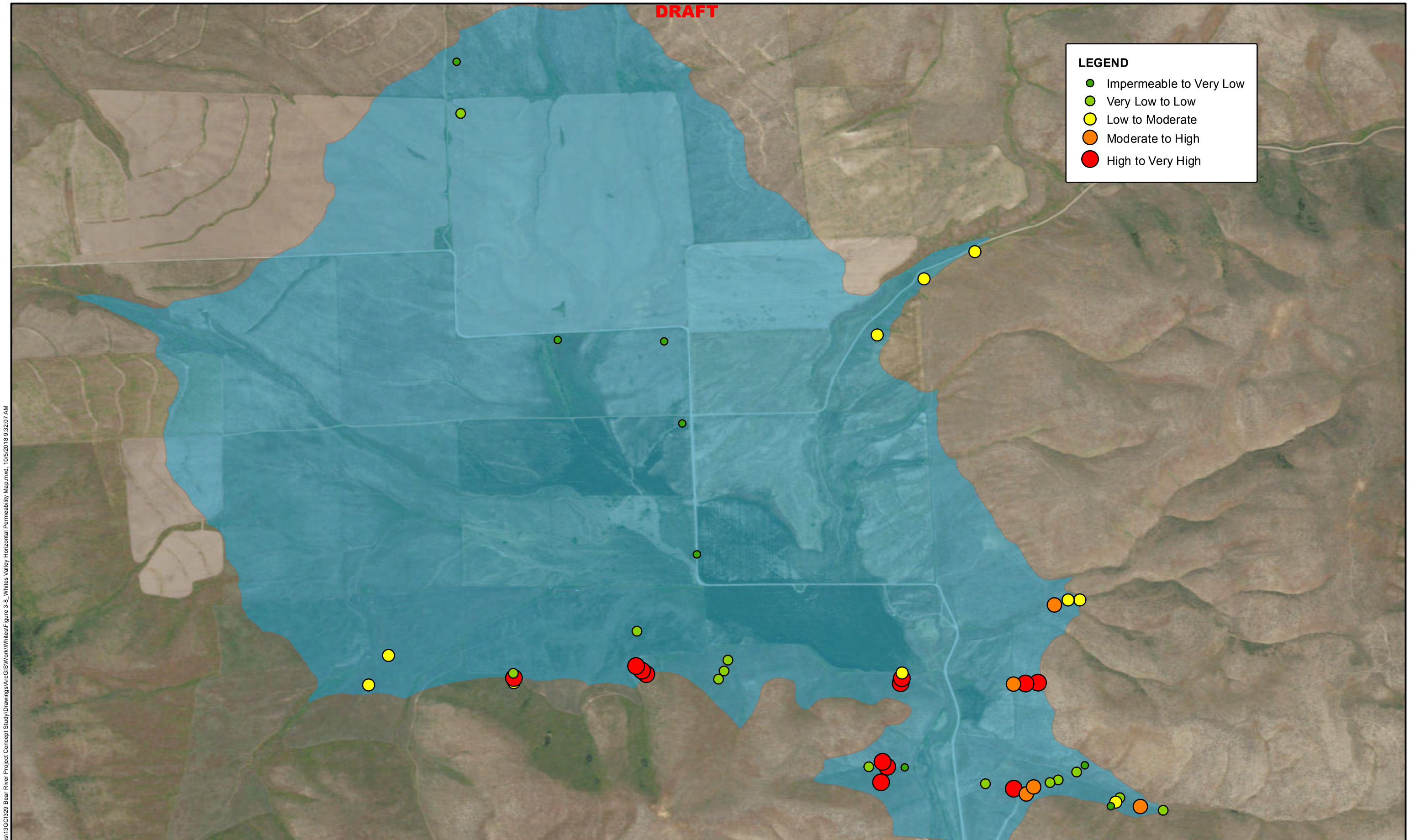
Whites Valley - Weighted Average of Verticall Hydraulic Permeability at Test Pit Locations

N

0 450 900 1,800 Feet

Figure 3-11

J:\PROJECTS\Bowen Collins\13GC\329 Bear River Project Concept Study\Drawings\ArcGIS\Work\Whites\Figure 3-7_Whites Valley Vertical Permeability Map.mxd, 10/5/2018 9:33:17 AM



GERHART COLE

Bear River Project Concept Study

Whites Valley - Weighted Average of Horizontal Hydraulic Permeability at Test Pit Locations

N

0 450 900 1,800 Feet

Figure 3-12

J:\PROJECTS\Bowen Collins\13GC\329 Bear River Project Concept Study\Drawings\ArcGIS\Work\Whites\Figure 3-8_Whites Valley Horizontal Permeability Map.mxd, 10/5/2018 9:32:07 AM

4.1 RECOMMENDATIONS FOR ADDITIONAL STUDIES

We understand that the studies to date have focused on providing the design team with information to study the feasibility of constructing a reservoir at Whites Valley. As stated in our proposals additional studies would follow depending on the findings from the initial studies. We have identified the following as necessary area of additional study for geotechnical and geologic considerations:

- Complete phase 2 of the seepage study that would consist of completing field permeability studies in areas where seepage loses are expected from the initial study. .
- It is anticipated that additional rock coring and test holes will be required prior to moving to final design,

4.2 LIMITATIONS

The assessments and recommendations presented in this document are based on limited field studies and laboratory testing, as well as our understanding of the project's design and manner of construction. If the project's design or manner of construction changes, or if conditions are found later that are different from those described, we should be notified immediately so that we can make revisions as necessary.

This document was prepared solely for the use of the addressee and may not contain sufficient information for other parties or uses.

We represent that our services are performed within the limitations prescribed by our Client, in a manner consistent with the level of care and skill ordinarily exercised by other professional consultants under similar circumstances. No other representation, expressed or implied, and no warranty or guarantee is included or intended. We do not assume responsibility for the accuracy of information provided by others.

Bues, S.S., 1963, Geology of the central Blue Springs Hills: unpublished Ph.D. thesis, UCLA, 1:48:000.

Doelling, H.H., 1980, Geology and mineral resources of Box Elder County: Utah Geological and Mineral Survey Bulletin 115, 251 p., 1:125,000.

Elliott, A.H., and Harty, K.M., 2010, Landslide maps of Utah, Tremonton 30'x60' Quadrangle: Utah Geological Survey Map 246DM, 1:100,000.

Faegri, K., Iversen, J., Kaland, P.E., Krzywinski, K., 1989. Textbook of pollen analysis. 4th edition. Wiley, New York.

Jordan, T.E., Allmendinger, R.W., and Crittenden, M.D., Jr., 1988a, Geologic map of the Howell Quadrangle, Box Elder County, Utah: Utah Geological and Mineral Survey Map 107, 1:24,000.

Jordan, T.E., Crittenden, M.D., Jr., Allmendinger, R.W., and Miller, D.M., 1988b, Geologic map of the Thatcher Mountain Quadrangle, Box Elder County, Utah: Utah Geological and Mineral Survey Map 109, 1:24,000.

Hecker, S., 1993, Quaternary tectonics of Utah with emphasis on earthquake-induced characterization: Utah Geological Survey Bulletin 127, 157 p.

Lund, W.R., Christenson, G.E., Batatian, D.L., and Nelson, C.V., 2016, Guidelines for Evaluating Surface-Fault-Rupture Hazards in Utah, *in* Bowman, S. D., and Lund, W. R. *eds.,* Guidelines for Investigation Geologic Hazards and Preparing Engineering-Geology Reports, with a Suggested Approach to Geologic Hazards Ordinances in Utah: Utah Geological Survey, Circular 122, 217 p, Chapter 3.

McCalpin, J.P., 2009, Paleoseismology, 2nd edition: Elsevier, Chapters 2A, 3, and 9.

McCalpin, J., Robison, R.M., and Garr, J.D., 1992, Neotectonics of the Hansel Valley-Pocatello Valley corridor, northern Utah and southern Idaho, in Gori, P.L., and Hays, W.W., eds., Assessment of regional earthquake hazards and risk along the Wasatch front, Utah: U.S. Geological Survey Professional Paper 1500, p. G1-G18.

Miller, D.M., Crittenden, M.D., Jr., and Jordan, T.E., 1991, Geologic map of the Lampo Junction Quadrangle, Box Elder County, Utah: Utah Geological and Mineral Survey Map 136, 1:24,000.

Miller, D.M., and Phelps, G.A., 2016, The Pilot Valley Shoreline: An Early Record of Lake Bonneville Dynamics, in, Oviatt, C.G., and Shroder, J.F. Jr., eds, Lake Bonneville a Scientific Update: Elsevier, Developments in Earth Surface Processes, vol. 20, p. 60-74.

Murphy, B.E., Beus, S.S., and Oviatt, C.G., 1985, Provisional Geologic Map of the Limekiln Knoll Quadrangle, Box Elder County, Utah: Utah Geological and Mineral Survey, Map 79, 1:24,000.

Oviatt, C.G., 2014, The Gilbert episode in the Great Salt Lake basin, Utah: Utah Geological Survey Miscellaneous Publication 14-3, 20 p.

Oviatt, C.G., 2015, Chronology of Lake Bonneville, 30,000 to 10,000 yr B.P.: Quaternary Science Reviews, 110, p 166-171.

Powers, et al., 2007, Construction Dewatering and Groundwater Control New Methods and Applications, Third Edition, John Wiley and Sons 2007

Stokes, W.L., 1962, Geologic map of northwestern Utah: Utah State Land Board, 1:250,000.

Stuiver, M., Reimer, P.J., and Reimer, R.W., 2017, CALIB Radiocarbon Calibration Version 7.1, accessed online http://calib.org/calib/, 2016-12-6.

U.S. Bureau of Reclamation, 2001, Engineering Geology Field Manual, Second Edition, Volume 1: Technical Service Center, Bureau of Reclamation, U.S. Department of the Interior, accessed online http://www.usbr.gov/pmts/geology/geoman.html

U.S. Geological Survey, 2016, Quaternary fault and fold database of the United States: accessed online http://earthquakes.usgs.gov/hazards/qfaults

Utah Division of Water Rights, 2017, Well Drilling Database: accessed online http://maps.waterrights.utah.gov/EsriMap/map.asp?layersToAdd=wellsearch.

Appendix A

Whites Valley - Test Hole Logs and Core Photographs

Unified Soil Classification System (USCS)

DRAFT

Material Types	Major Soil Divisions		Group Symbol and Legend	Typical Names
COARSE-GRAINED SOILS >50% retained on No. 200 sieve	GRAVELS >50% of coarse fraction retained on No. 4 Sieve	Clean GRAVELS (little or no fines)	GW	Well-Graded GRAVEL, GRAVEL-sand mixtures, few fines
			GP	Poorly-Graded GRAVEL, GRAVEL-sand mixtures, few fines
		GRAVELS with fines (appreciable amount of fines)	GM	Silty GRAVEL, GRAVEL-sand silt mixtures
			GC	Clayey GRAVEL, GRAVEL-sand clay mixtures
	SANDS >50% of coarse fraction passing the No. 4 sieve	Clean SANDS (little or no fines)	SW	Well-Graded SAND, SAND-gravel mixtures, few fines
			SP	Poorly-Graded SAND, SAND-gravel mixtures, few fines
		SANDS with fines (appreciable amount of fines)	SM	Silty SAND, SAND-silt mixtures
			SC	Clayey SAND, SAND-clay mixtures
FINE-GRAINED SOILS >50% Passing No. 200 Sieve	SILTS and CLAYS liquid limit < 50	Inorganic 1) CF > 30%: + Sandy/Gravelly 2) CF = 15-30% + with sand/gravel	CL	Lean CLAY, Gravelly/Sandy CLAY, low to med. plasticity
			ML	SILT, Gravelly/Sandy SILT, no to slight plasticity
		Organic	OL	Organic CLAY or SILT
	SILTS and CLAYS liquid limit < 50	Inorganic 1) CF > 30%: + Sandy/Gravelly 2) CF = 15-30% + with sand/gravel	CH	Fat CLAY, Gravelly/Sandy Fat CLAY, high plasticity
			MH	Elastic SILT, Gravelly/Sandy Elastic SILT, low to high plasticity
		Organic	OH	Organic CLAY or SILT
Highly orgainc soils		Primarily Organic Matter; Organic Odor	PT	PEAT
Boulders / Cobbles		> 50% (by volume) particles > 3"	COBBLES BOULDERS	Boulders (>12"); Cobbles (>3" and <12")

Other Material Symbols

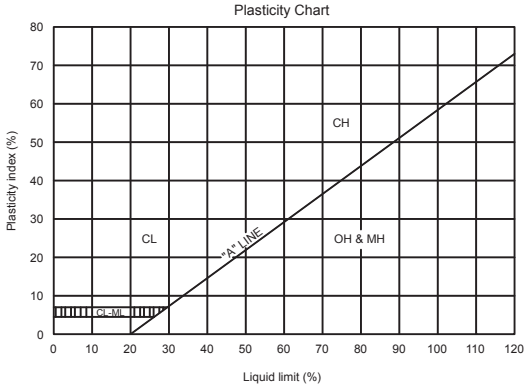
- Bedrock
- Asphalt
- Concrete
- Topsoil
- Fill

Sample Types

- Auger Cuttings
- Continuous sampler
- Grab Sample
- No Recovery
- Shelby Tube
- Standard Penetration Test (SPT)
- California Sampler
- Rock Core
- Modified California Sampler
- Other (see remarks)
- Piston Sampler (Shelby Tube)
- Split Spoon
- Vane Shear

Apparent water level

Measured water level



Descriptors for Coarse Grained Soils

Apparent Density	Dr (%)	SPT	MC	CAL
very loose	0-15	<4	<6	<8
loose	15-35	4-10	6-15	8-20
med. dense	35-65	10-30	15-42	20-56
dense	65-85	30-50	42-72	56-96
very dense	85-100	>50	>72	>96

Descriptors for Fine Grained Soils

Consistency	Su (psf)	SPT	MC	CAL
very soft	< 250	<2	<2	<2
soft	250-500	2-4	2-4	2-5
med. stiff	500-1000	4-8	4-10	5-11
stiff	1000-2000	8-15	10-19	11-22
very stiff	2000-4000	15-30	19-37	22-45
hard	>4000	>30	>37	>45

SPT - Standard split spoon (SPT): 2" OD, 1.375" ID
MC - Modified California: 2.5" OD, 1.875" ID
CAL - California: 3" OD, 2.375" ID

Stratification

Description	Criteria
Seam	1/16" to 1/2"
Layer	1/2" to 12"
Occasional	<= 1 per ft. thickness
Frequent	> 1 per ft. thickness

Modifiers

Description	Est. (%)
Trace	<5
Some	5-12
With	>12

Descriptors for Moisture

Description	Criteria
Dry	Absence of moisture, dusty, dry to the touch
Moist	Damp but no visible water
Wet	Visible free water, usually soil is below water table

Descriptors for Particle Size

Description	Criteria
Boulder	>12" : larger than a basketball
Cobble	3-12" : larger than a grapefruit
Coarse Gravel	3/4-3" : larger than a grape
Fine Gravel	No.4-3/4" : larger than a pea
Coarse Sand	No.10-4 : larger than rock salt grain
Medium Sand	No.40-4 : larger than window screen opening
Fine Sand	No.200-40 : larger than a sugar grain

Descriptios for Particle Angularity

Description	Criteria
Angular	Sharp edges, rel. plane sides, unpolished surface
Subangular	Similar to angular, but with rounded edges
Subrounded	Nearly plane sides, well-rounded corners & edges
Rounded	Smoothly curved sides and no edges

Abbreviated Soil Classification Symbols (after ASTM D2488 X.5)

Prefix	Suffix
s = sandy	s = with sand
g = gravelly	g = with gravel
	c = with cobbles
	b = with boulders

Abbreviated system for supplementary presentations when complete description is referenced. Examples:

Group Symbol and Full Name	Abbreviated
Sandy Lean CLAY (CL)	s(CL)
Poorly Graded SAND with silt and gravel	(SP-SM)g
Poorly Graded GRAVEL with sand, cobbles, and boulders (GP)	(GP)scb
Gravelly SILT with sand and cobbles (ML)	g(ML)sc

General Notes:
1) Strata graphic lines on the logs represent approximate boundaries.
2) No warranty is provided as to the continuity of soil conditions between points explored and sample locations.
3) Logs represent soil conditions observed at the point of exploration on the date indicated.
4) Visual methods were used to classify the materials in general accordance with the Unified Soils Classification Systems; actual designations based on laboratory methods may vary.

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Legend to Soil Descriptions

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KEY TO SOIL AND ROCK CORE LOG

Depth, feet	ROCK CORE						Lithology	MATERIAL DESCRIPTION	Discontinuity Drawing	Discontinuity Type	DISCONTINUITY DESCRIPTION	Point Load Test Results (psi)	Packer Test Intervals	SOIL SAMPLES		FIELD NOTES
	Run No.	Recovery, %	RQD, %	Fractures Density	Weathering	Hardness								Type Number	Sampling Resistance	
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17

COLUMN DESCRIPTIONS

1 DEPTH: Distance (in feet) below the collar of the borehole.

2 RUN NO.: Number of the individual coring interval.

3 RECOVERY: Rock Coring: Amount (in percent) of core recovered from the coring interval; calculated as length of core recovered divided by length of run. Actual soil recovery in driven sampler as a percentage of the sampler penetration.

Soil/Rock Sampling: Ratio of sample length to recovered sample amount.

4 RQD: (Rock Quality Designation) Amount (in percent) of intact core (pieces of sound core greater than 4 inches in length) in each coring interval; calculated as the sum of lengths of intact core divided by length of core run. RQD of moderately weathered / altered rock does not meet soundness requirements, but provides some indication of rock quality with respect to the degree of fracturing.

5 FRACTURES DENSITY: (Fracture Frequency) The density of naturally occurring fractures in each foot of core; does not include mechanical breaks (induced by drilling) or healed fractures. See Sheet 2 for explaination and additional information. "NA" indicates not applicable due to lack of core recovery.

6 WEATHERING: The process of chemical or mechanical degradation of rock. See Sheet 2 for additional information.

7 HARDNESS: See Sheet 2 for explanation and additional information.

8 LITHOLOGY: A graphic log of material encountered using symbols to represent differing soil and types; graphic symbols are explained below.

9 DESCRIPTION: Rock: Lithologic description in this order: rock type, grain size, texture, color, strength, and other features; descriptive terms are defined on the attached sheets and tables. A detailed description of overburden material is not necessarily provided.

Soil or weathered rock: See sheet 2 for explanation and additional information.

10 DISCONTINUITY DRAWING: Sketch of the naturally occurring fractures and mechanical breaks, showing the angle of the fractures relative to the cross-sectional axis of the core. Intensely fractured material are not included in fractured drawings (see core photos, if available). "NR" indicates no recovery.

11 DISCONTINUITY TYPE: See Sheet 2 for explanation and additional Information

12 DISCONTINUITY DESCRIPTION: Orientation, Surface Shape, Roughness, Aperture, Filling Thickness, Filling Type, See Sheet 2 for explanation and additional Information

13 POINT LOAD TEST RESULTS: The testing results from point load tests.

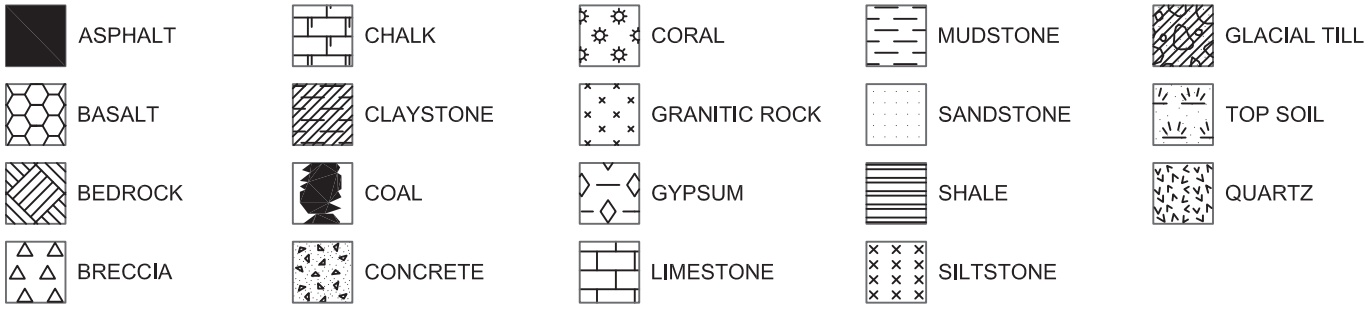
14 PACKER TEST INTERVALS: Testing permeability and water sampling in different regions of test hole by isolation of depths using inflatable packers or bladders.

15 SAMPLE TYPE \ NUMBER: Type of soil sample collected at depth interval shown; sampler symbols are explained below. Sample identification number.

16 SAMPLING RESISTANCE.: Number of blows to advance driven sampler each 6-inch drive interval, or distance noted, using a 140-lb hammer with a 30-inch drop (unless otherwise noted).

17 FIELD NOTES: Comments an observation regarding drilling or sampling made by driller or field personnel.

TYPICAL MATERIAL GRAPHIC SYMBOLS FOR ROCK



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LEGEND TO
SOIL & ROCK DESCRIPTIONS
SHEET 1 OF 2

KEY TO SOIL AND ROCK CORE LOG

DRAFT

ROCK WEATHERING / ALTERATION

Weathering descriptors (Extracted from USBR, 2001)

Descriptors		Diagnostic features					
		Chemical weathering - Discoloration and/or oxidation		Mechanical weathering Grain boundary conditions (disaggregation) primarily for granitics and some coarse grained sediments	Texture and solutioning		
Alpha numeric descriptor	Descriptive term	Body of rock	Fracture surfaces[2]		Texture	Solutioning	General characteristics (strength, excavation, etc.)[3]
W1	Fresh	No discoloration, not oxidized	No discoloration or oxidation	No separation, intact (tight)	No change	No solutioning	Hammer rings when crystalline rocks are struck. Almost always rock excavation except for naturally weak or weakly cemented rocks such as siltstones or shale.
W2	Slightly Weathered to Fresh[1]						
W3	Slightly Weathered	Discoloration or oxidation is limited to surface of, or short distance from fractures; some feldspar crystals are dull.	Minor to complete discoloration or oxidation of most surfaces.	No visible separation, intact (tight).	Preserved.	Minor leaching of some soluble minerals may be noted.	Hammer rings when crystalline rocks are struck. Body of rock not weakened. With few exceptions, such as siltstones or shales, classifies as rock excavation.
W4	Moderately to Slightly Weathered[1]						
W5	Moderately Weathered	Discoloration or oxidation extends from fractures, usually throughout; Fe-Mg minerals are "rusty," feldspar crystals are "cloudy."	All fracture surfaces are discolored or oxidized.	Partial separation of boundaries visible.	Generally preserved.	Soluble minerals may be mostly leached.	Hammer does not ring when rock is struck. Body of rock is slightly weakened. Depending on fracturing, usually is rock excavation except in naturally weak rocks such as siltstone or shales.
W6	Intensely to Moderately Weathered[1]						
W7	Intensely Weathered	Discoloration or oxidation throughout; all feldspars and Fe-Mg minerals are altered to clay to some extent; or chemical alteration produces in situ disaggregation, see grain boundary conditions	All fracture surfaces are discolored or oxidized, surfaces friable.	Partial separation, rock is friable; in semiarid conditions granitica are disaggregated.	Texture alerted by chemical disintegration (hydration, argillation).	Leaching of soluble minerals may be complete.	Dull sound when struck with hammer; usually can be broken with moderate to heavy manual pressure or by light hammer blow without reference to planes of weakness such as incipient or hairline fractures, or veinlets. Rock is significantly weakened. Usually common excavation.
W8	Very Intensely Weathered						
W9	Decomposed	Discolored or oxidized throughout, but resistant minerals such as quartz may be unaltered; all feldspar and FE-Mg minerals		Complete separation of grain boundaries (disaggregated).	Resembles a soil, partial or complete remnant rock structure may be preserved; leaching of soluble minerals usually complete.		Can be granulated by hand. Always common excavation. Resistant minerals such as quartz may be present as "stringers" or "dikes."

Note: This chart and its horizontal categories are more readily applied to rocks with feldspars and mafic minerals. Weathering in various sedimentary rocks, particularly limestones and poorly indurated sediments, will not always fit the categories established. This chart and weathering categories may have to be modified for particular site conditions or alteration such as hydrothermal effects; however, the basic framework and similar descriptors are to be used.

1) Combination descriptors are permissible where equal distribution of both weathering characteristics are present over significant intervals or where characteristics present are "in between" the diagnostic feature. However, dual descriptors should not be used where significant, identifiable zones can be delineated. When given as a range, only two adjacent terms may be combined (i.e., decomposed to lightly weathered or moderately weathered to fresh) are not acceptable.

2) Does not include directional weathering along shears or faults and their associated features. For example, a shear zone that carried weathering to great depths into a fresh rock mass would not require the rock mass to be classified as weathered.

3) These are generalization and should not be used as diagnostic features for weathering or excavation classification. These characteristics vary to a large extent based on naturally weak materials or cementation and type of excavation.

ROCK HARDNESS

Rock Hardness/strength descriptors (Extracted from USBR, 2001)

Alpha numeric descriptor	Descriptor	Criteria
H1	Extremely hard	Core, fragment, or exposure cannot be scratched with knife or sharp pick; can only be chipped with repeated heavy hammer blows.
H2	Very hard	Cannot be scratched with knife or sharp pick. Core or fragment breaks with repeated heavy hammer blows.
H3	Hard	Can be scratched with knife or sharp pick with difficulty (heavy pressure). Heavy hammer blow required to break specimen.
H4	Moderately hard	Can be scratched with knife or sharp pick with light or moderate pressure. Core or fragment breaks with moderate hammer blow
H5	Moderately soft	Can be grooved 1/16 inch (2 mm) deep by knife or sharp pick with moderate or heavy pressure. Core or fragment breaks with light hammer blow or heavy manual pressure.
H6	Soft	Can be grooved or gouged easily by knife or sharp pick with light pressure, can be scratched with fingernail. Breaks with light to moderate manual pressure.
H7	Very soft	Can be readily indented, grooved or gouged with fingernail, or carved with a knife. Breaks with light manual pressure.
Any bedrock unit softer than H7, is to be described using USBR 5000 consistency descriptors		

Note: Although "sharp pick" is included in these definitions, descriptions of ability to be scratched, grooved, or gouged by a knife is the preferred criteria.

11 Discontinuity Type:

Fa - Fault
Jo - Joint
Sh - Shear
Fo - Foliation
V - Vein
Be - Bedding
Me - Mechanical break

12 DISCONTINUITY DESCRIPTIONS

a Orientation, Angle perpendicular to core

b Surface Shape of Joint:

Pl - Planer
Wa - Wavy
St - Stepped
Ir - Irregular

c Roughness of Surface:

Fracture roughness descriptors (Extracted from USBR, 2001)

Alpha numeric descriptor	Descriptor	Criteria
R1	Stepped	Near-normal steps and ridges occur on the fracture surface
R2	Rough	Large angualr asperities can be seen.
R3	Moderately rough	Asperities are clearly visible and fracture surface feels abrasive.
R4	Slightly rough	Small asperities on the fracture surface are visible and can be felt
R5	Smooth	No asperities, smooth to the touch
R6	Polished	Extremely smooth and shiny.

d Aperture:

Fracture openness descriptors (Extracted from USBR, 2001)

Alpha numeric descriptor	Descriptor	Criteria
O0	Tight	No visible separation
O1	Slightly open	Less than 0.003 ft [1/32 inch (in)] (<1 mm)
O2	Moderately open	0.003 to 0.01 ft [1/32 in to 1/8 in] (1 to 3 mm)
O3	Open	0.01 to 0.03 ft [1/8 to 3/8 in] (3 to 10 mm)
O4	Moderately wide	0.03 ft [3/8' to 0.1 ft (10 to 30 mm)
O5	Wide	Greater than 0.1 ft (>30 mm) (record actual openness)

e Filling Thickness:

Fracture filing thickness (Extracted from USBR, 2001)

Alpha numeric descriptor	Descriptor	Criteria
T0	Clean	No film coating
T1	Very thin	Less than 0.003 ft [1/32 in] (<1 mm)
T2	Moderately thin	0.003 to 0.01 ft [1/32 to 1/8 in] (1 to 3
T3	Thin	0.01 to 0.03 ft [1/8 to 3/8 in] (3 to 10
T4	Moderately thick	0.03 ft [3/8 in] to 0.1 ft (10 to 30 mm)
T5	Thick	Greater than 0.1 ft (>30 mm) (record actual thickness)

f Filling Type:

Ca - Clay
Ca - Calcite
Fe - Iron Oxide
Gy - Gypsum

U.S. Bureau of Reclamation, 2001, Engineering Geology Field Manual, Second Edition, Volume 1: Technical Service Center, Bureau of Reclamation, U.S. Department of the Interior.

GERHART COLE

LEGEND TO
SOIL & ROCK DESCRIPTIONS
SHEET 2 OF 2

DRAFT

Project: Bear River Project Concept Study
Project Location: Whites Valley
Project Number: 13GCI329

Log of Test Hole 15-TH-WV-01

Date(s) Drilled	8/10/15-8/24/15	Logged By	E. Lips	Checked By	P. Gerhart
Drilling Method	ODEX/Rotary Wash/HQ3	Drill Bit Size/Type	3.83" HQ-3 6FM	Total Depth Drilled (feet)	115.5
Drill Rig Type	CME 75	Drilling Contractor	Bedke Geotechnical F.S.	Hammer Weight/ Drop(lbs/in.)	Automatic Trip Hammer
Apparent Groundwater Depth		Latitude / Longitude	41.84604, -112.31765	Ground Surface Elevation (feet)	5191.7
Test Hole Backfill	Benonite Grout	Comments		Elevation Datum	NAVD88

Depth (feet)	ROCK CORE: Run No.	Recovery,%	R Q D, %	Fracture Density	Weathering	Hardness	Lithology	MATERIAL DESCRIPTION	Discontinuity Drawing	Discontinuity Type	DISCONTINUITY DESCRIPTION	Point Load Test Results (psi)	Packer Test Intervals	SOIL SAMPLES: Type	Number	Sampling Resistance	FIELD NOTES
0								CALCAREOUS SANDSTONE, fine grained to very fine grained, well sorted, light brown to light gray, thiny bedded to moderately bedded, moderately hard to hard, contacts sharp with few thin interbeds shale. Intensely weathered at surface, weathering decreases with depth. (Oquirrh Formation, (PPo)									Description from outcrop at cut in hill slope. TH-WV-01 approximately 5 feet below origninal ground surface at top of bedrock.
1															Grab 1		
2																	
3															Grab 2		
4																	
5															Grab 3		
6															SPT-1	20-22-33 [55]	
7																	
8																	
9																	
10															SPT-2	30-34-48 [82]	
11																	
12																	
13																	
14																	
15															SPT-3	40-50/2" [R]	
16																	
17																	
18																	
19																	
20																	

NEW ROCK CORE LOG TH_LOGS_#2_BEAR_RIVER.GPJ GERHART.GDT 9/23/15

GERHART COLE

DRAFT

Project: Bear River Project Concept Study
Project Location: Whites Valley
Project Number: 13GCI329

Log of Test Hole 15-TH-WV-01

Depth (feet)	ROCK CORE: Run No.	Recovery,%	R Q D, %	Fracture Density	Weathering	Hardness	Lithology	MATERIAL DESCRIPTION	Discontinuity Drawing	Discontinuity Type	DISCONTINUITY DESCRIPTION	Point Load Test Results (psi)	Packer Test Intervals	SOIL SAMPLES: Type	Number	Sampling Resistance	FIELD NOTES
20								SANDSTONE, (broken into SAND, gravelly), with layers of siltstone and shale - very dense, dry, light brown, noncalcaerous.							SPT-4	26-49-38 [87]	
21																	
22																	
23																	
24																	
25																	ODEX to 25 feet then switch to rotary wash with a tricone bit,
26																	
27																	
28																	
29																	
30								SANDSTONE, light brown to yellow, loose friable interbeds of gray shale and yellow siltstone							SPT-5	37-43 -50/4" [R]	
31																	
32																	
33																	
34																	
35								SANDSTONE, as above, with thin layer of hard fine grained sandstone, very few interbeds of shale.							SPT-6	38-42 -50/2" [R]	
36																	
37																	
38																	
39																	
40															SPT-7	46-34-35 [69]	
41																	
42																	
43																	
44																	

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Project: Bear River Project Concept Study
Project Location: Whites Valley
Project Number: 13GCI329

Log of Test Hole 15-TH-WV-01

Depth (feet)	ROCK CORE: Run No.	Recovery, %	R Q D, %	Fracture Density	Weathering	Hardness	Lithology	MATERIAL DESCRIPTION	Discontinuity Drawing	Discontinuity Type	DISCONTINUITY DESCRIPTION	Point Load Test Results (psi)	Packer Test Intervals	SOIL SAMPLES: Type	Number	Sampling Resistance	FIELD NOTES
45								Interbedded sandstone and shale. Sandstone light brown to yellow, friable, shale, very thinly bedded gray and yellow									
46															SPT-8	22-39-39 [78]	
47																	
48																	
49																	
50																	
51															SPT-9	39-50/5" -50/4" [0]	
52																	
53																	
54																	
55															SPT-10	50/2" [R]	
56																	
57																	
58																	
59																	
60								Gray calcareous sandstone in cuttings							SPT-11	100/2" [R]	Slow drilling from 60 to 65 feet
61																	
62																	
63																	
64																	
65				FD-7				CALCAREOUS SANDSTONE, fine grained to very fine frained, gray, thinly bedded		JO JO	80-90°, PL, R4, O1, T1 65-70°, PL, R4, O1, T1						Switched to HQ core drilling
66	1	100	39	FD-7	W1	H3				JO JO	18°, PL, R4 15°, PL, R4						
67				FD-6						JO	80°, PL, R4	2904					
68	2	100	30	FD-6	W1	H4											
69										JO	70-80°, PL, R4						

NEW ROCK CORE LOG TH LOGS #2 BEAR RIVER.GPJ GERHART.GDT 9/24/15

GERHART COLE

DRAFT

Project: Bear River Project Concept Study
Project Location: Whites Valley
Project Number: 13GCI329

Log of Test Hole 15-TH-WV-01

Depth (feet)	ROCK CORE Run No.	Recovery,%	R Q D, %	Fracture Density	Weathering	Hardness	Lithology	MATERIAL DESCRIPTION	Discontinuity Drawing	Discontinuity Type	DISCONTINUITY DESCRIPTION	Point Load Test Results (psi)	Packer Test Intervals	SOIL SAMPLES Type	Number	Sampling Resistance	FIELD NOTES
				FD-7						JO	15°, PL, R5, O1, T1, CL, CA						
70				FD-7						ME							
71	2	100	30	FD-7	W1	H4				JO	20-25°, PL, R4						
				FD-7						JO	80-90°, PL, R4						
72				FD-7						JO	15-20°, PL, R5, O1, T1, CL, CA						
										JO	15-20°, PL, R5, O1, T1, CL						
73				FD-7													
74				FD-6						JO	80-90°, ST, R4, O1						
75	3	100	22	FD-7	W1	H4				JO	15-20°, PL, R4, O1, T1, CL, CA						
76				FD-7						JO	15-20°, PL, R4, O1, T1, CL, CA						
77				FD-7						JO	70-80°, ST, R4						
										ME							
78				FD-8						JO	80-90°, PL, R4	4015					
79				FD-8						JO	80-90°, ST, R4, O1, T1, CL, CA						
80	4	88	0	FD-8	W1	H4				JO	45-50°, PL, R4						
81				FD-8						JO	NUMEROUS 15-20°, PL, R4						
										JO	45-50°, PL, R4, O2, T2, CA						
82				FD-8													
83	5	100	0	FD-8	W1	H4				JO	15-20°, PL, O3, T3, CA						
84				FD-7						JO	15-25°, PL, O1-O3, T1-T3, CA						
85				FD-8													
86	6	69	12	FD-7	W1	H4											
87				FD-7						JO	70-90°, ST						
										JO	90°, ST, R4, O2, T2, CA						
88				FD-9						JO	15-25°, PL, R4, O1, T1, CA						
89				FD-8							RUBBLE						
90	7	87	0	FD-8	W1	H4											
91				FD-8						JO	10°, PL, R4, O1, T1,CA						
92				FD-8						JO	10-15°, PL, R4, O1, T1, CA						
										JO	80-90°, ST, R5, O1, T1, CA						
93	8	97	22	FD-7	W1	H3				ME		3258					

GERHART COLE

DRAFT

Project: Bear River Project Concept Study
Project Location: Whites Valley
Project Number: 13GCI329

Log of Test Hole 15-TH-WV-01

Depth (feet)	ROCK CORE Run No.	Recovery, %	R Q D, %	Fracture Density	Weathering	Hardness	Lithology	MATERIAL DESCRIPTION	Discontinuity Drawing	Discontinuity Type	DISCONTINUITY DESCRIPTION	Point Load Test Results (psi)	Packer Test Intervals	SOIL SAMPLES Type	Number	Sampling Resistance	FIELD NOTES
94				FD-7						JO	70-90°, PL, R4, O1, T1, CA						
95				FD-7						JO	15-20°, PL, R5, O2, T2, CA						
96	8	97	22	FD-7	W1	H3				JO JO	10-15°, PL, R4, O1, T1, CA 70-90°, ST, R5, O1-O2, T1-T2, ca						
97				FD-7						ME JO	10-15°, PL, R4, O1, T1, CA						
98										JO	90°, ST, R3, O2, T2, CL						
99				FD-8													
100	9	75	7	FD-8	W1	H4					RUBBLE						
101				FD-7													
102				FD-8	W1	H4				JO JO JO	15°, PL, R3 80-90°, ST, R5, O3, T1, CA 10-15°, PL, R3-R4, O1, T1, CL						
103				FD-7				Increasing shale interbeds, thin, gray to yellow		JO	80-90°, ST, R5, O3, T1, CA, CL						
104				FD-6						JO	20°, PL, R4, O1, T1, CA, CL	4833					
105	10	86	8	FD-6						JO	10-15°, PL, R4, O2, T2, CA, CL						
106				FD-6						JO	60-90°, ST, R4, O1, T1, CA						
107				FD-7						ME							
108				FD-8						JO	10-15°, PL, R4, O1, T1, CA						
109				FD-7						JO	30°, PL, R5, CL, CA						
110	11	95	0	FD-7	W1	H4				JO	10-15°, PL, R4, O0-O1, TO-T1, CL, CA						
111				FD-8						JO	70-90°, ST, R5, O2, T1, CL, CA						
112				FD-8	W1	H4											
113				FD-8													
114	12	68	0	FD-8						JO JO	80-90°, CL, CA 15°, PL, O2, T2, CA, CL						
115										JO	50-65°, PL, R4, O2, T1, CL, CA						
116								Bottom of Test Hole at 115.5 feet.									
117																	
118																	

NEW ROCK CORE LOG TH_LOGS #2_BEAR_RIVER.GPJ GERHART.GDT 9/24/15

GERHART COLE

DRAFT

Project: Bear River Project Concept Study
Project Location: Whites Valley
Project Number: 13GCI329

Log of Test Hole 14-TH-WV-02

Date(s) Drilled	11/5/14-11/7/14, 11/18/14, 11/20/14-11/21/14	Logged By	E. Lips/ R. Buhler	Checked By	P. Gerhart
Drilling Method	Rotary Wash/HQ3	Drill Bit Size/Type	3.83" HQ-3 6FM	Total Depth Drilled (feet)	98.0
Drill Rig Type	CME 75	Drilling Contractor	Bedke Geotechnical F.S.	Hammer Weight/ Drop(lbs/in.)	Automatic Trip Hammer
Apparent Groundwater Depth	None measured; 6/11/2015	Latitude / Longitude	41.84597, -112.31896	Ground Surface Elevation (feet)	5046.8
Test Hole Backfill	Piezometer Well	Comments		Elevation Datum	NAVD88

Depth (feet)	ROCK CORE: Run No.	Recovery,%	R Q D, %	Fracture Density	Weathering	Hardness	Lithology	MATERIAL DESCRIPTION	Discontinuity Drawing	Discontinuity Type	DISCONTINUITY DESCRIPTION	Point Load Test Results (psi)	Packer Test Intervals	SOIL SAMPLES: Type	Number	Sampling Resistance	FIELD NOTES
0								SILT, medium to soft, sandy with trace gravel, fine sand, moist, brown, (ML)									
1																	
2																	
3								Thin gravel layer at 2.5 ft.									
4								Thin gravel layer at 4 ft.									
5															SPT-1	4-4-5-5 [9]	
6																	
7																	
8																	
9																	
10															SPT-2	5-4-4-4 [8]	
11																	
12																	
13								SAND, loose, silty and gravelly, fine to coarse sand, fine to medium gravel, wet, brown, (SM)									
14																	
15															SPT-3	0-0-7-5 [7]	
16																	
17																	
18																	
19																	
20															SPT-4	8-4-5-4	

NEW ROCK CORE LOG TH_LOGS_#2_BEAR_RIVER.GPJ GERHART.GDT 9/23/15

GERHART COLE

DRAFT

Project: Bear River Project Concept Study
Project Location: Whites Valley
Project Number: 13GCI329

Log of Test Hole 14-TH-WV-02

Sheet 2 of 5

Depth (feet)	ROCK CORE Run No.	Recovery,%	RQD, %	Fracture Density	Weathering	Hardness	Lithology	MATERIAL DESCRIPTION	Discontinuity Drawing	Discontinuity Type	DISCONTINUITY DESCRIPTION	Point Load Test Results (psi)	Packer Test Intervals	SOIL SAMPLES Type	Number	Sampling Resistance	FIELD NOTES
20																	
21														SPT-4		[9] 8-4-5-4 [9]	
22																	
23								GRAVEL, medium dense, silty with sand, fine to medium gravel, fine to coarse sand, wet, brown, (GM)									
24																	
25								CALCAREOUS SANDSTONE/SANDY LIMESTONE, fine grained, gray, calcareous, thin to very thin bedded, (OQUIRRH FORMATION, PPo)		JO	85°, PL, R2, O2, T2, CA & CL			SPT-5		12-30 -50/4" [R]	
26	1	72	10		W1	H3-H4				JO	85°, PL, R2, O2, T2, CA & CL						
27										BE ME ME	25°, PL, R5, O0, T0						
28				FD7													
29				FD8						BE	15°, PL, R4, CL & CA						
30	2	83	18	FD6	W1	H3-H4				BE	3-17°, PL, R4, CL & CA						
31				FD7						BE	12°, PL, R4, CL & CA						
32										BE	Numerous Be						
33				FD8						JO	82°, PL, R4-R5, T2, CL						
34				FD8						BE	15°, PL, R4, CL						
35	3	82	15	FD7	W1	H3-H4				BE	Numerous ~15-17°, PL, R4, O0-O2, T0-T2, CA & CL						
36				FD5						JO	70-85°, Wa, R4, O2, T1, CL						
37																	
38																	
39																	
40	4	0	0														
41																	
42				FD4													
43				FD4						BE	15°, PL, R4						
44	5	100	74		W1	H3-H4											

NEW ROCK CORE LOG TH_LOGS_#2_BEAR_RIVER.GPJ GERHART.GDT 9/23/15

GERHART COLE

DRAFT

Project: Bear River Project Concept Study
Project Location: Whites Valley
Project Number: 13GCI329

Log of Test Hole 14-TH-WV-02

Depth (feet)	Run No.	Recovery, %	R Q D, %	Fracture Density	Weathering	Hardness	Lithology	MATERIAL DESCRIPTION	Discontinuity Drawing	Discontinuity Type	DISCONTINUITY DESCRIPTION	Point Load Test Results (psi)	Packer Test Intervals	SOIL SAMPLES Type	SOIL SAMPLES Number	SOIL SAMPLES Sampling Resistance	FIELD NOTES
45				FD3						BE	18°, PL, R4						
				FD5				(CONT.) SANDSTONE/SANDY LIMESTONE, fine grained, light gray to tan, calcareous, thin to very thin bedded, (OQUIRRH FORMATION, PPo)									
46	5	100	74	FD7	W1	H3-H4				BE	15°, PL, R4						
47										BE	14°, PL, R4						
48										JO	70-90°, Wa, R5						
				FD6													
49										JO	60°, PL, R5,						
				FD6				@ 49.3 ft, 3 inch bed of limestone and sandstone gravel		ME							
50										BE	15°, PL						
	6	80	27	FD4	W1	H3-H4				JO	80-90°, Wa, R4						
51								@ 51 ft, 3 inch bed of sandstone and sandy limestone gravel with sand and clay		JO	90-30°, Wa, O0-1						
				FD6						JO	60°, PL, R4						
52				FD4						JO	65°, PL, R4, O0-1						
53								@52.6 ft, 2 inch bed of sandstone and sandy limestone gravel with sand and clay		ME							
				FD3													
54										ME							
				FD3						ME	Me on bedding						
										JO	30°, PL, R5, O0						
55	7	100	67	FD4	W1	H3-H4				JO	60°, PL, R5, O1-2, T1-2, CA						
56										ME							
				FD5						JO	60°, PL, R5						
57				FD5				@57.2 ft, 3 inch bed of clayey sandstone and sandy limestone and sand		ME							
										ME							
58												2086					
				FD6													
59										JO	30°, Wa						
				FD7													
60						H7											
	8	93	48	FD5	W1	H3-H4		@ 60 ft, 1 foot bed of clayey sandstone and sandy limestone gravel, highly decomposed and fractured									
61					W1	H3-H4											
				FD5						JO	80°, Wa, R4, CA & CL						
62																	
				FD7													
63										BE	8°, Wa, R4, CA & CL						
				FD5													
64										ME							
				FD5													
65										BE	12°, St, R3, T2, CA & CL						
	9	100	73	FD4	W1	H3-H4				BE	20°, Wa, R3, T1-T2, CA & CL						
66										BE	20°, St, R3, T2, CA & CL						
				FD5													
67										BE	18°, Wa, R3, T1						
				FD6													
										JO	45°, Wa, R3						
68																	
	10	100	67	FD5	W1	H3-H4		@ 68 ft, 3 inch bed of fine angular sandstone and sandy limestone gravel,		JO	80°, Wa, R3, T1						
										BE	10°, St, R3						
69																	

NEW ROCK CORE LOG TH_LOGS #2_BEAR_RIVER.GPJ GERHART.GDT 9/23/15

GERHART COLE

DRAFT

Project: Bear River Project Concept Study
Project Location: Whites Valley
Project Number: 13GCI329

Log of Test Hole 14-TH-WV-02

Depth (feet)	ROCK CORE Run No.	Recovery, %	R Q D, %	Fracture Density	Weathering	Hardness	Lithology	MATERIAL DESCRIPTION	Discontinuity Drawing	Discontinuity Type	DISCONTINUITY DESCRIPTION	Point Load Test Results (psi)	Packer Test Intervals	SOIL SAMPLES Type	Number	Sampling Resistance	FIELD NOTES
				FD5				some silt		JO BE	70°, Wa, T4, CL & CA 20°, St, CL						
70				FD6				(CONT.) SANDSTONE/SANDY LIMESTONE, fine grained, light gray to tan, calcareous, thin to very thin bedded, (OQUIRRH FORMATION, PPo) @ 72.1 ft, 4 inch bed of fine angular sandstone and sandy limestone gravel, some silt		BE	20°, R3, T1						
71	10	100	67	FD7	W1	H3-H4				JO	80-90°, Wa, R2						
72				FD4						JO JO BE	40°, Wa, R3 80°, Wa, R3						
73				FD5						BE	5°, Wa, R3, CA & CL						
74				FD3						JO BE BE	80-90°, Wa, R3, T1, CA & CL 10° 10°, Wa, R3, CL						
75	11	100	82	FD3	W1	H3-H4											
76				FD5													
77				FD5						BE	18°, Wa, R3, CA & CL						
78				FD7						BE JO	10°, Wa, R3 80-90°, R3						
79				FD7						JO	60°, Wa, R3, CA & CL						
80	12	100	50	FD7	W1	H3-H4					Clay filling T3-T4,						
81				FD5						JO JO	60-90°, R3, Wa, CA & CL 80°, R3, Wa						
82				FD5						ME JO	75°, R3, Wa, T1, CA & CL						
83				FD5						JO BE BE	75-90°, Wa, R3, CA & CL 10°, R3, Wa, CL 10°, R3, Wa						
84				FD6													
85	13	100	58	FD5	W1	H3-H4											
86				FD5						JO	80-90°, Wa, R3, CA & CL						
87				FD5						JO ME JO	70°, Wa, R3, 90°, R3, T2, CA & CL						
88				FD5						JO JO ME JO BE	70°, PL, R5 90°, PL, R5 75-90°, St, R5, O1, T1, CA 12°	2280					
89				FD3													
90	14	95	47	FD5	W1	H3-H4				ME JO BE JO	70°, St, O0, 15°, 50-90°, St, R5, O1-O2, T1-T2, CA						
91				FD5													
92				FD5						JO	85°, PL, R3, CA						
93	15	102	35	FD6													

NEW ROCK CORE LOG TH_LOGS #2_BEAR_RIVER.GPJ GERHART.GDT 9/23/15

GERHART COLE

DRAFT

Project: Bear River Project Concept Study
Project Location: Whites Valley
Project Number: 13GCI329

Log of Test Hole 14-TH-WV-02

Depth (feet)	ROCK CORE: Run No.	Recovery, %	R Q D, %	Fracture Density	Weathering	Hardness	Lithology	MATERIAL DESCRIPTION	Discontinuity Drawing	Discontinuity Type	DISCONTINUITY DESCRIPTION	Point Load Test Results (psi)	Packer Test Intervals	SOIL SAMPLES: Type	Number	Sampling Resistance	FIELD NOTES
94								(CONT.) SANDSTONE/SANDY LIMESTONE, fine grained, light gray to tan, calcareous, thin to very thin bedded, (OQUIRRH FORMATION, PPo)		JO	50°, PL, R5, CA						
				FD5						JO	90°, PL, R3, CA						
95										ME							
										ME							
				FD4						JO	85°, PL						
96	15	102	35							ME							
										JO	90°, PL, R5, CA, CL						
				FD4						ME	15°, PL, R5						
97										BE							
										JO	73°, PL, R3, CA, CL	2213					
										BE	14°, PL, R5						
98										ME							
								Bottom of Test Hole at 98 feet.									
99																	
100																	
101																	
102																	
103																	
104																	
105																	
106																	
107																	
108																	
109																	
110																	
111																	
112																	
113																	
114																	
115																	
116																	
117																	
118																	

GERHART COLE

DRAFT

Project: Bear River Project Concept Study **Project Location:** Whites Valley **Project Number:** 13GCI329	**Log of Test Hole 15-TH-WV-03** Sheet 1 of 5

Date(s) Drilled	6/8/15-6/19/15	Logged By	R. Buhler	Checked By	P. Gerhart
Drilling Method	Rotary Wash/HQ3	Drill Bit Size/Type	3.83" HQ-3 6FM	Total Depth Drilled (feet)	95.0
Drill Rig Type	CME 75	Drilling Contractor	Bedke Geotechnical F.S.	Hammer Weight/ Drop(lbs/in.)	
Apparent Groundwater Depth		Latitude / Longitude	41.84607, -112.32051	Ground Surface Elevation (feet)	5048.1
Test Hole Backfill	Benonite Grout	Comments	Angled Hole at 20 degrees from Vertical; Azimuth 275°	Elevation Datum	NAVD88

Depth (feet)	ROCK CORE: Run No.	Recovery,%	R Q D, %	Fracture Density	Weathering	Hardness	Lithology	MATERIAL DESCRIPTION	Discontinuity Drawing	Discontinuity Type	DISCONTINUITY DESCRIPTION	Point Load Test Results (psi)	Packer Test Intervals	SOIL SAMPLES: Type	Number	Sampling Resistance	FIELD NOTES
0								DRILLED THROUGH OVERBURDEN - Based on Drill action - Loose or soils from surface to approximately 20 feet, 20 to 29.4 ft gravels or possible weather bedrock									Rotary Wash Drilling with casing to 29.4 ft.
1																	
2																	
3																	
4																	
5																	
6																	
7																	
8																	
9																	
10																	
11																	
12																	
13																	
14																	
15																	
16																	
17																	
18																	
19																	
20																	

NEW ROCK CORE LOG TH_LOGS_#2_BEAR_RIVER.GPJ GERHART.GDT 9/23/15

GERHART COLE

DRAFT

Project: Bear River Project Concept Study
Project Location: Whites Valley
Project Number: 13GCI329

Log of Test Hole 15-TH-WV-03

Depth (feet)	ROCK CORE: Run No.	Recovery, %	R Q D, %	Fracture Density	Weathering	Hardness	Lithology	MATERIAL DESCRIPTION	Discontinuity Drawing	Discontinuity Type	DISCONTINUITY DESCRIPTION	Point Load Test Results (psi)	Packer Test Intervals	SOIL SAMPLES: Type	Number	Sampling Resistance	FIELD NOTES
20																	
21																	
22																	
23																	
24																	
25																	
26																	
27																	
28																	
29																	
30				FD9				CALCAREOUS SANDSTONE/SANDY LIMESTONE, fine grained, gray, calcareous, thin to very thin bedded, (OQUIRRH FORMATION, PPo)									HW Casing installed to 29.4 feet.
31	1	54	13	FD9	W1	H3-H4					Intensely fractured, and gravel pieces						
				FD8						JO	60°, PL, R4, CA						
32										JO	90°, WA, R4, CA						
				FD9							Intensely fractured 32 to 33.1 ft						
33										JO	50°, PL, R3						
				FD8				@ 33.2 ft, 5 inch bed of clayey sandy limestone gravel			Intensely fractured with clay filling						
34										JO	30°, PL, O1, T1, CL						
	2	66	20	FD7	W1	H3-H4				JO	0°, PL, R4, O2, T2						
35										JO	35-90°, WA, O1, T1, CL						
				FD7						JO	5°, PL, O1, T1, CL						
36										JO	30°, WA, R3, CL						
37																	
38																	
				FD8													
39	3	63	0		W4	H7				JO	50°, PL, O1, T1, FE, CA						
				FD9	W1	H3-H4				JO	20°, PL, FE, CA						
40								@ 39.7 ft, 5 inch bed of clayey sandstone gravel and sandy limestone gravel		JO	90°, WA, R3, T2, O2, FE						
				FD8						JO	0°, PL, R3, O2, T2, CL, FE						
41										JO	0°, PL, R3, O2, T2, CL						
										JO	70°, WA, R3						Minimal water circulation for Run #3 and Run #4
				FD8													
42										JO	15°, PL, R3, O1						
	4	83	0		W1	H3-H4				JO	15°, PL, R3, O1						
				FD8						JO	90°, PL, R3, O1, T1						
										JO	30°, WA, R3, O2, T2						
43										JO	Numerous fractures 42.2 to 43 ft						
				FD9						ME	70°-90°, WA, T3, O2, T2, FE, CL						
44	5	0	0														

NEW ROCK CORE LOG TH_LOGS_#2_BEAR_RIVER.GPJ GERHART.GDT 9/23/15

GERHART COLE

DRAFT

Project: Bear River Project Concept Study
Project Location: Whites Valley
Project Number: 13GCI329

Log of Test Hole 15-TH-WV-03

Depth (feet)	Run No.	Recovery, %	RQD, %	Fracture Density	Weathering	Hardness	Lithology	MATERIAL DESCRIPTION	Discontinuity Drawing	Discontinuity Type	DISCONTINUITY DESCRIPTION	Point Load Test Results (psi)	Packer Test Intervals	SOIL SAMPLES Type	Number	Sampling Resistance	FIELD NOTES
45																	
46	5	0	0														
47																	
48																	
49																	
50	6	40	0	FD9	W1	H3-H4		@50 ft 18 inch zone of highly fracted gravel limestone with sand, clay, and sandstone gravel			Intensely fractured 50 to 51.5 ft						
51				FD8						JO JO	65°, PL, R3, CL, CA 60°, PL, R3, CL, CA						Coring was slow from 51 to 57 feet.
52				FD7						JO JO JO	50°, PL, R3, O1, T1, CA 60°, PL, R3, O1, T1, CA 40°, PL, R3, O2, T2, CA						
53				FD7						ME JO JO	40°, PL, R3, O2, T2, CA 60°, PL, R3, O1, T1, FE, CA 40°, PL, R3, O1, T1, FE						
54	7	100	48	FD5	W1	H3-H4				JO JO JO	50°, WA, R4, O1, T1, CA 50°, WA, R4, O1, T1, CA 50°, WA, R4, O1, T1, CA						
55				FD5						JO BE JO	40°, PL 90°, PL, R2, O1-O2, T1-T2 60°, PL, T3, O1, T1, CA						
56				FD5						JO BE JO	40°, PL 90°, PL, O1, T1, CA 45°, PL						
57				FD8						BE BE ME	45°, PL 40°, WA, R4, O1, T1, CA 50°, PL, R3						
58				FD7						JO JO ME	70°, WA, R4, O2, T2, CA 60°, PL, R4, O1, T1, CA 50°, WA, R4, O1, T1, CA						
59	8	100	49	FD7	W1	H3-H4				JO JO JO	30°, WA, R4, O2, T2, CA 40°, PL, R4, O1, T1, CA	2817					
60				FD7						ME JO JO	45°, PL, R4, O1, T1, CA, CL 40°						
61				FD8						JO BE JO	60°-75°, WA, O1, T1, CA 60°-90°, WA, R3, O1, T1, CL, FE						
62	9	88	0	FD8	W1	H3-H4				JO ME JO	Intensely fractured/broken 30°, PL, R3, O1 30°, PL, R3, O1						
63				FD8						JO JO ME	90°, PL, R3, O1, T1, FE 30°, PL, R3, O2, T2, CL, FE 90°, WA, R3, O2, T2, FE						
64				FD8						JO JO JO	50°, WA, R3, FE 40°, PL, R2, O1, T1 Numerous 40°, PL, R2, CL, T1, CA						Circulation was lost @ 63.6 feet
65	10	97	42	FD7	W1	H3-H4				JO JO JO	30°, PL, R2, O2-O3, T2-T3, CA 40°, PL, R3, O1, T1, CA, FE						Some circulation returned at 64 feet
66				FD7						JO ME JO	70°, PL, R2, O2, T2, CA 55°, PL, R3, O1, T1, CA 40°, PL, R3, O2, T2, CL, CA						
67										JO BE ME	30°, PL 30°, PL, R3, O2, T2, CL, CA						
68	11	89	64	FD5	W1	H3-H4				ME JO JO	85°, WA, R4, O1, T1, CA 30°, PL 30°, PL						
69										BE ME BE	30°, PL, R3, O1, T1, CA 40°, WA, R3, O2, T2, CL 40°, WA, O2, T2, CL 40°, PL, R3, O1, T1, CA,						

NEW ROCK CORE LOG TH LOGS #2 BEAR RIVER.GPJ GERHART.GDT 9/23/15

GERHART COLE

DRAFT

Project: Bear River Project Concept Study
Project Location: Whites Valley
Project Number: 13GCI329

Log of Test Hole 15-TH-WV-03

Depth (feet)	Run No.	Recovery, %	RQD, %	Fracture Density	Weathering	Hardness	Lithology	MATERIAL DESCRIPTION	Discontinuity Drawing	Discontinuity Type	DISCONTINUITY DESCRIPTION	Point Load Test Results (psi)	Packer Test Intervals	SOIL SAMPLES Type	Number	Sampling Resistance	FIELD NOTES
70	11	89	64	FD5 FD7	W1	H3-H4				JO JO JO JO JO JO JO JO JO JO JO JO JO	CL 85°, WA, O1, T1, CA 40°, PL, O3, T3, CA 20°, WA, O2, T2, CA 45°, PL, O1, T1, FE 70°, PL, R4, O1, T1, FE, CA 50°, PL, R4, O1, T1, FE, CA 80°, WA, O1, T1, CA 40°, PL, R4, O2, T2, CA 40°, PL, R3, O1, T1 Intensely fractured and broken 71 to 74.5 ft						
71																	
72	12	30	0	FD8 FD9													Difficult coring from 71.5 to 87 feet, due to blockage of bit.
73	13	0	0														
74				FD8						JO	60°, PL, O3, T3,						
75	14	100	36	FD8	W1	H3-H4				JO BE JO	Intensely fractured and broken 74.7 to 75 ft 50°, WA, R3, O3, T3 45°						
76				FD7				@ 75.4 ft, 2 inch bed of calcite		JO JO JO JO	45°, PL, O5, T5, CA 50°, PL, R2, O1, FE, CL 40°, P, O3, T3, CA 40°, PL, R3, O1, FE, CA						
77				FD8	W1-W2	H3-H4		@ 76.4 ft, 2 inch bed of calcite		ME BE	30°, WA, O5, T5, CA Intensely fractured 77 to 77.8 ft						
78	15	96	0	FD8						JO JO JO JO JO JO JO	60°, WA, R3, O1, T1, CA 60°, WA, R3, O1, T1, FE 30°, WA, R3, FE 25°, WA, R3, O2, T2, CL 75°, WA, R4, CL 25°, PL, R4, O1, T1, CL 30°, PL, R4, O1, T1, CL						
79																	
	16	50	0	FD8													
80																	
81	17	43	0		W1-W2	H3-H4											
				FD8													
82																	
83																	
84	18	43	20	FD7	W1-W2	H3-H4				JO	30°, ST, R3						Circulation was good and coring advanced from 84 to 86 feet
85				FD9						ME JO JO	35°, WA, O1, CL 90°, PL, R4, CL						
86										ME							Difficult coring from 86 to 87 feet, very little circulation and bit blockage
87	19	70	0	FD9	W1-W2	H3-H4					Intensely fractured and broken 86 to 87 ft 87 to 92 feet very little recovery and fractured and broken						
88												1970					Due to circulation loss, grouted hole at end of day on 6/12/2015. Returned on 6/17/2015 to drill out grout with a NQ size core barrel. At approximately 66 ft hole core returned in core barrel. See pictures for recovery.
89	20	14	0														
90																	
91				FD9	W1-W2	H3-H4											
92											92 to 95 feet some recovery but fractured and broken						
93	21	43	11														

NEW ROCK CORE LOG TH_LOGS #2_BEAR_RIVER.GPJ GERHART.GDT 9/23/15

GERHART COLE

DRAFT

Project: Bear River Project Concept Study
Project Location: Whites Valley
Project Number: 13GCI329

Log of Test Hole 15-TH-WV-03

Depth (feet)	ROCK CORE: Run No.	Recovery,%	R Q D, %	Fracture Density	Weathering	Hardness	Lithology	MATERIAL DESCRIPTION	Discontinuity Drawing	Discontinuity Type	DISCONTINUITY DESCRIPTION	Point Load Test Results (psi)	Packer Test Intervals	SOIL SAMPLES: Type	Number	Sampling Resistance	FIELD NOTES
94	21	43	11	FD9	W1-W2	H3-H4											
95								Bottom of Test Hole at 95 feet.									Due to no circulation return and difficulting in advancing hole was stopped at 95 feet.
96																	
97																	
98																	
99																	
100																	
101																	
102																	
103																	
104																	
105																	
106																	
107																	
108																	
109																	
110																	
111																	
112																	
113																	
114																	
115																	
116																	
117																	
118																	

GERHART COLE

DRAFT

Project: Bear River Project Concept Study
Project Location: Whites Valley
Project Number: 13GCI329

Log of Test Hole TH-WV-04

Date(s) Drilled	11/26/14	Logged By	E. Lips	Checked By	P. Gerhart
Drilling Method	HSA	Drill Bit Size/Type	8-in HSA; 4.25 ID	Total Depth Drilled (feet)	52.0 feet
Drill Rig Type	CME 75	Drilling Contractor	Bedke Geotechnical F.S.	Hammer Weight/ Drop(lbs/in.)	Automatic Trip Hammer
Apparent Groundwater Depth		Latitude / Longitude	41.85641, -112.32608	Ground Surface Elevation (feet)	5097.3
Comments		Test Hole Backfill	Benonite Grout	Elevation Datum	NAVD88

Elevation, feet	Depth, feet	SAMPLES Type	Number	Sampling Resistance	Recovery, inches	Graphic Log	MATERIAL DESCRIPTION	FIELD NOTES
	0						SAND, very loose, silty, roots, brown, (SM), [TOPSOIL]	
5095							CLAY, with sand - soft, fine to medium sand, moist, brown, low plasticity to medium plasticity, (CL)	
	5		SPT-01	2-2-2-2 [4]				
5090								
	10		SPT-02	2-2-2-3 [4]				
5085								
	15		SPT-03	1-2-2-2 [4]	18		SILT, some sand - very loose, fine sand, dry, brown, low plasticity, (ML)	
5080								
	20		SPT-04	0-0-1-1 [1]	24		CLAY, some sand - very loose, some thin sand layers, moist, brown, low plasticity, (CL)	
5075								
	25		SPT-05	0-0-0-0 [0]	24		Soil wet at 25 feet	
5070							Few silty sand lenses from 28 to 30 feet, less than 6 inches thick Water at 28 feet	
	30							

GERHART COLE

DRAFT

Project: Bear River Project Concept Study
Project Location: Whites Valley
Project Number: 13GCI329

Log of Test Hole TH-WV-04

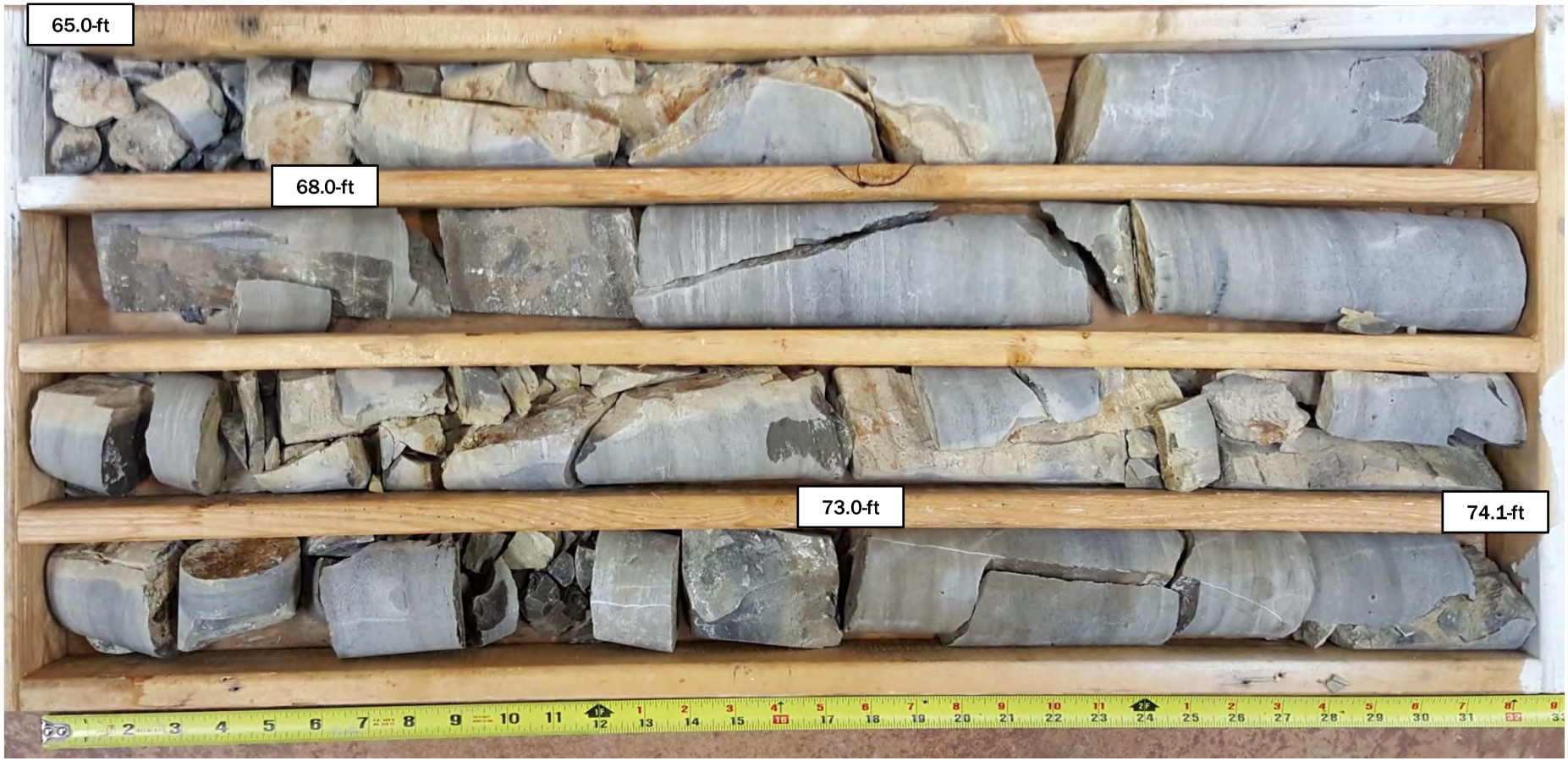
Elevation, feet	Depth, feet	SAMPLES Type	Number	Sampling Resistance	Recovery, inches	Graphic Log	MATERIAL DESCRIPTION	FIELD NOTES
	30	SPT	06	0-0-0-0 [0]	10		CLAY, with sand - very soft, fine to coarse sand, wet, brown, low plasticity to medium plasticity, (CL)	
5065								
	35	SPT	07	0-0-0-0 [0]	24		Silty sand layers less than 2" thick at 36 to 37 feet	
5060							Very thin layer of black silt at 39 to 39.2 feet	
	40	SPT	08	1-2-2-3 [4]	24		CLAY, some sand - soft, thin sand lenses, wet, brown, low to medium plasticity (CL)	
5055								
							GRAVEL, silty, with sand - medium dense, fine to medium gravel, fine to coarse sand, wet, brown, (GM)	
	45	SPT	09	12-18-21 -19 [39]	18			
5050								
	50	SPT	10	3-3-4-4 [7]	24		CLAY, some sand - medium stiff, moist, brown, (CL)	
5045							Bottom of Test Hole at 52 feet.	
	55							
5040								
	60							
5035								
	65							

SOIL TEST HOLE TH_LOGS_#2_BEAR_RIVER.GPJ GERHART.GDT 10/4/18

GERHART COLE

DRAFT

Location:	15-TH-WV-01	Box Number:	1	Run(s):	1,2,3	Depth(ft):	65.0-74.1



Notes:

1. This photo log is for information purposes only. It is intended to assist in showing features discussed in the attached field logs.

Reference: Log of Referenced Test Hole

PHOTOGRAPHIC SUMMARY OF ROCK CORE

Bear River Project Concept Study
Whites Valley

GERHART COLE

Figure: A1

DRAFT

Location:	15-TH-WV-01	Box Number:	2	Run(s):	3,4,5	Depth(ft):	74.1-83.5

Notes:

1. This photo log is for information purposes only. It is intended to assist in showing features discussed in the attached field logs.

Reference: Log of Referenced Test Hole

PHOTOGRAPHIC SUMMARY OF ROCK CORE

Bear River Project Concept Study
Whites Valley

GERHART COLE

Figure: A2

DRAFT

Location:	15-TH-WV-01	Box Number:	3	Run(s):	5,6,7,8	Depth(ft):	83.5-94.0

Notes:

1. This photo log is for information purposes only. It is intended to assist in showing features discussed in the attached field logs.

Reference: Log of Referenced Test Hole

PHOTOGRAPHIC SUMMARY OF ROCK CORE

Bear River Project Concept Study
Whites Valley

GERHART COLE

Figure: A3

DRAFT

Location:	15-TH-WV-01	Box Number:	4	Run(s):	8,9,10	Depth(ft):	94.0-105.0

Notes:

1. This photo log is for information purposes only. It is intended to assist in showing features discussed in the attached field logs.

Reference: Log of Referenced Test Hole

PHOTOGRAPHIC SUMMARY OF ROCK CORE

Bear River Project Concept Study
Whites Valley

GERHART COLE

Figure: A4

DRAFT

Location:	15-TH-WV-01	Box Number:	5	Run(s):	10,11,12	Depth(ft):	105.0-115.5

Notes:

1. This photo log is for information purposes only. It is intended to assist in showing features discussed in the attached field logs.

Reference: Log of Referenced Test Hole

PHOTOGRAPHIC SUMMARY OF ROCK CORE

Bear River Project Concept Study
Whites Valley

GERHART COLE

Figure: A5

DRAFT

Location:	14-TH-WV-02	Box Number:	1	Run(s):	1,2,3	Depth(ft):	24.8-37.1

Notes:

1. This photo log is for information purposes only. It is intended to assist in showing features discussed in the attached field logs.

Reference: Log of Referenced Test Hole

PHOTOGRAPHIC SUMMARY OF ROCK CORE

Bear River Project Concept Study
Whites Valley

GERHART COLE

Figure: A6

DRAFT

Location:	14-TH-WV-02	Box Number:	2	Run(s):	4,5,6	Depth(ft):	37.1-53

Notes:

1. This photo log is for information purposes only. It is intended to assist in showing features discussed in the attached field logs.

Reference: Log of Referenced Test Hole

PHOTOGRAPHIC SUMMARY OF ROCK CORE

Bear River Project Concept Study
Whites Valley

GERHART COLE

Figure: A7

DRAFT

Location:	14-TH-WV-02	Box Number:	3	Run(s):	7,8	Depth(ft):	53-62.8

Notes:

1. This photo log is for information purposes only. It is intended to assist in showing features discussed in the attached field logs.

Reference: Log of Referenced Test Hole

PHOTOGRAPHIC SUMMARY OF ROCK CORE

Bear River Project Concept Study
Whites Valley

GERHART COLE

Figure: A8

DRAFT

Location:	14-TH-WV-02	Box Number:	4	Run(s):	8,9,10,11	Depth(ft):	62.8-71.2

Notes:

1. This photo log is for information purposes only. It is intended to assist in showing features discussed in the attached field logs.

Reference: Log of Referenced Test Hole

PHOTOGRAPHIC SUMMARY OF ROCK CORE

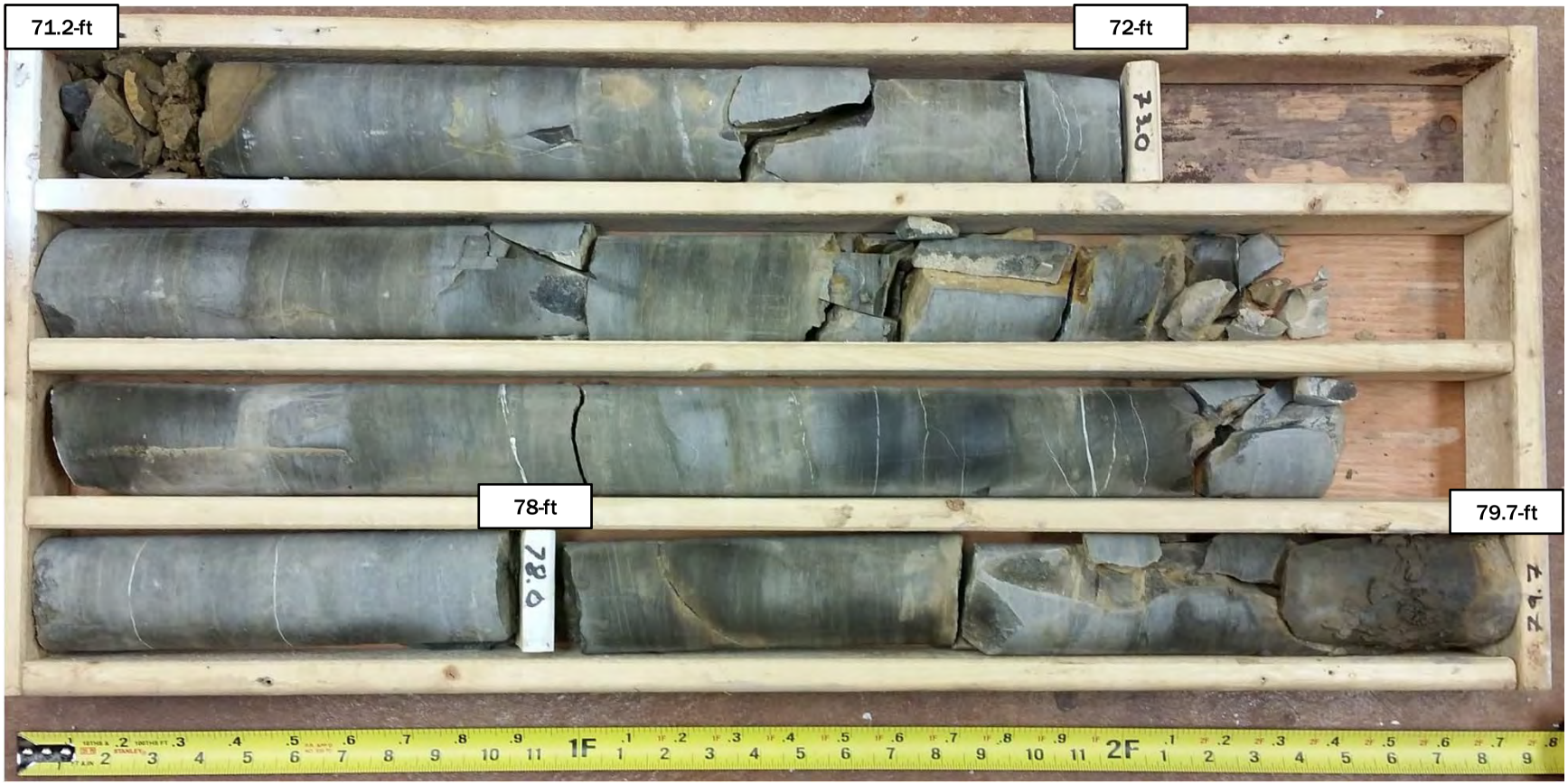
Bear River Project Concept Study
Whites Valley

GERHART COLE

Figure: A9

DRAFT

Location:	14-TH-WV-02	Box Number:	5	Run(s):	11,12,13	Depth(ft):	71.2-79.7



Notes:

1. This photo log is for information purposes only. It is intended to assist in showing features discussed in the attached field logs.

Reference: Log of Referenced Test Hole

PHOTOGRAPHIC SUMMARY OF ROCK CORE

Bear River Project Concept Study
Whites Valley

GERHART COLE

Figure: A10

DRAFT

Location:	14-TH-WV-02	Box Number:	6	Run(s):	14,15	Depth(ft):	79.7-88

Notes:

1. This photo log is for information purposes only. It is intended to assist in showing features discussed in the attached field logs.

Reference: Log of Referenced Test Hole

PHOTOGRAPHIC SUMMARY OF ROCK CORE

Bear River Project Concept Study
Whites Valley

GERHART COLE

Figure: A11

DRAFT

Location:	14-TH-WV-02	Box Number:	7	Run(s):	16,17	Depth(ft):	88-97.2

Notes:

1. This photo log is for information purposes only. It is intended to assist in showing features discussed in the attached field logs.

Reference: Log of Referenced Test Hole

PHOTOGRAPHIC SUMMARY OF ROCK CORE

Bear River Project Concept Study
Whites Valley

GERHART COLE

Figure: A12

DRAFT

Location:	14-TH-WV-02	Box Number:	8	Run(s):	17	Depth(ft):	97.2-

Notes:

1. This photo log is for information purposes only. It is intended to assist in showing features discussed in the attached field logs.

Reference: Log of Referenced Test Hole

PHOTOGRAPHIC SUMMARY OF ROCK CORE

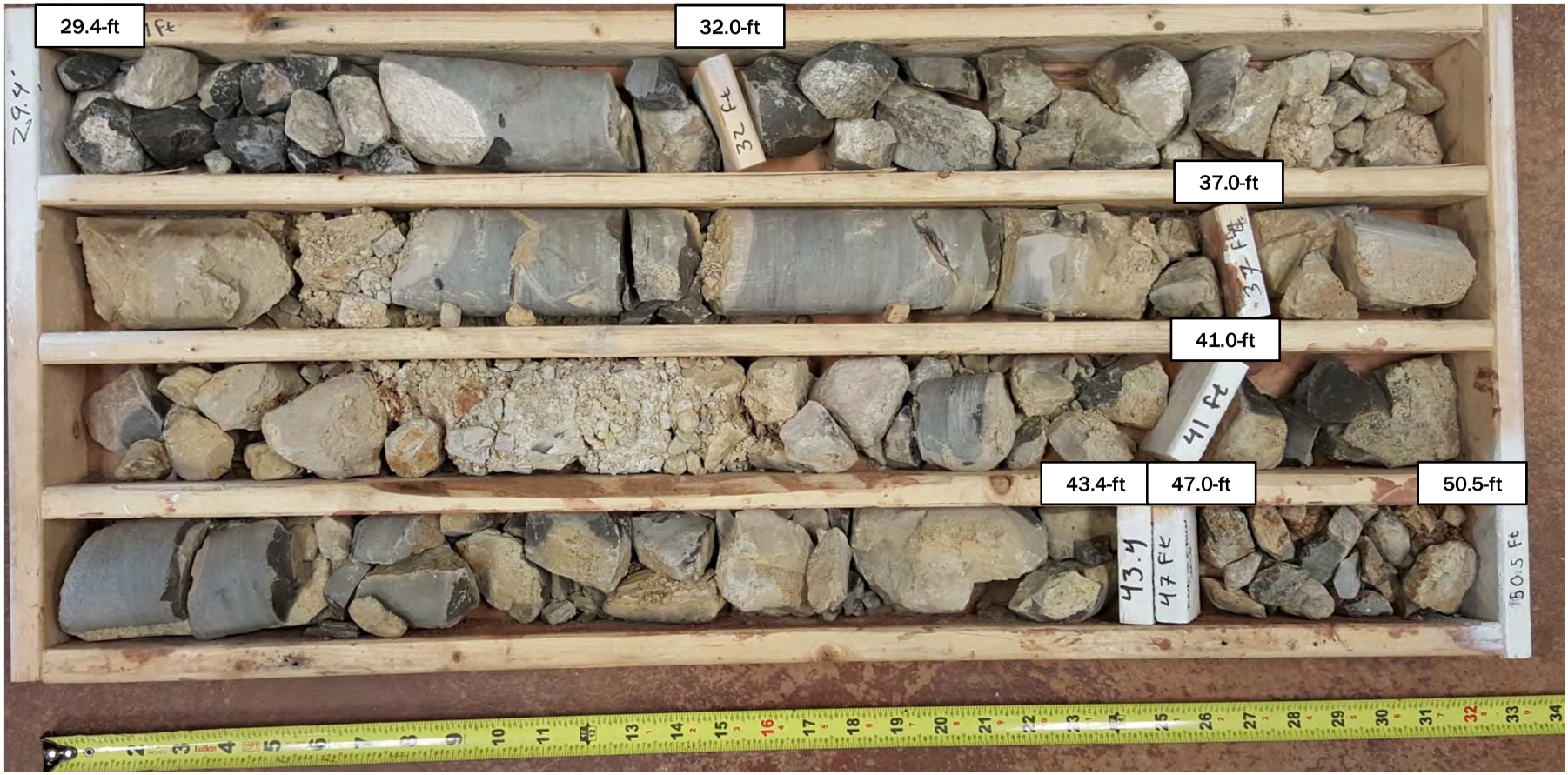
Bear River Project Concept Study
Whites Valley

GERHART COLE

Figure: A13

DRAFT

Location:	15-TH-WV-03	Box Number:	1	Run(s):	1,2,3,4,5,6	Depth(ft):	29.4-50.5



Notes:

1. This photo log is for information purposes only. It is intended to assist in showing features discussed in the attached field logs.

Reference: Log of Referenced Test Hole

PHOTOGRAPHIC SUMMARY OF ROCK CORE

Bear River Project Concept Study
Whites Valley

GERHART COLE

Figure: A14

DRAFT

Location:	15-TH-WV-03	Box Number:	2	Run(s):	6,7,8	Depth(ft):	50.5-59.0

Notes:

1. This photo log is for information purposes only. It is intended to assist in showing features discussed in the attached field logs.

Reference: Log of Referenced Test Hole

PHOTOGRAPHIC SUMMARY OF ROCK CORE

Bear River Project Concept Study
Whites Valley

GERHART COLE

Figure: A15

DRAFT

Location:	15-TH-WV-03	Box Number:	3	Run(s):	8,9,10,11	Depth(ft):	59.0-68.6

Notes:

1. This photo log is for information purposes only. It is intended to assist in showing features discussed in the attached field logs.

Reference: Log of Referenced Test Hole

PHOTOGRAPHIC SUMMARY OF ROCK CORE

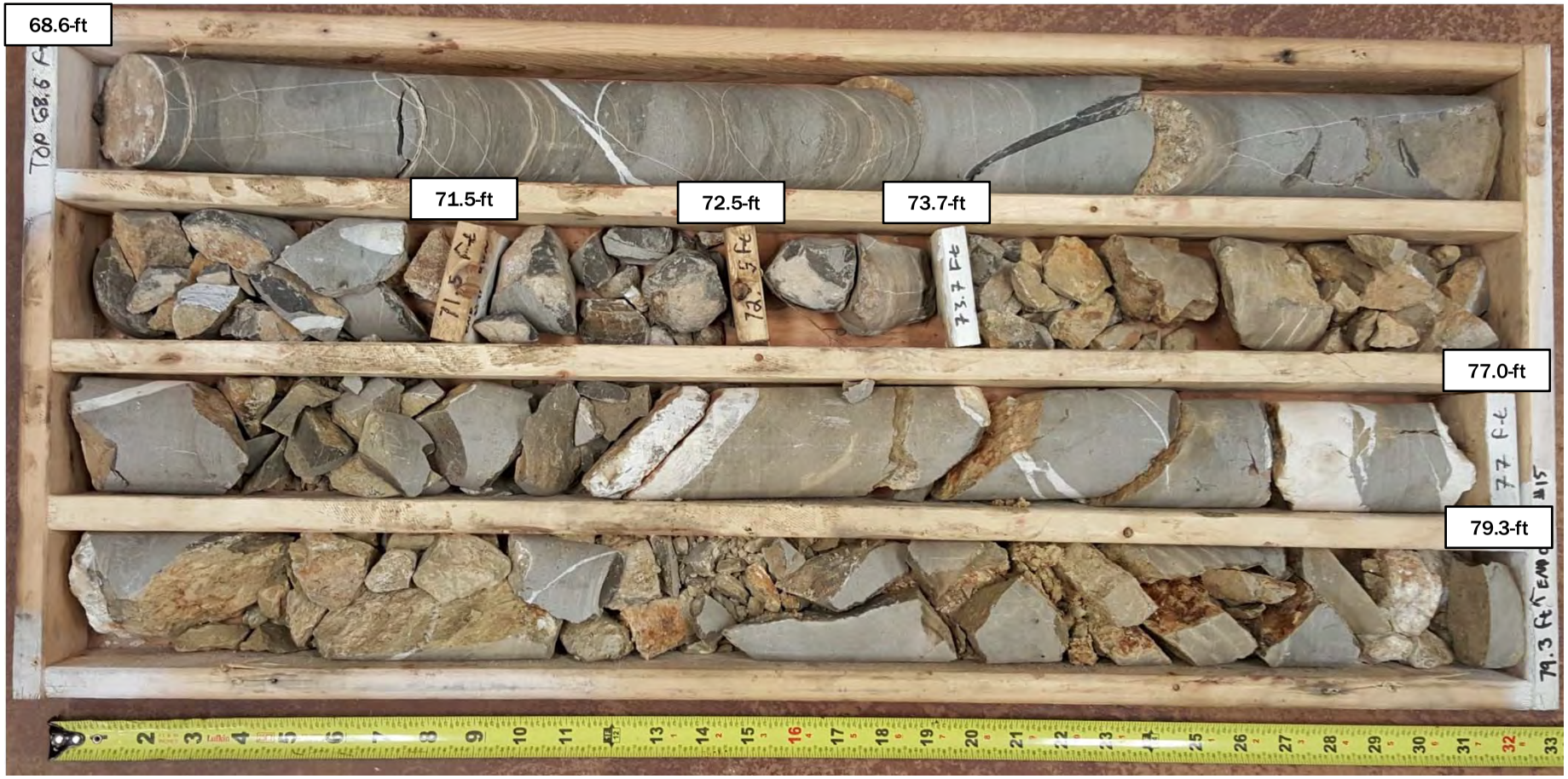
Bear River Project Concept Study
Whites Valley

GERHART COLE

Figure: A16

DRAFT

Location:	15-TH-WV-03	Box Number:	4	Run(s):	11,12,13,14, 15	Depth(ft):	68.6-79.3



Notes:

1. This photo log is for information purposes only. It is intended to assist in showing features discussed in the attached field logs.

Reference: Log of Referenced Test Hole

PHOTOGRAPHIC SUMMARY OF ROCK CORE

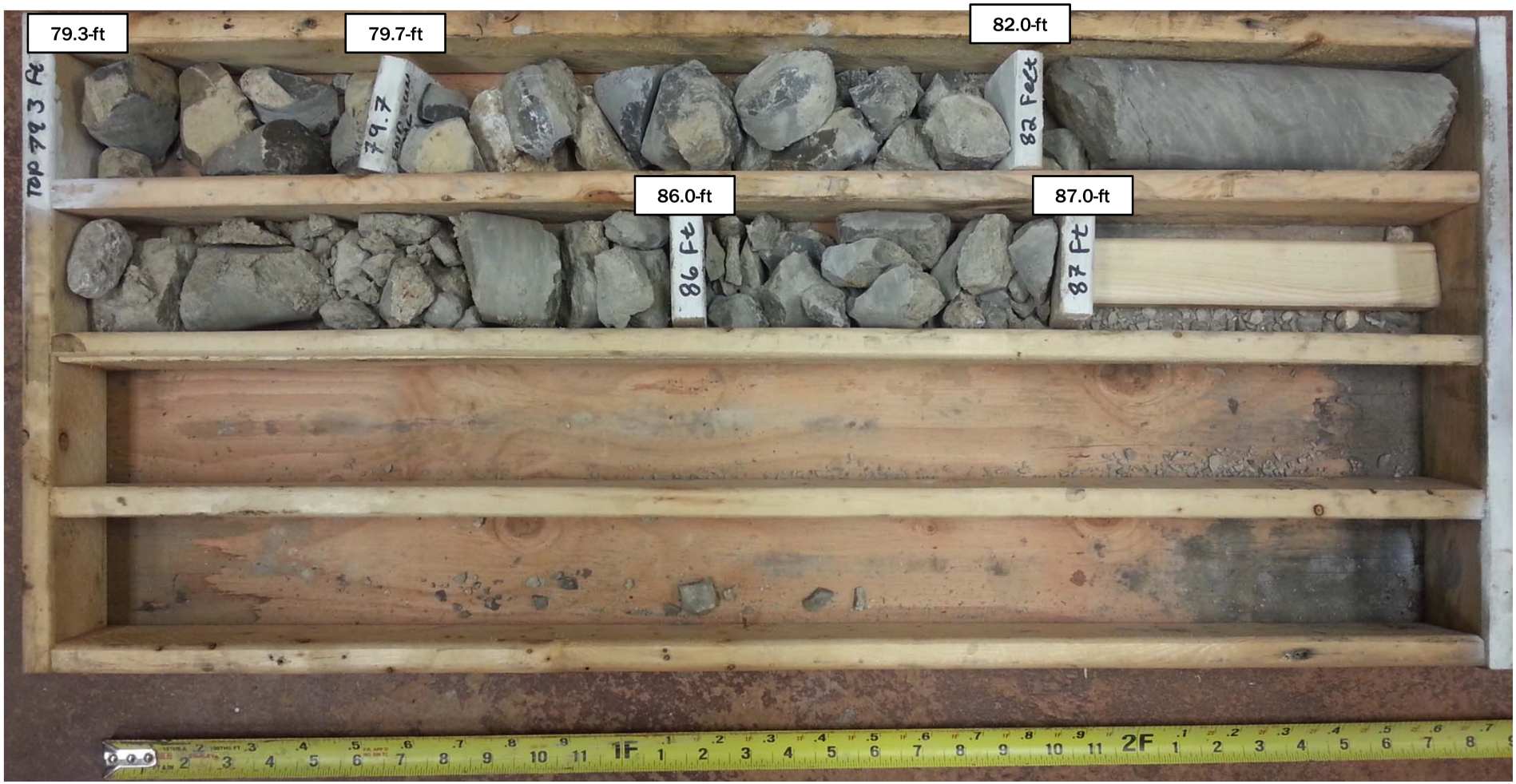
Bear River Project Concept Study
Whites Valley

GERHART COLE

Figure: A17

DRAFT

Location:	15-TH-WV-03	Box Number:	5	Run(s):	15, 16, 17, 18, 19	Depth(ft):	79.3-87.0



Notes:

1. This photo log is for information purposes only. It is intended to assist in showing features discussed in the attached field logs.

Reference: Log of Referenced Test Hole

PHOTOGRAPHIC SUMMARY OF ROCK CORE

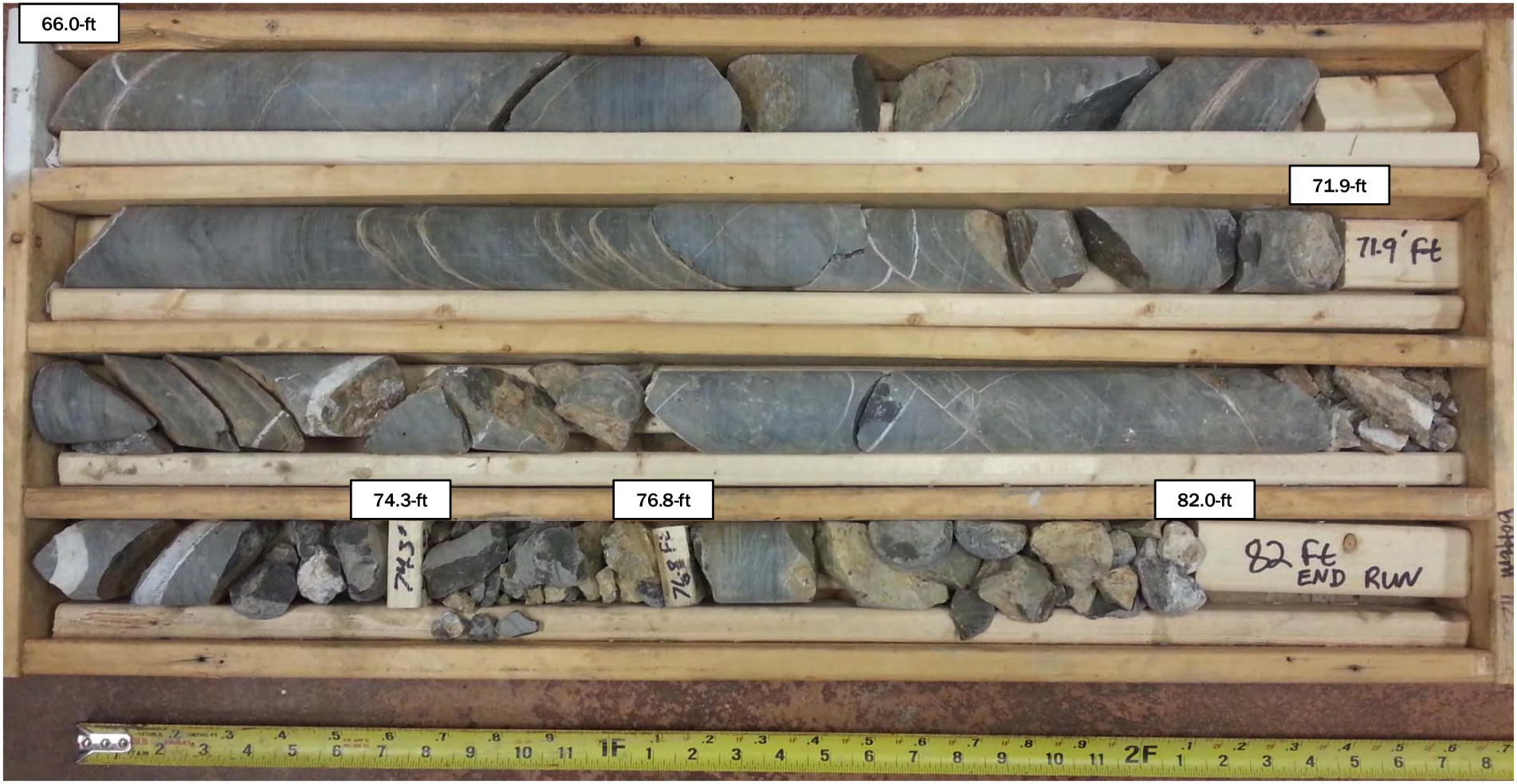
Bear River Project Concept Study
Whites Valley

GERHART COLE

Figure: A18

DRAFT

Location:	15-TH-WV-03	Box Number:	6	Run(s):	NQ Size Rock	Depth(ft):	66.0-82.0



Notes:

1. This photo log is for information purposes only. It is intended to assist in showing features discussed in the attached field logs.

Reference: Log of Referenced Test Hole

PHOTOGRAPHIC SUMMARY OF ROCK CORE

Bear River Project Concept Study
Whites Valley

GERHART COLE

Figure: A19

DRAFT

Location:	15-TH-WV-03	Box Number:	7	Run(s):	NQ Size Rock	Depth(ft):	82.0-95.0

Notes:

1. This photo log is for information purposes only. It is intended to assist in showing features discussed in the attached field logs.

Reference: Log of Referenced Test Hole

PHOTOGRAPHIC SUMMARY OF ROCK CORE

Bear River Project Concept Study
Whites Valley

GERHART COLE

Figure: A20

Appendix B

Whites Valley – Test Pit Logs and Photographs

Project: Bear River Project

Project Location: Whites Valley

Project Number: 13GCI329

DRAFT

LOG OF TEST PIT 16-TP-WV-01

Date(s) Excavated	09/21/2016	Logged By	R. Buhler	Checked By	R. Cole
Approximate Length (feet)	12	Approximate Width (feet)	4	Approximate Depth (feet)	6.0
Excavation Equipment	CAT 316E	Excavation Contractor	WPFI (Christopher Maybee)	Approximate Pit Trend	NW - SE
Groundwater Depth (feet)	Not Found	Date Measured		Approximate Surface Elevation (feet)	5212.4 (Approx.)
Comments				Latitude / Longitude	41.84776 , -112.31264

Elevation, feet	Depth, feet	Sample Type	Number	Graphic Log	MATERIAL DESCRIPTION	FIELD NOTES
	1				SILT, sandy, some gravel, reddish brown, angular gravel, (ML), [TOPSOIL],	
	2				CLAY, some sand, some gravel - medium stiff, brown, moist, fine to coarse angular gravel, (ML)	
	3					
			GB-1			
	4					
5208						
	5					
	6				Bottom of Hole at 6 feet	
	7					
	8					
	9					
5203						
	10					
	11					
	12					
	13					
	14					
5198						
	15					

GERHART COLE

Project: Bear River Project

Project Location: Whites Valley

Project Number: 13GCI329

DRAFT

LOG OF TEST PIT 16-TP-WV-02

Date(s) Excavated	09/21/2016	Logged By	R. Buhler	Checked By	R. Cole
Approximate Length (feet)	12	Approximate Width (feet)	4	Approximate Depth (feet)	6.0
Excavation Equipment	CAT 316E	Excavation Contractor	WPFI (Christopher Maybee)	Approximate Pit Trend	N - S
Groundwater Depth (feet)	Not Found	Date Measured		Approximate Surface Elevation (feet)	5226.5 (Approx.)
Comments				Latitude / Longitude	41.84728 , -112.31174

Elevation, feet	Depth, feet	Sample Type	Number	Graphic Log	MATERIAL DESCRIPTION	FIELD NOTES
	1				SILT, sandy, with gravel - loose, dark brown, fine to coarse angular gravel, dry, (ML), [TOPSOIL]	
	2				GRAVEL, silty, with sand - dense, dry, light brown, angular gravel and cobbles (6" to 12"), matrix supported, (GP-GM)	
	3					
			BULK-01			
	4				gravel grades to clast supported at 4 ft	
5222						
	5					
	6				Bottom of Hole at 6 feet	
	7					
	8					
	9					
5217						
	10					
	11					
	12					
	13					
	14					
5212						
	15					

GERHART COLE

Project: Bear River Project

Project Location: Whites Valley

Project Number: 13GCI329

DRAFT

LOG OF TEST PIT 16-TP-WV-03

Date(s) Excavated	09/21/2016	Logged By	R. Buhler	Checked By	R. Cole
Approximate Length (feet)	10	Approximate Width (feet)	4	Approximate Depth (feet)	5.0
Excavation Equipment	CAT 316E	Excavation Contractor	WPFI (Christopher Maybee)	Approximate Pit Trend	E - W
Groundwater Depth (feet)	Not Found	Date Measured		Approximate Surface Elevation (feet)	5256.8 (Approx.)
Comments				Latitude / Longitude	41.8472 , -112.311

Elevation, feet	Depth, feet	Sample Type	Number	Graphic Log	MATERIAL DESCRIPTION	FIELD NOTES
					CLAY, sandy, some gravel, (CL), [TOPSOIL]	
	1					
					CLAY, some sand - soft, moist, brown, (CL)	
	2					
	3					
	4					
			GB-01			
5252	5				Bottom of Hole at 5 feet	
	6					
	7					
	8					
	9					
5247	10					
	11					
	12					
	13					
	14					
5242	15					

GERHART COLE

Project: Bear River Project

Project Location: Whites Valley

Project Number: 13GCI329

DRAFT

LOG OF TEST PIT 16-TP-WV-04

Date(s) Excavated	09/21/2016	Logged By	T. Reed	Checked By	R. Buhler
Approximate Length (feet)		Approximate Width (feet)		Approximate Depth (feet)	6.0
Excavation Equipment	CAT 316E	Excavation Contractor	WPFI (Christopher Maybee)	Approximate Pit Trend	
Groundwater Depth (feet)	Not Found	Date Measured		Approximate Surface Elevation (feet)	5200.8 (Approx.)
Comments				Latitude / Longitude	41.8491 , -112.31405

Elevation, feet	Depth, feet	Sample Type	Number	Graphic Log	MATERIAL DESCRIPTION	FIELD NOTES
					CLAY, with sand, some gravel, (CL), [TOPSOIL]	
	1				CLAY, with sand, some gravels - medium stiff, dry to moist, light tan, fine to coarse angular gravel, matrix supported, (CL)	
	2					
	3					
	4					
5196	5					
	6				Bottom of Hole at 6 feet	
	7					
	8					
	9					
5191	10					
	11					
	12					
	13					
	14					
5186	15					

GERHART COLE

Project: Bear River Project

Project Location: Whites Valley

Project Number: 13GCI329

DRAFT

LOG OF TEST PIT 16-TP-WV-05

Date(s) Excavated	09/21/2016	Logged By	T. Reed	Checked By	R. Buhler
Approximate Length (feet)	12	Approximate Width (feet)	4	Approximate Depth (feet)	10.0
Excavation Equipment	CAT 316E	Excavation Contractor	WPFI (Christopher Maybee)	Approximate Pit Trend	N - S
Groundwater Depth (feet)	Not Found	Date Measured		Approximate Surface Elevation (feet)	5170.3 (Approx.)
Comments				Latitude / Longitude	41.84888 , -112.31445

Elevation, feet	Depth, feet	Sample Type	Number	Graphic Log	MATERIAL DESCRIPTION	FIELD NOTES
	1				SILT, sandy, with gravels (ML), [TOPSOIL}	
	2, 3				SILT with sand, trace gravels - medium stiff, light brown, fine to coarse angular gravels, calcium carbonate on gravels, mottled roots, matrix supported, dry to moist, (ML)	
5166, 5161	4, 5, 6, 7, 8, 9				CLAY, with sand, with gravels, - medium stiff, moist, light tan, fine to coarse gravels and cobbles up to 6", (CL)	
5156	10, 11, 12, 13, 14, 15				Bottom of Hole at 10 feet	

GERHART COLE

Project: Bear River Project

Project Location: Whites Valley

Project Number: 13GCI329

DRAFT

LOG OF TEST PIT 16-TP-WV-06

Date(s) Excavated	09/21/2016	Logged By	T. Reed	Checked By	R. Buhler
Approximate Length (feet)	12	Approximate Width (feet)	4	Approximate Depth (feet)	3.0
Excavation Equipment	CAT 316E	Excavation Contractor	WPFI (Christopher Maybee)	Approximate Pit Trend	E - W
Groundwater Depth (feet)	Not Found	Date Measured		Approximate Surface Elevation (feet)	5210.7 (Approx.)
Comments				Latitude / Longitude	41.85256 , -112.31603

Elevation, feet	Depth, feet	Sample Type	Number	Graphic Log	MATERIAL DESCRIPTION	FIELD NOTES
					SILT, with sand, some gravels, some cobbles - medium stiff, light grayish brown, angular cobbles and gravels, roots, (ML), [TOPSOIL]	
	1				LIMESTONE to SANDY LIMESTONE hard, gray, highly fractured into gravel and 8" cobbles, infilling of some fractures with silt and sand, dipping steeply to west 60 to 70 degrees	
	2					
	3				Bottom of Hole at 3 feet	
	4					
5206	5					
	6					
	7					
	8					
	9					
5201	10					
	11					
	12					
	13					
	14					
5196	15					

GERHART COLE

Project: Bear River Project

Project Location: Whites Valley

Project Number: 13GCI329

DRAFT

LOG OF TEST PIT 16-TP-WV-07

Date(s) Excavated	09/21/2016	Logged By	T. Reed	Checked By	R. Buhler
Approximate Length (feet)	12	Approximate Width (feet)	4	Approximate Depth (feet)	4.1
Excavation Equipment	CAT 316E	Excavation Contractor	WPFI (Christopher Maybee)	Approximate Pit Trend	E - W
Groundwater Depth (feet)	Not Found	Date Measured		Approximate Surface Elevation (feet)	5166 (Approx.)
Comments				Latitude / Longitude	41.85252 , -112.31655

Elevation, feet	Depth, feet	Sample Type	Number	Graphic Log	MATERIAL DESCRIPTION	FIELD NOTES
					SILT, with sand, some gravels, some cobbles - medium stiff, light grayish brown, angular cobbles and gravels, roots, (ML), [TOPSOIL]	
	1				GRAVEL, silty, with sand, with cobbles - dense, light gray to brown with calcium carbonate staining, dry, angular gravels, clast supported, (GM)	
	2					
			BULK-1			
	3					
	4				LIMESTONE to SANDY LIMESTONE hard, gray, highly fractured, dipping steeply to west 60 to 70 degrees	
					Bottom of Hole at 4.1 feet	
5161	5					
	6					
	7					
	8					
	9					
5156	10					
	11					
	12					
	13					
	14					
	15					

GERHART COLE

Project: Bear River Project

Project Location: Whites Valley

Project Number: 13GCI329

DRAFT

LOG OF TEST PIT 16-TP-WV-08

Date(s) Excavated	09/21/2016	Logged By	T. Reed	Checked By	R. Buhler
Approximate Length (feet)	12	Approximate Width (feet)	4	Approximate Depth (feet)	10.0
Excavation Equipment	CAT 316E	Excavation Contractor	WPFI (Christopher Maybee)	Approximate Pit Trend	NW-SE
Groundwater Depth (feet)	Not Found	Date Measured		Approximate Surface Elevation (feet)	5136.9 (Approx.)
Comments				Latitude / Longitude	41.85254 , -112.3169

Elevation, feet	Depth, feet	Sample Type	Number	Graphic Log	MATERIAL DESCRIPTION	FIELD NOTES
					SILT, sandy, some gravels, some cobbles - medium stiff, light grayish brown, angular cobbles and gravels, roots, dry, (ML), [TOPSOIL]	
	1				GRAVEL, clayey, some sand - loose to medium dense, moist, light brown to tan, fine gravel, fine to coarse sand, low plasticity, (GC)	
	2				Calcium carbonate staining dry to moist to 2.5 feet	
	3					
	4					
5132	5					
	6					
	7					
	8					
	9					
			GB-1			
5127	10				Bottom of Hole at 10 feet	
	11					
	12					
	13					
	14					
	15					

GERHART COLE

Project: Bear River Project

Project Location: Whites Valley

Project Number: 13GCI329

DRAFT

LOG OF TEST PIT 16-TP-WV-09

Date(s) Excavated	09/21/2016	Logged By	T. Reed	Checked By	R. Buhler
Approximate Length (feet)	11	Approximate Width (feet)	4	Approximate Depth (feet)	10.0
Excavation Equipment	CAT 316E	Excavation Contractor	WPFI (Christopher Maybee)	Approximate Pit Trend	NW-SE
Groundwater Depth (feet)	Not Found	Date Measured		Approximate Surface Elevation (feet)	5241.9 (Approx.)
Comments				Latitude / Longitude	41.85598 , -112.31429

Elevation, feet	Depth, feet	Sample Type	Number	Graphic Log	MATERIAL DESCRIPTION	FIELD NOTES
					SILT, with sand, trace gravel, some cobbles - medium stiff, light grayish brown, angular cobbles and gravels, roots, dry, (ML), [TOPSOIL]	
	1				CLAY, some, trace gravel - soft to medium stiff, moist, light brown to tan, fine to coarse angular gravel, calcium carbonate staining, (CL)	
	2					
	3					
	4					
5237	5					
	6					
	7				GRAVEL and COBBLES, silty, some sand - dense to very dense, light tan, fine to coarse angular gravel and cobbles up to 9", appears to be weathered bedrock, clast supported, dry to moist, (GM)	
	8					
	9					
5232	10				Bottom of Hole at 10 feet	
	11					
	12					
	13					
	14					
	15					

GERHART COLE

Project: Bear River Project

Project Location: Whites Valley

Project Number: 13GCI329

DRAFT

LOG OF TEST PIT 16-TP-WV-10

Date(s) Excavated	09/21/2016	Logged By	T. Reed	Checked By	R. Buhler
Approximate Length (feet)	12	Approximate Width (feet)	4	Approximate Depth (feet)	10.0
Excavation Equipment	CAT 316E	Excavation Contractor	WPFI (Christopher Maybee)	Approximate Pit Trend	NE-SW
Groundwater Depth (feet)	Not Found	Date Measured		Approximate Surface Elevation (feet)	5220.3 (Approx.)
Comments				Latitude / Longitude	41.85566 , -112.31522

Elevation, feet	Depth, feet	Sample Type	Number	Graphic Log	MATERIAL DESCRIPTION	FIELD NOTES
					SILT, sandy, trace gravel, some cobbles - medium stiff, light grayish brown, angular cobbles and gravels, roots, dry, (ML), [TOPSOIL]	
	1				GRAVEL with sand, with silt - dense to very dense, light brown to gray, fine to coarse gravels and cobbles up to 12", matrix supported, (GP-GM)	
	2				CLAY, with sand - medium stiff, moist, yellow, fine sand, iron oxide, (CL)	
	3					
5216	4					
	5					
	6					
	7					
	8					
	9					
5211			GB-1			
	10				Bottom of Hole at 10 feet	
	11					
	12					
	13					
	14					
5206						
	15					

GERHART COLE

Project: Bear River Project

Project Location: Whites Valley

Project Number: 13GCI329

DRAFT

LOG OF TEST PIT 16-TP-WV-11

Date(s) Excavated	09/22/2016	Logged By	T. Reed	Checked By	R. Buhler
Approximate Length (feet)	13	Approximate Width (feet)	4	Approximate Depth (feet)	13.0
Excavation Equipment	CAT 316E	Excavation Contractor	WPFI (Christopher Maybee)	Approximate Pit Trend	E - W
Groundwater Depth (feet)	Not Found	Date Measured		Approximate Surface Elevation (feet)	5203.3 (Approx.)
Comments				Latitude / Longitude	41.85512 , -112.31696

Elevation, feet	Depth, feet	Sample Type	Number	Graphic Log	MATERIAL DESCRIPTION	FIELD NOTES
					GRAVEL, silty, with sand, some cobbles - medium stiff, moist, light brown, interbedded clast and matrix supported gravel layers, fine to coarse gravels and cobbles up to 4", fine to coarse sand, (CL)	
	1					
	2					
	3					
	4					
5199						
	5		BULK-1			
	6					
	7					
	8					
	9					
5194						
	10					
	11					
	12					
	13				Bottom of Hole at 13 feet	
	14					
5189						
	15					

GERHART COLE

Project: Bear River Project

Project Location: Whites Valley

Project Number: 13GCI329

DRAFT

LOG OF TEST PIT 16-TP-WV-12

Date(s) Excavated	09/23/2016	Logged By	T. Reed	Checked By	R. Buhler
Approximate Length (feet)	10	Approximate Width (feet)	4	Approximate Depth (feet)	11.0
Excavation Equipment	CAT 316E	Excavation Contractor	WPFI (Christopher Maybee)	Approximate Pit Trend	NW - SE
Groundwater Depth (feet)	Not Found	Date Measured		Approximate Surface Elevation (feet)	5236.5 (Approx.)
Comments				Latitude / Longitude	41.85262 , -112.33205

Elevation, feet	Depth, feet	Sample Type	Number	Graphic Log	MATERIAL DESCRIPTION	FIELD NOTES
	1				CLAY, with sand, trace gravels - (CL), [TOPSOIL]	
	2				CLAY, with sand, trace gravels - medium stiff, dry to moist, yellowish brown, fine to coarse angular gravels, some cobbles up to 5", (ML)	
	3				SANDSTONE - soft, fractured, sand and silt infilling, dips to north 10 degrees, dry, becomes harder with depth	
5232	4					
	5					
	6					
	7					
	8					
	9					
5227	10					
	11				Bottom of Hole at 11 feet	
	12					
	13					
	14					
5222	15					

GERHART COLE

Project: Bear River Project

Project Location: Whites Valley

Project Number: 13GCI329

DRAFT

LOG OF TEST PIT 16-TP-WV-13

Date(s) Excavated	09/23/2016	Logged By	T. Reed	Checked By	R. Buhler
Approximate Length (feet)	11	Approximate Width (feet)	4	Approximate Depth (feet)	3.5
Excavation Equipment	CAT 316E	Excavation Contractor	WPFI (Christopher Maybee)	Approximate Pit Trend	N - S
Groundwater Depth (feet)	Not Found	Date Measured		Approximate Surface Elevation (feet)	5222.6 (Approx.)
Comments				Latitude / Longitude	41.85316 , -112.33244

Elevation, feet	Depth, feet	Sample Type	Number	Graphic Log	MATERIAL DESCRIPTION	FIELD NOTES
					CLAY, with sand, trace gravels, (CL), [TOPSOIL]	
	1				CLAY, with sand, trace gravels - medium stiff, dry to moist, dark grayish brown, fine to coarse angular gravels, some cobbles up to 8", cobbles coated with calcium carbonate, dry to moist, (CL),	
	2					
	3				LIMESTONE, hard, light gray, fractured, fractures filled with sand and silt, dips 10 deg. to south	
					Bottom of Hole at 3.5 feet	
	4					
5218						
	5					
	6					
	7					
	8					
	9					
5213						
	10					
	11					
	12					
	13					
	14					
5208						
	15					

GERHART COLE

Project: Bear River Project

Project Location: Whites Valley

Project Number: 13GCI329

DRAFT

LOG OF TEST PIT 16-TP-WV-14

Date(s) Excavated	09/23/2016	Logged By	T. Reed	Checked By	R. Buhler
Approximate Length (feet)	12	Approximate Width (feet)	4	Approximate Depth (feet)	5.0
Excavation Equipment	CAT 316E	Excavation Contractor	WPFI (Christopher Maybee)	Approximate Pit Trend	N - S
Groundwater Depth (feet)	Not Found	Date Measured		Approximate Surface Elevation (feet)	5201.5 (Approx.)
Comments				Latitude / Longitude	41.8532 , -112.33266

Elevation, feet	Depth, feet	Sample Type	Number	Graphic Log	MATERIAL DESCRIPTION	FIELD NOTES
					CLAY, with sand - medium stiff, light grayish brown, roots, dry to moist, (CL), [TOPSOIL]	
	1				CLAY, with sand, trace gravels - medium stiff, dry to moist, light tan, fine to coarse angular gravels, some cobbles up to ", (ML)	
	2					
	3					
	4				LIMESTONE, hard, light gray, fractured, fractures filled with sand and silt, dips 5 deg. to south	
5197						
	5				Bottom of Hole at 5 feet	
	6					
	7					
	8					
	9					
5192						
	10					
	11					
	12					
	13					
	14					
5187						
	15					

GERHART COLE

Project: Bear River Project

Project Location: Whites Valley

Project Number: 13GCI329

DRAFT

LOG OF TEST PIT 16-TP-WV-15

Date(s) Excavated	09/26/2016	Logged By	T. Reed	Checked By	R. Buhler
Approximate Length (feet)	11	Approximate Width (feet)	4	Approximate Depth (feet)	11.0
Excavation Equipment	CAT 316E	Excavation Contractor	WPFI (Christopher Maybee)	Approximate Pit Trend	NE - SW
Groundwater Depth (feet)	Not Found	Date Measured		Approximate Surface Elevation (feet)	5168.8 (Approx.)
Comments				Latitude / Longitude	41.85194 , -112.32953

Elevation, feet	Depth, feet	Sample Type	Number	Graphic Log	MATERIAL DESCRIPTION	FIELD NOTES
					SILT, with clay, with sand, trace gravel - medium stiff to stiff, wet to dry, dark grayish brown, fine to coarse angular gravels, (ML), [TOPSOIL]	
	1					
					SILT, with clay, with sand - medium stiff, reddish brown to brown, moist to dry, (ML)	
	2					
	3					
					CLAY, with silt, some gravel - medium stiff to stiff, moist, reddish brown to light tan, fine to coarse gravels and cobbles up to 4", (CL)	
	4					
5164	5					
	6					
	7				Size and amount of cobbles increase substantially, to 9" max.	
	8					
	9					
5159	10					
					Bedrock	
	11				Bottom of Hole at 11 feet	
	12					
	13					
	14					
5154	15					

GERHART COLE

Project: Bear River Project

Project Location: Whites Valley

Project Number: 13GCI329

DRAFT

LOG OF TEST PIT 16-TP-WV-16

Date(s) Excavated	09/26/2016	Logged By	T. Reed	Checked By	R. Buhler
Approximate Length (feet)	11	Approximate Width (feet)	4	Approximate Depth (feet)	10.5
Excavation Equipment	CAT 316E	Excavation Contractor	WPFI (Christopher Maybee)	Approximate Pit Trend	NE - SW
Groundwater Depth (feet)		Date Measured		Approximate Surface Elevation (feet)	5149.9 (Approx.)
Comments				Latitude / Longitude	41.85259 , -112.3297

Elevation, feet	Depth, feet	Sample Type	Number	Graphic Log	MATERIAL DESCRIPTION	FIELD NOTES
	1				SILT, with clay, with sand, trace gravel -moist to dry, dark grayish brown, fine to coarse angular gravels up to 3", fine to medium sand, (ML) [TOPSOIL]	
	2, 3, 4, 5, 6				SILT, with clay, some gravels - stiff, reddish brown to brown, fine to coarse gravels and cobbles up to 5", moist to dry	
5145						
	7, 8				CLAY, with sand, trace gravels - stiff, moist, light tan, fine to coarse gravels and cobbles up to 5", (CL)	
	9, 10				CLAY, with silt - medium stiff, moist, brown, moist, massive, (CL)	
5140						
	11				Bottom of Hole at 10.5 feet	
	12, 13, 14, 15					

GERHART COLE

Project: Bear River Project

Project Location: Whites Valley

Project Number: 13GCI329

DRAFT

LOG OF TEST PIT 16-TP-WV-17

Date(s) Excavated	09/26/2016	Logged By	T. Reed	Checked By	R. Buhler
Approximate Length (feet)	12	Approximate Width (feet)	4	Approximate Depth (feet)	12.0
Excavation Equipment	CAT 316E	Excavation Contractor	WPFI (Christopher Maybee)	Approximate Pit Trend	NE - SW
Groundwater Depth (feet)		Date Measured		Approximate Surface Elevation (feet)	5132.3 (Approx.)
Comments				Latitude / Longitude	41.85281 , -112.32939

Elevation, feet	Depth, feet	Sample Type	Number	Graphic Log	MATERIAL DESCRIPTION	FIELD NOTES
					SILT, with sand, with clay, moist to dry, dark grayish brown, roots, fine sand, (ML), [TOPSOIL]	
	1, 2				CLAY, trace gravel - stiff, dry, reddish brown to brown, blocky, fine to medium angular gravels up to 1.5", (CL)	
	3, 4, 5				SILT, with sand, trace gravels - medium stiff, moist, reddish brown to brown, fine to medium angular gravels up to 2", a few cobbles up to 5", fine to medium sand, (ML)	
5128						
	6, 7, 8, 9, 10, 11				CLAY, with sand - stiff, moist, brown, fine sand, massive, (CL)	
5123						
	12				Bottom of Hole at 12 feet	
	13, 14					
5118						
	15					

GERHART COLE

Project: Bear River Project

Project Location: Whites Valley

Project Number: 13GCI329

DRAFT

LOG OF TEST PIT 16-TP-WV-18

Date(s) Excavated	09/26/2016	Logged By	T. Reed	Checked By	R. Buhler
Approximate Length (feet)	12	Approximate Width (feet)	4	Approximate Depth (feet)	6.0
Excavation Equipment	CAT 316E	Excavation Contractor	WPFI (Christopher Maybee)	Approximate Pit Trend	N - S
Groundwater Depth (feet)		Date Measured		Approximate Surface Elevation (feet)	5143.1 (Approx.)
Comments				Latitude / Longitude	41.85223 , -112.32348

Elevation, feet	Depth, feet	Sample Type	Number	Graphic Log	MATERIAL DESCRIPTION	FIELD NOTES
					SILT, with sand, with clay, moist to dry, dark grayish brown, fine sand, roots, (ML), [TOPSOIL]	
	1					
	2				GRAVEL, silty, with sand - dense, dry, dark grayish brown, medium to coarse clast supported angular gravels and cobbles up to 12", fine sand, (GM)	
	3					
5139	4					
					SILT, with clay, with sand - stiff, dry, light tan, coarse matrix supported gravels and cobbles up to 9", (ML)	
	5				LIMESTONE - hard, fractured, calcareous silt infilling	
	6				Bottom of Hole at 6 feet	
	7					
	8					
5134	9					
	10					
	11					
	12					
	13					
5129	14					
	15					

GERHART COLE

Project: Bear River Project

Project Location: Whites Valley

Project Number: 13GCI329

DRAFT

LOG OF TEST PIT 16-TP-WV-19

Date(s) Excavated	09/26/2016	Logged By	T. Reed	Checked By	R. Buhler
Approximate Length (feet)	12	Approximate Width (feet)	4	Approximate Depth (feet)	7.5
Excavation Equipment	CAT 316E	Excavation Contractor	WPFI (Christopher Maybee)	Approximate Pit Trend	E - W
Groundwater Depth (feet)		Date Measured		Approximate Surface Elevation (feet)	5107.3 (Approx.)
Comments				Latitude / Longitude	41.85242 , -112.32335

Elevation, feet	Depth, feet	Sample Type	Number	Graphic Log	MATERIAL DESCRIPTION	FIELD NOTES
					SILT, with clay, with sand, trace gravels, moist to dry, dark grayish brown, fine to medium angular gravels up to 1.5", fine sand, moist to dry, (ML) [TOPSOIL]	
	1				Abundant gravels and cobbles up to 4"	
	2				GRAVEL, silty, with sand - medium dense, dry, tan to brown, fine to coarse matrix supported angular gravel and cobbles up to 12", (GM)	
	3					
5103	4					
	5					
	6					
	7					
					Bottom of Hole at 7.5 feet	
	8					
5098	9					
	10					
	11					
	12					
	13					
5093	14					
	15					

GERHART COLE

Project: Bear River Project

Project Location: Whites Valley

Project Number: 13GCI329

DRAFT

LOG OF TEST PIT 16-TP-WV-20

Date(s) Excavated	09/26/2016	Logged By	T. Reed	Checked By	R. Buhler
Approximate Length (feet)	11	Approximate Width (feet)	4	Approximate Depth (feet)	10.0
Excavation Equipment	CAT 316E	Excavation Contractor	WPFI (Christopher Maybee)	Approximate Pit Trend	N - S
Groundwater Depth (feet)		Date Measured		Approximate Surface Elevation (feet)	5093.3 (Approx.)
Comments				Latitude / Longitude	41.85281 , -112.32368

Elevation, feet	Depth, feet	Sample Type	Number	Graphic Log	MATERIAL DESCRIPTION	FIELD NOTES
					SILT, with sand, with clay, some gravel, moist to dry, dark grayish brown, fine to coarse angular gravels up to 3", fine sand, roots, (ML) [TOPSOIL]	
	1, 2, 3				CLAY, with sand, some gravel - medium stiff, dry, reddish brown to brown, fine to coarse angular matrix supported gravel and cobbles up to 6", fine to medium sand, dry, (CLL)	
5089	4, 5				GRAVEL, silty, with sand - dense, brown, dry, fine to coarse angular matrix supported gravel to cobbles up to 8", fine to medium sand, (GM)	
5084	6, 7, 8, 9				CLAY, with sand, some gravel - medium stiff, tan to brown, fine to coarse matrix supported angular gravels and cobbles to 5" max, moist, (CL)	
	10				Bottom of Hole at 10 feet	
5079	11, 12, 13, 14, 15					

GERHART COLE

Project: Bear River Project

Project Location: Whites Valley

Project Number: 13GCI329

DRAFT

LOG OF TEST PIT 16-TP-WV-21

Date(s) Excavated	09/26/2016	Logged By	T. Reed	Checked By	R. Buhler
Approximate Length (feet)	12	Approximate Width (feet)	4	Approximate Depth (feet)	9.0
Excavation Equipment	CAT 316E	Excavation Contractor	WPFI (Christopher Maybee)	Approximate Pit Trend	E - W
Groundwater Depth (feet)		Date Measured		Approximate Surface Elevation (feet)	5110.1 (Approx.)
Comments				Latitude / Longitude	41.84905 , -112.32359

Elevation, feet	Depth, feet	Sample Type	Number	Graphic Log	MATERIAL DESCRIPTION	FIELD NOTES
					SILT, with clay, with sand, few gravels, moist, dark grayish brown, fine to coarse angular gravel up to 3", fine to medium sand, roots, (ML), [TOPSOIL]	
	1				CLAY, with silt, with sand, some gravel - medium stiff, reddish brown, medium to coarse matrix supported angular gravels and cobbles up to 8", moist to dry, calcium carbonate mottling, (CL)	
	2					
	3					
5106	4				Little to no mottling below 4.5'	
	5					
	6					
	7					
	8					
5101	9				Bottom of Hole at 9 feet	
	10					
	11					
	12					
	13					
5096	14					
	15					

GERHART COLE

Project: Bear River Project

Project Location: Whites Valley

Project Number: 13GCI329

DRAFT

LOG OF TEST PIT 16-TP-WV-22

Date(s) Excavated	09/26/2016	Logged By	T. Reed	Checked By	R. Buhler
Approximate Length (feet)	11	Approximate Width (feet)	4	Approximate Depth (feet)	7.0
Excavation Equipment	CAT 316E	Excavation Contractor	WPFI (Christopher Maybee)	Approximate Pit Trend	N - S
Groundwater Depth (feet)		Date Measured		Approximate Surface Elevation (feet)	5090.5 (Approx.)
Comments				Latitude / Longitude	41.84916 , -112.32308

Elevation, feet	Depth, feet	Sample Type	Number	Graphic Log	MATERIAL DESCRIPTION	FIELD NOTES
					SILT, with sand, some gravel, moist, dark grayish brown, medium to coarse angular gravels and cobbles up to 4", roots, (ML), [TOPSOIL]	
	1				CLAY, with sand, some gravel - medium stiff, dry, light tan, medium to coarse angular matrix supported gravel and cobbles up to 6", (CL)	
	2					
	3					
	4					
5086						
	5				SILTSTONE - soft, fractured, sand and silt infilling, dips to south 10 degrees, dry	
	6					
	7				Bottom of Hole at 7 feet	
	8					
	9					
5081						
	10					
	11					
	12					
	13					
	14					
5076						
	15					

GERHART COLE

Project: Bear River Project

Project Location: Whites Valley

Project Number: 13GCI329

DRAFT

LOG OF TEST PIT 16-TP-WV-23

Date(s) Excavated	09/26/2016	Logged By	T. Reed	Checked By	R. Buhler
Approximate Length (feet)	11	Approximate Width (feet)	4	Approximate Depth (feet)	10.5
Excavation Equipment	CAT 316E	Excavation Contractor	WPFI (Christopher Maybee)	Approximate Pit Trend	E - W
Groundwater Depth (feet)		Date Measured		Approximate Surface Elevation (feet)	5075.7 (Approx.)
Comments				Latitude / Longitude	41.84887 , -112.32141

Elevation, feet	Depth, feet	Sample Type	Number	Graphic Log	MATERIAL DESCRIPTION	FIELD NOTES
					SILT, with sand, some gravel, moist, dark grayish brown, fine to coarse angular gravels and cobbles up to 5", fine to medium sand, roots, (ML) [TOPSOIL]	
	1				CLAY, with silt, with sand - medium stiff, moist, tan to brown, fine sand, (CL)	
					CLAY, with sand, with clay, some gravel - medium stiff, dry, light tan, medium to coarse angular matrix supported gravel and cobbles up to 6", calcium carbonate coating on clasts, fine to medium sand, dry, (ML)	
	2					
	3					
	4					
5071	5					
	6					
	7					
	8					
	9					
5066	10					
					Bottom of Hole at 10.5 feet	
	11					
	12					
	13					
	14					
5061	15					

GERHART COLE

Project: Bear River Project

Project Location: Whites Valley

Project Number: 13GCI329

DRAFT

LOG OF TEST PIT 16-TP-WV-24

Date(s) Excavated	09/23/2016	Logged By	T. Reed	Checked By	R. Buhler
Approximate Length (feet)	10	Approximate Width (feet)	4	Approximate Depth (feet)	10.0
Excavation Equipment	CAT 316E	Excavation Contractor	WPFI (Christopher Maybee)	Approximate Pit Trend	NW - SE
Groundwater Depth (feet)	Not Found	Date Measured	9/23/201	Approximate Surface Elevation (feet)	5260.8 (Approx.)
Comments				Latitude / Longitude	41.85257 , -112.33784

Elevation, feet	Depth, feet	Sample Type	Number	Graphic Log	MATERIAL DESCRIPTION	FIELD NOTES
					SILT, with sand, dry, grayish brown, roots, (ML), [TOPSOIL]	
	1					
	2				CLAY, trace gravels - stiff, reddish brown, blocky, fine gravel, (CL)	
	3					
	4				SAND, silty, with gravel - medium dense to dense, moist, light tan, fine angular gravel, fine to coarse sand, calcium carbonate coating on gravel, (SM)	
5256	5					
	6					
	7					
	8					
	9					
5251	10		GB-1		Bottom of Hole at 10 feet	
	11					
	12					
	13					
	14					
5246	15					

GERHART COLE

Project: Bear River Project

Project Location: Whites Valley

Project Number: 13GCI329

DRAFT

LOG OF TEST PIT 16-TP-WV-25

Date(s) Excavated	09/23/2016	Logged By	T. Reed	Checked By	R. Buhler
Approximate Length (feet)	13	Approximate Width (feet)	4	Approximate Depth (feet)	10.0
Excavation Equipment	CAT 316E	Excavation Contractor	WPFI (Christopher Maybee)	Approximate Pit Trend	NE - SW
Groundwater Depth (feet)	Not Found	Date Measured	9/25/201	Approximate Surface Elevation (feet)	5241 (Approx.)
Comments				Latitude / Longitude	41.85275 , -112.33788

Elevation, feet	Depth, feet	Sample Type	Number	Graphic Log	MATERIAL DESCRIPTION	FIELD NOTES
					SILT, with sand, dry, dark grayish brown, roots, (ML), [TOPSOIL]	
	1				CLAY - stiff, moist, reddish brown, blocky, fine gravel, (CL)	
	2					
	3					
	4				SAND, silty, with gravel - medium dense to dense, dry to moist, light tan, fine angular gravel, fine to coarse sand, calcium carbonate coating on gravel, (SM)	
5236	5					
	6					
	7				less calcium carbonate at 7 feet and color grades to tan	
	8					
	9					
5231	10				Bottom of Hole at 10 feet	
	11					
	12					
	13					
	14					
	15					

GERHART COLE

Project: Bear River Project

Project Location: Whites Valley

Project Number: 13GCI329

DRAFT

LOG OF TEST PIT 16-TP-WV-26

Date(s) Excavated	09/23/2016	Logged By	T. Reed	Checked By	R. Buhler
Approximate Length (feet)	12	Approximate Width (feet)	4	Approximate Depth (feet)	9.5
Excavation Equipment	CAT 316E	Excavation Contractor	WPFI (Christopher Maybee)	Approximate Pit Trend	E - W
Groundwater Depth (feet)	Not Found	Date Measured	9/23/201	Approximate Surface Elevation (feet)	5224 (Approx.)
Comments				Latitude / Longitude	41.85299 , -112.33788

Elevation, feet	Depth, feet	Sample Type	Number	Graphic Log	MATERIAL DESCRIPTION	FIELD NOTES
					SILT, with sand, dry to moist, dark grayish brown, roots, (ML), [TOPSOIL]	
	1					
	2				CLAY, trace gravel - stiff, moist, brown to reddish brown, blocky clay, fine gravel, roots, (CL)	
	3					
	4				Calcium carbonate coating mottling in layers 1/4" to 1/2" thick	
5219	5					
	6					
	7					
	8					
	9					
					Bottom of Hole at 9.5 feet	
5214	10					
	11					
	12					
	13					
	14					
	15					

GERHART COLE

Project: Bear River Project

Project Location: Whites Valley

Project Number: 13GCI329

DRAFT

LOG OF TEST PIT 16-TP-WV-27

Date(s) Excavated	09/23/2016	Logged By	T. Reed	Checked By	R. Buhler
Approximate Length (feet)	11	Approximate Width (feet)	4	Approximate Depth (feet)	10.5
Excavation Equipment	CAT 316E	Excavation Contractor	WPFI (Christopher Maybee)	Approximate Pit Trend	N - S
Groundwater Depth (feet)	Not Found	Date Measured		Approximate Surface Elevation (feet)	5222.9 (Approx.)
Comments				Latitude / Longitude	41.85247 , -112.34391

Elevation, feet	Depth, feet	Sample Type	Number	Graphic Log	MATERIAL DESCRIPTION	FIELD NOTES
					SILT, some sand, dry, dark grayish brown, roots, fine sand, dry, (ML), [TOPSOIL]	
	1				CLAY, with silt, some gravel - stiff, moist, reddish brown, blocky clay, fine to coarse angular gravels, (CL)	
	2				GRAVEL, silty, with sand - medium dense, dry to moist, light grayish brown, fine to coarse gravel, matrix supported, (GM)	
	3					
	4				CLAY - stiff, moist, reddish brown, massive, (CL)	
5218	5				SILT, with sand, some gravel - medium stiff, moist, brown, fine to coarse angular gravel, fine to coarse sand, (ML)	
	6					
	7				CLAY, trace gravel - stiff, moist, reddish brown, fine to coarse angular gravel, moist, (CH)	
	8					
	9					
5213	10		GB-1			
					Bottom of Hole at 10.5 feet	
	11					
	12					
	13					
	14					
	15					

GERHART COLE

Project: Bear River Project

Project Location: Whites Valley

Project Number: 13GCI329

DRAFT

LOG OF TEST PIT 16-TP-WV-28

Date(s) Excavated	09/23/2016	Logged By	T. Reed	Checked By	R. Buhler
Approximate Length (feet)	12	Approximate Width (feet)	4	Approximate Depth (feet)	11.5
Excavation Equipment	CAT 316E	Excavation Contractor	WPFI (Christopher Maybee)	Approximate Pit Trend	N - S
Groundwater Depth (feet)	Not Found	Date Measured		Approximate Surface Elevation (feet)	5202.3 (Approx.)
Comments				Latitude / Longitude	41.85373 , -112.34309

Elevation, feet	Depth, feet	Sample Type	Number	Graphic Log	MATERIAL DESCRIPTION	FIELD NOTES
					SILT with sand, dry, dark grayish brown, blocky, roots, (ML), [TOPSOIL]	
	1				CLAY - stiff, moist, reddish brown, blocky, (CL)	
	2					
	3					
	4				GRAVEL, silty, with sand - medium dense, dry, light tan to tan, fine to coarse angular gravel, calcium carbonate on clasts, matrix supported, (GM)	
5198	5					
	6					
	7					
	8				CLAY, with sand, trace gravel - medium stiff to stiff, moist, tan to brown, massive, (CL)	
	9					
5193	10					
	11		GB-1			
					Bottom of Hole at 11.5 feet	
	12					
	13					
	14					
5188	15					

GERHART COLE

Project: Bear River Project

Project Location: Whites Valley

Project Number: 13GCI329

DRAFT

LOG OF TEST PIT 16-TP-WV-29

Date(s) Excavated	09/21/2016	Logged By	R. Buhler	Checked By	R. Buhler
Approximate Length (feet)	10	Approximate Width (feet)	4	Approximate Depth (feet)	10.0
Excavation Equipment	CAT 316E	Excavation Contractor	WPFI (Christopher Maybee)	Approximate Pit Trend	N - S
Groundwater Depth (feet)	Not Found	Date Measured	9/27/201	Approximate Surface Elevation (feet)	5230 (Approx.)
Comments				Latitude / Longitude	41.84759 , -112.31277

Elevation, feet	Depth, feet	Sample Type	Number	Graphic Log	MATERIAL DESCRIPTION	FIELD NOTES
					SILT, sandy, some gravel, dry to moist, reddish brown, angular gravel, (ML), [TOPSOIL],	
	1				GRAVEL, silty, sandy - loose to medium dense, moist, dark brown, fine to coarse angular gravel, a few cobbles up to 4" in size, matrix supported, (GM)	
	2					
	3					
	4					
5225	5				CLAY, some sand, some gravel - soft to medium stiff, moist, brown, (CL)	
			GB-1			
	6					
	7					
	8					
	9					
5220	10				Bottom of Hole at 10 feet	
	11					
	12					
	13					
	14					
	15					

GERHART COLE

Project: Bear River Project

Project Location: Whites Valley

Project Number: 13GCI329

DRAFT

LOG OF TEST PIT 16-TP-WV-30

Date(s) Excavated	09/21/2016	Logged By	R. Buhler	Checked By	R. Buhler
Approximate Length (feet)	10	Approximate Width (feet)	4	Approximate Depth (feet)	6.0
Excavation Equipment	CAT 316E	Excavation Contractor	WPFI (Christopher Maybee)	Approximate Pit Trend	N - S
Groundwater Depth (feet)	Not Found	Date Measured		Approximate Surface Elevation (feet)	5254 (Approx.)
Comments				Latitude / Longitude	41.84742 , -112.31298

Elevation, feet	Depth, feet	Sample Type	Number	Graphic Log	MATERIAL DESCRIPTION	FIELD NOTES
	1				CLAY, some gravel, moist, reddish brown, angular gravel, (CL), [TOPSOIL]	
	2				CLAY, some sand, some gravel - soft to medium stiff, moist, black to dark gray, fine to coarse subangular gravel, (CL)	
	3					
			GB-1			
	4				CLAY, with gravel, some sand - soft to medium stiff, moist, reddish brown, high plasticity, (CH)	
5249	5					
			GB-2			
	6				Bottom of Hole at 6 feet	
	7					
	8					
	9					
5244	10					
	11					
	12					
	13					
	14					
	15					

GERHART COLE

Project: Bear River Project

Project Location: Whites Valley

Project Number: 13GCI329

DRAFT

LOG OF TEST PIT 16-TP-WV-31

Date(s) Excavated	09/22/2016	Logged By	T. Reed	Checked By	R. Buhler
Approximate Length (feet)	12	Approximate Width (feet)	4	Approximate Depth (feet)	9.0
Excavation Equipment	CAT 316E	Excavation Contractor	WPFI (Christopher Maybee)	Approximate Pit Trend	NE - SW
Groundwater Depth (feet)	Not Found	Date Measured		Approximate Surface Elevation (feet)	5221.3 (Approx.)
Comments				Latitude / Longitude	41.87846 , -112.34028

Elevation, feet	Depth, feet	Sample Type	Number	Graphic Log	MATERIAL DESCRIPTION	FIELD NOTES
					CLAY, with sand, dry, light grayish brown, roots, pinholes, moist, dry, (CL), [TOPSOIL]	
	1				CLAY, some sand - medium stiff, moist, reddish brown, fine gravel, high plasticity, (CH)	
	2					
	3					
			GB-1			
5217	4					
	5				Increasing sand with depth	
	6					
	7					
	8					
	9				Bottom of Hole at 9 feet	
5212						
	10					
	11					
	12					
	13					
	14					
5207						
	15					

GERHART COLE

Project: Bear River Project

Project Location: Whites Valley

Project Number: 13GCI329

DRAFT

LOG OF TEST PIT 16-TP-WV-32

Date(s) Excavated	09/22/2016	Logged By	T. Reed	Checked By	R. Buhler
Approximate Length (feet)	12	Approximate Width (feet)	4	Approximate Depth (feet)	9.0
Excavation Equipment	CAT 316E	Excavation Contractor	WPFI (Christopher Maybee)	Approximate Pit Trend	N - S
Groundwater Depth (feet)	Not Found	Date Measured	9/22/201	Approximate Surface Elevation (feet)	5192.3 (Approx.)
Comments				Latitude / Longitude	41.87627 , -112.3401

Elevation, feet	Depth, feet	Sample Type	Number	Graphic Log	MATERIAL DESCRIPTION	FIELD NOTES
					SILT, sandy, moist, dark brown, disturbed soil, (ML), [TOPSOIL}	
	1				CLAY, sandy, trace gravel - soft to medium stiff, moist, dark brown, (CL)	
	2					
	3					
	4					
5188						
	5					
	6					
	7					
	8					
	9				Bottom of Hole at 9 feet	
5183						
	10					
	11					
	12					
	13					
	14					
5178						
	15					

GERHART COLE

Project: Bear River Project

Project Location: Whites Valley

Project Number: 13GCI329

DRAFT

LOG OF TEST PIT 16-TP-WV-33

Date(s) Excavated	09/22/2016	Logged By	T. Reed	Checked By	R. Buhler
Approximate Length (feet)	11	Approximate Width (feet)	4	Approximate Depth (feet)	10.0
Excavation Equipment	CAT 316E	Excavation Contractor	WPFI (Christopher Maybee)	Approximate Pit Trend	E - W
Groundwater Depth (feet)	Not Found	Date Measured		Approximate Surface Elevation (feet)	5241.4 (Approx.)
Comments				Latitude / Longitude	41.87052 , -112.31857

Elevation, feet	Depth, feet	Sample Type	Number	Graphic Log	MATERIAL DESCRIPTION	FIELD NOTES
					SILT, with sand, some gravel, dry, light grayish brown, fine, roots, (ML), [TOPSOIL]	
	1				CLAY, with sand, some gravel - medium stiff, dry to moist, dark brown, fine sand, fine gravel, (CL)	
	2					
	3					
	4		GB-1			
5237						
	5					
	6					
	7					
	8				GRAVEL, clayey, with silt - dense, dry to moist, light tan to gray, fine to coarse gravel, numerous angular cobbles up to 8 to 10", mostly matrix supported, (GC)	
	9					
5232						
	10				Bottom of Hole at 10 feet	
	11					
	12					
	13					
	14					
5227						
	15					

GERHART COLE

Project: Bear River Project

Project Location: Whites Valley

Project Number: 13GCI329

DRAFT

LOG OF TEST PIT 16-TP-WV-34

Date(s) Excavated	09/22/2016	Logged By	T. Reed	Checked By	R. Buhler
Approximate Length (feet)	12	Approximate Width (feet)	4	Approximate Depth (feet)	10.0
Excavation Equipment	CAT 316E	Excavation Contractor	WPFI (Christopher Maybee)	Approximate Pit Trend	E - W
Groundwater Depth (feet)	Not Found	Date Measured		Approximate Surface Elevation (feet)	5220 (Approx.)
Comments				Latitude / Longitude	41.8694 , -112.32077

Elevation, feet	Depth, feet	Sample Type	Number	Graphic Log	MATERIAL DESCRIPTION	FIELD NOTES
					SILT, with sand, some gravel - medium stiff, light grayish brown, fine, roots, dry, (ML), [TOPSOIL]	
	1				GRAVEL, silty, with sand - medium dense to dense, dry to moist, light grayish brown, fine to coarse angular gravel, matrix supported, dry to moist, (GM)	
	2					
	3		BULK-1			
	4					
5215	5				SILT, sandy, trace gravel - medium stiff, tan to brown, fine to coarse gravel, moist, (ML)	
	6				grades to SILT with sand, trace gravel at 6 feet and yellowish brown	
	7					
	8					
	9					
5210	10				Bottom of Hole at 10 feet	
	11					
	12					
	13					
	14					
	15					

GERHART COLE

Project: Bear River Project

Project Location: Whites Valley

Project Number: 13GCI329

DRAFT

LOG OF TEST PIT 16-TP-WV-35

Date(s) Excavated	09/22/2016	Logged By	T. Reed	Checked By	R. Buhler
Approximate Length (feet)	10	Approximate Width (feet)	4	Approximate Depth (feet)	10.0
Excavation Equipment	CAT 316E	Excavation Contractor	WPFI (Christopher Maybee)	Approximate Pit Trend	NE - SW
Groundwater Depth (feet)	Not Found	Date Measured		Approximate Surface Elevation (feet)	5216.9 (Approx.)
Comments				Latitude / Longitude	41.86689 , -112.32264

Elevation, feet	Depth, feet	Sample Type	Number	Graphic Log	MATERIAL DESCRIPTION	FIELD NOTES
	1				GRAVEL, silty, with sandy, dry to moist, light grayish brown, fine angular, gravels, blocky, matrix supported, (GM)	
	2				CLAY, with sand - medium stiff to stiff, moist, light brown to yellowish brown, fine to coarse gravels, (CL)	
	3					
	4					
5212	5					
	6					
	7					
	8					
	9					
5207	10				Bottom of Hole at 10 feet	
	11					
	12					
	13					
	14					
	15					

GERHART COLE

Project: Bear River Project

Project Location: Whites Valley

Project Number: 13GCI329

DRAFT

LOG OF TEST PIT 16-TP-WV-36

Date(s) Excavated	09/22/2016	Logged By	T. Reed	Checked By	R. Buhler
Approximate Length (feet)	11	Approximate Width (feet)	4	Approximate Depth (feet)	11.0
Excavation Equipment	CAT 316E	Excavation Contractor	WPFI (Christopher Maybee)	Approximate Pit Trend	E - W
Groundwater Depth (feet)	Not Found	Date Measured		Approximate Surface Elevation (feet)	5098 (Approx.)
Comments				Latitude / Longitude	41.85792 , -112.33023

Elevation, feet	Depth, feet	Sample Type	Number	Graphic Log	MATERIAL DESCRIPTION	FIELD NOTES
					CLAY, with sand, trace gravel, some cobbles, dry, light grayish brown, fine, roots, (CL), [TOPSOIL]	
	1				CLAY, with sand - medium stiff, moist to wet below 5 ft, tan to brown, (CL-ML)	
	2					
	3					
	4					
5093	5					
	6					
	7					
	8					
	9					
5088	10					
	11				Bottom of Hole at 11 feet	
	12					
	13					
	14					
	15					

GERHART COLE

Project: Bear River Project

Project Location: Whites Valley

Project Number: 13GCI329

DRAFT

LOG OF TEST PIT 16-TP-WV-37

Date(s) Excavated	09/22/2016	Logged By	T. Reed	Checked By	R. Buhler
Approximate Length (feet)	11	Approximate Width (feet)	4	Approximate Depth (feet)	11.0
Excavation Equipment	CAT 316E	Excavation Contractor	WPFI (Christopher Maybee)	Approximate Pit Trend	E - W
Groundwater Depth (feet)	Not Found	Date Measured		Approximate Surface Elevation (feet)	5122.9 (Approx.)
Comments				Latitude / Longitude	41.86337 , -112.33084

Elevation, feet	Depth, feet	Sample Type	Number	Graphic Log	MATERIAL DESCRIPTION	FIELD NOTES
					CLAY, with sand, trace gravel, some cobbles, dry, light grayish brown, fine, roots, dry, (CL), [TOPSOIL]	
	1				CLAY, with sand, some gravel - medium stiff, moist to wet, reddish brown, thin gravel layers, subrounded to subangular gravel, cobbles up to 4", clast supported in thin gravel layers, moist to wet, (CL-ML)	
	2					
	3		GB-1			
	4				CLAY, with sand - medium stiff, moist, light brown to tan, moist, (ML)	
5118	5					
	6					
	7					
	8					
	9					
5113	10					
	11				Bottom of Hole at 11 feet	
	12					
	13					
	14					
	15					

GERHART COLE

Project: Bear River Project

Project Location: Whites Valley

Project Number: 13GCI329

DRAFT

LOG OF TEST PIT 16-TP-WV-38

Date(s) Excavated	09/22/2016	Logged By	T. Reed	Checked By	R. Buhler
Approximate Length (feet)	12	Approximate Width (feet)	4	Approximate Depth (feet)	10.0
Excavation Equipment	CAT 316E	Excavation Contractor	WPFI (Christopher Maybee)	Approximate Pit Trend	NE - SW
Groundwater Depth (feet)	Not Found	Date Measured		Approximate Surface Elevation (feet)	5153.3 (Approx.)
Comments				Latitude / Longitude	41.8668 , -112.33159

Elevation, feet	Depth, feet	Sample Type	Number	Graphic Log	MATERIAL DESCRIPTION	FIELD NOTES
					CLAY, trace gravels, dry, dark brown, trace fine to coarse angular gravels, roots, (CL)	
	1				CLAY, with sand - medium stiff, moist, tan to light brown, calcium carbonate staining, mottling, (CL)	
	2					
	3				trace gravel at 2.5 ft, less mottling and calcium carbonate staining, thin layers of clast supported fine gravels, pockets of silty sand	
5149	4				grades to some gravel and medium stiff at 4 ft, cobbles up to 5" moist	
	5					
	6				Increasing gravel content with depth	
	7					
	8					
5144	9					
	10				Bottom of Hole at 10 feet	
	11					
	12					
	13					
5139	14					
	15					

GERHART COLE

Project: Bear River Project

Project Location: Whites Valley

Project Number: 13GCI329

DRAFT

LOG OF TEST PIT 16-TP-WV-39

Date(s) Excavated	09/22/2016	Logged By	T. Reed	Checked By	R. Buhler
Approximate Length (feet)	11	Approximate Width (feet)	4	Approximate Depth (feet)	10.0
Excavation Equipment	CAT 316E	Excavation Contractor	WPFI (Christopher Maybee)	Approximate Pit Trend	N - S
Groundwater Depth (feet)	Not Found	Date Measured		Approximate Surface Elevation (feet)	5117.3 (Approx.)
Comments				Latitude / Longitude	41.86686 , -112.33603

Elevation, feet	Depth, feet	Sample Type	Number	Graphic Log	MATERIAL DESCRIPTION	FIELD NOTES
	1				CLAY, with sand - moist to dry, grayish brown, roots, pinholes, moist, dry, (CL), [TOPSOIL]	
	2				CLAY, trace sand - medium stiff, moist, brown to tan, fine sand, (CL)	
	3					
5113	4					
	5				Increasing clay content with depth	
	6					
	7					
	8					
5108	9					
	10				Bottom of Hole at 10 feet	
	11					
	12					
	13					
5103	14					
	15					

GERHART COLE

Project: Bear River Project

Project Location: Whites Valley

Project Number: 13GCI329

DRAFT

LOG OF TEST PIT 16-TP-WV-40

Date(s) Excavated	09/23/2016	Logged By	T. Reed	Checked By	R. Buhler
Approximate Length (feet)	13	Approximate Width (feet)	4	Approximate Depth (feet)	9.0
Excavation Equipment	CAT 316E	Excavation Contractor	WPFI (Christopher Maybee)	Approximate Pit Trend	N - S
Groundwater Depth (feet)	Not Found	Date Measured		Approximate Surface Elevation (feet)	5142.2 (Approx.)
Comments				Latitude / Longitude	41.85471 , -112.33273

Elevation, feet	Depth, feet	Sample Type	Number	Graphic Log	MATERIAL DESCRIPTION	FIELD NOTES
	1				CLAY, with sand, trace gravel, dry to moist, grayish brown, fine to coarse angular gravels, (CL), [TOPSOIL]	
	2				CLAY, some gravel - stiff, moist, brown to reddish brown, fine to coarse angular gravels, cobbles up to 4", fine roots, (CL)	
	3					
5138	4					
	5				SILT, with sand, some gravels - medium stiff to stiff, moist, tan to brown, fine to coarse gravels, (ML)	
	6					
	7					
	8					
5133	9				Bottom of Hole at 9 feet	
	10					
	11					
	12					
	13					
5128	14					
	15					

GERHART COLE

Project: Bear River Project

Project Location: Whites Valley

Project Number: 13GCI329

DRAFT

LOG OF TEST PIT 16-TP-WV-41

Date(s) Excavated	09/21/2016	Logged By	R. Buhler	Checked By	R. Buhler
Approximate Length (feet)	12	Approximate Width (feet)	4	Approximate Depth (feet)	8.0
Excavation Equipment	CAT 316E	Excavation Contractor	WPFI (Christopher Maybee)	Approximate Pit Trend	N - S
Groundwater Depth (feet)	Not Found	Date Measured		Approximate Surface Elevation (feet)	5181.7 (Approx.)
Comments				Latitude / Longitude	41.84851 , -112.31517

Elevation, feet	Depth, feet	Sample Type	Number	Graphic Log	MATERIAL DESCRIPTION	FIELD NOTES
					SILT, gravelly, some sand, dry to moist, dark gray to black, angular coarse gravel, matrix supported, (ML), [TOPSOIL}	
	1				CLAY, with sand, some gravel, - medium stiff to stiff, dry to moist, dark gray to black, angular coarse gravel, matrix supported, (CL)	
	2					
	3					
	4					
5177	5					
			GB-1			
	6					
	7					
	8				Bottom of Hole at 8 feet	
	9					
5172	10					
	11					
	12					
	13					
	14					
5167	15					

GERHART COLE

Project: Bear River Project

Project Location: Whites Valley

Project Number: 13GCI329

DRAFT

LOG OF TEST PIT 16-TP-WV-42

Date(s) Excavated	09/21/2016	Logged By	R. Buhler	Checked By	R. Buhler
Approximate Length (feet)	12	Approximate Width (feet)	4	Approximate Depth (feet)	10.0
Excavation Equipment	CAT 316E	Excavation Contractor	WPFI (Christopher Maybee)	Approximate Pit Trend	NE - SW
Groundwater Depth (feet)	Not Found	Date Measured		Approximate Surface Elevation (feet)	5184.3 (Approx.)
Comments				Latitude / Longitude	41.8484 , -112.31551

Elevation, feet	Depth, feet	Sample Type	Number	Graphic Log	MATERIAL DESCRIPTION	FIELD NOTES
	1, 2				SILT, gravelly, some sand - medium stiff, dark gray to black, angular coarse gravel, matrix supported, dry to moist, (ML), [TOPSOIL}	
5180	3, 4, 5, 6, 7, 8, 9				CLAY, with gravel, with sand - medium stiff, moist, reddish brown, fine to coarse gravel angular, some 4 to 6" cobbles, (CL)	
5175	9		GB-1			
	10				Bottom of Hole at 10 feet	
5170	11, 12, 13, 14, 15					

GERHART COLE

Project: Bear River Project

Project Location: Whites Valley

Project Number: 13GCI329

DRAFT

LOG OF TEST PIT 16-TP-WV-43

Date(s) Excavated	10/06/2016	Logged By	T. Reed	Checked By	R. Buhler
Approximate Length (feet)	11	Approximate Width (feet)	4	Approximate Depth (feet)	4.5
Excavation Equipment	CAT 316E	Excavation Contractor	WPFI (Christopher Maybee)	Approximate Pit Trend	NE - SW
Groundwater Depth (feet)		Date Measured		Approximate Surface Elevation (feet)	5164.6 (Approx.)
Comments				Latitude / Longitude	41.84815 , -112.31702

Elevation, feet	Depth, feet	Sample Type	Number	Graphic Log	MATERIAL DESCRIPTION	FIELD NOTES
					SILT, with sand, with clay - loose, dark grayish brown, moist, roots, (ML) [TOPSOIL]	
	1		BULK-01		GRAVEL, silty, with sand, some cobbles - medium dense, fine to coarse angular matrix supported gravel to cobbles up to 9", dry, (GM)	Large fractured bedrock clast in layer (15")
	2				LIMESTONE, slightly weathered, very fractured, silt infilling fractures of up to 3" in width	
	3					
	4				LIMESTONE, fresh, fractured, silt infilling fractures of up to 0.5" in width, dips to south at 15 degrees	
5160					Bottom of Hole at 4.5 feet	
	5					
	6					
	7					
	8					
	9					
5155						
	10					
	11					
	12					
	13					
	14					
5150						
	15					

GERHART COLE

Project: Bear River Project

Project Location: Whites Valley

Project Number: 13GCI329

DRAFT

LOG OF TEST PIT 16-TP-WV-44

Date(s) Excavated	10/06/2016	Logged By	T. Reed	Checked By	R. Buhler
Approximate Length (feet)	12	Approximate Width (feet)	4	Approximate Depth (feet)	10.0
Excavation Equipment	CAT 316E	Excavation Contractor	WPFI (Christopher Maybee)	Approximate Pit Trend	E - W
Groundwater Depth (feet)		Date Measured		Approximate Surface Elevation (feet)	5195.3 (Approx.)
Comments				Latitude / Longitude	41.84793 , -112.3165

Elevation, feet	Depth, feet	Sample Type	Number	Graphic Log	MATERIAL DESCRIPTION	FIELD NOTES
	1				SILT, with sand, few gravels - loose, dark grayish brown, fine to coarse angular gravels to cobbles up to 6", moist to dry, roots, (ML) [TOPSOIL]	
	2		BULK-01		GRAVEL, silty, with sand, with cobbles - dense, tan, fine to coarse angular matrix supported gravel to cobbles up to 8", abundant carbonate mottling, dry, (GM)	
	3				Carbonate mottling decreases to none	
5191	4					
	5					
	6					
	7					
	8					
5186	9					
	10				Bottom of Hole at 10 feet	
	11					
	12					
	13					
5181	14					
	15					

GERHART COLE

Project: Bear River Project

Project Location: Whites Valley

Project Number: 13GCI329

DRAFT

LOG OF TEST PIT 16-TP-WV-45

Date(s) Excavated	10/06/2016	Logged By	T. Reed	Checked By	R. Buhler
Approximate Length (feet)	13	Approximate Width (feet)	4	Approximate Depth (feet)	8.0
Excavation Equipment	CAT 316E	Excavation Contractor	WPFI (Christopher Maybee)	Approximate Pit Trend	NW - SE
Groundwater Depth (feet)		Date Measured		Approximate Surface Elevation (feet)	5183.7 (Approx.)
Comments				Latitude / Longitude	41.84822 , -112.3162

Elevation, feet	Depth, feet	Sample Type	Number	Graphic Log	MATERIAL DESCRIPTION	FIELD NOTES
					SILT, with sand, trace gravel - loose, dark grayish brown, coarse angular gravel to cobbles up to 6", roots, moist, (ML) [TOPSOIL]	
	1				Gravely, silty, with sand, - dense, tan, fine to coarse subangular matrix supported gravels to cobbles up to 8", dry, abundant carbonate mottling, (GM)	
	2					
	3				Carbonate mottling decreases to none	
	4					
5179	5					
	6					
	7					
			GB-01			
	8				Bottom of Hole at 8 feet	
	9					
5174	10					
	11					
	12					
	13					
	14					
5169	15					

GERHART COLE

Project: Bear River Project

Project Location: Whites Valley

Project Number: 13GCI329

DRAFT

LOG OF TEST PIT 16-TP-WV-46

Date(s) Excavated	10/06/2016	Logged By	T. Reed	Checked By	R. Buhler
Approximate Length (feet)	12	Approximate Width (feet)	4	Approximate Depth (feet)	10.0
Excavation Equipment	CAT 316E	Excavation Contractor	WPFI (Christopher Maybee)	Approximate Pit Trend	N - S
Groundwater Depth (feet)		Date Measured		Approximate Surface Elevation (feet)	5095.9 (Approx.)
Comments				Latitude / Longitude	41.84835 , -112.3182

Elevation, feet	Depth, feet	Sample Type	Number	Graphic Log	MATERIAL DESCRIPTION	FIELD NOTES
					SILT, with sand, with clay - loose, dark grayish brown, moist, roots, (ML) [TOPSOIL]	
	1				CLAY, with silt - stiff, brown, blocky, dry to moist, trace fine roots, (CL)	
	2		GB-01			
	3					
	4					
5091	5					
	6					
	7					
	8				SILT, with sand, with clay, with gravel, some cobbles - medium stiff, light tan, fine to coarse subangular to subrounded matrix supported gravels to cobbles up to 5", moist to dry, (ML)	
	9					
			BULK-02			
5086	10				Bottom of Hole at 10 feet	
	11					
	12					
	13					
	14					
	15					

GERHART COLE

Project: Bear River Project

Project Location: Whites Valley

Project Number: 13GCI329

DRAFT

LOG OF TEST PIT 16-TP-WV-47

Date(s) Excavated	10/06/2016	Logged By	T. Reed	Checked By	R. Buhler
Approximate Length (feet)	12	Approximate Width (feet)	4	Approximate Depth (feet)	5.0
Excavation Equipment	CAT 316E	Excavation Contractor	WPFI (Christopher Maybee)	Approximate Pit Trend	NE - SW
Groundwater Depth (feet)		Date Measured		Approximate Surface Elevation (feet)	5170.4 (Approx.)
Comments				Latitude / Longitude	41.84841 , -112.32255

Elevation, feet	Depth, feet	Sample Type	Number	Graphic Log	MATERIAL DESCRIPTION	FIELD NOTES
					SILT, with sand, trace gravel - loose, dark grayish brown, fine to coarse angular matrix supported gravel to cobbles up to 5", (ML) [TOPSOIL]	
	1				SILT, with clay, with sand, some gravel - medium stiff, tan to brown, fine to coarse angular matrix supported gravel to cobbles up to 4", dry, (ML)	
	2				GRAVEL, silty, with sand, with cobbles - medium dense, light tan, fine to coarse angular matrix supported gravel to cobbles up to 6", carbonate coating on clasts, dry, (GM)	
	3					
	4					
5166			BULK-01		LIMESTONE, fresh, fractured, silt infilling fractures, dips to south at 10 degrees	
	5				Bottom of Hole at 5 feet	
	6					
	7					
	8					
	9					
5161						
	10					
	11					
	12					
	13					
	14					
5156						
	15					

GERHART COLE

Project: Bear River Project

Project Location: Whites Valley

Project Number: 13GCI329

DRAFT

LOG OF TEST PIT 16-TP-WV-48

Date(s) Excavated	10/06/2016	Logged By	T. Reed	Checked By	R. Buhler
Approximate Length (feet)	12	Approximate Width (feet)	4	Approximate Depth (feet)	2.0
Excavation Equipment	CAT 316E	Excavation Contractor	WPFI (Christopher Maybee)	Approximate Pit Trend	N - S
Groundwater Depth (feet)		Date Measured		Approximate Surface Elevation (feet)	5121.5 (Approx.)
Comments				Latitude / Longitude	41.84927 , -112.32249

Elevation, feet	Depth, feet	Sample Type	Number	Graphic Log	MATERIAL DESCRIPTION	FIELD NOTES
					SILT, with sand, with gravel - loose, dark grayish brown, coarse angular gravel to cobbles up to 10", roots, moist, (ML)	
	1				GRAVEL, silty, with sand, with cobbles - dense, light tan, fine to coarse angular gravel to cobbles up to 10", carbonate coating on clasts, dry, (GM)	
			BULK-01		LIMESTONE, fresh, fractured, silt infilling fractures	
	2				Bottom of Hole at 2 feet	
	3					
	4					
5117						
	5					
	6					
	7					
	8					
	9					
5112						
	10					
	11					
	12					
	13					
	14					
5107						
	15					

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DRAFT

Location:	16-TP-WV-01	**Description:**	Test Pit – 1 excavation to ~ 4 ft.

Location:	16-TP-WV-01	**Description:**	Test Pit – 1 excavation to ~ 6 ft.

SELECT PHOTOS OF TEST PIT FIELD STUDIES

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Figure B50

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DRAFT

Location:	16-TP-WV-02	**Description:**	Test Pit – 1 full excavation to ~ 6 ft.

Location:	16-TP-WV-02	**Description:**	Test Pit – 1 excavation to ~ 6 ft.

SELECT PHOTOS OF TEST PIT FIELD STUDIES

Bear River Project Concept Study
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Figure B51

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DRAFT

Location:	16-TP-WV-03	**Description:**	Test Pit – 3 full excavation to ~ 5 ft.

SELECT PHOTOS OF TEST PIT FIELD STUDIES

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Figure B52

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DRAFT

Location:	16-TP-WV-04	**Description:**	Test Pit – 4 full excavation to ~ 6 ft.

Location:	16-TP-WV-04	**Description:**	Test Pit – 4 full excavation to ~ 6 ft.

SELECT PHOTOS OF TEST PIT FIELD STUDIES

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Figure B53

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DRAFT

Location:	16-TP-WV-05	**Description:**	Test Pit – 5 excavation to ~ 5 ft.

Location:	16-TP-WV-05	**Description:**	Test Pit – 5 full excavation to ~ 10 ft.

SELECT PHOTOS OF TEST PIT FIELD STUDIES

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Figure B54

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DRAFT

Location:	16-TP-WV-06	**Description:**	Test Pit – 6; full excavation to ~ 3 ft.

Location:	16-TP-WV-06	**Description:**	Test Pit – 6 excavation spoils

SELECT PHOTOS OF TEST PIT FIELD STUDIES

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Figure B55

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DRAFT

Location:	16-TP-WV-07	**Description:**	Test Pit – 7; excavation to ~ 3 ft.

Location:	16-TP-WV-07	**Description:**	Test Pit – 7 excavation spoils

SELECT PHOTOS OF TEST PIT FIELD STUDIES

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Figure B56

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DRAFT

Location:	16-TP-WV-08	**Description:**	Test Pit – 8; excavation to ~ 6.5 ft.

Location:	16-TP-WV-08	**Description:**	Test Pit – 8; excavation to ~ 10 ft.

SELECT PHOTOS OF TEST PIT FIELD STUDIES

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Figure B57

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DRAFT

Location:	16-TP–WV-09	**Description:**	Test Pit – 9; excavation spoils

Location:	16-TP–WV-09	**Description:**	Test Pit – 9; excavation to ~ 10 ft.

SELECT PHOTOS OF TEST PIT FIELD STUDIES

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Figure B58

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DRAFT

Location:	16-TP–WV-10	**Description:**	Test Pit – 10; excavation to ~ 5 ft

Location:	16-TP–WV-10	**Description:**	Test Pit – 10; excavation spoils

SELECT PHOTOS OF TEST PIT FIELD STUDIES

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Figure B59

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DRAFT

Location:	16-TP–WV-10	**Description:**	Test Pit – 10; full excavation to ~ 10 ft

SELECT PHOTOS OF TEST PIT FIELD STUDIES

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Figure B60

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DRAFT

Location:	16-TP–WV-11	**Description:**	Test Pit – 11; upper part of excavation ~ 3 ft – and excavation spoils

Location:	16-TP–WV-11	**Description:**	Test Pit – 11; full excavation to 13

SELECT PHOTOS OF TEST PIT FIELD STUDIES

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Figure B61

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DRAFT

Location:	16-TP–WV-12	**Description:**	Test Pit – 12; excavation ~ 5 ft

Location:	16-TP–WV-12	**Description:**	Test Pit – 12; excavation spoils

SELECT PHOTOS OF TEST PIT FIELD STUDIES

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Figure B62

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Location:	16-TP–WV-12	**Description:**	Test Pit – 12; full excavation to ~ 11 ft

SELECT PHOTOS OF TEST PIT FIELD STUDIES

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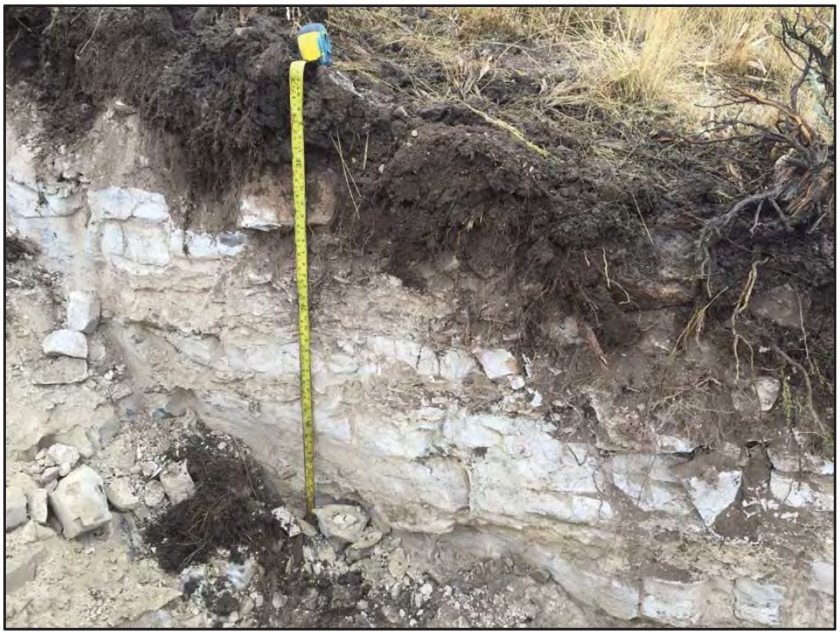
Figure B63

DRAFT



Location:	16-TP–WV-13	**Description:**	Test Pit – 13; excavation ~ 3.5 ft

Location:	16-TP–WV-13	**Description:**	Test Pit – 13; excavation ~ 3.5 ft

SELECT PHOTOS OF TEST PIT FIELD STUDIES

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Figure B64

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DRAFT

Location:	16-TP–WV-14	**Description:**	Test Pit – 13; excavation ~ 5 ft

Location:	16-TP–WV-14	**Description:**	Test Pit – 13; excavation ~ 5 ft

SELECT PHOTOS OF TEST PIT FIELD STUDIES:

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Figure B65

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DRAFT

Location:	16-TP–WV-15	**Description:**	Test Pit – 15; excavation ~ 5 ft

Location:	16-TP–WV-15	**Description:**	Test Pit – 15; excavation spoils

SELECT PHOTOS OF TEST PIT FIELD STUDIES

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Figure B66

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DRAFT

Location:	16-TP–WV-15	**Description:**	Test Pit – 15; full excavation to ~ 11 ft

SELECT PHOTOS OF TEST PIT FIELD STUDIES:

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Figure B67

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DRAFT

Location:	16-TP–WV-16	**Description:**	Test Pit – 16; excavation ~ 7 ft

Location:	16-TP–WV-16	**Description:**	Test Pit – 16; full excavation ~ 10.5 ft

SELECT PHOTOS OF TEST PIT FIELD STUDIES:

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Figure B68

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DRAFT

Location:	16-TP–WV-17	**Description:**	Test Pit – 17; excavation ~ 6 ft

Location:	16-TP–WV-17	**Description:**	Test Pit – 17

SELECT PHOTOS OF TEST PIT FIELD STUDIES

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Figure B69

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DRAFT

Location:	16-TP–WV-18	**Description:**	Test Pit – 18; excavation ~ 5 ft

Location:	16-TP–WV-18	**Description:**	Test Pit – 18; excavation spoils

SELECT PHOTOS OF TEST PIT FIELD STUDIES

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Figure B70

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DRAFT

Location:	16-TP–WV-19	**Description:**	Test Pit – 19; excavation ~ 3 ft

Location:	16-TP–WV-19	**Description:**	Test Pit – 19; excavation to 7.5 ft

SELECT PHOTOS OF TEST PIT FIELD STUDIES

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Figure B71

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DRAFT

Location:	16-TP–WV-20	**Description:**	Test Pit – 20; excavation ~ 4 ft

Location:	16-TP–WV-20	**Description:**	Test Pit – 20; full excavation to 10 ft

SELECT PHOTOS OF TEST PIT FIELD STUDIES

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Figure B72

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DRAFT

Location:	16-TP–WV-21	**Description:**	Test Pit – 21; excavation ~ 6 ft

Location:	16-TP–WV-21	**Description:**	Test Pit – 21; full excavation to 9 ft

SELECT PHOTOS OF TEST PIT FIELD STUDIES

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Figure B73

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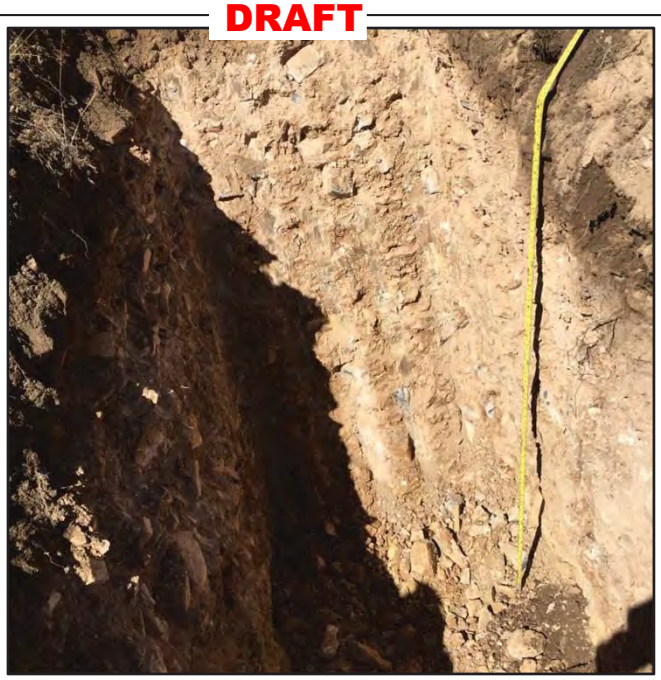
DRAFT



Location:	16-TP–WV-22	**Description:**	Test Pit – 22; excavation ~ 5 ft

Location:	16-TP–WV-22	**Description:**	Test Pit - 22 – Excavation spoils

SELECT PHOTOS OF TEST PIT FIELD STUDIES

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Figure B74

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DRAFT

Location:	16-TP–WV-23	**Description:**	Test Pit – 23; excavation ~ 5 ft

Location:	16-TP–WV-23	**Description:**	Test Pit – 23 – Full excavation ~10.5 ft

SELECT PHOTOS OF TEST PIT FIELD STUDIES

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Figure B75

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DRAFT

Location:	16-TP–WV-24	**Description:**	Test Pit – 24; excavation ~ 5 ft

Location:	16-TP–WV-24	**Description:**	Test Pit – 24 – Full excavation ~10 ft

SELECT PHOTOS OF TEST PIT FIELD STUDIES

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Figure B76

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DRAFT

Location:	16-TP–WV-25	**Description:**	Test Pit – 25; excavation ~ 2 ft

Location:	T16-P–WV-25	**Description:**	Test Pit – 25 – Full excavation ~10 ft

SELECT PHOTOS OF TEST PIT FIELD STUDIES

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Figure B77

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DRAFT

Location:	16-TP–WV-26	**Description:**	Test Pit – 26; excavation ~ 5 ft

Location:	16-TP–WV-26	**Description:**	Test Pit – 26 – Full excavation ~9.5 ft

SELECT PHOTOS OF TEST PIT FIELD STUDIES

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Figure B78

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DRAFT

Location:	16-TP–WV-27	**Description:**	Test Pit – 27; excavation ~ 5 ft

Location:	16-TP–WV-27	**Description:**	Test Pit – 27 – Full excavation ~10.5 ft

SELECT PHOTOS OF TEST PIT FIELD STUDIES

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Figure B79

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DRAFT

Location:	16-TP–WV-28	**Description:**	Test Pit – 28; excavation ~ 5 ft

Location:	16-TP–WV-28	**Description:**	Test Pit – 28 – Full excavation ~11.5 ft

SELECT PHOTOS OF TEST PIT FIELD STUDIES:

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Figure B80

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DRAFT

Location:	16-TP–WV-29	**Description:**	Test Pit – 29; excavation ~ 5 ft

Location:	16-TP–WV-29	**Description:**	Test Pit – 29 – Full excavation ~10 ft

SELECT PHOTOS OF TEST PIT FIELD STUDIES

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Figure B81

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DRAFT

Location:	16-TP–WV-30	**Description:**	Test Pit – 30 – Full excavation ~6 ft

SELECT PHOTOS OF TEST PIT FIELD STUDIES

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Figure B82

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DRAFT

Location:	16-TP–WV-31	**Description:**	Test Pit – 31; full excavation ~ 9 ft

Location:	16-TP–WV-31	**Description:**	Test Pit – 31 – excavation spoils

SELECT PHOTOS OF TEST PIT FIELD STUDIES

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Figure B83

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DRAFT

Location:	16-TP–WV-32	**Description:**	Test Pit – 32; full excavation ~ 9 ft

SELECT PHOTOS OF TEST PIT FIELD STUDIES

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Figure B84

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DRAFT

Location:	16-TP–WV-33	**Description:**	Test Pit – 33; full excavation ~ 10 ft

Location:	16-TP–WV-33	**Description:**	Test Pit – 33 – excavation spoils

SELECT PHOTOS OF TEST PIT FIELD STUDIES

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Figure B85

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DRAFT

Location:	16-TP–WV-34	**Description:**	Test Pit – 31; full excavation ~ 10 ft

SELECT PHOTOS OF TEST PIT FIELD STUDIES

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Figure B86

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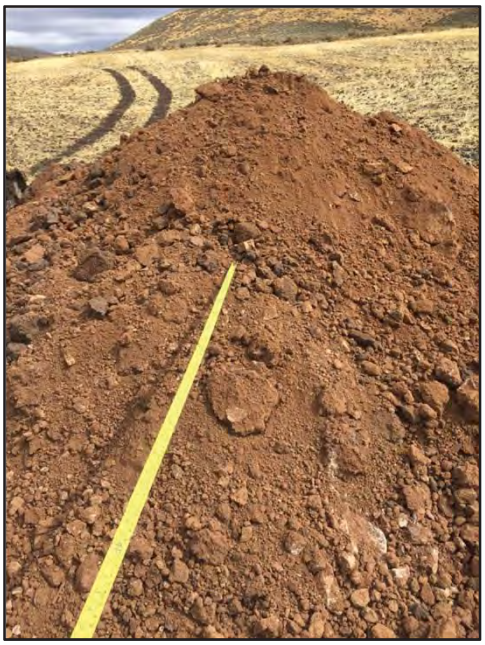
DRAFT

Location:	16-TP–WV-35	**Description:**	Test Pit – 35; full excavation ~ 10 ft



Location:	16-TP–WV-35	**Description:**	Test Pit – 35 – excavation spoils

SELECT PHOTOS OF TEST PIT FIELD STUDIES

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Figure B87

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DRAFT

Location:	16-TP–WV-36	**Description:**	Test Pit – 36; excavation ~ 5 ft

Location:	16-TP–WV-36	**Description:**	Test Pit – 36 – full excavation ~ 11 ft

SELECT PHOTOS OF TEST PIT FIELD STUDIES

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Figure B88

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DRAFT

Location:	16-TP–WV-37	**Description:**	Test Pit – 37; excavation ~ 5 ft

Location:	16-TP–WV-37	**Description:**	Test Pit – 37 – full excavation ~ 11 ft

SELECT PHOTOS OF TEST PIT FIELD STUDIES

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Figure B89

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DRAFT

Location:	16-TP–WV-38	**Description:**	Test Pit – 38; excavation ~ 3 ft

Location:	16-TP–WV-38	**Description:**	Test Pit – 38 – excavation spoils

SELECT PHOTOS OF TEST PIT FIELD STUDIES

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Figure B90

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DRAFT

Location:	16-TP–WV-39	**Description:**	Test Pit – 39; excavation ~ 5 ft

Location:	16-TP–WV-39	**Description:**	Test Pit – 39 – full excavation ~ 10 ft

SELECT PHOTOS OF TEST PIT FIELD STUDIES

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Figure B91

J:\PROJECTS\Bowie Resources\16GCI744 SUFCO Waste Rock\Analyses\Report

DRAFT

Location:	16-TP–WV-40	**Description:**	Test Pit – 40; excavation ~ 5 ft

Location:	16-TP–WV-40	**Description:**	Test Pit – 40 – full excavation ~ 9 ft

SELECT PHOTOS OF TEST PIT FIELD STUDIES

Bear River Project Concept Study
Whites Valley

GERHART COLE

Figure B92

J:\PROJECTS\Bowie Resources\16GCI744 SUFCO Waste Rock\Analyses\Report

DRAFT

Location:	16-TP–WV-41	Description:	Test Pit – 41 – full excavation ~ 8 ft

SELECT PHOTOS OF TEST PIT FIELD STUDIES

Bear River Project Concept Study
Whites Valley

GERHART COLE

Figure B93

J:\PROJECTS\Bowie Resources\16GCI744 SUFCO Waste Rock\Analyses\Report

DRAFT

Location:	16-TP–WV-42	Description:	Test Pit – 42 – full excavation ~ 10 ft

SELECT PHOTOS OF TEST PIT FIELD STUDIES

Bear River Project Concept Study
Whites Valley

GERHART COLE

Figure B94

J:\PROJECTS\Bowie Resources\16GCI744 SUFCO Waste Rock\Analyses\Report

DRAFT

Location:	16-TP–WV-43	**Description:**	Test Pit – 43; excavation ~ 5 ft

Location:	16-TP–WV-43	**Description:**	Test Pit – 43 – Excavation spoils

SELECT PHOTOS OF TEST PIT FIELD STUDIES

Bear River Project Concept Study
Whites Valley

GERHART COLE

Figure B95

J:\PROJECTS\Bowie Resources\16GCI744 SUFCO Waste Rock\Analyses\Report

DRAFT

Location:	16-TP–WV-44	**Description:**	Test Pit – 44; excavation ~ 6 ft

Location:	16-TP–WV-44	**Description:**	Test Pit – 44 – full excavation ~ 10 ft

SELECT PHOTOS OF TEST PIT FIELD STUDIES

Bear River Project Concept Study
Whites Valley

GERHART COLE

Figure B96

J:\PROJECTS\Bowie Resources\16GCI744 SUFCO Waste Rock\Analyses\Report

DRAFT

Location:	16-TP–WV-45	Description:	Test Pit – 45 – full excavation ~ 8 ft

SELECT PHOTOS OF TEST PIT FIELD STUDIES

Bear River Project Concept Study
Whites Valley

GERHART COLE

Figure B97

J:\PROJECTS\Bowie Resources\16GCI744 SUFCO Waste Rock\Analyses\Report

DRAFT

Location:	16-TP–WV-46	**Description:**	Test Pit – 46; excavation ~ 4.5 ft

Location:	16-TP–WV-46	**Description:**	Test Pit – 46 – full excavation ~ 10 ft

SELECT PHOTOS OF TEST PIT FIELD STUDIES

Bear River Project Concept Study
Whites Valley

GERHART COLE

Figure B98

J:\PROJECTS\Bowie Resources\16GCI744 SUFCO Waste Rock\Analyses\Report

DRAFT

Location:	16-TP–WV-47	**Description:**	Test Pit – 47 – full excavation ~ 5 ft

Location:	16-TP–WV-47	**Description:**	Test Pit – 47 – excavation ~ 5 ft

SELECT PHOTOS OF TEST PIT FIELD STUDIES

Bear River Project Concept Study
Whites Valley

GERHART COLE

Figure B99

J:\PROJECTS\Bowie Resources\16GCI744 SUFCO Waste Rock\Analyses\Report

DRAFT

Location:	16-TP–WV-48	**Description:**	Test Pit – 48 – full excavation ~ 2 ft

Location:	16-TP–WV-48	**Description:**	Test Pit – 48 – excavation spoils

SELECT PHOTOS OF TEST PIT FIELD STUDIES

Bear River Project Concept Study
Whites Valley

GERHART COLE

Figure B100

J:\PROJECTS\Bowie Resources\16GCI744 SUFCO Waste Rock\Analyses\Report

Appendix C

Whites Valley – Cone Penetration Test Sounding

DRAFT

PRESENTATION OF SITE INVESTIGATION RESULTS

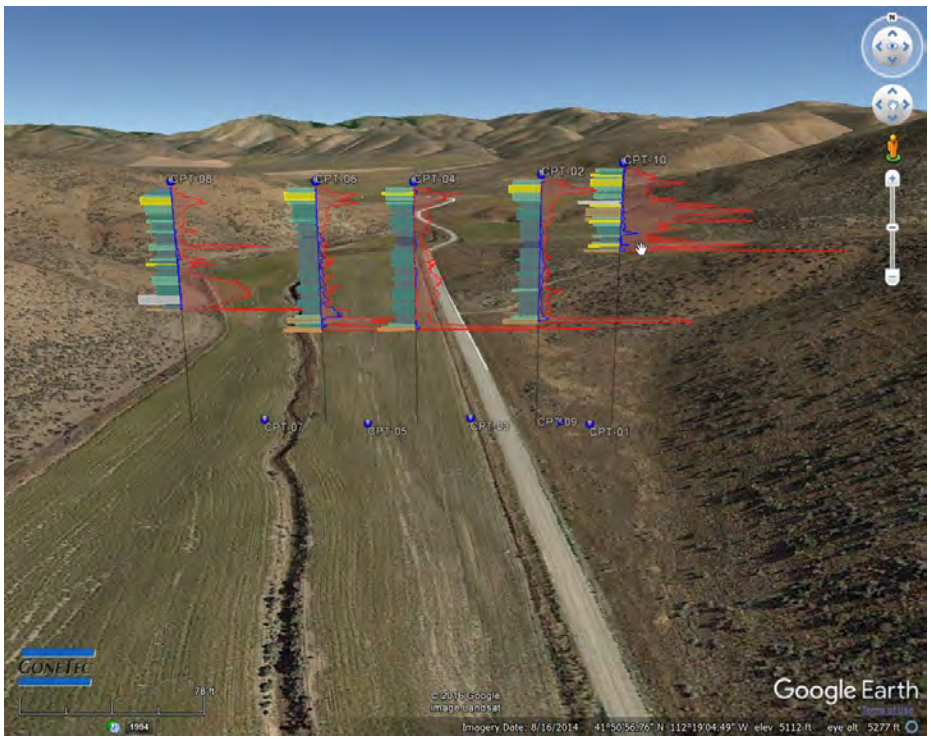
White's Valley Project

Prepared for:

Gerhart Cole, Inc.

ConeTec Job No: 16-52096

Project Start Date: 11-Oct-2016
Project End Date: 11-Oct-2016
Report Date: 12-Oct-2016



Prepared by:

ConeTec Inc.
3750 West 500 South
Salt Lake City, UT 84104

Tel: (801) 973-3801
Fax: (801) 973-3802

Email: saltlakecity@conetec.com
www.conetec.com
www.conetecdataservices.com

DRAFT

Introduction

The enclosed report presents the results of the site investigation program conducted by ConeTec, Inc. for Gerhart Cole, Inc. of Draper, Utah. The program consisted of advancing cone penetration tests at ten locations. No pore pressure dissipation testing was performed in the soundings due to groundwater anticipated to be deeper than the depth of the CPT soundings. The phreatic surface used for the CPT interpretations in all of the soundings is based on a depth greater than the deepest CPT sounding.

Project Information

Project	
Client	Gerhart Cole, Inc.
Project	White's Valley
ConeTec job number	16-52096

The sounding locations are shown on the image below. The remaining tables outline details associated with the equipment used to perform this investigation.

Rig Description	Deployment System	Test Type
CPT truck rig	25 ton truck mounted cylinder	CPTu

Coordinates			
Test Type	Collection Method	EPSG Number	Transformation File (If applicable)
CPT	USB/Serial GPS	4326 (WGS 84/Lat-Long)	CPT

Cone Penetration Test (CPT)	
Depth reference	Depths are referenced to the existing ground surface at the time of each test.
Tip and sleeve data offset	0.1 meter This has been accounted for in the CPT data files.
Additional comments	None

Cone Description	Cone Number	Cross Sectional Area (cm^2)	Sleeve Area (cm^2)	Tip Capacity (bar)	Sleeve Capacity (bar)	Pore Pressure Capacity (psi)
430:T1500F15U500	430	15	225	1500	15	500

Limitations

This report has been prepared for the exclusive use of Gerhart Cole, Inc. (Client) for the project titled "White's Valley Project". The report's contents may not be relied upon by any other party without the express written permission of ConeTec, Inc. (ConeTec). ConeTec has provided site investigation services, prepared the factual data reporting, and provided geotechnical parameter calculations consistent with current best practices. No other warranty, expressed or implied, is made.

The information presented in the report document and the accompanying data set pertain to the specific project, site conditions and objectives described to ConeTec by the Client. In order to properly understand the factual data, assumptions and calculations, reference must be made to the documents provided and their accompanying data sets, in their entirety.

The cone penetration tests (CPTu) are conducted using an integrated electronic piezocone penetrometer and data acquisition system manufactured by Adara Systems Ltd. of Richmond, British Columbia, Canada.

ConeTec's piezocone penetrometers are compression type designs in which the tip and friction sleeve load cells are independent and have separate load capacities. The piezocones use strain gauged load cells for tip and sleeve friction and a strain gauged diaphragm type transducer for recording pore pressure. The piezocones also have a platinum resistive temperature device (RTD) for monitoring the temperature of the sensors, an accelerometer type dual axis inclinometer and a geophone sensor for recording seismic signals. All signals are amplified down hole within the cone body and the analog signals are sent to the surface through a shielded cable.

ConeTec penetrometers are manufactured with various tip, friction and pore pressure capacities in both 10 cm^2 and 15 cm^2 tip base area configurations in order to maximize signal resolution for various soil conditions. The 15 cm^2 penetrometers do not require friction reducers as they have a diameter larger than the deployment rods. The 10 cm^2 piezocones use a friction reducer consisting of a rod adapter extension behind the main cone body with an enlarged cross sectional area (typically 44 mm diameter over a length of 32 mm with tapered leading and trailing edges) located at a distance of 585 mm above the cone tip.

The penetrometers are designed with equal end area friction sleeves, a net end area ratio of 0.8 and cone tips with a 60 degree apex angle.

All ConeTec piezocones can record pore pressure at various locations. Unless otherwise noted, the pore pressure filter is located directly behind the cone tip in the "u_2" position (ASTM Type 2). The filter is 6 mm thick, made of porous plastic (polyethylene) having an average pore size of 125 microns (90-160 microns). The function of the filter is to allow rapid movements of extremely small volumes of water needed to activate the pressure transducer while preventing soil ingress or blockage.

The piezocone penetrometers are manufactured with dimensions, tolerances and sensor characteristics that are in general accordance with the current ASTM D5778 standard. ConeTec's calibration criteria also meet or exceed those of the current ASTM D5778 standard. An illustration of the piezocone penetrometer is presented in Figure CPTu.

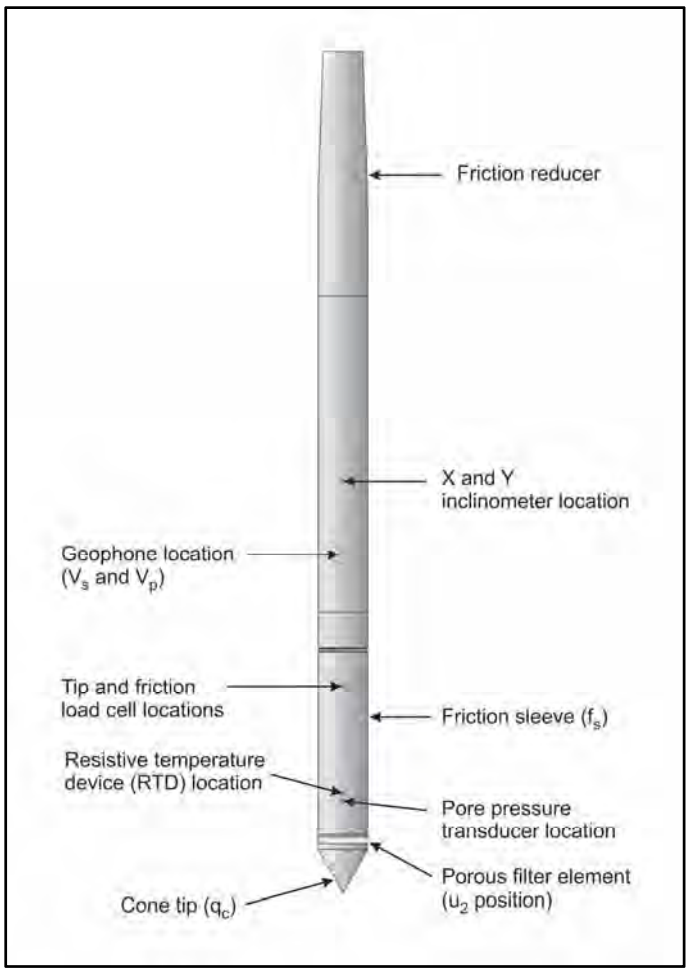


Figure CPTu. Piezocone Penetrometer (15 cm^2)

The ConeTec data acquisition systems consist of a Windows based computer and a signal conditioner and power supply interface box with a 16 bit (or greater) analog to digital (A/D) converter. The data is recorded at fixed depth increments using a depth wheel attached to the push cylinders or by using a spring loaded rubber depth wheel that is held against the cone rods. The typical recording intervals are either 2.5 cm or 5.0 cm depending on project requirements; custom recording intervals are possible. The system displays the CPTu data in real time and records the following parameters to a storage media during penetration:

- Depth
- Uncorrected tip resistance (q_c)
- Sleeve friction (f_s)
- Dynamic pore pressure (u)
- Additional sensors such as resistivity, passive gamma, ultra violet induced fluorescence, if applicable

All testing is performed in accordance to ConeTec's CPT operating procedures which are in general accordance with the current ASTM D5778 standard.

Prior to the start of a CPTu sounding a suitable cone is selected, the cone and data acquisition system are powered on, the pore pressure system is saturated with either glycerin or silicone oil and the baseline readings are recorded with the cone hanging freely in a vertical position.

The CPTu is conducted at a steady rate of 2 cm/s, within acceptable tolerances. Typically one meter length rods with an outer diameter of 1.5 inches are added to advance the cone to the sounding termination depth. After cone retraction final baselines are recorded.

Additional information pertaining to ConeTec's cone penetration testing procedures:

- Each filter is saturated in silicone oil or glycerin under vacuum pressure prior to use
- Recorded baselines are checked with an independent multi-meter
- Baseline readings are compared to previous readings
- Soundings are terminated at the client's target depth or at a depth where an obstruction is encountered, excessive rod flex occurs, excessive inclination occurs, equipment damage is likely to take place, or a dangerous working environment arises
- Differences between initial and final baselines are calculated to ensure zero load offsets have not occurred and to ensure compliance with ASTM standards

The interpretation of piezocone data for this report is based on the corrected tip resistance (q_t), sleeve friction (f_s) and pore water pressure (u). The interpretation of soil type is based on the correlations developed by Robertson (1990) and Robertson (2009). It should be noted that it is not always possible to accurately identify a soil type based on these parameters. In these situations, experience, judgment and an assessment of other parameters may be used to infer soil behavior type.

The recorded tip resistance (q_c) is the total force acting on the piezocone tip divided by its base area. The tip resistance is corrected for pore pressure effects and termed corrected tip resistance (q_t) according to the following expression presented in Robertson et al, 1986:

$$q_t = q_c + (1-a) \bullet u_2$$

where: q_t is the corrected tip resistance
q_c is the recorded tip resistance
u_2 is the recorded dynamic pore pressure behind the tip (u_2 position)
a is the Net Area Ratio for the piezocone (0.8 for ConeTec probes)

The sleeve friction (f_s) is the frictional force on the sleeve divided by its surface area. As all ConeTec piezocones have equal end area friction sleeves, pore pressure corrections to the sleeve data are not required.

The dynamic pore pressure (u) is a measure of the pore pressures generated during cone penetration. To record equilibrium pore pressure, the penetration must be stopped to allow the dynamic pore pressures to stabilize. The rate at which this occurs is predominantly a function of the permeability of the soil and the diameter of the cone.

The friction ratio (Rf) is a calculated parameter. It is defined as the ratio of sleeve friction to the tip resistance expressed as a percentage. Generally, saturated cohesive soils have low tip resistance, high

friction ratios and generate large excess pore water pressures. Cohesionless soils have higher tip resistances, lower friction ratios and do not generate significant excess pore water pressure.

A summary of the CPTu soundings along with test details and individual plots are provided in the appendices. A set of interpretation files were generated for each sounding based on published correlations and are provided in Excel format in the data release folder. Information regarding the interpretation methods used is included in an appendix.

For additional information on CPTu interpretations, refer to Robertson et al. (1986), Lunne et al. (1997), Robertson (2009), Mayne (2013, 2014) and Mayne and Peuchen (2012).

References

ASTM D5778-12, 2012, "Standard Test Method for Performing Electronic Friction Cone and Piezocone Penetration Testing of Soils", ASTM, West Conshohocken, US.

Lunne, T., Robertson, P.K. and Powell, J. J. M., 1997, “Cone Penetration Testing in Geotechnical Practice”, Blackie Academic and Professional.

Mayne, P.W., 2013, “Evaluating yield stress of soils from laboratory consolidation and in-situ cone penetration tests”, Sound Geotechnical Research to Practice (Holtz Volume) GSP 230, ASCE, Reston/VA: 406-420.

Mayne, P.W. and Peuchen, J., 2012, “Unit weight trends with cone resistance in soft to firm clays”, Geotechnical and Geophysical Site Characterization *4,* Vol. 1 (Proc. ISC-4, Pernambuco), CRC Press, London: 903-910.

Mayne, P.W., 2014, “Interpretation of geotechnical parameters from seismic piezocone tests”, CPT’14 Keynote Address, Las Vegas, NV, May 2014.

Robertson, P.K., Campanella, R.G., Gillespie, D. and Greig, J., 1986, “Use of Piezometer Cone Data”, Proceedings of InSitu 86, ASCE Specialty Conference, Blacksburg, Virginia.

Robertson, P.K., 1990, “Soil Classification Using the Cone Penetration Test”, Canadian Geotechnical Journal, Volume 27: 151-158.

Robertson, P.K., 2009, “Interpretation of cone penetration tests – a unified approach”, Canadian Geotechnical Journal, Volume 46: 1337-1355.

The appendices listed below are included in the report:

- Cone Penetration Test Summary and Standard Cone Penetration Test Plots

DRAFT

Cone Penetration Test Summary and Standard Cone Penetration Test Plots

CONETEC

DRAFT

Job No:	16-52096
Client:	Gerhart Cole
Project:	White's Valley
Start Date:	11-Oct-2016
End Date:	11-Oct-2016

CONE PENETRATION TEST SUMMARY

Sounding ID	File Name	Date	Cone	Final Depth (ft.)	Latitude[1]	Longitude	Elevation[2] (ft.)	Refer to Notation Number
CPT-01	16-52096_CP01	11-Oct-2016	430:T1500:F15:U500	31.50	41.846350	-112.318897	5057	
CPT-02	16-52096_CP02	11-Oct-2016	430:T1500:F15:U500	39.04	41.846375	-112.319065	5056	
CPT-03	16-52096_CP03	11-Oct-2016	430:T1500:F15:U500	41.67	41.846417	-112.319275	5055	
CPT-04	16-52096_CP04	11-Oct-2016	430:T1500:F15:U500	39.70	41.846406	-112.319449	5054	
CPT-05	16-52096_CP05	11-Oct-2016	430:T1500:F15:U500	40.52	41.846392	-112.319609	5054	
CPT-06	16-52096_CP06	11-Oct-2016	430:T1500:F15:U500	40.35	41.846425	-112.319751	5054	
CPT-07	16-52096_CP07	11-Oct-2016	430:T1500:F15:U500	35.76	41.846424	-112.319953	5054	
CPT-08	16-52096_CP08	11-Oct-2016	430:T1500:F15:U500	34.61	41.846432	-112.320196	5054	
CPT-09	16-52096_CP09	11-Oct-2016	430:T1500:F15:U500	34.45	41.846381	-112.318987	5056	
CPT-10	16-52096_CP10	11-Oct-2016	430:T1500:F15:U500	22.15	41.846383	-112.318819	5059	

1. The coordinates are based on the WGS84 Datum and have an accuracy of ±30 feet.
2. Elevations are referenced to the ground surface and are derived from the Google Earth Elevation for the recorded coordinates.

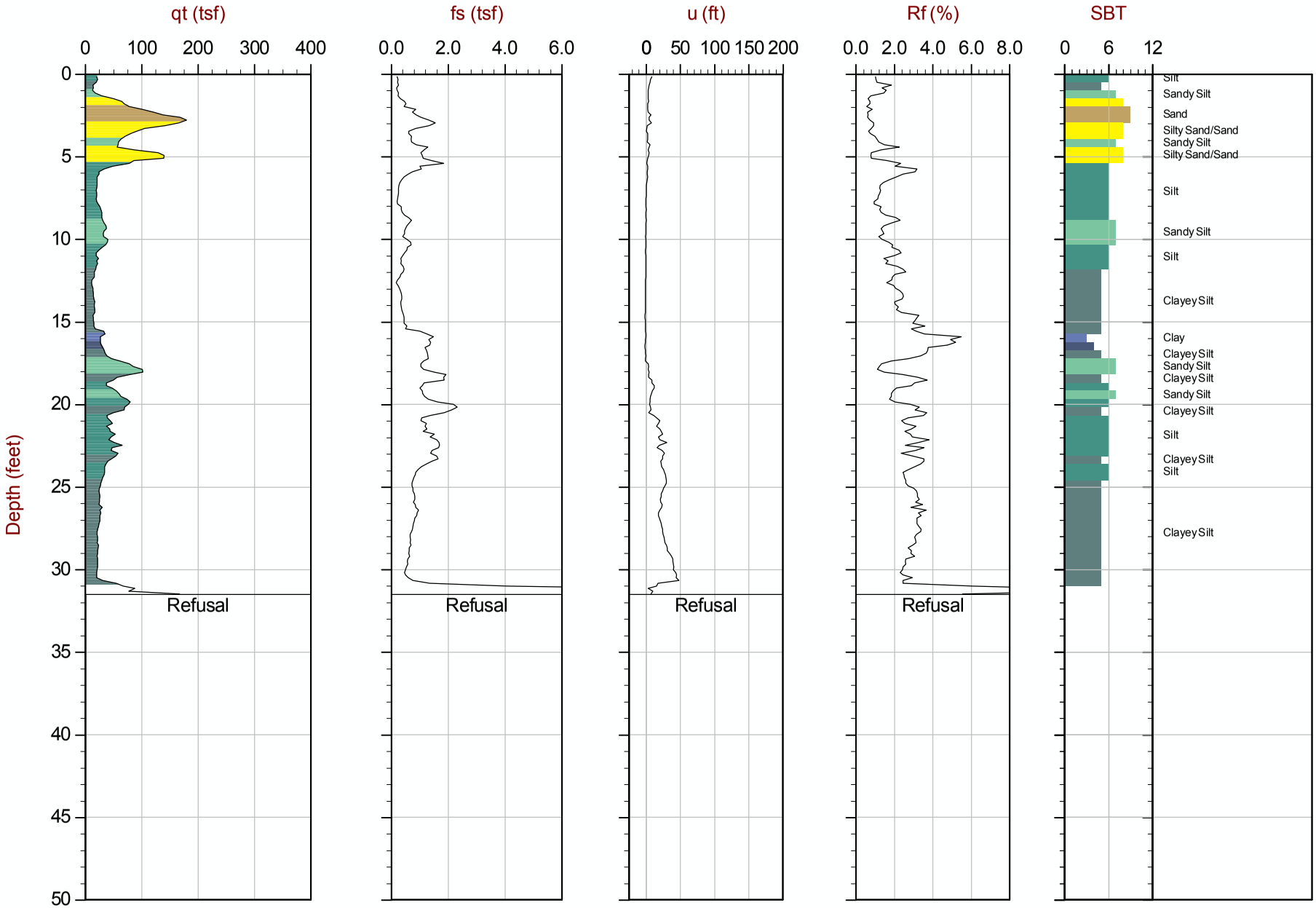
DRAFT

CONETEC

Gerhart Cole

Job No: 16-52096
Date: 10:11:16 08:58
Site: Whites Valley

Sounding: CPT-01
Cone: 430:T1500F15U500



Max Depth: 9.600 m / 31.50 ft
Depth Inc: 0.050 m / 0.164 ft
Avg Int: 0.150 m

File: 16-52096_CP01.COR
Unit Wt: SBT Zones

SBT: Robertson and Campanella, 1986
Coords: Lat: 41.846350 Long: -112.318897
● Equilibrium Pore Pressure from Dissipation

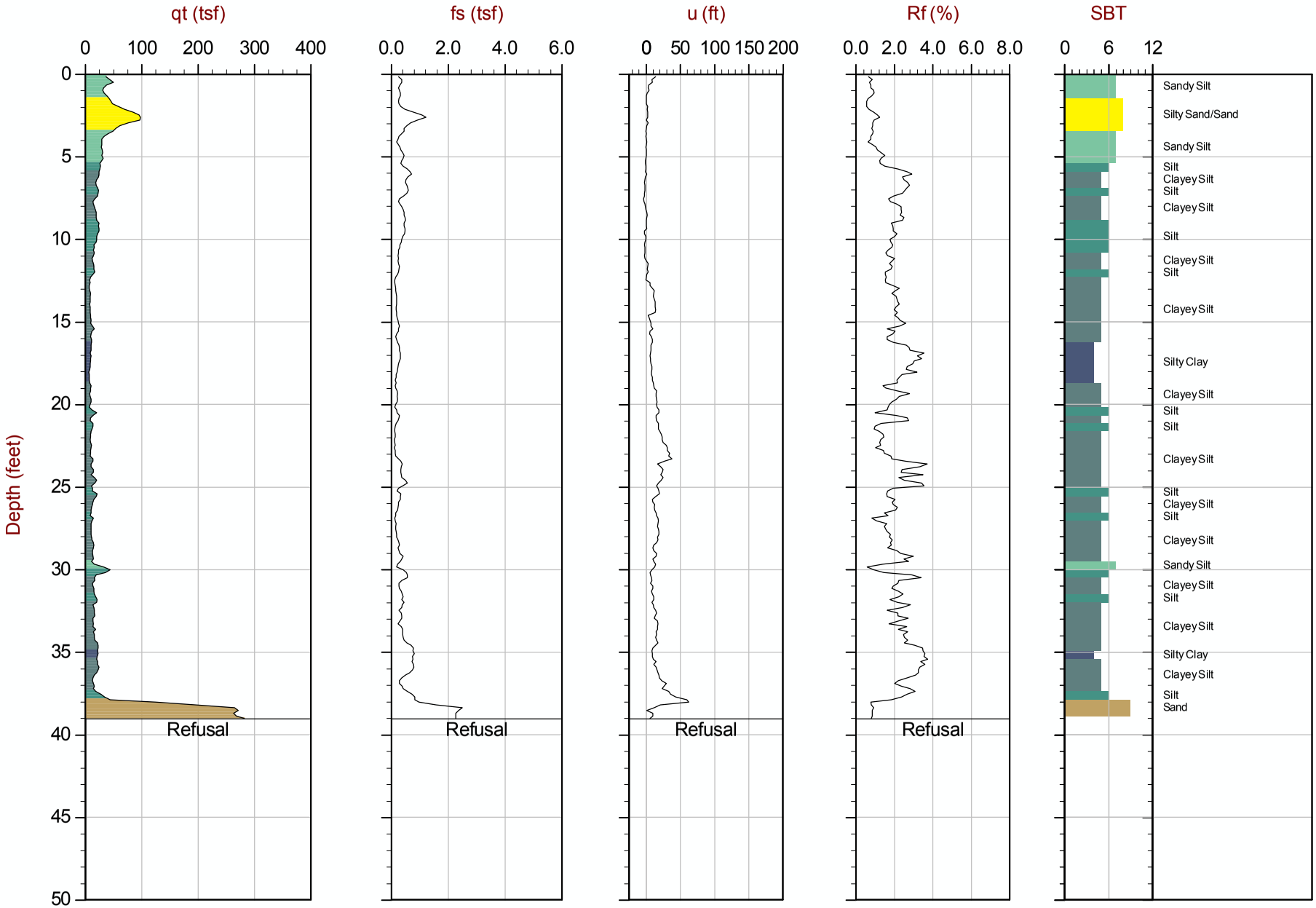
DRAFT

CONETEC

Gerhart Cole

Job No: 16-52096
Date: 10:11:16 09:47
Site: Whites Valley

Sounding: CPT-02
Cone: 430:T1500F15U500



Max Depth: 11.900 m / 39.04 ft
Depth Inc: 0.050 m / 0.164 ft
Avg Int: 0.150 m

File: 16-52096_CP02.COR
Unit Wt: SBT Zones

SBT: Robertson and Campanella, 1986
Coords: Lat: 41.846375 Long: -112.319065
● Equilibrium Pore Pressure from Dissipation

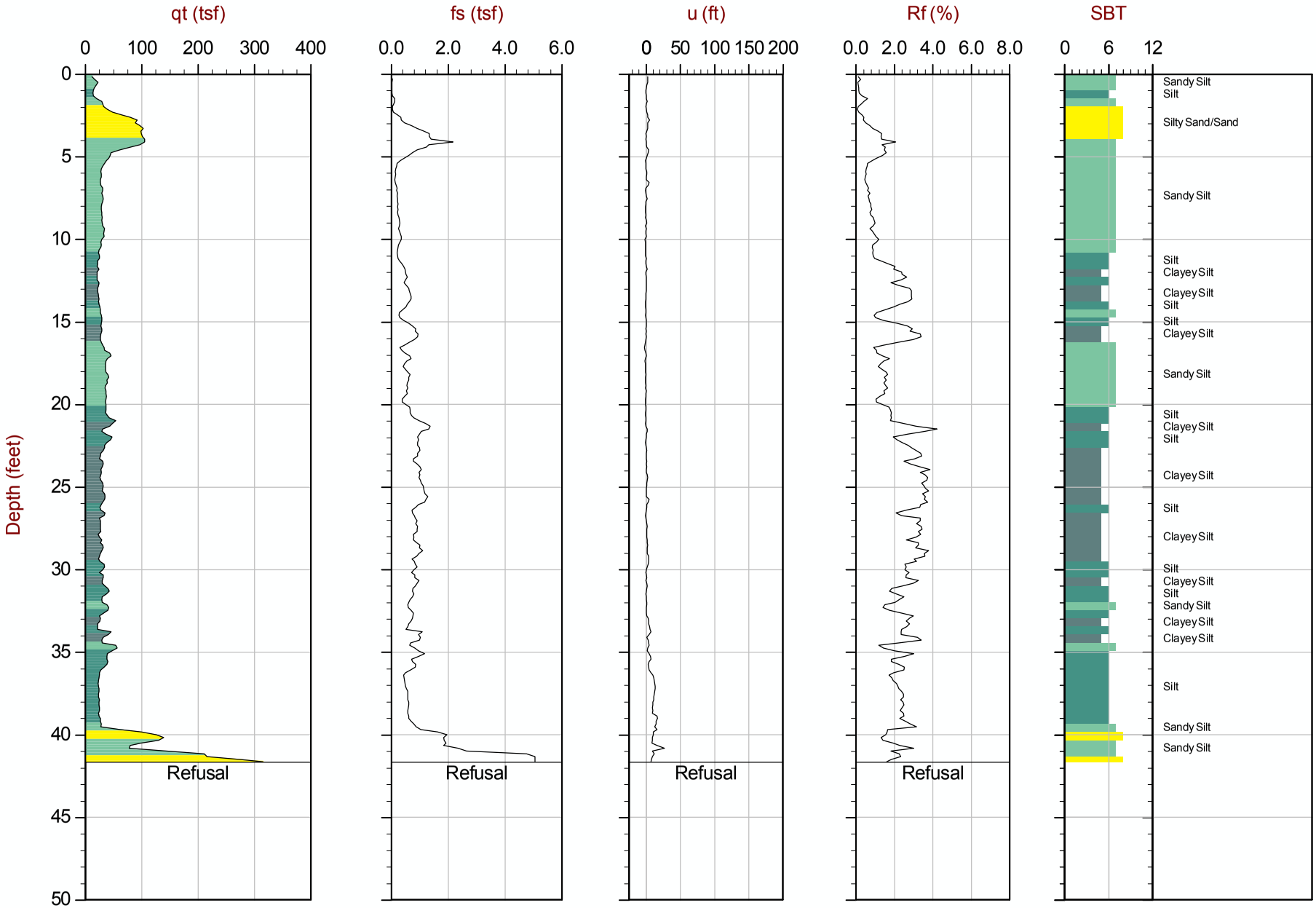
DRAFT

CONETEC

Gerhart Cole

Job No: 16-52096
Date: 10:11:16 10:39
Site: Whites Valley

Sounding: CPT-03
Cone: 430:T1500F15U500



Max Depth: 12.700 m / 41.67 ft
Depth Inc: 0.050 m / 0.164 ft
Avg Int: 0.150 m

File: 16-52096_CP03.COR
Unit Wt: SBT Zones

SBT: Robertson and Campanella, 1986
Coords: Lat: 41.846417 Long: -112.319275
● Equilibrium Pore Pressure from Dissipation

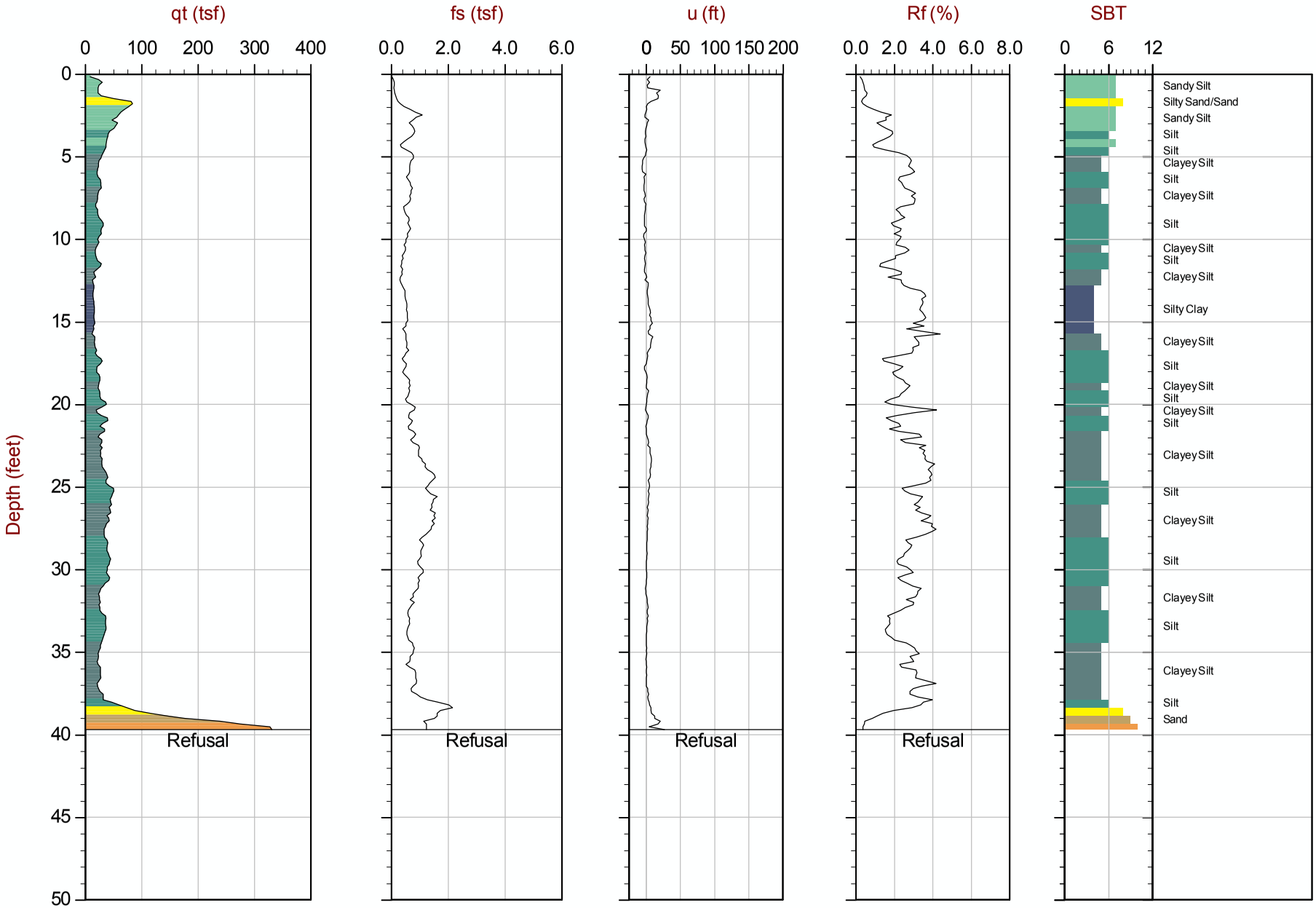
DRAFT

CONETEC

Gerhart Cole

Job No: 16-52096
Date: 10:11:16 11:22
Site: Whites Valley

Sounding: CPT-04
Cone: 430:T1500F15U500



Max Depth: 12.100 m / 39.70 ft
Depth Inc: 0.050 m / 0.164 ft
Avg Int: 0.150 m

File: 16-52096_CP04.COR
Unit Wt: SBT Zones

SBT: Robertson and Campanella, 1986
Coords: Lat: 41.846406 Long: -112.319449
● Equilibrium Pore Pressure from Dissipation

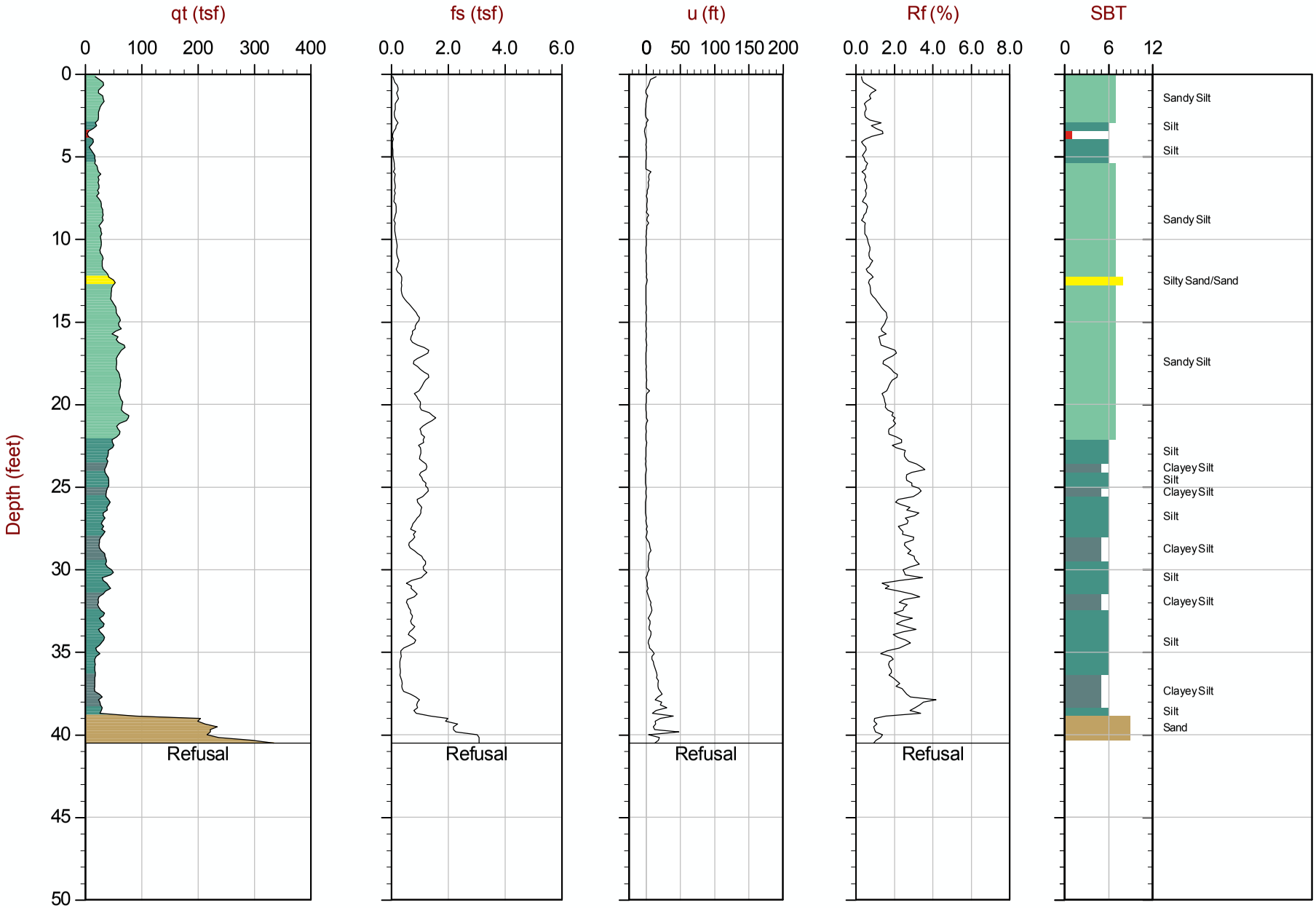
DRAFT

CONETEC

Gerhart Cole

Job No: 16-52096
Date: 10:11:16 11:58
Site: Whites Valley

Sounding: CPT-05
Cone: 430:T1500F15U500



Max Depth: 12.350 m / 40.52 ft
Depth Inc: 0.050 m / 0.164 ft
Avg Int: 0.150 m

File: 16-52096_CP05.COR
Unit Wt: SBT Zones

SBT: Robertson and Campanella, 1986
Coords: Lat: 41.846392 Long: -112.319609
● Equilibrium Pore Pressure from Dissipation

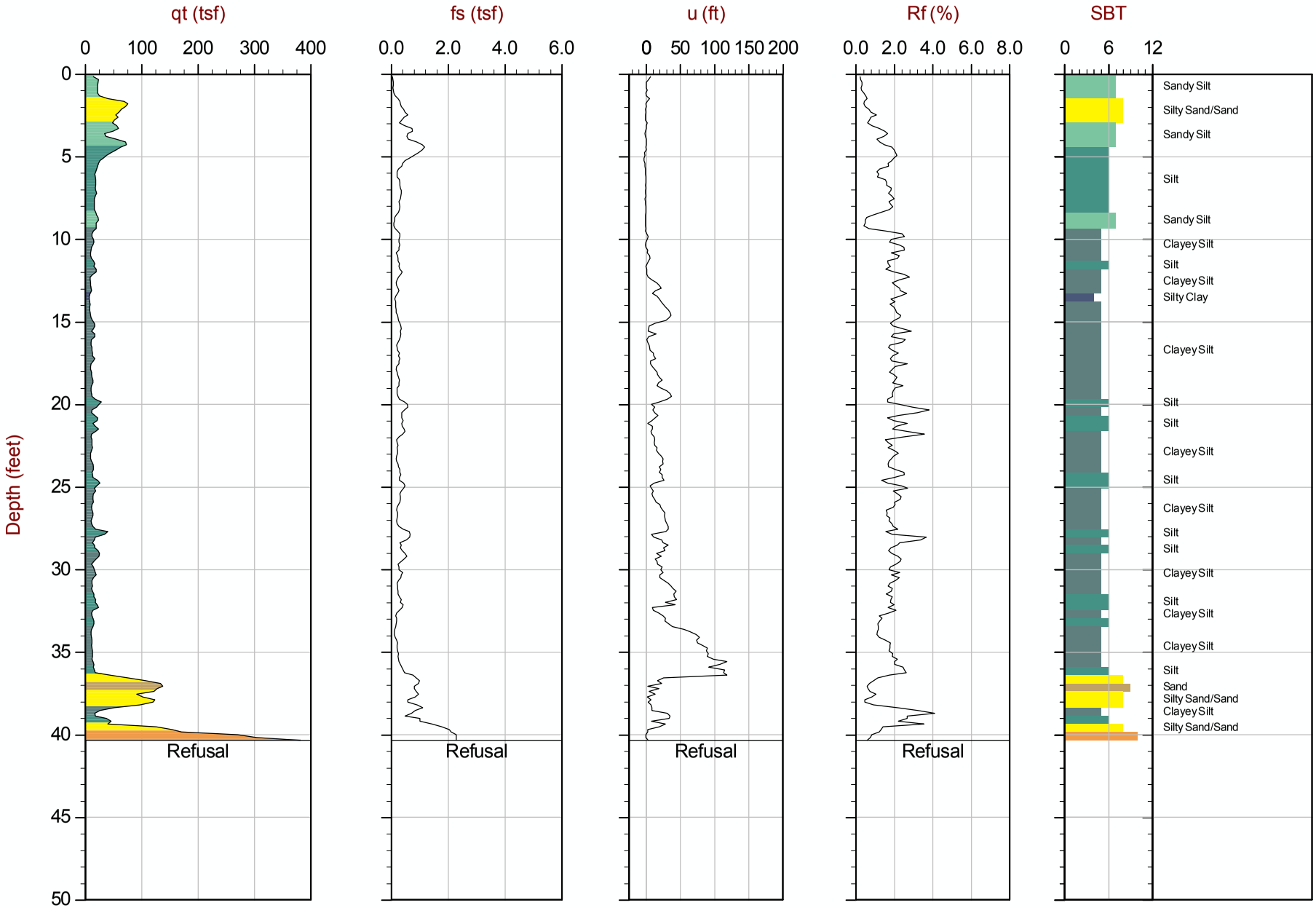
DRAFT

CONETEC

Gerhart Cole

Job No: 16-52096
Date: 10:11:16 12:39
Site: Whites Valley

Sounding: CPT-06
Cone: 430:T1500F15U500



Max Depth: 12.300 m / 40.35 ft
Depth Inc: 0.050 m / 0.164 ft
Avg Int: 0.150 m

File: 16-52096_CP06.COR
Unit Wt: SBT Zones

SBT: Robertson and Campanella, 1986
Coords: Lat: 41.846425 Long: -112.319751
● Equilibrium Pore Pressure from Dissipation

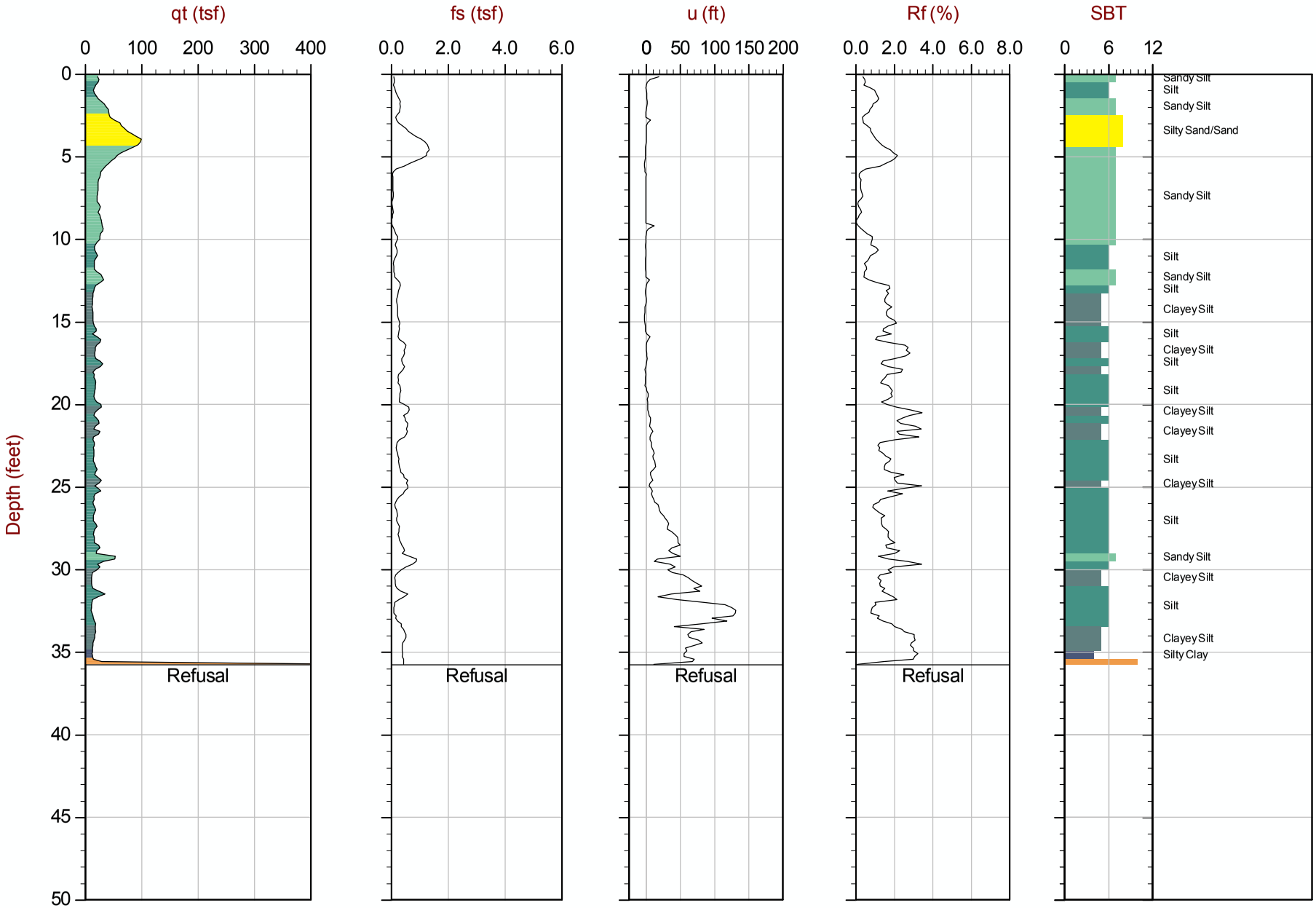
DRAFT

CONETEC

Gerhart Cole

Job No: 16-52096
Date: 10:11:16 13:41
Site: Whites Valley

Sounding: CPT-07
Cone: 430:T1500F15U500



Max Depth: 10.900 m / 35.76 ft
Depth Inc: 0.050 m / 0.164 ft
Avg Int: 0.150 m

File: 16-52096_CP07.COR
Unit Wt: SBT Zones

SBT: Robertson and Campanella, 1986
Coords: Lat: 41.846424 Long: -112.319953
● Equilibrium Pore Pressure from Dissipation

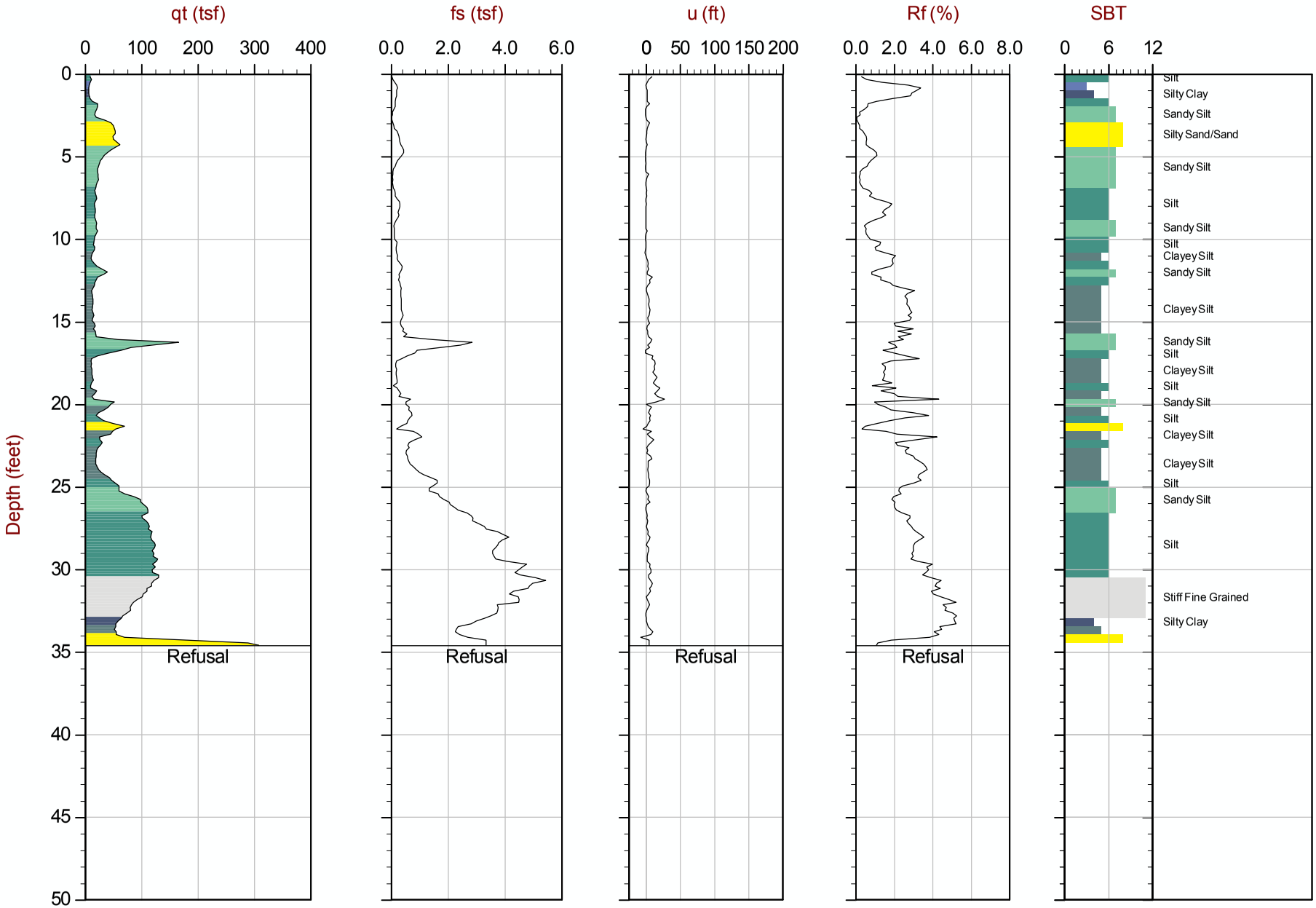
DRAFT

CONETEC

Gerhart Cole

Job No: 16-52096
Date: 10:11:16 14:13
Site: Whites Valley

Sounding: CPT-08
Cone: 430:T1500F15U500



Max Depth: 10.550 m / 34.61 ft
Depth Inc: 0.050 m / 0.164 ft
Avg Int: 0.150 m

File: 16-52096_CP08.COR
Unit Wt: SBT Zones

SBT: Robertson and Campanella, 1986
Coords: Lat: 41.846432 Long: -112.320196
● Equilibrium Pore Pressure from Dissipation

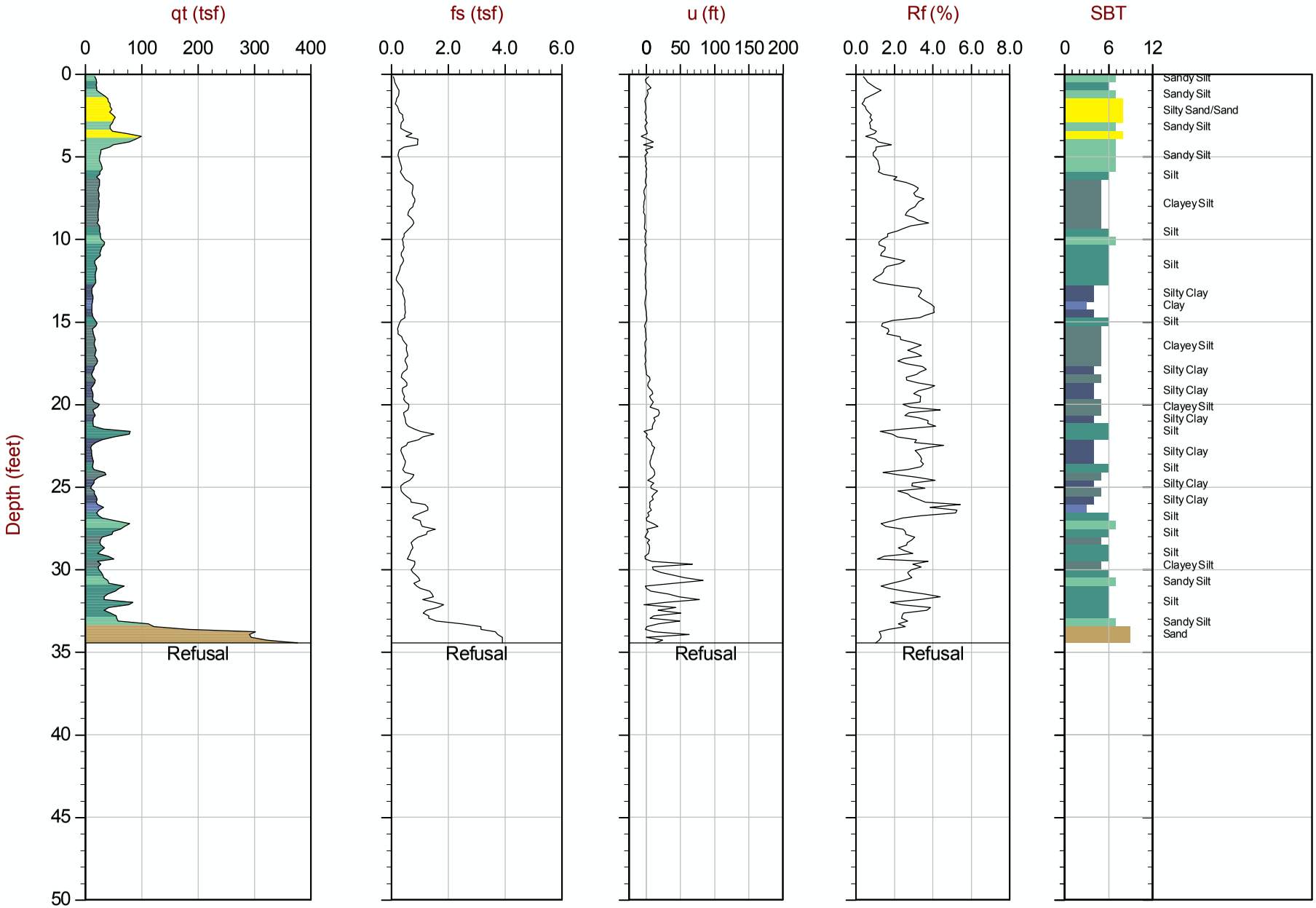
DRAFT

CONETEC

Gerhart Cole

Job No: 16-52096
Date: 10:11:16 15:08
Site: Whites Valley

Sounding: CPT-09
Cone: 430:T1500F15U500



Max Depth: 10.500 m / 34.45 ft
Depth Inc: 0.050 m / 0.164 ft
Avg Int: 0.150 m

File: 16-52096_CP09.COR
Unit Wt: SBT Zones

SBT: Robertson and Campanella, 1986
Coords: Lat: 41.846381 Long: -112.318987
● Equilibrium Pore Pressure from Dissipation

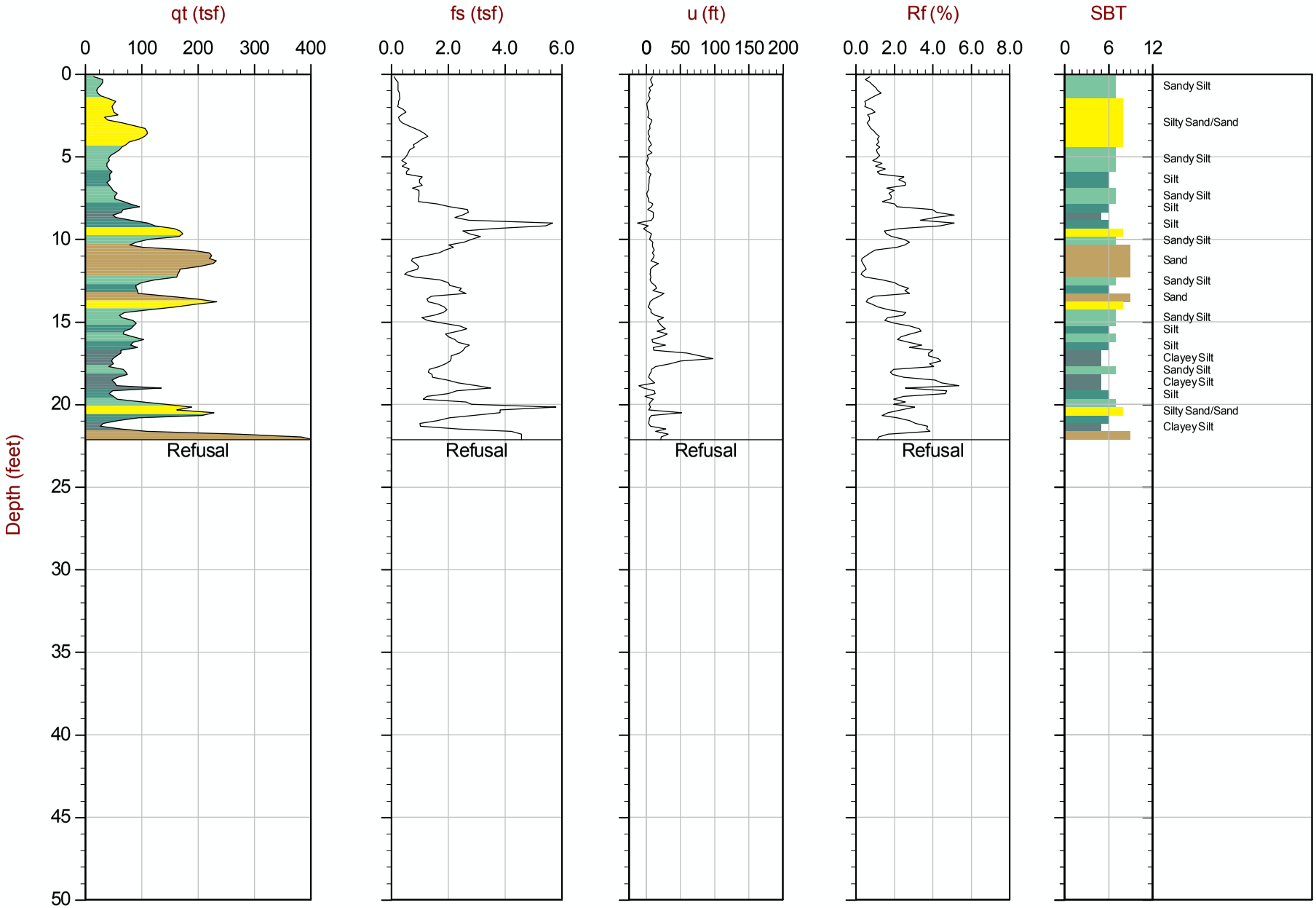
DRAFT

CONETEC

Gerhart Cole

Job No: 16-52096
Date: 10:11:16 15:38
Site: Whites Valley

Sounding: CPT-10
Cone: 430:T1500F15U500



Max Depth: 6.750 m / 22.15 ft
Depth Inc: 0.050 m / 0.164 ft
Avg Int: 0.150 m

File: 16-52096_CP10.COR
Unit Wt: SBT Zones

SBT: Robertson and Campanella, 1986
Coords: Lat: 41.846383 Long: -112.318819
● Equilibrium Pore Pressure from Dissipation

Appendix D

Whites Valley – Seismic Refraction Survey

September 22, 2015

RE: SEISMIC REFRACTION SURVEY - WHITE'S VALLEY

Based on the project objective and site conditions, Sage Earth Science conducted a seismic refraction P-wave velocity profile at the Northern Utah site. The objective of the survey is to determine the P velocity profile of the shallow subsurface (0-150 ft.) for the purpose of determining depth to rock and seismic velocity of the rock and overlying materials.

P-wave survey (refraction)

Given a physical setting of increasing density with depth, and by measuring the travel time of a compression wave (*p-wave*) between known points, the seismic refraction method can be used to determine the depth to a refracting horizon(s), the seismic velocity of the refracting horizon(s), as well as thickness and velocities of the overlying materials.

Figure 1 seismograph and field equipment

Approximately 1,315 feet p-wave refraction profile was acquired. The profile was located at the site as directed by the customer. Data acquisition was performed in accordance with ASTM standard, **ASTM D 5777-00** *Standard Guide for Using the Seismic Refraction Method for Subsurface Investigation.* Data were reduced using PlotRefra™ seismic refraction tomographic inversion software produced by Geometrics Inc.

Table 1. Seismic Survey data acquisition parameters

recording instrument	Bison 9024 s/n 6-93913 seismograph
geophone	Mark products – 4.5 Hz. vertical
Geophone/station spacing	5 meter (16.4 ft.)
number of channels	24
Overall spread length	377 ft.
sample rate	0.25 millisecond
number of samples	4,000
record length	1 second
low pass filter	120 Hz.
low cut filter	4 Hz.
seismic source	16 pound sledge hammer
source locations	Channel 1,5,10,15,20 and 24
Processing software	PlotRefra™ Tomographic inversion software, Geometrics, Inc.

2184 Channing Way, Suite 110, Idaho Falls, ID 83404
telephone: (208)522-5049, Fax: (208)528-6200, email: sageearthscience@yahoo.com
http://www.sageearthscience.com

Discussion

The following figure shows the compression wave velocity profile at the location shown in figure 3. Location and elevation data were provided by the customer and drawn manually from Google Earth.

The seismic velocities mapped across the site are characterized by a contrast between three general velocity zones. The first zone consists of low density materials exhibiting a velocity V_P of less than 3,000 feet per second. This material is composed of poorly consolidated sediments or heavily weathered material. The second zone is a mid-range velocity V_P from 3,000 to 6,000 fps. Based on correlation with test hole logs, this material is likely a low density rock, with significant fracturing and weathering The high velocity zone is a range of velocity V_P greater than 6,000 feet per second and should be considered more dense rock than the overlying material with less a lesser degree of fracturing.

As a general guide, quoting from the ASTM standard, **ASTM D 5777-00** *Standard Guide for Using the Seismic Refraction Method for Subsurface Investigation*

> *The seismic refraction method provides the velocity of compressional P-waves in subsurface materials. Although the P-wave velocity can be a good indicator of the type of soil or rock, it is not a unique indicator. Table 2 shows that each type of sediment or rock has a wide range of seismic velocities, and many of these ranges significantly overlap. While the seismic refraction technique measures the seismic velocity of seismic waves in earth materials, it is the interpreter who based on knowledge of the local conditions or other data, or both, must interpret the seismic refraction data and arrive at a geologically reasonable solution*
>
> *According to Mooney (8), P-wave velocities are generally greater for:*
> *1. Denser rocks than lighter rocks*
> *2. Older rocks than younger rocks*
> *3. Igneous rocks than sedimentary rocks*
> *4. Solid rocks than rocks with crack and fractures*
> *5. Unweathered rocks than weathered rocks*
> *6. Consolidated sediments than unconsolidated sediments*
> *7. Water saturated rocks/sediments than unsaturated rocks/sediments*
> *8. Wet soils than dry soils*

These velocity ranges and descriptions should be correlated with other site information including test pits, test hole logs, and other available information.

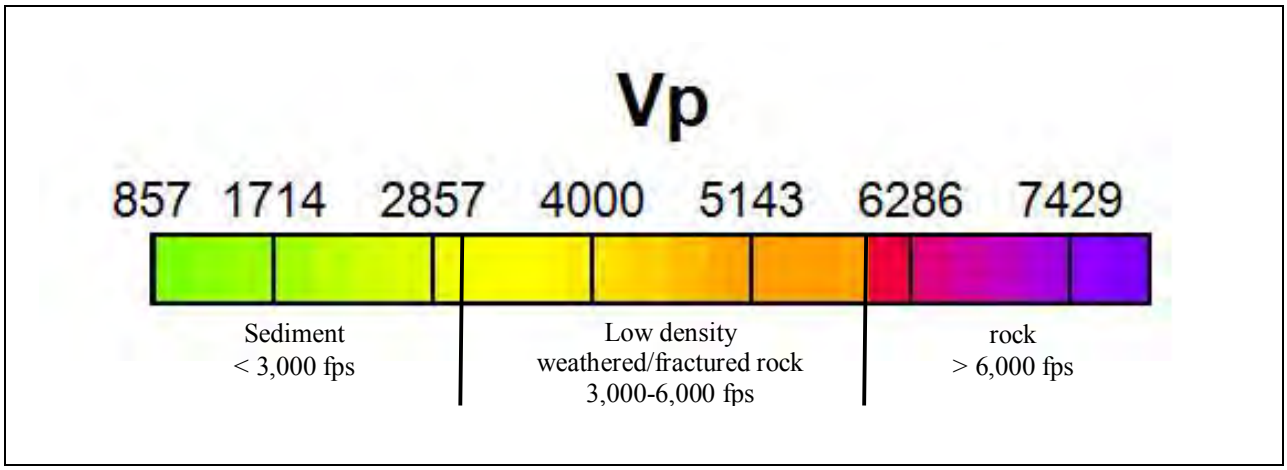


Figure 2. General compression wave velocity range of materials

Glen Carpenter / principal

White's Valley Profile

Figure 3. White's Valley profile location *(location and scale approximate)*

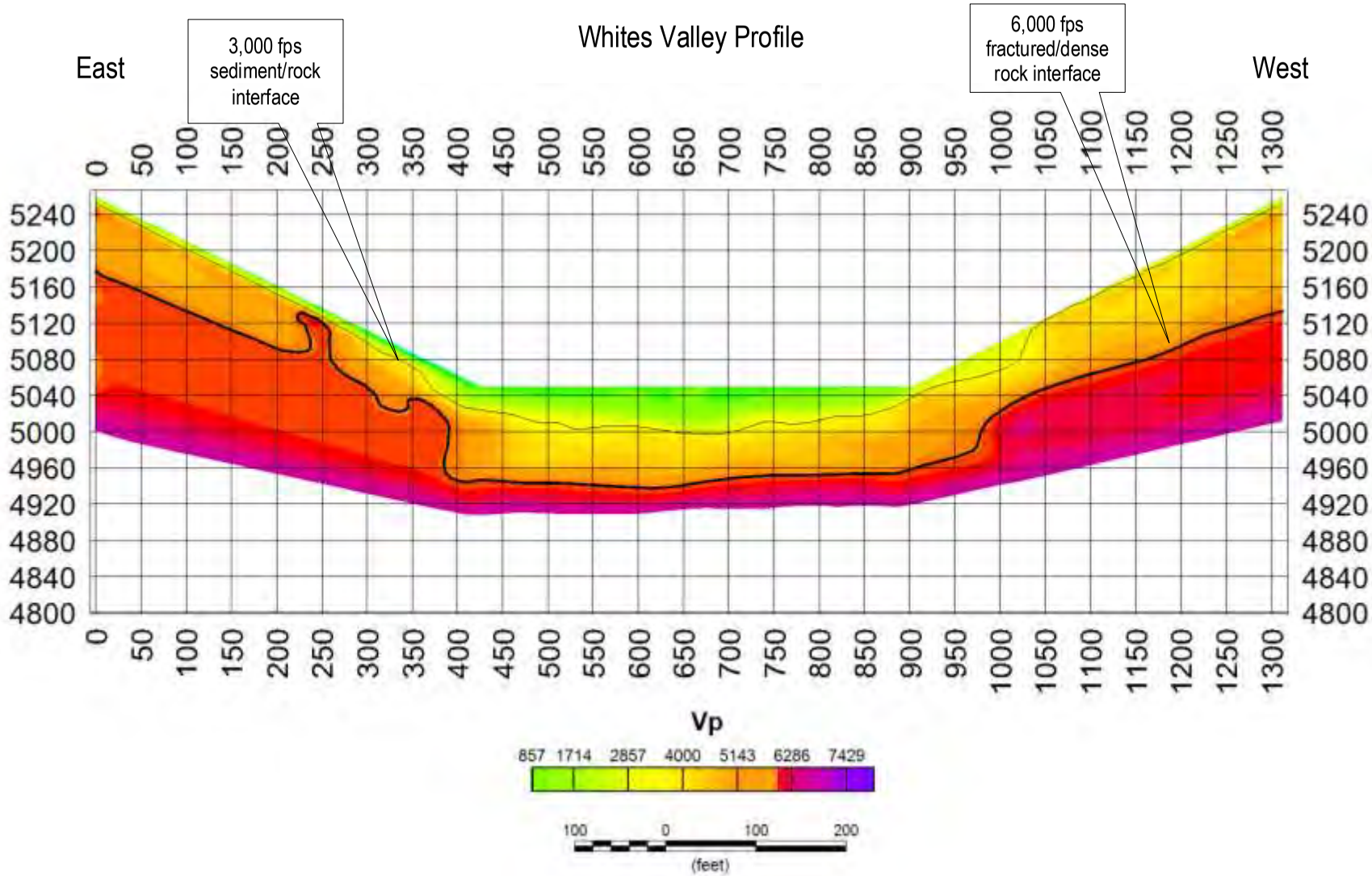


Figure 4. Whites Valley profile compression wave velocity profile (V_P)

DRAFT

November 11, 2016

RE: SEISMIC REFRACTION SURVEY - WHITE'S VALLEY (PHASE II) REV 2

Based on the project objective and site conditions, Sage Earth Science conducted a series of seismic P-wave refraction velocity profiles at the Northern Utah site. The objective of the survey is to determine the P velocity profile of the shallow subsurface (0-40 ft.) for the purpose of determining depth to rock and seismic velocity of the rock and overlying materials.

This is the second phase of work that began in 2015. The objective of this second phase of work was to provide better resolution focused in the near surface (0-40 ft). To achieve this, a closer geophone spacing was used (6.56 ft.) limiting the overall spread length to 150 feet and approximate depth of investigation to 40 or 50 feet depending on the subsurface conditions.

P-wave survey (refraction)

Given a physical setting of increasing density with depth, and by measuring the travel time of a compression wave (*p-wave*) between known points, the seismic refraction method can be used to determine the depth to a refracting horizon(s), the seismic velocity of the refracting horizon(s), as well as thickness and velocities of the overlying materials.

Figure 1 seismograph and field equipment

Approximately 1,125 feet p-wave refraction profile was acquired at the locations shown in figure 4. The profiles were located at the site as directed by the customer. Data acquisition was performed in accordance with ASTM standard, **ASTM D 5777-00** *Standard Guide for Using the Seismic Refraction Method for Subsurface Investigation.* Data were reduced using PlotRefra™ seismic refraction tomographic inversion software produced by Geometrics Inc.

Table 1. Seismic Survey data acquisition parameters

recording instrument	Bison 9024 s/n 6-93913 seismograph
geophone	Mark products – 4.5 Hz. vertical
Geophone/station spacing	6.56 ft. (2 meter)
number of channels	24
Overall spread length	151 ft.
sample rate	0.25 millisecond
number of samples	1,000
record length	0.25 seconds
low pass filter	120 Hz.
low cut filter	16 Hz.
seismic source	16 pound sledge hammer
source locations	Channel 1,5,10,15,20 and 24
Processing software	PlotRefra™ Tomographic inversion software, Geometrics, Inc.

Discussion

The following figures show the compression wave velocity profile at the locations shown in figure 3. Location and elevation data were taken manually from Google Earth and should be considered approximate.

The seismic velocities mapped across the site are characterized by a contrast between three general velocity zones. The first zone consists of very low density materials exhibiting a velocity V_P of less than 1,100 feet per second. This material is composed of poorly consolidated sediments or heavily weathered material. The second zone is a mid-range velocity V_P from 1,100 fps to 2,000 fps. This low velocity material is likely sediment. The high velocity zone is a range of velocity V_P greater than 2,000 feet per second and should be considered weathered rock.

The following figure 2 show an example of the velocity profile. The colored contours and contour lines, show areas of equal velocity. The vertical lines show the individual velocity profiles upon which the colors are based. When choising a horizion, the interpreted selects points of inflection where the calculated velocity begins to increase significantly. Geologically, the horizon may be a sigificantly sharper feature. The mathmatical calculation with typically be more gradual due to the nature com the observations and calculation.

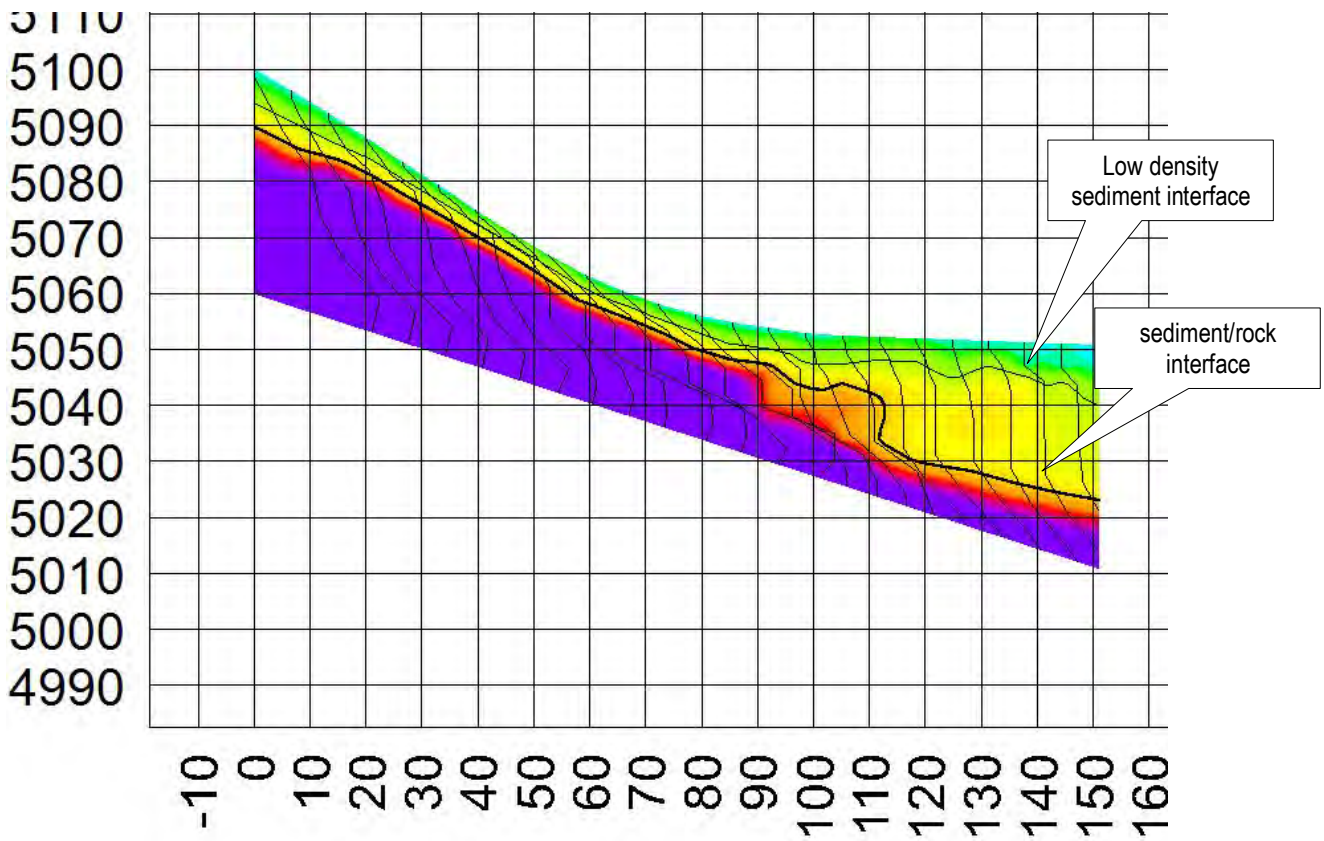


Figure 2. Representative velocity profile with color contours, contours, and vertical velocity profiles.

As a general guide, quoting from the ASTM standard, **ASTM D 5777-00** *Standard Guide for Using the Seismic Refraction Method for Subsurface Investigation*

> *The seismic refraction method provides the velocity of compressional P-waves in subsurface materials. Although the P-wave velocity can be a good indicator of the type of soil or rock, it is not a unique indicator. Table 2 shows that each type of sediment or rock has a wide range of seismic velocities, and many of these ranges significantly overlap. While the seismic refraction technique measures the seismic velocity of seismic waves in earth materials, it is the interpreter who based on knowledge of the local conditions or other data, or both, must interpret the seismic refraction data and arrive at a geologically reasonable solution*
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> *According to Mooney (8), P-wave velocities are generally greater for:*
> *1. Denser rocks than lighter rocks*
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> *4. Solid rocks than rocks with crack and fractures*
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> *6. Consolidated sediments than unconsolidated sediments*
> *7. Water saturated rocks/sediments than unsaturated rocks/sediments*
> *8. Wet soils than dry soils*

These velocity ranges and descriptions should be correlated with other site information including test pits, test hole logs, and other available information.

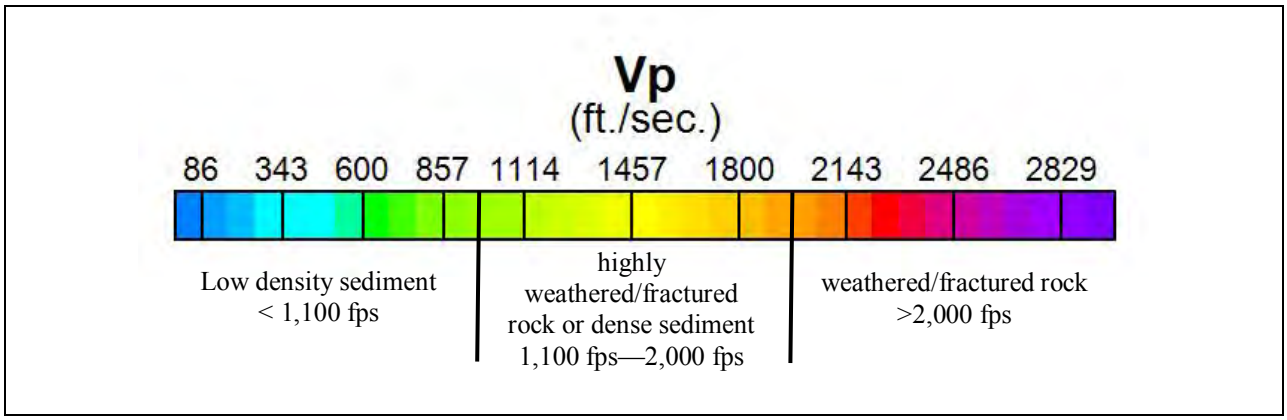


Figure 3. General compression wave velocity range of materials

Glen Carpenter / principal

DRAFT

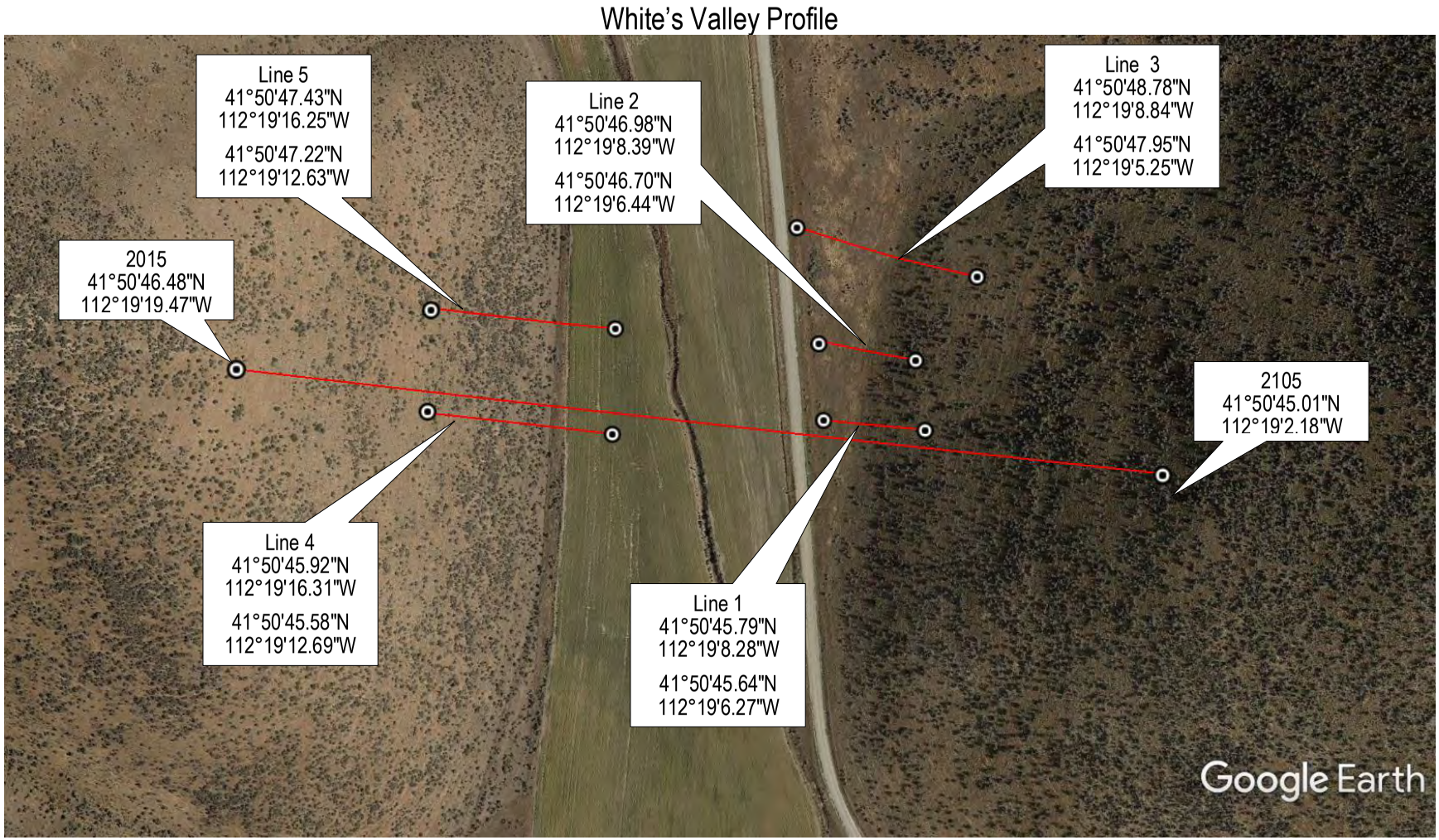
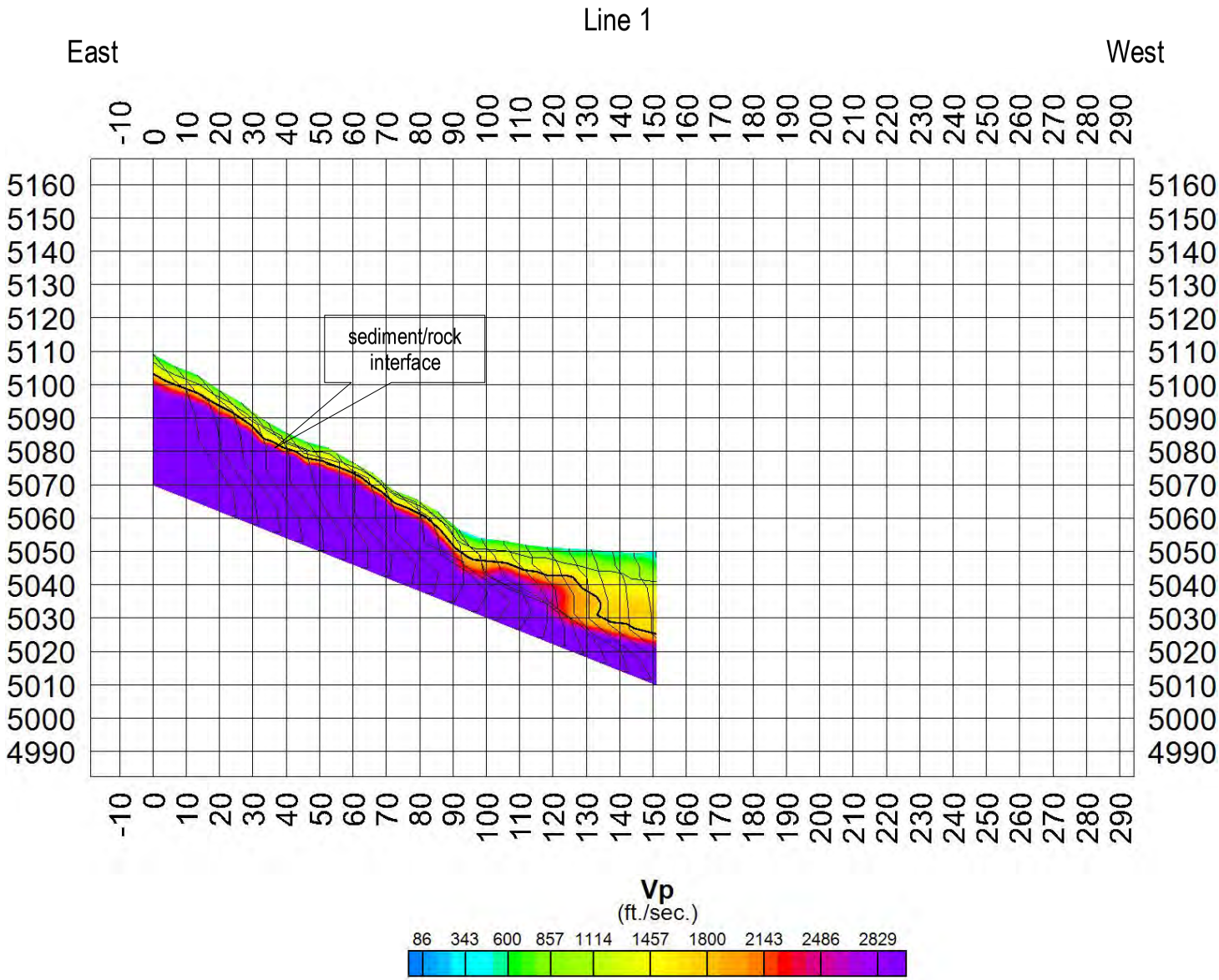
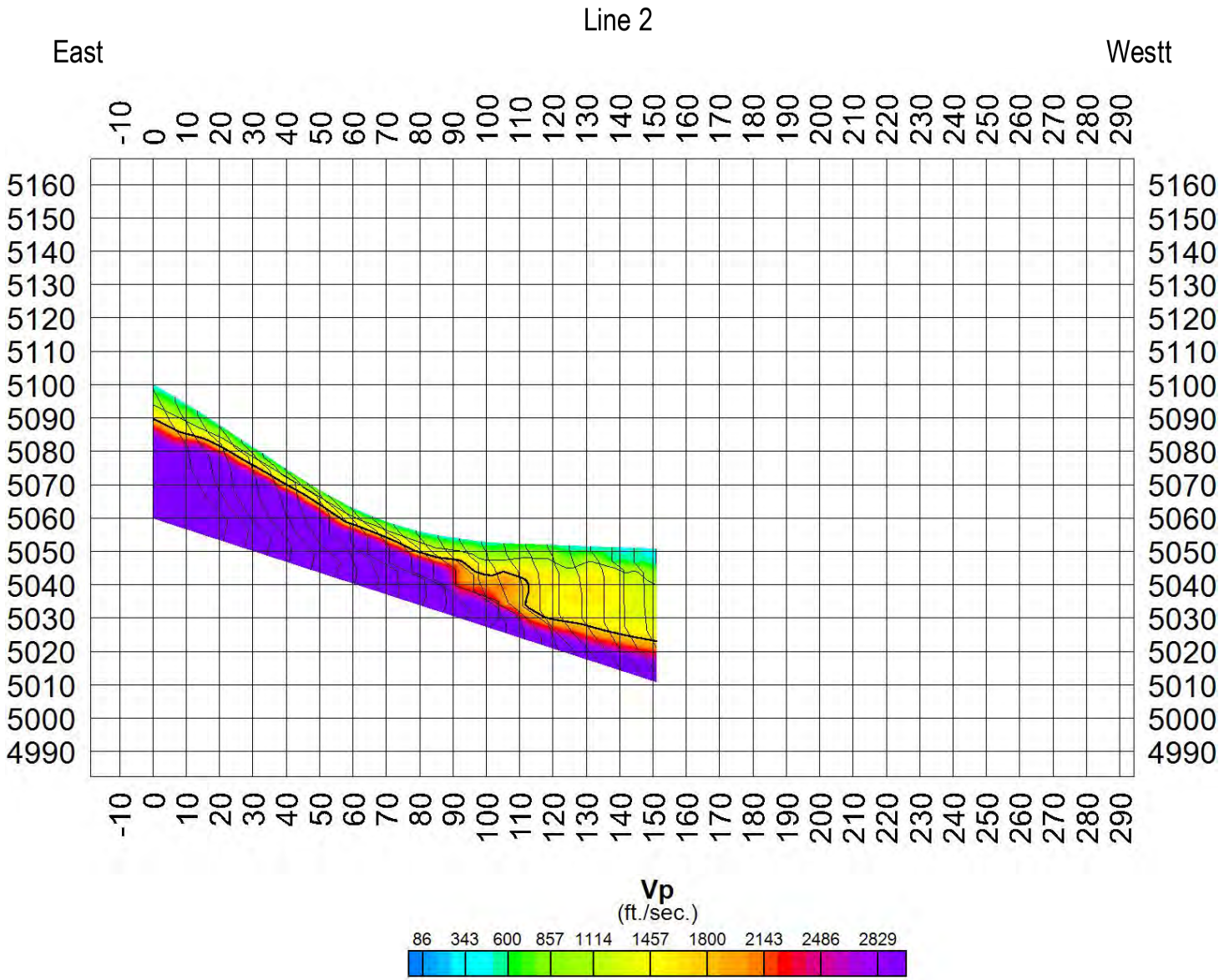


Figure 4. White's Valley profile locations *(location and scale approximate)*

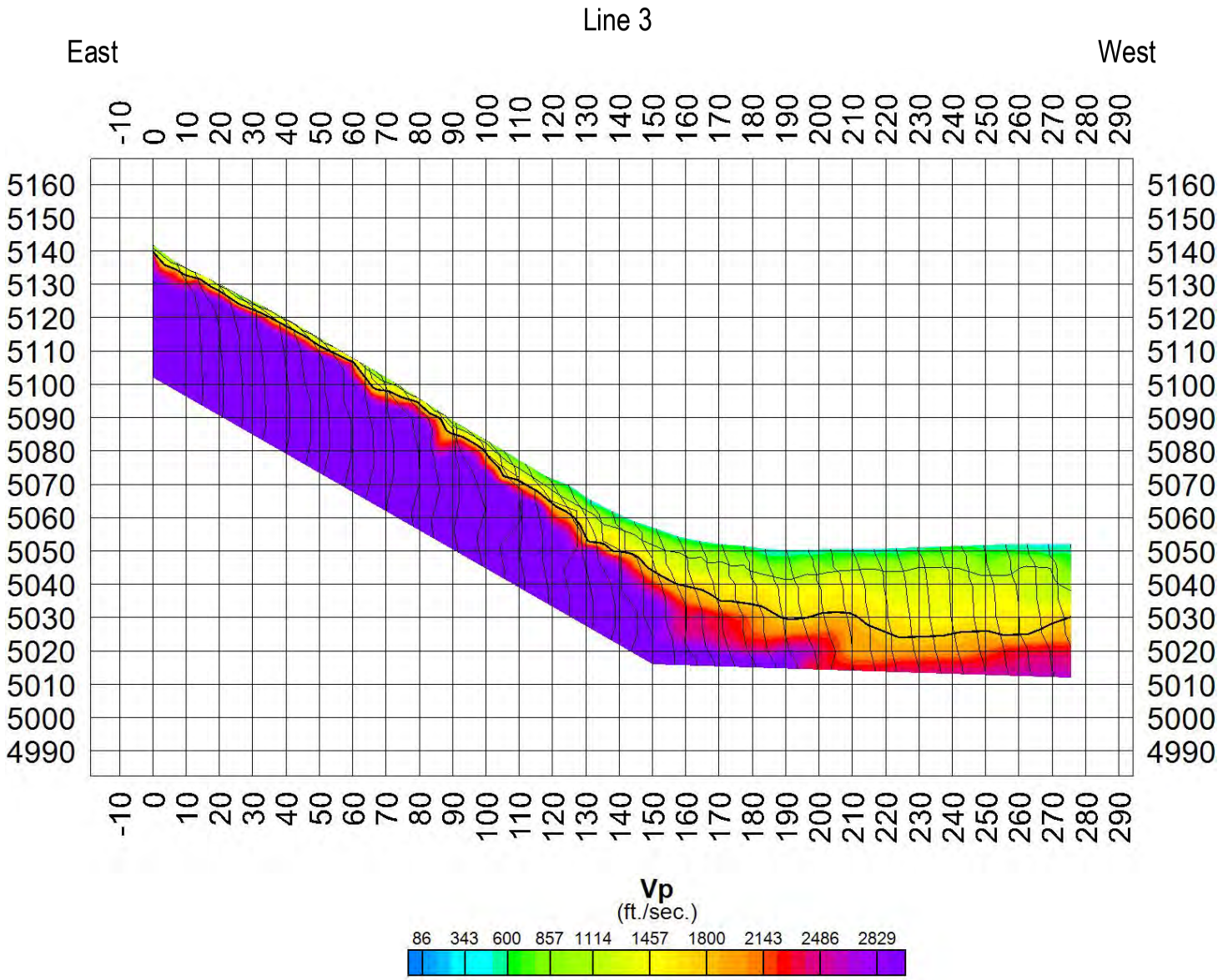
DRAFT


Line 1
East
West
sediment/rock interface
Vp
(ft./sec.)
86 343 600 857 1114 1457 1800 2143 2486 2829

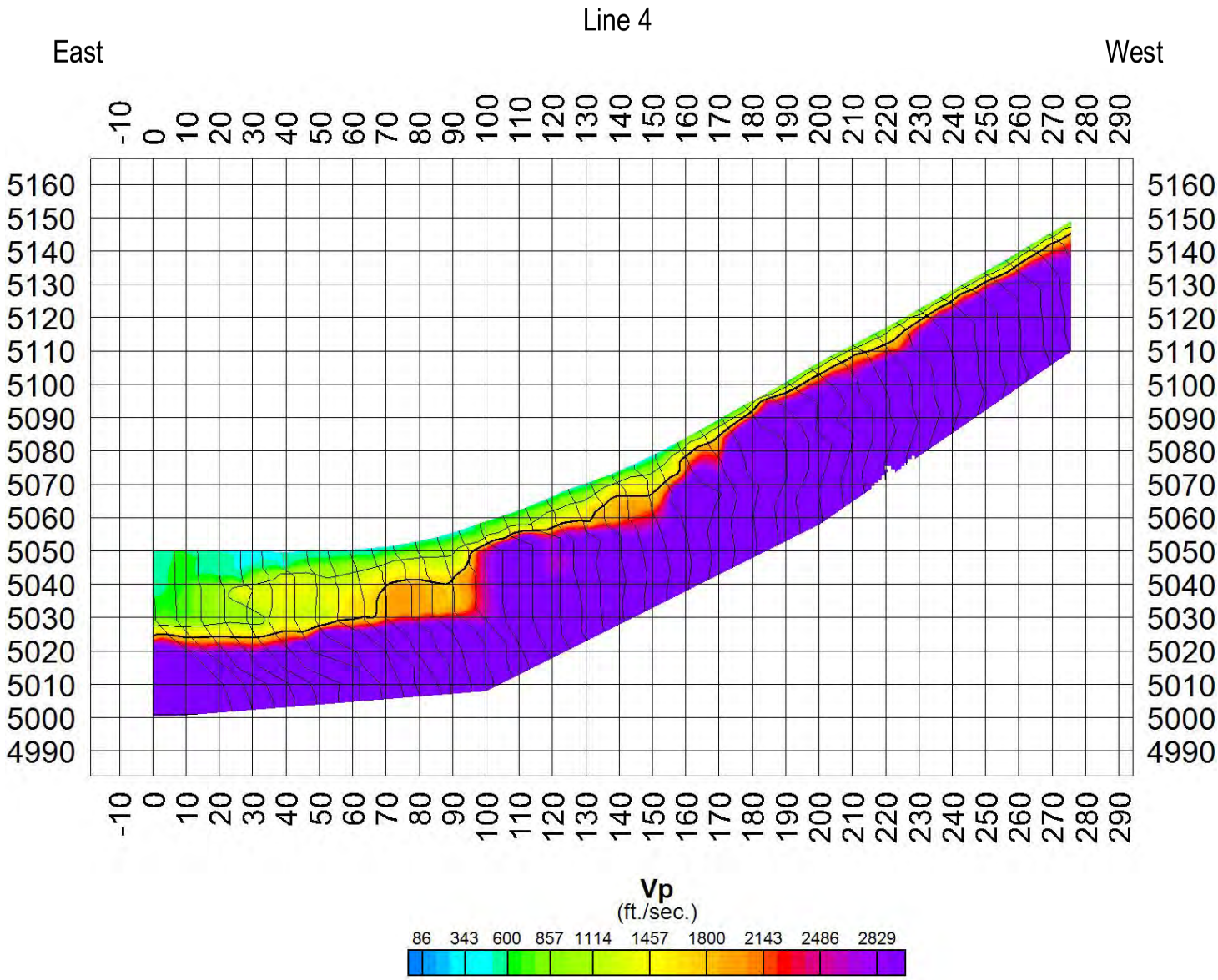
DRAFT


Line 2
East
Westt
-10 0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200 210 220 230 240 250 260 270 280 290
5160 5150 5140 5130 5120 5110 5100 5090 5080 5070 5060 5050 5040 5030 5020 5010 5000 4990
Vp
(ft./sec.)
86 343 600 857 1114 1457 1800 2143 2486 2829

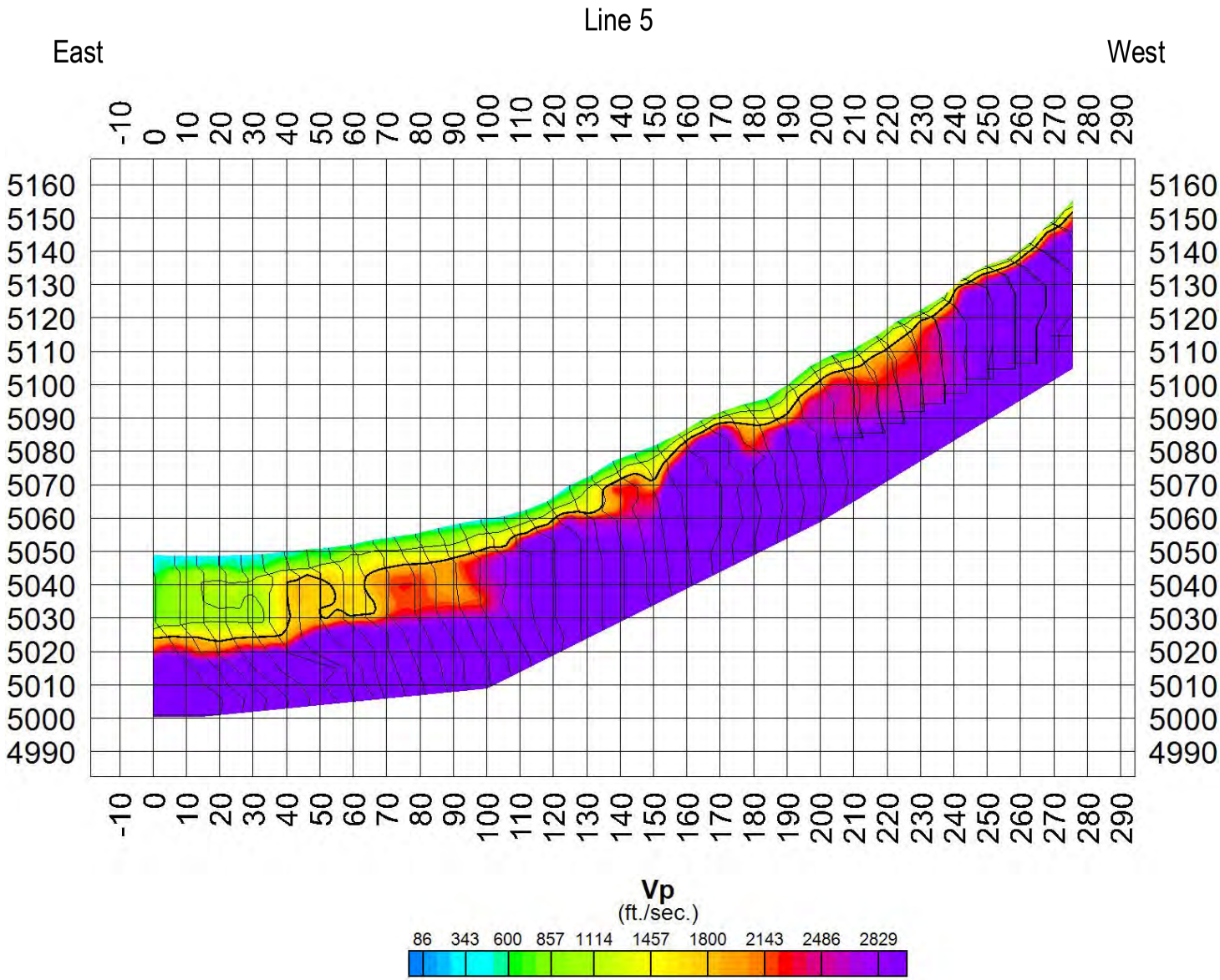
DRAFT


Line 3
East
West
-10 0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200 210 220 230 240 250 260 270 280 290
5160 5150 5140 5130 5120 5110 5100 5090 5080 5070 5060 5050 5040 5030 5020 5010 5000 4990
Vp
(ft./sec.)
86 343 600 857 1114 1457 1800 2143 2486 2829

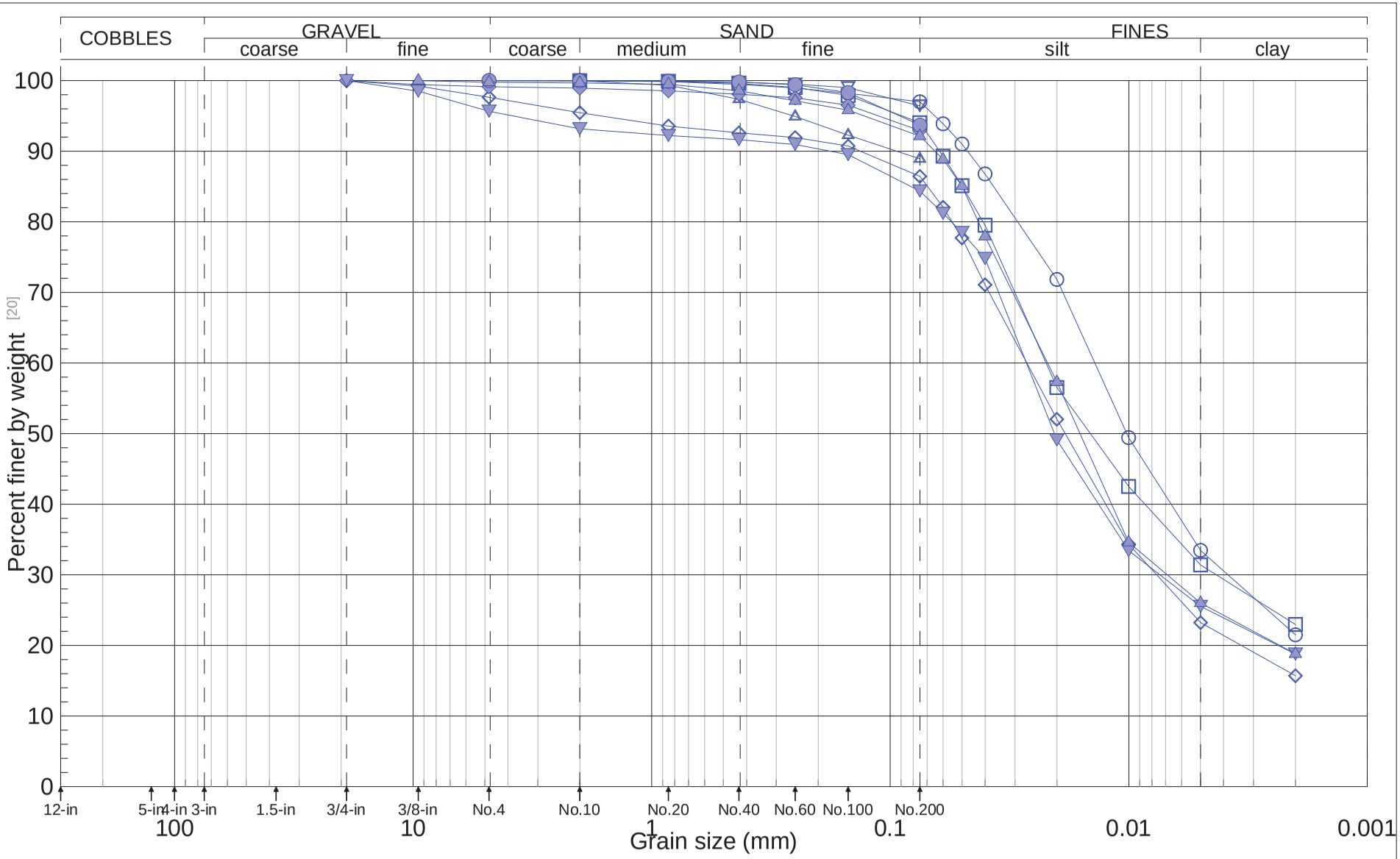
DRAFT


Line 4
East
West
-10 0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200 210 220 230 240 250 260 270 280 290
5160 5150 5140 5130 5120 5110 5100 5090 5080 5070 5060 5050 5040 5030 5020 5010 5000 4990
Vp
(ft./sec.)
86 343 600 857 1114 1457 1800 2143 2486 2829

DRAFT


Line 5
East
West
-10 0 10 20 30 40 50 60 70 80 90 100 110 120 130 140 150 160 170 180 190 200 210 220 230 240 250 260 270 280 290
5160 5150 5140 5130 5120 5110 5100 5090 5080 5070 5060 5050 5040 5030 5020 5010 5000 4990
Vp
(ft./sec.)
86 343 600 857 1114 1457 1800 2143 2486 2829

DRAFT



◇14-TH-WV-04 at 0-5
▽14-TH-WV-04 at 5-10
○14-TH-WV-04 at 10-15
△14-TH-WV-04 at 15-20
□14-TH-WV-04 at 20-25
◇14-TH-WV-04 at 25-30
▽14-TH-WV-04 at 30-35
○14-TH-WV-04 at 35-40
△14-TH-WV-04 at 40-45

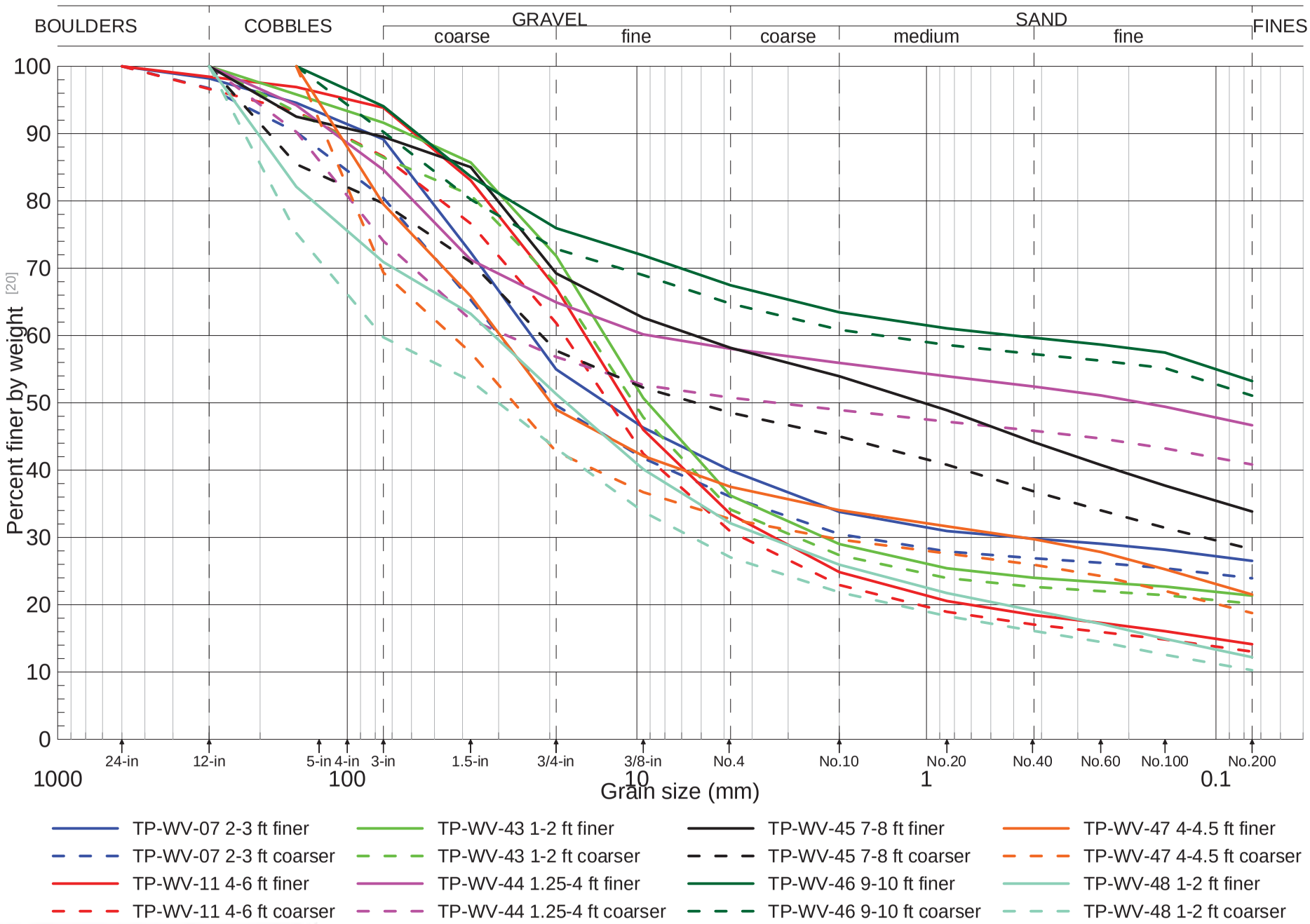
GERHART COLE

Grain-Size Analysis - 15-TH-WV-04

Bear River Project Concept Study - Whites Valley

Figure D-1

DRAFT



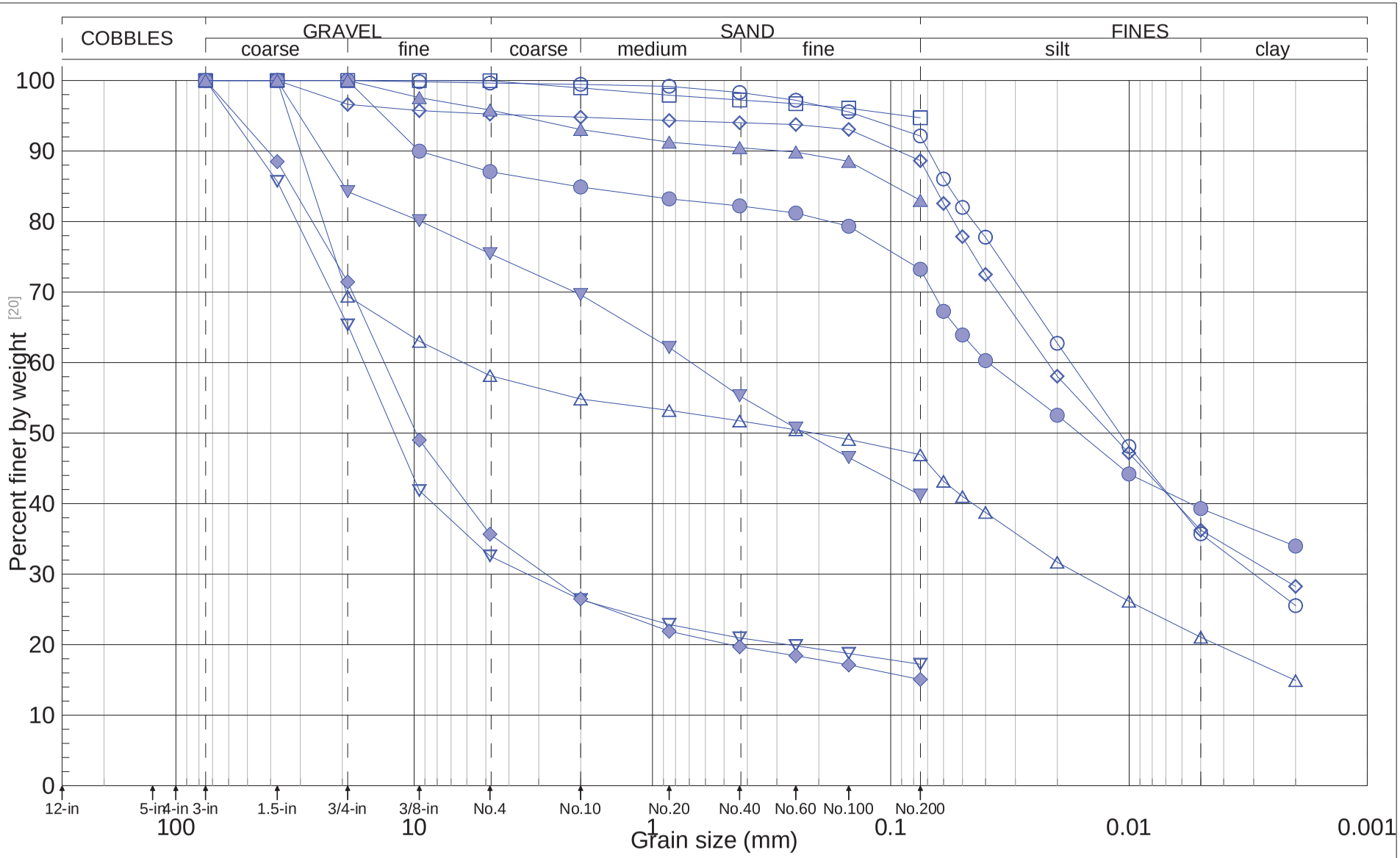
GERHART COLE

Grain-Size Analysis - Sheet 1 of 3

Bear River Project Concept Study - Whites Valley

Figure D-2a

DRAFT



◇16-TP-WV-01 at 3 ft
▽16-TP-WV-02 at 3-4 ft
○16-TP-WV-03 at 4-5 ft
△16-TP-WV-08 at 9-10 ft
□16-TP-WV-10 at 9-10 ft
◇16-TP-WV-11 at 4-6 ft
▽16-TP-WV-24 at 10 ft
●16-TP-WV-27 at 10 ft
▲16-TP-WV-28 at 11 ft

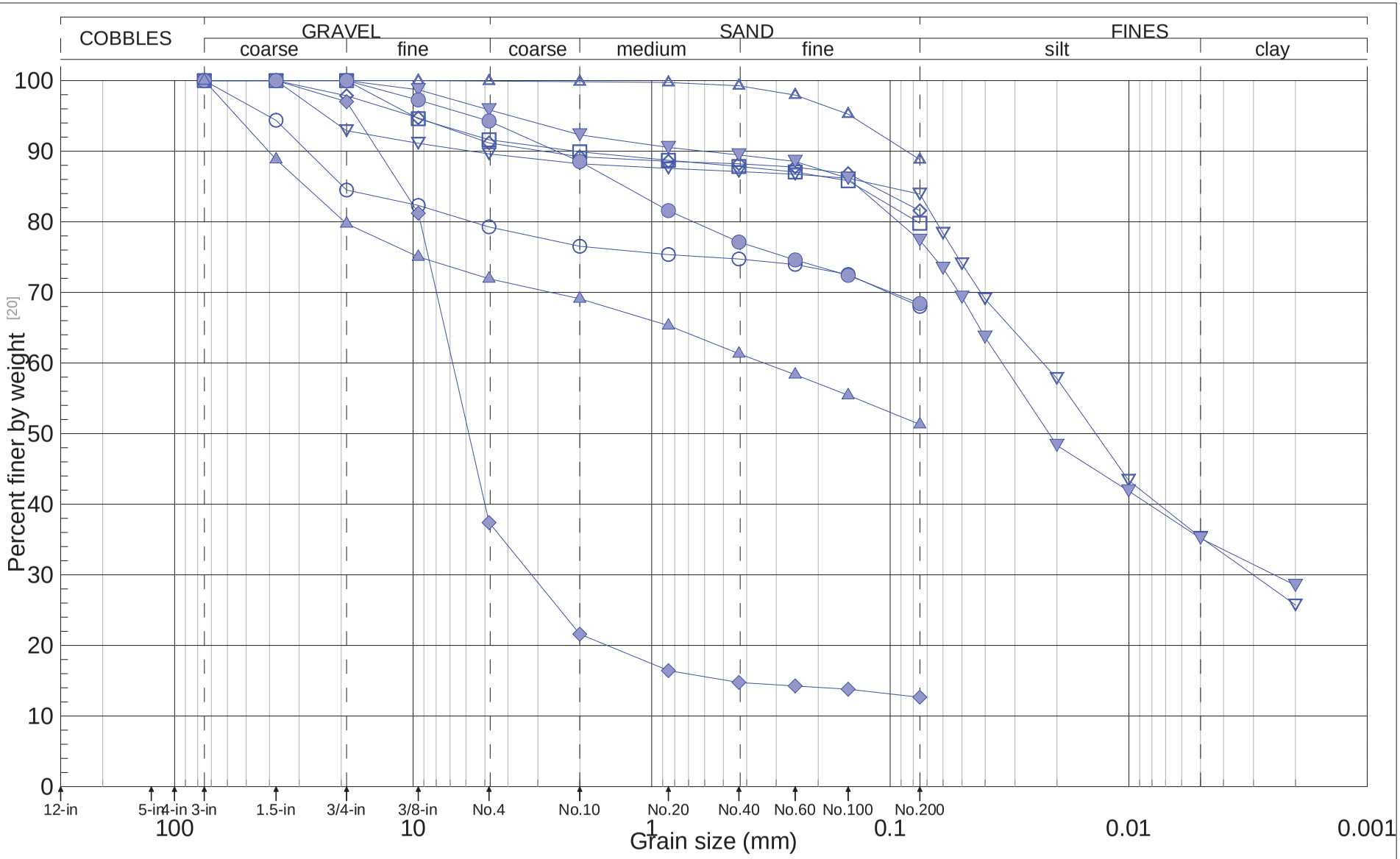
GERHART COLE

Grain-Size Analysis - Sheet 2 of 3

Bear River Project Concept Study - Whites Valley

Figure D-2b

DRAFT



◇16-TP-WV-29 at 5-6 ft
▽16-TP-WV-30 at 3-4 ft
○16-TP-WV-30 at 5-6 ft
△16-TP-WV-31 at 3-4 ft
□16-TP-WV-33 at 3-5 ft
◆16-TP-WV-34 at 2-4 ft
▼16-TP-WV-37 at 2-4 ft
●16-TP-WV-41 at 5-6 ft
▲16-TP-WV-42 at 9-10 ft

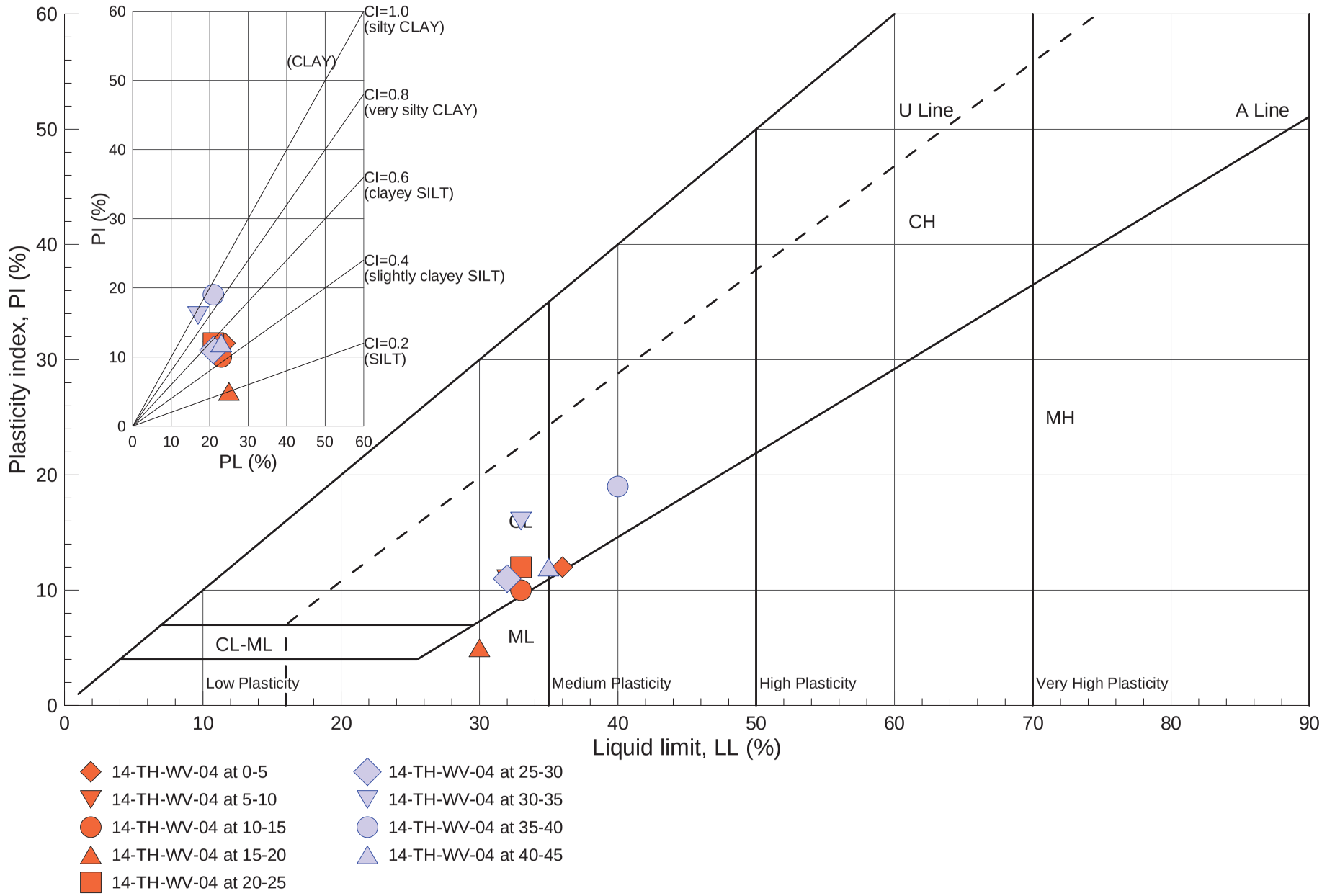
GERHART COLE

Grain-Size Analysis - (Sheet 3 of 3)

Bear River Project Concept Study - Whites Valley

Figure D-2c

DRAFT



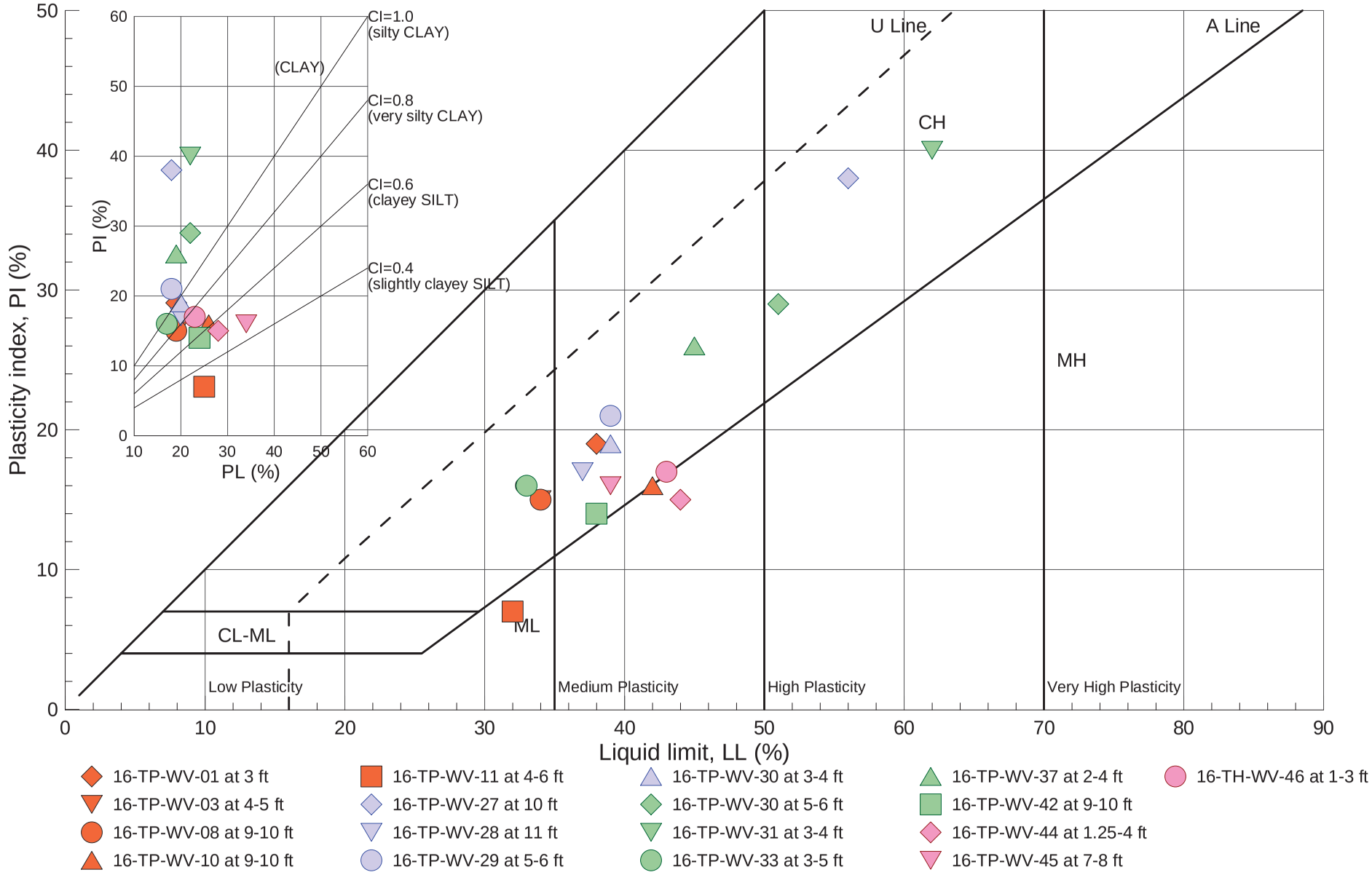
GERHART COLE

Casagrande's Plasticity Chart (Atterberg Limits); 14-TH-WV-04

Bear River Project Concept Study - Whites Valley

Figure D-3

DRAFT



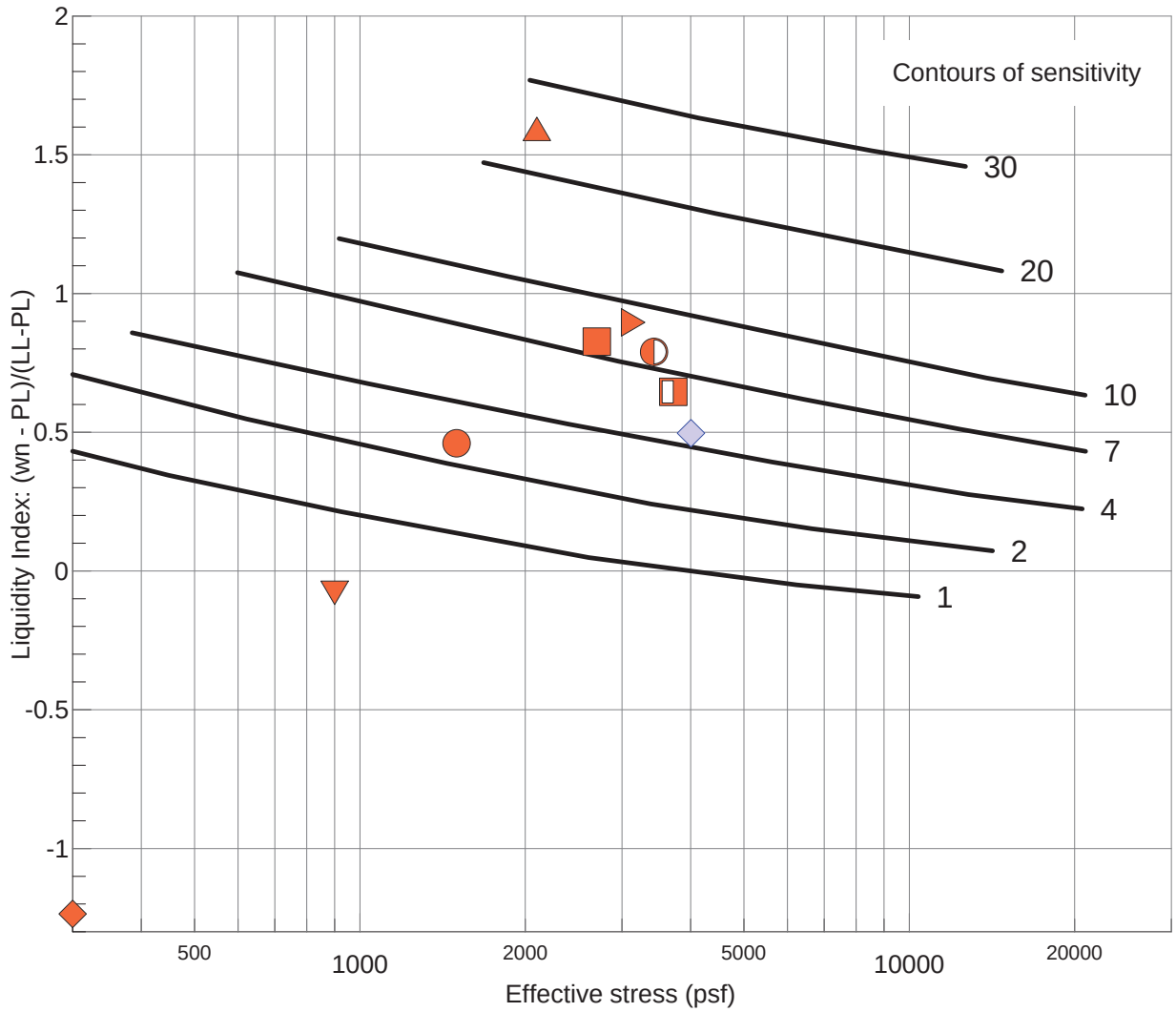
GERHART COLE

Casagrande's Plasticity Chart (Atterberg Limits)

Bear River Project Concept Study - Whites Valley

Figure D-4

DRAFT



- 14-TH-WV-04 at 0-5
- 14-TH-WV-04 at 5-10
- 14-TH-WV-04 at 10-15
- 14-TH-WV-04 at 15-20
- 14-TH-WV-04 at 20-25
- 14-TH-WV-04 at 25-30
- 14-TH-WV-04 at 30-35
- 14-TH-WV-04 at 35-40
- 14-TH-WV-04 at 40-45

GERHART COLE	Sensitivity, LI, and Effective Stress Relationships (Mitchell,1993)	
	Bear River Project Concept Study - Whites Valley	Figure D-5

DRAFT

Triaxial Test - Isotropic Consolidated Sheared Undrained Measuring Pore Pressure (CIU-PP) - *After ASTM D4767 and USBR 5750*

GERHART COLE

Project: Whites Valley/Bear River Project
No: 13GCI329
Location: Whites Valley
Date: 06-Jan-15
Tested by: zg
Reduced by: zg
Checked by: dab

TH/TP/Sample: 14-TH-WV-04
Depth: 0-15
Sample descrition: brown clay
USCS classification: not requested
Sample type: remolded

	Test Number	S1	60 psi	S2	24 psi	S3	160 psi
		Initial	Bef. Shr. MethodB [e]	Initial	Bef. Shr. MethodB [e]	Initial	Bef. Shr. MethodB [e]
Unit weight data	Sample ht., H (in) 0°	5.893		5.978		6.014	
	120°	5.901		5.980		6.015	
	240°	5.896		5.983		6.016	
	Avg. height, Havg (in)	5.897	5.877	5.980	5.940	6.015	5.835
	Avg. height, Havg (cm)	14.978	14.927	15.190	15.088	15.278	14.821
	ΔHsc (in) [a]		0.02		0.040		0.180
	Sample dia., D (in) top	2.804		2.805		2.808	
	mid	2.811		2.805		2.807	
	bot	2.805		2.806		2.802	
	Avg. dia., Davg (in)	2.808	2.727	2.805	2.776	2.806	2.640
	Avg. dia., Davg (cm)	7.132	6.927	7.125	7.050	7.127	6.705
	Avg. area, Aavg (in^2)	6.192	5.841	6.181	6.051	6.184	5.473
	Avg. area, Aavg (cm^2)	39.946	37.687	39.875	39.041	39.896	35.307
	Wt. rings + wet soil (g)	1125.76	1143.44	1126.23	1167.25	1126.44	1122.58
	Wt. rings (g)	0.00	0.00	0.00	0.00	0.00	0.00
	Volume, Vo (in^3)	36.5	34.3	37.0	35.9	37.2	31.9
	Vo (cm^3)	598.3	562.5	605.7	589.1	609.5	523.3
	Vo (ft^3)	0.0211	0.0199	0.0214	0.0208	0.0215	0.0185
Moisture	Wet soil + tare (g)	382.22	1288.32	378.75	1312.57	348.60	1266.79
	Dry soil + tare (g)	342.29	1077.28	338.62	1076.01	313.50	1093.43
	Tare (g)	150.57	145.17	145.42	145.85	142.67	144.25
	Moisture content, w (%)	20.8	22.6	20.8	25.4	20.5	18.3
Phase Relationships	Gs, assumed	2.65	2.65	2.65	2.65	2.65	2.65
	Mass total (g)	1125.8	1142.7	1126.2	1169.7	1126.4	1105.1
	Mass of solids (g)	931.7	931.7	932.5	932.5	934.4	934.4
	Volume (cm^3)	598.3	562.5	605.7	589.1	609.5	523.3
	Volume of water (cm^3)	194.0	210.9	193.7	237.2	192.0	170.7
	Volume of solids (cm^3)	351.6	351.6	351.9	351.9	352.6	352.6
	Volume of voids (cm^3)	246.7	210.9	253.8	237.2	256.9	170.7
	Volume of air (cm^3)	52.7	0.0	60.1	0.0	64.9	0.0
	Void ratio, e	0.702	0.600	0.721	0.674	0.729	0.484
	Porosity, n	0.412	0.375	0.419	0.403	0.422	0.326
	Volumetric moisture, T	0.324	0.375	0.320	0.403	0.315	0.326
	Saturation, S (%) [c]	78.66	100.00	76.32	100.00	74.73	100.00
	Dry density (gm/cm^3)	1.557	1.656	1.540	1.583	1.533	1.786
	Wet unit wt., gm (pcf)	117.5	126.8	116.1	124.0	115.4	131.8
	Dry unit wt., gd (pcf)	97.2	103.4	96.1	98.8	95.7	111.5

Notes:

[a] ΔHsc (in) = change in height during saturation and consolidation

[b] ΔVs = change in volume during saturation, ΔVc = change in volume during consolidation

[c] Saturation before shear set to 100% for phase calculations

[d] Before shear Aavg using method A; where Ac (Method A) = (Vo-DVs - DVc)/(Ho-DHsc)

[e] Before shear Aavg using method B; where Ac (Method B) = (Vwf + Vs)/Hc

Compaction specifications:	Target	As Compacted Avg.
gd (pcf)	95.7	96.3
w (%)	21.3	20.7

DRAFT

Triaxial Test - Isotropic Consolidated Sheared Undrained
Measuring Pore Pressure (CIU-PP) *- After ASTM D4767 and USBR 5750*

GERHART COLE

Project:	**Whites Valley/Bear River Project**	**TH/TP/Sample:**	**14-TH-WV-04**
No:	**13GCI329**	**Depth:**	**0-15**
Location:	Whites Valley	Sample descrition:	brown clay
Date:	42010	USCS classification:	not requested
Tested by:	zg	Sample type:	remolded

X:\PROJECTS\13GCI329 Bear River Project Concept Study\Whites Valley\[TX_CU3pts_WV_TH-04at0-15-v02.xlsx]SUM

Test Number		S1 at 60 psi	S2 at 24 psi	S3 at 160 psi
Test information	Total backpressure (psi)	55.0	60.0	70.0
	Skempton B	0.94	0.94	0.94
	t-90 (min)	6.1	3.1	7.9
	t-100 (min)	10.1	7.9	9.9
	t-50 (min)	1.4	0.7	1.8
	Strain rate (%/hr)	2.40	1.20	2.40
	Strain rate (%/min)	0.04	0.02	0.04
	Membrane correction	Yes	Yes	Yes
	Filter paper correction	No filter paper	No filter paper	No filter paper
Max principal stress ratio (s1/s3), failure criteria	Strain at failure, ef (%)	15.45	9.56	15.39
	Time to failure, tf (min)	386.3	477.8	384.7
	Obliquity, s'1/s'3	3.151	3.534	3.509
	Excess pore pressure, u (psi)	35.64	16.75	108.18
	q = q' = (s1+s3)/2 (psi)	26.20	9.19	65.02
	p' = (s'1+s'3)/2 (psi)	50.56	16.44	116.84
	p = (s1+s3)/2 (psi)	86.20	33.19	225.02
	Effective major principal stress, s'1 (psi)	76.76	25.62	181.86
	Effective minor principal stress, s'3 (psi)	24.36	7.25	51.82
	Total major pincipal stress, s1 (psi)	112.40	42.37	290.03
	Total minor pincipal stress, s3 (psi)	60.00	24.00	160.00
	Skemption A at failure, Af	0.68	0.91	0.83
	Secant friction angle, phi-s (deg)	31.2	34.0	33.8
		Effective stress	Total stress	
	Friction angle, phi (deg)	33.4	16.9	
	Cohesion intercept, c (psi)	0.0	0.0	
Peak deviator stress (s1-s3), failure criteria	Strain at failure, ef (%)	19.97	15.08	15.39
	Time to failure, tf (min)	499.2	753.9	384.7
	Deviator stress, s1-s3 (psi)	54.17	19.80	130.03
	Excess pore pressure, u (psi)	34.30	15.94	108.18
	q = q' = (s1+s3)/2 (psi)	27.09	9.90	65.02
	p' = (s'1+s'3)/2 (psi)	52.79	17.96	116.84
	p = (s1+s3)/2 (psi)	87.09	33.90	225.02
	Effective major principal stress, s'1 (psi)	79.88	27.86	181.86
	Effective minor principal stress, s'3 (psi)	25.70	8.06	51.82
	Total major pincipal stress, s1 (psi)	114.17	43.80	290.03
	Total minor pincipal stress, s3 (psi)	60.00	24.00	160.00
	Skemption A at failure, Af	0.63	0.81	0.83
	Secant friction angle, phi-s (deg)	30.9	33.5	33.8
		Effective stress	Total stress	
	Friction angle, phi (deg)	33.3	17.0	
	Cohesion intercept, c (psi)	0.0	0.0	

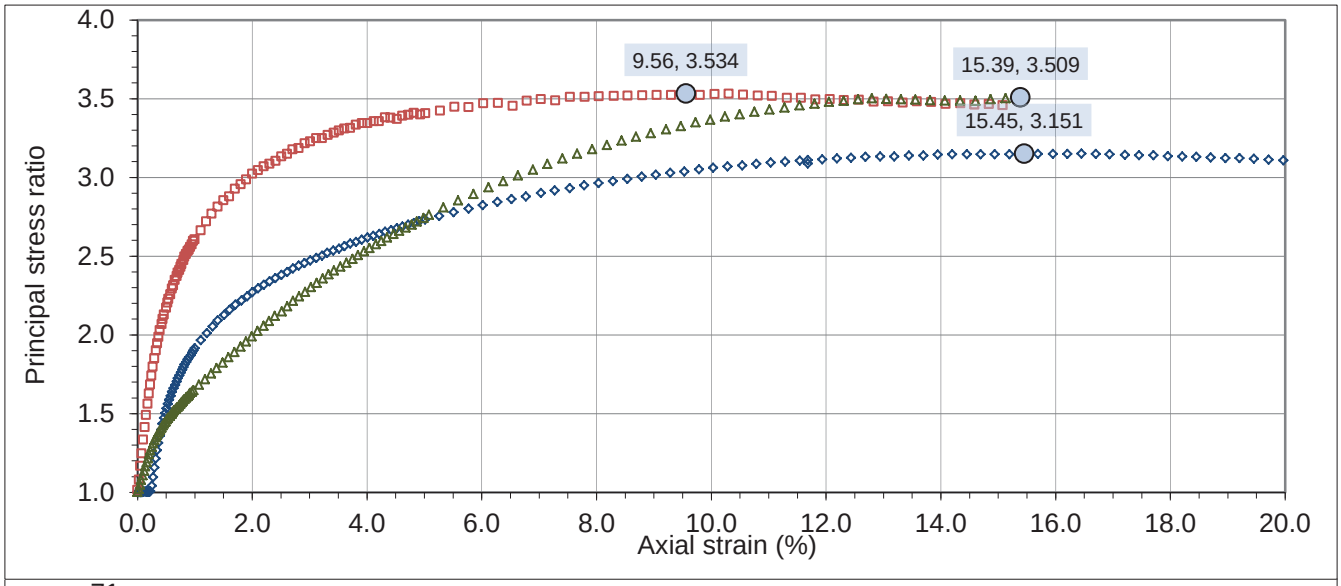
Comments:

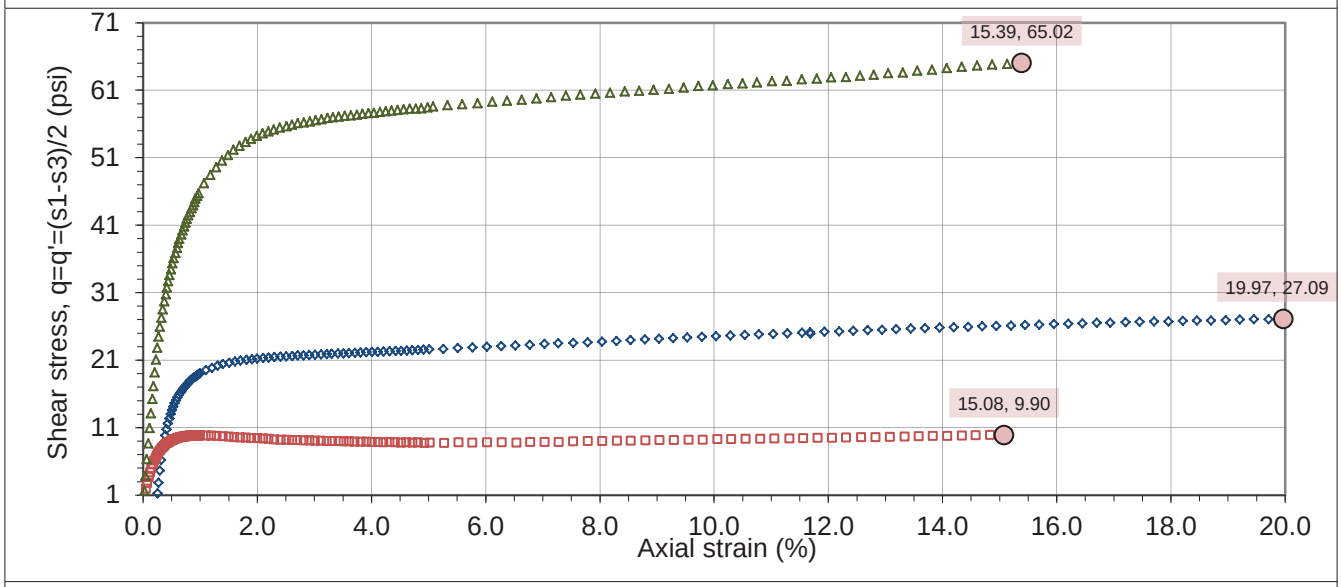
DRAFT

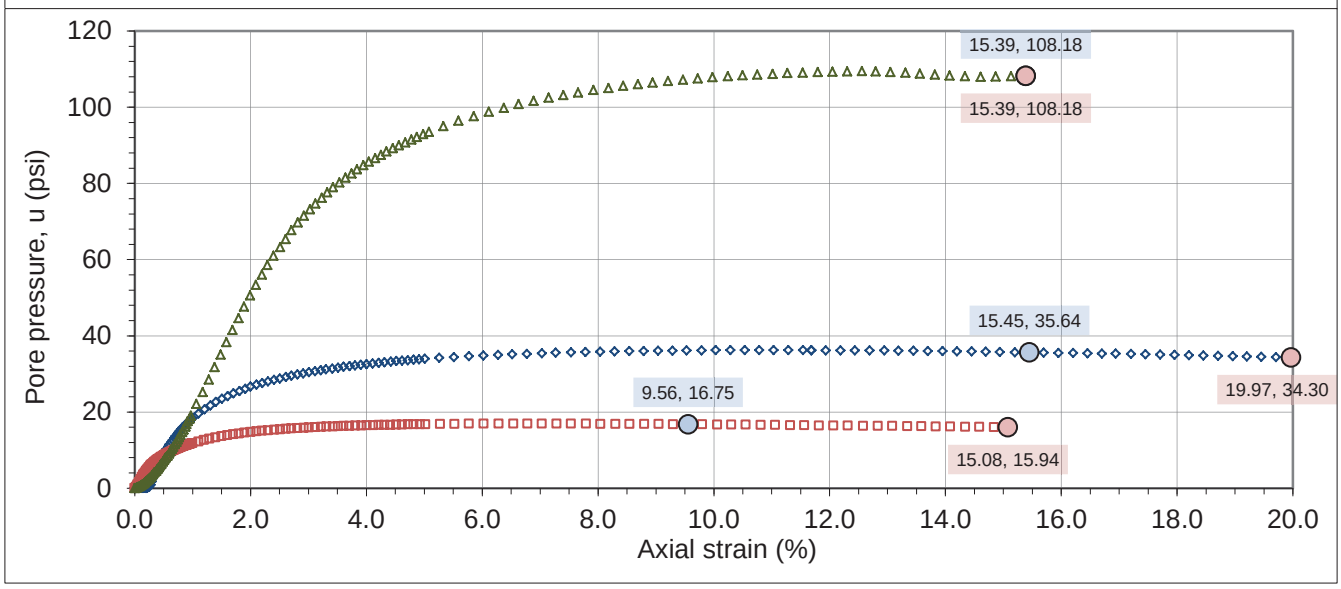
Triaxial Test - Isotropic Consolidated Sheared Undrained
Measuring Pore Pressure (CIU-PP) *- After ASTM D4767 and USBR 5750*

GERHART COLE

Project: Whites Valley/Bear River Project **TH/TP/Sample: 14-TH-WV-04**
No: 13GCI329 **Depth: 0-15**







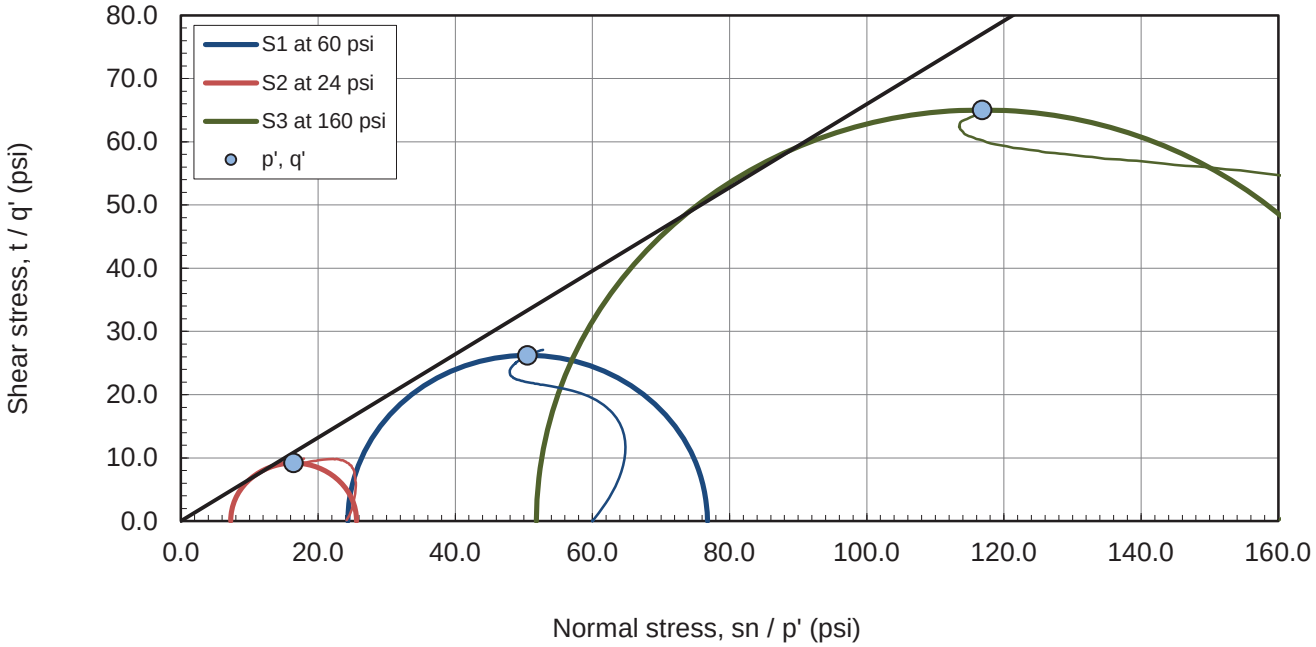
DRAFT

Triaxial Test - Isotropic Consolidated Sheared Undrained
Measuring Pore Pressure (CIU-PP) *- After ASTM D4767 and USBR 5750*

GERHART COLE

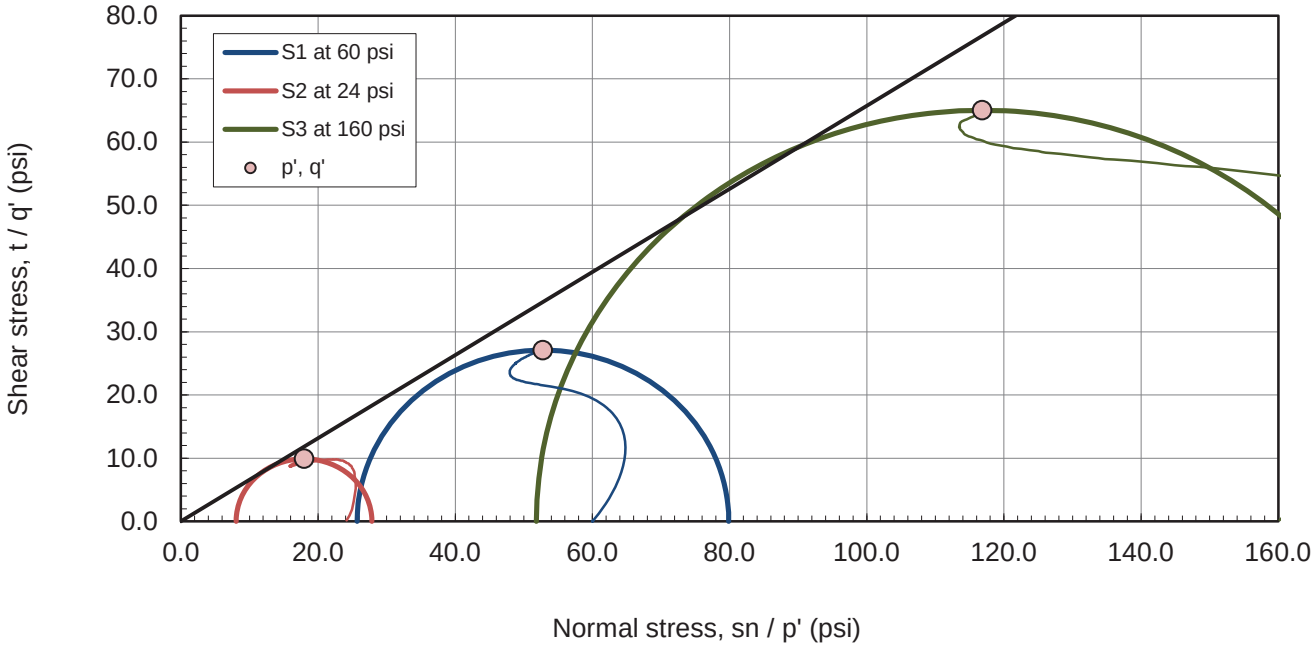
Project: **Whites Valley/Bear River Project** **TH/TP/Sample:** **14-TH-WV-04**
No: **13GCI329** **Depth:** **0-15**

Effective stress results



Max principal stress ratio (s'1/s'3), failure criteria Mohr and p' - q' space plots

Effective stress results



Peak deviator stress (s1-s3), failure criteria Mohr and p' - q' space plots

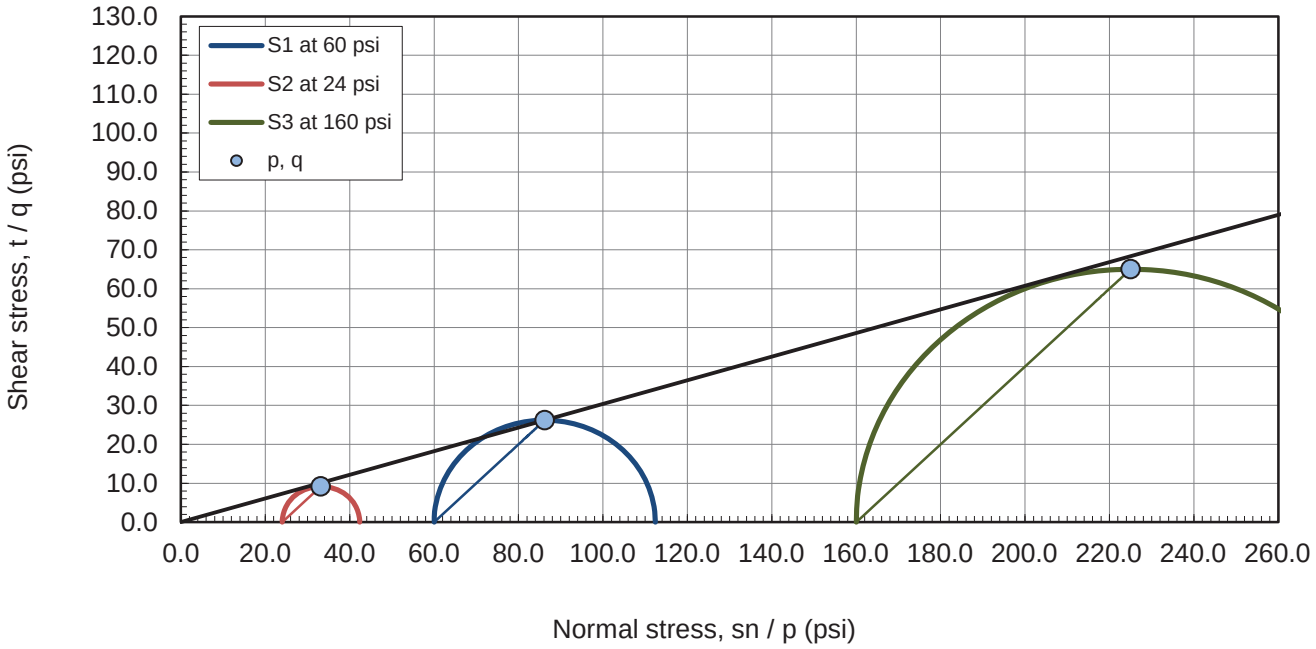
DRAFT

Triaxial Test - Isotropic Consolidated Sheared Undrained
Measuring Pore Pressure (CIU-PP) *- After ASTM D4767 and USBR 5750*

GERHART COLE

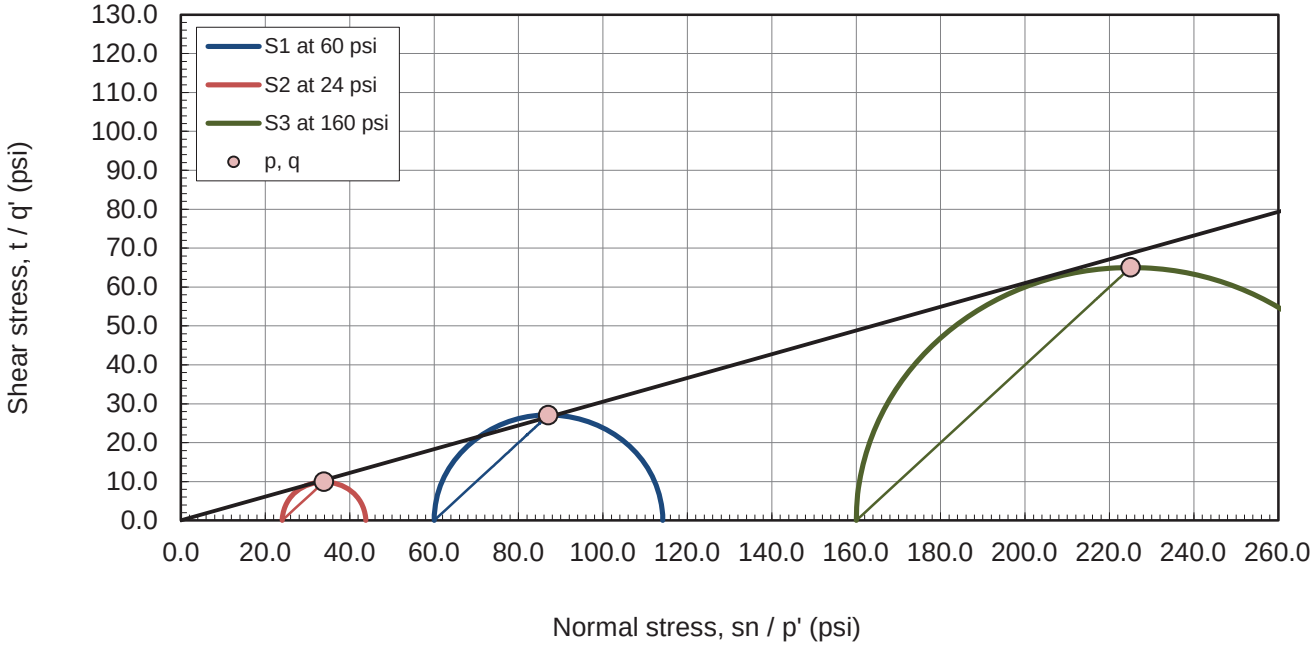
Project: Whites Valley/Bear River Project **TH/TP/Sample: 14-TH-WV-04**
No: 13GCI329 **Depth: 0-15**

Total stress results



Max principal stress ratio (s1/s3), failure criteria Mohr and p - q space plots - effective stress results

Total stress results



Peak deviator stress (s1-s3), failure criteria Mohr and p - q space plots

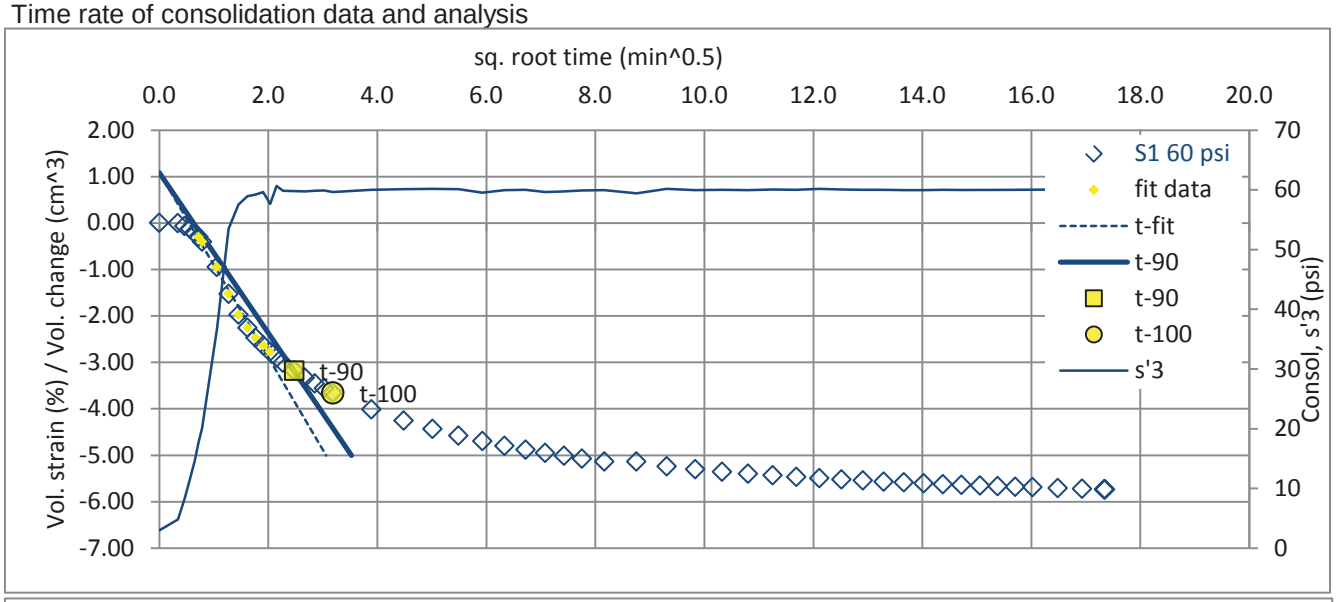
DRAFT

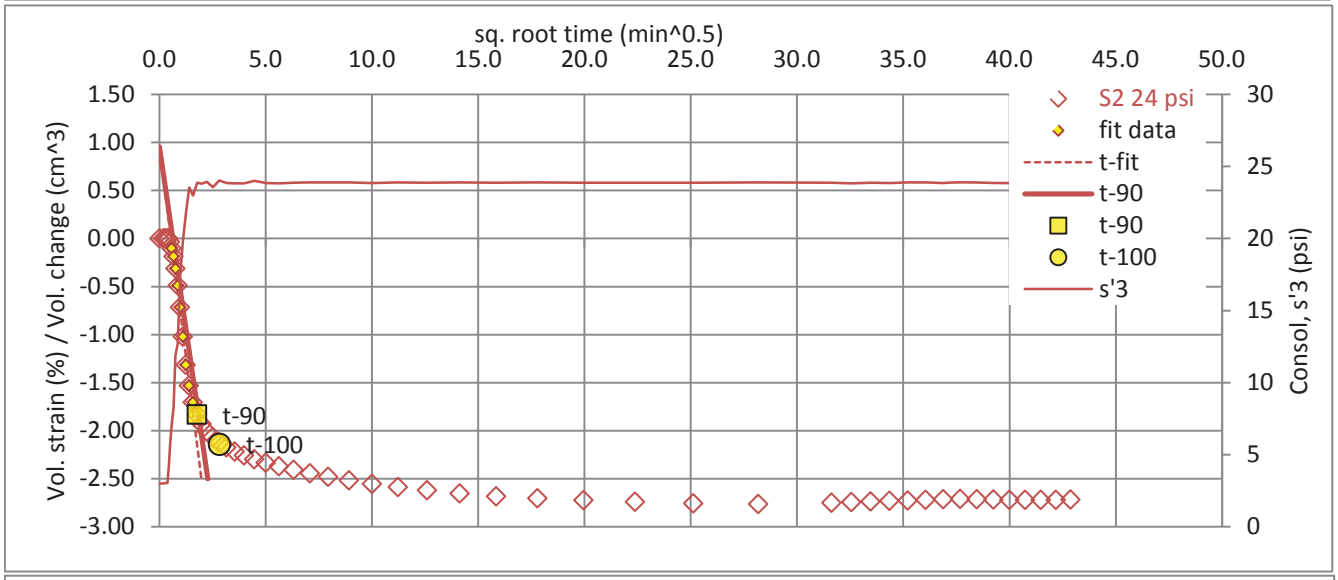
Triaxial Test - Isotropic Consolidated Sheared Undrained
Measuring Pore Pressure (CIU-PP) *- After ASTM D4767 and USBR 5750*

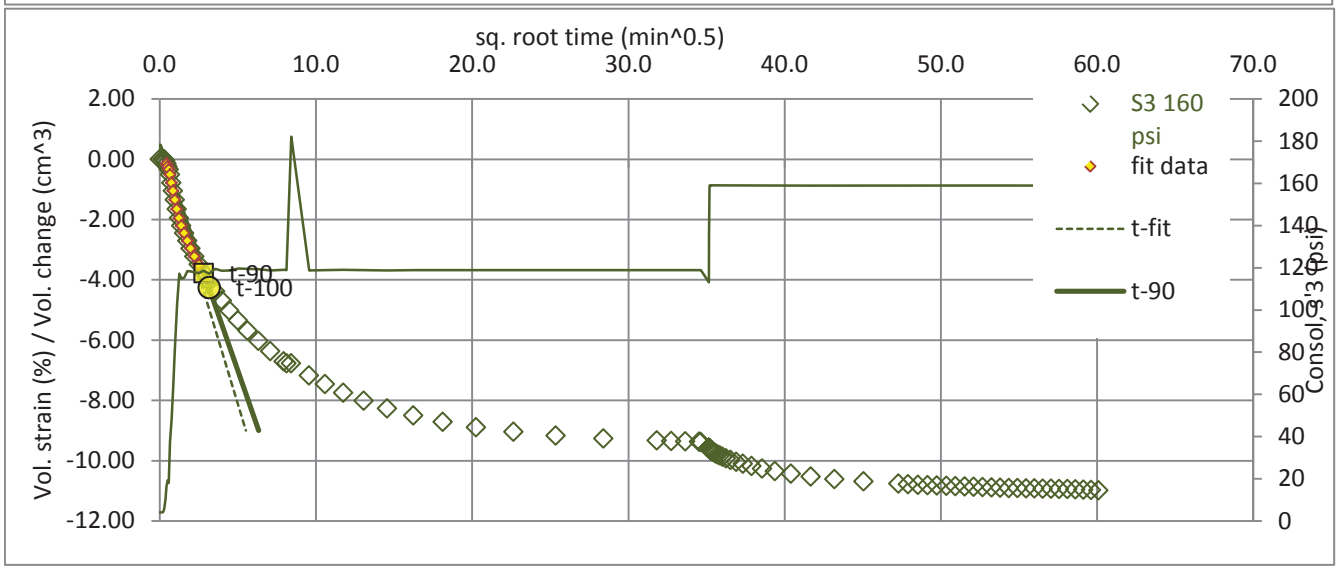
GERHART COLE

Project: Whites Valley/Bear River Project **TH/TP/Sample: 14-TH-WV-04**
No: 13GCI329 **Depth: 0-15**

Time rate of consolidation data and analysis







DRAFT

Triaxial Test - Isotropic Consolidated Sheared Undrained Measuring Pore Pressure (CIU-PP) - *After ASTM D4767 and USBR 5750*

GERHART COLE

Project: Whites Valley/Bear River Project
No: 13GCI329
Location: Whites Valley
Date: 06-Jan-15
Tested by: zg
Reduced by: zg
Checked by: dab

TH/TP/Sample: 14-TH-WV-04
Depth: 15-30
Sample descrition: brown clay
USCS classification: not requested
Sample type: remolded

	Test Number	S1	24 psi	S2	60 psi	S3	160 psi
		Initial	Bef. Shr. MethodB [e]	Initial	Bef. Shr. MethodB [e]	Initial	Bef. Shr. MethodB [e]
Unit weight data	Sample ht., H (in) 0°	5.965		5.971		5.978	
	120°	5.976		5.974		5.979	
	240°	5.968		5.982		6.004	
	Avg. height, Havg (in)	5.970	5.930	5.976	5.906	5.987	5.887
	Avg. height, Havg (cm)	15.163	15.061	15.178	15.000	15.207	14.953
	ΔHsc (in) [a]		0.04		0.070		0.100
	Sample dia., D (in) top	2.805		2.803		2.806	
	mid	2.805		2.805		2.803	
	bot	2.803		2.803		2.802	
	Avg. dia., Davg (in)	2.805	2.782	2.804	2.731	2.804	2.729
	Avg. dia., Davg (cm)	7.123	7.066	7.122	6.937	7.121	6.932
	Avg. area, Aavg (in^2)	6.177	6.077	6.175	5.858	6.173	5.850
	Avg. area, Aavg (cm^2)	39.854	39.209	39.839	37.791	39.825	37.744
	Wt. rings + wet soil (g)	1197.51	1223.92	1197.24	1210.36	1197.63	1197.30
	Wt. rings (g)	0.00	0.00	0.00	0.00	0.00	0.00
	Volume, Vo (in^3)	36.9	36.0	36.9	34.6	37.0	34.4
	Vo (cm^3)	604.3	590.5	604.7	566.9	605.6	564.4
	Vo (ft^3)	0.0213	0.0209	0.0214	0.0200	0.0214	0.0199
Moisture	Wet soil + tare (g)	377.87	1396.74	403.23	1328.93	373.17	1342.13
	Dry soil + tare (g)	343.85	1192.92	368.93	1145.25	339.47	1163.20
	Tare (g)	144.42	173.34	172.92	119.01	145.40	144.95
	Moisture content, w (%)	17.1	20.0	17.5	17.9	17.4	17.6
Phase Relationships	Gs, assumed	2.65	2.65	2.65	2.65	2.65	2.65
	Mass total (g)	1197.5	1227.5	1197.2	1201.3	1197.6	1199.7
	Mass of solids (g)	1023.0	1023.0	1018.9	1018.9	1020.4	1020.4
	Volume (cm^3)	604.3	590.5	604.7	566.9	605.6	564.4
	Volume of water (cm^3)	174.5	204.5	178.3	182.4	177.2	179.3
	Volume of solids (cm^3)	386.0	386.0	384.5	384.5	385.1	385.1
	Volume of voids (cm^3)	218.3	204.5	220.2	182.4	220.6	179.3
	Volume of air (cm^3)	43.8	0.0	41.9	0.0	43.4	0.0
	Void ratio, e	0.565	0.530	0.573	0.474	0.573	0.466
	Porosity, n	0.361	0.346	0.364	0.322	0.364	0.318
	Volumetric moisture, T	0.289	0.346	0.295	0.322	0.293	0.318
	Saturation, S (%) [c]	79.95	100.00	80.98	100.00	80.34	100.00
	Dry density (gm/cm^3)	1.693	1.732	1.685	1.797	1.685	1.808
	Wet unit wt., gm (pcf)	123.7	129.8	123.6	132.3	123.5	132.7
	Dry unit wt., gd (pcf)	105.7	108.1	105.2	112.2	105.2	112.9

Notes:

[a] ΔHsc (in) = change in height during saturation and consolidation

[b] ΔVs = change in volume during saturation, ΔVc = change in volume during consolidation

[c] Saturation before shear set to 100% for phase calculations

[d] Before shear Aavg using method A; where Ac (Method A) = (Vo-DVs - DVc)/(Ho-DHsc)

[e] Before shear Aavg using method B; where Ac (Method B) = (Vwf + Vs)/Hc

Compaction specifications:	Target	As Compacted Avg.
gd (pcf)	104.5	105.4
w (%)	18.0	17.3

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Triaxial Test - Isotropic Consolidated Sheared Undrained
Measuring Pore Pressure (CIU-PP) *- After ASTM D4767 and USBR 5750*

GERHART COLE

Project:	**Whites Valley/Bear River Project**	**TH/TP/Sample:**	**14-TH-WV-04**
No:	**13GCI329**	**Depth:**	**15-30**
Location:	Whites Valley	Sample descrition:	brown clay
Date:	1/6/2015	USCS classification:	not requested
Tested by:	zg	Sample type:	remolded

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	Test Number	S1 at 24 psi	S2 at 60 psi	S3 at 160 psi
Test information	Total backpressure (psi)	65.0	52.0	57.0
	Skempton B	0.95	0.95	0.95
	t-90 (min)	2.4	3.1	2.5
	t-100 (min)	5.0	6.3	5.0
	t-50 (min)	0.6	0.7	0.6
	Strain rate (%/hr)	1.20	2.40	1.20
	Strain rate (%/min)	0.02	0.04	0.02
	Membrane correction	Yes	Yes	Yes
	Filter paper correction	No filter paper	No filter paper	No filter paper
Max principal stress ratio (s1/s3), failure criteria	Strain at failure, ef (%)	9.06	14.64	13.40
	Time to failure, tf (min)	453.0	365.9	669.8
	Obliquity, s'1/s'3	3.695	3.944	3.582
	Excess pore pressure, u (psi)	17.07	41.90	124.49
	q = q' = (s1+s3)/2 (psi)	9.34	26.65	45.85
	p' = (s'1+s'3)/2 (psi)	16.27	44.74	81.36
	p = (s1+s3)/2 (psi)	33.34	86.65	205.85
	Effective major principal stress, s'1 (psi)	25.61	71.39	127.20
	Effective minor principal stress, s'3 (psi)	6.93	18.10	35.51
	Total major pincipal stress, s1 (psi)	42.68	113.29	251.69
	Total minor pincipal stress, s3 (psi)	24.00	60.00	160.00
	Skemption A at failure, Af	0.91	0.79	1.36
	Secant friction angle, phi-s (deg)	35.0	36.5	34.3
		Effective stress	Total stress	
	Friction angle, phi (deg)	34.0	11.7	
	Cohesion intercept, c (psi)	0.9	5.3	
Peak deviator stress (s1-s3), failure criteria	Strain at failure, ef (%)	15.08	15.13	15.17
	Time to failure, tf (min)	754.2	378.3	758.7
	Deviator stress, s1-s3 (psi)	22.05	53.64	94.21
	Excess pore pressure, u (psi)	15.36	41.69	123.23
	q = q' = (s1+s3)/2 (psi)	11.02	26.82	47.10
	p' = (s'1+s'3)/2 (psi)	19.66	45.13	83.87
	p = (s1+s3)/2 (psi)	35.02	86.82	207.10
	Effective major principal stress, s'1 (psi)	30.69	71.95	130.98
	Effective minor principal stress, s'3 (psi)	8.64	18.31	36.77
	Total major pincipal stress, s1 (psi)	46.05	113.64	254.21
	Total minor pincipal stress, s3 (psi)	24.00	60.00	160.00
	Skemption A at failure, Af	0.70	0.78	1.31
	Secant friction angle, phi-s (deg)	34.1	36.5	34.2
		Effective stress	Total stress	
	Friction angle, phi (deg)	34.0	11.7	
	Cohesion intercept, c (psi)	0.8	6.2	

Comments:

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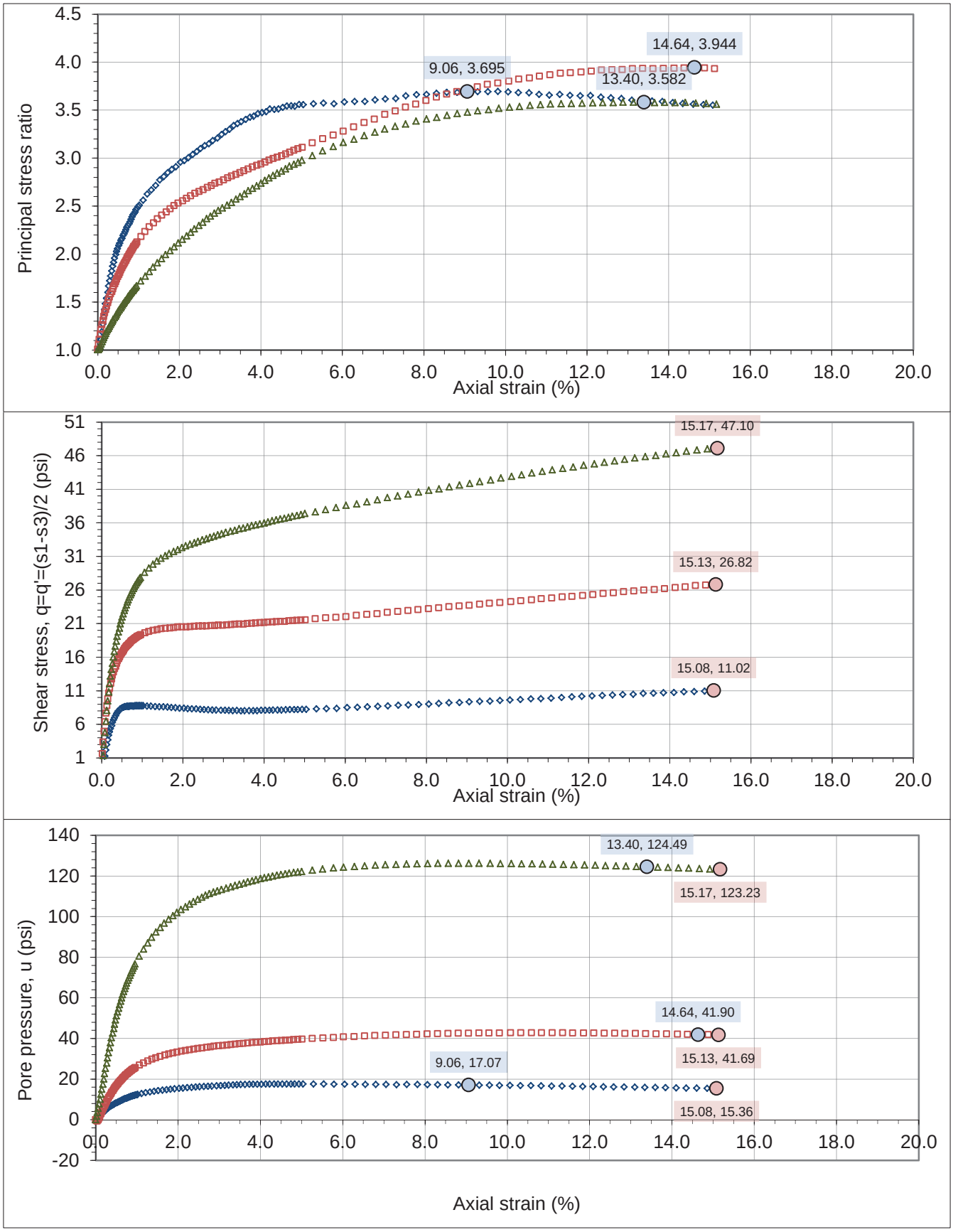
Triaxial Test - Isotropic Consolidated Sheared Undrained
Measuring Pore Pressure (CIU-PP) *- After ASTM D4767 and USBR 5750*

GERHART COLE

Project: Whites Valley/Bear River Project **TH/TP/Sample: 14-TH-WV-04**
No: 13GCI329 **Depth: 15-30**



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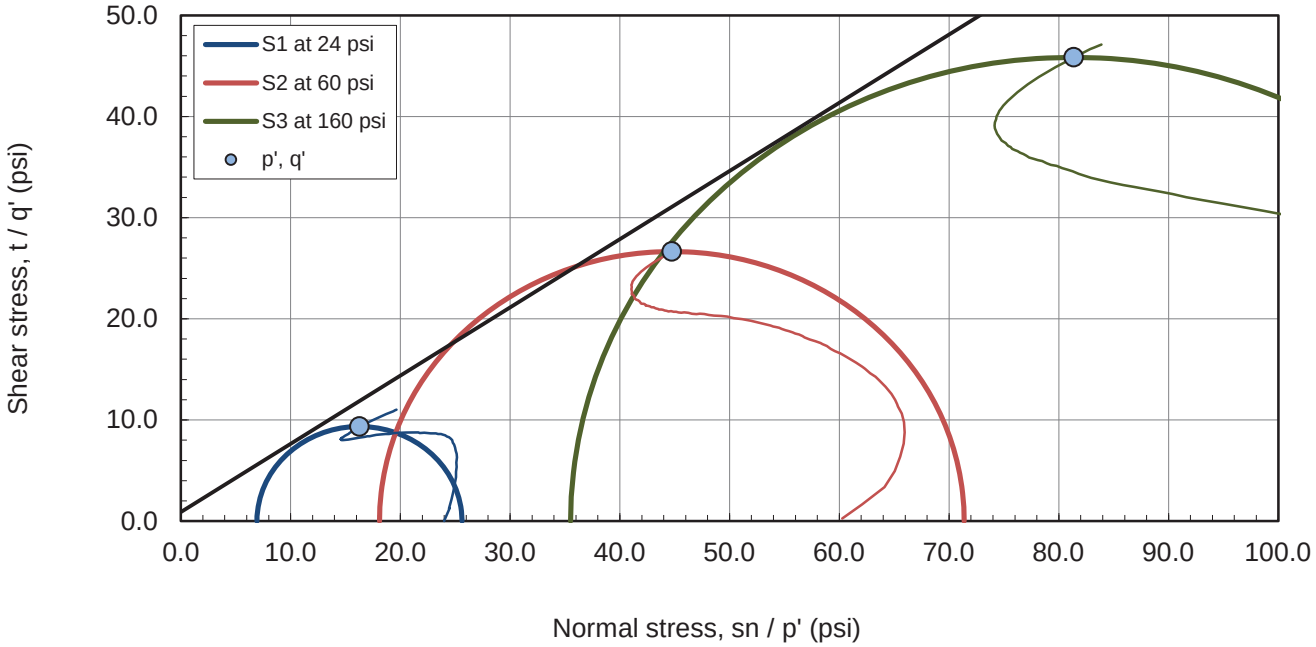
Triaxial Test - Isotropic Consolidated Sheared Undrained
Measuring Pore Pressure (CIU-PP) *- After ASTM D4767 and USBR 5750*

GERHART COLE

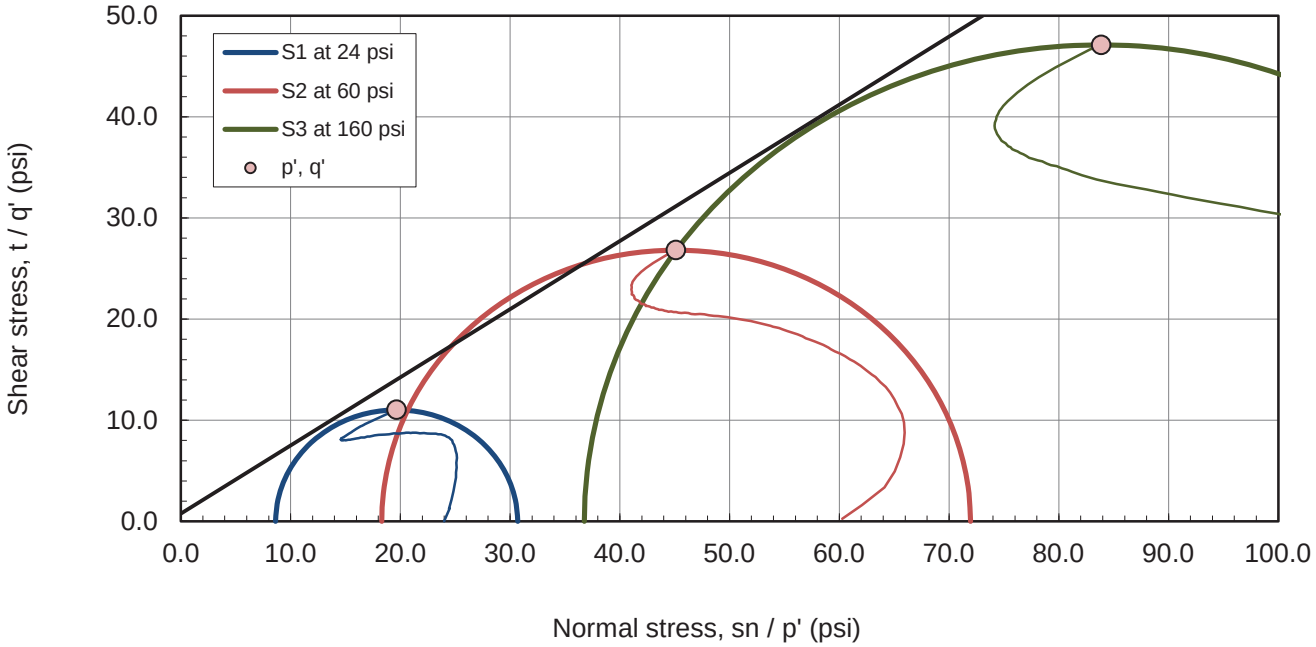
Project: Whites Valley/Bear River Project **TH/TP/Sample: 14-TH-WV-04**
No: 13GCI329 **Depth: 15-30**

Effective stress results



Max principal stress ratio (s'1/s'3), failure criteria Mohr and p' - q' space plots

Effective stress results



Peak deviator stress (s1-s3), failure criteria Mohr and p' - q' space plots

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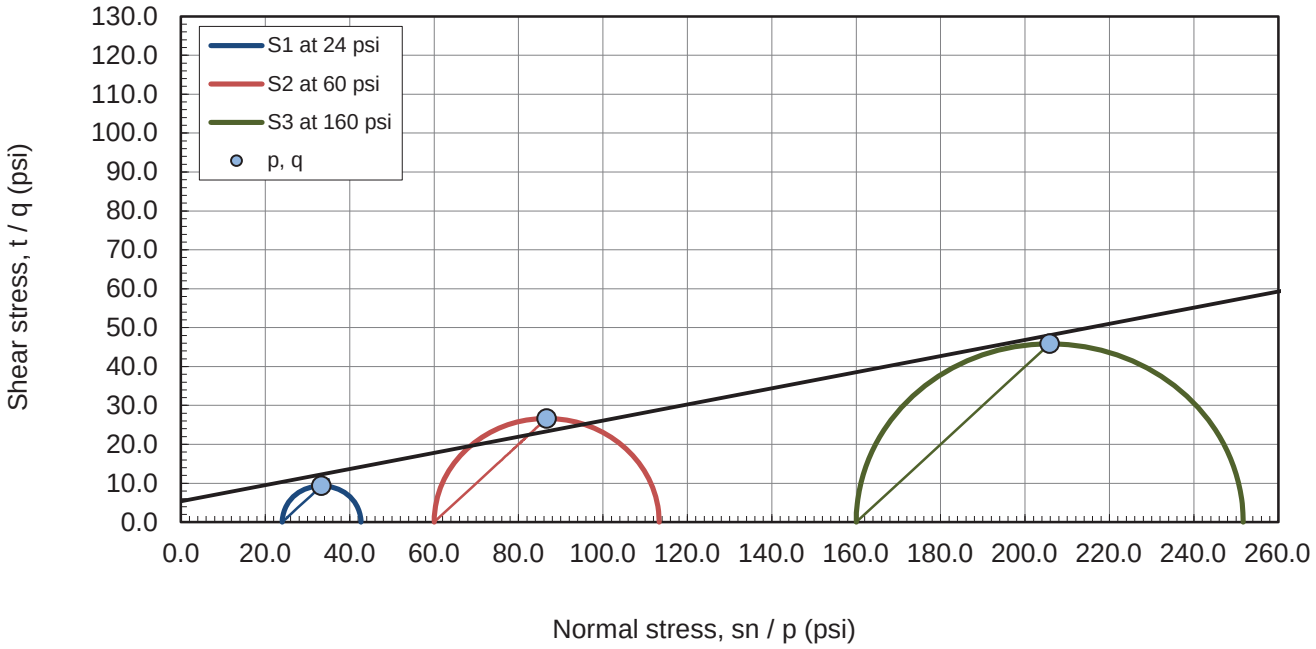
Triaxial Test - Isotropic Consolidated Sheared Undrained
Measuring Pore Pressure (CIU-PP) *- After ASTM D4767 and USBR 5750*

GERHART COLE

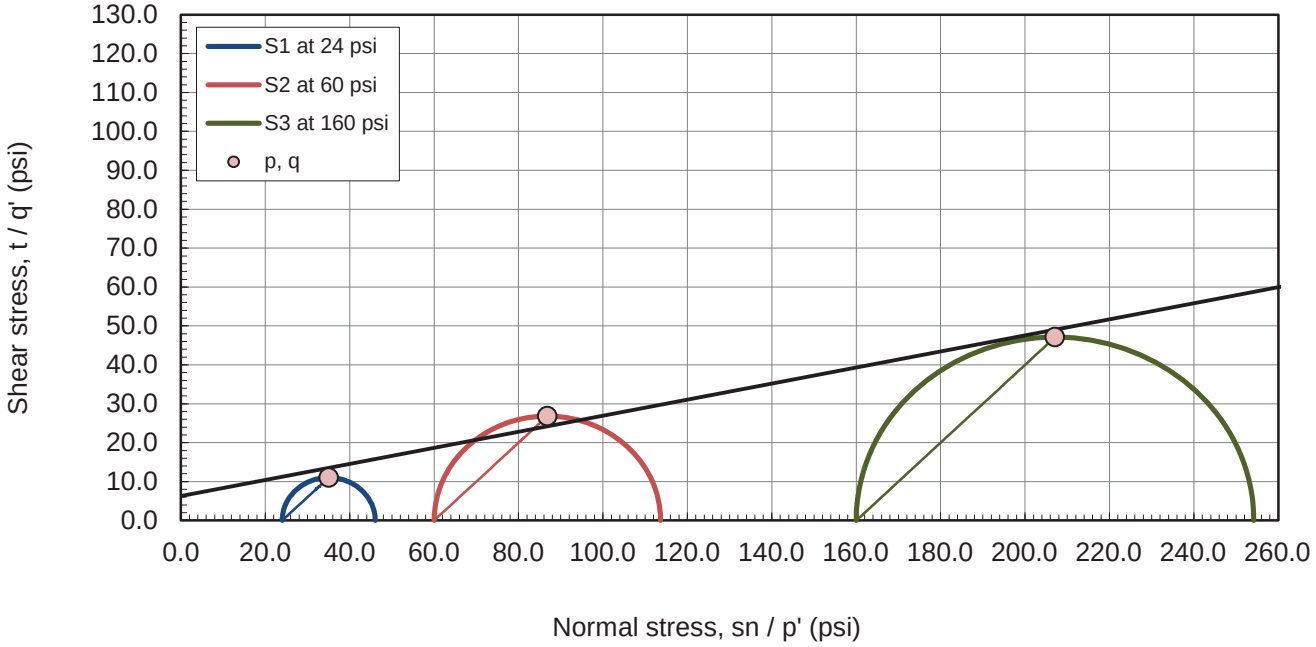
Project: Whites Valley/Bear River Project **TH/TP/Sample: 14-TH-WV-04**
No: 13GCI329 **Depth: 15-30**

Total stress results



Max principal stress ratio (s1/s3), failure criteria Mohr and p - q space plots - effective stress results

Total stress results



Peak deviator stress (s1-s3), failure criteria Mohr and p - q space plots

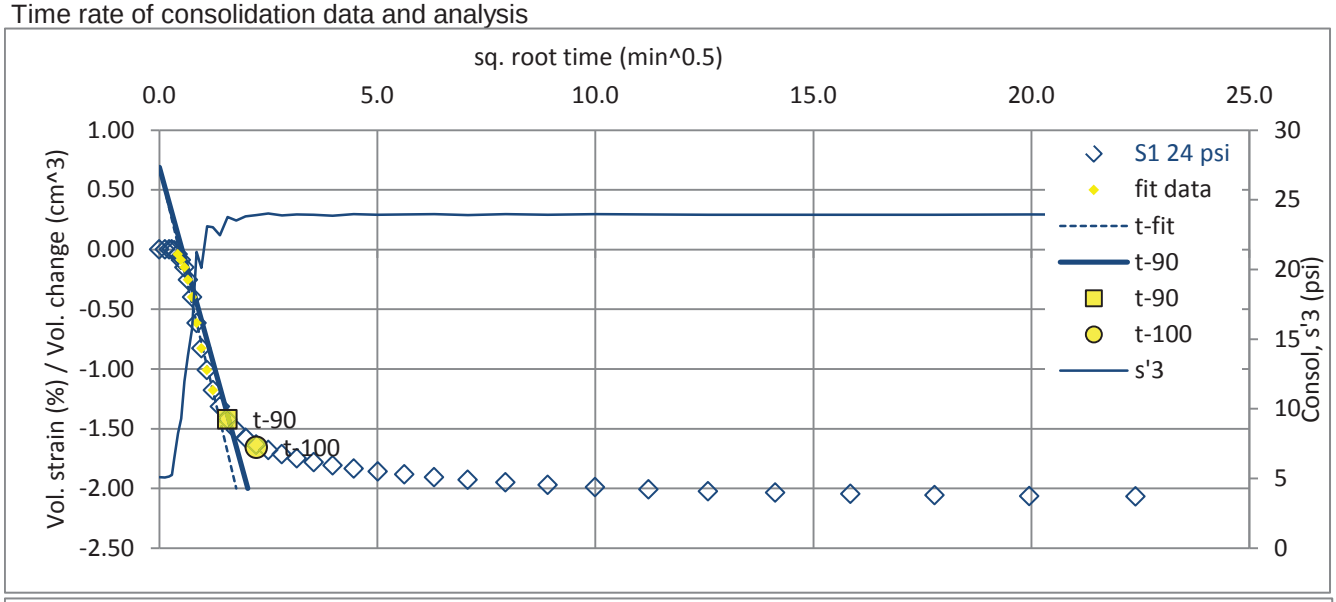
DRAFT

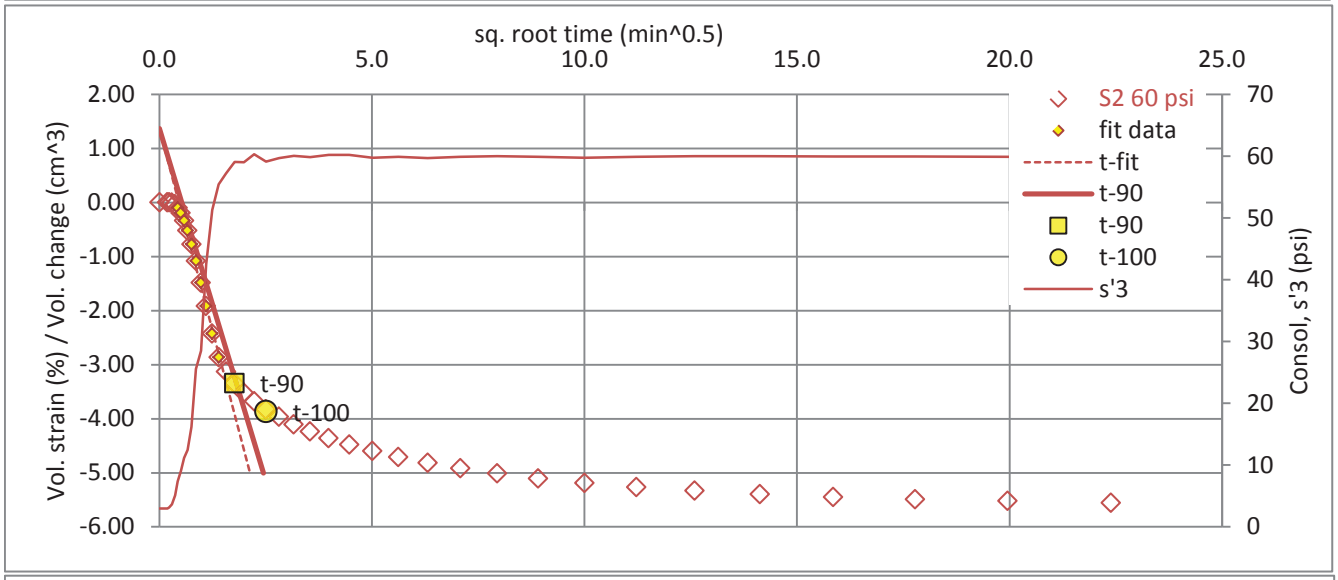
Triaxial Test - Isotropic Consolidated Sheared Undrained
Measuring Pore Pressure (CIU-PP) *- After ASTM D4767 and USBR 5750*

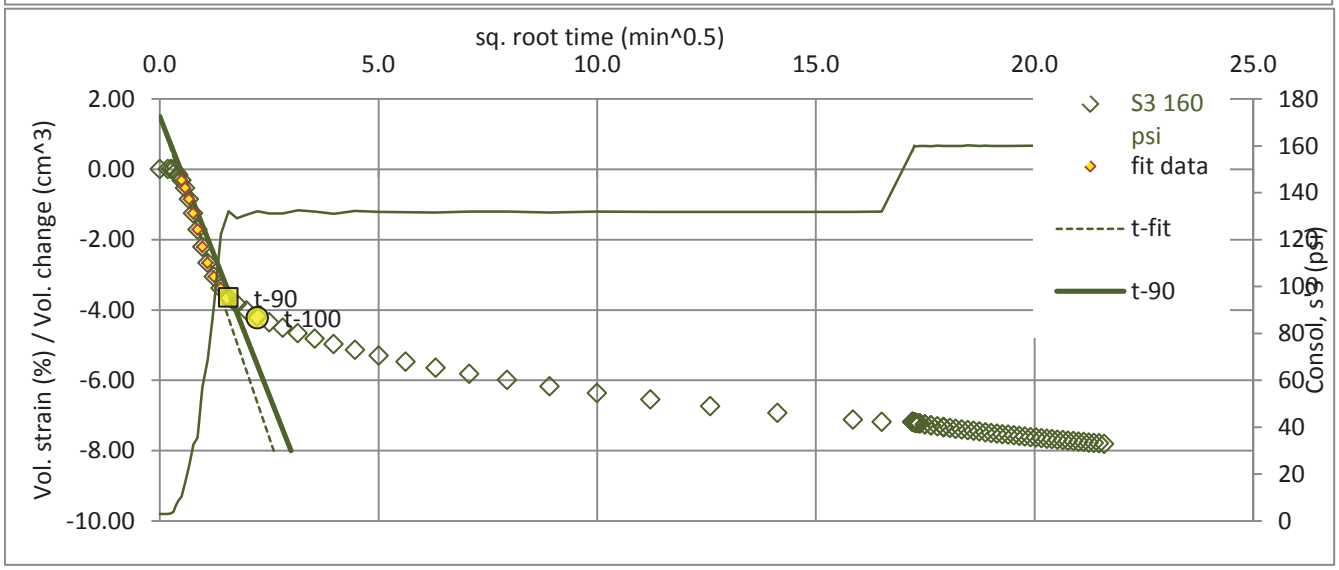
GERHART COLE

Project: Whites Valley/Bear River Project **TH/TP/Sample: 14-TH-WV-04**
No: 13GCI329 **Depth: 15-30**

Time rate of consolidation data and analysis







DRAFT

Hydraulic Conductivity Test - Back Pressure, Flexible Wall

after ASTM D5084 Method C

GERHART COLE

Project: Whites Valley/Bear River
No: 13GCI329
Location: Whites Valley
Date: 7-Jan-15
Tested by: zmg
Reduced by: zmg
Reviewed by: dab

TH/TP/Sample: 14-TH-WV-04
Depth: 0-15
Sample descrition: brown clay
USCS classification: not requested
Sample type: Laboratory Compacted
Comments:

	Initial (o)	Final (f)
Sample Height, H (in)	3.072	3.002
Sample Diameter, D (in)	2.804	2.855
Sample Length, L (cm)	7.803	7.625
Sample Area, A (cm^2)	39.839	41.293
Sample Volume, V (cm^3)	310.86	314.86
Wt. Rings + Wet Soil (g)	581.41	587.12
Wt. Rings (g)	0.00	0.00
Wet Soil + Tare (g)	258.51	732.04
Dry Soil + Tare (g)	235.33	624.20
Tare (g)	126.63	144.96
Weight of solids, Ws (g)	479.22	479.22
Moisture Content, w (%)	21.32	22.50
Wet Unit Wt., g_m (pcf)	116.8	116.4
Dry Unit Wt, g_d (pcf)	96.2	95.0
Volume solids (cm^3)	180.84	180.84
Volume of voids (cm^3)	130.03	134.03
Void ratio, e	0.72	0.60
Porosity, n	0.42	0.37
Volumetric moisture, T	0.33	0.37
Saturation, S (%)	78.6	100.0
Phase Relaionships for Assumed Gs =		2.65

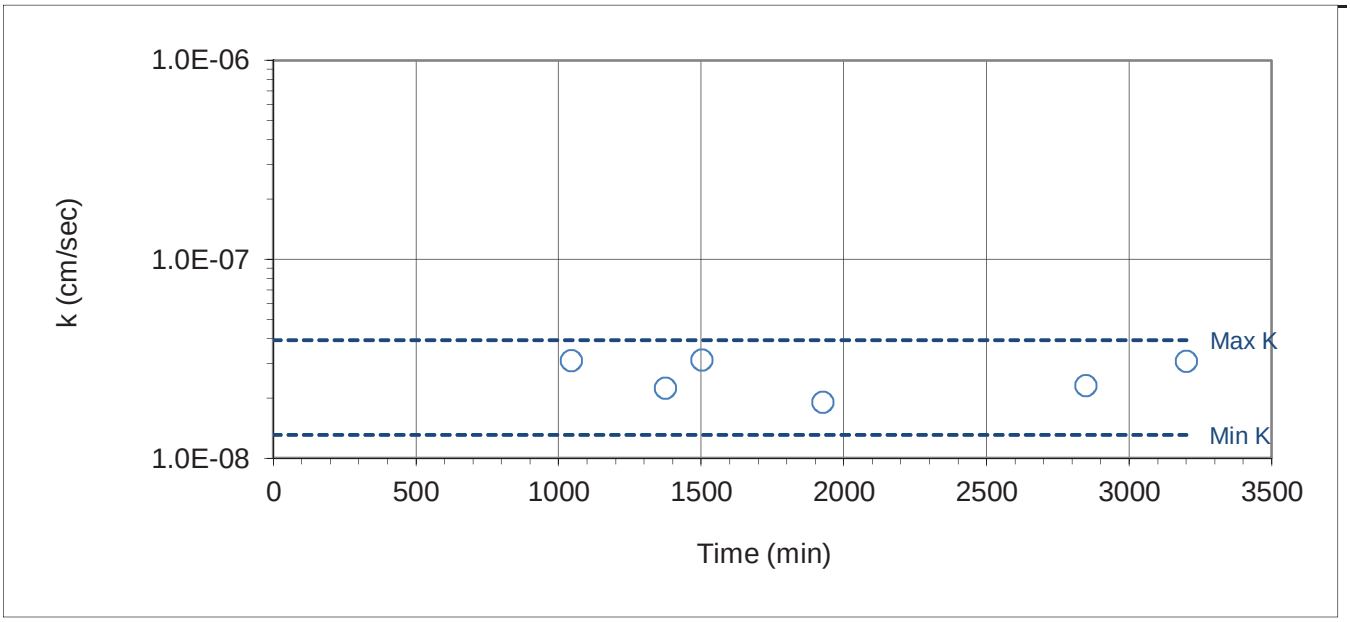
[a] Saturation set to 100% for phase calculations

	(%) w
Optimum moisture content (%)	21.3
Maximum dry unit weight (pcf)	100.7

Cell No. / Base No. / Top No.	A1	A2	A3
pw (gm/cm^3)		1.00	Assumed
Permeant liquid used		deaired	
Total backpressure (psi)		50	
Effective horiz. con. stress (psi)		60	
Effective vert. con. stress (psi)		60	
		Initial (o)	Final (f)
B value		0.28	0.98
External Burette (cm^3)		5.00	11.00
Cell Pressure (psi)		5.0	55.0
System volume coefficient (cm^3/psi)		0.20	
System volume change (cm^3)		10.00	
Net sample volume change (cm^3)		4.00	
Base burette ground length, l_b (cm)		69.5	
Top burette ground length, l_t (cm)		69.9	
Pipet area, api / apo (cm^2)		0.865	0.865
Annulus area, aai / aao (cm^2)		3.105	4.176
Conversion, reading to cm head (cm/rd)		1.156	

K average last 6 values = 2.6E-08

K corrected to 20ºC



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DRAFT

Project: **Whites Valley/Bear River** **TH/TP/Sample:** **14-TH-WV-04**

No: **13GCI329** **Depth:** **0-15**

Location: Whites Valley Sample descrition: brown clay

Permeability Data

time (min)	time (sec)	Burrett reading Base	Top	hp (psi)	$h_{(i/f)}$ (cm)	i	K (cm/sec)	Avg. Temp (ºC)	Visc. Ratio Rt	Pore Vol	K^b (cm/sec)
	[pipet]	0.00	25.00	0.0	28.5	3.7					
1375.0	82500	0.30	24.70	0.0	27.8	3.6	2.4E-08	22.5	0.94	0.00	2.2E-08
552.0	33120	0.40	24.60	0.0	27.6	3.6	2.0E-08	22.5	0.94	0.00	1.9E-08
922.0	55320	0.60	24.40	0.0	27.1	3.6	2.4E-08	22.5	0.94	0.00	2.3E-08
352.0	21120	0.70	24.30	0.0	26.9	3.5	3.2E-08	22.5	0.94	0.01	3.1E-08
	[pipet]	0.00	25.00	0.5	63.7	8.3					
1047.0	62820	0.70	24.30	0.5	62.0	8.1	3.3E-08	22.5	0.94	0.01	3.1E-08
456.0	27360	1.00	24.00	0.5	61.3	8.0	3.3E-08	22.5	0.94	0.01	3.1E-08

K average last 6 values = 2.6E-08

K corrected to 20ºC

DRAFT

One-Dimensional Collapse / Swell Properties of Soils

After ASTM D4647 and USBR 5410

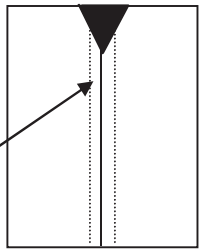
GERHART COLE

Project: **Whites Valley**
No: **13GCI329**
Location: Whites Valley
Date: 09-Jan-15
Tested by: zmg
Reduced by: zmg
Checked by: dab

TH/TP/Sample: **14-TH-WV-04**
Depth: **0-15**
Sample description: brown clay
Visual description: brown clay
USCS classification: Not requested

Test type / method: A
Sample type: remolded
Moisture content (%): 20.6
Dry unit weight (pcf): 96.2

Compaction specifications: 95% of max
Target moisture content (%): 21
Target dry unit weight (pcf): 96
Specimen After Test
Final Hole (mm): 1.0



Dispersive Classification: **ND1 - Nondisperisve**

Clock Time	Head (in)	Flow			Turbidity From Side						Completely Clear From Top	Particles Falling			Remarks
		ml	sec	Rate (ml/sec)	Very Dark	Dark	Moderately Dark	Slightly Dark	Barely Visible	Completely Clear		None	Few	Heavy	
15:08	2	11.0	60	0.2						X	X	X			
	2	15.0	60	0.3						X	X	X			
	2	14.0	60	0.2						X	X	X			
	2	14.0	60	0.2						X	X	X			
	2	15.0	60	0.3						X	X	X			
15:16	7	35.0	60	0.6						X	X	X			
	7	35.0	60	0.6						X	X	X			
	7	35.0	60	0.6						X	X	X			
15:22	15	59.0	60	1.0						X	X	X			
	15	60.0	60	1.0						X	X	X			
	15	60.0	60	1.0						X	X	X			
	15	60.0	60	1.0						X	X	X			
15:30	40	100.0	60	1.7						X	X	X			
	40	90.0	50	1.8						X	X	X			
	40	90.0	50	1.8						X	X	X			
	40	90.0	50	1.8						X	X	X			

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One-Dimensional Collapse / Swell Properties of Soils

After ASTM D4647 and USBR 5410

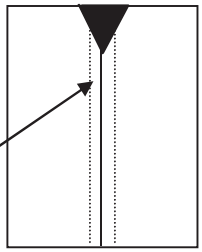
GERHART COLE

Project: **Whites Valley**
No: **13GCI329**
Location: Whites Valley
Date: 12-Jan-15
Tested by: zmg
Reduced by: zmg
Checked by: dab

TH/TP/Sample: **14-TH-WV-04**
Depth: **15-30**
Sample description: brown clay
Visual description: brown clay
USCS classification: Not requested

Test type / method: A
Sample type: remolded
Moisture content (%): 17.9
Dry unit weight (pcf): 104.6

Compaction specifications: 95% of max
Target moisture content (%): 18
Target dry unit weight (pcf): 105
Specimen After Test
Final Hole (mm): 1.0



Dispersive Classification: **ND1 - Nondisperisve**

Clock Time	Head (in)	Flow			Turbidity From Side						Completely Clear From Top	Particles Falling			Remarks
		ml	sec	Rate (ml/sec)	Very Dark	Dark	Moderately Dark	Slightly Dark	Barely Visible	Completely Clear		None	Few	Heavy	
11:09	2	11.0	60	0.2						X	X	X			
	2	14.0	60	0.2						X	X	X			
	2	13.0	60	0.2						X	X	X			
	2	13.0	60	0.2						X	X	X			
	2	12.0	60	0.2						X	X	X			
11:18	7	34.0	60	0.6						X	X	X			
	7	34.0	60	0.6						X	X	X			
	7	34.0	60	0.6						X	X	X			
	7	34.0	60	0.6						X	X	X			
11:26	15	59.0	60	1.0						X	X	X			
	15	58.0	60	1.0						X	X	X			
	15	58.0	60	1.0						X	X	X			
	15	58.0	60	1.0						X	X	X			
11:35	40	95.0	50	1.9						X	X	X			
	40	96.0	50	1.9						X	X	X			
	40	95.0	50	1.9						X	X	X			
	40	96.0	50	1.9						X	X	X			

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One-Dimensional Collapse / Swell Properties of Soils

After ASTM D4647 and USBR 5410

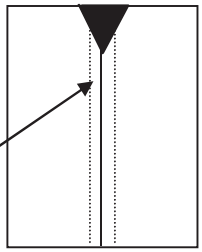
GERHART COLE

Project: **Whites Valley**
No: **13GCI329**
Location: Whites Valley
Date: 12-Jan-15
Tested by: zmg
Reduced by: zmg
Checked by: dab

TH/TP/Sample: **14-TH-WV-04**
Depth: **30-45**
Sample description: brown clay
Visual description: brown clay
USCS classification: Not requested

Test type / method: A
Sample type: remolded
Moisture content (%): 16.8
Dry unit weight (pcf): 104.8

Compaction specifications: 95% of max
Target moisture content (%): 19
Target dry unit weight (pcf): 103
Specimen After Test
Final Hole (mm): 1.0



Dispersive Classification: **ND1 - Nondisperisve**

Clock Time	Head (in)	Flow			Turbidity From Side						Completely Clear From Top	Particles Falling			Remarks
		ml	sec	Rate (ml/sec)	Very Dark	Dark	Moderately Dark	Slightly Dark	Barely Visible	Completely Clear		None	Few	Heavy	
15:28	2	17.0	60	0.3						X	X	X			
	2	15.0	60	0.3						X	X	X			
	2	15.0	60	0.3						X	X	X			
	2	16.0	60	0.3						X	X	X			
	2	15.0	60	0.3						X	X	X			
15:36	7	38.0	60	0.6						X	X	X			
	7	39.0	60	0.7						X	X	X			
	7	38.0	60	0.6						X	X	X			
	7	39.0	60	0.7						X	X	X			
	7	38.0	60	0.6						X	X	X			
15:45	15	64.0	60	1.1						X	X	X			
	15	65.0	60	1.1						X	X	X			
	15	64.0	60	1.1						X	X	X			
	15	64.0	60	1.1						X	X	X			
15:55	40	100.0	50	2.0						X	X	X			
	40	91.0	45	2.0						X	X	X			
	40	90.0	45	2.0						X	X	X			
	40	90.0	45	2.0						X	X	X			
	40	90.0	45	2.0						X	X	X			

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Laboratory Compaction Characteristics of Soil

(ASTM D698 / D1557)

GERHART COLE

Project: Whites Valley/Bear River Project
No: 13GCI329
Date: 31-Dec-14
Tested by: zmg
Reduced by: zmg
Reviewed by: dab

Comments:

TH/TP/Sample: 14-TH-WV-04
Depth: 0-15
Location: Whites Valley

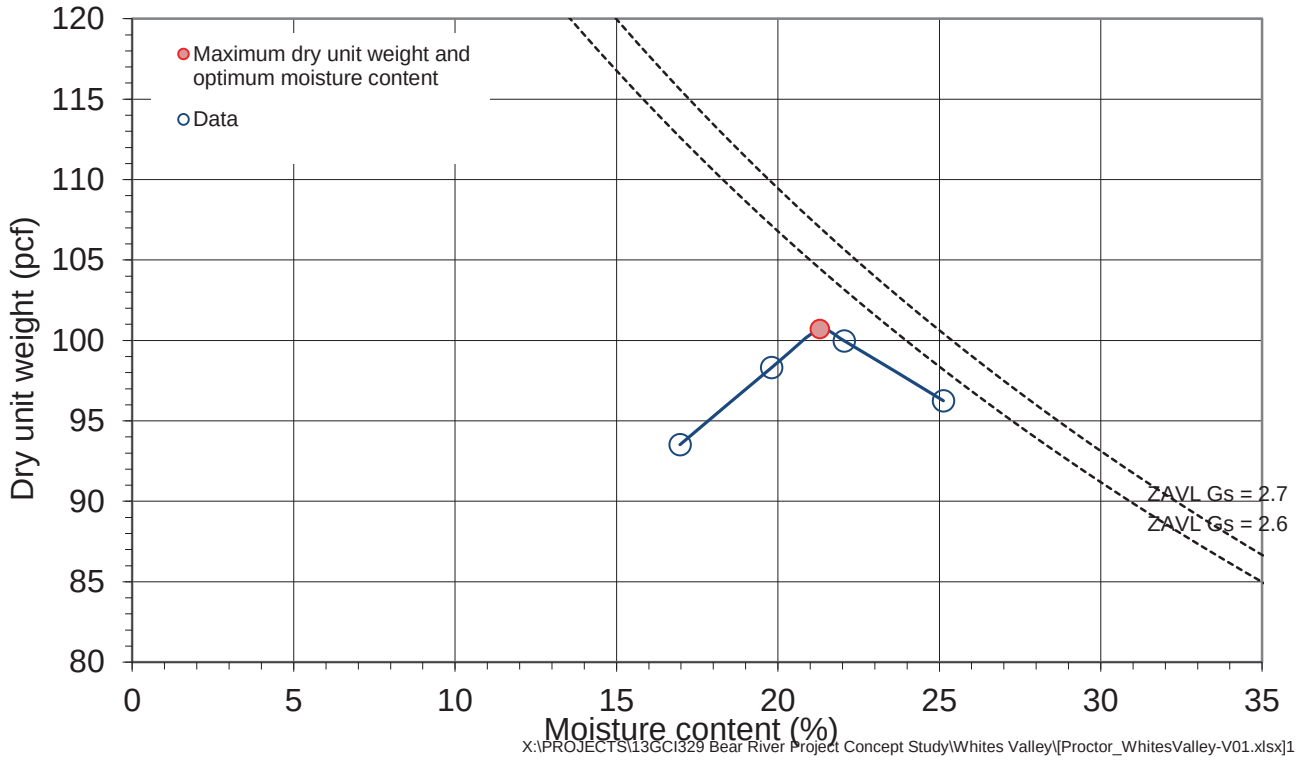
Test Summary

Method: ASTM D698 B
Mold volume (ft^3): 0.0333

Optimum moisture content (%): 21.3
Maximum dry unit weight (pcf): 100.7

Sample Description: brown clay
Engineering Classification: Not requested
As-received moisture content (%): Not requested
Preparation method: Moist
Rammer: Manual
Rock Correction: No

Point Number	as-is	+3	+6	+9
Wt. mold + wet soil (g)	5906.0	6033.0	6097.0	6073.0
Wt. mold (g)	4252	4252	4252	4252
Moist unit wt., gd (pcf)	109.4	117.8	122.0	120.4
Wet soil + tare (g)	271.75	311.5	295.25	265.15
Dry soil + tare (g)	253.02	283.97	268.17	240.88
Tare (g)	142.63	144.98	145.41	144.28
Moisture content, w (%)	17.0	19.8	22.1	25.1
Dry unit wt., gd (pcf)	93.5	98.3	100.0	96.3



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Laboratory Compaction Characteristics of Soil

(ASTM D698 / D1557)

GERHART COLE

Project: Whites Valley/Bear River Project
No: 13GCI329
Date: 31-Dec-14
Tested by: zmg
Reduced by: zmg
Reviewed by: dab

Comments:

TH/TP/Sample: 14-TH-WV-04
Depth: 15-30
Location: Whites Valley

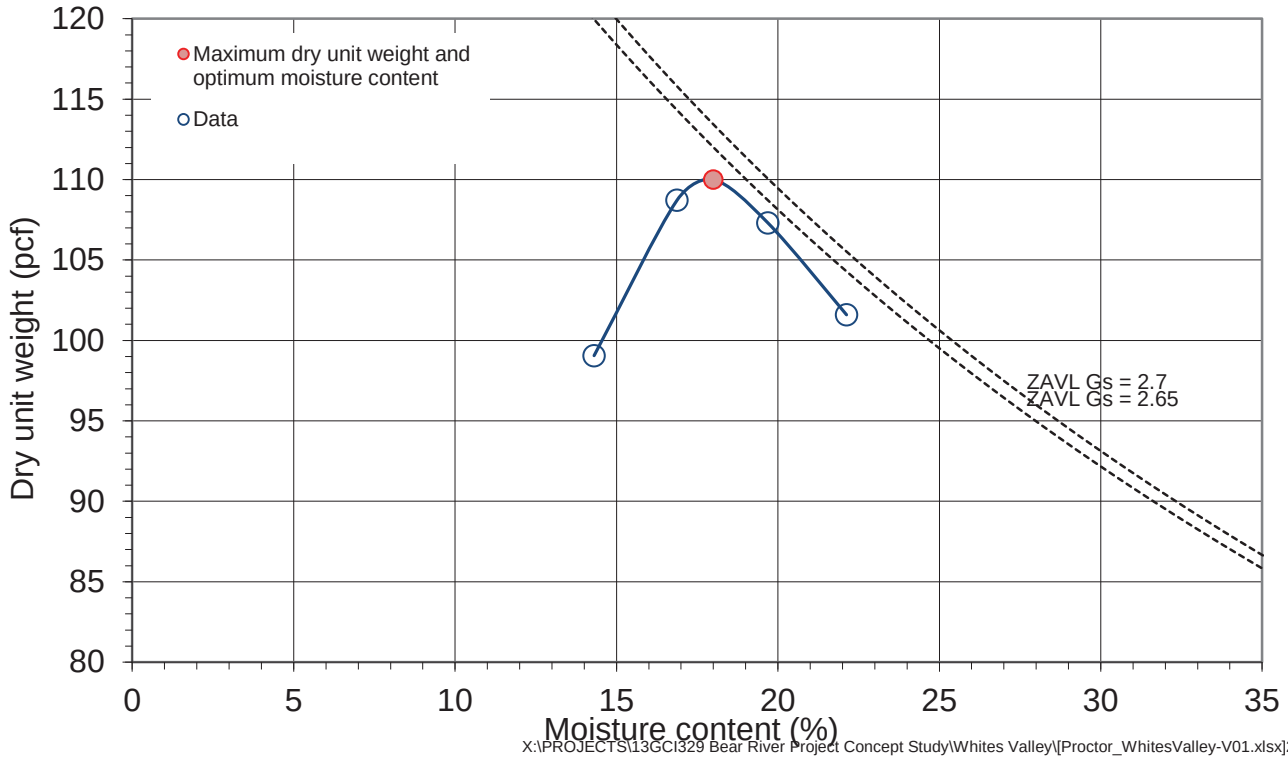
Test Summary

Method: ASTM D698 B
Mold volume (ft^3): 0.0333

Optimum moisture content (%): 18
Maximum dry unit weight (pcf): 110

Sample Description: brown clay
Engineering Classification: Not requested
As-received moisture content (%): Not requested
Preparation method: Moist
Rammer: Manual
Rock Correction: No

Point Number	start	+3	+6	-3
Wt. mold + wet soil (g)	6173.0	6194.0	6128.0	5964.0
Wt. mold (g)	4252	4252	4252	4252
Moist unit wt., gd (pcf)	127.1	128.4	124.1	113.2
Wet soil + tare (g)	287.06	337.89	311.77	313.41
Dry soil + tare (g)	263.9	310.75	278.32	295.84
Tare (g)	126.63	172.89	127.13	173.02
Moisture content, w (%)	16.9	19.7	22.1	14.3
Dry unit wt., gd (pcf)	108.7	107.3	101.6	99.1



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Laboratory Compaction Characteristics of Soil

(ASTM D698 / D1557)

GERHART COLE

Project: Whites Valley/Bear River Project
No: 13GCI329
Date: 31-Dec-14
Tested by: zmg
Reduced by: zmg
Reviewed by: dab

Comments:

TH/TP/Sample: 14-TH-WV-04
Depth: 30-45
Location: Whites Valley

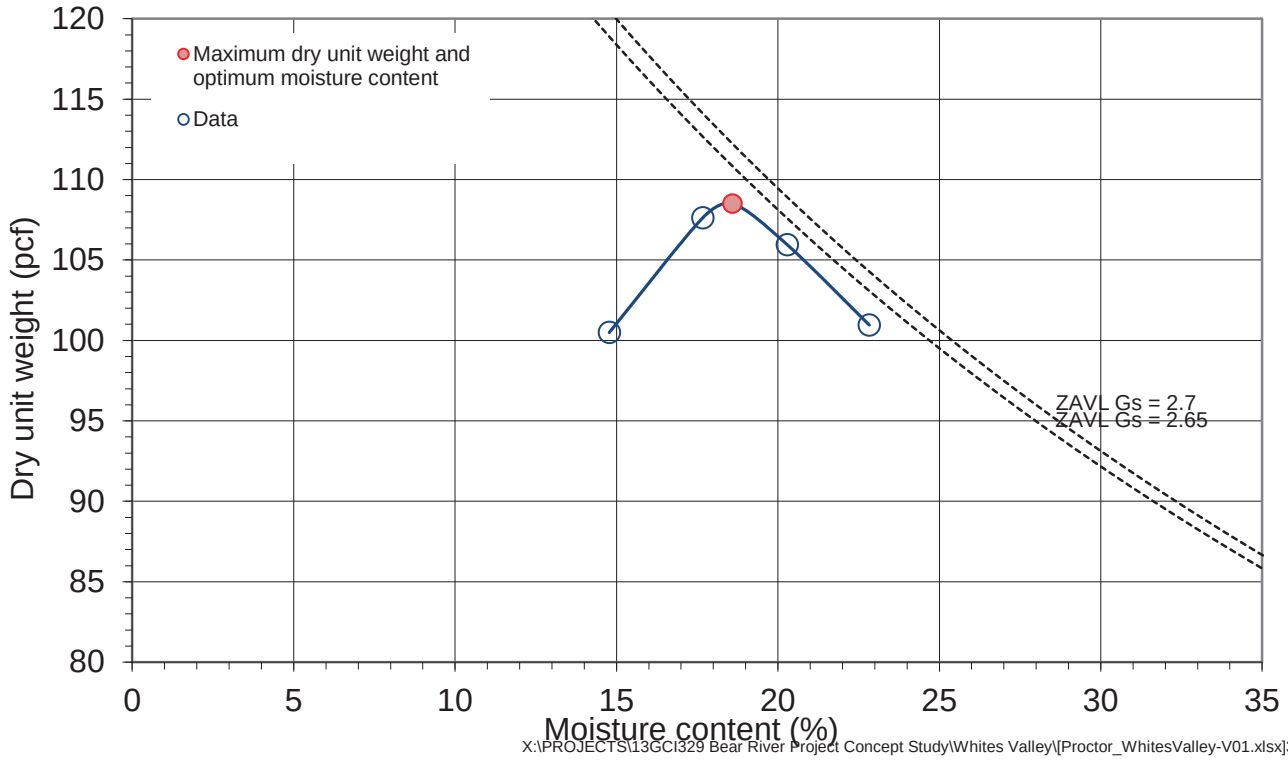
Test Summary

Method: ASTM D698 B
Mold volume (ft^3): 0.0333

Optimum moisture content (%): 18.6
Maximum dry unit weight (pcf): 108.5

Sample Description: brown clay
Engineering Classification: Not requested
As-received moisture content (%): Not requested
Preparation method: Moist
Rammer: Manual
Rock Correction: No

Point Number	start	-3	+3	+6
Wt. mold + wet soil (g)	6167.0	5996.0	6179.0	6127.0
Wt. mold (g)	4252	4252	4252	4252
Moist unit wt., gd (pcf)	126.7	115.3	127.4	124.0
Wet soil + tare (g)	371.85	330.45	402.41	373.11
Dry soil + tare (g)	335.1	303.33	358.6	330.69
Tare (g)	127.17	119.79	142.67	144.88
Moisture content, w (%)	17.7	14.8	20.3	22.8
Dry unit wt., gd (pcf)	107.6	100.5	106.0	101.0



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Determination of the Point Load Strength Index of Rock

After ASTM D 5731

GERHART COLE

Project: Bear River Project Concept Study - Whites Valley

No: 13GCI329

Location: Box Elder County

Date: 21-Sep-15

Tested By: zmg Reduced by: zmg Reviewed by: rrb

Sample Info.	Test Hole/Pit:	15-TH-WV-01	15-TH-WV-01	15-TH-WV-01	15-TH-WV-01
	Sample:				
	Depth:	67-67.7	78-78.5	93-93.3	104.104.2
	Date Sampled:	8/15/15-8/24/15	8/15/15-8/24/15	8/15/15-8/24/15	8/15/15-8/24/15
	Sample type	Core	Core	Core	Core
	Moisture condition:	Laboratory air dry	Laboratory air dry	Laboratory air dry	Laboratory air dry
Test Data	Distance between platen points, D (in.):	2.4	2.4	2.4	2.4
	D (mm):	60.0	60.0	60.0	60.0
	Smallest specimen width, W (in.):	3.5	2.5	2.0	1.5
	W (mm):	88.9	63.5	50.8	38.1
	Equivalent core area, D_e^2 (mm^2):	3600.0	3600.0	3600.0	3600.0
	Failure Pressure P_f, (psi):	2904	4015	3258	4833
	Effective area of jack piston A_e, (cm^2):	9.48	9.48	9.48	9.48
	Effective area of jack piston A_e, (in^2):	1.47	1.47	1.47	1.47
	Failure load, P (lbf):	4267	5900	4787	7102
	P (N):	18981	26243	21295	31590
Test Results	Point load strength index, I_s (MPa):	5.27	7.29	5.92	8.77
	Size correction factor, F:	1.086	1.086	1.086	1.086
	PLSI 50mm equivalent, $I_{s(50)}$ (MPa):	5.72	7.91	6.42	9.53
	Correlation factor, C:	24.5	24.5	24.5	24.5
	Uniaxial compressive strength, d_{uc} (MPa):	140.22	193.87	157.32	233.37
	Uniaxial compressive strength, d_{uc} (psi):	20338	28118	22817	33847
	Break type:	Perpendicular	Perpendicular	Perpendicular	Perpendicular
	Photo before break:				
	Photo after break:				

Notes:

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Determination of the Point Load Strength Index of Rock

After ASTM D 5731

GERHART COLE

Project: Bear River Project Concept Study - Whites Valley

No: 13GCI329

Location: Box Elder County

Date: 21-Sep-15

Tested By: zmg Reduced by: zmg Reviewed by: rrb

Sample Info.	Test Hole/Pit:	14-TH-WV-02	14-TH-WV-02	14-TH-WV-02	
	Sample:				
	Depth:	58-58.6	88-88.4	97.2-97.5	
	Date Sampled:	11/5/14-11/21/14	11/5/14-11/21/14	11/5/14-11/21/14	
	Sample type	Core	Core	Core	
	Moisture condition:	Laboratory air dry	Laboratory air dry	Laboratory air dry	
Test Data	Distance between platen points, D (in.):	2.4	2.4	2.4	
	D (mm):	60.0	60.0	60.0	
	Smallest specimen width, W (in.):	2.5	2.0	1.5	
	W (mm):	63.5	50.8	38.1	
	Equivalent core area, D_e^2 (mm^2):	3600.0	3600.0	3600.0	
	Failure Pressure P_f, (psi):	2086	2280	2213	
	Effective area of jack piston A_e, (cm^2):	9.48	9.48	9.48	
	Effective area of jack piston A_e, (in^2):	1.47	1.47	1.47	
	Failure load, P (lbf):	3065	3350	3252	
	P (N):	13635	14903	14465	
Test Results	Point load strength index, I_s (MPa):	3.79	4.14	4.02	
	Size correction factor, F:	1.086	1.086	1.086	
	PLSI 50mm equivalent, $I_{s(50)}$ (MPa):	4.11	4.49	4.36	
	Correlation factor, C:	24.5	24.5	24.5	
	Uniaxial compressive strength, d_{uc} (MPa):	100.72	110.09	106.86	
	Uniaxial compressive strength, d_{uc} (psi):	14609	15968	15498	
	Break type:	Parallel to planes of weakness	Perpendicular	Perpendicular	
	Photo before break:				
	Photo after break:				

Notes:

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Determination of the Point Load Strength Index of Rock

After ASTM D 5731

GERHART COLE

Project: Bear River Project Concept Study - Whites Valley

No: 13GCI329

Location: Box Elder County

Date: 21-Sep-15

Tested By: zmg Reduced by: zmg Reviewed by: rrb

Sample Info.	Test Hole/Pit:	15-TH-WV-03	15-TH-WV-03		
	Sample:				
	Depth:	59-59.5	88-88.4		
	Date Sampled:	6/8/15-6/19/15	6/8/15-6/19/15		
	Sample type	Core	Core		
	Moisture condition:	Laboratory air dry	Laboratory air dry		
Test Data	Distance between platen points, D (in.):	2.4	1.8		
	D (mm):	60.0	45.0		
	Smallest specimen width, W (in.):	1.5	2.0		
	W (mm):	38.1	50.8		
	Equivalent core area, D_e^2 (mm^2):	3600.0	2025.0		
	Failure Pressure P_f, (psi):	2817	1970		
	Effective area of jack piston A_e, (cm^2):	9.48	9.48		
	Effective area of jack piston A_e, (in^2):	1.47	1.47		
	Failure load, P (lbf):	4139	2895		
	P (N):	18413	12876		
Test Results	Point load strength index, I_s (MPa):	5.11	6.36		
	Size correction factor, F:	1.086	0.954		
	PLSI 50mm equivalent, $I_{s(50)}$ (MPa):	5.55	6.06		
	Correlation factor, C:	24.5	22.0		
	Uniaxial compressive strength, d_{uc} (MPa):	136.02	133.41		
	Uniaxial compressive strength, d_{uc} (psi):	19728	19350		
	Break type:	Perpendicular	Parallel to planes of weakness		
	Photo before break:				
	Photo after break:				

Notes:

Appendix F

Whites Valley – Discontinuity Data

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Discontinuity Data
Left Abutment - Near 15-TH-WV-01

ID	Azimuth	Dip	Latitude	Longitude
1	260.8	87.8	41.846146	-112.317582
2	193.4	71.4	41.846114	-112.317647
3	275.9	80.3	41.845623	-112.316998
4	184.1	89.4	41.84622	-112.317697
5	261.8	82.7	41.845782	-112.317387
6	252.5	85.2	41.846091	-112.317472
7	180.8	86.3	41.846157	-112.317609
8	265.4	81.9	41.84593	-112.317351
9	254.5	83.2	41.846224	-112.317607
10	184	83.7	41.846201	-112.31744
11	283	84.2	41.845466	-112.316937
12	120.3	11.3	41.846187	-112.317588
13	182.7	73	41.846196	-112.317599
14	259.9	83	41.846094	-112.317578
15	173.2	76.3	41.846179	-112.317581
16	184.8	72.4	41.846189	-112.31757
17	259.1	81.8	41.846149	-112.317419
18	113.1	19.1	41.84624	-112.317553
19	359.1	86.3	41.84625	-112.317658
20	260	79	41.846188	-112.317554
21	164.2	85.6	41.846147	-112.317371
22	265.4	75.7	41.846277	-112.317497
23	167.6	82.2	41.846302	-112.317603
24	268.3	74.4	41.845902	-112.317573
25	249.3	81.3	41.846514	-112.317706
26	184.3	84.8	41.846295	-112.317401
27	266.3	73.2	41.846188	-112.31749
28	255.6	71.5	41.846221	-112.317518
29	183.6	79.4	41.84612	-112.317555
30	237.7	76	41.846222	-112.317602
31	115.3	17.4	41.846202	-112.317111
32	158.5	80.1	41.846276	-112.317583
33	265	70.7	41.846327	-112.317202
34	155.1	81.1	41.846301	-112.317457
35	255.8	74.6	41.846332	-112.317509
36	167.2	87	41.84635	-112.317577

Notes: Located with handheld GPS using NAD27

Discontinuity Data
Right Abutment - Test Pit

ID	Azimuth	Dip	Longitude	Latitude
1	309.9	11.9	41.845999	-112.321118
2	308.4	12.5	41.846014	-112.321188
3	307.3	7.7	41.84602	-112.321207
4	283.6	10.9	41.846	-112.321203
5	290.9	7.3	41.846022	-112.321232
6	286.5	8.6	41.846022	-112.321232
7	292.9	11	41.846027	-112.321229
8	266.4	82.3	41.845971	-112.32109
9	83.9	88.9	41.845971	-112.32109
10	86.9	84.7	41.845973	-112.32113
11	78.8	84.8	41.845973	-112.32113
12	87.2	83.5	41.845992	-112.321131
13	164.2	79.5	41.845977	-112.321201
14	157.8	84.9	41.845977	-112.321201
15	339.9	88.2	41.845977	-112.321201
16	340.4	89.5	41.845977	-112.321201
17	161.7	85.1	41.845969	-112.321191
18	184.4	48.6	41.845989	-112.321087
19	176.4	55.6	41.845989	-112.321087

Notes: Located with handheld GPS using NAD27

Discontinuity Data
Left Abutment - Trench 18-TR-02

ID	Azimuth	Dip	Latitude	Longitude
1	97	15.2	41.846703	-112.318696
2	99	15	41.846687	-112.318592
3	363.3	88.7	41.846688	-112.31865
4	171.3	83.9	41.846678	-112.318673
5	276.2	83.7	41.846708	-112.318682
6	86.2	88.1	41.846713	-112.318667
7	145.8	87.4	41.846727	-112.318646
8	232.5	80.4	41.846728	-112.318648
9	230.4	76	41.846709	-112.318645
10	153.5	89.5	41.846709	-112.318645
11	80.5	9.4	41.846701	-112.318683
12	108.4	8.6	41.846695	-112.318668
13	329.9	85.3	41.846719	-112.318722
14	237.5	76.9	41.846711	-112.318718
15	98.7	87.5	41.846707	-112.318693
16	88.5	17	41.846702	-112.3187
17	209.9	80.3	41.846696	-112.31868
18	82.8	18.1	41.846698	-112.318715
19	93.4	11.5	41.846705	-112.318731
20	337.2	89.2	41.84668	-112.31871
21	162.9	89.1	41.846664	-112.318685
22	224.4	89.1	41.846664	-112.318685
23	158.1	83.5	41.84666	-112.318653
24	223.4	73.3	41.84666	-112.318653
25	97.5	15.7	41.846662	-112.318652
26	167	89.3	41.846671	-112.318655
27	280.7	81.8	41.846671	-112.318655
28	315.8	72.5	41.846693	-112.318614
29	58.4	11.4	41.846668	-112.318582
30	272.2	83.6	41.846663	-112.318586
31	176.8	80.2	41.846662	-112.31861
32	92.9	86.3	41.84671	-112.318565
33	80.3	6.1	41.846706	-112.318614
34	234.5	78.9	41.846707	-112.318578
35	167.4	84	41.846751	-112.31864
36	215.6	80.5	41.846667	-112.318604
37	357.4	77.8	41.846701	-112.318588

Discontinuity Data
Left Abutment - Trench 18-TR-02

ID	Azimuth	Dip	Latitude	Longitude
38	106.2	13	41.846713	-112.318494
39	237.7	77.6	41.846742	-112.318511
40	205.1	83.6	41.846755	-112.318515
41	298.2	70.4	41.846749	-112.31852
42	318.1	64.4	41.846731	-112.318557
43	98.5	17.1	41.846709	-112.318588
44	326.1	68.8	41.846677	-112.318594
45	172.3	81.8	41.846691	-112.318589
46	71.1	11	41.846691	-112.318589
47	162.1	89.6	41.846678	-112.318586
48	280	85.2	41.846678	-112.318586
49	106.3	13	41.846672	-112.318616
50	19.3	74	41.846587	-112.318553
51	334	76	41.846611	-112.318607
52	106.6	19.2	41.846643	-112.318646
53	104	14.8	41.846625	-112.318634
54	115.1	15.4	41.84666	-112.318667
55	344	89.9	41.846669	-112.318683
56	110.4	13.8	41.846531	-112.318512
57	327.7	85.3	41.846588	-112.318579
58	283.4	82.2	41.846563	-112.318563
59	168.9	89.4	41.846553	-112.318559
60	99.9	16.1	41.846581	-112.318551
61	161.9	89	41.846597	-112.31855
62	259	83.8	41.846656	-112.318572
63	335.9	89	41.846657	-112.318574
64	150.6	88.5	41.846664	-112.318535
65	256.8	87.1	41.846666	-112.318549
66	322.3	71.8	41.84669	-112.318528
67	284.3	75.5	41.846688	-112.318542
68	97.3	8.6	41.846722	-112.318529
69	324	75.8	41.84671	-112.31851
70	211	83.2	41.84674	-112.318506
71	106.2	18.3	41.846764	-112.318509
72	361	81.2	41.846773	-112.318517
73	109.4	16.3	41.845941	-112.318471

Notes: Located with handheld GPS using NAD27

Discontinuity Data
Right Abutment - Trench 18-TR-01

ID	Azimuth	Dip	Latitude	Longitude
1	323.2	86	41.846247	-112.32108
2	-19.5	88	41.846341	-112.3211
3	307.7	29.5	41.846338	-112.32108
4	68.5	70.9	41.846327	-112.32077
5	153.7	89.7	41.846328	-112.3208
6	162.6	65.5	41.846339	-112.32087
7	265.9	29.6	41.846345	-112.32091
8	332.4	86.6	41.846359	-112.32092
9	95	84.2	41.846366	-112.32091
10	317	31	41.846325	-112.32099
11	153.5	88.7	41.846309	-112.32089
12	186	87.4	41.846301	-112.32078
13	139.6	59.3	41.846342	-112.32076
14	147	88.7	41.846299	-112.32079
15	281	23.8	41.846306	-112.3208
16	350	87.9	41.846334	-112.32087
17	102.4	81.6	41.846334	-112.32091
18	124.1	49.9	41.846334	-112.32091
19	347.3	15.4	41.8464	-112.32102
20	32.6	89.9	41.846365	-112.32095
21	306.1	74.1	41.846335	-112.32092
22	295.2	81.6	41.846334	-112.32093
23	162.1	67.4	41.846334	-112.32094
24	156.1	81.9	41.846462	-112.32112
25	91.9	81.6	41.84624	-112.32081
26	197.4	80.9	41.84624	-112.32081
27	187.1	78.9	41.846306	-112.32084
28	299.3	24.3	41.846418	-112.32082
29	161.1	85.8	41.846325	-112.32091
30	266.7	84.2	41.84633	-112.3209
31	135.6	70.9	41.846319	-112.32085
32	139.4	78.1	41.846341	-112.32085
33	161	88.1	41.846322	-112.3208
34	355.6	88.3	41.846296	-112.32076
35	311	22.5	41.846326	-112.32081
36	312	22.2	41.846345	-112.32081
37	-190.9	88.8	41.846345	-112.32081

Discontinuity Data
Right Abutment - Trench 18-TR-01

ID	Azimuth	Dip	Latitude	Longitude
38	311.8	26.5	41.846343	-112.32081
39	178.2	85.3	41.846346	-112.32081
40	106.6	63.7	41.84636	-112.32083
41	295.3	26.3	41.846341	-112.32081
42	192	76.1	41.846315	-112.32081
43	311.7	20.9	41.846341	-112.32076
44	84.2	81.3	41.846341	-112.32076
45	160.2	87.3	41.846335	-112.32074
46	295.4	30.5	41.846317	-112.32085
47	93.1	61.5	41.846338	-112.32068
48	12.7	69	41.846338	-112.32068
49	209.4	71	41.846306	-112.32068
50	305.4	25.7	41.846327	-112.32068

Notes: Located with handheld GPS using NAD27

J:\PROJECTS\Bowen Collins\13GCI329 Bear River Project Concept Study\Drawings\ArcGIS\Work\Cutler Site Map.mxd, 9/17/2015 12:20:26 PM

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Bear River Project Concept Sutdy (13GCI329)

Above Cutler - Site and Exploration Map

N

0 185 370 740 Feet

Figure 2.1

Project: Bear River Project
Project Location: Above Cutler
Project Number: 13GCI329

Log of Test Hole TH-CUT-03

Date(s) Drilled	9/10/14	Logged By	D. Billings	Checked By	P. Gerhart
Drilling Method	Rotary wash with water	Drill Bit Size/Type	Drag bit with HW Casing	Total Depth Drilled (feet)	52.0 feet
Drill Rig Type	CME 75	Drilling Contractor	Bedke Geotechnical F.S.	Hammer Weight/ Drop(lbs/in.)	Automatic trip hammer
Apparent Groundwater Depth	18.2 feet	Latitude / Longitude	41.80215, -111.91069	Ground Surface Elevation (feet)	
Comments		Test Hole Backfill	Piezometer Well	Elevation Datum	NAVD88

Elevation, feet	Depth, feet	SAMPLES Type	Number	Sampling Resistance	Recovery, inches	Graphic Log	MATERIAL DESCRIPTION	FIELD NOTES
	0						SAND, loose, some silt, fine to medium grained, occasional roots, dry to wet, very dark brown to orangish brown, (SP-SM)	
	5			1-2-4-4 [6]	14.0			Casing communicating with ground surface -- invalid permeability testing results.
				2-4-7-7 [11]	16.0		SAND, loose to medium dense, silty, fine to medium grained, moist to wet, orangish brown, (SM)	
	10			3-5-3-4 [8]	13.0		- wet at 10 feet	
				1-0-1-4 [1]	14.0			
	15				6.0		CLAY, very soft, sandy, frequent interbedded sandy silt layers to 8-inch, wet, pinkish brown to dark brownish orange, (CL)	
				0-0-0-0 [0]	24.0			
				0-1-0-1 [1]	24.0			
	20				23.0		CLAY, very soft, high plasticity, wet, purplish gray to reddish gray to dark gray, (CH)	
							- dark gray to black	
	25			0-0-0-1 [0]	24.0			
	30				20.0			
	35			0-0-0-2 [0]	24.0			
	40				21.0			
	45			0-0-0-3 [0]	24.0			
	50							

GERHART COLE

Project: Bear River Project
Project Location: Above Cutler
Project Number: 13GCI329

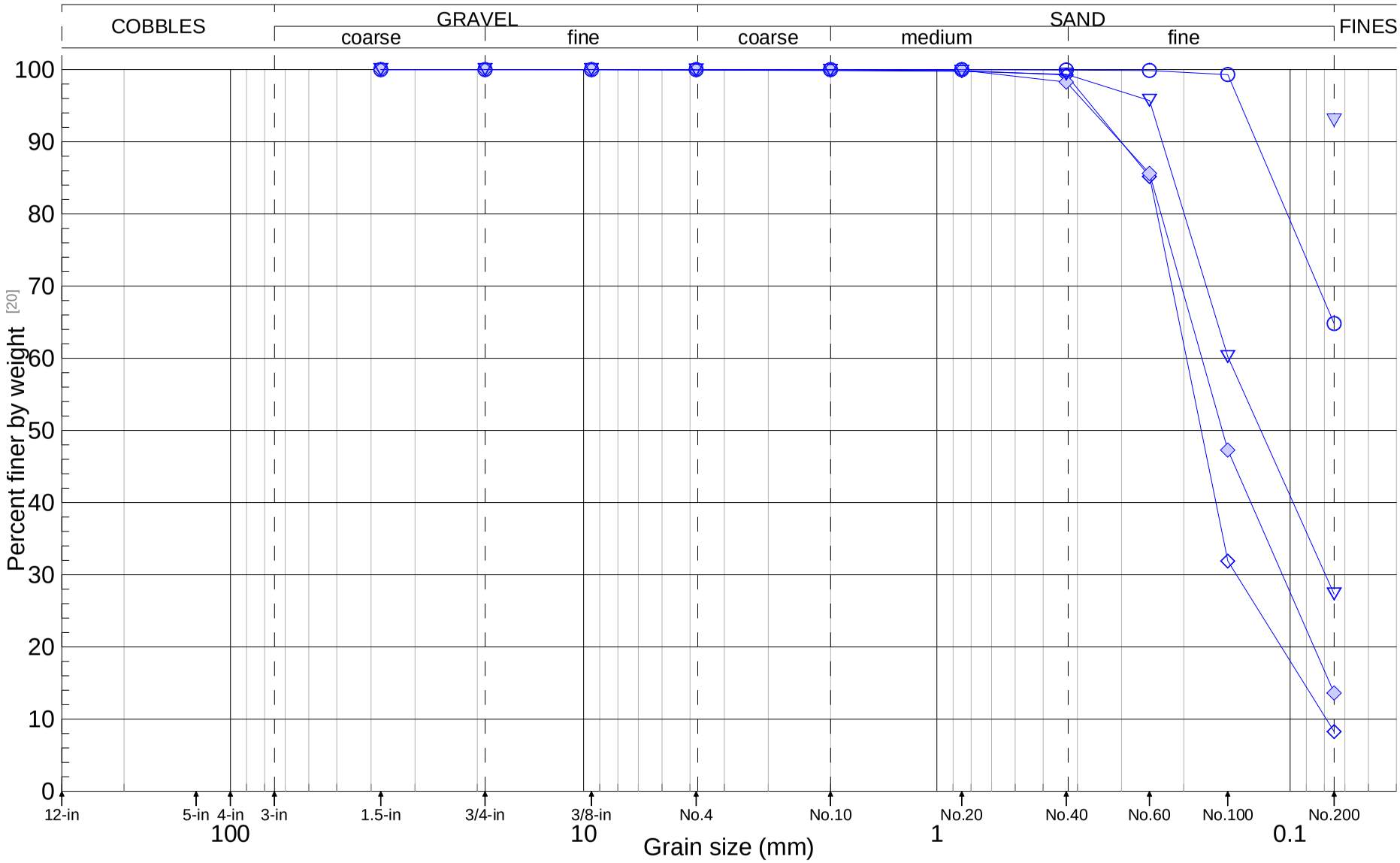
Log of Test Hole TH-CUT-03

Elevation, feet	Depth, feet	SAMPLES Type	SAMPLES Number	SAMPLES Sampling Resistance	SAMPLES Recovery, inches	Graphic Log	MATERIAL DESCRIPTION	FIELD NOTES
	50							
							Bottom of Test Hole at 52.0 feet. Piezometer data Screen 52-47 ft 10-20 Sand 52-42 Bentonite Chips 42-0 ft	
	55							
	60							
	65							
	70							
	75							
	80							
	85							
	90							
	95							
	100							
	105							

Table 2-1 Laboratory Test Result Summary

Bear River Project Concept Study- Above Cutler (13GCI329)

Test Hole	Depth (ft)	Moisture content (%)	Dry unit weight (pcf)	Moist / Sat. unit weight (pcf)	Atterberg Limits					Grain-Size			Grain-Size Analysis (Percent Finer)										Other Tests (Interpretative Data in Appendix)
					LL (%)	PL (%)	PI (%)	Cohesive Index, CI	Liquidity Index, LI	GRAVEL (No.4 - 3")	SAND (No.200-No.4)	FINES (<No.200)	1.5-in (37.5 mm)	3/4-in (19 mm)	3/8-in (9.5 mm)	No.4 (4.75 mm)	No.10 (2 mm)	No.20 (0.85 mm)	No.40 (0.425 mm)	No.60 (0.25 mm)	No.100 (0.15 mm)	No.200 (0.075 mm)	
TH-CUT-03	5-7	14.8								0	92	8	100	100	100	100	100	100	99	85	32	8	
TH-CUT-03	7.5-9.5	15.9								0	86	14	100	100	100	100	100	100	98	86	47	14	
TH-CUT-03	10-12	24.7								0	73	27	100	100	100	100	100	100	99	96	60	27	
TH-CUT-03	12.5-14.5	36.2								0	7	93	100	100	100	100	100	99	99	99	98	93	
TH-CUT-03	15.5-16.5	37.5			30	22	8	0.36	1.9														Pinhole, Proctor
TH-CUT-03	16.5-17.5	28.8			NP					0	35	65	100	100	100	100	100	100	100	100	99	65	
TH-CUT-03	20-22	69.7	58	97.9	75	31	44	1.42	0.9														1D Consolidation
TH-CUT-03	25-27	51.9			61	27	34	1.26	0.7														
TH-CUT-03	30-31.5																						CU
TH-CUT-03	40-41.5	55.6	67	104	66	27	39	1.44	0.7														1D Consolidation



◇TH-CUT-03 at 5-7
◆TH-CUT-03 at 7.5-9.5
▽TH-CUT-03 at 10-12
▼TH-CUT-03 at 12.5-14.5
○TH-CUT-03 at 16.5-17.5
●
△
▲

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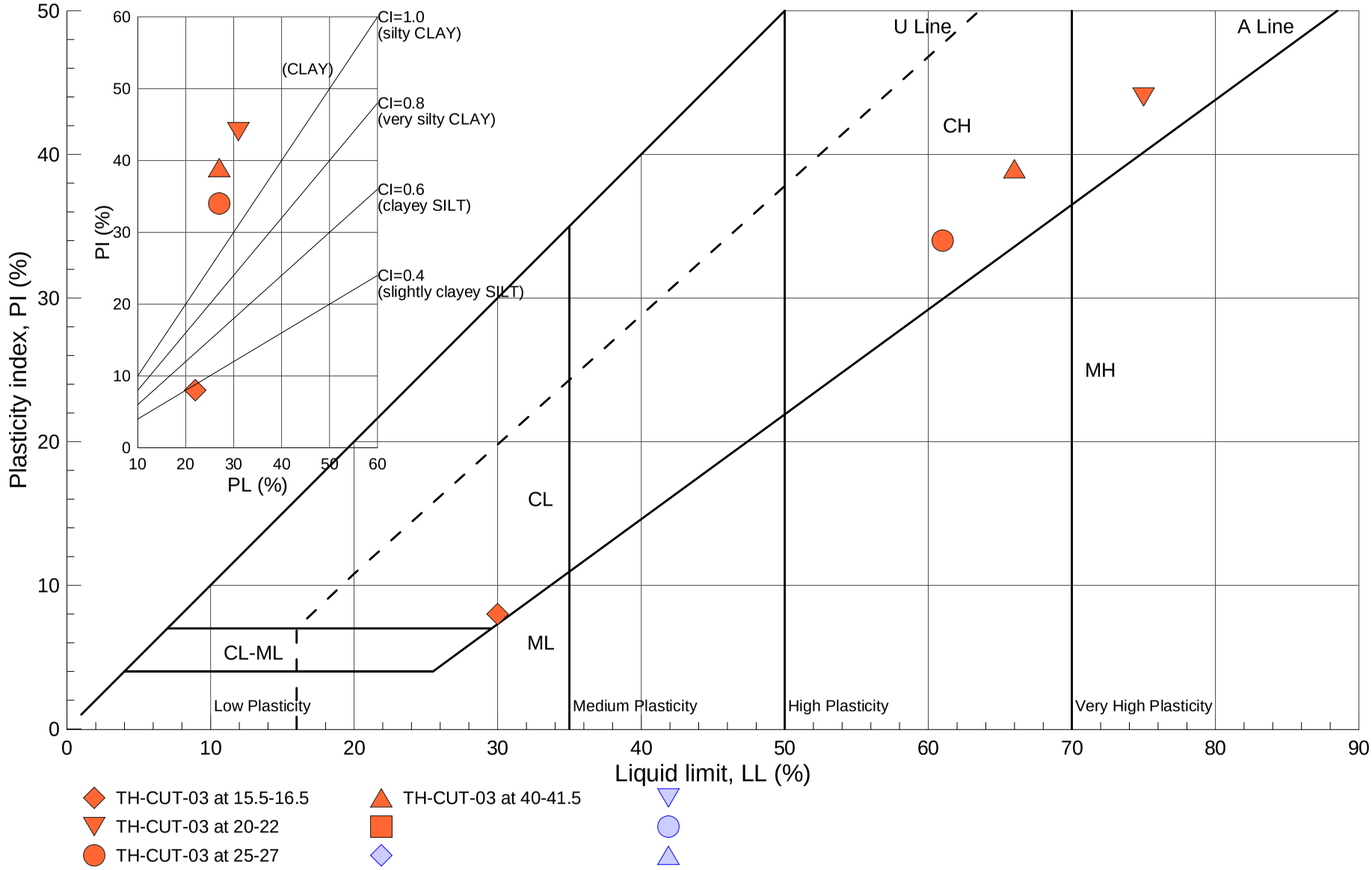
Grain-Size Analysis

Bear River Project Concept Study- Above Cutler (13GCI329)

Figure B-1



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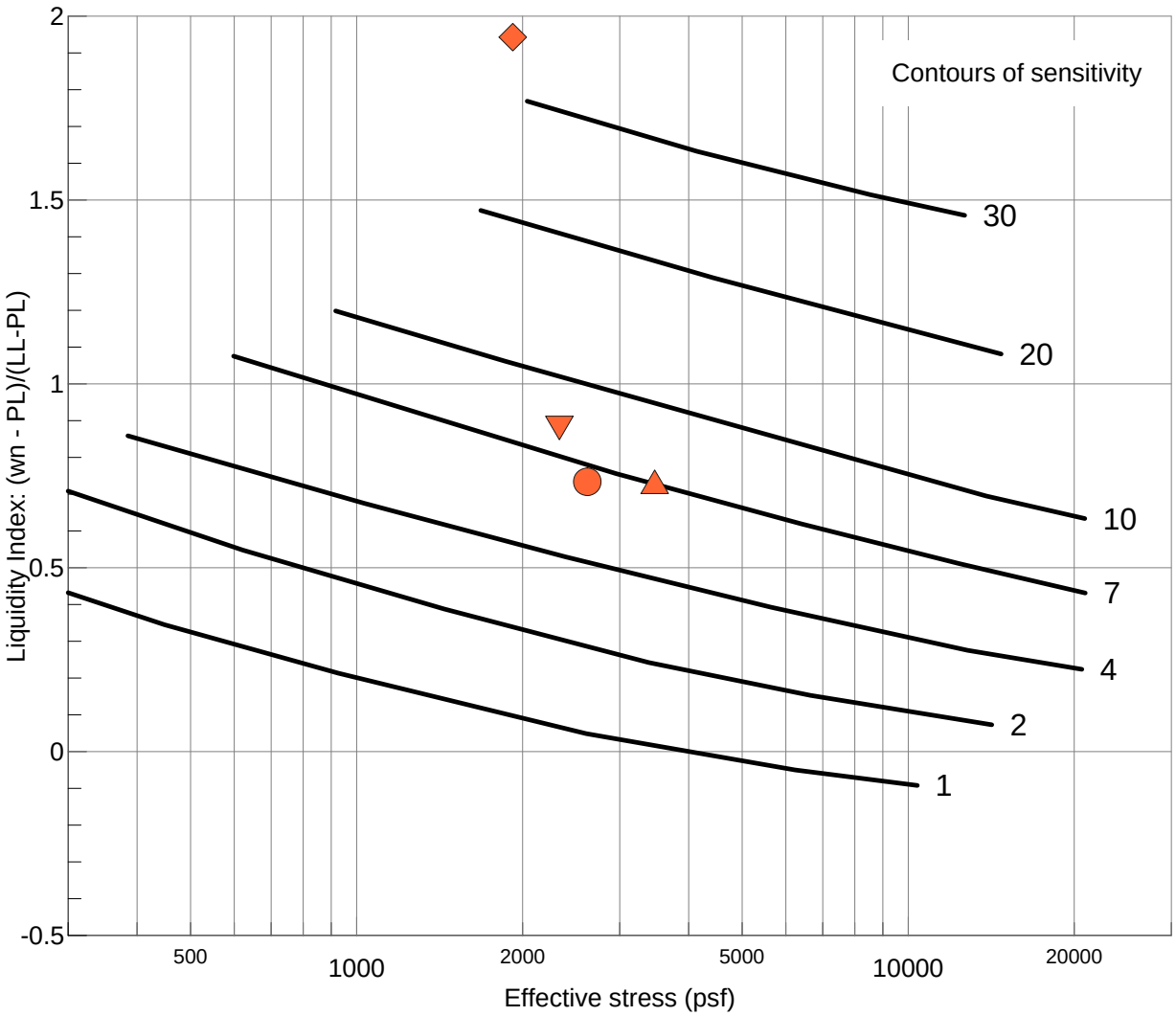
Casagrande's Plasticity Chart (Atterberg Limits)

Bear River Project Concept Study- Above Cutler (13GCI329)

Figure B-2



- TH-CUT-03 at 15.5-16.5
- TH-CUT-03 at 20-22
- TH-CUT-03 at 25-27
- TH-CUT-03 at 40-41.5

GERHART COLE	Sensitivity, LI, and Effective Stress Relationships (Mitchell,1993)	
	Bear River Project Concept Study- Above Cutler (13-329)	Figure B-3

One-Dimensional Consolidation Properties of Soils
After ASTM D2435 and USBR 5700

GERHART COLE

Project:	**Bear River**	**TH/TP/Sample:**	**TH-CUT-03**
No:	**13GCI329**	**Depth:**	**20-22 (22)**
Location:	Cache County, Utah	Sample description:	dark gray to black clay
Date:	24-Sep-14	USCS classification:	not requested
Tested by:	zg	Sample type:	Rel. undisturbed, Shelby Tube
Reduced by:	zg	Inundation stress (psf):	100, beginning
Checked by:	dab	Swell pressure (psf):	130
Comments:		Test method:	B
		Preparation procedure:	trimmed

Phase Relationships

	Initial	Final
Height, H (in)	1.0000	0.7244
Height, H (cm)	2.540	1.840
Dia., D (in)	2.500	2.500
Dia., D (cm)	6.350	6.350
Wt. rings + wet soil (g)	340.52	322.82
Wt. rings (g)	214.38	214.38
Wet soil + tare (g)	309.39	
Dry soil + tare (g)	241.95	
Tare (g)	145.15	
Moisture cont., w (%)	69.7	45.9
Gs, assumed	2.75	2.75
Mass total (g)	126.1	108.4
Mass of solids (g)	74.3	74.3
Volume (cm^3)	80.4	58.3
Vol. of water (cm^3)	51.8	34.1
Vol. of solids (cm^3)	27.0	27.0
Vol. of voids (cm^3)	53.4	31.2
Vol. of air (cm^3)	1.6	-2.9
Area, A (cm^2)	31.7	31.7
Ht. solids, Hs (cm)	0.854	0.854
Void ratio, e	1.975	1.155
Porosity, n	0.664	0.536
Vol.moisture, T	0.644	0.585
Saturation, S (%)	97	109
Dry density (gm/cm^3)	0.924	1.276
Wet unit wt., gm (pcf)	97.9	116.2
Dry unit wt., gd (pcf)	57.7	79.6

Vertical Stress - Deformation Results

Vert. stress (psf)	Corr. Dial, dfc [a] (in)	Hc [b] (in)	Vert. strain, ev	Load duration (min)	t-90 (min)	Hdr (in)	Cv (ft^2/day)
Seating	0.0000	1.0000	0.0000	0			
100	0.0000	1.0000	0.0000	40			
200	0.0007	0.9993	0.0007	16			
400	0.0056	0.9944	0.0056	64			
800	0.0121	0.9879	0.0121	35	6.3	0.49557	0.33
1,600	0.0234	0.9766	0.0234	51	7.9	0.49112	0.26
3,200	0.0531	0.9469	0.0531	83	12.6	0.48087	0.15
6,400	0.1661	0.8339	0.1661	105	79.4	0.4452	0.02
12,800	0.2695	0.7305	0.2695	227	63.1	0.39109	0.02
25,600	0.3378	0.6622	0.3378	126	50.3	0.34816	0.02
12,800	0.3308	0.6692	0.3308	60			
3,200	0.3071	0.6929	0.3071	60			
800	0.2756	0.7244	0.2756	120			
200	0.2418	0.7582	0.2418	240			

Data Interpretation Summary

Preconsolidation stress, s'p (psf)	---	
Compression ratio, CR	---	To be determined by the Geotechnical Engineer
Recompression ratio, RR	---	

Notes:
[a] Dfc = end of increment deformation corrected for machine, porous stone, and filter paper deformation
[b] Hc = height at end of consolidation of each vert. stress
[c] Hdr = height at 50 consolidation computed from D90 using sq-root time method
[d] Cv computed from Taylor (1948) aquare root of time method (note 1 in^2/min = 10 ft^2/day)

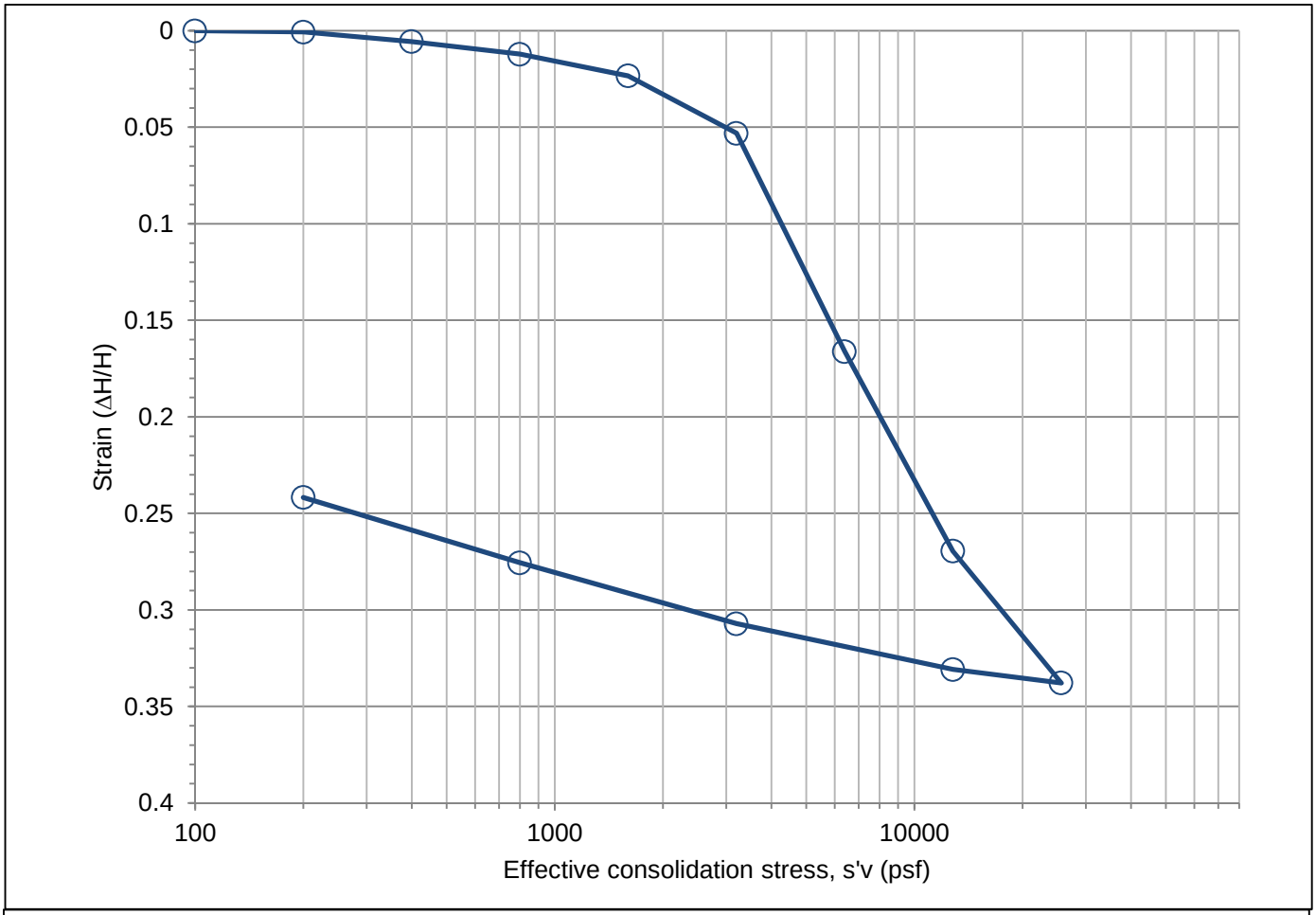
One-Dimensional Consolidation Properties of Soils

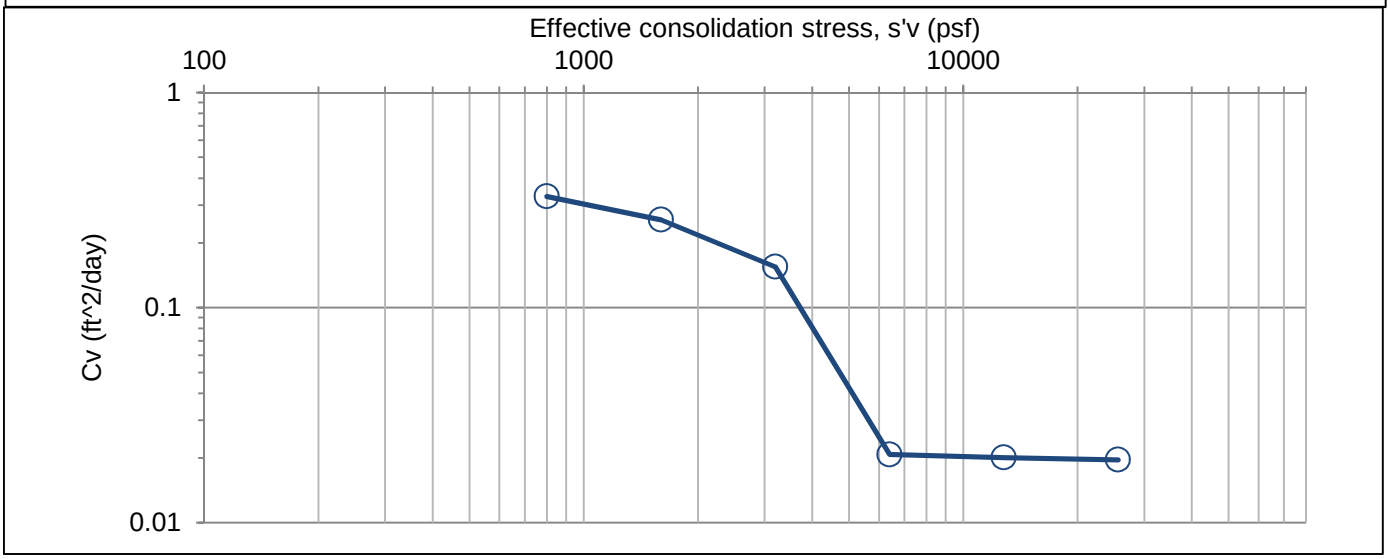
After ASTM D2435 and USBR 5700

GERHART COLE

Project: Bear River | **TH/TP/Sample:** TH-CUT-03

No: 13GCI329 | **Depth:** 20-22 (22)





One-Dimensional Consolidation Properties of Soils
After ASTM D2435 and USBR 5700

GERHART COLE

Project:	**Bear River**	**TH/TP/Sample:**	**TH-CUT-03**
No:	**13GCI329**	**Depth:**	**40-41.5 (41.5)**
Location:	Cache County, Utah	Sample description:	dark gray to black clay
Date:	25-Sep-14	USCS classification:	not requested
Tested by:	zg	Sample type:	Rel. undisturbed, Shelby Tube
Reduced by:	zg	Inundation stress (psf):	100, beginning
Checked by:	dab	Swell pressure (psf):	135
Comments:		Test method:	B
		Preparation procedure:	trimmed

Phase Relationships

	Initial	Final
Height, H (in)	1.0000	0.7353
Height, H (cm)	2.540	1.868
Dia., D (in)	2.500	2.500
Dia., D (cm)	6.350	6.350
Wt. rings + wet soil (g)	347.81	329.96
Wt. rings (g)	214.39	214.39
Wet soil + tare (g)	320.73	
Dry soil + tare (g)	256.25	
Tare (g)	140.20	
Moisture cont., w (%)	55.6	34.7
Gs, assumed	2.75	2.75
Mass total (g)	133.4	115.6
Mass of solids (g)	85.8	85.8
Volume (cm^3)	80.4	59.1
Vol. of water (cm^3)	47.7	29.8
Vol. of solids (cm^3)	31.2	31.2
Vol. of voids (cm^3)	49.3	28.0
Vol. of air (cm^3)	1.6	-1.8
Area, A (cm^2)	31.7	31.7
Ht. solids, Hs (cm)	0.985	0.985
Void ratio, e	1.579	0.897
Porosity, n	0.612	0.473
Vol.moisture, T	0.592	0.504
Saturation, S (%)	97	107
Dry density (gm/cm^3)	1.066	1.450
Wet unit wt., gm (pcf)	103.5	122.0
Dry unit wt., gd (pcf)	66.6	90.5

Vertical Stress - Deformation Results

Vert. stress (psf)	Corr. Dial, dfc [a] (in)	Hc [b] (in)	Vert. strain, ev	Load duration (min)	t-90 (min)	Hdr (in)	Cv (ft^2/day)
Seating	0.0000	1.0000	0.0000	0			
100	0.0004	0.9996	0.0004	63			
400	0.0030	0.9970	0.0030	41			
800	0.0077	0.9923	0.0077	41	12.6	0.49733	0.17
1,600	0.0153	0.9847	0.0153	63	12.6	0.49427	0.16
3,200	0.0283	0.9717	0.0283	43	12.6	0.4891	0.16
6,400	0.0746	0.9254	0.0746	103	39.8	0.47425	0.05
12,800	0.1792	0.8208	0.1792	177	79.4	0.43655	0.02
25,600	0.2524	0.7476	0.2524	184	63.1	0.3921	0.02
51,200	0.3131	0.6869	0.3131	240	50.1	0.35862	0.02
25,600	0.3080	0.6920	0.3080	60			
6,400	0.2890	0.7110	0.2890	60			
1,600	0.2647	0.7353	0.2647	120			
400	0.2382	0.7618	0.2382	200			

Data Interpretation Summary

Preconsolidation stress, s'p (psf)	---	
Compression ratio, CR	---	To be determined by the Geotechnical Engineer
Recompression ratio, RR	---	

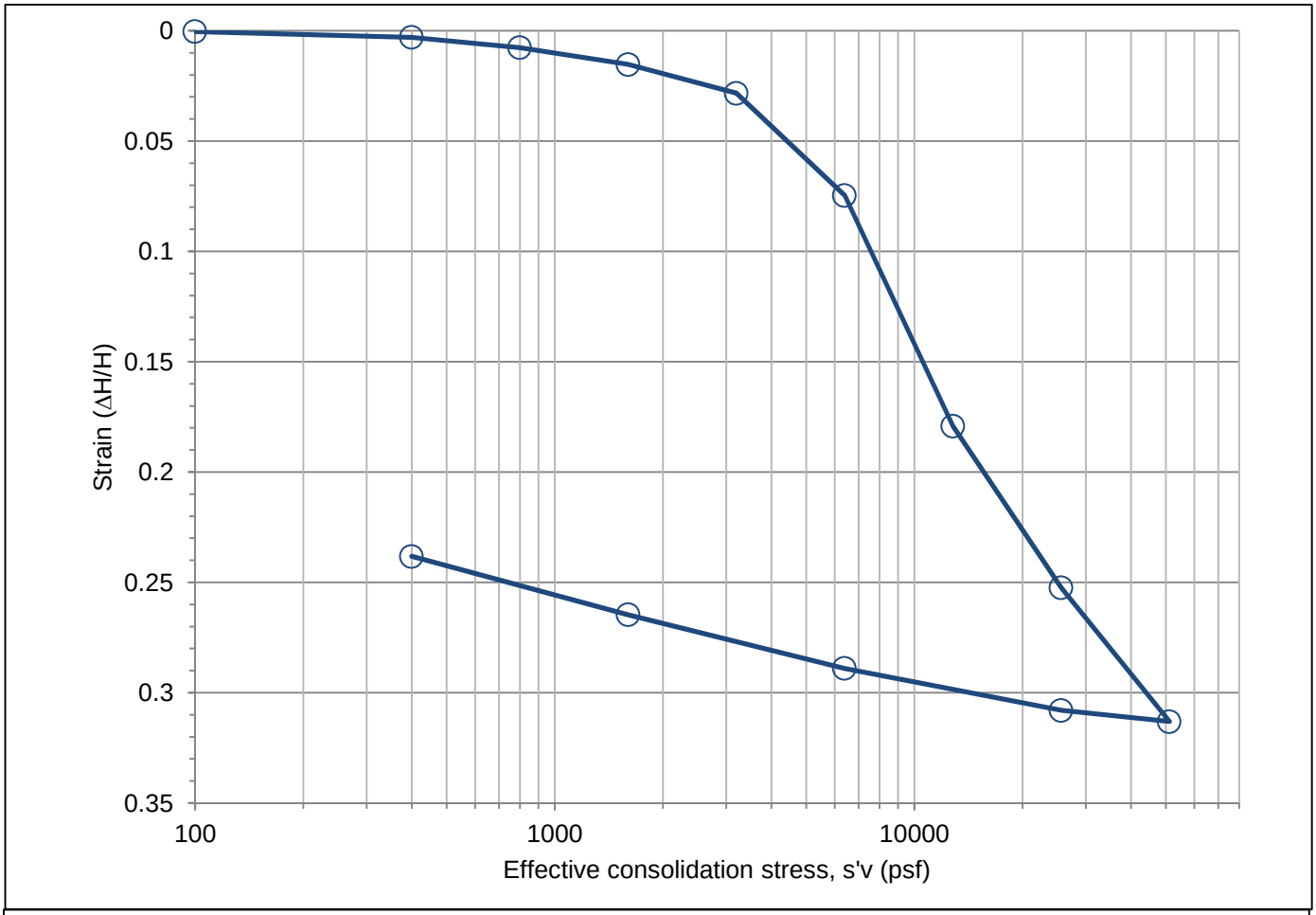
Notes:
[a] Dfc = end of increment deformation corrected for machine, porous stone, and filter paper deformation
[b] Hc = height at end of consolidation of each vert. stress
[c] Hdr = height at 50 consolidation computed from D90 using sq-root time method
[d] Cv computed from Taylor (1948) aquare root of time method (note 1 in^2/min = 10 ft^2/day)

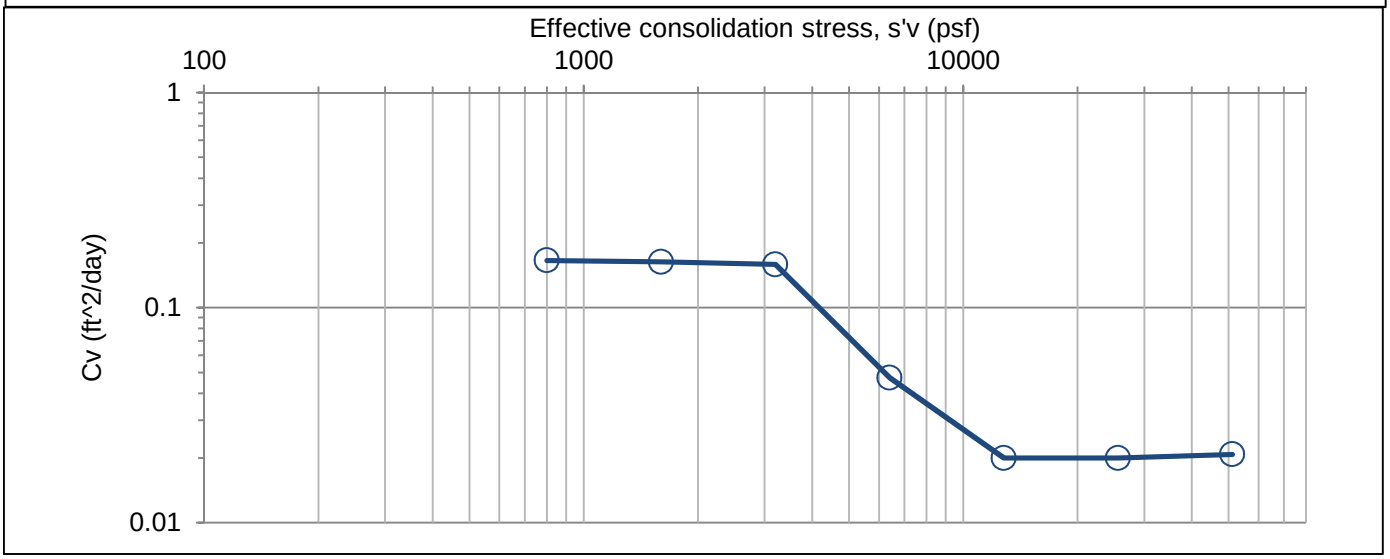
One-Dimensional Consolidation Properties of Soils
After ASTM D2435 and USBR 5700

GERHART COLE

Project: Bear River
No: 13GCI329

TH/TP/Sample: TH-CUT-03
Depth: 40-41.5 (41.5)





Triaxial Test - Isotropic Consolidated Sheared Undrained Measuring Pore Pressure (CIU-PP) - *After ASTM D4767 and USBR 5750*

GERHART COLE

Project:	**Bear River - Above Cutler**	**TH/TP/Sample:**	**TH-CUT-03**
No:	**13GCI329**	**Depth:**	**30-31.5**
Location:	Cache County Utah	Sample description:	purpleish gray clay
Date:	26-Aug-15	USCS classification:	CH
Tested by:	zmg	Sample type:	undisturbed
Reduced by:	zmg	Notes:	
Checked by:	rrb		

	Test Number	S1	55 psi	S2	30 psi	S3	20 psi
		Initial	Bef. Shr. MethodB [e]	Initial	Bef. Shr. MethodB [e]	Initial	Bef. Shr. MethodB [e]
Unit weight data	Sample ht., H (in) 0°	5.750		5.733		5.755	
	120°	5.761		5.735		5.754	
	240°	5.754		5.733		5.747	
	Avg. height, Havg (in)	5.755	5.505	5.734	5.654	5.752	5.672
	Avg. height, Havg (cm)	14.618	13.983	14.564	14.360	14.610	14.407
	ΔHsc (in) [a]		0.25		0.08		0.08
	Sample dia., D (in) top	2.834		2.809		2.838	
	mid	2.790		2.795		2.642	
	bot	2.815		2.808		2.835	
	Avg. dia., Davg (in)	2.807	2.695	2.802	2.715	2.739	2.657
	Avg. dia., Davg (cm)	7.130	6.846	7.116	6.897	6.958	6.748
	Avg. area, Aavg (in^2)	6.189	5.706	6.165	5.791	5.893	5.544
	Avg. area, Aavg (cm^2)	39.932	36.814	39.776	37.364	38.021	35.767
	Wt. rings + wet soil (g)	1040.48	976.15	1042.57	1005.90	975.89	953.92
	Wt. rings (g)	0.00	0.00	0.00	0.00	0.00	0.00
	Volume, Vo (in^3)	35.6	31.4	35.3	32.7	33.9	31.4
	Vo (cm^3)	583.7	514.8	579.3	536.6	555.5	515.3
	Vo (ft^3)	0.0206	0.0182	0.0205	0.0189	0.0196	0.0182
Moisture	Wet soil + tare (g)	209.13	1120.59	153.48	1148.24	250.99	1098.55
	Dry soil + tare (g)	184.33	879.53	143.10	878.09	214.26	839.70
	Tare (g)	126.10	144.75	119.88	142.69	126.95	145.36
	Moisture content, w (%)	42.6	32.8	44.7	36.7	42.1	37.3
Phase Relationships	Gs, assumed	2.65	2.65	2.65	2.65	2.65	2.65
	Mass total (g)	1040.5	969.1	1042.6	985.2	975.9	943.0
	Mass of solids (g)	729.7	729.7	720.5	720.5	686.9	686.9
	Volume (cm^3)	583.7	514.8	579.3	536.6	555.5	515.3
	Volume of water (cm^3)	310.8	239.4	322.1	264.7	289.0	256.1
	Volume of solids (cm^3)	275.4	275.4	271.9	271.9	259.2	259.2
	Volume of voids (cm^3)	308.4	239.4	307.4	264.7	296.3	256.1
	Volume of air (cm^3)	-2.4	0.0	-14.7	0.0	7.3	0.0
	Void ratio, e	1.120	0.869	1.131	0.973	1.143	0.988
	Porosity, n	0.528	0.465	0.531	0.493	0.533	0.497
	Volumetric moisture, T	0.532	0.465	0.556	0.493	0.520	0.497
	Saturation, S (%) [c]	100.79	100.00	104.78	100.00	97.54	100.00
	Dry density (gm/cm^3)	1.250	1.418	1.244	1.343	1.237	1.333
	Wet unit wt., gm (pcf)	111.3	117.5	112.4	114.6	109.7	114.2
	Dry unit wt., gd (pcf)	78.0	88.5	77.6	83.8	77.2	83.2

Notes:

[a] ΔHsc (in) = change in height during saturation and consolidation

[b] ΔVs = change in volume during saturation, ΔVc = change in volume during consolidation

[c] Saturation before shear set to 100% for phase calculations

[d] Before shear Aavg using method A; where Ac (Method A) = (Vo-DVs - DVc)/(Ho-DHsc)

[e] Before shear Aavg using method B; where Ac (Method B) = (Vwf + Vs)/Hc

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Triaxial Test - Isotropic Consolidated Sheared Undrained
Measuring Pore Pressure (CIU-PP) *- After ASTM D4767 and USBR 5750*

GERHART COLE

Project:	**Bear River - Above Cutler**	**TH/TP/Sample:**	**TH-CUT-03**
No:	**13GCI329**	**Depth:**	**30-31.5**
Location:	Cache County Utah	Sample description:	purpleish gray clay
Date:	26-Aug-15	USCS classification:	CH
Tested by:	zmg	Sample type:	undisturbed

X:\PROJECTS\13GCI329 Bear River Project Concept Study\Bear River\[TX_CU3pts_TH-CUT-03_30-31-5ft-v02.xlsx]SUM

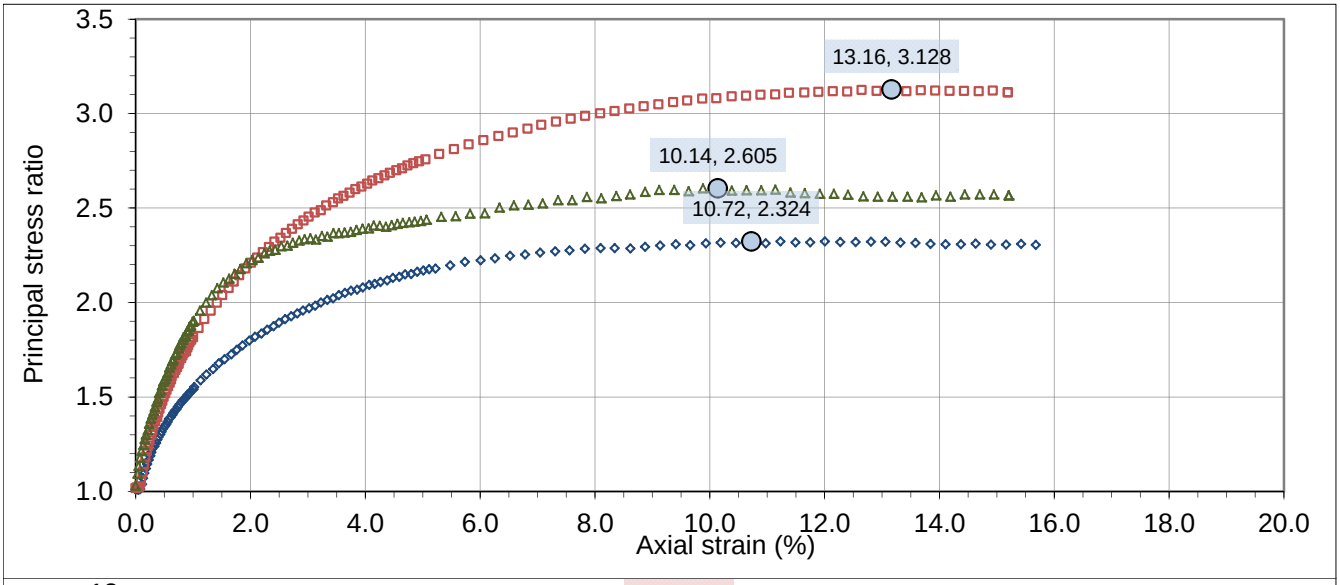
Test Number		S1 at 55 psi	S2 at 30 psi	S3 at 20 psi
Test information	Total backpressure (psi)	40.0	40.0	40.0
	Skempton B	0.97	0.97	0.95
	t-90 (min)	570.2	480.2	300.2
	t-100 (min)	750.1	660.2	420.2
	t-50 (min)	133.2	112.2	70.1
	Strain rate (%/hr)	0.50	0.50	0.50
	Strain rate (%/min)	0.008	0.008	0.008
	Membrane correction	Yes	Yes	Yes
	Filter paper correction	No filter paper	No filter paper	No filter paper
Max principal stress ratio (s1/s3), failure criteria	Strain at failure, ef (%)	10.72	13.16	10.14
	Time to failure, tf (min)	1286.6	1579.7	1216.9
	Obliquity, s'1/s'3	2.324	3.128	2.605
	Excess pore pressure, u (psi)	36.60	22.72	12.87
	q = q' = (s1+s3)/2 (psi)	12.18	7.74	5.72
	p' = (s'1+s'3)/2 (psi)	30.59	15.02	12.85
	p = (s1+s3)/2 (psi)	67.18	37.74	25.72
	Effective major principal stress, s'1 (psi)	42.77	22.76	18.57
	Effective minor principal stress, s'3 (psi)	18.40	7.28	7.13
	Total major pincipal stress, s1 (psi)	79.37	45.48	31.44
	Total minor pincipal stress, s3 (psi)	55.00	30.00	20.00
	Skemption A at failure, Af	1.50	1.47	1.13
	Secant friction angle, phi-s (deg)	23.5	31.0	26.4
		Effective stress	Total stress	
	Friction angle, phi (deg)	19.6	8.9	
	Cohesion intercept, c (psi)	2.1	1.8	
Peak deviator stress (s1-s3), failure criteria	Strain at failure, ef (%)	9.41	4.74	2.85
	Time to failure, tf (min)	1128.7	568.6	341.6
	Deviator stress, s1-s3 (psi)	24.44	16.74	12.82
	Excess pore pressure, u (psi)	36.31	20.30	10.34
	q = q' = (s1+s3)/2 (psi)	12.22	8.37	6.41
	p' = (s'1+s'3)/2 (psi)	30.91	18.07	16.07
	p = (s1+s3)/2 (psi)	67.22	38.37	26.41
	Effective major principal stress, s'1 (psi)	43.13	26.44	22.48
	Effective minor principal stress, s'3 (psi)	18.69	9.70	9.66
	Total major pincipal stress, s1 (psi)	79.44	46.74	32.82
	Total minor pincipal stress, s3 (psi)	55.00	30.00	20.00
	Skemption A at failure, Af	1.49	1.21	0.81
	Secant friction angle, phi-s (deg)	23.3	27.6	23.5
		Effective stress	Total stress	
	Friction angle, phi (deg)	21.0	8.1	
	Cohesion intercept, c (psi)	1.3	2.8	

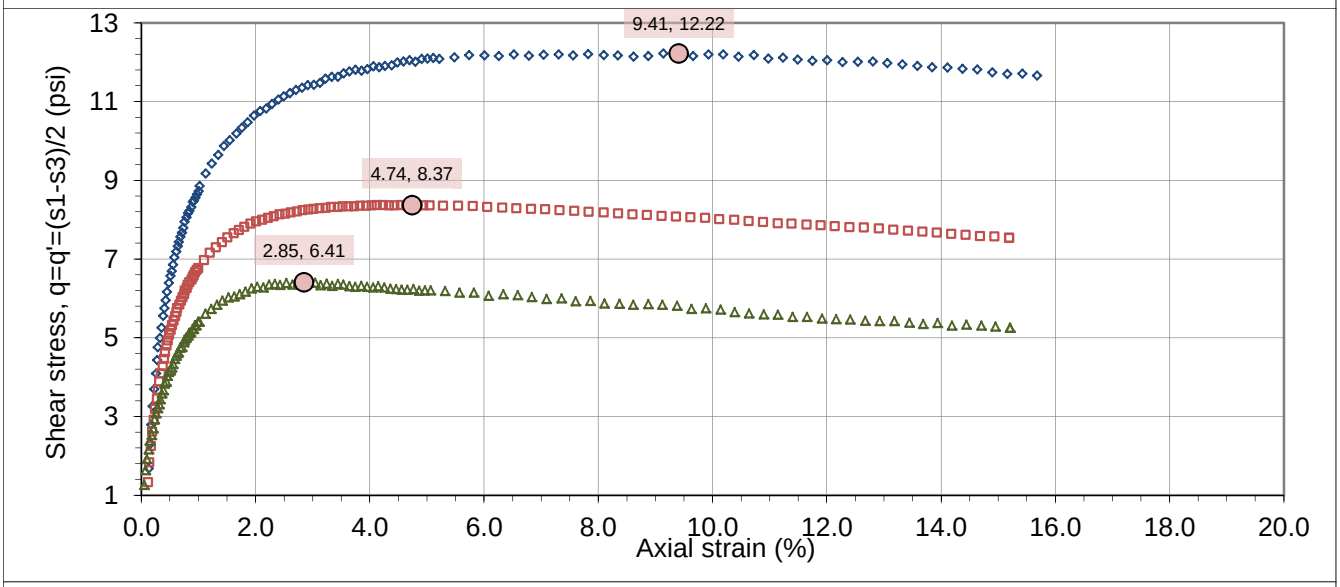
Comments:

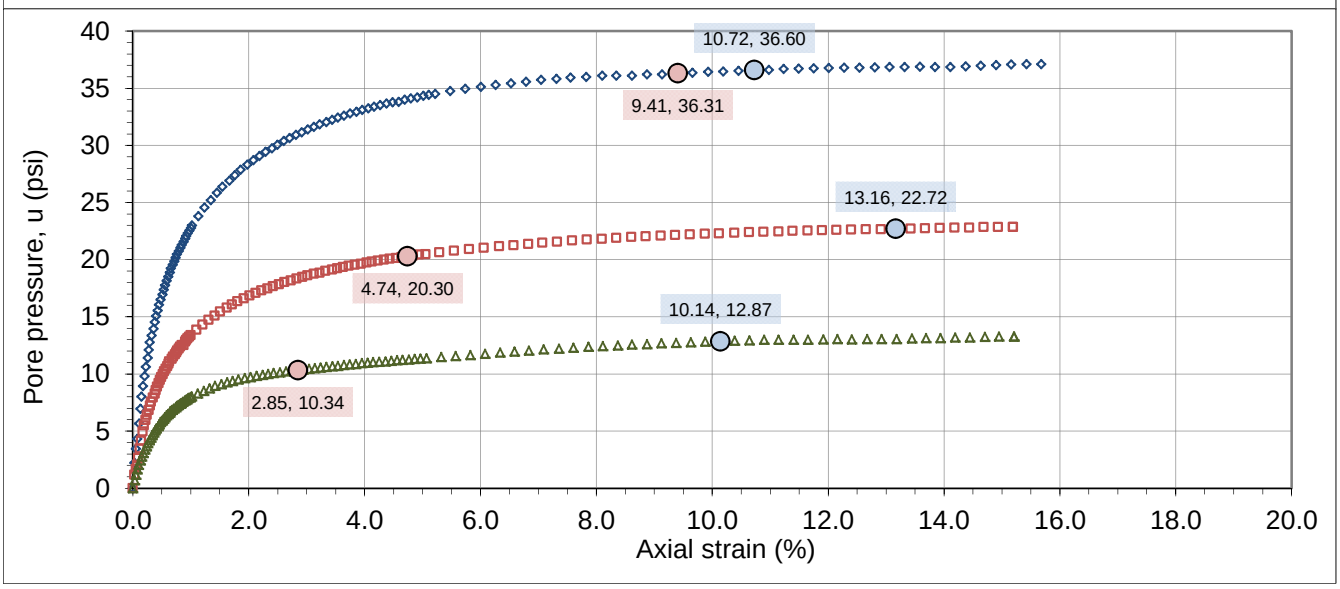
Triaxial Test - Isotropic Consolidated Sheared Undrained
Measuring Pore Pressure (CIU-PP) *- After ASTM D4767 and USBR 5750*

GERHART COLE

Project: Bear River - Above Cutler **TH/TP/Sample: TH-CUT-03**
No: 13GCI329 **Depth: 30-31.5**





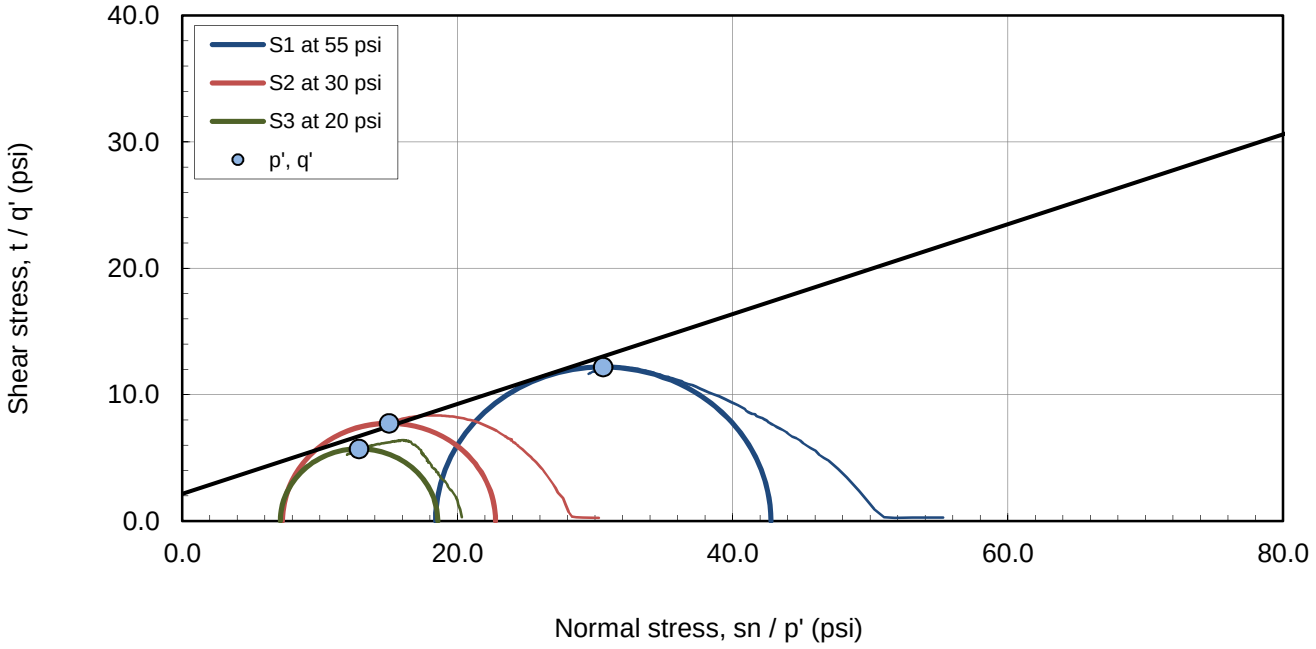


Triaxial Test - Isotropic Consolidated Sheared Undrained
Measuring Pore Pressure (CIU-PP) *- After ASTM D4767 and USBR 5750*

GERHART COLE

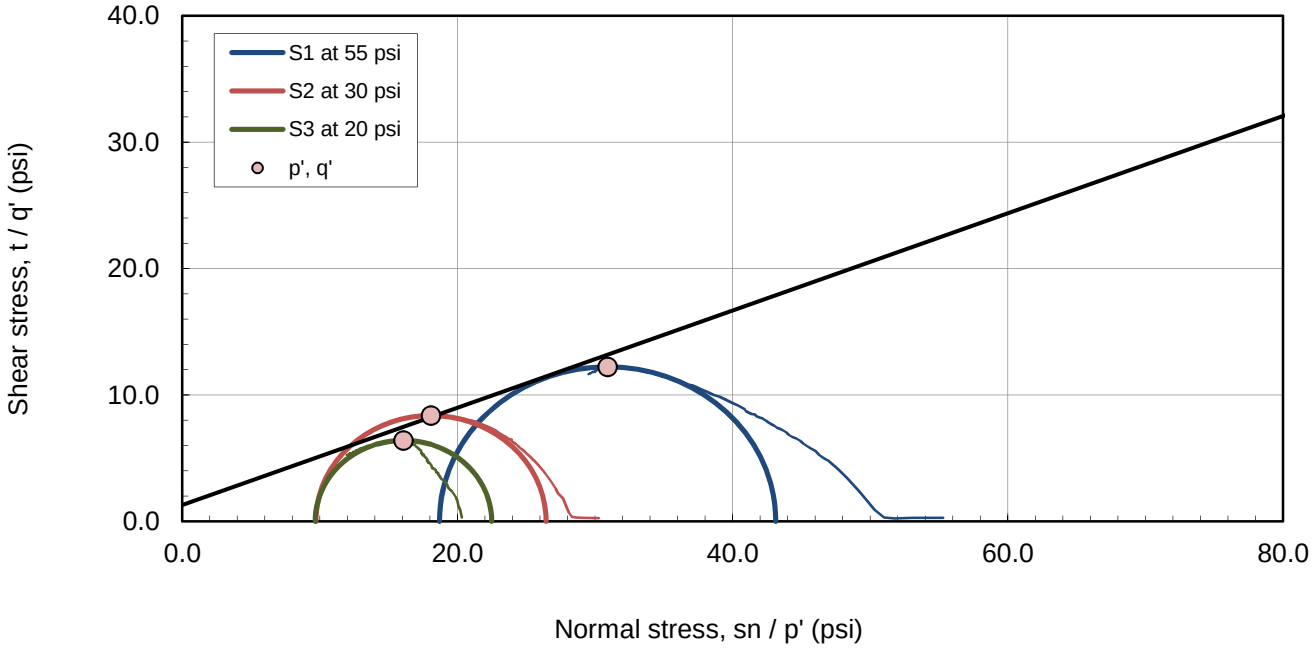
Project: **Bear River - Above Cutler** **TH/TP/Sample:** **TH-CUT-03**
No: **13GCI329** **Depth:** **30-31.5**

Effective stress results



Max principal stress ratio (s'1/s'3), failure criteria Mohr and p' - q' space plots

Effective stress results



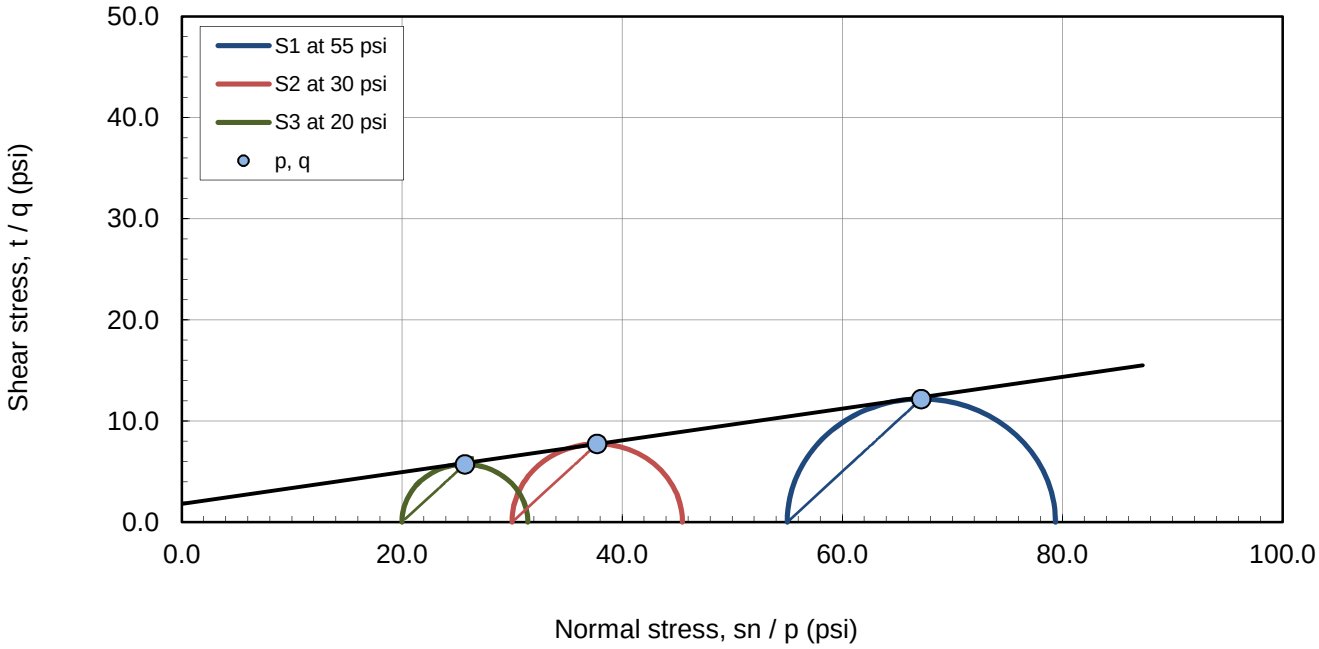
Peak deviator stress (s1-s3), failure criteria Mohr and p' - q' space plots

Triaxial Test - Isotropic Consolidated Sheared Undrained
Measuring Pore Pressure (CIU-PP) *- After ASTM D4767 and USBR 5750*

GERHART COLE

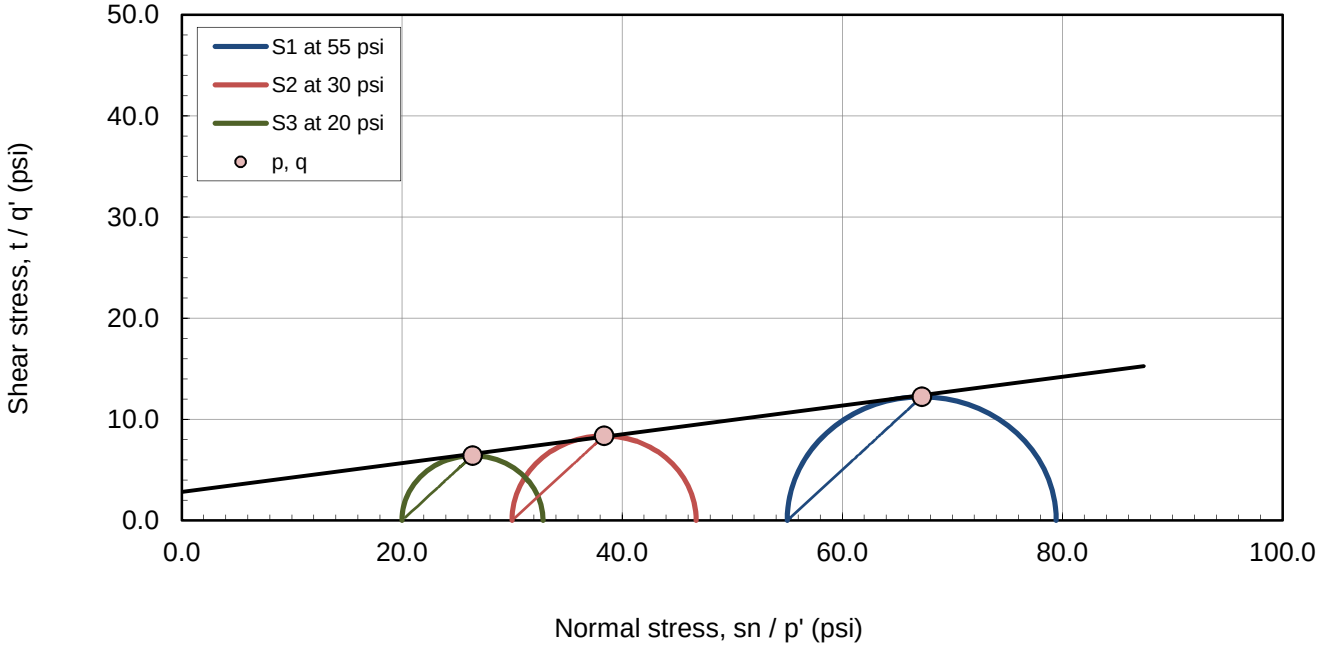
Project: **Bear River - Above Cutler** **TH/TP/Sample:** **TH-CUT-03**
No: **13GCI329** **Depth:** **30-31.5**

Total stress results



Max principal stress ratio (s1/s3), failure criteria Mohr and p - q space plots - effective stress results

Total stress results



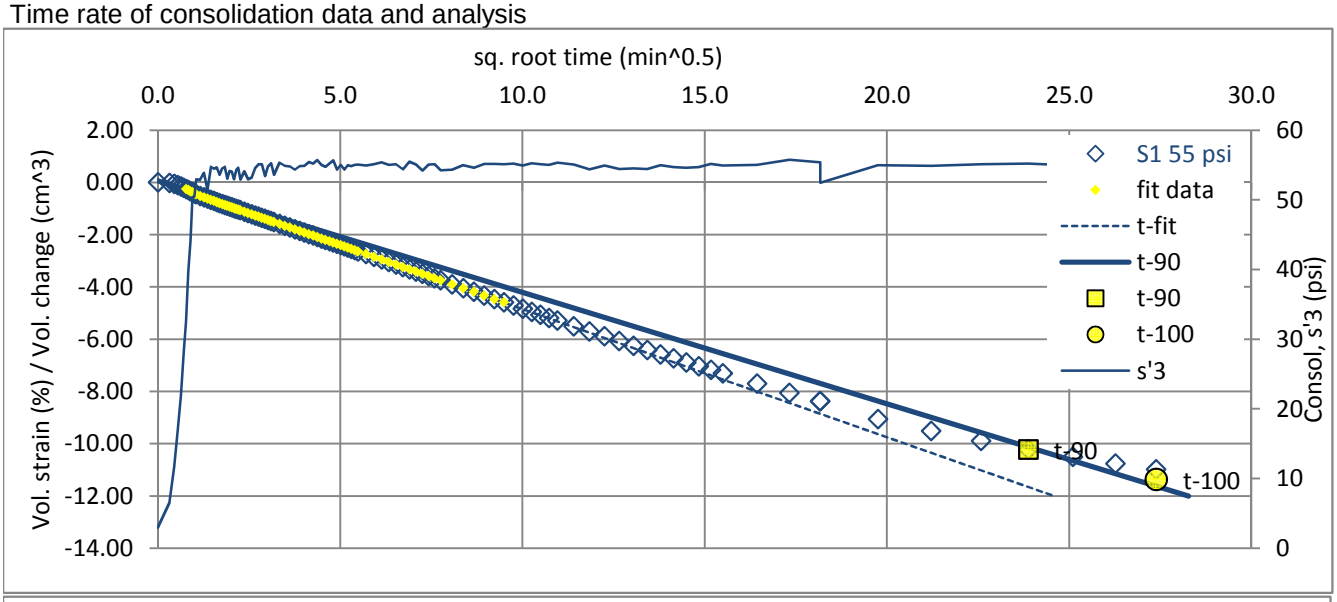
Peak deviator stress (s1-s3), failure criteria Mohr and p - q space plots

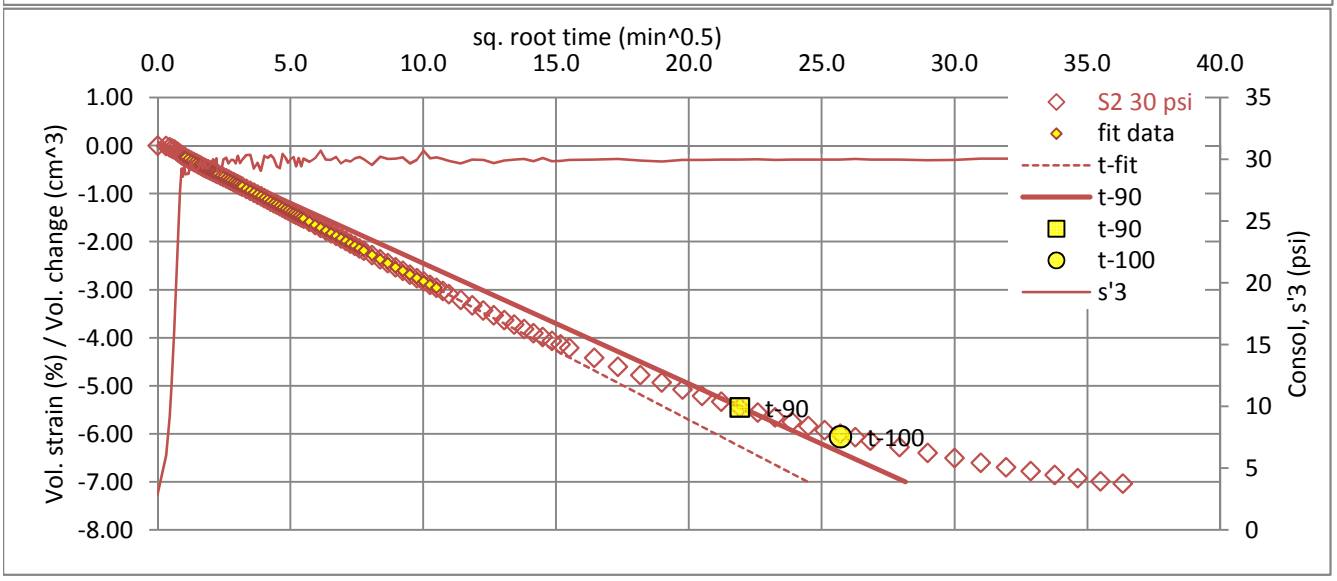
Triaxial Test - Isotropic Consolidated Sheared Undrained
Measuring Pore Pressure (CIU-PP) *- After ASTM D4767 and USBR 5750*

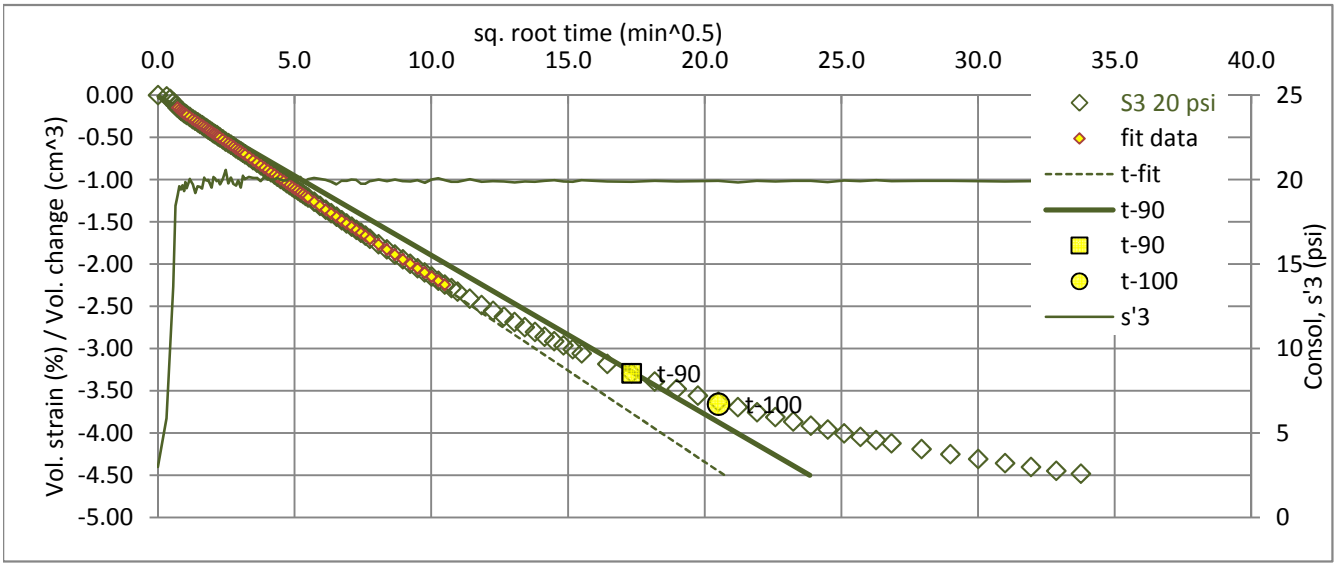
GERHART COLE

Project: Bear River - Above Cutler **TH/TP/Sample: TH-CUT-03**
No: 13GCI329 **Depth: 30-31.5**

Time rate of consolidation data and analysis







Laboratory Compaction Characteristics of Soil
(ASTM D698 / D1557)

GERHART COLE

Project: Bear River
No: 13GCI329
Date: 30-Sep-14
Tested by: zg
Reduced by: zg
Reviewed by: dab

TH/TP/Sample: TH-CUT-03
Depth: 15-16.5
Location: **Cache County, UT**
Comments: Used Harvard mini compaction device. Spring = 20 lb, 4 layers, 25 blows per layer.

Test Summary

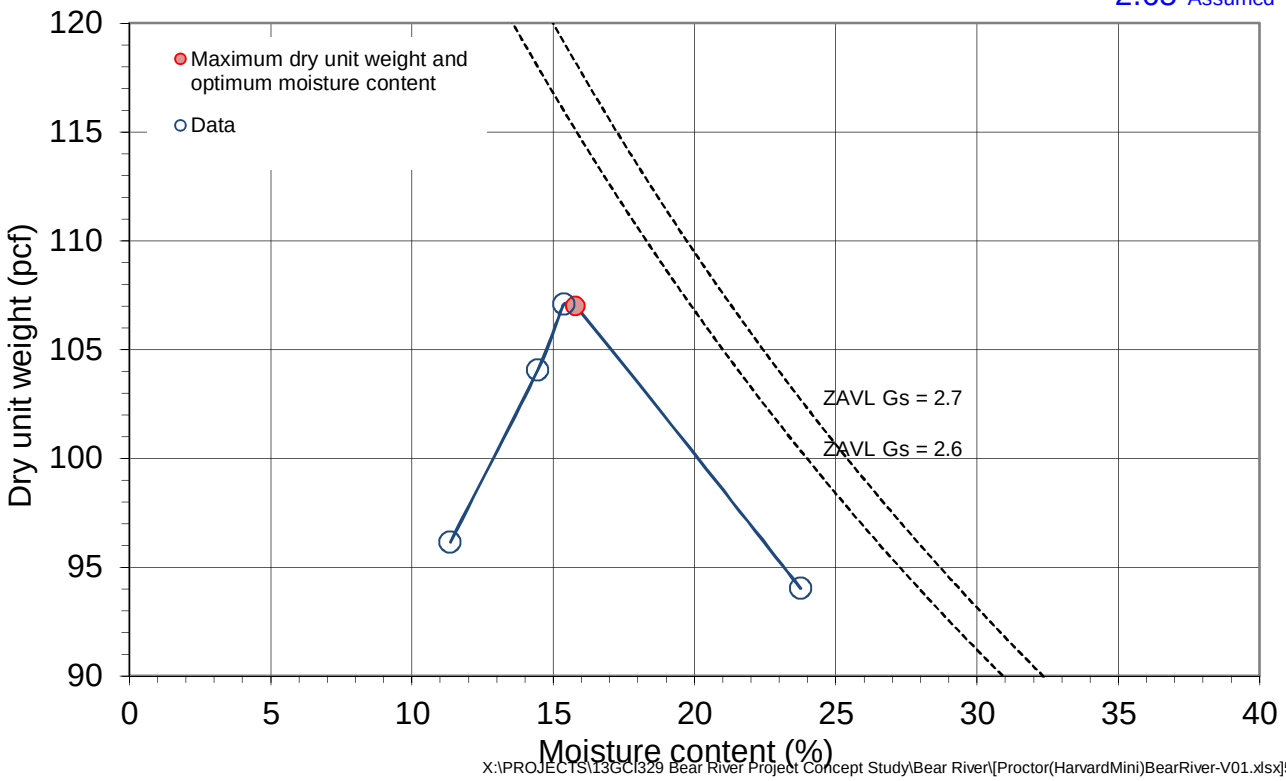
Method: Harvard Mini
Mold volume (ft^3): 0.0022

Optimum moisture content (%): 15.8
Maximum dry unit weight (pcf): 107

Sample Description: --
Engineering Classification: CL
As-received moisture content (%): Not requested
Preparation method: Moist
Rammer: Manual
Rock Correction: No

Point Number	16	20	14	18
Wt. mold + wet soil (g)	538.0	535.3	526.1	542.5
Wt. mold (g)	419.08	419.08	419.08	419.08
Moist unit wt., gd (pcf)	119.1	116.4	107.1	123.5
Wet soil + tare (g)	28.44	24.76	27.8	26.81
Dry soil + tare (g)	26.65	22.7	26.39	25.1
Tare (g)	14.26	14.03	13.98	13.98
Moisture content, w (%)	14.4	23.8	11.4	15.4
Dry unit wt., gd (pcf)	104.0	94.0	96.1	107.1

2.65 Assumed



Pinhole Dispersion Test

After ASTM D4647 and USBR 5410

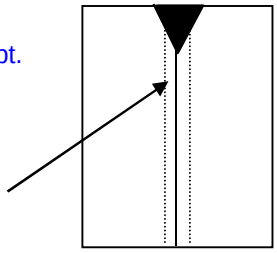
GERHART COLE

Project: **Bear River**
No: **13GCI329**
Location: Cache County, Utah
Date: 17-Oct-14
Tested by: zg
Reduced by: zg
Checked by: dab

TH/TP/Sample: **TH-CUT-03**
Depth: **15-16.5**
Sample description: dark brown clay
USCS classification: CL

Test type / method: A
Sample type: remolded
Moisture content (%): 14.2
Dry unit weight (pcf): 103.1

Compaction specifications: 95% of opt.
Target moisture content (%): 16
Target dry unit weight (pcf): 102
Specimen After Test
Final Hole (mm): 1.0



Dispersive Classification: **ND1 - Nondisperisve**

Clock Time	Head (in)	Flow			Turbidity From Side						Completely Clear From Top	Particles Falling			Remarks
		ml	sec	Rate (ml/sec)	Very Dark	Dark	Moderately Dark	Slightly Dark	Barely Visible	Completely Clear		None	Few	Heavy	
16:10	2	12.0	60	0.2					X			X			
	2	13.0	60	0.2					X			X			
	2	14.0	60	0.2					X			X			
	2	15.0	60	0.3						X		X			
	2	15.0	60	0.3						X		X			
16:19	7	34.0	60	0.6					X			X			
	7	36.0	60	0.6						X		X			
	7	36.0	60	0.6						X		X			
16:24	15	60.0	60	1.0						X		X			
	15	62.0	60	1.0						X		X			
	15	63.0	60	1.1						X		X			
	15	64.0	60	1.1						X		X			
	15	64.0	60	1.1						X		X			
16:35	40	89.0	45	2.0						X		X			
	40	91.0	45	2.0						X		X			
	40	93.0	45	2.1						X		X			
	40	93.0	45	2.1						X		X			
	40	94.0	45	2.1						X		X			

CHAPTER 9

LITHOS TUNNELING INFORMATION

LITHOS ENGINEERING

12567 W. Cedar Drive, Suite 104
Lakewood, Colorado 80228
303.625.9502
www.LithosEng.com

April 24, 2017
Project No. 17028-0

Bowen Collins & Associates
154 14000 S
Draper UT 84020

Attention: Mr. Thayne Clark, P.E., Principal

Regarding: Proposed Bear River Tunnels ROM Cost
Garland, Utah

Mr. Clark:

The purpose of this letter is to provide a rough order of magnitude (ROM) cost estimate for two proposed tunnels located northwest of Garland, Utah in response to your email dated April 11, 2017. We have reached out to several contractors and cost estimating resources to develop conceptual means and methods and associated ROM costs. We understand the details of the proposed tunnels are sensitive and have not disclosed owner, engineer, or specific project name information while preparing this estimate.

Project Background

The project involves delivering raw water from a proposed reservoir in the Whites Valley south to near UT-305 and then east to the Bear River Valley near Garland, Utah. Two tunnels may be necessary: one as part of the dam outlet works and another beneath the West Hills and Cal Mountain. For the purposes of this estimate, we have assumed the following parameters:

- Two tunnels at 18,000 ft and 1,000 ft long;
- 10 ft finished diameter, pressurized and mortar lined;
- No shafts. The portals are at-grade through colluvium and slope wash;
- Moderately to highly fractured limestone/sandstone with strengths between 14-34 KSI;
- Faults zones and chert layers may be encountered;
- No groundwater; and
- Overburden ranges from 0 - 1,500 ft.

Note each of the assumptions above have extreme implications for cost. The sizing of the tunnel drives the type and size of equipment. Shafts may increase the total project cost by 5-20%, depending on complexity and depth. The fractured nature of the material and high overburden stress drives whether the rock can support itself upon excavation or if initial support consisting of a combination of steel ribs, wooden lagging, rock bolts, shotcrete, mesh, and other elements erected with or without a shield is necessary. In addition, material parameters affect the type of excavation equipment, be it drill and blast or a type of tunnel boring machine (TBM), as well as the excavation rate for the equipment.

Means and Methods

Understanding that site specific geotechnical data is necessary to refine means and methods, conceptual tunneling methods include TBM and drill and blast. A TBM will be most efficient for the longer tunnel. The type of TBM, including single shield, double shield, or main beam, will depend on ground conditions and the degree to which the rock can safely and adequately support itself or require time-consuming and

costly initial support. A double shield is optimal in that flexibility is allowed in the initial support and thus excavation rate; however, a main beam TBM generally has a higher excavation rate as it requires less support in suitable ground conditions. A TBM has a large power demand and higher operating cost; however, the cost is generally balanced by the higher excavation rate.

Drill and blast techniques may be more cost-effective for the shorter tunnel. Drill and blast generally carries more safety risks and is slower, but the lower cost of equipment and lower power demands make it cost-effective for shorter lengths. A TBM may also be used for the shorter tunnel.

The geotechnical investigation for the tunnels may include, as a minimum, large-scale geological mapping, horizontal and vertical borings, and surface-based geophysics near the tunnel portals. The data obtained from this investigation will enable a contractor to develop and propose suitable means and methods in coordination with and suitable to the tunnel engineer's design.

Costing

Lithos has obtained a range of ROM cost estimates from $83.6 to $134.6 million for the completion of both tunnels using current day rates. Due to the ever-increasing cost of material and labor, these rates are subject to increase by a typical construction inflation cost index of 4% per year The table below presents a summary of present-day costs:

Source	Cost ($/lineal foot)	Total Tunneling Cost (million)	Note
Peregoy Estimating Services	6,780 (long tunnel) 12,600 (short tunnel)	$134.6	Independent tunnel estimator. Proposes TBM for long tunnel and drill and blast for short tunnel.
Michels Corp.	4,070 – 8,350	$118.0*	Large Utility contractor. Numbers based on Earth Pressure Balance excavation.
Pacific Boring	4,500	$85.5	Contractor. TBM proposed.
SAK	4,200 – 4,600	$83.6*	Contractor. TBM proposed.

*Average cost-per-foot values used

Closure

Should you or the owner have any questions regarding the information contained in this letter, or wish to pursue more-in depth analysis, please feel free to contact the undersigned at benny@lithoseng.com or 303.590.8306. We look forward to seeing this project succeed and to discussing ways in which we can bring value to your team.

Sincerely,

Lithos Engineering

Ryan Marsters, PE, PG
Senior Associate

Benny Siljenberg, PE
Vice President

LITHOS ENGINEERING

CHAPTER 10

DETAILED COST ESTIMATES AND PIPELINE UNIT COSTS

Bear River Development
Main Conveyance Pipelines Cost Estimates

TABLE A-10.1

Last Update: *11/22/17*

Bear River Pipeline - Fielding to West Haven WTP -

Cost Item	EQUIV. LENGTH QTY	EQUIV. UNIT*	UNIT PRICE	ACTUAL LENGTH (LF)	TOTAL	Comments
Fielding to West Haven Pipeline Reaches	279,774			217,498		
144" Fielding PS Pipeline	4,189	Eq.LF	$2,195	3,580	$9,200,000	pump station suction pipe
120" Fielding PS Pipeline	1,849	Eq.LF	$1,562	1,580	$2,890,000	pump station discharge pipe
114" Fielding Junction Vault to Brigham City	140,728	Eq.LF	$1,436	112,958	$202,040,000	
Land Acquisition Cost	1	LS	$24,980,000		$24,980,000	
90" Brigham to Willard	60,810	Eq.LF	$1,024	45,190	$62,270,000	
Land Acquisition Cost	1	LS	$10,000,000		$10,000,000	
90" Willard to West Haven WTP	78,235	Eq.LF	$1,024	59,351	$80,110,000	proposed main alignment
Land Acquisition Cost	1	LS	$6,330,000		$6,330,000	
Ancillary Facilities						
Metered Turnouts	1	LS	$800,000		$800,000	
Valve Vault	1	LS	$800,000		$800,000	
				TOTAL	**$ 399,420,000**	

ADDER for 40k AF Fielding Reservoir (Pump Station to Junction Box)

Cost Item	EQUIV. LENGTH QTY	EQUIV. UNIT*	UNIT PRICE	ACTUAL LENGTH (LF)	TOTAL	Comments
Pipeline Reach - Small Fielding to Jct Vault						
120" from 40kaf Fielding PS to Junction Vault	15,500	LF	$1,700	15,500	**$26,350,000**	add this amount for all Fielding 40k AF options

Bear River Pipeline - Fielding to South Willard Reservoir to West Haven WTP -

Cost Item	EQUIV. LENGTH QTY	EQUIV. UNIT*	UNIT PRICE	ACTUAL LENGTH (LF)	TOTAL	Comments
Fielding to West Haven Pipeline Reaches	291,463			227,473		
144" Fielding PS Pipeline	4,189	Eq.LF	$2,195	3,580	$9,200,000	pump station suction and discharge pipes
120" Fielding PS Pipeline	1,849	Eq.LF	$1,562	1,580	$2,890,000	pump station suction and discharge pipes
114" Fielding Junction Vault to Brigham City	140,728	Eq.LF	$1,436	112,958	$202,040,000	
Land Acquisition Cost	1	LS	$24,980,000		$24,980,000	
90" Brigham to Willard	60,810	Eq.LF	$1,024	45,190	$62,270,000	
Land Acquisition Cost	1	LS	$10,000,000		$10,000,000	
90" Willard to South Willard Res to West Haven	89,925	Eq.LF	$1,024	69,325	$92,080,000	adjusted alignment to the west in power corridor
Land Acquisition Cost	1	LS	$25,720,000		$25,720,000	assumed land acquisition adjacent to power corridor
Ancillary Facilities						
Metered Turnouts	1	LS	$800,000		$800,000	
Valve Vault	1	LS	$800,000		$800,000	
				TOTAL	**$ 430,780,000**	

Whites Valley Pipeline - Fielding Reservoir Junction Vault to Whites Valley Dam

Cost Item	EQUIV. LENGTH QTY	EQUIV. UNIT*	UNIT PRICE	ACTUAL LENGTH (LF)	TOTAL	Comments
Pipeline Reach						
120" Fielding PS to Whites Valley Dam	98,489	Eq.LF	$1,562	92,070	$153,840,000	Option 3
Land Acquisition Cost	1	LS	$3,860,000		$3,860,000	
				TOTAL	**$ 157,700,000**	

LONGER Cache County Connection Pipeline (for Fielding 70k AF Option)

Cost Item	EQUIV. LENGTH QTY	EQUIV. UNIT*	UNIT PRICE	ACTUAL LENGTH (LF)	TOTAL	Comments
Pipeline Reaches						
78" Fielding Junction Vault to Cutler	56,791	Eq.LF	$840	46,967	$47,710,000	
Metered Connection to Junction Vault	1	LS	$225,000		$225,000	includes valve & flow meter vault
Land Acquisition Cost	1	LS	$2,260,000		$2,260,000	
				TOTAL	**$ 50,195,000**	

SHORTER Cache County Connection Pipeline (for Fielding 40k AF Option)

Cost Item	EQUIV. LENGTH QTY	EQUIV. UNIT*	UNIT PRICE	ACTUAL LENGTH (LF)	TOTAL	Comments
Pipeline Reaches						
78" Fielding Junction Vault to Cutler	41,291	Eq.LF	$840	31,467	$34,690,000	USING EST. LF BETWEEN 40k & 70k DAMS
Metered Connection to Junction Vault	1	LS	$225,000		$225,000	includes valve & flow meter vault
Land Acquisition Cost	1	LS	$2,260,000		$2,260,000	
				TOTAL	**$ 37,175,000**	

** Equivalent Length (Eq.LF) represents a cost weighted length for the pipeline, based on cost factors such as utilities, etc.*

Bear River Development
Pump Station Cost Estimating

TABLE A-10.2

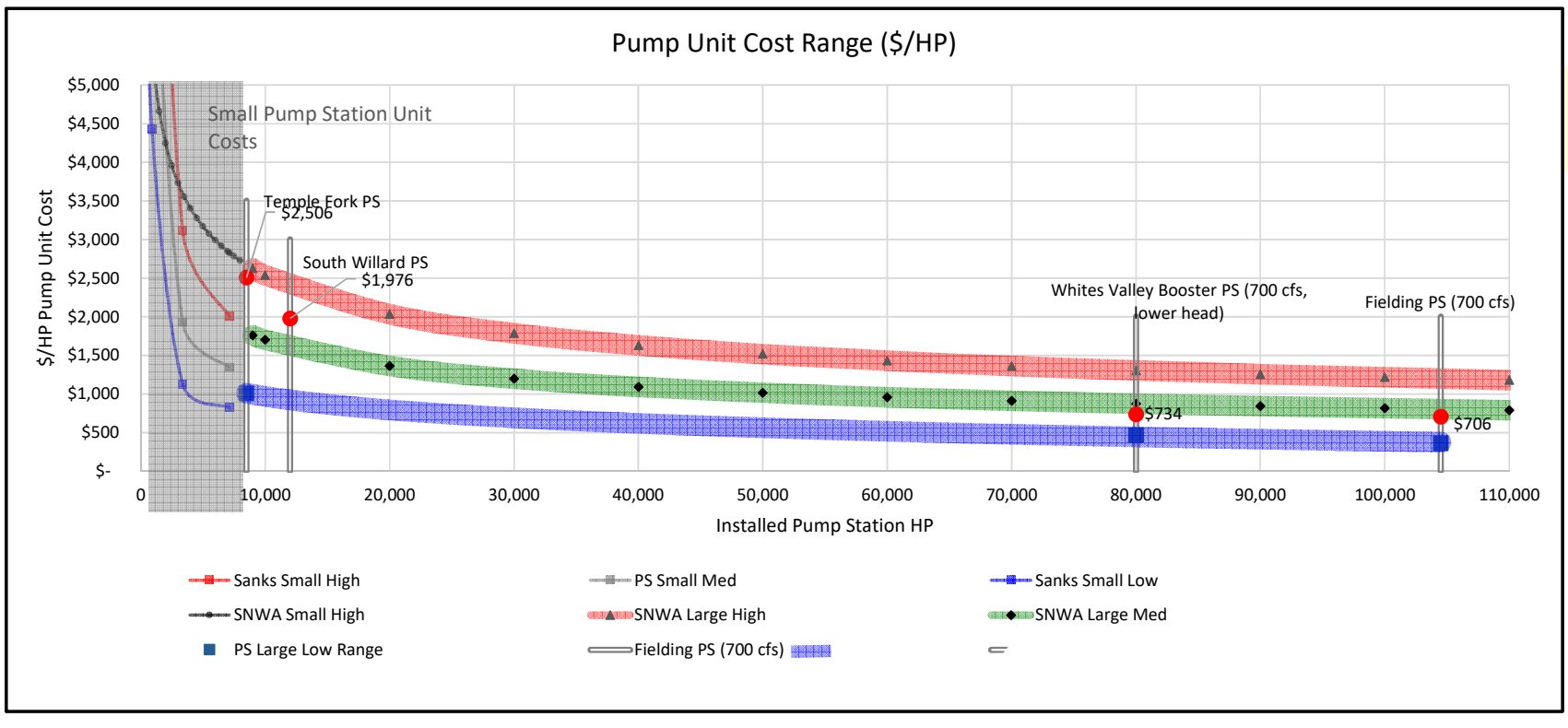
Last Update: *11/22/17*

Bear River Pump Station Costs

Cost Item	TOTAL INSTALLED HP*	UNIT		UNIT PRICE	TOTAL PS COST	Comments
Fielding PS (700 cfs)	104,500	HP	Est:	**$706**	**$73,777,000**	Cost Estimate, Calc'd $/HP
Whites Valley Booster PS (700 cfs, lower head)	80,000	HP	Est:	**$734**	**$58,708,000**	Cost Estimate, Calc'd $/HP
Temple Fork PS	8,500	HP	Est:	**$2,506**	**$21,300,000**	Cost Estimate, Calc'd $/HP (includes power)
South Willard PS	12,000	HP	Est:	**$1,976**	**$23,717,000**	Cost Estimate, Calc'd $/HP (includes power)

0 * Installed HP determined by peak flow, reservoir max WSE, pump size variabilities, and back-up pump (redundancy) needs

2000 HP shown will vary from final required pump station HP, due to changes in final reservoir head and peak flow



Bear River Development **TABLE A-10.3**

Fielding Reservoir (70k AF) Facilities Cost

Last Update: *08/30/17*

70k AF Fielding Reservoir					
Cost Item	**QTY**	**UNIT**	**UNIT PRICE**	**TOTAL**	**Comments**
Dam & Reservoir Facilities (70,000 AC-FT)			**Subtotal**	**$76,728,000**	
Clear and Grub Dam Footprint	720,000	SF	$0.25	$180,000	
Cutoff Trench Excavation	40,000	CY	$5.00	$200,000	
Embankment Earthwork					
Embankment Shell Zone	630,000	CY	$6.00	$3,780,000	source: reservoir basin/slopes, some processing & dryi
Filter Zone	170,000	CY	$48.00	$8,160,000	source: assume imported from < 20mi RT
Clay Core Zone	150,000	CY	$8.50	$1,275,000	source: reservoir basin, some processing & lots of dryir
Riprap Shell (upstream)	50,000	CY	$49.00	$2,450,000	source: assume imported from < 50mi RT
Crest Road Material	1,000	CY	$25.00	$25,000	source: assume imported from < 20mi RT
Dam Construction Dewatering & River Control	1	LS	$1,100,000	$1,100,000	
Toe Drain & Drain Collection System	1	LS	$200,000	$200,000	
Monitor Wells & Piezometers	12	EA	$15,000	$180,000	
Spillway					
Channel Excavation	1,600,000	CY	$5.00	$8,000,000	
Seepage Cutoff Wall (CB)	44,000	SF	$20.00	$880,000	assume 80' deep 30" slurry trench
Foundation Stabilization	1	LS	$2,000,000	$2,000,000	piers or other stabilization approach
Chute Concrete Work	5,462	CY	$800	$4,370,000	
Radial Gates	6	EA	$1,200,000	$7,200,000	30'x30' radial gates installed
Radial Gate Structure/Concrete	2,900	CY	$800	$2,320,000	
Stilling Basin Concrete	2,200	CY	$800	$1,760,000	
Plunge Pool Excavation	5,000	CY	$5.00	$25,000	250'x50'x10'
Rip Rap	60,000	CY	$49.00	$2,940,000	source: assume imported from < 50mi RT
Outlet Works					
Outlet Tower Structure & Gate	1	LS	$1,520,000	$1,520,000	
Outlet Tunnel	850	LF	$8,000	$6,800,000	10' diameter - from guard gate to pipe
Outlet to River Flow Control/Metering Structure	1	LS	$615,000	$615,000	River Flow & Emergency reservoir drain
Energy Dissipation Structure to River	1	LS	$250,000	$250,000	
Dam Instrumentation & Controls	1	LS	$250,000	$250,000	level sensors, piezos, gate sensors, gen SCADA
Reservoir & Miscellaneous Facilities					
Access Road to Dam and Pump Station	1	LS	$800,000	$800,000	
Maintenance Building	4,800	SF	$120	$576,000	
Maintenance Building Electric	1	EA	$72,000	$72,000	
Road Relocations & Bridge in Reservoir Area	1	LS	$10,300,000	$10,300,000	large bridge required Hwy 30
Utility & Structure Buy-Outs in Reservoir Area	1	LS	$6,200,000	$6,200,000	
Clear and Grub Reservoir Area	1	LS	$300,000	$300,000	
Inlet					
Inlet Flow Control Vault & Energy Dissipation	1	LS	$2,000,000	$2,000,000	to bypass the hydropower
Land Acquisition & Wetland Mitigation			**Subtotal**	**$34,627,000**	
Reservoir Area + 20%	2,040	AC	$2,366	$4,827,000	
Wetland Mitigation Estimate	298	AC	$100,000	$29,800,000	
			TOTAL	**$ 111,355,000**	does not include power cost in this number

Bear River Development
Fielding Reservoir (40k AF) Facilities Cost

TABLE A-10.4

Last Update: *08/30/17*

40k AF Fielding Reservoir					
Cost Item	**QTY**	**UNIT**	**UNIT PRICE**	**TOTAL**	**Comments**
Dam & Reservoir Facilities (40,000 AC-FT)			**Subtotal**	**$151,447,000**	
Clear and Grub Dam Footprint	2,480,000	SF	$0.25	$620,000	
Cutoff Trench Excavation	140,000	CY	$5.00	$700,000	
Embankment Earthwork					
Embankment Shell Zone	2,030,000	CY	$6.00	$12,180,000	source: reservoir basin/slopes, some processing & dryi
Filter Zone	400,000	CY	$48.00	$19,200,000	source: assume imported from < 20mi RT
Clay Core Zone	550,000	CY	$8.50	$4,675,000	source: reservoir basin, some processing & lots of dryir
Riprap Shell (upstream)	170,000	CY	$49.00	$8,330,000	source: assume imported from < 50mi RT
Crest Road Material	2,000	CY	$25.00	$50,000	source: assume imported from < 20mi RT
Dam Construction Dewatering & River Control	1	LS	$1,300,000	$1,300,000	
Toe Drain & Drain Collection System	1	LS	$250,000	$250,000	
Monitor Wells & Piezometers	18	EA	$15,000	$270,000	
Spillway					
Channel Excavation	3,900,000	CY	$5.00	$19,500,000	
Seepage Cutoff Wall (CB)	144,000	SF	$20.00	$2,880,000	assume 80' deep 30" slurry trench
Chute Concrete Work	4,200	CY	$800	$3,360,000	
Foundation Stabilization	1	LS	$2,000,000	$2,000,000	piers or other stabilization approach
Radial Gates	6	EA	$1,200,000	$7,200,000	30'x30' radial gates installed
Radial Gate Structure/Concrete	2,900	CY	$800	$2,320,000	
Stilling Basin Concrete	2,175	CY	$800	$1,740,000	
Plunge Pool Excavation	5,000	CY	$5.00	$25,000	
Rip Rap	82,000	CY	$49.00	$4,018,000	source: assume imported from < 50mi RT
Outlet Works					
Outlet Tower Structure & Gate	1	LS	$1,520,000	$1,520,000	
Outlet Tunnel	2,000	LF	$8,000	$16,000,000	10' diameter - from guard gate to pipe
Outlet to River Flow Control/Metering Structure	1	LS	$615,000	$615,000	River Flow & Emergency reservoir drain
Energy Dissipation Structure to River	1	LS	$250,000	$250,000	
Dam Instrumentation & Controls	1	LS	$250,000	$250,000	level sensors, piezos, gate sensors, gen SCADA
Reservoir & Miscellaneous Facilities					
Access Road to Dam and Pump Station	1	LS	$800,000	$800,000	
Maintenance Building	4,800	SF	$120	$576,000	
Maintenance Building Electric	1	EA	$72,000	$72,000	
Road Relocations in Reservoir Area	1	LS	$5,100,000	$5,100,000	
Canal Relocation (10' Dia Pipe)	2,400	LF	$1,500	$3,600,000	
Highway Bridge Over Spillway	1	LS	$5,000,000	$5,000,000	
Utility & Structure Buy-Outs in Reservoir Area	1	LS	$3,200,000	$3,200,000	
Clear and Grub Reservoir Area	1	LS	$150,000	$150,000	
OTHER					
Inlet Flow Control Vault & Energy Dissipation	1	LS	$2,000,000	$2,000,000	to bypass the hydropower
Pipeline from 40kaf Fielding PS to Junction	13,560	LF	$1,600	$21,696,000	10' diameter buried pipeline
Land Acquisition & Wetland Mitigation			**Subtotal**	**$18,080,000**	
Reservoir Area + 20%	1,344	AC	$2,366	$3,180,000	
Wetland Mitigation Estimate	149	AC	$100,000	$14,900,000	
			TOTAL	**$ 169,527,000**	does not include power cost in this number

Bear River Development
Pump Station at Fielding Cost

TABLE A-10.5

Last Update: *11/16/17*

Pump Station at Fielding (700 cfs & 104,500 HP)

Cost Item	QTY	UNIT	UNIT PRICE	TOTAL	Comments
Pump Station	Cost / HP = $706		**Subtotal**	**$73,777,000**	
Site Work	1	LS	$2,100,000	$2,100,000	
Pump Station Structure & Control Building	30,000	SF	$200	$6,000,000	About 340' x 88' sized building
Foundation Stabilization	1	LS	$1,200,000	$1,200,000	
Bridge Crane	1	EA	$950,000	$950,000	
Pumps, Motors, and Cans	1	LS	$29,831,000	$29,831,000	see backup calcs for breakdown
Concrete Encasement of Cans	1	LS	$279,486	$280,000	
Mechanical, Valves, & Piping	1	LS	$10,464,000	$10,464,000	see backup calcs for breakdown
Surge Protection Facilities	1	LS	$5,000,000	$5,000,000	
Electrical & Controls	1	LS	$10,150,000	$10,150,000	
RMP Impact Study	1	EA	$500,000	$500,000	
RMP Substation	1	EA	$6,000,000	$6,000,000	60 MVA
Power Line	3.1	MI	$420,000	$1,302,000	345 kV
Power Costs			**Subtotal**	**$0**	
Pump Power Costs			$0	$0	assumed to be part of project operations cost
Hydro Power Plant & Power Recovery			$0	$0	Not included in project cost
Land Acquisition & Wetland Mitigation			**Subtotal**	**$2,355,000**	
PS Site Area	150	AC	$2,366	$355,000	
Wetland Mitigation Estimate	20	AC	$100,000	$2,000,000	
			TOTAL	**$ 76,132,000**	

Fielding Pump Station Size Variations	Installed HP		$ per Installed HP	TOTAL	Comments
Horsepower 750 cfs	111,500	HP	$706	**$78,719,000**	Combinations A,B,C,E, F, G, J, K, L, M
Horsepower 590 cfs	52,900	HP	$706	**$37,348,000**	Combination I
Horsepower 590 cfs	90,000	HP	$706	**$63,540,000**	Combination I

Fielding Pump Station Power Costs

Global Assumptions:

		pump/motor efficiency	83%
598	ft TDH at peak	interest rate	3.00%
505	ft TDH at avg	period	20 yrs
		Energy Cost	$0.037 kWh (average annual rate)
		Peak Power Charge	$13.50 kW *
		Power Recovery	0% No significant recovery since flow mostly goes south to West Haven WTP

Last Update: *07/13/17*

* assumes 3 mo full peak, 6 mo 1/4 peak, 3 mo 1/10 peak

750 cfs Pump Station Power Cost			**Subtotal**	**$106,835,000**	Present Cost
Pump Power Costs	750	cfs	61,600	peak hp	peak PS flow & HP
Inputs	250	cfs	17,400	avg hp	average annual flow rate & hp
Annual Energy Use / Cost	113,662,600	kWh		$4,206,000	energy cost
Annual Peak Power Use / Cost	45,900	kW		$2,975,000	peak power charge/month *
			Annual Energy Cost	**$7,181,000**	per year @ average operation
			Present Worth	$106,835,000	present worth of power consuption cost
			Hydro Power Plant & Power Recovery	$0	
			Total Annual Energy Cost	**$106,835,000**	Present Cost

590 cfs Pump Station Power Cost			**Subtotal**	**$34,010,000**	Present Cost
435	ft TDH at peak				
83	ft TDH at avg				
Pump Power Costs	590	cfs	35,300	peak hp	peak PS flow & HP
Inputs	204	cfs	2,400	avg hp	average annual flow rate & hp
Annual Energy Use / Cost	15,677,600	kWh		$581,000	energy cost
Annual Peak Power Use / Cost	26,300	kW		$1,705,000	peak power charge/month *
			Annual Energy Cost	**$2,286,000**	per year @ average operation
			Present Worth	$34,010,000	present worth of power consuption cost
			Hydro Power Plant & Power Recovery	$0	
			Total Annual Energy Cost	**$34,010,000**	Present Cost

Bear River Development **TABLE A-10.6**

Whites Valley Reservoir (170k AF) Facilities Cost

Last Update: *08/30/17*

170k AF Whites Valley Reservoir					
Cost Item	**QTY**	**UNIT**	**UNIT PRICE**	**TOTAL**	**Comments**
Dam Facilities (170,000 AC-FT)			**Subtotal**	**$84,016,000**	
Clear and Grub Dam Footprint	1,020,000	SF	$0.25	$255,000	
Overburden Mass Excavation (footprint of dam)	830,000	CY	$5.00	$4,150,000	includes clay core excavation and 24' overburden excav
Bedrock Foundation Prep / Dental Grout	3,145	CY	$200	$629,000	assume 4" of grout on average on 25% of footprint
Embankment Earthwork					
Rockfill Zone 3	2,770,000	CY	$5.00	$13,850,000	source: reservoir basin, no processing
Transition Zone 2	850,000	CY	$6.50	$5,525,000	source: reservoir basin, some processing
Filter/Drain Zones	380,000	CY	$48.00	$18,240,000	source: assume imported from < 20mi RT
Clay Core Zone 1	750,000	CY	$7.50	$5,625,000	source: reservoir basin, some processing
Riprap Shell (upstream)	70,000	CY	$49.00	$3,430,000	source: assume imported from < 50mi RT
Crest Road Material	1,000	CY	$25.00	$25,000	source: assume imported from < 20mi RT
Foundation Grout Curtain	1	LS	$2,800,000	$2,800,000	GCI: Depth=80', spacing=10', length=1550'
Toe Drain & Drain Collection System	1	LS	$200,000	$200,000	
Monitor Wells & Piezometers	14	EA	$20,000	$280,000	
Reservoir Basin Seepage Reduction Blanket	823,000	CY	$7.50	$6,173,000	3 ft thick, onsite clay
Clear and Grub Blanket Footprint	170	AC	$2,178	$371,000	
Power Supply to Dam Site	8.25	MI	$76,000	$627,000	12.47 kV Line
Dam Access/County Roads Cut Vol	160,000	CY	$10.00	$1,600,000	assume 20' wide road, 50% rock rippable exc., no haul
Dam Access/County Roads Gravel Vol	20,000	CY	$25.00	$500,000	assume 6" of gravel on 20' wide road
Spillway					
Rock & Channel Excavation & Rip Rap	1	LS	$810,000	$810,000	
Concrete Work	700	CY	$650	$455,000	includes walls, sill, cutoff, 50 ft chute floor
Outlet Works					
Inlet/Outlet Structure & Gate	1	LS	$1,270,000	$1,270,000	dual structure - for inlet and outlet from reservoir
Upstream Inlet/Outlet Tunnel	470	LF	$12,600	$5,922,000	10' diam bore tunnel
Downstream Inlet/Outlet Tunnel	455	LF	$18,900	$8,600,000	larger bore tunnel (15')
Downstream Inlet/Outlet Pipe and Supports	455	LF	$865	$394,000	cost of pipe, supports, walkway, lighting, etc.
General Excavation & Site Work	1	LS	$350,000	$350,000	intake & control building
Bulkhead	1	EA	$120,000	$120,000	joining upstream tunnel with downstream pipe
Outlet Flow Control Structure					
Flow Control Valve & Meter Vault	1	LS	$615,000	$615,000	Emergency reservoir drain
Bypass to Stream Energy Dissapation Struct.	1	LS	$250,000	$250,000	Emergency reservoir drain
Pig Launch & Main Flow Meter Vault	1	LS	$700,000	$700,000	
Instrumentation & Controls	1	LS	$250,000	$250,000	level sensors, piezos, gate sensors, gen SCADA
Junction Valve Vault (NO Cache connection)			**Subtotal**	**$3,594,000**	
Main Vault Structure	1	LS	$1,500,000	$1,500,000	includes site work, excavation, mechanical
Flow Meter Vault	1	LS	$200,000	$200,000	stand-alone vault
Pig Launch & Meter Structure (to the BRP)	1	LS	$675,000	$675,000	stand-alone vault
Pig Launch & Meter Structure (to the Whites)	1	LS	$750,000	$750,000	stand-alone vault
Electrical & Controls	1	LS	$469,000	$469,000	combined EI&C cost
WV Booster Pump Station (700 cfs lower head)	Cost / HP = $734		**Subtotal**	**$58,708,000**	Varies based on PS total hp req'd to Wvalley
Site Work	1	LS	$1,200,000	$1,200,000	
Intake Screens	1	LS	$750,000	$750,000	
Yard Piping	1	LS	$850,000	$850,000	
Bridge Crane	1	EA	$750,000	$750,000	
Pump Station Building	17,100	SF	$200	$3,420,000	About 195' x 88 ' size building
Pumps, Motors & Cans	10	EA	$2,277,000	$22,770,000	
Concrete Encasement of 96" Cans	1	LS	$118,000	$118,000	
Mechanical ,Valves & Piping	1	LS	$5,910,000	$5,910,000	see backup calcs for specifics
Surge Protection Facilities	1	LS	$4,000,000	$4,000,000	
PS Electrical & Controls	1	EA	$7,240,000	$7,240,000	Includes pump station and maintenance building
RMP Impact Study	1	EA	$500,000	$500,000	
RMP Substation	1	EA	$8,000,000	$8,000,000	75 MVA
Power Line	8.00	MI	$400,000	$3,200,000	230 kV
Whites Valley Booster Pump Station Site Facilities			**Subtotal**	**$13,647,000**	Assume same cost regardless of pump size
Site Work	1	LS	$500,000	$500,000	
Pump/Hydro Station Access Road	1	LS	$250,000	$250,000	
Misc. Yard Piping	3,000	LF	$200	$600,000	
Maintenance Building	8,000	SF	$120	$960,000	
Maintenance Building Electrical	1	EA	$72,000	$72,000	
Main Flow Meter Vault	1	LS	$200,000	$200,000	
Bypass/Holding Lined Reservoir	38	ACRE	$170,000	$6,460,000	Includes excavation, fill, prep, and liner
Flow Control Valve (into reservoir)	1	LS	$2,000,000	$2,000,000	to bypass the hydropower
Pig Retrieval Structure (from Whites)	1	LS	$750,000	$750,000	dump to reservoir
Pig Exit Structure (from Jct Vault)	1	LS	$300,000	$300,000	
Pig Waste Reducing Valve Vault	1	LS	$220,000	$220,000	
Pig Waste Inflow Boxes (to reservoir)	1	LS	$125,000	$125,000	
Reservoir/Site Electrical & Controls	1	LS	$1,210,000	$1,210,000	
Pump Power Costs			**Subtotal**	**$0**	
See Whites Valley PS Power Cost Calcs					varies by combination/flow rate
Land Acquisition & Wetland Mitigation			**Subtotal**	**$6,810,000**	
Reservoir Area + 25%	2,500	AC	$1,500	$3,750,000	
Junction Valve Vault	20	AC	$3,000	$60,000	
Pump/Hydro Station & Reservoir Facility	200	AC	$2,000	$400,000	
Wetland Mitigation Estimate	26	AC	$100,000	$2,600,000	
			TOTAL	**$ 166,775,000**	does not include power cost in this number

Bear River Development

Whites Valley Reservoir (400k AF) Facilities Cost

TABLE A-10.7

Last Update: *11/09/17*

400k AF Whites Valley Reservoir					
Cost Item	**QTY**	**UNIT**	**UNIT PRICE**	**TOTAL**	**Comments**
Dam Facilities (400,000 AC-FT)			**Subtotal**	**$117,418,000**	
Clear and Grub Dam Footprint	1,890,000	SF	$0.25	$473,000	
Overburden Mass Excavation (footprint of dam)	1,860,000	CY	$5.00	$9,300,000	includes clay core excavation and 24' overburden excav
Bedrock Foundation Prep / Dental Grout	5,828	LS	$200	$1,166,000	assume 4" of grout on average on 25% of footprint
Embankment Earthwork					
Rockfill Zone 3	6,840,000	CY	$5.00	$34,200,000	source: reservoir basin, no processing
Transition Zone 2	2,140,000	CY	$6.50	$13,910,000	source: reservoir basin, some processing
Filter/Drain Zones	1,000	CY	$48.00	$48,000	source: assume imported from < 20mi RT
Clay Core Zone 1	1,330,000	CY	$7.50	$9,975,000	source: reservoir basin, some processing
Riprap Shell (upstream)	130,000	CY	$49.00	$6,370,000	source: assume imported from < 50mi RT
Crest Road Material	2,000	CY	$25.00	$50,000	source: assume imported from < 20mi RT
Foundation Grout Curtain	1	LS	$4,600,000	$4,600,000	GCI: Depth=100', spacing=10', length=2310'
Toe Drain & Drain Collection System	1	LS	$250,000	$250,000	
Monitor Wells & Piezometers	14	EA	$26,000	$364,000	
Reservoir Basin Seepage Reduction Blanket	947,000	CY	$7.50	$7,103,000	3 ft thick, onsite clay
Clear and Grub Blanket Footprint	195	AC	$2,178	$426,000	
Power Supply to Dam Site	8	MI	$400,000	$3,300,000	12.47 kV Line
Dam Access/County Roads Cut Vol	158,000	CY	$10.00	$1,580,000	assume 20' wide road, 50% rock rippable exc., no haul
Dam Access/County Roads Gravel Vol	20,000	CY	$25.00	$500,000	assume 6" of gravel and 20' wide road
Spillway					
Rock & Channel Excavation & Rip Rap	1	LS	$891,000	$891,000	
Concrete Work	735	CY	$650	$478,000	
Outlet Works					
Inlet/Outlet Structure & Gate	1	LS	$1,270,000	$1,270,000	dual structure - for inlet and outlet from reservoir
Upstream Inlet/Outlet Tunnel	670	LF	$12,600	$8,442,000	10' diam bore tunnel
Downstream Inlet/Outlet Tunnel	528	LF	$18,900	$9,980,000	larger bore tunnel (15')
Downstream Inlet/Outlet Pipe and Supports	528	LF	$865	$457,000	cost of pipe, supports, walkway, lighting, etc.
General Excavation & Site Work	1	LS	$350,000	$350,000	intake & control building
Bulkhead	1	EA	$120,000	$120,000	joining upstream tunnel to downstream pipe
Outlet Flow Control Structure					
Flow Control Valve & Meter Vault	1	LS	$615,000	$615,000	Emergency reservoir drain
Bypass to Stream Energy Dissapation Struct.	1	LS	$250,000	$250,000	Emergency reservoir drain
Pig Launch & Main Flow Meter Vault	1	LS	$700,000	$700,000	
Instrumentation & Controls	1	LS	$250,000	$250,000	level sensors, piezos, gate sensors, gen SCADA
Junction Valve Vault			**Subtotal**	**$3,594,000**	same as 170k AF estimate
Whites Valley Booster Pump Station					See Variable Whites Valley Booster PS table
Whites Valley Booster Pump Station Site Facilities			**Subtotal**	**$13,647,000**	same as 170k AF estimate
Pump Power Costs			**Subtotal**	**$0**	
See Whites Valley PS Power Cost Calcs					varies by combination/flow rate
Land Acquisition & Wetland Mitigation			**Subtotal**	**$8,802,000**	
Reservoir Area + 25%	3,828	AC	$1,500	$5,742,000	
Junction Valve Vault	20	AC	$3,000	$60,000	
Pump/Hydro Station & Reservoir Facility	200	AC	$2,000	$400,000	
Wetland Mitigation Estimate	26	AC	$100,000	$2,600,000	
			TOTAL	**$ 143,461,000**	does not include power cost in this number

Bear River Development **TABLE A-10.8**

Whites Valley Reservoir Various Sized Facilities Cost

Last Update: 11/22/17

Whites Valley Reservoir & Booster Pump Station - VARIOUS SIZES						Pump Station Peak HP **
Cost Item	**QTY**	**UNIT**	**UNIT PRICE**	**TOTALS ***	**Comments**	
305k AF			TOTAL	$101,090,000	**Combo H**	PS Redundancy %: 125% ***
Dam Facilities	305	k AF		$93,430,000	Using Trendline Equation	
Land Acquisition	3,375	AC	$1,500	$5,060,000	Reservoir Area + 25%	
Pump Station	85,000	HP	$734	$62,380,000	installed HP @ $/HP calc'd from 170kaf pump	Calc'd HP: 68,000
309k AF			TOTAL	$101,740,000	**Combo F**	
Dam Facilities	309	k AF		$94,030,000	Using Trendline Equation	
Land Acquisition	3,406	AC	$1,500	$5,110,000	Reservoir Area + 25%	
Pump Station	85,100	HP	$734	$62,450,000	installed HP @ $/HP calc'd from 170kaf pump	Calc'd HP: 68,100
319k AF			TOTAL	$103,360,000	**Combo G**	
Dam Facilities	319	k AF		$95,600,000	Using Trendline Equation	
Land Acquisition	3,438	AC	$1,500	$5,160,000	Reservoir Area + 25%	
Pump Station	85,500	HP	$734	$62,740,000	installed HP @ $/HP calc'd from 170kaf pump	Calc'd HP: 68,400
330k AF			TOTAL	$105,350,000	**Combo B**	
Dam Facilities	330	k AF		$97,480,000	Using Trendline Equation	
Land Acquisition	3,513	AC	$1,500	$5,270,000	Reservoir Area + 25%	
Pump Station	86,100	HP	$734	$63,180,000	installed HP @ $/HP calc'd from 170kaf pump	Calc'd HP: 68,900
333k AF			TOTAL	$105,910,000	**Combo E**	
Dam Facilities	333	k AF		$98,010,000	Using Trendline Equation	
Land Acquisition	3,531	AC	$1,500	$5,300,000	Reservoir Area + 25%	
Pump Station	86,400	HP	$734	$63,400,000	installed HP @ $/HP calc'd from 170kaf pump	Calc'd HP: 69,100
360k AF			TOTAL	$111,450,000	**Combo A**	
Dam Facilities	360	k AF		$103,370,000	Using Trendline Equation	
Land Acquisition	3,656	AC	$1,500	$5,480,000	Reservoir Area + 25%	
Pump Station	87,300	HP	$734	$64,070,000	installed HP @ $/HP calc'd from 170kaf pump	Calc'd HP: 69,800
400k AF					**Combo C**	
Pump Station	89,000	HP	$734	$65,310,000	installed HP @ $/HP calc'd from 170kaf pump	Calc'd HP: 71,200
540k AF			TOTAL	$188,010,000	**Combo J, L, M**	
Dam Facilities	540	k AF		$178,600,000	Using Trendline Equation + $10M	
Land Acquisition	4,538	AC	$1,500	$6,810,000	Reservoir Area + 25%	
Pump Station	94,000	HP	$734	$68,980,000	installed HP @ $/HP calc'd from 170kaf pump	Calc'd HP: 75,100
610k AF			TOTAL	$235,870,000	**Combo K**	
Dam Facilities	610	k AF		$226,240,000	Using Trendline Equation + $15M	
Land Acquisition	4,684	AC	$1,500	$7,030,000	Reservoir Area + 25%	
Pump Station	96,100	HP	$734	$70,520,000	installed HP @ $/HP calc'd from 170kaf pump	Calc'd HP: 76,900
Wetland Mitigation	26	AC	$100,000	**$2,600,000**	assume same wetland impact no matter the size	

* Common wetland mitigation unit cost included in each TOTAL

** Peak Pump Station HP from Whites Valley Booster Pump Station Power Costs Calcs

*** Redundancy percent based on initial design and layout of pump station for 170k ac-ft WV Dam

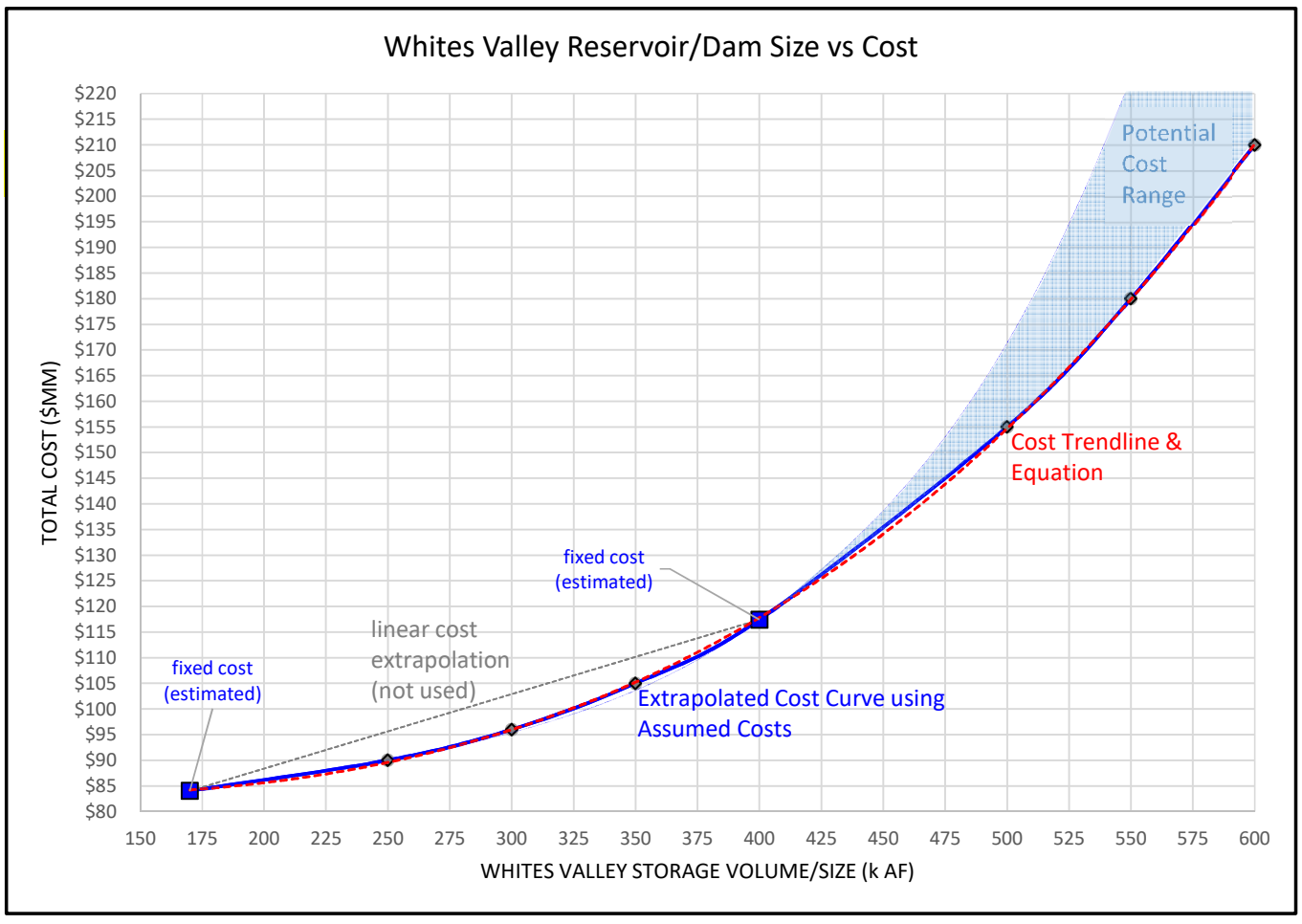
Estimated Cost

Assumed Cost

Storage (k AF)	Cost ($MM)	$/k AF	Trendline Equation *	cost per AF ($k)
170	$ 84.02	$ 0.49	$ 82.24	$484
250	$ 90.00	$ 0.36	$ 86.94	$348
300	$ 96.00	$ 0.32	$ 92.70	$309
350	$ 105.00	$ 0.30	$ 101.27	$289
400	$ 117.42	$ 0.29	$ 113.15	$283
500	$ 155.00	$ 0.31	$ 149.00	$298
550	$ 180.00	$ 0.33	$ 174.02	$316
600	$ 210.00	$ 0.35	$ 204.45	$341

* Utilizing trendline equation:

$y = 7E\text{-}07x^3 - 7E\text{-}05x^2 - 0.0055x + 81.754$



Bear River Development
Whites Valley Booster Pump Station Power Costs

TABLE A-10.9

Last Update: 11/09/17

Global Assumptions:

pump/motor efficiency	83%	
interest rate	3.00%	
period	20	yrs
Energy Cost	$0.037	kWh (average annual rate)
Peak Power Charge	$13.50	kW *
Power Recovery	50%	recover 50% of energy costs through hydropower (recovery includes both capital & energy)

$$hp = \frac{Q(cfs) * TDH(ft) * 62.4}{550 * \text{Pump eff } (\%)}$$

* assumes 3 mo full peak, 6 mo 1/4 peak, 3 mo 1/10 peak

Whites Valley Booster Pump Power Costs	360k AF			Combination A				
Pump Power Costs	680	cfs	69,800	peak hp	peak PS flow & HP	5,335	ft WSE Whites Valley Res	
Flow to WV	159	cfs	12,300	avg hp	average annual flow rate & hp	748	ft TDH at peak	
Annual Energy Use / Cost	80,347,700	kWh		$2,973,000	energy cost	562	ft TDH at avg	115,111 afy
Annual Peak Power Use / Cost	52,000	kW		$3,370,000	peak power charge/month *		All average TDHs assume WV Reservoir half full	
			Annual Energy Cost	**$6,343,000**				
			Present Worth	$94,368,000	present worth of power consuption cost			
	Hydro Power Plant & Power Recovery			($47,184,000)				
TOTAL Annual Energy Cost				**$ 47,184,000**	Present Cost			

Whites Valley Booster Pump Power Costs	330k AF			Combination B				
Pump Power Costs	680	cfs	68,900	peak hp	peak PS flow & HP	5,325	ft WSE Whites Valley Res	
Inputs	156	cfs	11,900	avg hp	average annual flow rate & hp	738	ft TDH at peak	
Annual Energy Use / Cost	77,734,800	kWh		$2,877,000		556	ft TDH at avg	112,939 afy
Annual Peak Power Use / Cost	51,400	kW		$3,331,000	peak power charge/month *			
			Annual Energy Cost	**$6,208,000**				
			Present Worth	$92,359,000	present worth of power consuption cost			
	Hydro Power Plant & Power Recovery			($46,179,500)				
TOTAL Annual Energy Cost				**$ 46,180,000**	Present Cost			

Whites Valley Booster Pump Power Costs	400k AF			Combination C				
Pump Power Costs	680	cfs	71,200	peak hp	peak PS flow & HP	5,350	ft WSE Whites Valley Res	
Inputs	161	cfs	12,600	avg hp	average annual flow rate & hp	763	ft TDH at peak	
Annual Energy Use / Cost	82,307,400	kWh		$3,046,000		569	ft TDH at avg	116,559 afy
Annual Peak Power Use / Cost	53,100	kW		$3,441,000	peak power charge/month *			
			Annual Energy Cost	**$6,487,000**				
			Present Worth	$96,510,000	present worth of power consuption cost			
	Hydro Power Plant & Power Recovery			($48,255,000)				
TOTAL Annual Energy Cost				**$ 48,255,000**	Present Cost			

Whites Valley Booster Pump Power Costs	170k AF			Combination D				
Pump Power Costs	680	cfs	63,200	peak hp	peak PS flow & HP	5,264	ft WSE Whites Valley Res	
Inputs	104	cfs	7,500	avg hp	average annual flow rate & hp	677	ft TDH at peak	
Annual Energy Use / Cost	48,992,500	kWh		$1,813,000		524	ft TDH at avg	75,293 afy
Annual Peak Power Use / Cost	47,100	kW		$3,053,000	peak power charge/month *			
			Annual Energy Cost	**$4,866,000**				
			Present Worth	$72,394,000	present worth of power consuption cost			
	Hydro Power Plant & Power Recovery			($36,197,000)				
TOTAL Annual Energy Cost				**$ 36,197,000**	Present Cost			

Whites Valley Booster Pump Power Costs	333k AF			Combination E				
Pump Power Costs	680	cfs	69,100	peak hp	peak PS flow & HP	5,327	ft WSE Whites Valley Res	
Inputs	138	cfs	10,600	avg hp	average annual flow rate & hp	740	ft TDH at peak	
Annual Energy Use / Cost	69,242,700	kWh		$2,562,000		557	ft TDH at avg	99,907 afy
Annual Peak Power Use / Cost	51,500	kW		$3,338,000	peak power charge/month *			
			Annual Energy Cost	**$5,900,000**				
			Present Worth	$87,777,000	present worth of power consuption cost			
	Hydro Power Plant & Power Recovery			($43,888,500)				
TOTAL Annual Energy Cost				**$ 43,889,000**	Present Cost			

Whites Valley Booster Pump Power Costs	309k AF			Combination F				
Pump Power Costs	680	cfs	68,100	peak hp	peak PS flow & HP	5,317	ft WSE Whites Valley Res	
Inputs	155	cfs	11,800	avg hp	average annual flow rate & hp	730	ft TDH at peak	
Annual Energy Use / Cost	77,081,500	kWh		$2,853,000		552	ft TDH at avg	112,215 afy
Annual Peak Power Use / Cost	50,800	kW		$3,292,000	peak power charge/month *			
			Annual Energy Cost	**$6,145,000**				
			Present Worth	$91,422,000	present worth of power consuption cost			
	Hydro Power Plant & Power Recovery			($45,711,000)				
TOTAL Annual Energy Cost				**$ 45,711,000**	Present Cost			

Whites Valley Booster Pump Power Costs	319k AF			Combination G				
Pump Power Costs	680	cfs	68,400	peak hp	peak PS flow & HP	5,320	ft WSE Whites Valley Res	
Inputs	147	cfs	11,200	avg hp	average annual flow rate & hp	733	ft TDH at peak	
Annual Energy Use / Cost	73,162,100	kWh		$2,707,000		553	ft TDH at avg	106,423 afy
Annual Peak Power Use / Cost	51,000	kW		$3,305,000	peak power charge/month *			
			Annual Energy Cost	**$6,012,000**				
			Present Worth	$89,443,000	present worth of power consuption cost			
	Hydro Power Plant & Power Recovery			($44,721,500)				
TOTAL Annual Energy Cost				**$ 44,722,000**	Present Cost			

Whites Valley Booster Pump Power Costs	305k AF			Combination H				
Pump Power Costs	680	cfs	68,000	peak hp	peak PS flow & HP	5,315	ft WSE Whites Valley Res	
Inputs	139	cfs	10,600	avg hp	average annual flow rate & hp	729	ft TDH at peak	
Annual Energy Use / Cost	69,242,700	kWh		$2,562,000		551	ft TDH at avg	100,631 afy
Annual Peak Power Use / Cost	50,700	kW		$3,286,000	peak power charge/month *			
			Annual Energy Cost	**$5,848,000**				
			Present Worth	$87,003,000	present worth of power consuption cost			
	Hydro Power Plant & Power Recovery			($43,501,500)				
TOTAL Annual Energy Cost				**$ 43,502,000**	Present Cost			

Whites Valley Booster Pump Power Costs	540k AF			Combinations J, L, M				
Pump Power Costs	680	cfs	75,100	peak hp	peak PS flow & HP	5,392	ft WSE Whites Valley Res	
Inputs	168	cfs	13,600	avg hp	average annual flow rate & hp	805	ft TDH at peak	
Annual Energy Use / Cost	88,839,700	kWh		$3,288,000		590	ft TDH at avg	121,626 afy
Annual Peak Power Use / Cost	56,000	kW		$3,629,000	peak power charge/month *			
			Annual Energy Cost	**$6,917,000**				
			Present Worth	$102,907,000	present worth of power consuption cost			
	Hydro Power Plant & Power Recovery			($51,453,500)				
TOTAL Annual Energy Cost				**$ 51,454,000**	Present Cost			

Whites Valley Booster Pump Power Costs	610k AF			Combination K				
Pump Power Costs	680	cfs	76,900	peak hp	peak PS flow & HP	5,411	ft WSE Whites Valley Res	
Inputs	168	cfs	13,900	avg hp	average annual flow rate & hp	824	ft TDH at peak	
Annual Energy Use / Cost	90,799,400	kWh		$3,360,000		600	ft TDH at avg	121,626 afy
Annual Peak Power Use / Cost	57,300	kW		$3,714,000	peak power charge/month *			
			Annual Energy Cost	**$7,074,000**				
			Present Worth	$105,243,000	present worth of power consuption cost			
	Hydro Power Plant & Power Recovery			($52,621,500)				
TOTAL Annual Energy Cost				**$ 52,622,000**	Present Cost			

Bear River Development
Temple Fork Reservoir Facilities Cost

TABLE A-10.10

Last Update: *11/09/17*

Temple Fork Reservoir

Cost Item	QTY	UNIT	UNIT PRICE	TOTAL	Comments
Dam Facilities			**Subtotal**	**$73,532,000**	
Clear and Grub Dam Footprint	160,000	SF	$0.25	$40,000	
Foundation/Abutmnt Overburden Excavation	120,000	CY	$6.00	$720,000	20ft excavation depth
Foundation Grout Curtain	1	LS	$3,600,000	$3,600,000	GCI: Depth=120', spacing=10', length=1240'
Bedrock Foundation Prep / Dental Grout	1,000	CY	$200	$200,000	assume 4" of grout on average on 50% of footprint
Roller Compacted Concrete Dam	790,000	CY	$80.00	$63,200,000	source: aggregate fr/basin, plant on site, cement impo
Dam Construction Dewatering & River Control	1	LS	$500,000	$500,000	
Toe Drain & Drain Collection System	1	LS	$100,000	$100,000	
Monitor Wells & Piezometers	8	EA	$20,000	$160,000	
Spillway					
Concrete Work	1,300	CY	$800	$1,040,000	
Plunge Pool Excavation	4,000	CY	$5.00	$20,000	
Plunge Pool Riprap	1,100	CY	$35.00	$39,000	local source
Outlet Works					
Inlet/Outlet Structure & Gates (on face of RCC)	1	LS	$1,900,000	$1,900,000	acts as both inlet structure and outlet intake
54" Pipe in RCC Dam	305	LF	$450	$138,000	just welded steel pipe material with tie downs
Instrumentation & Controls	1	LS	$250,000	$250,000	
Ancillary Facilities					
Access Road & USFS Road Excavation	120,000	CY	$10.00	$1,200,000	assume some rock excavation for road cuts
Dam Access/County Roads Gravel Volumes	9,000	CY	$25.00	$225,000	
Clear and Grub Reservoir Area	1	LS	$200,000	$200,000	
Supply/Discharge Pipe			**Subtotal**	**$2,169,000**	
Pipeline (PS to Dam)	2,325	LF	$520	$1,209,000	Appurtenences Included
Flow Control Valve & Box to Temple Fk Creek	1	LS	$200,000	$200,000	to maintain minimum flow in Temple Fk Creek
Flow Meter Vault	1	LS	$170,000	$170,000	
Control Valve Vault (to river)	1	LS	$440,000	$440,000	
Energy Dissapation Structure to Logan River	1	LS	$150,000	$150,000	
Supply Pump Station	Cost / HP =	$2,506	**Subtotal**	**$21,300,000**	
Site Work & Excavation	1	LS	$500,000	$500,000	$1,594.12
Dewatering & River Control	1	LS	$550,000	$550,000	
Intake/Pump Sump Structure & Control Building	1	LS	$1,700,000	$1,700,000	
Screens & Rakes	1	LS	$750,000	$750,000	
Pumps & Motors	1	LS	$5,500,000	$5,500,000	
Mechanical, Valves & Piping	1	LS	$1,200,000	$1,200,000	
Surge Protection Facilities	1	LS	$2,000,000	$2,000,000	
Electrical & Controls	1	LS	$1,350,000	$1,350,000	
RMP Impact Study	1	EA	$250,000	$250,000	
RMP Substation	1	EA	$2,500,000	$2,500,000	10 MVA
Power Line	20.0	MI	$250,000	$5,000,000	46 kV
Land Acquisition & Wetland Mitigation			**Subtotal**	**$1,000,000**	
Leases, Easements, & Legal	1	LS	$450,000	$450,000	
Wetland Mitigation Estimate	5.5	AC	$100,000	$550,000	

Temple Fork Pump Station Power Costs

Assumptions:

		pump/motor efficiency	83%	
Pump TDH:		interest rate	3.00%	
426	ft TDH at peak	period	20	yrs
420	ft TDH at avg	Energy Cost	$0.037	kWh
		Peak Power Charge	$13.50	kW *
2,896	afy	Power Recovery	50%	recover 50% of energy costs through hydropower (recovery includes both capital & energy)

* assumes 2 mo full peak, 4 mo 1/4 peak, 6 mo 1/20 peak

Pump Station Power Cost			**Subtotal**	**$2,008,000**	Present Cost
Pump Power Costs	100	cfs	5,900	peak hp	peak PS flow & HP
Inputs	4	cfs	300	avg hp	average annual flow rate & hp
Annual Energy Use / Cost	1,959,700	kWh		$73,000	energy cost
Annual Peak Power Use / Cost	4,400	kW		$197,000	peak power charge/month *
			Annual Energy Cost	**$270,000**	per year @ average operation
			Present Worth	$4,017,000	present worth of power consuption cost
	Hydro Power Plant & Power Recovery			-$2,009,000	
			Total Annual Energy Cost	**$2,008,000**	Present Cost
			TOTAL	**$ 100,009,000**	

Bear River Development
South Willard Reservoir & Facilities Cost

TABLE A-10.11

Last Update: *08/30/17*

South Willard Reservoir

Cost Item	QTY	UNIT	UNIT PRICE	TOTAL	Comments
Dam Facilities			**Subtotal**	**$151,102,500**	
Clear and Grub Dam Footprint	22,170,000	SF	$ 0.25	$5,542,500	
Overburden Mass Excavation (footprint of dam)	4,110,000	CY	$3.00	$12,330,000	
Embankment Earthwork					
Embankment Shell Zone	14,410,000	CY	$6.00	$86,460,000	source: reservoir basin/slopes, processing & drying
Filter Zone	55,000	CY	$48.00	$2,640,000	source: assume imported from < 20mi RT
Riprap Shell (upstream)	720,000	CY	$49.00	$35,280,000	source: assume imported from < 50mi RT
Crest Road Material	10,000	CY	$25.00	$250,000	source: assume imported from < 20mi RT
Toe Drain & Drain Collection System	1	LS	$2,000,000	$2,000,000	
Pump Low Level Intake Channel Excavation	27,404	CY	$6.00	$165,000	Channel to lowest point in reservoir floor - saturated
Monitor Wells & Piezometers	50	EA	$10,000	$500,000	
Spillway					
Concrete Work	300	CY	$650	$195,000	
Plunge Pool Excavation & Riprap	1	LS	$50,000	$50,000	
Main Inlet Pipe & Facilities					
Inlet Energey Dissipation Structure	1	LS	$225,000	$225,000	
Pig Retreival Vault	1	LS	$625,000	$625,000	
Pig Waste Pipe 36"	1,000	LF	$250	$250,000	
Pig Waste Sleeve Valve & Vault	1	LS	$250,000	$250,000	
Pig Waste Discharge Structure & Holding Pond	1	LS	$275,000	$275,000	
Dewatering	1	LS	$125,000	$125,000	
Pig Launch & Flow Meter Vault					After pump station
Pig & Flow Meter Vault	1	LS	$660,000	$660,000	
Ancillary Facilities					
Dam PS Access Road	1	LS	$250,000	$250,000	
Clear and Grub Reservoir Area	1	LS	$200,000	$200,000	
Utility & Structure Buy-Outs in Reservoir Area	1	LS	$2,830,000	$2,830,000	11 house purchases
Discharge Pump Station	Cost / HP =	$1,976	**Subtotal**	**$23,717,000**	
Site Work & Excavation	1	LS	$850,000	$850,000	
Yard Piping	1	LS	$450,000	$450,000	
Dewatering	1	LS	$250,000	$250,000	
Intake/Pump Sump Structure & Control Building	9,750	SF	$175	$1,707,000	About 150' x 65 ' size building
Screens & Racks Structure	1	LS	$950,000	$950,000	
Pumps & Motors	1	LS	$7,750,000	$7,750,000	
Mechanical, Valves & Piping	1	LS	$3,100,000	$3,100,000	
Surge Protection Facilities	1	LS	$3,500,000	$3,500,000	
Electrical & Controls	1	LS	$2,160,000	$2,160,000	
RMP Impact Study	1	EA	$250,000	$250,000	
Power Supply & Substation	1	LS	$2,750,000	$2,750,000	10 MVA
Land Acquisition & Wetland Mitigation			**Subtotal**	**$209,496,000**	
Reservoir Area + 25%	4,000	AC	$4,374	$17,496,000	
Wetland Mitigation Estimate	1,920	AC	$100,000	$192,000,000	

South Willard Pump Station Power Cost

Assumptions:

		pump/motor efficiency	83%	
Pump TDH:		interest rate	3.00%	
236	ft TDH at peak	period	20	yrs
156	ft TDH at avg	Energy Cost	$0.037	kWh
		Peak Power Charge	$13.50	kW
115,835	afy	Power Recovery	50%	recover 50% of energy costs through hydropower (recovery includes both capital & energy)

* assumes 3 mo full peak, 6 mo 1/2 peak, 3 mo 1/10 peak

Pump Station Power Cost			**Subtotal**	**$12,117,500**	Present Cost
Pump Power Costs	381	cfs	12,400	peak hp	peak PS flow & HP
Inputs	160	cfs	3,500	avg hp	average annual flow rate & hp
Annual Energy Use / Cost	22,863,200	kWh		$846,000	energy cost
Annual Peak Power Use / Cost	9,200	kW		$783,000	peak power charge/month *
			Annual Energy Cost	**$1,629,000**	per year @ average operation
			Present Worth	$24,235,000	present worth of power consuption cost
	Hydro Power Plant & Power Recovery			-$12,117,500	
			Total Annual Energy Cost	**$12,117,500**	Present Cost
			TOTAL	**$ 396,433,000**	

Bear River Development
Above Cutler Reservoir & Facilities Cost

TABLE A-10.12

Last Update: *08/30/17*

Above Cutler Reservoir					
Cost Item	**QTY**	**UNIT**	**UNIT PRICE**	**TOTAL**	**Comments**
Dam Facilities			**Subtotal**	**$79,586,000**	
Clear and Grub Dam Footprint	2,100,000	SF	$ 0.25	$525,000	
Overburden Mass Excavation (footprint of dam)	160,000	CY	$5.00	$800,000	clay core excavation
Embankment Earthwork				$0	
Embankment Shell Zone	480,000	CY	$6.00	$2,880,000	source: reservoir basin/slopes, processing & drying
Filter Zone	410,000	CY	$48.00	$19,680,000	source: assume imported from < 20mi RT
Clay Core Zone	60,000	CY	$8.50	$510,000	source: reservoir basin, processing & lots of drying
Riprap Shell (upstream)	140,000	CY	$49.00	$6,860,000	source: assume imported from < 50mi RT
Crest Road Material	1,000	CY	$25.00	$25,000	source: assume imported from < 20mi RT
Dam Construction Dewatering & River Control	1	LS	$1,300,000	$1,300,000	
Toe Drain & Drain Collection System	1	LS	$200,000	$200,000	
Monitor Wells & Piezometers	12	EA	$15,000	$180,000	
Spillway					
Concrete Work	6,810	CY	$800	$5,448,000	gate structure, chute, energy dissipation basin
Foundation Stabilization	1	LS	$2,000,000	$2,000,000	piers or other stabilization approach
Radial Gates	6	EA	$1,200,000	$7,200,000	30'x30' radial gates installed
Operations Building	1,500	SF	$120	$180,000	
Inlet/Outlet Channel Excavation	421,000	CY	$5.00	$2,105,000	
Backfill	75,000	CY	$6.00	$450,000	
Inlet Channel Rip Rap	21,100	CY	$49.00	$1,034,000	
Plunge Pool Rip Rap	11,600	CY	$49.00	$569,000	
Outlet Works					
Outlet Structure & Gates	1	LS	$1,200,000	$1,200,000	8'x8' gate and racks
Outlet Pipe	345	LF	$2,000	$690,000	concrete encased
River Flow Measurement Flume	1	LS	$900,000	$900,000	
Dewatering	1	LS	$90,000	$90,000	
Instrumentation & Controls	1	LS	$110,000	$110,000	
Ancillary Facilities					
Access Road	1	LS	$350,000	$350,000	
Road/Utilities Relocations	1	LS	$17,900,000	$17,900,000	
Private Structure Buy-Outs	1	LS	$6,000,000	$6,000,000	
Clear and Grub Reservoir Area	1	LS	$400,000	$400,000	
Land Acquisition & Wetland Mitigation			**Subtotal**	**$205,920,000**	
Reservoir Area (Residential)	400	AC	$100,000	$40,000,000	
Reservoir Area + 15% (Rural Res/Ag)	5,664	AC	$5,000	$28,320,000	
Wetland Mitigation Estimate	1,376	AC	$100,000	$137,600,000	
			TOTAL	**$ 285,506,000**	

Bear River Development
Cub River Reservoir & Facilities Cost

TABLE A-10.13

Last Update: *08/30/17*

Cub River Reservoir					
Cost Item	**QTY**	**UNIT**	**UNIT PRICE**	**TOTAL**	**Comments**
Dam Facilities			**Subtotal**	**$54,448,000**	
Clear and Grub Dam Footprint	830,000	SF	$ 0.25	$207,500	
Overburden Mass Excavation (footprint of dam)	170,000	CY	$5.00	$850,000	excavation for clay core
Embankment Earthwork					
Embankment Shell Zone	420,000	CY	$6.00	$2,520,000	source: reservoir basin/slopes, processing & drying
Filter Zone	220,000	CY	$48.00	$10,560,000	source: assume imported from < 20mi RT
Clay Core Zone	110,000	CY	$8.50	$935,000	source: reservoir basin, processing & lots of drying
Riprap Shell (upstream)	60,000	CY	$49.00	$2,940,000	source: assume imported from < 50mi RT
Crest Road Material	1,100	CY	$25.00	$27,500	source: assume imported from < 20mi RT
Dam Construction Dewatering & River Control	1	LS	$900,000	$900,000	
Toe Drain & Drain Collection System	1	LS	$200,000	$200,000	
Monitor Wells & Piezometers	12	EA	$15,000	$180,000	
Spillway					
Concrete Work	2,550	CY	$800	$2,040,000	gate structure, chute, energy dissipation basin
Foundation Stabilization	1	LS	$1,000,000	$1,000,000	piers or other stabilization approach
Radial Gates	2	EA	$1,100,000	$2,200,000	30'x35' radial gates installed
Operations Building	1,200	SF	$120	$144,000	
Inlet/Outlet Channel Excavation	63,000	CY	$5.00	$315,000	
Backfill	40,000	CY	$6.00	$240,000	
Inlet Channel Rip Rap	3,000	CY	$49.00	$147,000	
Plunge Pool Rip Rap	4,200	CY	$49.00	$206,000	
Outlet Works					
Outlet Structure & Gates	1	LS	$1,150,000	$1,150,000	2 - 6'x6' gate and racks
Outlet Pipes	946	LF	$863	$816,000	6' diam pipe, encased in concrete
River Flow Measurement Flume	1	LS	$450,000	$450,000	
Dewatering	1	LS	$60,000	$60,000	
Instrumentation & Controls	1	LS	$110,000	$110,000	
Ancillary Facilities					
Access Road	1	LS	$150,000	$150,000	
Road/Utilities Relocations	1	LS	$17,500,000	$17,500,000	
Private Structure Buy-Outs	1	LS	$8,400,000	$8,400,000	
Clear and Grub Reservoir Area	1	LS	$200,000	$200,000	
Land Acquisition & Wetland Mitigation			**Subtotal**	**$59,013,000**	
Reservoir Area (Residential)	270	AC	$100,000	$27,000,000	
Reservoir Area + 15% (Rural Res/Ag)	1,483	AC	$5,000	$7,413,000	
Wetland Mitigation Estimate	246	AC	$100,000	$24,600,000	
			TOTAL	**$ 113,461,000**	

TABLE A-10.14

Pipeline Cost Estimates

Updated: July 5, 2017

Pipeline Unit Cost*:	
Size (in)	$/LF
72	$773
90	$1,024
114	$1,436
120	$1,562

ALL linked to Cost Estimate Table.xlsx

* Applied to Equivalent Length to get total construction costs for pipeline

	Fielding to Cutler	Fielding to Whites	Fielding to Willard		Willard to West Haven	Willard to South Willard to West Haven
Size (in)	72	120	90	114	90	90
Length (ft)	48,558	92,070	45,190	112,958	59,351	69,325
Eq. Length (ft)	**58,700**	**98,489**	**60,810**	**140,728**	**78,235**	**89,925**
Construction Cost ($MM)	$45.38	$153.83	$62.26	$202.04	$80.10	$92.07
Land Cost ($MM)	**$2.25**	**$3.86**	**$9.99**	**$24.97**	**$6.32**	**$25.71**
Reach Total Cost ($MM)	$47.63	$157.69	$72.25	$227.01	$86.42	$117.78
Total Cost ($MM)	$47.63	$157.69	$299.26		$86.42	$117.78

linked to Cost Estimate Table.xlsx

linked to Cost Estimate Table.xlsx

Pipe Dia	Installation $/LF *
36	$254
42	$351
48	$443
54	$529
60	$612
66	$693
72	**$773**
78	$854
84	$937
90	**$1,024**
96	$1,116
108	$1,320
114	**$1,436**
120	**$1,562**
126	$1,700
132	$1,852
144	$2,203

* 2017 Updated Pipeline Costs

from: P:\State of Utah\Division of Water Resources\Bear River Project-Phase 2-2014\Cost Estimate *Pipeline_Cost_Memo_Figures02 2017.xlsx*

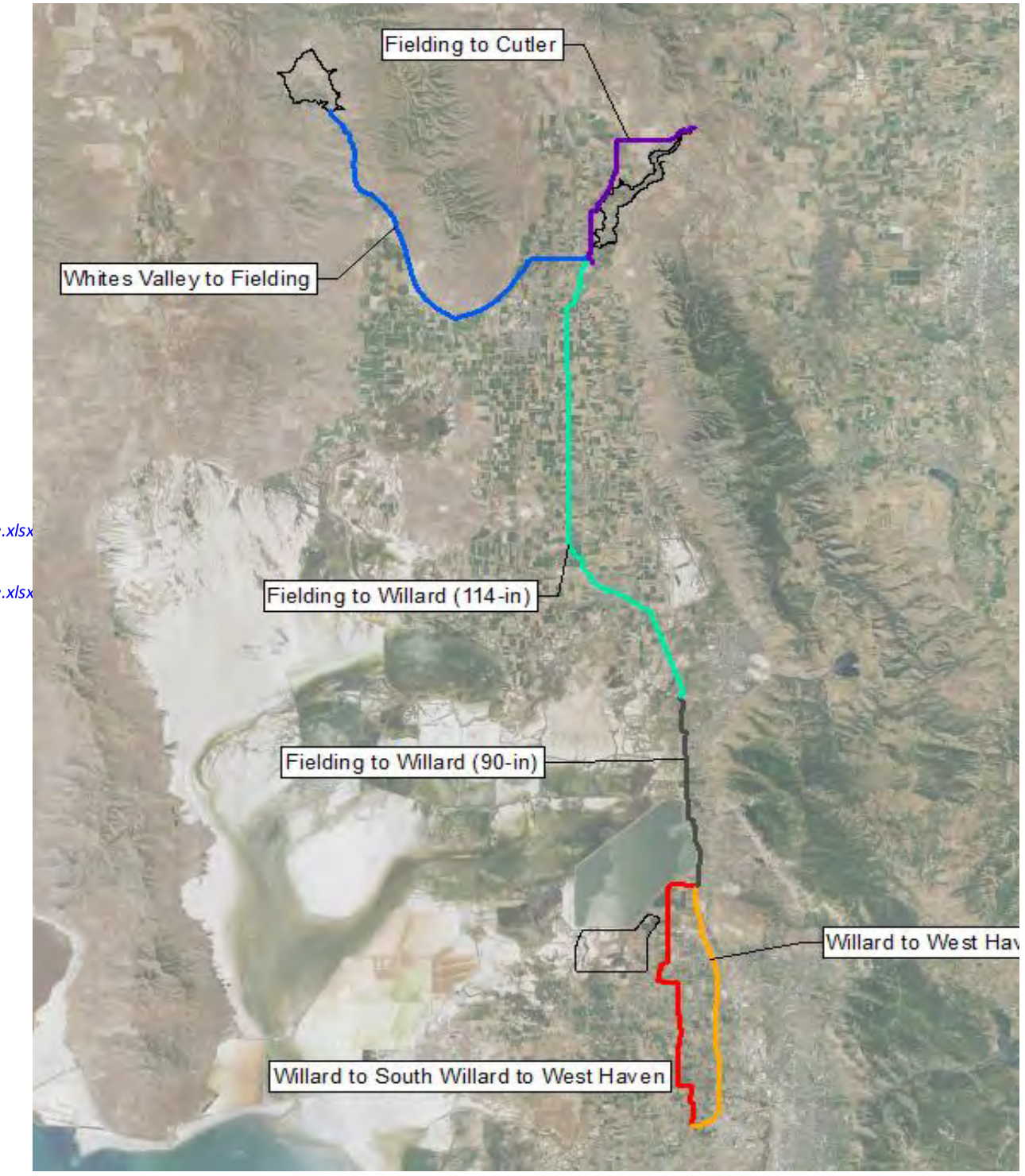
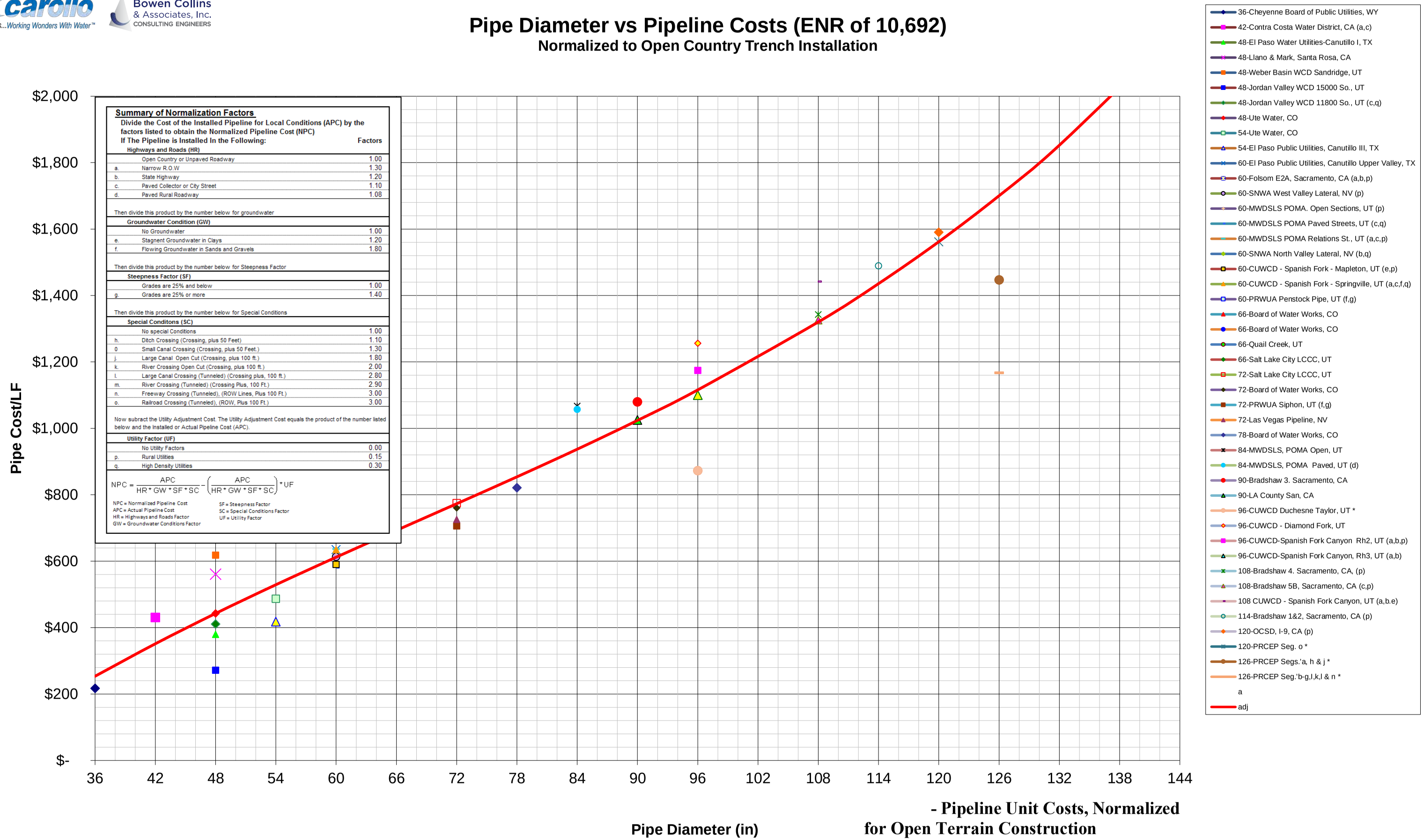


FIGURE A-10.1

Pipe Diameter vs Pipeline Costs (ENR of 10,692)

Normalized to Open Country Trench Installation



Summary of Normalization Factors

Divide the Cost of the Installed Pipeline for Local Conditions (APC) by the factors listed to obtain the Normalized Pipeline Cost (NPC)

If The Pipeline is Installed In the Following:		Factors
Highways and Roads (HR)		
	Open Country or Unpaved Roadway	1.00
a.	Narrow R.O.W	1.30
b.	State Highway	1.20
c.	Paved Collector or City Street	1.10
d.	Paved Rural Roadway	1.08
Then divide this product by the number below for groundwater		
Groundwater Condition (GW)		
	No Groundwater	1.00
e.	Stagnent Groundwater in Clays	1.20
f.	Flowing Groundwater in Sands and Gravels	1.80
Then divide this product by the number below for Steepness Factor		
Steepness Factor (SF)		
	Grades are 25% and below	1.00
g.	Grades are 25% or more	1.40
Then divide this product by the number below for Special Conditions		
Special Conditons (SC)		
	No special Conditions	1.00
h.	Ditch Crossing (Crossing, plus 50 Feet)	1.10
0	Small Canal Crossing (Crossing, plus 50 Feet.)	1.30
j.	Large Canal Open Cut (Crossing, plus 100 ft.)	1.80
k.	River Crossing Open Cut (Crossing, plus 100 ft.)	2.00
l.	Large Canal Crossing (Tunneled) (Crossing plus, 100 ft.)	2.80
m.	River Crossing (Tunneled) (Crossing Plus, 100 Ft.)	2.90
n.	Freeway Crossing (Tunneled), (ROW Lines, Plus 100 Ft.)	3.00
o.	Railroad Crossing (Tunneled), (ROW, Plus 100 Ft.)	3.00
Now subract the Utility Adjustment Cost. The Utility Adjustment Cost equals the product of the number listed below and the Installed or Actual Pipeline Cost (APC).		
Utility Factor (UF)		
	No Utility Factors	0.00
p.	Rural Utilities	0.15
q.	High Density Utilities	0.30

$$NPC = \frac{APC}{HR * GW * SF * SC} - \left(\frac{APC}{HR * GW * SF * SC}\right) * UF$$

NPC = Normalized Pipeline Cost
APC = Actual Pipeline Cost
HR = Highways and Roads Factor
GW = Groundwater Conditions Factor
SF = Steepness Factor
SC = Special Conditions Factor
UF = Utility Factor

CHAPTER 11

DETAILED HYDRAULIC ANALYSIS

TABLE A-11.1

Pipeline Hydraulic Calculations - Fielding Reservoir to Whites Valley Reservoir

Last updated: 11/9/2017

Pipeline Hydraulic Calculations

Given Values							Calculated Values														
Pipe Section	Start Sta. (ft)	End Sta. (ft)	Dia. (in)	HW C	Flow (cfs)	Downstrm Press. Req. (psi)	Upstream Control	Start Elev. (ft)	End Elev. (ft)	Length (ft)	Velocity (fps)	hl per foot (ft)	hl (ft)	Min. Press. Sta. (ft)	Min. Press. HGL (ft)	Min. Press. (psi)	Max. Static Press. Sta. (ft)	Static Press. HGL (ft)	Max. Press. (psi)	Start HGL (ft)	End HGL (ft)
1	0	2,850	120	120	750	192.3	Pump	4,240.0	4,344.4	2,850	9.55	0.0019	5.4	2,400	4,789.4	191.11	300	4,794.0	237.35	4,794.0	4,788.6
2	2,850	62,100	120	120	680	10	Other	4,344.4	4,671.1	59,250	8.66	0.0016	94.4	62,100	4,694.2	10.00	5,600	4,794.0	213.10	4,788.6	4,694.2
3	62,100	92,050	120	120	680	151.5	Pump	4,671.1	5,042.1	29,950	8.66	0.0016	47.7	92,050	5,392.0	151.50	62,100	5,439.7	332.74	5,439.7	5,392.0
4																					
5																					

Pump Station Calculations

Given Values							Calculated Values							Whites Valley Reservoir Data						
Pump Elev (ft)	Static Suction Head (ft)	Static Discharge Head (ft)	Est System Losses (ft)	Ground Elevation (ft)	Low WSE (ft)	End Elevation (ft)	Flow (cfs)	Sum HL Due to Friction (ft)	Total Dynamic Head (ft)	Motor Eff (%)	Pump Eff (%)	Pump Horse Power (HP)	PS Name	Dam Station (ft)	Pool Elevation (ft)	Crest Elev. (ft)	Dam Ground Elev. (ft)	Embankment Height (ft)	WSE Begin Sta. (ft)	WSE End Sta. (ft)
4,240.0	-10	104.4	30	4,248.5	4,230	4,344.4	750		594.0	94%	88%	61,104	Fielding	92,050	5,392.0	5,402.0	5,042.1	359.9	92,050	100,000
4,665.0	0	727.0	30		4,665	5,392.0	680		804.7	94%	88%	75,054	Whites							

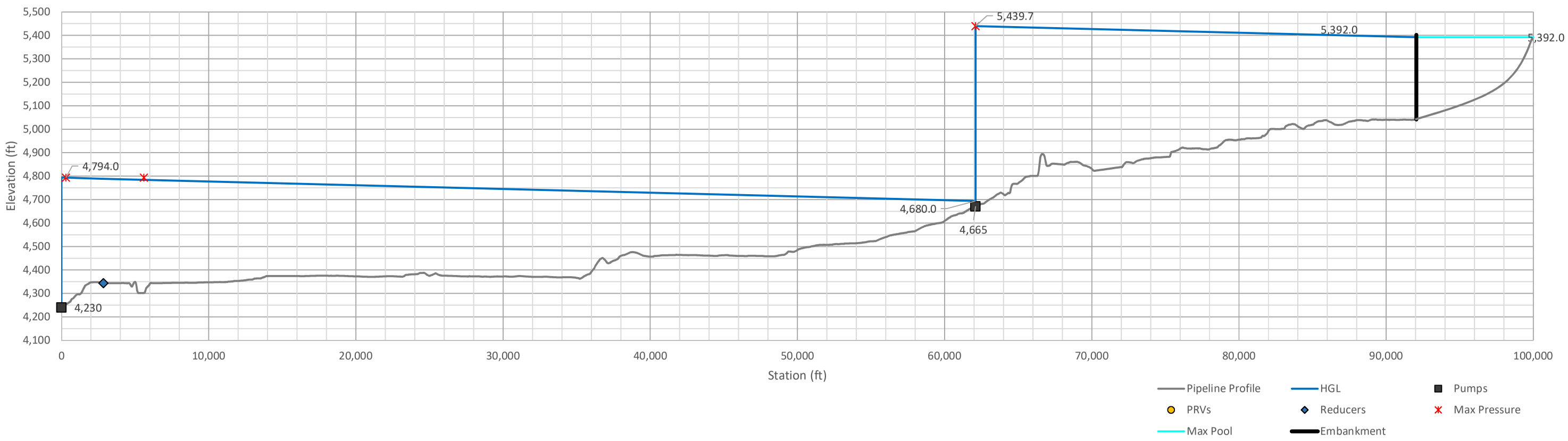


TABLE A-11.2

Pipeline Hydraulic Calculations - Fielding Reservoir to West Haven WTP

Last updated: 11/9/2017

Pipeline Hydraulic Calculations

Given Values							Calculated Values														
Pipe Section	Start Sta. (ft)	End Sta. (ft)	Dia. (in)	HW C	Flow (cfs)	Downstrm Press. Req. (psi)	Upstream Control	Start Elev. (ft)	End Elev. (ft)	Length (ft)	Velocity (fps)	hl per foot (ft)	hl (ft)	Min. Press. Sta. (ft)	Min. Press. HGL (ft)	Min. Press. (psi)	Max. Static Press. Sta. (ft)	Static Press. HGL (ft)	Max. Press. (psi)	Start HGL (ft)	End HGL (ft)
1	0	2,800	120	120	480	118.1	Pump	4,240.0	4,345.0	2,800	6.11	0.0008	2.3	2,450	4,618.1	117.00	0	4,620.2	160.91	4,620.2	4,617.8
2	2,800	112,900	114	120	480	112.2	Other	4,345.0	4,240.5	110,100	6.77	0.0011	118.1	18,600	4,600.9	112.00	0	4,620.2	160.91	4,617.8	4,499.7
3	112,900	202,500	90	120	300	51.9	Other	4,240.5	4,252.6	89,600	6.79	0.0014	127.3	202,500	4,372.4	51.86	153,100	4,620.2	171.81	4,499.7	4,372.4
4	202,500	217,900	90	120	300	40.0	Other	4,252.6	4,258.1	15,400	6.79	0.0014	21.9	215,900	4,353.3	31.65	205,500	4,620.2	161.01	4,372.4	4,350.5
5																					

Pump Station Calculations

Given Values							Calculated Values					
Pump Elev (ft)	Static Suction Head (ft)	Static Discharge Head (ft)	Est System Losses (ft)	Ground Elevation (ft)	Low WSE (ft)	Max Elevation (ft)	Flow (cfs)	Sum HL Due to Friction (ft)	Total Dynamic Head (ft)	Motor Eff (%)	Pump Eff (%)	Pump Horse Power (HP)
4,240.0	-10	107.97	10	4,248.5	4,230	4,348.0	480		400.2	94%	88%	26,345

Fielding Reservoir Data

Dam Station (ft)	Pool Elevation (ft)	Crest Elev. (ft)	Dam Ground Elev. (ft)	Embankment Height (ft)	WSE Begin Sta. (ft)	WSE End Sta. (ft)
200	4,300.0	4,310.0	4,240.0	70.0	1000	0

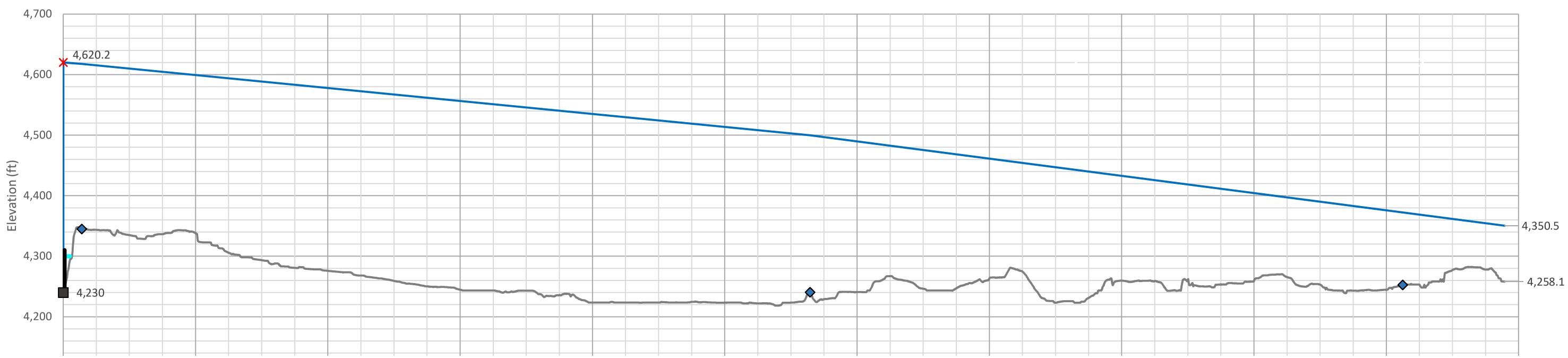


TABLE A-11.3

Pipeline Hydraulic Calculations - Whites Reservoir to West Haven WTP

Last updated: 11/9/2017

Pipeline Hydraulic Calculations

Given Values							Calculated Values														
Pipe Section	Start Sta. (ft)	End Sta. (ft)	Dia. (in)	HW C	Flow (cfs)	Downstrm Press. Req. (psi)	Upstream Control	Start Elev. (ft)	End Elev. (ft)	Length (ft)	Velocity (fps)	hl per foot (ft)	hl (ft)	Min. Press. Sta. (ft)	Min. Press. HGL (ft)	Min. Press. (psi)	Max. Static Press. Sta. (ft)	Static Press. HGL (ft)	Max. Press. (psi)	Start HGL (ft)	End HGL (ft)
1	0	30,000	120	120	480	301.5	Res	5,042.1	4,670.7	30,000	6.11	0.0008	25.1	2,850	5,389.9	150.57	30,000	5,392.3	312.36	5,392.3	5,367.2
2	30,000	89,250	120	120	480	117.5	PRV	4,670.7	4,344.6	59,250	6.11	0.0008	49.5	30,000	4,665.5	-2.25	86,450	4,680.0	163.76	4,665.5	4,616.0
3	89,250	109,000	114	120	480	120.0	Other	4,344.6	4,318.3	19,750	6.77	0.0011	21.2	104,950	4,599.8	111.23	109,000	4,680.0	156.59	4,616.7	4,595.5
4	109,000	199,500	114	120	480	112.5	Other	4,318.3	4,239.5	90,500	6.77	0.0011	97.1	199,400	4,499.5	111.93	194,550	4,680.0	199.79	4,596.5	4,499.3
5	199,500	304,350	90	120	300	40.0	Other	4,239.5	4,258.1	104,850	6.79	0.0014	149.0	302,350	4,353.3	31.69	239,300	4,680.0	197.71	4,499.5	4,350.5

Pump Station Calculations

Given Values							Calculated Values					
Pump Elev (ft)	Static Suction Head (ft)	Static Discharge Head (ft)	Est System Losses (ft)	Ground Elevation (ft)	Low WSE (ft)	Max Elevation (ft)	Flow (cfs)	Sum HL Due to Friction (ft)	Total Dynamic Head (ft)	Turbine Eff (%)	Generator Eff (%)	Hydro Generated (HP)

Whites Valley Reservoir Data

Dam Station (ft)	Pool Elevation (ft)	Crest Elev. (ft)	Dam Ground Elev. (ft)	Embankment Height (ft)	WSE Begin Sta. (ft)	WSE End Sta. (ft)
500	5,392.0	5,402.0	5,040.1	361.9	2000	0

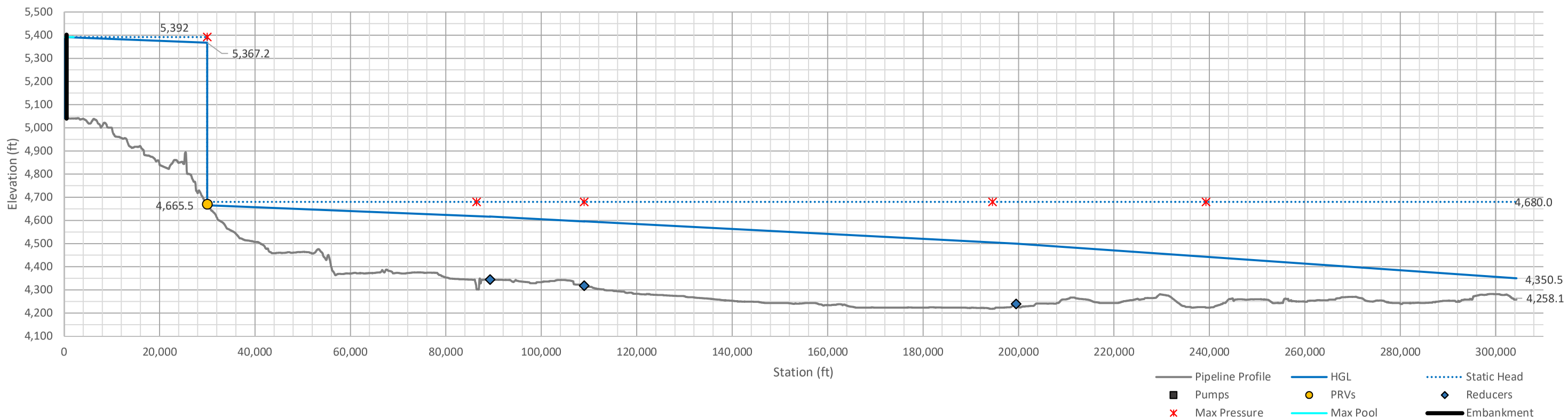


TABLE A-11.4

Pipeline Hydraulic Calculations - Whites Valley Reservoir to Fielding Reservoir

Last updated: 11/9/2017

Pipeline Hydraulic Calculations

Given Values							Calculated Values														
Pipe Section	Start Sta. (ft)	End Sta. (ft)	Dia. (in)	HW C	Flow (cfs)	Downstrm Press. Req. (psi)	Upstream Control	Start Elev. (ft)	End Elev. (ft)	Length (ft)	Velocity (fps)	hl per foot (ft)	hl (ft)	Min. Press. Sta. (ft)	Min. Press. HGL (ft)	Min. Press. (psi)	Max. Static Press. Sta. (ft)	Static Press. HGL (ft)	Max. Press. (psi)	Start HGL (ft)	End HGL (ft)
1	0	30,000	120	120	480	301.5	Res	5,042.1	4,670.7	30,000	6.11	0.0008	25.1	2,850	5,389.9	150.57	300	5,392.3	152.50	5,392.3	5,367.2
2	30,000	92,700	120	120	480	135.3	PRV	4,670.7	4,300.0	62,700	6.11	0.0008	52.4	5,609,555	0.0	-1,861.47	30,000	4,680.0	4.02	4,665.0	4,612.6
3	92,700	92,750																		4,612.6	4,300.0
4	93,750	94,750																		4,300.0	4,300.0
5																					

Pump Station Calculations

Given Values							Calculated Values					
Pump Elev (ft)	Static Suction Head (ft)	Static Discharge Head (ft)	Est System Losses (ft)	Ground Elevation (ft)	Low WSE (ft)	Max Elevation (ft)	Flow (cfs)	Sum HL Due to Friction (ft)	Total Dynamic Head (ft)	Motor Eff (%)	Pump Eff (%)	Hydro Generated (HP)

Whites Valley Reservoir Data

Dam Station (ft)	Pool Elevation (ft)	Crest Elev. (ft)	Dam Ground Elev. (ft)	Embankment Height (ft)	WSE Begin Sta. (ft)	WSE End Sta. (ft)
200	5,392.0	5,402.0	5,040.8	361.2	500	0

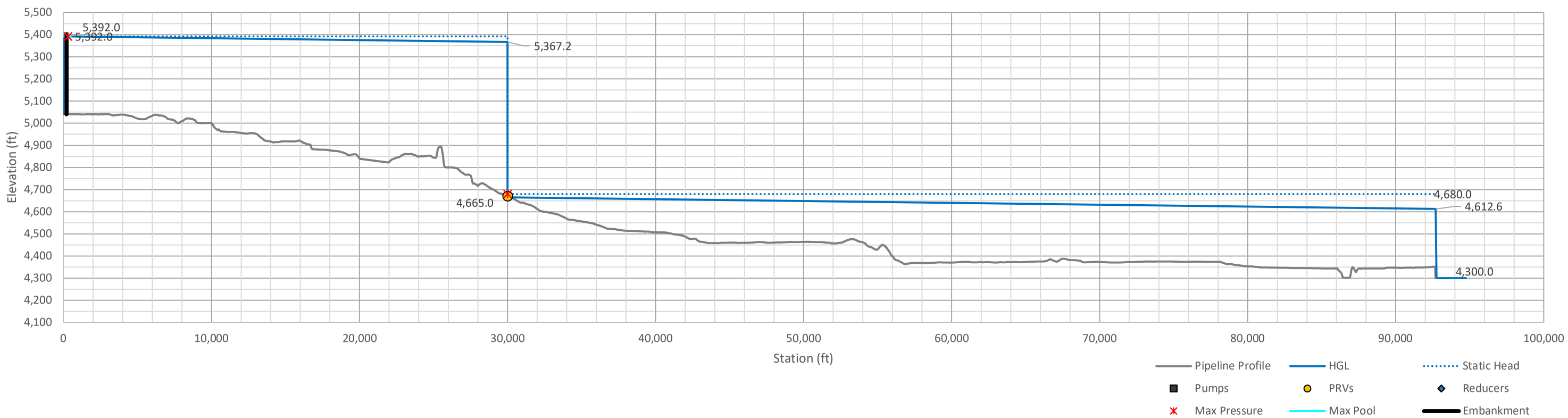


TABLE A-11.5

Pipeline Hydraulic Calculations - Whites Valley Reservoir to Fielding Reservoir

Last updated: 11/9/2017

Pipeline Hydraulic Calculations

Given Values							Calculated Values														
Pipe Section	Start Sta. (ft)	End Sta. (ft)	Dia. (in)	HW C	Flow (cfs)	Downstrm Press. Req. (psi)	Upstream Control	Start Elev. (ft)	End Elev. (ft)	Length (ft)	Velocity (fps)	hl per foot (ft)	hl (ft)	Min. Press. Sta. (ft)	Min. Press. HGL (ft)	Min. Press. (psi)	Max. Static Press. Sta. (ft)	Static Press. HGL (ft)	Max. Press. (psi)	Start HGL (ft)	End HGL (ft)
1	0	30,000	120	120	660	293.0	Res	5,042.1	4,670.7	30,000	8.40	0.0015	45.21	6,200	5,383.4	149.19	30,000	5,392.8	312.57	5,392.8	5,347.5
2	30,000	92,700	120	120	660	140.8	PRV	4,670.7	4,245.2	62,700	8.40	0.0015	94.49	30,000	4,665.0	-2.47	92,700	4,680.0	188.22	4,665.0	4,570.5
3	92,700	141,250	78	120	180	34.6	Other	4,245.2	4,436.9	48,550	5.42	0.0011	53.79	135,800	4,522.8	10.92	92,850	4,680.0	188.72	4,570.5	4,516.7
4	141,250	141,250																		4,516.71	4,395.00
5	142,250	143,250																		4,395.00	4,395.00

Pump Station Calculations

Given Values							Calculated Values					
Pump Elev (ft)	Static Suction Head (ft)	Static Discharge Head (ft)	Est System Losses (ft)	Ground Elevation (ft)	Low WSE (ft)	Max Elevation (ft)	Flow (cfs)	Sum HL Due to Friction (ft)	Total Dynamic Head (ft)	Motor Eff (%)	Pump Eff (%)	Hydro Generated (HP)

Whites Valley Reservoir Data

Dam Station (ft)	Pool Elevation (ft)	Crest Elev. (ft)	Dam Ground Elev. (ft)	Embankment Height (ft)	WSE Begin Sta. (ft)	WSE End Sta. (ft)
200	5,392.0	5,402.0	5,040.8	361.2	750	0

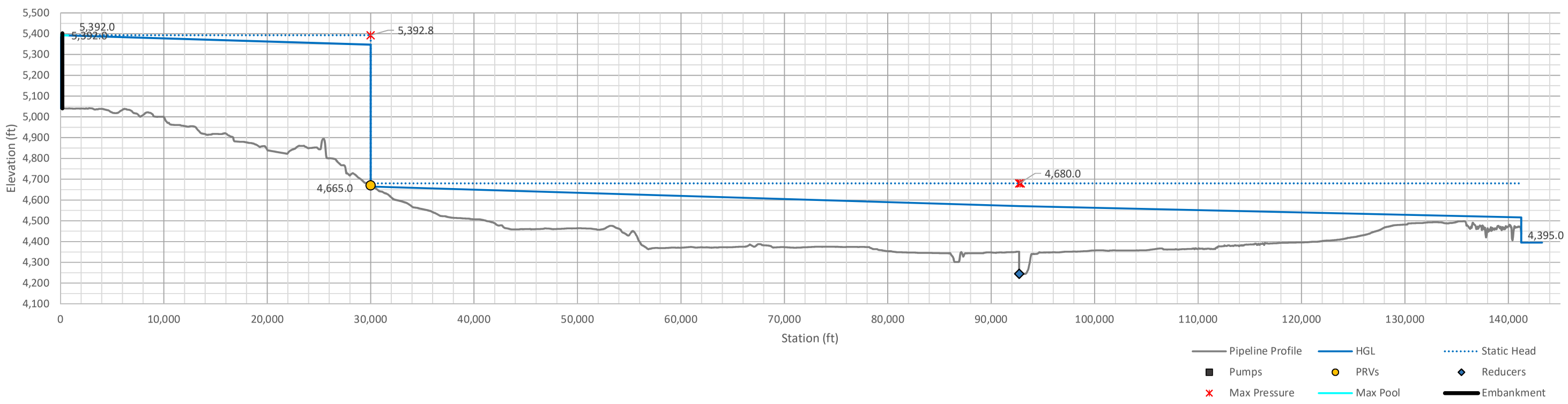


TABLE A-11.6

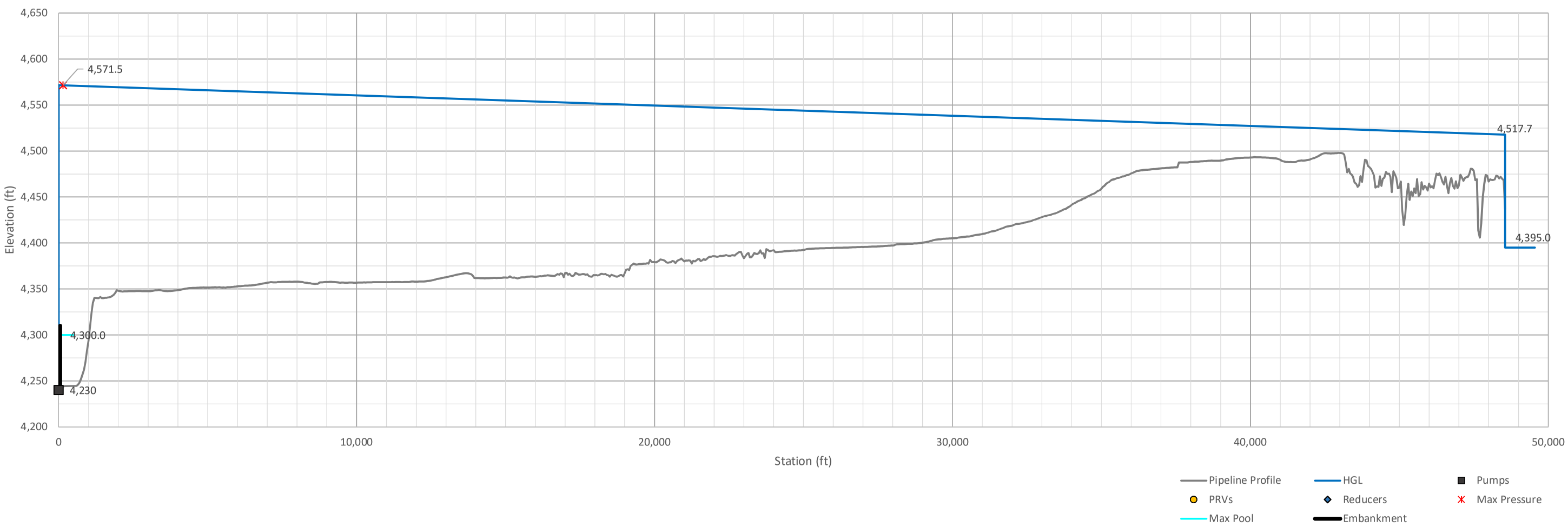
Pipeline Hydraulic Calculations - Fielding Reservoir to Cutler Reservoir

Last updated: 11/9/2017

Pipeline Hydraulic Calculations

Given Values							Calculated Values														
Pipe Section	Start Sta. (ft)	End Sta. (ft)	Dia. (in)	HW C	Flow (cfs)	Downstrm Press. Req. (psi)	Upstream Control	Start Elev. (ft)	End Elev. (ft)	Length (ft)	Velocity (fps)	hl per foot (ft)	hl (ft)	Min. Press. Sta. (ft)	Min. Press. HGL (ft)	Min. Press. (psi)	Max. Static Press. Sta. (ft)	Static Press. HGL (ft)	Max. Press. (psi)	Start HGL (ft)	End HGL (ft)
1	0	48,550	78	120	180	35	Pump	4,240.0	4,436.9	48,550	5.42	0.0011	53.8	43,050	4,523.8	11.25	150	4,571.5	141.76	4,571.5	4,517.7
2	48,550	48,550																		4,517.74	4,395.00
3	49,050	49,550																		4,395.00	4,395.00
4																					
5																					

Pump Station Calculations													Fielding Reservoir Data						
Given Values							Calculated Values												
Pump Elev (ft)	Static Suction Head (ft)	Static Discharge Head (ft)	Est System Losses (ft)	Ground Elevation (ft)	Low WSE (ft)	Max Elevation (ft)	Flow (cfs)	Sum HL Due to Friction (ft)	Total Dynamic Head (ft)	Motor Eff (%)	Pump Eff (%)	Pump Horse Power (HP)	Dam Station (ft)	Pool Elevation (ft)	Crest Elev. (ft)	Dam Ground Elev. (ft)	Embankment Height (ft)	WSE Begin Sta. (ft)	WSE End Sta. (ft)
4,240.0	-10		30		4,230.0	4,497.9	180		371.5	94%	88%	9,172	50	4,300.0	4,310.0	4,240.0	70.0	500	0



AGENCY/STAKEHOLDER COORDINATION

COORDINATION SUMMARY

The BC&A/HDR project team held quarterly progress meetings with DWRe staff and the Work Group. In addition, DWRe and the project team met at various times with the parties listed above to present the development plan and solicit input.

The purpose of these initial communications and meetings with agencies and stakeholders was to provide advance notice concerning the study, and to ask about their project concerns and unique issues, specifically environmental and planned land uses within the study area. Participating in these meetings informed these interested organizations and helped the project team gain an understanding of what issues and decision-making criteria are most important to the potentially impacted communities. Table 12-1 lists these meetings and the general outcomes.

Table 12-1
Stakeholder Meetings

Date	Entity	Participants	Outcome
8/27/2014	BRWCD	Marisa Egbert, Bill Leeflang, Terry Warner, Phil Gerhart	Discussed the process for obtaining access for drilling from the Bear River Migratory Bird Refuge (BRMBR). UDWRe will submit an official request with factual information
9/3/2014	US Forest Service, Logan Ranger District	Bob Fotheringham, Phil Gerhart, Terry Warner, Mike Collins	Geotechnical exploration plans at Temple Fork and special use permitting needs
9/9/2014	Cache County	Marisa Egbert, Bob Fotheringham, Mike Collins	General project overview
10/6/2014	JVWCD	Marisa Egbert	General project overview
10/9/2014	Utah Board of Water Resources	Eric Millis	
10/22/2014	Division of Wildlife staff	Eric Millis, Bill Leeflang, Marisa Egbert, Terry Warner	General project overview
10/29/2014	Great Salt Lake Advisory Council	Marisa Egbert, Mike Collins	General project overview
10/31/2014	Utah Water Quality Section staff	Marisa Egbert	General project overview
11/4/2014	Utah Water Quality Board	Marisa Egbert	General project overview
11/6/2014	Resource Development Coordination Committee	Eric Millis, Bill Leeflang, Marisa Egbert, Mike Collins, Terry Warner	General project overview; COE recommended initial informal coordination
11/10/2014	DNR Staff	Eric Millis, Todd Adams, Marisa Egbert, Terry Warner	General project overview
1/20/2015	DWR Aquatics Section staff	Marisa Egbert	Discussed concerns and need for conservation pool in reservoirs to provide for fish and wildlife and recreation uses
1/21/2015	Box Elder County Mayors	Marisa Egbert	General project overview
2/12/2015	Utah Water Quality Task Force, Utah Department of Agriculture	Marisa Egbert, Todd Adams, Steve Thurin, Terry Warner	General project overview. Questions or concerns: conservation pool, who owns? How will in-stream flows be considered?

Date	Entity	Participants	Outcome
2/18/2015	UTA	Marisa Egbert, Thayne Clark	Discussed the overview of the Bear River Project, and the pipeline alignment through the Willard area just east of Willard Bay
2/24/2015	US Army Corps of Engineers, Bountiful Regulatory Office	Eric Millis, Bill Leeflang, Marisa Egbert, Mike Collins, Steve Thurin, Terry Warner	General project description. Then discussion of the permit application process. Discussion on project phasing and typical 404 permit terms. Discussion on permitting strategy.
3/29/2015	North Utah Water Conference	Bob Fotheringham, Voneene Jorgensen	General Project overview
3/30/2015	USU Water Conference	Marisa Egbert	General project overview
4/5/2015	USU Runoff Conference	Marisa Egbert	General project overview
4/22/2015	USU/Audubon/Logan River Task Force	Marisa Egbert	General project overview
4/14/2015	Division of Wildlife Aquatics Section	Marisa Egbert	General project overview
5/11/2015	Great Salt Lake Issues Forum – Panel	Eric Millis, Bob Fotheringham	
5/25/2015	Box Elder Association of Governments Presentation		
11/30/2015	WBWCD Board of Trustees	Marisa Egbert, Mike Collins	General project overview
1/20/2016	League of Women Voters, Bountiful	Marisa Egbert	General project overview. Showed a great deal of interest in water issues, measures
Summer '16	Great Salt Lake Advisory Council	Marisa Egbert, Mike Collins	Discussion of low GSL levels
11/01/2016	Great Salt Lake Advisory Council	Marisa Egbert, Mike Collins	Working with other agencies to develop lake model (IWRA)
11/03/2016	Division of Water Rights	Marisa Egbert	Provided high-level overview of Bear River development
December 2016	UTA	Marisa Egbert, Thayne Clark	Discussion on potential of sharing property for Bear River pipeline and future UTA expansion Continue to work with them for future activities. Possibility of public meeting(s) in February

CHAPTER 14

WHITE PAPER ON GREAT SALT LAKE IMPACT FROM DEVELOPMENT

Utah State University

From the SelectedWorks of Sarah E. Null

2015

Impacts of Water Development on Great Salt Lake and the Wasatch Front

Sarah Null
Wayne A. Wurtsbaugh
Craig Miller
Peter Wilcock
Maura Hahnenberger, et al.

Available at: https://works.bepress.com/sarah_null/57/

White paper

February 24, 2015

Impacts of Water Development on Great Salt Lake and the Wasatch Front

Wayne Wurtsbaugh[1], Craig Miller[2], Sarah Null[1], Peter Wilcock[1], Maura Hahnenberger[3], Frank Howe[1,4]

Utah State University[1]; [2]Utah Division of Water Resources; [3]Salt Lake Community College; [4]Utah Division of Wildlife Resources

Summary

Although droughts and floods produce short-term fluctuations in the elevation of Great Salt Lake, water diversions since the arrival of 19th Century pioneers represent a persistent reduction in water supply to the lake, decreasing its elevation by 11 feet and exposing much of the lake bed. As Utah moves forward, we need to be aware of the impacts of lowered lake levels and make decisions that serve the interests of all Utahns. In particular, proposals to further develop the water supply of the Great Salt Lake should carefully consider potential impacts to the health of the lake and examine the tradeoffs. There are no water rights to protect Great Salt Lake, so water development currently focuses solely on whether there is water upstream to divert. If future water projects reduce the supply of water to the lake, its level will continue to drop.[1] Although water conservation has reduced urban per capita use by 18 percent, overall municipal water use has increased by 5 percent because of our growing population.[2] To significantly reduce water use, a balanced conservation ethic needs to consider all uses, including agriculture, which consumes 63 percent of the water in the Great Salt Lake Basin.

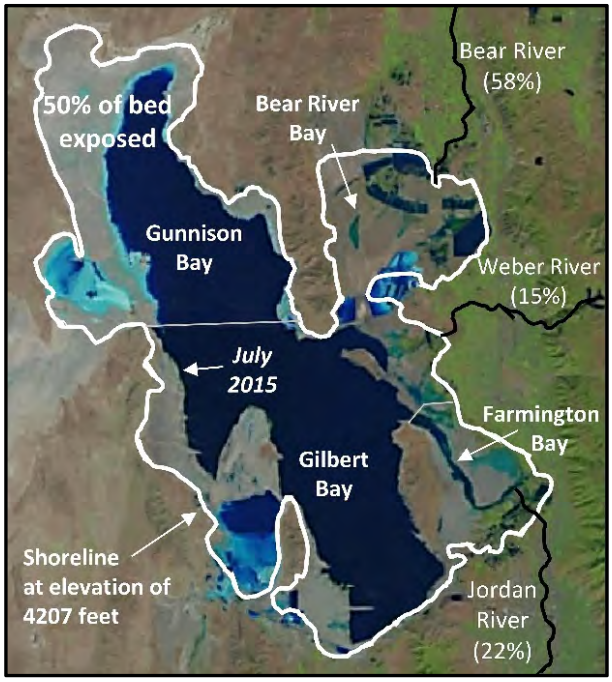


Figure 1. Great Salt Lake showing its major bays and the relative contribution (%) of each of the major river inflows. The white line shows the lake margin at its average natural elevation of 4,207 feet and the July 2015 NASA photograph shows the lake at near record-low levels, exposing half of the lake bed.

Increased awareness of how water use is lowering Great Salt Lake will help us avoid the fate of other salt lakes such as the Aral Sea in Central Asia or California's Owens Lake, both of which have been desiccated and now cause severe environmental problems. We must look beyond the next few decades and decide how we value the lake for future generations. Lower lake levels will increase dust pollution and related human health impacts, and reduce industrial and environmental function of Great Salt Lake. We must be willing to make decisions now that preserve Great Salt Lake's benefits and mitigate its negative impacts into the coming centuries.

Introduction

Utah's Great Salt Lake is immensely valuable as an environmental, cultural, and economic resource. A 2012 analysis by Bioeconomics[3] estimated the economic value of the lake at $1.32 billion per year for mineral extraction, brine shrimp cyst production, and recreation. The abundant food and wetlands of the lake attract 3 million shorebirds, as many as 1.7 million eared grebes, and hundreds of thousands of waterfowl during spring and fall migrations. Because of this, it has been designated as a Western Hemisphere Shorebird Reserve Network Site. Notably, the lake is the namesake of Utah's capital city, which underscores its cultural significance.

Great Salt Lake lies in a terminal basin (*Figure 1*). This means water flowing into it only leaves by evaporation. Freshwater lakes have river outflows, but not Great Salt Lake. Its tributaries bring trace amounts of salt, which is left behind when water evaporates. The concentrated salts, including sodium, chloride, potassium, sulfate, magnesium and others, provide a valuable resource for mineral extraction companies. Because most of the lake is too salty for fish to survive, millions of migratory birds are the dominant predators of the abundant brine shrimp and brine flies that can tolerate the salty waters in the main lake. Bear River Bay and Farmington Bay, which receive freshwater inflows and are less salty, harbor an even greater diversity of insects, crustaceans and fish which are also important prey for the bird community.

Since the lake is in a closed basin, it naturally rises with greater water supply during wet periods and falls during droughts. On top of this natural pattern, water supply to the lake has decreased over time as more and more of it is consumed for agricultural, industrial and urban uses. As water supply decreases, the lake level falls. There are compensating factors that can slow shrinkage of the lake when water supply is reduced. First, as the elevation declines, the size of the lake decreases, and thus, there is less evaporative surface area. Second, as the lake shrinks, salts become more concentrated, which further reduces evaporation.[4] These processes slow, but do not stop, the decrease in lake elevation when water supply decreases. The lake's elevation and salinity equilibrate to the amount of water flowing into it from rivers, rainwater and groundwater. For example, if there was a 25 percent decrease in streamflow to the lake, its elevation would slowly drop and, after 15 years, equilibrate at an elevation about 2.2 feet lower.[4]

Effects of water withdrawals on Great Salt Lake levels

Although fluctuations in rainfall and river flow cause the lake level to rise and fall, there has been no significant long-term change in precipitation[5] and water supply[6] from mountain tributaries since the pioneers arrived in 1847 (*Figure 2A*). In contrast, water development and river diversions over more than a century and a half have produced a persistent reduction in water supply to the lake (*Figure 2B*). Some of the diverted water is lost via evaporation from agricultural fields, urban landscaping, and industrial activity, including losses from salt ponds. These reduced stream flows have been offset by eight percent with imported water from the Colorado River Basin through the Central Utah Project, as well as return flows from upstream diversions. Overall, however, *consumptive water use has reduced net river inflow to the lake by 39 percent over the past 150 years*.[7] This consumptive water use causes the Great Salt Lake to shrink (*Figure 2C*, red line). Although wet periods like those in the mid-1980s and the current drought cause water supply and lake levels to fluctuate, the lake level has persistently declined since the pioneers arrived.[8] This contrasts strikingly with the constant long-term average of precipitation and river flow in the upper watersheds noted above and in *Figure 2A*.

This decline in lake level is more obvious when compared against a hydrological model[9] that estimates lake elevation if no consumptive use of water occurred (*Figure 2C*, blue line). This analysis demonstrates that *without* consumptive water use, the *long-term* trend in the lake level since 1847 would have been flat with a natural mean elevation of 4,207 feet. Put another way, the lake is now 11 feet lower than it would have been if we were not diverting water for agricultural, industrial, urban and impounded wetland uses. This 11-foot elevation drop has reduced the volume of the lake by 48 percent. Table 1 shows how much each of the various uses of water have contributed to the decrease in lake level.

Any future development of water will cause the lake to drop more. For example, the Utah Division of Water Resources estimates that water consumption associated with the proposed Bear River Development Project[10] would decrease the level of Great Salt Lake approximately 8.5 inches. This would expose about another 30 square miles of lake bed.[11] The logic is straightforward: if less water is delivered to the lake, the lake level must drop. This is an inevitable consequence of ever increasing water consumption.

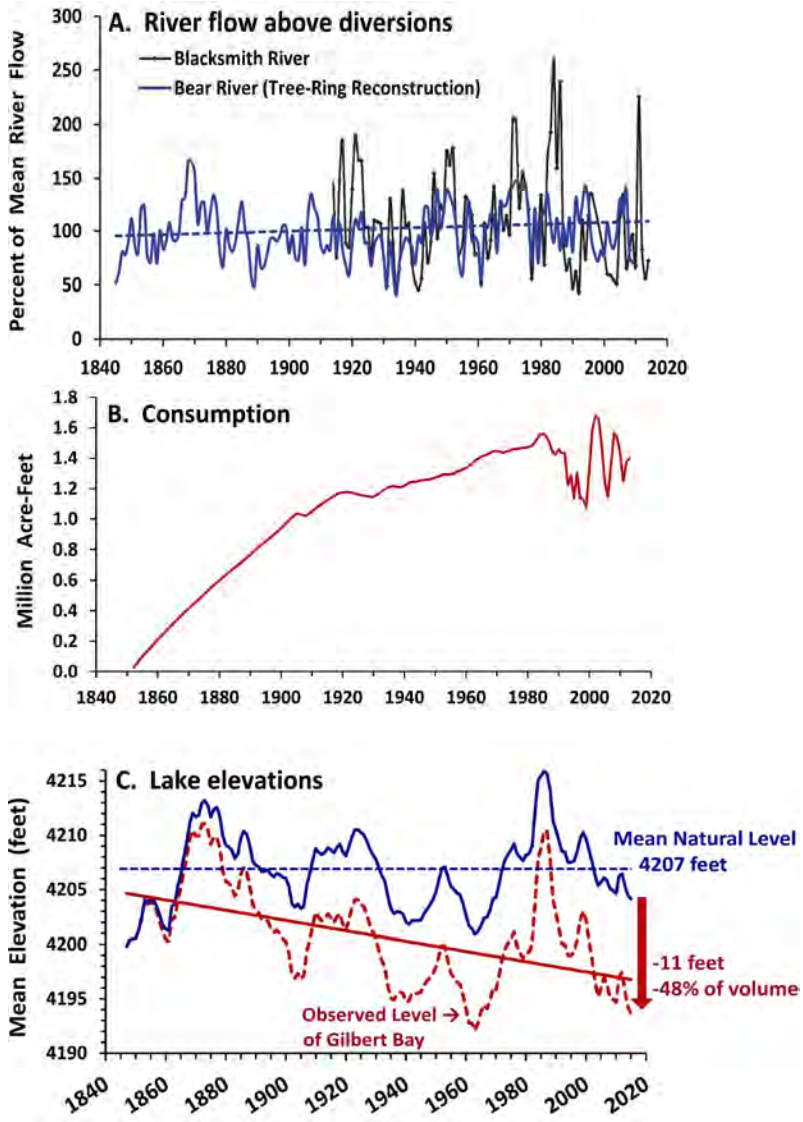


Figure 2. A. Water flow in headwater streams (Blacksmith River gage data; Bear River flow based on tree-ring reconstructions[6]). **B.** Estimated consumptive use of water for agriculture, salt ponds, wetlands and cities. **C.** Observed level of Great Salt Lake (dashed red line). The solid blue line shows a model of lake elevation in the absence of consumptive water uses. Averaged over the last 10 years, water use has lowered the lake 11 feet and decreased its volume by 48 percent.

Impacts of lowered lake levels

Dust & health—Water diversions and drought have reduced lake area from around 1,600 square miles when the pioneers arrived to 1,050 square miles in 2015. The exposed 550 square miles of lake bed increases the potential for locally severe dust storms. *Figure 1* shows lake area at an elevation of 4,207 feet, the 1847-2015 average estimated lake level if there had been no diversions (*Figure 2C*), and the level in July 2015 as the lake approached its lowest recorded level. At the current lake elevation, 48% of the lake bed is exposed compared to when the lake is at 4,207 feet.

Decreased lake elevation, however, affects various bays of the lake differently. Shallow Bear River and Farmington Bays are particularly impacted, and at the current lake level, more than three-quarters of their lake beds are exposed, making them potential sources of dust that influence Wasatch Front communities.

Table 1. Types of human water consumption (depletions) and their influence on decreasing the level of the Great Salt Lake (Source, Utah Division of Water Resources, 2016).

Source and percent of water use	Median estimated decrease in lake level (Total = 11.1 ft)
Agricultural (63%)	7.0 feet
Mineral extraction—salt ponds (13%)	1.4 feet
Municipal & industrial (11%)	1.3 feet
Impounded wetlands (10%)	1.1 feet
Reservoir evaporation (3%)	0.3 feet

The increase in exposed lake bed from water withdrawals and drought can have important consequences for human health. Airborne mineral dust increases hospital visits for respiratory and cardiovascular diseases[12], and increases rates of death[13]. Dust exposure also increases the prevalence of asthma, inhibits immune response, and results in cellular and DNA damage, lung infection, and respiratory disease. Additionally, the dust can transport bacteria and microorganisms that negatively impact human and ecosystem health.[14] When Great Salt Lake is at its mean natural elevation (4,207 feet), it produces only small amounts of dust due to the limited area of exposed dry lake bed. However, as exposed lake bed increases, more dust is produced from this area, causing dust storms such as seen in *Figure 3.*[15] Increased dust production following lake desiccation has occurred in numerous other closed basins nationally and internationally, including Owens Lake in California[16], Lake Urmia in Iran, and the Aral Sea in Kazakhstan and Uzbekistan. In each case the primary cause of rapid desiccation has been increased water withdrawals for agriculture and other consumptive uses. For example, diversions from the Owens River for the city of Los Angeles desiccated Owens Lake by 1926, causing it to become one of the largest sources of particulate matter (PM10) pollution in the country.[17] This dust affects about 40,000 permanent residents in the region, causing asthma and other health problems. As a consequence, since 2000, the City of Los Angeles has spent $1.3 billion for dust mitigation[18] and by 2018 will have spent more than $2.1 billion[19]. Because most of Utah's population is located near Great Salt Lake, health impacts from exposed lake bed could potentially affect even more people. Ongoing studies are estimating the magnitude of the dust impact from the exposed Great Salt Lake shoreline on Wasatch Front communities.[20] Other researchers are investigating how dust increases snowmelt rates and decreases water runoff from high-elevation mountains.[21]

Figure 3. Dust storm coming off the Great Salt Lake viewed from Olympus Cove looking NW towards Salt Lake City. This August 5, 2015 dust storm was caused by a large thunderstorm with 40-50 mph winds at the north end of the Great Salt Lake which lifted dust off the dry lake shore. Webcam image, 6:35 PM.

Mineral Extraction Industry—The exposed lake bed also creates problems for the mineral extraction industry located around the periphery of the lake. Low lake levels have a positive effect of

concentrating minerals, which facilitates their extraction. However, as lake level drops, it becomes increasingly difficult and expensive to deliver brine from the lake to the salt ponds and processing plants. For example, in 2014 Morton Salt was required to dig a five-mile long canal to access the lake's water, and some companies in Gunnison Bay find that it is now cost-prohibitive to pump brine to their distant facilities.

Recreation—Similar problems are experienced by the Great Salt Lake boating community. At the current low lake level, the marina on Antelope Island is not functional for most boats, and the larger Great Salt Lake Marina is currently being dredged at a cost of more than $1.5 million to allow access to the lake. Additional water losses would cause even more severe problems. Recreational use for hunting in Bear River and Farmington Bays is also limited by a shrinking and saltier water body. Altogether, recreation in and around Great Salt Lake contributes about $135 million to Utah's economy.[3]

Environmental health and the brine shrimp industry—Reducing freshwater inflows to Great Salt Lake increases its salinity, which has important consequences for brine shrimp and other invertebrates (*Figure 4*). Brine shrimp rely on intermediate salinities to grow and reproduce. If salinity levels are too low, as they were in the mid-1980s, predatory insects can proliferate and obliterate the brine shrimp.[22] Conversely, when salinities are too high, the shrimp become stressed and eventually, reproduction fails.[23] The salinity level in Gilbert Bay is currently 16 percent, considerably above the optimum for brine shrimp. Nevertheless, the commercial harvest of brine shrimp cysts is still profitable. However, if diversions and drought continue and salinities rise above 20 percent, brine shrimp production is estimated to be reduced to less than 10 percent of optimal.[23] This will severely reduce the $57 million commercial brine shrimp harvest and provide less forage for birds.

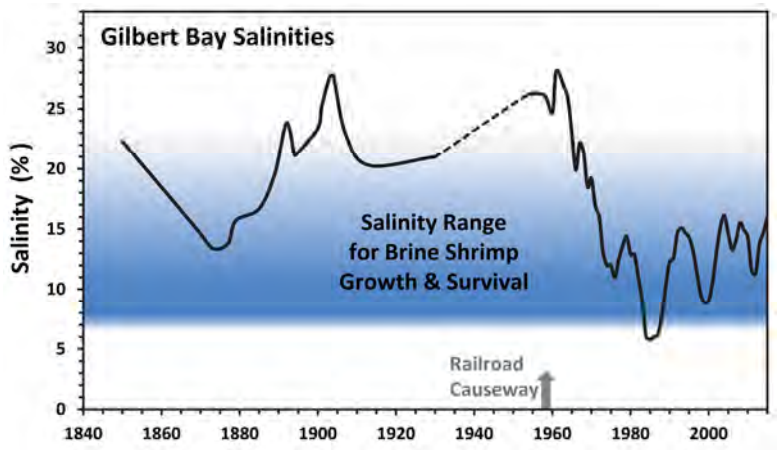


Figure 4. Changes in salinity of Great Salt Lake's southern arm and the range of salinities for growth and survival of brine shrimp. After the railroad causeway was constructed salts concentrated in the north arm, with lower salinities in the south. Dark blue indicates optimal salinities (8-12%) for brine shrimp. For reference, seawater salinity is 3.5%.

Avian usage—Reduced lake levels influence the enormous bird populations that rely on Great Salt Lake for migration and reproduction; species as diverse as American avocets, mallards, swans, and pelicans are all negatively impacted by low lake levels.[24] Most important, critical nesting sites in the shallow areas of Farmington and Bear River Bays nearly disappear at low lake levels (*Figure 1*). These bays are essentially fresh-water estuaries that produce abundant food resources, and support a high density and diversity of birds.[25] When these estuaries shrink, this premier waterfowl production area and its associated $70 million waterfowl hunting industry is threatened.[26] Secondly, increases in salinity in Gilbert Bay, the largest portion of the lake, will decrease food available for those birds, such as grebes, shorebirds, and gulls that feed on brine shrimp and brine flies (*Figure 4*). Additionally, further water diversions could result in more frequent water shortages for the vital freshwater bird sanctuaries such as the Bear River Migratory Bird Refuge that line much of the eastern shore of the lake.[27] The problem of decreasing habitat for birds at Great Salt Lake is exacerbated because many other

western saline lakes that host birds are similarly affected by water diversions and drought: California's Salton Sea[28], Mono Lake[29], and Owens Lake[30], as well as Oregon's Abert Lake[31] are stark examples of environmental harm to saline lakes when water is depleted by consumptive uses.

Conclusion

Figure 5 summarizes how water use and climatic fluctuations influence Great Salt Lake. Climate fluctuations, such as the flooding in the mid-1980s and the current drought, cause flooding and drying cycles with 5-30 year intervals[6]. Consumptive water uses, however, produce a persistent decrease in water supply to the lake and thus, lake levels (*Figure 2*). Since the pioneers arrived in 1847, there has been no significant long-term trend in precipitation or streamflow out of the mountains (*Figure 2A*). Consumptive uses, however, have reduced the lake level by 11 feet, decreased its volume by 48%, increased lake salinity, and exposed approximately 50% of the lake bed. This has increased wind-blown dust, impaired the use of marinas, and caused costly logistical constraints for the mineral extraction industry. Shallow Bear River Bay and Farmington Bay have been particularly impacted by desiccation, thus reducing wetland habitat and their use by waterfowl and shorebirds. Additional water development in the basin, exacerbated by long-term climate variability, may further reduce the lake's level unless conservation efforts are increased for urban, industrial, and especially agricultural uses. Utah needs to be aware of how water developments in the past, and those proposed for the future, affect the lake and the important resources it provides, as well as human health and the economic stability.

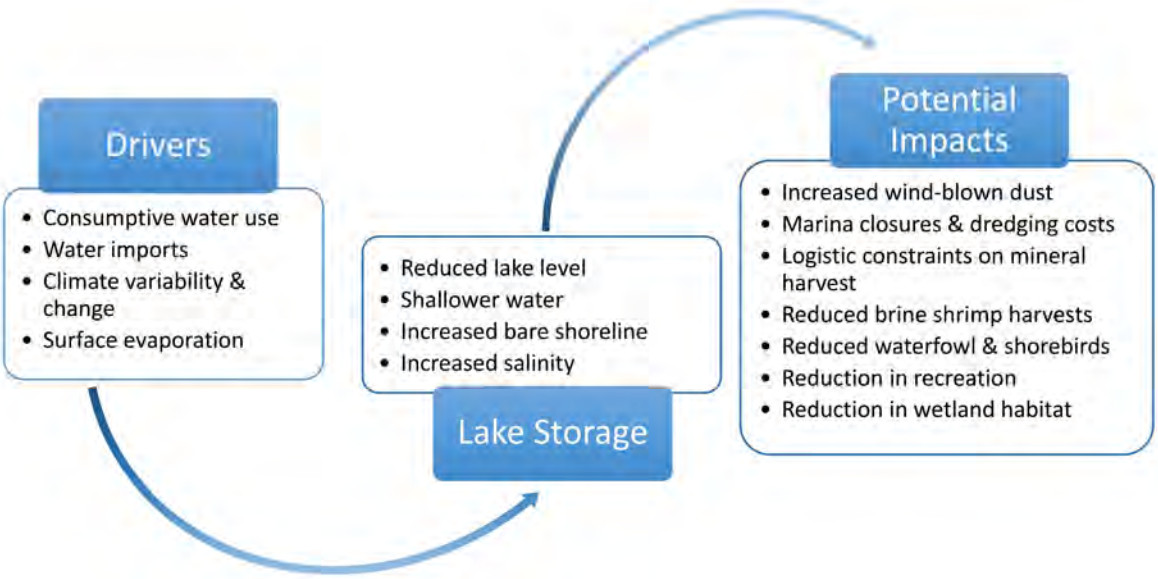


Figure 5. Summary of external forces influencing lake area and volume, and the effects of these changes on Great Salt Lake's natural resources.

Acknowledgements.

Justin DeRose from the U.S. Forest Service provided important tree-ring reconstructions of precipitation and river discharge and contributed to other aspects of the paper. David Tarboton of Utah State University contributed substantially to some of the concepts presented here. Mary-Ann Muffoletto from Utah State University edited the paper. Todd Adams, Eric Klotz, Marisa Egbert, David Cole and Josh Palmer of the Utah Division of Water Resources, and Mike Collins, Bryan Dixon and Lynn de Freitas provided comments on earlier drafts of the paper. The final document does not necessarily represent their views or the views of their organizations.

Footnotes

[1] Fornataro, E.A. 2008. The last untapped river in Utah: An argument against the development of the Bear River. J. Land, Resources and Environmental Law 28: 141-162. http://epubs.utah.edu/index.php/jlrel/article/viewFile/103/93.

[2] Although per-capita urban water use has decreased 18% in the watershed, overall urban use has increased from 131,400 acre-feet in the 1989-2000 period, to 138,800 acre-feet in the 2010-2014 period, a 5.6% increment (Utah Division of Water Resources data).

[3] Bioeconomics. 2012. Economic significance of the Great Salt Lake to the State of Utah. Prepared for the State of Utah Great Salt Lake Advisory Council, Salt Lake City, Utah. 50 p. http://www.gslcouncil.utah.gov/docs/2012/Jan/GSL_FINAL_REPORT-1-26-12.PDF, accessed 8 February 2014.

[4] Mohammed, I.N., and Tarboton, D.G. 2012. An examination of the sensitivity of the Great Salt Lake to changes in inputs. Water Resources Research 48. 1-17, DOI 10.1029/2012wr011908.

[5] Rainfall for the Wasatch Front was derived from a composite rain gage available from the National Oceanographic and Atmospheric Administration, http://w2.weather.gov/climate/xmacis.php?wfo=slc. Despite droughts and wet cycles, there has been no significant ($p = 0.52$) long-term change from 1875-2015. Regression; inches = 24.67 - 0.00465 *year; $p = 0.52$, not significant.

[6] River flow in the upper tributaries was based on the 100-year continuous record from the Blacksmith Fork (USGS gage # 10113500), a tributary to the Logan River, and on tree-ring estimates of precipitation. In high precipitation years, trees form thicker growth rings, such that the widths of these rings can be correlated with measured flows in rivers for the years when flow data are available. The tree ring widths in years prior to documented river flows can then be used to estimate flows in those years. Here, we've presented flow estimates for the Bear River at a site high in the watershed and above any water diversion structures (USGS gage # 10011500; DeRose, R.J. et al. 2015, A millennium-length reconstruction of Bear River stream flow, Utah. J. of Hydrology, doi: 10.1016/j.jhydrol.2015.01.014). Similar reconstructions for the Weber River and Logan Rivers also demonstrate that there has been no long-term decrease in river flow in upper basins (Bekker, M.F. et al. 2014. A 576-Year Weber River streamflow reconstruction from tree rings for water resource risk assessment in the Wasatch Front, Utah. JAWRA J. of the Am. Wat. Resources Assoc. 50, 1338–1348. doi:10.1111/jawr.12191, Allen, E.B. et al. 2013. A tree-ring based reconstruction of Logan River streamflow, northern Utah. Water Resources Res. 49, 8579–8588. doi:10.1002/2013WR014273). Also see DeRose, R.J., et al. 2014. Tree-ring reconstruction of the level of Great Salt Lake, USA. The Holocene 24, 805–813. doi:10.1177/0959683614530441. These reconstructions document long-term droughts and wet cycles more severe than have been documented since 1847. During these cycles the lake dried significantly more than our current situation and at other times expanded beyond even the flooding seen in the mid-1980s.

The regression line in Figure 2A is a composite of the Blacksmith River flow and the tree-ring estimated flow for the Bear River, and shows no significant trend ($n = 267$, $p = 0.085$). Similarly, there were no significant trends when the Blacksmith River ($n = 98$, $p = 0.349$) and the Bear River tree-ring data ($n = 165$, $p = 0.078$) were analyzed separately.

[7] Estimates of agricultural and reservoir consumptive use (called depletions by hydrologists) for the last 30 years were computed from net crop evapotranspiration less winter carryover soil moisture storage on a per-acre basis. Reservoir depletions were calculated as net average annual evaporation times 80% of maximum surface area (Hill, R. W. 1994.

Consumptive use of irrigated crops in Utah, Utah Agr. Exp. Station. Res. Report #145; Water Rights web site, http://www.waterrights.utah.gov/cgi-bin/damview.exe). Bear Lake and Utah Lake were not included in this calculation, meaning that the actual evapotranspiration depletions may be somewhat larger than shown.

To obtain weather inputs for these calculations, 30-year (1971-2000) average weather data were extracted from PRISM (http://www.prism.oregonstate.edu/). Municipal depletions were calculated by subtracting estimated impervious surface runoff from municipal -calculated consumptive use. Evapotranspiration from impounded open water wetlands was estimated using an area of 56,000 acres (Emerson, R. and T. Hooker. 2011. Utah wetland functional classification and Landscape profile generation within Bear River Bay, Great Salt Lake, Utah. USGS, https://www.mendeley.com/profiles/richard-emerson1/) multiplied by the net average annual evaporation (GridET program; author Clay Lewis, 2015, https://github.com/claytonscottlewis/GridETURL). Mineral extraction depletion was calculated as 75% of lake withdrawals (Compass Minerals, personal communication). Depletions due to evaporative losses in the basin were then lowered by the amount of water imported from the Colorado River Basin.

The 39% decrease in river inflow to the lake is based on a 10-year average (2003-2012). This calculation accounts for the importation of Colorado River water into the basin. The 39% decrease due to depletions is calculated based on total depletions (corrected for Colorado R. imports) of 1,451,000 acre-feet (Utah DWR) and current river inflow to the lake of 2,303,000 acre-feet (Mohammed, I.N. and D.G. Tarboton, 2012).

The data use for the depletion estimates are a composite of early data analyses in the Utah Division of Water Resources, and more detailed data after 1989. Depletions prior to 1970 were taken from estimates of R. Palmer and G.L. Whittaker (Unpublished data, Utah Division of Water Resources). The post-1989 data shows short-term responses to droughts and wet cycles, and is thus irregular. Consequently, the data in Figure 2B were smoothed with a 5-point running average.

Estimates of water depletions are imprecise. Consequently, additional analyses of the effects of depletions on the lake's level are warranted and may change the results somewhat. Nevertheless, the absence of a long-term trend in rainfall[5] and mountain runoff over the past 170 years (Fig. 2A), when compared to the persistent decrease in lake level (Fig. 2C), indicates that water use and consumption is having a major impact on the lake. Additional analyses of water use on the lake are ongoing as part of the Great Salt Lake Integrated Water Resource Model being developed by the Division of Forestry, Fire and State Lands.

[8] Linear regression for red line in Fig. 2C, Lake Elevation (feet) = 4291.3 - 0.0469 * year; $p < 0.0001$. Highly significant decline.

[9] To estimate what the elevation of the lake would be if water was not used for consumption we added the difference between past and current depletions as an annual input to the Great Salt Lake. The influence of lake area and salt concentration on the evaporation rate from the lake surface were included in the model.

[10] Bear River Development Project. Utah Division of Natural Resources. http://www.gslcouncil.utah.gov/docs/2014/10Oct/BearRiverPipelineProject.pdf.

[11] The Utah Division of Water Resources estimates that the proposed diversion of 220,000 acre-feet of Bear Water will result in a depletion of 85,670 acre-feet of water delivery to Great Salt Lake. They estimate that this will cause the lake to decrease a mean of 8.5 inches and a maximum of 14 inches in elevation (C. Miller, personal communication). Assuming a mean decrease of 8.5 inches from the current lake level (4193.1 feet), an additional 30 square miles of lake bed would be exposed. If the decrease was 14 inches, 45 square miles would be exposed. The areas of exposure were calculated from the bathymetric data provided by David Tarboton (Utah State Univ.) and does not include the areas in salt ponds.

[12] Grineski, S.E., Staniswalis, J.G., Bulathsinhala, P., Peng, Y, Gill, T.E., 2011. Hospital admissions for asthma and acute bronchitis in El Paso, Texas: do age, sex, and insurance status modify the effects of dust and low wind events? Environ. Res. 111, 1148-55. DOI: 10.1016/j.envres.2100.06.007.

[13] Giannadaki, D., Pozzer, A., Lelieveld, J. 2014. Modeled global effects of airborne desert dust on air quality and premature mortality. Atmos. Chem. Phys. 14, 957-968. http://dx.DOI: 10.5194/acp-14-957-2014.

[14] Griffin, D.W., Kellog, C.A., 2004. Dust storms and their impact on ocean and human health: dust in the earth's atmosphere. EcoHealth 1, 284-295. http://dx.DOI.org/10.1007/s10393-004-0120-8.

[15] Dust events from Great Salt Lake and other areas in Utah are described in Hahnenberger, M., Nicoll, K., 2012. Meteorological characteristics of dust storm events in the eastern Great Basin of Utah, U.S.A. Atmospheric Environment, 60, 601-612, ISSN 1352-2310, http://dx.doi.org/10.1016/j.atmosenv.2.

[16] Larsen, R. 2014. The half-life of a lake. Virginia Quarterly Review 90, 24-25. DOI: 10.1353/vqr.2014.0068.

[17] Great Basin Unified Air Pollution Control District (GBUAPCD). Owens Lake Dust Mitigation. http://www.gbuapcd.org/owenslake.htm.

[18] Smith, D. 2014. Settlement reached over dust control measures at Owens Lake. Los Angeles Daily News, November 14, 2014. http://www.dailynews.com/general-news/20141114/settlement-reached-over-dust-control-measures-at-owens-lake.

[19] Phillip Kiddoo, personal communication, Great Basin Unified Air Pollution Control District, Air Pollution Control Officer. January 28, 2016.

[20]Utah Division of Forestry, Fire & State Lands grant. http://www.ffsl.utah.gov/index.php/grant-programs/state-lands-research-grants?showall=&start=1.

[21] Dust increases sunlight absorption and hastens snowmelt, particularly in areas above tree line. See: Maurer, G.E. and D.R. Bowling. 2015. Dust effects on snowpack melt and related ecosystem processes are secondary to those of forest canopy structure and interannual snowpack variability. Ecohydrology 8:1005-1023.

[22] Wurtsbaugh, W.A. 1992. Food-web modification by an invertebrate predator in the Great Salt Lake (USA). Oecologia 89:168-175.

[23] Barnes, B.D. and W.A. Wurtsbaugh. 2015. The effects of salinity on plankton and benthic communities in the Great Salt Lake, Utah, USA: a microcosm experiment. Can. J. Fish. Aquatic Sci. DOI: 10.1139/cjfas-2014-0396. Null, S., W. Wurtsbaugh and C. Miller. 2013. Can the causeway in the Great Salt Lake be used to manage salinity? Friends of Great Salt Lake Newsletter Vol. 19 No. 1 & 2: 14-15. http://www.fogsl.org/images/stories/2013/2MayNewsletterreduced.pdf.

[24] Frank Howe, Utah Division of Wildlife Resources, personal communication, 15 January 2016.

[25] Paul, D.S., and A.E. Manning. Great Salt Lake waterbird survey five-year report (1997-2001). 1 Oct. 2008. Great Salt Lake Ecosystem Program and Utah Division of Wildlife Resources. Accessed Jan. 19, 2016. http://www.wildlife.utah.gov/gsl/waterbirdsurvey/. https://www.census.gov/prod/2012pubs/fhw11-nat.pdf.

[26] U.S. Fish and Wildlife Service. 2014. 2011 National Survey of fishing, hunting, and wildlife-associated recreation: Utah. U.S. Department of the Interior, U.S. Fish and Wildlife Service, and U.S. Department of Commerce, U.S. Census Bureau.

[27] Welsh, LW, Endter-Wada J, Downard R, and Kettenring KM. 2013. Developing adaptive capacity to droughts: the rationality of locality. Ecology and Society 18: 7. http://dx.doi.org/10.5751/ES-05484-180207.

[28] Case, HLI, Boles J, Delgado A, et al. 2013. Salton Sea ecosystem monitoring and assessment plan. U.S. Geological Survey Open-File Report: 2013-1133. (http://pubs.er.usgs.gov/publication/ofr20131133).

[29] Patten, D.T., F.P. Conte, W.E. Cooper, J. Dracup, S. Dreiss, K. Harper, G.L. Hunt, P. Kilham, H.E. Klieforth, J.M. Melack and S.A. Temple. The Mono Basin ecosystem—effects of changing lake level. National Academy Press, Washington, D.C. 272p. http://www.nap.edu/read/1007/chapter/1.

[30] Reheis, M.C., 1997, Dust deposition downwind of Owens (Dry) Lake, 1991-1994—Preliminary findings: Journal of Geophysical Research (Atmospheres), v. 102, no. D22, p. 25,999-26,008.

[31] The Oregonian. Oregon's only saltwater lake is disappearing, and scientists don't know why. http://www.oregonlive.com/lake-abert/; Moore, J.N. In press. Recent desiccation of western Great Basin saline lakes: Lessons from Lake Abert, Oregon, U.S.A. Sci. of the Total Environment.

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