Lake Powell Pipeline

Final Study Report 5
Groundwater Resources

April 2016

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Final Groundwater Resources Study Report
Executive Summary

ES-1 Introduction

This study report describes the results and findings of an analysis to evaluate groundwater resources impacts along the proposed alternative alignments of the Lake Powell Pipeline Project (LPP Project), No Lake Powell Water Alternative, and No Action Alternative. The purpose of the analysis, as defined in the 2008 Groundwater Resources Study Plan prepared for the Federal Energy Regulatory Commission (Commission), was to identify potential impacts of the alternatives on groundwater resources during construction, operation and maintenance, and identify measures to mitigate impacts of the groundwater conditions.

ES-2 Methodology

The analysis of impacts on groundwater resources follows methodology identified and described in the Preliminary Application Document, Scoping Document No. 1 and the Groundwater Resources Study Plan filed with the Commission.

ES-3 Key Results of the Groundwater Resources Impact Analyses

Significance criteria were established based on the following impact topics identified in the Study Plan: shallow groundwater, groundwater recharge, groundwater-surface water interactions, and water quality. With respect to the impact topics, any measurable, long-term depletion, degradation, or change in availability of groundwater resources relative to baseline conditions would be considered a significant impact. Impacts are considered significant only if they would occur within the design life of the LPP Project (75 years), and could not be mitigated by design or Best Management Practices (BMPs).

ES-3.1 LPP Project Alternatives

No significant groundwater resource impacts are expected for the LPP Project alternative alignments with the incorporation of design considerations and BMPs. A few sites have been identified with potential shallow groundwater; however, BMPs aimed at minimizing drawdown, groundwater migration, and surface erosion during construction would prevent any significant impacts. Other standard construction and operational BMPs would prevent any significant impacts on groundwater recharge, groundwater-surface water interactions, and water quality impacts.

ES-3.2 No Lake Powell Water Alternative

Groundwater resources would be significantly impacted. Pressure would continue and increase on groundwater resources as the projected shortage of available water would require maximization of the groundwater resource usage. In addition, groundwater recharge would be significantly impacted. This alternative would eliminate outside lawn and landscape watering. Currently, most of the water used for this purpose originates from surface water, primarily the Virgin River. Eliminating outside watering would reduce the amount of groundwater recharge. This would be a significant long term impact. The reduced groundwater recharge would reduce non-sewered return flows to the Virgin River by 15,500 to

17,017 acre-feet per year (21.4 to 23.5 cubic feet per second, on average) by 2052, a projected reduction of 77 to 80 percent compared to baseline conditions. This would be a measurable, significant long-term impact on Virgin River flows.

ES-3.3 No Action Alternative

Groundwater resources would be significantly impacted. Pressure would continue and increase on groundwater resources as the projected shortage of available water would require maximization of the groundwater resource usage. Eventually, the capacity of the aquifers would be exceeded and depletion would occur, limiting the availability of water for use. No impacts are expected to occur on groundwater recharge, groundwater-surface water interactions, and water quality.

Chapter 1
Introduction

1.1 Introduction

This chapter presents a summary description of the Lake Powell Pipeline (LPP) Project alignment alternatives, the No Lake Powell Water Alternative, and the No Action Alternative. It introduces the area studied for environmental resources. It provides an overview of the proposed LPP Project, including each alignment alternative and locator maps.

The LPP Project would deliver Utah's Colorado River water from Lake Powell to the service areas of Washington County Water Conservancy District (WCWCD) and Kane County Water Conservancy District (KCWCD). The LPP Project action alternatives studied include various pipeline and penstock system configurations. Each action alternative would deliver 86,249 acre-feet of municipal and industrial (M&I) use water to the following southwest Utah water conservancy district service areas:

- WCWCD would receive 82,249 acre-feet annually.
- KCWCD would receive up to 4,000 acre-feet annually.

One of the LPP systems previously studied included a conveyance system for the Central Iron County Water Conservancy District (CICWCD), which would have delivered approximately 13,249 acre-feet annually to the Cedar Valley area. The various alternatives were under study when the CICWCD decided to withdraw from the LPP Project, and this conveyance system is no longer being considered.

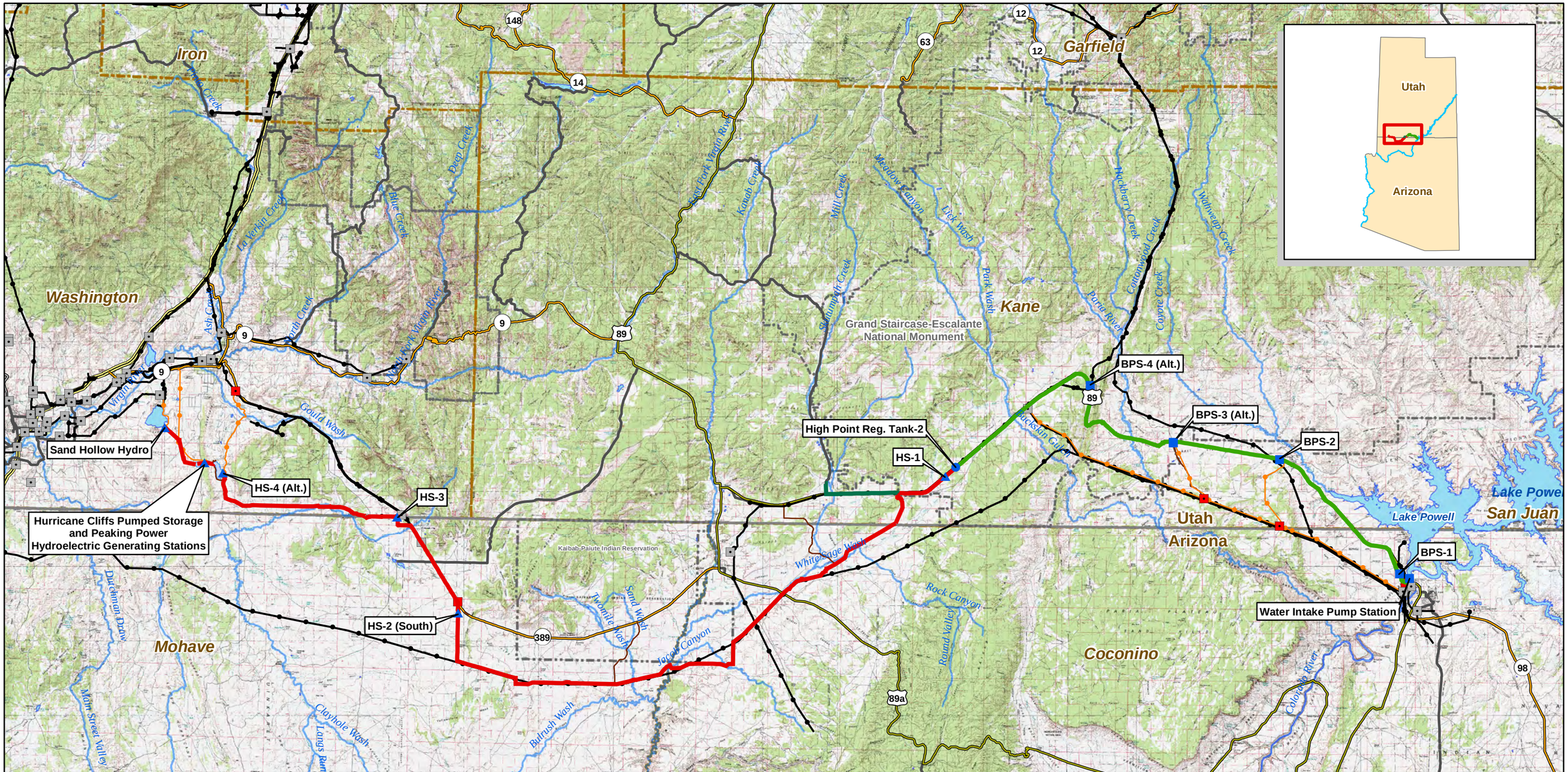
1.2 Summary Description of LPP Project Alignment Alternatives

Three primary pipeline and penstock alignment alternatives are described in this section, along with the electrical power transmission line alignments for providing power to the pump stations and a natural gas supply line alignment alternative. The pipeline and penstock alignment alternatives share common segments between the intake at Lake Powell and delivery at Sand Hollow Reservoir, and they differ spatially in, through and around Kaibab-Paiute Indian Reservation.

The South Alternative (Proposed Action) extends south around Kaibab-Paiute Indian Reservation. The Existing Highway Alternative follows an Arizona state highway through Kaibab-Paiute Indian Reservation. The Southeast Corner Alternative follows the Navajo-McCullough Transmission Line corridor through the southeast corner of Kaibab-Paiute Indian Reservation. The Electric Transmission Line alignments are common to all the pipeline and penstock alignment alternatives. The Natural Gas Supply Line Alignment Alternative is common to all pipeline and penstock alignment alternatives. The natural gas pipeline alignment would be coincident to the buried waterline and would not have a different alignment, as compared to transmission line alignments. Figure 1-1 shows the overall proposed project from Lake Powell near Page, Arizona to Sand Hollow Reservoir, Utah.

1.2.1 South Alternative

The South Alternative consists of four systems: **Water Intake, Water Conveyance, Hydro,** and **KCWCD** (see Figure 1-1).



Project Pump Station
Project Regulating Tank
Project Hydro Station
Substation
Proposed Substation

Water Conveyance System
Hydro System - Proposed Action (Penstock Segment)
KCWCD System
Project Transmission Lines
Existing Transmission Lines

Interstate
US Highway
ST Highway
Hwy
Major Road
Access Roads

Hurricane Cliffs Forebay/Afterbay
Lakes & Reservoirs
Major Rivers & Streams

National Park/Monument
Tribal Lands
State Boundaries
County Boundaries

FERC Project Number:
12966-001
BLM Serial Numbers:
AZA-34941
UTU-85472

N

0 2.5 5 10 15 20 Miles

Lake Powell Pipeline Project

Spatial Reference: UTM Zone 12N, NAD-83

UDWRe **Figure 1-1** MWH

Lake Powell Pipeline Proposed Action

The **Water Intake System** would pump Lake Powell water via submerged horizontal tunnels and vertical shafts into the LPP. The intake pump station would be constructed and operated adjacent to the west side of Lake Powell, approximately 2,000 feet northwest of Glen Canyon Dam in Coconino County, Arizona. An enclosed pump station building would house vertical turbine pumps with electric motors, electrical controls, and other equipment at a ground level elevation of 3,745 feet above mean sea level (AMSL).

The **Water Conveyance System** would convey water diverted from Lake Powell at the Intake System through a buried 69-inch diameter pipeline for about 51 miles, parallel with Highway 89 in Coconino County, Arizona and Kane County, Utah, to a buried regulating tank (High Point Regulating Tank-2) along Highway 89 at ground level elevation 5,691 feet AMSL. The pipeline would be a line of connected pipes used for carrying water over a long distance. Figure 1-2 shows the LPP Project Water Intake and Water Conveyance systems. The High Point Regulating Tank-2 would be the LPP Project topographic high point (Figure 1-2). The pipeline would be sited within a utility corridor established by Congress in 1998 that extends 500 feet south and 240 feet north of the Highway 89 centerline on public land administered by Bureau of Land Management (BLM) (U.S. Congress 1998). Figure 1-3 shows the typical 100-foot-wide right-of-way and 20-foot-wide temporary construction easement for the water conveyance system pipeline, adjacent to and away from the highway.

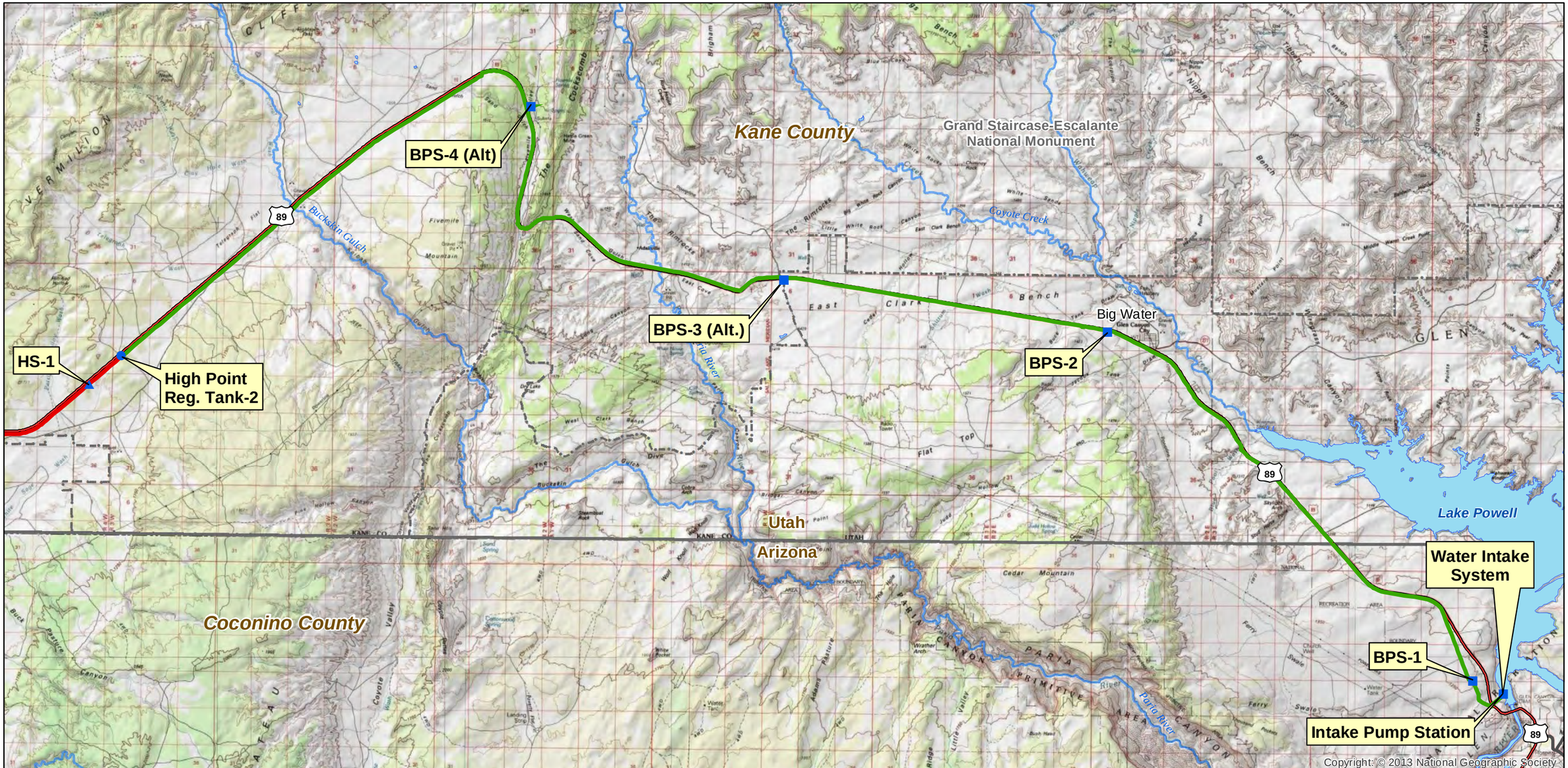
Four booster pump stations (BPS) along the pipeline would pump water to the high point regulating tank. Each BPS would house vertical turbine pumps with electric motors, electrical controls, and other equipment. Additionally, each BPS site would have a buried forebay tank, buried surge tanks, pig retrieval and launching stations, and a surface emergency overflow detention basin. BPS-1 would be located within Glen Canyon National Recreation Area (GCNRA) adjacent to an existing Arizona Department of Transportation maintenance facility, along a segment of abandoned highway, west of Highway 89. The BPS-1 site would cover about six acres and be surrounded by security fencing.

BPS-2 would be on land administered by Utah School and Institutional Trust Lands Administration (SITLA) near Big Water, Utah, on the south side of Highway 89. The BPS-2 site would cover about five acres and be surrounded by security fencing.

BPS-3 (Alt.) would be on land administered by BLM Kanab Field Office, near the east boundary of Grand Staircase-Escalante National Monument (GSENM) on the south side of Highway 89, within the Congressionally-designated utility corridor. The BPS-3 (Alt.) site would cover about five acres and be surrounded by security fencing.

BPS-4 (Alt.) would be located on private land east of Highway 89 and west of the Cockscomb geologic feature (Figure 1-2). The BPS-4 (Alt.) site would cover about six acres and be surrounded by security fencing. The proposed pipeline alignment west of the Cockscomb geologic feature would be situated adjacent to the south boundary of the Congressionally-designated utility corridor.

The proposed pipeline alignment would continue parallel to Highway 89 to the buried High Point Regulating Tank-2 at 5,691 feet AMSL, which would be the topographic high point of the LPP Project (Figure 1-2). The Water Conveyance System would terminate at High Point Regulating Tank-2. The buried High Point Regulating Tank-2 would cover about four acres and be surrounded by security fencing.



- Project Pump Station
- Project Regulating Tank
- Project Hydro Station
- Water Conveyance System
- Hydro System - Proposed Action (Penstock Segment)
- KCWCD System
- Interstate
- US Highway
- ST Highway
- Hwy
- Major Road
- Lakes & Reservoirs
- Major Rivers & Streams
- National Park/Monument
- State Boundaries

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N

0 0.5 1 2 3 4 Miles

Lake Powell Pipeline Project

Spatial Reference: UTM Zone 12N, NAD-83

UDWRe **Figure 1-2** MWH

Lake Powell Pipeline Intake and Water Conveyance System

Figure 1-3 shows the typical 100-foot-wide right-of-way and 20-foot-wide temporary construction easement for the hydro system penstock adjacent to, and away from, the highway. Four in-line hydro generating stations (HS-1, HS-2 [South], HS-3, and HS-4 [Alt.]), with substations located along the penstock, would generate electricity and help control water pressure in the penstock. Each in-line hydro station would consist of a building housing the generator units, an afterbay reservoir, retention basin, pig retrieval and launching stations, switchyard, and maintenance parking area, all surrounded by perimeter security fencing.

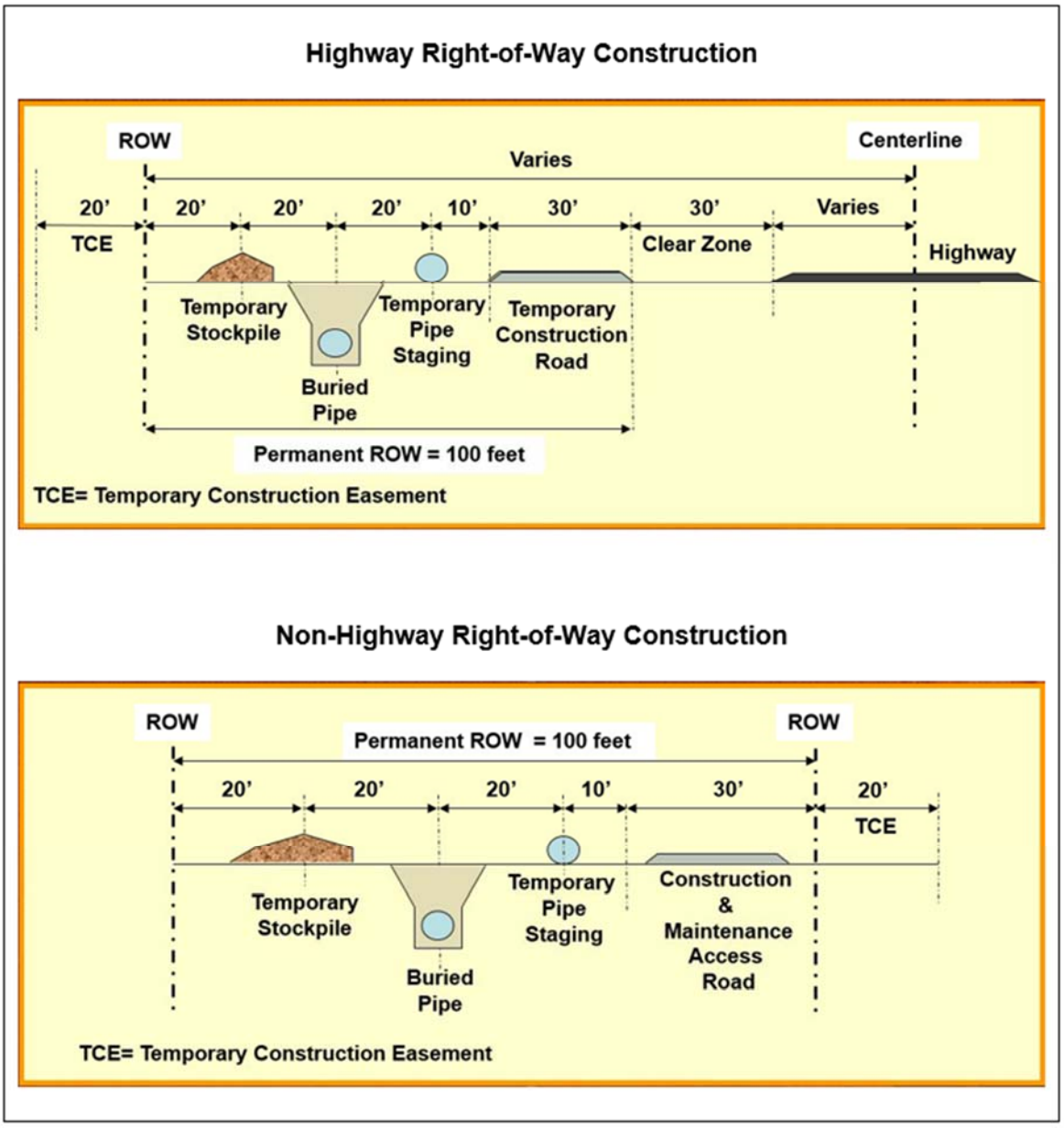


Figure 1-3
Pipeline and Penstock Right-of-Way

The **Hydro System** would convey the water from High Point Regulating Tank-2, at a topographic high point in the LPP Project with ground level elevation 5,691 feet AMSL, for about 87.5 miles through a buried 69-inch diameter penstock in Kane and Washington counties, Utah, and Coconino and Mohave counties, Arizona, to Sand Hollow Reservoir near St. George, Utah (Figure 1-4). A penstock is an enclosed pipe that delivers water to hydroelectric turbines.

A short penstock segment would convey the water to HS-1. This in-line hydro station would generate up to one megawatt (MW) of electricity at a site along Highway 89 within GSENM, and the penstock would continue west along Highway 89 to the GSENM west boundary. The HS-1 site would cover about five acres.

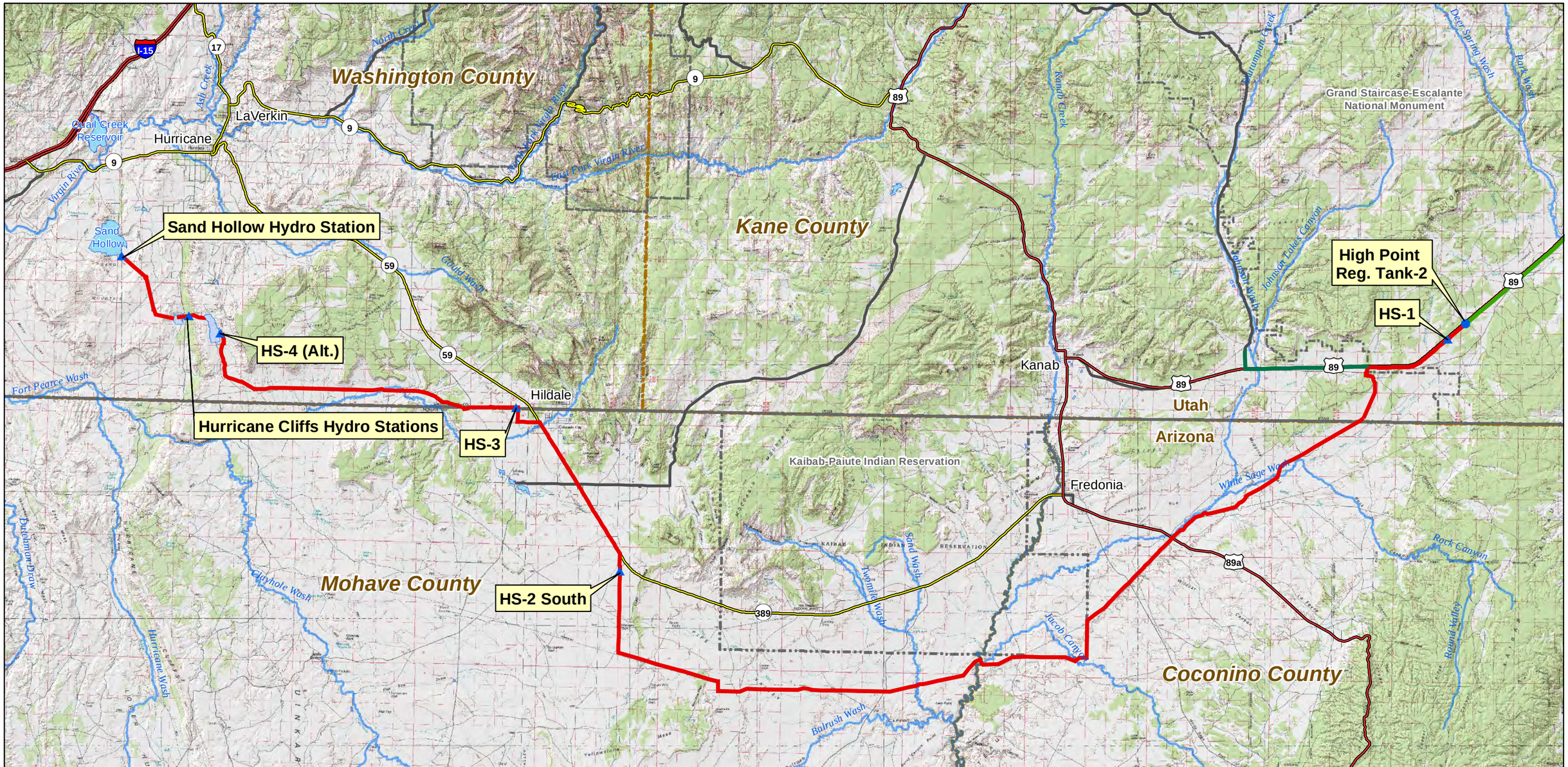
The penstock alignment would turn south from Highway 89 through private land and BLM-administered public lands into White Sage Wash. It would continue across White Sage Wash and then parallel Navajo-McCullough Transmission Line, crossing Highway 89 Alt. and Forest Highway 22 toward the southeast corner of Kaibab-Paiute Indian Reservation. The penstock alignment would run parallel to and south of the Kaibab-Paiute Indian Reservation south boundary, crossing Kanab Creek and Bitter Seeps Wash. It would continue across Moonshine Ridge and Cedar Ridge to Yellowstone Road. At this point, the penstock alignment would run north along Yellowstone Road to Arizona State Route 389 west of Kaibab-Paiute Indian Reservation. HS-2 (South) would be located west of Kaibab-Paiute Indian Reservation on private land east of Yellowstone Road. HS-2 (South) would generate up to one MW of electricity. The HS-2 (South) site would cover about five acres. The penstock alignment would continue northwest along the south side of Arizona State Route 389 past Colorado City to Hildale City, Utah, and HS-3. HS-3 would be located on private land west of Hildale City, Utah, north of and adjacent to Uzona Road. HS-3 would generate up to one MW of electricity. The HS-3 site would cover about five acres. A turnout for future delivery of 13,249 acre-feet of WCWCD's allocation of LPP Project water to Apple Valley would be located immediately west of HS-3.

The penstock alignment would follow Uzona Road west through Canaan Gap and south of Little Creek Mountain, turning north to HS-4 (Alt.) above the proposed Hurricane Cliffs forebay reservoir. HS-4 (Alt.) would be located on about three acres of public land administered by the BLM. HS-4 (Alt.) would generate up to 1.7 MW of electricity and would discharge into the forebay reservoir.

The forebay reservoir would be contained in a valley between two dams (south and north), maintaining active storage of 11,255 acre-feet of water. The forebay reservoir and two dams would cover about 500 acres of public land administered by BLM and would be surrounded by security fencing. A low-pressure tunnel would convey the water to a high-pressure vertical shaft in the bedrock forming the Hurricane Cliffs, connected to a high-pressure tunnel near the bottom of the Hurricane Cliffs. The high-pressure tunnel would connect to a penstock conveying the water to a 35-MW-capacity peaking power hydroelectric generating station and a 300-MW-capacity pumped storage hydroelectric generating station.

The Hurricane Cliffs hydroelectric generating stations and tailrace channel would cover about 50 acres of public land administered by BLM and would be surrounded by security fencing. The tailrace channel would discharge into an afterbay reservoir with 3,551 acre-feet of operating capacity, which is contained by a single dam in the valley below the Hurricane Cliffs. The afterbay reservoir and dam would cover about 200 acres of public land administered by BLM and would be surrounded by security fencing.

Water would be released from the forebay reservoir through the hydro generating system to meet peak power demands. Water would be pumped from the afterbay reservoir into the forebay reservoir during periods of off-peak power demand. The forebay and afterbay reservoirs would not be open to public access because the water levels would fluctuate rapidly during daily operations. A low pressure tunnel would convey the water northwest from the afterbay reservoir to a penstock, continuing to the Sand



Project Pump Station
Project Regulating Tank
Project Hydro Station
Hurricane Cliffs Forebay/Afterbay
Lakes & Reservoirs
Water Conveyance System
Hydro System - Proposed Action (Penstock Segment)
KCWCD System
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N

0 1 2 4 6 8 Miles

Lake Powell Pipeline Project

Spatial Reference: UTM Zone 12N, NAD-83

UDWRe **Figure 1-4** MWH

Lake Powell Pipeline Hydro System Proposed Action

Hollow Hydro Station, which would generate up to 4.2 MW of electricity. The Sand Hollow Hydro Station would be located on land owned by WCWCD and cover about five acres adjacent to Sand Hollow Reservoir. The LPP Project water would discharge from the Sand Hollow Hydro Station into the existing Sand Hollow Reservoir.

The **KCWCD System** would convey water diverted from Lake Powell through the LPP at the west GSENM boundary for about eight miles through a buried 24-inch diameter pipeline in Kane County, Utah, near the mouth of Johnson Canyon. The pipeline would parallel the south side of Highway 89 across Johnson Wash and then run north for 5000 feet to the mouth of Johnson Canyon (Figure 1-4).

1.2.2 Existing Highway Alternative

The Existing Highway Alternative consists of four systems: **Water Intake, Water Conveyance, Hydro,** and **KCWCD**. The **Water Intake** and **Water Conveyance** systems would be the same as described for the South Alternative. The **Hydro System** would convey water diverted at Lake Powell from High Point Regulating Tank 2 at the LPP Project topographical high point (5,691 feet AMSL) for about 80.5 miles through a buried 69-inch diameter penstock in Kane and Washington counties, Utah, and Coconino and Mohave counties, Arizona, to Sand Hollow Reservoir near St. George, Utah (Figure 1-5). The alternative alignment parallels Highway 89 to the west and south boundary of GSENM and continues along Highway 89 to Lost Spring Gap. Four in-line hydro generating stations (HS-1, HS-2 [Hwy], HS-3, and HS-4 [Alt.]) located along the penstock would generate electricity and help control water pressure in the penstock. The HS-1, HS-3 and HS-4 (Alt.) hydro stations would be the same as described for the South Alternative.

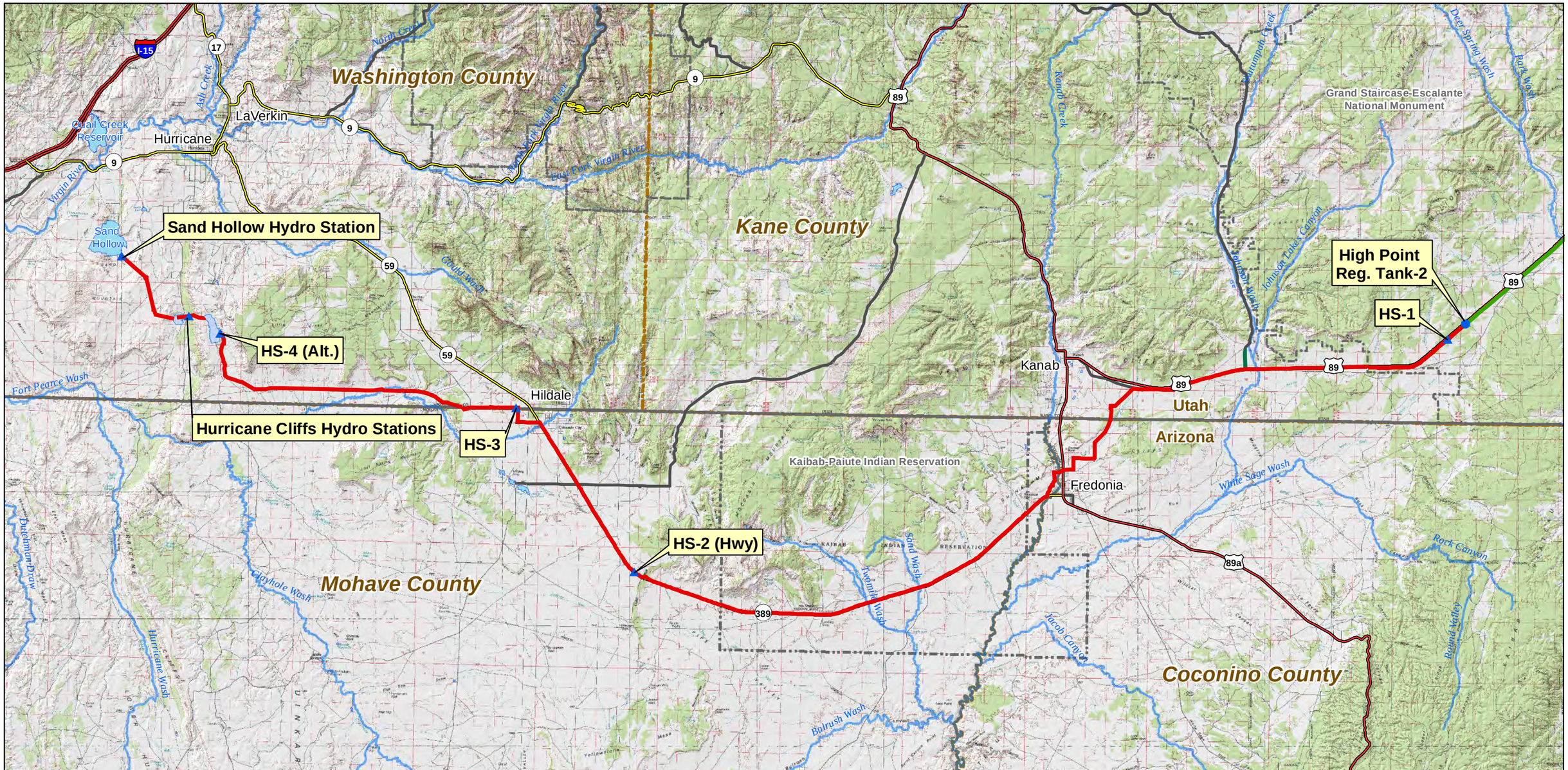
The penstock downstream from the proposed HS-1 would be sited along the south side of Highway 89 within GSENM. The penstock would parallel the south side of Highway 89 west of GSENM, continue past Johnson Wash and follow Lost Spring Gap southwest, crossing Highway 89 Alt. and Kanab Creek in the north end of Fredonia, Arizona. It would continue south, paralleling Kanab Creek to Arizona State Route 389, where it would run west, adjacent to the north side of Route 389 through Kaibab-Paiute Indian Reservation past Pipe Spring National Monument. The penstock would continue along the north side of Arizona State Route 389 through the west half of Kaibab-Paiute Indian Reservation to 1.8 miles west of Cedar Ridge (intersection of Yellowstone Road with Highway 89), where it would then follow the same alignment as the South Alternative to Sand Hollow Reservoir. HS-2 (Hwy) would be sited 0.5 miles west of Cedar Ridge along the north side of Arizona State Route 389. HS-2 (Hwy) would generate approximately 0.8MW of electricity and cover 8.7 acres of private land.

The **KCWCD System** would convey water diverted at Lake Powell from the LPP Project along Highway 89 north along Johnson Canyon Road for 5,000 feet through a buried 24-inch diameter pipeline in Kane County, Utah to the mouth of Johnson Canyon (Figure 1-5).

1.2.3 Southeast Corner Alternative

The Southeast Corner Alternative consists of four systems: **Water Intake, Water Conveyance, Hydro,** and **KCWCD**. The **Water Intake**, **Water Conveyance**, and **KCWCD** systems would be the same as described for the South Alternative.

The **Hydro System** would be the same as described for the South Alternative from High Point Regulating Tank 2 at the LPP Project topographical high point (5,691 feet AMSL) to the east boundary of Kaibab-Paiute Indian Reservation. At the east boundary of Kaibab-Paiute Indian Reservation, the penstock alignment would parallel the north side of the Navajo-McCullough Transmission Line corridor in Coconino County, Arizona, through the southeast corner of the Kaibab-Paiute Indian Reservation for



Project Pump Station
Project Regulating Tank
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Hurricane Cliffs Forebay/Afterbay
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Water Conveyance System
Hydro System - Existing Highway Alternative (Penstock Segment)
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FERC Project Number:
12966-001
BLM Serial Numbers:
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UTU-85472

N

0 1 2 4 6 8 Miles

Lake Powell Pipeline Project

Spatial Reference: UTM Zone 12N, NAD-83

UDWRe **Figure 1-5** MWH

Lake Powell Pipeline
Hydro System
Existing Highway Alternative

about 3.8 miles. The penstock would then follow the South Alternative alignment south of the south boundary of the Kaibab-Paiute Indian Reservation, continuing to Sand Hollow Reservoir (Figure 1-6). The Southeast Corner Alternative would be about 85.7 miles long from High Point Regulating Tank-2 to Sand Hollow Reservoir.

1.2.4 Transmission Line Alignments

Transmission line alignments have been identified to transmit electric power to pump stations in the Water Intake and Water Conveyance systems, and to transmit electric power generated by hydroelectric stations in the Hydro System. The transmission lines that would serve the Water Intake and Water Conveyance systems are located in the east half of the LPP Project. The transmission lines that would serve the Hydro System are located in the west half of the LPP Project.

The proposed new **Water Intake Transmission Line** would begin at Glen Canyon Substation and run parallel to Highway 89 for about 2,500 feet to a new switch station, cross Highway 89 at the Intake access road intersection, and continue northeast to a new electrical substation on the Intake Pump Station site. This 69 kV transmission line would be 0.9 mile long in Coconino County, Arizona (Figure 1-7).

The proposed new **BPS-1 Transmission Line** would begin at the new switch station located on the south side of Highway 89 and parallel the LPP Project Water Conveyance System alignment to a new electrical substation on the BPS-1 site west of Highway 89. The 69 kV transmission line would be about one mile long in Coconino County, Arizona (Figure 1-7).

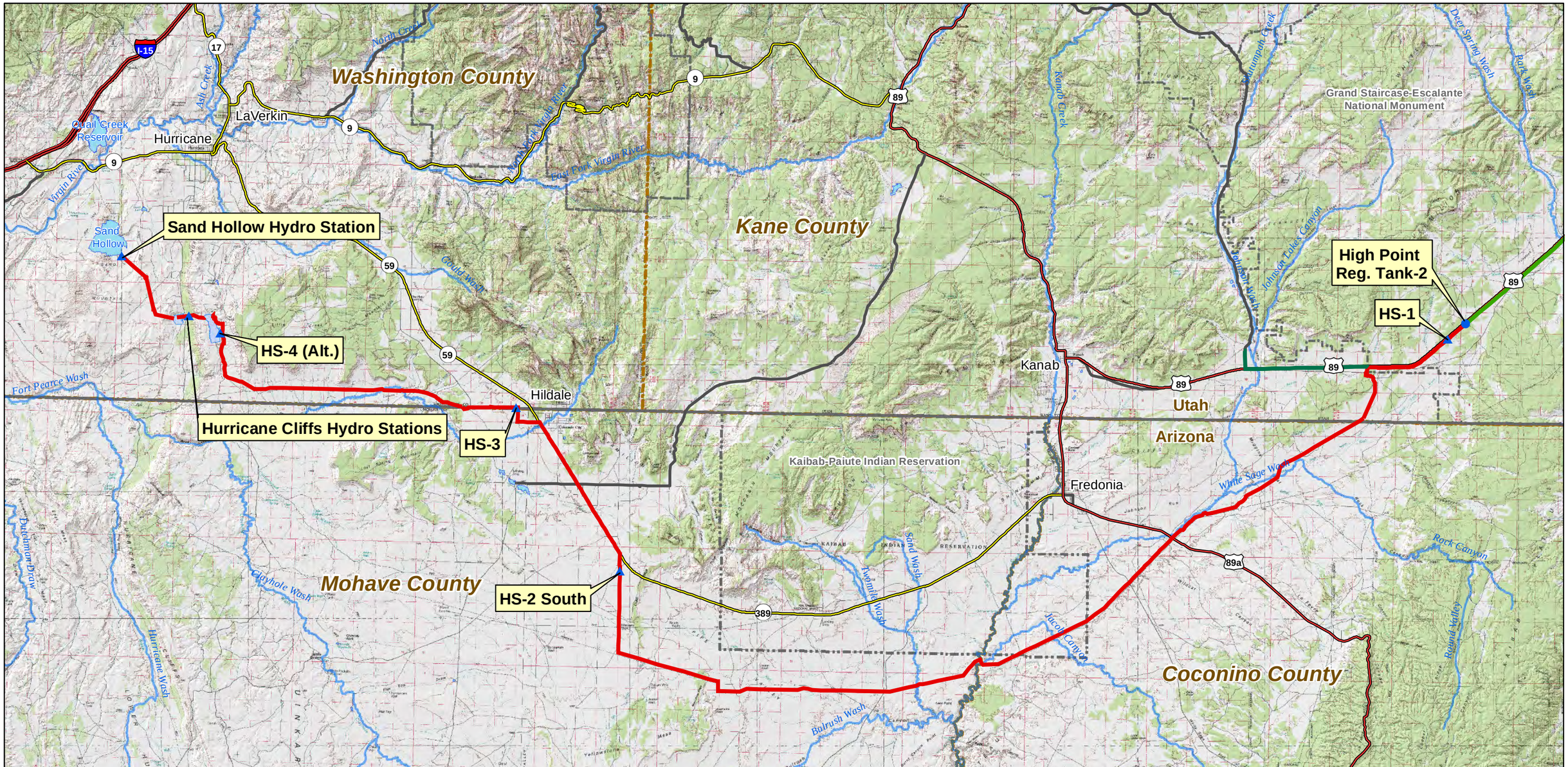
The proposed new **Glen Canyon to Buckskin Transmission Line** would consist of a 230 kV transmission line from the Glen Canyon Substation to the Buckskin Substation, running parallel to the existing 138 kV transmission line. This transmission line upgrade would be about 36 miles long through Coconino County, Arizona, and Kane County, Utah (Figure 1-7).

The existing **Buckskin Substation** would be upgraded as part of the proposed project to accommodate the additional power loads from the new 230 kV Glen Canyon to Buckskin transmission line. The substation upgrade would require an additional five acres of land within GSENM adjacent to the existing substation in Kane County, Utah (Figure 1-7).

The existing **Paria Substation** would be upgraded as part of the proposed project to accommodate the additional power loads to BPS-4 (Alt.). The substation upgrade would require an additional two acres of privately-owned land adjacent to the existing substation in Kane County, Utah (Figure 1-7).

The proposed new **BPS-2 Transmission Line** would consist of a new three-ring switch station along the new 230 kV Glen Canyon to Buckskin Transmission Line, a new transmission line from the switch station to a new substation west of Big Water, and a connection to BPS-2 substation in Kane County, Utah. The new transmission line would parallel an existing distribution line that runs northwest, north, and then northeast to Big Water. This new 138 kV transmission line alignment would be about seven miles long across Utah SITLA-administered land, with a 138 kV connection to a new electrical substation on the BPS-2 site (Figure 1-7).

The proposed new **BPS-3 Alt. Transmission Line South** would consist of a new three-ring switch station along the new 230 kV Glen Canyon to Buckskin Transmission Line, and a new transmission line from the switch station north along an existing BLM road to a new electrical substation on the BPS-3 (Alt.) site near the GSENM east boundary and within the Congressionally-designated utility corridor. This new 138 kV transmission line alignment would be about 5.9 miles long in Kane County, Utah (Figure 1-7).



Project Pump Station
Project Regulating Tank
Project Hydro Station
Hurricane Cliffs Forebay/Afterbay
Lakes & Reservoirs
Water Conveyance System
Hydro System - Southeast Corner Alternative (Penstock Segment)
KCWCD System
Major Rivers & Streams
Interstate
US Highway
ST Highway
Hwy
Major Road
National Park/Monument
Tribal Lands
State Boundaries
County Boundaries

FERC Project Number:
12966-001
BLM Serial Numbers:
AZA-34941
UTU-85472

N

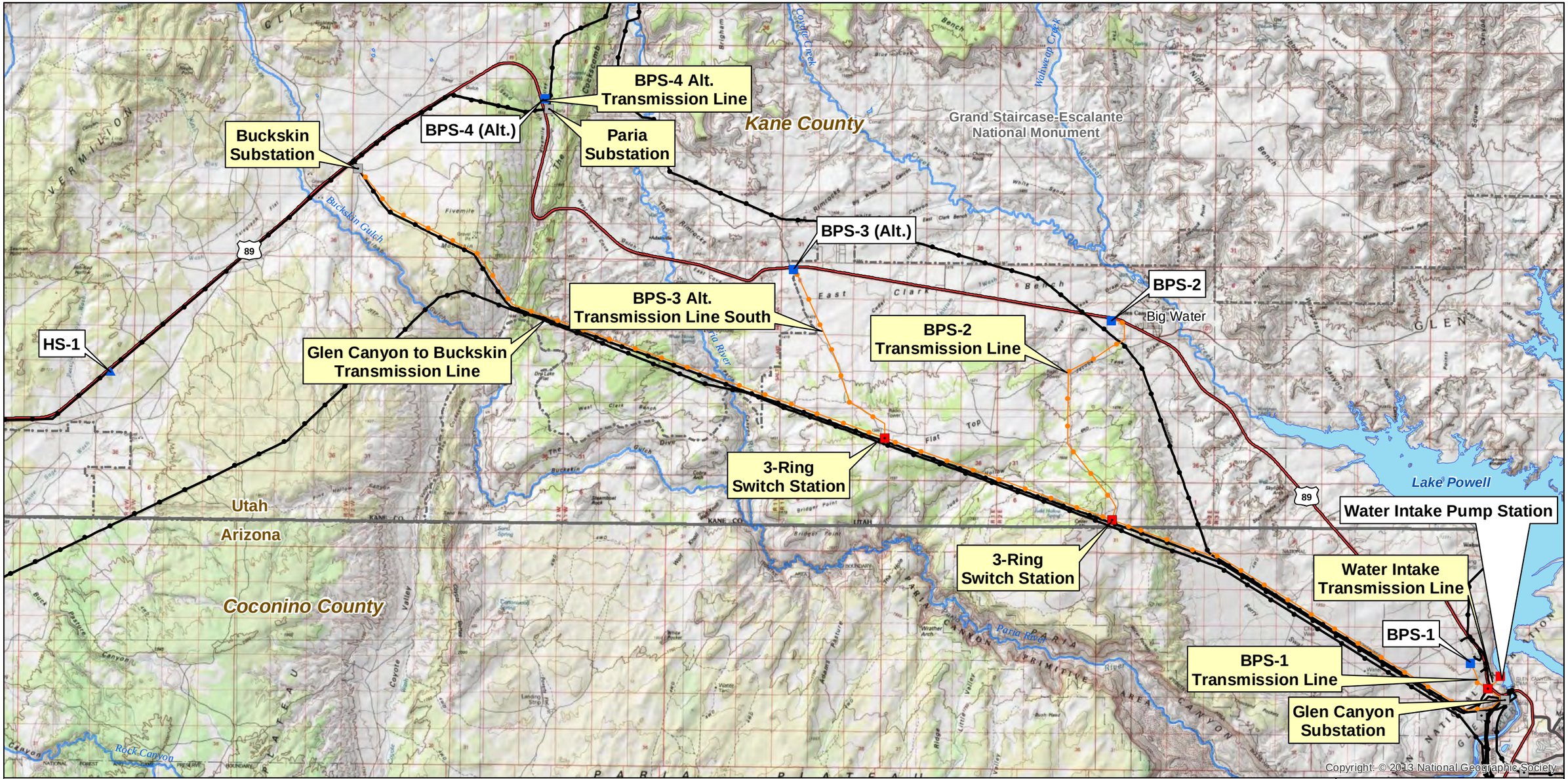
0 1 2 4 6 8 Miles

Lake Powell Pipeline Project

Spatial Reference: UTM Zone 12N, NAD-83

UDWRe **Figure 1-6** MWH

Lake Powell Pipeline
Hydro System
Southeast Corner Alternative



Project Intake Pump Station
Project Pump Station
Project Hydro Station
Substation
Proposed Substation
Project Transmission Lines
Existing Transmission Lines
Interstate
US Highway
ST Highway
Hwy
Major Road
Lakes & Reservoirs
Major Rivers & Streams
National Park/Monument
State Boundaries

FERC Project Number:
12966-001
BLM Serial Numbers:
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UTU-85472

N

0 0.5 1 2 3 4 Miles

Lake Powell Pipeline Project

Spatial Reference: UTM Zone 12N, NAD-83

UDWRe **Figure 1-7** MWH

Lake Powell Pipeline Proposed Transmission Lines East

The proposed new **BPS-4 Alt. Transmission Line** would begin at the upgraded Paria Substation and run north to a new electrical substation on the BPS-4 Alternative site. This 69 kV transmission line would be about 0.4 mile long in Kane County, Utah (Figure 1-7).

The proposed new **HS-1 Transmission Line** would begin at the new HS-1 and tie into the existing 69 kV transmission line along Highway 89 from the Buckskin Substation to the Johnson Substation. The HS-1 69 kV transmission line would be about 400 feet long in Kane County, Utah (Figure 1-8).

The proposed new **HS-2 (South) Transmission Line** would connect the HS-2 hydroelectric station and substation along the South Alternative to an existing 138 kV transmission line paralleling Arizona State Route 389. This new 34.5 kV transmission line would be about 0.9 mile long in Mohave County, Arizona (Figure 1-8).

The new **HS-2 (Highway) Transmission Line** alternative would directly connect the HS-2 hydroelectric station and substation along the Existing Highway Alternative to an existing 138 kV transmission line paralleling Arizona State Route 389. This new 34.5 kV transmission line would be about 200 feet long in Mohave County, Arizona.

The proposed new **HS-3 Transmission Line** would connect the HS-3 hydroelectric station and substation to the existing Twin Cities Substation in Hildale City, Utah. The new 12.47 kV transmission line would be about 0.6 mile long in Washington County, Utah (Figure 1-8).

The proposed new **HS-4 (Alt.) Transmission Line** would connect the HS-4 (Alt.) hydroelectric station and substation to an existing transmission line parallel to Utah State Route 59. The new 69 kV transmission line would be about 7.5 miles long in Washington County, Utah (Figure 1-8).

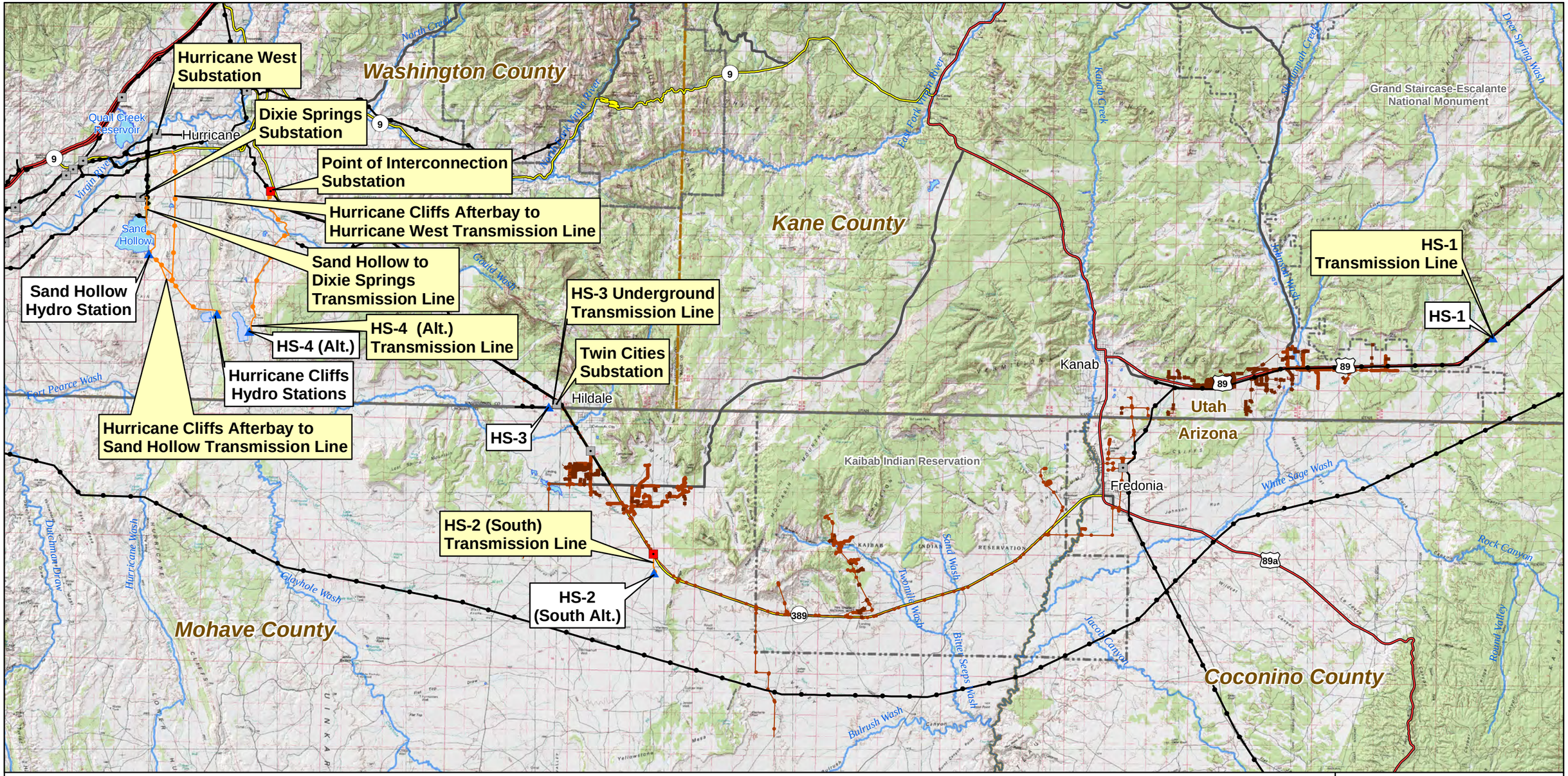
The proposed new **Hurricane Cliffs Afterbay to Sand Hollow Transmission Line** would consist of a new 69 kV transmission line, which would run northwest from the Hurricane Cliffs peaking power plant and substation to the Sand Hollow Hydro substation. This new 69 kV transmission line would be about 4.9 miles long in Washington County, Utah (Figure 1-8).

The proposed new **Hurricane Cliffs Afterbay to Hurricane West Transmission Line** would consist of a new 345 kV transmission line, running from the Hurricane Cliffs pumped storage power plant northwest and then north to the planned Hurricane West 345 kV substation. This new 345 kV transmission line would be about 10.9 miles long in Washington County, Utah (Figure 1-8).

The proposed new **Sand Hollow to Dixie Springs Transmission Line** would consist of a new 69 kV transmission line, running from the Sand Hollow Hydro substation around the east side of Sand Hollow Reservoir and north to the existing Dixie Springs Substation. This new 69 kV transmission line would be about 3.4 miles long in Washington County, Utah (Figure 1-8).

1.2.5 Natural Gas Pipeline and Generators Alternative

Natural gas engine-driven generation systems to power electric pumps would be an alternative to powering the LPP Project pump stations by electricity via transmission lines. Recent discussions with Questar Gas Company (local natural gas supplier) indicated that capacity would be available in the Kern River natural gas pipeline, which is located west of St. George, Utah, to supply natural gas for this alternative. Questar Gas Company indicated the company has future plans to extend a high pressure natural gas pipeline from the Kern River line to Hurricane, Utah. The Questar Gas pipeline would be sized to supply natural gas to the LPP Project if it is determined that a single-purpose, dedicated high pressure gas line would be extended to service the LPP pump stations. Based on the preliminary pump



Project Hydro Station
Substation
Proposed Substation
Project Transmission Lines
Existing Transmission Lines
Existing OH Primary Line
Existing UG Primary Line
Hurricane Cliffs Forebay/Afterbay
Lakes & Reservoirs
Major Rivers & Streams
Interstate
US Highway
ST Highway
Hwy
Major Road
National Park/Monument
Tribal Lands
State Boundaries
County Boundaries

FERC Project Number:
12966-001
BLM Serial Numbers:
AZA-34941
UTU-85472

N

0 1 2 4 6 8 Miles

Lake Powell Pipeline Project

Spatial Reference: UTM Zone 12N, NAD-83

UDWRe **Figure 1-8** MWH

Lake Powell Pipeline Proposed Transmission Lines West

selection and fuel requirements, the natural gas supply pipeline would be 12 inches in diameter to provide natural gas supply for the LPP Project pump stations. The pipeline would likely be successively reduced in size as it delivers gas to each of the pump stations.

1.2.5.1 Natural Gas Transmission Line Connection

The natural gas supply line alternative would connect to the proposed Questar Gas Transmission Line from the existing Kern River line to Hurricane City. The natural gas supply line would connect to the high pressure gas transmission line at a proposed gate station southeast of Sand Hollow Reservoir. The proposed gate station would be located adjacent to the alignment of the extension of the Southern Corridor Highway, which is the existing alignment of Sand Hollow Road east of Sand Hollow Reservoir (Figure 1-9).

1.2.5.2 Natural Gas Supply Line

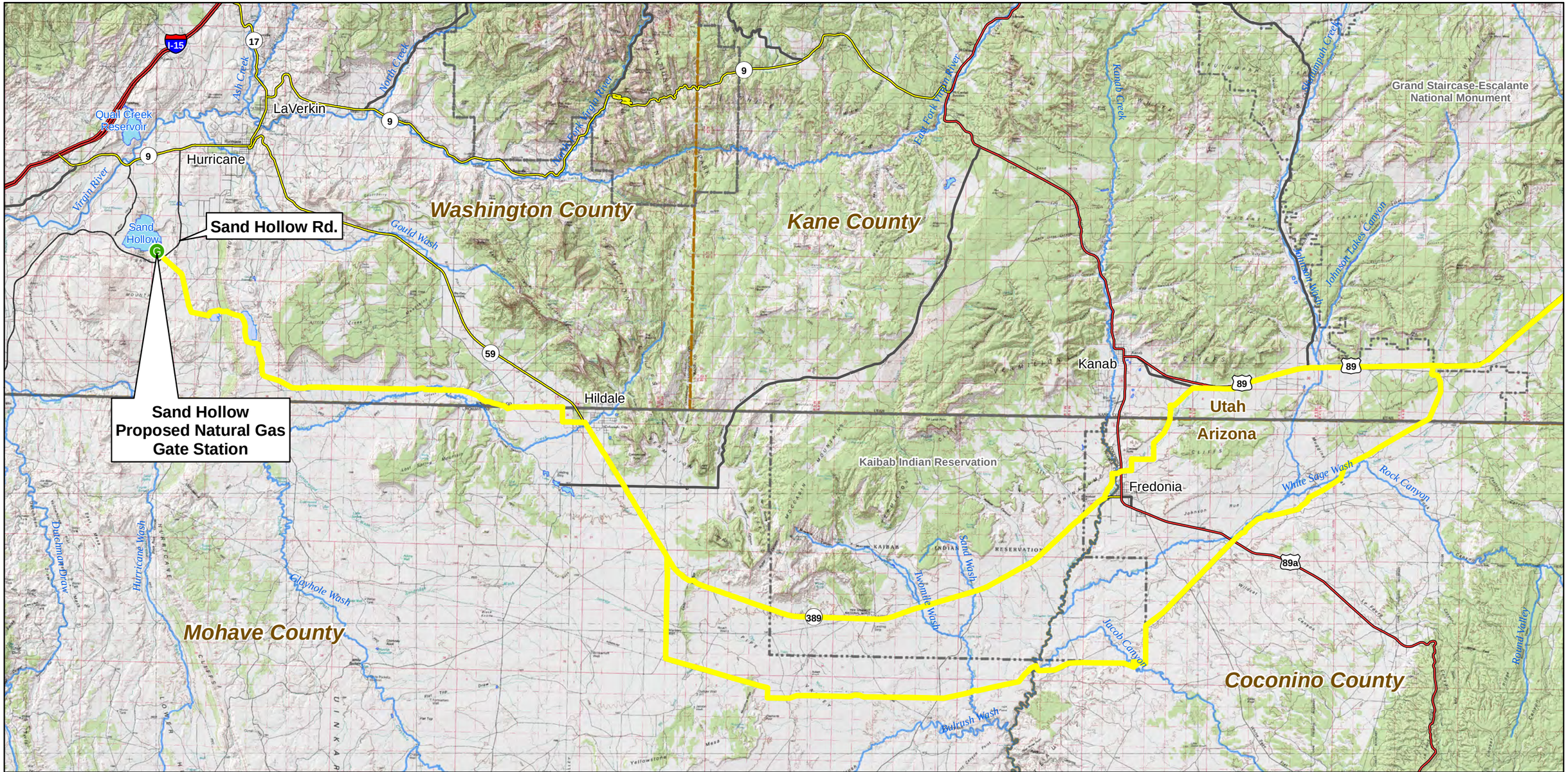
The proposed natural gas supply line would be an intermediate high pressure line and would operate between approximately 250 to 300 psi at the gate station connection. Because of pressure losses in the pipeline it is anticipated that the pressure at each of the LPP pump stations would vary between 50 and 100 psi, which would meet the requirements of the natural gas generators. The pipeline would be constructed of strong carbon steel and have a dielectric coating, such as a fusion bonded epoxy or extruded polyethylene. It would be installed with a minimum four feet of cover and be provided with cathodic protection (a technique that involves inducing an electric current through the pipe to ward off corrosion and rusting). The pipeline would be designed, constructed, tested, and operated at a minimum in accordance with all applicable requirements included in the U.S. DOT regulations in 49 CFR Part 192, “Transportation of Natural Gas and other Gas by Pipeline: Minimum Federal Safety Standards,” and other applicable federal and state regulations.

The natural gas supply line would follow the proposed LPP ROW from the Sand Hollow Gate Station to the intake pump station near Page, Arizona. The line would be about 138.5 miles long and installed a minimum of 10 feet from the edge of the proposed water pipeline in a separately excavated trench within the LPP ROW. Figure 1-9 shows the west alignment of the natural gas supply line as proposed and an alternative alignment along Arizona State Route 389 and through Fredonia, Arizona, parallel to the Existing Highway Alternative alignment, both to the west GSENM boundary. Figure 1-10 shows the east alignment of the natural gas supply line as proposed from the west GSENM boundary to the water intake pump station.

Sectionalizing valves would be required along the natural gas supply line alignment. These valves are safety devices used for emergency shut down or maintenance. The natural gas supply line sectionalizing valves would be required at approximately 20-mile intervals because of the gas line’s remoteness. The main line valve sites would cover a 40-foot by 40-foot area surrounded by a chain link fence within the confines of the permanent LPP pipeline ROW. The valves would be above ground and connected to the buried natural gas supply line. Additionally, pig launching or receiving equipment would be installed within the fenced areas. Pigs are devices that are placed into a natural gas supply line to clean the inside walls or to monitor its internal and external condition. Launching and receiving equipment is connected to the natural gas supply line to enable pigs to be inserted into or removed from the pipeline.

1.2.5.3 Natural Gas Generators

Natural gas generators would be used to supply power to operate the electric pumps at the LPP pump stations. The size of the electric pumps is approximately 18 feet from center to center when configured.



Natural Gas Gate Station
Natural Gas Supply Line Alignment
Hurricane Cliffs Forebay/Afterbay
Lakes & Reservoirs
Major Rivers & Streams
Interstate
US Highway
ST Highway
Hwy
Major Road
National Park/Monument
Tribal Lands
State Boundaries
County Boundaries

FERC Project Number:
12966-001
BLM Serial Numbers:
AZA-34941
UTU-85472

N

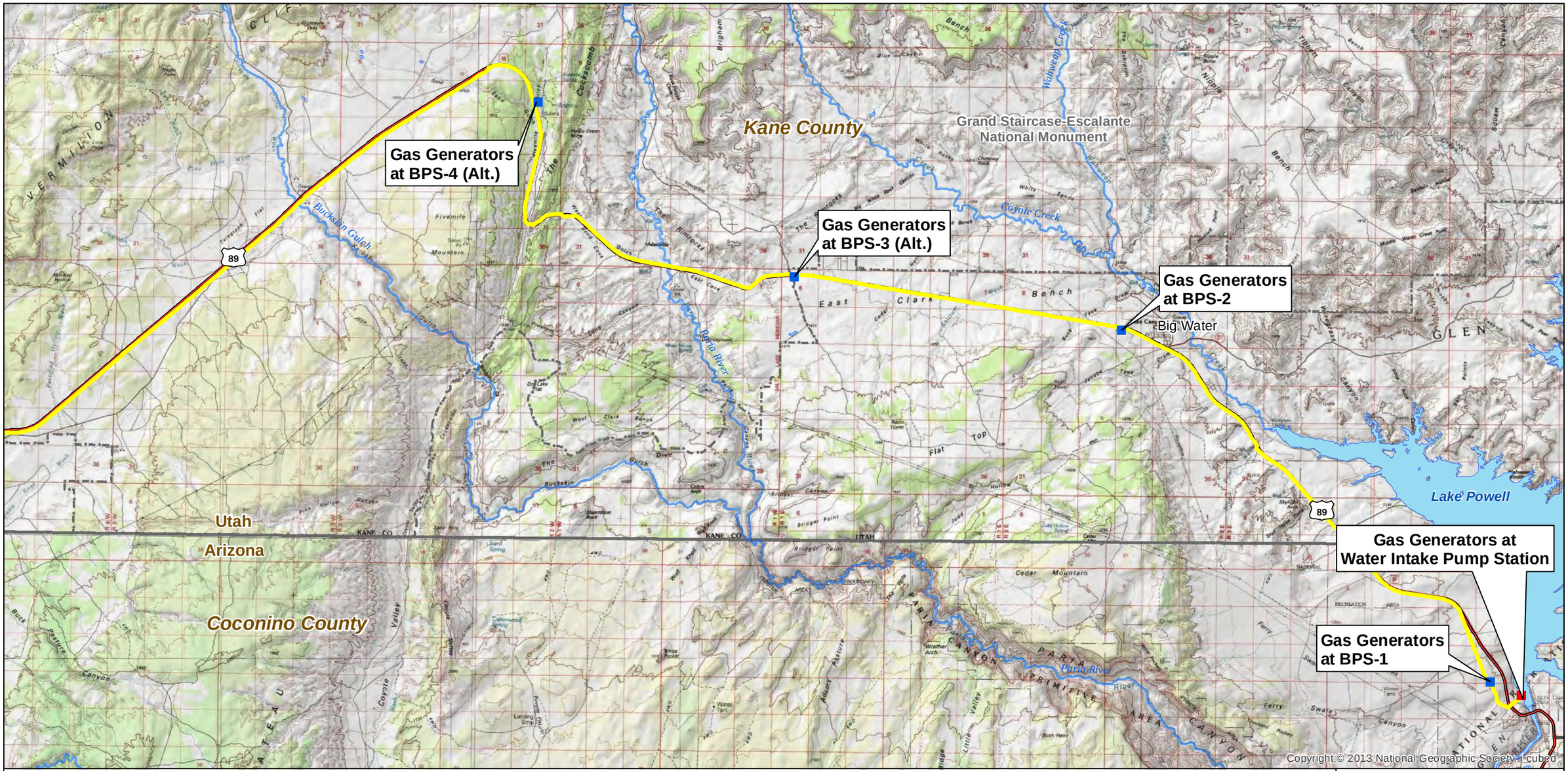
0 2 4 6 8 10 Miles

Lake Powell Pipeline Project

Spatial Reference: UTM Zone 12N, NAD-83

UDWRe **Figure 1-9** MWH

Lake Powell Pipeline Natural Gas Supply Line and Generators West Alternatives



Project Water Intake Pump Station

Gas Generators at Booster Pump Station

Natural Gas Supply Line Alignment

Interstate

US Highway

ST Highway

Hwy

Major Road

Lakes & Reservoirs

Major Rivers & Streams

National Park/Monument

State Boundaries

FERC Project Number:
12966-001
BLM Serial Numbers:
AZA-34941
UTU-85472

N

0 1 2 3 4 Miles

Lake Powell Pipeline Project

Spatial Reference: UTM Zone 12N, NAD-83

UDWRe **Figure 1-10** MWH

Lake Powell Pipeline Natural Gas Supply Line and Generators East Alternative

The overall pump station building size would be 14 feet wider and 18 feet longer than the pump stations which are powered by electricity from transmission lines.

The natural gas generators would be approximately 35 feet long by eight feet wide by nine feet high. The intake pump station building size for the natural gas generators would be approximately 65 feet wide by 170 feet long by 50 feet high, and located adjacent to the pump station electrical room within the five-acre site designated for each pump station. The booster pump station building size for the natural gas generators would be 65 feet wide and 39 feet high, with lengths ranging from 114 feet to 162 feet long. Each natural gas generator would require a 24-inch diameter stack, with guide wires, extending above the building roof to disperse the exhaust gases. The five stacks (four operating natural gas generators plus one standby natural gas generator) at the intake pump station would extend 20 feet above the top of the 55-foot tall building. The stacks at BPS-1, BPS-2, BPS-3 (Alt.), and BPS-4 (Alt.) would extend 61 feet above the top of the buildings to a total height of 100 feet above the ground surface. The natural gas generators at the intake pump station and BPS-4 (Alt.) would require emission control systems to meet air quality standards.

The natural gas generators alternative at the LPP pump stations would require an annual natural gas supply of 2,855,400 million British thermal units (MMBtu). Table 1-1 shows the annual natural gas consumption at the proposed project intake pump station and booster pump stations 1 through 4.

Table 1-1
Water Conveyance System Natural Gas Generator Annual Fuel Consumption

Pump Station	Site Elevation Feet MSL	Number of Pumps	Motor (HP)	Total Motor (kW)	Natural Gas Generator GE Model	# of Units[1]	Emission Control Required	Generator Total kW[2]	Annual Fuel Consumption (MMbtu)[3]
IPS	3,750	5	3000	11,190	JGS 620 F09	4+1	Yes	12,120	729,000
BPS-1	4,111	5	1500	5,595	JGS 620 F09	2+1	No	5,992	364,500
BPS-2	4,311	5	1750	6,530	JGS 620 F09	3+1	No	8,895	425,400
BPS-3 Alt.	4,657	5	2500	9,325	JGS 620 F09	4+1	No	11,652	607,500
BPS-4 Alt.	5,001	5	3000	11,190	JGS 620 F09	5+1	Yes	14,430	729,000
Total		**25**		**43,830**		**18+5**		**53,089**	**2,855,400**

Notes:
[1] Number of operating units plus standby generator
[2] Total generator capacity without standby generator
[3] The annual fuel consumption is based on all pumps operating at rated motor horsepower, 8400 hours/year operation with generators loaded at 87 percent on the average.

1.3 Summary Description of No Lake Powell Water Alternative

The No Lake Powell Water Alternative would involve a combination of developing remaining available surface water and groundwater supplies, developing reverse osmosis treatment of existing low quality water supplies, and eliminating residential outdoor water use in the WCWCD service area. This alternative could provide a total of 86,249 acre-feet of water annually to WCWCD and KCWCD for M&I use without diverting Utah's water from Lake Powell.

1.3.1 WCWCD No Lake Powell Water Alternative

1.3.1.1 Background

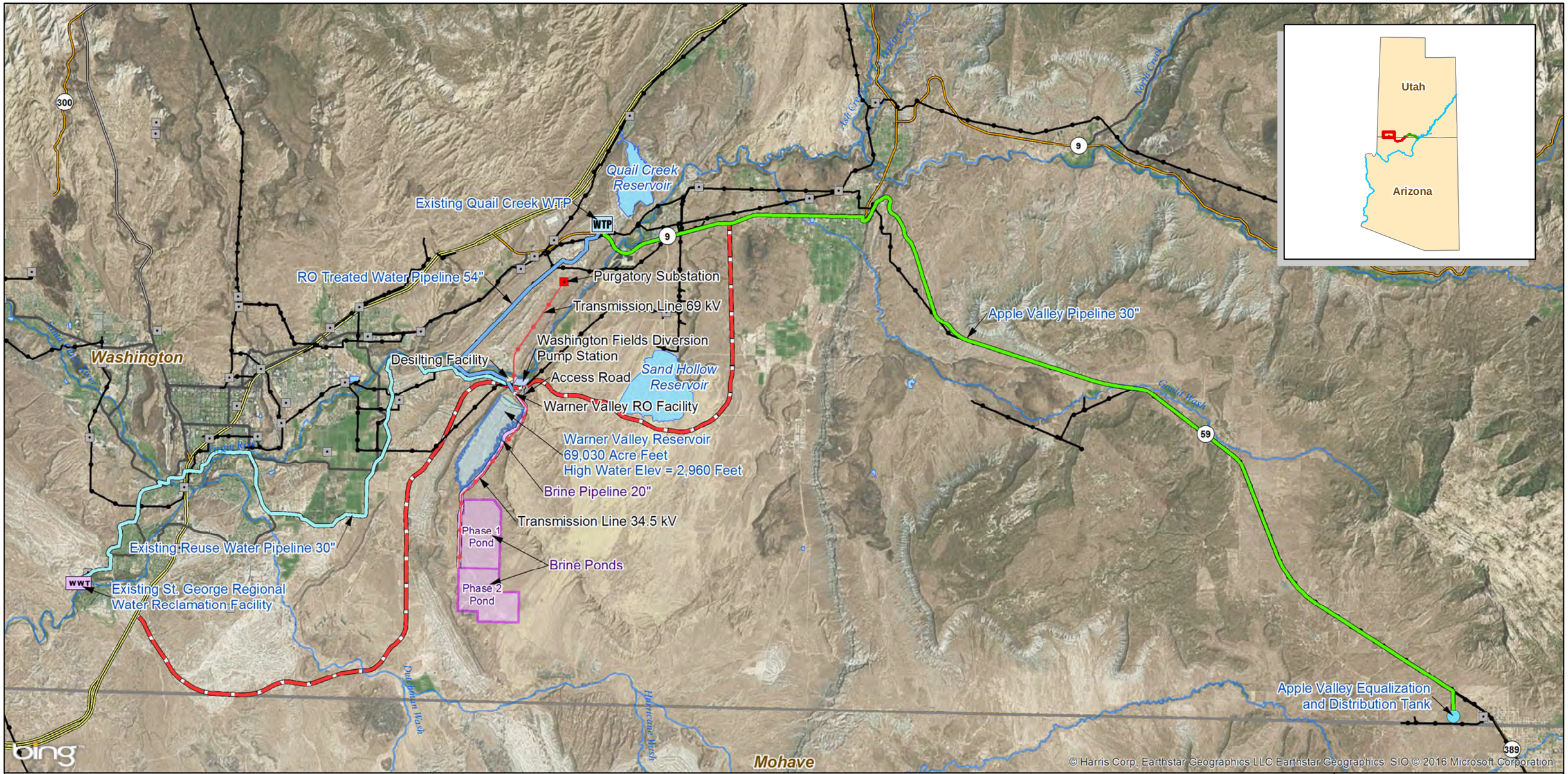
The WCWCD LPP allocation would be 82,249 acre-feet per year, and the WCWCD No Lake Powell Water alternative would need to supply 82,249 acre-feet per year to meet the same future water demands. In addition to the direct supply from Utah's Colorado River water, the water supplied by the LPP Project would provide additional wastewater reuse supply provided that sufficient storage is available.

The No Lake Powell Water Alternative would serve the same population as the LPP Project. WCWCD would implement other future water development projects currently planned by the District, develop additional water reuse/reclamation programs, continue to implement new water conservation measures, and convert additional agricultural water use to M&I use as a result of urban development in agricultural areas through 2028. Remaining planned and future water supply projects include the Ash Creek Pipeline (2,840 acre-feet per year), Sand Hollow recharge/recovery (3,000 acre-feet per year), Westside groundwater wells arsenic treatment (5,000 acre-feet per year), and development/yield increase of existing groundwater wells (2,830 acre-feet per year). Along with existing supplies, these future water supplies would yield an estimated 72,842 acre-feet per year of potable water and 8,505 acre-feet per year secondary water by 2028.

Under the No Lake Powell Water Alternative, actions in addition to the currently planned WCWCD projects would be taken to meet the water demand that would have been supplied by the Lake Powell Pipeline, as described below.

1.3.1.2 WCWCD No Lake Powell Water Alternative Features

Beginning in 2025, Washington County residential outdoor potable water use would be permanently re-purposed to indoor potable water use to help meet increasing indoor potable water demands. The WCWCD would develop a reverse osmosis (RO) advanced water treatment facility near the Washington Fields Diversion in Washington County, Utah, to treat up to 50,000 acre-feet per year of diverted Virgin River water, which has a high total dissolved solids (TDS) concentration, mixed with an additional 19,030 acre-feet per year of reuse water. WCWCD would develop the Warner Valley Reservoir to store the reuse water and diverted Virgin River water prior to RO treatment. A water distribution pump station and pipeline would be constructed to convey 13,249 acre-feet of potable water from Quail Creek Water Treatment Plant to the Apple Valley area of Washington County. Figure 1-11 shows the primary conceptual components of the No Lake Powell Water Alternative. Table 1-2 summarizes available supplies and projected demands under the No Lake Powell Water Alternative and the LPP Project alternatives.



WTP Quail Creek WTP (Existing)
WWT St. George Regional Water Reclamation Facility (Existing)
Substation
Substation (Future)
Warner Valley Transmission Line
Existing Transmission Lines
Desilting Facility
RO WTP
Washington Fields Diversion Pump Station
Lakes & Reservoirs
Brine Evaporation Ponds
Access Road
Apple Valley Pipeline 30"
Brine Pipeline 20"
Existing Reuse Water Pipeline 30"
RO Treated Water Pipeline 54"
Major Rivers & Streams
Interstate
US Highway
ST Highway
Hwy
Major Road
Southern Corridor Highway
State Boundaries
County Boundaries

FERC Project Number:
12966-001
BLM Serial Numbers:
AZA-34941
UTU-85472

N

0 0.75 1.5 3 4.5 6 Miles

Lake Powell Pipeline Project

Spatial Reference: UTM Zone 12N, NAD-83

UDWRe **Figure 1-11** MWH

No Lake Powell Water Alternative Primary Infrastructure

Table 1-2

Available Supplies and Projected Demands Under the

No Lake Powell Water and Lake Powell Pipeline Project Alternatives

	No Lake Powell Water Alternative	**Lake Powell Pipeline Project Alternative**
Existing Supplies	67,677	67,677
Planned Projects	13,670	13,670
Lake Powell Pipeline Project	0	82,249
RO Treatment of Virgin River and Reuse Water	57,883	0
Agricultural Conversion	0[1]	10,080
Reuse	17,100[2]	36,130
2060 Total Supply	156,330	209,806
2060 Total Demand	133,119[3]	185,285
Surplus in 2060	**23,211**	**24,521**

Notes:
[1]Agricultural conversion water included in RO treatment.
[2]19,030 acre-feet per year additional reuse included in RO treatment.
[3]Demand reduced 52,166 acre-feet per year from elimination of residential outdoor watering.

1.3.1.2.1 Re-Purposing Potable Water Use. The No Lake Powell Water Alternative would permanently eliminate residential outdoor potable water use in Washington County, re-purposing the portion of potable water used for residential outdoor watering to indoor potable use. Projections of future water use through 2060 account for population growth, climate change (projected 6 percent reduction of Virgin River flows by 2050 [Reclamation 2014]), and water conservation (35 percent reduction in per capita water use from 2000 to 2060). Potable water in Washington County is consumed for residential indoor and outdoor uses, commercial uses, institutional uses, and industrial uses. These potable water uses would total 130,245 acre-feet per year by 2052, the year the LPP Project water is anticipated to be fully utilized (UDWRe 2015). Gradually eliminating residential outdoor potable water use starting in 2025 would provide the growing population with potable water for indoor use through 2045; however, re-purposing residential outdoor potable water use to indoor use would not increase the water supply and would have to be accompanied by adding another water supply to meet the growing demand. Re-purposing residential outdoor potable water use to indoor potable use would require converting traditional residential outdoor landscapes and uses to either landscaping requiring no irrigation or desert landscapes compatible with the local climate. Residential water users would be responsible for converting their traditional outdoor landscapes to non-irrigated or desert landscapes. If no additional water supply was added in Washington County after 2025 and potable water use continued to meet residential indoor and outdoor purposes, then the projected population would completely utilize the potable water supply of 72,842 acre-feet per year by 2028.

1.3.1.2.2 Reverse Osmosis Water Treatment. Washington County's additional future water supply under the No Lake Powell Water Alternative would be dependent on two water sources: 1) Virgin River water diverted at the Washington Fields Diversion; and 2) reuse water from an expanded St. George Regional Water Reclamation Facility. WCWCD would develop a RO advanced water treatment facility

near Washington Fields Diversion in Washington County, Utah. The RO facility would be designed to treat 50,000 acre-feet of de-silted water per year diverted from the Virgin River at Washington Fields Diversion. St. George Regional Wastewater Reclamation Facility would provide an additional 19,030 acre-feet of water per year to be treated at the RO facility. The RO facility would be necessary to remove the high concentrations of TDS present in both the Virgin River and the effluent from the St. George Regional Wastewater Reclamation Facility. The reuse facility has a current capacity of approximately 7,800 acre-feet per year, with a future design capacity of 11,760 acre-feet per year. An additional 7,830 acre-feet per year of future wastewater reclamation capacity would need to be added to meet the total reuse water requirement of 19,030 acre-feet per year for RO processing inflow. The RO process would separate the TDS from the water, resulting in two products: 1) a treated water product; and 2) a brine product consisting of highly concentrated salts. A two-stage RO process would be applied to the brine solution to recover additional water and reduce the brine volume for enhanced evaporation. The RO-treated water product would be pH-adjusted to neutral pH, dosed with sodium silicate, mixed with conventionally-treated water from the Quail Creek Water Treatment Plant, and disinfected for distribution throughout the WCWCD service area. The RO advanced water treatment facility would process up to 64,313 acre-feet per year and produce up to 57,883 acre-feet per year of water suitable for M&I potable indoor use. The two-stage RO process would remove 90 percent of the TDS. The remaining 10 percent rejection (6,430 acre-feet per year) of brine by-product from the RO treatment process would require evaporation and disposal meeting State of Utah water quality regulations. The RO water treatment plant would process approximately 64,313 acre-feet per year of inflow water from Warner Valley Reservoir storage to meet the 2052 water demand under the No Lake Powell Water Alternative.

The RO water treatment plant processes would consist of pressurized, parallel ultra-filtration units, an influent storage tank with acid added to adjust the pH, pressurized cartridge filtration to remove additional particles from the water, high pressure pumping to pass the water through the parallel RO membrane units, a product water storage tank with saturated lime solution added to adjust the pH of the treated product water prior to disinfection and distribution as potable water, and brine storage tanks in series with the two-stage RO process units for further brine reduction. These water treatment processes would be housed in a water treatment building with electrical, mechanical, chemical storage and metering, heating/air conditioning/ventilation, and SCADA systems. A seven-mile long buried 54-inch diameter pipeline would convey the product water from a pump station at the RO water treatment plant to the Quail Creek Water Treatment Plant. The RO water treatment plant would add RO membrane units in phases as necessary to meet the growing water demand. The RO water treatment plant would be powered by electricity, requiring a 2.8-mile long 69-kV power transmission line from the proposed Purgatory Substation.

The concentrated brine product (6,430 acre-feet per year) would be pumped from the brine tanks through a pipeline to an evaporation apron, spray system and double-lined pond, and then pumped into spray headers over a series of double-lined ponds with leak detection and recovery systems. The enhanced evaporation ponds would be located south of Warner Valley Reservoir and would cover approximately 2,000 acres, developed in two phases. A buried brine conveyance pipeline approximately 4.4 miles long would convey the concentrated brine to the enhanced evaporation ponds. A 4.4-mile long 34.5-kV power transmission line would be extended from the RO water treatment plant to the enhanced evaporation ponds to provide electricity for the pumps spraying the brine solution. The brine solids would be evaporated for approximately 25 years in the Phase 1 ponds, and then dried, collected and disposed in an approved solid waste landfill. The Phase 2 enhanced evaporation ponds would be used during the following 25 years to continue evaporating the brine by-product. Additional infrastructure would be required as part of this alternative, including a de-silting facility, pump stations, pipelines, switch stations and substations, blending and storage tanks, and other associated earthwork.

1.3.1.2.3 Secondary Water Storage in Warner Valley Reservoir. WCWCD would develop the Warner Valley Reservoir to store diverted Virgin River water and reuse water from the St. George Regional Water Reclamation Facility, which would be delivered as inflow to the RO advanced water treatment facility. Warner Valley Reservoir would be located south-southwest of the Washington Fields Diversion. An earth-fill embankment with a clay core and rock-riprap facing would be constructed across the north entrance to the natural valley. The reservoir would have a maximum active storage volume of 69,030 acre-feet and would cover approximately 1,130 acres, including the earth-fill embankment. A large pump station would be constructed at the Washington Fields Diversion to pump the diverted Virgin River water into the Warner Valley Reservoir. The pump station would be powered by electricity via the 69-kV transmission line from the Purgatory Substation to the RO water treatment plant. The reservoir would store Virgin River water diverted at the Washington Fields Diversion (50,000 acre-feet per year) mixed with St. George Regional Water Reclamation Facility effluent (19,030 acre-feet per year), accounting for annual average evaporation (4,717 acre-feet per year), to produce up to 57,883 acre-feet of RO product water (assuming 90 percent recovery). The brine product from RO treatment would total approximately 6,430 acre-feet per year.

1.3.1.2.4 Water Distribution to Apple Valley. The largest remaining contiguous land area available for development in Washington County would be in Apple Valley. WCWCD would develop a pump station and 28-mile long pipeline to deliver 13,249 acre-feet per year of potable water from the Quail Creek Water Treatment Plant near Hurricane City to the Apple Valley area to meet future residential and commercial water demands.

1.3.2 KCWCD No Lake Powell Water Alternative

The KCWCD No Lake Powell Water Alternative would rely on existing water supplies, water conservation measures resulting in reduced water use, and future water development projects consisting of new groundwater production. Reliable water supplies (projected to be 2,170 acre-feet per year in 2035) for the area served by KCWCD (Kanab City and Johnson Canyon), adjusted for projected stream flow reductions (4.2 percent in 2035) resulting from climate change and a planning reserve (10 percent), would be exceeded by projected M&I water demands by 27 acre-feet per year within the KCWCD service area in 2035. KCWCD projected potable water demand in 2060 would be 3,435 acre-feet per year, with a potable water deficit of 1,334 acre-feet per year. Additional groundwater in the Kanab Creek drainage basin could be developed to provide up to 6,615 acre-feet per year of potable water within the aquifer's estimated safe yield. The quality of this water would likely require advanced water treatment. The developed groundwater from the Kanab Creek drainage basin would be pumped and conveyed through an eight-mile long pipeline to the Johnson Canyon drainage basin. The Johnson Canyon drainage basin comprises the potable water supply service area served by KCWCD in the area that could be served by the LPP Project.

1.4 Summary Description of the No Action Alternative

No new intake, water conveyance or hydroelectric features would be constructed or operated under the No Action Alternative. FERC would not issue a license for the LPP Project. The Utah Board of Water Resources' Colorado River water rights consisting of 86,249 acre-feet per year would not be diverted from Lake Powell and would continue to flow into the lake until the water is used for another State of Utah purpose.

1.4.1 WCWCD No Action Alternative

Under the No Action Alternative, WCWCD would complete the Ash Creek Project, planned groundwater development and continue to implement planned conservation programs. Wastewater reuse would be utilized to the maximum extent storage allows. Existing and future water supplies totaling 72,840 acre-feet per year potable and 8,505 acre-feet per year secondary would meet projected M&I water demand within the WCWCD service area through approximately 2028, exhausting all water planning reserves. Each supply source would be phased in to meet the M&I potable and secondary water demand associated with the forecasted population.

The No Action Alternative would not provide WCWCD with any reserve water supply (e.g., water to meet annual shortages because of drought, emergencies, and other losses). The No Action Alternative would not provide adequate water supply to meet projected water demands beyond 2028. There would be a projected water shortage of approximately 102,903 acre-feet per year in 2060 within the WCWCD service area under the No Action Alternative.

1.4.2 KCWCD No Action Alternative

KCWCD would use existing water supplies to meet potable water demands through 2035. Reliable water supplies are projected to be 2,101 acre-feet per year in 2060.

The No Action Alternative would not provide KCWCD with any reserve water supply (e.g., water to meet annual shortages because of drought, emergencies, and other losses). The No Action Alternative would not provide adequate water supply to meet projected water demands beyond 2035. There would be a projected water shortage of approximately 1,334 acre-feet per year in 2060 within the KCWCD service area under the No Action Alternative.

1.5 Purposes of Study

This technical report describes the results and findings of an evaluation of groundwater resources along the proposed alternative pipeline alignments of the LPP Project (Project). The purpose of the study, as defined in the 2008 Groundwater Resources Study Plan (UBWR 2008) prepared for the Federal Energy Regulatory Commission (FERC), was to identify potential impacts of the LPP Project on groundwater resources during construction, operation and maintenance, and identify measures to mitigate impacts of the groundwater conditions.

1.5.1 Identified Issues

The following groundwater issues were identified for analysis in the Groundwater Resources Study Plan. The identified issues are used to frame the impact topics presented in Section 1.5.2.

- Groundwater levels at the water intake site
- Groundwater levels at locations where the pipeline would cross streams
- Groundwater levels at the forebay and afterbay reservoirs
- Groundwater levels and trends associated with existing recharge at Sand Hollow Reservoir
- Groundwater quality and trends associated with existing recharge at Sand Hollow Reservoir
- Projected groundwater quality changes associated with recharge of Lake Powell water at Sand Hollow Reservoir Identification of groundwater production wells within the projected recharge spheres of influence on water quantity and quality at Sand Hollow Reservoir
- Projections of surface water and groundwater interactions at the Virgin River

1.5.2 Impact Topics

The following impact topics are addressed in this Groundwater Resources Study Report:

- Impacts on groundwater resources from LPP Project construction, operation, and/or maintenance
- Seepage from unlined forebay and afterbay reservoirs influencing groundwater recharge, and if so, resulting impacts
- Groundwater recharge resulting from the LPP Project affecting groundwater-surface water interactions
- Changes in groundwater quality resulting from the LPP Project

Chapter 2
Methodology

2.1 General

Information was obtained and developed for this study by performing a review of relevant available reports and maps as well as field observations. This chapter describes the methodology for obtaining the groundwater resources data and information.

Several documents, including technical reports, scientific and engineering journal publications, and other literature were previously reviewed and information compiled. This information was documented in technical memoranda. Additional literature review involving groundwater resource conditions has been performed for this report by identifying and reviewing available technical reports, maps, and literature that was not previously reviewed, to determine what is known of the hydrogeologic conditions regionally and at specific, potentially problematic locations along the alternative alignments. In addition, field inspections were performed to verify and improve on information obtained from the literature review.

2.2 Assumptions

Several assumptions were made because of the preliminary nature of the work and limited data availability, particularly with respect to existing groundwater levels and locations. For example, because of the lack of data, it is assumed in the report that all previously measured groundwater levels represent current year levels. The following list of assumptions are used in the report:

- Pipeline trench depths will not exceed 16 feet in most places, and will never exceed 30 feet
- Pipelines and associated features will be constructed in accordance with Best Management Practices (BMPs) to avoid impacts on groundwater resources
- Dry drainages and washes (intermittent streams) are defined as channels or washes in which water flows only as a result of storm events or snowmelt runoff. For the purposes of this report, it is assumed that dry drainages or washes do not intercept the water table, otherwise they would flow for longer durations.
- Groundwater levels recorded prior to the current year are reasonably representative of baseline levels
- Temporary groundwater production wells would be constructed in five-mile intervals if needed along all LPP Project alignments to provide water for construction activities. Aquifer conditions would be suitable for production at these intervals. These wells would be used for brief, temporary periods, generally no more than 30 days in most instances, and would be pumped at rates that would not result in substantial or long-term impacts on other groundwater users. The wells would be abandoned in accordance with state law after they were no longer needed, protecting against the possibility of subsequent contamination of groundwater quality. The water will be used for dust control on roads and along the pipeline to obtain proper moisture conditions for compaction.
- The hydropower forebay and peaking reservoir afterbay at the Hurricane Cliffs would be lined as applicable to prevent substantial seepage of water into the subsurface. The lining system would reduce the rate of seepage sufficient to prevent discharge of groundwater from the face of the Hurricane Cliffs.

2.3 Data Used

The information that was reviewed for this study included the following maps, documents, and databases. The complete references are found in the References Section at the end of the report. In addition, a review of documents at the Tribal Administration Building of the Kaibab Band of Paiute Indians was performed, although no additional relevant information was identified. The list below presents the information consulted:

- Arizona Department of Water Resources (ADWR) Well Registry
- HAL (Hansen, Allen & Luce) 2005. Washington County Water Conservancy District, Petition for Classification of the Navajo/Kayenta and Upper Ash Creek Aquifers, Final Report
- MWH 2009. Lake Powell Pipeline Phase I Preliminary Engineering and Environmental Studies Task 5 - Develop and Analyze Alternatives. Revised Technical Memorandum 5.13C, Aquifer Recharge Issues
- Reclamation (U.S. Bureau of Reclamation) 2007. Unpublished water quality sampling data for Wahweap Sampling Station, Lake Powell, Wahweap Sampling Station
- UAC R317 2007. Utah Administrative Code, Rule Title 317, Water Quality
- USGS (U.S. Geological Survey) 1985. Study and Interpretation of the Chemical Characteristics of Natural Water: U.S. Geological Survey Water-Supply Paper 2554
- USGS 1999. User's Guide to PHREEQC (Version 2) – A Computer Program for Speciation, Batch-Reaction, One-Dimensional Transport, and Inverse Geochemical Calculations. D.L. Parkhurst and C.A.J. Apel. USGS Water-Resource Investigations Report 99-4259
- USGS 2000. Geohydrology and Numerical Simulation of Ground-Water Flow in the Central Virgin River Basin of Iron and Washington Counties, Utah: Utah Department of Natural Resources Technical Publication No. 116
- USGS 2005. Pre- and Post-Reservoir Ground-Water Conditions and Assessment of Artificial Recharge at Sand Hollow, Washington County, Utah, 1995-2005: U.S. Geological Survey Scientific Investigations Report 2005-5185
- USGS 2007. Assessment of Artificial Recharge at Sand Hollow Reservoir, Washington County, Utah, Updated to Conditions Through 2006: U.S. Geological Survey Scientific Investigations Report 2007-5023
- USGS 2009. Assessment of Artificial Recharge at Sand Hollow Reservoir, Washington County, Utah, Updated to Conditions Through 2007: U.S. Geological Survey Scientific Investigations Report 2009-5050
- USGS 2010a. National Water Information System (NWIS) database.
- USGS 2012. 2012. Assessment of Managed Aquifer Recharge at Sand Hollow Reservoir, Washington County, Utah, Updated to Conditions Through 2012: U.S. Geological Survey Scientific Investigations Report 2013-5057.
- Utah Department of Environmental Quality, Division of Water Quality (DEQ-DWQ) 2007. Utah Ground Water Quality Protection Program, Aquifer Classification Maps for Utah's Groundwater.
- Utah Division of Water Rights (UDWRi) Well Drilling Database
- Washington County Water Conservancy District (WCWCD) 2005. Geology Along the Route of the Lake Powell Water Pipeline, Utah and Arizona: Report WCWCD-02

2.4 Impact Analysis Methodology

2.4.1 Intake Pump Station Construction Dewatering Impacts

Some construction activities associated with the drilling and cutting of shafts, tunnels, and a pump chamber forebay at the Intake Pump Station (IPS) would require temporary dewatering until the facilities are constructed and lined. Below the water table, groundwater is expected to seep from the rock mass into the IPS shafts and tunnels during construction. For shaft drilling, dewatering may not be necessary because the shafts are expected to be drilled using the blind bore shaft drilling method, which does not normally require dewatering. However, dewatering probably would be required for construction of lateral tunnels into Lake Powell and for cutting and construction of the pump forebay chamber and forebay connector tunnels.

A drilling and testing program was performed to characterize geologic and hydrogeologic conditions at the IPS site. The drilling and testing program, which included four cored boreholes, was undertaken to investigate subsurface conditions and perform geotechnical evaluations of the Navajo Sandstone bedrock, which is generally at or very near the ground surface. A preliminary analysis of the IPS site hydrogeologic conditions was performed as part of the drilling program. Static groundwater levels in each drill hole were measured, and packer tests were performed at selected intervals below the water table to estimate the sandstone's hydraulic characteristics (hydraulic conductivity, a measure of the rate at which water can move through rock or soil at a standardized gradient). These data were used to estimate rates at which dewatering may need to occur below the water table for construction activities that would require dewatering.

Groundwater inflows during dewatering would likely be collected by a combination of dewatering wells and a system of drains and sumps constructed in the bottom of the excavations. Groundwater inflows would be collected in the sumps and then pumped to the surface where it would be discharged into portable water tanks and particles settled and removed prior to disposal to minimize effects during construction and to protect water quality in the reservoir. The collected hydrogeologic data provided the basis for an estimate of maximum expected groundwater inflow volume for the intake shafts, forebay connector tunnels and forebay chamber.

Discharge of drilling fluids would require treatment to remove solids. Discharge would pass through one or more tanks with sufficient residence time to allow suspended particles to settle; the clarified water would then be conveyed to the Glen Canyon Dam spillway and discharged on the downstream side so no discharge would enter Lake Powell. It is anticipated that fluids circulated during shaft and tunnel construction would discharge into one end of a trench or settling tank or basin. Using typical settling velocities for particles in water (Fifield, J. 2001) and assuming a particle size of very fine sand (from sandstone), a settling velocity was estimated. The settling velocity was used to estimate settling tank or basin dimensions and minimum retention time requirements.

2.4.2 Pipeline and Penstock Impacts

2.4.2.1 Stream Channel Crossings

One indicator of shallow groundwater is flowing water in stream channels, especially if flow occurs for several months per year. Pipeline and penstock crossings of stream channels where groundwater intercepts the channel because of a shallow water table would require dewatering of the trench during construction at the crossing and possibly for some distance along the pipeline alignment in either direction away from the channel. Intercepted groundwater would require disposal by land application to avoid drainage back into a live stream.

The locations of stream channels and washes were determined during field investigations as well as from topographic maps. An evaluation of whether the shallow groundwater table was likely to be intercepted at each stream channel crossing was made by considering a number of factors, including the following:

- Presence or absence of water in channel at time of survey (late summer)
- Presence or absence of phreatophytes along stream channel near crossing
- Channel morphology – evidence of sustained flow vs. high-flow, low duration scour and deposition of primarily coarse sediments, even if several miles from coarse material source
- Stream flow records from USGS online database, if available
- Nearby well groundwater level measurements, if available
- Local topography

The presence or absence of water in a stream channel at any given time is not always a reliable indicator of the depth to water table or the probability of encountering groundwater during construction trenching. This is because groundwater levels tend to fluctuate based on seasonal recharge, precipitation events, and other factors. LPP Project alignments were categorized into areas of probability of requiring dewatering based on the estimated depth to groundwater. Table 2-1 shows the categorization criteria.

- **High Probability Scenario.** Pipeline construction is likely to result in encountering groundwater at or near stream crossings that will require dewatering
- **Medium Probability Scenario.** Although unlikely, there is a possibility that groundwater will be encountered during pipeline construction at or near stream crossings
- **Low/Negligible Probability Scenario.** It is highly unlikely that groundwater will be encountered during pipeline construction at or near stream crossings that will require dewatering

Table 2-1
Dewatering Probability Categories

Anticipated Depth to Groundwater (ft)	Probability of Dewatering Requirement During Construction	Typical Crossings Encountered
0 to 16	High	Perennial streams
16 to 30	Medium	Seasonal low-flow streams and dry washes with riparian/phreatophyte vegetation
> 30	Low	Dry washes or ephemeral streams

2.4.2.2 Groundwater Well Locations and Water Level Measurement Records

Well locations, water level measurements, and related information were obtained from hydrogeologic reports, from the Utah Division of Water Rights (UDWRi) well drilling database (UDWRi 2010), from the Arizona Department of Water Resources (ADWR) Well Registry (ADWR 2009), and from the USGS National Water Information System (NWIS) database (USGS 2009). The well information was used to locate existing groundwater levels along the length of the pipeline.

In addition to available records review, Geographic Information Systems (GIS) applications were used to enable the visualization of geographical and geospatial data to aid in the decision making process. The GIS planning tool used for this assessment was ArcGIS Explorer. Previously created and geo-referenced base maps, layers and shape files were imported into ArcGIS Explorer in a readily available format and geo-referenced within the system. The files consisted of the LPP Project pipeline alignments, hydraulic structures, reservoirs, streams, roadway maps, topographic maps, and well locations. Overall, these various layers of data were combined on an interactive GIS platform to provide the most effective method to determine the following:

- Location of existing groundwater wells along the LPP Project alignments
- Proximity of groundwater wells to the LPP Project alignments
- All major river and stream drainages crossed by the LPP Project alignments
- Depth to groundwater in the general vicinity of the LPP Project alignments (including near stream crossings)
- Depth to groundwater at or near LPP Project features

Data used for this project included GIS layers, field reports of well geologic or construction logs (where available), photographs and satellite imagery. A listing of all the base maps and layers imported into ArcGIS Explorer and used for the groundwater assessment is shown in Table 2-2.

Groundwater table levels were reviewed using available well logs from the UDWRi and ADWR databases. Groundwater table levels for wells within 1000 feet of the pipeline alignment were estimated using the water level measurements on record in the well logs. Well logs and information that was ambiguous with regard to water table depth or suggested artesian conditions were omitted from the review unless the depth to first water was recorded in the data. As with surface water crossings, the risks to groundwater were categorized as high (water table 16 feet or less deep), medium (water table between 16 and 30 feet), or low (water table 30 feet or greater).

Table 2-2 GIS Layers Used for Groundwater Assessment		
GIS Layer Name	**Description**	**Purpose**
lake_powell_pipeline Map_10_5_09	Location of the LPP Project pipeline (Existing Highway alternative and South Transmission alternative)	Used to locate the pipeline alignment with respect to stream crossings
streams	Location of all major streams, washes and dry drainages for the states of Arizona and Utah	Used to locate streams and washes along the length of the LPP Project Pipeline
major_rivers_streams	Location of major streams for the States of Arizona and Utah	Used to locate major streams along the length of the LPP Project Pipeline
lakes_and_reservoirs	Locations of all major lakes and reservoirs in the general vicinity of the LPP Project pipeline	Used to locate water bodies along the length of the LPP Project Pipeline
US_topo_maps	USGS topographic map	Used to determine surface elevations and other topographical features not available on the aerial maps
adwrwell_lpp_clip2	Contains locations and information contained in the ADWR well registry database of every registered groundwater well in Arizona	Used to determine existing groundwater levels along LPP Project pipeline
GW1 through GW8	Contains locations and information extracted from the USGS National Water Information System registry database on every registered groundwater well in Utah and Arizona	Used to determine existing groundwater levels along LPP Project pipeline

2.4.3 Unlined Afterbay Reservoir Recharge Impacts

Afterbay reservoir locations were determined from preliminary engineering drawings. Only one open-air unlined reservoir is planned, the Hurricane Cliffs Pump Storage Afterbay reservoir. Impacts on groundwater resources at this location associated with seepage from the afterbay reservoir were evaluated by determining approximate depth to groundwater using USGS NWIS data and by reviewing NRCS soils maps. Well locations also were determined using the USGS NWIS database.

2.4.4 Groundwater – Surface Water Interactions

Interactions between groundwater and surface water were evaluated by identifying locations where groundwater recharge associated with the LPP Project could affect surface water discharge rates or water

quality. This was accomplished by reviewing topographic and geologic maps, as well as USGS reports relevant to this issue.

2.4.5 Water Quality Impacts

2.4.5.1 Data Review and Modeling

Water quality data from hydrogeologic reports and from unpublished data sets were used for preliminary geochemical modeling at Sand Hollow Reservoir. The USGS geochemical modeling tool PHREEQC was used to evaluate the potential for precipitation or dissolution associated with blending of water from Lake Powell with groundwater underlying Sand Hollow Reservoir.

The USGS prepared a model of geochemical interactions resulting from blending of water from Lake Powell with groundwater at Sand Hollow Reservoir. The results of this modeling have not yet been documented in a final report by the USGS. A summary of findings was obtained from the USGS via personal communication.

2.4.5.2 Recharge Evaluation

A preliminary evaluation of recharge was performed at Sand Hollow Reservoir. The evaluation included a review of well logs, soil maps, geologic maps, and calculations for estimating infiltration capacity. The results of PHREEQC modeling were incorporated into the recharge evaluation for Sand Hollow Reservoir. The findings of this evaluation were documented in a technical memorandum, included as Appendix A.

Chapter 3
Affected Environment (Baseline Conditions)

3.1 Impact Area

The area of potential effect for Groundwater Resources includes a corridor encompassing both sides of each of the alignments identified and described in Sections 1.2.1 (South Alternative), 1.2.2 (Existing Highway Alternative), and 1.2.3 (Southeast Corner Alternative). The corridor extends approximately 200 feet on either side of each alternative alignment. However, where groundwater and well data were scarce (which included much of the LPP Project alignments), the closest available groundwater data were used if it was likely to be reasonably representative of conditions near the alignments.

The Transmission Line Alignments described in Section 1.2.4 were not included in the Groundwater Resources study because these alternatives would not affect groundwater resources.

3.2 Overview of Baseline Conditions

3.2.1 Lake Powell Pipeline

3.2.1.1 Intake Pump Station Construction Dewatering

Water table elevations matched the elevation of Lake Powell during the drilling program. Groundwater is expected to seep from the rock mass into the IPS shafts and tunnels during construction. Groundwater dewatered from drains, sumps, and dewatering wells would be pumped to the surface where it would be discharged into portable water tanks and particles settled and removed prior to disposal to minimize effects during construction and to protect water quality when discharged in the spillway at Glen Canyon Dam and thus the Colorado River downstream of the dam.

The collected hydrogeologic data provided the basis for an estimate of maximum expected groundwater inflow volume for the intake shafts, forebay connector tunnels and forebay chamber. Groundwater inflows of maximum expected volume are approximated as follows:

- 1000 gpm for one of the 19-ft diameter intake shafts
- 1,500 gpm for two 19-ft diameter intake shafts if shafts are constructed simultaneously
- 200 gpm for one of the forebay connector tunnels
- 400 gpm for the forebay chamber

Therefore the maximum rate of dewatering that would need to occur at any given time would be 1,500 gpm. Dewatering or extraction wells could be constructed around the footprint of the underground construction area. The wells would pump water from the rock mass in the vicinity of the construction area to lower the potentiometric surface and discharge it directly into the temporary holding tanks for settling of suspended solids, treatment facility thereby reducing the potential groundwater inflow volumes into the shafts and tunnels. The relatively low permeability of the Navajo Sandstone in which the structures would be constructed would require close well spacing.

Discharge of drilling fluids would require treatment to remove solids. Discharge would pass through one or more tanks with sufficient residence time to allow suspended particles to settle; the clarified water

would then be conveyed to the Glen Canyon Dam spillway and discharged on the downstream side so no discharge would enter Lake Powell.

It is anticipated that fluids circulated during shaft and tunnel construction will discharge into one end of a trench or rectangular tank. Using typical settling velocities for particles in water (Fifield, J. 2001. Designing for Effective Sediment and Erosion Control on Construction Sites. Forester Press, Santa Barbara, CA) and assuming a particle size of very fine sand (from sandstone), a settling velocity (Vs) of approximately 0.02 ft/sec can be expected. If the tank depth is assumed to be 4 ft deep, a residence time (Tr) of at least 200 seconds would be required to settle a particle at the water surface. For a conservatively high estimate of 1,500 gpm discharge and assuming a tank width of 8 feet (a practical width for transport by truck), the velocity of linear flow from one end of the tank is:

Vf = Q/A = (1500 gal/min)(1 ft3/7.48 gal)(1 min/60 sec)/((8 ft)(4 ft) = 0.1 ft/sec

The minimum length of the tank would need to be:

L = (Vf)(Tr) = (0.1 ft/sec)(200 sec) = 20 ft

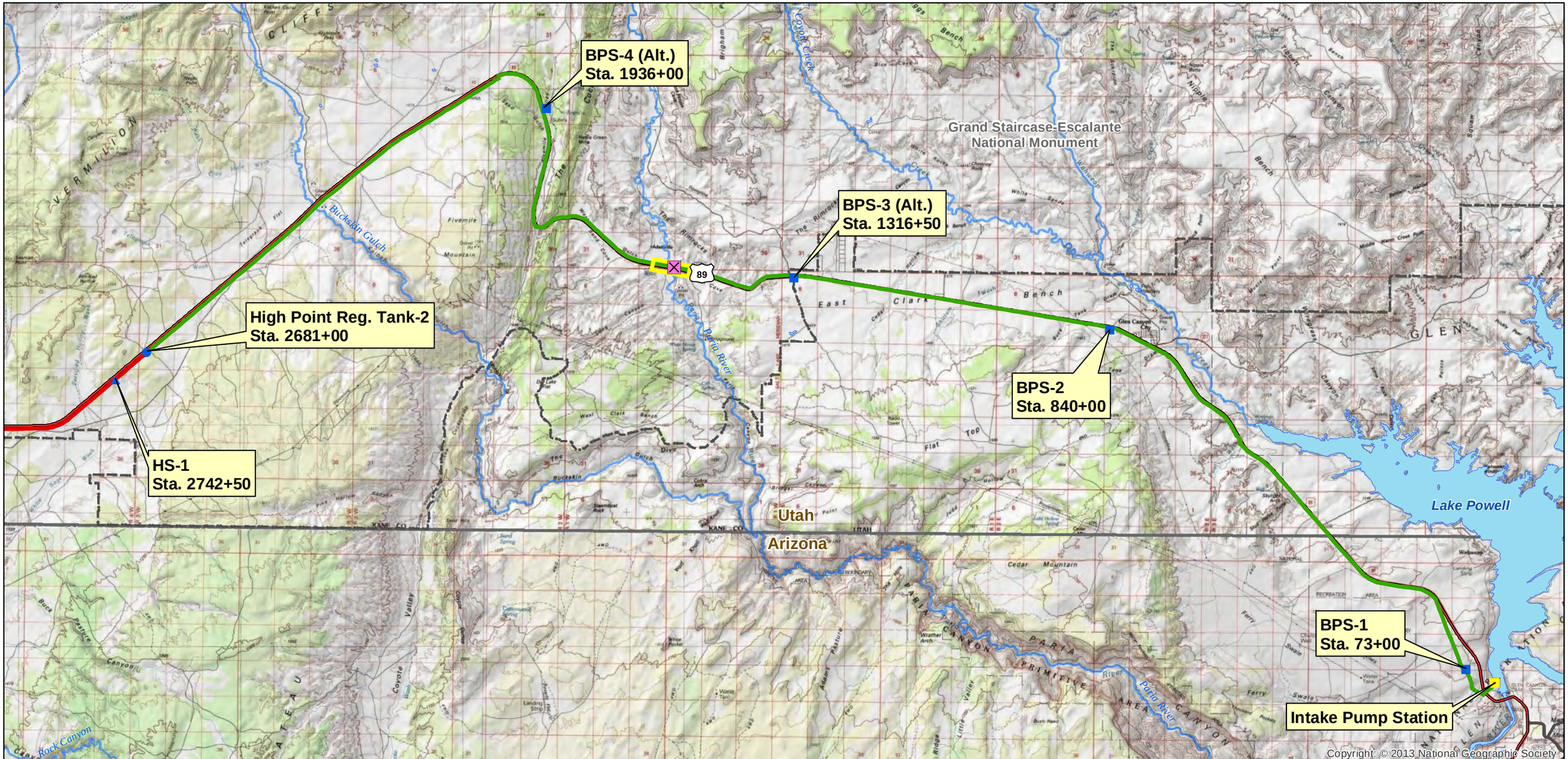
Therefore, a settling tank or basin would be about 8 ft x 20 ft x 4 ft deep to remove very fine sand particles. Settling of solids is likely to involve two tanks or basins in series, with the decant from the first tank or basin flowing from the top of the water column into the second tank or basin. Baffles at the end of each tank or basin would help to distribute the flow velocity evenly across the width of the tank or basin. Once clarified, water that is not recirculated would be pumped to the Glen Canyon Dam right spillway and discharged on the downstream side away from Lake Powell into the Colorado River.

3.2.1.2 Shallow Groundwater

3.2.1.2.1 Stream Channel Crossings. The potential to encounter groundwater along most of the LPP Project alignments is low, because most of the alignments are located across areas where groundwater has been historically recorded at low levels, often with few water production wells. Table 3-1 presents stream crossings and washes along the alignments and the estimated probability of encountering groundwater during construction, requiring dewatering. Estimated depths to groundwater were obtained from relevant well water level measurements where available, which are discussed in greater detail in Section 3.2.1.1.2. If no direct information was found for determining depth to groundwater at channel crossings, it was assumed that crossings where stream flow occurs much of the year would be at high risk, crossings of infrequent, intermittent-flowing streams would be at medium risk, and crossings of normally-dry washes would be at low risk. The locations where stream channel crossings present a medium to high risk of encountering groundwater during construction are shown in Figure 3-1 for the Water Conveyance System and Figure 3-2 for the Hydro System (all alignments).

Table 3-1 LPP Stream Channel Crossings		
Stream Channel	**Probability of Encountering Groundwater**	**Rationale**
Existing Highway Alternative		
Paria River	High	Streamflow occurs in all seasons of the year
Buckskin Gulch	Medium	Typically dry but flows in wet periods
Johnson Wash	Low	Typically dry
Kanab Creek	High	Streamflow occurs in all seasons of the year; high water table in area wells
Cottonwood Creek	Low/Medium	Anecdotal account of flow other than after storm events
Sand Wash	Low/Medium	Anecdotal account of flow other than after storm events
Two Mile Wash/Sand Wash	Low/Medium	Anecdotal account of flow other than after storm events
Cane Beds/Short Creek	High	Short Creek flows part of the year; medium to high measured water table in area wells
South Pipeline Alternative		
White Sage Wash	Low	Typically dry
Jacob Canyon Wash	Low	Typically dry
Kanab Creek	High	Streamflow occurs much of the year
Bitter Seeps Wash	Low	Typically dry
Southeast Corner Alternative		
Jacob Canyon Wash	Low	Typically dry

3.2.1.2.2 Groundwater Wells. Depth to groundwater away from stream channel crossings was determined from well logs and USGS water level measurement records. These were used to identify areas where there is a medium to high risk of encountering groundwater during construction of the pipeline. The locations where there is a medium to high risk of encountering groundwater are shown in Figure 3-1 for the Water Conveyance System and Figure 3-2 for the Hydro System. A list of well numbers of well logs used for determining risks to groundwater is provided in Appendix B.



- Shallow Ground Water Stream Crossings
- Probable Groundwater Areas
- Water Conveyance System
- Hydro System - South Alternative
- KCWCD System
- Project Intake Pump Station
- Project Pump Station
- Project Regulating Tank
- Project Hydro Station
- Interstate
- US Highway
- ST Highway
- Hwy
- Major Road
- Lakes & Reservoirs
- Major Rivers & Streams
- National Park/Monument
- State Boundaries

FERC Project Number:
12966-001
BLM Serial Numbers:
AZA-34941
UTU-85472

N

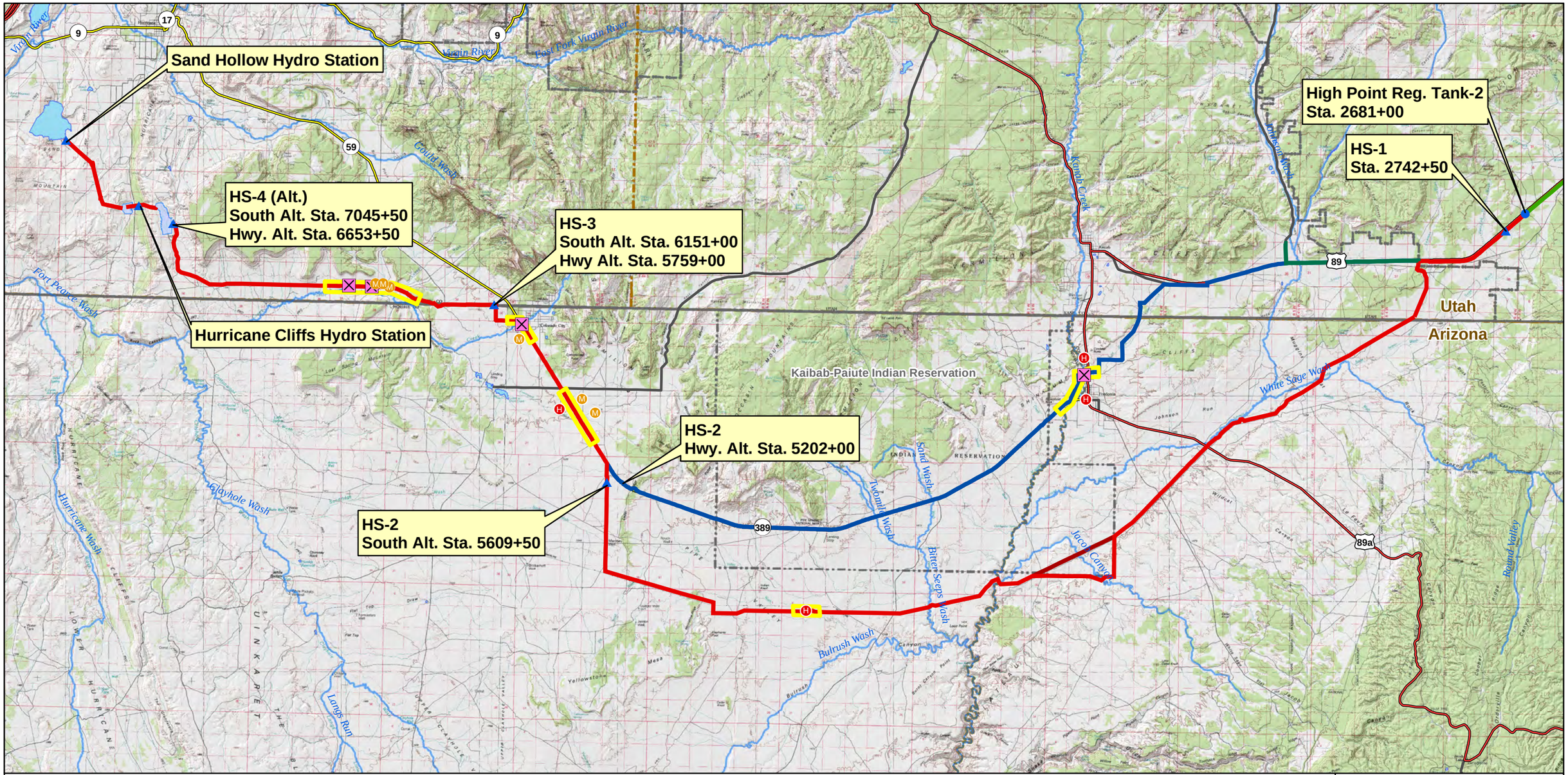
0 0.5 1 2 3 4 Miles

Lake Powell Pipeline Project

Spatial Reference: UTM Zone 12N, NAD-83

UDWRe **Figure 3-1** MWH

Lake Powell Pipeline Potential Shallow Groundwater Locations Water Conveyance System



Shallow Ground Water Stream Crossings
High Water Table Risk - 16'-30'
Medium Water Table Risk - 0'-16'
Project Pump Station
Project Regulating Tank
Project Hydro Station

Probable Groundwater Areas
Hurricane Cliffs Forebay/Afterbay
Water Conveyance System
Hydro System - South Alternative
Hydro System, Existing Highway Alternative
KCWCD System
Hydro System, Southeast Corner Alternative

Interstate
US Highway
ST Highway
Hwy
Major Road
Major Rivers & Streams

National Park/Monument
Tribal Lands
State Boundaries
County Boundaries
Lakes & Reservoirs

FERC Project Number:
12966-001
BLM Serial Numbers:
AZA-34941
UTU-85472

N

0 1.25 2.5 5 7.5 10 Miles

Lake Powell Pipeline Project

Spatial Reference: UTM Zone 12N, NAD-83

UDWRe **Figure 3-2** MWH

Lake Powell Pipeline Potential Shallow Groundwater Locations Hydro System

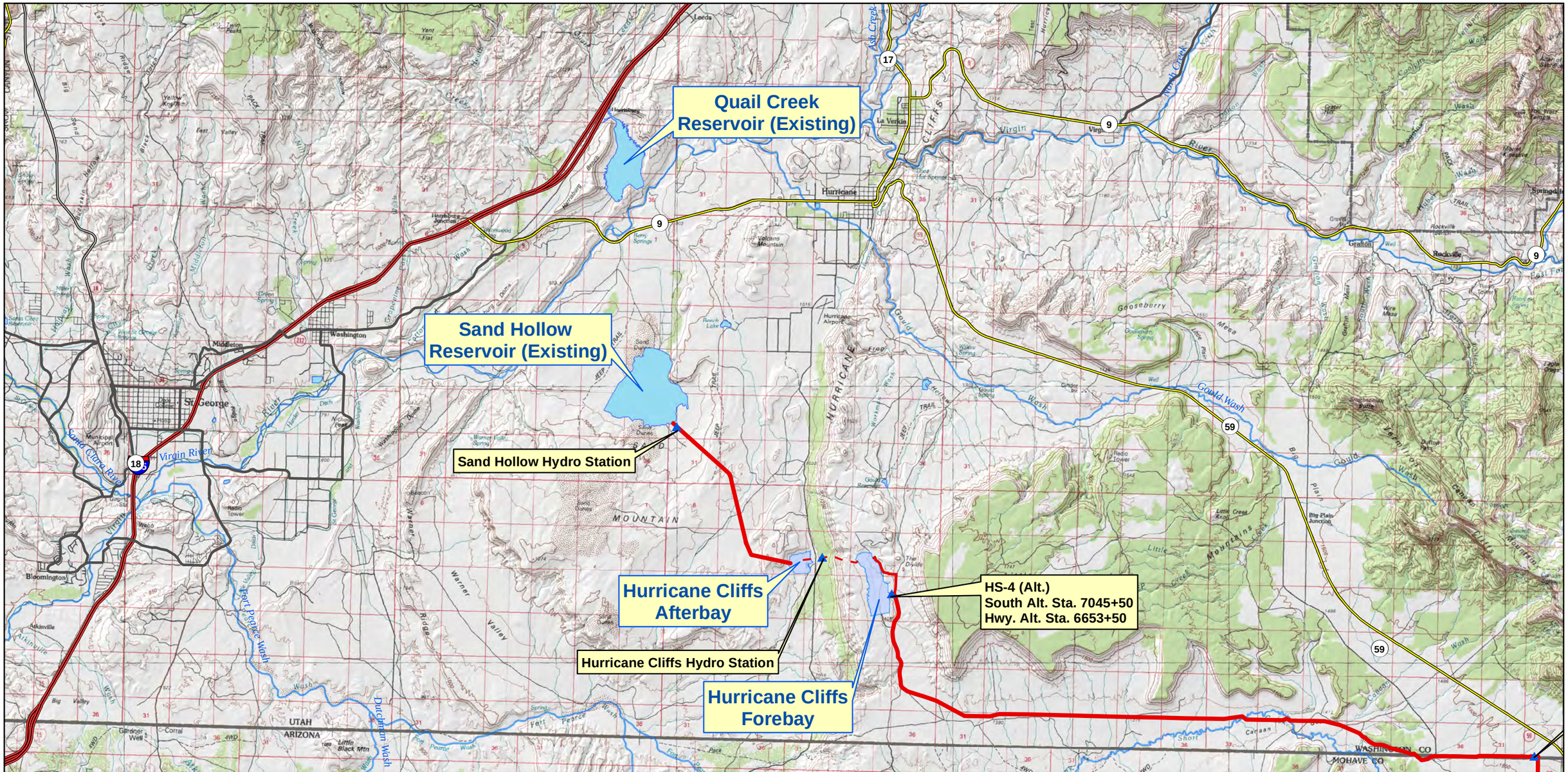
3.2.1.3 Afterbay Reservoir Recharge

Two open-air reservoirs could be constructed as part of the LPP Project, including the Hurricane Cliffs Hydrostation forebay reservoir and the Hurricane Cliffs Hydrostation afterbay reservoir. Both reservoirs are located near the Hurricane Cliffs, as shown in Figure 3-3. Only the Hurricane Cliffs Hydrostation afterbay reservoir would not be lined to prevent substantial seepage.

Seepage from the pumped storage afterbay reservoir is likely because the reservoir would overlie generally coarse-grained alluvial sediments with moderate to high rates of permeability. However, well measurements in the vicinity of the pumped storage afterbay reservoir show that groundwater is deep, and few, if any, existing groundwater users are currently in the area. Recharge from the pumped storage afterbay reservoir may result in localized groundwater mounding. No known wells are currently located within one mile of the pumped storage afterbay reservoir. If mounding eventually extends out from the pumped storage afterbay reservoir to existing or future production wells or if the water table rises as a result of recharge from the pumped storage afterbay reservoir, it would provide a positive hydraulic benefit to groundwater resource users. However, because no drilling geologic data that extends to the water table are available at this location, it is not known whether any impermeable layers may exist that would impede recharge to the deep aquifer.

3.2.1.4 Groundwater – Surface Water Interactions

Only one location within the LPP Project has the potential to be affected by groundwater-surface water interactions. This would be at Sand Hollow Reservoir and the nearby Virgin River. Recharge from the existing Sand Hollow Reservoir, which began filling in 2002, affects groundwater levels near Sand Hollow Reservoir by causing mounding of the groundwater table. This mound now extends from the underlying water table to the bottom of the reservoir, and therefore cannot get much larger. Some of the recharge is recovered by production wells. Flow within the Navajo Sandstone aquifer system underlying Sand Hollow Reservoir is northward and westward, and intercepts the Virgin River both north and west of the reservoir. Ongoing studies by the USGS (USGS 2005; 2007; 2009; 2012) suggest that the water levels within the aquifer are no longer changing substantially as a result of recharge from Sand Hollow Reservoir. Therefore rates of discharge to the Virgin River are assumed to be approximately stabilized



- Project Pump Station
- Project Regulating Tank
- Project Hydro Station
- Water Conveyance System
- Hydro System - South Alignment Alternative
- Interstate
- US Highway
- ST Highway
- Hwy
- Major Road
- National Park/Monument
- Tribal Lands
- State Boundaries
- County Boundaries
- Hurricane Cliffs Forebay/Afterbay
- Lakes & Reservoirs
- Major Rivers & Streams

FERC Project Number: 12966-001
BLM Serial Numbers: AZA-34941 UTU-85472

N

0 0.5 1 2 3 4 Miles

Lake Powell Pipeline Project

Spatial Reference: UTM Zone 12N, NAD-83

UDWRe **Figure 3-3** MWH

Lake Powell Pipeline Project Reservoirs

and are unlikely to change substantially as a result of recharge from the reservoir, regardless of the source of water filling the reservoir.

3.2.1.5 Water Quality

Groundwater quality within the LPP Project study area may only be affected at the proposed Hurricane Cliffs Hydropower afterbay reservoir and at the existing Sand Hollow Reservoir because discharges to unlined reservoirs would only occur at these two locations. No water quality data were identified for groundwater in the vicinity of the afterbay reservoir. Therefore it is not possible to identify baseline conditions at this location.

Water quality at Sand Hollow Reservoir has been characterized by ongoing USGS investigations (USGS 2005; 2007; 2009; 2012). The effects of recharge using Virgin River water, which is similar in concentrations of total dissolved solids and most individual constituents to Lake Powell water, have been documented by the USGS. Current recharge at Sand Hollow Reservoir has resulted in a trend toward higher TDS, caused in part by the higher TDS of Virgin River water as it blends with underlying groundwater, as well as a probable leaching effect of salts within the soil. This leaching appears to be diminishing, because groundwater quality near the reservoir appears to be improving after an initial increase in TDS. If current trends continue, groundwater underlying Sand Hollow Reservoir will become similar to the recharge water. A more extensive discussion is provided in the Recharge Technical Report, included in Appendix A.

Chapter 4
Environmental Consequences (Impacts)

4.1 Significance Criteria

The following criteria were used in this evaluation to determine whether impacts associated with the LPP Project and appurtenances would be significant. Significance criteria were established based on the impact topics identified herein, which were identified in the Study Plan. Impacts are considered significant only if they would occur within the design life of the LPP Project (75 years), and could not be mitigated by design.

4.1.1 Intake Pump Station Construction Dewatering

Dewatering associated with construction of the IPS would be a significant impact on groundwater resources if dewatering would result in a measurable, long-term depletion of groundwater resources to resource users, relative to baseline conditions.

4.1.2 Shallow Groundwater

Dewatering of shallow groundwater to facilitate construction along any of the LPP Project alignments would be a significant impact on groundwater resources if dewatering would result in a measurable, long-term depletion of groundwater resources to resource users, relative to baseline conditions.

4.1.3 Groundwater Recharge

Groundwater recharge associated with the LPP Project would be a significant impact on groundwater resources if resulting recharge would result in a measurable, long-term change in availability of groundwater resources to resource users, relative to baseline conditions.

4.1.4 Groundwater-Surface Water Interactions

Groundwater-surface water interactions associated with recharge that would occur as part of the LPP Project would be a significant impact on groundwater resources if the recharge would result in measurable, long-term changes in the rates or locations of groundwater-surface water interactions, relative to baseline conditions.

4.1.5 Water Quality

Changes in water quality associated with the LPP Project alternatives would be a significant impact on groundwater resources if the changes would degrade groundwater quality, either by changing the state aquifer classification or by increasing concentrations of constituents such that they would exceed state numerical standards for drinking water.

4.2 Potential Impacts Eliminated From Further Analysis

No impacts were eliminated from further analysis.

4.3 South Alternative Impacts

4.3.1 Construction Impacts

4.3.1.1 Intake Pump Station Construction Dewatering

Construction dewatering for the IPS would be of a duration of potentially numerous months. This would result in a cone of depression of the water table around the IPS to the north, west and south. The water table in boreholes at the IPS location indicate that groundwater in the Navajo Sandstone at that location is in hydraulic connection with Lake Powell, so the lake would serve as a recharge boundary which would limit the cone of depression eastward and would provide much of the water that would be pumped over the long term. The relatively low permeability of the Navajo Sandstone aquifer matrix would result in a steep groundwater gradient within the cone of depression that would limit the extent of drawdown around the IPS facility during construction dewatering. A review of Arizona Department of Water Resources Well Registry identified no production wells within one mile of the proposed IPS site. Because of the isolation of the proposed IPS facility, no production wells would be affected. No measurable impacts would occur and no significant impacts would occur.

4.3.1.2 Shallow Groundwater

Shallow groundwater would be encountered at the Paria River and Kanab Creek near Fredonia, and possibly at the Cane Beds -Short Creek area in the Colorado City area. Shallow groundwater probably would be encountered at the Sand Hollow Reservoir outlet. Although possible, it is unlikely that shallow groundwater would be encountered elsewhere. Best management practices (BMPs) would be incorporated to limit drawdown during construction dewatering to the minimum drawdown necessary for safe and effective construction. BMPs would be utilized to prevent groundwater migration along trench bedding where shallow groundwater is encountered. A list of anticipated BMPs that would be required for construction are provided in Appendix C. Drawdown would be temporary, no longer than necessary for construction purposes, which would not cause long-term or extensive depletion of groundwater levels or available supplies. Disposal of dewatered groundwater would be performed using BMPs to prevent excessive erosion. Therefore, no measurable impacts and no significant impacts are expected to occur.

4.3.1.3 Groundwater Recharge

Construction of the South Alternative would not affect any known groundwater recharge. The South alignment does not cross through any observed or documented groundwater recharge areas. No impacts would occur.

4.3.1.4 Groundwater-Surface Water Interactions

Dewatering disposal during construction would be performed using BMPs to prevent erosion or other impacts on surface water. Therefore, no impacts and no significant impacts would occur as a result of construction dewatering. No other impacts would occur.

4.3.1.5 Water Quality

Groundwater quality would not be affected by short-term dewatering or other construction-related work. Therefore, no impacts would occur and no significant construction impacts would occur on groundwater quality.

4.3.2 Operational Impacts

4.3.2.1 Intake Pump Station Long-Term Operation

The shafts and tunnels would be lined which would minimize or eliminate groundwater inflow. After construction is completed, the groundwater table would stabilize at or near the water level elevation of Lake Powell. No measurable impacts on groundwater would occur.

4.3.2.2 Shallow Groundwater

Occasional water releases from pipeline and penstock drains would occur at low points in the profile. These temporary drain releases to streams and dry washes would have no measurable impacts on shallow groundwater. If released surface water recharged to the ground in these streams and dry washes, the resulting impacts on shallow groundwater would be positive and intermittent. No significant impacts would occur on shallow groundwater.

4.3.2.3 Groundwater Recharge

Substantial groundwater recharge would only occur at the afterbay reservoir and at Sand Hollow Reservoir. At the afterbay reservoir, recharge would be to a deep aquifer in the Navajo sandstone utilized by very few groundwater resource users. If any recharge reaches the aquifer, it would result in an increase in groundwater levels. This would be a positive, long-term impact on groundwater resources.

Recharge at Sand Hollow Reservoir from LPP water would continue the hydraulic recharge conditions similar to baseline conditions where recharge of diverted Virgin River water occurs in the reservoir. Therefore, no distinguishable impacts and no significant impacts would occur on groundwater resources.

4.3.2.4 Groundwater-Surface Water Interactions

Groundwater-surface water interactions would be similar to baseline conditions. Therefore, no measurable impacts and no significant impacts would occur.

4.3.2.5 Water Quality

During operations, infrequent releases of LPP Project water could occur from drain valves at low points in the pipeline during brief winter maintenance and inspection periods of not longer than two weeks. The LPP water released to the low points are existing ephemeral drainages that could receive discharges for up to two days. The quality of this water would be the same as in Lake Powell, and recharge would occur as the water is discharged from the pipeline drain. Groundwater quality would not be measurably affected during long-term operation of the LPP Project from these infrequent discharges.

Water quality impacts associated with the LPP Project would be similar to baseline conditions because of the similarity of Virgin River water quality to the Lake Powell water that would be delivered to Sand Hollow Reservoir. Therefore, no measurable impacts and no significant impacts would occur on groundwater resources.

Recharge at the afterbay reservoir is of unknown quantity into an aquifer of unknown quality; however, recharge would be into a deep aquifer with few or no groundwater users. Therefore, no measurable impacts and no significant impacts are expected to occur.

4.4 Existing Highway Alternative Impacts

4.4.1 Construction Impacts

4.4.1.1 Intake Pump Station Construction Dewatering

Impacts would be the same as for the South Alternative. No significant impacts would occur.

4.4.1.2 Shallow Groundwater

Impacts would be similar to the South Alternative. No significant impacts would occur.

4.4.1.3 Groundwater Recharge

No measurable impacts would occur.

4.4.1.4 Groundwater-Surface Water Interactions

Dewatering disposal during construction would incorporate BMPs that would prevent erosion or other impacts on surface water. Therefore, no measurable impacts and no significant impacts would occur as a result of construction dewatering. No other impacts would occur.

4.4.1.5 Water Quality

Groundwater quality would not be affected by short-term dewatering or other construction-related work. Therefore, no measurable impacts and no significant construction impacts would occur.

4.4.2 Operational Impacts

4.4.2.1 Intake Pump Station Long-Term Operation

Impacts would be the same as for the South Alternative. No measurable impacts would occur.

4.4.2.2 Shallow Groundwater

No measurable impacts would occur.

4.4.2.3 Groundwater Recharge

No measurable impacts would occur.

4.4.2.4 Groundwater-Surface Water Interactions

No measurable impacts would occur.

4.4.2.5 Water Quality

Potential unmeasurable impacts would be the same as described for the South Alternative in Section 4.3.2.5.

4.5 Southeast Corner Alternative Impacts

4.5.1 Construction Impacts

4.5.1.1 Intake Pump Station Construction Dewatering

Impacts would be the same as for the South Alternative. No significant impacts would occur.

4.5.1.2 Shallow Groundwater

Impacts would be similar to the South Alternative. No significant impacts would occur on shallow groundwater.

4.5.1.3 Groundwater Recharge

No measurable impacts would occur.

4.5.1.4 Groundwater-Surface Water Interactions

Dewatering disposal during construction would incorporate BMPs that would prevent erosion or other impacts on surface water. Therefore, no measurable impacts and no significant impacts would occur as a result of construction dewatering. No other impacts would occur. A list of anticipated BMPs that would be required for construction are provided in Appendix C.

4.5.1.5 Water Quality

BMPs would be utilized during construction to prevent accidental releases of fuel or chemicals and to minimize disposal of turbid water that could affect groundwater quality. Therefore, no significant construction impacts would occur. A list of anticipated BMPs that would be required for construction are provided in Appendix C.

4.5.2 Operational Impacts

4.5.2.1 Intake Pump Station Long-Term Operation

No measurable impacts would occur.

4.5.2.2 Shallow Groundwater

No measurable impacts would occur.

4.5.2.3 Groundwater Recharge

No measurable impacts would occur.

4.5.2.4 Groundwater-Surface Water Interactions

No measurable impacts would occur.

4.5.2.5 Water Quality

Potential unmeasurable impacts would be the same as described for the South Alternative in Section 4.3.2.5.

4.6 Natural Gas Pipeline and Generators Alternative Impacts

4.6.1 Construction Impacts

4.6.1.1 Intake Pump Station Construction Dewatering

The impacts would be the same as for the South Alternative. No significant impacts would occur.

4.6.1.2 Shallow Groundwater

Impacts would be similar to the South Alternative described in Section 4.3.1.1., except the natural gas pipeline alternative trench would be three feet deep and construction would have a lower probability of encountering shallow groundwater. No measurable impacts and no significant impacts would occur on shallow groundwater.

4.6.1.3 Groundwater Recharge

No measurable impacts would occur.

4.6.1.4 Groundwater-Surface Water Interactions

Dewatering disposal during construction would incorporate BMPs that would prevent erosion or other impacts on surface water. Therefore, no measurable impacts and no significant impacts would occur as a result of construction dewatering. No other impacts would occur. A list of anticipated BMPs that would be required for construction are provided in Appendix C.

4.6.1.5 Water Quality

Groundwater quality would not be affected by short-term dewatering or other construction-related work. Therefore, no significant construction impacts would occur. A list of anticipated BMPs that would be required for construction are provided in Appendix C.

4.6.2 Operational Impacts

4.6.2.1 Intake Pump Station Long-Term Operation

No measurable impacts would occur.

4.6.2.2 Shallow Groundwater

No measurable impacts would occur.

4.6.2.3 Groundwater Recharge

No measurable impacts would occur.

4.6.2.4 Groundwater-Surface Water Interactions

No measurable impacts would occur.

4.6.2.5 Water Quality

No measurable impacts would occur.

4.7 No Lake Powell Water Alternative

4.7.1 WCWCD No Lake Powell Water Alternative

4.7.1.1 Intake Pump Station Construction Dewatering

The IPS would not be constructed so no dewatering would be needed. No impacts would occur.

4.7.1.2 Shallow Groundwater

Shallow groundwater resources would be affected as water supplies become increasingly scarce. Increasing demands for water supply would maximize groundwater resource usage. Shallow groundwater recharged to the Navajo sandstone aquifer beneath and around Sand Hollow Reservoir would be reserved for use during dry periods to compensate for any deficit between annual supply and demand.

4.7.1.3 Groundwater Recharge

The No Lake Powell Water Alternative would eliminate outdoor landscape watering with potable water. Currently, most of the water used for this purpose originates from surface water, primarily the Virgin River. Elimination of outdoor watering with potable water would eliminate groundwater recharge in the St. George metropolitan area except for secondary water used for irrigating landscapes in LaVerkin, Toquerville and Hurricane. Under the No Lake Powell Water Alternative, a reduction in potable outdoor water irrigation would occur in the WCWCD service area of St. George and surrounding areas, which would reduce the volume of groundwater recharge. The estimated reduction in residential outdoor potable water use by 2052 (the projected year when all LPP Proposed Action water would be utilized) would be between 51,633 acre-feet per year and 56,724 acre-feet per year when compared to the Proposed Action. UDWRe estimates that approximately 50 percent of current residential potable water used for outdoor residential watering is consumed by evapotranspiration, and the remaining 50 percent is recharged to groundwater. Non-sewered return flows of potable water are projected by UDWRe to decrease from 50

percent to 30 percent between 2010 and 2050 resulting from increased water conservation measures and more efficient use of potable water for outdoor watering. UDWRe estimates that approximately 20 percent of commercial potable water use is used for outside watering, and approximately 80 percent of institutional potable water use is used for outside watering. This would be a long-term adverse impact and would be a significant long-term adverse impact on groundwater recharge in the St. George metropolitan area.

4.7.1.4 Groundwater-Surface Water Interactions

Under the No Lake Powell Water Alternative, the reduction in recharge from outdoor watering, discussed in Section 4.7.1.3, would affect return flows to the Virgin River. This recharge eventually becomes return flow to the Virgin River. The reduction in potable outdoor water use and water efficiency improvements would reduce the percent of outdoor residential, commercial and institutional irrigation water recharged to the aquifer to about 30 percent of the total.
Thus, from 15,500 to 17,017 acre-feet per year (21.4 to 23.5 cubic feet per second, on average) of return flow to the Virgin River would not occur by 2052, a reduction of non-sewered return flows of 77 to 80 percent when compared to baseline conditions. This would be a measurable, significant impact on groundwater-surface water interactions.

4.7.1.5 Water Quality

The No Lake Powell Water Alternative could adversely impact groundwater quality in the St. George metropolitan area through recharge only with lower quality secondary surface water for outdoor irrigation. Groundwater quality could gradually decrease from increased concentration of TDS associated with the secondary irrigation water, mostly supplied from reuse effluent. Moderate adverse impacts on groundwater quality could occur. These impacts could be significant on groundwater quality in the St. George metropolitan area.

4.7.2 KCWCD No Lake Powell Water Alternative

4.7.2.1 Intake Pump Station Construction Dewatering

Construction of the IPS would not occur, so no impacts would occur.

4.7.2.2 Shallow Groundwater

The Kanab Creek aquifer would be further developed to meet demands for M&I water in the KCWCD service area for Kanab and Johnson Canyon. The shallow aquifer associated with Kanab Creek would be further depleted and this would be a minor impact on groundwater resources in the Kanab area.

4.7.2.3 Groundwater Recharge

No measurable impacts would occur.

4.7.2.4 Groundwater-Surface Water Interactions

No measurable impacts would occur.

4.7.2.5 Water Quality

No measurable impacts would occur.

4.8 No Action Alternative

4.8.1 WCWCD No Action Alternative

4.8.1.1 Intake Pump Station Construction Dewatering

Construction of the IPS would not occur, so no impacts would occur.

4.8.1.2 Shallow Groundwater

Shallow groundwater resources would be affected as water supplies become increasingly scarce. Increasing demands for water supply would maximize groundwater resource usage. Shallow groundwater recharged to the Navajo sandstone aquifer beneath and around Sand Hollow Reservoir would be reserved for use during dry periods to compensate for any deficit between annual supply and demand.

4.8.1.3 Groundwater Recharge

No impacts would occur.

4.8.1.4 Groundwater-Surface Water Interactions

No impacts would occur.

4.8.1.5 Water Quality

No impacts would occur.

4.8.2 KCWCD No Action Alternative

4.8.2.1 Intake Pump Station Construction Dewatering

Construction of the IPS would not occur, so no impacts would occur.

4.8.2.2 Shallow Groundwater

Pressure would increase on groundwater resources as the projected shortage of available water would require maximization of the groundwater resource usage. Eventually, the capacity of the aquifers would be exceeded and depletion would occur, limiting the availability of water for use. This would cause a significant long term impact.

4.8.2.3 Groundwater Recharge

No impacts would occur.

4.8.2.4 Groundwater-Surface Water Interactions

No impacts would occur.

4.8.2.5 Water Quality

No impacts would occur.

Chapter 5
Mitigation and Monitoring

5.1 South Alternative

The following protection, mitigation and enhancement measures would be implemented to protect and mitigate potential effects on groundwater resources. A list of anticipated BMPs that would be implemented during construction are provided in Appendix C.

5.1.1 Planning

UDWRe would prepare site specific groundwater Best Management Practices (BMPs) and implement a Spill Prevention, Control and Countermeasures Plan (SPCCP) to minimize the potential for groundwater contamination from uncontrolled or unmitigated releases of hazardous materials. The SPCCP would include measures such as using portable containment pads for refueling and servicing construction equipment to prevent hazardous material spills on the ground surface where it could come into contact with surface and/or groundwater.

5.1.2 Site Stabilization and Erosion Control

UDWRe would specify hydroseeding, mulching, soil stabilizers (binders), silt fences, geotextiles, and erosion control blankets as necessary on disturbed soils to protect against soil erosion, excessive surface water runoff, and ponding that could transfer construction-related contaminants into the soil and/or groundwater.

5.1.3 Dewatering

If dewatering is necessary, water would be pumped to an acceptable, properly designed dewatering basin. The stored water can be used for onsite construction activities, discharged into evaporation/infiltration basins or land-applied in adjacent land with prior permission. Pumping would be limited to the flow rate necessary to achieve dewatering for safe and stable trench construction activities and would occur no longer than necessary to complete construction within the open trench interval.

5.1.4 Pollutant Removal and Peak Runoff Control

UDWRe would require construction contractors to manage and control all sediment from dewatered groundwater using earth dikes, drainage swales, ditches, velocity dissipation devices, slope drains and/or similar methods. At the IPS, settling tanks or basins would be used to remove suspended solids from discharge. The treated water would be pumped to the Glen Canyon Dam spillway to be discharged and would flow from there into the Colorado River downstream of the dam.

5.1.5 Streambank Stabilization and Antidegradation

Construction locations with severe channel instability problems would be avoided. Stabilization and erosion control measures would be implemented to prevent any increase in sedimentation, siltation and turbidity to the stream as a result of construction activity. Runoff and contaminants from staging areas would be prevented from entering stream and dry washes by using secondary containment structures.

Directional drilling may be used in geologically sensitive locations to minimize potential for groundwater contamination. All drilling fluids would be captured and accounted for during drilling activities.

5.1.6 Stormwater Percolation

Infiltration trenches would be used to percolate uncontaminated run-on and runoff stormwater as applicable. All infiltration trenches would be reclaimed to approximate original contour following construction completion of each segment.

5.1.7 Waste Management

All construction waste generated would be handled, stored and disposed of under prevailing codes and regulations. Lined containment structures would be used where applicable to prevent groundwater contamination from construction waste.

5.1.8 Monitoring

No monitoring would be required.

5.2 Existing Highway Alternative

5.2.1 Mitigation

Mitigation measures for the Existing Highway Alternative would be the same as described for the South Alternative in Section 5.1.

5.2.2 Monitoring

No monitoring would be required.

5.3 Southeast Corner Alternative

5.3.1 Mitigation

Mitigation measures for the Southeast Corner Alternative would be the same as described for the South Alternative in Section 5.1.

5.3.2 Monitoring

No monitoring would be required.

5.4 Natural Gas Pipeline and Generators Alternative

5.4.1 Mitigation

Mitigation measures for the Natural Gas Pipeline and Generators Alternative would be the same as described for the South Alternative in Section 5.1.

5.4.2 Monitoring

No monitoring would be required.

5.5 No Lake Powell Water Alternative

5.5.1 Mitigation

Alternative water supplies, combined with extensive water conservation measures, would be necessary to restrict increased groundwater demands from population growth under the No Lake Powell Water Alternative.

5.5.2 Monitoring

Groundwater levels would require regular monitoring to determine continued trends and rates of depletion to maintain adequate groundwater supply for future growth under the No Lake Powell Water Alternative.

5.6 No Action Alternative

5.6.1 Mitigation

Alternative water supplies, combined with extensive water conservation measures, would be necessary to restrict increased groundwater demands from population growth under the No Action Alternative.

5.6.2 Monitoring

Groundwater levels would require regular monitoring to determine continued trends and rates of depletion to maintain adequate groundwater supply for future growth under the No Action Alternative.

Chapter 6
Unavoidable Adverse Impacts

6.1 South Alternative

The South Alternative would have unmeasurable short-term unavoidable adverse impacts on groundwater resources. Construction impacts would include potential groundwater dewatering and disposal in areas near the Paria River and near the Cane Beds -Short Creek area. The South Alternative would have no long-term unavoidable adverse impacts on groundwater resources.

6.2 Existing Highway Alternative

The Existing Highway Alternative would have the same unavoidable adverse impacts on groundwater resources as described for the South Alternative in Section 6.1.

6.3 Southeast Corner Alternative

The Southeast Corner Alternative would have the same unavoidable adverse impacts on groundwater resources as described for the South Alternative in Section 6.1.

6.4 Natural Gas Pipeline and Generators Alternative

The Natural Gas Pipeline and Generators Alternative would have the same unavoidable adverse impacts on groundwater resources as described for the South Alternative in Section 6.1.

6.5 No Lake Powell Water Alternative

The No Lake Powell Water Alternative would have no short-term unavoidable adverse impacts on groundwater resources. It would have major long-term unavoidable adverse impacts on groundwater resources in the St. George metropolitan area resulting from eliminating outdoor irrigation with potable water, reducing shallow groundwater recharge except for those areas irrigated with secondary water. The elimination of shallow groundwater recharge from outdoor irrigation with potable water would reduce groundwater discharge to the Virgin River and could reduce stream flows, increase water temperature, and decrease DO concentrations during summer months, all resulting in potential adverse impacts on aquatic organisms. Depletion of groundwater supplies would result in reduced availability of water and higher pumping costs. Economic and population growth would eventually be limited by high cost of water and depletion of groundwater resources. Agricultural irrigation ultimately would not occur and groundwater recharge would not occur as a result of agricultural irrigation.

6.6 No Action Alternative

Depletion of groundwater supplies would result in reduced availability of water and higher pumping costs. Economic and population growth would eventually be limited by high cost of water and depletion of groundwater resources. Agricultural irrigation ultimately would not occur and groundwater recharge would not occur as a result of agricultural irrigation.

Chapter 7
Cumulative Impacts

This chapter analyzes cumulative impacts that may occur from construction and operation of the proposed LPP project when combined with the impacts of other past, present, and reasonably foreseeable future actions and projects after all proposed mitigation measures have been implemented. Only those resources with the potential to cause cumulative impacts are analyzed in this chapter.

7.1 South Alternative

The South Alternative would have no short-term cumulative impacts on groundwater resources. The South Alternative would have positive, long-term cumulative effects on groundwater resources resulting from LPP water recharge into the Navajo sandstone aquifer under Sand Hollow Reservoir.

7.2 Existing Highway Alternative

The Existing Highway Alternative would have the same cumulative impacts as described for the South Alternative in Section 7.1.

7.3 Southeast Corner Alternative

The Southeast Corner Alternative would have the same cumulative impacts as described for the South Alternative in Section 7.1.

7.4 Natural Gas Pipeline and Generators Alternative

The Natural Gas Pipeline and Generators Alternative would have no short-term or long term cumulative impacts on groundwater resources.

7.5 No Lake Powell Water Alternative

The No Lake Powell Water Alternative would have no short-term or long-term cumulative impacts on groundwater resources.

7.6 No Action Alternative

The No Action Alternative would have no short-term or long-term cumulative impacts on groundwater resources.

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Glossary

Alluvium. A deposit of soil particles transported by flowing water.

Aquifer. Rock or sediment in a formation or formations which is saturated and sufficiently permeable to transmit usable quantities to a well or spring.

Baseflow. The part of stream discharge derived from groundwater seeping into the stream.

Dewatering. The process of removing water from an excavation and surrounding rock or soil to facilitate below-ground construction activities.

Dry Wash. A desert drainage channel that is normally dry except following a significant runoff such as a large storm or snowmelt.

Ephemeral Stream. A stream that flows only in response to precipitation events.

Groundwater. The water contained in interconnected pores below the surface.

Penstock: A high-pressure conduit extending from the first upstream water surface or source to the turbine.

Phreatophyte. A deep-rooted plant that relies for moisture on subsurface conditions that are at saturation or near saturation most of its life cycle.

Pipeline: A line of connected pipes used for carrying water over a long distance.

Recharge. The process whereby water is introduced into an aquifer.

Riparian. Zone adjacent to river and stream banks that accommodates plant species that require greater water use than upland species.

Abbreviations and Acronyms

ADWR	Arizona Department of Water Resources
Alt.	Alternative
AMSL	Above Mean Sea Level
BLM	Bureau of Land Management
BMP	Best Management Practice
BPS	Booster Pump Station
CFR	Code of Federal Regulations
DEQ	Department of Environmental Quality
DWQ	Division of Water Quality
FERC	Federal Energy Regulatory Commission
GCNRA	Glen Canyon National Recreation Area
GIS	Geographical Information System
GOPB	Governor's Office of Planning and Budget
GPCD	Gallons Per Capita Per Day
GSENM	Grand Staircase-Escalante National Monument
HAL	Hansen, Allen & Luce
HPRT	High Point Regulating Tank
HS	Hydro Station
IPS	Intake Pump Station
KCWCD	Kane County Water Conservancy District
KPIR	Kaibab-Paiute Indian Reservation
kV	Kilovolt
LPP	Lake Powell Pipeline
M&I	Municipal and Industrial

MMBtu	Million British Thermal Units
MSL	Mean Sea Level
MW	Megawatt
MWH	MWH Americas, Inc.
NWIS	National Water Information System
PHREEQC	pH-REdox-EQuilibrium C program
RO	Reverse Osmosis
ROW	Right of Way
SHR	Sand Hollow Reservoir
SITLA	School and Institutional Trust Land Administration
SPCCP	Spill Prevention, Control and Countermeasures Plan
TDS	Total Dissolved Solids
UAC	Utah Administrative Code
UBWR	Utah Board of Water Resources
UDWRi	Utah Division of Water Rights
UDWRe	Utah Division of Water Resources
USDOT	U.S. Department of Transportation
USGS	U.S. Geological Survey
WCWCD	Washington County Water Conservancy District

Appendix A
Revised Technical Memorandum 5.13C
Aquifer Recharge Issues

Appendix A
Lake Powell Pipeline Phase I - Preliminary Engineering and Environmental Studies

Task 5 - Develop and Analyze Alternatives

Revised Technical Report 5.13C
Aquifer Recharge Issues

Prepared for:

Utah Division of Water Resources

May 2009

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TM 5.13C PUMP STATION FEATURES

5.13C.1 INTRODUCTION

The proposed Lake Powell Pipeline (LPP) would provide a new water supply of approximately 100,000 af/yr to southwest Utah communities including St. George and possibly Kanab, as well as surrounding areas.

It is anticipated that groundwater recharge will be a component of the proposed LPP project. Some of this groundwater recharge would be incidental; however, groundwater recharge would occur near WCWCD wellfields. This memorandum considers the feasibility of groundwater recharge, with a focus on water quality and regulatory issues as well as potential concerns for future users.

5.13C.2 PROPOSED PROJECT

5.13C.2.1 General

The LPP water would be pumped at a maximum flowrate of approximately 93 mgd from an intake at Lake Powell and transported in a raw water pipeline. The terminus of the initial pipeline segment from Lake Powell to the St. George area is proposed to be the existing Sand Hollow Reservoir east of St. George.

Sand Hollow Reservoir currently is used as off-line storage to supply the existing Quail Creek WTP, for aquifer recharge, and for recreation. Surplus water from the Virgin River is pumped into Sand Hollow Reservoir during periods of excess river flow and lower demand, and then water from Sand Hollow Reservoir is conveyed back into Quail Creek Reservoir during periods of low river flow and high demand. Quail Creek Reservoir also is filled by a direct diversion from the Virgin River and currently provides the raw water supply for the Quail Creek WTP. Groundwater from wells adjacent to Sand Hollow Reservoir (up to 20 mgd maximum in the future) is pumped into the Quail Creek WTP treated water transmission system, downstream of the WTP, for distribution to potable water users. All of these facilities are owned and operated by the WCWCD.

5.13C.3 EXISTING CONDITIONS

5.13C.3.1 Water Supply

Water supply sources in the WCWCD service area includes groundwater derived from wells and springs, from surface water captured in reservoirs and from direct diversion from streams and rivers.

5.13C.3.1.1 Surface Water

Surface water is made available by means of local streamflow diversions but is primarily captured by reservoirs. Major reservoirs in the vicinity include Quail Creek Reservoir, Sand Hollow Reservoir, and Lake Powell, the last being by far the largest.

5.13C.3.1.1.1 Quail Creek Reservoir

Quail Creek Reservoir is owned and operated by WCWCD. The reservoir is supplied with water that gravity flows from Quail Creek, but most of the water in the reservoir is diverted from the nearby Virgin River. It has a full-pool surface area of 590 acres and a capacity of 40,325 acre-feet. The Quail

Creek watershed area covers 592,577 acres and has an annual average inflow of 22,000 acre-feet. The maximum depth of the reservoir is 190 feet, and the water is contained by two dams. The reservoir provides drinking water to the St. George metropolitan area and is treated at an on-site water treatment plant. Minimum stream flows and excess flows are released to the Virgin River downstream of the larger of the two dams (UGS 1999; Utah DEQ-DWQ 2007a).

5.13C.3.1.1.2 Sand Hollow Reservoir

Sand Hollow Reservoir is owned and operated by WCWCD. The full-pool surface area is approximately 1,300 acres and a capacity of 50,000 acre-feet (USGS 2005). The reservoir water supply originates from the Virgin River. Sand Hollow Reservoir is filled on-demand and therefore does not have excess discharge. The reservoir also is used for aquifer recharge.

5.13C.3.1.1.3 Lake Powell

Lake Powell is the largest reservoir in Utah. The reservoir has a full-pool surface area of 162,700 acres and a design storage capacity of 24,322,000 acre-feet. Lake Powell is stored behind Glen Canyon Dam, built on the Colorado River two miles south of the Utah-Arizona border, with a Colorado River watershed of 65,800,000 acres. The dam is owned and operated by the U.S. Bureau of Reclamation. The watershed above Glen Canyon Dam includes most of eastern and southern Utah, western Colorado, and southwestern Wyoming, as well as relatively smaller areas in the Central/Southern Rocky Mountains in northeastern Arizona and northwestern New Mexico. The watershed area is largely high desert of the Colorado Plateau but derives much of its runoff from the west slopes of the Central Rocky Mountains, as well as the Uintah Mountains along the Utah-Wyoming border and the Wind River Mountains in western Wyoming. Average inflow is approximately 12,000,000 acre/feet per year (Reclamation 2005).

5.13C.3.1.2 Groundwater

Groundwater is used throughout the area and is obtained primarily from wells, with lesser quantities derived from springs. Groundwater is obtained from shallow alluvial aquifers within river valleys, from basalt bedrock, and from shallow to deep fractured and weakly cemented sedimentary rock aquifers, most notably the Navajo Sandstone aquifer system but from others as well.

5.13C.3.1.2.1 Navajo Sandstone Aquifer

In the vicinity of the Sand Hollow Reservoir, recharge to groundwater occurs from direct precipitation on overlying surface land within the subdrainage south and east of the Virgin River and west of the Hurricane Cliffs. During the period following construction of Sand Hollow Reservoir in 2002, recharge from the reservoir has occurred to the shallow unconsolidated overburden (alluvial and eolian sand), to the basalt bedrock north of the reservoir, and primarily to the underlying Navajo Sandstone (USGS 2005).

Sand Hollow Reservoir was filled with water pumped from the Virgin River starting in 2002 and completed in 2005. The rate of seepage from the reservoir that has recharged the underlying Navajo Aquifer has declined from 2002, when the reservoir began filling, to 2006 (USGS 2007). A number of production wells near the reservoir are benefiting from recharge because the hydraulic influence of recharge from the reservoir is raising water table elevations, thereby providing more hydraulic head

to reduce pumping lift requirements. The groundwater is pumped from the wells, owned and operated by the WCWCD, for use in St. George and nearby communities west of the reservoir.

5.13C.4 GROUNDWATER QUALITY STANDARDS

Groundwater quality protection standards in Utah are specified in UAC 317-6 and are based on established groundwater quality numerical standards as well as on beneficial uses. Aquifers are assigned a protection standard based upon the designated beneficial uses; however, only a limited number of aquifers in the State of Utah have been assigned a groundwater classification. Groundwater classifications are presented in **Table 5.13C.1**. Numerical groundwater quality standards are found in UAC R317-6-2 and are presented in **Table 5.13C.2**.

Table 5.13C.1 – Groundwater Classes for the State of Utah (UAC R317-6-3)

Classification	Title	Definition
IA	Pristine Groundwater	Meets groundwater quality standards with TDS <500 mg/L
IB	Irreplaceable Groundwater	Meets groundwater water quality standards with no comparable replacement source
IC	Ecologically Important Groundwater	Important to wildlife habitat
II	Drinking Water Quality Groundwater	Meets groundwater quality standards with TDS >500 mg/L but <3,000 mg/L
III	Limited Use Groundwater	Does not meet groundwater standards and/or TDS >3,000 mg/L but <10,000 mg/L
IV	Saline Groundwater	TDS >10,000 mg/L

TDS = Total Dissolved Solids

5.13C.4.1 Class IA Protection Levels

In addition to the parameters listed in **Tables 5.13C.1** and **5.13C.2**, UAC 317-6 also requires compliance with the following degradation requirements when discharging to groundwater:

- TDS may not exceed 1.25 times background concentrations, or background plus two standard deviations
- When a contaminant is not detectable in background, the affected groundwater may not exceed the greater of 0.1 times the numerical groundwater quality standard value, or the limit of analytical detection
- When a contaminant is detectable in background, the affected groundwater may not exceed the greater of 1.25 times the background concentration, or 0.25 times the numerical groundwater quality standard value, or background plus two standard deviations
- In no case will the concentration of a contaminant in affected groundwater be allowed to exceed the numerical groundwater quality standard.

Table 5.13C.2 – Utah Numerical Groundwater Quality Standards

Parameter Description	Value
Physical Characteristics	
Color (units)	15.0
Corrosivity (characteristic)	Noncorrosive
Odor (threshold number)	3.0
pH (units)	6.5-8.5
Inorganic Chemicals (mg/L)	
Bromate	0.01
Chloramine (as Cl2)	4
Chlorine (as Cl2)	4
Chlorine Dioxide	0.8
Chlorite	1.0
Cyanide (free)	0.2
Fluoride	4.0
Nitrate (as N)	10.0
Nitrite (as N)	1.0
Total Nitrate/Nitrite (as N)	10.0
Metals (mg/L)	
Antimony	0.006
Asbestos (fibers/l and > 10 microns in length)	7.0 × 106
Arsenic	0.05
Barium	2.0
Beryllium	0.004
Cadmium	0.005
Chromium	0.1
Copper	1.3
Lead	0.015
Mercury	0.002
Selenium	0.05
Silver	0.1
Thallium	0.002
Zinc	5.0
Organic Chemicals (mg/L)	
Pesticides and PCBs	
Alachlor	0.002
Aldicarb	0.003
Aldicarb sulfone	0.002
Aldicarb sulfoxide	0.004
Atrazine	0.003
Carbofuran	0.04
Chlordane	0.002
Dalapon (sodium salt)	0.2
Dibromochloropropane (DBCP)	0.0002
2, 4-D	0.07
Dichlorophenoxyacetic acid (2, 4-) (2,4D)	0.07

Parameter Description	Value
Dinoseb	0.007
Diquat	0.02
Endothall	0.1
Endrin	0.002
Ethylene Dibromide (EDB)	0.00005
Glyphosate	0.7
Heptachlor	0.0004
Heptachlor epoxide	0.0002
Lindane	0.0002
Methoxychlor	0.04
Oxamyl (Vydate)	0.2
Pentachlorophenol	0.001
Picloram	0.5
Polychlorinated Biphenyls	0.0005
Simazine	0.004
Toxaphene	0.003
2, 4, 5-TP (Silvex)	0.05
Volatile Organic Chemicals (mg/L)	
Benzene	0.005
Benzo (a) pyrene (PAH)	0.0002
Carbon tetrachloride	0.005
1, 2 – Dichloroethane	0.005
1, 1 – Dichloroethylene	0.007
1, 1, 1-Trichloroethane	0.200
Dichloromethane	0.005
Di (2-ethylhexyl) adipate	0.4
Di (2-ethylhexyl) phthalate	0.006
Dioxin (2,3,7,8-TCDD)	0.00000003
para – Dichlorobenzene	0.075
o-Dichlorobenzene	0.6
cis-1,2 dichloroethylene	0.07
trans-1,2 dichloroethylene	0.1
1,2 Dichloropropane	0.005
Ethylbenzene	0.7
Hexachlorobenzene	0.001
Hexachlorocyclopentadiene	0.05
Monochlorobenzene	0.1
Styrene	0.1
Tetrachloroethylene	0.005
Toluene	1
Trichlorobenzene (1,2,4-)	0.07
Trichloroethane (1,1,1-)	0.2
Trichloroethane (1,1,2-)	0.005
Trichloroethylene	0.005
Vinyl chloride	0.002

Parameter Description	Value
Xylenes (Total)	10
Other Organic Chemicals	
Five Haloacetic Acids (HAA5) [Monochloroacetic acid; Dichloroacetic acid; Trichloroacetic acid; Bromoacetic acid; Dibromoacetic acid]	0.06
Total Trihalomethanes (TTHM)	0.08
Radionuclides	
Radium-226 + Radium-228	5pCi/l
Gross alpha, including Radium-226 but excluding Radon and Uranium	15pCi/l
Uranium	0.030 mg/l
Beta particle and photon radioactivity	4 millirem/year a

Notes:
a. Except for the radionuclides listed below, the concentration of man-made radionuclides causing four millirem total body or organ dose equivalents shall be calculated on the basis of a two liter per day drinking water intake using the 168 hour data listed in "Maximum Permissible Body Burden and Maximum Permissible Concentration Exposure", NBS Handbook 69 as amended August 1962, U.S. Department of Commerce. If two or more radionuclides are present, the sum of their annual dose equivalent to the total body or to any organ shall not exceed four millirem/year. Average annual concentrations assumed to produce a total body or organ dose of four millirem/year:
Radionuclide Critical Organ Concentration
Tritium Total Body 20,000 pCi/L
Strontium-90 Bone Marrow 8 pCi/L
b. A permit specific ground water quality standard for any pollutant not specified above may be established by the State at a level that will protect public health and the environment. This permit limit may be based on U.S. Environmental Protection Agency maximum contaminant level goals, health advisories, risk based contaminant levels, standards established by other regulatory agencies and other relevant information.

5.13C.4.2 Class II Protection Levels

In addition to the parameters listed in **Tables 5.13C.1** and **5.13C.2**, UAC 317-6 also requires compliance with the following degradation requirements for industrial discharges to groundwater:

- TDS may not exceed 1.25 times background concentrations, or background plus two standard deviations
- When a contaminant is not detectable in background, the affected groundwater may not exceed the greater of 0.25 times the numerical groundwater quality standard value, or the limit of analytical detection
- When a contaminant is detectable in background, the affected groundwater may not exceed the greater of 1.25 times the background concentration, or 0.25 times the numerical groundwater quality standard value, or background plus two standard deviations
- In no case will the concentration of a contaminant in affected groundwater be allowed to exceed the numerical groundwater quality standard.

5.13C.4.3 Class III Protection Levels

In addition to the parameters listed in **Tables 5.13C.1** and **5.13C.2**, UAC 317-6 also requires compliance with the following degradation requirements for industrial discharges to groundwater:

- TDS may not exceed 1.25 times background concentrations, or background plus two standard deviations
- When a contaminant is not detectable in background, the affected groundwater may not exceed the greater of 0.5 times the numerical groundwater quality standard value, or the limit of analytical detection
- When a contaminant is detectable in background, the affected groundwater may not exceed the greater of 1.5 times the background concentration, or 0.5 times the numerical groundwater quality standard value, or background plus two standard deviations
- In no case will the concentration of a contaminant in affected groundwater be allowed to exceed the numerical groundwater quality standard. If the background concentration exceeds the numerical groundwater quality standard, no increase will be allowed.

5.13C.5 AQUIFER CLASSIFICATIONS

Within the LPP project vicinity, one aquifer have been classified, the Navajo/Kayenta Aquifer in the St. George area of Washington County. The portion of the Navajo/Kayenta Aquifer associated with Sand Hollow Reservoir is in the Navajo Sandstone, therefore the aquifer is referred to herein as the Navajo Sandstone Aquifer.

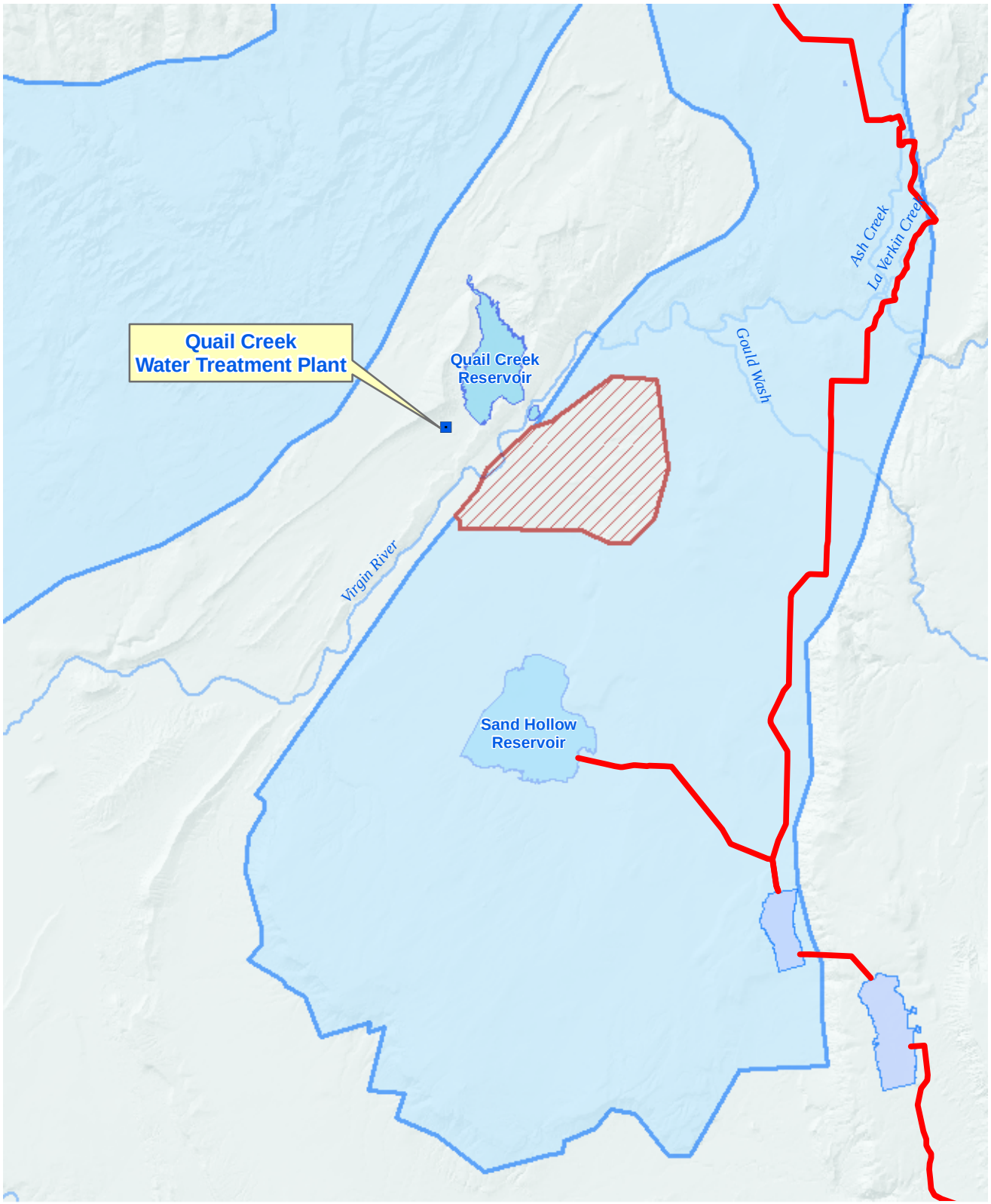
5.13C.5.1 Navajo Sandstone Aquifer

WCWCD applied for aquifer classification in Washington County and a small part of Iron County in 2005 (HAL 2005). The application was approved by Utah DEQ in 2007. Most of the Navajo Sandstone Aquifer in the vicinity of Sand Hollow Reservoir is designated Class IA, with a small area west of Hurricane/north of Sand Hollow Reservoir and a larger area north of St George designated as Class II. The aquifer classification areas designated near Sand Hollow Reservoir are provided in **Figure 5.13C.1**.

5.13C.6 SURFACE WATER QUALITY

5.13C.6.1 Lake Powell

Lake Powell water quality has been monitored at various locations. The U.S. Geological Survey (USGS) water quality sampling location nearest to the LPP intake pump station is at Wahweap Bay, just south of the Utah-Arizona state boundary at 2.4 miles from Glen Canyon Dam and 2.1 miles from the proposed intake site. Sample data used for this evaluation were taken at various depths throughout the water column at approximately monthly or bi-monthly intervals from June 1995 to March 2004 for laboratory analyses. Profile sampling (field parameters, including temperature, pH, electrical conductivity, dissolved oxygen (DO), turbidity, oxygen reduction potential (ORP) and total dissolved solids (TDS) were collected for various depths at approximately monthly intervals from January 2002 to March 2007. Not all samples were analyzed at each sampling event, but enough samples were collected to provide some characterization. The average, minimum, and maximum concentrations determined from sampling at the Wahweap Bay sampling site are presented in Table 5.13C-3. Samples



Legend

- Water Treatment Plants
- Project Alignment
- Hurricane Cliffs Forebay/Afterbay
- Major Rivers & Streams
- Lakes/Reservoirs

Aquifer Class

- Class 1A - Pristine Aquifer
- Class II - Drinking Water Aquifer

0 2,700 5,400 10,800 16,200 21,600 Feet

Lake Powell Pipeline Project

1:130,000 Scale

Spatial Reference: UTM Zone 12N, NAD-83

N

UDWR Figure 5.13C.1 MWH

Sand Hollow Reservoir Area Groundwater Quality Classification

collected from various water depths have been placed into groups (0-5 meter (m), 5-50 m, 50-100 m, >100 m). Concentrations shown in **Table 5.13C.3** are presented in mg/L unless otherwise noted.

5.13C.6.2 Sand Hollow Reservoir

Limited water quality parameters for water in Sand Hollow Reservoir have been collected and analyzed from 10 samples collected by the USGS during the period when the reservoir was being filled from September 2002 to January 2006 (USGS 2005; USGS 2007). The 2006 sample was analyzed for a limited suite of parameters. In general, the water quality is good, with slightly elevated specific conductance (from 710 to 1,000 µS/cm) and pH ranging from 7.6 to 8.8, the highest readings being slightly above standards for drinking water, but generally meeting those standards.

Table 5.13C.3 – Water Quality for Lake Powell at Wahweap Bay Sampling Station, Arizona

Parameter	Depth (m)	Average	Minimum	Maximum	Remarks
Temperature (ºC)	0-5	17.3	8.3	27.4	
	5-50	12.6	7.3	27.0	
	50-100	8.0	6.5	11.0	
	>100	7.7	6.4	8.7	
	Overall	10.7	6.4	27.4	
pH (S.U.)	0-5	8.1	7.5	9.0	a) Single day, 4/7/04; all other sample events >6.9
	5-50	7.7	2.1a	9.1	
	50-100	7.4	2.2a	8.1	
	>100	7.5	6.2	8.0	
	Overall	7.6	2.1a	9.1	
Conductivity (µS)	0-5	786	650	892	
	5-50	806	569	1018	
	50-100	949	716	1074	
	>100	987	880	1084	
	Overall	878	569	1084	
Dissolved Oxygen	0-5	8.1	5.9	10.7	
	5-50	6.5	1.7	12.1	
	50-100	4.3	1.9	8.2	
	>100	4.2	0.5	8.4	
	Overall	5.6	0.5	12.1	
Turbidity (NTU)	0-5	2.3	0b	34.2	b) Turbidity recorded at 0 NTU - uncommon in natural surface waters; presumably <0.1 NTU
	5-50	2.5	0b	16.4	
	50-100	3.7	0b	17.9	
	>100	3.9	0b	20.3	
	Overall	3.1	0	34.2	
TDS (field)	0-5	517	434	612	
	5-50	526	364	652	
	50-100	611	458	717	
	>100	638	563	717	
	Overall	569	364	717	

Parameter	Depth (m)	Average	Minimum	Maximum	Remarks
TSS (lab)	0-5	4.1	4.0	7.8	
	5-50	4.1	4.0	5.8	
	50-100	4.2	3.9	14.2	
	>100	5.9	4.0	15.3	
	Overall	4.3	3.9	15.3	
Ca	0-5	56.8	45.4	69.4	
	5-50	60.7	47.3	79.5	
	50-100	64.3	45.5	82.6	
	>100	74.7	53.3	95.9	
	Overall	64.3	45.4	95.9	
Mg	0-5	20.0	15.8	23.4	
	5-50	20.5	15.0	24.6	
	50-100	21.3	15.8	27.9	
	>100	24.7	17.9	29.5	
	Overall	21.7	15.0	29.5	
Na	0-5	54.4	39.4	69.0	
	5-50	57.2	41.0	76.4	
	50-100	60.2	39.8	85.7	
	>100	74.4	46.3	97.5	
	Overall	61.7	39.4	97.5	
K	0-5	2.6	1.0	7.0	
	5-50	2.5	1.0	4.0	
	50-100	2.3	1.0	4.3	
	>100	2.7	1.0	4.7	
	Overall	2.5	1.0	7.0	
CO3	0-5	0.8	0.0	2.2	
	5-50	0.9	0.0	1.8	
	50-100	0.7	0.0	1.0	
	>100	0.8	0.0	1.0	
	Overall	0.8	0.0	2.2	
HCO3	0-5	152	116	182	
	5-50	160	127	209	
	50-100	163	133	186	
	>100	178	141	214	
	Overall	163	116	214	
Alkalinity	0-5	126	95	164	
	5-50	132	113	171	
	50-100	136	109	184	
	>100	147	115	239	
	Overall	135	95	239	
Cl	0-5	35.0	26.4	51.8	
	5-50	38.1	24.9	59.2	
	50-100	42.6	25.6	74.8	
	>100	58.5	31.8	81.9	
	Overall	43.8	24.9	81.9	

Parameter	Depth (m)	Average	Minimum	Maximum	Remarks
SO4	0-5	176	140	221	
	5-50	184	124	232	
	50-100	190	136	272	
	>100	228	170	292	
	Overall	195	124	292	
SiO2	0-5	7.5	6.2	8.8	
	5-50	7.7	6.4	8.7	
	50-100	8.4	7.0	9.4	
	>100	8.5	7.1	9.9	
	Overall	8.1	6.2	9.9	
Fe	0-5	0.0042	0.004	0.0106	
	5-50	0.004	0.004	0.0042	
	50-100	0.004	0.004	0.0059	
	>100	0.0041	0.004	0.0087	
	Overall	0.0041	0.004	0.0106	
Total P as P	0-5	0.0	0.0	0.1	
	5-50	0.0	0.0	0.1	
	50-100	0.0	0.0	0.1	
	>100	0.0	0.0	0.1	
	Overall	0.0	0.0	0.1	
O-phosphate as P	0-5	0.0	0.0	0.0	
	5-50	0.0	0.0	0.5	
	50-100	0.0	0.0	0.0	
	>100	0.0	0.0	0.1	
	Overall	0.0	0.0	0.5	
NH3 as N	0-5	0.0	0.0	0.2	
	5-50	0.0	0.0	0.1	
	50-100	0.0	0.0	0.3	
	>100	0.0	0.0	0.2	
	Overall	0.0	0.0	0.3	
NO2+NO3 as N	0-5	0.1	0.0	0.4	
	5-50	0.2	0.0	0.4	
	50-100	0.3	0.0	0.5	
	>100	0.4	0.2	0.5	
	Overall	0.3	0.0	0.5	
TKN as N	0-5	0.2	0.1	0.9	
	5-50	0.2	0.1	0.9	
	50-100	0.3	0.1	6.3	
	>100	0.2	0.1	0.6	
	Overall	0.2	0.1	6.3	

Note:
All values in mg/L unless otherwise noted.
Source: Reclamation 2007.

5.13C.7 GROUNDWATER QUALITY

5.13C.7.1 St. George Metropolitan Area

Groundwater quality in the St. George metropolitan area was characterized by the USGS in connection with a hydrogeologic modeling study (USGS 2000). Additional groundwater characterization in the Sand Hollow Reservoir vicinity was performed by the USGS as part of a study evaluating recharge of groundwater from Sand Hollow Reservoir (USGS 2005; USGS 2007). The former study evaluated the three major aquifers in the St. George area, whereas the latter study was limited to the Navajo Aquifer region near Sand Hollow Reservoir in connection with an evaluation of groundwater recharge from the reservoir. This technical memorandum primarily addresses issues affected by the proposed Lake Powell Pipeline project, therefore groundwater quality in the St. George area is considered in the vicinity of Sand Hollow and Quail Creek reservoirs.

5.13C.7.1.1 Groundwater Near Sand Hollow Reservoir

Sand Hollow Reservoir overlies primarily Navajo Sandstone and Quaternary basalt flows on top of the Navajo Sandstone. A thin veneer of sandy eolian soils covers part of the rock outcrop. Prior to construction and filling of Sand Hollow Reservoir, groundwater flowed northward. During the period following the filling of Sand Hollow Reservoir, the groundwater flow direction is still primarily northward, but mounding as a result of recharge has created a local outward flow component in all directions (USGS 2005). Volumetrically, the primary flow remains northward toward the Virgin River and away from the groundwater table mound. The dominant northward flow direction precludes recharge from the Pine Valley Mountains, northwest of the reservoir area, considered the primary source of regional groundwater recharge (USGS 2000), the Hurricane Cliffs to the east, and the Virgin River to the north and west. This suggests that natural recharge in the vicinity of the reservoir occurs largely as a result of local precipitation within Sand Hollow. This is consistent with oxygen isotope analyses on groundwater in the Sand Hollow area, which is more similar to oxygen isotope analytical results for local precipitation than it is to groundwater elsewhere in the region that is recharged at a higher altitude in the Pine Valley Mountains (USGS 2005). This controls the aquatic chemical characteristics of the natural groundwater prior to construction of Sand Hollow Reservoir.

Prior to construction of Sand Hollow Reservoir, groundwater sampling from wells and springs open to the Navajo Aquifer and in the vicinity of the reservoir indicate two general types of water quality. Samples from most locations have generally low (less than 500 mg/L) total dissolved solids (TDS), relatively cool temperature (less than 20ºC), and are classified as a calcium-magnesium-carbonate type. This water quality is generally consistent with water quality elsewhere in the Navajo Aquifer, with slightly lower TDS concentrations probably because of local (Sand Hollow) recharge that would be unaffected by transport over or through other formations (USGS 2000; USGS 2005).

A cluster of samples collected from wells north of the current location of the Sand Hollow Reservoir, south and east of the Virgin River and west of the City of Hurricane, have higher TDS (greater than 500 mg/L); samples from these wells tend to be warmer than at other locations, with some samples measured at greater than 20ºC. The warmer, higher TDS concentration wells are generally of the calcium-sodium-sulfate type and are believed to represent a blending with deeper geothermal

groundwater migrating up into the Navajo Aquifer through faults and fractures associated with the Hurricane Fault Zone a few miles to the west (USGS 2000).

Sampling of monitoring and production wells in the immediate vicinity of Sand Hollow Reservoir was conducted by the USGS as part of a study of the effects of artificial recharge of Virgin River water on the Navajo Aquifer in Sand Hollow. The locations of these wells are shown in **Figure 5.13C.2**. Sampling began at some locations between 1999 and 2001, before construction and filling of the reservoir with Virgin River water. Periodic or one-time sampling of selected wells occurred up through 2006, and reflects the effects, if any, caused by aquifer recharge. Analytical results of this sampling, as well as samples collected from the Virgin River and from Sand Hollow Reservoir, are shown in **Table 5.13C.4**. A complete discussion of this study is provided by Heilweil and others (USGS 2005) and by Heilweil and Susong (USGS 2007).

Table 5.13C.4 – Pre- and Post-Filling Groundwater Quality Conditions at Sand Hollow Reservoir

Map Number	Well Name	Date Sampled	Specific Conductance (µS)	pH (standard units)	Total Dissolved Solids (mg/L)
5	WD 10	10/12/2001 1	375	7.8	202
		09/13/2001	365	7.8	-
		05/07/2003	350	7.8	-
		10/13/2003	350	7.7	-
6	Well 4	08/29/2001	480	8.0	-
		09/11/2002	495	8.1	297
		10/15/2003	475	7.9	-
8	WD 4	04/02/1999	355	8.2	-
		12/18/2002	350	7.7	205
		01/19/2006	345	8.0	-
9	WD 6	05/15/2001	130	7.6	88
		08/28/2001	185	7.7	-
		09/09/2002	290	7.7	167
		12/17/2002	400	7.6	-
		03/19/2003	425	7.5	251
		05/07/2003	450	7.5	276
		06/09/2003	390	7.8	-
		08/04/2003	350	7.5	234
		10/06/2003	400	7.6	239
		01/08/2004	300	7/7	172
		05/03/2004	700	7.4	446
		02/09/2005	445	7.9	269
		04/05/2005	460	7.6	-
		01/19/2006	684	7.6	-
10	Well 8	10/08/2002	550	7.5	323
		10/09/2003	430	7.6	242
		09/21/2004	530	7/7	312

28	North Dam 3A	10/08/2002	4,430	8.0	3,020
		12/18/2002	2,830	8.0	1,890
		03/19/2003	1,200	7.9	750
		06/10/2003	1,330	7.8	842
		08/04/2003	1,130	7.8	677
		10/09/2003	1,230	7.8	723
		01/08/2004	1,220	8.2	779
		05/03/2004	1,300	7.7	828
		09/21/2004	980	7.7	610
		10/29/2004	905	7.9	-
		12/14/2004	960	8.0	-
		02/10/2005	960	7.7	614
		04/05/2005	960	7.8	-
		01/19/2006	835	8.0	-
30	North Dam Drain	09/11/2002	2,090	8.0	1,450
		12/18/2002	1,530	8.1	1,070
		03/19/2003	1,400	8.0	923
		05/08/2003	1,250	8.0	810
		06/10/2003	430	8.1	829
		08/06/2003	920	8.1	659
		01/08/2004	980	8.3	624
		05/03/2004	1,050	7.9	637
32	WD RJ	04/02/1999	560	8.2	-
		12/17/2002	530	7.7	309
		01/18/2006	550	7.7	-
33	WD 5	04/03/1999 1	540	8.3	-
		12/17/2002	530	7.8	311
		01/18/2006	528	7.9	-
34	WD 3	12/19/2000	465	-	-
		01/18/2006	460	7.9	-
36	WD 11	06/14/2001 1	420	7.8	232
		12/16/2002	455	7.6	-
		06/09/2003	650	7.9	386
		08/05/2003	700	7.8	482
		10/07/2003	800	7.8	460
		01/06/2004	770	7.8	450
		05/03/2004	680	7.7	440
		09/20/2004	920	8.2	-
		02/09/2005	960	8.1	667
		01/18/2006	977	7.9	-

37	WD 9	05/23/2001 1	335	7.7	-
		09/14/2001	280	7.4	-
		09/11/2002	335	7.9	189
		05/07/2003	315	7.8	-
		06/09/2003	350	7.7	230
		08/05/2003	720	7.5	344
		10/07/2003	740	7.5	445
		01/06/2004	630	7.7	405
		05/03/2004	545	7.4	240
		09/20/2004	750	7.8	480
		02/09/2005	780	7.6	50.3
		04/09/2005	815	7.7	-
		01/18/2006	1,233	7.9	-
38	Basin 1	07/22/1999 1	-	-	-
		09/10/2001	620	7.6	-
39	Slope 1a	04/28/1999 1	270	8.1	000
		09/12/2001	240	7.9	000
		09/09/2002	270	8.0	150
		03/20/2003	265	7.8	-
43	Hole O	06/11/2001 1	465	7.6	-
		09/11/2001	425	8.0	000
44	WD 8	05/21/2001 1	300	7.7	168
		09/12/2001	305	7.7	-
		09/09/2002	305	7.9	173
		05/08/2003	340	7.5	-
		10/16/2003	355	7.4	-
46	Basin 2	07/21/1999 1	295	8.1	-
		08/27/2001	290	7.8	-
47	WD 13	08/30/2001	275	8.1	000
		10/16/2003	225	8.2	000
50	WD 7	09/10/2001	380	7.8	-
		05/07/2003	390	7.9	-
		10/08/2003	395	7.8	230
VR 2	Virgin River	08/29/2001	850	8.4	-
		10/03/2001	820	8.2	-
		11/27/2001	850	8.1	-

RES 3	Reservoir	09/10/2002	1,000	8.8	669
		03/20/2003	830	8.2	525
		06/10/2003	850	8.2	-
		08/06/2003	920	7.6	568
		10/07/2003	910	8.4	569
		01/08/2004	870	8.4	523
		05/05/2004	710	8.2	442
		09/22/2004	765	8.5	-
		02/10/2005	855	8.4	546
		01/18/2006	815	8.5	-

Notes:
1 Sample collected in open hole prior to well installation.
2 Surface water measured or sampled at Virgin River near Virgin, Utah.
3 Surface water measured or sampled in Sand Hollow Reservoir, Utah.

Nine samples were collected prior to filling the reservoir from shallow wells (250 feet deep or less) in late August or early September 2001, and therefore could be expected to represent similar shallow groundwater conditions. The sampled wells were from locations all around the perimeter of the current reservoir footprint as well as from within its interior. Specific conductance for samples from this sampling event ranged from a low of 185 µS to a high of 620 µS, with only one sample below 240 µS and one sample above 380 µS. The median value was 290 µS. By comparison, specific conductance for the Virgin River during that sampling period was 850 µS, which is generally consistent with sampling analyses collected before and after that date.

Only limited TDS concentration data are available for wells sampled prior to filling Sand Hollow Reservoir, although many wells have TDS data collected during and after filling. Measured TDS concentrations in wells prior to filling the reservoir ranged from 88 mg/L in well #9 to 232 mg/L in well #36. No TDS analyses were conducted for the August-September 2001, pre-reservoir sampling event.

Hem (USGS 1985) has identified a linear relationship between specific conductance and TDS concentration. Although the relationship is not universally applicable, it generally holds true that the ratio of the TDS concentration to specific conductance is typically between 0.55 and 0.75. A comparison of TDS ratios to specific conductance for data collected at various wells in the Sand Hollow area confirms this relationship, with most ratios between about 0.60 and 0.68. Assuming that a ratio of 0.65 is reasonably representative, the median TDS value for shallow groundwater from the August-September 2001 pre-reservoir sampling event can be derived from the median value for specific conductance and is estimated to be approximately 190 mg/L. Using the Virgin River specific conductance of 850 µS for the August-September 2001 sampling event, the estimated TDS concentration for Virgin River water is approximately 550 mg/L. Measurements for both specific conductance and TDS in samples collected from Sand Hollow Reservoir water have generally been consistent with the measured specific conductance and estimated TDS concentration for the Virgin River, as expected since the river water is the source of water in the reservoir.

The USGS study results show that recharge of the Navajo Aquifer from Virgin River water at Sand Hollow Reservoir is affecting some groundwater quality parameters at some locations but seems to have limited effect at other locations. Samples collected closer to the reservoir generally show more influence than samples collected from wells further away, presumably because reservoir water hadn't migrated outward as far as the outer wells at the time of sampling and/or because mingling with natural aquifer water had diluted the effects of reservoir recharge water further from the point of recharge. Both water quality and the lateral range of influence from reservoir water generally have increased over time.

One indication of groundwater quality changes associated with recharge may be observed by looking at trends in the specific conductance of samples collected at selected locations on multiple dates. By looking at changes in specific conductance over time, beginning with samples collected prior to filling of the reservoir (initiated in March 2002), the influence of Virgin River water on Navajo Aquifer groundwater quality can be observed. Most wells closer to the reservoir show a greater change in specific conductance (and presumably also TDS concentration) than wells further away. In most instances where specific conductance has been influenced by recharge, this change is upward. Samples from well #9, for example, located just north of the reservoir, had a measured specific conductance of 185 µS when sampled in August 2001. This increased over time to 684 µS when sampled in January 2006, an increase of over 300 percent. Similarly, groundwater sampled from well #36, just west of the reservoir, showed an increase in specific conductance from 420 µS in June 2001 to 977 µS in January 2006, more than doubling. Other wells further from the reservoir have shown lower increases or no change (USGS 2005; USGS 2007). Specific conductance in some well samples is actually higher than in reservoir water, suggesting that some initial leaching of salts may have occurred from vadose zone soils.

5.13C.7.1.1.1 Groundwater Near Quail Creek Reservoir

Quail Creek Reservoir is constructed in the hogsback depression created by the Virgin River Anticline, immediately north of the Virgin River. The reservoir is underlain by mudstone and evaporite/shale of the Shnabkaib Member of the Moenkopi Formation. It is highly fractured in places because of its association with the Virgin River Anticline, and a high gypsum content causes the rock to be very soluble, especially in fracture zones which contributed to failure of one of the dams in 1989 (UGS 2000). The Shnabkaib Member is normally considered to be of low permeability and therefore not a point of recharge to underlying groundwater, although extensive fracturing and dissolution of gypsum may result in some limited local recharge. Although locally important from a dam safety perspective, overall groundwater movement through the Moenkopi Formation is small, and the recharge contribution from Quail Creek Reservoir is unlikely to be an important factor in groundwater quantity or quality.

5.13C.8 COMPATIBILITY OF LAKE POWELL WATER WITH GROUNDWATER

5.13C.8.1 General Regulatory Issues

The Utah Department of Environmental Quality, Division of Water Quality (DEQ-DWQ), has indicated that recharge of Lake Powell water at Sand Hollow Reservoir would be considered a beneficial use and would be subject to the requirements of "permit by rule" (Utah DEQ-DWQ 2008a). Under a permit by rule as defined by DEQ (Utah DEQ-DWQ 2008b), some degradation of groundwater quality would be allowed as long as the overall impact to the aquifer water quality is "de minimus", being within the numerical groundwater quality standards for the aquifer classification. For example, some increase in TDS concentrations would be allowed in a Class IA aquifer, as long as the overall TDS concentrations of the aquifer remained below 500 mg/L and the other parameter standards were met. For a Class II aquifer, TDS concentration would need to remain below 3,000 mg/L on average. Thus, with the TDS concentration of Lake Powell water at or above 500 mg/L, recharge to a Class IA aquifer might be acceptable if the resulting blended groundwater has a TDS of less than 500 mg/L and other water quality parameters are met. Lake Powell water could readily be recharged to a Class II aquifer, with the resulting groundwater quality possibly improving over current conditions.

Aesthetically, the effect of replacing drinking water with TDS concentrations below 300 mg/L with a blend of groundwater and Lake Powell water with a higher TDS may be noticeable to water users, but would be less noticeable than if 100 percent Lake Powell water is used. Conversely, some reduction of TDS associated with recharge of Lake Powell water to a location with higher TDS concentrations in groundwater may also have an aesthetically noticeable effect which may, or may not, be considered an improvement by local water consumers. If recharged in an area with high TDS, the resulting blend of existing lower-quality groundwater and Lake Powell water may be aesthetically unacceptable for development as potable water. The extent of the aesthetic effects would depend on how much mixing of natural groundwater and Lake Powell recharge water occurs before extraction. This would be determined, in a large measure, by the distance between the point(s) of recharge (the recharge basin or basins, or possibly injection wells) and points of extraction (production wells). The further the distance between the points of injection and the points of extraction, the more mixing would occur and the less noticeable the aesthetic effect would be. This must be balanced against the hydraulic head benefit of recharge, since the closer the wells are to the points of recharge, the greater the increase in water table elevation.

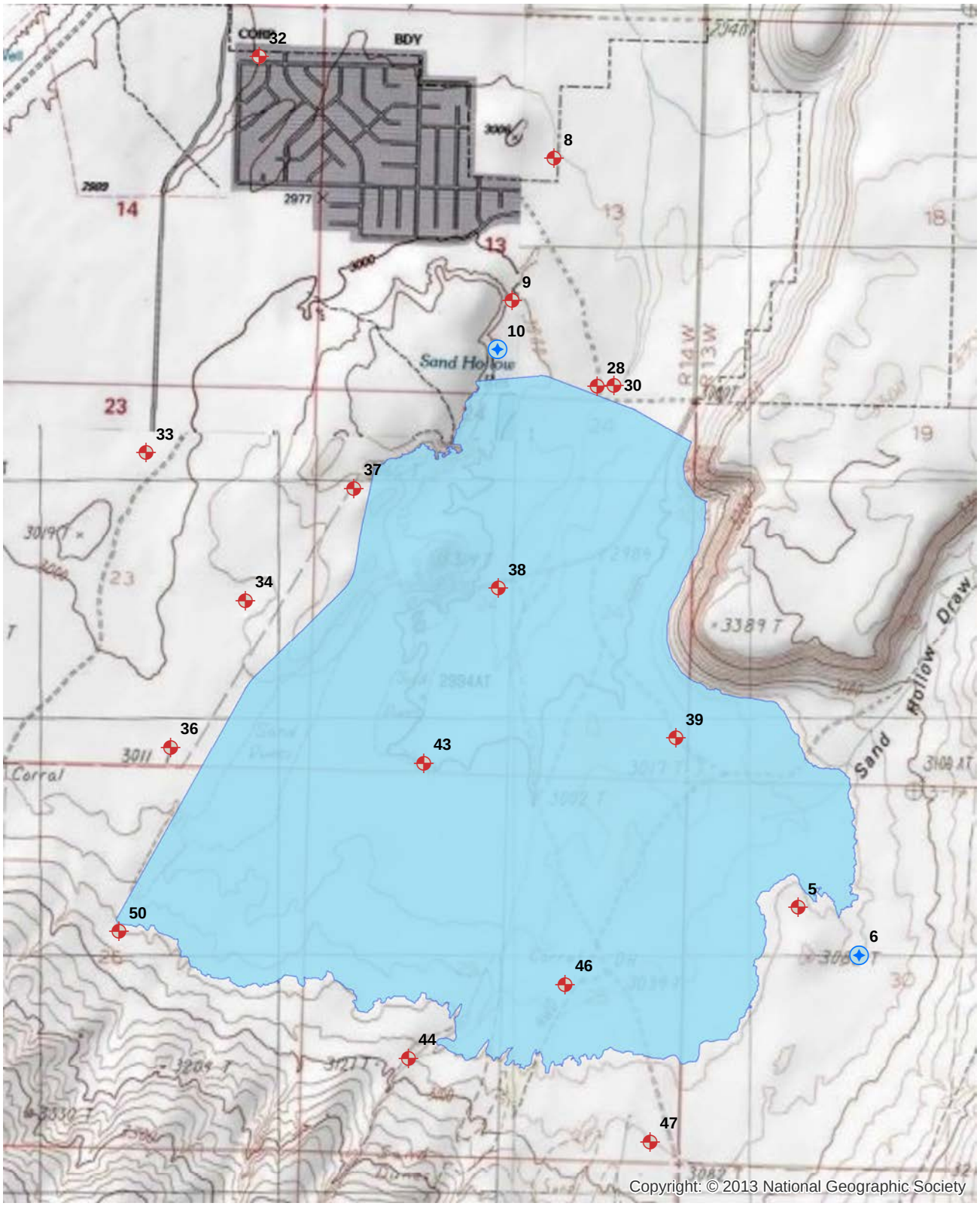
5.13C.8.2 Navajo Sandstone Aquifer

Recharge of water from Lake Powell to the Navajo Sandstone Aquifer underlying the Sand Hollow area would result in a blend of water types that would affect the existing groundwater quality. The effects may be similar to what is currently occurring as a result of recharging Virgin River water because water quality in the Virgin River is reasonably similar to Lake Powell water quality, although TDS concentrations in Lake Powell may be marginally higher. In general, groundwater quality would tend to become more like the recharge source water. The current water quality in the Navajo Sandstone Aquifer near Sand Hollow Reservoir is in transition, as the blended waters tend toward an eventual equilibrium, although changes in the rate of recharge are anticipated as well as rates of groundwater pumping; as a result, water quality concentrations of TDS, pH, hardness, and other parameters may

tend to shift upward or downward over time within a range of upper and lower concentrations depending on recharge and well pumping rates. Ultimately, groundwater constituent concentrations would tend to be higher for most parameters than currently occurs, with groundwater nearest the reservoir exhibiting the highest constituent concentrations and groundwater furthest away from the reservoir exhibiting the lowest constituent concentrations. Further away from the reservoir, the effects of recharge on groundwater quality may be negligible as the water quality of current recharge sources (primarily direct precipitation) are greater than the effects of recharge from the bed of Sand Hollow Reservoir.

Blending of Lake Powell water with existing groundwater may affect the equilibrium between solution and dissolution of minerals in groundwater and the aquifer matrix (soil or porous bedrock). A disruption of equilibrium may result in precipitation of some minerals in the aquifer, or it may cause some minerals to dissolve. Precipitation of minerals would have two effects: 1) it would reduce the concentrations of the precipitating minerals in the resulting groundwater quality; and 2) it would reduce the aquifer permeability by filling porous voids with the precipitated minerals. Dissolution of minerals would increase the concentrations of the dissolved minerals in the resulting groundwater quality and may increase aquifer permeability, although this latter change may be temporary as the overlying materials settle into the resulting void spaces. In extreme situations, dissolution of minerals could result in surface subsidence, although such conditions would be rare.

Preliminary modeling of the potential for precipitation or dissolution of minerals was performed by MWH for blending of Lake Powell water with groundwater in the Navajo Sandstone Aquifer using the USGS PHREEQC modeling program (USGS 1999). Average concentrations of water from sampling at Wahweap Bay in Lake Powell at a depth of 50 to 100 meters were used for this modeling, because this depth likely would correspond to the depths of pump station intakes on Lake Powell. It is important to note that other water quality data have been used for evaluating Lake Powell water in addition the data presented herein; the Wahweap Bay data were selected for PHREEQC modeling because of the depth-differential results available. A simulated blending of this water with water from Well WD-RJ (No. 32 on **Figure 5.13C.2**), near Sand Hollow Reservoir and within the anticipated lateral range of influence, was performed to predict the likelihood of precipitation or dissolution of minerals. Blending was modeled at ratios of groundwater to Lake Powell water of 90 percent to 10 percent, 50 percent to 50 percent, and 10 percent to 90 percent, respectively. The resulting minerals projected by the blending would be expected to precipitate if the change in saturation index from existing groundwater conditions projected by the model for each associated mineral is positive, and conversely, the minerals would be expected to dissolve if the change in projected saturation index from existing groundwater conditions is negative. Large saturation index values, either negative or positive, are more likely to result in dissolution or precipitation than smaller values. Note that the probability of either dissolution or precipitation and the resulting impacts on aquifer permeability and water quality depend on many factors, including the concentrations of the parameters involved in the reactions, the presence or absence of associated minerals in the aquifer matrix, variations in rates of recharge, and other factors. Thus, a high saturation index, either positive or negative, does not mean that the associated reaction would occur, rather that the potential for the reaction exists.



Legend

- Ground-water monitoring well
- Production Well
- Lakes/Reservoirs

0 500 1,000 2,000 3,000 Feet

Lake Powell Pipeline Project

1:24,000 Scale

Spatial Reference: UTM Zone 12N, NAD-83

N

UDWR Figure 5.13C.2 MWH

Groundwater Sampling Wells - Sand Hollow Reservoir Vicinity

Overall, this modeling suggests that there is a low potential for precipitation of most minerals in the Navajo Sandstone Aquifer as a result of blending with Lake Powell water. Precipitation of some iron oxide minerals could occur, but because the concentration of iron in Lake Powell and Navajo Sandstone Aquifer waters is relatively low, this is not likely to be of concern. The potential for mineral dissolution exists, with high negative saturation indices for gypsiferous minerals. Gypsum is not present in the Navajo Sandstone Aquifer in significant quantities, therefore the likelihood of dissolution of gypsum minerals is low on the basis of these modeling results. Additional modeling is recommended for a more comprehensive evaluation of the potential for precipitation and/or dissolution.

5.13C.8.3 Additional Evaluation Needs

Studies of the long-term recharge potential from Sand Hollow Reservoir to the underlying shallow aquifer will be required. Existing studies (USGS 2005; USGS 2007) may serve as a foundation for future evaluations. Future studies should more thoroughly investigate the potential for precipitation of minerals in groundwater as a result of mixing Lake Powell water with Navajo aquifer groundwater. Impacts on groundwater quality from Lake Powell water also should be investigated. Possible changes in the rate of groundwater discharge to the Virgin River as a result of long-term groundwater recharge at Sand Hollow Reservoir also should be considered.

5.13C.9 CASE STUDY: TUCSON, ARIZONA, CENTRAL ARIZONA PROJECT

The City of Tucson, Arizona may be used as a case study for providing some indication of the potential problems that may result from incompatibility of imported Colorado River water with existing natural groundwater supplies. This case study is presented not because the problems that occurred with the Tucson project are expected to occur in southwest Utah, but rather as an indication of how problems may be prevented with proper planning and attention to details.

Colorado River water was delivered into the Tucson area as part of the Central Arizona Project (CAP). Water was conveyed to a newly constructed water treatment plant and treated to meet drinking water standards, but little regard was given to the existing water quality that had been in use for many years. The direct, un-recharged, introduction of treated CAP water into the Tucson water distribution system in 1992, resulted in “discolored, smelly, foul-tasting,” or rusty water. The main cause attributed to this problem was the release of corrosion by-products which had accumulated on the interiors of miles of un-lined metallic pipelines installed earlier in the century.

The difference in pH between CAP water (7.6) and previously used ground water (7.9) as well as other water quality parameters such as dissolved oxygen (DO) and TDS/hardness were contributing factors to the release of the corrosion by-products from the pipe interiors. The CAP water reacted with both potable distribution system mains and with customer plumbing. The CAP water’s higher mineral content was not believed to be a primary factor in the problems that developed. Other possible causes of problems included the sudden introduction of CAP water without gradual blending, reversals in flow direction in the distribution system, increases in flow velocities, and changes in water pressure. The changes resulted in release of corrosion by-products and in some instances, pipe failure from excessive pitting. Subsequent complaints about the water quality resulted in discontinued use of the

direct distribution of CAP water to residents (City of Tucson 2008). Numerous lawsuits were served on the City by various customers and interest groups.

In 2001, the CAP allocation was re-directed into a remediation program designated "Clearwater." Clearwater uses a surface basin recharge program located west of Tucson. Groundwater is pumped as before but with the benefit of the CAP recharge. The water treatment plant originally constructed to treat CAP water was largely rendered dormant, with some limited use for pH control and for chlorination disinfection of pumped blended groundwater from new extraction wells constructed near the water treatment plant (City of Tucson 2008).

During the period following implementation of the Clearwater program, blending of CAP water and existing groundwater has not been found to cause any of the water quality issues that occurred during the initial 1992-94 incident. A survey of Tucson potable water users found that the blended water is considered by many to taste better than unblended water previously provided. However, TDS from the CAP-recharged water is causing a gradual increase in TDS concentrations in extracted groundwater, and there is some concern that increased TDS will become an issue if the increased TDS from CAP recharge is not addressed. The average TDS concentration increased by more than 100 mg/L resulting from introduction of CAP recharge in 2002 through 2006. Hardness and sodium concentrations also have increased. No elevated levels of disinfection byproduct (DBP) levels have been recorded during the 1992-94 CAP implementation or in the new blended water (City of Tucson 2008). It is believed that disinfection by-product (DBP) precursors in CAP water are being removed in the aquifer.

Currently, recharged CAP water comprises about 50 percent of the potable water supply in Tucson. TDS concentrations range from about 280 mg/L or to above 400 mg/L in some wells and are continuing to increase (City of Tucson 2008). The recharge system is considered to be a success because the infiltration and blending of CAP water with groundwater reduces the TDS and other components of CAP water and also removes organic compounds, therefore DPBs have not been problematic. Future treatment such as demineralization may be necessary to prevent TDS concentrations from rising above acceptable levels. This may include construction of a centralized reverse-osmosis treatment facility, although the eventual approach to this problem has not yet been determined.

5.13C.9 SUMMARY

Aquifer recharge using Lake Powell water appears to be technically feasible for groundwater at Sand Hollow Reservoir. Current proposals for recharge include infiltration from the existing Sand Hollow Reservoir. Recharge in the KCWCD service area is anticipated to be only incidental from the surface water impoundment currently under construction, therefore aquifer recharge at this location is not considered in this memorandum.

It is anticipated that recharge of Lake Powell water will result in increased TDS concentrations and possibly other constituents, but that the requirements of the Utah Department of Environmental Quality can probably be met under the terms of a Permit by Rule if numerical groundwater standards for the designated aquifer classes can be achieved. Concerns about aesthetic effects of potential increases in TDS concentrations and those of other constituents should be considered in final selection

of the recharge processes and locations. Considerations pertaining to determining final recharge locations should consider the permeability of underlying materials as well as the proximity to production wells, balancing the hydraulic head benefits of locating recharge facilities near wells and the aesthetic benefits of locating recharge facilities further from wells, allowing greater blending with existing groundwater.

Additional evaluation of the potential changes of Lake Powell water recharge on groundwater quality is recommended. These evaluations should consider a range of water quality parameters, including TDS, hardness, disinfection byproducts, and other constituents. Additional studies are recommended to identify the best locations and means of aquifer recharge, and to verify that the plugging potential via mineral precipitation is minimal.

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_____ 2007c. Utah Department of Environmental Quality, Division of Water Quality, Utah Ground Water Quality Protection Program, Aquifer Classification Maps for Utah's Groundwater. http://www.waterquality.utah.gov/GroundWater/aquifermap.htm.

_____ 2008a. R. Herbert, Utah Department of Environmental Quality, Division of Ground Water Quality, Ground Water Quality Protection Program Chief, personal telephone communication, January 9, 2008.

_____ 2008b. Utah Ground Water Facilities Permitted by Rule. http://www.waterquality.utah.gov.GroundWater/gwPBRfacilties.htm.

APPENDIX B
WELL LOGS REVIEWED TO ESTIMATE DEPTHS TO GROUNDWATER

UTAH WELLS							
Well ID Number	Township	Range	Section	Water Level (ft below surface)	Borehole Depth (ft)	Open Intervals Depth (ft)	Notes
A44491	43S	3E	32	278	875	NA	First water 635-645 ft
A17209	43S	2E	10	273	450	330-450	First water 280 ft
A28959	43S	2E	11	210	610	320	First water 320 ft
A73567	43S	2E	13	201	625	315-625	First water 294 ft
A30515	43S	2E	13	322	605	NA	First water 412 ft
A30515	43S	2E	13	230	661	NA	First water 356 ft
A31224	42S	2E	14	247	537	NA	First water 243 ft
A21880	43S	1E	1	460	520	NA	First water 470 ft
A13091	43S	1E	2	470	778	NA	First water 495 ft
A13092	43S	1E	2	485	782	NA	First water 485 ft
A14116	43S	1E	2	490	620	NA	First water 490 ft
NA	43S	1W	3	148	302	275-300	First water 180 ft
A44751	43S	1W	3	312	645	610-525	First water 270 ft
A36382	43S	1W	4	300	695	NA	Water level before casing 112 ft
A24022	42S	2W	2	DRY	500	NA	Dry hole
A69823	42S	2W	2	DRY	500	NA	Dry hole
A28444	42S	2W	2	DRY	500	NA	Dry hole
A39863	43S	3W	3	60	404	NA	First water 60 ft
A18984	43S	4W	29	85	140	NA	First water 90 ft
A27205	43S	4W	30	35.5	140	93-98	First water 85 ft
A18080	43S	4W	32	DRY	381	NA	Dry hole
A18567	43S	4W	32	65	140	80-140	First water 45 ft
A23579	43S	4W	32	DRY	400	NA	Dry hole
A10923	43S	11W	28	50	150	NA	First water 90 ft
A38025	43S	11W	28	53	105	77-87	First water 45 ft
A58606	43S	11W	28	42	120	48-105	First water 45 ft
A10923	43S	11W	31	47	95	NA	First water 50 ft
A38025	43S	11W	32	DRY	110	NA	Dry hole
A18148	43S	11W	33	54	120	61-65	
NA	43S	11W	33	85	170	36-170	First water 85 ft
NA	43S	11W	33	54	150	80-97	First water 45 ft
A33363	43S	11W	34	65	80	70-75	First water 65 ft
A32848	43S	11W	36	51	100	NA	
A50221	43S	12W	34	26	80	NA	First water >55 ft
A27850	43S	13W	5	500	530	NA	First water 503 ft
A32318	42S	13W	5	18	54	NA	
A13293	42S	13W	18	66	258	NA	First water 66 ft
A13843	42S	13W	18	60	194	NA	First water 66 ft
A24194	42S	13W	18	65	1005	120-340 &&	First water 65 ft; multiple open intervals deeper
A25994	42S	13W	19	214	965	135-295 &&	First water >223 ft; multiple open intervals deeper
A8103	42S	13W	20	337	410	NA	
01-81-004-M-05	42S	13W	30	117	134	117-122	Monitoring well
A16498	42S	13W	30	155	450	52-450	
A12214	42S	13W	30	112	600	NA	First water 150 ft
A12892	42S	13W	12	35	165	16-165	First water 45 ft

APPENDIX C
BMPs for Groundwater Resource Protection

All pipelines, penstocks, and associated features would be constructed in accordance with Best Management Practices (BMPs) to avoid any negative impacts on the surrounding areas. It is assumed that site specific BMPs for activities like mobilization, clearing and grubbing, earthwork, stockpile management, landscaping, erosion control, drainage work, temporary stream crossing construction, road construction, dewatering and trenching operations will be implemented during construction. Typical BMPs implemented include, but are not limited to, filter fences, straw bales, interceptor dikes, swales, sediment traps, detention basins, mulching, seeding and/or re-vegetation as applicable. In addition, erosion and sediment control BMPs may be used to prevent sediment and contaminants from entering groundwater. Some BMPs that may be implemented at several locations along the LPP containing high groundwater and at stream channel crossings are described below in Table C-1.

Note that these BMPs are intended only to serve as a general guideline for avoiding groundwater contamination, waste and depletion and may not be applicable to every construction scenario. The onsite engineer and/or appropriate regulators should determine the appropriateness of an individual BMP to the construction site.

TABLE C-1
CONSTRUCTION SITE BMPS

	BMP	Description
1	Planning	Involves preparation of site specific groundwater BMPs and implementation of a Spill Prevention, Control and Countermeasures Plan (SPCC) to minimize the potential for groundwater contamination due to uncontrolled or unmitigated releases of hazardous materials.
2	Site stabilization and erosion control	Involves hydroseeding, mulching, soil stabilizers (binders), silt fences, geotextiles, and erosion control blankets to protect against erosion and excessive surface water runoff.
3	Dewatering	If dewatering is necessary, water must be pumped to an acceptable, properly designed dewatering basin. The stored water can be used for onsite construction activities, discharged into evaporation/infiltration basins or land applied in adjacent farmland with prior permission. Pumping will be limited to the flowrate necessary to achieve dewatering for safe and stable trench construction activities and will occur no longer than necessary to complete construction within the open trench interval.
4	Pollutant removal and peak runoff control	Requires that all sediment from the dewatered groundwater be controlled and managed by using earth dikes, drainage swales, ditches, velocity dissipation devices, slope drains and/or similar methods.
5	Streambank stabilization and antidegradation	Locations with severe channel instability problems should be avoided. Stabilization and erosion control measures shall be implemented to prevent any increase in sedimentation, siltation and turbidity to the stream as a result of construction activity. Runoff and contaminants