Lake Powell Pipeline Project

Final Study Report 18
Surface Water Resources

April 2016

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Surface Water Resources Study Report
Executive Summary

ES.1 Introduction

This study report describes the results and findings of an analysis to evaluate surface water resource 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 Surface Water Resources Study Plan prepared for the Federal Energy Regulatory Commission (Commission), was to identify potential surface water resource impacts from construction, maintenance, and operation of the alternatives, and identify and document measures to mitigate potential impacts as necessary.

ES.2 Methodology

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

ES.3 Key Results of the Surface Water Resources Impact Analyses

Reclamation's Colorado River System Simulation (CRSS) model results showed small differences in Lake Powell storage and releases to the Colorado River when the South Alternative (Proposed Action) was compared to the No Action for the Hydrologic Modeling Analysis. Table ES-1 shows the simulated differences of Lake Powell releases and water storage in Lake Powell for the 86K depletions and both inflow hydrology scenarios. Differences in releases are minor for all of the cases evaluated. The minor differences in releases would have a negligible impact on stage in the lower Colorado River. The relatively minor impacts on Lake Powell storage are unlikely to affect Reclamation's ability to make planned high flow releases from Lake Powell for downstream habitat and geomorphology purposes.

The Virgin River Daily Simulation Model (VRDSM) is a FORTRAN-based yield model used to evaluate potential changes in operations on the Virgin River in southwest Utah. Two simulations were performed with the model. Scenario 1 simulated the Base Case with full utilization of Virgin River water rights, without any additional storage or Lake Powell Pipeline deliveries. Scenario 2 represents the South Alternative (Proposed Action) and simulates future conditions with the expanded secondary system utilizing 3,000 acre feet of re-regulating storage and 82,249 acre feet of annual Lake Powell Pipeline deliveries to Washington County Water Conservancy District (WCWCD). The model simulates the maximum yield in the St. George area with a specified maximum shortage in the worst year (10 percent in the LPP Project simulations), while providing firm secondary water supplies to Hurricane and the Washington Fields areas. Model results show similar Virgin River streamflows between the two scenarios for simulated gages. Table ES-2 shows average annual values and
Figure **ES-1** shows simulated average monthly flows at the Utah-Arizona state line. Flow duration curves are shown in Figure ES-2 and
Figure **ES-3** for the Virgin River below Washington Fields and the Virgin River at the Utah-Arizona State line, respectively. Flow duration curves for the other simulated model nodes show very little difference between scenarios.

Table ES-1
86K AF Simulations, Summary of Lake Powell Simulation Average of Annual Differences

	Absolute Difference			Percent Difference		
Percentile	**10th**	**50th**	**90th**	**10th**	**50th**	**90th**
DNF Release Difference (AFY)	0	0	-69,202	0%	0%	-1%
CC Release Difference (AFY)	-80,846	-383	-61,593	-1%	0%	-1%
DNF Storage Difference (AF)	-300,640	-170,789	-24,145	-3%	-1%	0%
CC Storage Difference (AF)	-21,915	-195,564	-45,068	-2%	-2%	0%

Notes: AF = acre-foot; AFY = acre-foot per year
Data based on CRSS results
Difference = South Alternative (Proposed Action) – No Action
Percent Difference = Difference/No Action
DNF = Direct Natural Flow
CC = Climate Change

Table ES-2
Average Simulated Virgin River Flows

	Virgin River below Quail Creek		Virgin River below Washington Fields Diversion		Virgin River at UT-AZ State Line	
	Scenario 1	Scenario 2	Scenario 1	Scenario 2	Scenario 1	Scenario 2
Annual Average (cfs)	144	140	58	55	129	132
Average Annual (AFY)	104,351	101,442	42,205	39,482	92,977	95,234

Notes: cfs = cubic foot per second; AF = acre-foot; AFY = acre-foot per year
Scenario 1: Full utilization of Virgin River water rights without LPP deliveries to St. George area
Scenario 2: Future conditions with LPP Project deliveries (82,249 AFY) and 3,000 AF re-regulating storage of secondary water

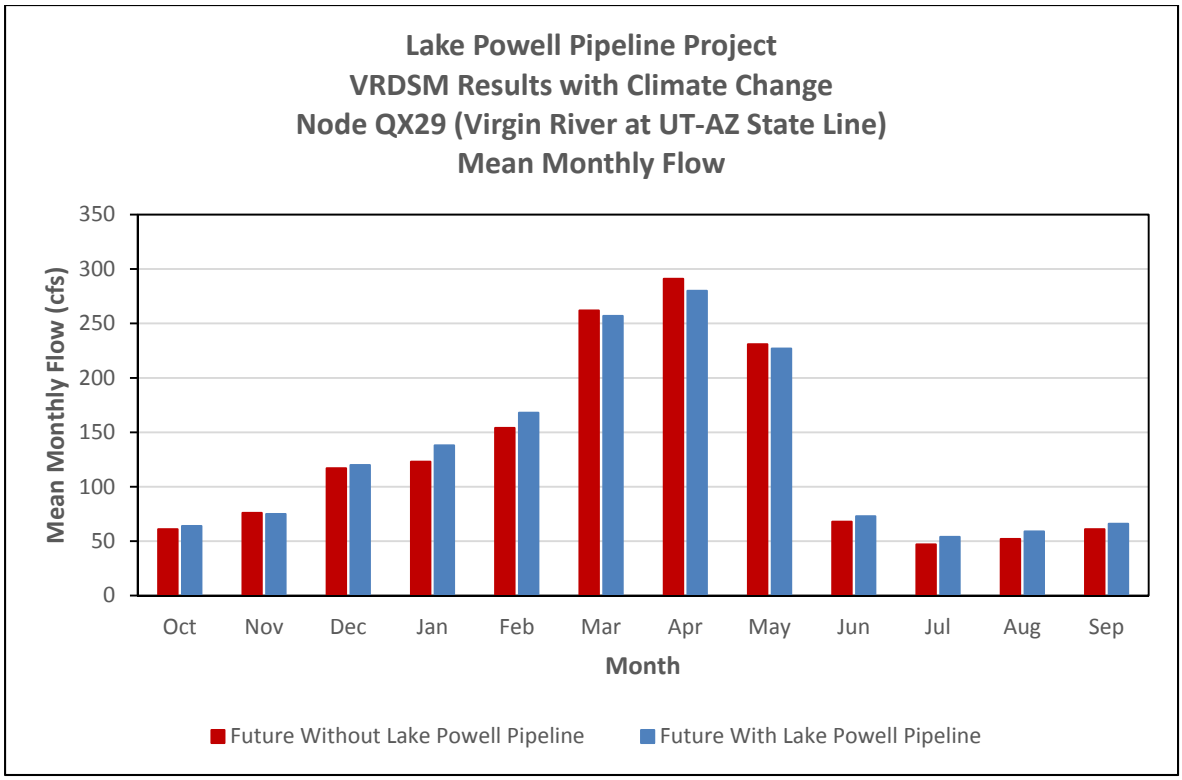


Figure ES-1
Virgin River at UT-AZ State Line – Simulated Monthly Flows

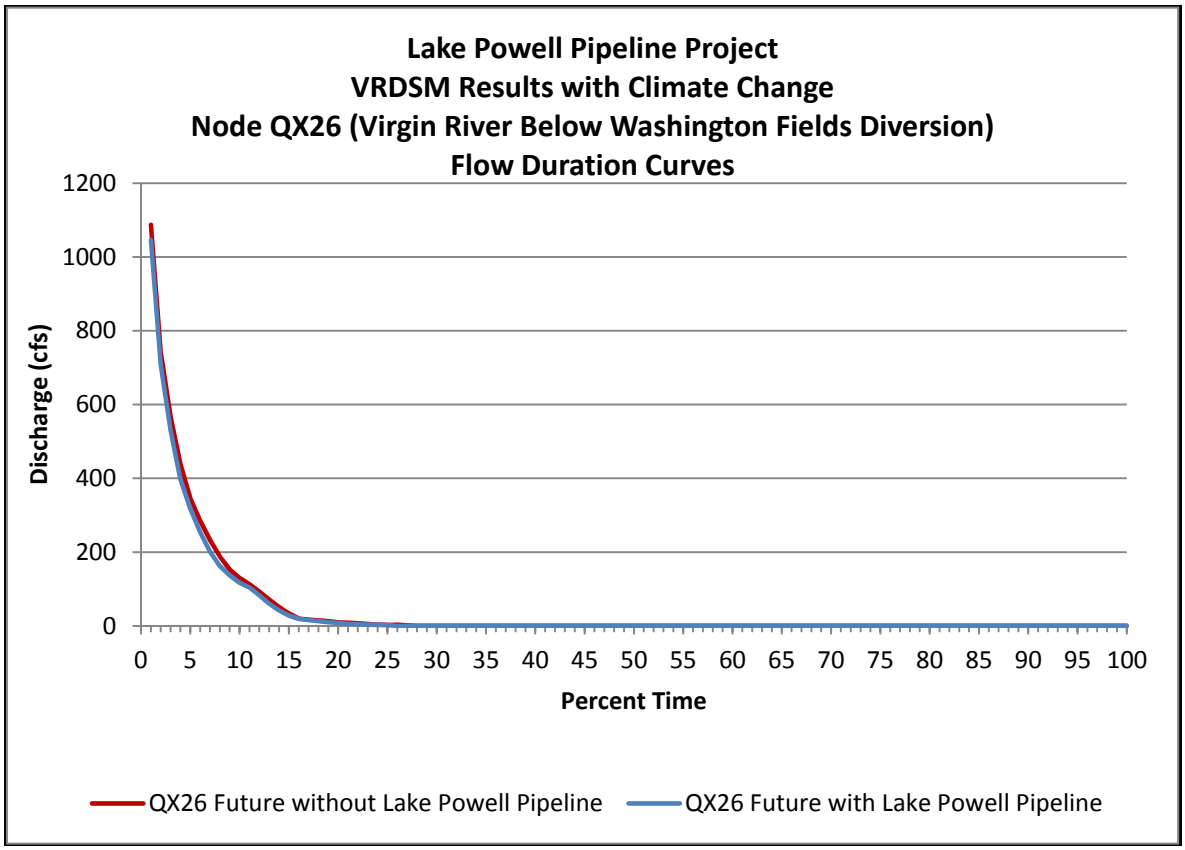


Figure ES-2
Simulated Flow Duration Curves for Virgin River Below Washington Fields Diversion

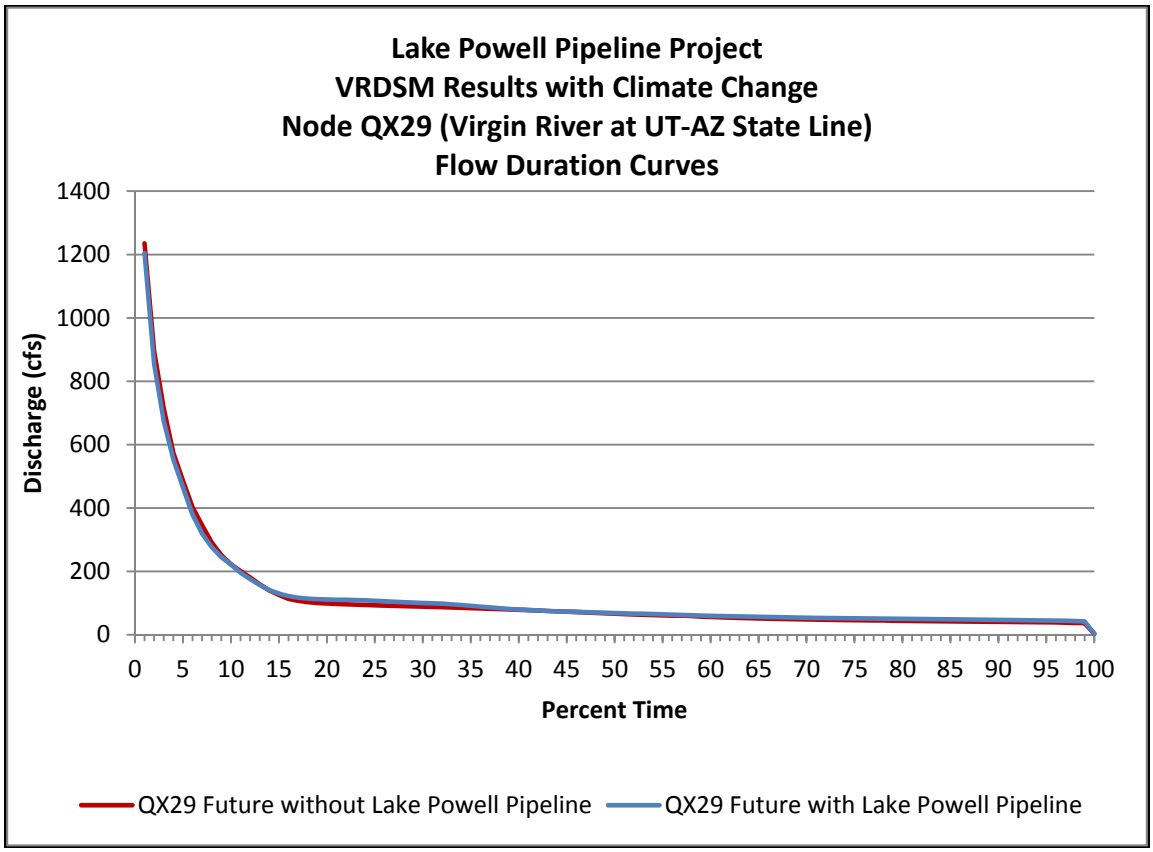


Figure ES-3
Simulated Flow Duration Curves for Virgin River at UT-AZ State Line

The LPP Project does not include the construction of any on-channel reservoirs. The pipeline and penstock would be buried below all stream channel crossing inverts. The impacts on peak flows of streams and rivers would be negligible. Erosion and stream movement in southwest Utah are primarily attributed to peak flow events, and the LPP Project would not have ongoing impacts on geomorphology.

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.

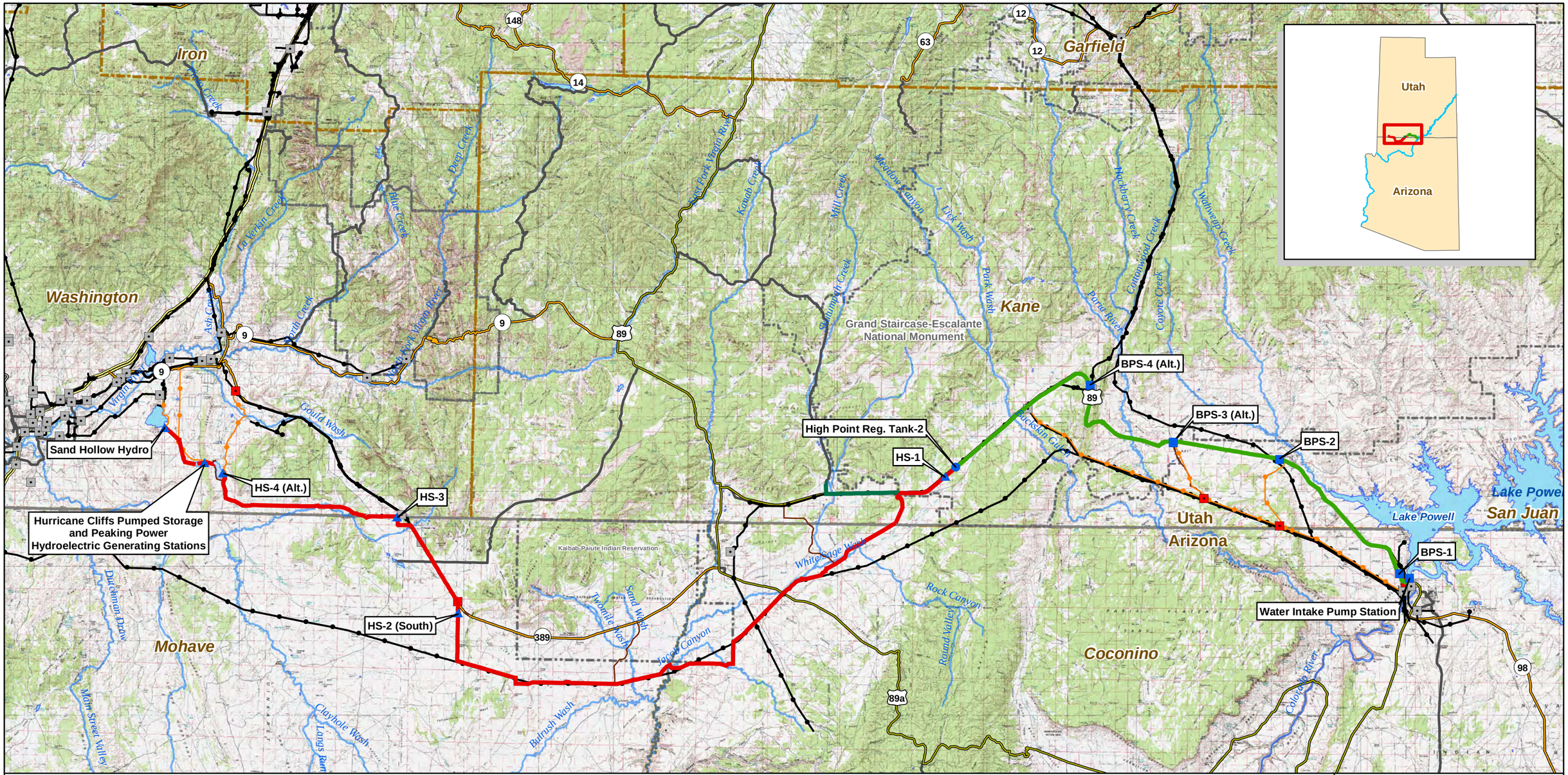
1.2 Summary Description of LPP Project Alignment Alternatives

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).


Iron
Garfield
Washington
Kane
Mohave
Coconino
Utah
Arizona
Grand Staircase-Escalante
National Monument
Kaibab-Paiute Indian Reservation
Lake Powell
San Juan
Sand Hollow Hydro
Hurricane Cliffs Pumped Storage
and Peaking Power
Hydroelectric Generating Stations
HS-1
HS-2 (South)
HS-3
HS-4 (Alt.)
High Point Reg. Tank-2
BPS-1
BPS-2
BPS-3 (Alt.)
BPS-4 (Alt.)
Water Intake Pump Station
Project Pump Station
Project Regulating Tank
Project Hydro Station
Substation
Proposed Substation
Water Conveyance System
Hydro System - South Alternative
(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
GSENM-Boundary
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.

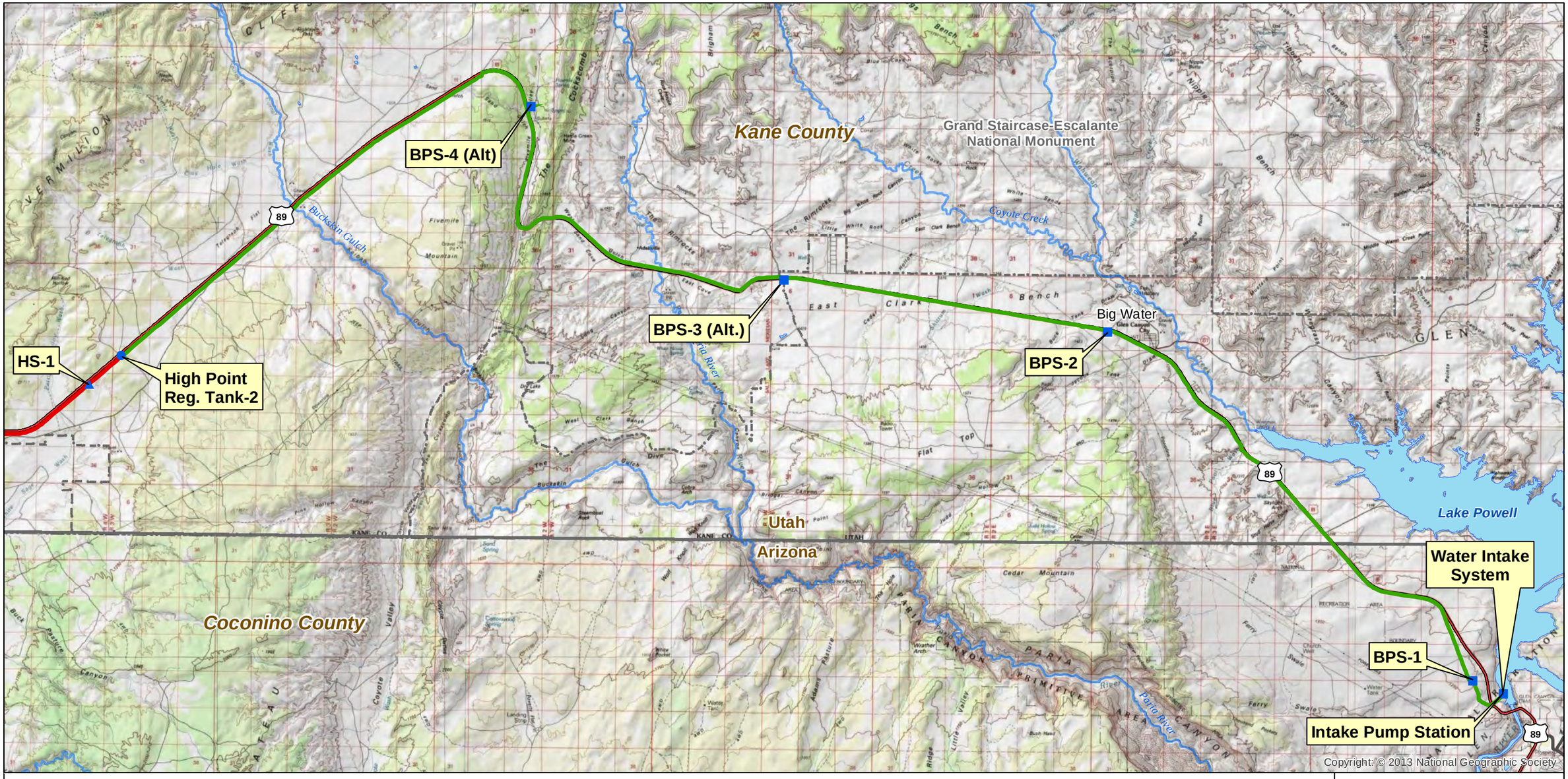
Four booster pump stations (BPS) along the pipeline would pump water to the high point regulating tank. Each BPS would house vertical turbine pumps with electric motors, electrical controls, and other equipment. Additionally, each BPS site would have a buried forebay tank, buried surge tanks, pig retrieval 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 - South Alternative (Penstock Segment)
- KCWCD System
- Interstate
- US Highway
- ST Highway
- Hwy
- Major Road
- Lakes & Reservoirs
- Major Rivers & Streams
- National Park/Monument
- GSENM Boundary
- State Boundaries

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

0 0.5 1 2 3 4 Miles

N

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.

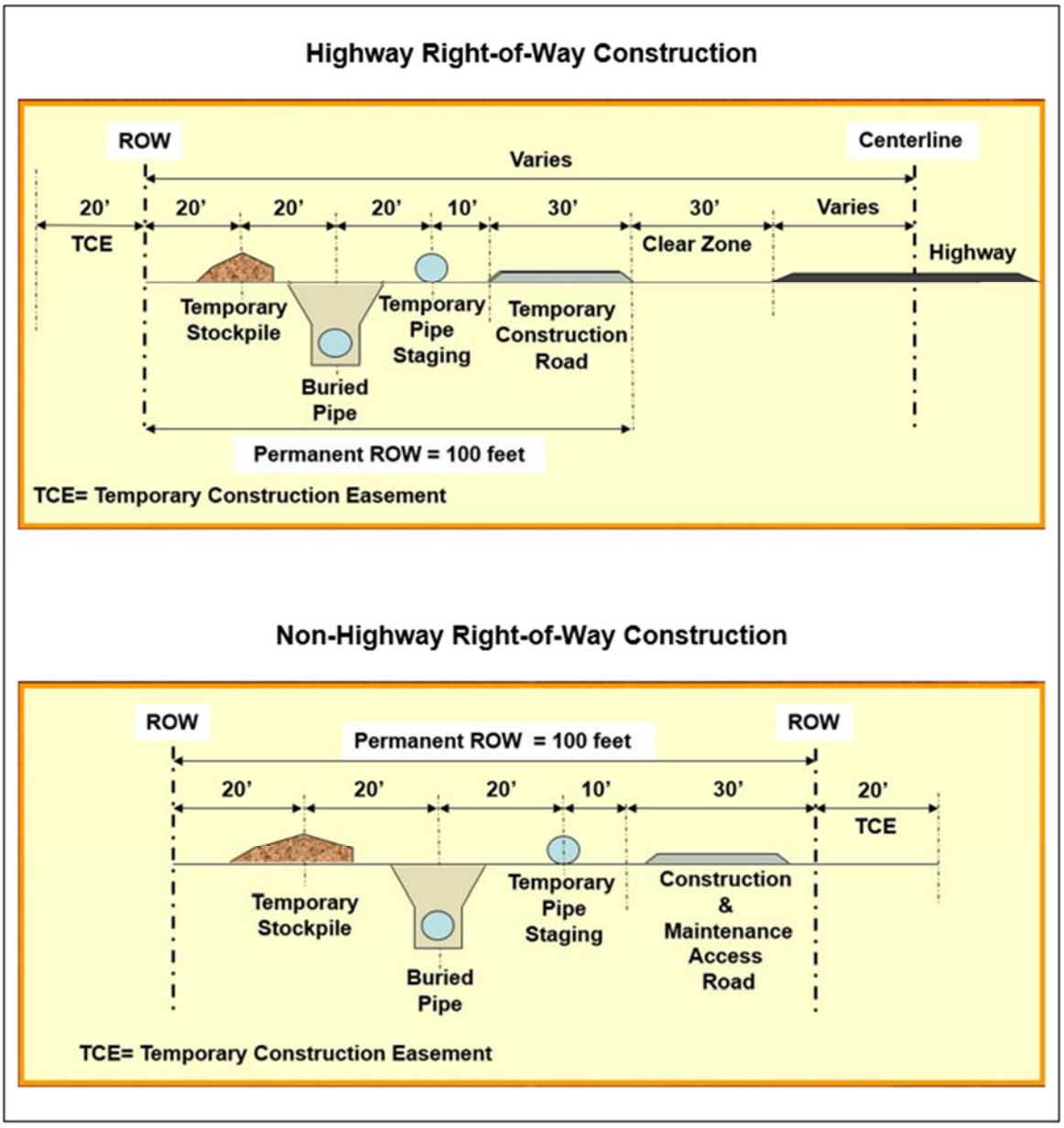


Figure 1-3
Pipeline and Penstock Right-of-Way

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.

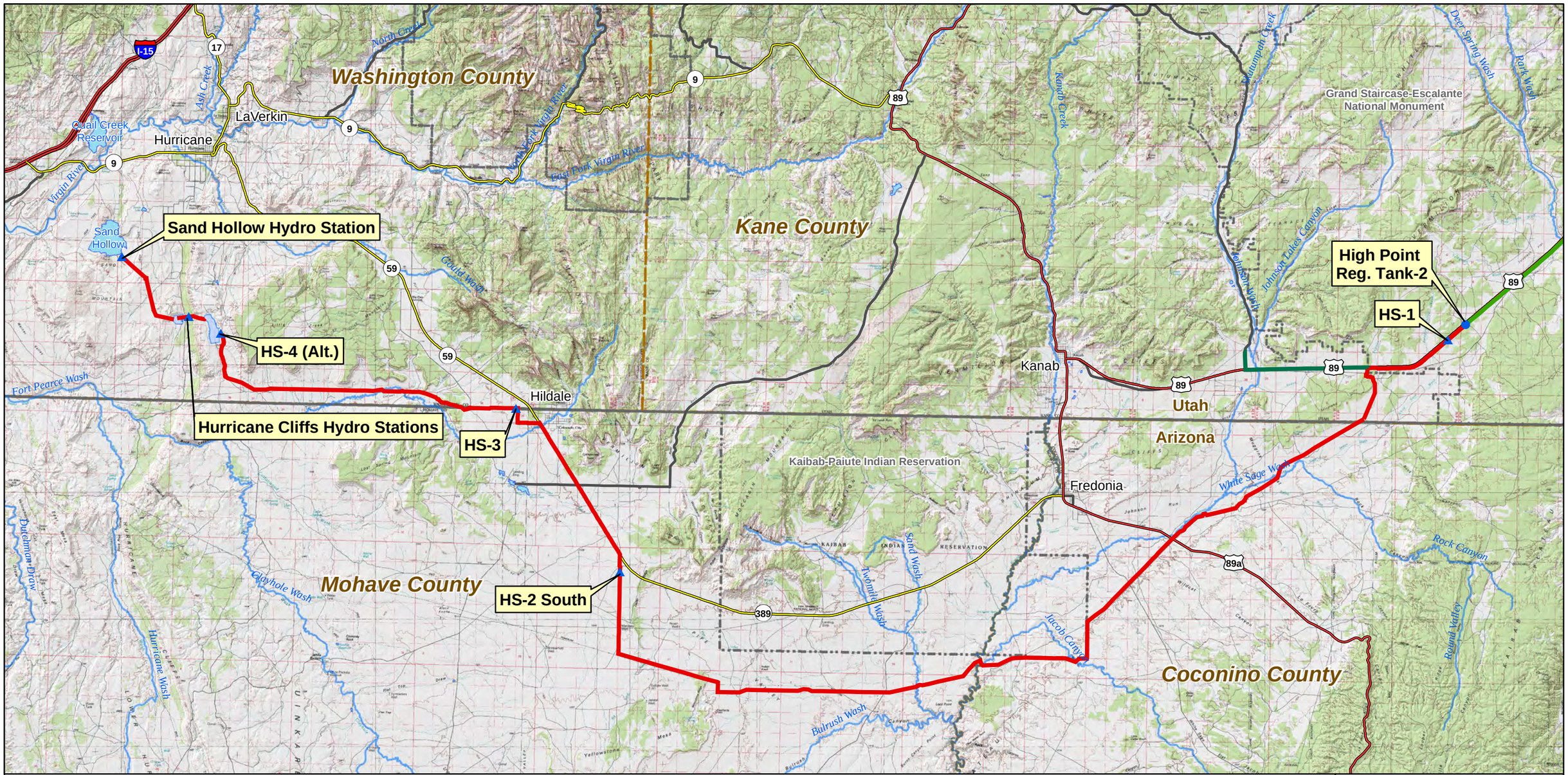
The penstock alignment would turn south from Highway 89 through private land and BLM-administered public lands into White Sage Wash. It would continue across White Sage Wash and then parallel Navajo-McCullough Transmission Line, crossing Highway 89 Alt. and Forest Highway 22 toward the southeast corner 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 - South Alternative (Penstock Segment)
- KCWCD System
- Major Rivers & Streams
- Interstate
- US Highway
- ST Highway
- Hwy
- Major Road
- National Park/Monument
- GSENM Boundary
- 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 1-4** MWH

Lake Powell Pipeline
Hydro System
South Alternative

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.

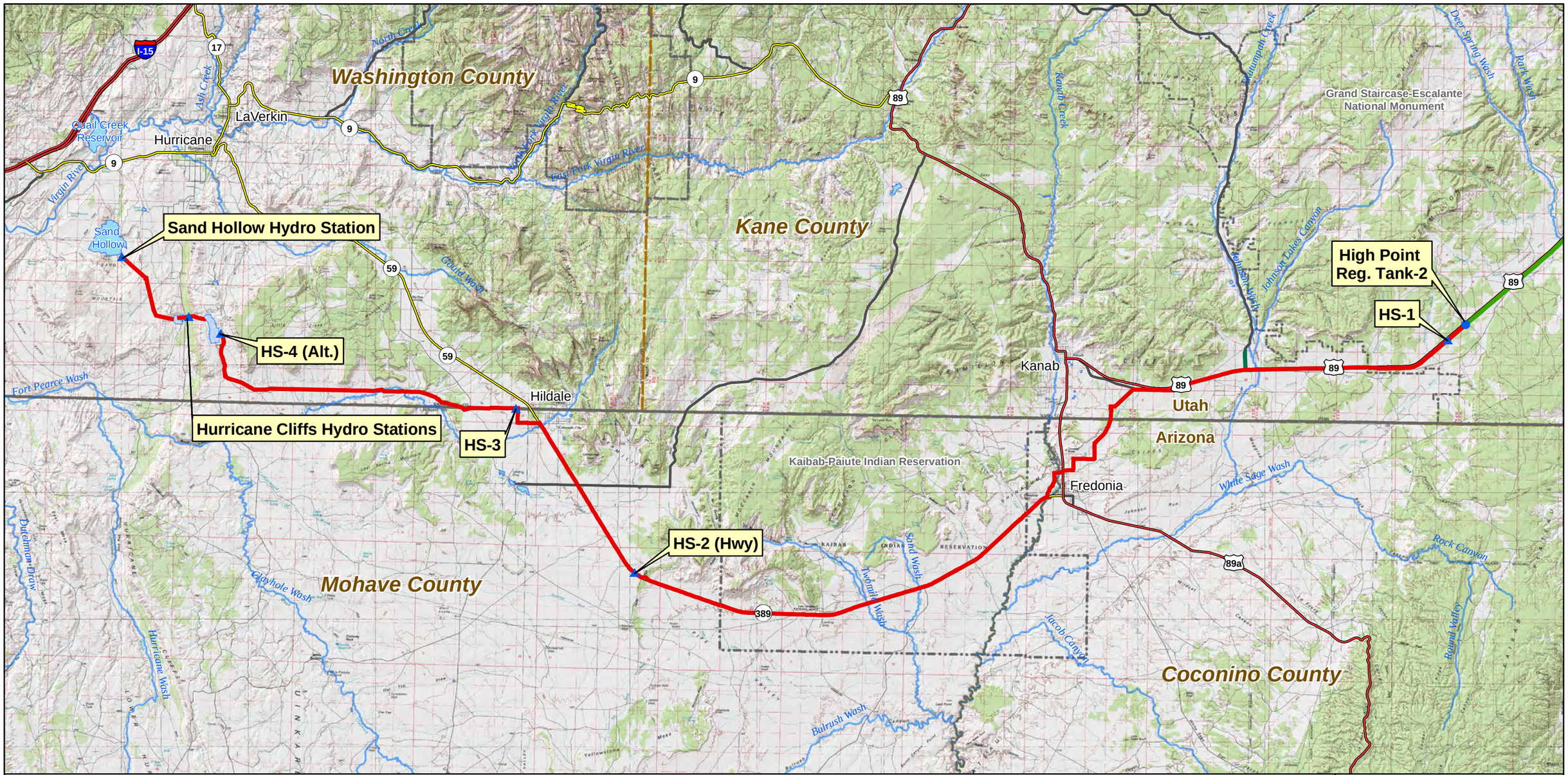
The penstock downstream from the proposed HS-1 would be sited along the south side of Highway 89 within GSENM. The penstock would parallel the south side of Highway 89 west of GSENM, continue past Johnson Wash and follow Lost Spring Gap southwest, crossing Highway 89 Alt. and Kanab Creek in the north 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
- Project Hydro Station
- Hurricane Cliffs Forebay/Afterbay
- Lakes & Reservoirs
- Water Conveyance System
- Hydro System - Existing Highway Alternative (Penstock Segment)
- KCWCD System
- Major Rivers & Streams
- Interstate
- US Highway
- ST Highway
- Hwy
- Major Road
- National Park/Monument
- GSENM Boundary
- 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 1-5** 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).

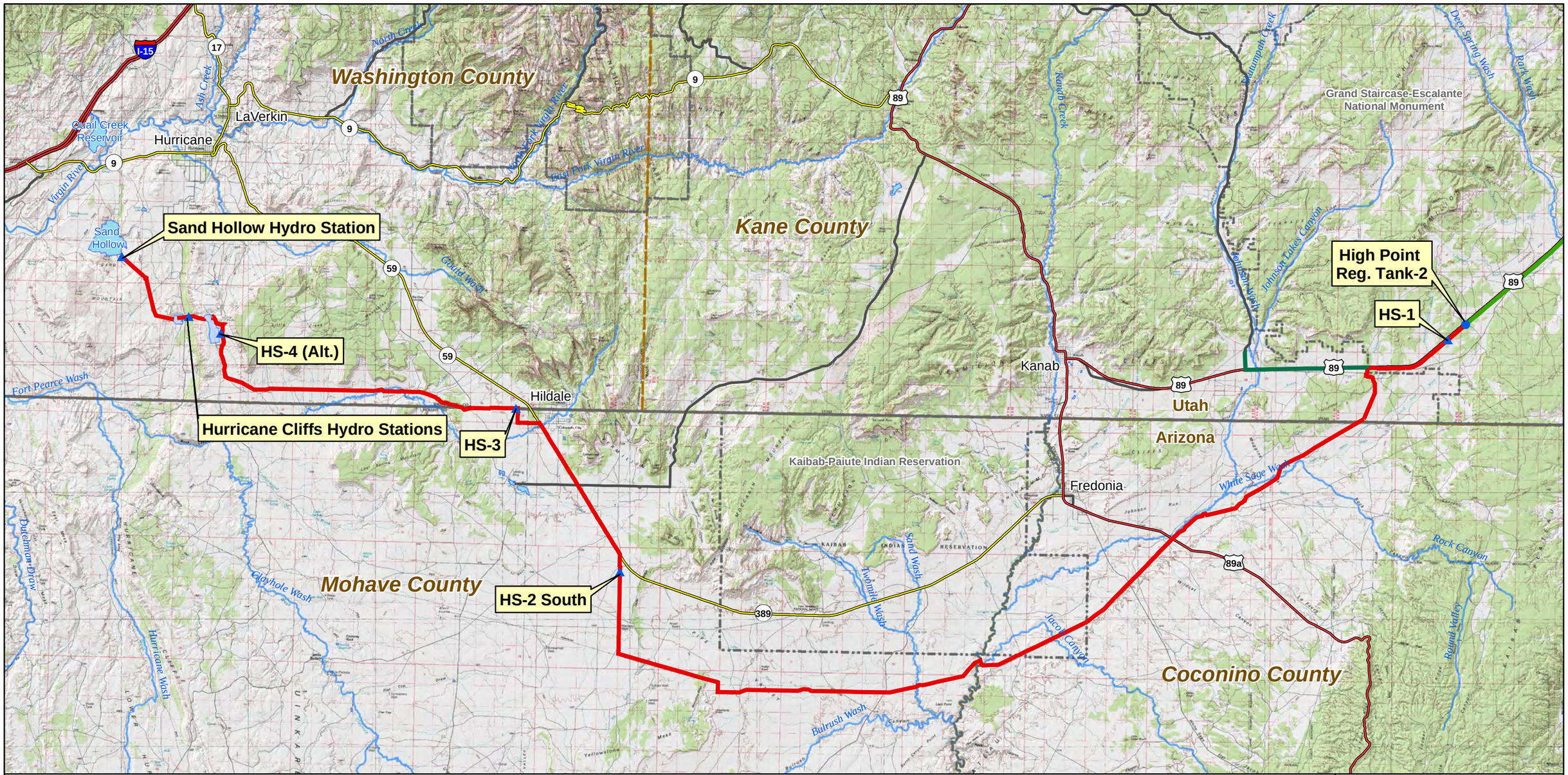
The proposed new **Glen Canyon to Buckskin Transmission Line** would consist of a 230 kV transmission line from the Glen Canyon Substation to the Buckskin Substation, running parallel to the existing 138 kV transmission line. This transmission line upgrade would be about 36 miles long through Coconino 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
- GSENM Boundary
- Tribal Lands
- State Boundaries
- County Boundaries

FERC Project Number: 12966-001
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N

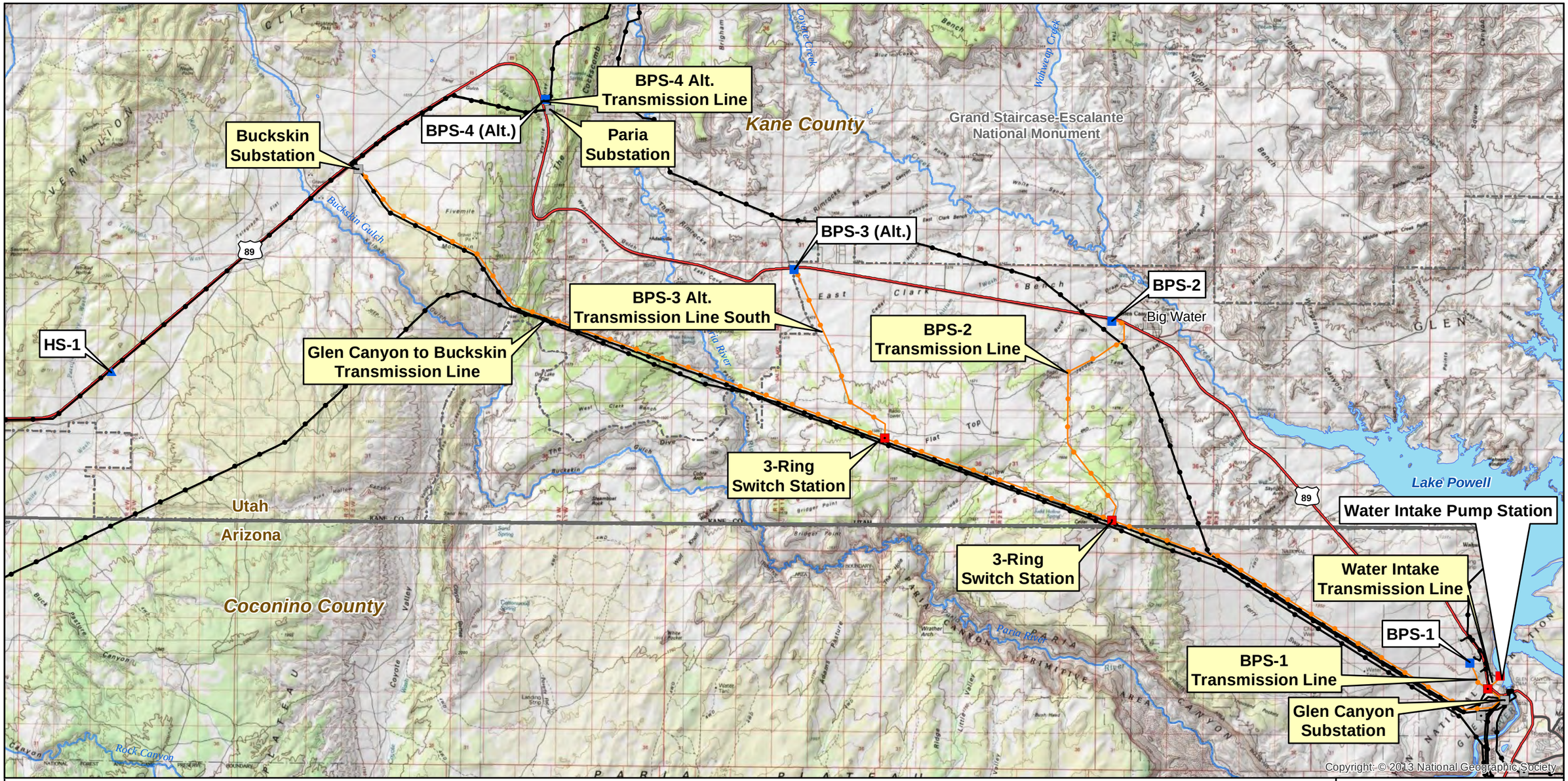
0 1 2 4 6 8 Miles

Lake Powell Pipeline Project

Spatial Reference: UTM Zone 12N, NAD-83

UDWRe **Figure 1-6** 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
GSENM Boundary
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 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).

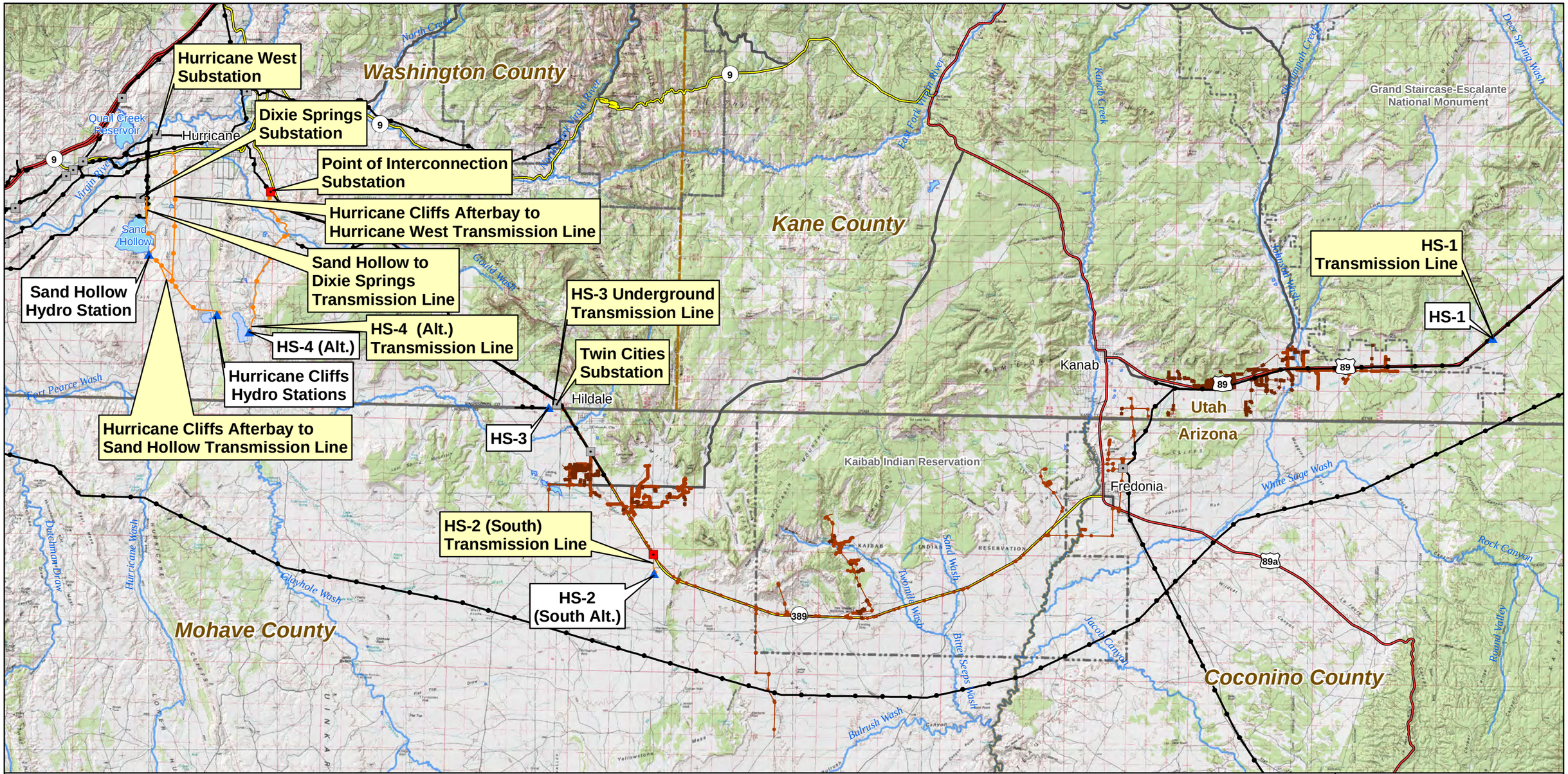
The proposed new **Hurricane Cliffs Afterbay to Sand Hollow Transmission Line** would consist of a new 69 kV transmission line, which would run northwest from the Hurricane Cliffs peaking power plant and substation to the Sand Hollow Hydro substation. This new 69 kV transmission line would be about 4.9 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
- GSENM Boundary
- 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

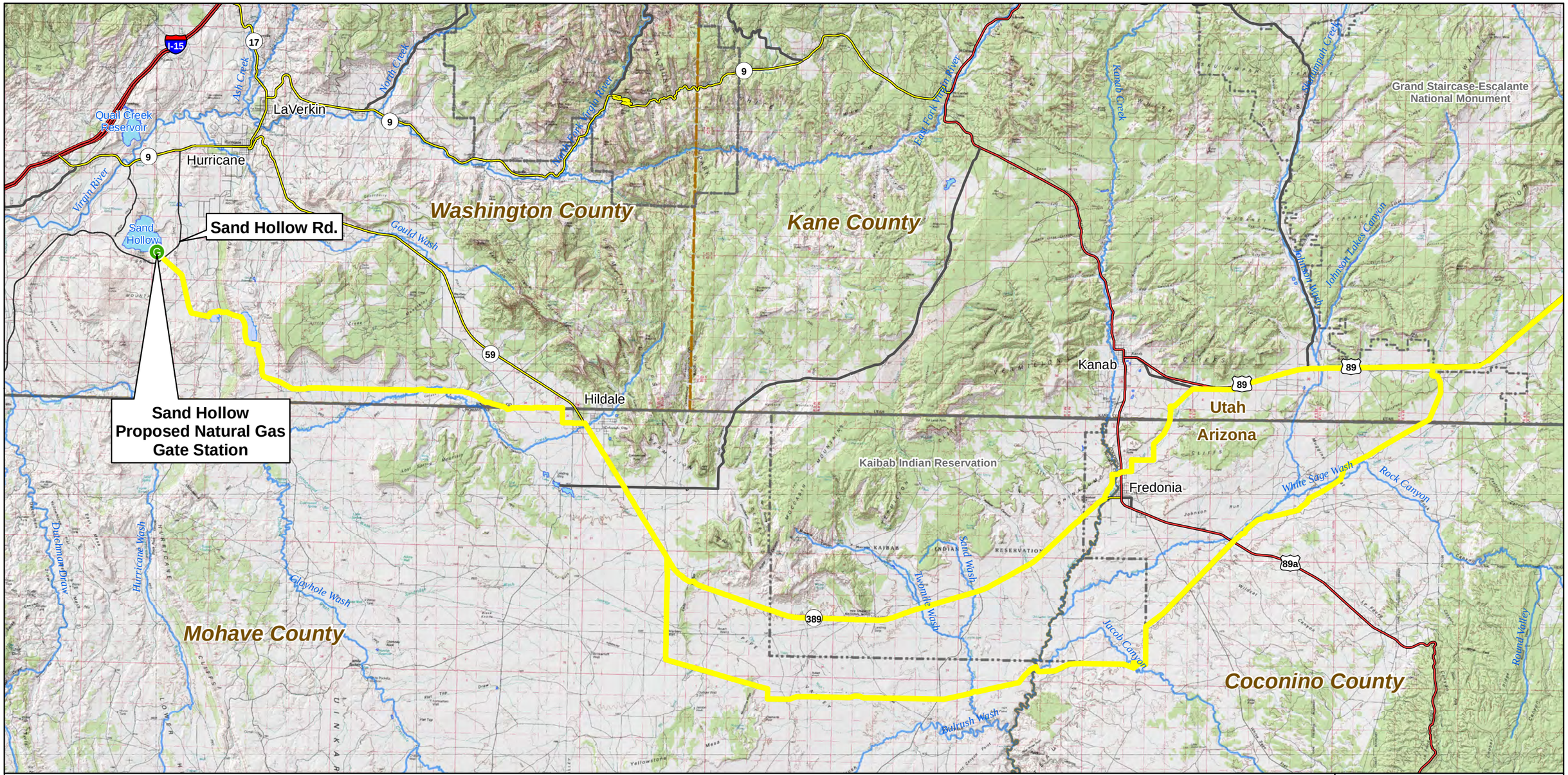
The proposed natural gas supply line would be an intermediate high pressure line and would operate between approximately 250 to 300 psi at the gate station connection. Because of pressure losses in the pipeline it is anticipated that the pressure at each of the LPP pump stations would vary between 50 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
- GSENM Boundary
- Tribal Lands
- State Boundaries
- County Boundaries

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

N

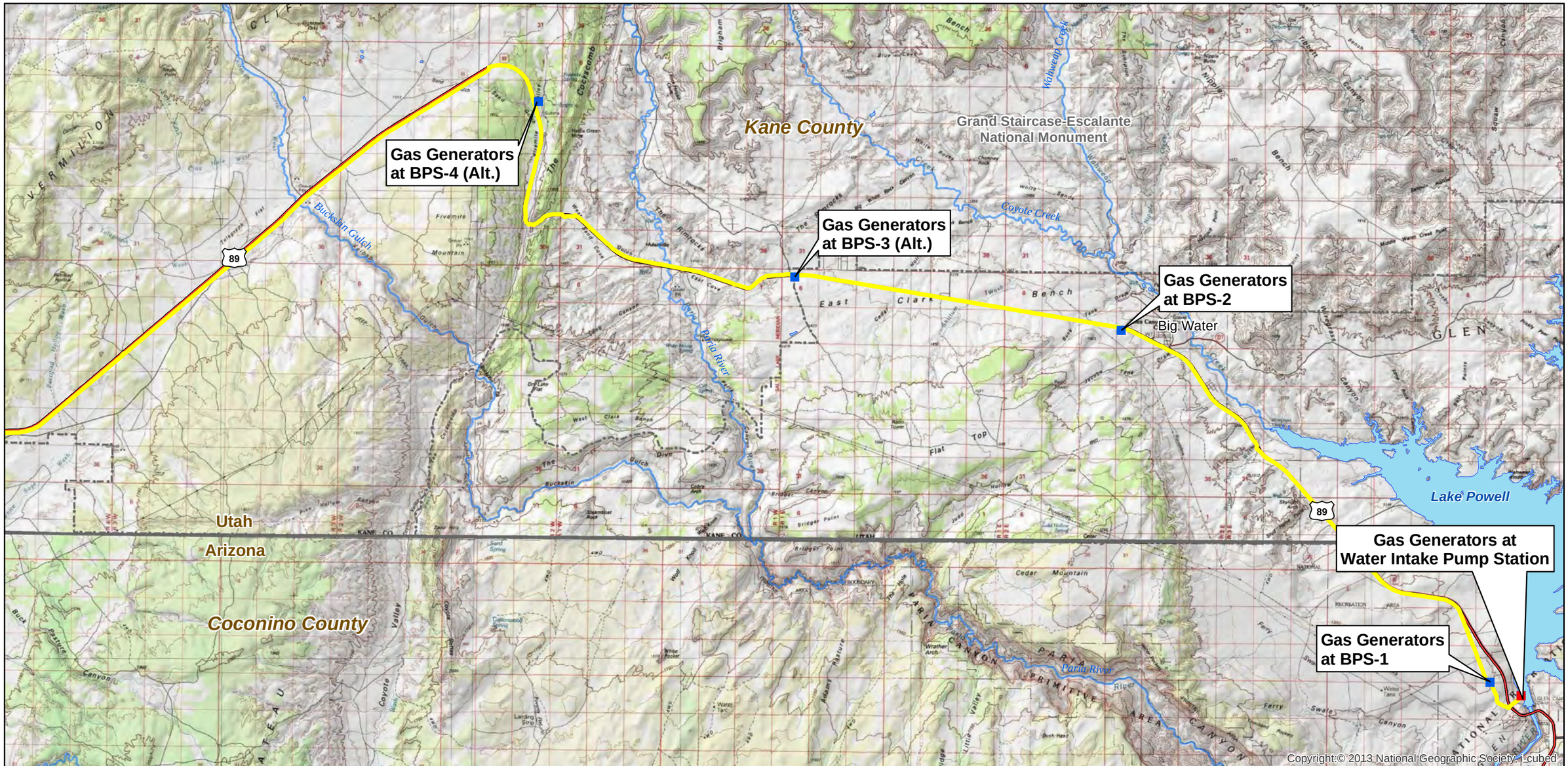
0 2 4 6 8 10 Miles

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
- GSENM Boundary
- 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

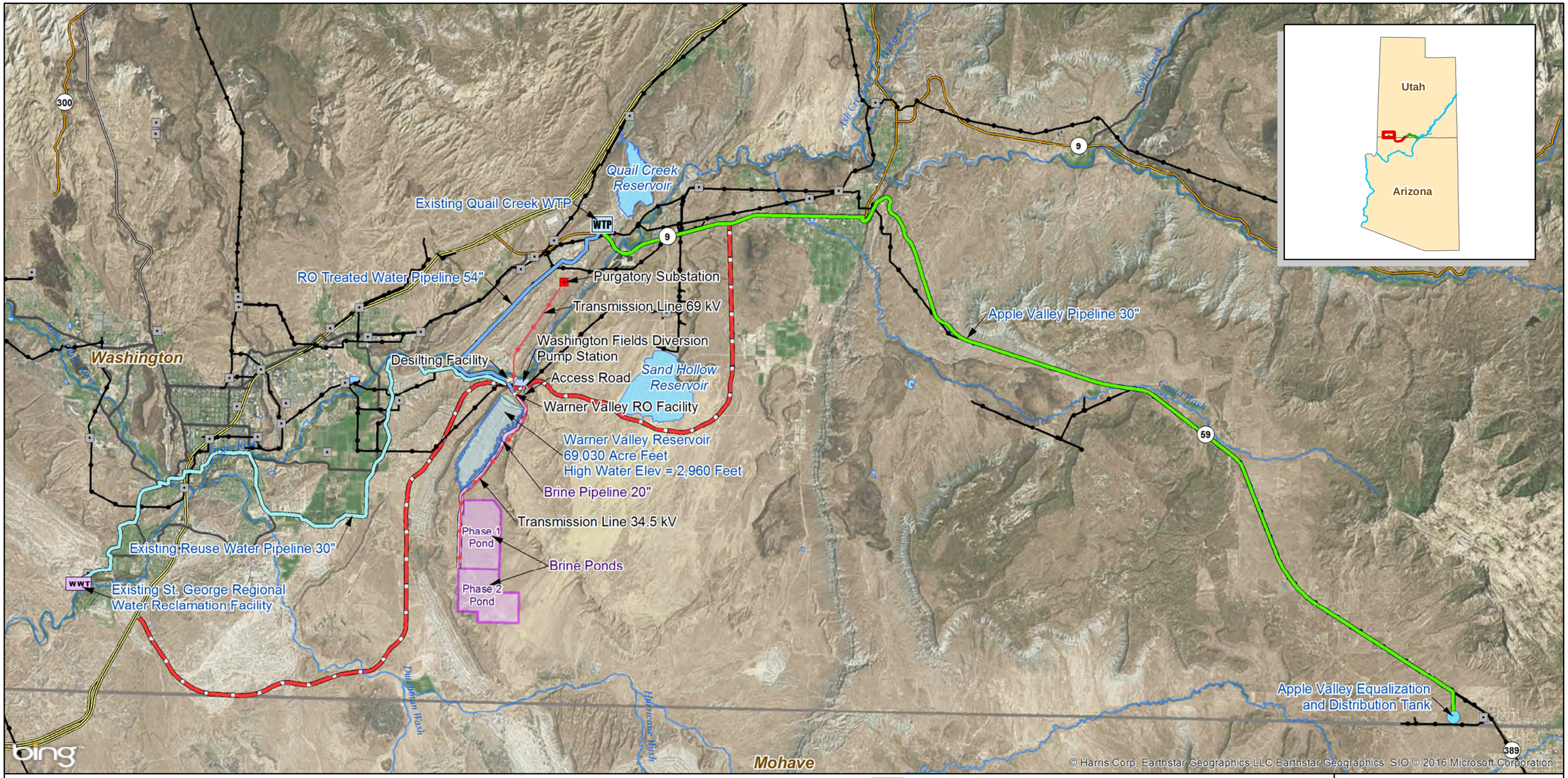
The WCWCD LPP allocation would be 82,249 acre-feet per year, and the WCWCD No Lake Powell Water alternative would need to supply 82,249 acre-feet per year to meet the same future water demands. In addition to the direct supply from Utah's Colorado River water, the water supplied by the LPP Project would 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 Impact Topics

The following impact topics are addressed in the Surface Water Resources Study Report:

- Streams
- Return Flows
- Reservoirs
- Peak Flows
- Geomorphology

Chapter 2
Methodology

The following sections describe the methodology for analyzing the study area and the effects of the LPP Project on surface water resources.

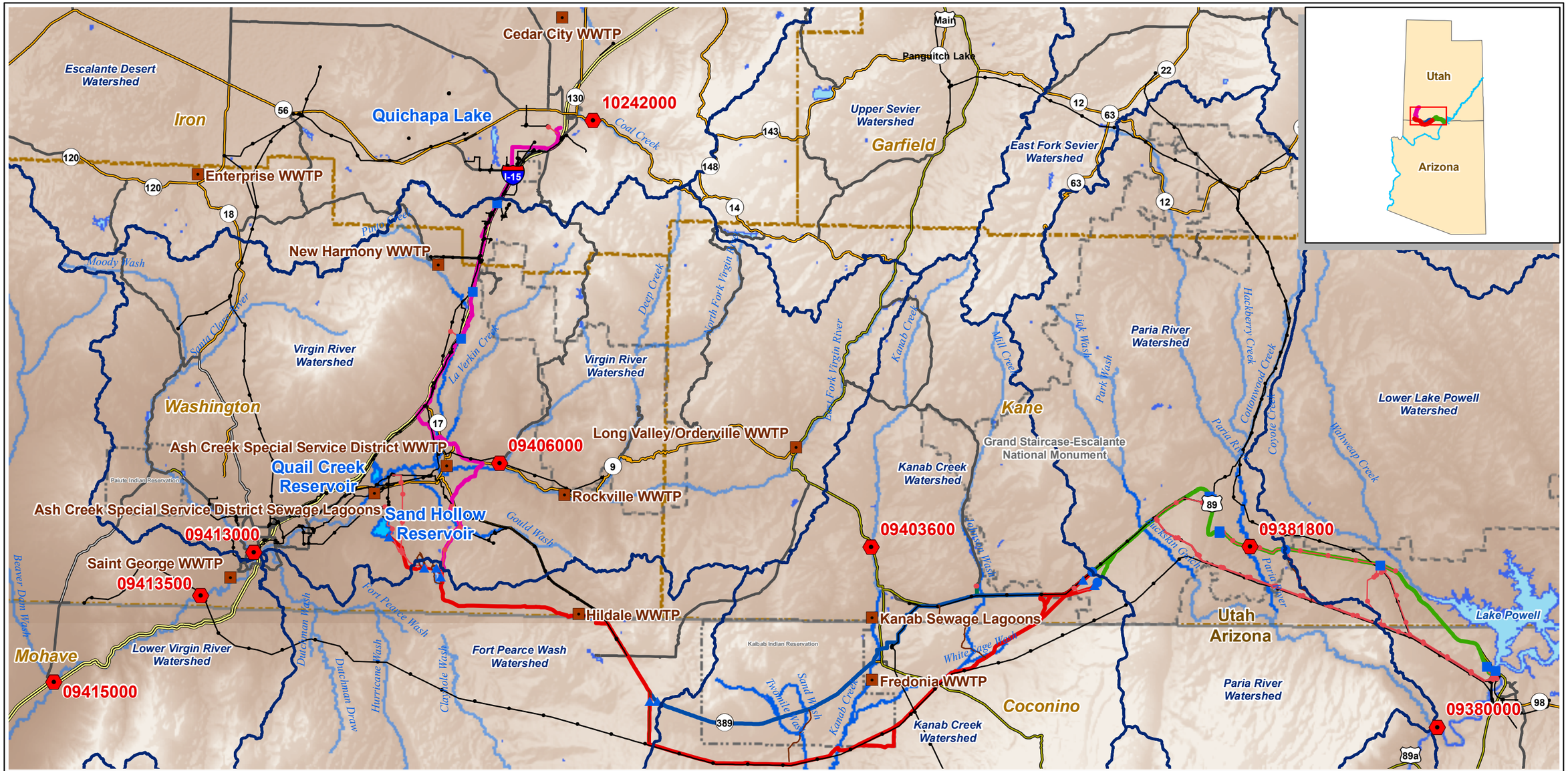
2.1 Study Area

The surface water study area encompasses the surface waters potentially affected by the LPP Project and the No Lake Powell Water Alternative. Figure 2-1 shows the HUC 8 watershed boundaries and stream gage locations in the surface water resources study area.

Table 2-1 lists the streams that could be affected by any of the pipeline alignments of the LPP Project. Causes of potential effects range from the pipeline physically crossing the stream channel, to changes in diversion of streamflows, to changes in the flow regime from return flows.

Table 2-1
List of Potentially Affected Streams by LPP Alternatives

Creek	Intermittent/Perennial	County	Cause of Potential Effect
Colorado River	Perennial	Coconino	Change in flows due to effects on storage in Lake Powell
Virgin River	Perennial	Washington	Sewered and non-sewered return flows
Kanab Creek	Intermittent (downstream of Kanab)	Kane, Mohave	Sewered and non-sewered return flows, crossing
Santa Clara River	Perennial	Washington	Non-sewered return flows
Paria River	Perennial	Kane	Crossing
Buckskin Gulch	Intermittent	Kane	Crossing
Coyote Wash	Intermittent	Kane	Crossing
Johnson Wash	Intermittent	Kane	Crossing
White Sage Wash	Intermittent	Coconino	Crossing
Sandy Canyon Wash	Intermittent	Mohave	Crossing
Sand Wash	Intermittent	Mohave	Crossing
Two-Mile Wash	Intermittent	Mohave	Crossing
Bitter Seeps Wash	Intermittent	Mohave	Crossing
Gould Wash	Intermittent	Washington	Non-sewered return flows
Fort Pierce Wash	Perennial	Washington	Non-sewered return flows, runoff captured in Hurricane Cliffs Forebay and Afterbay



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

Lake Powell Pipeline Project

Spatial Reference: UTM Zone 12N, NAD-83

UDWR **Figure 2-1** MWH

HUC 8 Watershed Boundaries and Stream Gage Locations

The following reservoirs could potentially be affected because of changes in operations: Lake Powell, Quail Creek Reservoir and Sand Hollow Reservoir.

2.2 Streams

2.2.1 Existing Conditions

Historical streamflows in areas that could potentially be affected by the South Alternative (Proposed Action) or No Lake Powell Water Alternative are documented using historical streamflow data to document the existing surface water conditions. Data were obtained from the USGS NWIS database for locations on the Colorado River, Paria River, Virgin River, Kanab Creek, and Santa Clara River with the longest periods of record and/or in key locations (USGS 2009). Streamflows at all locations where enough data are available were summarized using the following charts:

- Flow exceedance curve
- Daily flows time series
- Daily mean and range of flows
- Monthly mean flows
- Annual mean flows

2.2.2 Direct Effects

The effects on Colorado River streamflows are based on the results of water resources modeling performed by the Bureau of Reclamation. The effects on streamflows in Washington County are based on the results of a local system water resources model developed by Utah Division of Water Resources (UDWRe). Effects on the remaining streams are based on a qualitative analysis.

2.2.2.1 Virgin River Daily Simulation Model

The Virgin River Daily Simulation Model (VRDSM) is a mean daily simulation model of the Virgin River developed by the Utah Division of Water Resources. At present it is a FORTRAN-based yield model used to evaluate potential changes in operations on the Virgin River in southwest Utah. The model simulates the river system from the Virgin River at Virgin gage to the Utah-Arizona state line for a 73-year period from 1941-2013. The model simulates the Quail Creek project, Sand Hollow Reservoir, pump-back from the Washington Fields diversion to Sand Hollow Reservoir, hydropower plants in operation within the Washington County Water Conservancy District (WCWCD) and instream flow requirements (UDWRe 1998). The model has the capability to simulate additional regulating storage, an expanded secondary system for the St. George area and the importation of Lake Powell reservoir water to Sand Hollow Reservoir by the proposed Lake Powell Pipeline. The model is not explicitly adjusted with ungaged gains and losses to match historical gaged streamflows.

Inflow to the model includes streamflow records from the Virgin River at the Virgin gage and the main Virgin River tributary inflow, including Ash Creek/LaVerkin Creek, Quail Creek/Leeds Creek and the Santa Clara River. The U.S. Geological Survey (USGS) streamgage located on the Virgin River near the town of Virgin (USGS 09406000) provides long-term records for the Virgin River at Virgin (1909-1971 and then 1979 to the present). Discontinued streamflow records (1972-1978) were estimated using the Virgin River near Hurricane gage, which began in 1967, and equations from the model. Short-term records are available on Ash Creek and LaVerkin Creek. Missing data were estimated with correlations to the Virgin gage. Missing years at the Santa Clara River gage (1941-1950 and 1955-1983) were filled in

from the Division of Water Resources monthly model of the Santa Clara River. The monthly flows from the model were divided by the number of days in the month to obtain the daily inflows (UDWRe 1998).

The model simulates the maximum yield in the St. George area with a specified maximum shortage in the worst year (10 percent in the Lake Powell Pipeline project simulations), while providing firm secondary water supplies to the Hurricane, LaVerkin and Washington Fields areas. Flow is diverted year-round in the Quail Creek pipeline to provide flows to the Hurricane and LaVerkin diversions, Pah Tempe hydropower flows and flow to Quail Creek Reservoir. If the natural flow is less than 86 cfs at the Washington Fields Diversion, no water is diverted to Quail Creek Reservoir (UDWRe 1998). A schematic of the model is provided in Figure 2-2. See Appendix 1 for more information regarding the VRDSM.

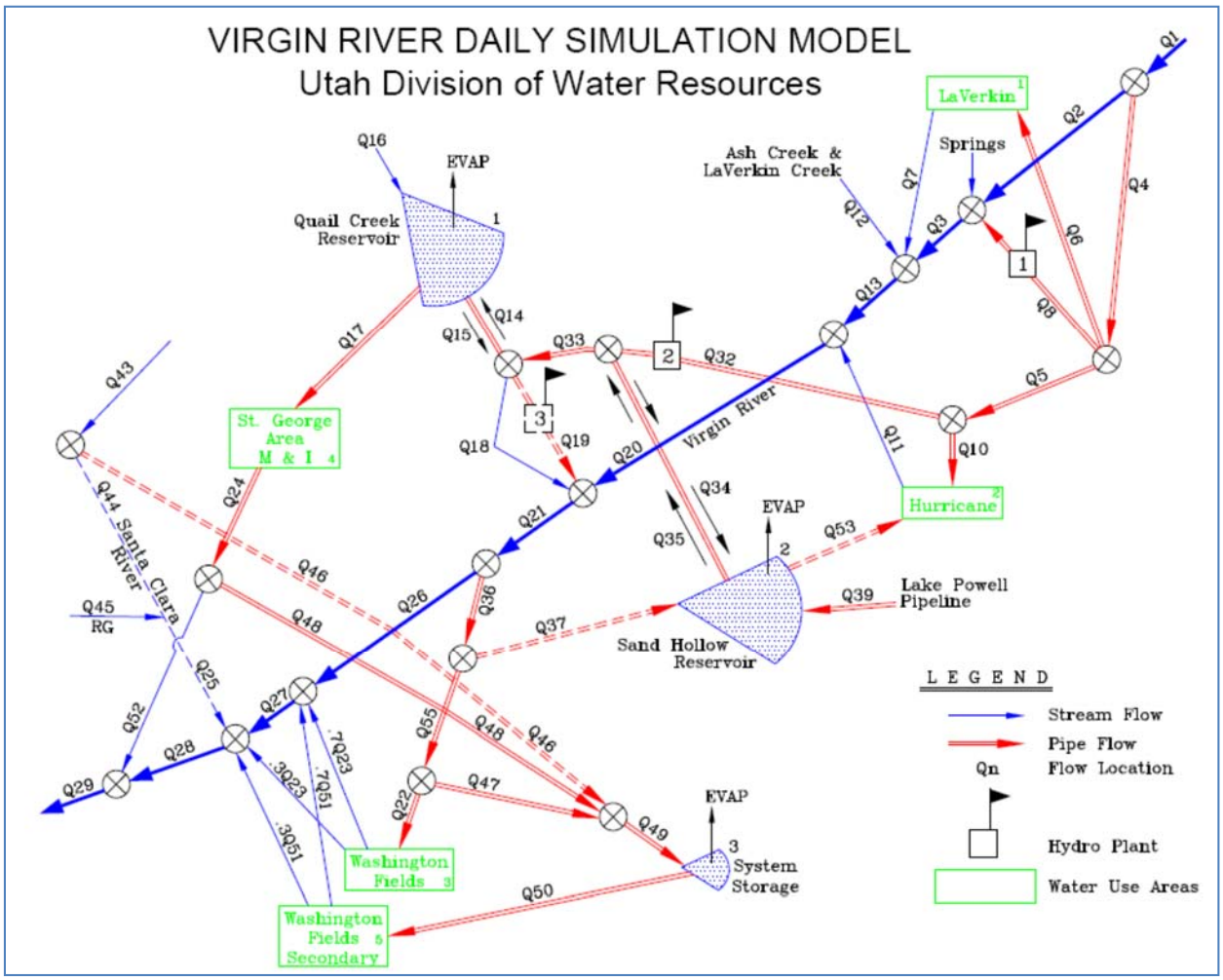


Figure 2-2
Virgin River Daily Simulation Model Schematic (UDWRe 2011 and 2015)

2.2.2.1.1 Virgin River Daily Simulation Model Scenarios. Two simulations were performed with the VRDSM. Scenario 1 simulated the Base Case conditions of full utilization of Virgin River water rights, without any additional storage or LPP Project deliveries. Scenario 2 represents the Proposed Action future conditions with the expanded secondary system utilizing 3,000 acre feet of re-regulating storage and

82,249 acre feet of annual LPP Project deliveries into Sand Hollow Reservoir. The scenarios incorporated the following assumptions (UDWRe 2011 and 2015):

1) No water delivered through re-regulating storage will return to the river
2) Capacity on the re-use treatment plant will accommodate all return flow from the St. George area municipal and industrial (M&I) and no Virgin River Water will be used for new secondary demands
3) Carrying capacity of the infrastructure at the Washington Fields Diversion will not limit what can be diverted there

Annual demands remained the same for the LaVerkin, Hurricane, and Washington Fields service areas (1, 2 and 3) in all scenario simulations. Demands for service areas 4 and 5, labeled in Figure 2-2 as St. George area M&I and Washington Fields Secondary, varied between scenarios as these areas were optimized for yield by the model's solver. Service area 4 represents the M&I demands in the St. George metropolitan area. Service Area 5 includes all new secondary demands that will be placed on the reuse system in the St. George metropolitan area (UDWRe 2010b). Daily demand distributions remained the same for all service areas, in all scenarios simulated.

2.2.2.2 Lower Colorado River and Lake Powell Model

The State of Utah contracted with Reclamation to perform additional simulations using the Colorado River System Simulation (CRSS). The model simulates storage effects on Lake Powell and streamflow effects on the Colorado River with a monthly time step.

Two scenarios were simulated:

- South Alternative, or with Lake Powell Pipeline with maximum depletions of 86,249 AFY (86k scenario)
- No Action, or no pipeline out of Lake Powell

For both scenarios, it was assumed that Upper Basin depletions in the Colorado River basin would remain constant at current 2015 levels, except for reasonably foreseeable future project depletions. A reasonably foreseeable future depletion is one which has state legislation, or a tribal resolution or federal Indian water settlement, or a federal finding of no significant impact (FONSI) or record of decision (ROD). Those depletions assumed reasonably foreseeable include the Central Utah Project, Animas-La Plata, Dolores Project, Navajo-Gallup, Ute Indian Compact, and Navajo Indian Irrigation Project. Further details on the CRSS model depletions nodes can be found in Attachment A of Appendix 2, containing Reclamation's full report (Reclamation 2015a). The No Action alternative assumes that if the Lake Powell Pipeline is not developed, Utah's unallocated water would not be developed somewhere else in the state. This analysis isolates the effect of adding a new project (Lake Powell Pipeline) to the mix of existing and reasonably foreseeable depletions in the Colorado River system.

Two input hydrology scenarios were evaluated:

- Historical Hydrology, Direct Natural Flow (DNF) – Developed from the observed streamflow record from 1906 to 2010 from 29 individual inflow points on the Colorado River System. Natural flow is the observed flow adjusted for the effects of diversions and the operation of reservoirs upstream of the flow gage. This natural flow record was developed by Reclamation and is used extensively in their hydrologic modeling and Environmental Impact Statements (EIS). In

this inflow scenario, the existing historical record of natural flows was used to create a number of different future hydrologic sequences using a resampling technique known as the Index Sequential Method (ISM). The ISM results in a number of different future hydrologic sequences that allows calculation of uncertainty. This scenario was the primary inflow dataset used for the 2007 Shortage EIS and one of the 2012 Basin Study inflow scenarios. DNF results in 105 simulated outcomes for each month, which are summarized using non-parametric statistics including the 10th, 50th, and 90th percentiles.

- Climate Change Hydrology (CC) – Developed from climate change projections used in the 2012 Basin Study, this dataset consists of 112 "traces" of climate change projections of future monthly streamflow. The 112 traces were developed using General Circulation Model output from the CMIP3 (Coupled Model Intercomparison Project 3) projections of future temperature and precipitation.

Two Lake Powell Pipeline depletion schedules were used, one based on historical hydrology and one based on climate change hydrology. For both schedules, pipeline depletions are zero for the years 2015 through 2023. Pipeline depletions start at 15,468 acre-feet per year in the year 2024 and increase each year to a total of 86,249 acre-feet in the year 2048 for the historical hydrology scenario and the year 2049 for the climate change hydrology scenario. The depletion schedules can be seen in Figure 2-3.

The results of Reclamation's 86K scenario simulations are summarized in Chapter 4, Sections 4.3 and 4.4 as they represent the State of Utah's current water right for the LPP Project. Reclamation's full report is included as Appendix 2 (Reclamation 2015a).

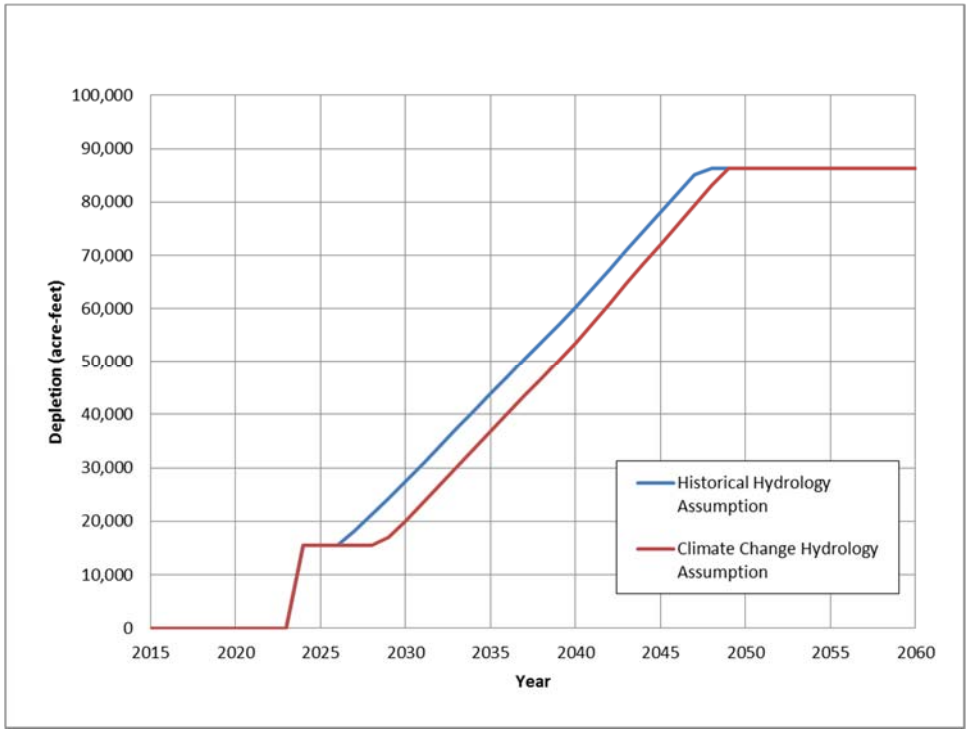


Figure 2-3
Simulated Lake Powell Pipeline Depletion Schedules

2.3 Reservoirs

Reservoirs are analyzed using historical storage data and area-elevation-capacity curves for existing and potentially affected facilities including Lake Powell, Quail Creek Reservoir, and Sand Hollow Reservoir. The impact analyses for reservoirs is based on the results of the local system model and the CRSS model described in Section 2.2.

2.4 Peak Flows

The flood flow discussion summarizes Federal Emergency Management Agency (FEMA) Flood Insurance Study estimates of peak flows. For locations with no recent FEMA Flood Insurance Study, estimates of peak flows developed by the USGS based on regression equations are summarized.

The impact analyses discuss potential effects of the project on peak flows. The effects on peak flows are expected to be minor because the project does not include any permanent changes to stream channels. However, the analysis discusses how changes in drainage area and storage, such as those caused by construction of the Hurricane Cliffs Hydropower facilities, could affect peak flows downstream.

2.5 Geomorphology

The geomorphic discussion includes a summary of general geomorphic characteristics described in existing studies. The impact analyses include a qualitative discussion of how the estimated changes in baseflows, based on modeling results, and peak flows, based on the peak flow discussion, might affect stream stability.

2.6 Cumulative Effects

Cumulative effects are based on the effects of the action alternatives combined with the effects of other "reasonably foreseeable" actions. A formal list of reasonably foreseeable actions, activities independent of the LPP Project that could result in cumulative effects when combined with the effects of the LPP Project, will likely be developed for the NEPA process. The only reasonably foreseeable action likely to affect surface waters within Kane and Washington counties is ongoing urban development. Urban development and land use activities would occur with the projected population growth in these counties. This would result in increased water runoff from impermeable surfaces in the urban centers in Kane and Washington counties. These indirect cumulative effects are discussed qualitatively in Chapter 7.

For Lake Powell and the Lower Colorado River, other actions that could result in cumulative effects have already been incorporated into the CRSS modeling. Such actions include future increases in consumptive use of the Colorado River water in the Upper Division states, intrastate water transfers in the Lower Division states and other constraints on operation of the Colorado River system (Reclamation 2007).

2.7 Study Period

There is a different study period for the affected environment and effects analysis. Historical streamflow and storage data are summarized for October 1940 through September 2008 (water years 1941 through 2008) to document the affected environment. The Virgin River Daily Simulation Model utilizes a same study period from water year 1940 to 2013. Total demand for the VRDSM is optimized for yield based on supply and a 10 percent maximum shortage occurring in any one year at a given service area.

Reclamation's CRSS model uses historical hydrology to develop numerous inflow hydrology traces that are applied as simulated inflow hydrology for the years 2015 through 2060. South Alternative (Proposed Action) runs include future demand scenarios with increasing depletions from Lake Powell from when the LPP Project comes online in 2024 through 2048 for an 86K maximum depletion.

Chapter 3
Affected Environment

Utah's surface waters are prone to extremes of floods and droughts. Five major floods have occurred in recent history, the most recent in 2005. In addition, six multi-year statewide droughts have been recorded, the most recent form 1999-2002 (USGS 2003 and JE Fuller 2007). The following summaries of streamflows and reservoir storage reflect this variability. Figure 2-1 depicts the locations of USGS gages where streamflows are summarized.

3.1 Water Regulation

The Utah Division of Water Rights regulates water allocation and distribution. Utah abides by the prior appropriation system. The State Engineer administers Utah's water law. Surface and groundwaters in most of the study area are considered fully appropriated, meaning that there is no additional water available to be claimed for beneficial use.

Therefore, the State of Utah's Colorado River rights from Lake Powell would be administered according to its water rights, whether it is utilized by Utah consistent with the No Action Alternative or through the Lake Powell Pipeline. According to the prior appropriation doctrine, the rights of senior water rights holders, including tribal water rights, must be protected with or without the LPP, regardless of hydrology, including potential hydrology affected by climate change. Under future climate change with lower streamflow, water available to junior water rights holders in the region could decline.

3.2 Streams

Table 3-1 summarizes the period of record for daily streamflows dating back to 1941. All streamflow data and stream gage photographs were obtained from the USGS NWIS database (USGS 2009) unless otherwise noted. Conditions of streams potentially affected by the LPP Project without recent daily flow records are described based on available information such as drainage area.

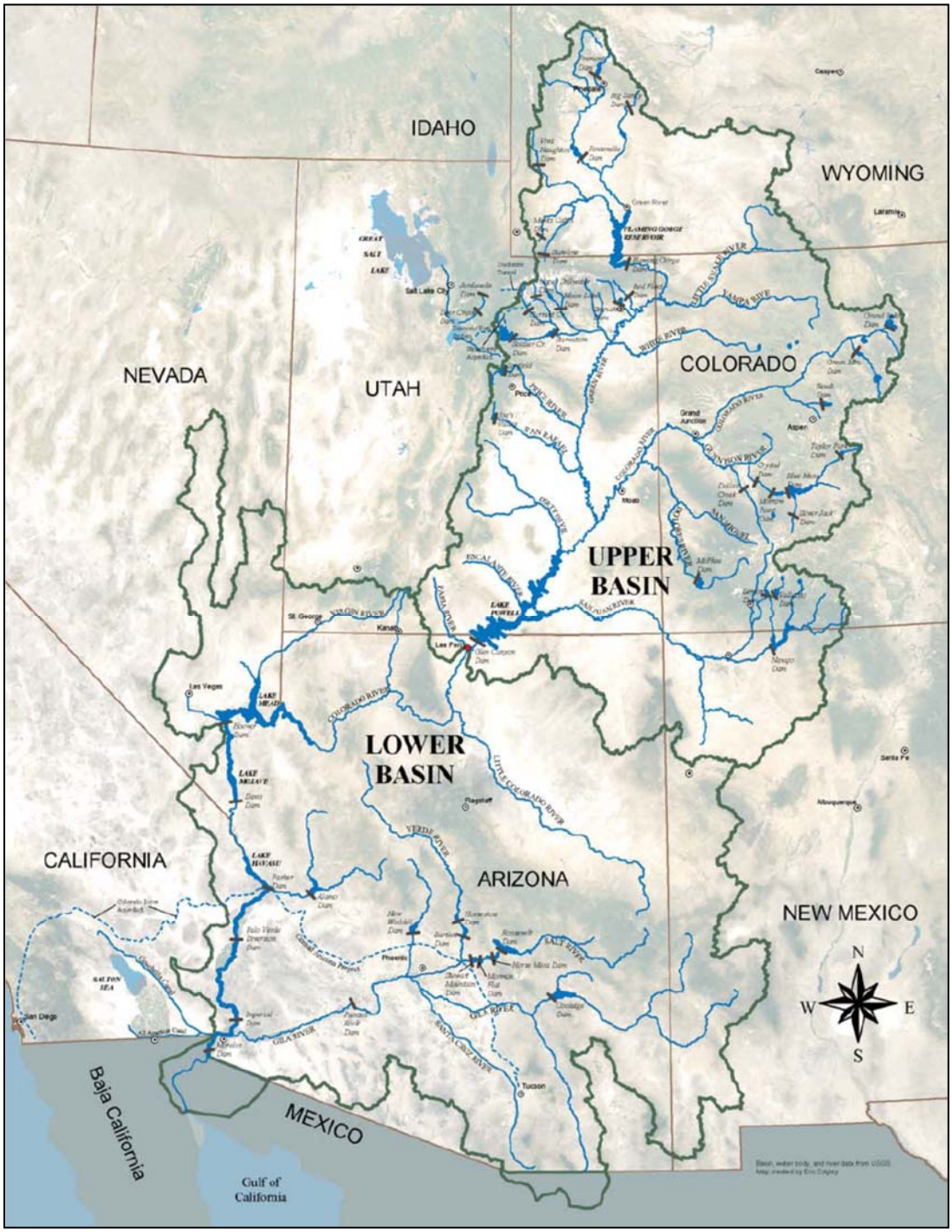
Table 3-1
Streamflow Periods of Record for Locations of Interest

Gage Number	Location	Period of Record (Water Years)	Drainage Area (square miles)	Mean Flow (cfs)
09403600	Kanab Creek near Kanab, UT	1979 – 2008	194	11.8
09406000	Virgin River at Virgin, UT	1941 – 1972, 1979 – 2008	956	198
09413500	Virgin River near St. George, UT	1951 – 1957, 1992 – 2008	4,123	188
09415000	Virgin River at Littlefield, AZ	1941 - 2008	5,090	241
09413000	Santa Clara at St. George, UT	1951 – 1956, 1985 – 2008	541	14.8
09380000	Colorado River at Lees Ferry, AZ	1941 – 2008	111,800	13,791
09381800	Paria River near Kanab	2002 – 2008	647	19.8

Source: 2008 water data reports, Mean Flow calculated for period of record summarized in report with exception of Colorado River which is calculated for water years 1965 – 2008 (after Glen Canyon Dam construction).

3.2.1 Colorado River

The Colorado River is an important resource for the southwest United States. It drains an area of more than 244,000 square miles and passes through seven states and Mexico. Many reservoirs have been constructed in the Colorado River system to regulate the water for various uses. More than 24 million people from Salt Lake City, to Phoenix, to Denver, to San Diego rely on the river for water supply (UDWRe 2002). The river is also used for agricultural irrigation, recreation, and power generation. Figure 3-1 depicts the Colorado River Basin.



Source: UDWRe (2002)

Figure 3-1
Colorado River Basin

The rules pertaining to division of the flow of the Colorado River are referred to as the Law of the River. The Law of the River is comprised of compacts (e.g., Colorado River Compact), court decisions and decrees, and regulatory guidelines. The Colorado River Compact (Compact) is one of many documents constituting the Law of the River. It divides the river basin into the Upper Basin (comprised of Colorado, New Mexico, Utah and Wyoming) and the Lower Basin (comprised of Nevada, Arizona and California). The Lee Ferry[1] Compact Point divides the system into the Upper Basin and Lower Basin. In general, each basin is allocated 7.5 million acre-feet (MAF) per year. The Upper Basin states cannot deplete the flow of the river below 7.5 MAF during any period of ten consecutive years. The Law of the River allocates the State of Utah 23 percent of the Upper Basin apportionment (Reclamation 2007), which equates to 1.725 MAF of the 7.5 MAF Upper Basin allocation.

The Colorado River below Lake Powell is part of the study area because it is located downstream of the LPP intake. At this point, the Colorado River flows through a narrow part of Glen Canyon. Flows are greatly modified from natural streamflows because of the impoundment of Lake Powell behind Glen Canyon Dam, which began filling in 1963, and many other storage facilities located on the Colorado River and its tributaries upstream of Lake Powell. The Lees Ferry gage is located on the Colorado River 15.5 miles downstream of Glen Canyon Dam. Flows at Lees Ferry are primarily the result of releases made from the dam. Releases are made by Reclamation based on complicated guidelines developed to fulfill multiple purposes that are consistent with the Law of the River as briefly described below.

Releases from the Glen Canyon Dam are scheduled on an annual, monthly, and hourly basis. Annual release volumes are made according to the Long Range Operating Criteria (LROC) of Colorado River Reservoirs, which includes a minimum objective release of 8.23 MAF, storage equalization between Lake Powell and Lake Mead under prescribed conditions, and the avoidance of spills. Annual releases greater than the minimum can be made for a variety of reasons based on operation requirements (Reclamation 2007).

Each spring, the Secretary of the Interior declares the Colorado River water supply availability for the Lower Basin States in terms of Normal, Surplus, or Shortage. This declaration affects the operation of Lake Powell for the following year. Operating guidelines for the Normal and Surplus conditions have long been established. Interim Guidelines for Shortage conditions were established in 2007. The Interim Guidelines will be in effect for operating decisions through 2026. These guidelines direct the Annual Operating Plan, which determines the water supply available to the Lower Basin water users and annual releases from Lake Powell. The four operational tiers for Lake Powell and Lake Mead and releases from Lake Powell are as follows (Reclamation 2008):

- Equalization Tier – greater than 9.5 MAF
- Upper Level Balancing Tier – between 7.48 and 9.5 MAF
- Mid-Elevation Tier – 7.48 MAF
- Lower Elevation Balancing Tier - between 7.48 and 9.5 MAF

Shorter-term Glen Canyon Dam release constraints are currently based on the 1996 Glen Canyon ROD, which was developed consistent with the Grand Canyon Protection Act of 1992 (Reclamation 2007). These constraints are summarized in Table 3-2.

[1] The spelling of the gage location and compact point is different

Table 3-2
Glen Canyon Dam Release Constraints

Parameter	Release (cfs)	Conditions
Maximum Flow [1]	25,000	
Minimum Flow	5,000	Nighttime
	8,000	7 am to 7 pm
Ascending Ramp Rate	4,000	Per hour
Descending	1,500	Per hour
Daily fluctuations [2]	5,000 to 8,000	

Notes:
[1] Non-emergency, non-extreme hydrological conditions
[2] Daily fluctuation limit is 5,000 cfs for months with release volumes less than 0.6 maf; 6,000 cfs for monthly release volumes of 0.6 MAF to 0.8 maf; and 8,000 cfs for monthly volumes over 0.8 maf.
Source: Reclamation 2007

Figure 3-2 summarizes daily streamflow for the Colorado River at Lees Ferry gage. This gage is located upstream of the Lee Ferry Compact Point with a tributary, Paria River, entering the Colorado River in between (Figure 3-3). The hydrograph of the Colorado River changed drastically after Lake Powell began to fill. Glen Canyon Dam operation has reduced peak flows, increased minimum flows, and increased the diurnal range in discharge because of hydropower operations. Figure 3-4 shows the daily mean and daily range of flows over the calendar year since 1970.

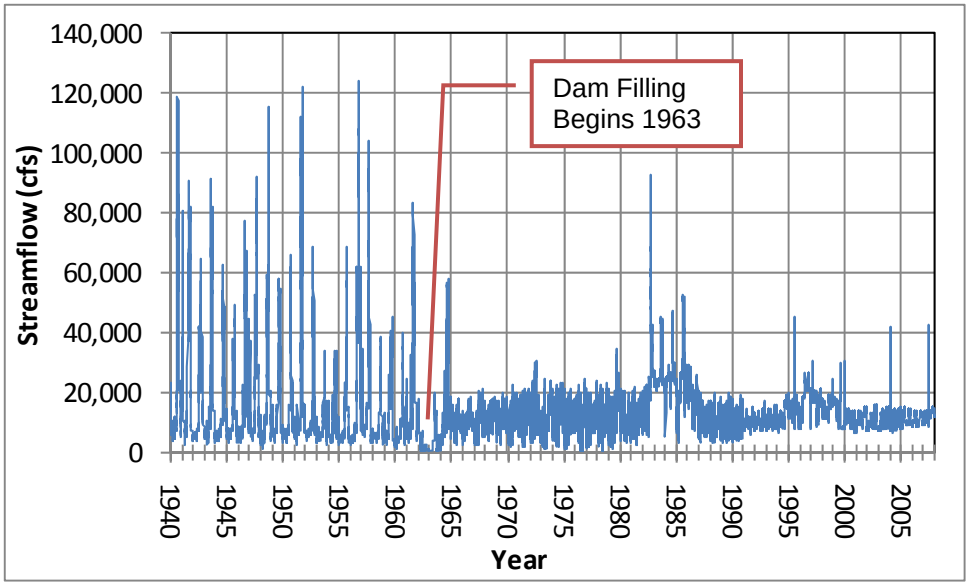
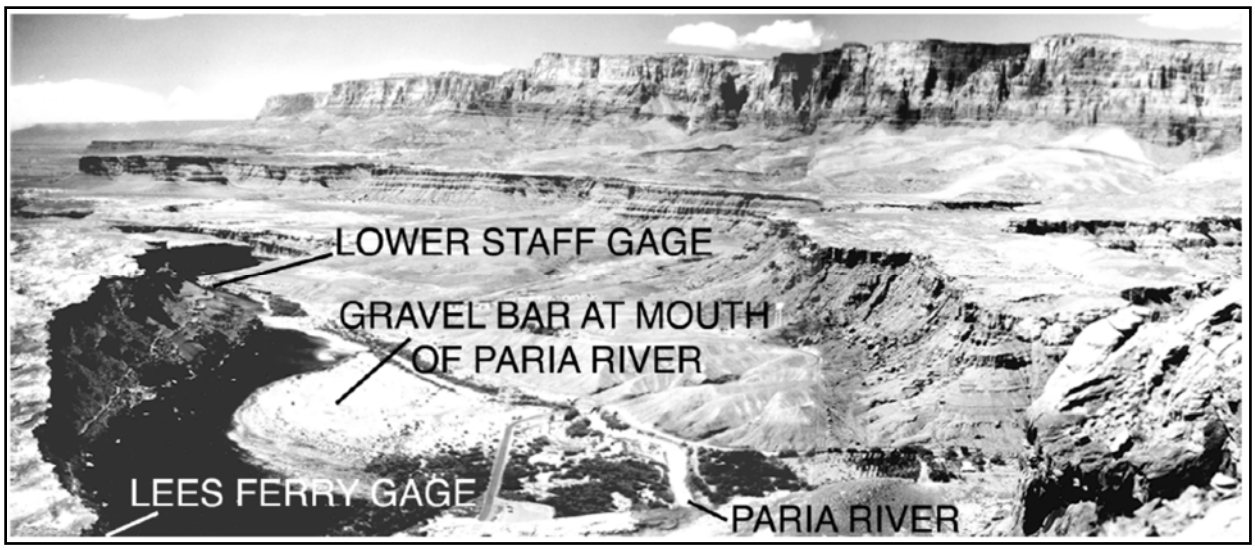


Figure 3-2
Colorado River at Lees Ferry Daily Flows



Source: Topping et al (2003)

Figure 3-3
Colorado River at Lees Ferry Facing Downstream (1995), Flow of 9,500 cfs

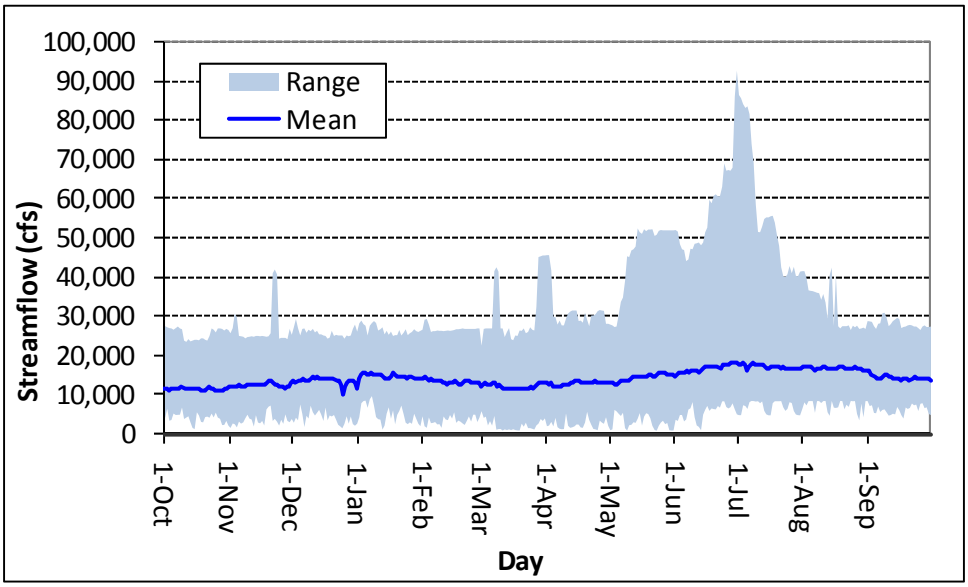


Figure 3-4
Colorado River at Lees Ferry Daily Mean and Range of Flow (1970-2008)

Figure 3-5 summarizes annual mean water year flows. Since 1968, the annual mean has equaled or exceeded 11,000 cfs. Figure 3-6 depicts the flow exceedance (or duration) curve, limited to 1970 to 2008 to capture flows after the filling of Lake Powell. The curve shows a median flow of the Colorado River at Lees Ferry of about 13,000 cfs for this period.

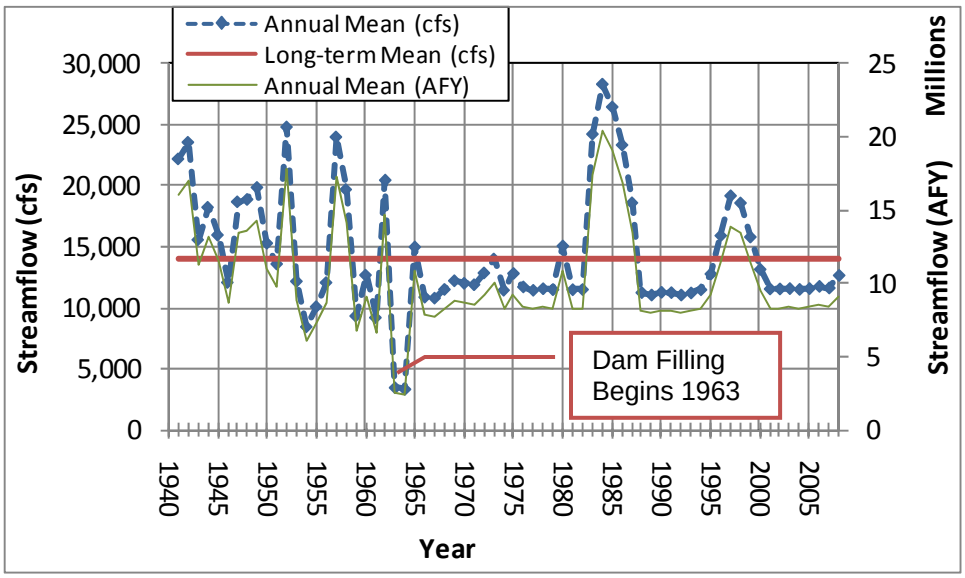


Figure 3-5
Colorado River at Lees Ferry Annual Mean Flows

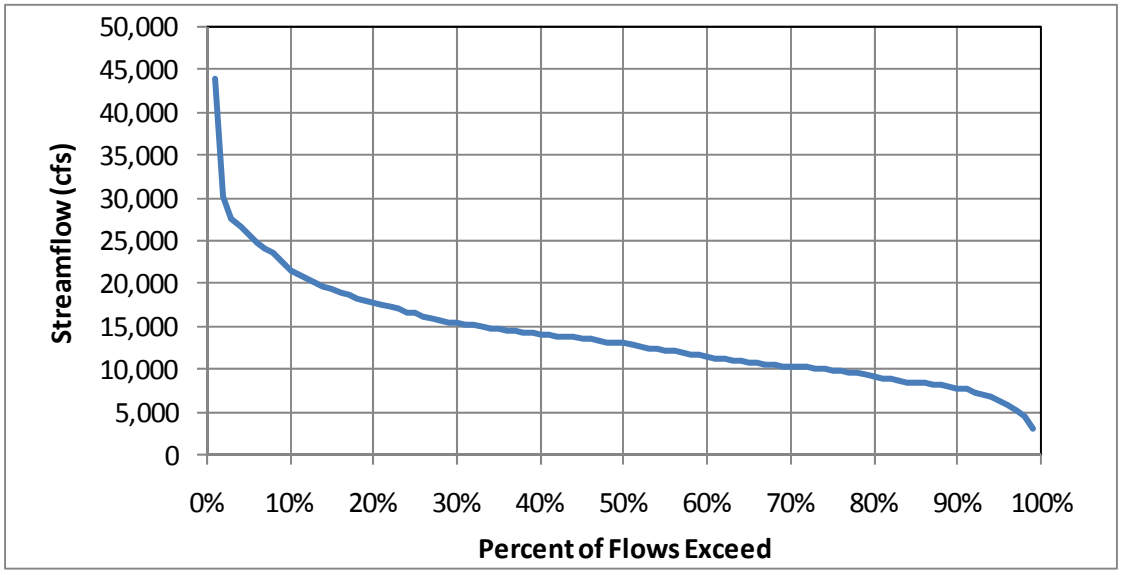


Figure 3-6
Colorado River at Lees Ferry Flow Exceedance (1970 – 2008)

Flows in the Colorado River at Lees Ferry can vary considerably from year to year. Figure 3-7 and Figure 3-8 depict historical flows for a year with the minimum flow, 2004, and a year with higher flows, 1998. Depending on the month, Surplus years can result in sustained flows more than 10,000 cfs higher than flows occurring under Shortage or Normal conditions. Figure 3-9 depicts the stage-discharge rating curve for the Colorado River at Lees Ferry gage.

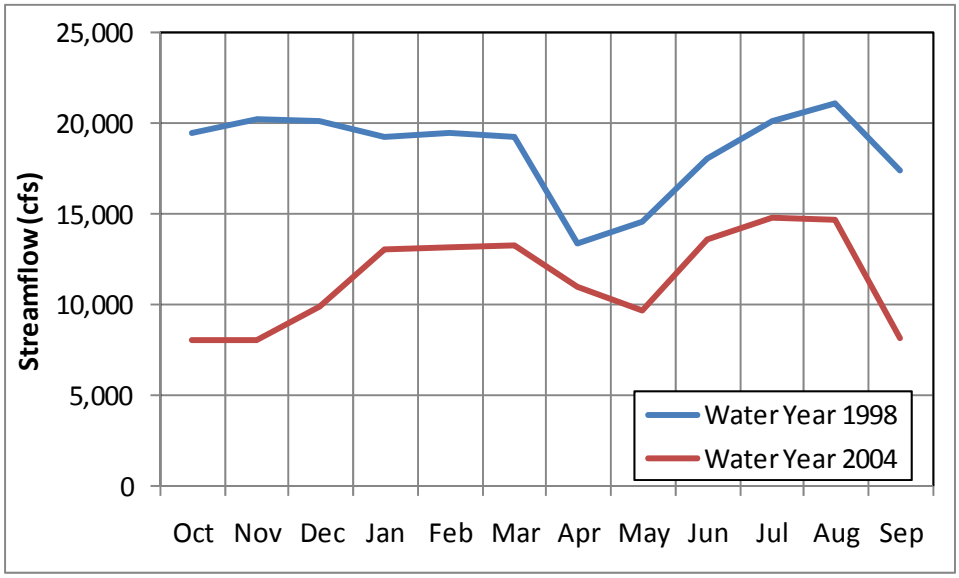


Figure 3-7
Colorado River at Lees Ferry Monthly Mean Flows (Wet and Dry Year)

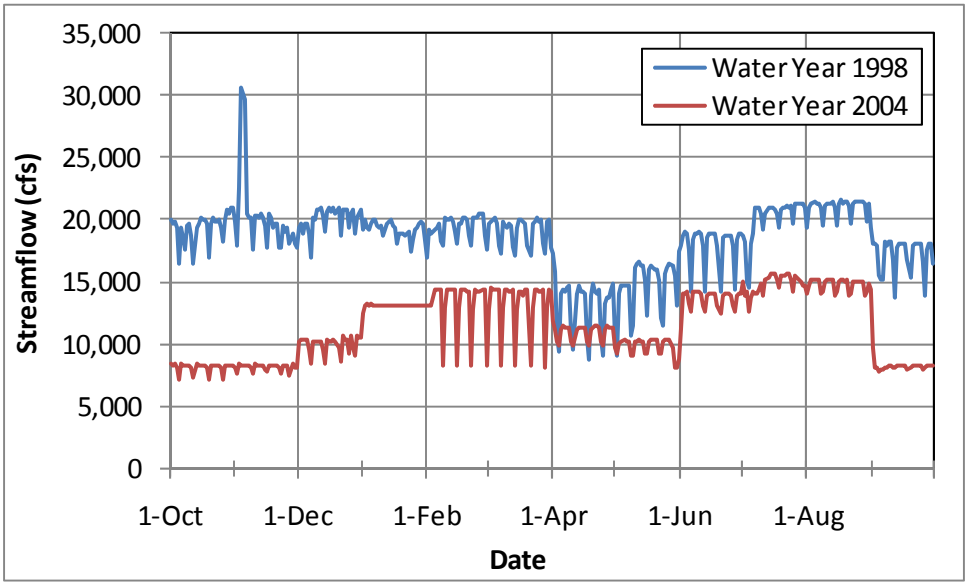


Figure 3-8
Colorado River at Lees Ferry Daily Flows (Wet and Dry Year)

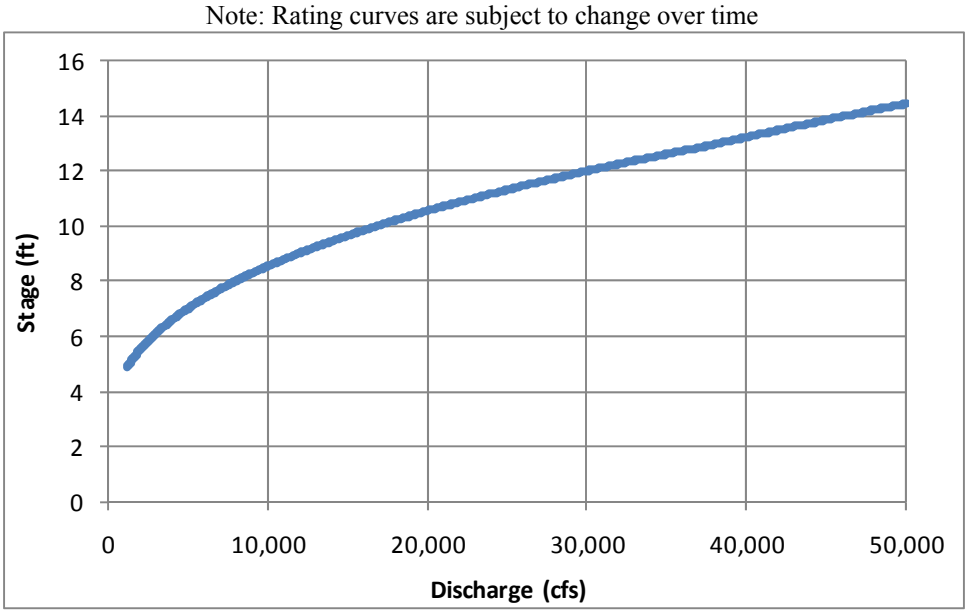


Figure 3-9
Colorado River at Lees Ferry – Stage Discharge Rating Curve

3.2.2 Virgin River Drainages

The Virgin River lies within the lower Colorado River basin. The Virgin River basin is bound by mountains with elevations reaching over 10,000 feet with the Bull Valley and Beaver Dam mountains to the west, the Harmony Mountains to the north, the Glendale Bench and Block Mesas to the east. The lowest elevation is about 2,500 feet where the Virgin River crosses the state line with Arizona. The majority of Virgin River streamflow originates as snow with runoff resulting in high flows from March through May. The greatest water producing area is the headwaters of the North Fork of the Virgin River (UDWRe 1993).
In the Virgin River watershed in Utah, most of the public water supply is provided through the WCWCD. Figure 3-10 depicts the WCWCD service area along with the cities and surface water features.
Figure 3-11 is a schematic of the Virgin River basin in Utah. The data is valid through 1990 and there have been some changes in river operation in that time including the construction of Sand Hollow Reservoir, although the major 1890 priority irrigation diversions have been unchanged. Therefore, the volumes shown in the figure, particularly downstream of the diversion to the reservoirs, do not necessarily represent current conditions. However, it provides a general idea of the magnitude of streamflow in the Virgin River system.

Central Iron County Water Conservancy District

Washington County Water Conservancy District

Kane County Water Conservancy District

Iron County

Washington County

Kane County

Utah

Arizona

Cedar City

Paiute Indian Reservation

Irontown

Enterprise

Enterprise WWTP

Kanarraville

New Harmony

New Harmony WWTP

Moody Wash

Beaver Dam Wash East Fork

Pinto Creek

Rock Drawl

Deep Creek

North Fork Virgin River

Blue Creek

Left Fork North Creek

Zion National Park

Toquerville

Leeds

La Verkin

Virgin

Hurricane

Quail Creek Reservoir

Ash Creek

La Verkin Creek

North Creek

Springdale

Rockville

Rockville WWTP

Glendale

Orderville

Long Valley/Orderville WWTP

East Fork Virgin River

Kanab Creek

Paiute Indian Reservation

Ivins

Santa Clara

Washington City

Virgin River

Ash Creek Special Service District Sewage Lagoons

Sand Hollow Reservoir

Proposed Warner Valley Reservoir

Gould Wash

Saint George

Saint George WWTP

Fort Pearce Wash

Hildale WWTP

Hildale City

Kanab

Kanab Sewage Lagoons

Beaver Dam Wash

Santa Clara River

Project Pump Station
Project Regulating Tank
Project Hydro Station
Project Transmission Line
Existing Transmission Line

Water Conveyance System
Hydro System - South Alignment Alternative
Hydro System - Highway Alignment Alternative
Kane County Pipeline System
Cedar Valley Pipeline System

Interstate
US Highway
ST Highway
Hwy
Major Road

Water Conservancy Districts
State Boundaries
Hurricane Cliffs Forebay/Afterbay
Lakes/Reservoirs
Major Rivers & Streams

National Park/Monument
Tribal Lands
County Boundaries
Cities
Wastewater Treatment Plants

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

N

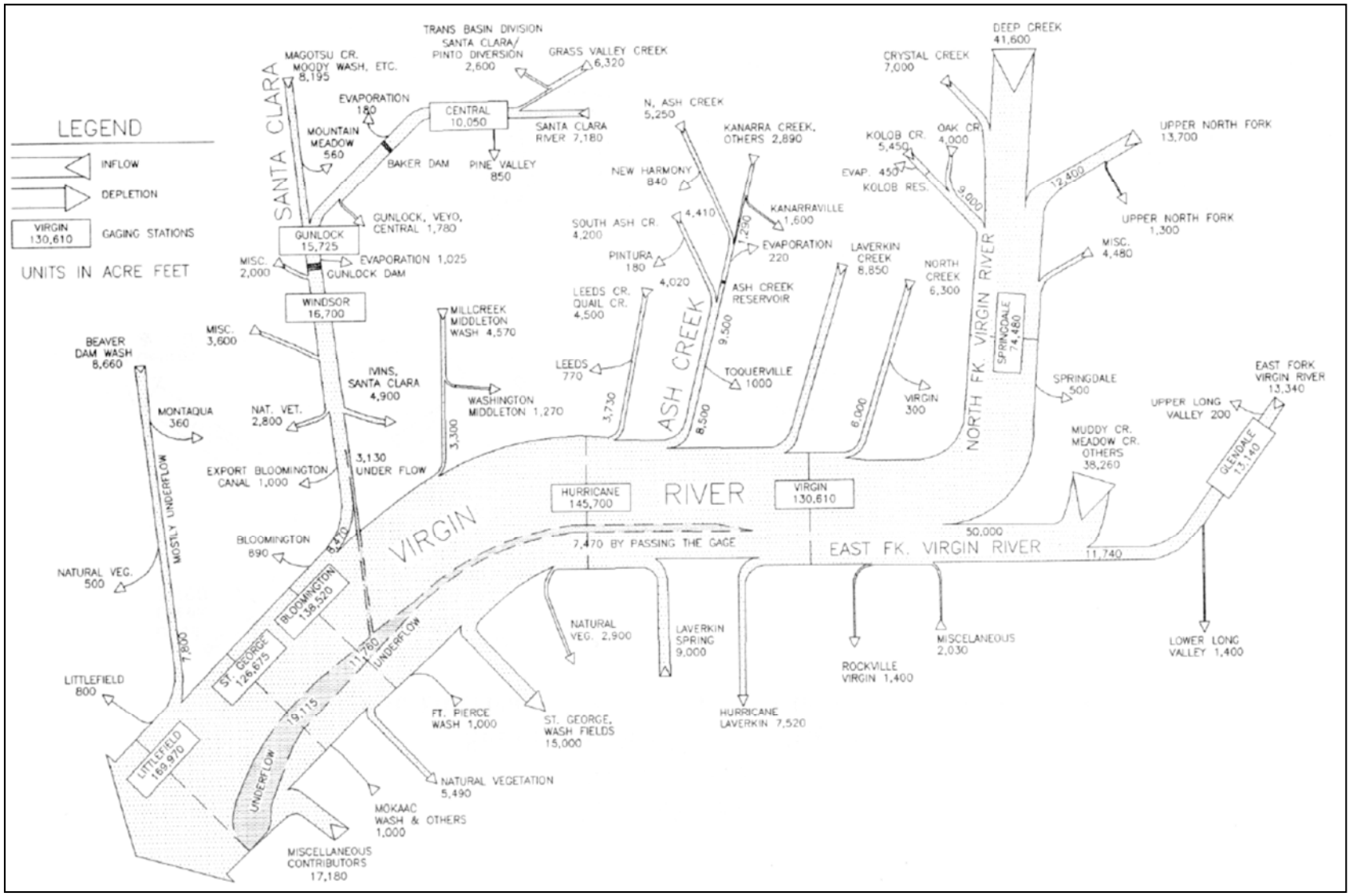
0 2 4 8 12 Miles

Lake Powell Pipeline Project

Spatial Reference: UTM Zone 12N, NAD-83

UDWR **Figure 3-10** MWH

Washington County Water Conservancy District



Source: Modified From UDWRe (1993), flow numbers do not represent current conditions

Figure 3-11
Virgin River System in Utah – Streamflow and Depletion Chart (1941-1990)

Historical streamflows are summarized at the following locations in the Virgin River Basin:

- Virgin River at Virgin, UT
- Virgin River at St. George, UT
- Virgin River at Littlefield, AZ
- Santa Clara River at St. George

Figure 3-12 demonstrates the Virgin River is typically a gaining stream from Virgin, UT to Littlefield, AZ in fall and early winter months. From January through August, flows decrease through St. George and increase again downstream of the state line. Historical canal company diversions dry-dammed the Virgin River immediately downstream of the current Quail Creek Diversion and at the Washington Fields Diversion.

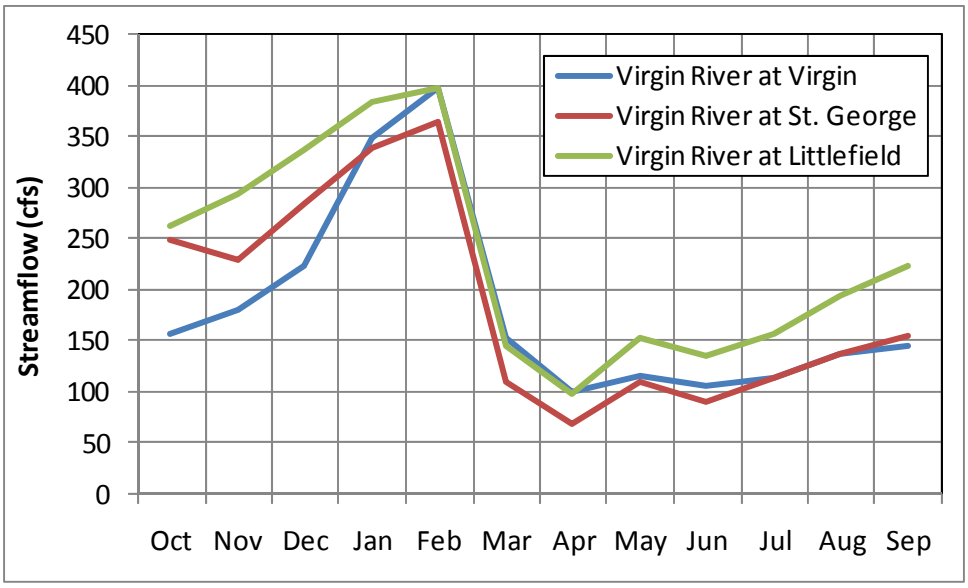


Figure 3-12
Monthly Streamflows in the Virgin River from Virgin, UT to Littlefield, AZ

WCWCD operates its system in accordance with the priority water rights of the three major historical diversions on the Virgin River, so that the lesser of 86 cfs or the natural flow in the river reaches the Washington Fields Diversion (UDWRe 1993).

3.2.2.1 Virgin River at Virgin, UT

This gage location is upstream of any major diversions and upstream of areas that would receive LPP Project water. Therefore, it is upstream from the potential impacts of return flows under the South Alternative (Proposed Action). Figure 3-13 depicts the historical daily flows for the Virgin River. Figure 3-14 shows the daily mean and daily range of flows over the calendar year based on the period of record. Figure 3-15 shows the flow exceedance curve for the gage. The 90 percent exceedance value is 68 cfs (i.e. 90 percent of flows exceed 68 cfs), while the 10 percent exceedance value is 320 cfs. The median flow, which corresponds to the 50 percent exceedance level, is 122 cfs.

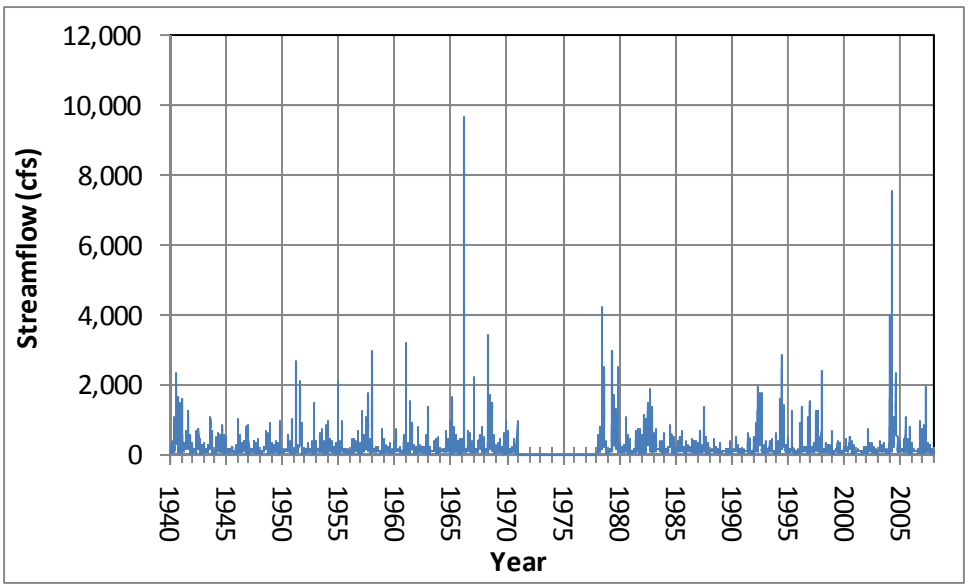


Figure 3-13
Virgin River at Virgin, Daily Flows

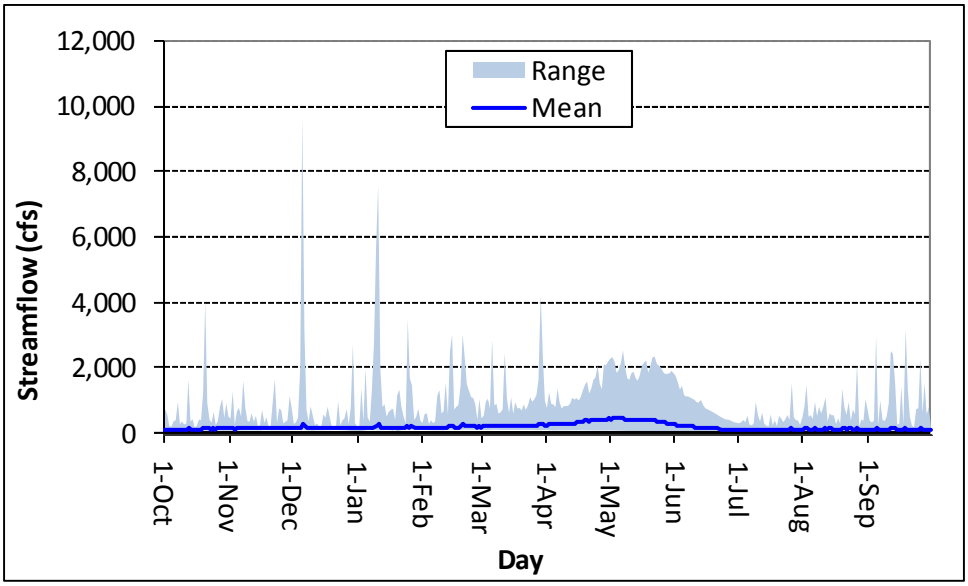


Figure 3-14
Virgin River at Virgin, Daily Mean and Range of Flow

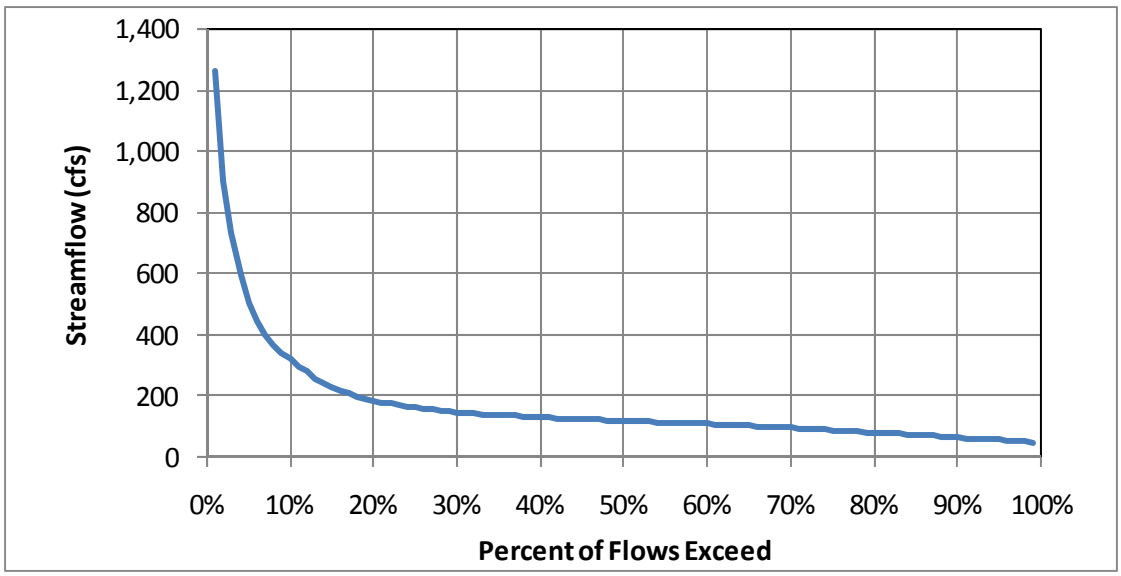


Figure 3-15
Virgin River at Virgin, Daily Flow Exceedance

Figure 3-16 shows monthly mean flows for the Virgin River at Virgin. The flows show a distinct seasonal pattern with peak flows in May. Monthly mean and annual mean flows do not show the variation that can occur in the Virgin River on a daily basis. Large fluctuations in Virgin River daily and weekly flows reflect the large percentage of the drainage basin comprised of impervious area (exposed bedrock) and relatively short time of concentration during precipitation runoff events. Figure 3-17 shows the variation in streamflow from year to year. The long term mean annual streamflow is 182 cfs. Annual streamflow is usually greater than 100 cfs and in high flow years can exceed 300 to 400 cfs. Figure 3-18 shows the stage discharge rating curve for the Virgin River at Virgin.

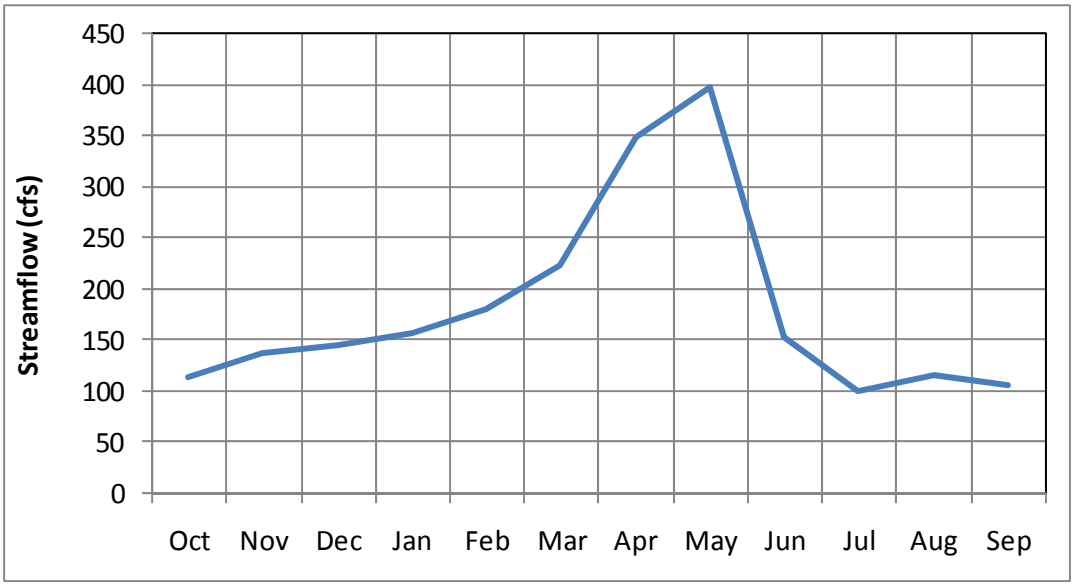


Figure 3-16
Virgin River at Virgin, Monthly Mean Flows

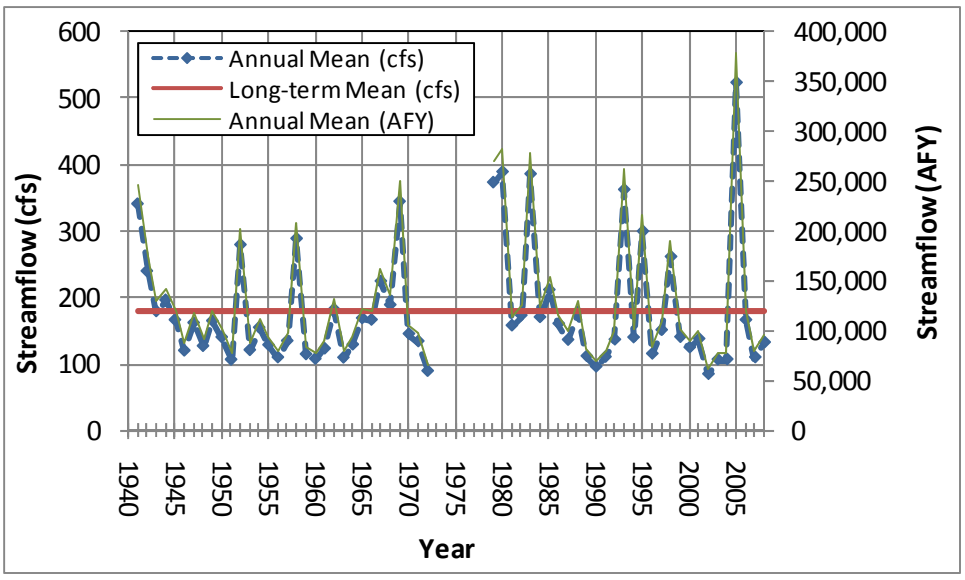


Figure 3-17
Virgin River at Virgin, Annual Mean Flows

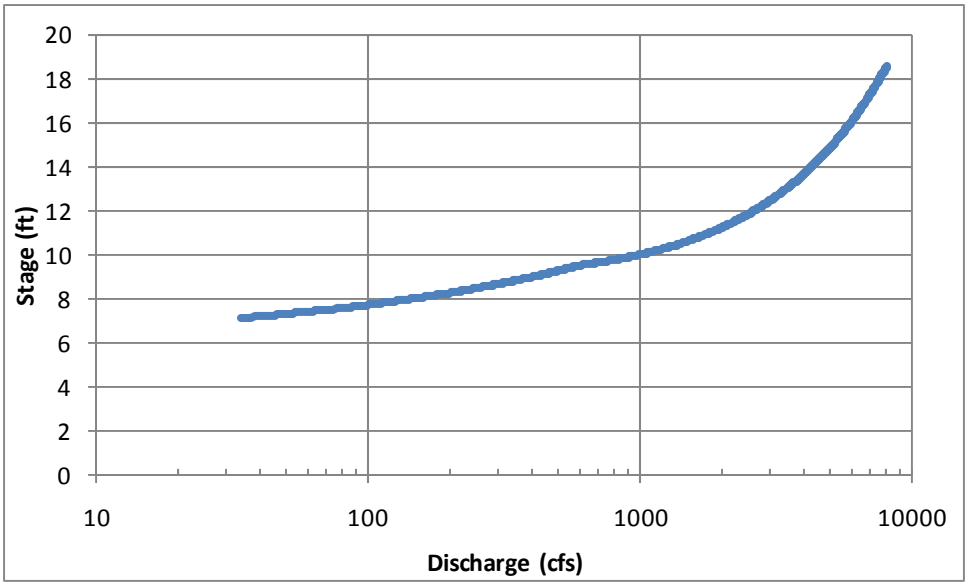


Figure 3-18
Virgin River at Virgin – Stage Discharge Rating Curve
Note: Rating curves are subject to change over time

3.2.2.2 Virgin River Near St. George, UT

The St. George gage is located downstream of town where the Virgin River enters a canyon section. Figure 3-19 is a USGS photograph of the gage location. There are several major inflows and diversions from the Virgin River between the Virgin and St. George gages including:

- Diversion to Quail Creek Reservoir, Hurricane and LaVerkin
- Diversion to St. George, Washington Fields
- Inflow from Santa Clara River, Ash Creek, LaVerkin Creek, LaVerkin Spring
- Return flows from St. George wastewater treatment facility

Figure 3-19
Virgin River Near St. George Gage Location

As shown in the daily streamflow chart in Figure 3-20, the period of record for this gage is relatively short. Figure 3-21 shows the daily mean and daily range of flows over the calendar year based on the period of record. Figure 3-22 shows the flow exceedance curve for the Virgin River for the period of 1992 through 2006. The 90 percent exceedance value is 26 cfs, while the 10 percent exceedance value is 460 cfs. The median flow is 110 cfs.

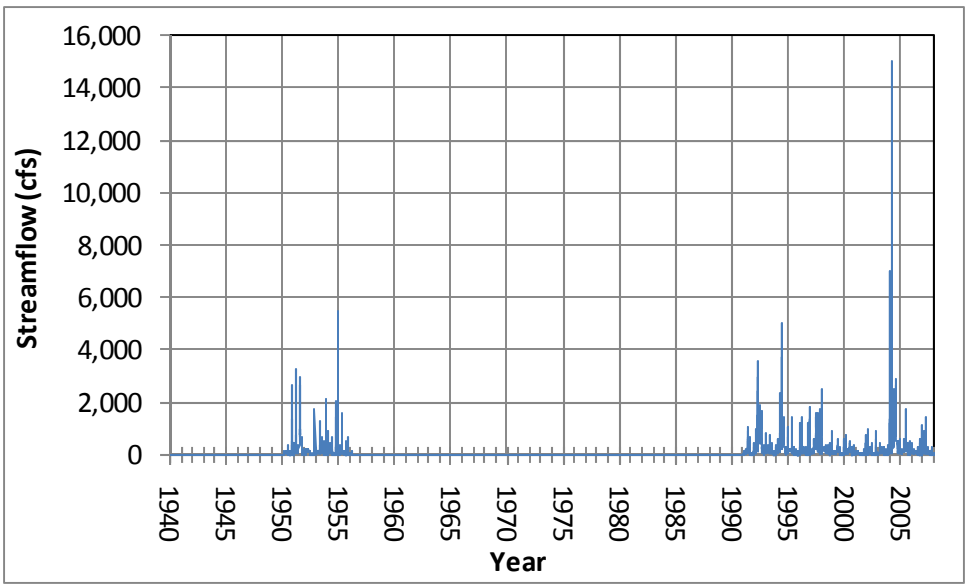


Figure 3-20
Virgin River Near St. George, Daily Flows

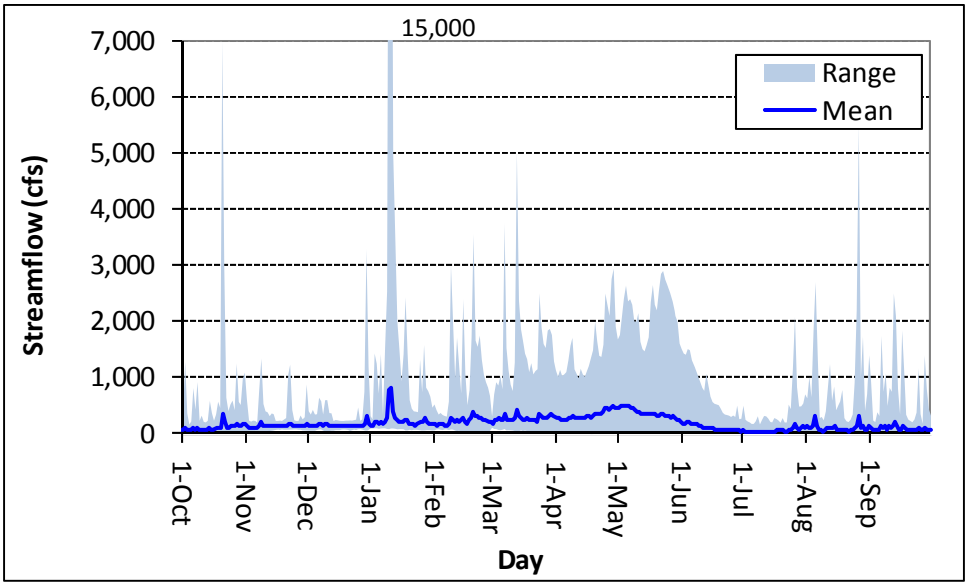


Figure 3-21
Virgin River Near St. George, Daily Mean and Range of Flow

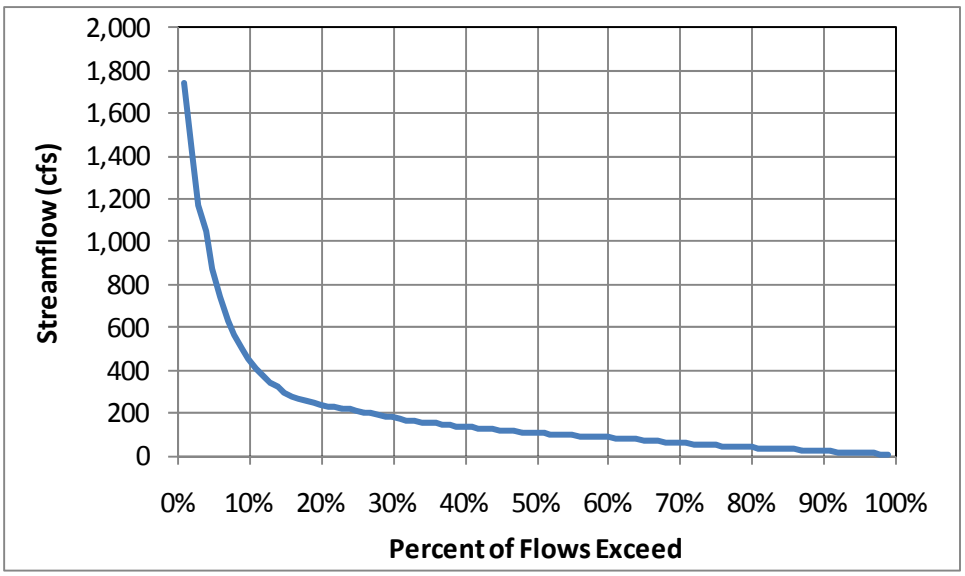


Figure 3-22
Virgin River Near St. George Flow Exceedance (1992 – 2006)

Figure 3-23 depicts monthly mean flows for the Virgin River at the St. George gage for the period of 1992 through 2006. Compared to the upstream location, peak seasonal flows occur in late spring with low flows in summer. Figure 3-24 shows the historical annual mean flows in the Virgin River. The long term annual mean was not calculated due to the short period of record. Figure 3-25 depicts the stage-discharge curve for the gage.

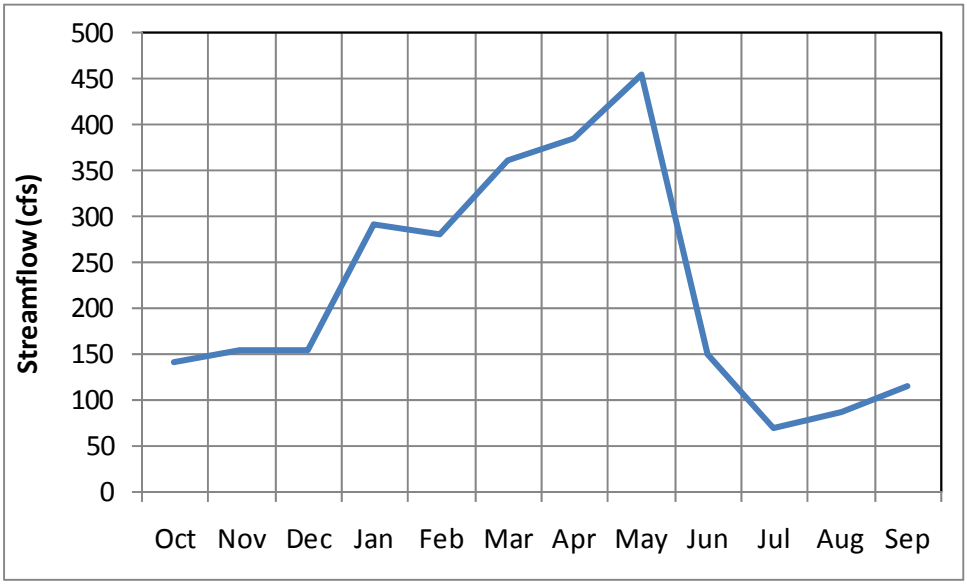


Figure 3-23
Virgin River Near St. George Monthly Mean Flows (1992 – 2006)

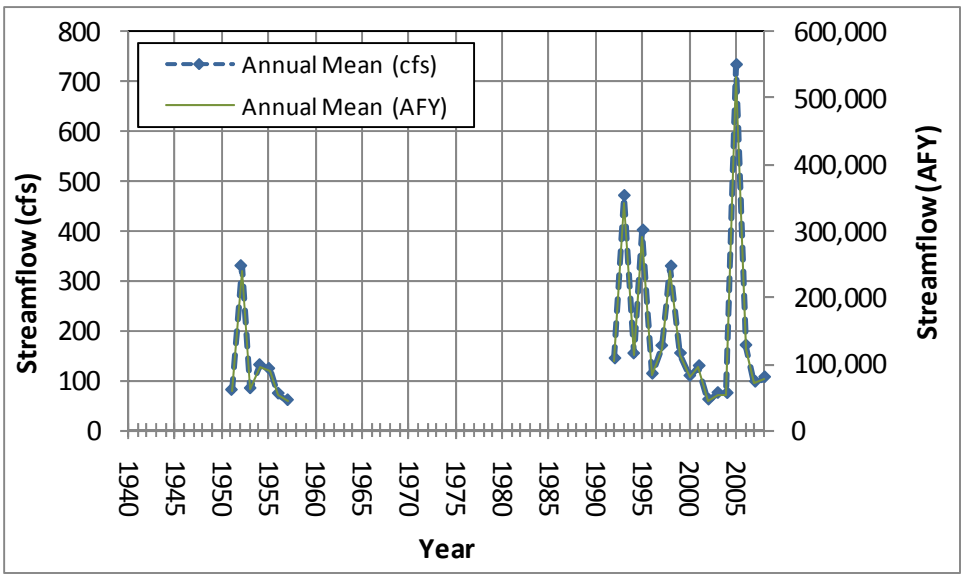


Figure 3-24
Virgin River Near St. George Annual Mean Flows

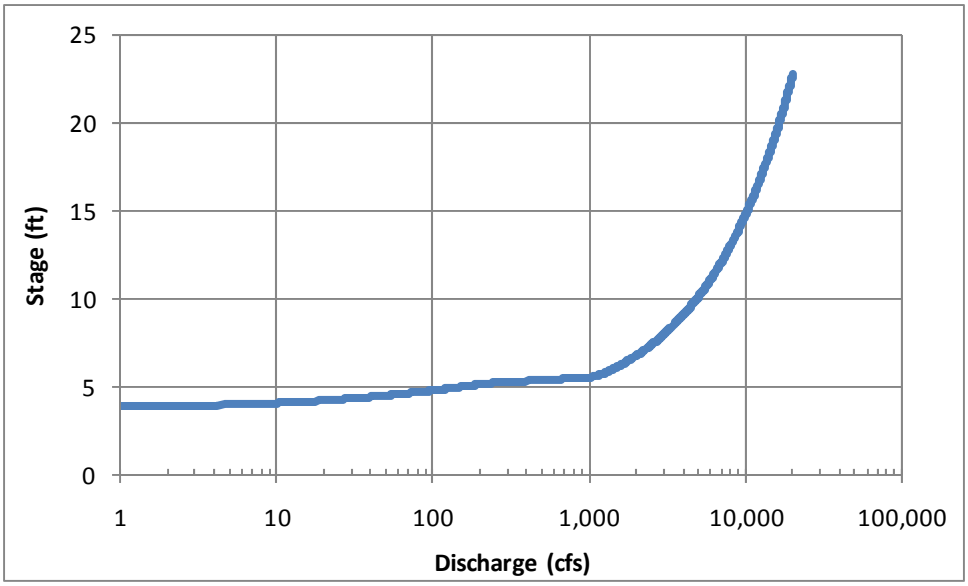


Figure 3-25
Virgin River Near St. George – Stage Discharge Rating Curve
Note: Rating curves are subject to change over time

3.2.2.3 Virgin River at Littlefield, AZ

The Virgin River at Littlefield, Arizona gage is located a few miles downstream of the state line. Figure 3-26 depicts historical daily flows. Figure 3-27 shows the daily mean and daily range of flows over the calendar year based on the period of record. Figure 3-28 shows the flow exceedance curve. The 90 percent exceedance value is 62 cfs, while the 10 percent exceedance value is 401 cfs. The median flow is 145 cfs.

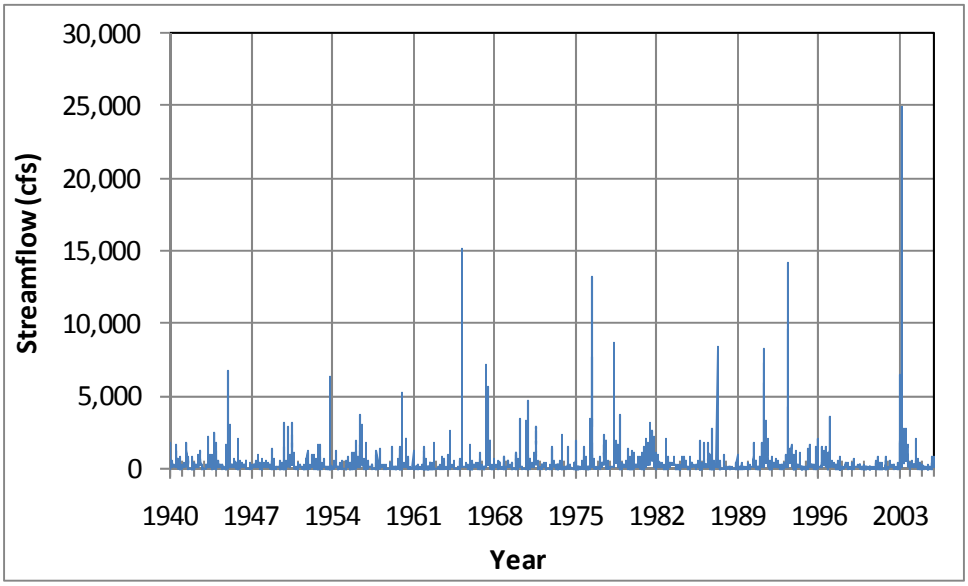


Figure 3-26
Virgin River at Littlefield, Daily Flows

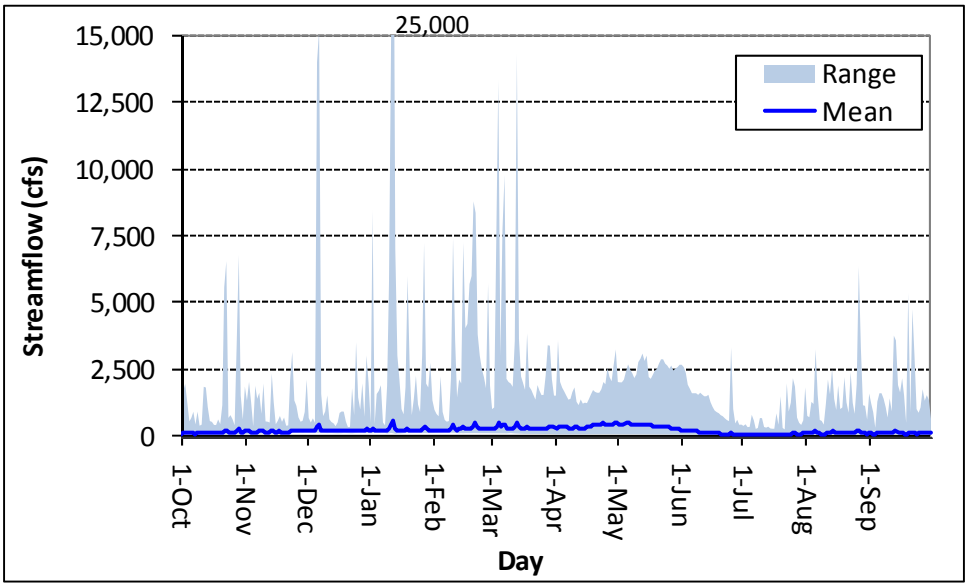


Figure 3-27
Virgin River at Littlefield, Daily Mean and Range of Flow

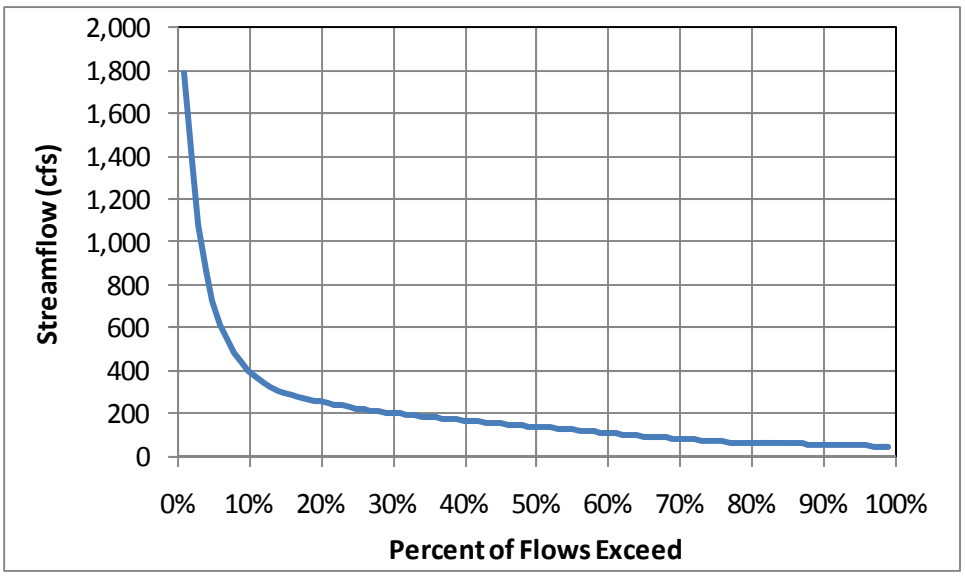


Figure 3-28
Virgin River at Littlefield, Flow Exceedance

Figure 3-29 shows monthly average flows for the Virgin River at Littlefield. Similar to the upstream locations, peak flows occur in late summer with low flows in the fall. Figure 3-30 depicts the historical annual mean flows. The long term mean is 235 cfs. Figure 3-31 depicts the stage-discharge curve for the gage.

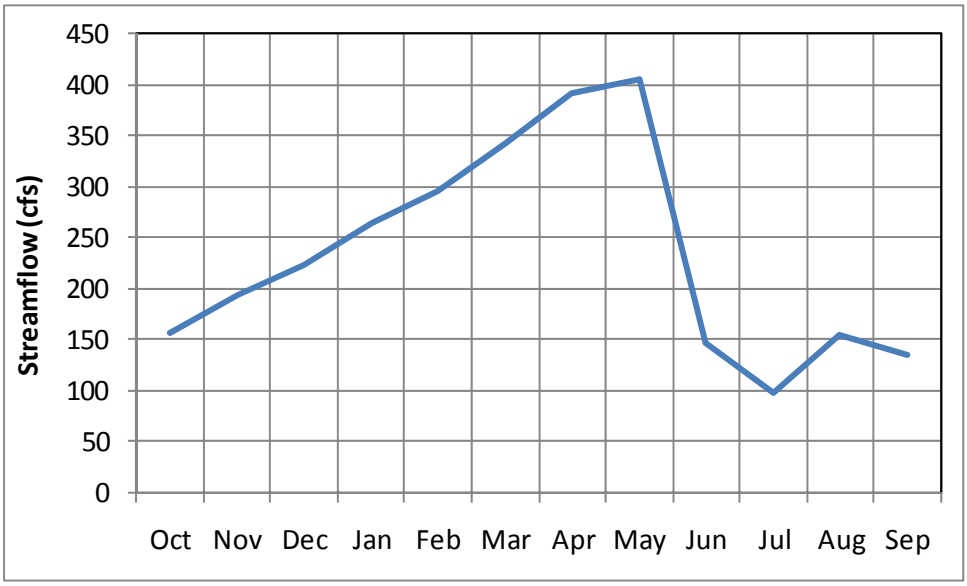


Figure 3-29
Virgin River at Littlefield, Monthly Mean Flows

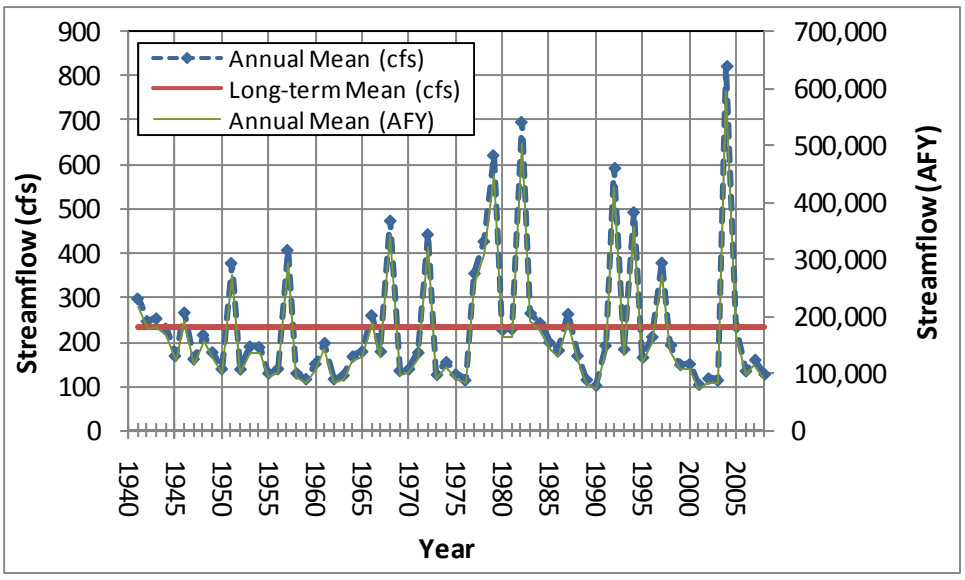


Figure 3-30
Virgin River at Littlefield, Annual Mean Flows

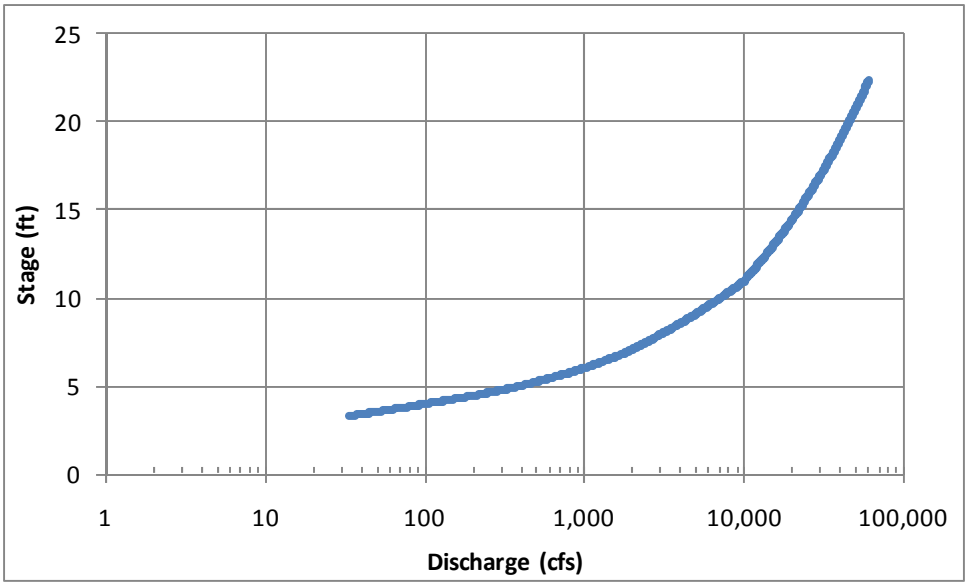


Figure 3-31
Virgin River at Littlefield – Stage Discharge Rating Curve
Note: Rating curves are subject to change over time

3.2.2.4 Santa Clara River at St. George

The Santa Clara River originates in the Pine Valley Mountain Wilderness north of St. George. This perennial stream flows though several communities including Ivins and Santa Clara before its confluence with the Virgin River at the southern end of St. George. The Santa Clara River at St. George gage is located about a mile upstream of the confluence with the Virgin River. The flow of the Santa Clara River is regulated by an upstream reservoir and irrigation diversions. Figure 3-32 shows the daily historical

flows in the Santa Clara River. There is a gap in the streamflow record between 1956 and 1985. Figure 3-33 shows the daily mean and daily range of flows over the calendar year based on the period of record. Figure 3-34 shows the flow exceedance curve. The 90 percent exceedance value is 1 cfs, while the 10 percent exceedance value is 27 cfs. The median flow is 4 cfs.

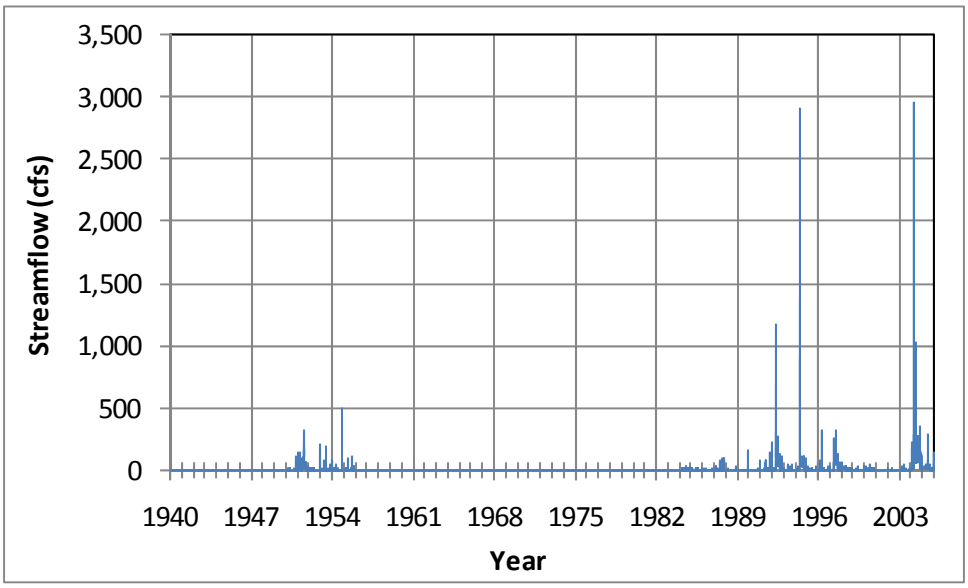


Figure 3-32
Santa Clara River at St. George Daily Flows

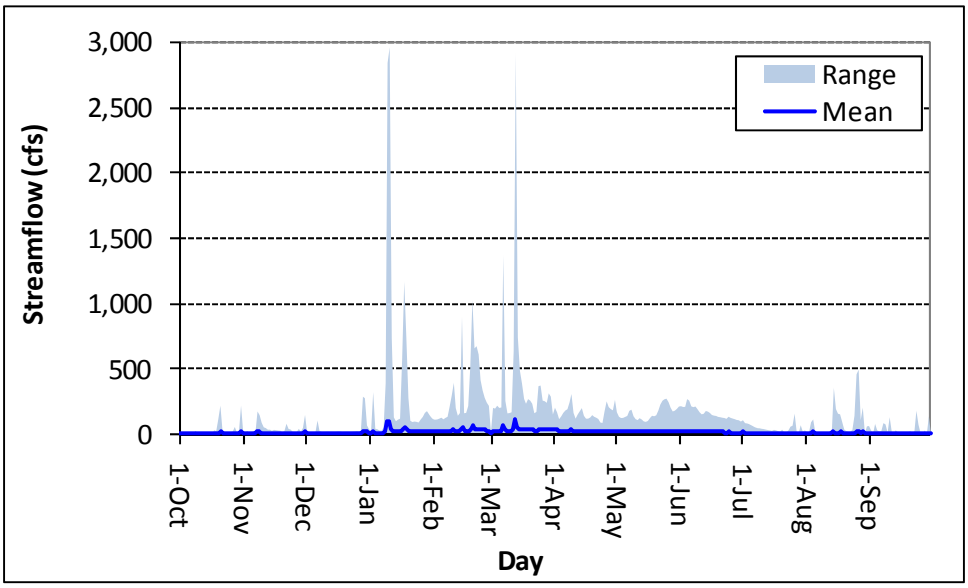


Figure 3-33
Santa Clara River at St. George Daily Mean and Range of Flow

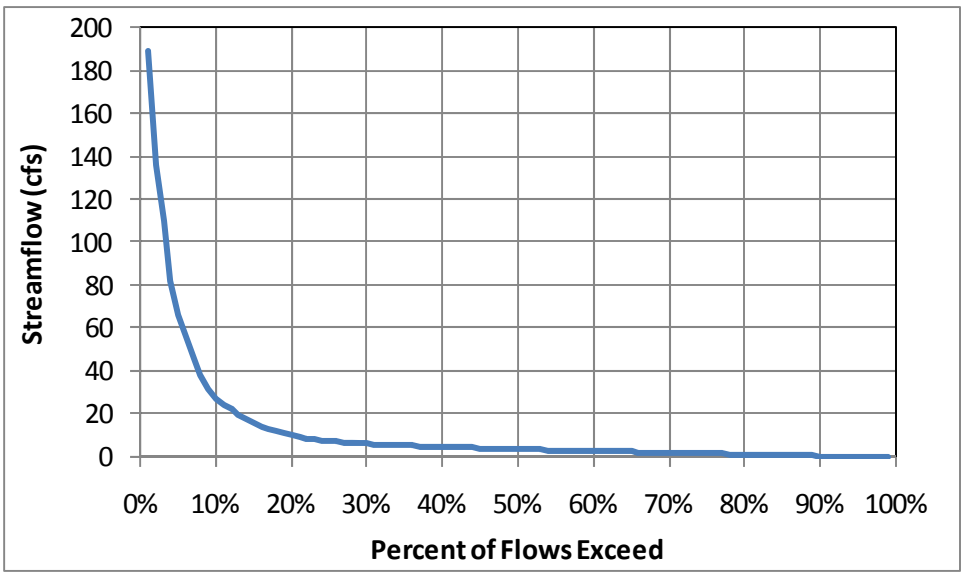


Figure 3-34
Santa Clara River at St. George Flow Exceedance

Figure 3-35 shows monthly mean flows for the Santa Clara River. Peak flows occur in spring with low flows occurring in late summer into fall. Figure 3-36 shows the historical annual mean streamflow; the long-term mean is not depicted due to the relatively short period of record. Figure 3-37 depicts the stage-discharge curve for the gage.

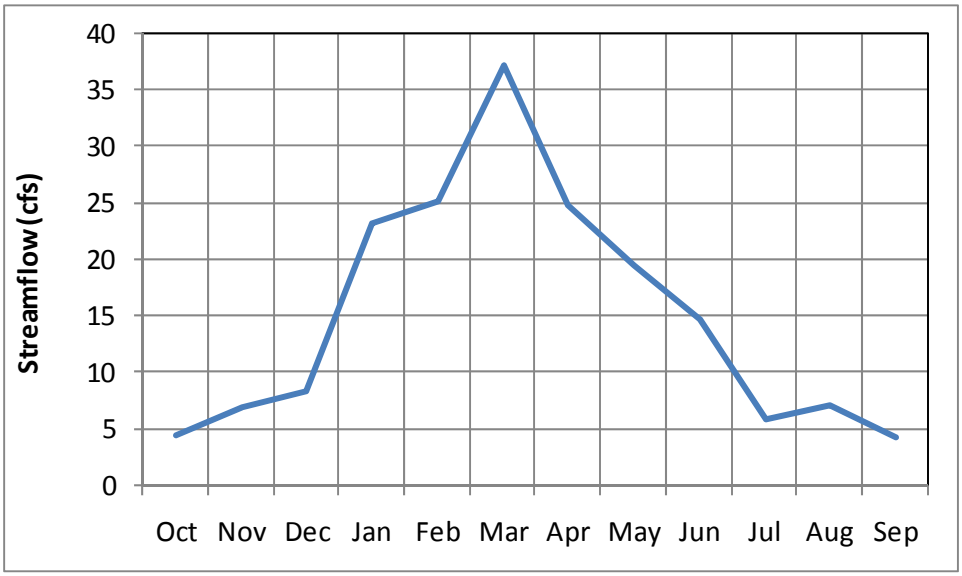


Figure 3-35
Santa Clara River at St. George Monthly Mean Flows

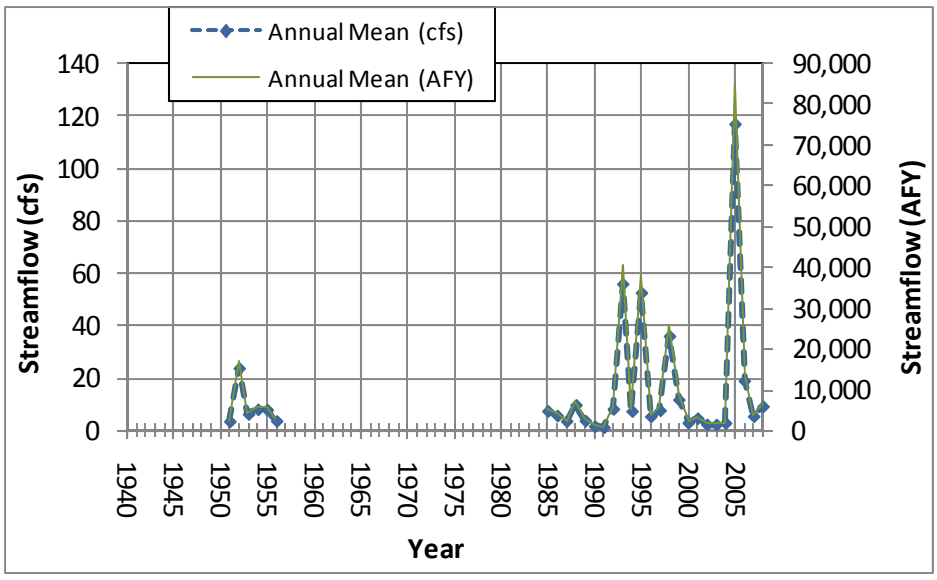


Figure 3-36
Santa Clara River at St. George Annual Mean Flows

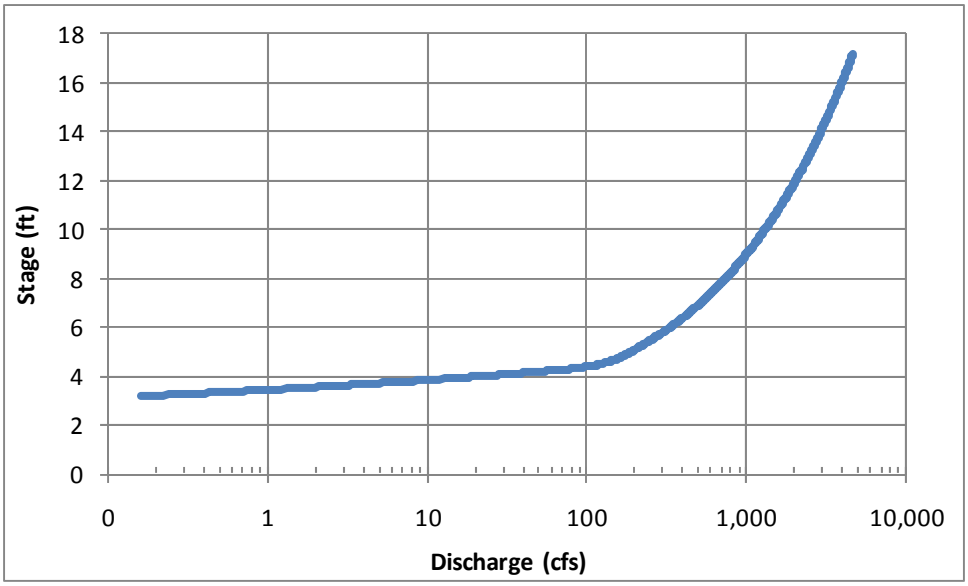


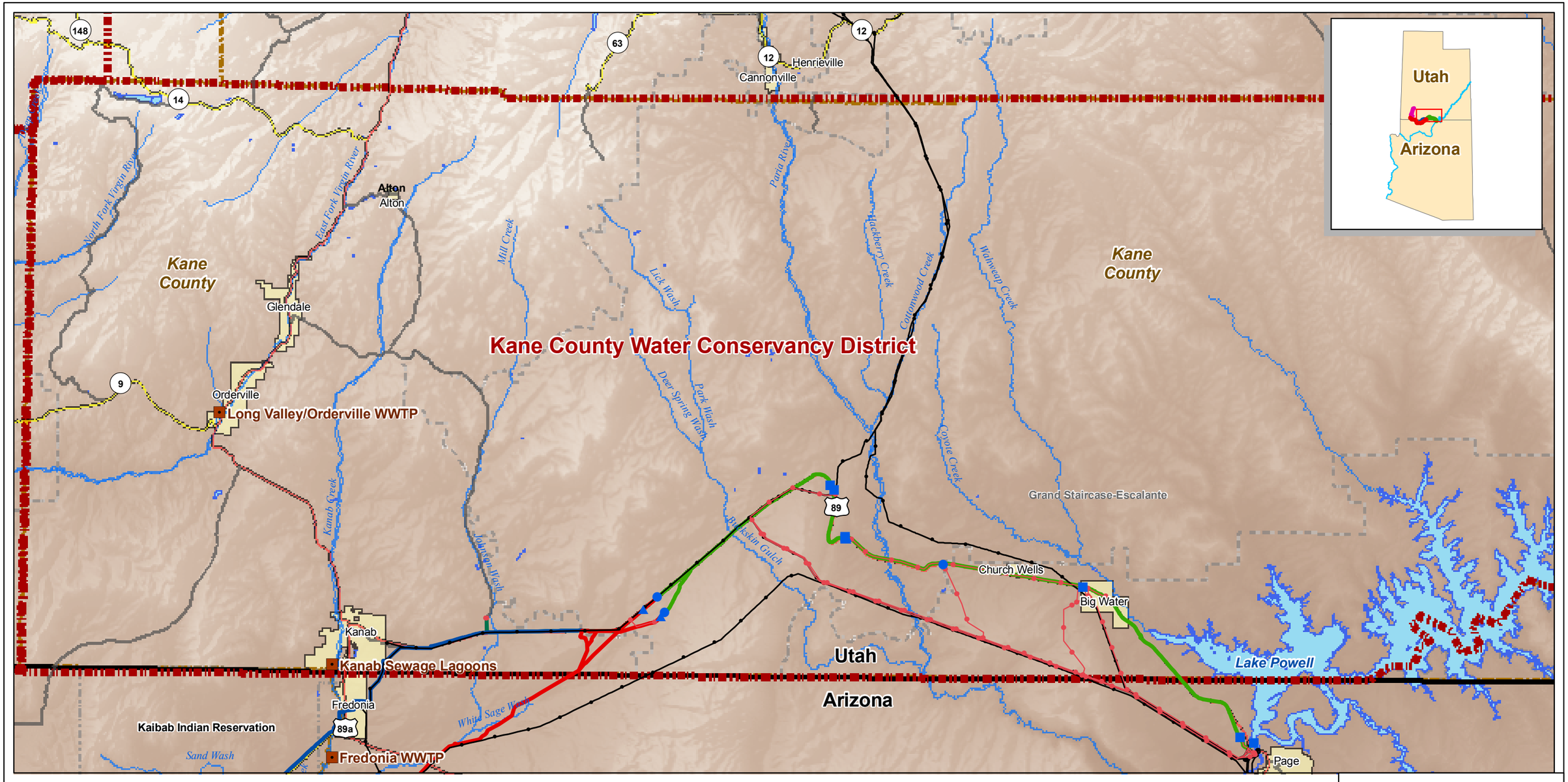
Figure 3-37
Santa Clara River at St. George – Stage Discharge Rating Curve
Note: Rating curves are subject to change over time

3.2.2.5 Other Potentially Affected Streams

Fort Pierce Wash could be affected by non-sewered return flows. This stream does not have an active stream gage within the study area.

3.2.3 Kane, Mohave and Coconino County Drainages

Figure 3-38 shows the KCWCD service area and project facilities within the area. The additional water supply to KCWCD could potentially affect return flows in Kanab Creek in Utah and in Arizona. In addition, the pipeline would cross several washes in Kane, Mohave, and Coconino counties with the crossing locations dependent on which alignment is selected. With the exception of Kanab Creek and the Paria River, all of the crossings would be of intermittent streams, as listed in Table 2-1.



- Wastewater Treatment Plants
- Project Pump Station
- Project Regulating Tank
- Project Hydro Station
- Project Transmission Line
- Existing Transmission Line
- Water Conveyance
- Hydro System - South Alignment Alternative
- Hydro System - Highway Alignment Alternative
- KCWCD Pipeline System
- Cedar Valley Pipeline
- Interstate
- US Highway
- ST Highway
- Hwy
- Major Road
- Water Conservancy Districts
- State Boundaries
- Hurricane Cliffs Forebay/Afterbay
- Lakes/Reservoirs
- Major Rivers & Streams
- National Park/Monument
- Tribal Lands
- County Boundaries
- Cities

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

N

0 2.5 5 10 15 Miles

Lake Powell Pipeline Project

Spatial Reference: UTM Zone 12N, NAD-83

UDWRe **Figure 3-38** MWH

Kane County Water Conservancy District

3.2.3.1 Kanab Creek

In southern Utah, Kanab Creek drains a narrow valley from north to south with peak elevations of 9,000 feet in the Dixie National Forest. Most of the watershed upstream of Kanab is undeveloped. The Kanab Creek near Kanab gage is located 3.5 miles north of Kanab at an elevation of 5,060 feet. Downstream of the gage, Kanab Creek is generally completely diverted at Kanab City.

Figure 3-39 shows the historical daily flows in Kanab Creek upstream of the Kanab diversion. Figure 3-40 shows the daily mean and daily range of flows over the calendar year based on the period of record. Figure 3-41 depicts the flow exceedance curve. The 90 percent exceedance value is 5 cfs, while the 10 percent exceedance value is 19 cfs. The median flow is 9 cfs.

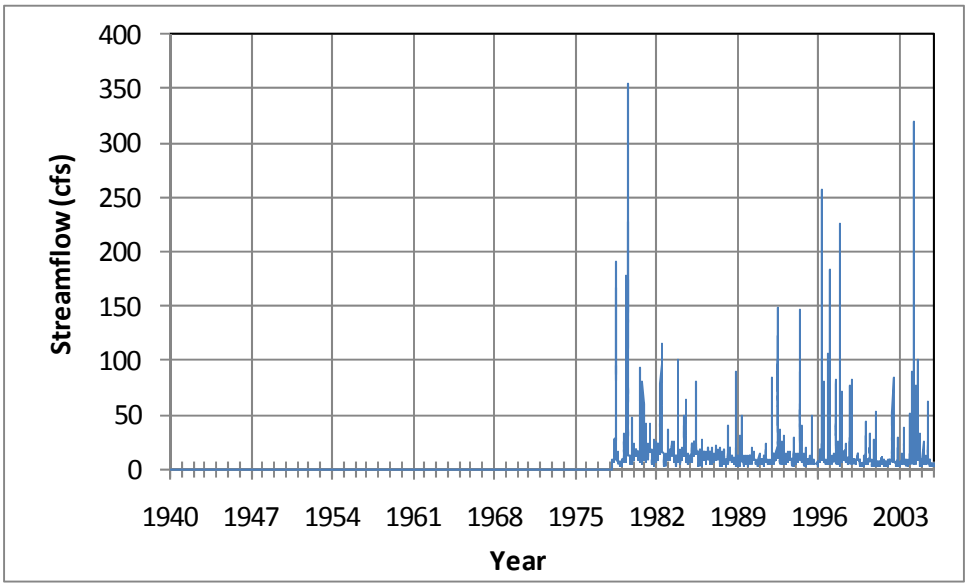


Figure 3-39
Kanab Creek Near Kanab, Daily Flows

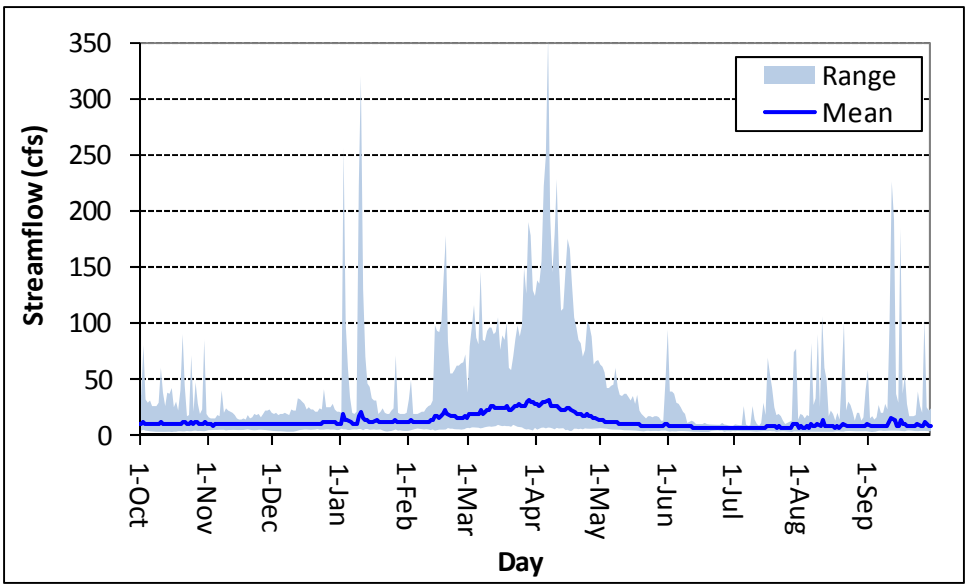


Figure 3-40
Kanab Creek Near Kanab, Daily Mean and Range of Flow

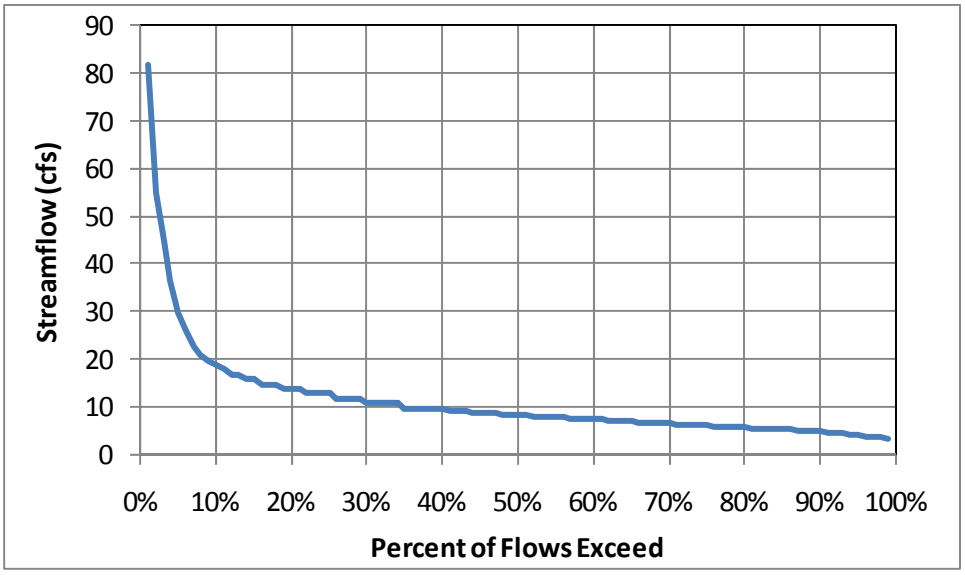


Figure 3-41
Kanab Creek Near Kanab, Flow Exceedance

Figure 3-42 shows the mean monthly flows for Kanab Creek. Peak flows occur in spring and low flows in summer. Figure 3-43 shows historical annual mean streamflows. The long-term mean annual streamflow is 12 cfs. Figure 3-44 depicts the stage-discharge curve for the gage.

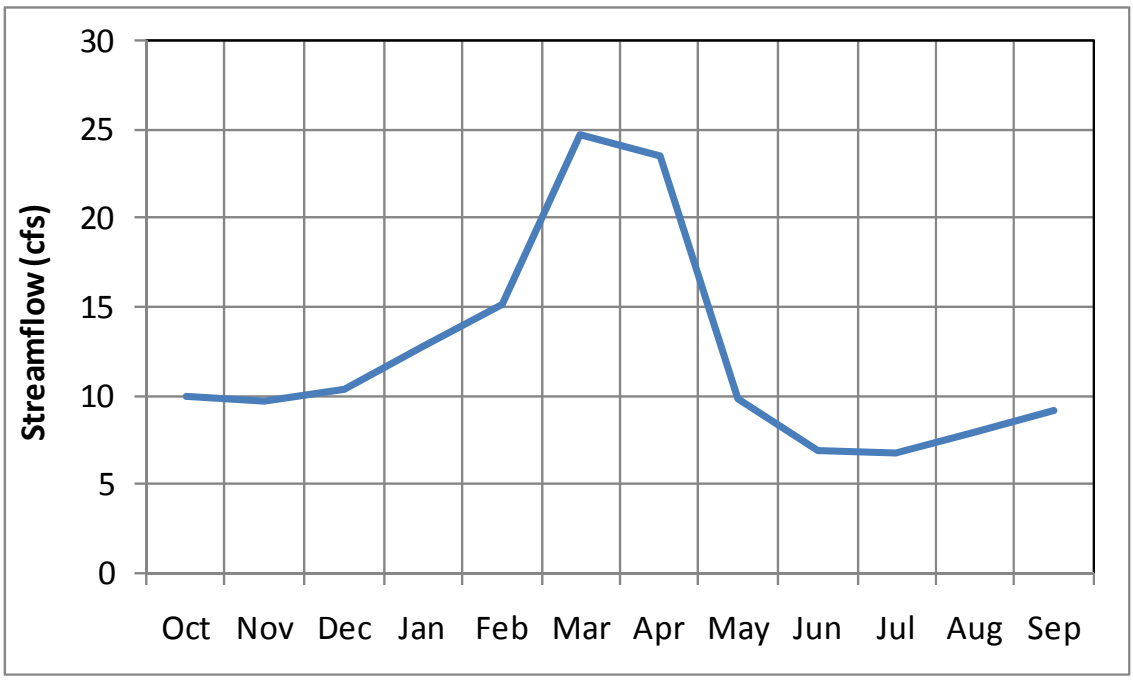


Figure 3-42
Kanab Creek Near Kanab, Monthly Mean Flows

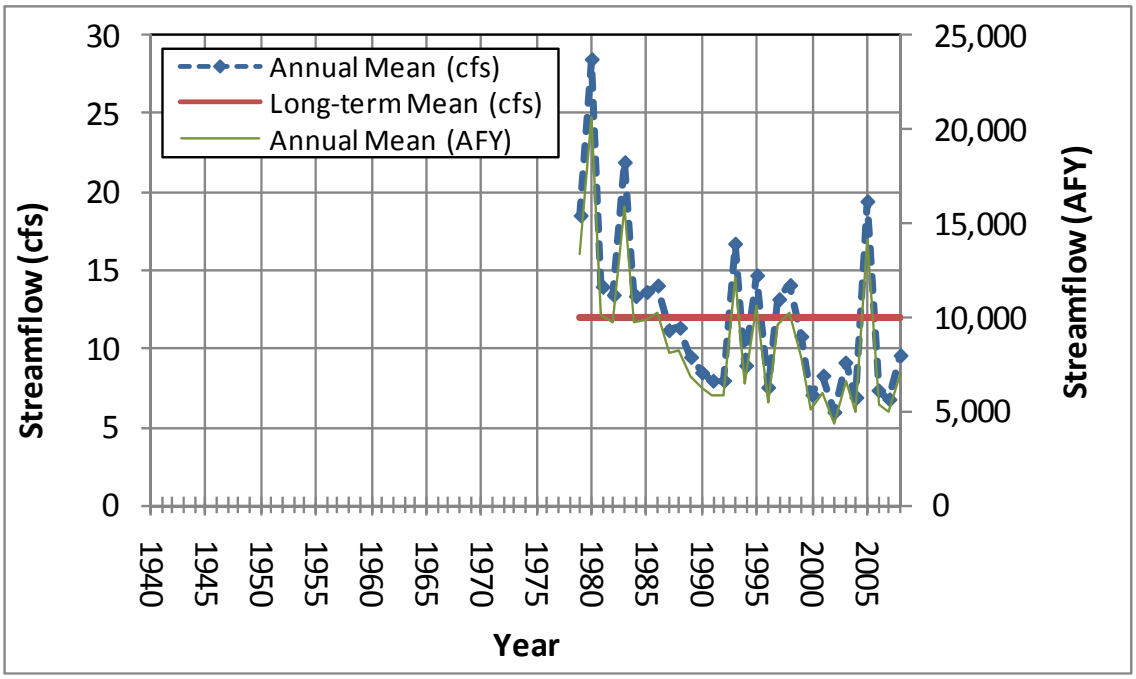


Figure 3-43
Kanab Creek Near Kanab Annual Mean Flows

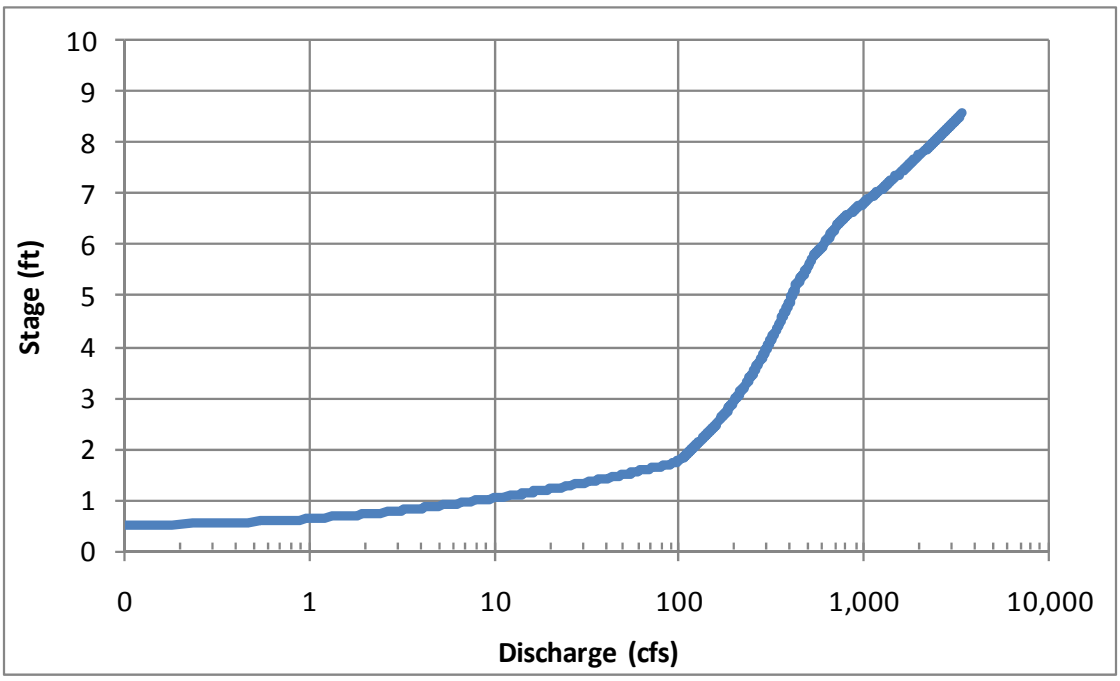


Figure 3-44
Kanab Creek Near Kanab – Stage Discharge Rating Curve
Note: Rating curves are subject to change over time

3.2.3.2 Paria River

The Paria River originates near Bryce Canyon National Park and drains to the south through Grand Staircase Escalante National Monument. The Paria River is eventually tributary to the Colorado River between Glen Canyon Dam and Lees Ferry.

The LPP Project would cross the Paria River at Highway 89, Utah the same location as a relatively new stream gage site. At this point, the drainage area is 647 square miles. The USGS streamflow gage named "Paria River near Kanab" has a short period of record and the gage records are considered poor. Therefore, only a limited set of streamflow charts are presented. Figure 3-45 shows daily flows for the Paria River near Kanab period of record. Although flows are mostly less than 40 cfs, there are sporadic and short-term peak flow events. Figure 3-46 shows the daily mean and daily range of flows over the calendar year based on the six-year period of record. During this period, peak flows occurred from August through January. Figure 3-47 depicts the flow exceedance curve. The 90 percent exceedance value is 0 cfs, while the 10 percent exceedance value is 38 cfs. The median flow is 7 cfs. Figure 3-48 depicts the stage-discharge curve for the gage. Annual means for the period of record range from 10.9 cfs in 2003 to 42.1 cfs in 2005.

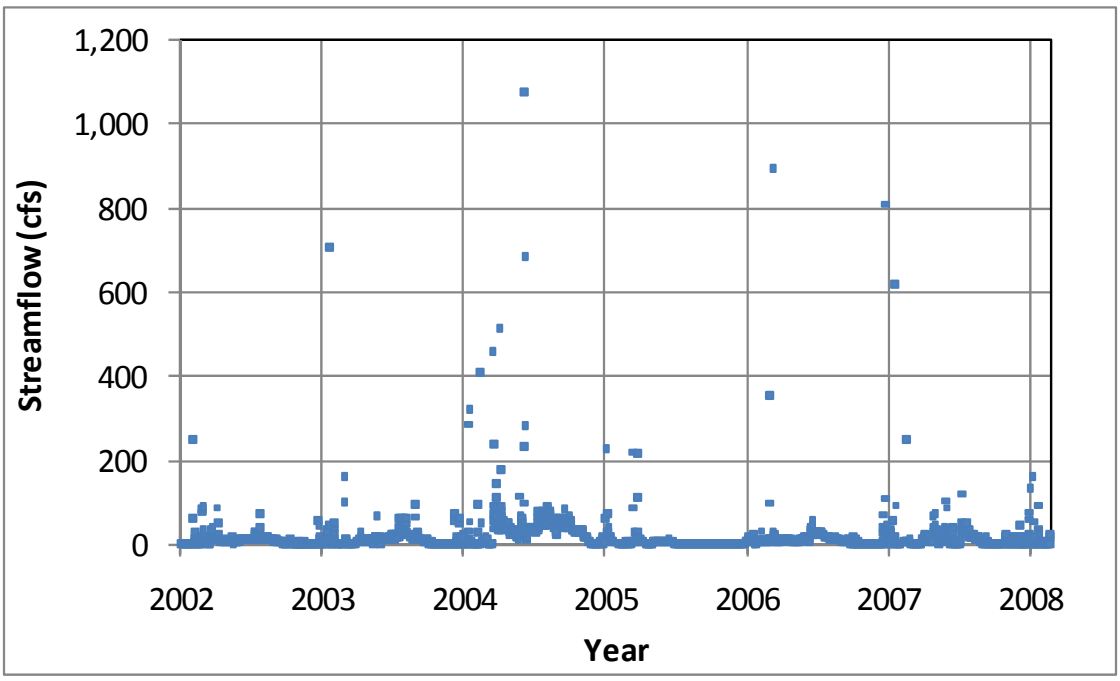


Figure 3-45
Paria River Near Kanab, Daily Flows

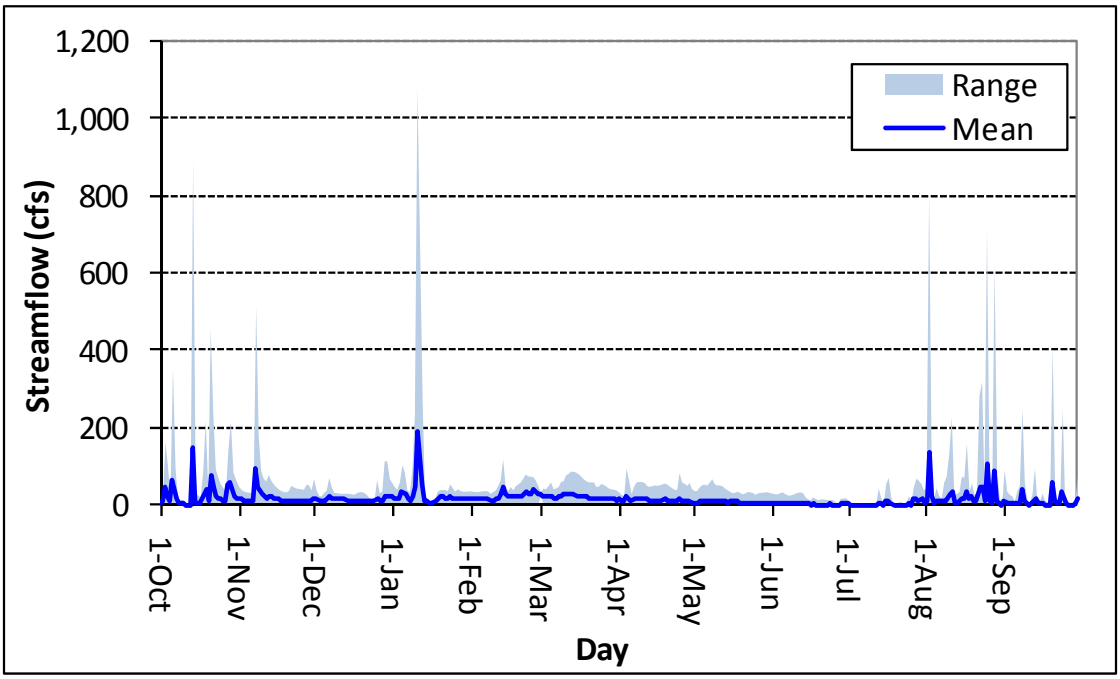


Figure 3-46
Paria River Near Kanab, Daily Mean and Range of Flow

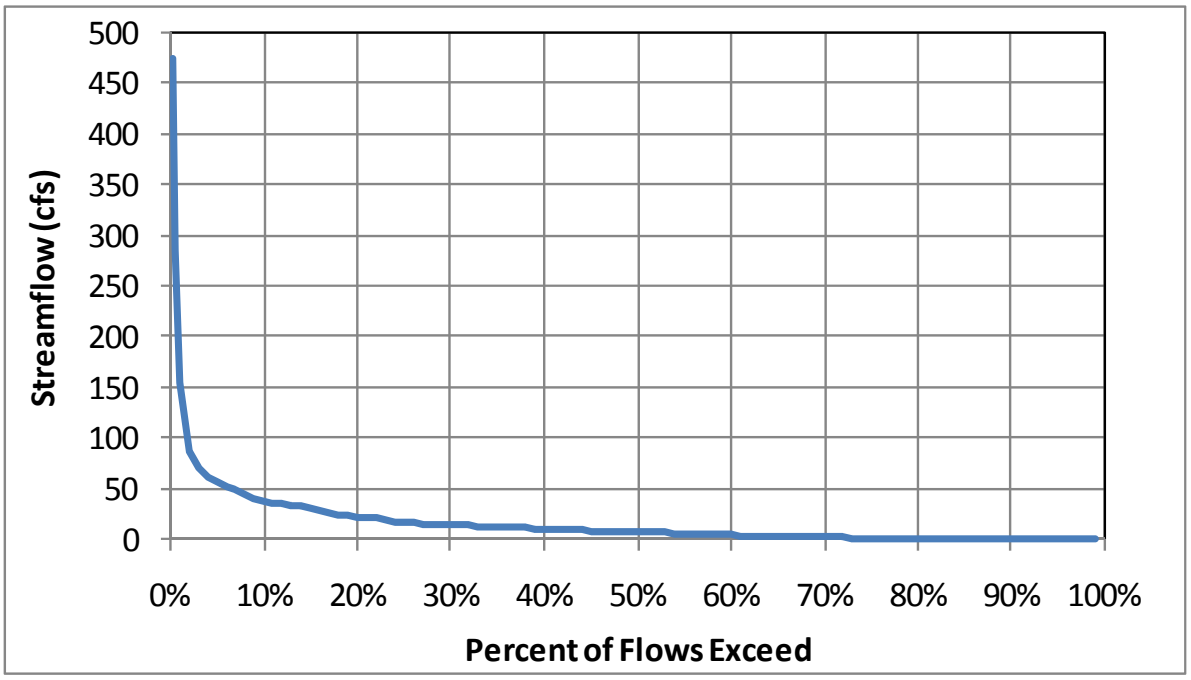


Figure 3-47
Paria River Near Kanab Flow Exceedance

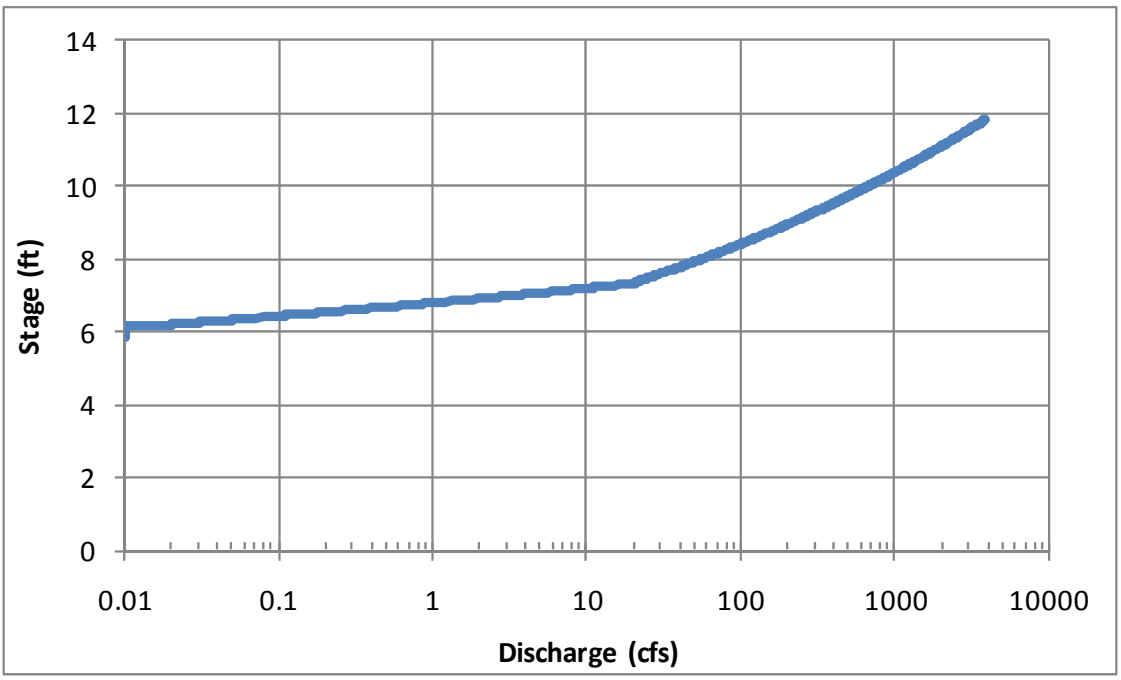


Figure 3-48
Paria River Near Kanab – Stage Discharge Rating Curve
Note: Rating curves are subject to change over time

3.3 Return Flows

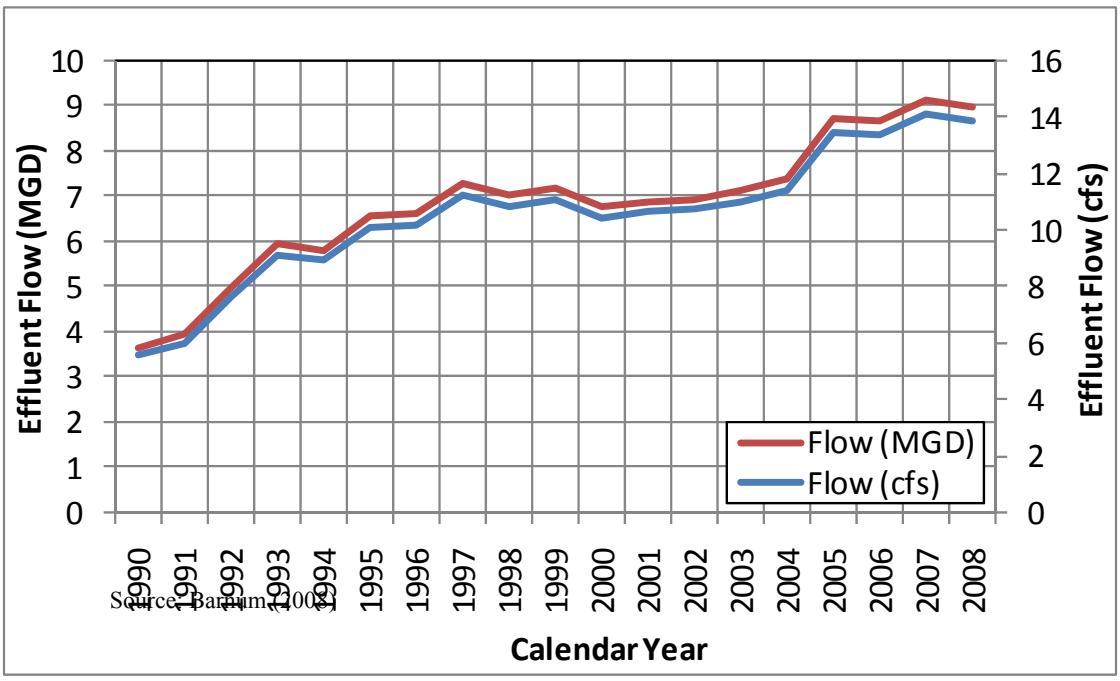
The St. George wastewater treatment plant serves the communities of St. George, Ivins, Santa Clara, and Washington. According to the 2010 State of Utah Municipal and Industrial Water Supply and Use Study, communities served by the St. George WWTP in the Kanab Creek/Virgin River Basin used 43 percent of total municipal and industrial (M&I) water use indoors and 57 percent outdoors. A total of 14,878 acre-feet returned to the wastewater treatment facility at St. George, 87 percent of the total indoor use. Most of the wastewater treatment plant flow, 97 percent, was considered sewered return flow and returned to the Virgin River. Of the 22,807 acre-feet of outdoor water use, UDWRe assumed that 50 percent returned to the Virgin River as non-sewered return flow (UDWRe 2014). Table 3-3 summarizes water use and return flow estimates for 2010 for communities that would be involved in the LPP Project.

Table 3-3
2010 Water Use and Return Flow Summary for Major LPP Water Users (AF)

Water Supplier	Total Water Use	Outdoor Water Use	Non-Sewered Return Flow	Indoor Water Use	Wastewater Treatment Inflow	Sewered Return Flow
Ivins	1,521.3	914.2	457.1	607.1	523.5	513
Santa Clara Municipal	1,579.2	980	490	599.2	548	537
St. George City	30,140.6	16,725	8,362	13,416	11,710	11,258
Washington Municipal	6,590.7	4,188	2093.9	2,403	2,097	2,055
Total St. George WWTP					**14,878**	**14,363**
Toquerville	489.5	385.4	192.7	104.1	96.1	94.2
Hurricane	5,181.3	3,440	1720	1,741	1,559	1,528
LaVerkin	775.0	446.1	223.1	328.9	306.2	300.1
Total Ash Creek WWTP					**1,961**	**1,922**
Kanab	1,440.6	871.2	435.6	569.4	533.9	263.2

Source: UDWRe 2014

The St. George WWTP discharges to the Virgin River southwest of St. George (Figure 3-10). Figure 3-49 depicts historical flows through the wastewater treatment plant, which represent historical sewered return flows. Sewered return flows have increased at a steady rate since 1990. In 2008, wastewater effluent flows totaled 9 MGD, or about 14 cfs. In 2006, St. George completed a wastewater reuse plant that takes water from the WWTP and treats it for use as secondary water. The plant is designed for 10 mgd capacity. The wastewater reuse plant only has one current large customer, a golf course, but the Shivwits Band of the Paiute Tribe of Utah is entitled to 2,000 AF per year pursuant to the Shivwits Band of the Paiute Indian Tribe of Utah Water Rights Settlement Agreement (2001). The city has approved plans to store reuse water in a new 3,000 acre-foot reservoir and expand the system in the future. This expansion would reduce future sewered return flows to the Virgin River.



Source: Barnum (2008)

Figure 3-49
St. George Wastewater Plant Historical Effluent Flows

Wastewater for the towns of Toquerville, Hurricane, and LaVerkin, Utah is treated at the Ash Creek Special Service District wastewater treatment lagoons. For the communities served by the Ash Creek lagoons, 34 percent of M&I water use was indoor water use and 66 percent was outdoor water use. A total of 1,961 acre-feet returned to the Ash Creek lagoons, 90 percent of the total indoor use. Water from the lagoons is land applied and does not have a surface return flow to the Virgin River. However, after accounting for evaporation, UDWRe considered that 98 percent of the water delivered to the lagoons returned to the Virgin River. Of the 4,271acre-feet of outdoor water use, UDWRe assumed that 50 percent eventually returned to surface waters as non-sewered return flow (UDWRe 2009).

The City of Kanab uses a lagoon system for wastewater treatment. Water use data for 2010 showed that 40 percent of M&I water use was indoor water use and 60 percent was outdoor water use. A total of 534 acre-feet returned to the wastewater lagoons, 94 percent of the total indoor use. After accounting for evaporation, UDWRe considered that 42 percent of the water delivered to the lagoons returned to Kanab Creek. Of the 871 acre-feet of outdoor water use, UDWRe assumed that 50 percent eventually returned to surface waters as non-sewered return flow (UDWRe 2014).

3.4 Reservoirs

The following describes storage information for potentially affected reservoirs and lakes in the study area.

3.4.1 Lake Powell

Lake Powell is the reservoir impounded by Glen Canyon Dam. It is the second largest reservoir on the Colorado River and has a total storage capacity of 24.32 MAF. The reservoir is narrow, extending over 180 miles along the Colorado River and 80 miles up the San Juan River, and has a shoreline that is over

1,900 miles long. Lake Powell primarily provides water storage for use in meeting the delivery requirements to the Lower Colorado River consistent with the Law of the River. Releases are also timed for hydropower production. Lake Powell is an important regional resource for water-based recreation. Reclamation retains authority and discretion for the operation of Glen Canyon Dam and Lake Powell (Reclamation 2007).

The operating range of Lake Powell is between elevations 3,490 and 3,700 feet mean sea level. The elevation capacity curve for Lake Powell is shown in Figure 3-50. Pipeline intakes for LPP are proposed at three invert elevations: 3575, 3475, and 3375 feet above sea level.

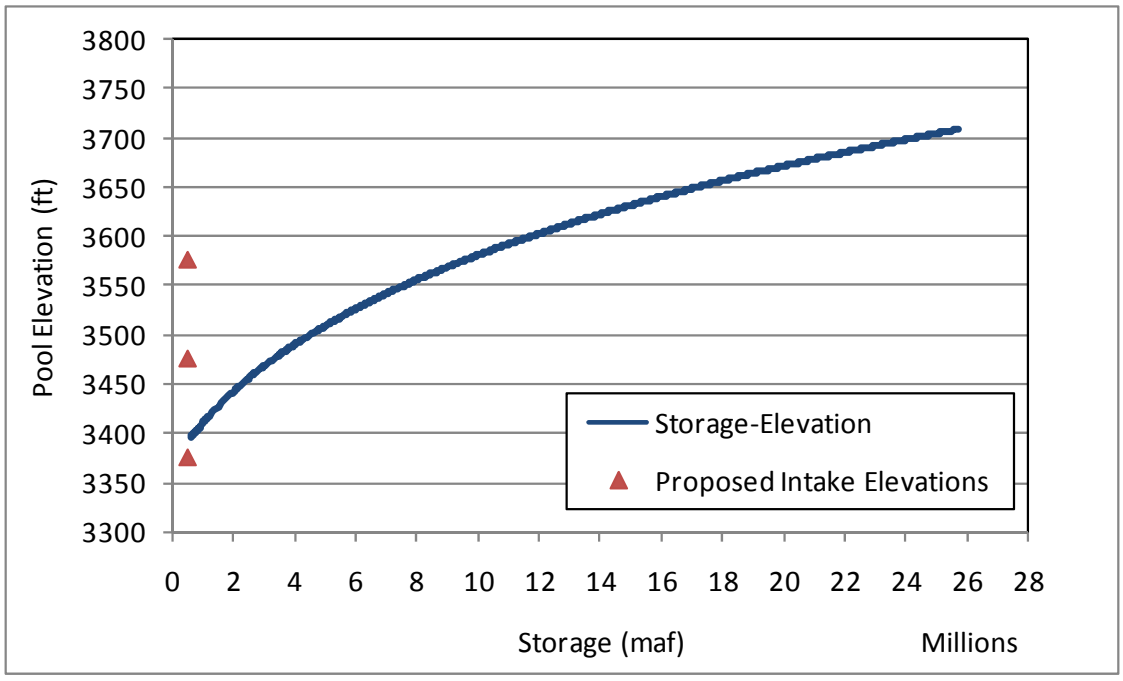
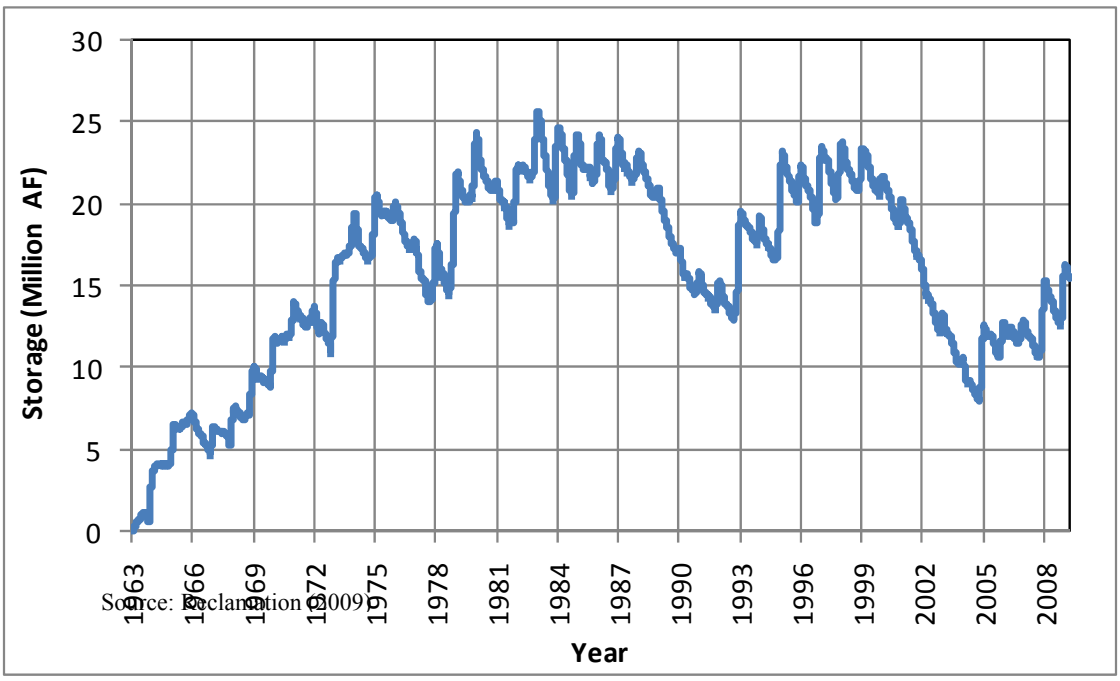


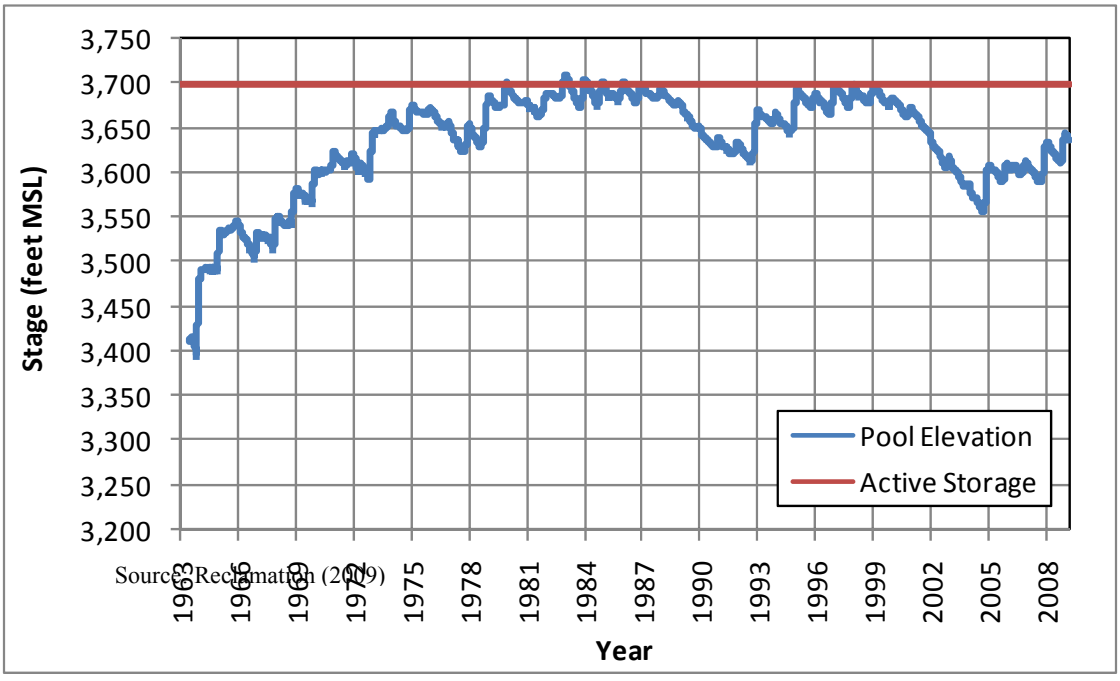
Figure 3-50
Lake Powell Elevation Capacity Curve

Historical storage data for Lake Powell is plotted in Figure 3-51, however, because of changes in the operational plans, historical data is not necessarily comparable to future conditions. The reservoir began filling in 1963. The fluctuations in elevations are primarily the result of highly variable hydrologic inflows into the Upper Colorado River Basin (Reclamation 2007). The substantial drawdown from 1999 through 2004 during the extended drought in the Upper Colorado River Basin is apparent. Figure 3-52 shows historical pool elevation, or stage, in Lake Powell. Emergency spills were made from the dam in 1983. Figure 3-53 depicts historical releases made from the dam.



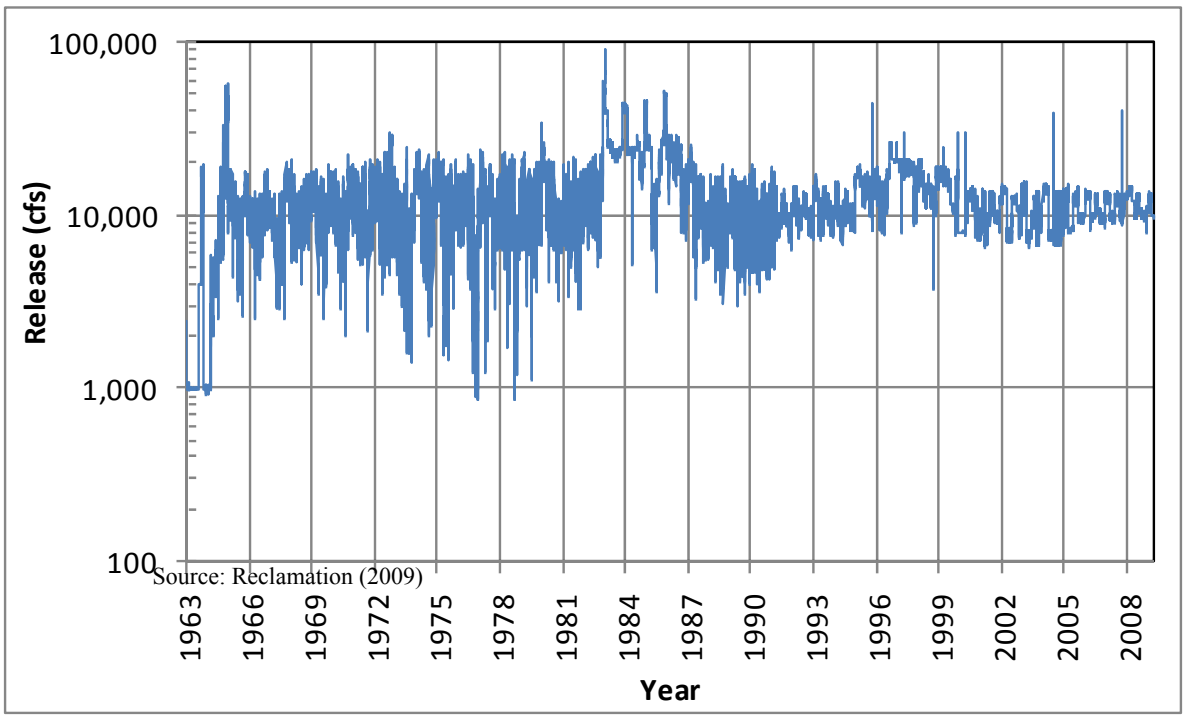
Source: Reclamation (2009)

Figure 3-51
Lake Powell Historical Storage



Source: Reclamation (2009)

Figure 3-52
Lake Powell Historical Stage



Source: Reclamation (2009)

Figure 3-53
Lake Powell Historical Daily Releases

3.4.2 Quail Creek Reservoir

Located approximately 15 miles northeast of St. George, Quail Creek Reservoir is formed by two dams on Quail Creek, a minor tributary to the Virgin River. The reservoir was constructed by WCWCD and was completed in April 1985. Quail Creek Reservoir is owned and operated by WCWCD to meet regional culinary M&I water demands. Water for storage in Quail Creek Reservoir originates in the Virgin River. It is diverted at the Quail Creek Diversion Dam, and is delivered to the reservoir through a pipeline. The diversion also supplies the towns of LaVerkin and Hurricane, the Hurricane Hydropower plant and Sand Hollow Reservoir before reaching Quail Creek Reservoir. Seepage from the reservoir returns to the Virgin River though Quail Creek. Based on modeling performed by UDWRe, the combined average annual yield of Quail Creek and Sand Hollow reservoirs is 24,922 acre-feet per year (UDWRe 2009). WCWCD operates a water treatment plant adjacent to the reservoir for culinary distribution to WCWCD customers.

The reservoir has a storage capacity of 40,000 acre-feet and has a surface area of 620 acres. It has a minimum pool of 5,525 acre-feet. The area-elevation-capacity curve is included as Figure 3-54. Historical storage is plotted in Figure 3-55.

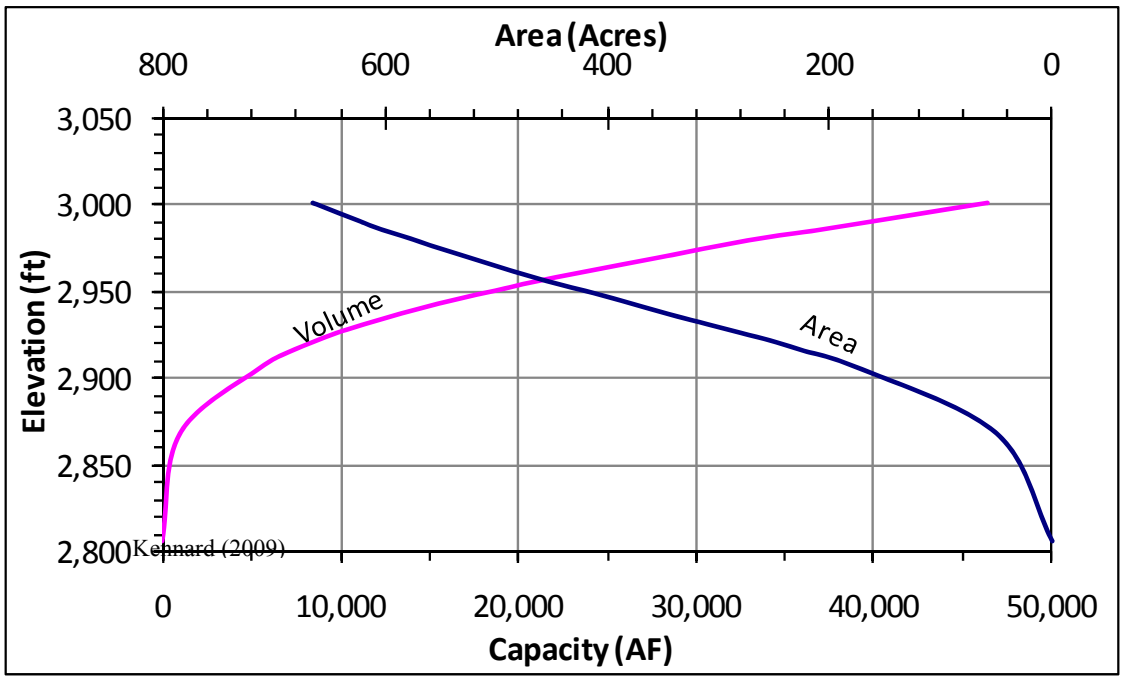


Figure 3-54
Area-Elevation-Capacity for Quail Creek Reservoir

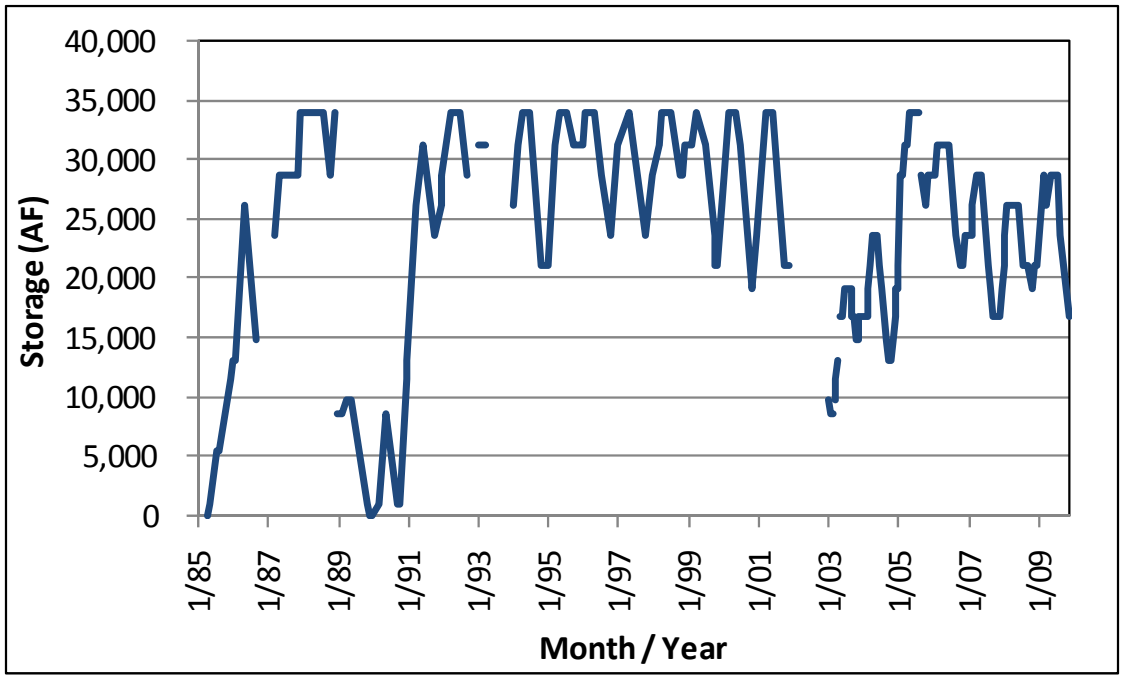


Figure 3-55
Quail Creek Reservoir Historical Storage
Source: Utah Division of Water Rights (2009) and Silva (2009)

3.4.3 Sand Hollow Reservoir

Sand Hollow Reservoir is a 50,000 acre-feet storage facility located about five miles southwest of Hurricane. The reservoir was constructed by WCWCD in 2002 and is used for culinary supply for WCWCD customers. Water to fill Sand Hollow Reservoir is conveyed from the Virgin River in the same pipeline serving Quail Creek Reservoir. The reservoir has an active pool of about 30,000 acre-feet and a drought pool of 20,000 acre-feet that would provide water supplies in an extreme drought. Sand Hollow Reservoir also serves as a groundwater recharge facility for the Navajo Sandstone Aquifer. Figure 3-56 shows the area-elevation capacity curve for Sand Hollow Reservoir. Figure 3-57 shows historical reservoir storage in Sand Hollow Reservoir.

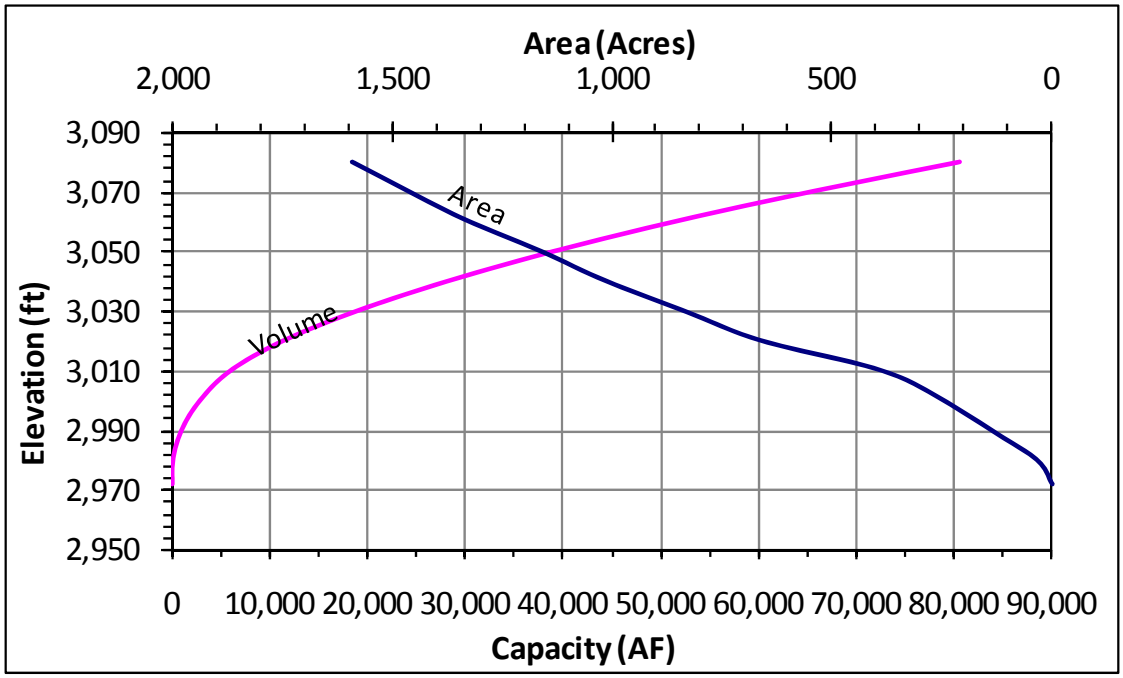


Figure 3-56
Area-Elevation-Capacity for Sand Hollow Reservoir
Data Source: Kennard (2009)

Figure 3-57
Historical Storage - Sand Hollow Reservoir
Data Source: Heilweil and Susong (2007) and UDWRe (2009)

3.5 Peak Flows

In the Kanab and Virgin River basins streams are prone to flash flooding from regional storm runoff or large snow runoff events from warm weather or rain on the snowpack. The unique rock formations in the study area convert nearly all precipitation to runoff. The sparse vegetation adds to the high flash flood potential of the region. The larger streams have potential for flooding caused by general storms originating in the Pacific Ocean (FEMA 2009).

Flood events can cause extreme erosion and sedimentation (UDWRe 1993 and UDWRe 1995). The 2005 flood in Washington County resulted in peak flows of 21,000 cfs at the Virgin River at Bloomington gage, close to the 100-year peak flow, and 6,200 cfs at the Santa Clara River at St. George gage, less than the 50-year peak flow. This flood resulted in an estimated $200 million in damage and a federal disaster declaration (FEMA 2009). The December 2010 flood in Washington County resulted in peak flows of 10,000 cfs at the Virgin River at Virgin gage, and 8,000 cfs at the Virgin River at St. George gage. The winter storm brought intense warm rain over mountain snow pack with high moisture content, producing stream flow conditions approximately a 50-year flood event. This flood cause widespread damage to WCWCD infrastructure and facilities, endangered fish recovery structures, municipal infrastructure, and private property.

Table 3-4 summarizes estimated peak flows for various return intervals for streams in the study area. The peak flow data comes from the following various sources:

- Santa Clara River, Fort Pierce Wash, and Virgin Rivers – 2009 Flood Insurance Study for Washington County
- Kanab Creek – Estimates using USGS regression equations because there is no recent Flood Insurance Study

Table 3-4
Summary of Estimated Peak Flows

Flooding Source and Location	Drainage Area (Sq. Miles)	Peak Flow (cfs)		
		10-Year	50-Year	100-Year
Santa Clara River				
• From USGS gage near Santa Clara to Santa Clara City limit	424	NA	NA	8,200
• From Santa Clara City limits to confluence with Sand Hollow Wash	446	2,450	6,000	8,200
• From confluence with Sand Hollow Wash to Dixie Dr. Bridge	538	3,650	9,150	12,500
• From Dixie Dr. Bridge to Virgin River	540	3,750	9,500	13,000
Fort Pierce Wash				
• From Utah State line to confluence with Virgin River	1,680	NA	NA	22,000
Virgin River				
• From USGS gage near Hurricane to Washington City limits	1,540	NA	NA	23,500
• From Washington City limit to confluence with Fort Pierce Wash	1,640	12,000	19,500	23,500
• From confluence with Fort Pierce Wash to St. George City limit	3,840	12,000	19,500	27,500
• From St. George City west limit to Utah/Arizona state line	4,000	NA	NA	27,500
Kanab Creek				
• Near Kanab	194	2,390	3,870	4,570

Source: Santa Clara and Virgin - FEMA (2009), Kanab – USGS (2010)
NA = not available

3.6 Geomorphic Conditions

3.6.1 Colorado River

Construction of Glen Canyon Dam modified the channel characteristics of the Colorado River downstream of Lake Powell. This is caused by sediment being trapped upstream of the dam and releases of clear water with the potential to erode the channel downstream of the dam.

A study of the 25 km downstream of the dam through Glen Canyon found that high releases that occurred in the 1960s and 1980s scoured substantial amounts of sediment from the channel bottom. The average size of bed material remaining in the channel is now 20 mm compared to 0.2 mm in 1956. Without peak flows, little change occurred to the channel bed between 1990 and 2004 (Grams et al 2007). The channel is now considered "armored" because the large size of channel material is resistant to movement from typical flows.

Several resources in Glen Canyon downstream of the dam and further downstream in the Grand Canyon are sensitive to geomorphology including:

- Archaeological sites
- Recreational uses such as sport fishing and associated day and overnight use on sand bars and alluvial terraces
- Spawning habitat for trout (gravel/cobble bed)
- Camping beaches

The Glen Canyon Adaptive Management Program allows scientists to test if high flows from the dam will:

- Remove or reduce predation of nonnative fish on endangered native fish
- Rejuvenate backwater habitats for native fish, especially the endangered humpback chub (*Gila cypha*)
- Re-deposit sand at higher elevations
- Preserve and restore camping beaches
- Reduce near-shore vegetation

High flow experimental releases from Glen Canyon Dam have been performed six times since 1996. The 2013 high flow release from Glen Canyon Dam was made when adequate sediment recruitment from tributary channels downstream of the dam was available for mobilization (Reclamation 2015b). Results determined from the high flow experimental releases indicate the greatest amount of sediment deposition occurs in river segments that are most enriched with tributary-derived sand. Effects of spring high flow experimental releases are believed to improve fish spawning and rearing conditions and increase the abundance of aquatic insects, which fish feed upon. The most recent high flow experimental release was made in November 2014. The experimental high flow releases have not resulted in changes to the annual total amount of water released from Glen Canyon Dam.

3.6.2 Remaining Study Area Streams

The Virgin River and Santa Clara River have both been the subject of geomorphic studies. The conclusions of the studies indicate that channel and bank changes for these streams generally result from peak flow events. UDWRe's basin plans for the Kanab Creek and Virgin River basins confirmed that much of the region is prone to flash flooding and associated erosion of stream banks and channels

(UDWRe 1993 and UDWRe 1995). FEMA's most recent Flood Insurance Study for Washington County (2009) further supported the conclusion that local streams are erosion prone:

> *Streams are generally comprised of highly mobile sands, which can result in significant erosion and deposition during flood events. This situation is compounded by fast growing vegetation within the channels and floodplains in the project area, which restrict conveyance capacity and provide a potential source of debris during flood events.*

None of the studies reviewed described the effects, if any, of baseflow on channel stability. The Virgin River and Santa Clara River are discussed in further detail below.

3.6.2.1 Virgin River Stability

The hazard of bank erosion and lateral channel movement on the Virgin River is extreme. For the last 1,000 years, peak flow events have caused numerous shifts in the active channel location (JE Fuller 2007). Erosion and channel migration is generally attributed to high flow events, although even moderate flooding can cause stability problems on the Virgin River near St. George (JE Fuller 2005). Prior to a major flood event in 2005, dense vegetation including tamarisk on both sides of the Virgin River low flow channel created a narrow corridor. The flood event of 2005 scoured away much of the vegetation and once again established a wider channel with steep unvegetated banks. As of 2007, the wider channel had not developed vegetation to stabilize the banks. In addition, wide point bars along much of the Virgin River indicated ongoing rapid lateral channel movement. With the vegetation lost since the 2005 flood, the Virgin River is now susceptible to greater channel and bank change during peak flow events (JE Fuller 2007).

Structures were added to portions of the Virgin River through St. George after the 2005 flood event to reduce the likelihood of erosion and channel migration in future floods. However, those structures implemented by the NRCS were only designed for the peak discharge of 2005, substantially less than the 100-year flow. According to JE Fuller (2007), these structures would be susceptible to overtopping and other types of failures for flows exceeding the 2005 flood but less than the 100-year flood event.

The December 2010 flood in Washington County resulted in peak flows of 10,000 cfs at the Virgin River at Virgin gage, and 8,000 cfs at the Virgin River at St. George gage. The winter storm brought intense warm rain over mountain snow pack with high moisture content, producing stream flow conditions approximately a 50-year flood event. This flood caused widespread damage to WCWCD infrastructure and facilities, endangered fish recovery structures, municipal infrastructure, and private property.

3.6.2.2 Santa Clara River Stability

The Santa Clara River remained relatively stable from 1938 to 1984 even though several peak flow events occurred during that period. Since 1984, channel instability tended to occur in areas where humans disturbed the floodplain, channel, and vegetation. JE Fuller (2007) concluded that stream velocities are such that the Santa Clara River through Santa Clara and St. George will erode if not protected. Historically, vegetation provided adequate protection and areas where vegetation has been disturbed are subject to lateral erosion and degradation during high flow events. The 2005 flood that occurred on the Santa Clara River was equivalent to about a 25-year flood and it resulted in serious channel movement and flood damage. Floods of greater magnitude are likely on the Santa Clara River and could potentially result in additional channel change.

Chapter 4
Environmental Consequences

This chapter describes the expected direct and indirect impacts of all of the LPP Project pipeline alignment alternatives together. Other than differences in river crossing locations, the effects on surface waters for any of the different LPP Project alternative alignments are similar.

4.1 Significance Criteria

Significance criteria were not developed for surface water resources because the changes estimated in this analysis were used to evaluate the significance of the impacts that flow and water level changes would have on other affected resources. These resources include surface water quality, wetlands and riparian resources, aquatic resources, special status aquatic resources, and special status wildlife species.

One significance criterion is identified regarding peak flows and geomorphology:

- Effects on peak flows and/or geomorphology that could result in impacts on property such as damage to bridges or other structures would represent a significant impact.

4.2 Potential Impacts Eliminated from Further Analysis

There are no potential impacts identified that were eliminated from further analysis.

4.3 Streams and Return Flows

4.3.1 Colorado River

The LPP Project impacts on the Colorado River are based on the results of modeling performed by Reclamation. This section summarizes the simulated releases from Lake Powell, documented in further detail in Appendix 2. The modeling methodology and scenarios are summarized in Section 2.2.2.2. More than 100 inflow hydrology datasets each are run for the DNF and CC scenarios resulting in over 100 sets of model results for both inflow hydrology approaches. These time series results, or traces, are summarized by ranking the results at each time step and determining the 10th, 50th, and 90th percentiles at each time step. These percentiles were selected to represent the high, low, and middle range of depletion scenarios and are presented to summarize DNF and CC results based on their probability of occurring. However, it is important to keep in mind that each percentile summary does not represent any one continuous trace, but rather a statistic that summarizes the results of all of the traces. Therefore, percentile results presented as a time series do not represent reservoir operations as they would occur sequentially under any particular inflow scenario. Figure 4-1 is an example from a previous Reclamation report of how selected traces and percentile statistics compare for simulated storage in Lake Mead. This example figure demonstrates how individual model traces may or may not correspond to one of the selected percentile values.

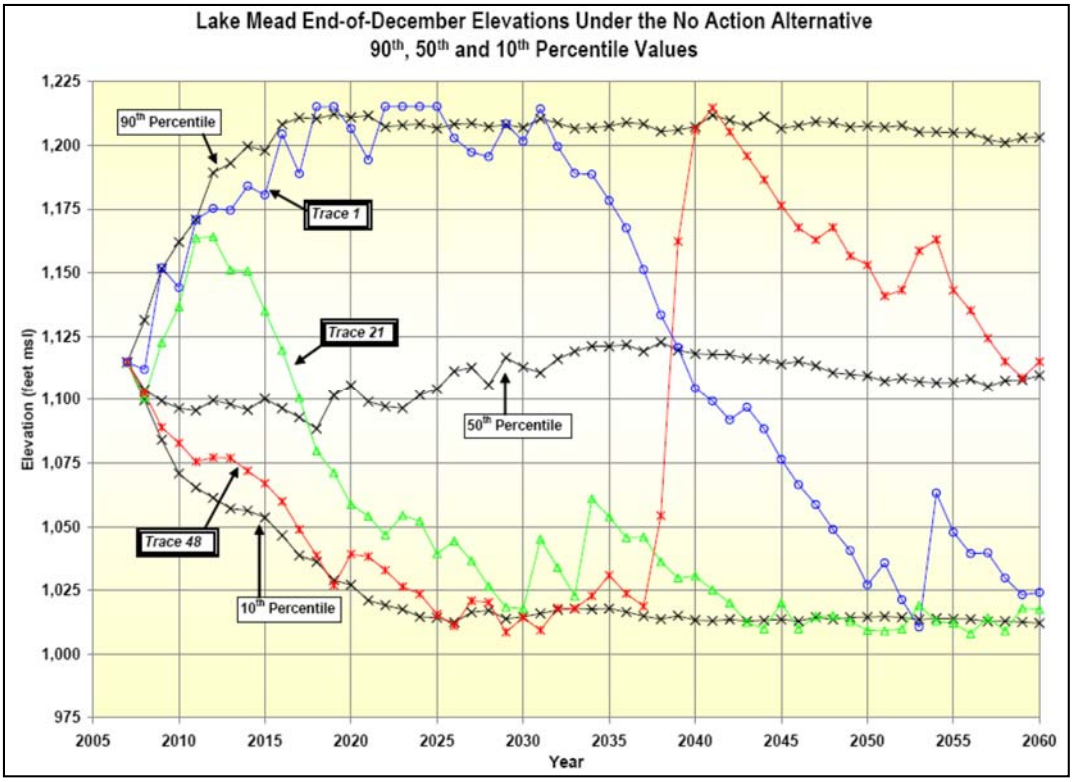


Figure 4-1
Example of Trace Results vs. Percentile Results
Source: Reclamation (2007)

4.3.1.1 Hydrologic Modeling Analysis

The Bureau of Reclamation (Reclamation) conducted a set of hydrologic modeling runs using Reclamation's long-term planning model, Colorado River Simulation System (CRSS), to analyze the difference between diverting water out of the Colorado River at Lake Powell through the Lake Powell Pipeline (South Alternative, Proposed Action) and not diverting the water (No Action scenario). Reclamation's modeling of LPP Project effects assumes that all future Upper Basin depletions *except* for the LPP and other future depletions assumed to be reasonably foreseeable are modeled as constant at the 2015 depletion levels for both scenarios.

Figure 4-2 illustrates some of the differences between the CC and DNF inflow simulations for the 86K pipeline scenario. Releases for the 50th percentile are plotted. The year 2027 is when reservoir operations in the simulation revert to the 2007 Shortage EIS No Action Alternative, a reduction in releases is apparent after that date. For the 50th percentile, there would be no difference between releases for the With Pipeline scenario and No Action for the DNF inflow hydrology and only minor differences for the CC hydrology. For the CC inflow hydrology, there would be slight differences in releases in 2 out of 46 simulated years. Table 4-1 summarizes the differences in annual releases for the 10th, 50th, and 90th percentiles. The differences summarized are small when compared with the large volume of water released to the Colorado River. Figure 4-3 depicts the percent difference time series results for releases from Lake Powell. Simulated releases for each of the inflow simulations are discussed in the following sections.

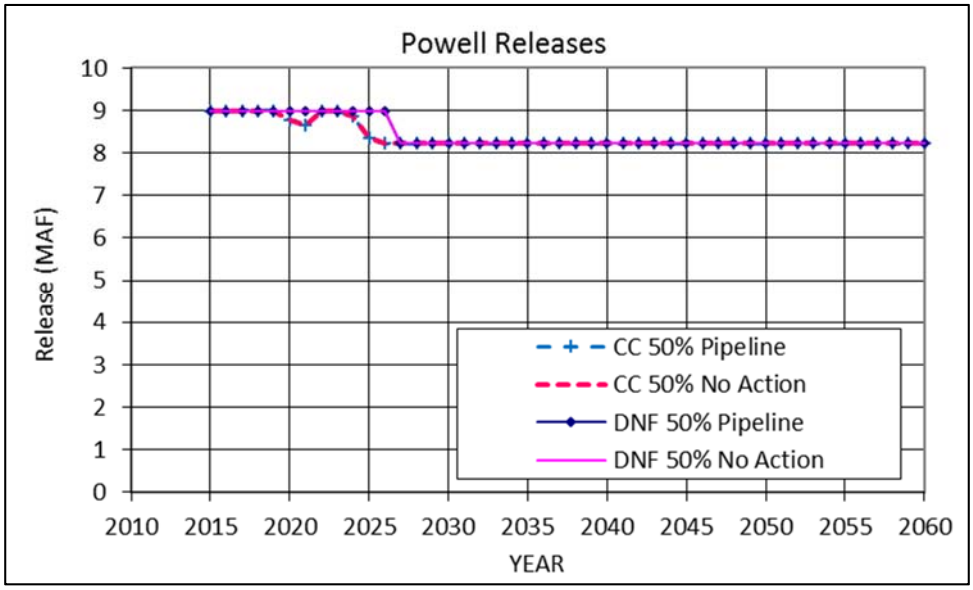


Figure 4-2
86K AF Simulations, 50th Percentile Lake Powell Releases Results

Table 4-1
86K AF Simulations, Summary of Lake Powell Annual Release Differences

	Acre-Feet per Year			Percent Difference		
Percentile	**10th**	**50th**	**90th**	**10th**	**50th**	**90th**
DNF Average Difference	0	0	-69,202	0%	0%	-1%
DNF Maximum Difference	0	0	-442,674	0%	0%	-3%
CC Average Difference	-80,846	-383	-61,593	-1%	0%	-1%
CC Maximum Difference	-382,075	-13,427	-311,526	-6%	0%	-3%

Notes: Data based on CRSS results
Difference = South Alternative (Proposed Action) – No Action
Percent Difference = Difference/No Action
DNF = Direct Natural Flow
CC = Climate Change

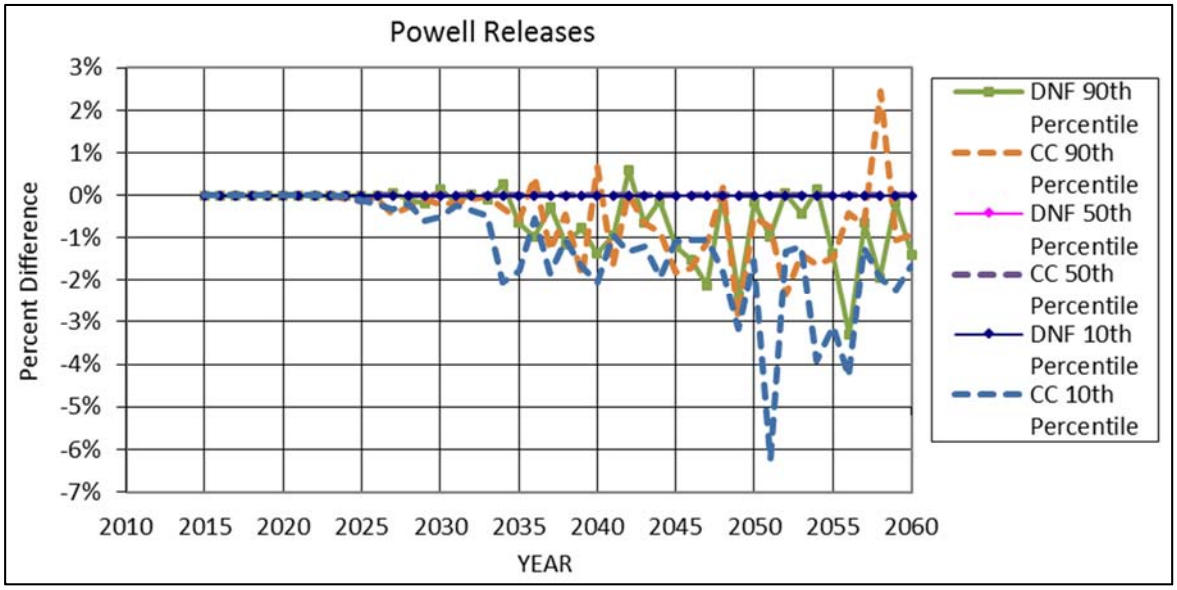


Figure 4-3
86K AF Simulations, Percent Difference in Lake Powell Releases

4.3.1.1.1 Direct Natural Flow (DNF), ISM Results. DNF was the primary inflow dataset used for the 2007 Shortage EIS and therefore the results of this analysis are more comparable to those performed for that EIS. Under the 86K pipeline scenario, releases from Lake Powell (for the South Alternative [With Pipeline] and No Action alternative) are equal at the 10th and 50th percentiles and differ at the 90th percentile in some years. At the 90th percentile, releases for the South Alternative (With Pipeline) are less than the No Action Alternative more often. As summarized in Table 4-1, the 90th percentile average South Alternative (With Pipeline) releases are 69,202 AFY less than No Action releases, a 1 percent difference. Figure 4-4 depicts the annual time series releases for the DNF scenario.

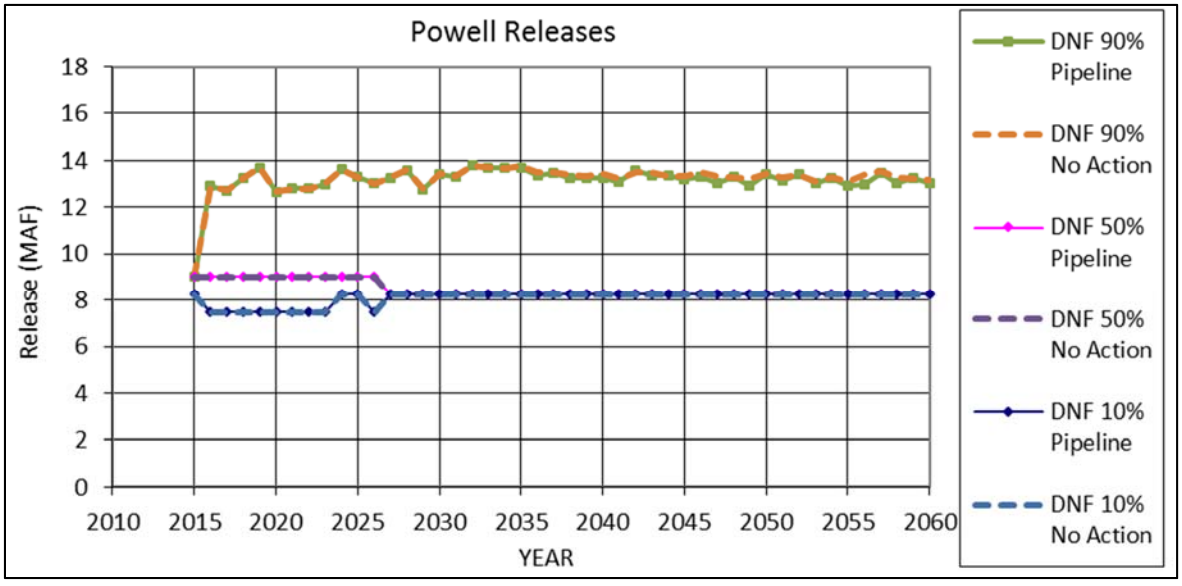


Figure 4-4
86K AF Simulations, DNF Lake Powell Releases Results

4.3.1.1.2 Climate Change (CC) Results. Although the CC and DNF simulations result in different water volumes released to the Colorado River, both showed minimal differences between the South Alternative (With Pipeline) and No Action. As summarized in Table 4-1, at the 90th percentile, average South Alternative (With Pipeline) releases are 61,593 AFY less than No Action Alternative releases, a 1 percent difference. Figure 4-5 depicts the annual time series releases for the CC scenario.

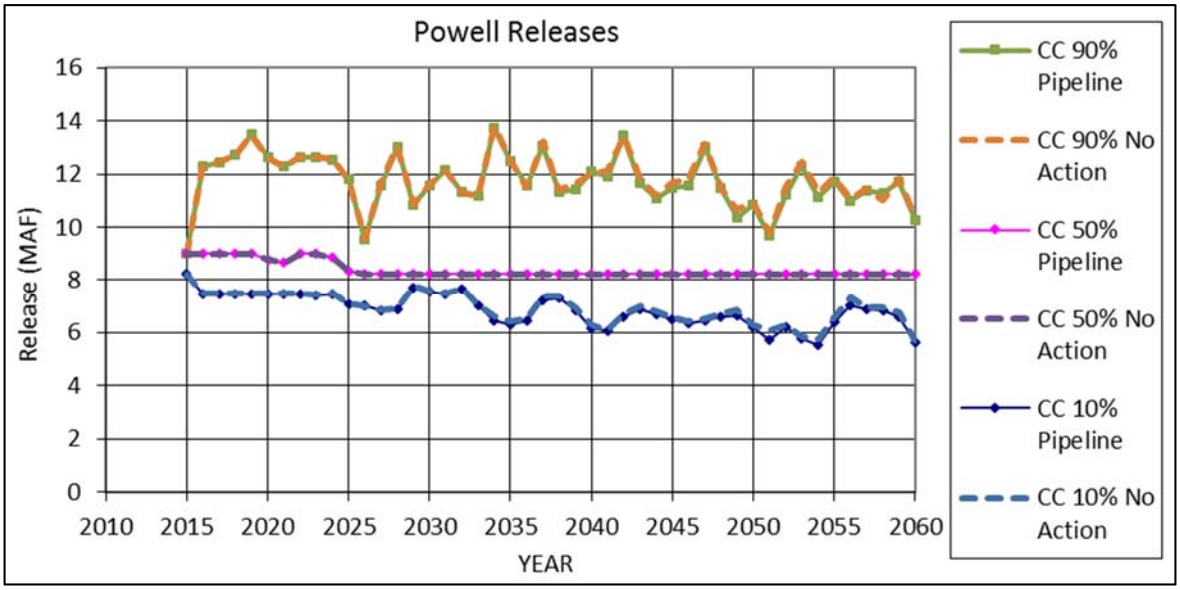


Figure 4-5
86K AF Simulations, CC Lake Powell Releases Results

4.3.2 Virgin River Drainages

The Virgin River Daily Simulation Model (UDWRe 2015) was used to evaluate hydrologic effects for two scenarios. Two simulations were performed with the model. Scenario 1 simulated the Base Case with full utilization of Virgin River water rights, without any additional storage or Lake Powell Pipeline deliveries. Scenario 2 represents the South Alternative (Proposed Action) future conditions with the expanded secondary system utilizing 3,000 acre feet of re-regulating storage and 69,000 acre feet of annual Lake Powell Pipeline deliveries. Future deliveries of 13,249 acre-feet would be made to the Apple Valley area of Washington County directly from the LPP Project, which are not included in the Virgin River Daily Simulation Model. The model simulates the maximum yield in the St. George area with a specified maximum shortage in the worst year (10 percent in the Lake Powell Pipeline project simulations), while providing priority water rights in accordance with their terms to the canal companies for Hurricane, LaVerkin and Washington Fields.

The model includes five service areas. In the simulations, water deliveries to the Hurricane, LaVerkin and Washington Fields service areas were unchanged between scenarios. Thus, return flows from these three service areas did not change between the simulations. Deliveries to service areas 4 and 5, representing the greater St. George area M&I demand and secondary use system were different between scenarios. Deliveries to these service areas are calculated by optimizing the resources in the model until a permitted shortage value is reached, in this case, 10 percent. Table 4-2 presents the deliveries made to each service area.

Table 4-2
Simulated Deliveries (acre-feet)

Service Area	Scenario 1-Base Case	Scenario 2- South Alternative (Proposed Action)
1-LaVerkin	2,628	2,628
2-Hurricane	13,484	13,484
3-Washington Fields	62,160	62,012
4-St George Area M&I	24,842	93,030
5-Washington Fields Secondary*	13,991	57,677
Total	**117,105**	**228,831**

Note:
*Difference in water delivered to Service Area 5 – Washington Fields Secondary between Scenario 1 and Scenario 2 represents reuse water from the St. George Regional Water Reclamation Facility

The USGS Annual Water Data Report provides qualitative descriptions about the accuracy of the USGS stream gage measurements. For the two USGS gages representative of flow in the Virgin River below Quail Creek Reservoir (USGS 09408150 and USGS 09413500), accuracies are described as "good" and "fair", respectively. A "good" rating means that measurements are within 10 percent of the actual flows and a "fair" rating represents daily discharge readings which are less accurate than "good" (USGS 2011). Differences in simulated streamflow along the Virgin River in the lower portion of the Washington County system were small, and within the degree of accuracy of the USGS stream gages in this area. Therefore, the differences between Virgin River flows under Scenario 1 (Base Case) and Scenario 2 (South Alternative (Proposed Action)) would not be measurable. Table 4-3 shows the Virgin River Daily Simulation Model flow results with a comparison between the two scenarios and USGS gage error.

Table 4-3
Virgin River Daily Simulation Model Flow Results
Comparison Between Climate Change 50th Percentile Base Case and Climate Change 50th Percentile Proposed Action (LPP)
With USGS Gage Accuracy

USGS Gage No.	Gage Accu.	VRDSM Node	Scenario and Description	Water Year Months (cfs)											
				Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
09408150 Virgin River Below Quail Creek	10%	QX21	1. Base Case	96	95	116	112	132	235	296	253	103	92	97	103
			2. Proposed Action	95	95	116	113	131	221	279	242	100	91	97	101
			Flow Difference	1	0	0	1	1	14	17	11	3	1	0	2
			Gage Accuracy (flow)	10	10	12	11	13	22	28	24	10	9	10	10
09413200 Virgin River Below Washington Fields Diversion	16%	QX26	1. Base Case	11	9	30	26	46	149	210	167	17	6	11	17
			2. Proposed Action	11	9	30	27	45	135	193	156	15	5	11	17
			Flow Difference	0	0	0	1	1	14	17	11	2	1	0	0
			Gage Accuracy (flow)	2	1	5	4	7	22	31	25	2	1	2	3
09413200 Virgin River Below Bloomington Bridge	16%	QX27	1. Base Case	40	46	75	78	100	199	253	201	46	31	36	43
			2. Proposed Action	44	50	79	83	103	189	240	196	49	36	40	48
			Flow Difference	4	4	4	5	3	10	13	5	3	5	4	5
			Gage Accuracy (flow)	6	7	12	12	16	30	38	31	7	5	6	7
09413200 Virgin River Below Santa Clara River	16%	QX28	1. Base Case	58	68	110	118	149	259	291	231	68	47	52	60
			2. Proposed Action	64	75	115	124	154	250	280	227	73	54	58	66
			Flow Difference	6	7	5	6	5	9	11	4	5	7	6	6
			Gage Accuracy (flow)	9	11	18	19	24	40	45	36	11	8	8	10
09413500 Virgin River at UT-AZ State Line	16%	QX29	1. Base Case	61	76	117	123	154	262	291	231	68	47	52	61
			2. Proposed Action	64	75	120	138	168	257	280	227	73	54	59	66
			Flow Difference	3	1	3	15	14	5	11	4	5	7	7	5
			Gage Accuracy (flow)	10	12	19	20	25	41	45	36	11	8	8	10

Key:
Flow difference exceeds USGS gage accuracy
Flow difference is less than or equal to USGS gage accuracy

Figure 4-6 shows simulated monthly average flows in the Virgin River below Quail Creek and Figure 4-7 shows the flow duration curves for the two scenarios. This location is downstream of return flows from Hurricane and LaVerkin, which do not change between simulations. It is also downstream of Quail Creek seepage and spill outflow to the Virgin River. This location is upstream of the Washington Fields Diversion, where the 86 cfs flow is measured.

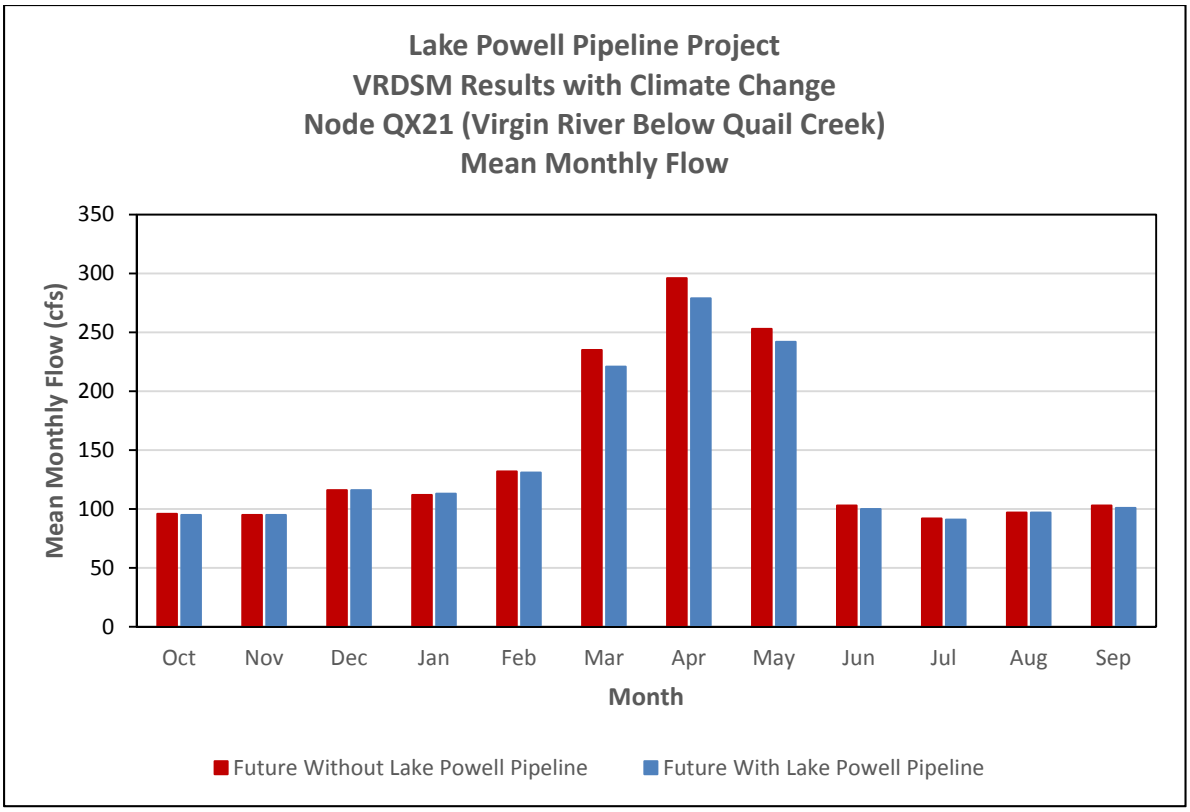


Figure 4-6
Virgin River Below Quail Creek – Simulated Monthly Flows

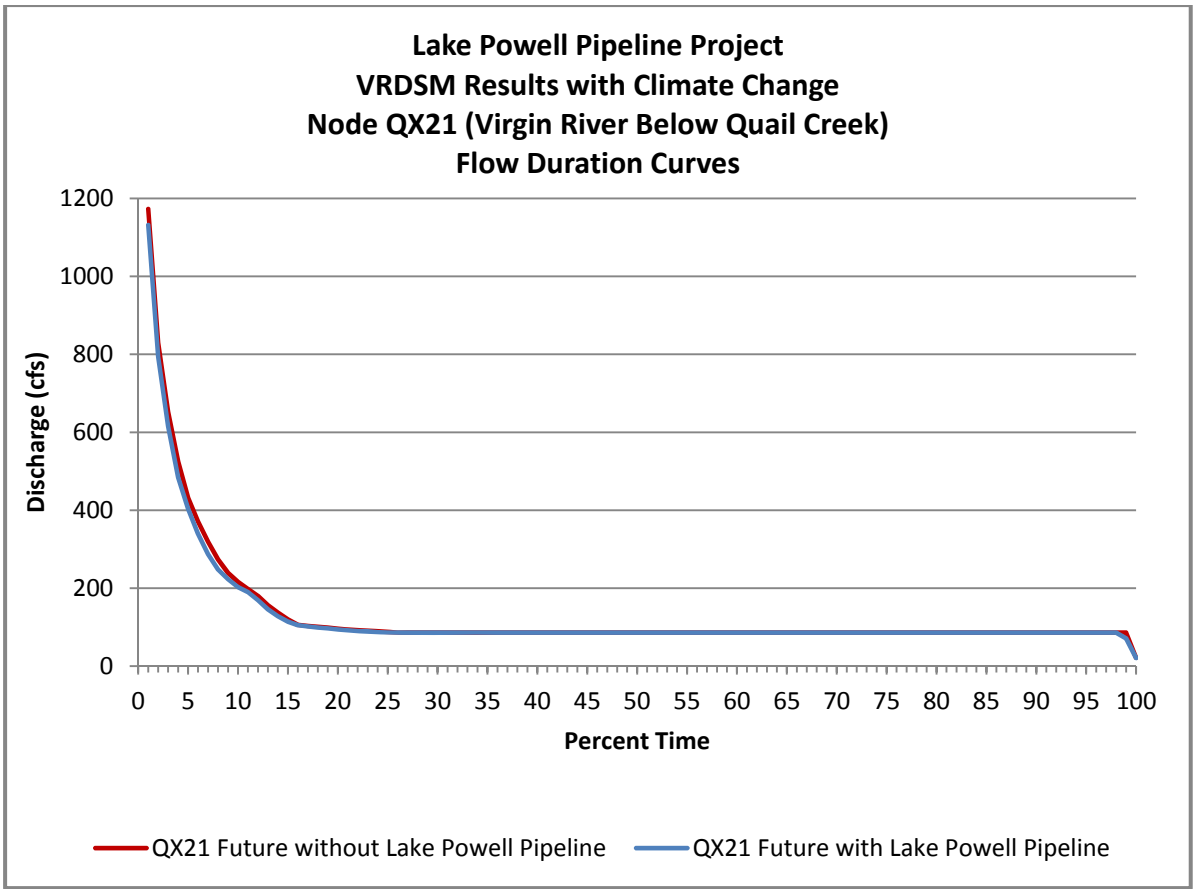


Figure 4-7
Virgin River Below Quail Creek – Simulated Flow Duration Curves

Figure 4-8 shows average monthly results for flow and Figure 4-9 shows flow duration curves for the Virgin River below the Washington Fields diversion. Both simulations resulted in low flows during the summer and fall months at this location as regulating storage is used and refilled in response to outdoor secondary water demand throughout the summer.

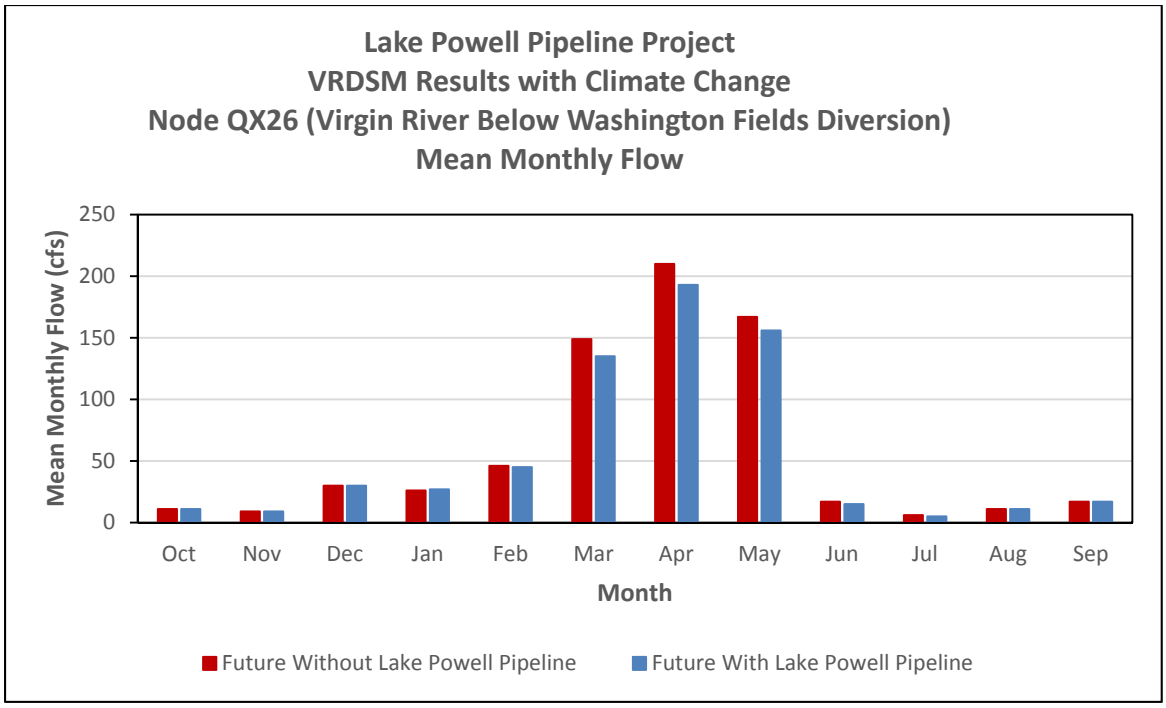


Figure 4-8
Virgin River Below Washington Fields Diversion – Simulated Monthly Flows

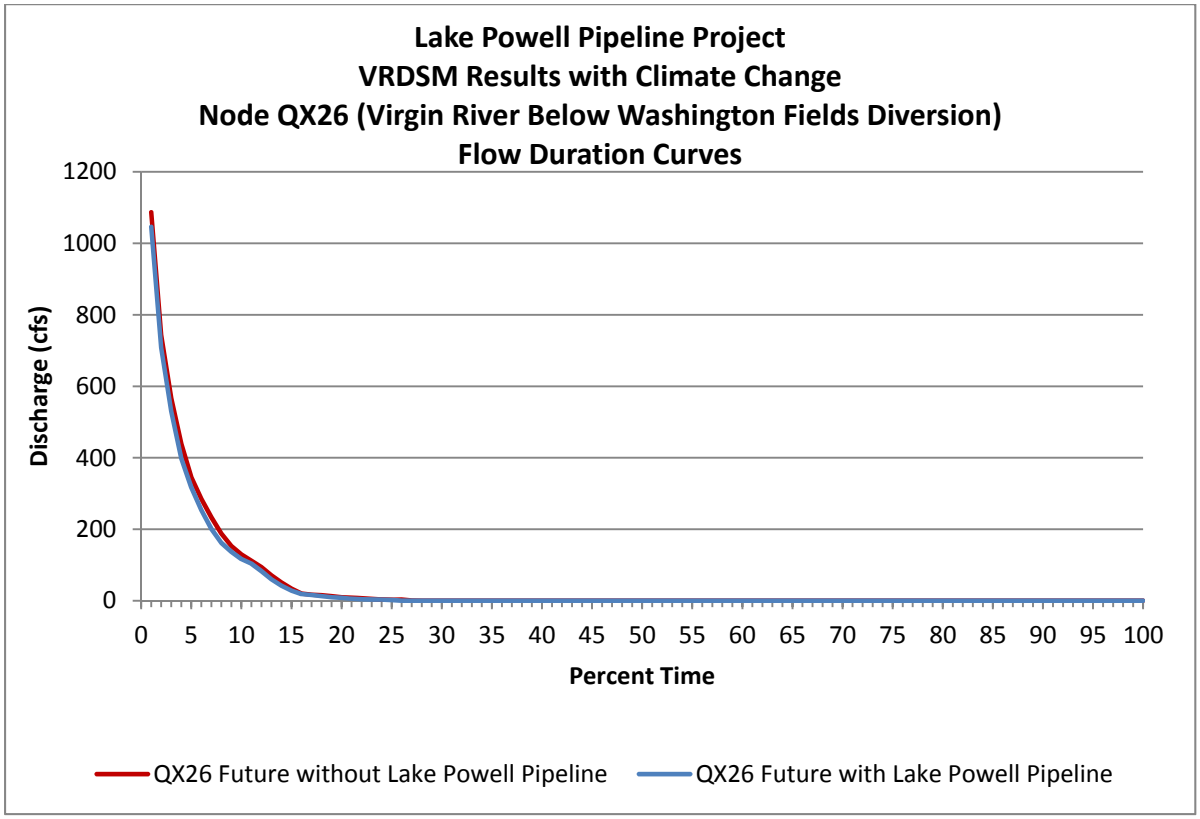


Figure 4-9
Virgin River Below Washington Fields Diversion – Simulated Flow Duration Curves

Figure 4-10 shows simulated monthly average flows in the Virgin River downstream of the Santa Clara River and immediately upstream of the St. George M&I land area return flow location. Figure 4-11 shows the simulated flow duration curves. Return flows from the Washington Fields land area are represented at this location.

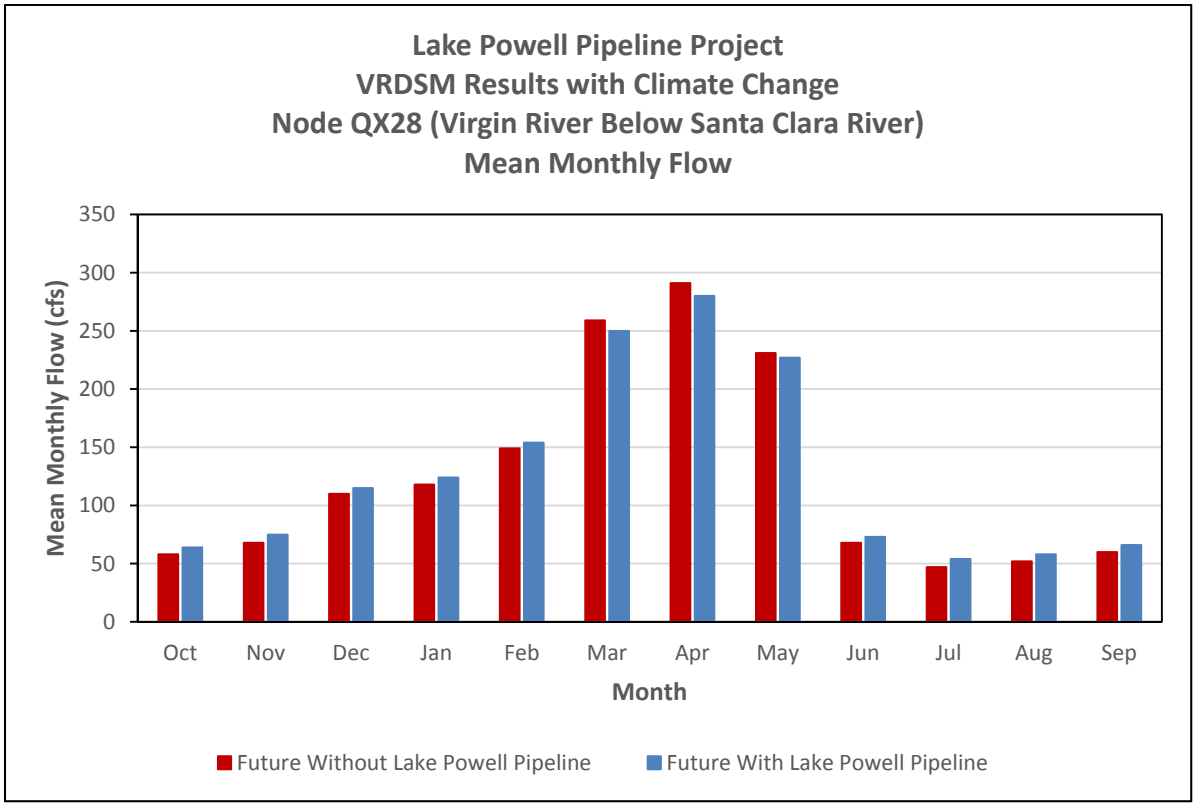


Figure 4-10
Virgin River Below Santa Clara River – Simulated Monthly Flows

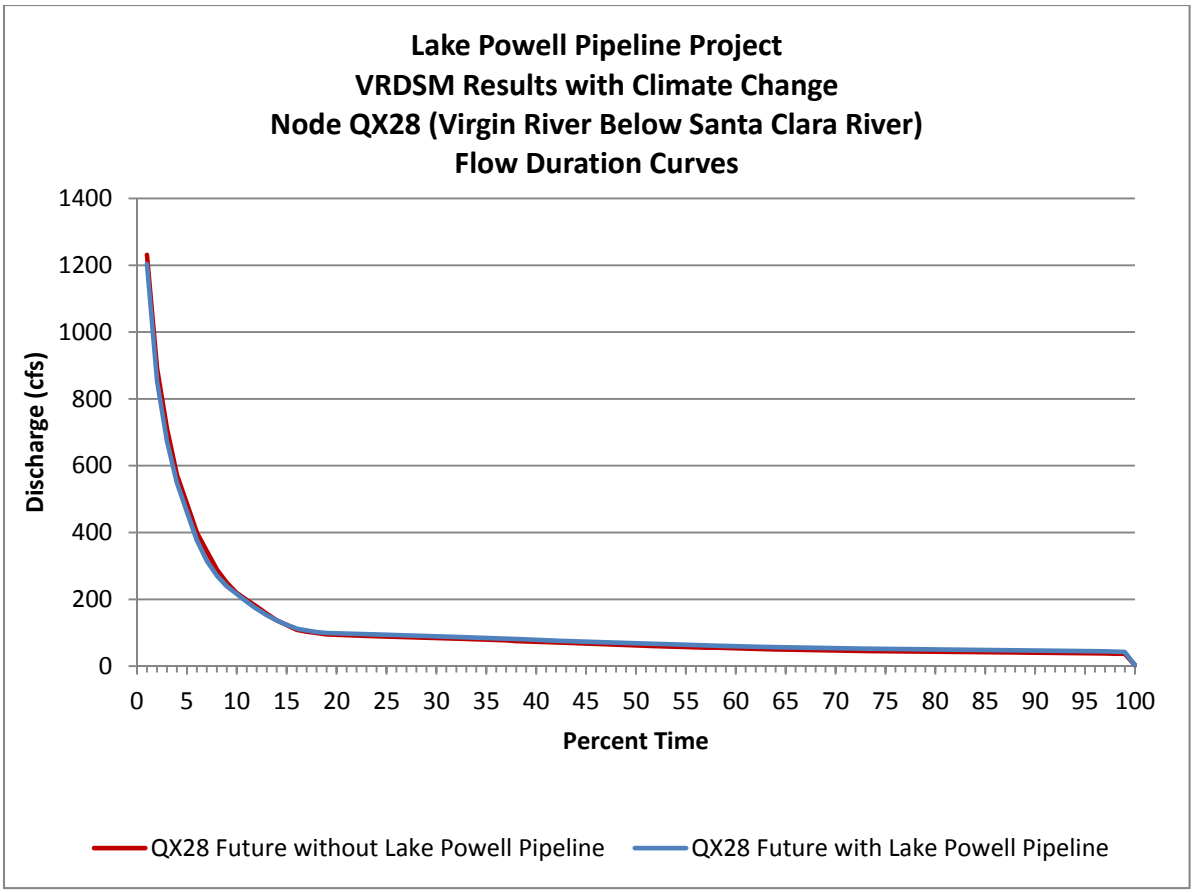


Figure 4-11
Virgin River Below Santa Clara River – Simulated Flow Duration Curves

Simulated monthly average flows for the Virgin River at the Utah-Arizona State line are shown in Figure 4-12 while simulated flow duration curves are shown in Figure 4-13. Flows at this location include return flows from the St. George M&I land area.

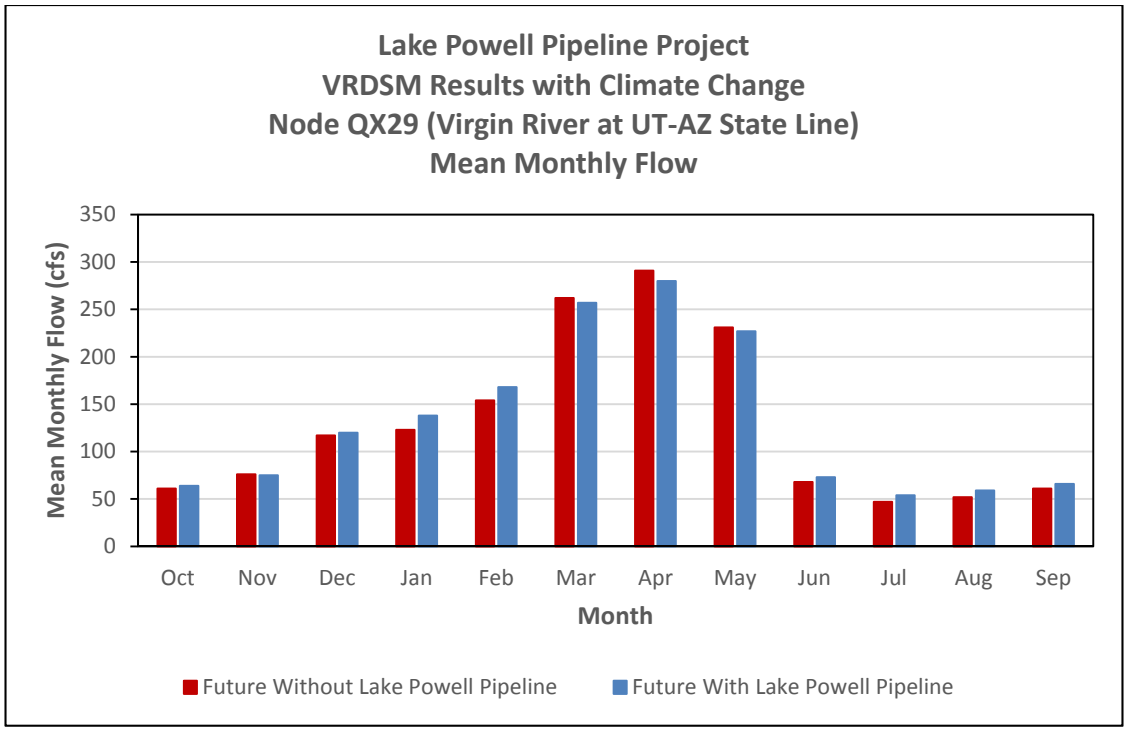


Figure 4-12
Virgin River at Utah-Arizona State Line – Simulated Monthly Flows

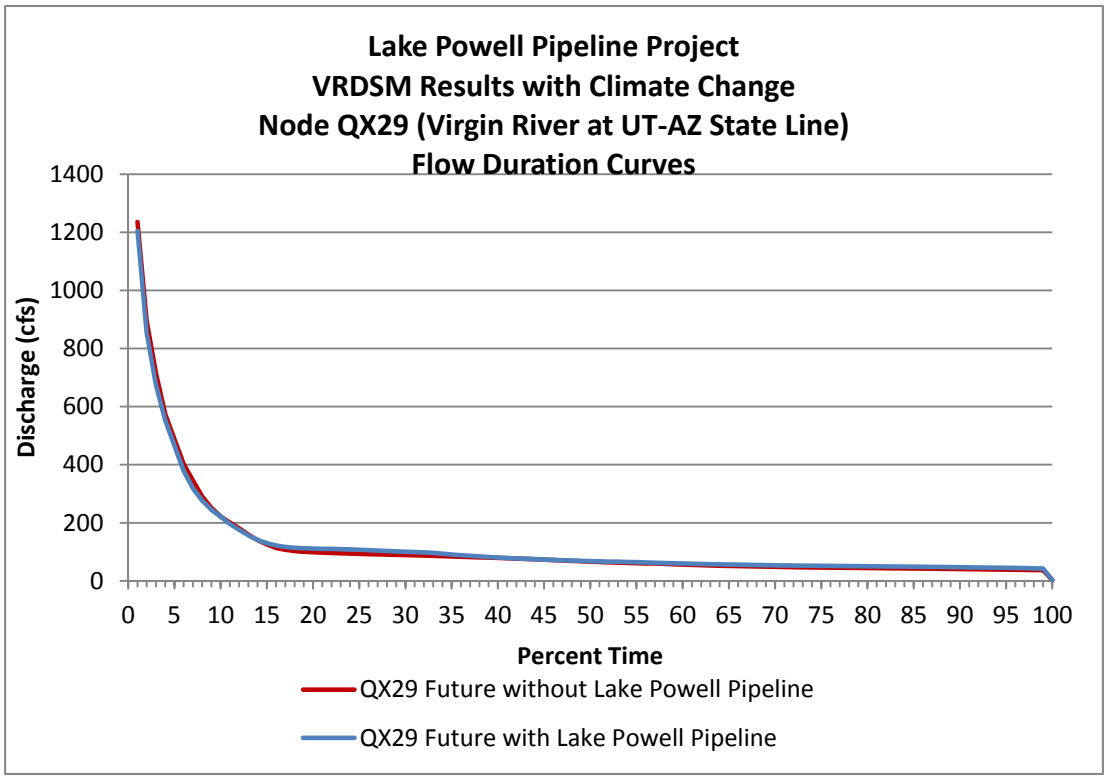


Figure 4-13
Virgin River at Utah-Arizona State Line – Simulated Flow Duration Curves

4.3.2.1 Stream Crossings

Ephemeral streams tributary to the Virgin River would be crossed by the LPP Project in Colorado City, Canaan Gap, near the forebay reservoir, and between the Hurricane Cliffs and Sand Hollow Reservoir. The penstock would be buried under ephemeral stream channels and construction activities would be planned to occur in the dry season when these channels typically would not be carrying water so that the LPP Project would not affect streamflows. Storms could cause flow in the channel or flash floods during the time of construction. Construction crews would have equipment on hand to divert flow around the construction area if this were to occur. This could have temporary and minor effects on natural streamflows, channel velocities and local erosion.

4.3.3 Kane, Mohave, and Coconino County Drainages

4.3.3.1 Return Flows

In the Lake Powell Pipeline Development Act, the Utah legislature allocated KCWCD up to 4,000 ac-ft. per year of LPP Project water, with the first LPP depletions beginning in 2035. The total amount of LPP water that could be distributed by KCWCD in the Johnson Canyon and Kanab areas of the District's service area is approximately 1,338 ac-ft. per year based upon the projected water demand. Should the actual water demand exceed the projected demand, KCWCD could receive additional LPP water from 1,338 ac-ft. per year up to 4,000 ac-ft. per year.

Assuming that the City of Kanab uses the full 4,000 acre-feet per year according to their 2005 water use patterns (see Table 3-3) this would result in an additional 800 acre-feet per year of non-sewered return flow. More than 1,400 acre-feet per year of additional flow would be delivered to Kanab's wastewater treatment facility, more than tripling the amount of water treated, and an additional 780 acre-feet per year of sewered return flow would accrue to Kanab Creek. The additional return flows would result in about 3 cfs of additional flow in Kanab Creek downstream of Kanab. If some of the 4,000 acre-feet per year allocated to KCWCD is used in the Johnson Canyon area or other parts of the KCWCD service area, return flows would attribute to local drainages proportional to the increase in water use and less return flow would accrue to Kanab Creek.

Figure 4-14 shows Kanab Creek downstream of Kanab, at the proposed location of the Existing Highway Alternative crossing. Based on field observations, the creek is frequently dry at this location and the channel is filled with vegetation. It is likely that additional return flows from LPP Project deliveries would result in more frequent flow in Kanab Creek downstream of Kanab.

Figure 4-14
Kanab Creek Near Arizona Route 389 in Fredonia - Facing Downstream

4.3.3.2 Stream Crossings

The LPP Project would cross intermittent and ephemeral streams in Kane, Mohave and Coconino counties as listed in Table 2-1 and shown in Figure 3-40. Multiple field visits of the South Alignment Kanab Creek crossing and Highway Alignment crossing locations show that these sites are frequently dry with no flow. At intermittent and ephemeral washes, open cuts for pipeline construction could be scheduled for the dry season to avoid affecting streamflows or ephemeral aquatic habitat. The pipeline would be buried under each stream channel once construction is completed such that the streams or stream flow would not be affected by LPP Project operation. Storms could cause flow in a channel or result in flash floods during the construction period. Construction crews would have equipment on hand to divert flow around the construction area if this were to occur. This could have temporary and minor effects on natural stream flows, channel velocities and local erosion.

There is typically a small amount of flow in the Paria River at the proposed crossing location at Highway 89. Figure 4-15 shows the highway bridge and USGS stream gage. The South Alternative (Proposed Action) includes an open cut across this reach for pipeline construction. The open cut would likely require construction in one half of the stream floodplain, using water bladder dams and culvert pipes to direct stream flow to another part of the wide channel cross section. Stream flows would not be measurably affected; however, the redirection of flow to a portion of the wide channel cross section could result in short-term effects including different flow velocities and potential bank and bed material erosion.

Figure 4-15
Paria River Near Kanab USGS Gage and Highway 89
Source: USGS (2009)

4.4 Reservoirs

4.4.1 Lake Powell

The effects on Lake Powell are based on the results of modeling completed by Reclamation. This section summarizes the findings of Reclamation's report, included in its entirety in Appendix 2.

4.4.1.1 Hydrologic Modeling Analysis

Reclamation's modeling of LPP Project effects assumes that all future Upper Basin depletions *except* for the LPP and other future depletions assumed to be reasonably foreseeable are modeled as constant at the 2015 depletion levels for both scenarios.

The South Alternative (With Pipeline) traces result in lower Lake Powell storage than the No Action Alternative. Figure 4-16 illustrates some of the differences between the CC and DNF simulations at the 50th percentile. For the 50th percentile results, reservoir storage would differ by 1.4 feet for the DNF hydrology and 2 feet for the CC hydrology. Table 4-4 summarizes the average difference in simulated reservoir pool elevation at the 10th, 50th, and 90th percentiles over the model period and the maximum difference in pool elevation over the period.

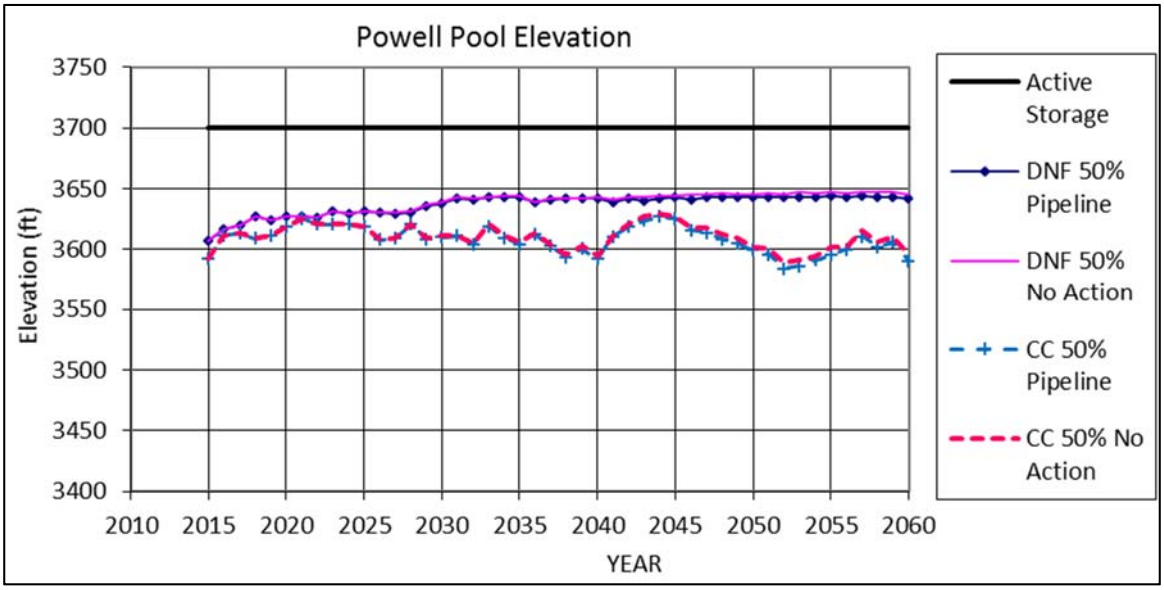


Figure 4-16
86K AF Simulations, 50th Percentile Lake Powell Stage Results

Table 4-4
86K AF Simulations, Summary of Lake Powell Pool Stage Differences (Feet)

Percentile	10th	50th	90th
DNF Average Difference	-3.7	-1.4	-0.2
DNF Maximum Difference	-10.3	-4.9	-0.5
CC Average Difference	-0.9	-2.0	-0.3
CC Maximum Difference	-7.0	-6.6	-2.1

Notes: Data based on CRSS results
Difference = South Alternative (Proposed Action) – No Action
DNF = Direct Natural Flow Inflow Hydrology
CC = Climate Change Inflow Hydrology

Figure 4-17 shows 50th percentile storage volumes for the two inflow scenarios. There are storage differences for both hydrologic input scenarios in the later years, when with Pipeline depletions are greater. Table 4-5 summarizes the average and maximum differences in simulated reservoir storage at the 10th, 50th, and 90th percentiles over the model period. Only the 10th percentile shows any years with differences greater than 5 percent. Additional details for the two inflow scenarios are included in the following sections.

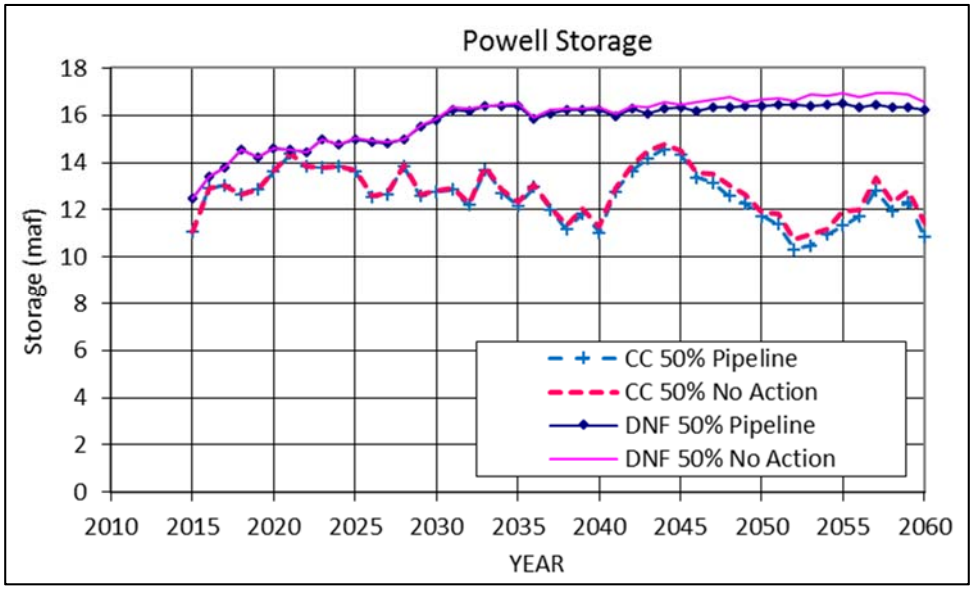


Figure 4-17
86K AF Simulations, 50th Percentile Lake Powell Storage Results

Table 4-5
86K AF Simulations, Summary of Lake Powell Storage Differences

	Absolute Difference (AF)			Percent Difference		
Percentile	**10th**	**50th**	**90th**	**10th**	**50th**	**90th**
DNF Average Difference	-300,640	-170,789	-24,145	-3%	-1%	0%
DNF Maximum Difference	-840,485	-603,912	-80,208	-9%	-4%	0%
CC Average Difference	-21,915	-195,564	-45,068	-2%	-2%	0%
CC Maximum Difference	-180,565	-628,955	-309,006	-16%	-5%	-1%

Notes: Data based on CRSS results
Difference = South Alternative (Proposed Action) – No Action
Percent Difference = Difference/No Action
DNF = Direct Natural Flow
CC = Climate Change

4.4.1.1.1 DNF Results. Figure 4-18 shows the DNF scenario results at the 10th, 50th, and 90th percentiles. There is little difference in reservoir storage for any of the percentiles until the later years when pipeline depletions are greater, which is most apparent in the 10th percentile.

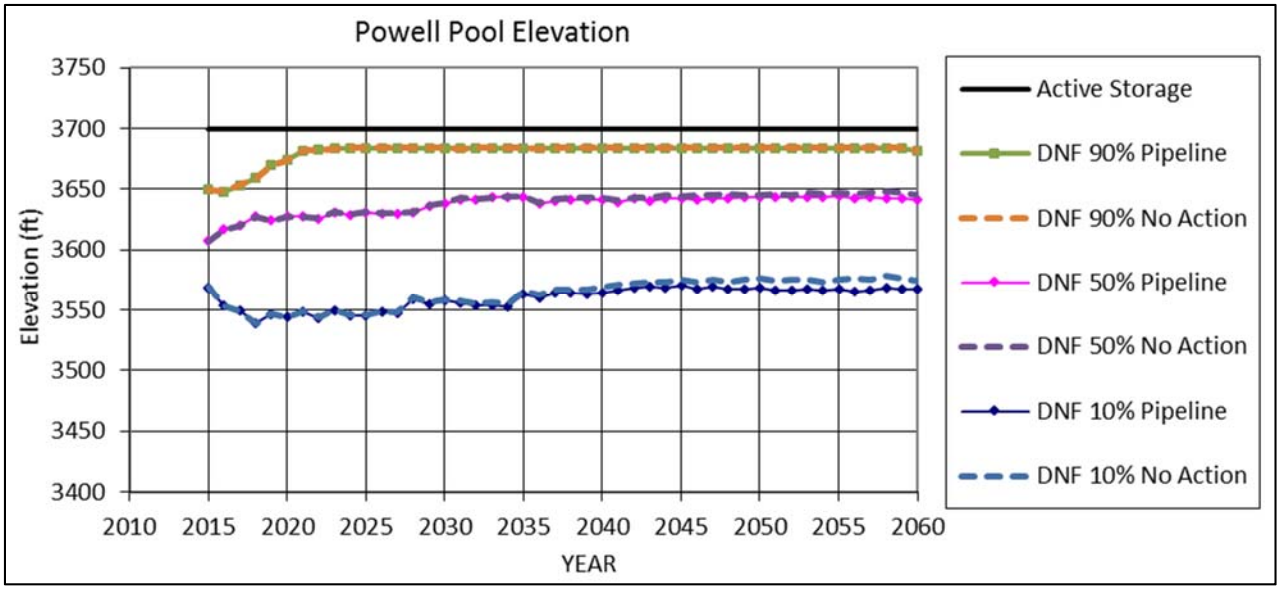


Figure 4-18
86K AF Simulations, Direct Natural Flow Lake Powell Stage Results

4.4.1.1.2 CC Results. Figure 4-19 shows the CC scenario results at the 10th, 50th, and 90th percentiles. Although the simulated reservoir levels are particularly different from the DNF results for the 10th percentile, the differences between the South Alternative (With Pipeline) and No Action storage levels are minimal. Differences between the two alternatives are very small throughout the simulation.

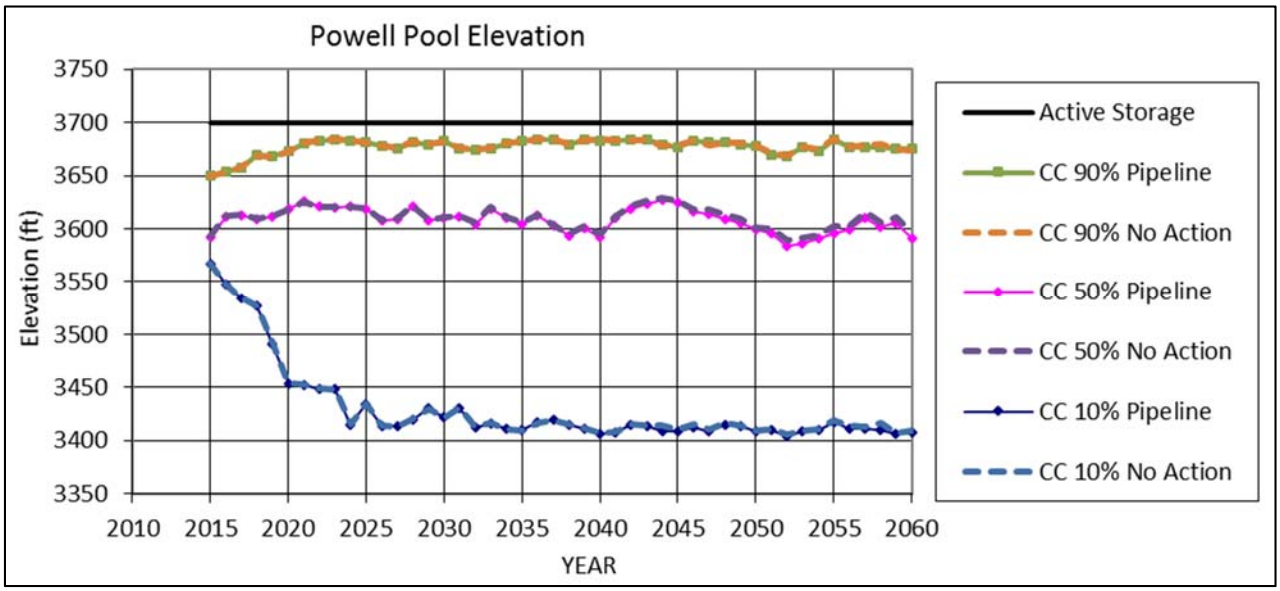


Figure 4-19
86K AF Simulations, Climate Change Lake Powell Stage Results

4.5 Peak Flows

The impacts on peak flows would be minimal because the South Alternative (Proposed Action) would not include the construction of any on-channel reservoirs. In cases of particularly erosive streams, the pipe may be protected by concrete encasement or a grade control structure that would be buried beneath the channel bed on the downstream side. If a grade control structure were to be uncovered during a high flow event, the structure could potentially affect peak flows and the geomorphology of the stream.

The Hurricane Cliffs Hydropower Forebay and Afterbay included in the South Alternative (Proposed Action) could affect peak flows slightly by modifying the drainage area tributary to Fort Pierce Wash. However the facilities would have a relatively small storage volume available for intercepting storm runoff, and therefore would result in an unmeasurable decrease in flood peaks and volumes downstream.

4.6 Geomorphology

As described in Chapter 3, streams in the study area are highly susceptible to erosion from peak flow events. The LPP Project would have no measurable impact on peak flow rates in the study area, and therefore, would not result in changes to stream channel movement or sediment transport during peak events. As described above, concrete pipe encasements or buried grade control structures that temporarily become uncovered during peak flow events could affect the natural stream response to peak flows.

There could be temporary geomorphology effects during construction at any stream crossings where water is actively flowing. Water bladder dams used as diversion structures and coffer dams during construction in stream channels would minimize local geomorphologic changes.

For the Colorado River downstream of Lake Powell, there would be little to no effect on flows in the Colorado River and therefore no change in the sediment transport or channel forming flows. In addition, because there would be little or no effect on storage in Lake Powell, there would not be any effect on the ability to conduct high flow experimental releases from Lake Powell. These high flow experimental releases have been shown to affect geomorphology in the lower Colorado River and the Grand Canyon.

Chapter 5
Mitigation and Monitoring

5.1 LPP Project Alternatives

(Water Conveyance System, Hydro System, Kane County Pipeline System, Transmission Line Alignments and Natural Gas Pipeline and Generators Alternative)

5.1.1 Mitigation

No mitigation would be required if Best Management Practices (BMPs) are implemented during construction and operations. BMPs would include coordination with appropriate Federal, State, local, and tribal agencies to acquire required permits for traffic controls and closures, development of traffic control plans, and scheduling construction during off-peak traffic hours as necessary.

5.1.1.1 Pipeline and Penstock Stream Crossings. Construction procedures at flowing, dry and ephemeral stream crossings, where applicable, would include planning for excavation during the most likely dry period during the year, installing temporary coffer dams at stream crossings, diverting streams and potential runoff flows through side channels to avoid excavation in active flow channels, minimizing the length of time open cuts are made through drainage channels, utilizing silt fence and straw bales to control potential erosion and sedimentation, and restoring channel bed and bank materials to pre-construction conditions. These measures would protect streams and channels from short-term effects during construction. There would be no adverse effects from implementing these short-term protection and mitigation measures. Stream alteration permits would be acquired before any undertaking any work requiring such permits.

Long-term protection and mitigation measures at stream crossings would include encasing the pipeline and penstock in reinforced concrete through the stream crossing area, installing structural grade controls downstream from encased pipelines and penstocks to prevent head-cutting and control local grades where a stream crosses a buried pipeline or penstock, and armoring the stream bed above a buried, concrete-encased pipeline or penstock with rock riprap to prevent erosion of pipeline bedding and soil from around encasements. There would be minimal long-term adverse localized effects on natural geomorphologic processes from implementing protection and mitigation measures at locations where the pipeline or penstock crosses streams and drainage channels.

5.2 No Lake Powell Water Alternative

There are no identified mitigation measures or monitoring for the No Lake Powell Water Alternative.

5.3 No Action Alternative

No mitigation or monitoring for surface water resource impacts would occur under the No Action Alternative

Chapter 6
Unavoidable Adverse Impacts

6.1 South Alternative

The South Alternative would have minor short-term unavoidable adverse impacts on surface water resources, including temporary diversions at actively flowing stream crossings. The South Alternative would have minor long-term unavoidable adverse impacts on surface water resources, including Lake Powell levels and associated volumes, Glen Canyon Dam releases to the Colorado River, Virgin River flows through the St. George metropolitan area, and minor cumulative impacts in combination with Bureau of Reclamation operating decisions on Lake Powell elevations and Glen Canyon Dam releases.

6.2 Existing Highway Alternative

The unavoidable adverse impacts of the Existing Highway Alternative on surface water resources would be the same as described for the South Alternative in Section 6.1.

6.3 Southeast Corner Alternative

The unavoidable adverse impacts of the Southeast Corner Alternative on surface water resources would be the same as described for the South Alternative in Section 6.1.

6.4 Transmission Line Alignments

The unavoidable adverse impacts of the Transmission Line Alignments on surface water resources would be the same as described for the South Alternative in Section 6.1.

6.5 Natural Gas Pipeline and Generators Alternative

The unavoidable adverse impacts of the Natural Gas Pipeline and Generators Alternative on surface water resources would be the same as described for the South Alternative in Section 6.1.

6.6 No Lake Powell Water Alternative

The No Lake Powell Water Alternative would have no short-term unavoidable adverse impacts on surface water resources. The No Lake Powell Water Alternative could have moderate long-term unavoidable adverse impacts and significant unavoidable adverse cumulative impacts on surface water resources in the St. George metropolitan area associated with repurposing St. George Water Reuse Project water for reverse osmosis treatment after mixing with diverted Virgin River water and storage in future re-regulating storage. Repurposing the reuse water as part of the supply for the reverse osmosis treatment would have unavoidable adverse effects on parks, golf courses, cemeteries and other areas that currently use reuse water for irrigation.

6.7 No Action Alternative

No unavoidable adverse impacts would occur with the No Action Alternative.

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 minimal short-term impacts on surface water resources during construction. Therefore, there would be no measurable cumulative impacts of the LPP alternatives on surface water resources when combined with other past, present, and reasonably foreseeable future actions. The unmeasurable short-term cumulative impacts would not be significant.

The South Alternative could have minimal long-term cumulative impacts on surface water resources in Lake Powell and Glen Canyon Dam releases when combined with the following past, present, and reasonably foreseeable future actions during operations:

Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead EIS and ROD

Operation of Glen Canyon Dam EIS and ROD

Interim Surplus Criteria EIS and ROD

Bureau of Reclamation and National Park Service Long-Term Experimental and Management Plan (LTEMP) EIS

These interrelated actions determine the elevation, storage, release, operational timing, and volume of water in Lake Powell and release rates, release volumes, and operational timing of Glen Canyon Dam releases to the Colorado River. The South Alternative would have minimal impacts on elevations, storage, release, operational timing and volume of water in Lake Powell, and when combined with these interrelated actions, there would be long-term minimal cumulative impacts on surface water resources. Similarly, the South Alternative would have minimal impacts on Glen Canyon Dam release rates, release volumes, and operational timing of releases and when combined with these interrelated actions, there would be long-term minimal cumulative impacts on surface water resources. These long-term cumulative impacts would not be physically measurable in Lake Powell and Glen Canyon Dam releases; however, they would result from depletions up to 86,249 acre-feet per year from Lake Powell and would have minimal cumulative impacts on Bureau of Reclamation operations and other actions implemented by the U.S. Department of the Interior. These cumulative impacts in surface water resources would be not be significant.

The South Alternative would have a long-term cumulative impact on surface water resources when combined with the St. George Wastewater Reuse Project. The South Alternative would involve utilizing 3,000 acre-feet of off-stream storage of reuse water as part of the City of St. George plan to maximize reuse storage and delivery with the LPP project water distribution throughout the St. George metropolitan area. This cumulative impact could result in changing the distribution of reuse water for parks, golf courses and cemeteries. The potential cumulative impact would not interfere with the 2,000 acre-feet per

year of reuse water belonging to the Shivwits Band of Paiute Indians; however, the future remaining reuse water could be managed in combination with other non-potable water supplies to meet system requirements.

7.2 Existing Highway Alternative

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

7.3 Southeast Corner Alternative

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

7.4 Transmission Line Alignments

The cumulative impacts of the Transmission Line Alignments would be the same as described for the South Alternative in Section 7.1.

7.5 Natural Gas Pipeline and Generators Alternative

The cumulative impacts of the Natural Gas Pipeline and Generators Alternative would be the same as described for the South Alternative in Section 7.1.

7.6 No Lake Powell Water Alternative

The No Lake Powell Water Alternative would have a long-term cumulative effect on surface water resources when combined with the operation of the St. George Wastewater Reuse Project. All of the available reclaimed wastewater effluent from the St. George Regional Wastewater Reclamation Facility would be conveyed to a future Warner Valley Reservoir for mixing with Virgin River water pumped from the Washington Fields Diversion, comprising the raw water supply for RO treatment processes. No reclaimed water would be available for reuse in city parks, golf courses and cemeteries. This cumulative effect on surface water resources could be moderate and could be a significant cumulative effect, due to cessation of irrigating city parks, golf courses and cemeteries with reuse water.

7.7 No Action Alternative

The No Action Alternative would have no cumulative impacts.

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Glossary

Culinary water – water suitable for drinking

Secondary water – water that has not been treated to drinking water standards but may be suitable for other uses such as irrigation or industrial processes

Baseflow – streamflow resulting from groundwater inflow to the stream; the flow that occurs during dry weather that is not the direct result of snowmelt or rainfall

Peak flow – the highest discharge in a stream, usually the result of large precipitation events or rapid snowmelt

Sewered return flows – the water supply that is not consumptively used and returns to surface waters via wastewater treatment facilities; generally the result of indoor water use

Non-sewered return flows - the water supply that is not consumptively used and returns to surface waters via storm drains and groundwater; generally the result of outdoor water use

Abbreviations and Acronyms

AF – acre-feet

AFY – acre-feet per year

BLM – Bureau of Land Management

CC – Climate Change

cfs – cubic feet per second

CICWCD – Central Iron County Water Conservancy District

Commission – Federal Energy Regulatory Commission

CRSS - Colorado River Basin hydrology and operations model

EIS – Environmental Impact Study

FEMA – Federal Emergency Management Agency

FERC – Federal Energy Regulatory Commission

FONSI – finding of no significant impact

FPS – Final Planning Study

GSENM – Grand Staircase-Escalante National Monument

KCWCD – Kane County Water Conservancy District

LPP – Lake Powell Pipeline

MAF – million acre-feet

MDG – million gallons per day

MSL – mean sea level

NAD – No Additional Depletions

NEPA - National Environmental Policy Act

ROD – Record of Decision

SITLA - Utah School and Institutional Trust Lands Administration

UCRC - Upper Colorado River Commission

UDWRe - Utah Division of Water Resources

USGS – United States Geological Survey

WCWCD – Washington County Water Conservancy District

List of Preparers

Name	Degree(s)	Role
MWH Consultant Team		
Lisa Fardal MWH, Inc.	M.S. - Civil Engineering B.A. - Biology B.A. – Environmental Studies	Surface Water Resources
Edwin Paulson MWH, Inc.	M.S. – Water Resources B.A. – Civil Engineering	Surface Water Resources
Brian Liming MWH, Inc.	M.S. – Civil and Environmental Engineering B.S. – Ecosystems Analysis	Report QA/QC Review
Diana Barnes MWH, Inc.	A.A. – Secretarial Science	Word Processing and Formatting

Appendix 1
Virgin River Daily Simulation Model and Description

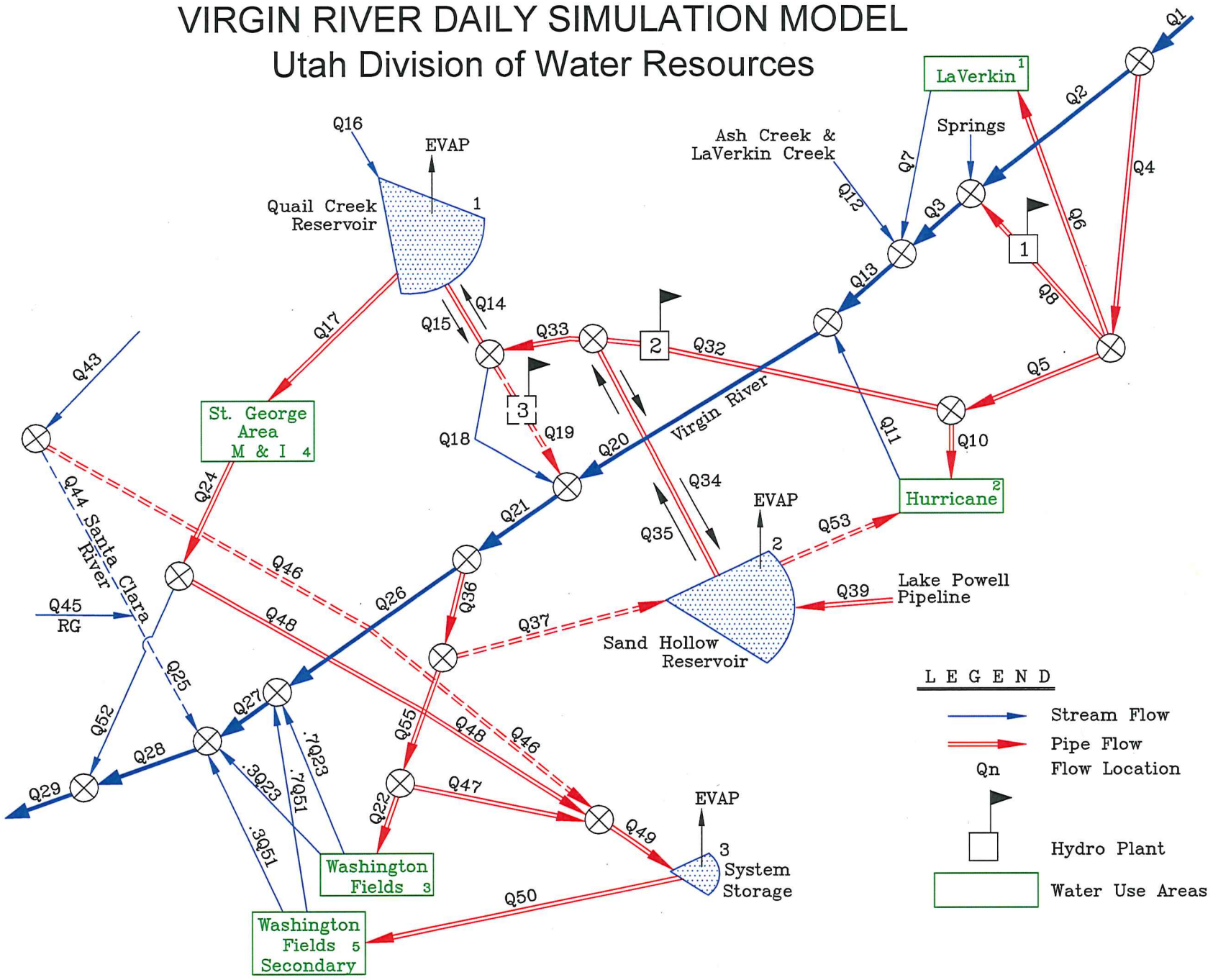
Lake Powell Pipeline
Virgin River Daily Simulation Model Flow Results
Comparison Between Climate Change 50th Percentile Existing Facilities and LPP Climate Change 50th Percentile
With USGS Gage Accuracy

USGS Gage No.	Gage Accu.	VRDSM Node	Scenario and Description	Water Year Months (cfs)											
				Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
09408150	10%	QX21	1. Future w/CC 50+Ex. F.	96	95	116	112	132	235	296	253	103	92	97	103
			2. LPP w/CC 50+3000SS	95	95	116	113	131	221	279	242	100	91	97	101
			Flow Difference	1	0	0	1	1	14	17	11	3	1	0	2
			Gage Accuracy (flow)	10	10	12	11	13	22	28	24	10	9	10	10
09413200	16%	QX26	1. Future w/CC 50+Ex. F.	11	9	30	26	46	149	210	167	17	6	11	17
			2. LPP w/CC 50+3000SS	11	9	30	27	45	135	193	156	15	5	11	17
			Flow Difference	0	0	0	1	1	14	17	11	2	1	0	0
			Gage Accuracy (flow)	2	1	5	4	7	22	31	25	2	1	2	3
09413200	16%	QX27	1. Future w/CC 50+Ex. F.	40	46	75	78	100	199	253	201	46	31	36	43
			2. LPP w/CC 50+3000SS	44	50	79	83	103	189	240	196	49	36	40	48
			Flow Difference	4	4	4	5	3	10	13	5	3	5	4	5
			Gage Accuracy (flow)	6	7	12	12	16	30	38	31	7	5	6	7
09413200	16%	QX28	1. Future w/CC 50+Ex. F.	58	68	110	118	149	259	291	231	68	47	52	60
			2. LPP w/CC 50+3000SS	64	75	115	124	154	250	280	227	73	54	58	66
			Flow Difference	6	7	5	6	5	9	11	4	5	7	6	6
			Gage Accuracy (flow)	9	11	18	19	24	40	45	36	11	8	8	10
09413500	16%	QX29	1. Future w/CC 50+Ex. F.	61	76	117	123	154	262	291	231	68	47	52	61
			2. LPP w/CC 50+3000SS	64	75	120	138	168	257	280	227	73	54	59	66
			Flow Difference	3	1	3	15	14	5	11	4	5	7	7	5
			Gage Accuracy (flow)	10	12	19	20	25	41	45	36	11	8	8	10

Key: Flow difference exceeds USGS gage accuracy

Flow difference is less than or equal to USGS gage accuracy

VIRGIN RIVER DAILY SIMULATION MODEL
Utah Division of Water Resources



USGS Discharge Measurement Quality Codes and Virgin River Gaging Stations

http://help.waterdata.usgs.gov/codes-and-parameters/discharge-measurement-quality-code

Discharge Measurement Quality Code

The code identifying a stream discharge measurement quality qualifier.

Code	Description	
E	Excellent	The data is within 2% (percent) of the actual flow
G	Good	The data is within 5% (percent) of the actual flow
F	Fair	The data is within 8% (percent) of the actual flow
P	Poor	The data are >8% (percent) of the actual flow

Code descriptions are presented in Water Year Summary for each gage site, in the Surface Water Records, Remarks section.

09413500 VIRGIN RIVER NEAR ST. GEORGE, UT

LOCATION - Lat 37°00'52", long 113°40'47" referenced to North American Datum of 1927, in NW 1/4 NE 1/4 SE 1/4 sec.30, T.43 S., R.16 W., Washington County, UT, Hydrologic Unit 15010010, Bureau of Land Management, on right bank immediately upstream from Beaver Dam Mountains Wilderness Area, and 8.0 mi southwest of St. George.
DRAINAGE AREA - 4,123 mi².
SURFACE-WATER RECORDS
PERIOD OF RECORD - October 1950 to December 1956, October 1991 to current year.
REVISED RECORDS - WDR UT-92-1: Drainage area.
GAGE - Water-stage recorder, crest-stage gage and concrete control. Elevation of gage is 2,400 ft above NGVD of 1929, from topographic map. October 1950 to December 1956, about 400 ft downstream at different datum. October 1991 to November 2009, 200 ft downstream at same datum.
REMARKS - Records fair except for estimated daily discharges, which are poor. Many diversions for irrigation upstream of station.
EXTREMES OUTSIDE PERIOD OF RECORD - Maximum discharge, 60,000 ft³/s (estimated), Jan 1, 1989, gage height, about 30.0 ft, result of Quail Creek reservoir dike failure.
EXTREMES FOR PERIOD OF RECORD - Maximum discharge, 25,100 ft³/s, Dec 21, 2010, gage height 20.98 ft, from flood marks; no flow at times in some years.
U.S. Department of the Interior, U.S. Geological Survey
Suggested citation: U.S. Geological Survey, 2015, National Water Information System data available on the World Wide Web (USGS Water Data for the Nation), accessed [May 11, 2015], at URL http://nwis.waterdata.usgs.gov/nwis/wys_rpt?dd_parm_cds=&adr_begin_date=2013-1001&adr_end_date=2014-09-30&site_no=09413500&agency_cd=USGS

09413200 VIRGIN RIVER NEAR BLOOMINGTON, UT

LOCATION - Lat 37°04'12", long 113°35'02" referenced to North American Datum of 1983, in SE 1/4 NW 1/4 SW 1/4 sec.06, T.43 S., R.15 W., Washington County, UT, Hydrologic Unit 15010010, on right bank 0.4 mi downstream from mouth of Santa Clara River, 100 ft upstream from I-15 bridge, about 1.5 mi northeast of Bloomington, and 2.5 mi south of St. George.
DRAINAGE AREA - 3,853 mi².
SURFACE-WATER RECORDS
PERIOD OF RECORD - September 1977 to current year.
REVISED RECORDS - WDR-UT-92-1: Drainage area.
GAGE - Water-stage recorder and crest-stage. Elevation of gage is 2,530 ft above NGVD of 1929, from topographic map. Prior to September 19, 1978 at site 1.25 mi downstream at different datum. Sep 19, 1978 to May 18, 1992 and Feb 25, 1993 to Nov 18, 1993 at site 650 ft upstream. May 18, 1992 to Feb 25, 1993 at site 880 ft upstream. Nov 18, 1993 to Apr 21, 2004 at site 700 ft upstream. Records for Sep 19, 1978 to Apr 21m 2004 at datum 10.0 ft higher. Apr 21, 2004 to Jan 27, 2005 700 ft upstream on right bank, same datum. Jan 27, 2005 to Nov 11, 2011 700 ft upstream left bank, same datum.
REMARKS - Records fair except for flows greater than 400 ft³/s and estimated daily discharges which are poor. Some regulation of flow by reservoirs and diversions for irrigation upstream of station.
EXTREMES FOR PERIOD OF RECORD - Maximum discharge, 60,000 ft³/s (estimated on basis of slope conveyance), Jan 1, 1989, gage height, 25.70 ft, result of Quail Creek reservoir dike failure; minimum daily discharge, 5.1 ft³/s, Jul 11, 2003.
U.S. Department of the Interior, U.S. Geological Survey
Suggested citation: U.S. Geological Survey, 2015, National Water Information System data available on the World Wide Web (USGS Water Data for the Nation), accessed [May 11, 2015], at URL
http://nwis.waterdata.usgs.gov/nwis/wys_rpt?dd_parm_cds=&adr_begin_date=2013-1001&adr_end_date=2014-09-30&site_no=09413200&agency_cd=USGS

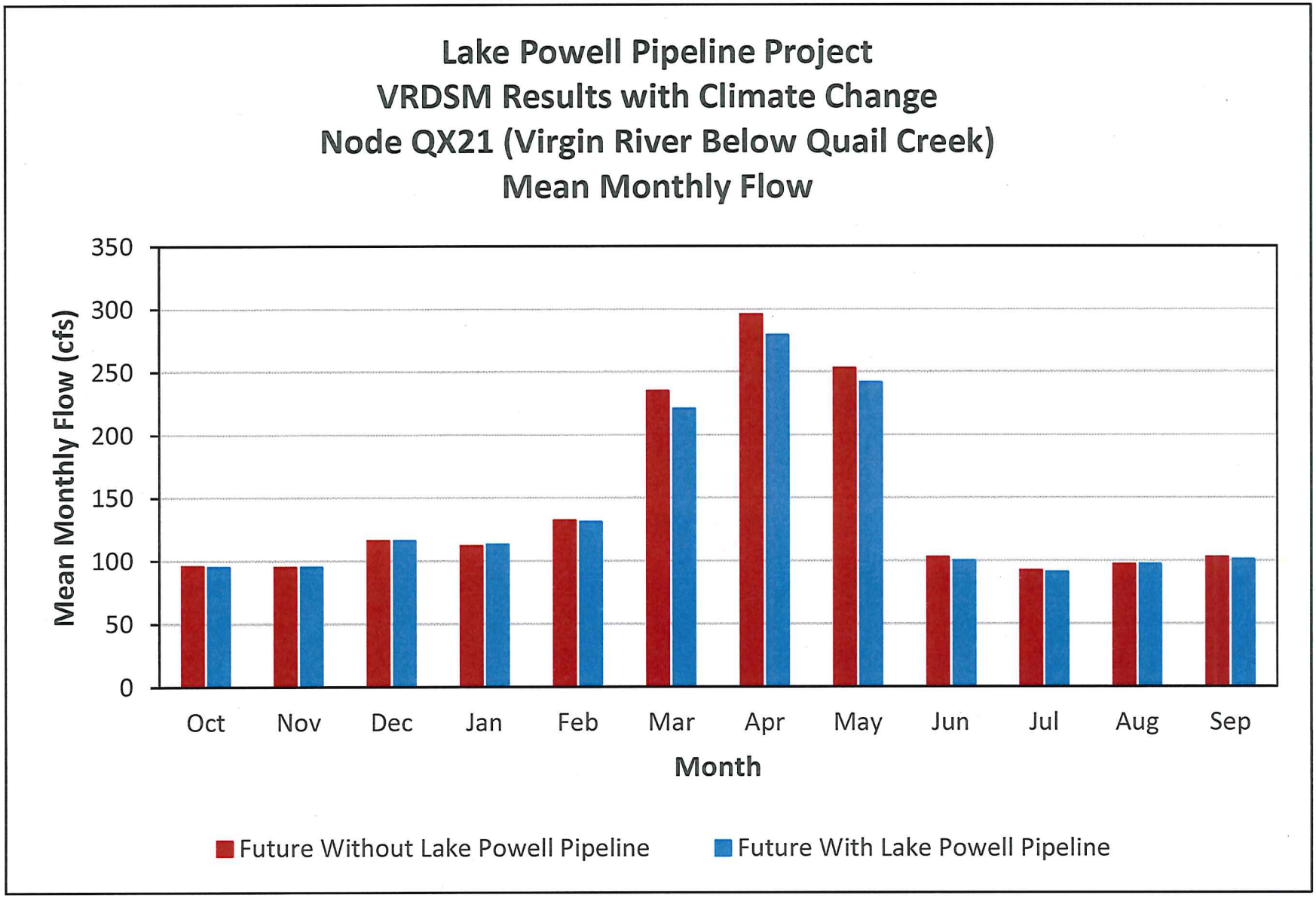
09408150 VIRGIN RIVER NEAR HURRICANE, UT

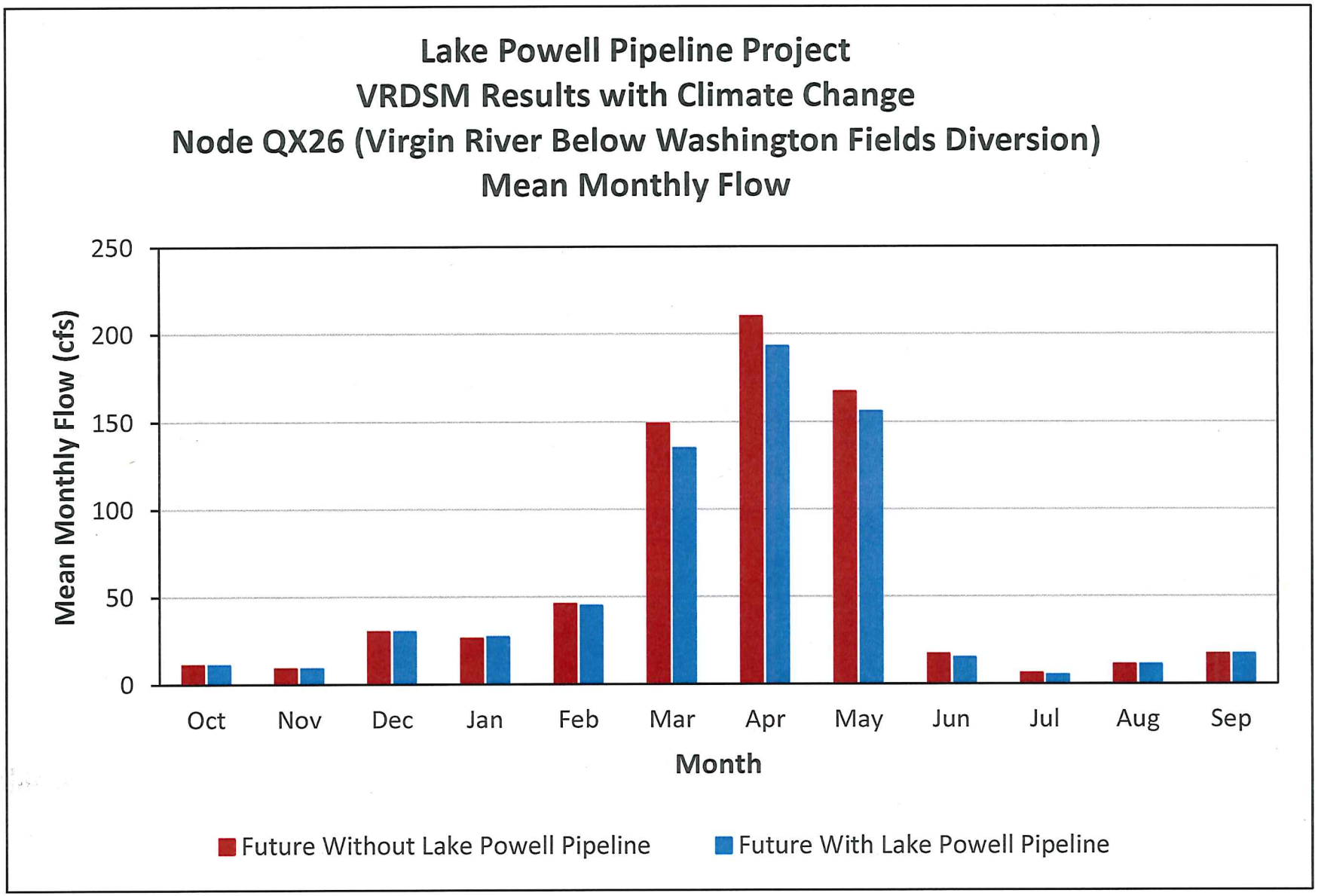
LOCATION - Lat 37°09'46", long 113°23'40" referenced to North American Datum of 1927, in NE 1/4 NE 1/4 SW 1/4 sec.02, T.42 S., R.14 W., Washington County, UT, Hydrologic Unit 15010008, on right bank, 1.8 mi downstream of Quail Creek Reservoir Dam, at upstream side of SR-9 bridge, 5.2 mi west of Hurricane.
DRAINAGE AREA - 1,493 mi².
SURFACE-WATER RECORDS
PERIOD OF RECORD - March 1967 to February 1989, October 1990 to current year.
REVISED RECORDS - WDR UT-78-1 and WDR UT-94-1: Drainage area.
GAGE - Water-stage recorder and crest-stage gage. Datum of gage is 2,836.33 ft above NGVD of 1929, (Utah Department of Transportation right-of-way marker). March 20, 1967 to February 14, 1989 at site 100 ft downstream at different datum; October 1, 1990 to March 30, 1993 at site 0.1 mi downstream at different datum; March 30, 1993 to July 31, 2008 at site 1.2 mi upstream at different datum.
REMARKS - Records good except for estimated daily discharges, which are poor. Since 1985, flow diverted about 14 mi upstream into a pipeline that feeds Quail Creek Reservoir (capacity 40,000 acre-feet), an offstream reservoir 1.8 mi upstream of gage, and since 2003 into Sand Hollow Reservoir (capacity 51,400 acre-feet), an offstream reservoir 2.8 mi southwest of gage. Flow subject to releases from Quail Creek Reservoir.
EXTREMES OUTSIDE PERIOD OF RECORD - Maximum stage known since at least 1909, 17.34 ft, Dec 6, 1966, from floodmarks; discharge, 20,100 ft³/s, from slope-area measurement, site and datum established Mar 1967.
EXTREMES FOR PERIOD OF RECORD - Maximum discharge, about 66,000 ft³/s, Jan 1, 1989, from slope-area measurement of Quail Creek Reservoir dike failure; minimum daily discharge, 22 ft³/s, Aug 29, 2002.
U.S. Department of the Interior, U.S. Geological Survey
Suggested citation: U.S. Geological Survey, 2015, National Water Information System data available on the World Wide Web (USGS Water Data for the Nation), accessed [May 11, 2015], at URL
http://nwis.waterdata.usgs.gov/nwis/wys_rpt?dd_parm_cds=&adr_begin_date=2013-1001&adr_end_date=2014-09-30&site_no=09408150&agency_cd=USGS

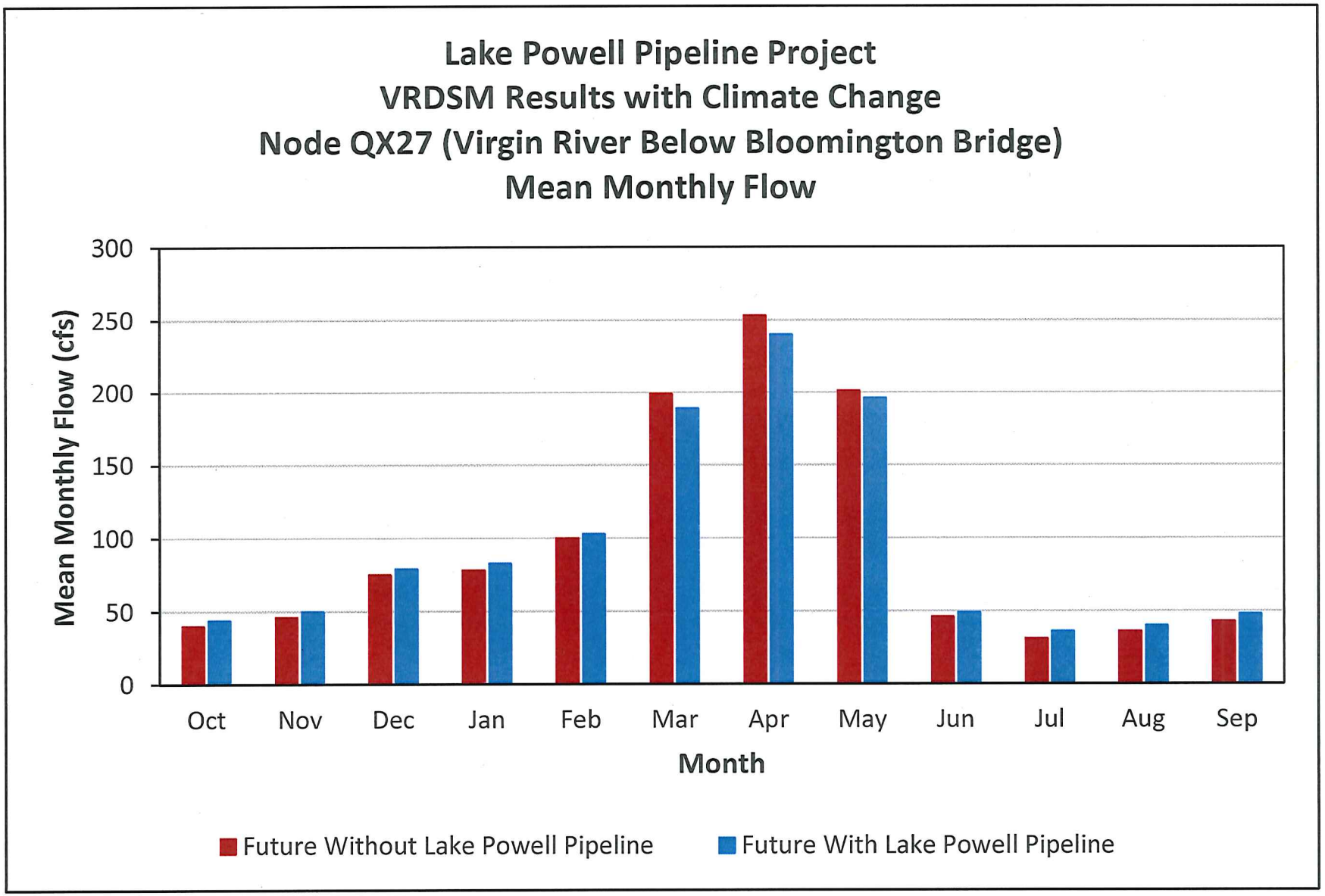
Virgin River Daily Simulation Model
Input Data Assumptions

Future Without LPP Scenario 1	Sometimes called the "Base Case", the future without the LPP represents the Virgin River System as it is currently developed with existing facilities under full utilization of water rights, if it were to exist in it's present state since 1941, the period of record. Demand in Land Areas 4 and 5 are iteratively adjusted such that the maximum shortage for either of these Land Areas never exceeds ten percent.
Future With LPP Scenario 2	69,000 acre-feet of water imported by the LPP from Lake Powell. This scenario also includes a re-regulating water storage facility with capacity of 3,000 acre-feet (Graveyard Wash Reservoir). Virgin River water is not used to satisfy demand in Land Area 5 (Washington Fields Secondary).

Scenario	Demand for Land Area 5 (acre-feet)	Threshold (cfs)	Reuse Capacity (cfs)	System Storage (acre-feet)	Total Deliveries (acre-feet)	St. George (acre-feet_	Washington Fields (acre-feet)	Secondary with Converted Washington Fields (acre-feet_
1 Future Without LPP	Optimized	1,000	100	0	100,993	24,842	62,160	13,991
2 Future With LPP	Optimized	1,000	200	3,000	212,720	93,030	62,012	57,677


Lake Powell Pipeline Project
VRDSM Results with Climate Change
Node QX21 (Virgin River Below Quail Creek)
Mean Monthly Flow
Mean Monthly Flow (cfs)
350
300
250
200
150
100
50
0
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Month
Future Without Lake Powell Pipeline
Future With Lake Powell Pipeline


Lake Powell Pipeline Project
VRDSM Results with Climate Change
Node QX26 (Virgin River Below Washington Fields Diversion)
Mean Monthly Flow
Mean Monthly Flow (cfs)
250
200
150
100
50
0
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Month
Future Without Lake Powell Pipeline
Future With Lake Powell Pipeline


Lake Powell Pipeline Project
VRDSM Results with Climate Change
Node QX27 (Virgin River Below Bloomington Bridge)
Mean Monthly Flow
Mean Monthly Flow (cfs)
300
250
200
150
100
50
0
Oct
Nov
Dec
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Feb
Mar
Apr
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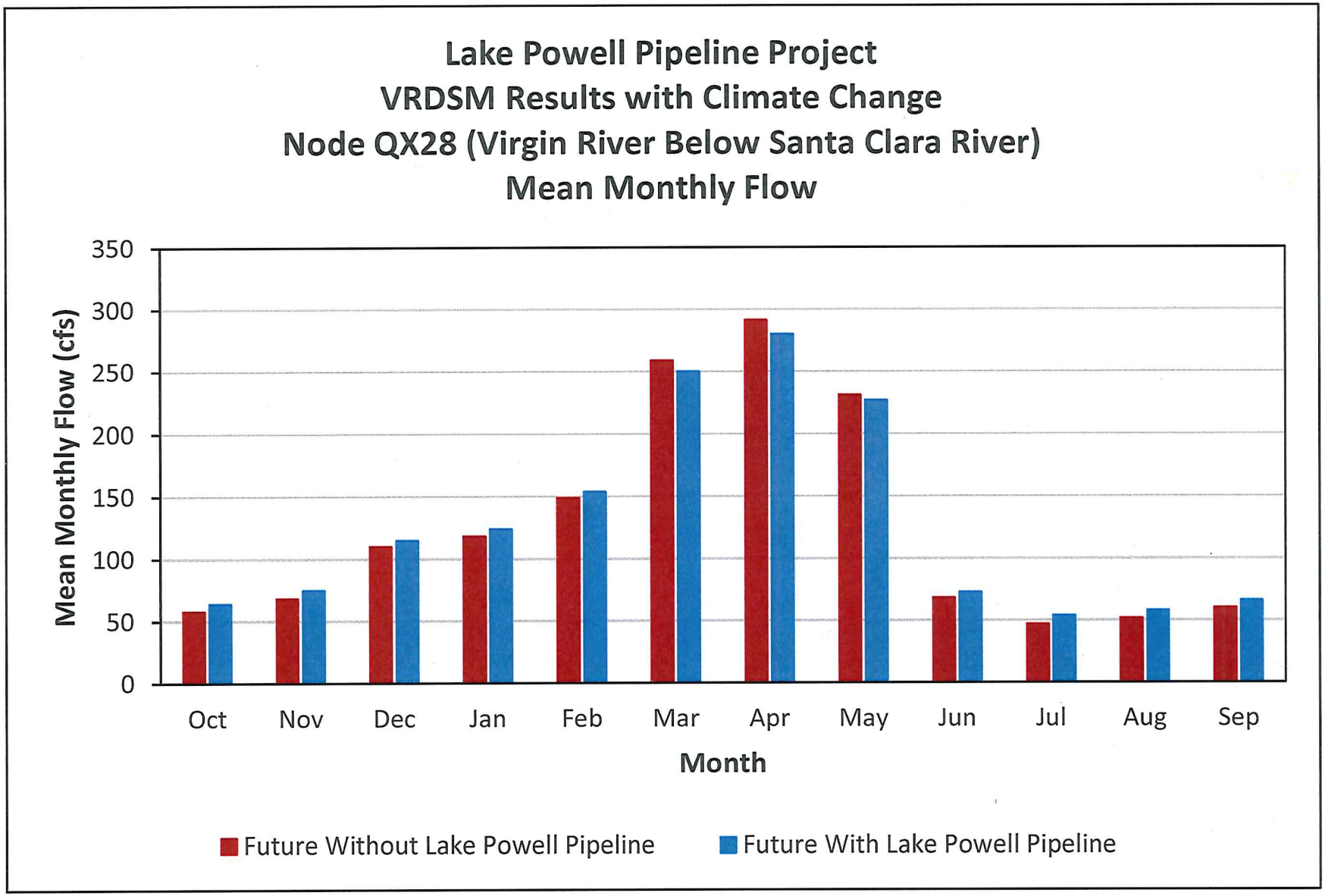
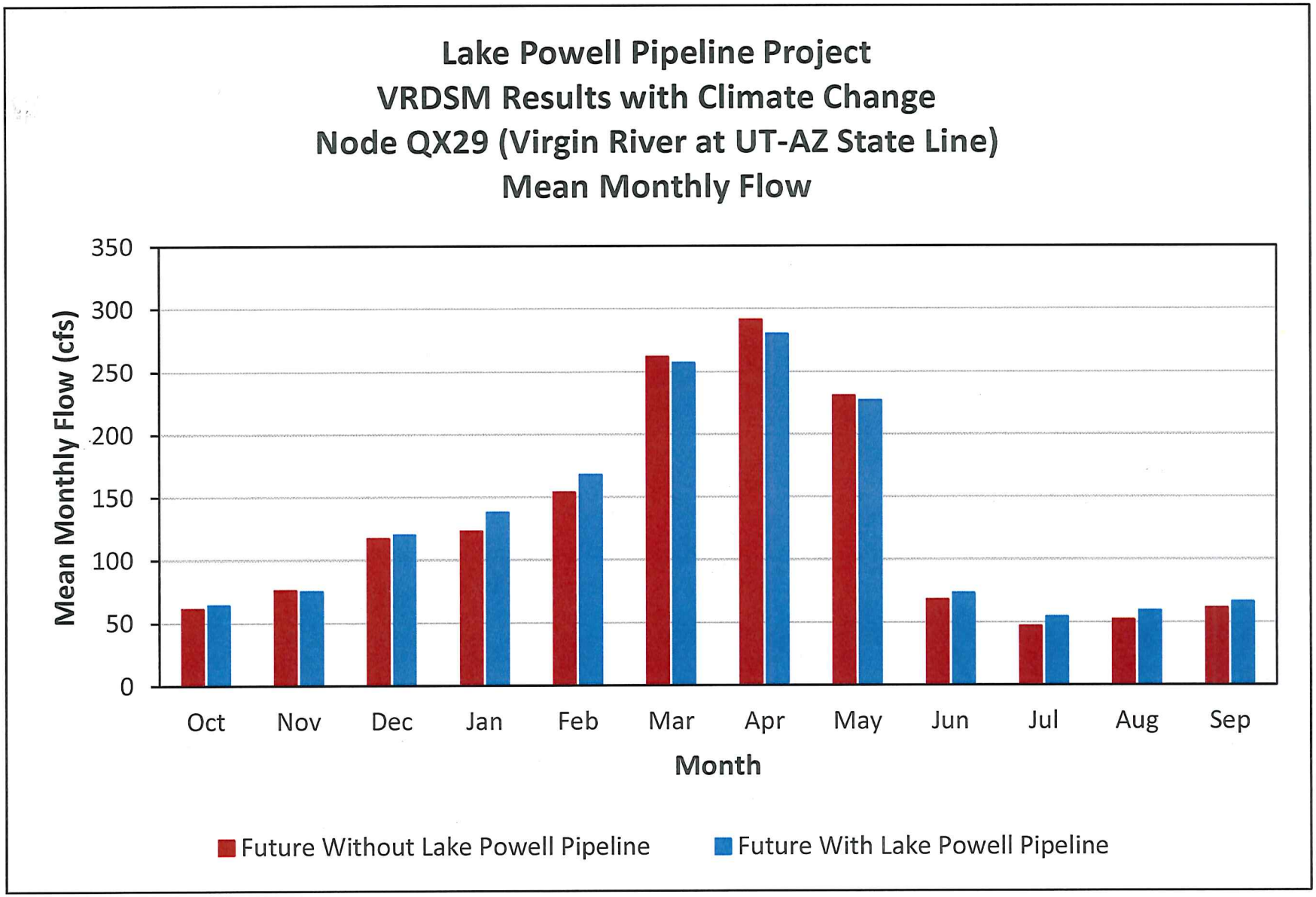
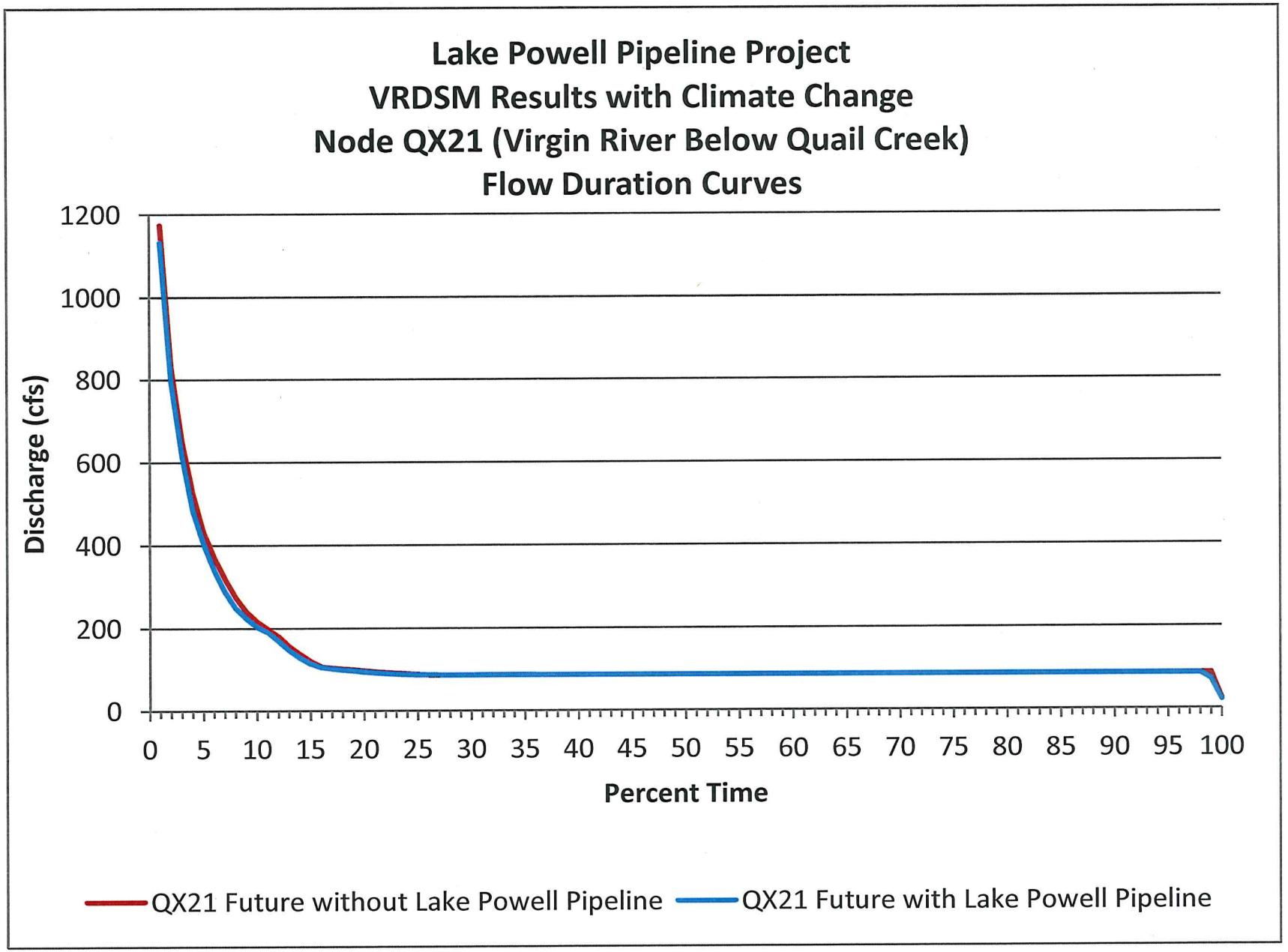
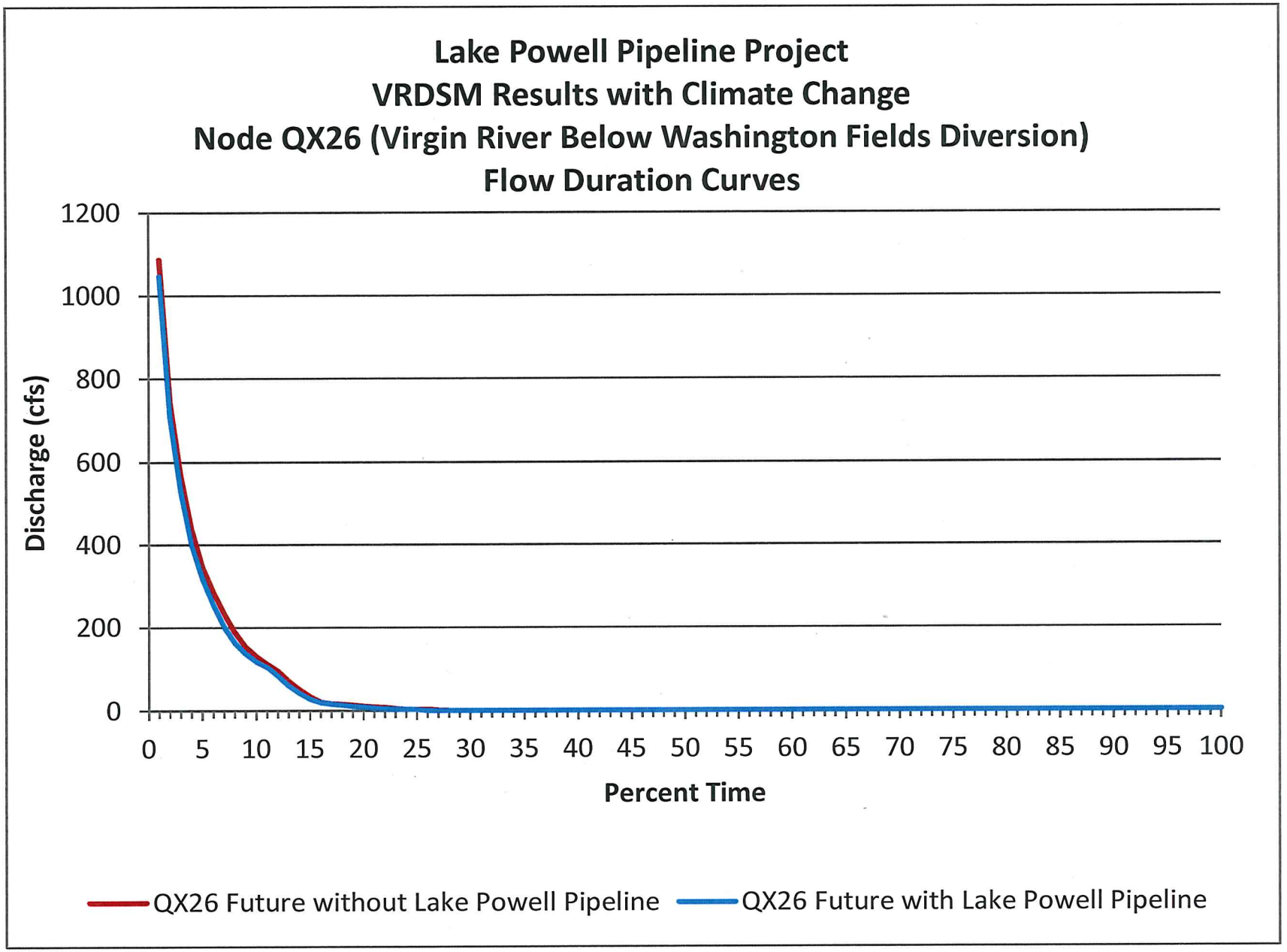
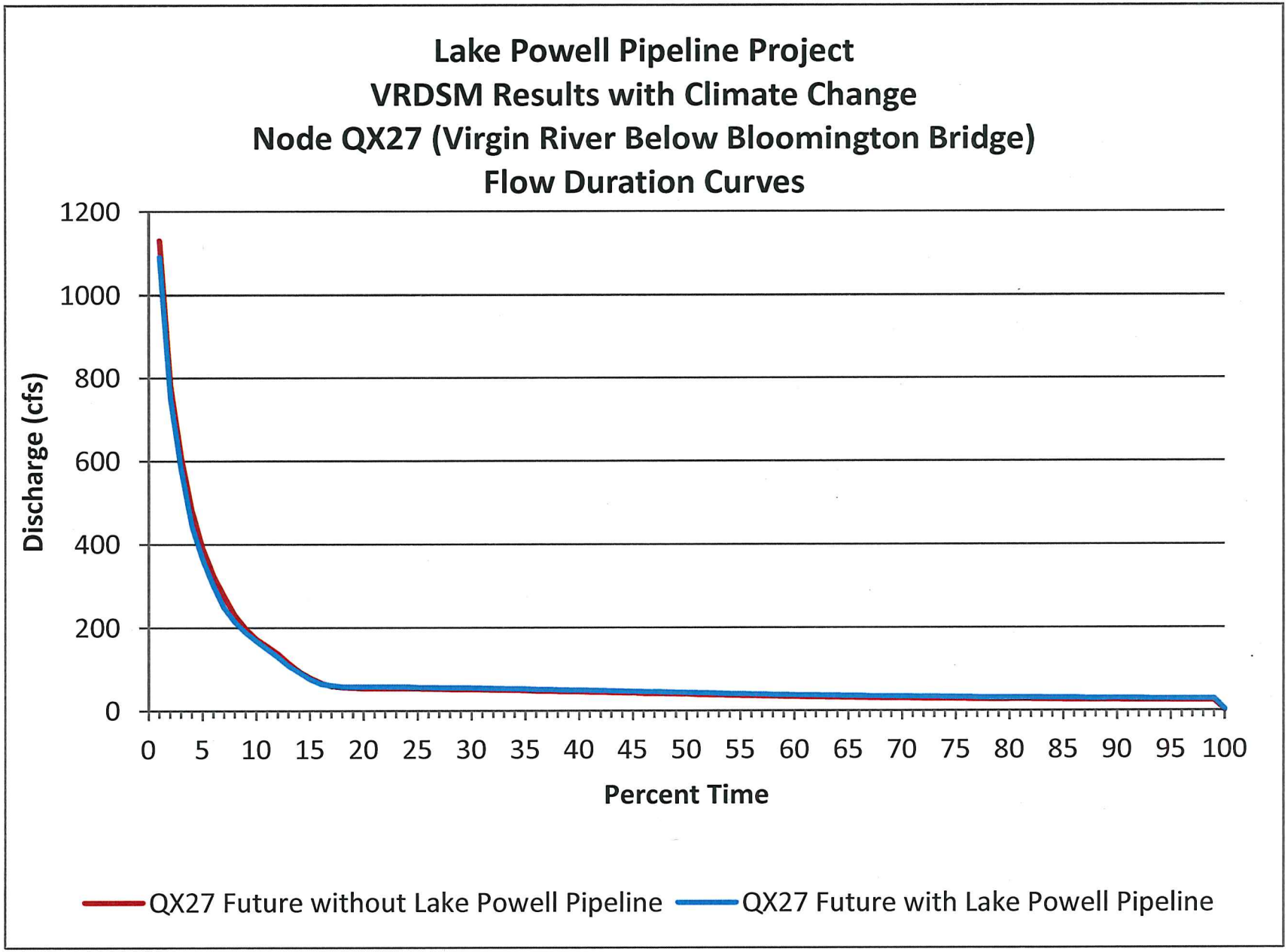
Jun
Jul
Aug
Sep
Month
Future Without Lake Powell Pipeline
Future With Lake Powell Pipeline

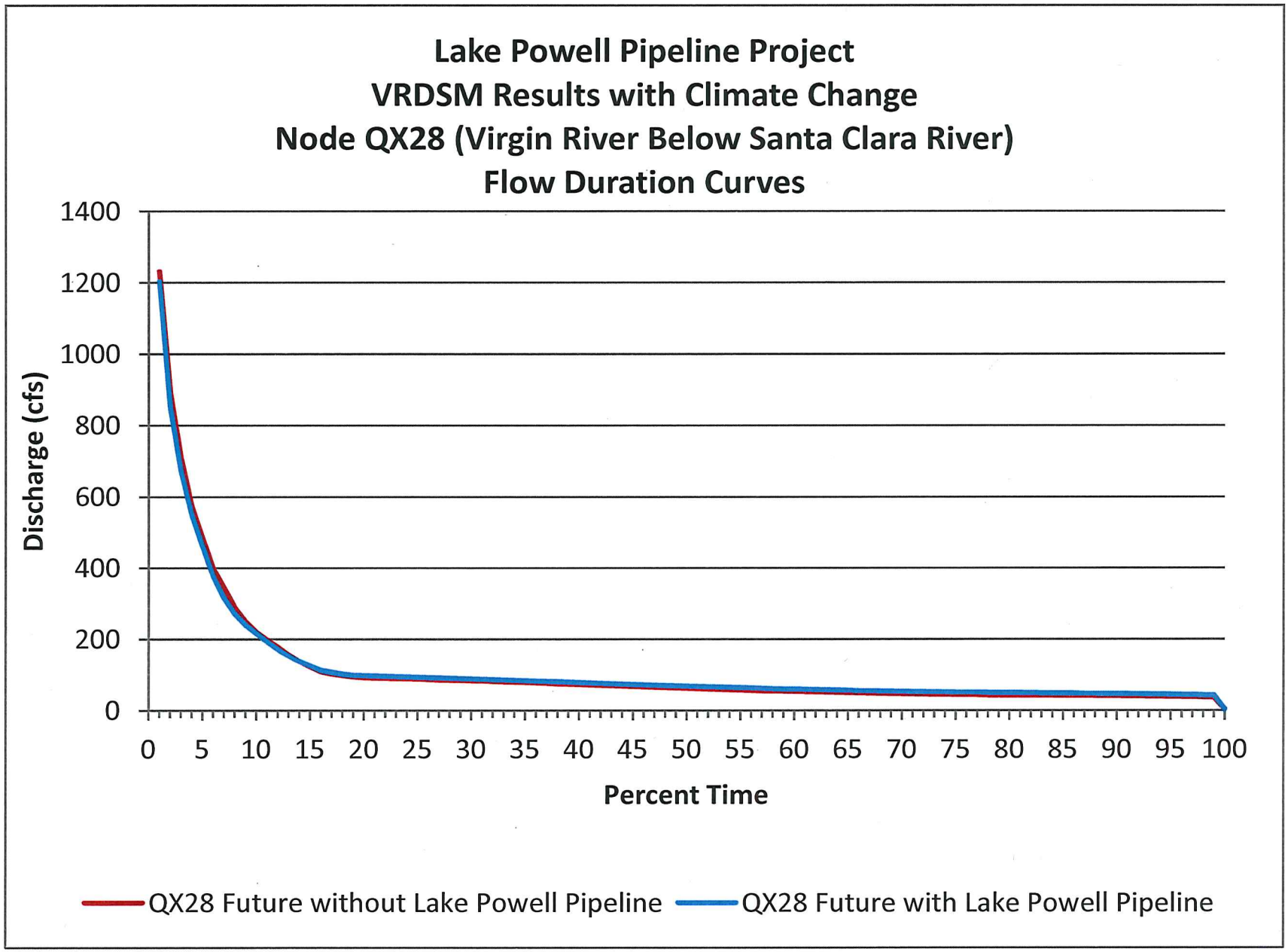

Lake Powell Pipeline Project
VRDSM Results with Climate Change
Node QX28 (Virgin River Below Santa Clara River)
Mean Monthly Flow
Mean Monthly Flow (cfs)
350
300
250
200
150
100
50
0
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Month
Future Without Lake Powell Pipeline
Future With Lake Powell Pipeline

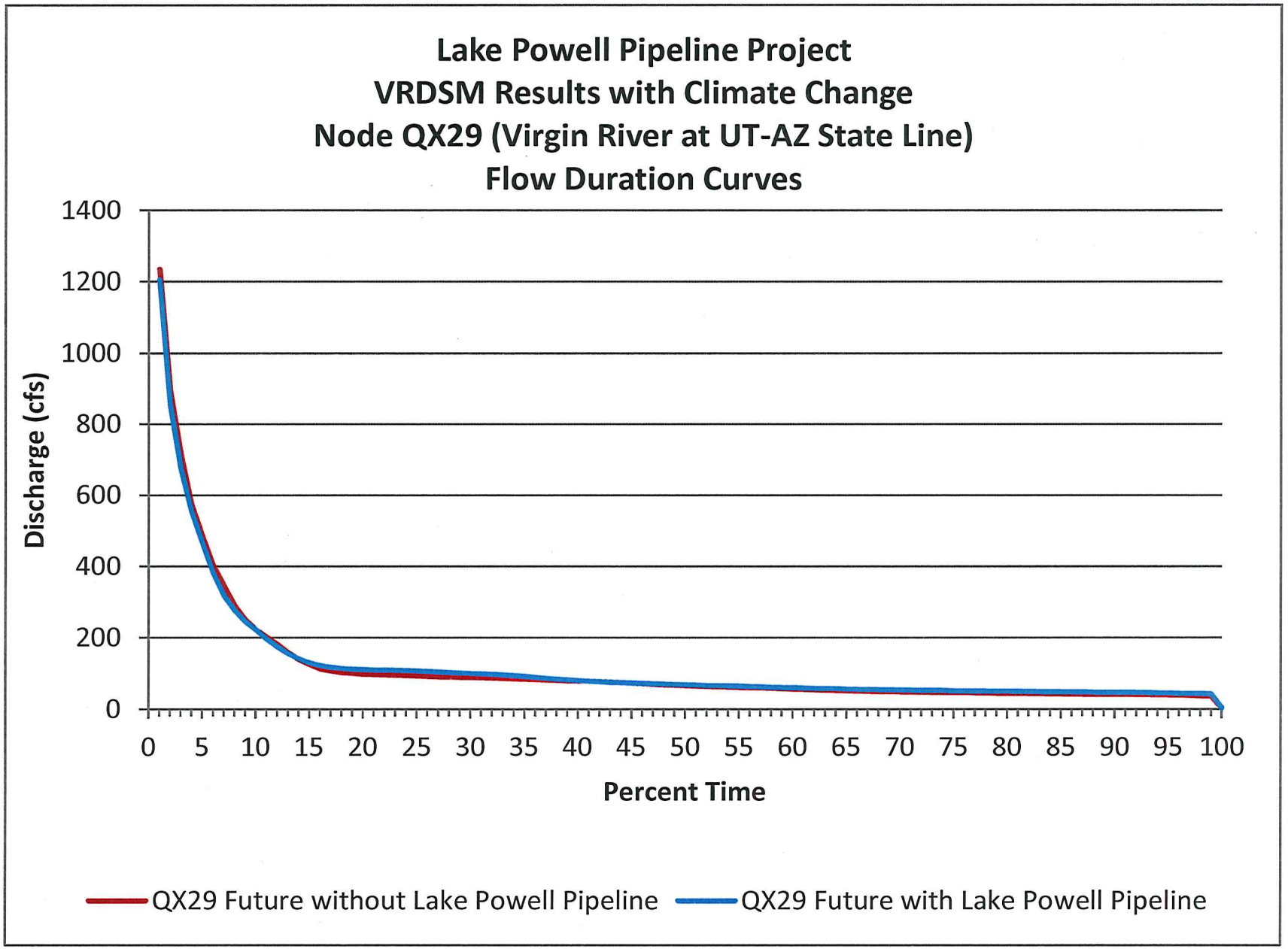

Lake Powell Pipeline Project
VRDSM Results with Climate Change
Node QX29 (Virgin River at UT-AZ State Line)
Mean Monthly Flow
Mean Monthly Flow (cfs)
350
300
250
200
150
100
50
0
Oct
Nov
Dec
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Month
Future Without Lake Powell Pipeline
Future With Lake Powell Pipeline


Lake Powell Pipeline Project
VRDSM Results with Climate Change
Node QX21 (Virgin River Below Quail Creek)
Flow Duration Curves
Discharge (cfs)
1200
1000
800
600
400
200
0
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
Percent Time
QX21 Future without Lake Powell Pipeline
QX21 Future with Lake Powell Pipeline


Lake Powell Pipeline Project
VRDSM Results with Climate Change
Node QX26 (Virgin River Below Washington Fields Diversion)
Flow Duration Curves
Discharge (cfs)
1200
1000
800
600
400
200
0
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
Percent Time
QX26 Future without Lake Powell Pipeline
QX26 Future with Lake Powell Pipeline


Lake Powell Pipeline Project
VRDSM Results with Climate Change
Node QX27 (Virgin River Below Bloomington Bridge)
Flow Duration Curves
Discharge (cfs)
1200
1000
800
600
400
200
0
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
Percent Time
QX27 Future without Lake Powell Pipeline
QX27 Future with Lake Powell Pipeline


Lake Powell Pipeline Project
VRDSM Results with Climate Change
Node QX28 (Virgin River Below Santa Clara River)
Flow Duration Curves
Discharge (cfs)
1400
1200
1000
800
600
400
200
0
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
Percent Time
QX28 Future without Lake Powell Pipeline
QX28 Future with Lake Powell Pipeline


Lake Powell Pipeline Project
VRDSM Results with Climate Change
Node QX29 (Virgin River at UT-AZ State Line)
Flow Duration Curves
Discharge (cfs)
1400
1200
1000
800
600
400
200
0
0 5 10 15 20 25 30 35 40 45 50 55 60 65 70 75 80 85 90 95 100
Percent Time
QX29 Future without Lake Powell Pipeline
QX29 Future with Lake Powell Pipeline

Appendix 2
Reclamation Colorado River Model Report

-DRAFT-

Lake Powell Pipeline Hydrologic Modeling

September 14, 2015
Katrina Grantz

Overview

Through coordination with the State of Utah Division of Water Resources (State), the Bureau of Reclamation (Reclamation) conducted several hydrologic modeling runs using Reclamation's long-term planning model, Colorado River Simulation System (CRSS). The results of these model runs have been provided to the State for use in its planning for the Lake Powell Pipeline (LPP) project to determine potential impacts on the hydrology of the Colorado River System.

This report presents the results of one set of hydrologic modeling runs. Previous hydrologic modeling analyses were provided to the State in August 2009 and November 2010. In March 2014, Reclamation performed a statistical analysis of climate change data in the Virgin River basin for the State. The climate change analysis resulted in new projections for the pumping schedule and the rate at which the Lake Powell Pipeline depletions would increase over time. The results presented here are very similar to those presented in previous reports, but include the new climate change information, updated reservoir initial conditions, and additional historic flow data.

A key assumption in this modeling is that all future Upper Basin depletions *except* for the Lake Powell Pipeline and other future depletions assumed to be reasonably foreseeable are modeled as constant at the 2015 depletion levels for the entire model run. In this context, a reasonably foreseeable future depletion is one which has state legislation, or a tribal resolution or Federal Indian water settlement, or a Federal finding of no significant impact (FONSI) or record of decision (ROD). See the Discussion section of this document for further discussion and Attachment A: ReasonablyForeseeable DepletionNodes.xls for specific CRSS model depletion nodes. This modeling assumption is different than standard CRSS model runs that are used in a long-term basin-wide planning context (e.g., the 2012 Colorado River Basin Water Supply and Demand Study (Basin Study[1])). CRSS runs performed in a basin-wide planning context typically project that future Upper Basin depletions increase throughout the entire model run period. The model runs presented in this report analyze the difference between diverting water out of the Colorado River at Lake Powell through the Lake Powell Pipeline (pipeline scenario) and not diverting the water (no pipeline scenario). In this analysis, the State's total depletions in the pipeline and no pipeline scenarios differ by the

[1] Colorado River Basin Water Supply and Demand Study Final Study Report available at: http://www.usbr.gov/lc/region/programs/crbstudy/finalreport/index.html

volume of water being diverted to the Lake Powell Pipeline. This modeling approach isolates the impact of diverting water to the Lake Powell Pipeline project.

Two alternatives were compared in this analysis: (1) Upper Basin depletions held constant at 2015 levels *except* reasonably foreseeable depletions (no action alternative or no pipeline scenario) and (2) all Upper Basin depletions held constant at 2015 levels *except* reasonably foreseeable depletions *and* the Lake Powell Pipeline (action alternative or with the Lake Powell Pipeline scenario).

The first section of this report presents an overview of the data. Next, the general methodology and technical assumptions of CRSS are reviewed, followed by the technical assumptions specific to this study and model runs. The modeling results are then presented with an analysis of the differences between the action and no action alternatives. A discussion section concludes the report.

Data

In this study, two future depletion scenarios were modeled: (1) no Lake Powell Pipeline depletions and (2) Lake Powell Pipeline depletions up to 86 kaf per year.
For both scenarios, it was assumed that Upper Basin depletions without state legislation, or a tribal resolution or Federal Indian water settlement, or a Federal finding of no significant impact (FONSI) or record of decision (ROD) remained constant at the 2015 depletion levels currently in CRSS. Those depletions assumed reasonably foreseeable include Central Utah Project, Animas-La Plata, Dolores Project, Navajo-Gallup, Ute Indian Compact, and Navajo Indian Irrigation Project. See the discussion section for further details and Attachment A for CRSS model depletions nodes not held constant. Note that the 2015 depletions levels modeled are based upon the Upper Basin depletion schedules in CRSS and not the observed (or computed) depletions reported in the 2015 Consumptive Uses and Losses report[2] which was not available at the time of this analysis or the writing of this report and will later be prepared by Reclamation.

For each depletion scenario (no pipeline and pipeline), two future inflow hydrology scenarios were modeled. One inflow scenario uses data from the observed streamflow record (1906-2010). The other inflow scenario uses hydrologic data derived from climate change driven streamflow projections[3] to represent a range of possible future inflows under the assumption of climate change in the Colorado River Basin. These data and methods are discussed in further detail below.

Future Depletion Scenarios

[2] Colorado River System Consumptive Uses and Losses Reports available at: http://www.usbr.gov/uc/library/envdocs/reports/crs/crsul.html

[3] Climate change data and information available at: http://gdo-dcp.ucllnl.org/downscaled_cmip_projections/dcpInterface.html#Welcome

1. No Action

Under the no action alternative, Lake Powell Pipeline depletions were assumed to be zero for the entire model run (2015-2060). Depletion data for all other locations in CRSS were the depletion Schedule B (current projected trends) from the Basin Study. These data were provided by each of the Basin States for the 2012 Basin Study and represent the most current demand data available for CRSS. See Basin Study Technical Report C – Water Demand Assessment[4] for further detail. For the analysis presented here, all Upper Basin depletions were held constant at 2015 levels for the years 2015 to 2060 except those identified as reasonably foreseeable.

2. Action Alternative

Lake Powell Pipeline depletion data for the action alternative were provided by the State. Two pipeline depletion schedules were provided: (1) pipeline depletions based on historic hydrology assumptions and (2) pipeline depletions based on climate change hydrology assumptions. The two pipeline depletion schedules differ based on the assumed future water available in the Virgin River Basin and the resulting timing of additional water to be diverted through the Lake Powell Pipeline under each of the hydrologic scenarios. In both action alternative pipeline depletion schedules the Lake Powell Pipeline maximum annual depletion is 86,249 acre-feet. Also for both schedules, pipeline depletions are zero for the years 2015 through 2023. Pipeline depletions start at 15,468 acre-feet per year in the year 2024 and increase each year to a total of 86,249 acre-feet in the year 2048 for the historic hydrology scenario and the year 2049 for the climate change hydrology scenario. The action alternative pipeline depletion schedules are provided in Attachment B: PipelineDepletions.xls. Annual pipeline depletion volumes were disaggregated to monthly volumes based upon pump data that determined the number of pump days required each year. It was assumed that the pumps would operate at a constant flow rate from the first day of operation until the number of pump days was fulfilled each year. In addition, it was assumed that no pumping would occur the first 15 days of January each year to accommodate annual pipeline maintenance. In this modeling, Colorado Basin future total annual depletions are significantly lower than those modeled in the 2012 Basin Study and the 2007 Final Environmental Impact Statement (EIS) of the Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead (2007 Interim Guidelines EIS[5]). This is because for the purposes of this analysis all depletions except the Lake Powell Pipeline and those identified as reasonably forseeable were held constant at 2015 depletion levels.

[4] Colorado River Basin Water Supply and Demand Study Technical Report C – Water Demand Assessment available at: http://www.usbr.gov/lc/region/programs/crbstudy/finalreport/techrptC.html

[5] 2007 Final EIS of the Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead, available at: http://www.usbr.gov/lc/region/programs/strategies/FEIS/index.html

Future Inflow Hydrology Scenarios

1. Historic Hydrology - Direct Natural Flow (DNF)

The future hydrology used as input to the model in this scenario consisted of samples taken from the historic record of natural flow in the river system over the 105-year period from 1906 through 2010 from 29 individual inflow points (or nodes) on the Colorado River System. Natural flow is the observed flow adjusted for the effects of diversions and the operation of reservoirs upstream of the flow gage. This natural flow record[6] was developed by Reclamation and is used extensively in their hydrologic modeling and Environmental Impact Statements (EIS). In this inflow scenario, the existing historical record of natural flows was used to create a number of different future hydrologic sequences using a resampling technique known as the Index Sequential Method (ISM[7]). The ISM provides the basis for quantification of the uncertainty and an assessment of the risk with respect to future inflows and is based upon the best available measured data. This inflow dataset and methodology was used as the primary inflow scenario in the 2007 Shortage EIS and one of the inflow scenarios used in the 2012 Basin Study.

2. Climate Change (CC) Hydrology

This future inflow hydrology scenario uses climate change projections used in the 2012 Basin Study. The data consist of 112 "traces" of climate change projections of simulated historic and future monthly streamflow from 1950 to 2099. The 112 streamflow projections were developed using General Circulation Model output of 112 future projections of temperature and precipitation output; the temperature and precipitation data was statistically downscaled to a gridded 15km x 15km spatial scale; and then utilized in a hydrologic model of the Colorado River Basin (Variable Infiltration Capacity, or VIC) to simulate future runoff[8]. The 112 projections of gridded future runoff were routed to streamflow at 29 select natural flow node locations in the Colorado River Basin, and bias corrected against Reclamation's historic natural streamflow data. Further information on this data and its use in in Colorado River Basin modeling are available in the Colorado River Basin Water Supply & Demand Study Final Study Report, Technical Report B – Supply.[9]

It should be mentioned that the climate change streamflow projections used in this study were developed using CMIP3 (Coupled Model Intercomparison Project 3) projections of future temperature and precipitation. Additional climate change projections (CMIP5) for temperature, precipitation and streamflow have recently become available; however, at

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[6] Colorado River Basin Natural Flow and Salt Data, available at: http://www.usbr.gov/lc/region/g4000/NaturalFlow/

[7] Index Sequential Method: Ouarda, T., Labadie, J.W., and Fontane, D.G. (1997), Index sequential hydrologic modeling for hydropower capacity estimation, *J. of the American Water Resources Association*, 33(6) 1337-1349; and Kendall, D.B. and Dracup, J.A. (1991), A comparison of index-sequential and AR(1) generated hydrologic sequences, *J. of Hydrology*, 122, 335-352.

[8] Technical Memorandum on West-Wide Climate Risk Assessments: Bias-Corrected and Spatially Downscaled Surface water Projections, available at: http://www.usbr.gov/WaterSMART/docs/west-wide-climate-risk-assessments.pdf

[9] Colorado River Basin Water Supply & Demand Study Final Study Report, Technical Report B – Supply, available at: http://www.usbr.gov/lc/region/programs/crbstudy/finalreport/index.html

the time of this report, additional analysis and data processing is needed before the CMIP5 data are ready for use in CRSS. Further information about the CMIP3 and CMIP5 climate and hydrology projections is available online[10].

Methodology

Hydrologic modeling of the Colorado River system was conducted using Reclamation's long-term planning model, CRSS. The hydrologic modeling provides projections of potential future Colorado River system conditions (e.g., reservoir elevations, reservoir releases, river flows) under the No Action alternative scenario for comparison with conditions under the Action alternative scenario. Due to uncertainties associated with future inflows into the system, multiple simulations were performed for each action alternative scenario in order to quantify the uncertainties in future conditions, and the modeling results are typically expressed in probabilistic terms.

This document provides an overview of the hydrologic modeling and the framework within which the many simulations were undertaken. Further details regarding the CRSS and its standard assumptions are available in the modeling appendix of the 2007 Interim Guidelines EIS[11].

Alternatives Modeled

One action alternative and one no action alternative were modeled. The action alternative is the 86kaf depletion scenario for the Lake Powell Pipeline described above. The no action alternative is the January 2015 official CRSS run and uses the same policy assumptions as the 2007 Shortage EIS preferred alternative, with the following two exceptions to the model assumptions (1) depletion Schedule A from the Basin Study was used, and (2) all Upper Basin depletions were held constant at 2015 levels *except* those identified as reasonably foreseeable.

Period of Analysis

Hydrologic modeling extends from 2015 through 2060.

Model Description

Future Colorado River system conditions under the action and no action alternatives were simulated using CRSS. The model framework of CRSS is a commercial river modeling software called Riverware[12]; a generalized river basin modeling software package developed by the University of Colorado through a cooperative arrangement with

[10] Downscaled CMIP3 and CMIP5 Climate Projections, available at: http://gdo-dcp.ucllnl.org/downscaled_cmip_projections/dcpInterface.html#About.
[11] Final EIS – Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake MeadAppendix A – CRSS Model Documentation, available at: http://www.usbr.gov/lc/region/programs/strategies/FEIS/AppA.pdf
[12] Riverware: A generalized tool for complex reservoir system modeling, Edith A. Zagona, Terrance J. Fulp, Richard Shane, Timothy Magee, and H. Morgan Goranflo, Published in the Journal of the American Water Resources Association, August 2001.

Reclamation and the Tennessee Valley Authority. CRSS was originally developed by Reclamation in the early 1970s and was implemented in Riverware in 1996.

CRSS simulates the operation of the major reservoirs on the Colorado River on a monthly time-step and provides information regarding the projected future state of the system in terms of output variables including the amount of water in storage, reservoir elevations, releases from the dams, the amount of water flowing at various points throughout the system, and the diversions to and return flows from the water users throughout the system. The simulation uses a mass balance (or water budget) approach to account for water entering the system, water leaving the system (e.g., from consumptive use of water, trans-basin diversions, evaporation), and water moving through the system (i.e., either stored in reservoirs or flowing in river reaches). The model was used to project the future conditions of the Colorado River system on a monthly time-step for the period 2015 through 2060.

The input data for the model includes monthly future inflows (either DNF or CC), various physical process parameters such as the evaporation rates for each reservoir, initial reservoir conditions on January 1, 2015, and the future diversion and depletion schedules for entities in the Basin States and for Mexico. These future schedules were based on demand and depletion projections prepared and submitted by the Basin States for the 2012 Basin Study as the most up to date estimates for current and future depletions (Schedule A). In this analysis, except for reasonably foreseeable depletions, future Upper Basin depletions from Schedule A were assumed constant at 2015 levels; this assumption results in depletions significantly lower than the future depletion projections used in long term planning studies such as the Basin Study, which assumed that Upper Basin depletions will grow through 2060. Depletions (or water use) are defined here as diversions from the river less return flow credits, where applicable.

The rules of operation of the Colorado River mainstream reservoirs including Lake Powell are also provided as input to the model. These sets of operating rules describe how water is released and delivered under various hydrologic conditions.

General model assumptions:

- January 2015 initial conditions for all modeled reservoirs
    - Powell 3,597.75 ft
- Run duration: 2015-2060
- Runs revert to the 2007 Shortage Final EIS No Action Alternative in 2027
- Index sequential method used for the Direct Natural Flow period of record (1906-2010): 105 simulations.
- Climate change conditioned inflows: 112 simulations

Modifications to CRSS

Several modifications were made to the official version of CRSS to model the Lake Powell Pipeline for this analysis. Data were provided to Reclamation by the State to describing the location, timing and volume of water to be diverted through the Lake

Powell Pipeline in this analysis. A new diversion node, "Lake Powell Pipeline", was added to CRSS to simulate water being pumped directly from Lake Powell. The spatial structure of previous versions of CRSS simulated a diversion to the "St. George Pipeline" at a location slightly upstream from Lake Powell. The old "St. George Pipeline" diversion node was removed from the model for this analysis.

In addition, in the official version of the CRSS model, Upper Basin depletions increase over time based on demand and depletion projections prepared and submitted by the Upper Basin States. In this version of CRSS, only those Upper Basin depletions assumed reasonably foreseeable increased over the model run; all other future depletions were held constant at the 2015 level. In this study, Schedule A was assumed for future depletions. The depletion Schedule A (current projected trends) from the Basin Study represents the most current and best documented future projected demand data available for CRSS.

Results

Each alternative (action and no action) was modeled using both the DNF and CC future inflow scenarios, resulting in four model runs. For comparison purposes, the action alternative is compared to the no action alternative. The comparisons are made using both the DNF and CC future inflow scenarios. The following variables were evaluated:

- Powell pool elevation on Dec 31st (10th, 50th, 90th percentiles over time)
- Probability of Powell Dec 31st elevation < 3,490 ft
- Powell water year release (10th, 50th, 90th percentiles over time)
- Powell water year release (flow duration curve throughout time)
- Powell monthly releases (12 months) (10th, 50th, 90th percentiles over time)
- Flaming Gorge annual release (10th, 50th, 90th percentiles over time)
- Flaming Gorge pool elevation on Dec 31st (10th, 50th, 90th percentiles over time)

Post-processing and Interpretation Procedures

CRSS generates data on a monthly time-step for over 300 points (or nodes) on the Colorado River system. Furthermore, using the ISM on the natural flow record, the model generated 105 possible outcomes for each node for each month of the model run. For the climate change inflow scenarios, 112 possible outcomes were generated for each node and month in the run period. These very large data sets generated for each alternative can be visualized as three-dimensional data "cubes" with the axes of time, space (or node) and trace (or outcome for each future hydrology). The data were aggregated to reduce the volume of data and to facilitate comparison of the alternatives.

For aggregation of data, simple techniques were employed. For example, Lake Powell pool elevations were evaluated on an annual basis (i.e., end of December) to show long-term lake elevation trends as opposed to short-term fluctuations. Standard statistical techniques were used to analyze the 105 or 112 possible outcomes for a fixed time or particular temporal span. Statistics that were generated included the 10th, 50th and 90th percentiles. Percentiles were determined by simply ranking the outcomes at each time-step (from highest to lowest) and determining the value at the specified percentile. For example, 105 pool elevation values were generated for December 2015, one for each

natural flow inflow trace. These 105 values were ranked and then the 10th, 50th, and 90th percentile values were taken to statistically represent the distribution of pool elevations generated for December 2015. This process was then repeated for December 2016, December 2017, and so on. It is important to note that the 10th percentile values determined for December 2015, December 2016, and December 2017, do not necessarily come from the same inflow hydrology trace and do not represent a timeseries of elevations. Rather, the values are a statistical representation of the distribution of data at every timestep in the model run. This statistical method is used to view the results of all hydrologic sequences in a compact manner yet maintains the variability at high, medium, and low reservoir elevations that may be lost by averaging the results of all traces. Such a statistic provides information with regard to the probability (e.g., a 10 percent probability) of the variability of interest being at or below the 10th percentile value in a specified year.

Direct Natural Flow Results

Figure 1 shows the differences in Lake Powell pool elevation in December between the action alternative and the no action alternative at the 10th, 50th, and 90th percentiles. Prior to the year 2024, there are no differences at any percentile level. Between 2024 and 2060, the differences range between 0.2 ft and 10.3 ft at the 10th percentile, with Lake Powell elevation being lower in action alternative, with an average difference of 5.0 ft. In general, the pool elevation differences are larger later in the later modeled years. Differences at the 50th percentile level during 2024-2060 range from 0.1 ft to 4.4 ft, again with Lake Powell elevation being lower in the action alternative and with the larger of these differences generally occurring after 2048 and an average difference of 1.8 ft. Differences at the 90th percentile level range from 0 ft to 0.6 ft with an average difference

of 0.2 ft.

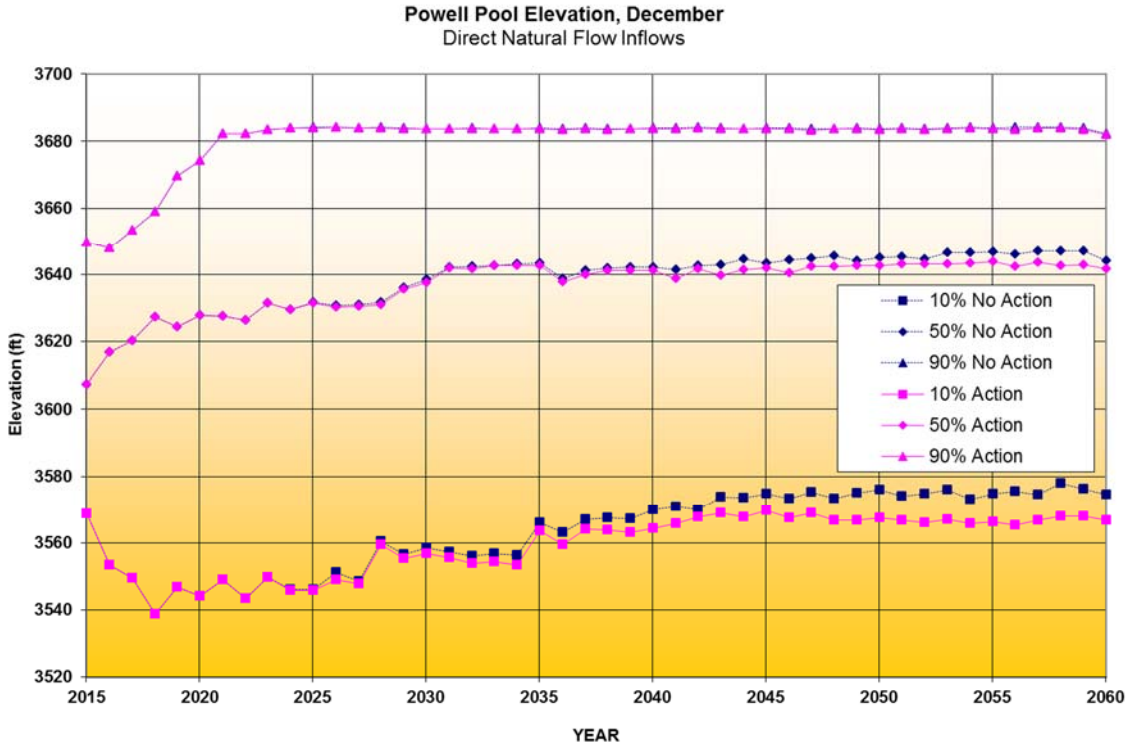


Figure 1. Lake Powell Pool Elevation, December. Direct natural flow inflows, 86kaf Lake Powell Pipeline maximum depletion.

Figure 2 shows probability of Lake Powell pool elevation being below 3,490 ft (minimum power pool) in March. March was chosen as this is the month the reservoir elevation is typically lowest. The action alternative scenario showed one additional trace (out of 105 traces) below minimum power pool in the years 2032 and 2033, representing a 0.1 percent increase in probability in each of those years. For the other 104 traces (99 percent of traces) in each of those years there were no differences between the no action

and action alternatives.

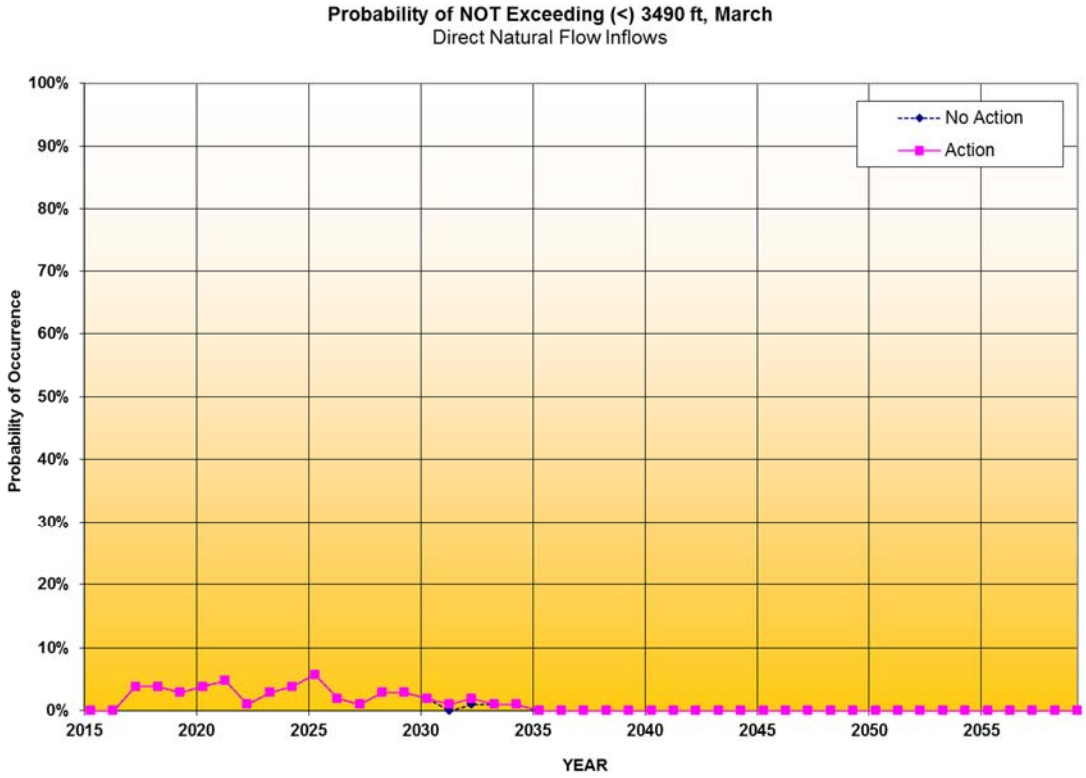


Figure 2. Probability of Lake Powell pool elevation being below 3,490 ft in March. Direct natural flow inflows, 86kaf Lake Powell Pipeline maximum depletion.

Figure 3 presents Lake Powell water year releases. For the 10th and 50th percentiles, there are no differences between the action and no action alternatives. For the 90th percentile, which reflects equalization releases from Lake Powell to Lake Mead or spill avoidance releases, the largest difference between the action and no action alternatives is approximately 368,000 acre-feet, or approximately 2.8 percent of the annual release, more being released in one year under the no action alternative. See Attachment C HistoricNaturalFlow_plots.xls for the differences in each year. In general the differences are greater in 2048-2060 simulated years, after the pipeline is at full build-out, and the later years result in the no action alternative releasing slightly more water. Note that with most Upper Basin depletions held constant at 2015 depletion levels, Lake Powell elevation increases over time thus resulting in more frequent and higher magnitude equalization and spill avoidance releases in both the action and no action alternatives.

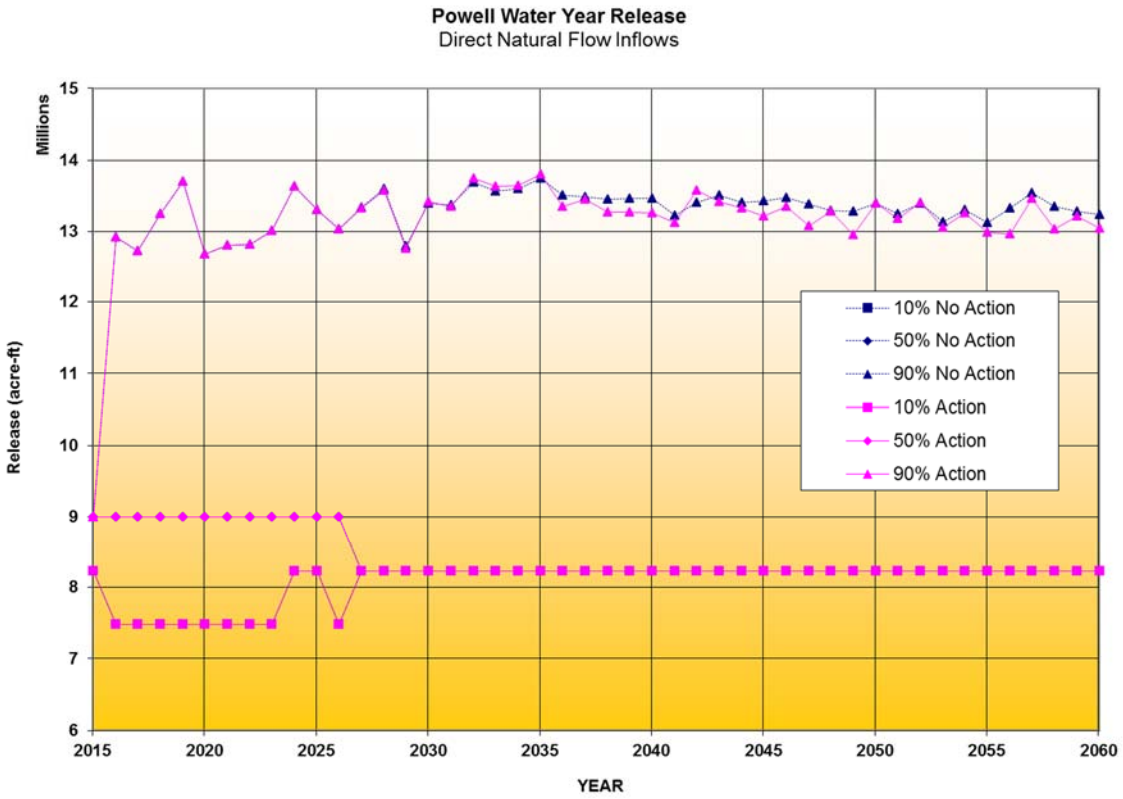
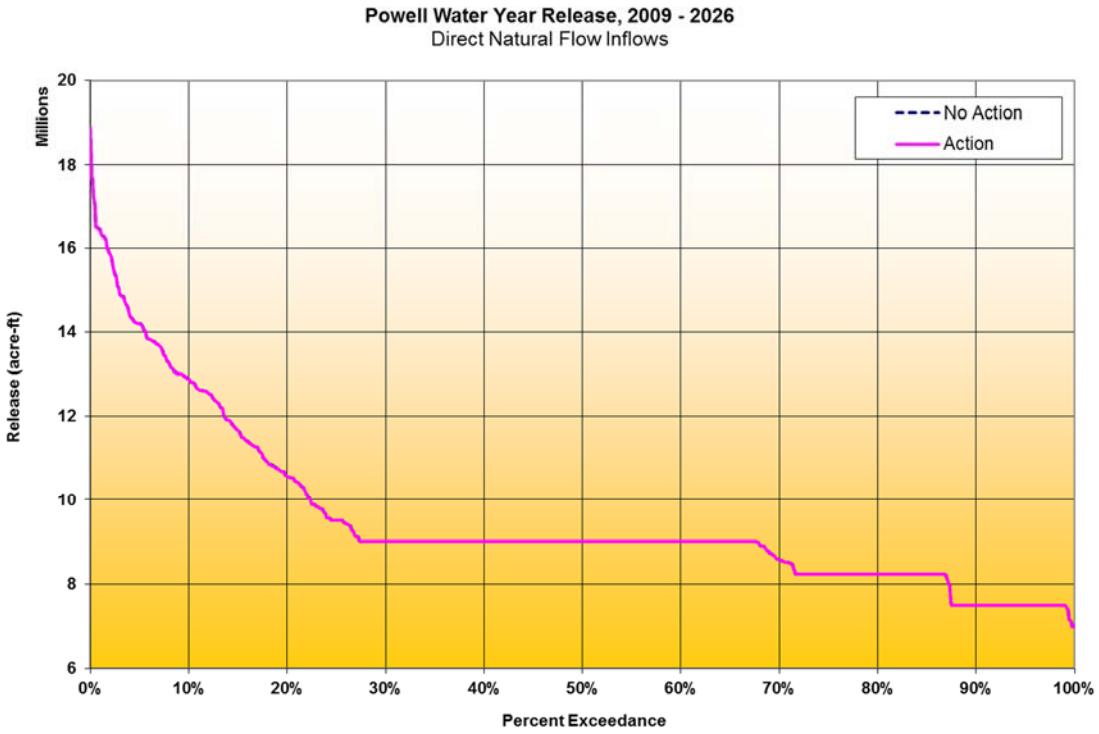
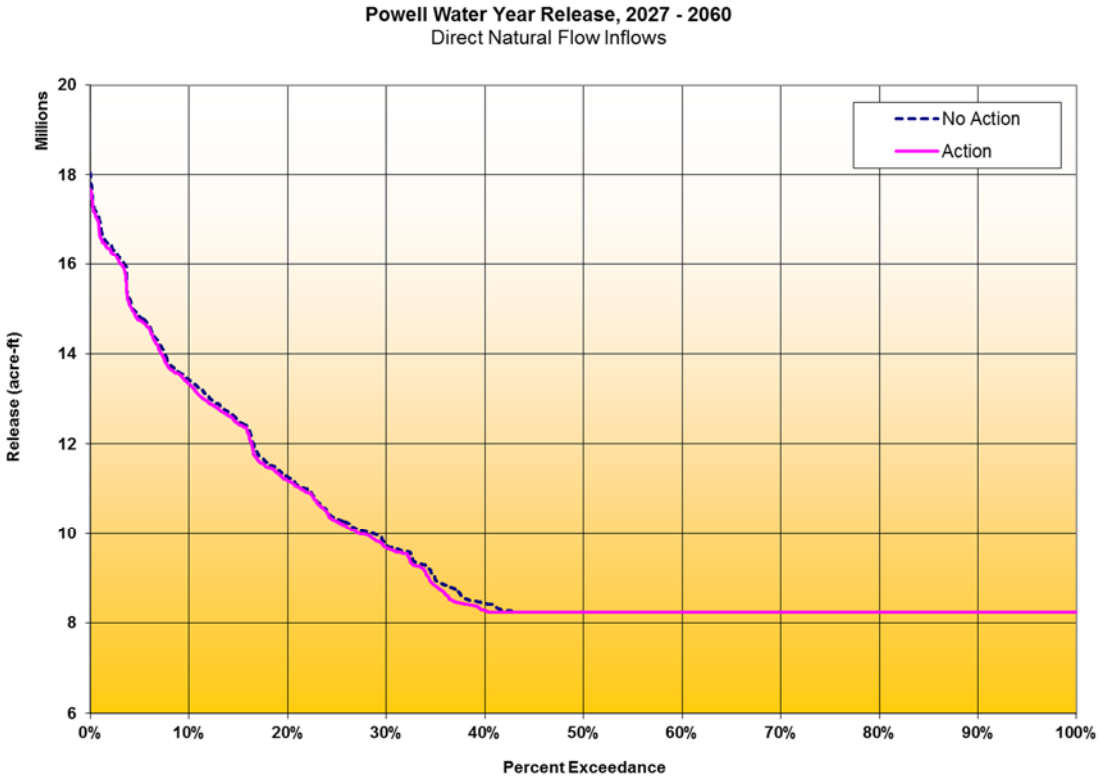


Figure 3. Lake Powell water year release. Direct natural flow inflows, 86kaf Lake Powell Pipeline maximum depletion.

The cumulative distribution function of Lake Powell annual releases throughout the Interim Guidelines period (2009-2026) and throughout the post-Interim Guidelines period (2027-2060) are presented in Figure 4 (a) and (b), respectively. In this figure, Lake Powell releases at every exceedance percentile (from 0 to 100) are plotted, rather than the three percentile plots shown in Figure 3. The Interim Guidelines and post-Interim Guidelines periods are plotted separately because operations at Lake Powell differ significantly between these two time periods. For a given exceedance probability, the corresponding release volume is generally greater for the no action alternative than the action alternative, however, particularly during the Interim period, the differences vary by both sign and magnitude throughout the curve. As evidenced in Figure 3, the greatest differences occur at the lower exceedance probabilities (higher percentiles), when Lake Powell is at higher elevation and making equalization releases to Lake Mead or releases for spill avoidance. The greatest difference of approximately 424000 acre-feet, or 2.7 percent for that year, more being released in the no action alternative occurs at the 3.6 percent exceedance level (96th percentile) during the post-Interim Guidelines period. During the Interim Guidelines period, releases greater than 8.23 million acre-feet occur 71.7 percent of the time in both the no action and action alternatives. During the post-Interim Guidelines period, releases greater than 8.23 million acre-feet occur 43.0 percent of the time in the no action alternative and 40.7 percent of the time in the action alternative. See Attachment C for the differences at each exceedance probability.


Powell Water Year Release, 2009 - 2026
Direct Natural Flow Inflows
Millions
Release (acre-ft)
20
18
16
14
12
10
8
6
No Action
Action
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percent Exceedance

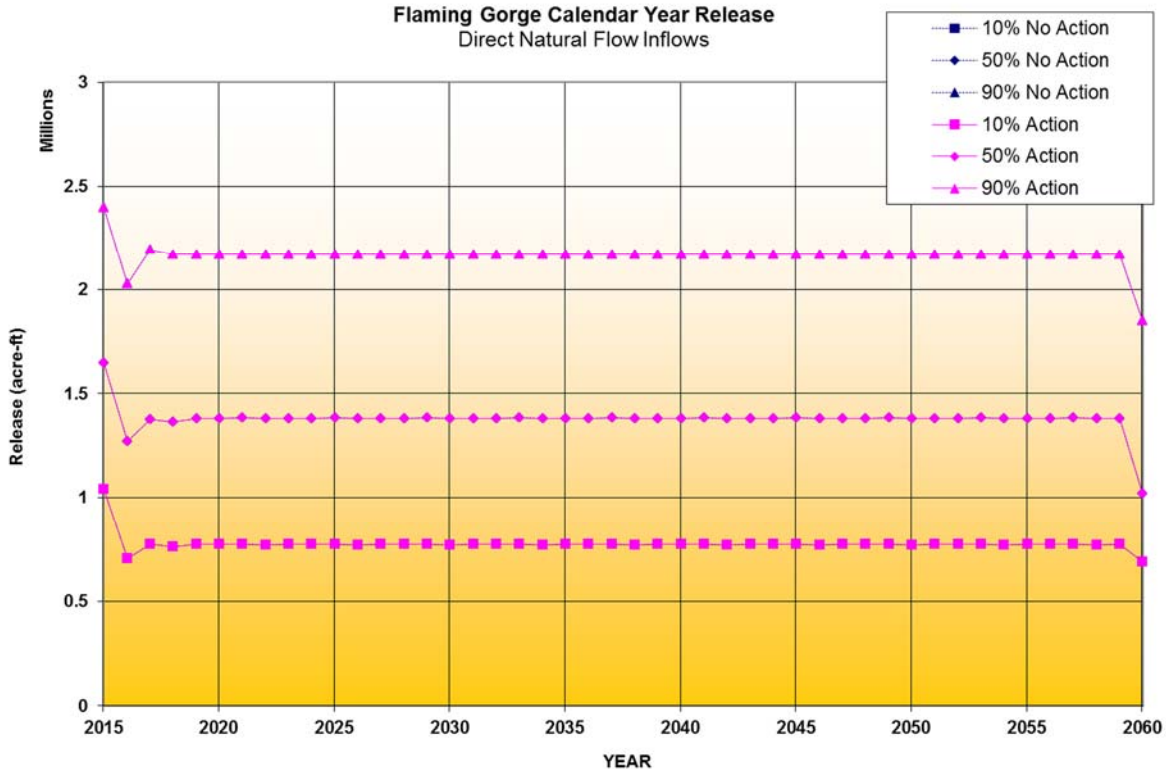
(a)


Powell Water Year Release, 2027 - 2060
Direct Natural Flow Inflows
Millions
Release (acre-ft)
20
18
16
14
12
10
8
6
No Action
Action
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Percent Exceedance

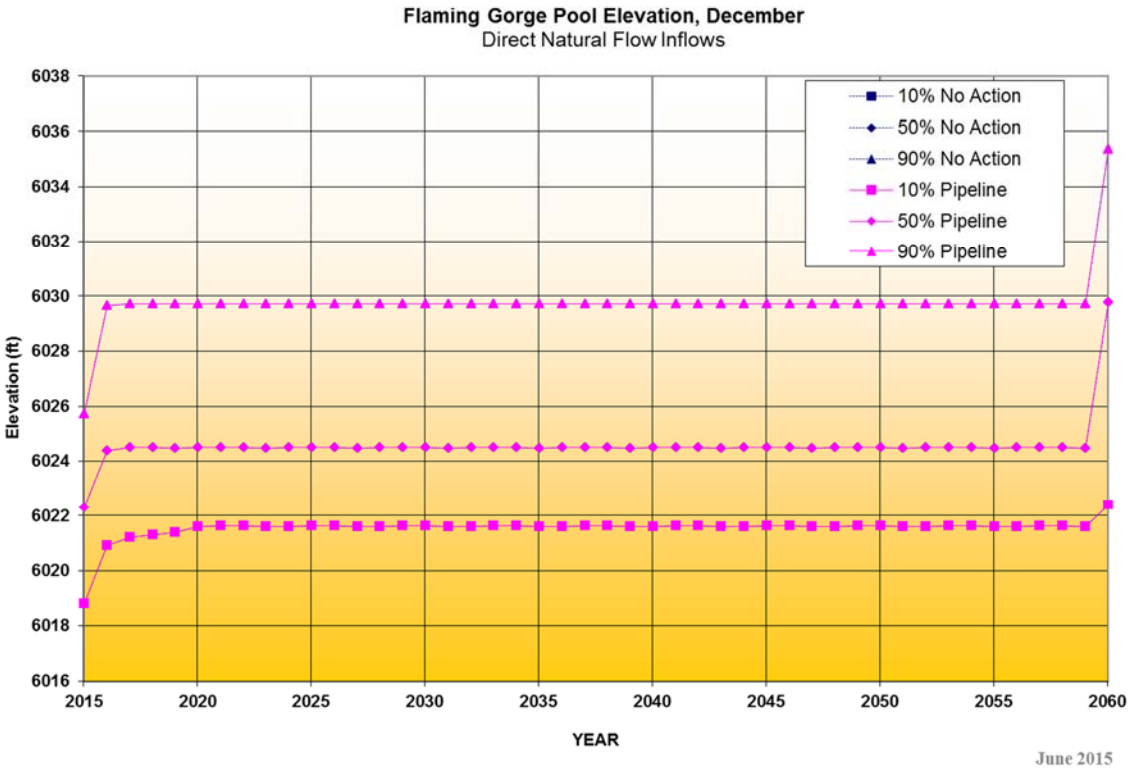
(b)

Figure 4. Lake Powell water year release, cumulative distribution function throughout time during the Interim Guidelines period (a) and during the post-Interim Guidelines period (b). Direct natural flow inflows, 86kaf Lake Powell Pipeline maximum depletion.

Flaming Gorge Reservoir annual releases (a) and end of December pool elevations (b) are shown in Figure 5. At the 10th, 50th, and 90th percentiles, there are no differences between the action and no action alternatives using DNF inflows.



(a)



(b)

Figure 5. Flaming Gorge Reservoir annual release (a) and December pool elevation (b). Direct natural flow inflows, 86kaf Lake Powell Pipeline maximum depletion.

The releases from Lake Powell in the month of June are shown in Figure 6. For results in every month, see Attachment C. May through July are the months that show the greatest differences between the action and no action alternatives. For all months, the differences are generally greatest at the 90th percentile level (i.e., for higher releases including spill avoidance and equalization). Overall, releases from Lake Powell are generally lower for the months of October, November, February and March, ranging approximately from 500,000 acre-feet to 800,000 acre-feet for the 10th percentile and 600,000 to 1,100,000 acre-feet for the 90th percentile. Releases in the months of April through September and December to January are generally higher, ranging approximately from 500,000 acre-feet to 900,000 acre-feet for the 10th percentile and 700,000 to 2,000,000 acre-feet for the 90th percentile. Differences between the action and no action alternatives are greatest in the months in which there are higher releases and in which there is higher year to year variability. Differences at the monthly timestep should be interpreted by considering general trends across several months rather than isolating single values in a single month and model year. This is because release volumes could be shifted among months resulting in different monthly values but the same total annual release.

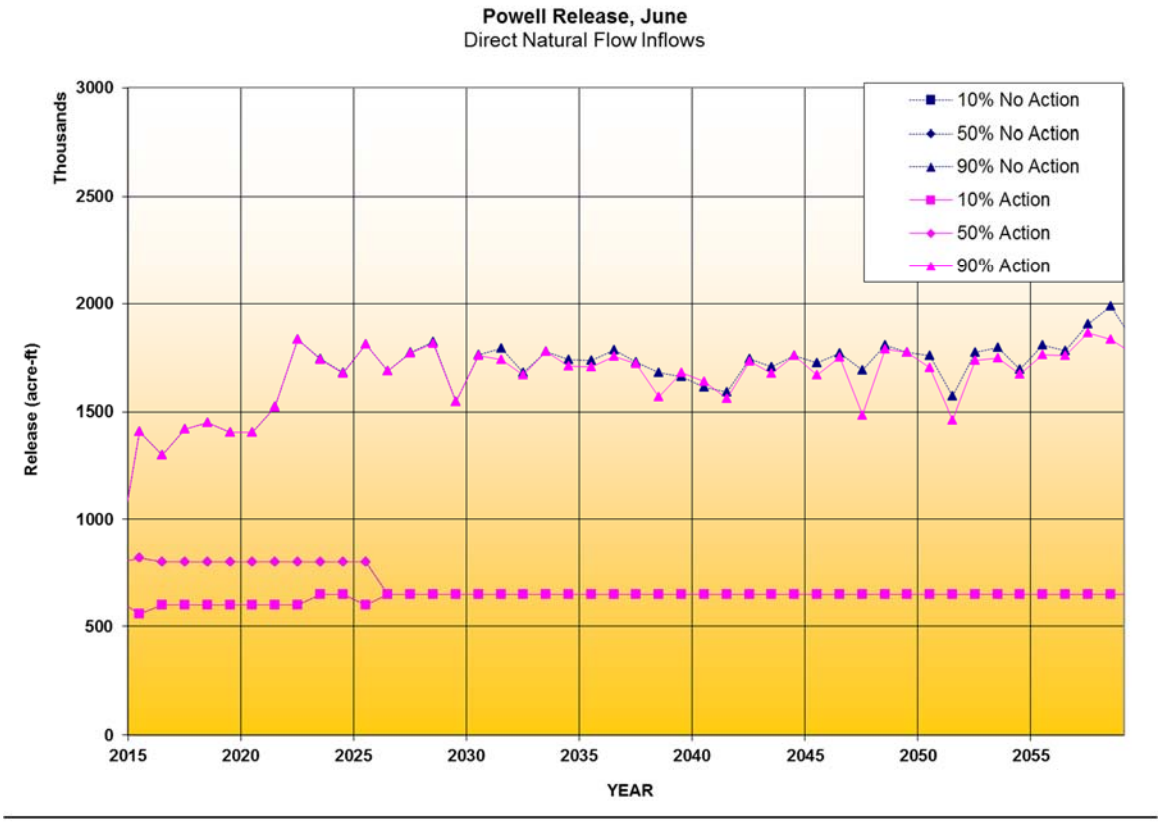


Figure 6. Lake Powell monthly release, June. Direct natural flow inflows, 86kaf Lake Powell Pipeline maximum depletion.

Climate Change Inflow Results

Figure 7 shows the differences in Lake Powell pool elevation in December between the 86K action alternative and the no action alternative at the 10th, 50th, and 90th percentiles for CC inflow scenario. The CC inflow scenario produces a wider variety and range of inflows, resulting in different future elevations of Lake Powell when compared with the DNF inflow scenario. Future Lake Powell elevations under the climate change inflow scenario are generally lower at the 10th percentile when compared with the DNF inflow scenario. However, overall, the differences between the action and no action alternatives are similar to those for the DNF simulations. Prior to the year 2024, there are no differences at any percentile level and in general, pool elevation differences are larger later in the later modeled years. The greatest difference for Lake Powell elevation in the CC inflow scenario occurs in the 50th percentile (i.e., median elevations), with a maximum simulated difference of 9.7 ft lower in the action alternative and an average difference of 3.7 ft for the years 2024 to 2060.Differences in the 10th percentile range from 0.1 to 2.0 ft with an average of 0.7 feet lower in the action alternative compared with the no action alternative. The greatest difference at the 90th percentile elevations is 2.0 ft with an average difference of 0.3 ft lower in the action alternative compared with the no action alternative.

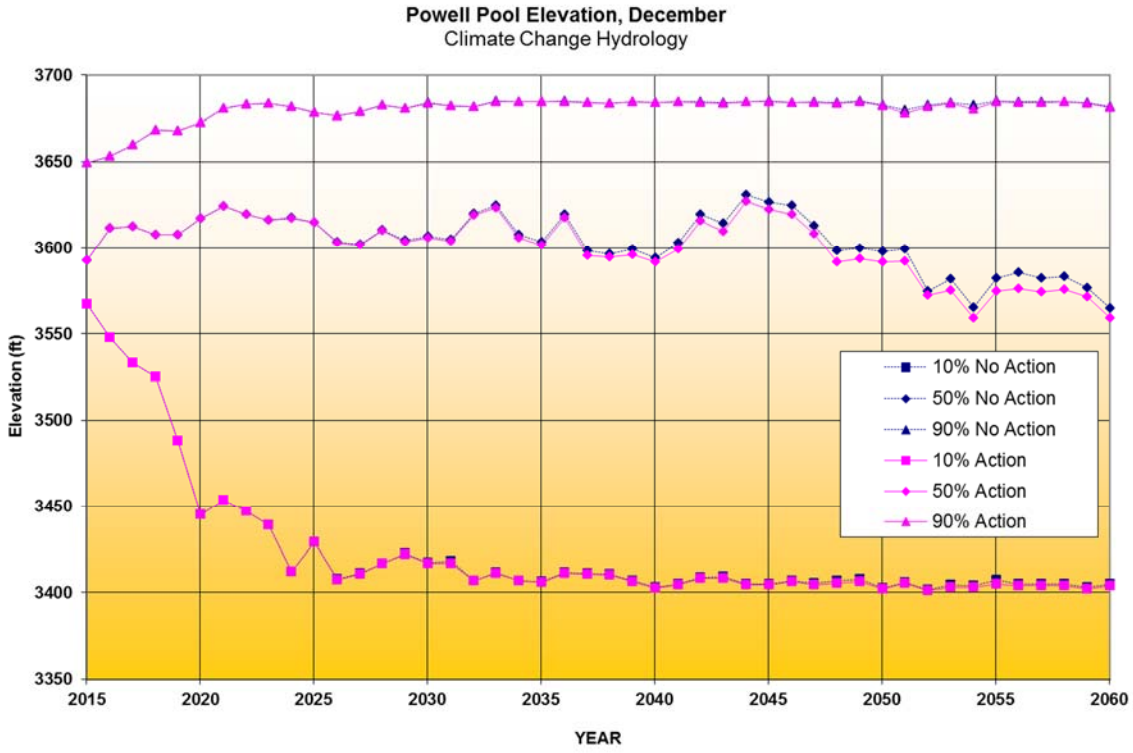


Figure 7. Lake Powell Pool Elevation, December. Climate change inflows, 86kaf Lake Powell Pipeline maximum depletion.

Overall, the probability of not exceeding Lake Powell's minimum power pool (3,490 ft) in March is higher in the CC inflow scenario compared to the DNF inflow scenario (Figure 8). In addition, differences between the action and no action alternatives for the CC inflows occur more frequently than did for the DNF inflows. The action alternative

results in slightly higher probabilities (0.9 percent to 2.7 percent higher) of Lake Powell being below minimum power pool in 19 of the 46 years simulated.

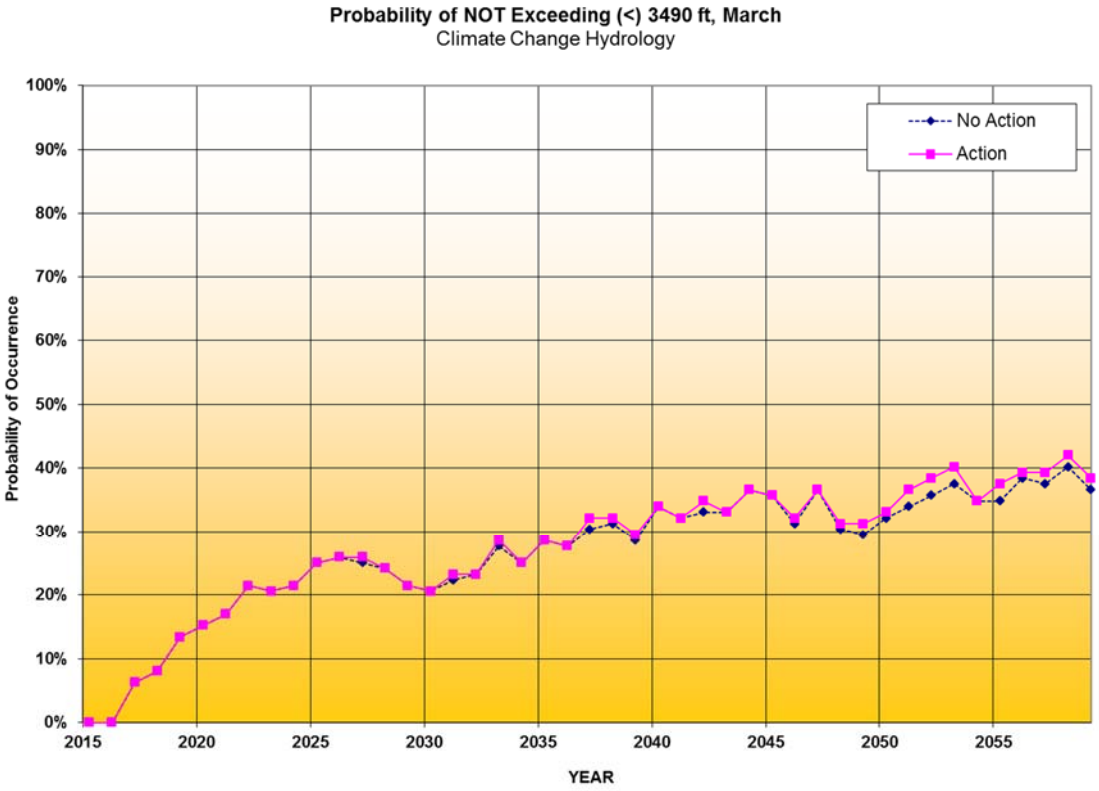


Figure 8. Probability of Lake Powell pool elevation being below 3490 ft in March. Climate change inflows, 86kaf Lake Powell Pipeline maximum depletion.

Results for CC inflows and Lake Powell water year releases are shown in Figure 9. The overall pattern of releases is different from the DNF inflow scenarios. Although the magnitudes of differences between the action and no action alternatives are similar to those for the DNF inflow scenario (Figure 3), these differences are seen at both the 10th percentile and the 90th percentile. The maximum difference in any one year for 10th percentile annual releases is 312,000 acre-ft, or 5.3 percent less being released in the action alternative. The average difference during the period 2024 through 2060 at the 10th percentile is 94,000 acre-ft less being released in the action alternative. The maximum difference in any one year for 90th percentile annual releases is 504,000 acre-ft, or 5.5 percent less being release in the action alternative. The average difference during the period 2024 through 2060 at the 90th percentile is 128,000 acre-ft less being released in the action alternative. See Attachment D ClimateChangeHydrology_plots.xls for the differences in each year.

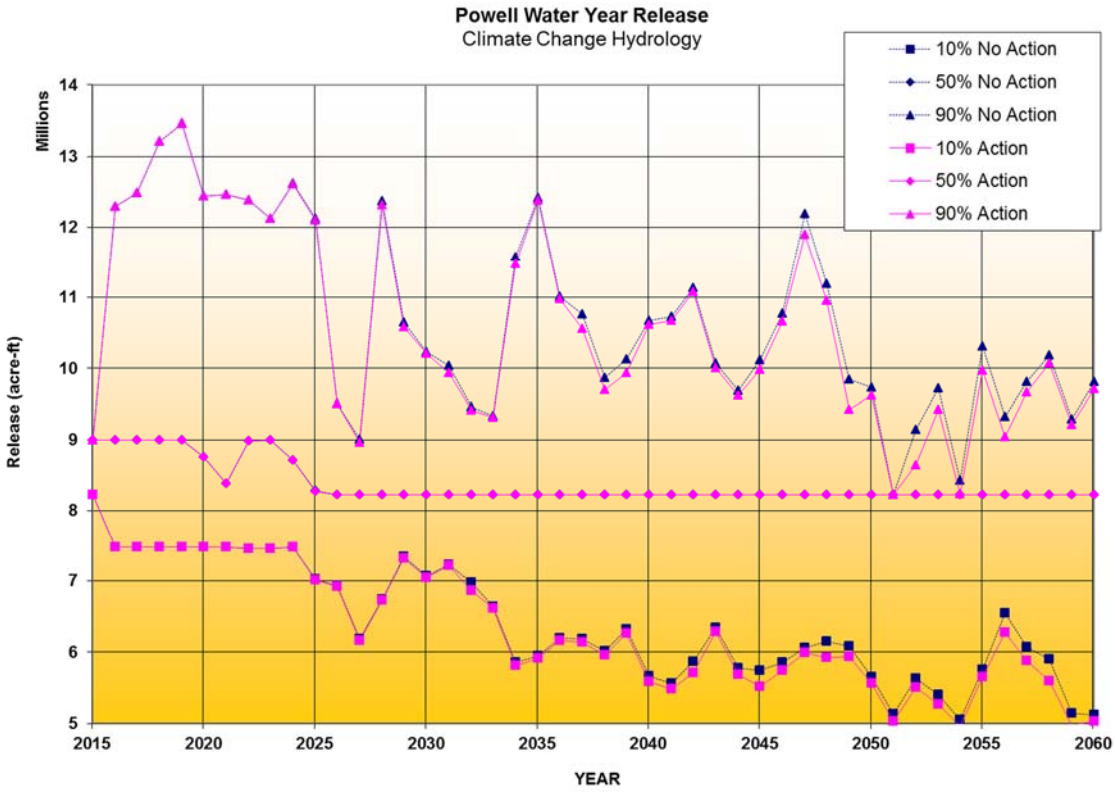
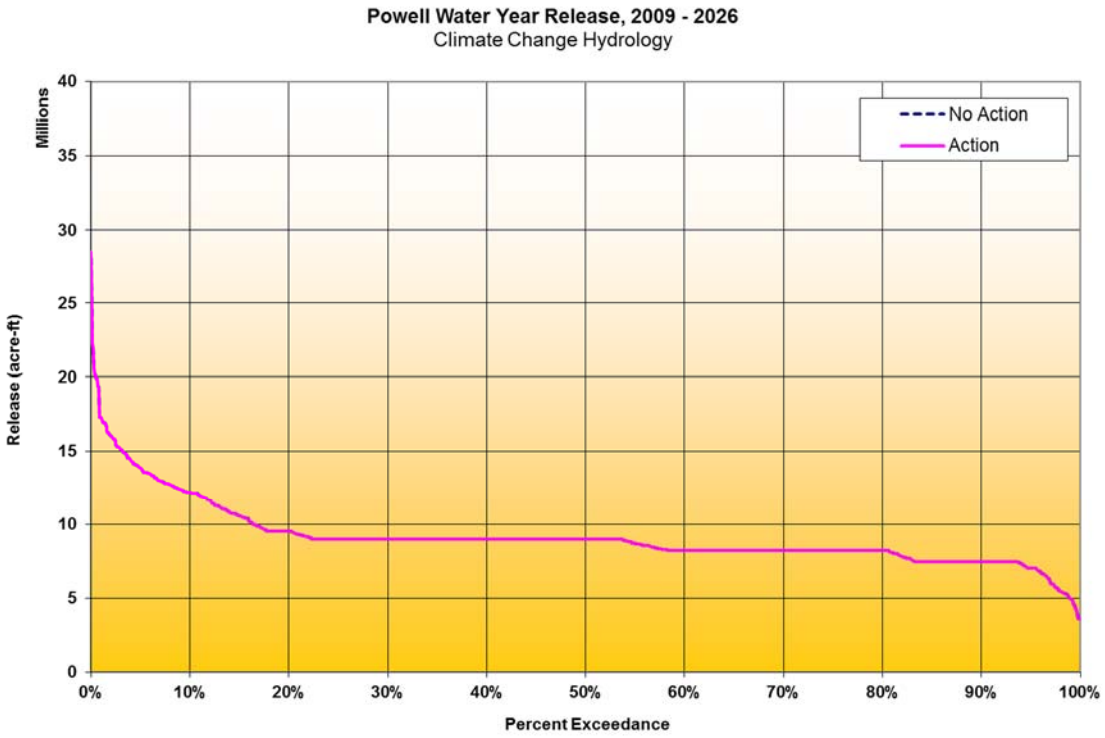


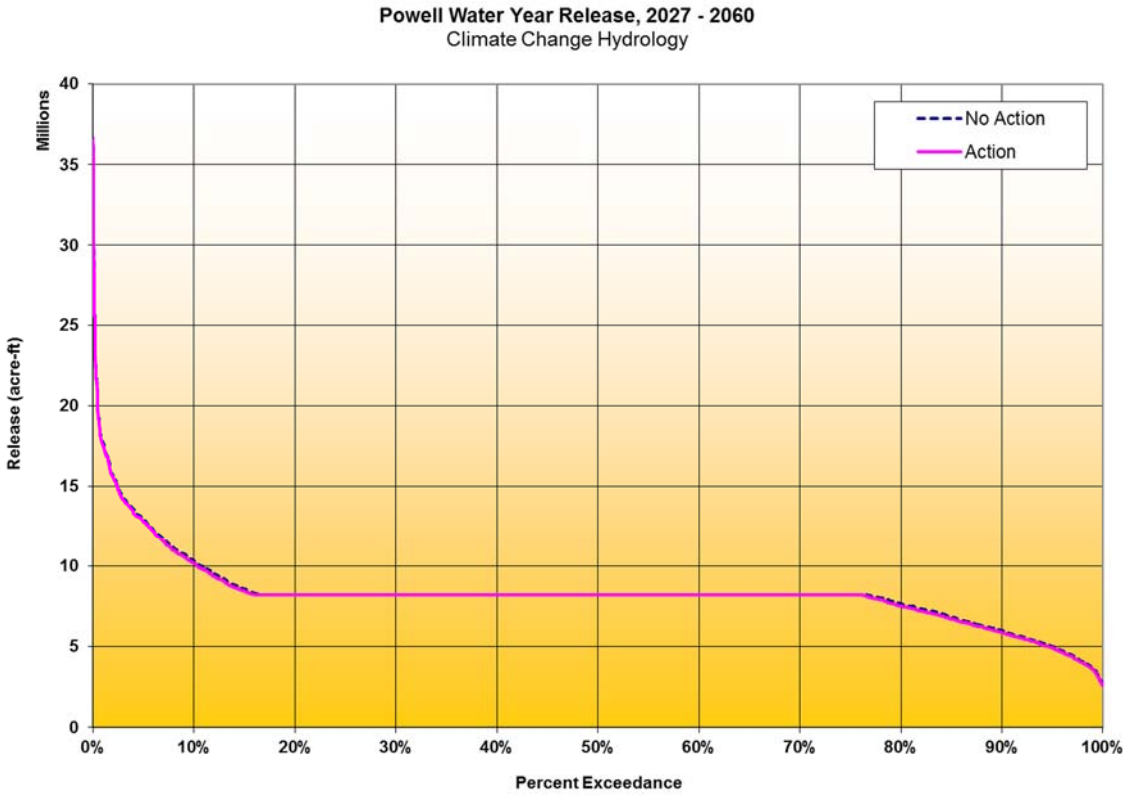
Figure 9. Lake Powell water year release. Climate change inflows, 86kaf Lake Powell Pipeline maximum depletion.

The cumulative distribution functions of Lake Powell releases throughout the Interim Guidelines period (2009-2026) and throughout the post-Interim Guidelines period (2027-2060) are presented in Figure 10 (a) and (b), respectively. In this figure, Lake Powell releases at every exceedance percentile (from 0 to 100) are plotted, rather than the three percentile plots shown in Figure 9. The Interim Guidelines and post-Interim Guidelines periods are plotted separately because operations at Lake Powell differ significantly between these two time periods. For a given exceedance probability, the corresponding release volume is generally greater for the no action alternative than the action, however, the differences vary by both sign and magnitude throughout the curve. As shown in Figure 9, the greatest differences generally occur at the lower exceedance probabilities (higher percentiles) when Lake Powell is making larger releases for equalization or spill avoidance *or* at the highest exceedance probabilities (lower percentiles) when Lake Powell is making releases of less than 8.23 million acre-feet. The greatest difference in annual volume is 267,000 acre-feet, or 2.0 percent of the annual volume in that year; with more being released in the no action alternative than the action alternative. This difference occurs at the 1.7 percent exceedance level (98 th percentile) and during the post-Interim Guidelines period. During the Interim Guidelines period, releases greater than 8.23 million acre-feet occur 58.3 percent of the time in both the action and no action alternatives. During the post-Interim Guidelines period, releases greater than 8.23 million acre-feet occur 16.4 percent of the time in the no action alternative and 16.0

percent of the time in the action alternative. See Attachment D for the differences at each exceedance probability.



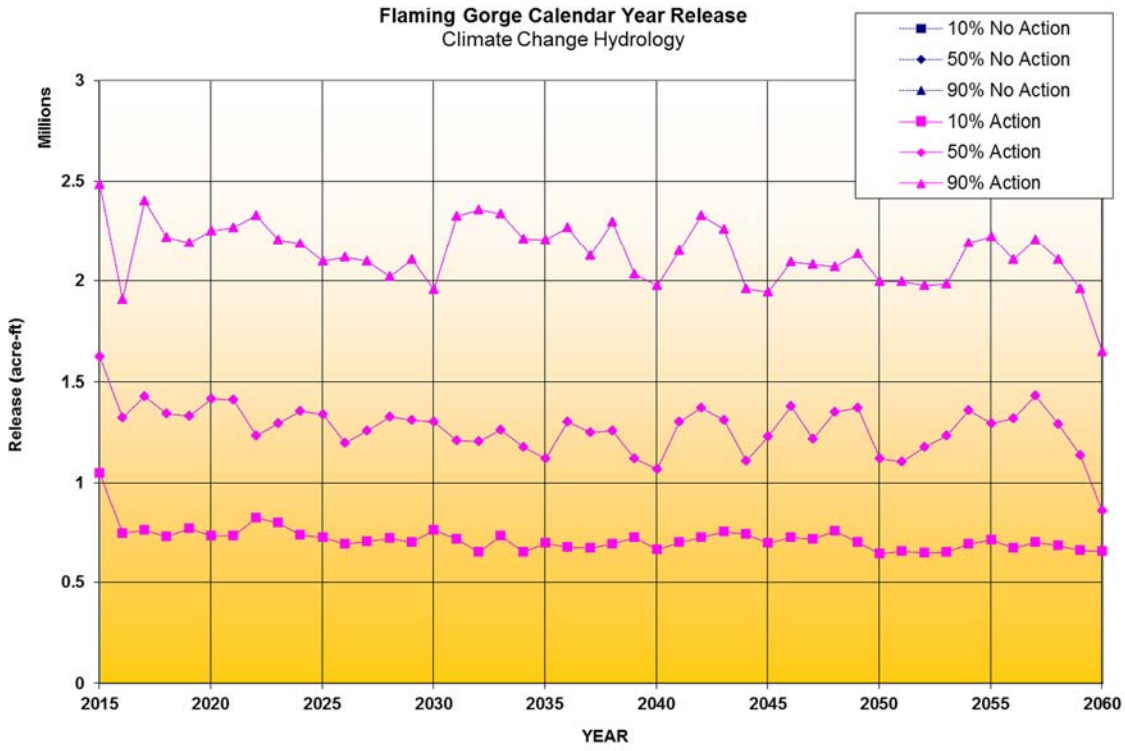
(a)



(b)

Figure 10. Lake Powell water year release, cumulative distribution function throughout time during the Interim Guidelines period (a) and during the post-Interim Guidelines period (b). climate change inflows, 86kaf Lake Powell Pipeline maximum depletion.

Flaming Gorge Reservoir annual releases (a) and end-of-December pool elevations (b) are shown in Figure 11. As with the DNF inflows, at the 10th, 50th, and 90th percentiles, there are no differences between the action and no action alternatives using CC inflows.



(a)

(b)

Figure 11. Flaming Gorge Reservoir annual release (a) and December pool elevation (b). Climate change inflows, 86kaf Lake Powell Pipeline maximum depletion.

The releases from Lake Powell in the month of June for the CC inflow scenario are shown in Figure 12. For results in every month, see Attachment D. Across all months, the differences are similar to those in the DNF inflow scenario with the differences generally being greater at the 90th percentile level and with very few differences at the 50th and 10th percentile levels. In June, the largest difference was 303,000 acre-ft, or 17.5percent, less being released in the action alternative. Average differences in June for the period 2024 through 2060 at the 90th percentile were 36,000 acre-ft. For all months, in some years the action alternative released more water, in others, the no action alternative resulted in larger releases. Differences at the monthly timestep should be interpreted by considering general trends across several months rather than isolating single values in a single month and model year. This is because release volumes could be shifted among months resulting in different monthly values but the same total annual release.

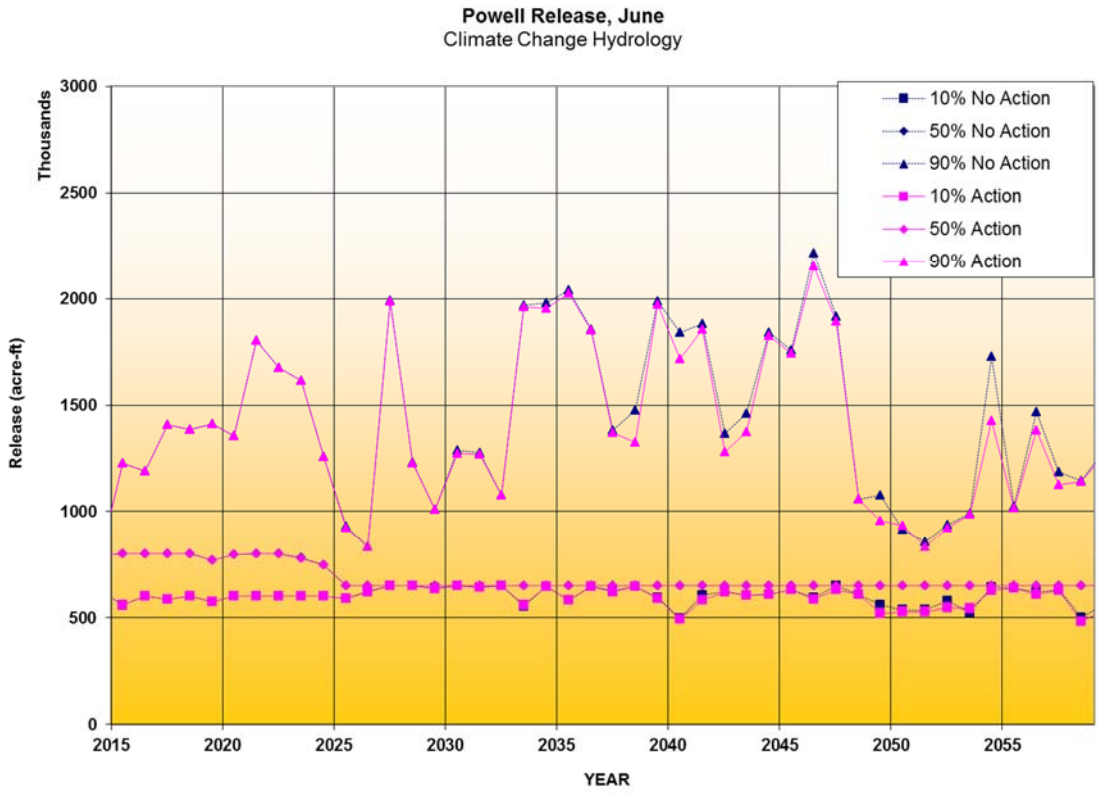


Figure 12. Lake Powell monthly release, June. Climate change inflows, 86kaf Lake Powell Pipeline maximum depletion.

Discussion

The results from these hydrologic model runs should be interpreted with consideration to the model assumptions. Unique to this analysis is the model assumption that no new projects or depletions will occur in the Upper Basin. This model assumption adopts a rigorous definition of what reasonably foreseeable future depletions are in the Upper Basin and is consistent with DOI NEPA Implementing Regulations. Under this approach, a reasonably foreseeable future depletion is one which has state legislation, or a tribal resolution or Federal Indian water settlement, or a Federal finding of no significant impact (FONSI) or record of decision (ROD). These are the criteria of certainty that a future depletion would occur at a particular time and place. This is a conservative approach to modeling the alternatives and takes the strictest approach to defining what is included and excluded for the cumulative impact analysis required by the Council on Environmental Quality's regulations 40 CFR 1508.7.[13]

[13] Cumulative impact is the impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency or person undertakes such actions. Cumulative impacts can result from individually minor but collectively significant actions taking place over a period of time.

It is recognized that the Upper Basin States plan to develop their compact allocated Colorado River water and, as such, it is highly unlikely that depletions will remain at the 2015 level in the future.

It should also be noted that the modeling effect of holding most Upper Basin depletions constant at 2015 levels results in depletions significantly lower than the future long-term depletion projections provided by the Upper Basin States which assume that Upper Basin depletions will grow through 2060. Lower depletions, in turn, result in Lake Powell's elevation increasing throughout the model run. Higher elevations at Lake Powell result in more frequent and higher magnitude equalization and spill avoidance releases in both the action and no action alternatives.

Note that these model results do not represent what the actual reservoir elevations or releases will be in any particular year. Model results should be interpreted based on the relative differences between the action and no action alternatives.

The results presented in this report are the product of statistical analysis performed on model results from the 105 (DNF) or 112 (CC) model traces. As described in the Post-Processing and Interpretation Procedures section, the 10th percentile data does not represent any one continuous trace, but rather is a statistic that summarizes the results of all the traces. Therefore, percentile results presented as a timeseries do not represent reservoir operations as they would occur sequentially in response to any particular inflow hydrology trace. The operational policy assumptions used in the 2007 Interim Guidelines EIS modeling, and subsequent ROD[14] were also applied in this study. That is, these model runs implement the Interim Guidelines through 2026 and revert to the 2007 Interim Guidelines Final EIS No Action Alternative for model years 2027-2060. The modeled Lake Powell Pipeline begins depleting water in 2024 and is at full build out in 2048 (DNF hydrology) and 2049 (CC hydrology). Thus, for this analysis the potential effects of the Lake Powell Pipeline project under the Interim Guidelines are evaluated for only three years, the first three years of the pipeline when the project is coming on line and pipeline depletions are lower. The effects of the pipeline at full build out are evaluated under post Interim Guidelines operational policies.

The model results presented in this report are sensitive to the inflow hydrology assumption. This analysis evaluated over 200 traces from two inflow assumptions: DNF and CC. The CC inflow scenario generally produced a wider variety and range of inflows, resulting in a wider range of projected future Lake Powell elevations and releases when compared with the DNF inflow scenario. In addition, future Lake Powell elevations and releases modeled under the CC inflow scenario were generally lower compared to the DNF inflow scenario. Overall, however, the general trend and pattern of differences between the action and no action alternatives were similar between the DNF and CC inflow scenarios.

[14] Record of Decision, Colorado River Interim Guidelines for Lower Basin Shortages and the Coordinated Operations for Lake Powell and Lake Mead, December 2007, available at: http://www.usbr.gov/lc/region/programs/strategies/RecordofDecision.pdf

Attachments List

Attachment A: ReasonablyForeseeableDepletionNodes.xls

Reasonable Forseeable Future Depletions Nodes in CRSS for LPP modeling, 2015

AZ UB Schedules.ArizonaMiscUses_LeChee_Depletion Requested
AZ UB Schedules.ArizonaMiscUses_LeChee_Diversion Requested
AZ UB Schedules.ArizonaMiscUses_NavajoPowerPlant_Depletion Requested
AZ UB Schedules.ArizonaMiscUses_NavajoPowerPlant_Diversion Requested
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CO Schedules.ColoradoNewMexAgAbvArch_COSoUte_Depletion Requested
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NM Schedules.SanJuanRiverEnergyAndMIFarmToShip_GallupMunWSNav_Depletion Requested
NM Schedules.SanJuanRiverEnergyAndMIFarmToShip_GallupMunWSNav_Diversion Requested
NM Schedules.SanJuanRiverEnergyAndMIFarmToShip_GallupNGWSP_Depletion Requested
NM Schedules.SanJuanRiverEnergyAndMIFarmToShip_GallupNGWSP_Diversion Requested
NM Schedules.SanJuanRiverEnergyAndMIFarmToShip_NavajoFutureUse_Depletion Requested
NM Schedules.SanJuanRiverEnergyAndMIFarmToShip_NavajoFutureUse_Diversion Requested
NM Schedules.SanJuanRiverEnergyAndMIFarmToShip_NavajoNGWSP_Depletion Requested
NM Schedules.SanJuanRiverEnergyAndMIFarmToShip_NavajoNGWSP_Diversion Requested
NM Schedules.SanJuanRiverEnergyAndMIFarmToShip_NavajoNGWSPexports_Depletion Requested
NM Schedules.SanJuanRiverEnergyAndMIFarmToShip_NavajoNGWSPexports_Diversion Requested
NM Schedules.SanJuanRiverEnergyAndMIFarmToShip_NMEnergyJicarillaLease_Depletion Requested
NM Schedules.SanJuanRiverEnergyAndMIFarmToShip_NMEnergyJicarillaLease_Diversion Requested
NM Schedules.SanJuanRiverEnergyAndMIFarmToShip_PNMJicarilla_Depletion Requested
NM Schedules.SanJuanRiverEnergyAndMIFarmToShip_PNMJicarilla_Diversion Requested
UT Schedules.AgAboveRandlette_AgUteCurr_Depletion Requested
UT Schedules.AgAboveRandlette_AgUteCurr_Diversion Requested
UT Schedules.AgUsesAboveGreenRUt_UteGreenMandI_Depletion Requested
UT Schedules.AgUsesAboveGreenRUt_UteGreenMandI_Diversion Requested
UT Schedules.AgUsesAboveGreenRUt_UteIndianCompactGreen_Depletion Requested
UT Schedules.AgUsesAboveGreenRUt_UteIndianCompactGreen_Diversion Requested
UT Schedules.DoloresAgUsesAbvCisco_UtahAg_Depletion Requested
UT Schedules.DoloresAgUsesAbvCisco_UtahAg_Diversion Requested
UT Schedules.DoloresAgUsesAbvCisco_UtahMI_Depletion Requested
UT Schedules.DoloresAgUsesAbvCisco_UtahMI_Diversion Requested
UT Schedules.DoloresAgUsesAbvCisco_UtahResEvap_Depletion Requested
UT Schedules.DoloresAgUsesAbvCisco_UtahResEvap_Diversion Requested
UT Schedules.MIUseBtwnGreendaleAndOuray_AdditionalJensenUnit_Depletion Requested
UT Schedules.MIUseBtwnGreendaleAndOuray_AdditionalJensenUnit_Diversion Requested
UT Schedules.UintahBasinWQIP_UintahBasinWQIP_Depletion Requested
UT Schedules.UintahBasinWQIP_UintahBasinWQIP_Diversion Requested
UT Schedules.UpalcoUintaBonnUtes_NewIndianLandsUte_Depletion Requested
UT Schedules.UpalcoUintaBonnUtes_NewIndianLandsUte_Diversion Requested

UT Schedules.UpalcoUintaBonnUtes_NonIndian_Depletion Requested
UT Schedules.UpalcoUintaBonnUtes_NonIndian_Diversion Requested
UT Schedules.UpalcoUintaBonnUtes_UintaProject_Depletion Requested
UT Schedules.UpalcoUintaBonnUtes_UintaProject_Diversion Requested
UT Schedules.UpalcoUintaBonnUtes_UpalcoProjectAg_Depletion Requested
UT Schedules.UpalcoUintaBonnUtes_UpalcoProjectAg_Diversion Requested
UT Schedules.UpalcoUintaBonnUtes_UpalcoReplacementMI_Depletion Requested
UT Schedules.UpalcoUintaBonnUtes_UpalcoReplacementMI_Diversion Requested
UT Schedules.UsesBetGreendaleAndOuray_JensenAreaAg_Depletion Requested
UT Schedules.UsesBetGreendaleAndOuray_JensenAreaAg_Diversion Requested
UT Schedules.UsesBetGreendaleAndOuray_UteUseSince1965_Depletion Requested
UT Schedules.UsesBetGreendaleAndOuray_UteUseSince1965_Diversion Requested
UT Schedules.UtahAgUses_UteIndianCompactWhite_Depletion Requested
UT Schedules.UtahAgUses_UteIndianCompactWhite_Diversion Requested