Lake Powell Pipeline

Draft Study Report 17
Surface Water Quality

March 2010

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Surface Water Quality Study Report
Executive Summary

ES-1 Introduction

This study report describes the results and findings of an analysis to evaluate surface water quality 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 Quality Study Plan prepared for the Federal Energy Regulatory Commission (Commission), was to evaluate the impacts on surface water quality caused by the proposed construction and operation of the LPP Project.

ES-2 Methodology

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

ES-3 Key Results of the Surface Water Quality Impact Analyses

Impacts on water quality were considered significant if construction, operation or maintenance activities would violate applicable surface water quality standards, substantially degrade surface water quality, or substantially alter existing drainage patterns of the site or area, including through alteration of a stream or river course in a manner resulting in substantial erosion or siltation on- or off-site.

ES-3.1 LPP Project Alternative

Construction of project facilities along any of the proposed alignments could cause temporary and occasional surface water quality impacts. Construction of project features could temporarily alter the existing drainage pattern of streams crossed by pipelines, which could result in erosion and siltation. In addition, temporary water quality impacts may occur at pipeline crossings of perennial streams and ephemeral washes if water is flowing during construction. Implementation of Best Management Practices and standard construction procedures during construction would avoid or minimize temporary water quality impacts, primarily consisting of turbidity and sediment recruitment.

Potential impacts on water quality considered for project operation include sediment transport and introduction of pollutants from pipeline discharges during operation and changes in total dissolved solids from the addition of large volumes of Lake Powell water to Sand Hollow Reservoir. Temporary and occasional discharges of sediment or organics-laden water or disinfected water (if required for quagga mussel control) from the pipeline during maintenance operations could result in exceedance of water quality objectives in receiving waters. With implementation of standard operation procedures to control pipeline discharges, operation of the LPP would not result in the violation of applicable surface water quality standards, or cause substantial degradation of surface water quality, or cause substantial alteration of the existing drainage pattern of the site or area.

ES-3.2 No Lake Powell Water Alternative

This alternative is expected to increase salt loading in surface waters from conservation measures that increase wastewater strength combined with increased wastewater reclamation. Additionally, the reverse osmosis treatment system would generate more than 3,700 acre-feet per year of brine which would require disposal. The restrictions on residential outdoor watering would significantly reduce recharge and are expected to result in changing the Virgin River from a gaining stream during the summer and fall months to a losing stream year round. This indirect impact would cause the stream water temperatures to increase because the cooler groundwater discharging to the stream under baseline conditions helps control the water temperature during the summer and fall months. Therefore, the No Lake Powell Water Alternative is expected to result in the violation of applicable surface water quality standards for temperature and cause substantial degradation of surface water quality. This would be a significant impact on water quality in the Virgin River and the organisms inhabiting the river.

ES-3.3 No Action Alternative

The No Action Alternative would not result in the violation of applicable surface water quality standards, or cause substantial degradation of surface water quality, or cause substantial alteration of the existing drainage pattern of the site or area.

Chapter 1
Introduction

1.1 Introduction

This chapter presents a summary description of the alternatives studied for the Lake Powell Pipeline (LPP) project, located in north central Arizona and southwest Utah (Figure 1-1) and identifies the issues and impact topics for the Surface Water Quality Study Report. The alternatives studied and analyzed include different alignments for pipelines and penstocks and transmission lines, a no Lake Powell water alternative, and the No Action alternative. The pipelines would convey water under pressure and connect to the penstocks, which would convey the water to a series of hydroelectric power generating facilities. The action alternatives would each deliver 86,249 acre-feet of water annually for municipal and industrial (M&I) use in the three southwest Utah water conservancy district service areas. Washington County Water Conservancy District (WCWCD) would receive 69,000 acre-feet, Kane County Water Conservancy District (KCWCD) would receive 4,000 acre-feet and Central Iron County Water Conservancy District (CICWCD) could receive up to 13,249 acre-feet each year.

1.2 Summary Description of Alignment Alternatives

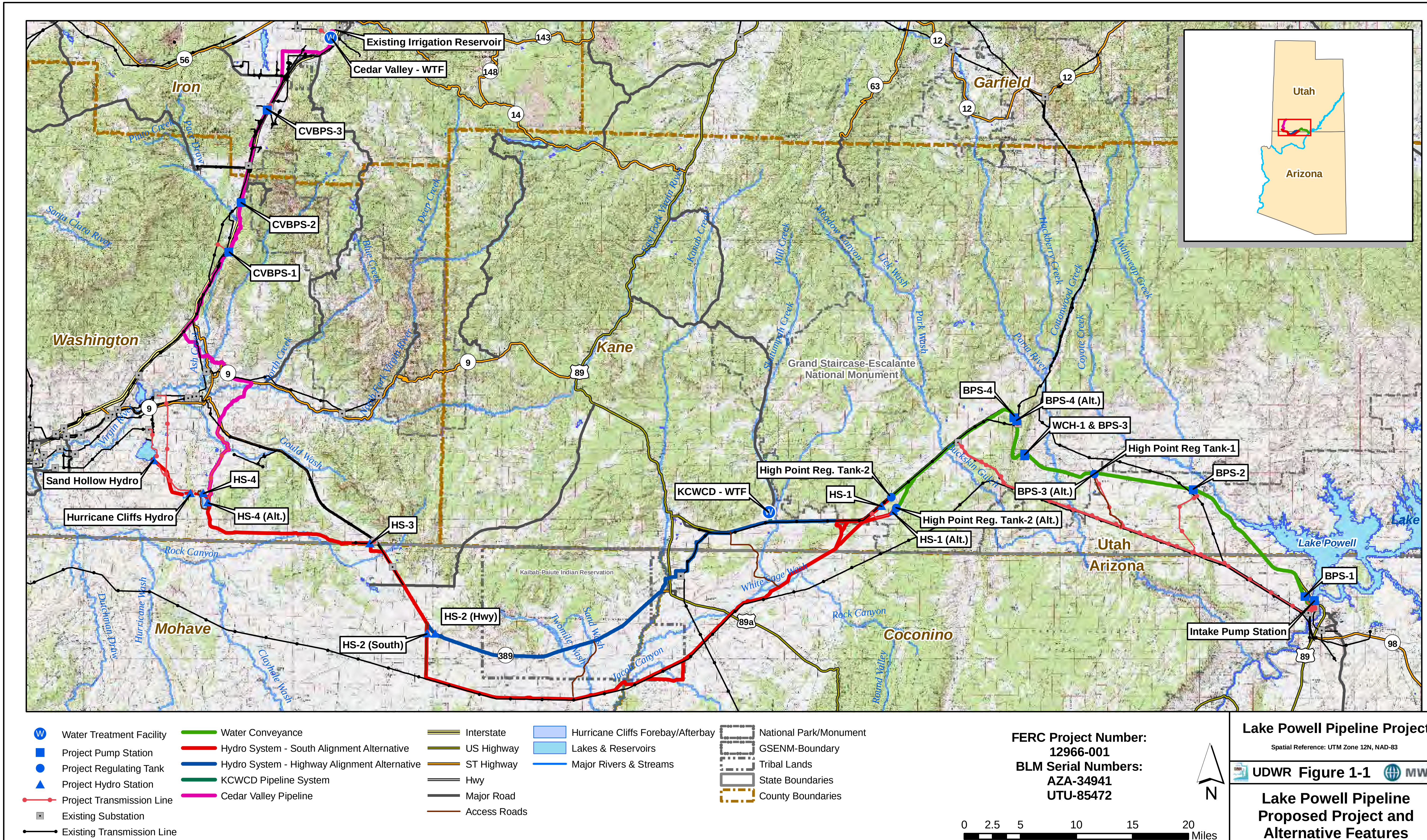
Three primary pipeline and penstock alignment alternatives are described in this section along with the electrical power transmission line alternatives. The pipeline and penstock alignment alternatives share common segments between the intake at Lake Powell and delivery at Sand Hollow Reservoir, and they are spatially different in the area through and around the Kaibab-Paiute Indian Reservation. The South Alternative extends south around the Kaibab-Paiute Indian Reservation. The Existing Highway Alternative follows an Arizona state highway through the Kaibab-Paiute Indian Reservation. The Southeast Corner Alternative follows the Navajo-McCullough Transmission Line corridor through the southeast corner of the Kaibab-Paiute Indian Reservation. The transmission line alignment alternatives are common to all the pipeline and penstock alignment alternatives. Figure 1-1 shows the overall proposed project and alternative features from Lake Powell near Page, Arizona to Sand Hollow and Cedar Valley, Utah.

1.2.1 South Alternative

The South Alternative consists of five systems: Intake, Water Conveyance, Hydro, Kane County Pipeline, and Cedar Valley Pipeline.

The **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 (Figure 1-2). The pump station enclosure would house vertical turbine pumps with electric motors, electrical controls, and other equipment at a ground level elevation of 3,745 feet mean sea level (MSL).

The **Water Conveyance System** would convey the Lake Powell water from the Intake System for about 51 miles through a buried 69-inch diameter pipeline parallel with U.S. 89 in Coconino County, Arizona and Kane County, Utah to a buried regulating tank (High Point Regulating Tank-2) on the south side of U.S. 89 at ground level elevation 5,695 feet MSL, which is the LPP project topographic high point


Existing Irrigation Reservoir
Cedar Valley - WTF
CVBPS-3
CVBPS-2
CVBPS-1
Iron
Garfield
Washington
Kane
Mohave
Coconino
Utah
Arizona
Grand Staircase-Escalante National Monument
Kaibab-Paiute Indian Reservation
Lake Powell
Lake
Sand Hollow Hydro
Hurricane Cliffs Hydro
HS-4
HS-4 (Alt.)
HS-3
HS-2 (Hwy)
HS-2 (South)
KCWCD - WTF
High Point Reg. Tank-2
HS-1
High Point Reg. Tank-2 (Alt.)
HS-1 (Alt.)
BPS-4
BPS-4 (Alt.)
WCH-1 & BPS-3
High Point Reg Tank-1
BPS-2
BPS-3 (Alt.)
BPS-1
Intake Pump Station
Santa Clara River
Pinto Creek
Gould Wash
Rock Canyon
Hurricane Wash
Dutchman Draw
Clayhole Wash
Twomile Wash
Sand Wash
Jacob Canyon
White Sage Wash
Buckskin Gulch
Paria River
Cottonwood Creek
Hackberry Creek
Coyote Creek
Wahweap Creek
Park Wash
Deer Creek
Kanab Creek
Mill Creek
Meadow Canyon
Round Valley
Utah
Arizona
Water Treatment Facility
Project Pump Station
Project Regulating Tank
Project Hydro Station
Project Transmission Line
Existing Substation
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
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
0 2.5 5 10 15 20 Miles
N
Lake Powell Pipeline Project
Spatial Reference: UTM Zone 12N, NAD-83
UDWR Figure 1-1 MWH
Lake Powell Pipeline Proposed Project and Alternative Features

Project Intake Pump Station
Project Booster Pump Station
Project Regulating Tank
Project Hydro Station
Water Conveyance System
Hydro System - South Alignment Alternative

Interstate
US Highway
ST Highway
Hwy
Major Road

Lakes & Reservoirs
Major Rivers & Streams
National Park/Monument
GSENM Boundary
State Boundaries

NGS USA Topographic Maps

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N

0 0.5 1 2 3 4 Miles

Lake Powell Pipeline Project

Spatial Reference: UTM Zone 12N, NAD-83

UDWR **Figure 1-2** MWH

Lake Powell Pipeline
Intake and
Water Conveyance Systems

(Figure 1-2). The pipeline would be sited within a utility corridor established by Congress in 1998 which extends 500 feet south and 240 feet north of the U.S. 89 centerline on public land administered by the Bureau of Land Management (BLM) (U.S. Congress 1998). Four booster pump stations (BPS) located along the pipeline would pump the water under pressure 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 substation, buried forebay tank and a surface emergency overflow detention basin. BPS-1 would be sited within the Glen Canyon National Recreation Area adjacent to an existing Arizona Department of Transportation maintenance facility located west of U.S. 89. BPS-2 would be sited on land administered by the Utah School and Institutional Trust Lands Administration (SITLA) near the town of Big Water, Utah on the south side of U.S. 89. BPS-3 and an in-line hydro station (WCH-1) would be sited at the east side of the Cockscomb geologic feature in the Grand Staircase-Escalante National Monument (GSENM) within the Congressionally-designated utility corridor. BPS-3 (Alt) is an alternative location for BPS-3 on land administered by the BLM Kanab Field Office near the east boundary of the GSENM on the south side of U.S. 89 within the Congressionally-designated utility corridor. Incorporation of BPS-3 (Alt.) into the LPP project would replace BPS-3 and WCH-1 at the east side of the Cockscomb geologic feature. BPS-4 would be sited on the west side of U.S. 89 and within the Congressionally-designated utility corridor in the GSENM on the west side of the Cockscomb geologic feature.

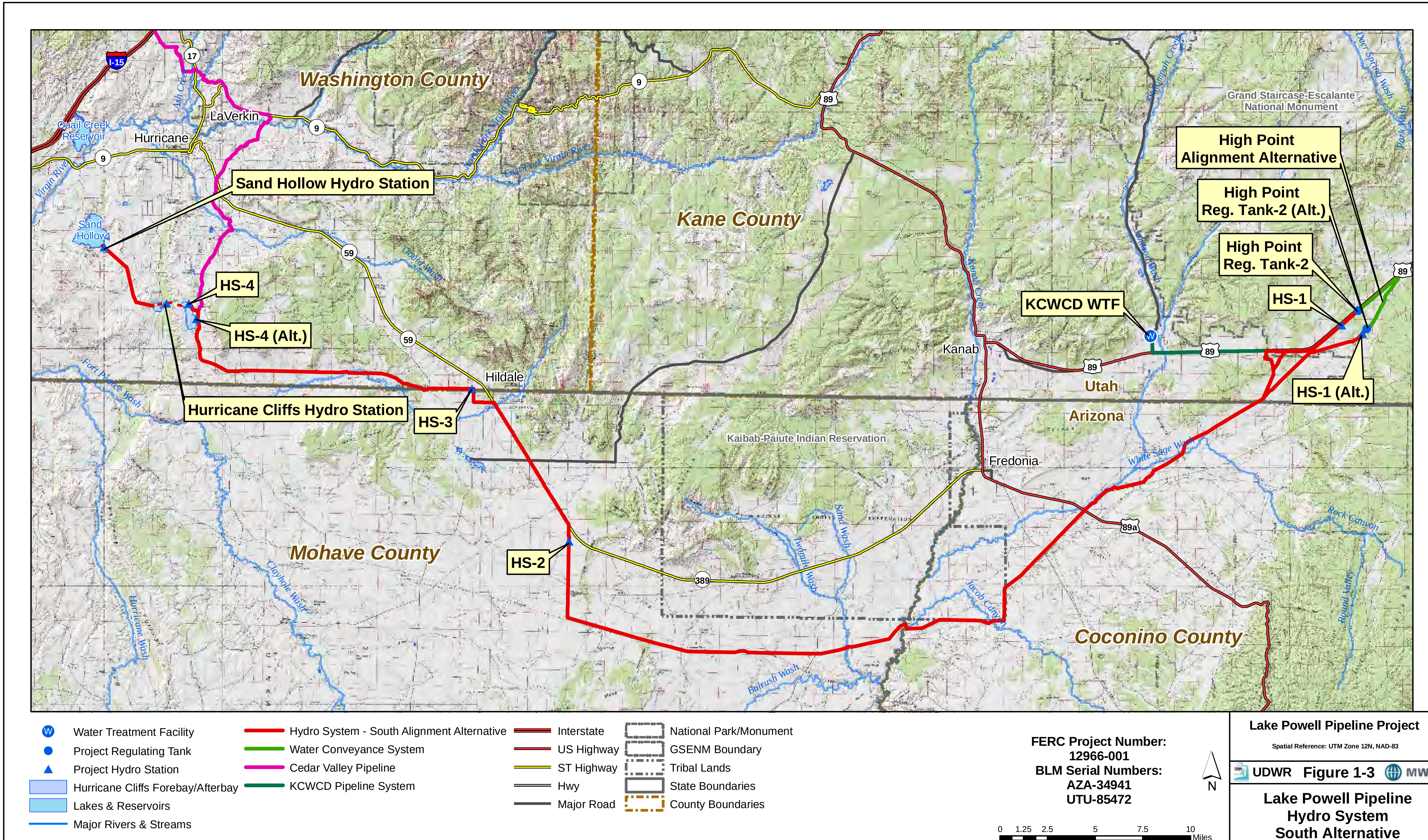
The High Point Alignment Alternative would diverge south from U.S. 89 parallel to the K4020 road and continue outside of the Congressionally-designated utility corridor to a buried regulating tank (High Point Regulating Tank-2 (Alt.) at ground level elevation 5,630 feet MSL, which would be the topographic high point of the LPP project along this alignment alternative (Figure 1-2). The High Point Alignment Alternative would include BPS-4 (Alt.) on private land east of U.S. 89 and west of the Cockscomb geologic feature (Figure 1-2). Incorporation of the High Point Alignment Alternative and BPS-4 (Alt.) into the LPP project would replace the High Point Regulation Tank-2 along U.S. 89, the associated buried pipeline and BPS-4 west of U.S. 89.

A rock formation avoidance alignment option would be included immediately north of Blue Pool Wash along U.S. 89 in Utah. Under this alignment option, the pipeline would cross to the north side of U.S. 89 for about 400 feet and then return to the south side of U.S. 89. This alignment option would avoid tunneling under the rock formation on the south side of U.S. 89 near Blue Pool Wash.

A North Pipeline Alignment option is located parallel to the north side of U.S. 89 for about 6 miles from the east boundary of the GSENM to the east side of the Cockscomb geological feature.

The **Hydro System** would convey the Lake Powell water from High Point Regulating Tank-2 at the high point at ground level elevation 5,695 feet MSL for about 87 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 1-3). The High Point Alignment Alternative would convey the Lake Powell water from High Point Regulating Tank-2 (Alt.) at the high point at ground level elevation 5,630 feet MSL 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 1-3). Four in-line hydro generating stations (HS-1, HS-2 HS-3 and HS-4) with substations located along the penstock would generate electricity and help control water pressure in the penstock. HS-1 would be sited on the south side of U.S. 89 within the Congressionally-designated utility corridor through the GSENM. The High Point Alignment Alternative would include HS-1 (Alt.) along the K4020 road within the GSENM and continue along a portion of the K3290 road.

The proposed penstock alignment and two penstock alignment options are being considered to convey the water from the west GSENM boundary south through White Sage Wash. The proposed penstock


Washington County
Kane County
Mohave County
Coconino County
Grand Staircase-Escalante National Monument
High Point Alignment Alternative
High Point Reg. Tank-2 (Alt.)
High Point Reg. Tank-2
HS-1
HS-1 (Alt.)
KCWCD WTF
Sand Hollow Hydro Station
HS-4
HS-4 (Alt.)
Hurricane Cliffs Hydro Station
HS-3
HS-2
LaVerkin
Hurricane
Quail Creek Reservoir
Sand Hollow
Hildale
Kanab
Fredonia
Utah
Arizona
Kaibab-Paiute Indian Reservation
Virgin River
Fort Pearce Wash
Hurricane Wash
Clayhole Wash
Gould Wash
East Fork Virgin River
North Fork Virgin River
Kanab Creek
Johnson Wash
Sand Wash
Twomile Wash
Jacob Canyon
Bulrush Wash
White Sage Wash
Rock Canyon
Deer Spring Wash
Paria Wash
Ash Creek
I-15
17
9
59
89
89a
389
Water Treatment Facility
Project Regulating Tank
Project Hydro Station
Hurricane Cliffs Forebay/Afterbay
Lakes & Reservoirs
Major Rivers & Streams
Hydro System - South Alignment Alternative
Water Conveyance System
Cedar Valley Pipeline
KCWCD Pipeline System
Interstate
US Highway
ST Highway
Hwy
Major Road
National Park/Monument
GSENM Boundary
Tribal Lands
State Boundaries
County Boundaries
FERC Project Number:
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AZA-34941
UTU-85472
N
0 1.25 2.5 5 7.5 10 Miles
Lake Powell Pipeline Project
Spatial Reference: UTM Zone 12N, NAD-83
UDWR
Figure 1-3
MWH
Lake Powell Pipeline
Hydro System
South Alternative

alignment would parallel the K3250 road south from U.S. 89 and follow the Pioneer Gap Road alignment around the Shinarump Cliffs. One penstock alignment option would parallel the K3285 road southwest from U.S. 89 and continue to join the Pioneer Gap Road around the Shinarump Cliffs. The other penstock alignment option would extend southwest through currently undeveloped BLM land from the K3290 road into White Sage Wash.

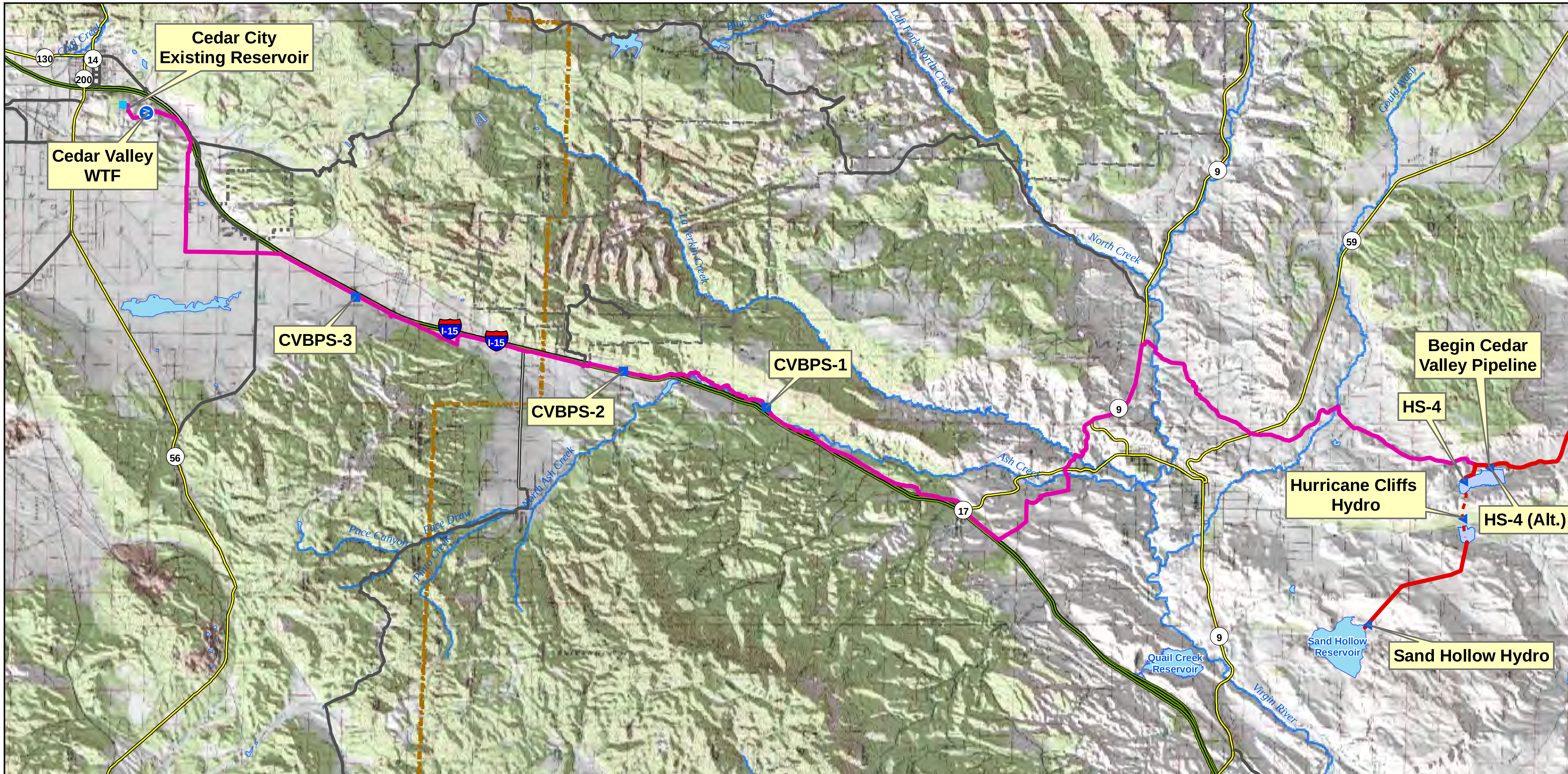
The penstock alignment would continue through White Sage Wash and then parallel to the Navajo-McCullough Transmission Line, crossing U.S. 89 Alt. and Forest Highway 22 toward the southeast corner of the Kaibab Indian Reservation. The penstock alignment would run parallel to and south of the south boundary of the Kaibab Indian Reservation, crossing Kanab Creek and Bitter Seeps Wash, across Moonshine Ridge and Cedar Ridge, and north along Yellowstone Road to Arizona State Route 389 west of the Kaibab Indian Reservation. HS-2 would be sited west of the Kaibab Indian Reservation. 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.

The penstock alignment would follow Uzona Road west through Canaan Gap and south of Little Creek Mountain and turn north to HS-4 (Alt.) above the proposed Hurricane Cliffs forebay reservoir. The forebay reservoir would be contained in a valley between a south dam and a north dam and maintain active storage of 11,255 acre-feet of water. 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 pumped storage hydro generating station. The pumped storage hydro generating station would connect to an afterbay reservoir contained by a single dam in the valley below the Hurricane Cliffs. A low pressure tunnel would convey the water northwest to a penstock continuing on to the Sand Hollow Hydro Station. The water would discharge into the existing Sand Hollow Reservoir.

The peaking hydro generating station option would involve a smaller, 200 acre-foot forebay reservoir with HS-4 discharging into the forebay reservoir, with the peaking hydro generating station discharging to a small afterbay connected to a penstock running north along the existing BLM road and west to the Sand Hollow Hydro Station. 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 peaking hydro generating station, which would discharge into a 200 acre-foot afterbay reservoir. A penstock would extend north from the afterbay reservoir along the existing BLM road and then west to the Sand Hollow Hydro Station. The water would discharge into the existing Sand Hollow Reservoir.

The **Kane County Pipeline System** would convey the Lake Powell water from the Lake Powell Pipeline at the west GSENM boundary for about 8 miles through a buried 24-inch diameter pipe in Kane County, Utah to a conventional water treatment facility located near the mouth of Johnson Canyon. The pipeline would parallel the south side of U.S. 89 across Johnson Wash and then run north to the new water treatment facility site (Figure 1-3).

The **Cedar Valley Pipeline System** would convey the Lake Powell water from the Lake Powell Pipeline just upstream of HS-4 or HS-4 (Alt.) for about 58 miles through a buried 36-inch diameter pipeline in Washington and Iron counties, Utah to a conventional water treatment facility in Cedar City, Utah (Figure 1-4). Three booster pump stations (CVBPS) located along the pipeline would pump the water under pressure to the new water treatment facility. The pipeline would follow an existing BLM road north from HS-4, cross Utah State Route 59 and continue north to Utah State Route 9, with an aerial crossing of the Virgin River at the Sheep Bridge. The pipeline would run west along the north side of Utah State Route 9 and parallel an existing pipeline through the Hurricane Cliffs at Nephi's Twist. The pipeline



- Water Treatment Facility
- Project Pump Station
- Project Hydro Station
- Hydro System - South Alignment Alternative
- Water Conveyance System
- Hurricane Cliffs Pressure Tunnel
- Cedar Valley Pipeline
- Interstate
- US Highway
- ST Highway
- Hwy
- Major Road
- Hurricane Cliffs Forebay/Afterbay
- Lakes & Reservoirs
- Major Rivers & Streams
- National Park/Monument
- County Boundaries
- Tribal Lands

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

0 1 2 4 6 8 Miles

N

Lake Powell Pipeline Project

Spatial Reference: UTM Zone 12N, NAD-83

UDWR **Figure 1-4** MWH

Cedar Valley Pipeline System

would continue across LaVerkin Creek, cross Utah State Route 17, and make an aerial crossing of Ash Creek. The pipeline would continue northwest to the Interstate 15 corridor and then northeast parallel to the east side of Interstate 15 highway right-of-way. CVBPS-1 would be sited adjacent to an existing gravel pit east of Interstate 15. CVBPS-2 would be sited on private property on the east side of Interstate 15 and south of the Kolob entrance to Zion National Park. CVBPS-3 would be sited on the west side of Interstate 15 in Iron County. The new water treatment facility would be sited near existing water reservoirs on a hill above Cedar City west of Interstate 15.

1.2.2 Existing Highway Alternative

The Existing Highway Alternative consists of five systems: Intake, Water Conveyance, Hydro, Kane County Pipeline, and Cedar Valley Pipeline. The Intake, Water Conveyance and Cedar Valley Pipeline systems would be the same as described for the South Alternative.

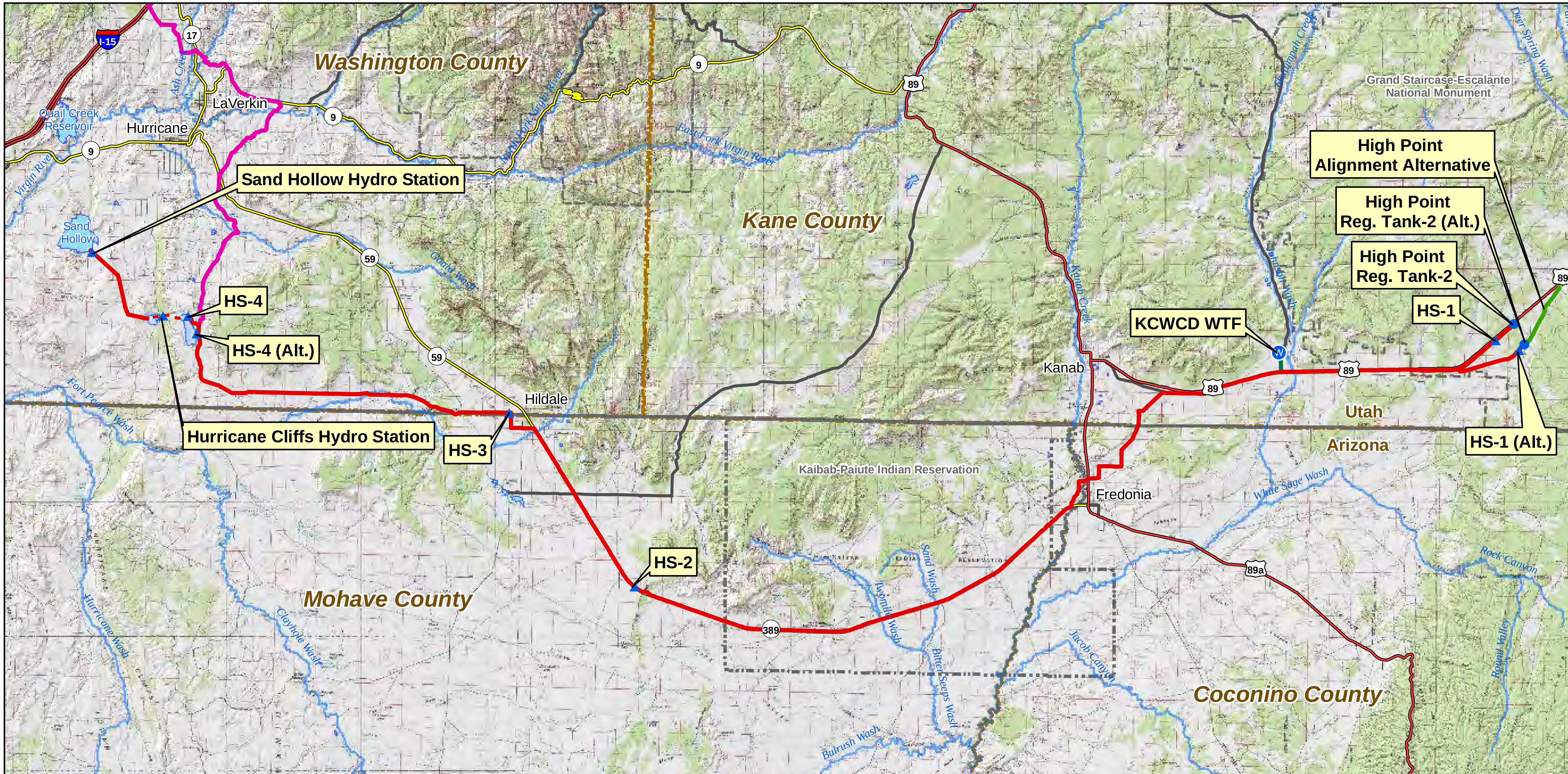
The **Hydro System** would convey the Lake Powell water from the regulating tank at the high point at ground elevation 5,695 feet MSL for about 80 miles through a buried 69-inch diameter penstock in Kane and Washington counties, Utah and Coconino and Mohave counties, Arizona to Sand Hollow Reservoir near St. George, Utah (Figure 1-5). The High Point Alignment Alternative would convey the Lake Powell water from High Point Regulating Tank-2 (Alt.) at the high point at ground level elevation 5,630 feet MSL 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 1-3). The High Point Alignment Alternative would rejoin U.S. 89 about 2.5 miles east of the west boundary of the GSENM. Four in-line hydro generating stations (HS-1, HS-2 HS-3 and HS-4) located along the penstock would generate electricity and help control water pressure in the penstock. HS-1 would be sited on the south side of U.S. 89 within the Congressionally-designated utility corridor through the GSENM. The High Point Alignment Alternative would include HS-1 (Alt.) along the K4020 road within the GSENM and continue along a portion of the K3290 road to its junction with the pipeline alignment along U.S. 89.

The penstock would parallel the south side of U.S. 89 west of the GSENM past Johnson Wash and follow Lost Spring Gap southwest, crossing U.S. 89 Alt. and Kanab Creek in the north end of Fredonia, Arizona. The penstock would run south paralleling Kanab Creek to Arizona State Route 389 and run west adjacent to the north side of this state highway through the 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 the Kaibab-Paiute Indian Reservation to 1.8 miles west of Cedar Ridge (intersection of Yellowstone Road with U.S. 89), from where it would follow the same alignment as the South Alternative to Sand Hollow Reservoir. HS-2 would be sited 0.5 mile west of Cedar Ridge along the north side of Arizona State Route 389.

The **Kane County Pipeline System** would convey the Lake Powell water from the Lake Powell Pipeline crossing Johnson Wash along U.S. 89 for about 1 mile north through a buried 24-inch diameter pipe in Kane County, Utah to a conventional water treatment facility located near the mouth of Johnson Canyon (Figure 1-5).

1.2.3 Southeast Corner Alternative

The Southeast Corner Alternative consists of five systems: Intake, Water Conveyance, Hydro, Kane County Pipeline, and Cedar Valley Pipeline. The Intake, Water Conveyance, Kane County Pipeline and Cedar Valley Pipeline systems would be the same as described for the South Alternative.



W	Water Treatment Facility
●	Project Regulating Tank
▲	Project Hydro Station
	Hurricane Cliffs Forebay/Afterbay
	Lakes & Reservoirs
	Major Rivers & Streams
	Water Conveyance
	Hydro System - South Alignment Alternative
	Hurricane Cliffs Pressure Tunnel
	Cedar Valley Pipeline
	KCWCD Pipeline System
	Interstate
	US Highway
	ST Highway
	Hwy
	Major Road
	National Park/Monument
	GSENM Boundary
	Tribal Lands
	State Boundaries
	County Boundaries

FERC Project Number:
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N

0 1.25 2.5 5 7.5 10 Miles

Lake Powell Pipeline Project

Spatial Reference: UTM Zone 12N, NAD-83

UDWR **Figure 1-5** MWH

Lake Powell Pipeline Hydro System Existing Highway Alternative

The **Hydro System** would be the same as described for the South Alternative between High Point Regulating Tank-2 and the east boundary of the 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 Indian Reservation for about 3.8 miles and 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).

1.2.4 Transmission Line Alternatives

Transmission line alternatives include the Intake (3 alignments), BPS-1, Glen Canyon to Buckskin, Buckskin Substation upgrade, Paria Substation upgrade, BPS-2, BPS-2 Alternative, BPS-3 North, BPS-3 South, BPS-3 Underground, BPS-3 Alternative North, BPS-3 Alternative South, BPS-4, BPS-4 Alternative, HS-1 Alternative, HS-2 South, HS-3 Underground, HS-4, HS-4 Alternative, Hurricane Cliffs Afterbay to Sand Hollow, Hurricane Cliffs Afterbay to Hurricane West, Sand Hollow to Dixie Springs, Cedar Valley Pipeline booster pump stations, and Cedar Valley Water Treatment Facility.

The proposed new **Intake Transmission Line** would begin at Glen Canyon Substation and run parallel to U.S. 89 for about 2,500 feet to a new switch station, cross U.S. 89 at the Intake access road intersection and continue northeast to the Intake substation. This 69 kV transmission line would be about 0.9 mile long in Coconino County, Arizona (Figure 1-7). One alternative alignment would run parallel to an existing 138 kV transmission line to the west, turn north to the new switch station, cross U.S. 89 at the Intake access road intersection and continue northeast to the Intake substation. This 69 kV transmission line alternative would be about 1.2 miles long in Coconino County, Arizona (Figure 1-7). Another alternative alignment would bifurcate from an existing transmission line and run west, then northeast to the new switch station, cross U.S. 89 at the Intake access road intersection and continue northeast to the Intake substation. This 69 kV transmission line alternative would be about 1.3 miles long in Coconino County, Arizona (Figure 1-7).

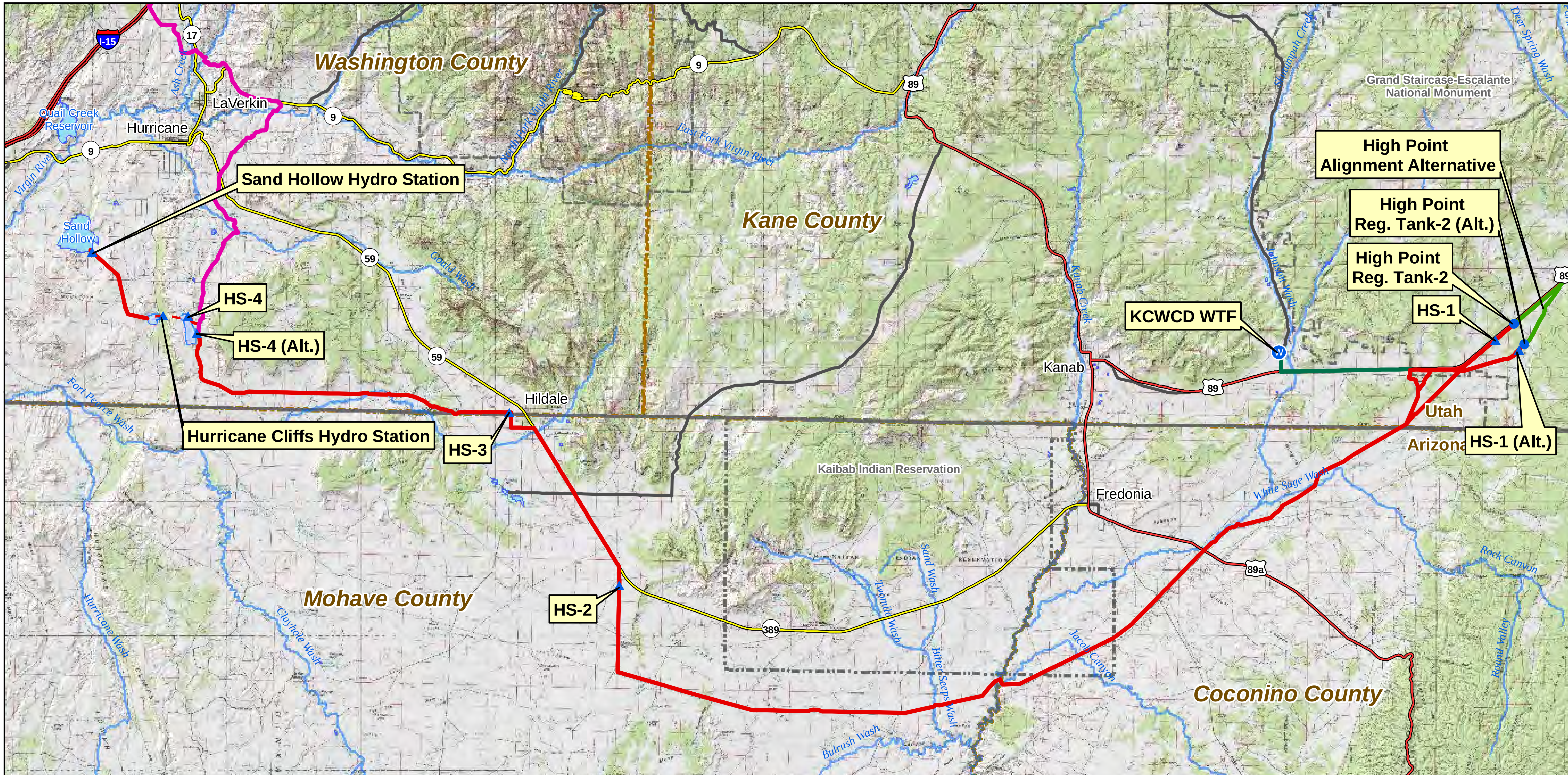
The proposed new **BPS-1 Transmission Line** would begin at the new switch station located on the south side of U.S. 89 and parallel the LPP Water Conveyance System alignment to the BPS-1 substation west of U.S. 89. This 69 kV transmission line would be about 1 mile long in Coconino County, Arizona (Figure 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 5 acres of land within the 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 Alternative. The substation upgrade would require an additional 2 acres of privately-owned land adjacent to the existing substation in Kane County, Utah (Figure 1-7).

The proposed new **BPS-2 Transmission Line** alternative would consist of a new 3-ring switch station along the existing 138 kV Glen Canyon to Buckskin Transmission Line and 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



Water Treatment Facility
Project Regulating Tank
Project Hydro Station
Hurricane Cliffs Forebay/Afterbay
Lakes & Reservoirs
Major Rivers & Streams

Water Conveyance System
Hydro System - Southeast Corner Alternative
Kane County Pipeline System
Cedar Valley Pipeline System

Interstate
US Highway
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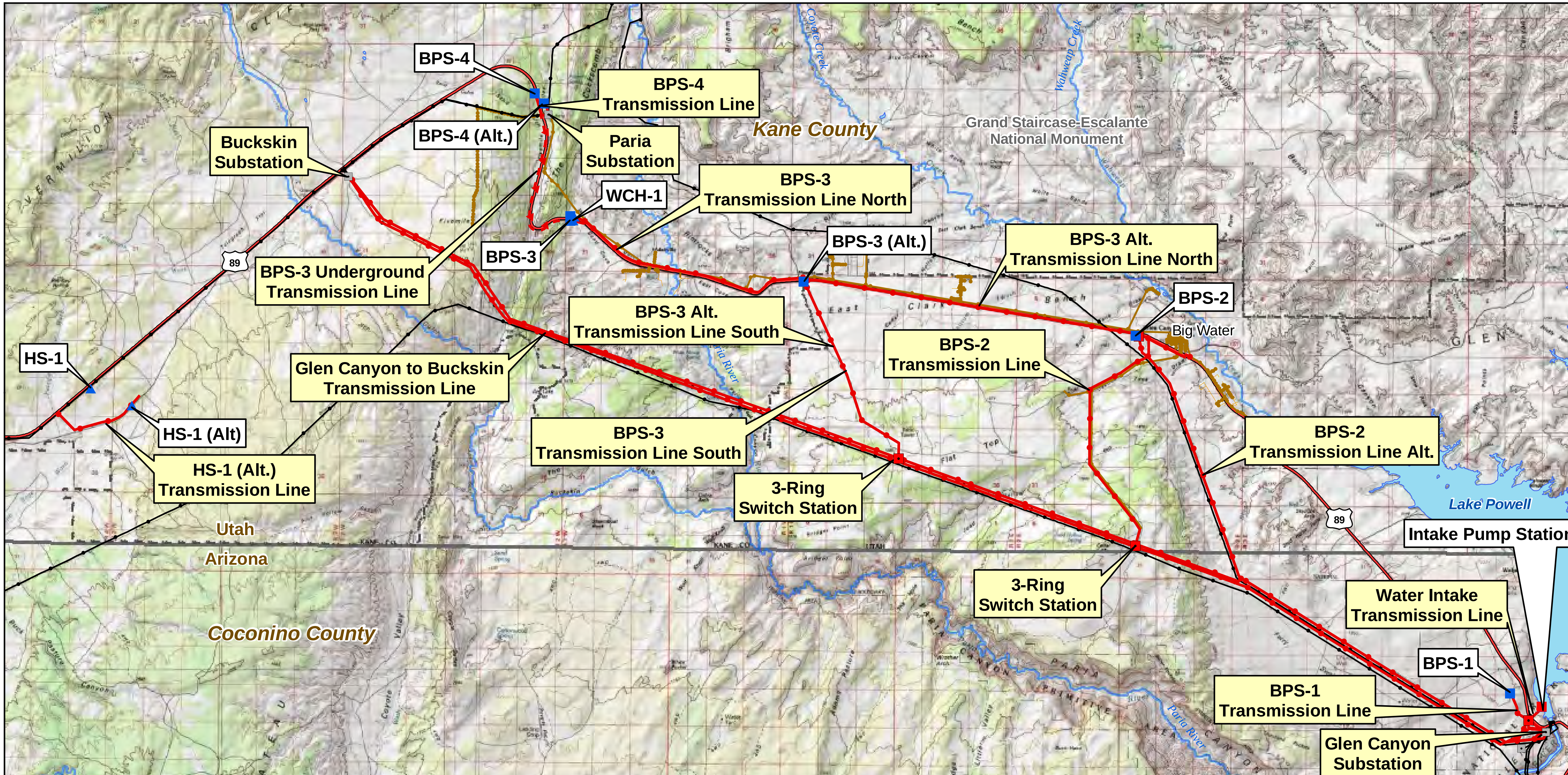
0 1.25 2.5 5 7.5 10 Miles

Lake Powell Pipeline Project

Spatial Reference: UTM Zone 12N, NAD-83

UDWR **Figure 1-6** MWH

Lake Powell Pipeline Hydro System Southeast Corner Alternative



- Project Intake Pump Station
- Project Booster Pump Station
- Project Hydro Station
- Existing Substation
- Proposed Substation
- Project Transmission Line
- Underground Project Transmission Line
- Existing Transmission Line
- Existing OH Primary Line
- Existing UG Primary Line
- Interstate
- US Highway
- ST Highway
- Hwy
- Major Road
- Lakes & Reservoirs
- Major Rivers & Streams
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0 0.5 1 2 3 4 Miles

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Lake Powell Pipeline Project

Spatial Reference: UTM Zone 12N, NAD-83

UDWR **Figure 1-7** MWH

Lake Powell Pipeline Transmission Line Alternatives East

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 alternative would be about 7 miles long across Utah SITLA-administered land, with a 138 kV connection to the BPS-2 substation (Figure 1-7).

The new **BPS-2 Alternative Transmission Line** would consist of a new 138 kV transmission line from Glen Canyon Substation parallel to the existing Rocky Mountain Power 230 kV transmission line, connecting to the BPS-2 substation west of Big Water. This new 138 kV transmission line alternative would be about 16.5 miles long in Coconino County, Arizona and Kane County, Utah crossing National Park Service-administered land, BLM-administered land and Utah SITLA-administered land (Figure 1-7).

The new **BPS-3 Transmission Line North** alternative would consist of a new 138 kV transmission line from BPS-2 paralleling the south side of U.S. 89 within the Congressionally designated utility corridor west to BPS-3 at the east side of the Cockscomb geological feature. This new 138 kV transmission line alternative would be about 15.7 miles long in Kane County, Utah (Figure 1-7).

The new **BPS-3 Transmission Line South** alternative would consist of a new 3-ring switch station along the existing 138 kV Glen Canyon to Buckskin Transmission Line and a new transmission line from the switch station north along an existing BLM road to U.S. 89 and then west along the south side of U.S. 89 within the Congressionally designated utility corridor to BPS-3 at the east side of the Cockscomb. This new 138 kV transmission line alternative would be about 12.3 miles long in Kane County, Utah (Figure 1-7).

The new **BPS-3 Underground Transmission Line** alternative would consist of a new buried 24.9 kV transmission line (2 circuits) from the upgraded Paria Substation to BPS-3 on the east side of the Cockscomb geological feature. This new underground transmission line would be parallel to the east and south side of U.S. 89 and would be about 4.1 miles long in Kane County, Utah (Figure 1-7).

The new **BPS-3 Alternative Transmission Line North** alternative would consist of a new 138 kV transmission line from BPS-2 paralleling the south side of U.S. 89 west to BPS-3 Alternative near the GSENM east boundary within the Congressionally-designated utility corridor. This new 138 kV transmission line alternative would be about 9.3 miles long in Kane County, Utah (Figure 1-7).

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

The new **BPS-4 Transmission Line** alternative would begin at the upgraded Paria Substation and run parallel to the west side of U.S. 89 north to BPS-4 within the Congressionally designated utility corridor. This new 138 kV transmission line would be about 0.8 mile long in Kane County, Utah (Figure 1-7).

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

The proposed new **HS-1 Alternative Transmission Line** would begin at the new HS-1 Alternative and run southwest parallel to the K4020 road and then northwest parallel to the K4000 road to the U.S. 89 corridor where it would tie into the existing 69 kV transmission line from the Buckskin Substation to the

Johnson Substation. This 69 kV transmission line would be about 3 miles long in Kane County, Utah (Figure 1-7).

The proposed new **HS-2 South Transmission Line** alternative 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 proposed new **HS-3 Underground 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 underground circuit would be about 0.6 mile long in Washington County, Utah (Figure 1-8).

The proposed new **HS-4 Transmission Line** would consist of a new transmission line from the HS-4 hydroelectric station and substation north along an existing BLM road to an existing transmission line parallel to Utah State Route 59. The new 69 kV transmission line would be about 8.2 miles long in Washington County, Utah (Figure 1-8).

The new **HS-4 Alternative Transmission Line** alternative would connect the HS-4 Alternative 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).

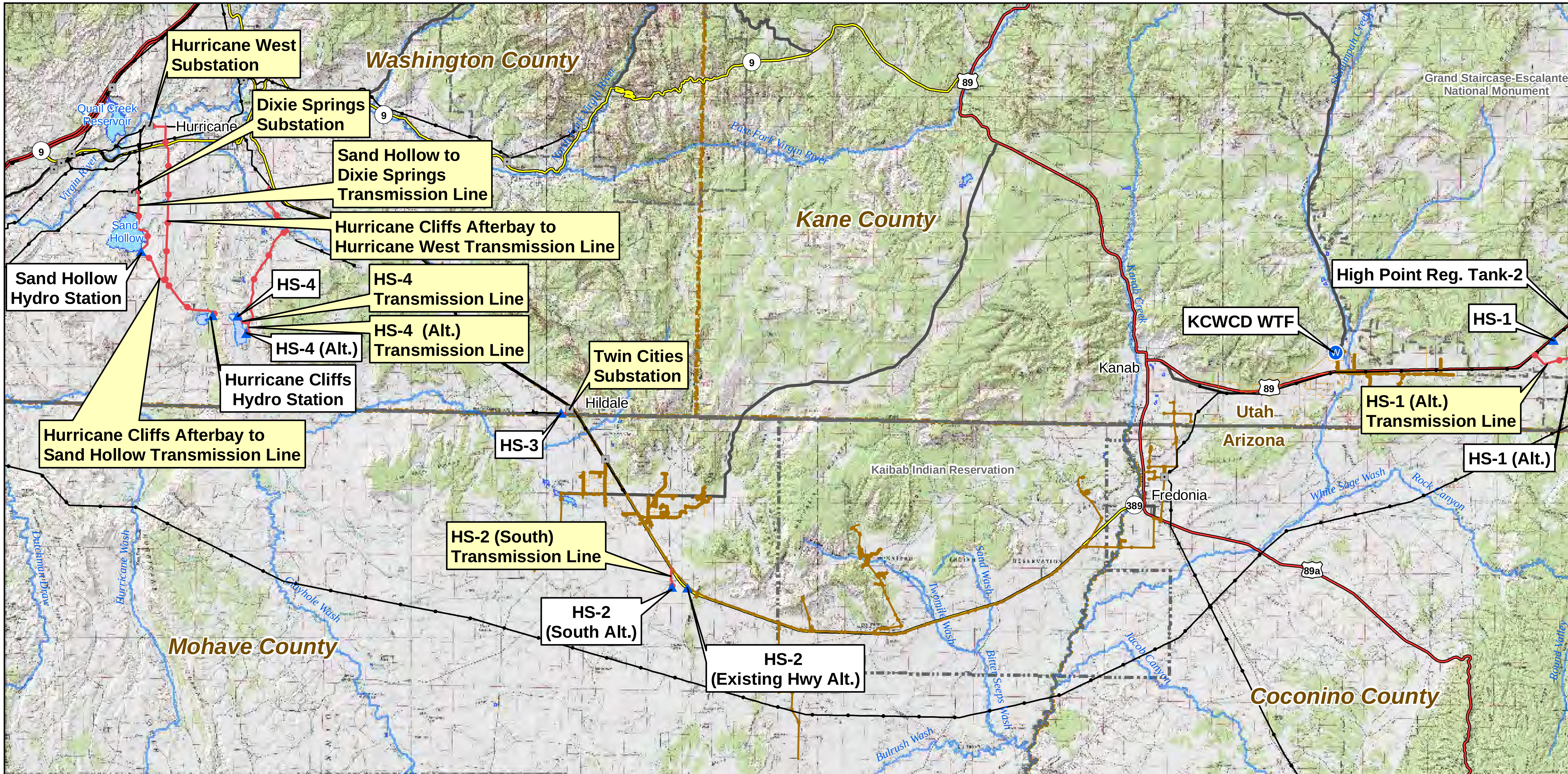
The proposed new **Hurricane Cliffs Afterbay to Sand Hollow Transmission Line** would consist of a new 69 kV transmission line from the Hurricane Cliffs peaking power plant and substation, and run northwest to the Sand Hollow Hydro Station substation. This new 69 kV transmission line would be about 4.9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

The three **Cedar Valley Pipeline** booster pump stations would require new transmission lines from existing transmission lines paralleling the Interstate 15 corridor. The new CVBPS-1 transmission line would extend southeast over I-15 from the existing transmission line to the booster pump station substation for about 1.3 miles in Washington County, Utah (Figure 1-9). The new CVBPS-2 transmission line would extend east over I-15 from the existing transmission line to the booster pump station substation for about 0.2 mile in Washington County, Utah (Figure 1-9). The new CVBPS-3 transmission line would extend west over I-15 from the existing transmission line and southwest along the west side of Interstate 15 to the booster pump station substation for about 0.6 mile in Iron County, Utah (Figure 1-9).

The **Cedar Valley Water Treatment Facility Transmission Line** would begin at an existing substation in Cedar City and run about 1 mile to the water treatment facility site in Iron County, Utah (Figure 1-9).



Water Treatment Facility
Project Regulating Tank
Project Hydro Station
Hurricane Cliffs Forebay/Afterbay
Lakes & Reservoirs
Major Rivers & Streams
Existing Substation
Project Transmission Line
Existing Transmission Line
Existing OH Primary Line
Existing UG Primary Line
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

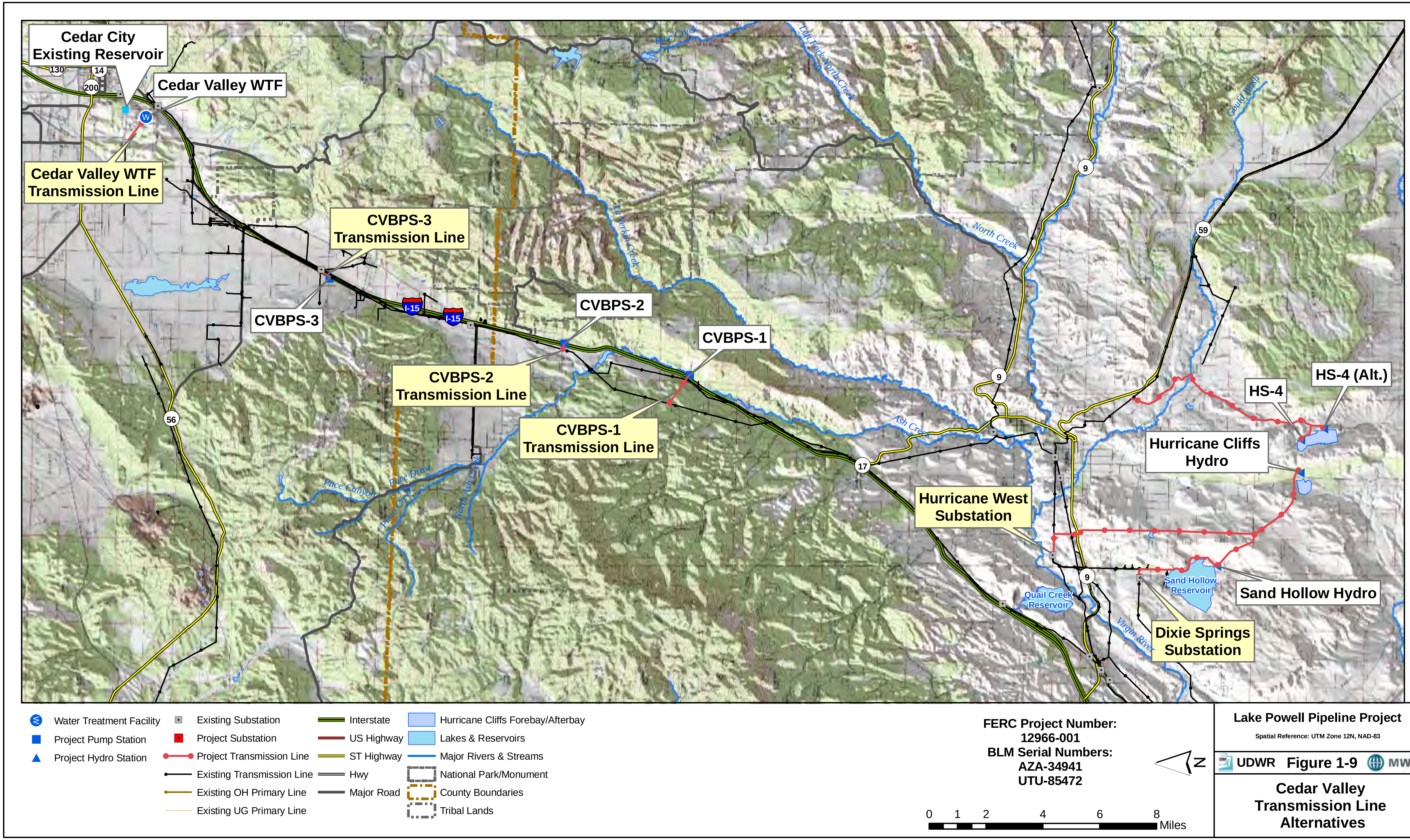
0 1.25 2.5 5 7.5 10 Miles

Lake Powell Pipeline Project

Spatial Reference: UTM Zone 12N, NAD-83

UDWR Figure 1-8 MWH

Lake Powell Pipeline Transmission Line Alternatives West


Cedar City Existing Reservoir
Cedar Valley WTF
Cedar Valley WTF Transmission Line
CVBPS-3 Transmission Line
CVBPS-3
CVBPS-2
CVBPS-2 Transmission Line
CVBPS-1
CVBPS-1 Transmission Line
Hurricane West Substation
Hurricane Cliffs Hydro
HS-4
HS-4 (Alt.)
Sand Hollow Hydro
Dixie Springs Substation
Sand Hollow Reservoir
Quail Creek Reservoir
Blue Creek
Left Fork North Creek
North Creek
Gould Wash
La Verkin Creek
Ash Creek
Virgin River
Pace Canyon
Pace Draw
Pinto Creek
North Ash Creek
I-15
130
14
200
56
9
59
17
Water Treatment Facility
Project Pump Station
Project Hydro Station
Existing Substation
Project Substation
Project Transmission Line
Existing Transmission Line
Existing OH Primary Line
Existing UG Primary Line
Interstate
US Highway
ST Highway
Hwy
Major Road
Hurricane Cliffs Forebay/Afterbay
Lakes & Reservoirs
Major Rivers & Streams
National Park/Monument
County Boundaries
Tribal Lands
FERC Project Number:
12966-001
BLM Serial Numbers:
AZA-34941
UTU-85472
0 1 2 4 6 8 Miles
N
Lake Powell Pipeline Project
Spatial Reference: UTM Zone 12N, NAD-83
UDWR
Figure 1-9
MWH
Cedar Valley Transmission Line Alternatives

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 reducing residential outdoor water use in the WCWCD and CICWCD service areas. This alternative could provide a total of 86,249 acre-feet of water annually to WCWCD, CICWCD and KCWCD for M&I use without diverting Utah's water from Lake Powell.

1.3.1 WCWCD No Lake Powell Water Alternative

The WCWCD would implement other future water development projects currently planned by the District, develop additional water reuse/reclamation, and convert additional agricultural water use to M&I use as a result of urban development in agricultural areas through 2020. Remaining planned and future water supply projects through 2020 include the Ash Creek Pipeline (5,000 acre-feet per year), Crystal Creek Pipeline (2,000 acre-feet per year), and Quail Creek Reservoir Agricultural Transfer (4,000 acre-feet per year). Beginning in 2020, WCWCD would convert agricultural water to secondary use and work with St. George City to maximize existing wastewater reuse, bringing the total to 96,258 acre-feet of water supply per year versus demand of 98,427 acre-feet per year, incorporating currently mandated conservation goals. The WCWCD water supply shortage in 2037 would be 70,000 acre-feet per year, 1,000 acre-feet more than the WCWCD maximum share of the LPP water. Therefore, the WCWCD No Lake Powell Water Alternative needs to develop 69,000 acre-feet of water per year to meet comparable supply and demand requirements as the other action alternatives.

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 40,000 acre-feet per year of Virgin River water with high total dissolved solids (TDS) concentration and other contaminants. The RO advanced water treatment facility would produce up to 36,279 acre-feet per year of water suitable for M&I use. The WCWCD would develop the planned Warner Valley Reservoir to store the diverted Virgin River water, which would be delivered to the RO advanced water treatment facility. The remaining 3,721 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 remaining needed water supply of 32,721 acre-feet per year to meet WCWCD 2037 demands would be obtained by reducing and restricting outdoor residential water use in the WCWCD service area. The Utah Division of Water Resources (UDWR) estimated 2005 culinary water use for residential outdoor watering in the communities served by WCWCD was 97.4 gallons per capita per day (gpcd) (UDWR 2009). This culinary water use rate is reduced by 30.5 gpcd to account for water conservation attained from 2005 through 2020, yielding 66.9 gpcd residential outdoor water use available for conversion to other M&I uses. The equivalent water use rate reduction to generate 32,721 acre-feet per year of conservation is 56.6 gpcd for the 2037 population within the WCWCD service area. Therefore, beginning in 2020, the existing rate of residential outdoor water use would be gradually reduced and restricted to 10.3 gpcd, or an 89.4 percent reduction in residential outdoor water use.

The combined 36,279 acre-feet per year of RO product water and 32,721 acre-feet per year of reduced residential outdoor water use would equal 69,000 acre-feet per year of M&I water to help meet WCWCD demands through 2037.

1.3.2 CICWCD No Lake Powell Water Alternative

The CICWCD would implement other future groundwater development projects currently planned by the District, purchase agricultural water from willing sellers for conversion to M&I uses, and convert additional agricultural water use to M&I use as a result of urban development in agricultural areas through 2020. Remaining planned and future water supply projects through 2020 include additional groundwater development projects (3,488 acre-feet per year), agricultural conversion resulting from M&I development (3,834 acre-feet per year), and purchase agricultural water from willing sellers (295 acre-feet per year). Beginning in 2020, CICWCD would have a total 19,772 acre-feet of water supply per year versus demand of 19,477 acre-feet per year, incorporating required progressive conservation goals. The CICWCD water supply shortage in 2060 would be 11,470 acre-feet per year. Therefore, the CICWCD No Lake Powell Water Alternative needs to develop 11,470 acre-feet of water per year to meet comparable supply and demand limits as the other action alternatives.

The remaining needed water supply of 11,470 acre-feet per year to meet CICWCD 2060 demands would be obtained by reducing and restricting outdoor residential water use in the CICWCD service area. The UDWR estimated 2005 culinary water use for residential outdoor watering in the communities served by CICWCD was 84.5 gpcd (UDWR 2007). A portion of this residential outdoor water would be converted to other M&I uses. The equivalent water use rate to obtain 11,470 acre-feet per year is 67.8 gpcd for the 2060 population within the CICWCD service area. Therefore, the existing rate of residential outdoor water use would be gradually reduced and restricted to 16.7 gpcd beginning in 2023, an 80 percent reduction in the residential outdoor water use rate between 2023 and 2060. The 11,470 acre-feet per year of reduced residential outdoor water use would be used to help meet the CICWCD demands through 2060.

1.3.3 KCWCD No Lake Powell Water Alternative

The KCWCD would use existing water supplies and implement future water development projects including new groundwater production, converting agricultural water rights to M&I water rights as a result of urban development in agricultural areas, and developing water reuse/reclamation. Existing water supplies (4,039 acre-feet per year) and 1,994 acre-feet per year of new ground water under the No Lake Powell Water Alternative would meet projected M&I water demand of 6,033 acre-feet per year within the KCWCD service area through 2060. The total potential water supply for KCWCD is about 12,140 acre-feet per year (4,039 acre-feet per year existing culinary plus secondary supply, and 8,101 acre-feet per year potential for additional ground water development up to the assumed sustainable ground water yield) without agricultural conversion to M&I supply. Short-term ground water overdrafts and new storage projects (e.g., Jackson Flat Reservoir) would provide reserve water supply to meet demands during drought periods and other water emergencies.

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. 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 or released according to the operating guidelines. Future population growth as projected by the Utah Governor's Office of Planning and Budget (GOPB) would continue to occur in southwest Utah until water and other potential limiting resources such as developable land, electric power, and fuel begin to curtail economic activity and population in-migration.

1.4.1 WCWCD No Action Alternative

The WCWCD would implement other future water development projects currently planned by the District, develop additional water reuse/reclamation, convert additional agricultural water use to M&I use as a result of urban development in agricultural areas, and implement advanced treatment of Virgin River water. The WCWCD could also limit water demand by mandating water conservation measures such as outdoor watering restrictions. Existing and future water supplies under the No Action Alternative would meet projected M&I water demand within the WCWCD service area through approximately 2020. The 2020 total water supply of about 96,528 acre-feet per year would include existing supplies, planned WCWCD water supply projects, wastewater reuse, transfer of Quail Creek Reservoir supplies, and future agricultural water conversion resulting from urban development of currently irrigated lands. Each future supply source would be phased in as needed to meet the M&I 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). Maximum reuse of treated wastewater effluent for secondary supplies would be required to meet the projected M&I water demand starting in 2020. The No Action Alternative would not provide adequate water supply to meet projected water demands from 2020 through 2060. There would be a potential water shortage of approximately 139,875 acre-feet per year in 2060 under the No Action Alternative (UDWR 2008b).

1.4.2 CICWCD No Action Alternative

The CICWCD would implement future water development projects including converting agricultural water rights to M&I water rights as a result of urban development in agricultural areas, purchasing “buy and dry” agricultural water rights to meet M&I demands, and developing water reuse/reclamation. The Utah State Engineer would act to limit existing and future ground water pumping from the Cedar Valley aquifer in an amount not exceeding the assumed sustainable yield of 37,600 ac-ft per year. Existing and future water supplies under the No Action Alternative meet projected M&I water demand within the CICWCD service area during the planning period through agricultural conversion of water rights to M&I use, wastewater reuse, and implementing “buy and dry” practices on irrigated agricultural land. Each future water supply source would be phased in as needed to meet the M&I demand associated with the forecasted population. The CICWCD No Action Alternative includes buying and drying of agricultural water rights covering approximately 8,000 acres between 2005 and 2060 and/or potential future development of West Desert water because no other potential water supplies have been identified to meet unmet demand. The No Action Alternative would not provide CICWCD with any reserve water supply (e.g., water to meet annual shortages because of drought, emergencies, and other losses) after 2010 (i.e., after existing supplies would be maximized).

1.4.3 KCWCD No Action Alternative

The KCWCD would use existing water supplies and implement future water development projects including new ground water production, converting agricultural water rights to M&I water rights as a result of urban development in agricultural areas, and developing water reuse/reclamation. Existing water supplies (4,039 acre-feet per year) and 1,994 acre-feet per year of new ground water under the No Action Alternative would meet projected M&I water demand of 6,033 acre-feet per year within the KCWCD service area through 2060. The total potential water supply for KCWCD is about 12,140 acre-feet per year (4,039 acre-feet per year existing culinary plus secondary supply, and 8,101 acre-feet per year potential for additional ground water development up to the assumed sustainable ground water yield) without agricultural conversion to M&I supply. Short-term ground water overdrafts and new storage projects (e.g., Jackson Flat Reservoir) would provide reserve water supply to meet demands during drought periods and other water emergencies.

1.5 Study Objectives

The goals of this study are to determine whether the construction and the operation or maintenance of the proposed LPP would negatively impact surface water quality in the project vicinity. Impacts on water quality are considered significant if construction and operation or maintenance activities would result in any of the following conditions:

- Violation of applicable surface water quality standards
- Substantial degradation of surface water quality
- Substantial alteration of the existing drainage pattern of the site or area, including through alternation of the course of a stream or river, in a manner, which would result in substantial erosion or siltation on- or off-site

The major surface water features in the vicinity of the LPP and the Cedar Valley Pipeline System include Kanab Creek, Ash Creek, Mill Creek, LaVerkin Creek, Paria River, and Virgin River. Major surface water reservoirs in the vicinity of the proposed project facilities include Quail Creek Reservoir, Sand Hollow Reservoir, and Lake Powell. There are also several ephemeral and dry washes along the proposed alignments. The primary objectives of this study with regard to surface water quality are:

- Identify the beneficial uses for the surface water bodies in the vicinity of the LPP and review their historical water quality in conjunction with their numeric water quality objectives
- Identify the impacts to water quality in surface water bodies due to the construction, operation, and/or maintenance of the LPP
- Determine the water quality impacts at the Sand Hollow Reservoir due to raw water deliveries from the Lake Powell Reservoir
- Identify measures for mitigating impacts on surface water quality

Chapter 2 of this report presents the data used and the methodology adopted to evaluate the impacts of the LPP on surface water quality. **Chapter 3** summarizes the historical water quality for the surface water bodies in the vicinity of the LPP. **Chapter 4** identifies the potential impacts on the surface water quality caused by the construction, operation, and/or maintenance of the LPP. **Chapter 5** identifies measures to mitigate the potential impacts on surface water quality.

Chapter 2
Methodology

This chapter describes the methodology adopted to evaluate the impacts on surface water quality caused by the proposed construction and operation of the LPP. The data reviewed and the assumptions made for the evaluation are presented.

2.1 Data Sources

Historical water quality data for the Virgin River, Paria River, Kanab Creek, Ash Creek, LaVerkin Creek, and Mill Creek were obtained from the Environmental Protection Agency's (EPA) STORET (www.epa.gov\storet) data system. Historical water quality data for the Sand Hollow Reservoir were obtained from a report produced by the United States Geological Survey (USGS) titled *Assessment of Managed Aquifer Recharge at Sand Hollow Reservoir, Washington County, Utah, Updated to Conditions through 2007*. Historical water quality data for the Lake Powell reservoir were obtained from a report produced by MWH titled *Technical Memorandum 5.13A: A Review of Water Quality and Treatment Issues* (MWH 2008).

2.2 Evaluation Methodology

The following tasks were completed to evaluate potential impacts on surface water quality caused by construction and operation of the proposed project:

- Review of beneficial use designations and water quality criteria
- Review of historical water quality data
- Establishment of significance criteria
- Impact assessment
- Identification of mitigation measures

2.2.1 Beneficial Uses and Water Quality Criteria

Designated beneficial uses for the major water bodies in the vicinity of the proposed project in the states of Utah and Arizona were reviewed. Numeric water quality protection criteria associated with each beneficial use for the following water quality parameters were then reviewed: pH, total dissolved solids (TDS), total suspended solids (TSS), temperature, metals, and pollution indicators such as total coliform.

2.2.2 Historical Water Quality Data

Based on review of historical water quality data, the minimum, average, and maximum values are presented for relevant water quality parameters. The historical water quality data for a water body are compared with numeric water quality objectives. Exceedance percentages are based on the number of samples that have concentrations in excess of the numeric objectives.

2.2.3 Significance Criteria

Impacts on water quality are considered significant if construction, operation or maintenance activities would result in any of the following conditions:

- Violation of applicable surface water quality standards
- Substantial degradation of surface water quality
- Substantial alteration of the existing drainage pattern of the site or area, including through alternation of the course of a stream or river, in a manner, which would result in substantial erosion or siltation on- or off-site

2.2.4 Impact Assessment

Potential impacts on surface water quality during construction and the operation of the proposed project would result from clearing and grading for pipeline, booster pump station, hydro generating station, and transmission line construction; the use of open-cut crossings for pipeline installation; changes to site drainage patterns; and maintenance activities such as pipeline flushing or draining. The primary concerns associated with these activities are the transport of sediment and the introduction of construction equipment-related pollutants during construction and maintenance operations into nearby surface water bodies. Assessment of water quality impacts from the inflow of Lake Powell water into Sand Hollow Reservoir is also analyzed. Changes in water quality parameters from baseline conditions are analyzed as impacts. Measurable water quality changes are evaluated for significant impacts by comparison with the significance criteria.

2.2.5 Mitigation Measures

Mitigation measures would be applied to any significant water quality impacts as applicable and available to avoid, minimize or reduce the level of impact to below the significance threshold. In compliance with the National Pollution Discharge Elimination System (NPDES) stormwater permit for construction activity, a Stormwater Pollution Prevention Program (SWPPP) would be developed and implemented for project construction activities. Best Management Practices (BMPs) to be implemented by the contractor would be specified in the SWPPP. Mitigation measures that may be implemented as BMPs are described as potential mitigation measures to protect water quality. The focus of the BMPs is on control of soil erosion and reduction in sediment recruitment to surface waters.

Chapter 3
Affected Environment (Baseline Conditions)

This chapter describes the historical water quality conditions of the surface water bodies in the states of Utah and Arizona that might be impacted from construction and operation of the LPP Project. The beneficial use protection classifications and historical water quality conditions are summarized for the surface water bodies. The historical water quality conditions for surface water bodies within Utah and Arizona are reviewed in conjunction with the surface water quality numeric criteria. A comprehensive review of the historical water quality data against the surface water quality numeric criteria for all sampled water quality constituents is beyond the scope of this chapter. Therefore, the review of historical water quality is limited to parameters such as pH, total dissolved solids (TDS), total suspended solids (TSS), temperature, metals, and pollution indicators such as total coliform.

3.1 Beneficial Use Designations - Utah

In Utah, water quality protection standards are based on designated state beneficial uses which are defined and classified in the Utah Administrative Code (UAC) R317-2. Use designations are provided in UAC R317-2-6 and include the classifications shown in Table 3-1.

Table 3-1
Beneficial Use Protection Classifications for Surface Waters of the State of Utah

Classification	Definition
1C	Protected for domestic purposes with prior treatment by treatment processes as required by the Utah Division of Drinking Water.
2A	Protected for frequent primary contact recreation where there is a high likelihood of ingestion of water or a high degree of bodily contact with the water. Examples include, but are not limited to, swimming, rafting, kayaking, diving, and water skiing.
2B	Protected for infrequent primary contact recreation. Also protected for secondary contact recreation where there is a low likelihood of ingestion of water or a low degree of bodily contact with the water. Examples include, but are not limited to, wading, hunting, and fishing.
3A	Protected for cold water species of game fish and other cold water aquatic life, including the necessary aquatic organisms in their food chain.
3B	Protected for warm water species of game fish and other warm water aquatic life, including the necessary aquatic organisms in their food chain.
3C	Protected for nongame fish and other aquatic life, including the necessary aquatic organisms in their food chain.
3D	Protected for waterfowl, shore birds and other water-oriented wildlife not included in Classes 3A, 3B, or 3C, including the necessary aquatic organisms in their food chain.
3E	Severely habitat-limited waters. Narrative standards will be applied to protect these waters for aquatic wildlife.
4	Protected for agricultural uses including irrigation of crops and stock watering.
5	Special category for the waters of the Great Salt Lake.

The pipeline alignments described in Chapter 1 of this report pass through the following surface water features:

Intake and Water Conveyance Systems: Paria River and Buckskin Gulch

Hydro System South Alternative: White Sage Wash, Jacob Canyon, Kanab Creek, Bitter Seeps Wash, Virgin River, LaVerkin Creek, and Ash Creek

Hydro System Existing Highway Alternative: Skutumpah Creek, Kanab Creek, Sand Wash, Two-Mile Wash, Gould Wash, Virgin River, LaVerkin Creek, and Ash Creek

Hydro System Southeast Corner Alternative: White Sage Wash, Jacob Canyon, Kanab Creek, Bitter Seeps Wash, Virgin River, LaVerkin Creek, and Ash Creek

Transmission Live Alternatives: Paria River and Gould Wash

Beneficial use protection classifications for major rivers and reservoirs in the LPP vicinity are displayed in Table 3-2. It should be noted that no specific designation is assigned to Sand Hollow Reservoir in UAC R317-2, although it is used for groundwater recharge. Beneficial use designations for several washes in the LPP vicinity are not provided in UAC R317.

Table 3-2
Beneficial Use Protection Classifications Designated for Major Rivers and Reservoirs in the LPP Vicinity, UAC R317-2-13

Water Body	Classifications
Ash Creek	2B, 3B, 4
Colorado River	1C, 2B, 3B, 4
Kanab Creek (lower)	2B, 3C, 4
La Verkin Creek(1)	None
Lake Powell	1C, 2A, 2B, 3B, 4
Mill Creek	1C, 2B, 3A, 4
Paria River	2B, 3C, 4
Quail Creek	1C, 2B, 3A, 4
Quail Creek Reservoir	1C, 2A, 2B, 3B, 4
Virgin River (above Quail Creek Diversion)	1C, 2B, 3C, 4
Sand Hollow Reservoir(2)	None
Virgin River (below Quail Creek Diversion)	2B, 3A, 4

(1), (2) Beneficial use designations for LaVerkin Creek and Sand Hollow Reservoir are not provided in UAC R317.

3.2 Historical Water Quality Conditions - Utah

Water quality data for the relevant surface water bodies were obtained from the Environmental Protection Agency's (EPA) STORET data system. Water quality data for the water bodies listed in Table 3-2 are summarized below. Water quality data should be reviewed in conjunction with factors such as flow rates, the number of samples, and the frequency and period of sampling. Averages were calculated based on an assumed concentration of zero for samples reported as "non-detect" because of variations in the method detection limits for the reported data. It should be noted that the average concentration values may not be representative of typical conditions because of the presence of outlier events. For example, the average TDS concentration of a water body may be significantly elevated in response to increased runoff during a 100-year storm event (an outlier event).

Historical water quality for the relevant surface waters in Utah is summarized in the following tables. In general, all water bodies exhibited concentrations for total coliform, total dissolved solids (TDS), and total suspended solids (TSS) in excess of their numeric water quality criteria. Recorded values for pH were within the specified numeric range for the majority of samples. Metals were detected in all water bodies. For the Virgin and the Paria rivers, metals were detected in concentrations that were in excess of their numeric water quality criteria.

3.2.1 Kanab Creek

In southern Utah, Kanab Creek drains a narrow valley from north to south with peak elevations nearing 8,000 feet. Downstream of Kanab in Kane County, Utah, Kanab Creek flows into Arizona near Fredonia. It flows through the Kaibab-Paiute Indian Reservation of the Kaibab Band of Paiute Indians and Kanab Creek Wilderness before its confluence with the Colorado River in Grand Canyon National Park. Peak flows occur in spring and low flows occur during the summer months. The characterization of Kanab Creek water quality is based upon water quality data obtained at three sampling stations (listed in Table 3-3). Key water quality parameters at each of the stations are summarized in Table 3-3.

Table 3-3
Kanab Creek Water Quality Sample Station Locations

Station ID	Station Name	Sampling Period	Latitude	Longitude
4951810	Kanab Creek at US89 Crossing	1978 to 1982, 1993 to 2006	37.10083	-112.547
4951830	Kanab Creek at Falls Crossing East of Glendale	1978 to 1980, 1996 to 2008	37.29111	-112.492
4951750	Kanab Creek below Kanab WWTP at the State Line	1976 to 1993, 2001 to 2003	37.00611	-112.536

Source: Utah Department of Environmental Quality

Numeric water quality criteria for Kanab Creek vary based on the different beneficial uses. Table 3-4 presents the most stringent numeric criteria for Kanab Creek for the relevant water quality parameters.

Table 3-4
Numeric Water Quality Criteria for Kanab Creek
Page 1 of 2

Constituent-Units	Numeric Criteria
Aluminum-µg/L	750
Cadmium-µg/L	2

Table 3-4 Numeric Water Quality Criteria for Kanab Creek Page 2 of 2	
Constituent-Units	**Numeric Criteria**
Chromium (VI)-µg/L	16
Copper-µg/L	13
Iron- µg/L	1,000
pH-Standard Units	6.5-9.0
Solids, Total Dissolved-mg/L	1,200
Temperature, water-deg C	27
Total Coliform- MPN(1)/100ml	206
Turbidity - NTU(2)/(increase of)	10
Zinc- µg/L	120

(1) Most Probable Number (MPN)
(2) Nephelometric Turbidity Units

3.2.2 Ash Creek

Ash Creek flows through Washington County in Utah. The characterization of Ash Creek water quality is based upon water quality data obtained at one sampling station (listed in Table 3-5). Key water quality parameters at this station are summarized in Table 3-5.

Table 3-5
Ash Creek Water Quality Sample Station Locations

Station ID	Station Name	Sampling Period	Latitude	Longitude
4950710	Ash Creek at Virgin River	1996 - 1997	37.21556	-113.286

Source: Utah Department of Environmental Quality

Numeric water quality criteria for Ash Creek vary based on the different beneficial uses. Table 3-6 presents the most stringent numeric criteria for Ash Creek for the relevant water quality parameters.

Table 3-6
Numeric Criteria for Ash Creek

Constituent-Units	Numeric Water Quality Criteria
pH-Standard Units	6.5-9.0
Solids, Total Dissolved-mg/L	1,200
Temperature, water-deg C	27
Turbidity - NTU (increase of)	10

3.2.3 Mill Creek

Mill Creek flows through Kane County in Utah. The characterization of Mill Creek water quality is based upon water quality data obtained at one sampling station (listed in Table 3-7). Key water quality parameters at this station are summarized in Table 3-7.

Table 3-7
Mill Creek Water Quality Sample Station Locations

Station ID	Station Name	Sampling Period	Latitude	Longitude
5994640	Mill Creek at Johnson/Robinson Diversion	1998 to 2001, 2003 to 2004	37.32861	-112.328
Source: Utah Department of Environmental Quality				

Numeric water quality criteria for Mill Creek vary based on the different beneficial uses. Table 3-8 presents the most stringent numeric criteria for the Mill Creek for the relevant water quality parameters.

Table 3-8
Numeric Criteria for Mill Creek

Constituent-Units	Numeric Criteria
Aluminum-µg/L	750
Chromium (VI)-µg/L	16
pH-Standard Units	6.5-9.0
Solids, Total Dissolved-mg/L	1200
Temperature, water-deg C	20
Turbidity - NTU (increase of)	10

Historical water quality data for the water bodies at the station locations listed in Tables 3-3, 3-5 and 3-7 are summarized in Tables 3-9, 3-10, 3-11, 3-12 and 3-13.

Table 3-9
Summary of Historical Water Quality at Kanab Creek (Station ID 4951810)

Parameter-Units	Minimum	Maximum	Average	Number of Samples	Remarks
Aluminum-µg/L	ND[1]	880	76	32	The numeric criterion for aluminum (1 hour average of 750 µg/L) was exceeded in one sample (3% of samples). Aluminum was detected in 11 samples (34% of samples).
Copper-µg/L	ND	42	3	47	The numeric criterion for copper (1 hour average of 13 µg/L) was exceeded in four samples (9% of samples). Copper was detected in 7 samples (15% of samples).
Iron- µg/L	ND	1,850	102	42	The numeric criterion for iron (1 hour average of 1,000 µg/L) was exceeded in two samples (5% of samples). Iron was detected in 23 samples (55% of samples).
pH-Standard Units	7.3	8.8	8.3	324	All samples were within the 6.5-9.0 range of the criterion.
Solids, Total Dissolved-mg/L	216	1,360	364	174	The numeric criterion for TDS (1,200 mg/L) was exceeded in 1 sample (<1% of samples). Approximately 82% of the samples measured had TDS concentrations less than 400 mg/L. A TDS concentration of 1,000 mg/L was exceeded in two samples (1% of samples).
Solids, Total Suspended (TSS)-mg/L	<1	9,744	558	160	Approximately 80% of the samples had TSS concentrations less than 500 mg/L. Approximately, 11% of the samples had concentrations in excess of 1,000 mg/L.
Specific Conductance, umho/cm	197	1,672	570	324	Approximately 81% of the total samples had a specific conductance that ranged between 400 umho/cm and 600 umho/cm. Approximately 8% of the total samples had a specific conductance that was greater than 800 umho/cm.
Temperature, water-deg C	0	31	15	157	The numeric criterion for temperature (27˚C) was exceeded in 9 samples (6% of samples).
Total Coliform- Most Probable No. (MPN)/100ml[2]	23	9,300	2,510	11	The numeric criterion for total coliform (206 MPN/100 ml) was exceeded in 10 samples (91% of samples).
Turbidity-NTU	0.7	10,276	430	172	Numeric criterion is based on an increase as a result of discharge.
Zinc- µg/L	ND	140	19	48	The numeric criterion for zinc (1 hour average of 120 µg/L) was exceeded in one sample (2% of samples). Zinc was detected in 15 samples (31% of samples).

Source: Summarized from EPA's STORET database. Water quality sampling and analysis were completed by the Utah Department of Environmental Quality.
(1) ND – non-detect.
(2) Most Probable Number (MPN); value shown as "average" represents the geometric mean of the samples.

Table 3-10
Summary of Historical Water Quality at Kanab Creek (Station ID 4951830)

Parameter-Units	Minimum	Maximum	Average	Number of Samples	Remarks
Copper-µg/L	ND[1]	30	4	15	The numeric criterion for copper (1 hour average of 13 µg/L) was exceeded in three samples (20% of samples). Copper was detected in 5 samples (33% of samples).
pH-Standard Units	7.2	9.2	8.2	200	The numeric criterion for pH was exceeded in one sample (<1% of samples).
Solids, Total Dissolved-mg/L	372	2,262	1,302	111	The numeric criterion for TDS was exceeded in 65 samples (59% of samples). Approximately 25% of the samples had TDS concentrations between 1,000 mg/L and 1,500 mg/L. Approximately 42% of the samples had TDS concentrations greater than 1,500 mg/L.
Solids, Total Suspended (TSS)-mg/L	<1	31,980	795	95	Approximately 70% of the measured TSS concentrations were lower than 200 mg/L. All measured concentrations in excess of 1,000 mg/L occurred after year 1999. TSS concentrations in excess of 5,000 mg/L were recorded during the months of July and August in year 2001 and year 2006.
Specific conductance-umho/cm	171	2,495	1,613	204	Approximately 80% of the sampled values were between 1,000 umho/cm and 2,000 umho/cm.
Temperature, water-deg C	0	29	11	93	The numeric criterion for temperature (27˚C) was exceeded in 3 samples (3% of samples).
Turbidity-NTU	1	6,979	256	110	The numeric criterion is based on an increase as a result of discharge.

Source: Data summarized from EPA's STORET database. Water quality sampling and analysis were completed by the Utah Department of Environmental Quality.

[1] ND – non-detect.

Table 3-11
Summary of Historical Water Quality at Kanab Creek (Station ID 4951750)

Parameter-Units	Minimum	Maximum	Average	Number of Samples	Remarks
Cadmium-µg/L	ND[1]	20	<1	82	The numeric criterion for cadmium (1 hour average of 2 µg/L) was exceeded in five samples (6% of samples). Cadmium was detected in 8 samples (10% of samples).
Chromium(VI)-µg/L	ND	100	8	15	The numeric criterion (1 hour average of 16 µg/L) for chromium was exceeded in one sample (7% of samples). Chromium was detected in 7 samples (47% of samples).
Copper-µg/L	ND	925	22	86	The numeric criterion for copper (1 hour average of 13 µg/L) was exceeded in 18 samples (21% of samples). Copper was detected in 30 samples (35% of samples).
pH	6.2	9.5	8.1	200	The numeric criterion for pH was exceeded in one sample (<1% of samples).
Solids, Total Dissolved-mg/L	230	1,494	988	123	The numeric criterion for TDS (1,200 mg/L) was exceeded in 38 samples (31% of samples).
Solids, Total Suspended (TSS)-mg/L	<1	28,700	1,354	118	Approximately 60% of the samples had a TSS concentration lower than 300 mg/L. Approximately 20% of the samples had a TSS concentration that ranged between 1,000 mg/L and 5,000 mg/L. Approximately 6% of the samples had concentrations in excess of 5,000 mg/L.
Specific conductance-umho/cm	13	2,800	1,312	224	Approximately 70% of the measured values varied between 1,000 umho/cm and 2,000 umho/cm. Approximately 42% of the measured values varied between 1,500 umho/cm and 2,000 umho/cm
Temperature, water-deg C	0.7	32.4	13	118	The numeric criterion for temperature (27˚C) was exceeded in 5 samples (4% of samples).
Total Coliform-MPN/100ml[3]	23	724,000	40,719	39	The numeric criterion for total coliform (206 MPN/100 ml) was exceeded in 34 samples (87% of samples).
Turbidity-NTU	0.35	3,164	153	115	The numeric criterion is based on an increase as a result of discharge.

Source: Data summarized from EPA's STORET database. Water quality sampling and analysis were completed by the Utah Department of Environmental Quality.
(1) ND – non-detect.
(3) Most Probable Number (MPN); value shown as "average" represents the geometric mean of the samples.

Table 3-12
Summary of Historical Water Quality at Ash Creek (Station ID 4950710)

Parameter-Units	Minimum	Maximum	Average	Number of Samples	Remarks
Metals	See notes at right.			5	The presence of metals was analyzed for five samples at this station. Aluminum, copper, cadmium, or chromium were not detected in these samples. Traces of barium were detected; however, the concentrations were well below the numeric criterion for barium.
pH-Standard Units	8.1	8.8	8.4	36	All samples were within the 6.5-9.0 range of the criterion.
Solids, Total Dissolved-mg/L	276	522	478	18	All samples were below the 1,200 mg/L criterion for TDS.
Solids, Total Suspended (TSS)-mg/L	<1	33	11	18	Two peaks in TSS concentration occurred during the sampling period, one in August 1996 and the other in December 1996 when the sampled concentrations were approximately three times the average concentration.
Specific conductance-umho/cm	402	748	689	36	None
Temperature, water-deg C	11	20	16	18	All samples were below the 27˚C criterion for temperature.
Turbidity-NTU	1	126	9	18	The numeric criterion is based on an increase as a result of discharge.

Source: Data summarized from EPA's STORET database. Water quality sampling and analysis were completed by the Utah Department of Environmental Quality.

Table 3-13
Summary of Historical Water Quality at Mill Creek (Station ID 5994640)

Parameter-Units	Minimum	Maximum	Average	Number of Samples	Remarks
pH-Standard Units	7.5	8.8	8.3	85	All samples were within the 6.5-9.0 range of the criterion.
Solids, Total Dissolved-mg/L	<1	1,818	769	44	The numeric criterion for TDS (1,200 mg/L) was exceeded in seven samples (16% of samples). Approximately 50% of the samples had TDS concentrations ranging from 400 mg/L to 750 mg/L.
Solids, Total Suspended (TSS)-mg/L	<1	25,380	848	42	Approximately 70% of the samples had TSS concentrations lower than 150 mg/L. The concentrations were in excess of 1,000 mg/L on four occasions during the months of February and March. During the month of July in year 2003, the TSS concentration recorded was in excess of 25,000 mg/L. A review of the flow records for that time period indicated flows in excess of 15 cfs during the months of July and August in year 2003 while the average flows for the sampling period was approximately 1 cfs.
Specific conductance-umho/cm	471	2,374	1,091	84	None
Temperature, water-deg C	0	30	11	41	The numeric criterion for temperature (20˚C) was exceeded in 11 samples (27% of samples).
Turbidity-NTU	1	6,349	350	44	The numeric criterion is based on an increase as a result of discharge.

Source: Data summarized from EPA's STORET database. Water quality sampling and analysis were completed by the Utah Department of Environmental Quality.

3.2.4 LaVerkin Creek

The headwaters of LaVerkin Creek, which is tributary to the Virgin River, are encompassed and protected by the LaVerkin Creek Wilderness located adjacent to the Kolob Canyons region of Zion National Park in Washington County, Utah. The characterization of LaVerkin Creek water quality is based upon water quality data obtained at three sampling stations (listed in Table 3-14). Key water quality parameters at each of the stations are summarized below. Numeric water quality criteria for LaVerkin Creek are not listed in the UAC R317.

Table 3-14
La Verkin Creek Water Quality Sample Station Locations

Station ID	Station Name	Sampling Period	Latitude	Longitude
ZION_EPA_LVC1	La Verkin Creek at Highway 17 Bridge	1976	37.22289	-113.278
4950800	La Verkin Creek at Lee Pass Trail	2005 to 2008	37.40722	-113.175
4950790	La Verkin Creek at Falls	2001 to 2002, 2004	37.29889	-113.247

Source: Utah Department of Environmental Quality

3.2.5 Paria River

The Paria River flows from the headwaters in Bryce Canyon National Park and Dixie National Forest through private agricultural lands in Garfield County, Utah and south through the Grand Staircase-Escalante National Monument (GSENM) into Arizona and the Colorado River below Glen Canyon Dam. The river flows through the Grand Staircase region, a series of multi-colored cliffs which begin at the rim of the Grand Canyon, and ascend over 5,000 feet across GSENM to end at the cliffs in Bryce Canyon. It flows through Kane County in Utah.

Section 303(d) and EPA's Water Quality Planning and Management Regulations (40 CFR Part 130), require that States report waterbodies (i.e., lakes, reservoirs, rivers, and streams) that do not support their designated beneficial use(s). In compliance with this requirement, segments of the Paria River are categorized as impaired for total dissolved solids, suspended solids, and *E. coli* (EPA 2006 and 2008). The characterization of water quality in the Paria River is based upon water quality data obtained at three sampling stations (listed in Table 3-15). Key water quality parameters at each of the stations are summarized in Table 3-15.

Table 3-15 Paria River Water Quality Sample Station Locations				
Station ID	**Station Name**	**Sampling Period**	**Latitude**	**Longitude**
4951850	Paria River at US 89 Crossing	1976 to 1988, 1998 to 2008	37.1075	-111.906
4951860	Paria River at Kodachrome Basin Road Crossing	2000 to 2004	37.52814	-112.043
5994550	Paria River at Old Town Site	1998 to 2008	37.2505	-111.954
Source: Utah Department of Environmental Quality				

Numeric water quality criteria for the Paria River vary based on the different beneficial uses. Table 3-16 presents the most stringent numeric criteria for Paria River for the relevant water quality parameters.

Table 3-16 Numeric Criteria for Paria River	
Constituent-Units	**Numeric Criteria**
Aluminum-µg/L	750
Cadmium-µg/L	2
Chromium (VI)-µg/L	16
Copper-µg/L	13
Iron-µg/L	1,000
Lead-µg/L	65
pH-Standard Units	6.5-9.0
Solids, Total Dissolved-mg/L	1,200
Temperature, water-deg C	27
Total Coliform- MPN/100ml	206
Turbidity - NTU (increase of)	10

Historical water quality data for the water bodies at the station locations listed in Tables 3-14 and 3-15 are summarized in Tables 3-17, 3-18, 3-19, 3-20, 3-21 and 3-22.

Table 3-17
Summary of Historical Water Quality at La Verkin Creek (Station ID ZION_EPA_LVC1)

Parameter-Units	Minimum	Maximum	Average	Number of Samples
Iron- µg/L	3,100	4,600	3,850	2
Lead- µg/L	ND[(1)]	10	5	2
Mercury- µg/L	ND	11	6	2
pH-Standard Units	7.8	7.8	7.8	2
Solids, Total Dissolved-mg/L	790	816	803	2
Solids, Total Suspended (TSS)-mg/L	119	198	159	2
Specific conductance-umho/cm	1,150	1,200	1,175	2
Temperature, water-deg C	2	2	2	2
Turbidity-NTU	68	110	89	2

Source: Data summarized from EPA's STORET database. Water quality sampling and analysis were completed by the Utah Department of Environmental Quality.

Note: Only two samples were collected at this site for each of the different water quality parameters. The samples were collected on consecutive days in March 1976.

Numeric criteria for La Verkin Creek are not listed in the UAC R317.

[(1)] ND – non-detect.

Table 3-18
Summary of Historical Water Quality at La Verkin Creek (Station ID 4950800)

Parameter-Units	Minimum	Maximum	Average	Number of Samples
Iron-µg/L	42	1,210	626	2
pH-Standard Units	8.1	8.6	8.4	21
Solids, Total Dissolved-mg/L	590	1,124	700	10
Solids, Total Suspended (TSS)-mg/L	13	180	57	7
Specific conductance-umho/cm	1	990	845	21
Temperature, water-deg C	0	28	13	11
Turbidity-NTU	1	132	17	10

Source: Data summarized from EPA's STORET database. Water quality sampling and analysis were completed by the Utah Department of Environmental Quality.

Numeric criteria for La Verkin Creek are not listed in the UAC R317.

Table 3-19
Summary of Historical Water Quality at LaVerkin Creek (Station ID 4950790)

Parameter-Units	Minimum	Maximum	Average	Number of Samples
Aluminum-µg/L	33	853	443	2
Iron-µg/L	42	1,210	626	2
pH-Standard Units	7.2	8.7	8.2	21
Solids, Total Dissolved-mg/L	590	1,124	700	10
Solids, Total Suspended (TSS)-mg/L	13	180	57	10
Specific conductance-umho/cm	1	990	845	21
Temperature, water-deg C	0	28	13	11
Turbidity-NTU	1	132	17	10

Source: Data summarized from EPA's STORET database. Water quality sampling and analysis were completed by the Utah Department of Environmental Quality.
Numeric criteria for LaVerkin Creek are not listed in the UAC R317.

Table 3-20
Summary of Historical Water Quality at Paria River Station ID (4951850)

Parameter-Units	Minimum	Maximum	Average	Number of Samples	Remarks
Aluminum-µg/L	ND[1]	708	131	8	The numeric criterion for aluminum (1 hour average of 750 µg/L) was not exceeded in any sample. Aluminum was detected in 4 samples (50% of samples).
Cadmium-µg/L	ND	5	<1	28	The numeric criterion for cadmium (1 hour average of 2 µg/L) was exceeded in one sample (4% of samples). Cadmium was detected in 8 samples (29% of samples).
Chromium(VI)-µg/L	ND	25	3	8	The numeric criterion for hexavalent chromium (1 hour average of 16 µg/L) was exceeded in the only sample where chromium was present (13% of samples); all other samples were non-detect.
Copper-µg/L	ND	425	26	29	The numeric criterion for copper (1 hour average of 13 µg/L) was exceeded in 10 samples (34% of samples). Copper was detected in 14 samples (48% of samples).
Iron-µg/L	ND	6,650	742	14	The numeric criterion for iron (1 hour average of 1,000 µg/L) was exceeded in 10 samples (71% of samples). Iron was detected in 9 samples (64% of samples).
Lead-µg/L	ND	250	13	30	The numeric criterion for lead (1 hour average of 65 µg/L) was exceeded in five samples (17% of samples). Aluminum was detected in 12 samples (40% of samples).
pH-Standard Units	7.0	9.7	8.2	131	The numeric criterion for pH (range of 6.5 - 9.0) was exceeded in four samples (3% of samples).
Solids, Total Dissolved-mg/L	504	2,744	1,188	73	The numeric criterion for TDS (1,000 mg/L) was exceeded in 56 samples (77% of samples). Approximately 60% of the collected samples had TDS concentrations that ranged from 1,000 mg/L to 1,500 mg/L.
Solids, Total Suspended (TSS)-mg/L	12	142,500	7,662	75	Approximately 45% of the samples had TSS concentrations lower than 500 mg/L. Approximately 30% of the samples had concentrations in excess of 1000 mg/L. There were several peaks throughout the sampling period where the TSS concentrations exceeded 10,000 mg/L. Approximately, 10% of the samples had TSS concentrations in excess of 10,000 mg/L.
Specific conductance-umho/cm	255	3,070	1,552	136	Specific conductance measured in over 50% of the collected samples ranged from 1,000 umho/cm to 1,500 umho/cm.
Temperature, water-deg C	0	33	14	66	The numeric criterion for temperature (27˚C) was exceeded in 5 samples (8% of samples).
Total Coliform-MPN/100ml[2]	23	43,000	7,144	9	The numeric criterion for total coliform (206 MPN/100 ml) was exceeded in seven samples (78% of samples).
Turbidity-NTU	9	52,208	2,253	66	The numeric criterion is based on an increase as a result of discharge.

Source: Data summarized from EPA's STORET database. Water quality sampling and analysis were completed by the Utah Department of Environmental Quality.
(1) ND – non-detect.
(2) Most Probable Number (MPN); value shown as "average" represents the geometric mean of the samples.

Table 3-21
Summary of Historical Water Quality at Paria River Station ID (4951860)

Parameter-Units	Minimum	Maximum	Average	Number of Samples	Remarks
Aluminum-µg/L	35	62	49	4	The numeric criterion for aluminum (1 hour average of 750 µg/L) was not exceeded in any sample.
Chromium-µg/L	5	10	7	5	The numeric criterion for chromium (1 hour average of 16 µg/L) was not exceeded in any sample.
Iron-µg/L	50	142	85	4	The numeric criterion for chromium (1 hour average of 1,000 µg/L) was not exceeded in any sample.
pH-Standard Units	7.0	8.6	8.1	33	All samples were within the 6.5-9.0 range of the criterion.
Solids, Total Dissolved-mg/L	838	4,030	1,726	18	The numeric criterion for TDS (1,000 mg/L) was exceeded in 12 samples (67% of samples). Approximately 62% of the samples have TDS concentrations lower than 1,500 mg/L.
Solids, Total Suspended (TSS)-mg/L	6	87,440	6,321	16	Approximately 40% of the samples had a TSS concentration lower than 100 mg/L. The high TSS of 87,440 mg/L represented an isolated event over the sampling period. The average TSS is 916 mg/L if that sampling event is excluded.
Temperature, water-deg C	0	28	11	15	The numeric criterion for temperature (27˚C) was exceeded in 1 samples (7% of samples).
Turbidity-NTU	2	54,380	3,404	18	The numeric criterion is based on an increase as a result of discharge.

Source: Data summarized from EPA's STORET database. Water quality sampling and analysis were completed by the Utah Department of Environmental Quality.

Table 3-22
Summary of Historical Water Quality at Paria River Station ID (5994550)

Parameter-Units	Minimum	Maximum	Average	Number of Samples	Remarks
Aluminum-µg/L	ND[(1)]	2,200	429	11	The numeric criterion for aluminum (1 hour average of 750 µg/L) was exceeded in two samples (18% of samples). Aluminum was detected in only three samples (27% of samples).
Cadmium-µg/L	ND	2.2	<1	11	The numeric criterion for cadmium (1 hour average of 2 µg/L) was exceeded in the only two samples in which it was detected (18% of samples).
Chromium-µg/L	ND	24	4	12	The numeric criterion for chromium (1 hour average of 16 µg/L) was exceeded in one sample (8% of samples). Chromium was detected in only two samples (17% of samples.
Copper-µg/L	ND	17,100	1425	12	The numeric criterion for copper (1 hour average of 13 µg/L) was exceeded in one sample (8% of samples). Copper was detected in only two samples (17% of samples).
Iron-µg/L	ND	5,310	599	14	The numeric criterion for iron (1 hour average of 1,000 µg/L) was exceeded in two samples (14% of samples).
Lead-µg/L	ND	574	53	11	The numeric criterion for lead (1 hour average of 65 µg/L) was exceeded in one sample (9% of samples).
pH-Standard Units	7.3	8.9	8.2	186	All samples were within the 6.5-9.0 range of the criterion.
Solids, Total Dissolved-mg/L	504	2,350	957	102	The numeric criterion for TDS (1,000 mg/L) was exceeded in 34 samples (33% of samples). Approximately 70% of the samples collected had TDS concentrations that ranged between 500 mg/L and 1,000 mg/L.
Solids, Total Suspended (TSS)-mg/L	4	188,100	6,039	95	Approximately 30% of the samples had TSS concentrations lower than 100 mg/L. Approximately 10% of the samples had TSS concentrations in excess of 10,000 mg/L.
Specific conductance-umho/cm	677	2,920	1,275	185	For approximately 82% of the samples, the specific conductance ranged between 1,000 umho/cm and 1,500 umho/cm.
Temperature, water-deg C	0	31	16	84	The numeric criterion for temperature (27˚C) was exceeded in 13 samples (15% of samples).
Turbidity-NTU	1	19,212	1,606	101	The numeric criterion is based on an increase as a result of discharge.

Source: Data summarized from EPA's STORET database. Water quality sampling and analysis were completed by the Utah Department of Environmental Quality.
[(1)] ND – non-detect.

3.2.6 Virgin River

Bound by mountains with elevations reaching over 10,000 feet, the Virgin River lies within the lower Colorado River basin. The lowest elevation is about 2,500 feet where the Virgin River crosses the state line with Arizona. Most Virgin River streamflow originates as snow, the runoff results in high flows from March through May. The greatest water producing area is the headwaters of the North Fork of the Virgin River. The headwaters of the Virgin River are located near Hurricane, Utah, in the high mountains of southern Utah, north and east of Zion National Park. The river flows through Utah and Arizona before entering Nevada near the City of Mesquite. The river is intermittent within Nevada, having no flow in some reaches during certain times of the year. The river flows southwesterly for about 25 miles through the unincorporated towns of Bunkerville and Riverside before emptying into the Overton Arm of Lake Mead.

Segments of the Virgin River are categorized on the Section 303(d) list as impaired for temperature, total phosphorus, selenium, iron, manganese, suspended solids, dissolved oxygen, total dissolved solids, silver, and total ammonia (EPA 2006 and 2008). The characterization of Virgin River water quality is based upon water quality data obtained at nine sampling stations (listed in Table 3-23). Key water quality parameters at each of the stations below the Quail Creek diversion are summarized below.

Table 3-23
Virgin River Water Quality Sample Station Locations

Station ID	Sampling Period	Latitude	Longitude
4950010	1976-1983	37.00000	-113.703
4950020	1984-2008	37.02014	-113.672
4950120	1977, 1989-2006	37.05222	-113.600
4950130	1976-1984, 1999	37.07306	-113.580
4950200	1975-1985, 1996-2007	37.08639	-113.556
4950260	1982-1983	37.11611	-113.500
4950300	2000-2002, 2004-2007	37.16278	-113.395
4950320	1976, 1982-2002, 2006-2007	37.16278	-113.395

Source: Utah Department of Environmental Quality

Numeric water quality criteria for the Virgin River vary based on the different beneficial uses. Table 3-24 presents the most stringent numeric criteria for the Virgin River for the relevant water quality parameters.

Table 3-24
Numeric Criteria for Virgin River (Below Quail Creek Diversion)
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Constituent-Units	Numeric Criteria
Aluminum-µg/L	750
Arsenic-µg/L	10
Barium-mg/L	1
Boron-µg/L	0.75
Cadmium-µg/L	2

Table 3-24
Numeric Criteria for Virgin River (Below Quail Creek Diversion)
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Constituent-Units	Numeric Criteria
Chromium (VI)-µg/L	16
Copper-µg/L	13
Iron-µg/L	1,000
Lead-µg/L	65
Mercury-µg/L	2.4
Nickel-µg/L	468
pH-Standard Units	6.5-9.0
Selenium-µg/L	18.4
Silver-µg/L	1.6
Solids, Total Dissolved-mg/L	1200
Temperature, water-deg C	20
Total Coliform-MPN/100ml	206
Turbidity-NTU (increase of)	10
Zinc-µg/L	120

Historical water quality data for the water bodies at the station locations listed in Table 3-23 are summarized in Tables 3-25, 3-26, 3-27, 3-28, 3-29, 3-30, 3-31, 3-32 and 3-33.

Table 3-25
Summary of Historical Water Quality at Virgin River Station ID (4950010)

Parameter-Units	Minimum	Maximum	Average	Number of Samples
Arsenic-µg/L	2	15	10	4
Boron-mg/L	650	695	677	3
Copper-µg/L	ND[1]	30	8	4
Iron-µg/L	1	2	2	4
Lead-µg/L	ND	30	8	4
Manganese-µg/L	50	325	191	4
Nickel-µg/L	ND	25	14	3
pH-Standard Units	7.9	8.4	8.1	5
Solids, Total Dissolved-mg/L	1,334	1,734	1,525	4
Solids, Total Suspended (TSS)-mg/L	97	612	380	3
Specific conductance- umho/cm	1,910	2,620	2,240	8
Temperature, water-deg C	3	18	14	5
Total Coliform-MPN/100ml[2]	4,600	4,600	4,600	1
Turbidity-NTU	29	300	175	4

Source: Data summarized from EPA's STORET database. Water quality sampling and analysis were completed by the Utah Department of Environmental Quality.
(1) ND – non-detect.
(2) Most Probable Number (MPN); value shown as "average" represents the geometric mean of the samples.

Table 3-26
Summary of Historical Water Quality at Virgin River Station ID (4950020)
Page 1 of 2

Parameter-Units	Minimum	Maximum	Average	Number of Samples	Remarks
Aluminum-µg/L	ND[1]	5,780	218	33	The numeric criterion for aluminum (1 hour average of 750 µg/L) was exceeded in two samples (6% of samples). Aluminum was detected in 9 samples (27% of samples).
Arsenic-µg/L	ND	23	9	128	The numeric criterion for arsenic (10 µg/L) was exceeded in 49 samples (38% of samples). Arsenic was detected in 117 samples (91% of samples).
Boron-mg/L	231	2,710	909	9	The numeric criterion for boron (0.75 mg/L) was exceeded in five samples (56% of samples).

Table 3-26
Summary of Historical Water Quality at Virgin River Station ID (4950020)

Parameter-Units	Minimum	Maximum	Average	Number of Samples	Remarks
Cadmium-µg/L	ND	35	1	101	The numeric criterion for cadmium (1 hour average of 2 µg/L) was exceeded in three samples (3% of samples). Cadmium was detected in 9 samples (9% of samples).
Copper-µg/L	ND	90	5	103	The numeric criterion for copper (1 hour average of 13 µg/L) was exceeded in 14 samples (14% of samples). Copper was detected in 17 samples (17% of samples).
Iron-µg/L	ND	1,160	2	53	The numeric criterion for iron (1 hour average of 1,000 µg/L) was exceeded in only one sample (2% of samples). Iron was detected in 26 samples (49% of samples).
pH-Standard Units	6.6	9.0	8.2	352	All samples were within the 6.5-9.0 range of the criterion.
Selenium-µg/L	ND	5	1	125	The numeric criterion for selenium (1 hour average of 18.4 µg/L) was not exceeded in any sample. Selenium was detected in 51 samples (41% of samples).
Solids, Total Dissolved-mg/L	472	3,990	1,856	187	The numeric criterion for TDS (1,200 mg/L) was exceeded in 158 samples (84% of samples). Approximately 88% of the samples collected exceeded the numeric criterion for TDS.
Solids, Total Suspended (TSS)-mg/L	4	14,580	736	184	Approximately 43% of the samples had TSS concentrations lower than 100 mg/L. Approximately 20% of the samples had TSS concentrations in excess of 500 mg/L.
Specific conductance-umho/cm	203	8,730	2,560	368	Approximately 75% of the samples had specific conductance in excess of 2,000 umho/cm.
Temperature, water-deg C	2	34	17	187	The numeric criterion for temperature (20˚C) was exceeded in 72 samples (39% of samples).
Total Coliform-MPN/100ml[(2)]	49	18,500	3,967	6	The numeric criterion of total coliform (206 MPN/100 ml) was exceeded in two samples (33% of samples).
Turbidity-NTU	29	300	175	4	The numeric criterion is based on an increase as a result of discharge.
Zinc-µg/L	ND	180	15	104	The numeric criterion for zinc (1 hour average of 120 µg/L) was exceeded in two samples (2% of samples). Zinc was detected in 42 samples (40% of samples).

Source: Data summarized from EPA's STORET database. Water quality sampling and analysis were completed by the Utah Department of Environmental Quality.
[(1)] ND – non-detect.
[(2)] Most Probable Number (MPN); value shown as "average" represents the geometric mean of the samples.

Table 3-27
Summary of Historical Water Quality at Virgin River Station ID (4950120)

Parameter-Units	Minimum	Maximum	Average	Number of Samples	Remarks
Aluminum-µg/L	ND[1]	85,900	3,089	28	The numeric criterion for aluminum (1 hour average of 750 µg/L) was exceeded in one sample (4% of samples). Aluminum was detected in 10 samples (36% of samples).
Arsenic-µg/L	ND	44	9	72	The numeric criterion for arsenic (10 µg/L) was exceeded in one sample (1% of samples). Arsenic was detected in 62 samples (9% of samples).
Barium-µg/L	35	203	84	42	The numeric criterion for barium (1 mg/L) was exceeded in one sample (2% of samples).
Boron-mg/L	219	1,190	768	6	The numeric criterion for boron (0.75 mg/L) was exceeded in four samples (67% of samples).
Cadmium-µg/L	ND	4	<1	49	The numeric criterion for cadmium (1 hour average of 2 µg/L) was exceeded in the one sample where it was detected (2% of samples).
Chromium-µg/L	ND	9	1	50	The numeric criterion for chromium (1 hour average of 16 µg/L) was not exceeded in any sample. Arsenic was detected in 5 samples (10% of samples).
Copper-µg/L	ND	39	4	48	The numeric criterion for copper (1 hour average of 13 µg/L) was exceeded in eight samples (17% of samples). Copper was detected in 9 samples (19% of samples).
Iron-µg/L	ND	195	30	36	The numeric criterion for iron (1 hour average of 1,000 µg/L) was not exceeded in any sample. Iron was detected in 20 samples (56% of samples).
pH-Standard Units	7.2	8.5	8.0	126	All samples were within the 6.5-9.0 range of the criterion.
Selenium-µg/L	ND	4	2	69	The numeric criterion for selenium (1 hour average of 18.4 µg/L) was not exceeded in any sample. Selenium was detected in 41 samples (59% of samples).
Solids, Total Dissolved-mg/L	488	3,216	1,988	40	The numeric criterion for TDS (1,200 mg/L) was exceeded in 34 samples (85% of samples).
Solids, Total Suspended (TSS)-mg/L	6	25,450	899	62	Approximately, 90% of the samples had TSS concentrations lower than 500 mg/L.
Specific conductance-umho/cm	362	4,867	2,651	124	None
Temperature, water-deg C	4	33	16	90	The numeric criterion for temperature (20˚C) was exceeded in 30 samples (33% of samples).
Total Coliform-MPN/100 mL[2]	200	240,000	36,513	8	The numeric criterion of total coliform (206 MPN/100 ml) was exceeded in six samples (75% of samples).
Turbidity-NTU	4	630	87	36	The numeric criterion is based on an increase as a result of discharge.
Zinc-µg/L	ND	413	18	51	The numeric criterion for zinc (1 hour average of 120 µg/L) was exceeded in one sample (2% of samples). Zinc was detected in 14 samples (27% of samples).

Source: Data summarized from EPA's STORET database. Water quality sampling and analysis were completed by the Utah Department of Environmental Quality.
[1] ND – non-detect.
[2] Most Probable Number (MPN); value shown as "average" represents the geometric mean of the samples.

Table 3-28
Summary of Historical Water Quality at Virgin River Station ID (4950130)

Parameter-Units	Minimum	Maximum	Average	Number of Samples	Remarks
Arsenic-µg/L	2	16	9	12	The numeric criterion for arsenic (10 µg/L) was exceeded in five samples (42% of samples).
Boron-mg/L	445	1,375	790	3	The numeric criterion for boron (0.75 mg/L) was exceeded in one sample (33% of samples).
Chromium(VI) -µg/L	ND[1]	4	1	3	The numeric criterion for chromium (1 hour average of 16 µg/L) was not exceeded in any sample. Chromium was detected in 1 sample (33% of samples).
Copper-µg/L	ND	20	8	11	The numeric criterion for copper (1 hour average of 13 µg/L) was exceeded in five samples (45% of samples). Copper was detected in 5 samples (45% of samples).
Iron-µg/L	5	5,300	1,231	14	The numeric criterion for iron (1 hour average of 1,000 µg/L) was exceeded in five samples (36% of samples).
Lead-µg/L	ND	50	8	11	The numeric criterion for lead (1 hour average of 65 µg/L) was not exceeded in any sample. Lead was detected in 5 samples (45% of samples).
Nickel-µg/L	ND	26	9	9	The numeric criterion for nickel (1 hour average of 468 µg/L) was not exceeded in any sample. Copper was detected in 5 samples (56% of samples).
pH-Standard Units	7.0	8.7	8.1	24	All samples were within the 6.5-9.0 range of the criterion.
Selenium-µg/L	ND	1	<1	11	The numeric criterion for selenium (1 hour average of 18.4 µg/L) was not exceeded in any sample. Selenium was detected in 2 samples (18% of samples).
Silver-µg/L	ND	15	2	12	The numeric criterion for silver (1 hour average of 1.6 µg/L) was not exceeded in both of the two samples that silver was detected (17% of samples).
Solids, Dissolved-mg/L	272	3,560	1,388	14	The numeric criterion for TDS (1,200 mg/L) was exceeded in seven samples (50% of samples).
Solids, Total Suspended (TSS)-mg/L	<1	9,999	1,618	20	Approximately 60% of the samples have TSS concentrations lower than 200 mg/L.
Specific conductance-umho/cm	434	4,180	1,893	23	None
Temperature, water-deg C	1	35	11	20	The numeric criterion for temperature (20˚C) was exceeded in 4 samples (20% of samples).
Total Coliform-MPN/100 ml[2]	930	46,000	18,926	10	The numeric criterion of total coliform (206 MPN/100 ml) was exceeded in all samples.
Turbidity-NTU	11	800	226	12	The numeric criterion is based on an increase as a result of discharge.
Zinc-µg/L	ND	50	14	11	The numeric criterion for zinc (1 hour average of 120 µg/L) was not exceeded in any sample. Zinc was detected in 7 samples (64% of samples).

Source: Data summarized from EPA's STORET database. Water quality sampling and analysis were completed by the Utah Department of Environmental Quality.
(1) ND – non-detect.
(2) Most Probable Number (MPN); value shown as "average" represents the geometric mean of the samples.

Table 3-29
Summary of Historical Water Quality at Virgin River Station ID (4950200)

Parameter-Units	Minimum	Maximum	Average	Number of Samples	Remarks
Arsenic-µg/L	2	20	9	57	The numeric criterion for arsenic (10 µg/L) was exceeded in 18 samples (32% of samples).
Barium-mg/L	37	600	123	15	The numeric criterion for barium (1 mg/L) was exceeded in nine samples (60% of samples).
Cadmium-µg/L	ND[1]	20	2	36	The numeric criterion for cadmium (1 hour average of 2 µg/L) was exceeded in nine samples (25% of samples). Cadmium was detected in 12 samples (33% of samples)
Copper-µg/L	ND	45	9	44	The numeric criterion for copper (1 hour average of 13 µg/L) was exceeded in 11 samples (25% of samples). Copper was detected in 25 samples (57% of samples).
Iron-µg/L	10	95	33	25	The numeric criterion for iron (1 hour average of 1,000 µg/L) was exceeded in five samples (20% of samples).
Lead-µg/L	ND	90	10	38	The numeric criterion for lead (1 hour average of 65 µg/L) was exceeded in one sample (3% of samples). Lead was detected in 18 samples (47% of samples)
pH-Standard Units	6.4	8.8	8.0	208	All but one sample was within the 6.5-9.0 range of the criterion (<1% of samples outside of criterion range).
Selenium-µg/L	ND	5	1	48	The numeric criterion for selenium (1 hour average of 18.4 µg/L) was not exceeded in any sample. Selenium was detected in 26 samples (54% of samples)
Silver-µg/L	ND	30	3	38	The numeric criterion for silver (1 hour average of 1.6 µg/L) was not exceeded in 11 samples (29% of samples). Silver was detected in 12 samples (32% of samples)
Solids, Dissolved-mg/L	424	4,072	1,964	103	The numeric criterion for TDS (1,200 mg/L) was exceeded in 83 samples (81% of samples).
Solids, Total Suspended (TSS)-mg/L	1	9,999	476	104	Approximately 87% of the samples collected had TSS concentrations lower than 500 mg/L.
Specific conductance-umho/cm	214	5,550	2,645	189	None
Temperature, water-deg C	1	35	15	115	The numeric criterion for temperature (20˚C) was exceeded in 37 samples (13% of samples).
Total Coliform-MPN/100 mL [2]	4	240,000	15,937	63	The numeric criterion of total coliform (206 MPN/100 ml) was exceeded in 58 samples (92% of samples).
Turbidity-NTU	1	1,600	109	91	The numeric criterion is based on an increase as a result of discharge.
Zinc-µg/L	ND	1,900	67	42	The numeric criterion for zinc (1 hour average of 120 µg/L) was exceeded in one sample (2% of samples). Zinc was detected in 32 samples (76% of samples).

Source: Data summarized from EPA's STORET database. Water quality sampling and analysis were completed by the Utah Department of Environmental Quality.
(1) ND – non-detect.
(2) Most Probable Number (MPN); value shown as "average" represents the geometric mean of the samples.

Table 3-30
Summary of Historical Water Quality at Virgin River Station ID (4950260)

Parameter-Units	Minimum	Maximum	Average	Number of Samples
Arsenic-µg/L	3	13	9	6
Chromium-µg/L	ND[1]	30	6	6
Copper-µg/L	ND	40	15	6
Iron-mg/L	<1	4	2	6
Lead-µg/L	ND	11	6	6
Magnesium-mg/L	27	61	41	6
Manganese-µg/L	90	660	363	6
Nickel-µg/L	ND	115	24	6
pH-Standard Units	7.6	8.6	8.2	10
Solids, Total Dissolved-mg/L	488	1,610	1,016	6
Solids, Total Suspended (TSS)-mg/L	4	1,566	600	6
Specific conductance-umho/cm	280	2,300	1,442	12
Temperature, water-deg C	6	34	16	6
Total Coliform-MPN/100 mL[2]	300	50,000	13,740	5
Turbidity-NTU	4	882	384	6
Zinc-µg/L	ND	70	32	6

Source: Data summarized from EPA's STORET database. Water quality sampling and analysis were completed by the Utah Department of Environmental Quality.

(1) ND – non-detect.

(2) Most Probable Number (MPN); value shown as "average" represents the geometric mean of the samples.

Table 3-31
Summary of Historical Water Quality at Virgin River Station ID (4950300)

Parameter-Units	Minimum	Maximum	Average	Number of Samples
Arsenic-µg/L	15	15	15	1
Boron-µg/L	793	793	793	1
Iron-µg/L	25	25	25	1
pH-Standard Units	7.8	8.4	8.1	6
Selenium-µg/L	3	3	3	1
Solids, Total Dissolved-mg/L	1,898	2,098	1,998	2
Solids, Total Suspended (TSS)-mg/L	26	40	33	2
Specific conductance-umho/cm	2,756	3,534	3,142	6
Temperature, water-deg C	7	32	21	4
Total Coliform-MPN/100 mL(1)	57	961	409	3
Turbidity-NTU	6	8	7	2

Source: Data summarized from EPA's STORET database. Water quality sampling and analysis were completed by the Utah Department of Environmental Quality.
(1)Most Probable Number (MPN); value shown as "average" represents the geometric mean of the samples.

Table 3-32
Summary of Historical Water Quality at Virgin River Station ID (4950320)

Parameter-Units	Minimum	Maximum	Average	Number of Samples	Remarks
Arsenic-µg/L	ND[1]	255	18	113	The numeric criterion for arsenic (10 µg/L) was exceeded in 78 samples (69% of samples). Arsenic was detected in 108 samples (96% of samples)
Barium-mg/L	ND	0.7	0.1	65	The numeric criterion for barium (1 mg/L) was not exceeded in any sample. Barium was detected in 48 samples (74% of samples).
Cadmium-µg/L	ND	20	<1	103	The numeric criterion for cadmium (1 hour average of 2 µg/L) was exceeded in one sample (1% of samples). Cadmium was detected in 9 samples (9% of samples)
Chromium-µg/L	ND	50	1	103	The numeric criterion for chromium (1 hour average of 16 µg/L) was exceeded in two samples (2% of samples). Chromium was detected in 12 samples (12% of samples).
Copper-µg/L	ND	150	5	105	The numeric criterion for copper (1 hour average of 13 µg/L) was exceeded in 15 samples (14% of samples). Copper was detected in 19 samples (18% of samples).
Iron-µg/L	ND	70	13	41	The numeric criterion for iron (1 hour average of 1,000 µg/L) was not exceeded in any sample. Iron was detected in 14 samples (34% of samples).
Lead-µg/L	ND	50	2	103	The numeric criterion for lead (1 hour average of 65 µg/L) was not exceeded in any sample. Lead was detected in 9 samples (9% of samples).
Nickel-µg/L	ND	22	11	10	The numeric criterion for nickel (1 hour average of 468 µg/L) was not exceeded in any sample. Nickel was detected in 7 samples (70% of samples).
pH-Standard Units	6.8	9.2	8.0	304	The numeric criterion for pH was exceeded in one sample (<1% of samples).
Selenium-µg/L	ND	6	1	113	The numeric criterion for selenium (1 hour average of 18.4 µg/L) was not exceeded in any sample. (Selenium was detected in 31 samples (27% of samples).
Solids, Total Dissolved-mg/L	362	2,964	1,484	161	The numeric criterion for TDS (1,200 mg/L) was exceeded in 109 samples (68% of samples).
Solids, Total Suspended (TSS)-mg/L	<1	32,550	640	165	Approximately 83% of the samples had concentrations lower than 500 mg/L.
Specific conductance-umho/cm	209	4,410	2,212	325	None
Temperature, water-deg C	2	31	15	169	The numeric criterion for temperature (20˚C) was exceeded in 38 samples (23% of samples).
Total Coliform-MPN/100 mL [2]	9	46,000	7,401	7	The numeric criterion of total coliform (206 MPN/100 ml) was exceeded in five samples (71% of samples).
Turbidity-NTU	1	9,100	192	161	The numeric criterion is based on an increase as a result of discharge.
Zinc-µg/L	ND	170	12	104	The numeric criterion for zinc (1 hour average of 120 µg/L) was exceeded in one sample (1% of samples). Zinc was detected in 35 samples (34% of samples).

Source: Data summarized from EPA's STORET database. Water quality sampling and analysis were completed by the Utah Department of Environmental Quality.
[1] ND – non-detect.
[2] Most Probable Number (MPN); value shown as "average" represents the geometric mean of the samples.

Table 3-33
Summary of Virgin River Water Quality – All Stations

Parameter-Units	Minimum	Maximum	Number of Samples	Criterion	Remarks
Arsenic-µg/L	ND	255	393	10	Most values near criterion
Copper- µg/L	ND	90	321	13	Mostly in compliance with water quality objectives
Iron- µg/L	ND	5,300	180	1,000	Mostly in compliance with water quality objectives
pH-Standard Units	6.6	9.2	1035	6.5-9.0	Almost always in compliance with water quality objectives
Solids, total dissolved-mg/L	272	4,072	517	1200	Often exceeds criterion
Solids, total Suspended (TSS)-mg/L	<1	32550	546	-	
Specific conductance-umho/cm	203	8,730	1055	-	
Temperature, water-deg C	0	35	596	20	Often exceeds criterion
Turbidity-NTU	1	882	316	10	Mostly in compliance with water quality objectives

3.3 Beneficial Use Designations - Arizona

In the State of Arizona, water quality protection standards are based on designated state beneficial uses which are defined and classified in the Arizona Administrative Code (AAC) R18-11-105. Use designations are provided in Title 18, Chapter 11 and include the classifications shown in Table 3-34.

Table 3-34
Beneficial Use Protection Classifications for Surface Waters of the State of Arizona (R18-11-105)

Designated Uses	Definition
A&Wc	Aquatic and Wildlife cold water
A&Ww	Aquatic and Wildlife warm water
A&We	Aquatic and Wildlife ephemeral
A&Wedw	Aquatic and Wildlife effluent dependent water
FBC	Full-body Contact
PBC	Partial-body Contact
DWS	Domestic Water Source
FC	Fish Consumption
AgI	Agricultural Irrigation
AgL	Agricultural Livestock Watering
U	Unique Water
EDW	Effluent-dependent Water
WWTP	Agricultural Livestock Watering

Beneficial use protection classifications for major rivers in the vicinity of the LPP alignments passing through the State of Arizona are provided in Table 3-35. There are numerous ephemeral washes along the proposed pipeline alignments. Beneficial use designations for these ephemeral washes in the LPP vicinity are not provided in AAC R18-11-105.

Table 3-35
Beneficial Use Protection Classifications Designated for Major Rivers and Reservoirs in the Vicinity of the LPP, AAC R317-2-13

Water Body	Classifications
Kanab Creek (lower)	A&Ww, FBC, DWS, FC, AgL
Paria River	A&Ww, FBC, FC

3.4 Historical Water Quality Conditions - Arizona

Water quality data for the relevant surface water bodies were obtained from the EPA's STORET data system. Water quality data for the water bodies listed in Table 3-35 are summarized in the following sections. Trends in historical water quality are not described because of the limited availability of data for the water bodies in Arizona.

3.4.1 Kanab Creek

Downstream of Kanab in Kane County, Utah, the Kanab Creek flows into Arizona near Fredonia. It flows through the Kaibab Indian Reservation of the Paiute people and the Kanab Creek Wilderness before its confluence with the Colorado River in Grand Canyon National Park. It flows through Mojave County, Arizona. The characterization of Kanab Creek water quality is based upon water quality data obtained at one sampling station (listed in Table 3-36).

Table 3-36
Kanab Creek Water Quality Sample Station Locations

Station ID	Station Name	Sampling Period	Latitude	Longitude
100576	Unknown	June 6, 1994	36.96125	-112.529305
Source: Arizona Department of Environmental Quality				

Numeric water quality criteria for Kanab Creek in the State of Arizona vary based on the different beneficial uses. Table 3-37 presents the most stringent numeric criteria for the Kanab Creek for the relevant water quality parameters.

Table 3-37
Numeric Criteria for Kanab Creek (Arizona)

Constituent-Units	Numeric Criteria
pH	6.5-9.0
Temperature, water-deg C (increase)	3
Total Coliform-MPN/100ml (single sample)	235
Dissolved Oxygen (mg/L)	6
Source: Arizona Department of Environmental Quality	

3.4.2 Paria River

The Paria River flows from its headwaters in Bryce Canyon National Park and Dixie National Forest through private agricultural lands in Garfield County, Utah and south through the GSENM into Arizona and the Colorado River below Glen Canyon Dam. It flows through Coconino County, Arizona. The characterization of Paria River water quality is based upon water quality data obtained at nine sampling stations (Table 3-38).

Table 3-38 Paria River Water Quality Sample Station Locations			
Station ID	**Sampling Period**	**Latitude**	**Longitude**
100617	2004-2005	36.87264	-111.6
100743	1990-2004	36.86472	-111.588
101073	1999-2001	36.86433	-111.596
101074	1999-2001	36.93189	-111.664
101075	1999-2001	36.95658	-111.743
101076	1999-2001	36.99519	-111.793
101077	1999-2001	37.0008666	-111.864255
101078	1999-2001	37.0019133	-111.8646433
101079	April 14, 2000	37.00143	-111.866
Source: Arizona Department of Environmental Quality			

Numeric water quality criteria for Paria River in the State of Arizona vary based on the different beneficial uses. Table 3-39 presents the most stringent numeric criteria for the Paria River for the relevant water quality parameters.

Table 3-39 Numeric Criteria for Paria River (Arizona)	
Constituent-Units	**Numeric Criteria**
pH	6.5-9.0
Temperature, water-deg C (increase)	3
Total Coliform-MPN/100ml (single sample)	235
Dissolved Oxygen (mg/L)	6
Source: Arizona Department of Environmental Quality	

Historical water quality data for the water bodies at the station locations listed in Tables 3-36 and 3-38 are summarized in Tables 3-40, 3-41, 3-42, 3-43, 3-44, 3-45, 3-46, 3-47 and 3-48.

Table 3-40
Summary of Historical Water Quality at Kanab Creek Station ID (100576)

Parameter-Units	Minimum	Maximum	Average	Number of Samples
Iron-µg/L	160	160	160	1
pH-Standard Units	8.2	8.8	8.5	2
Solids, Total Dissolved-mg/L	1,070	2,430	1,750	2
Solids, Total Suspended (TSS)-mg/L	10	10	10	1
Specific conductance-umho/cm	168	168	168	1
Temperature, water-deg C	23	23	23	1
Turbidity-NTU	6	8	7	2

Source: Data summarized from EPA's STORET database. Water quality sampling and analysis were completed by the Arizona Department of Environmental Quality.

Table 3-41
Summary of Historical Water Quality at Paria River Station ID (100617)

Parameter-Units	Minimum	Maximum	Average	Number of Samples
Arsenic, Inorganic-µg/L	12	29	18	4
Cadmium-µg/L	1	5	3	3
Copper-µg/L	3	110	39	6
Lead-µg/L	<1	75	32	6
Manganese-µg/L	1,300	5,500	2,900	4
Mercury-µg/L	3	5	4	3
pH-Standard Units	7.4	8.4	8.1	8
Selenium-µg/L	14	14	14	1
Solids, Total Dissolved-mg/L	510	1,400	893	8
Solids, Total Suspended (TSS)-mg/L	52	20,000	6,108	12
Specific conductance-umho/cm	796	1,960	1,332	8
Temperature, water-deg C	10	23	14	4
Zinc-µg/L	130	360	195	4

Source: Data summarized from EPA's STORET database. Water quality sampling and analysis were completed by the Arizona Department of Environmental Quality.

Table 3-42
Summary of Historical Water Quality at Paria River Station ID (100743)

Parameter-Units	Minimum	Maximum	Average	Number of Samples
Aluminum-µg/L	ND[1]	64	4	49
Antimony-µg/L	<1	3	1	4
Arsenic, Inorganic-µg/L	ND	3	1	162
Cadmium-µg/L	<1	16	2	14
Copper-µg/L	1	19	3	69
Iron-µg/L	1	1,800	40	85
Lead-µg/L	1	10	2	13
Manganese-µg/L	1	120	6	47
Mercury-µg/L	<1	1	<1	2
Molybdenum-µg/L	4	20	5	25
Nickel-µg/L	1	8	2	51
pH-Standard Units	7.2	8.4	8.0	197
Selenium-µg/L	1	14	2	152
Silver-µg/L	2	2	2	1
Solids, Total Dissolved-mg/L	386	656	506	182
Solids, Total Suspended (TSS)-mg/L	1	13	4	48
Specific conductance-umho/cm	637	1,010	816	164
Strontium-µg/L	594	1,000	745	79
Temperature, water-deg C	7	13	10	112
Turbidity-NTU	<1	2	1	90
Uranium-µg/L	3	4	3	23
Zinc-µg/L	1	20	6	57

Source: Data summarized from EPA's STORET database. Water quality sampling and analysis were completed by the Arizona Department of Environmental Quality.
[1] ND – non-detect.

Table 3-43
Summary of Historical Water Quality at Paria River Station ID (101073)

Parameter-Units	Minimum	Maximum	Average	Number of Samples
Boron-µg/L	ND[1]	120	60	2
Iron-µg/L	3,800	3,800	3,800	1
Magnesium-mg/L	25	47	36	2
Manganese-µg/L	ND	60	30	2
pH-Standard Units	8.3	8.4	8.3	3
Solids, Total Dissolved-mg/L	390	700	545	2
Solids, Total Suspended (TSS)-mg/L	32	280	156	2
Specific conductance-umho/cm	530	1,011	778	4
Temperature, water-deg C	22	25	23	2
Turbidity-NTU	32	331	153	3

Source: Data summarized from EPA's STORET database. Water quality sampling and analysis were completed by the Arizona Department of Environmental Quality.
(1) ND – non-detect.

Table 3-44
Summary of Historical Water Quality at Paria River Station ID (101074)

Parameter-Units	Minimum	Maximum	Average	Number of Samples
Iron-mg/L	1	1	1	1
Magnesium-mg/L	22	22	22	1
pH-Standard Units	8.3	8.5	8.4	2
Solids, Total Dissolved-mg/L	350	350	350	1
Solids, Total Suspended (TSS)-mg/L	16	250	133	2
Specific conductance-umho/cm	480	1,035	680	3
Temperature, water-deg C	15	19	17	2
Turbidity-NTU	50	475	263	2

Source: Data summarized from EPA's STORET database. Water quality sampling and analysis were completed by the Arizona Department of Environmental Quality.

Table 3-45
Summary of Historical Water Quality at Paria River Station ID (101075)

Parameter-Units	Minimum	Maximum	Average	Number of Samples
Iron-mg/L	1	1	1	1
Magnesium-mg/L	22	22	22	1
pH-Standard Units	8.4	8.4	8.4	2
Solids, Total Dissolved-mg/L	320	320	320	1
Solids, Total Suspended (TSS)-mg/L	28	260	144	2
Specific conductance-umho/cm	460	1,069	672	3
Temperature, water-deg C	22	23	22	2
Turbidity-NTU	400	400	400	1

Source: Data summarized from EPA's STORET database. Water quality sampling and analysis were completed by the Arizona Department of Environmental Quality.

Table 3-46
Summary of Historical Water Quality at Paria River Station ID (101076)

Parameter-Units	Minimum	Maximum	Average	Number of Samples
pH-Standard Units	8.3	8.4	8.3	2
Solids, Total Dissolved-mg/L	240	240	240	1
Solids, Total Suspended (TSS)-mg/L	26	250	138	2
Specific conductance-umho/cm	360	1,143	629	3
Temperature, water-deg C	10	15	13	2
Turbidity-NTU	26	492	287	3
Iron-mg/L	1	1	1	1
Magnesium-mg/L	17	17	17	1

Source: Data summarized from EPA's STORET database. Water quality sampling and analysis were completed by the Arizona Department of Environmental Quality.

Table 3-47
Summary of Historical Water Quality at Paria River Station ID (101077)

Parameter-Units	Minimum	Maximum	Average	Number of Samples
Barium-mg/L	<1	<1	<1	2
Beryllium-µg/L	ND[(1)]	1	<1	6
Iron-mg/L	1	1	1	1
Magnesium-mg/L	21	21	21	1
Manganese-mg/L	<1	<1	<1	1
pH-Standard Units	8.4	8.5	8.4	2
Solids, Total Dissolved-mg/L	390	390	390	1
Solids, Total Suspended (TSS)-mg/L	22	440	231	2
Specific conductance-umho/cm	460	1,445	790	3
Temperature, water-deg C	11	15	13	2
Turbidity-NTU	817	817	817	1

Source: Data summarized from EPA's STORET database. Water quality sampling and analysis were completed by the Arizona Department of Environmental Quality.
[(1)] ND – non-detect.

Table 3-48
Summary of Historical Water Quality at Paria River Station ID (101078)

Parameter-Units	Minimum	Maximum	Average	Number of Samples
Beryllium-µg/L	ND[(1)]	1	<1	6
Boron-mg/L	<1	<1	<1	1
Iron-mg/L	<1	<1	<1	1
Magnesium-mg/L	55	55	55	1
Manganese-mg/L	<1	<1	<1	1
pH-Standard Units	8.1	8.5	8.3	2
Solids, Total Dissolved-mg/L	910	910	910	1
Solids, Total Suspended (TSS)-mg/L	34	490	262	2
Specific conductance-umho/cm	1,100	1,448	1,243	3
Temperature, water-deg C	11	14	12	2
Turbidity-NTU	752	752	752	1

Source: Data summarized from EPA's STORET database. Water quality sampling and analysis were completed by the Arizona Department of Environmental Quality.
[(1)] ND – non-detect.

Table 3-49 summarizes the historical water quality for Paria River at Station ID 101079.

Table 3-49
Summary of Historical Water Quality at Paria River Station ID (101079)

Parameter-Units	Measured Value	Number of Samples
Barium-µg/L	120.0	1
Magnesium-mg/L	14.0	1
Manganese-mg/L	0.1	1
Solids, Total Dissolved-mg/L	200.0	1
Specific conductance-umho/cm	310.0	1

Source: Data summarized from EPA's STORET database. Water quality sampling and analysis were completed by the Arizona Department of Environmental Quality.

3.5 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 million acre-feet. The reservoir is narrow, extending over 180 miles along the Colorado River and 80 miles up the San Juan River, with 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* – the numerous compacts, federal laws, court decisions and decrees, contracts, and regulatory guidelines that apportion and regulate the use of Colorado River water among the seven basin states and Mexico. Releases are also timed for hydropower production. Lake Powell is an important regional resource for water-based recreation. A comprehensive description of Lake Powell's water quality is presented in *Technical Memorandum 5.13 A Review of Water Quality and Treatment Issues* (MWH 2008). A summary of Lake Powell water quality is presented in Table 3-50.

Table 3-50 Summary of Raw Water Quality – Lake Powell	
Parameter	**Untreated Lake Powell Water**
Ammonia (mg/L as N)	< 0.03
Calcium (mg/L as Ca)	60 to 80
Calcium Carbonate Precipitation Potential (CCPP) (mg/L as $CaCO_3$)	3
Chloride (mg/L)	50 to 80
Conductivity (umhos/cm)	800 to 1100
Dissolved Oxygen (mg/L)	saturated
Langlier Saturation Index (LSI)	0.15
Magnesium (mg/L as Mg)	20 to 28
Nitrate (mg/L as N)	< 0.6
pH – std units	7.8 to 8.2
Potassium (mg/L)	2.5 to 4.0
Silica (mg/L as SiO_2)	7 to 9
Sodium (mg/L)	65 to 90
Sulfate (mg/L)	210 to 280
TDS (mg/L)	540 to 680
Temperature (C)	7 to 16
Total Alkalinity (mg/L as $CaCO_3$)	135 to 180
Total Hardness (mg/L as $CaCO_3$)	240 to 320
Total Organic Carbon (mg/L)	2.0 to 3.0
Source: MWH 2008	

3.6 Sand Hollow Reservoir

Sand Hollow Reservoir is a 50,000 ac-ft storage facility located about 5 miles southwest of Hurricane. The reservoir was constructed by Washington County Water Conservancy District (WCWCD) in 2002 and is used for culinary raw water supply for WCWCD customers. Water to fill the 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 ground water recharge facility for the Navajo Sandstone Aquifer. There are no beneficial use designations in the UAC for the Sand Hollow Reservoir.

Historical water quality data for the Sand Hollow Reservoir were obtained from a report produced by the United States Geological Survey (USGS) titled *Assessment of Managed Aquifer Recharge at Sand Hollow Reservoir, Washington County, Utah, Updated to Conditions through 2007.* A summary of the historical water quality is presented in Table 3-51.

Table 3-51
Summary of Historical Water Quality – Sand Hollow Reservoir

Date sampled	Water temperature (°C)	Specific conductance (µS/cm)	pH (standard units)	Dissolved oxygen (mg/L and percent saturation)	Chloride (mg/L as Cl)	Bromide (mg/L as Br)	Arsenic (µg/ L as As)
9/10/2002	24.2	1,000	8.8	2.3(30%)	76	0.02	2
12/18/2002	7.9	860	8.4	10.2(99%)	-	-	-
3/20/2003	11.1	830	8.2	8.4(100%)	-	-	0.9
5/6/2003	17.6	820	-	3.1(38%)	-	-	-
6/10/2003	23.6	850	8.2	8.8(115%)	-	-	-
8/6/2003	26	930	7.6	3.6(50%)	-	-	2
10/7/2003	21.9	910	8.4	-	79.5	0.03	2.3
1/8/2004	7.1	870	8.4	11.7(110%)	-	-	1.2
5/5/2004	17.3	710	8.2	8.5(101%)	50	0.01	1.1
9/22/2004	18.9	770	8.5	7.2(86%)	-	-	-
2/10/2005	8.3	860	8.4	11.3(106%)	56	0.02	1.5
1/18/2006	6.9	820	8.5	11.9(108%)	44.8	0.04	1.4
2/14/2007	5.1	760	8.1	11.6(101%)	50.4	0.05	1.8

Source: USGS, 2007

In general, water quality in Lake Powell is better than the surface water quality of the water bodies in the vicinity of the proposed project facilities. In addition, Lake Powell acts as a large sedimentation basin which allows for the settlement of large suspended solids. Therefore, the concentration of suspended solids of the water to be delivered via the LPP is reduced. This also reduces the amount of sediment transport into the receiving waters. Chapter 4 evaluates the impacts on surface water bodies that would caused by the proposed construction and operation of the LPP. The impact on TDS concentrations in the Sand Hollow Reservoir due to the mixing of raw water from Lake Powell is also evaluated in Chapter 4.

Chapter 4
Environmental Consequences (Impacts)

This chapter presents the potential impacts on surface water quality that would be caused by the proposed LPP construction and operation. The major surface water features in the vicinity of the proposed project facilities include Kanab Creek, Ash Creek, Mill Creek, LaVerkin Creek, Paria River, and Virgin River. Major surface water reservoirs in the vicinity of the proposed pipelines include Quail Creek Reservoir, Sand Hollow Reservoir, and Lake Powell. In addition, there are numerous ephemeral washes that could be impacted by the proposed LPP construction and operation.

New facilities proposed under the LPP Project are: intake facilities in Lake Powell, large water conveyance pipelines, booster pump stations, hydro generating stations, and transmission lines. Potential impacts on water quality from the proposed facilities include:

- Sediment transport and introduction of pollutants from equipment used during construction
- Sediment transport and introduction of pollutants from pipeline discharges during operation
- Changes in total dissolved solids from the addition of large volumes of Lake Powell water to Sand Hollow Reservoir
- Changes in water quality from volume changes (Lake Powell and downstream in the Lower Colorado River)

4.1 Significance Criteria

Impacts on water quality are considered significant if construction, operation or maintenance activities would result in any of the following conditions:

- Violation of applicable surface water quality standards
- Substantial degradation of surface water quality
- Substantial alteration of the existing drainage pattern of the site or area, including through alteration of a stream or river course in a manner resulting in substantial erosion or siltation on- or off-site

Criteria for evaluating water quality in the surface water bodies in the vicinity of the proposed pipelines are based on beneficial uses and water quality objectives as determined by the Utah Administrative Code R317-2 and the Arizona Administrative Code (AAC) R18-11-105. Water quality impacts on the surface water bodies in the vicinity of the proposed project facilities are qualitatively described in this section.

4.2 Alignment Alternatives

The LPP Project pipeline and transmission line alignment alternatives are briefly described in Chapter 1. Impacts on surface water quality could occur from construction of the proposed project facilities, and from operations and maintenance activities. The pipeline and penstock alignment alternatives share common segments between the intake at Lake Powell and delivery at Sand Hollow Reservoir, and they are spatially different in the area through and around the Kaibab-Paiute Indian Reservation. The South Alternative extends south around the Kaibab-Paiute Indian Reservation. The Existing Highway Alternative follows an Arizona state highway through the Kaibab-Paiute Indian Reservation. The Southeast Corner Alternative follows the Navajo-McCullough Transmission Line corridor through the southeast corner of the Kaibab-Paiute Indian Reservation. Impacts on water quality during construction and operation of the project would be common for all alignment alternatives since they all cross the major surface water features described in Chapter 3.

4.2.1 Construction Phase

Construction of the proposed pipelines and other project facilities would require extensive earthwork with the potential to significantly impact natural surface water features in the project area. In addition to the proposed pipelines, the project includes construction of booster pump stations, hydro generating stations, and transmission lines. Staging areas for equipment and personnel and creation of temporary construction roadways, if warranted, would further disturb surface soils and create the potential for water quality impacts.

4.2.1.1 Clearing and Grading

Clearing and grading would reduce vegetation along the cleared sections of the right-of-way thereby increasing the exposure of underlying soils to erosion. Excavated loose soil can be transported into adjacent water bodies via wind and stormwater flows. The use of heavy equipment for construction could also result in increased compaction of the underlying soils which has the potential to increase runoff into surface water bodies. The increased runoff could transport the sediment into the water bodies, resulting in increased turbidity levels and sediment recruitment rates in the receiving water body. An increase in the suspended sediments would increase turbidity, reduce light penetration, and potentially reduce photosynthesis and oxygen production. Dissolved oxygen can be further reduced in affected areas from oxygen consumption by the organic components of the sediment matter.

4.2.1.2 Open-Cut Crossings

There would be several open-cut crossings of surface waters along the LPP. Open-cut pipeline installation offers lower cost, greater continuity of pipeline installation, and less risk of encountering unknowns during construction compared to trenchless construction techniques.

Construction of open-cut crossings disturbs channel banks and sediments and could increase sediment loading downstream, ultimately adversely impacting receiving waters. The extent of the impact would depend on the volume of sediments disturbed, composition of channel materials including sediment particle size, and volume of storm flows during construction activity. These factors would determine the density and downstream extent of sediment migration. Open-cut construction activity can also dislodge and transport channel bed sediments which could cause changes in downstream bottom contours and stream flow dynamics that could cause additional erosion and downstream sedimentation. Construction of open-cut crossings in areas with shallow groundwater may require trench dewatering and surface discharge operations that may degrade surface water quality of the receiving waters.

Typically, open-cut pipeline installation would be restricted to surface water bodies with intermittent or seasonal flows and construction would occur in dry conditions. However, in cases where continuous flow must be maintained in a waterway and an open-cut installation is proposed, a temporary culvert, pipeline and/or pumping system could be used to divert flows around the pipeline trench and discharge flows downstream. Diversions designed to allow fish passage must maintain suitable temperature and dissolved oxygen conditions for the length of the diversion.

4.2.1.3 Trenchless Construction Techniques

Some of the waterway crossings within the State of Utah may require trenchless installation to protect environmental resources. The Utah Division of Water Rights may require compliance with Utah Administrative Code Section R655 National Resources, Water Rights, which requires trenchless crossings of natural streams with year-round flows. Two perennial streams that could be subject to trenchless crossing requirements include the Paria River and LaVerkin Creek.

Trenchless crossings involve underground construction methods that avoid surface impacts above the pipe crossing. Trenchless construction often generates less groundwater than open-cut construction. In environmentally sensitive areas, trenchless crossings are often favored or required by permitting agencies. Five trenchless methods have been considered for LPP construction of stream crossings: conventional bore and jack, pipe ramming, microtunneling, horizontal directional drilling, and blasting. All except blasting consist of tunneling an oversized casing below the waterbody to be crossed, using two temporary vertical access shafts on each side of the crossing. The vertical access shafts would be constructed of sheet piles, soldier piles and lagging, caissons or trench boxes – or unsupported if located in firm rock. When groundwater is present, watertight shoring such as sheet piles must be used along with a dewatering system.

A pipe crossing would be constructed by pushing several sections of steel casing pipe forward from the drive shaft toward the retrieval shaft as the cutter head (located at the forward end of the casing) is excavating the tunnel. Soil material cut by the cutter head would be routed back through the casing and out the drive shaft. Once the casing is installed and the interior soil removed, the pipeline would be slipped into the casing while it is supported on casing skids. The pipe would be welded to the direct buried pipe at either side of the crossing to form a continuous pipeline. The interstitial space between the transmission pipeline and the casing would be filled with sand or grout.

Depending upon the type of trenchless construction, substantial volumes of soils may be excavated and large areas may be required for the staging of the tunneling equipment. Therefore, trenchless construction could reduce direct impacts on surface waters as compared with open-cut crossings but would result in increased erosion potential related to earthwork for vertical access points, soil stockpiles, and equipment staging areas and discharges from dewatering.

Trenchless crossings for LPP pipeline construction would be marginally feasible at the Paria River and LaVerkin Creek. The Paria River pipeline crossing site would be a minimum of 500 feet long and could be more than 800 feet long, which is the feasible limit for most trenchless pipeline construction techniques. The east bank of the Paria River has limited topography for a driving or receiving pit; the west bank of the Paria River is a riparian area that runs parallel to the pipeline alignment for approximately 0.25 mile. Although the Paria River is classified as a perennial stream, it flows intermittently at the U.S. Highway 89 crossing during the summer and fall months, and the high cost of installing the pipeline using a trenchless construction technique would be unnecessary when an open-cut installation could be scheduled during a no flow period. The LaVerkin Creek pipeline crossing would be infeasible to construct using trenchless techniques because the west stream bank area is occupied by residential homes that would preclude construction of a driving or receiving pit.

4.2.1.4 Intake and Discharge Construction

Construction of the intake structure at Lake Powell and the tailrace structure at Sand Hollow Reservoir could have potential impacts on water quality in these two reservoirs. The intake construction would be performed by constructing vertical shafts in the Navajo sandstone rock adjacent to Lake Powell, and then boring horizontal tunnels from inside the shafts toward the vertical cliff face in the reservoir. Each tunnel would be advanced toward the lake, with the excavated rock removed through the tunnel and up out of the vertical shafts for upland disposal. When the tunnel construction would reach the cliff face, a small quantity of ground-up Navajo sandstone pieces would fall into Lake Powell, which is not expected to change the turbidity in the reservoir and would not violate the water quality standards. Stormwater runoff from surface construction activities would be controlled using silt fences and collection ponds to store and settle particles from turbid water. No water or material discharges to Lake Powell would occur from the surface construction activities.

Construction of the Sand Hollow Hydropower Station would involve the use of a temporary cofferdam around the tailrace excavation and construction area to isolate it from Sand Hollow Reservoir and maintain water quality. The cofferdam could involve the use of a water bladder dam system and then pumping the water from the construction site into portable tanks for settling suspended particles before disposal by land application. Therefore, the tailrace construction would be performed in dewatered conditions and would not cause uncontrolled turbidity or other water quality impacts in Sand Hollow Reservoir.

4.2.1.5 Summary of Construction Impacts

Installation of project facilities along any of the proposed alignments could result in extensive areas of construction disturbance and short-term erosion-related water quality impacts. Clearing, grading, excavation, soil stockpiles, and backfilling operations would all disturb stable soils potentially resulting in sediment transport (via wind or stormwater flow) to adjacent water bodies. In addition to sediment, stormwater runoff from construction areas can mobilize potential hazardous substances used in construction such as fuels, oils, antifreeze, coolants, paints, solvents, and other substances. Dewatering potentially required for facilities installation can result in discharges with high sediment loads. These operations could violate applicable surface water quality standards (e.g., result in a discharge with turbidity levels more than 10 NTU greater than the receiving water) and substantially degrade surface water quality (increase sedimentation), and established beneficial uses could be impaired. Furthermore, construction of project facilities would temporarily alter the existing drainage pattern of the project site in a manner that could result in substantial erosion and siltation. Pipeline trenches and tunnels can become diversion points for stormwater flows, altering local flooding patterns. Depending upon the quantity of the sediment carried along with the runoff and toxicity of any hazardous materials carried by the stormwater, the direct impact on receiving water bodies could be potentially significant.

Temporary water quality impacts may occur at any of the pipeline crossings of streams and washes if water is flowing during construction. The use of Best Management Practices (BMPs) and standard construction procedures (SCPs) at pipeline crossings of streams would avoid or minimize temporary water quality impacts, primarily consisting of turbidity and sediment recruitment. The BMPs and SCPs would include the following:

- Construction of pipeline crossings of dry washes would be performed when the washes are dry.
- Construction of pipeline crossings of perennial or intermittent flowing streams (e.g., Paria River

and LaVerkin Creek) would be performed when the streams are either at low flows or are dry.

- Silt fences and/or straw bales would be temporarily installed upstream or up-gradient of wetlands to filter suspended sediments and bedload sediments to avoid sedimentation impacts during construction. If necessary, silt fences and/or straw bales would be installed in series to control sediments and turbidity generated by construction activities.

- Water bladder dams or similar structures would be used as necessary to form temporary coffer dams upstream of pipeline crossings for diversion of Paria River and LaVerkin Creek flows during construction. Culvert pipes would be installed at the existing slope of the streams to divert flow around the pipeline crossing work area. Stream flows would be diverted through the culvert pipes to control turbidity during construction of the pipeline crossings.

- Equipment usage and operation within temporarily dewatered reaches of stream channels would be minimized to protect stream bed substrates.

- Construction equipment working within the temporarily dewatered reaches of stream channels would be checked and regularly monitored for leaking hydraulic fluid, oil, grease, and fuel.

- All construction equipment refueling would be performed on upland areas to prevent fuel spills from contaminating stream substrates and the dewatered stream reaches.

- Construction trenches within dewatered stream reaches would be pumped as necessary to remove subsurface water. The water would be pumped into portable tanks for settling, and then land applied away from the streams for disposal.

- Silt fences would be installed across the stream channels within the dewatered construction areas downstream of the pipeline crossing excavation to capture sediments that may be mobilized by precipitation events during construction activities. The silt fence toe would be anchored into the stream bed with native material. The silt fence would be removed following completion of the pipeline crossing construction and native material used to anchor the silt fence toe would be returned to pre-construction conditions.

Incorporating these BMPs and SCPs into pipeline construction at crossings of streams and washes would protect water quality and result in minimal or unmeasurable water quality impacts. There would be no significant impacts on water quality at stream crossings from pipeline construction.

Construction activities at the intake site on Lake Powell and at the Sand Hollow Hydropower Station tailrace would not have measurable impacts on reservoir water quality. There would be no significant water quality impacts from construction activities at either reservoir.

4.2.2 Operations Phase

Operation and maintenance of booster pump stations, hydro generating stations, and the transmission lines would not result in routine water discharges or cause other impacts on water quality. Where applicable, booster pump stations would have surface emergency overflow detention basins. However, operation and maintenance of the proposed pipelines would include occasional water discharges with the potential to impact natural surface water features in the project area. In addition, operation of the project would alter the inflow water source to Sand Hollow Reservoir and change the volume of water (and potentially water quality) in Lake Powell and downstream in the Lower Colorado River.

4.2.2.1 Maintenance Pipeline Discharges

4.2.2.1.1 Pipeline Flushing. Based on the preliminary design information, it is anticipated that water from Lake Powell would enter the intake structure at depths to approximately 350 feet below the water surface. It is anticipated that the untreated water pumped into the LPP would have low concentrations of suspended solids and turbidity because a high percentage of suspended solids in inflows to Lake Powell settle out below this level. However, some pipeline flushing may be required to remove the smaller particles which enter the LPP and manage to settle in the pipeline. Flushing would only be required when pipeline flows are low enough for long periods of time to allow particles to settle. Flushing would be accomplished by increasing the pipeline flow to near-maximum rates to re-suspend particles that may have settled in the pipeline at lower flows. The flushed water would be discharged into the LPP Project forebay reservoir above the Hurricane Cliffs.

It is anticipated that standard operating procedures for the project would include measures to divert flows generated from flushing operations away from surface water bodies, to settling tanks and/or retention/percolation basins.

4.2.2.1.2 Drain Valves. Drain valves for draining the proposed LPP pipeline segments for maintenance and repairs would generally be installed at low points in the pipeline profile. Pipeline segment draining would occur in January for up to 15 days. The Conveyance System portion of the pipeline would be drained back to the booster pump stations, and low points in the pipeline would be drained to dry washes. Pipeline water drained to dry washes would be discharged at low rates to avoid transporting sediments and causing local turbidity and sediment recruitment to flowing streams or reservoirs.

The standard operating procedures for the LPP Project would include measures to divert flows generated from opening the drain valves away from surface water bodies, to settling tanks and/or retention/percolation basins, if warranted, or to control the release velocity to avoid uncontrolled erosion.

4.2.2.1.3 Pigging. The proposed pipelines would include provisions for “pigging”. Pigging refers to the practice of using pipeline inspection gauges or 'pigs' to perform maintenance operations such as cleaning and inspection on a pipeline without stopping the flow of water through the pipeline. This is accomplished by inserting the pig into a section of the pipeline. Water pressure in the pipeline is used to push the pig along the length of the pipe until it reaches the desired segment from where it is then removed.

Slime buildup in the pipeline would decrease conveyance capacity and the proposed pipelines may have to be cleaned/pigged once or twice a year. Standard operating procedures for the LPP Project would include measures to divert organic wastes such as biofilms detached from the pipeline during pigging operations away from surface water bodies to settling tanks or retention basins.

4.2.2.2 Pipeline Rupture

Although highly unlikely, a pipeline rupture from exceedances of pipeline capacity, seismic activity, or other catastrophic event could result in discharge of large amounts of untreated water which might mix with the local surface water supplies. Potential adverse water quality impacts would be limited to increased velocity in the receiving water and potentially increased turbidity and sedimentation because the quality of Lake Powell water is generally superior to local surface waters.

4.2.2.3 Quagga Mussel Control Program

The proposed project may include measures such as chemical addition to control the potential infestation of quagga mussels in LPP facilities. Depending on the selected control method, water within project pipelines may contain disinfectants and/or disinfection by-products with the potential to impact local surface waters if released during maintenance activities as described above. If chemicals are introduced in the raw water for quagga mussel control, then water releases related to maintenance activities would be contained and treated as necessary prior to release to local surface waters as part of standard operating procedures.

4.2.3 Water Quality Impacts on Sand Hollow Reservoir

Lake Powell water quality is similar to or superior to the quality of local surface waters, including the Virgin River, which is the primary inflow source to Sand Hollow Reservoir. Therefore, the impact of LPP Project deliveries on Sand Hollow Reservoir is focused on potential changes in total dissolved solids (TDS) concentrations. A TDS mass balance model was completed for the LPP deliveries to Sand Hollow Reservoir. The model is based on an annual time step for a planning period ranging from year 2020 to year 2060. A salt balance is performed for each time step which tracks the inflows, the outflows, and the corresponding change in storage in the reservoir. It is assumed that complete mixing occurs within Sand Hollow Reservoir. Inflows to the reservoir include raw water deliveries from Lake Powell, direct precipitation, and discharges from the Virgin River. Outflows from the reservoir include water lost to evaporation, groundwater seepage, and planned releases from the reservoir to meet raw water demands. It is assumed that the initial (year 2020) storage volume in the reservoir is 50,000 acre-fee and the corresponding TDS concentration in the reservoir is 600 milligrams per liter (mg/L). The inflow and outflow components considered for this evaluation are described below.

4.2.3.1 Inflows

- **Phased delivery of raw water from Lake Powell via the LPP** – Table 4-1 lists the planned phased deliveries of raw water from Lake Powell to Sand Hollow Reservoir. Annual deliveries increase from approximately 1,975 acre-feet per year (acre-feet per year) in 2020 to approximately 69,000 acre-feet per year in 2037. Annual deliveries remain constant at 69,000 acre-feet per year after 2037 through 2060. The TDS concentration in the raw water is assumed to be 540 mg/L.

- **Direct precipitation on the Reservoir** – It is assumed that most of the precipitation in the area either evaporates or is consumed by native vegetation because of the minimal precipitation in the area and the arid landscape. Therefore, runoff resulting from precipitation is not included as an inflow component. However, direct precipitation on the reservoir is considered as an inflow component. It is assumed that direct precipitation does not add any TDS load on the reservoir. Historical average annual precipitation for the St. George area is assumed to be 0.7 feet based on information available from the Western Regional Climate Center of the Desert Research Institute (DRI 2010). An elevation-area-capacity relationship for the reservoir is presented in Table 4-2. This relationship is used to estimate the total surface area at the beginning of each time step. The product of the total reservoir surface area (in acres) and the average annual precipitation (in feet) yields the total volume contributed by direct precipitation.

Table 4-1
Phased Delivery of Raw Water from Lake Powell to Sand Hollow Reservoir

Year	Planned Deliveries 69,000 acre-feet/year
2020	1,975
2021	5,842
2022	9,972
2023	14,115
2024	18,229
2025	22,312
2026	26,366
2027	32,389
2028	36,383
2029	40,347
2030	44,704
2031	49,091
2032	53,442
2033	57,759
2034	62,040
2035	66,787
2036	69,000
2037	69,000
2038	69,000
2039	69,000
2040	69,000
2041	69,000
2042	69,000
2043	69,000
2044	69,000
2045	69,000
2046	69,000
2047	69,000
2048	69,000
2049	69,000
2050	69,000
2051	69,000
2052	69,000
2053	69,000
2054	69,000
2055	69,000
2056	69,000
2057	69,000
2058	69,000
2059	69,000
2060	69,000

Table 4-2
Elevation-Area-Capacity Relationship for Sand Hollow Reservoir

Elevation (feet)	Area (acres)	Capacity (acre-feet)
2,972	0	0
2,980	34	64
2,990	138	931
3,000	246	2,835
3,010	385	5,939
3,020	658	11,317
3,030	834	18,858
3,040	1,011	28,128
3,050	1,159	38,970
3,060	1,322	51,360

- **Inflows from the Virgin River** – It is assumed that water from the Virgin River would be discharged into the reservoir when the volume of water lost by the reservoir via evaporation and seepage exceeds the inflows into the reservoir from precipitation and LPP deliveries. If the volume of the inflow water (LPP deliveries and precipitation) is greater than the volume of water lost to evaporation and seepage, it is assumed that there would be no diversions from the Virgin River to Sand Hollow Reservoir. It is assumed that inflows from the Virgin River have an average TDS concentration of 550 mg/l.

4.2.3.2 Outflows

- **Evaporation** – Based upon a review of historical data at the Sand Hollow Reservoir site (USGS 2009), average annual evaporation of 5 feet (or 60 inches) is assumed. The elevation-area-capacity show on Table 4-2 is used to estimate the total surface area at the beginning of each time step. The product of the total reservoir surface area (in acres) and the average annual evaporation (in feet) yields the total volume lost by evaporation. It is assumed that no TDS load is lost to evaporation.

- **Groundwater seepage –** Based upon a review of historical data at the Sand Hollow Reservoir site (USGS 2009), average groundwater seepage of 11,856 acre-ft/year is assumed. The TDS concentration associated with groundwater seepage at any time-step is assumed to be same as the TDS concentration of the reservoir at the beginning of that time-step.

- **Outflows from the Sand Hollow Reservoir to meet water demands –** It is assumed that all raw water deliveries from Lake Powell would be used to meet demands after offsetting reservoir losses to seepage and evaporation. It is assumed that there would be no releases from the reservoir if the volume of water lost to evaporation and seepage is higher than the inflows into the reservoir.

4.2.3.3 Model Results

The model indicates that the TDS concentration in the reservoir increases initially as the salt load inflows into the reservoir exceed the outflows. As planned deliveries from Lake Powell increase over time, the

TDS concentration in the reservoir gradually decreases and eventually stabilizes at a concentration of 576 mg/l at the end of year 2060 under full deliveries of LPP water. The variation in the TDS concentration in the Sand Hollow Reservoir is depicted in Figure 4-1. In summary, a minor reduction in TDS concentration would be anticipated at Sand Hollow Reservoir from the delivery of raw water from Lake Powell.

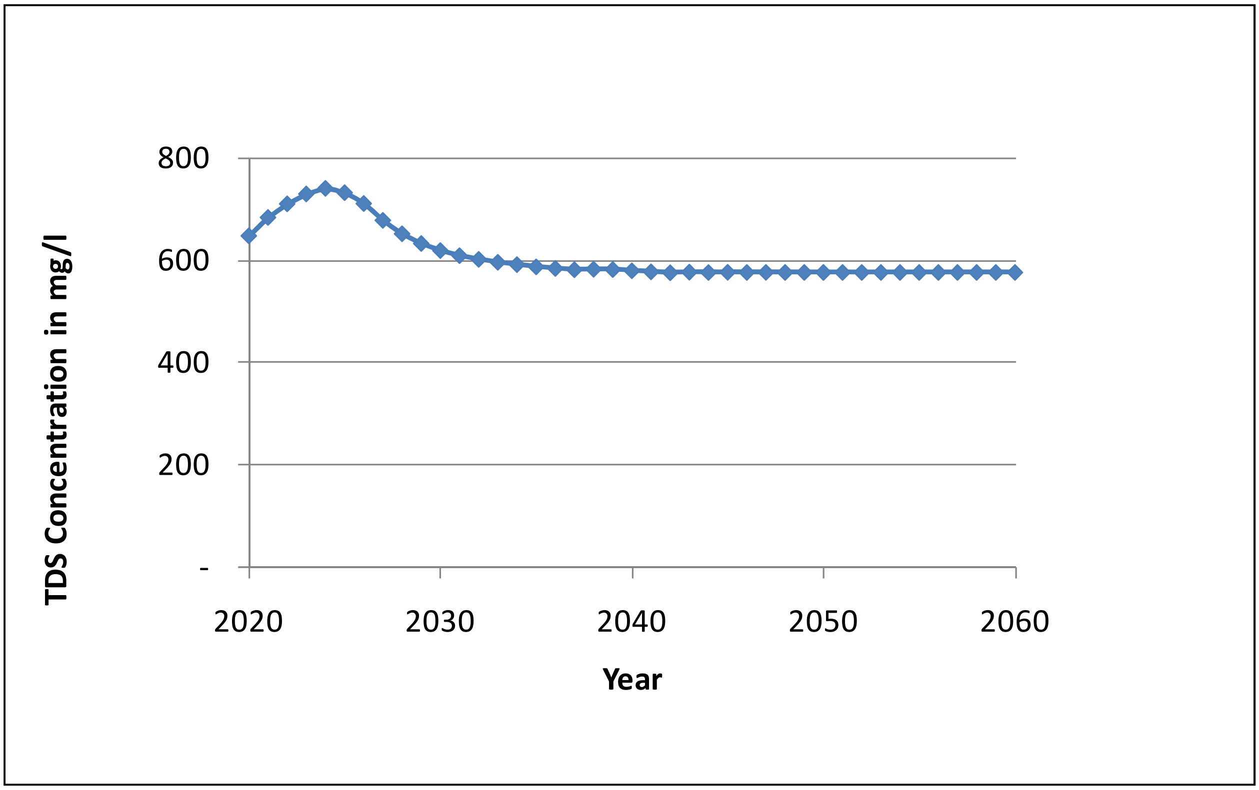

Figure 4-1
TDS Concentration versus Time (Sand Hollow Reservoir)

4.2.4 Water Quality Impacts on Lake Powell and the Lower Colorado River

Computer modeling was performed by the United States Bureau of Reclamation – Upper Colorado Region (Reclamation) to evaluate potential effects of the proposed LPP on temperature, total dissolved solids (TDS), and other water quality parameters for the following water bodies: Lake Powell, below Glen Canyon Dam, and the Lower Colorado River. The Colorado River Simulation System (CRSS) and Lake Powell CE-QUAL-W2 models were used to simulate water quality parameters in and below Lake Powell for the No Action and Proposed Action scenarios (USBR, 2010).

Water quality results from the Proposed Action pipeline diversion scenario were compared to the No Action Alternative scenario to determine effects, if any, on water quality. Water quality modeling results included temperature and dissolved oxygen in Lake Powell, temperature, TDS, and dissolved oxygen below Glen Canyon Dam from the CE-QUAL-W2 modeling, and TDS along the Lower Colorado River from the CRSS modeling. Other water quality parameters were simulated by the CE-QUAL-W2 model including nutrients and phytoplankton but quantitative results are not presented for these parameters. Additionally, CE-QUAL-W2 modeling of Glen Canyon Dam release temperatures at varying elevations was performed as part of the "Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead, Final Environmental Impact Statement" or Shortage Criteria EIS (U.S. Department of the Interior, 2007). Results from that modeling are interpreted based on the projected changes in Lake Powell water surface elevations as a result of the proposed LPP Project (USBR 2010).

4.2.4.1 Lake Powell

Lake Powell temperature and dissolved oxygen concentrations were evaluated at five day intervals for three reservoir locations and five depths. The three locations were above the dam, below the confluence of the San Juan River, and the upstream reservoir. The five depths were 5, 10, 25, 50, and 100 meters. Simulated reservoir temperatures for the 86K pipeline simulation were compared with the No Action Alternative simulation and were not different, on average, at depths above 25 meters and were 0.1°C colder at depths greater than 25 meters. Simulated reservoir dissolved oxygen concentrations for the 86K pipeline simulations were compared with the No Action Alternative simulation and were 0.1 mg/L lower at 25 and 50 meters and 0.3 mg/L lower at 100 meters (USBR 2010).

4.2.4.2 Glen Canyon Dam Releases

Modeled release results from Glen Canyon Dam for the No Action Alternative and Proposed Action pipeline simulations were evaluated for effects on temperature, TDS, and dissolved oxygen concentrations. Simulated mean dam release temperatures for the period 2045 to 2060 indicate that generally in the Proposed Action pipeline scenario, dam release temperatures are slightly colder in winter and spring months (colder by approximately 0.1°C) and slightly warmer (warmer by approximately 0.1°C) in summer and fall months compared with the No Action Alternative scenario (USBR 2010).

Glen Canyon Dam release temperatures often peak in October and simulated results show that when the reservoir is at or near full pool elevations, as was the case from 2050 to 2056, water temperatures of releases from the dam for the Proposed Action scenario were colder than in the No Action Alternative scenario. The release temperatures from the dam in the pipeline scenarios are colder when the reservoir is near full capacity because of the removal of warm water from the upper, warm layer of the reservoir by the pipeline. Simulated release temperatures for the Proposed Action scenario were warmer than the No Action Alternative scenario during summer and fall months when reservoir pool elevations were below full pool. The largest differences between the Proposed Action scenario and the No Action Alternative scenario coincided with the lowest reservoir pool elevations (USBR 2010). On average, the modeled results for the Proposed Action compared with the No Action Alternative were within 0.1°C for the 2045-2060 period. For individual years, differences of up to 0.91°C were predicted (USBR 2010).

TDS results from the No Action Alternative and Proposed Action models indicate that the average release TDS concentrations from 2045-2060 for the results of the three models are all within 1 mg/L of each other. The Proposed Action average TDS values are slightly higher than the No Action Alternative (USBR 2010).

Dissolved oxygen results from the No Action Alternative and Proposed Action models indicate that the average release dissolved oxygen concentrations from 2045-2060 for the three models are all within 0.11 mg/L of each other. The Proposed Action average dissolved oxygen concentrations are slightly lower than the No Action Alternative average DO concentrations (USBR 2010).

4.2.4.3 Lower Colorado River – Salinity

Numeric criteria have been established for salinity at three sites on the Lower Colorado River: below Hoover Dam, below Parker Dam, and above Imperial Dam. The salinity criteria at each of these sites are 723 mg/L, 749 mg/L, and 879 mg/L, respectively. The CRSS model simulated the period 2009 to 2060 using two inflow hydrology scenarios, direct natural flow (DNF) and nonparametric paleo-conditioned inflows (NPC). Under the DNF scenario, the historic record 1906-2006 was used to generate 101 simulations of the period 2009 to 2060. Under the NPC scenario, inflow hydrology was derived from tree-ring chronologies for 762 to 2005 on the Colorado River at Lee's Ferry and 125 simulations of the period 2009 to 2060 were generated.

The results of salinity modeling from the CRSS DNF hydrology and operations model comparing the No Action Alternative with the Proposed Action at these three sites indicate that no appreciable differences are found at the 90th, 50th, or 10th percentile levels. No appreciable differences were found under the NPC hydrology scenario (USBR 2010).

Detailed results of the water quality modeling are published in *Lake Powell Pipeline Water Quality Modeling Documentation* (USBR 2010) and are included in Appendix A of this report.

4.2.4.4 Summary of Operations Phase Impacts

A comparison of the raw water quality from Lake Powell and the water quality objectives for the major surface waters in the vicinity of the LPP is presented in Table 4-3. Based on the water quality simulation results, Lake Powell water quality would meet or be well within established water quality criteria and standards for the major surface water bodies in the vicinity of the proposed pipelines.

Table 4-3
Summary Comparison of Lake Powell Water Quality and Water Quality Criteria for Surface Waters in the Project Area

Parameter	Untreated Lake Powell Water	Numeric Criteria for Kanab Creek (UT)	Numeric Criteria for Ash Creek (UT)	Numeric Criteria for Mill Creek (UT)	Numeric Criteria for Paria River (UT)	Numeric Criteria for Virgin River (Below Quail Creek Diversion)	Numeric Criteria for Kanab Creek (AZ)	Numeric Criteria for Paria River (AZ)
Dissolved Oxygen (mg/L)	saturated	-	-	-	-	-	6	6
pH-Standard Units	7.8 to 8.2	6.5-9.0	6.5-9.0	6.5-9.0	6.5-9.0	6.5-9.0	6.5-9.0	6.5-9.0
TDS (mg/L)	540 to 680	1,200	1,200	1,200	1,200	1,200	-	-
Temperature (C)	7 to 16	27	27	20	27	20	-	-
Nitrate (mg/L as N)	< 0.6	4	4	4	4	4	-	-

Therefore, potential impacts on water quality considered for project operation include:

- Sediment transport and introduction of pollutants from pipeline discharges during operation
- Changes in total dissolved solids from the addition of large volumes of Lake Powell water to Sand Hollow Reservoir
- Changes in water quality from volume changes (Lake Powell and downstream in the Lower Colorado River)

Uncontrolled discharge of sediment or organics-laden water or disinfected water (if required for quagga mussel control) from the pipeline during maintenance operations could result in exceedence of water quality objectives in receiving waters. However, it is assumed that standard operating procedures for the LPP Project would include measures to divert pipeline discharges away from surface water bodies to settling tanks or retention basins and that any subsequent releases would be controlled to avoid adverse impacts. Discharges to surface waters during project operation, such as from a settling tank to a natural drainage, may be subject to UPDES or AZPDES permit requirements.

A TDS mass balance model for the LPP water delivery to Sand Hollow Reservoir indicates that TDS levels in Sand Hollow Reservoir would increase initially as the salt load of inflows exceeded outflows. Over time, however, TDS concentrations are predicted to stabilize at a level slightly below existing concentrations.

Modeling performed by Reclamation for water temperature, TDS and dissolved oxygen did not predict measurable or significant changes in Lake Powell, Glen Canyon Dam release, or in the Lower Colorado River for the Proposed Action compared with the No Action Alternative.

Therefore, with implementation of standard operation procedures to control pipeline discharges, operation of the LPP Project would not be anticipated to result in the violation of applicable surface water quality standards or cause substantial degradation of surface water quality or cause substantial alteration of the existing drainage pattern of the site or area.

4.2.5 Water Quality Impacts on the Virgin River

Water quality in the Virgin River would not be directly or indirectly affected by the Lake Powell Pipeline construction or operation. LPP construction activities would terminate at Sand Hollow Reservoir more than three miles east of the Virgin River. LPP project operation would supply raw water to Sand Hollow Reservoir for treatment in the Quail Creek Water Treatment Plant before distribution throughout the Washington County Water Conservancy District (WCWCD) service area. Following use in homes, businesses and institutions, the wastewater would be treated in wastewater treatment facilities and then further treated in the wastewater reclamation facility for reuse as secondary irrigation water. This water would be stored in existing and approved reservoirs in the St. George metropolitan area and used for outdoor watering. The Utah Division of Water Resources (UDWR) has modeled the Virgin River using the Virgin River Daily Simulation Model (VRDSM) for scenarios involving no LPP water and with LPP water to determine the potential for return flows to the Virgin River that could potentially affect stream flows and water quality. The VRDSM results indicate that LPP return flows to the Virgin River would be within the measurement accuracy of the USGS gages on the Virgin River and changes in river flows would not be measurable (UDWR 2011b). Therefore, potential impacts on stream flows and water quality in the Virgin River are eliminated from further analysis. A detailed analysis of the VRDSM model results is included in the draft Surface Water Resources Study Report (UBWR 2011).

4.3 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 restricting residential outdoor watering in the WCWCD and CICWCD service areas. This alternative could provide a total of 86,249 acre-feet of water annually to WCWCD, CICWCD and KCWCD for M&I use without diverting Utah's water from Lake Powell.

Construction of the facilities necessary for the No Lake Powell Water Alternative would result in water quality impacts related to soil disturbance and use of heavy equipment during construction. Construction impacts on water quality would be potentially significant and require the implementation of mitigation measures to reduce adverse effects.

Sand Hollow Reservoir would continue to receive Virgin River water as at present and water quality of the reservoir would be the same as existing conditions. The minor changes in temperature, TDS, and dissolved oxygen predicted for Lake Powell, Glen Canyon Dam release, and the Lower Colorado River would not occur with no diversion of Utah's water from Lake Powell.

Operation direct impacts could, however, include increased salt loading in surface waters from conservation measures increasing wastewater strength combined with increased wastewater reclamation. Additionally, the reverse osmosis treatment system would generate more than 3,700 acre-feet per year of brine which would require disposal. It is assumed that brine discharge would be via development of evaporation ponds because discharge of brine to surface water bodies would result in significant water quality impacts.

Indirect impacts under the No Lake Powell Water Alternative would be significant and include increased water temperatures in the Virgin River and tributary streams under the influence of groundwater recharge from outdoor watering in the St. George metropolitan area. The restrictions on residential outdoor watering would significantly reduce recharge and are expected to result in changing the Virgin River from a gaining stream during the summer and fall months to a losing stream year round. This indirect impact would cause the stream water temperatures to increase because the cooler groundwater discharging to the stream under baseline conditions helps control the water temperature during the summer and fall months.

Therefore, the No Lake Powell Water Alternative is expected to result in the violation of applicable surface water quality standards for temperature and cause substantial degradation of surface water quality. This would be a significant impact on water quality in the Virgin River and the organisms inhabiting the river.

4.3 No Action Alternative

Under the No Action Alternative, no new intake, water conveyance or hydroelectric features would be constructed or operated. 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 or released according to the operating guidelines. Future population growth as projected by the Utah Governor's Office of Planning and Budget

(GOPB) would continue to occur in southwest Utah until water and other potential limiting resources such as developable land, electric power, and fuel begin to curtail economic activity and population in-migration.

Under the No Action Alternative, none of the proposed project facilities would be constructed. Surface water features in the vicinity of the LPP would not be impacted by LPP construction activity and water quality would be expected to remain substantially the same as current conditions. Sand Hollow Reservoir would continue to receive Virgin River water as at present and water quality of the reservoir would be the same as existing conditions. Therefore, the No Action Alternative would not result in the violation of applicable surface water quality standards or cause substantial degradation of surface water quality or cause substantial alteration of the existing drainage pattern of the site or area.

Chapter 5
Mitigation and Monitoring

Construction of LPP Project facilities would result in extensive areas of construction disturbance and potentially significant, although short-term, water quality impacts. Erosion generating turbidity and sediment is the primary water quality concern during construction. In addition to sediment, stormwater runoff from construction areas can carry potential hazardous substances used in construction such as fuels, oils, antifreeze, coolants, paints, solvents, and other substances.

This section presents the types of measures to be implemented during project construction to mitigate the potential adverse impacts on surface water quality. These mitigation measures apply to the impacts associated with all proposed pipeline and transmission line alignments.

5.1 Compliance With NPDES Permitting

The proposed pipeline facilities for the conveyance of raw water from Lake Powell would pass through the states of Utah and Arizona. Both states have administrative programs for stormwater permitting in compliance with the National Pollution Discharge Elimination System (NPDES) permitting system. In Arizona, this program is called the Arizona Pollutant Discharge Elimination System (AZPDES). Arizona has general permit (AZG2008-001) that covers stormwater discharges from construction activities, except for those construction discharges in tribal lands. However, an individual permit is required when the general permit requirements do not accurately represent the activity at a facility and a permit is customized to the site. In Utah, this program is called the Utah Pollutant Discharge Elimination System (UPDES). Utah has a general permit (UTR300000) that covers stormwater discharges from construction activities. Alternately, an individual permit is issued for some construction projects.

In compliance with the NPDES permits for stormwater discharge associated with construction activity, a storm water pollution prevention plan (SWPPP) would be developed prior to the construction phase during final project design. The SWPPP would identify Best Management Practices (BMPs) that would be incorporated during construction to prevent or to minimize the entry of contaminants in the local surface water bodies. Implementation of the SWPPP would typically begin during initial clearing, grubbing, and grading operations, since these activities have the potential to increase erosion at the project sites. The SWPPP would be frequently referred to during the construction phase and amended as changes occur in construction operations, which could further reduce the potential for discharge of pollutants into the local surface water bodies.

The SWPPP would include the types of measures described in the following sections to mitigate the impacts on surface water quality during the construction of the proposed project facilities. The final SWPPP would be developed by, or in collaboration with, the contractor(s) and would be site-specific for each phase of the construction, and for all project facilities (pipelines, booster stations, transmission lines, hydro generating stations, etc.).

5.1.1 Erosion Control

BMPs for erosion control would be implemented to prevent the detachment of soil particles from the ground surface due to rainfall, wind, or flowing water. In general, steep slopes and large exposed areas in the vicinity of the construction site would require erosion control mechanisms. Erosion control BMPs would be implemented at slopes and areas where soil has been disturbed during construction. These areas would be protected from concentrated flows by intercepting, diverting, conveying, and discharging concentrated flows such that sediment removal and transport is prevented. Soil disturbed and stockpiled during construction would be moved to areas where there is minimum potential for accelerated erosion and sediment recruitment to streams and reservoirs. Selected BMPs to control erosion are described in the following sections.

5.1.1.1 Preservation of Existing Vegetation

Developed root systems of existing vegetation in the vicinity of the construction site hold the soil in place and prevent rapid drying of the soil thereby providing natural protection against erosion. Prior to clearing and grubbing activities, the contractor would develop a plan to preserve existing vegetation to minimize erosion. All vegetation identified for ultimate removal would be temporarily preserved and utilized for erosion control. Vegetated areas would be clearly marked and a buffer area would be provided to help to preserve these areas and take advantage of natural erosion prevention.

5.1.1.2 Soil Binders

The contractor(s) would use soil binders for disturbed areas that require temporary stabilization of the soil surface to prevent erosion caused by rainfall or wind. The binder would be selected based upon the type of the soil at the site. The selected soil binder would not be toxic to existing plant and animal life and would not pollute stormwater. Soil binders would be used only for flat, exposed areas and not for steep slopes. Soil binders would require a curing period of 24-hours upon application. Re-application may be required after storm events because soil binders offer only temporary protection. The soil binders can be plant-material based (guar, psyllium, starch, pitch and rosin emulsion etc.), polymeric emulsion based (acrylic copolymers and polymers, hydro-colloid polymers etc.), or cementitious based (gypsum, etc.).

5.1.1.3 Matting

For surfaces with slopes steeper than 3H:1V, the contractor(s) could install mats of natural materials to cover the soil surface to minimize erosion caused by the impact of rainfall. Such mats are generally installed in areas where the flow velocities are between 3 feet per second (fps) and 6 fps. The selected material would not be toxic to existing plant and animal life and would not pollute stormwater. The choice of the matting material is usually governed by the size of area, side slopes, surface conditions such as hardness, moisture, weed growth, and availability of materials. Geotextiles, plastic covers, and erosion control blankets are some of the natural and synthetic mattings commonly used. Organic matting materials have been found to be effective where re-vegetation would be provided by re-seeding. Jute, straw blanket, wood fiber blanket, coconut fiber blanket, coconut fiber mesh, etc. are some examples of organic matting materials.

5.1.1.4 Runoff Interception and Diversion

In order to prevent runoff from washing away disturbed soil, the contractor(s) would plan and design temporary structures to divert runoff to a designated location such as a sediment basin or trap. This would be performed by constructing drainage swales and earth dikes in areas where runoff is expected to impact an erodible area. An earth dike is a ridge constructed from compacted soil while a drainage swale is a sloped depression in the soil. Depending on the intensity of the storm and the expected flow rate, permanent structures may also be constructed to intercept and divert runoff. Diversion structures concentrate surface runoff and increase the flow velocity. All flows from the diversion structure would be directed to a flow stabilization structure such as a sediment basin which also allows for the settling of suspended solids. The contractor may install check dams along the drainage swales to reduce the effective slope of the channel, thereby reducing the velocity of flowing water, allowing sediment to settle and reduce erosion and sediment recruitment.

5.1.1.5 Dust Control

The contractor(s) would implement dust control measures to prevent sediment erosion and transport through wind. The contractor(s) would monitor the direction of the prevailing winds and plan accordingly for dust control. Disturbed soil would either be covered in small stockpiles or water or soil binders would be applied to keep them moist. Dust control by watering would have to be carried out at pre-determined intervals to avoid drying and erosion of the disturbed soil. The contractor(s) would also ensure that over watering does not occur. All trucks that haul soil would be equipped with covers for adequate dust control. The contractor(s) would implement track in/track out devices to reduce the transport of sediments by vehicles at specific locations.

5.1.2 Sediment Control

BMPs for sediment control would be implemented to prevent the transport of sediment particles by rain, wind, or flowing water. These BMPs would intercept and detain the runoff to allow sediment to settle and be trapped. Sediment control BMPs would be used in conjunction with erosion control BMPs to increase their effectiveness. Selected BMPs for sediment control are described in the following sections.

5.1.2.1 Silt Fence and Sandbag Barriers

The contractor(s) would install silt fences in areas where sediment transport occurs because of runoff in the form of sheet flows on level ground. A silt fence is made of a filter fabric attached to supporting poles and supported by wire mesh. The silt fence detains the flow, leading to sediment deposition behind the fence. In most cases, the detained water would be allowed to evaporate. Silt fences are temporary sediment control structures and would not be used in areas where the runoff is concentrated. The contractor would install sandbags to intercept and detain sheet flows. Unlike silt fences that can only be used on level ground, sand bags can be used on slopes to impound runoff and facilitate sedimentation. Sediment laden flows impounded and/or diverted by these structures may be directed to a sediment basin for settling and evaporation.

5.1.2.2 Sediment Basin

Prior to clearing and grubbing activities, the contractor(s) would develop a plan for identifying and constructing sediment basins at the construction sites. The sediment basins would be designed based on factors such as rainfall intensity, the expected precipitation volume, and the runoff flow rate. The sediment basins would be located such that they intercept maximum runoff from the disturbed areas. The contractor(s) would install sediment basins to allow settling of the suspended particles prior to discharging the runoff into a receiving water body. A sediment basin is a temporary structure formed by excavation or by the construction of an embankment. The contractor(s) would maintain the sediment basin until the site area is permanently protected against erosion. During construction, the contractor(s) would make provisions for the removal of accumulated sediments in the basin.

5.1.3 Hazardous Material Control

In order to minimize the potential for spills of potential contaminants into the surface water bodies, BMPs would be developed to identify specific fueling areas for construction vehicles and equipment. Procedures for handling hazardous material would be developed. Catch basins and absorbent pads to intercept fuel and other discharges from sedentary equipment would be developed. It is anticipated that the implementation of these BMPs would mitigate the potential impacts of contaminants entering receiving waters.

5.1.4 Final Site Stabilization

Implementation of construction BMPs is completed when final site stabilization can be documented. All disturbed areas must be either built on, paved, re-vegetated or have equivalent permanent, physical post-construction erosion controls in place. For stream crossings, bank re-contouring to close to pre-project conditions and revegetation would be completed. Where implemented, specific standards for revegetation would apply (e.g., 70 percent of pre-disturbance plant density is considered to be “finally stabilized” per the Utah NPDES stormwater general permit).

5.2 Compliance Monitoring

Compliance of the contractor(s) with the measures outlined in the SWPPP would be monitored as part of the overall project monitoring of environmental commitments. Routine inspection of BMPs would be required to confirm effectiveness, identify deficiencies and then document that deficiencies have been adequately addressed.

Chapter 6
Unavoidable Adverse Impacts

6.1 Proposed Action

6.1.1 Construction

Implementation of best management practices (BMPs), standard construction procedures (SCPs) and storm water pollution prevention plan (see Chapters 4 and 5) would minimize adverse impacts on surface water quality under any of the LPP alignment alternatives. Some temporary, direct and indirect adverse impacts could occur on surface water quality. Potential unavoidable adverse impacts include unmeasurable or minor increases in turbidity and sediment recruitment at perennial stream crossing sites.

6.1.2 Operation and Maintenance

Operation and maintenance of the Proposed Action would have a minor unavoidable adverse impact on surface water quality in Sand Hollow Reservoir. Total dissolved solids (TDS) concentrations would initially increase over baseline conditions as the salt load in the LPP inflow water exceeds the outflow from Sand Hollow Reservoir. Water quality modeling indicates the TDS concentration would decrease after the first several years of LPP operation as the LPP water with lower TDS concentration becomes the primary inflow source to Sand Hollow Reservoir. The TDS concentration would be lower than baseline conditions after 2028 and would stabilize at a lower concentration through 2060. There would be no other unavoidable adverse impacts on surface water quality under the Proposed Action.

6.2 No Lake Powell Water Alternative

The No Lake Powell Water Alternative is expected to have significant and unavoidable adverse indirect impacts on surface water quality in the Virgin River and tributaries under the influence of groundwater recharge from the St. George metropolitan area and Cedar Valley. Restrictions on residential outdoor landscape watering would reduce groundwater recharge and decrease subsurface return flows to the Virgin River, its tributary streams and Cedar Valley streams within the influence of local groundwater recharge. The decrease in subsurface return flows could adversely affect stream flows and increase water temperatures, with exceedance of temperature criteria during the summer months.

6.3 No Action Alternative

No unavoidable adverse impacts would occur.

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 cumulative impacts analysis is pending completion for identification of inter-related projects that would cause cumulative impacts with the LPP project.)

7.2 Existing Highway Alternative

(The cumulative impacts analysis is pending completion for identification of inter-related projects that would cause cumulative impacts with the LPP project.)

7.3 Southeast Corner Alternative

(The cumulative impacts analysis is pending completion for identification of inter-related projects that would cause cumulative impacts with the LPP project.)

7.4 Transmission Line Alternatives

(The cumulative impacts analysis is pending completion for identification of inter-related projects that would cause cumulative impacts with the LPP project.)

7.5 No Lake Powell Water Alternative

(The cumulative impacts analysis is pending completion for identification of inter-related projects that would cause cumulative impacts with the LPP project.)

7.6 No Action Alternative

The No Action Alternative would have no cumulative impacts.

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Appendix A
Water Quality Modeling Documentation

This section contains the documentation for the modeling and analyses performed by the U.S. Bureau of Reclamation (Reclamation) to evaluate the potential effects on water quality constituents of concern. Three different models were used to evaluate different water quality parameters and each is described in this appendix. The salinity module of the CRSS RiverWare™ model was used to evaluate changes in salinity concentrations for all alternatives. The CE-QUAL-W2 model was used to evaluate potential changes in temperature and water quality between the no action and action alternatives.

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Figures

A. Executive Summary - Lake Powell Pipeline Water Quality Modeling Documentation

Computer modeling was utilized to evaluate potential effects of the proposed Lake Powell Pipeline on temperature, total dissolved solids (TDS), and other water quality parameters. This section summarizes the water quality models and results. Detailed descriptions of the models, methods, and results are found in the Sections B through F.

A.1 Model Descriptions

The CRSS and Lake Powell CE-QUAL-W2 models were used to simulate water quality parameters in and below Lake Powell for the No Action, 86,000 acre-feet pipeline diversion, and 100,000 acre-feet pipeline diversion scenarios.

A.1.1 CRSS: Salinity Modeling

The CRSS Model is a rule-based simulation of operations in the Colorado River Basin based in the Riverware™ Modeling framework developed by CADSWES at the University of Colorado at Boulder. The version of the CRSS Model that was used for the hydrological and operational simulations of the Lake Powell Pipeline was also used to simulate salinity, or TDS, in the Colorado River Basin. The salinity model routes salinity through major stream reaches and seven reservoirs (Flaming Gorge, Starvation, Navajo, Powell, Mead, Mohave, and Havasu) in the Colorado River Basin. The model is intended for long-term simulations of salinity (15-20 years).

The model simulated the period 2009 to 2060 using two inflow hydrology scenarios, direct natural flow (DNF) and nonparametric paleo-conditioned inflows (NPC). In the DNF scenario the historic record 1906-2006 was used to generate 101 simulations of the period 2009 to 2060. In the NPC scenario inflow hydrology was derived from tree-ring chronologies for 762 to 2005 on the Colorado River at Lee's Ferry. 125 simulations of the period 2009 to 2060 were generated.

A.1.2 CE-QUAL-W2: Water Quality Modeling

CE-QUAL-W2 is a water quality model developed by the US Army Corps of Engineers for simulating hydrodynamics and water quality in long, narrow waterbodies such as reservoirs. The Lake Powell CE-QUAL-W2 Model calibrated to the historic time period 1990-2008 was used as the base for simulations of the Lake Powell Pipeline. The model simulates temperature, TDS, dissolved oxygen, nutrients, and algae in the reservoir and releases from Glen Canyon Dam.

The CE-QUAL-W2 simulations used results from the CRSS DNF hydrology simulations as inputs for tributary inflows and dam outflows in the water quality model scenarios. One of the 101 CRSS DNF hydrology simulations was selected to determine these inputs. From the simulation period 2009 to 2060 the years 2043 to 2060 were selected to use directly in the CE-QUAL-W2 model. This period was selected because the simulation years 2043 to 2060 corresponded to the natural flow years 1989-2006. This allowed other CE-QUAL-W2 inputs such as meteorology to use historical data.

A.2 Results

Water quality results from the two pipeline diversion scenarios were compared to the no action scenario to determine effects, if any, on water quality. Water quality modeling results included temperature and dissolved oxygen in Lake Powell, temperature, TDS, and dissolved oxygen below Glen

Canyon Dam from the CE-QUAL-W2 modeling, and TDS along the Lower Colorado River from the CRSS modeling. Other water quality parameters were simulated by the CE-QUAL-W2 model including nutrients and phytoplankton but quantitative results are not presented for these parameters. Additionally, CE-QUAL-W2 modeling of Glen Canyon Dam release temperatures at varying elevations was performed as part of the "Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead, Final Environmental Impact Statement" or Shortage Criteria EIS (U.S. Department of the Interior, 2007). Results from that modeling are interpreted based on the projected changes in Lake Powell water surface elevations as a result of the proposed Lake Powell Pipeline.

A.2.1 Lake Powell

Lake Powell temperature and dissolved oxygen concentrations were evaluated at five day intervals for three reservoir locations and five depths. The three locations are above the dam, below the confluence of the San Juan River, and the upstream reservoir. The five depths were 5, 10, 25, 50, and 100 meters.

Simulated reservoir temperatures in the 86K and 100K pipeline simulations were compared with the no action simulation and were not different, on average, at depths above 25 meters and were 0.1°C colder at depths greater than 25 meters.

Simulated reservoir dissolved oxygen concentrations in the 86Kand 100K pipeline simulations were compared with the no action simulation and were 0.1 mg/L lower at 25 and 50 meters and 0.3 mg/L lower at 100 meters.

A.2.2 Glen Canyon Dam

Modeled release results from Glen Canyon Dam for the no action, 86K pipeline, and 100K pipeline simulations were evaluated for effects on temperature, TDS, and dissolved oxygen concentrations.

Simulated mean dam release temperatures for the period 2045 to 2060 are shown in Table A-1 by month. Generally in the 86K and 100K pipeline scenarios dam release temperatures are slightly colder in winter and spring months and slightly warmer in summer and fall months compared with the no action scenario.

Table A-1: Glen Canyon Dam Release –Monthly Simulated Mean Temperatures, 2045-2060

Month	NA	86K	100K
January	9.15	9.05	9.04
February	8.05	7.96	7.96
March	7.81	7.75	7.75
April	8.08	8.04	8.04
May	8.57	8.56	8.56
June	8.95	8.98	8.99
July	9.20	9.23	9.25
August	9.67	9.76	9.78
September	10.26	10.32	10.34
October	10.61	10.69	10.72
November	10.86	10.91	10.92
December	10.52	10.44	10.45

Glen Canyon Dam release temperatures often peak in October and simulated results for that month (Table E-2) show that when the reservoir is at or near full pool elevations, as was the case from 2050 to 2056, temperature releases from the dam in the pipeline scenarios were colder than in the no action scenario. The release temperatures from the dam in the pipeline scenarios are colder when the reservoir is near full capacity because of the removal of warm water from the upper, warm layer of the reservoir by the pipeline. Simulated release temperatures in the pipeline scenarios were warmer than the no action scenario during summer and fall months when reservoir pool elevations were below full pool. The largest differences between the pipeline scenarios and the no action scenario coincided with the lowest reservoir pool elevations.

Table A-2: Glen Canyon Dam Release – Simulated October Temperatures, 2045-2060

Month	NA	86K	100K
Oct-45	10.54	10.57	10.58
Oct-46	10.83	11.00	11.04
Oct-47	10.58	10.83	10.86
Oct-48	10.12	10.32	10.37
Oct-49	10.88	11.07	11.09
Oct-50	9.54	9.34	9.31
Oct-51	9.74	9.53	9.51
Oct-52	9.59	9.47	9.47
Oct-53	9.92	9.82	9.82
Oct-54	9.52	9.46	9.45
Oct-55	8.80	8.61	8.61
Oct-56	8.99	8.95	8.96
Oct-57	11.10	11.11	11.12
Oct-58	12.54	12.75	12.81
Oct-59	13.79	14.51	14.70
Oct-60	13.24	13.66	13.73
Average	**10.61**	**10.69**	**10.72**

TDS results from the no action, 86K pipeline, and 100K pipeline models are shown in Figure A-1. Overall, the average release TDS concentrations from 2045-2060 for the results of the three models are all within 1 mg/L of each other. The 86K pipeline and 100K pipeline average TDS are just higher than the no action average.

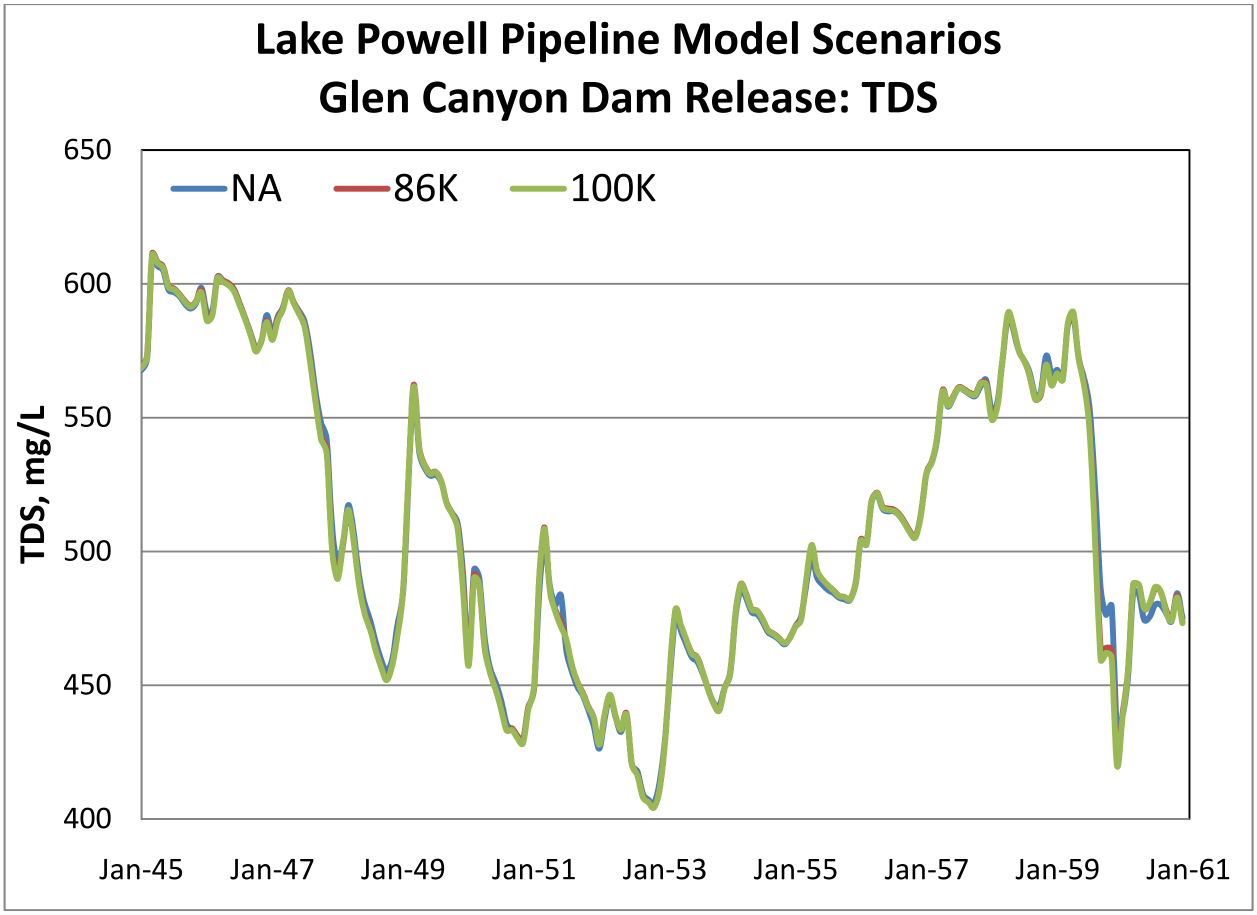

Figure A-1: Lake Powell Pipeline Models – Release TDS, 2045-2060

Dissolved oxygen results from the no action, 86K pipeline, and 100K pipeline models are shown in Figure A-2. Overall, the average release dissolved oxygen concentrations from 2045-2060 for the results of the three models are all within 0.11 mg/L of each other. The 86K pipeline and 100K pipeline average dissolved oxygen concentrations are just lower than the no action average.

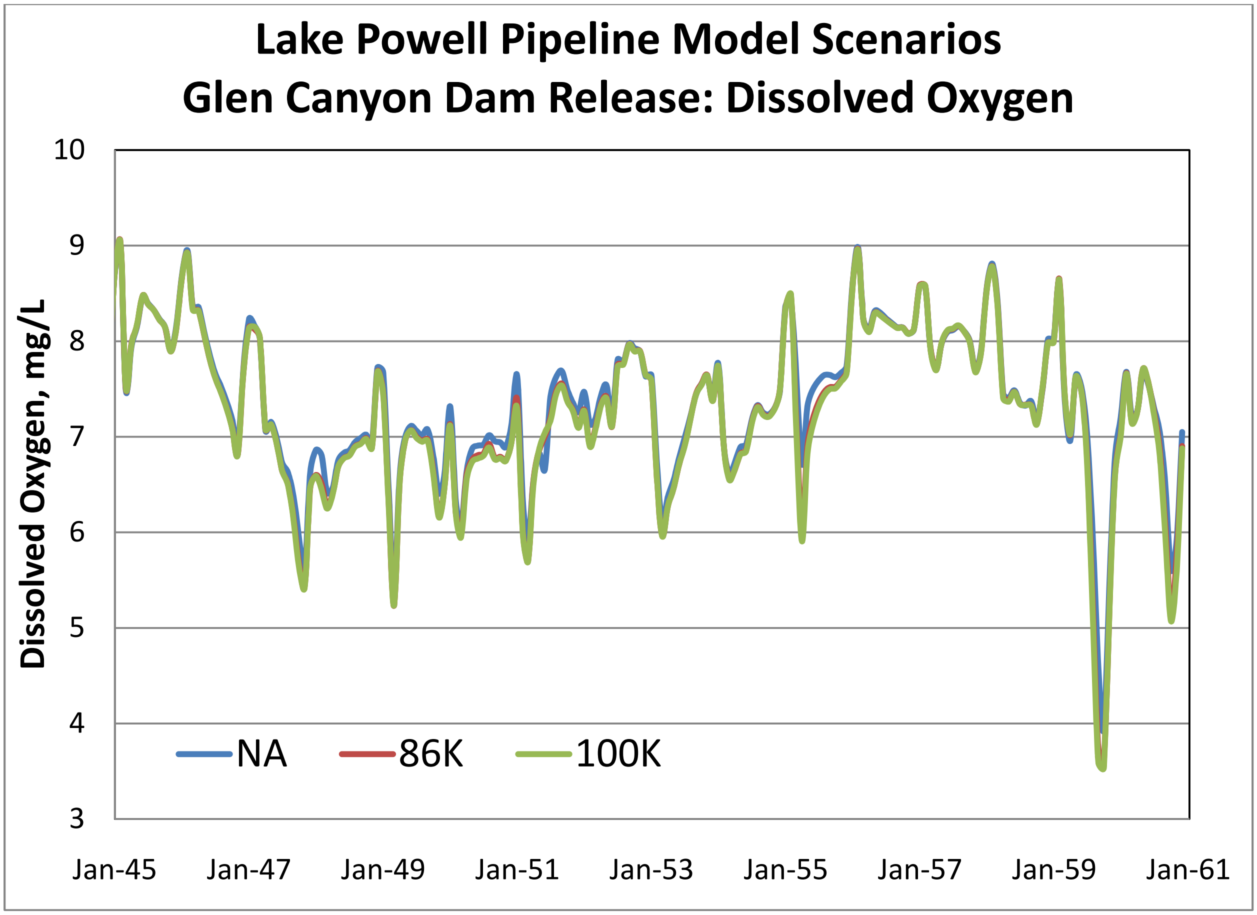

Figure A-2: Lake Powell Pipeline Models – Dissolved Oxygen Release, 2045-2060

A.2.3 Lower Colorado River – Salinity

Numeric criteria for salinity have been established for salinity at three sites on the Lower Colorado River: below Hoover Dam, below Parker Dam, and above Imperial Dam. The criteria at each of these sites are 723 mg/L, 749 mg/L, and 879 mg/L respectively. The results of salinity modeling from the CRSS DNF hydrology and operations model comparing the no action alternative with the 86,000 acre-feet pipeline diversion alternative at these three sites are shown in Figure A-3, Figure A-4, and Figure A-5, respectively. In each case no appreciable differences are found at the 90th, 50th, or 10th percentile levels. No appreciable differences were found for the 100,000 acre-feet pipeline diversion or for the NPC hydrology scenario.

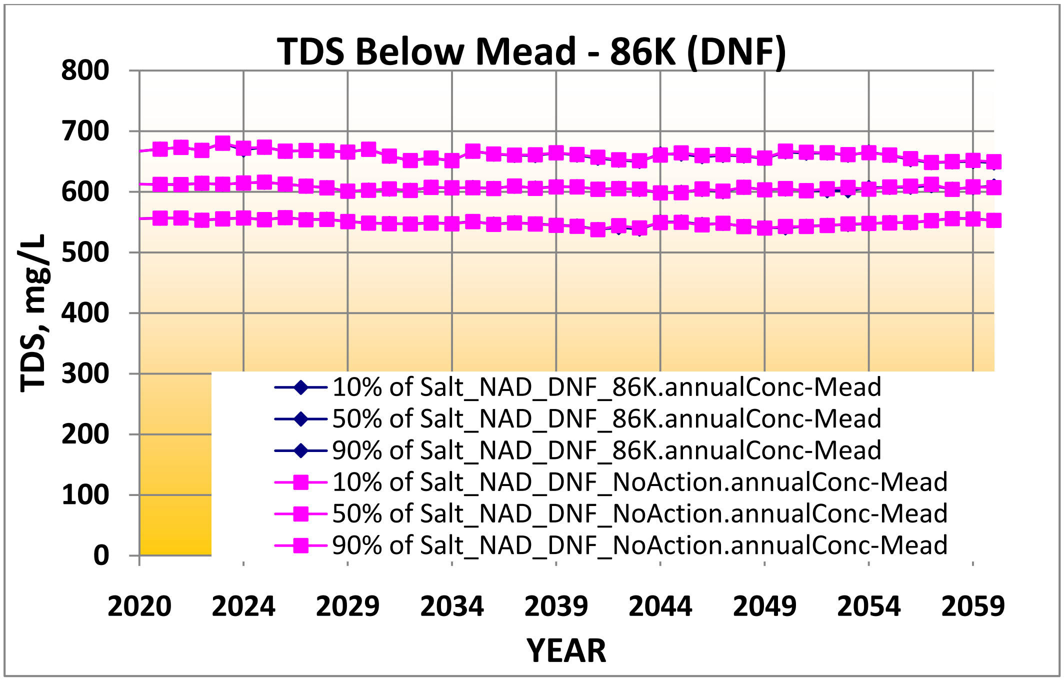

Figure A-3: CRSS DNF results – TDS below Lake Mead, 86K Pipeline Alternative, 2020-2060

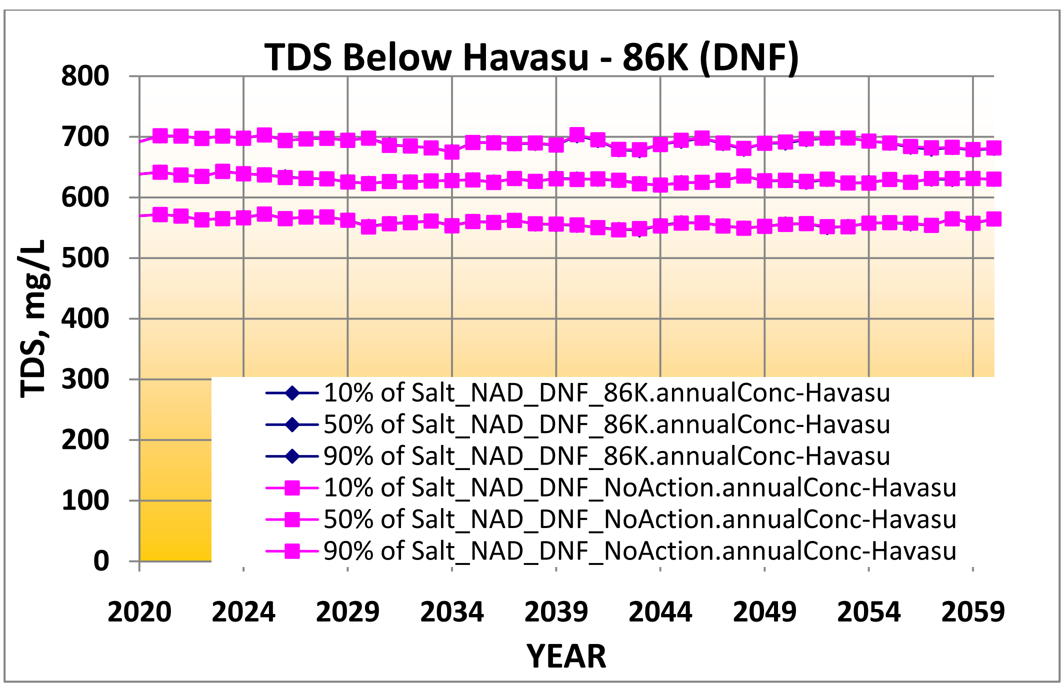

Figure A-4: CRSS DNF results – TDS below Lake Havasu, 86K Pipeline Alternative, 2020-2060

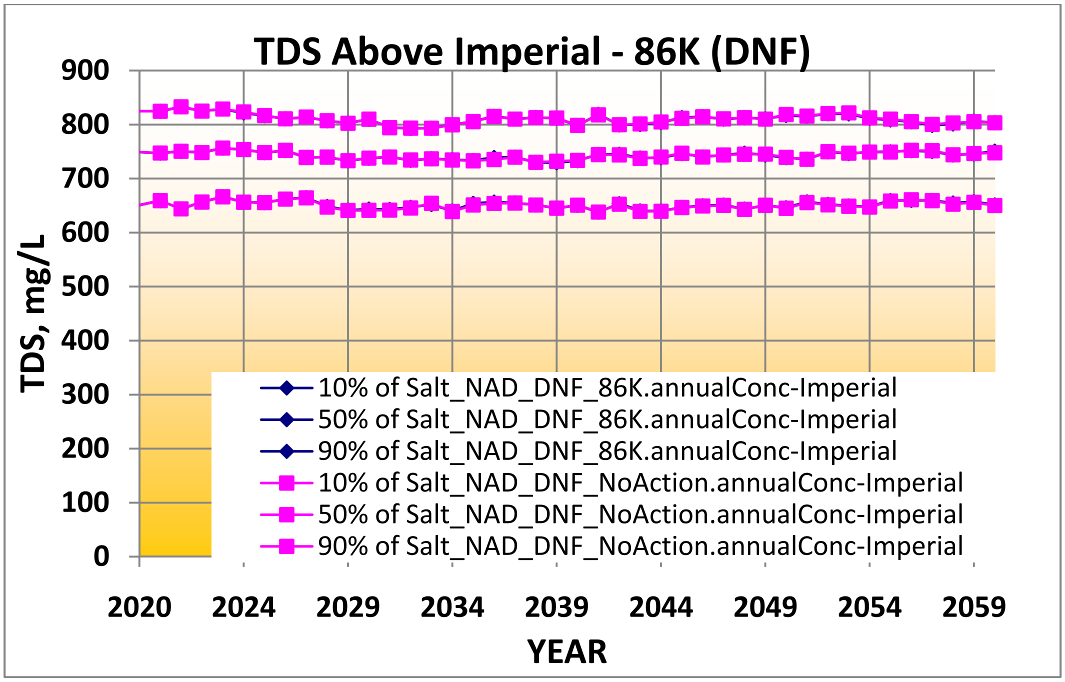

Figure A-5: CRSS DNF results – TDS above Imperial, 86K Pipeline Alternative, 2020-2060

A.2.4 Shortage Criteria EIS Modeling Results

A different approach to estimating release temperatures from Glen Canyon Dam was made to verify results from the CE-QUAL-W2 model and to provide estimates of temperatures for the more extreme drawdown of Lake Powell as shown by the results of the CRSS NPC model. This approach used the results of the Shortage Criteria EIS analysis of Glen Canyon Dam release temperatures to estimate the range of release temperatures during the months of July and October. Specifically, monthly reservoir pool elevations at the 90th, 50th, and 10th percentile levels as predicted by the CRSS model were used to determine release temperatures based on historical and modeled data. Table A-3 compares release temperatures of the no action and 86,000 acre-feet pipeline diversion alternatives for the DNF hydrology scenario's 90th, 50th, and 10th percentiles. Table A-4 compares release temperatures of the no action and 86,000 acre-feet pipeline diversion alternatives for the NPC hydrology scenario's 90th, 50th, and 10th percentiles.

Table A-3: No Action & 86K Pipeline DNF Pool Elevations & Release Temperatures

Scenario	Month	90th		50th		10th	
		Elev, ft	Temp, °C	Elev, ft	Temp, °C	Elev, ft	Temp, °C
No Action – DNF	July	3700.00	8.5 – 11	3678.71	8 – 11.5	3615.12	8 – 14
	October	3691.41	8.5 – 12	3673.83	7.5 – 12.5	3606.85	9.5 – 19
86K – DNF	July	3700.00	8.5 – 11	3675.94	8 – 11.5	3609.21	8 – 14
	October	3691.31	8.5 – 12	3669.67	7.5 – 12.5	3599.83	9.5 – 19

Table A-4: No Action & 86K Pipeline NPC Pool Elevations & Release Temperatures

Scenario	Month	90th		50th		10th	
		Elev, ft	Temp, °C	Elev, ft	Temp, °C	Elev, ft	Temp, °C
No Action – NPC	July	3700.00	8.5 – 11	3680.73	8 – 11.5	3550.98	11 – 21
	October	3691.36	8.5 – 12	3675.6	7.5 – 12.5	3537.55	13 – 22
86K – NPC	July	3700.00	8.5 – 11	3678.63	8 – 11.5	3542.09	11.5 – 22
	October	3691.19	8.5 – 12	3673.7	7.5 – 12.5	3527.64	13 – 22

Differences in temperature releases between the 86K pipeline and no action alternatives are unlikely to be apparent unless the reservoir is significantly drawn down and the differences in pool elevations are near or greater than 10 feet. The CRSS results for the NPC hydrology datasets have greater reductions in pool elevations for the 10th percentile and differences in release temperatures are more likely to be apparent. Even so, the estimated temperature ranges at the 10th percentile pool elevations for the 86K pipeline and no action alternatives differ by no more than 1°C in July and do not differ significantly in October. These results are consistent with release temperature results of the CE-QUAL-W2 modeling.

B. Salinity Modeling Using the Salinity Module of the CRSS RiverWare™ Model - Model and Approach Description

B.1 Model Description (Salinity Module of the CRSS RiverWare™ Model)

Salinity is the only water quality parameter modeled in CRSS. It is modeled as a conservative substance; therefore, dissolution and precipitation are not modeled. As with the hydrology component, salinity is modeled at a monthly time step and both reservoir and reach objects are assumed fully mixed over the month; thereby, requiring no lagging algorithms to route salt.

Seven of the twelve reservoirs (Flaming Gorge, Starvation, Navajo, Powell, Mead, Mohave, Havasu) are represented in CRSS model salinity. The reservoirs Flaming Gorge, Navajo, Powell, Mead, and Mohave use a Huen or Predictor-Corrector numerical method to route salinity through the reservoirs. The reservoirs Starvation and Havasu use a weighting method developed by Reclamation that facilities routing salinity in a reservoir that has a small storage to inflow ratio. Under this scenario standard numeric methods, such as the Huen method, can become numerically unstable. Both methods assume the reservoirs are fully mixed at a monthly time step. Flaming Gorge, Powell, and Mead include salinity in their bank storage computation. Water flows into the bank at the current time step concentration and fully mixes with the “bank” water. Water flows out of the “bank” at the current time step “bank” concentration.

Salt can enter the river system from either a natural source, salt loading resulting from irrigated agriculture return flows, or from flows imported into the system. Salt can leave the system from flows exported out of the system. Additionally, water quality improvement projects represent salt prevented from entering the system as the result of salinity control measures.

B.2 Input data

The CRSS salinity component requires several salinity specific data inputs. These include natural salinity at 24 nodes throughout the Colorado River System, future levels of salt loading resulting from agriculture, the concentration of exported and imported flows, future levels of salinity control, and initial reservoir salinity concentrations.

Salinity associated with the available natural flow data (described in Section 3.3) is computed with a single site salinity model (Prairie, Rajagopalan, Fulp, & Zagona, 2005). This model uses a nonparametric regression method based on local polynomial estimation, which describes the variability of salt mass as a function of flow. The model is defined as: natural salt mass = f(natural streamflow) The main feature is that the function f is estimated locally. The implementation steps are as follows.

1) At any value of the streamflow, say x*, K-nearest neighbors (K-NN) are identified from the observations.

2) To the K-NN a polynomial of order p is fit.

3) The fitted polynomial is then used to estimate the salt mass corresponding to the streamflow x*.

The number of nearest neighbors (K) and the order of polynomial p are estimated for the observed data using objective criteria, Generalized Cross Validation (GCV). The local estimation of the function f provides the capability to capture any arbitrary features (linear or nonlinear) that might be present in the data; besides, this obviates making any assumptions as to the underlying form of the function f (linear in the case of traditional linear regression approach).

Natural salt mass, required in compute the flow-salt regressions, is computed by removing anthropogenic influences (upstream reservoir regulation, salt loading from agriculture return flows, and salt removed with exports) affecting salt from observed historic data. Natural salt mass data from 1971-1995 were used for the 15 Upper Basin gauges, matching the time period used in the 2005 Triennial Review. The 9 Lower Basin gauges were modeled based on 1971-2005 natural salt mass data. Once the monthly regression relationships were determined for each gauge the associated natural salt for the natural flows from 1906-2004 are computed.

Salt loading resulting from agriculture is available at an annual time step and disaggregated to monthly values for modeling purposes. The concentrations of exported and imported flows are developed from available historic data at each export location and held constant through time. Future levels of salinity control are estimated from hydro-salinity studies performed for each salinity control project. Initial reservoir salinity concentrations were set based on the latest historic values available. These are the December 2005 values reported by the USGS with the exception of Davis and Parker Dam, which were assumed to be equivalent to Mead concentration since a December 2005 value is not available.

B.3 Calibration

To ensure the regressions properly capture the flow-salt relationship the regressions used to determine natural salt based on the 1971-1995 natural flows is input in a CRSS based model. The model is run with historic data representing salt loading from agriculture, concentration of exported flows, levels of salinity control, and initial reservoir salinity concentrations for the time period 1971-1995. If the simulated historic salinity concentrations below Powell and above Imperial Dam compare well with the actual historic salinity at these locations the model is properly calibrated (Prairie & Callejo, 2005).

B.4 Limitations

Since the regression relationship between flow and salt is based on post-1971 values future projections are limited to simulating the post-1971 flow and salt relationship. A changing relationship cannot be modeled.

Limited data is available describing the monthly salt loading resulting from agriculture. Annual estimates are disaggregated for modeling purposes and monthly salinity results are typically aggregated to an annual time step before analysis of results. The variability of annual salt loading resulting from agriculture is not well understood; therefore, the annual estimate is held constant over all years. This assumption forces the variability in agricultural salt loading to be back computed into the natural salt mass. Therefore, it is important to recognize that the natural salt mass, as well as the natural flow, is NOT only what would naturally have occurred throughout the basin without anthropogenic effects. It also incorporates the error in any assumptions or in the accuracy of our estimates of the anthropogenic effects that we removed from the historic gauge records.

Lastly, the CRSS salinity component is generally intended for long-term modeling (15-20 years) and reservoir salinity is highly sensitive to initial reservoir conditions for the first 10-12 years. More accurately determining initial reservoir conditions will greatly improve the accuracy of the first 10-12 years of results. After these first 10-12 years the initial conditions have minimal impact on model results.

C. Reservoir Modeling Using CE-QUAL-W2 - Model Description

C.1 CE-QUAL-W2 Model Description

CE-QUAL-W2 is a two dimensional, longitudinal/vertical, hydrodynamic, and water quality model. The model assumes lateral homogeneity and, therefore, is best suited for relatively long and narrow water bodies exhibiting longitudinal and vertical water quality gradients (Cole & Wells, 2003). Development and evolution of CE-QUAL-W2 has spanned three decades. The U.S. Army Corp of Engineers (USACE), J.E. Edinger and Associates (Edinger), and Dr. Scott Wells at Portland State have been the major developers in recent years. Although CE-QUAL-W2 version 3.6 is available the version currently used in this analysis is 3.2. Certain modifications to the code were made specifically to version 3.2 and have not yet been migrated to version 3.6.

C.1.1 Model Capabilities & Limitations

The CE-QUAL-W2 model is capable of predicting water surface elevations, velocities, temperatures, and a number of water quality constituents. Water is routed through cells in a computational grid in which each grid cell is completely mixed at time step. Geometrically complex water bodies can be represented through multiple branches and cells. Multiple inflows and outflows to the water body are represented through point/nonpoint sources, branches, precipitation, and other methods. Tools for modeling hydraulic structures such as spillways and pipes are available. Output from the model provides options for detailed and convenient analyses.

Several assumptions and approximations are made in the model in order to simulate hydrodynamics, transport, and water quality processes. The model solves for gradients in the longitudinal and vertical directions but assumes lateral gradients are negligible. This assumption may be inappropriate for water bodies with significant lateral variations. Turbulence is modeled through eddy coefficients of which the user must decide which scheme is most appropriate for an application. Vertical momentum is not explicitly modeled and in water bodies with significant vertical acceleration results may be inaccurate. Water quality processes are extremely complex and the model uses simplified approaches to reach solutions.

C.1.2 Bathymetry

A CE-QUAL-W2 model uses the bathymetry, or depth measurements describing the shape and volume of a waterbody to create a computational grid. The computational grid is a two-dimensional numeric representation of a water body. The two dimensions represented are the longitudinal and vertical dimensions, or the length and depth of a water body which are divided into longitudinal segments and vertical layers. The lateral dimension, or width, is not represented in the grid but an average width is computed and used to determine volume. Since the model grid is two-dimensional it assumes that modeled parameters do not vary significantly in the lateral direction. This assumption has been found appropriate in relatively long and narrow water bodies.

The components of the grid are, from smallest to largest, cells, segments, branches, and water bodies. The cell is a single vertical layer within a single segment. Segments consist of one or more cells, branches are one or more longitudinal segments, and a water body is one or more branches. A computational grid represents dimensions from a single water body.

The volume of the grid is computed by multiplying a cell's length, thickness, and width. The sum of all cells within the grid is then the total storage for the water body. The computational grid storage is compared to actual storage-capacity values to verify the model bathymetry accuracy.

C.1.3 Input Data

Applications of the CE-QUAL-W2 model rely on the quality and availability of input data. Typical input data required for model applications include meteorological, inflow and outflow, water temperature, water quality, and calibration data. These data most often determine the accuracy and usefulness of an application.

C.1.4 Model Calibration

Model calibration involves comparing field observed data to modeled, or predicted, results. The observed values are typically vertical profile and reservoir discharge observations for temperature and other water quality parameters. Calibration statistics are generated by computing the absolute mean error (AME). This computation is the sum of the absolute value of the model predicted value minus the field observed value, which is then divided by the total number of observations. This describes, on average, the difference between predicted and observed values.

Model calibration involves several model iterations during which model parameters and assumptions are evaluated and adjusted to achieve a better match with observed data. Model calibration is confirmed by testing the results of adjustments to model parameters and assumptions under various conditions which the water body is subject to such as hydrologic and meteorological variations.

C.2 Lake Powell Historic Water Quality Model

This section describes the Lake Powell application of the CE-QUAL-W2 model including the bathymetry, inputs, assumptions, and calibration. This model simulates historic conditions at Lake Powell for the period 1990 through 2008 and is calibrated and verified with observed field data for the same time period. To differentiate between this Lake Powell model and other models used in the evaluation of the Lake Powell Pipeline this model will be referred to as the Lake Powell historic water quality model, or historic model, from this point forward.

C.2.1 General Description

The Lake Powell historic model simulates hydrodynamics including reservoir discharges, temperature, salinity, dissolved oxygen, phytoplankton and the decay of organic matter. The model uses a geometric, computational grid and various input data to simulate these processes. The grid is discussed in the following section. Input data describe meteorological conditions, inflows, outflows, and water quality parameters. Meteorological data are collected from Page, Arizona and Hanksville, Utah. Gaged streamflow records from the Colorado River (combination of the Colorado, Green, and San Rafael Rivers), San Juan River, and the Dirty Devil River are used to represent reservoir inflows. For inflows where little or no data is available estimates are made. Records of discharges from Glen Canyon Dam represent reservoir outflow. Water quality data from major tributaries, where available, represent inflow water quality. These datasets have been collected from the Bureau of Reclamation, United States Geological Survey, National Park Service - Glen Canyon National Recreation Area, National Climatic Data Center, and Utah and Arizona state and local agency records.

C.2.2 Lake Powell Bathymetry

Bathymetry for Lake Powell is available from topographic maps of the reservoir area which were created prior to its filling. The National Park Service – Glen Canyon National Recreation Area converted these maps to digital format and the digital maps were used to create the computational grid of the Lake Powell historic model. To account for sediment accumulation in the reservoir basin modifications were made to the computational grid based on the most recent reservoir sediment survey conducted by the Bureau of Reclamation in 1986 (Ferrari, 1988). The grid is composed of 9 branches, 90 segments, and 97 layers. Each layer in the grid is 1.75 meters thick. Branches 1 through 9 represent the following channels and/or bays of the reservoir:

1. Main (Colorado River) channel
2. Bullfrog Bay
3. Escalante River channel
4. San Juan River channel
5. Rock Creek Bay
6. Last Chance Bay
7. Warm Creek Bay
8. Navajo Canyon
9. Wahweap Bay

Figure C-1 is a diagram of the Lake Powell model bathymetry showing a top view of the computational grid. Branches 1 through are visible in this view. The diagram is color coded to indicate the upstream (green) and downstream (blue) segments of each branch and the confluence segment of a tributary branch (red). Figure C-2 is a diagram of branch 1 of the Lake Powell model bathymetry as shown from the side. This view depicts the individual segments and layers in the branch.

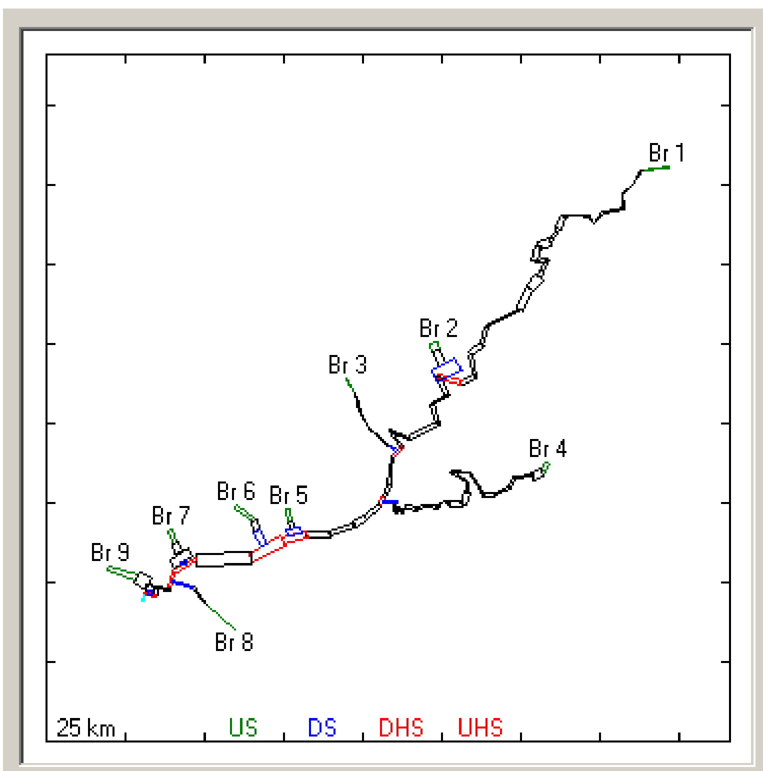

Figure C-1: Lake Powell Bathymetry - Top View

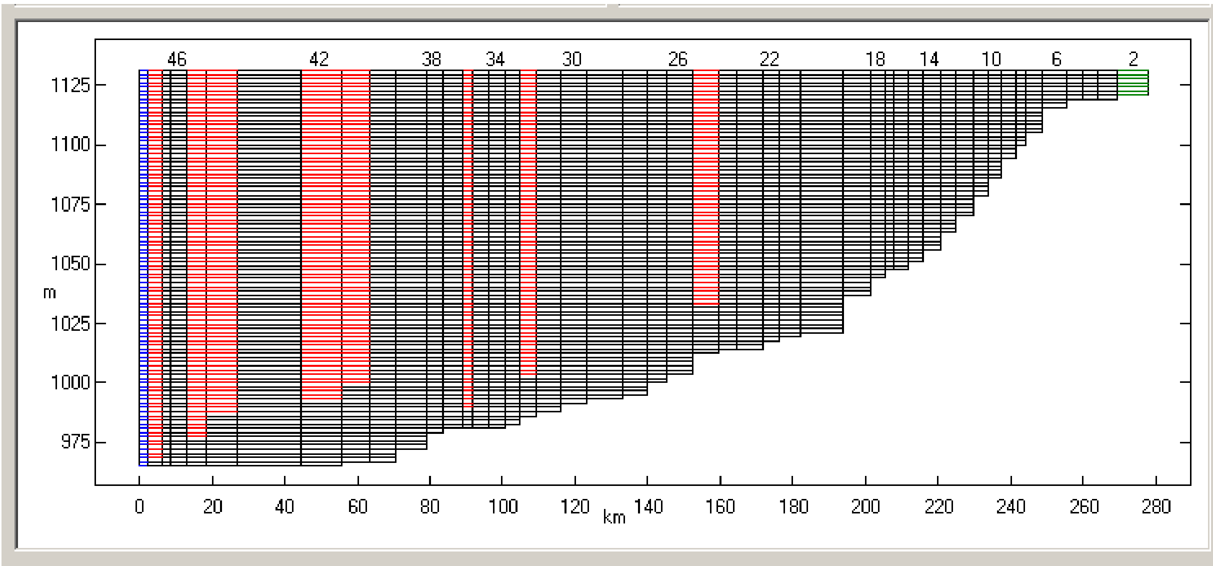

Figure C-2: Lake Powell Bathymetry - Side View

C.2.3 Lake Powell Model Assumptions

Several assumptions are inherent in the Lake Powell historic model and other assumptions are made to connect different data sets and to produce more accurate results. The input data used in the model are the best available and are assumed to be accurate representations of meteorology, flow, and water quality parameters. Additional assumptions, described below, may also affect model accuracy and reliability.

C.2.3.1 Meteorological Conditions

Meteorological conditions are represented in the model by temperature, dewpoint, and wind data measured at Page, Arizona and cloud cover measured at Hanksville, Utah. Data from these sources are combined into one dataset to represent meteorological conditions for the entire reservoir. Although meteorological conditions likely vary across the reservoir the model assumes the conditions are the same at all times and locations.

C.2.3.2 Water Balance

The model is calibrated to reproduce observed water surface elevations on the reservoir. This involves comparing modeled water surface elevations with observed water surface elevations. The difference between the two observations is the error in the water balance and represents elements of the water budget which are not directly measured and are difficult to estimate. To minimize this error an additional water input referred to as the distributed tributary is created. This is a derived input that calculates the volume required to balance the water budget, whether positive or negative. The distributed tributary represents estimated elements of Lake Powell's water budget such as precipitation, ungaged tributary inputs, bank storage, ground water, and other source/sinks. The model distributes this inflow (positive or negative) evenly across the top layer in the computational grid. Water quality constituent concentrations of distributed tributary gains to the reservoir are assumed to match Colorado River inflow concentrations.

C.2.3.3 Sediment Delta Interactions

Over the life of Lake Powell sediment deltas have accumulated at the mouths of major and minor tributaries. Deposition and scour of these deltas creates interactions which effect reservoir water quality parameters such as dissolved oxygen, nutrients, plankton, and more. The CE-QUAL-W2 model does not explicitly model these interactions. This is on the edge of modeling and data gathering technology at this time. The interactions are either not represented or an alternate approach is used to model them. The impacts of these interactions on water quality in the reservoir are not insignificant and until the approaches used are studied further the modeled results for dissolved oxygen, nutrients, and plankton are considered qualitative.

C.2.3.4 Code Modifications

The version of CE-QUAL-W2 used for the Lake Powell historic model is version 3.2 with a modification of the model source code. Reclamation contracted Environmental Resources Management, Inc. (ERM) to assist in code modification of the CE-QUAL-W2 model. The modifications were implemented to improve thermal and chemical calibration of the Lake Powell historic model as well as other Reclamation applications of the CE-QUAL-W2 model. The specific modification allows for a time-varying adjustment to the evaporative wind speed coefficients in the CE-QUAL-W2 model (Cole & Wells, 2003). In the Lake Powell historic model the coefficients are varied by month and the monthly coefficients are repeated for each year in the simulation. The resulting thermal and chemical calibration of the Lake Powell historic model improved following the code modification and monthly adjustment of evaporative wind speed coefficients (Williams, 2007). Evaporation totals were compared with Reclamation estimated monthly evaporation values as a calibration check.

C.2.4 Lake Powell Model Calibration

The Lake Powell historic model is continuously being updated and calibrated as additional years are added to the simulation period and as model methods improve. The Lake Powell historic model used in this application is calibrated for temperature and total dissolved solids for the period 1990-2008. Calibrations results for dissolved oxygen are also presented, but as mentioned previously, these are considered qualitative. Calibration results and statistics were determined by comparing predicted results with observed data from 20 reservoir locations and for discharges from the dam. Observed data have been collected by several agencies over the life of the reservoir (Vernieu W. , 2009). The AME statistic is used specifically to evaluate model calibration. Calibration efforts for other water quality parameters such as nutrients and algae still continue and modeled results for these parameters are qualitative only.

C.2.4.1 Temperature Calibration

Temperature calibration of the historic model compares modeled temperature results to observed reservoir profile and release data. Calibrations statistics for reservoir profiles are shown for 20 reservoir locations in Table C-1. The number of profiles collected at each location from 1990 through 2008 is also given in the table. The AME of the temperature profiles is 0.78°C. The model calibration for reservoir temperatures has, on average, a 4% error when compared with the typical variation in surface temperatures at Wahweap of 7 to 26°C. Modeled and observed reservoir release temperatures are displayed in Figure C-3. The AME of the reservoir release temperatures is 0.45°C. Compared with the historical variation of 7 to 16°C during the modeled time period the model calibration for reservoir releases has, on average, a 5% error.

Table C-1: Lake Powell Historic Model Temperature Calibration – Reservoir Profiles

Station	AME	Profiles
Forebay (CR0.5)	0.76	18
Wahweap (CR2.4)	0.59	210

Romano Narrows (CR23.7)	0.42	9
Crossing of the Fathers (CR45.3)	0.52	73
Oak (CR90.5)	0.59	71
San Juan Confluence (CR100.1)	0.60	50
Escalante (CR116.9)	0.65	65
Iceberg (CR139.5)	0.66	53
Lake (CR158.7)	0.75	51
Bullfrog (CR169.2)	0.83	64
Moki (CR177.2)	0.75	49
Knowles (CR193.3)	0.85	51
Lower Good Hope Bay (CR208.5)	1.05	63
Scorup (CR225.5)	1.20	65
Hite Basin (CR238.7)	1.32	63
Cha Canyon (SJR19.3)	0.60	62
Lower Piute Bay (SJR32.9)	0.73	55
Upper Piute Bay (SJR43.1)	0.89	60
Alcove Canyon (SJR53.0)	1.58	15
Lower Zahn Bay (SJR62.5)	1.15	40
Average	**0.78**	

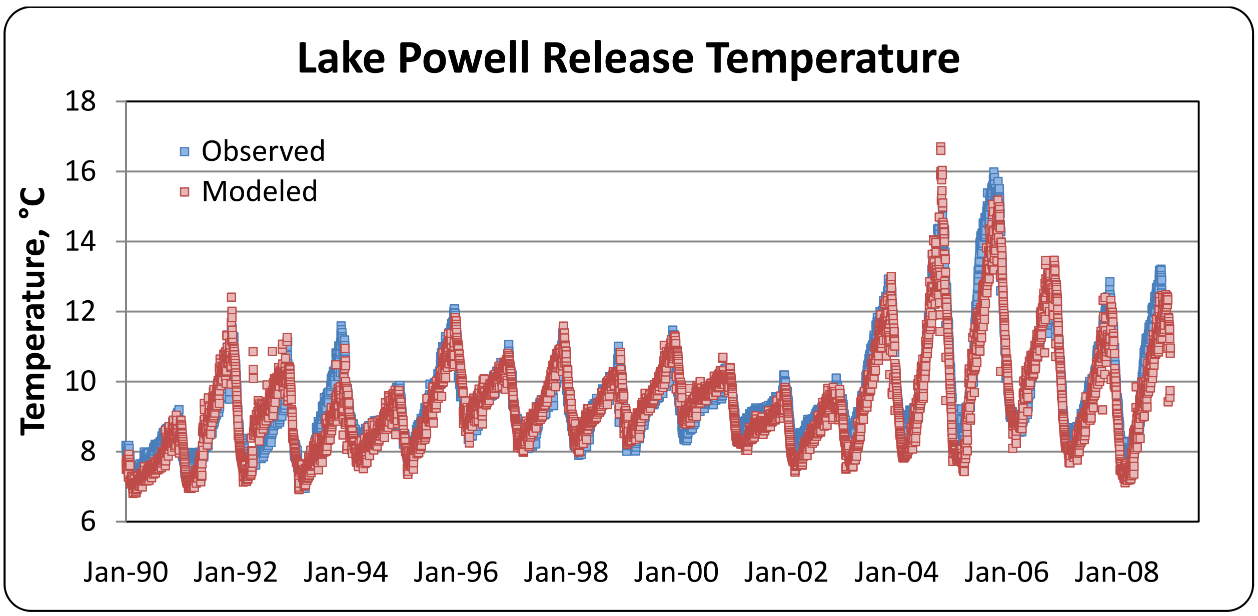

Figure C-3: Lake Powell Historic Model Temperature Calibration – Reservoir Release

C.2.4.2 Total Dissolved Solids Calibration

Total dissolved solids (TDS) calibration of the historic model compares modeled TDS results to observed reservoir profile and release data. Calibrations statistics for reservoir profiles are shown for 20 reservoir locations in Table C-2. The AME of the TDS profiles is 32 mg/L. The model calibration for reservoir TDS concentration has, on average, an 8% error when compared with the typical variation in TDS concentrations at Wahweap of 300 to 700 mg/L. Modeled and observed reservoir release TDS concentrations are displayed in Figure C-4. The AME of the reservoir release TDS concentrations is 18 mg/L. Compared with the historical variation of 400 to 600 mg/L during the modeled time period the model calibration for reservoir releases has, on average, a 9% error.

Table C-2: Lake Powell Historic Model TDS Calibration – Reservoir Profiles

Station	AME	Profiles
Forebay (CR0.5)	32	19
Wahweap (CR2.4)	25	211
Romano Narrows (CR23.7)	22	9
Crossing of the Fathers (CR45.3)	20	72
Oak (CR90.5)	25	71
San Juan Confluence (CR100.1)	27	50
Escalante (CR116.9)	27	65
Iceberg (CR139.5)	31	53
Lake (CR158.7)	33	51
Bullfrog (CR169.2)	32	64
Moki (CR177.2)	38	49
Knowles (CR193.3)	42	51
Lower Good Hope Bay (CR208.5)	44	53
Scorup (CR225.5)	52	65
Hite Basin (CR238.7)	56	63
Cha Canyon (SJR19.3)	26	62
Lower Piute Bay (SJR32.9)	25	55
Upper Piute Bay (SJR43.1)	28	60
Alcove Canyon (SJR53.0)	31	15
Lower Zahn Bay (SJR62.5)	37	40
Average	**32**	

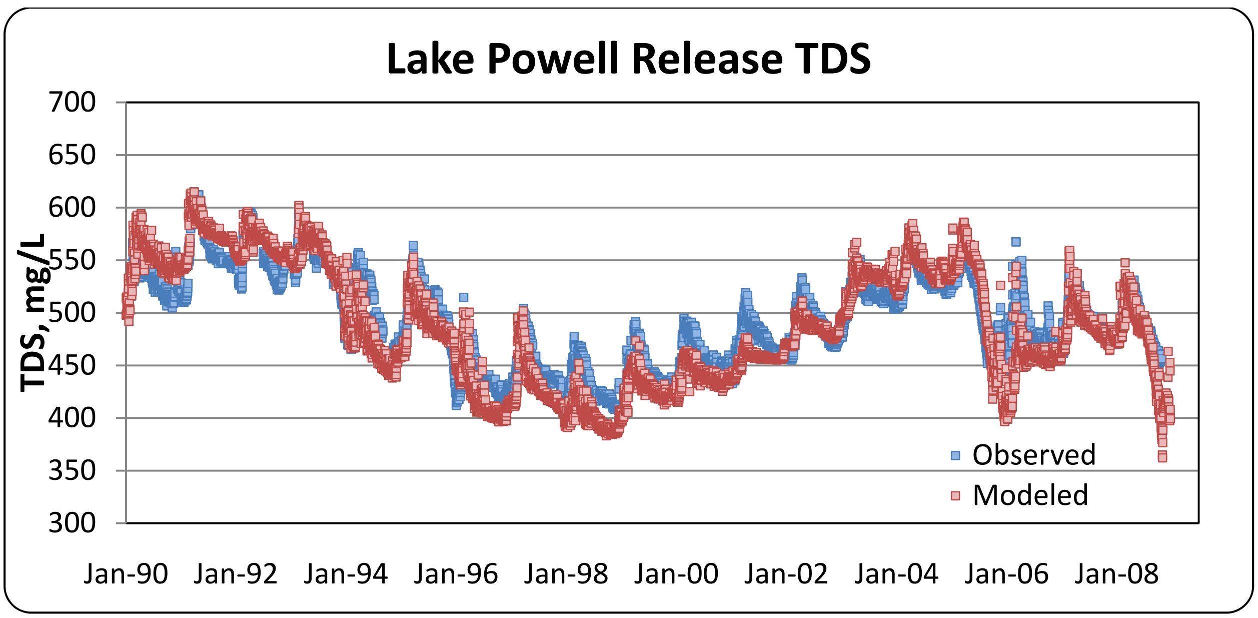

Figure C-4: Lake Powell Historic Model TDS Calibration – Reservoir Release

C.2.4.3 Dissolved Oxygen Calibration

The dissolved oxygen calibration is still in its initial stages of development and is of limited value for use in the Lake Powell Pipeline water quality studies. An empirical method was used to represent the processes affecting dissolved oxygen concentrations in the reservoir (Williams, 2007). The AME of the dissolved oxygen profiles is 1.2 mg/L. The model error for dissolved oxygen is, on average, 15% when compared with the typical variation in dissolved oxygen at Wahweap of 2 to 10 mg/L. Model prediction of dissolved oxygen is expected to be improved with further refinement of the empirical method. Dissolved oxygen is not shown for dam releases because the available observed dissolved oxygen data are collected from below the hydropower turbines in the dam. Hydropower generation at Glen Canyon Dam results in increased dissolved oxygen and a comparison of modeled and historic release dissolved oxygen values for calibration is not possible.

Table C-3: Lake Powell Historic Model Dissolved Oxygen Calibration – Reservoir Profiles

Station	AME	Profiles
Forebay (CR0.5)	1.18	19
Wahweap (CR2.4)	1.23	213
Romano Narrows (CR23.7)	0.95	9
Crossing of the Fathers (CR45.3)	1.19	73
Oak (CR90.5)	1.18	71
San Juan Confluence (CR100.1)	1.29	50
Escalante (CR116.9)	1.22	65
Iceberg (CR139.5)	1.23	53
Lake (CR158.7)	1.15	51
Bullfrog (CR169.2)	1.11	65
Moki (CR177.2)	1.19	49
Knowles (CR193.3)	1.25	51
Lower Good Hope Bay (CR208.5)	1.11	63
Scorup (CR225.5)	1.04	65
Hite Basin (CR238.7)	0.99	63
Cha Canyon (SJR19.3)	1.31	62
Lower Piute Bay (SJR32.9)	1.31	55
Upper Piute Bay (SJR43.1)	1.27	60
Alcove Canyon (SJR53.0)	1.84	15
Lower Zahn Bay (SJR62.5)	1.44	40
Average	**1.21**	

D. Lake Powell Pipeline Models Water Quality Simulations

Water quality effects from the proposed Lake Powell Pipeline on Lake Powell and the Colorado River below Glen Canyon Dam were evaluated using the CE-QUAL-W2 hydrodynamic and water quality model which was described in Section C.1 above. The three pipeline scenarios which were evaluated for effects on water quality were the No Action, 86,000 Acre-Feet Diversion, and 100,000 Acre-Feet Diversion scenarios.

D.1 Models Descriptions

The Lake Powell Pipeline water quality models were based from the Lake Powell historic model for calibrated model parameters. The historic model was described in Section C.2 above. For each pipeline scenario a single water quality model was developed. Each model simulates the same time period and includes the same set of inputs and assumptions except for reservoir outflows, pipeline diversion volumes, and resulting effects on reservoir elevations, releases, and system storage operation. In this way the effects of the proposed pipeline can be isolated and compared with the No Action, or zero pipeline depletion, scenario.

D.1.1 Relation to CRSS Model

Simulating the hydrology and operations of Lake Powell required using results from the Colorado River Simulation System (CRSS) modeling, specifically the No Additional Depletions (NAD) simulations. These results provided monthly reservoir inflow, outflow, pool elevation, and pipeline diversions for the water quality models. The CRSS NAD modeling consisted of two future inflow hydrology scenarios, direct natural flow by the Index Sequential Method, and nonparametric paleo-conditioned inflows. These scenarios and the results from the CRSS modeling are described in detail in “Lake Powell Pipeline Hydrologic Modeling: No Additional Depletions Sensitivity Analysis” (Grantz, 2010).

CRSS results from the direct natural flow simulations were used because the water quality models are based from the Lake Powell historic water quality model. The reason for this is the direct natural flows in the CRSS simulations are taken from the historic record and correspond to the historic meteorological data used by the historic water quality model. By selecting the corresponding time period in a CRSS model trace the meteorological data from the Lake Powell historic model can be matched with the corresponding hydrology from the CRSS models. Trace 49 was selected from each of the 86,000 acre-feet, 100,000 acre-feet and no action (zero diversion) CRSS NAD models to provide reservoir inflows, outflow, elevations, and pipeline diversions values for the water quality models. The time period 2043-2060 from the CRSS models was selected for the water quality simulations. This future period corresponds to the historic natural flows for the years 1989 to 2006. The year 2043 also coincides with the second year of full diversions for the pipeline in the 86,000 acre-feet diversion scenario. The 2043-2060 Lake Powell pool elevations from the CRSS NAD model, Trace 49 are shown in Figure D-1. For reference, full pool elevation is 3,700 feet. As shown by the graph this time period covers a broad range of wet and dry conditions as reflected by Lake Powell pool elevations.

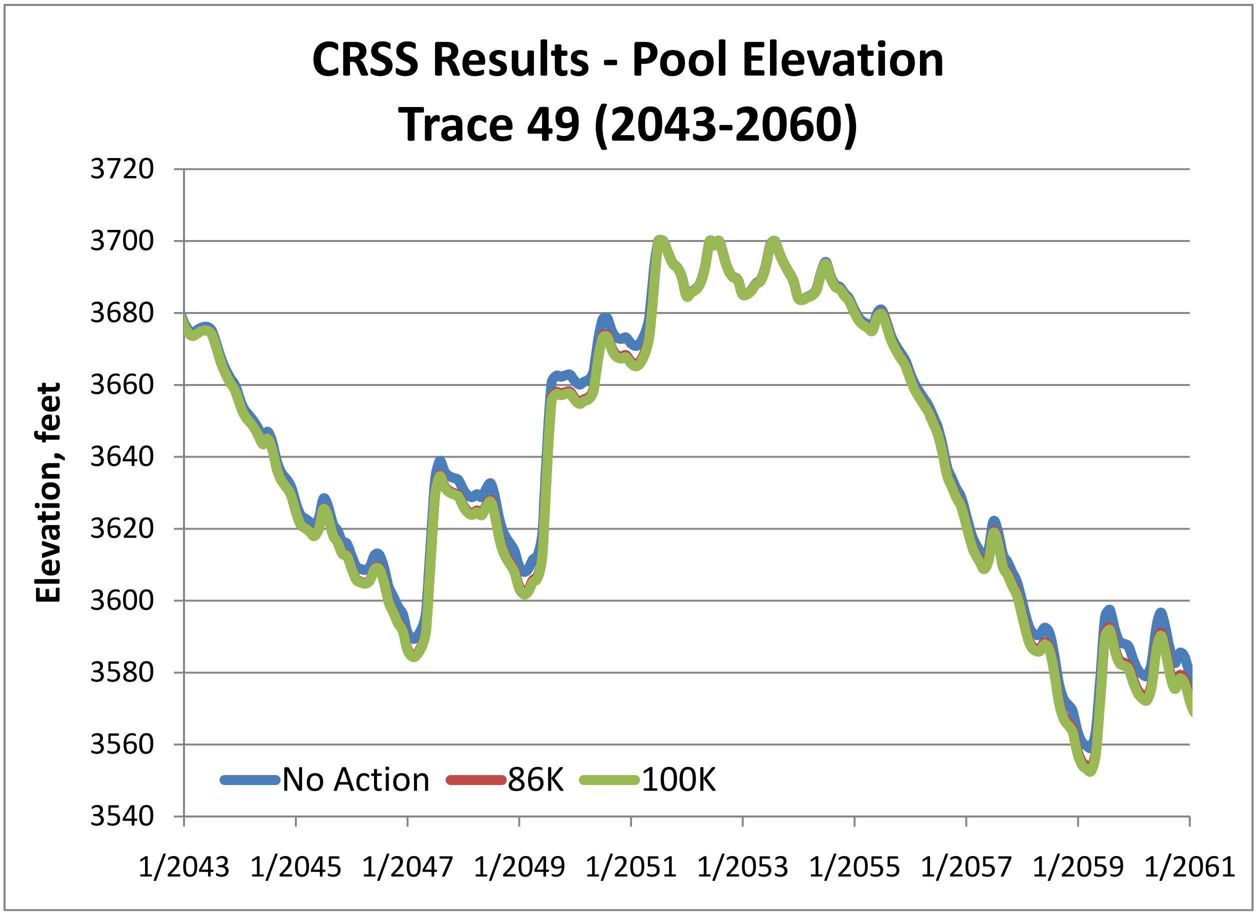

Figure D-1: Trace 49 Pool Elevation 2043-2060, CRSS NAD Model Results

D.1.2 No Action Water Quality Model

The Lake Powell no action water quality model, or no action model, simulates temperature and water quality in and below Lake Powell for the zero pipeline diversion, or no action, scenario from 2043-2060. The no action model uses the reservoir inflow, outflow, and pool elevation results from Trace 49 of the CRSS NAD direct natural flow no action simulation. This is the baseline model from which comparisons to the pipeline diversion, or action alternative, scenarios are made.

D.1.3 86,000 Acre-Feet Pipeline Diversion Water Quality Model

The Lake Powell 86,000 acre-feet pipeline diversion water quality model, or 86K pipeline model, simulates temperature and water quality in and below Lake Powell and in the pipeline for the 86,000 acre-feet pipeline diversion scenario from 2043-2060. The 86K pipeline model uses the reservoir inflow, outflow, and pool elevation results from Trace 49 of the CRSS NAD direct natural flow 86,000 acre-feet depletion simulation. The 86K pipeline model simulates the diversion of 86,249 acre-feet from a location just upstream of Glen Canyon Dam for each year of the simulation. The model computational grid was modified by splitting the segment just above the dam into two segments. This modification allowed the outflow results for reservoir releases and pipeline diversions to be analyzed separately.

D.1.4 100,000 Acre-Feet Pipeline Diversion Water Quality Model

The Lake Powell 100,000 acre-feet pipeline diversion water quality model, or 100K pipeline model, simulates temperature and water quality in and below Lake Powell and in the pipeline for the 100,000 acre-feet pipeline diversion scenario from 2043-2060. The 100K pipeline model uses the reservoir inflow, outflow, and pool elevation results from Trace 49 of the CRSS NAD direct natural flow 100,000 acre-feet depletion simulation. The 100K pipeline model simulates the diversion of 99,970 acre-feet from a location just upstream of Glen Canyon Dam for each year of the simulation. The model computational grid was modified by splitting the segment just above the dam into two segments. This modification allowed the outflow results for reservoir releases and pipeline diversions to be analyzed separately.

D.2 Model Inputs

The inputs for the no action, 86k pipeline, and 100K pipeline models consist of meteorological data, tributary temperature and water quality, reservoir inflows, outflows, and reservoir initial conditions. The 86K pipeline and the 100K pipeline models also include inputs for the pipeline diversions.

Inputs for meteorological data and tributary temperature and water quality for all models were identical to historic model inputs for those parameters from 1989-2006.

Modeled reservoir inflows and outflows for the no action, 86K pipeline, and 100K pipeline models were built from monthly results from corresponding CRSS model scenarios. Reservoir inflows for the three scenarios were identical in each month of the simulation. The inflows represent a drought period (2043-2046) followed by a wet period (2047-2053) followed by an extended drought (2054-2060). The annual inflows are shown in Table D-1. Inflows were distributed between the Colorado River and San Juan River tributaries of Lake Powell. Daily inflows for the two major rivers were generated by using the ratio of CRSS monthly inflow volume and historic monthly inflow volume to adjust the historic daily inflow rate.

Table D-1: Lake Powell Pipeline Model Annual Inflow

Year	Inflow, AC-FT
2043	5,659,949
2044	4,992,175
2045	6,963,497
2046	6,406,489
2047	13,005,468
2048	6,209,788
2049	15,118,404
2050	10,329,817
2051	16,289,510
2052	12,074,667
2053	11,129,159
2054	7,123,060
2055	6,130,271
2056	3,592,287
2057	6,019,592
2058	5,134,732
2059	10,356,259
2060	8,260,164

Monthly outflow volumes were converted to monthly average outflow rates for dam discharges. Monthly outflow volumes between the three scenarios only differed when the reservoir was near its storage capacity and the inflow volume was large. In these cases the pipeline scenarios released slightly less water as illustrated in Figure D-2.

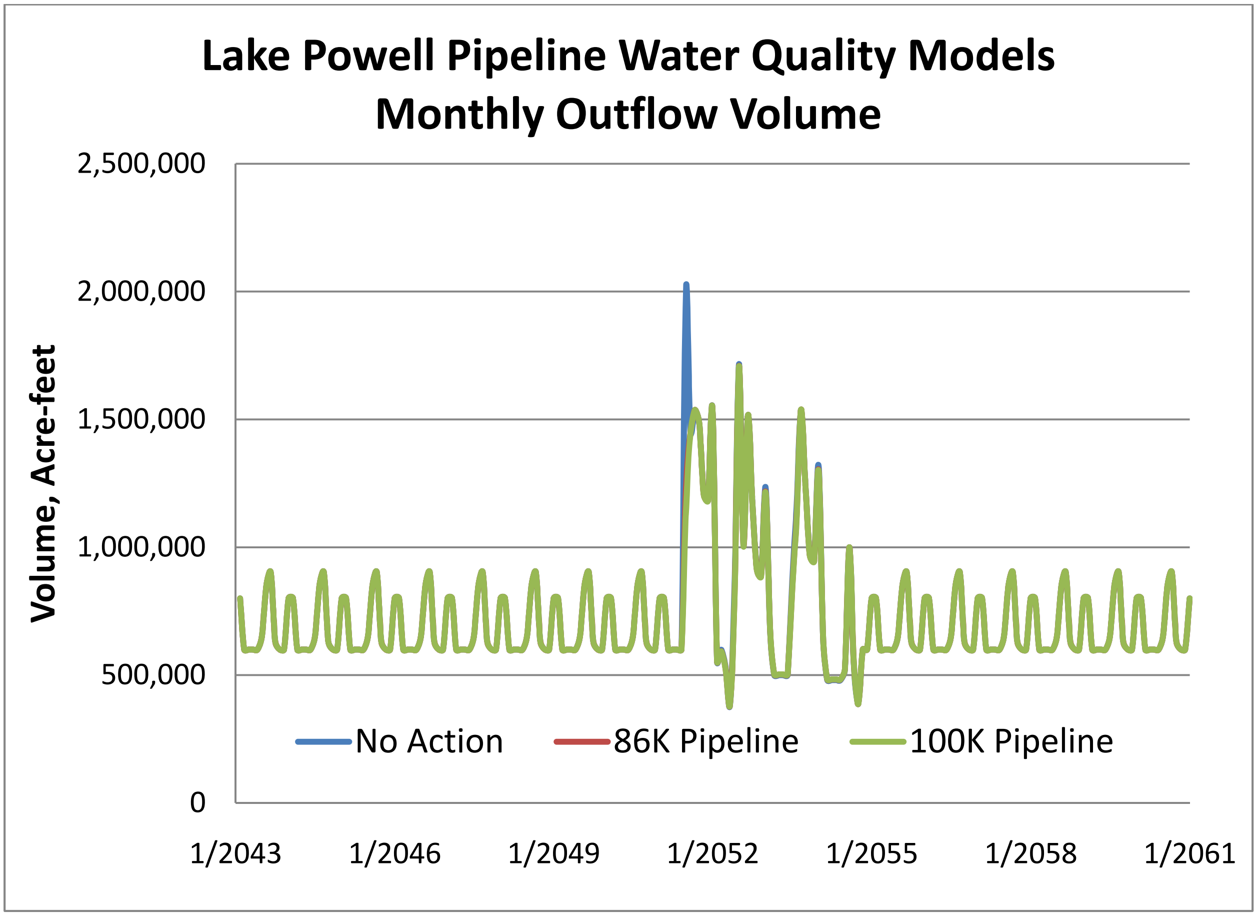

Figure D-2: Lake Powell Pipeline Water Quality Models – Monthly Outflow Volume

Reservoir initial conditions in the model included pool elevation, temperature, TDS, and dissolved oxygen. The initial pool elevation of each model was set as the December 31, 2042 pool elevation from each corresponding CRSS model. In all models the initial temperature was set at 8°C, the initial TDS concentration was set at 500 mg/L, and the initial dissolved oxygen concentration was set at 7 mg/L. These values were determined from the modeler's best estimate of January conditions if the entire reservoir were completely mixed. The reservoir does not often completely mix, however, and initial conditions can influence model results. To account for this an additional historic year (1989) was added to each model and the first two years of each model are intended to reset the reservoir to more representative thermal and water quality conditions. For these reasons model results from the first two years are not considered in the analyses.

The pipeline intakes are represented in the model by withdrawals at three elevations: 3,575 feet, 3,475 feet, and 3,375 feet. The operation of the intakes assumes water is withdrawn from the upper 100 feet of the lake and only a single intake is used for the withdrawals. The operation of the intakes is, therefore, determined by reservoir pool elevation. The upper intake is operated for reservoir pool elevations between 3,711 and 3,600 feet, the middle intake is operated between 3,600 and 3,500 feet, and the lower intake is operated between 3,400 and 3,500 feet.

The schedule for pipeline diversions in the 86,000 and 100,000 acre-feet scenarios breaks the diversions down into monthly volumes and shows the 86,000 acre-feet diversion reaches capacity in 2042 while the 100,000 acre-feet diversion reaches capacity in 2046 (see Attachment A). Pipeline maintenance is scheduled for the first 15 days in January of each year. Pipeline diversion inputs in the 86K pipeline and 100K pipeline models were converted from the monthly volumes used in the CRSS models to average daily flow rates which result in the same daily flow rate each day of the year. Leap years are accounted for by leaving the daily flow rate unchanged and assuming an additional day that the pipeline is offline in January. This results in slightly different monthly diversion volumes for January and February in leap years but does not affect model results.

D.3 Model Calibration

Prior to evaluating results from the water quality model simulations several iterations of the model are done to calibrate the reservoir pool elevations. The process calibrates the water quality model generated reservoir pool elevations with the CRSS monthly pool elevations. Following several iterations the absolute mean error in reservoir pool elevations of the no action, 86K pipeline, and 100K pipeline models was approximately 0.1 meters.

E. Water Quality Results

Water quality results are provided from the CRSS modeling for TDS and from the CE-QUAL-W2 modeling for temperature, TDS, and dissolved oxygen. Since dissolved oxygen is influenced by a number of water quality parameters including nutrients, organic matter, phytoplankton, and biological interactions it is assumed to be representative of effects on reservoir water quality in general. The two action alternatives for pipeline diversions are evaluated against the no action alternative for effects of the action alternatives on Lake Powell and on releases from Glen Canyon Dam. Results from the water quality models do not include the first two simulated years (2043 & 2044) since these years are simulated to establish representative thermal and water quality conditions in the reservoir. TDS results from CRSS modeling also include evaluation at locations downstream of Glen Canyon Dam where numeric criteria for TDS have been established.

E.1.1 Lake Powell

Lake Powell temperature and water quality concentrations were evaluated at five day intervals for three reservoir locations and five depths. The three locations are all in the Colorado River channel of the reservoir and are specifically above the dam, below the confluence of the San Juan River, and above Bullfrog Bay (see Figure E-1). These locations represent the downstream reservoir (above the dam), interactions from the confluence of the major tributaries (below the confluence of the San Juan River), and the upstream reservoir (above Bullfrog Bay). The five depths provide information about the top, warm layer of water known as the epilimnion; the middle layer which transitions from the top, warm layer to the bottom, cold layer and is known as the metalimnion or thermocline; and the bottom, cold layer known as the hypolimnion. The five depths are 0, 10, 25, 50, and 100 meters (0, 33, 82, 164, and 328 feet) as measured from the water surface at each location. Above Bullfrog Bay only includes four depths since it is not 100 meters deep.

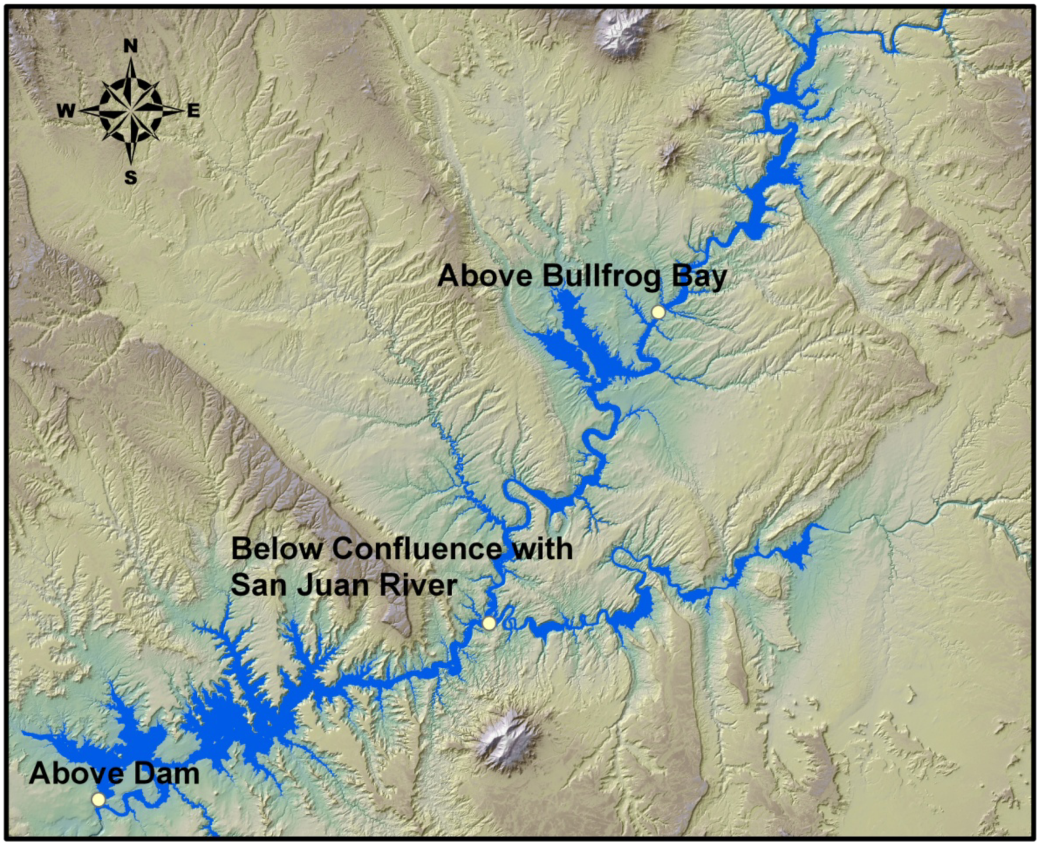

Figure E-1: Lake Powell Evaluation Locations

E.1.1.1 Temperature

Simulated reservoir temperatures were compared for the no action, 86K pipeline, and 100K pipeline models at the several reservoir locations and depths. Compared with the no action the reservoir temperatures are, on average, 0.1°C colder at depths greater than 25 meters in the 86K and 100K pipeline alternatives. The pipeline diverts water from the upper 30 meters (100 feet) in the reservoir which reduces the volume of warmer water in the reservoir. The modeled results for each scenario are found in Attachment B.

The differences in reservoir temperatures are very small and are actually less than the instrument accuracy of typical temperature sensors used to measure in situ water temperature. For example the YSI 6560 temperature sensor manufactured by YSI Incorporated has an accuracy of +/- 0.15°C (YSI Inc.). The Hydrolab temperature sensor manufactured by Hach® has an accuracy of +/- 0.10 °C (Hach Environmental).

E.1.1.2 Dissolved Oxygen

Results for dissolved oxygen are included for the purpose of assessing effects to reservoir water quality other than TDS. As discussed in previous sections dissolved oxygen is influenced by many factors including sediment delta interactions which were not explicitly modeled but instead represented by an empirical method. There are significant uncertainties about the impact of these interactions on reservoir water quality as the reservoir ages and model simulations of water quality parameters such as dissolved oxygen provide limited information. However, the no action, 86K pipeline, and 100K pipeline models have the same assumptions regarding water quality and comparison of the values provides information about the effects of the pipeline on reservoir water quality. The empirical method used to represent oxygen demand assumes increased oxygen demand at lower reservoir pool elevations (Williams, 2007). This assumption is based on the conclusions of others (Vernieu, Hueftle, & Gloss, 2005).

Simulated reservoir dissolved oxygen concentrations at reservoir locations and depths were compared for the no action, 86K pipeline, and 100K pipeline models. Compared with the no action the reservoir dissolved oxygen concentrations are 0.1 mg/L lower at 25 and 50 meters and 0.3 mg/L lower at 100 meters in the 86K and 100K pipeline alternatives. Modeled results for each scenario are found in Attachment B.

The differences in dissolved oxygen concentrations are very small and, except for the reservoir bottom, are actually less than the instrument accuracy of typical dissolved oxygen sensors used to measure in situ dissolved oxygen. For example The ROX™ optical dissolved oxygen sensor has an accuracy of +/- 0.1 mg/L and the YSI 6562 Rapid Pulse dissolved oxygen sensor has an accuracy of +/- 0.2 mg/L (YSI Inc.). The Hach LDO™ dissolved oxygen sensor has an accuracy of +/- 0.1 mg/L (Hach Environmental).

E.1.2 Glen Canyon Dam Releases

Modeled release results from Glen Canyon Dam for the no action, 86K pipeline, and 100K pipeline models were evaluated for effects on temperature, TDS, and dissolved oxygen concentrations. Nutrients such as phosphorus and nitrogen were part of the model simulation and results are discussed briefly. The evaluations used monthly flow-weighted means for. A summary of modeled results for all parameters can be found in Attachment C. Results including detailed output from the no action, 86K pipeline, and 100K pipeline models are included in Attachments K, L, and M, respectively.

E.1.2.1 Temperature

Simulated dam release temperatures were compared for the no action, 86K pipeline, and 100K pipeline models. Mean dam release temperatures for the period 2045 to 2060 are shown in Table E-1 by month. Generally in the 86K and 100K pipeline scenarios dam release temperatures are slightly colder in winter and spring months and slightly warmer in summer and fall months compared with the no action scenario. The most extreme differences in modeled results compared with the no action occurred in October, 2059 where the 86K pipeline was 0.72°C warmer and the 100K pipeline was 0.91°C warmer, and in December, 2051 the 86K pipeline was 0.32°C colder and the 100K pipeline was 0.33°C colder.

Table E-1: Glen Canyon Dam Release –Monthly Simulated Mean Temperatures, 2045-2060

Month	NA	86K	100K
January	9.15	9.05	9.04
February	8.05	7.96	7.96
March	7.81	7.75	7.75
April	8.08	8.04	8.04
May	8.57	8.56	8.56
June	8.95	8.98	8.99
July	9.20	9.23	9.25
August	9.67	9.76	9.78
September	10.26	10.32	10.34
October	10.61	10.69	10.72
November	10.86	10.91	10.92
December	10.52	10.44	10.45

The average temperature differences between the scenarios are less than the measurement accuracy of current instrument technology (see Section E.1.1.1 above) but averaging the data also masks some variations. These variations show up in the summer and fall months and are best explained using modeled results. Glen Canyon Dam release temperatures often peak in October and simulated results for that month (Table E-2) show that the pipeline scenarios are not always warmer than results from the no action scenario. When the reservoir is at or near full pool elevations, as was the case from 2050 to 2056 (see Figure D-1), temperature releases in the pipeline scenarios were colder than in the no action scenario. During these years releases in the pipeline scenarios were colder than in the no action scenario for nearly every month, but the differences were generally very small. The reason the release temperatures in the pipeline scenarios are colder when the reservoir is near full capacity is the removal of warm water from the upper, warm layer of the reservoir by the pipeline. The 86K pipeline and 100K pipeline simulated release temperature results are very similar during winter/spring months when reservoir pool elevations are near full.

Table E-2: Glen Canyon Dam Release – Simulated October Temperatures, 2045-2060

Month	NA	86K	100K
Oct-45	10.54	10.57	10.58
Oct-46	10.83	11.00	11.04
Oct-47	10.58	10.83	10.86
Oct-48	10.12	10.32	10.37
Oct-49	10.88	11.07	11.09
Oct-50	9.54	9.34	9.31
Oct-51	9.74	9.53	9.51
Oct-52	9.59	9.47	9.47
Oct-53	9.92	9.82	9.82
Oct-54	9.52	9.46	9.45
Oct-55	8.80	8.61	8.61
Oct-56	8.99	8.95	8.96
Oct-57	11.10	11.11	11.12
Oct-58	12.54	12.75	12.81
Oct-59	13.79	14.51	14.70
Oct-60	13.24	13.66	13.73
Average	**10.61**	**10.69**	**10.72**

Simulated release temperatures in the pipeline scenarios were warmer than in the no action scenario during summer and fall months and when reservoir pool elevations were not near full capacity. The largest differences between the pipeline scenarios and the no action scenario coincided with the lowest reservoir pool elevations. The two pipeline scenarios also have some differences between them for release temperatures with the 100K pipeline results being warmer during the summer and fall months when reservoir pool elevations are not near full capacity.

E.1.2.2 Total Dissolved Solids

The TDS results from the CE-QUAL-W2 water quality modeling provide detailed information about the effects of the two pipeline alternatives on TDS but these results are not as robust as the TDS results from the CRSS modeling. The CRSS model covers a much broader range of hydrology, system demands, and reservoir operations and also includes current and planned salinity control projects. TDS results from the CE-QUAL-W2 model are provided because they support and confirm the CRSS model results.

TDS results from the no action, 86K pipeline, and 100K pipeline models are shown in Figure E-2. Overall, the average release TDS concentrations from 2045-2060 for the results of the three models are all within 1 mg/L of each other with the 86K pipeline and 100K pipeline averages being higher than the no action average. The largest difference in any one month for the 86K pipeline was 23 mg/L lower than the no action results. Results from the 86K pipeline were never more than 6 mg/L higher than the no action for any one month. The largest difference in any one month for the 100K pipeline is 27 mg/L lower than the no action results. Results from the 100K pipeline were never more than 7 mg/L higher than the no action for any one month. The standard laboratory analysis for determining TDS has a precision of 21 mg/L (Eaton, Clesceri, Rice, & Greendberg, 2005).

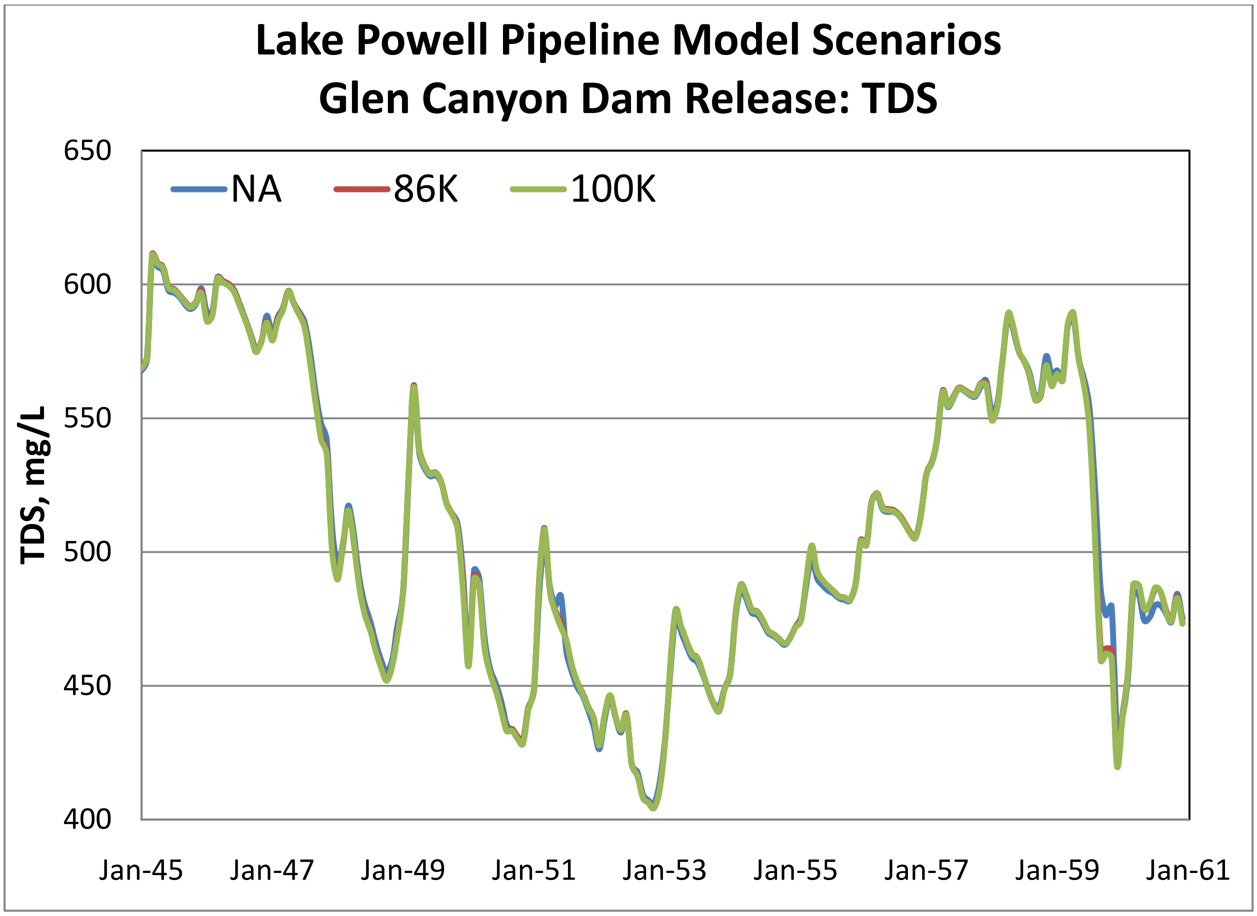

Figure E-2: Lake Powell Pipeline Models – Release TDS, 2045-2060

E.1.2.3 Dissolved Oxygen

Dissolved oxygen results from the no action, 86K pipeline, and 100K pipeline models are shown in Figure E-3. Overall, the average release dissolved oxygen concentrations from 2045-2060 for the results of the three models are all within 0.11 mg/L of each other with the 86K pipeline and 100K pipeline averages being lower than the no action average. The largest difference in any one month for the 86K pipeline was 0.88 mg/L lower than the no action results. The largest difference in any one month for the 100K pipeline was 1.02 mg/L lower than the no action results.

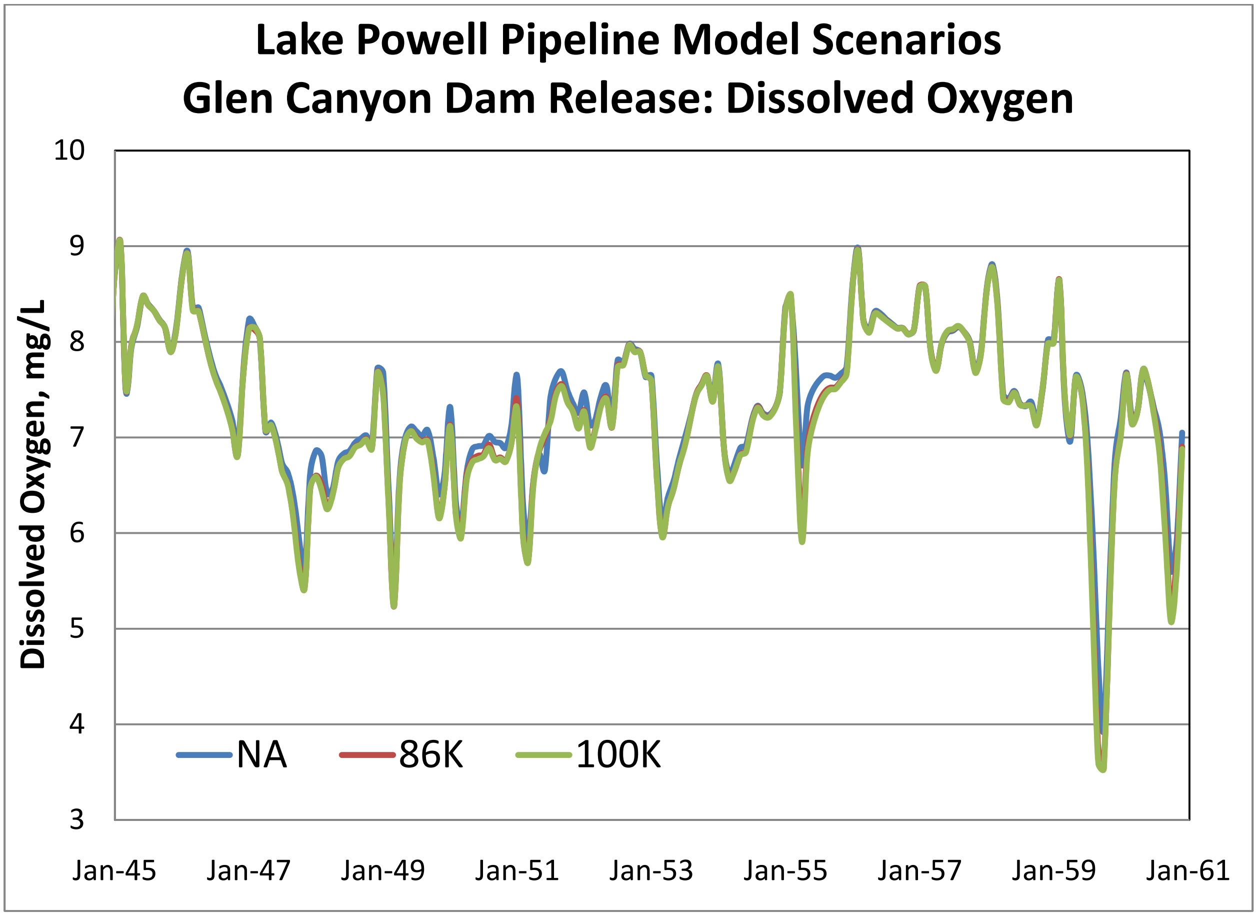

Figure E-3: Lake Powell Pipeline Models – Dissolved Oxygen Release, 2045-2060

Absolute values of the results were presented but the assumptions used in the modeling should be considered before interpreting these results. The difference between dissolved oxygen concentrations of dam releases for the three modeled scenarios is often too small to be measured by field instrumentation. The greatest differences occur when the reservoir pool elevations are lowest. In general, unusually low dissolved oxygen concentrations in dam releases have a higher probability of occurrence at low reservoir pool elevations (<3600 feet). Low reservoir elevations occur at slightly higher frequencies in the 86K pipeline and 100K pipeline scenarios.

E.1.2.4 Nutrients

Nutrients such as phosphorus, nitrate-nitrogen, and ammonia-nitrogen are modeled parameters in the water quality models. These, and other parameters, are essential for certain modeled processes which influence the dissolved oxygen concentrations in the reservoir. Modeled results for these parameters from the no action, 86K pipeline, and 100K pipeline are included in Attachment C. These parameters were not, however, part of rigorous model calibration. Results are not presented in any detail other than to state that no significant differences were noted. Further analysis of these results is not recommended considering the assumptions used.

E.1.3 TDS downstream of Glen Canyon Dam

TDS downstream of Glen Canyon Dam was simulated using the CRSS hydrology and operations model. The salinity, or TDS, component of CRSS was developed to simulate long-term salinity conditions in the Colorado River Basin (U.S. Department of the Interior, 2005). Modeled results are presented for four locations: below Lake Powell, below Lake Mead (Hoover Dam), below Lake Havasu (Parker Dam), and above Imperial Reservoir and Dam. The latter three locations are the sites of numeric criteria established for TDS in 1975 (U.S. Department of the Interior, 2005). Results are presented in graphs in which the 90th, 50th, and 10th statistical percentiles are compared for the pipeline and no action alternatives. Results include the DNF and NPC hydrology scenarios simulated by CRSS. Results are presented for the years 2020-2060 and only TDS results for the 86K pipeline alternative are included in this document. All results from the CRSS TDS modeling are available in Attachment N.

The first four graphs present the results of the 86K pipeline alternative for the DNF hydrology scenario. Figure E-4 is TDS below Lake Powell, Figure E-5 is TDS below Lake Mead, Figure E-6 is TDS below Lake Havasu, and Figure E-7 is TDS above Imperial Reservoir & Dam. As can be seen in each graph, there is no visual difference between the 86K pipeline and no action alternatives for the 90th, 50th, and 10th statistical percentiles. The DNF hydrology results for the 100K pipeline alternative also do not show any difference from the no action alternative.

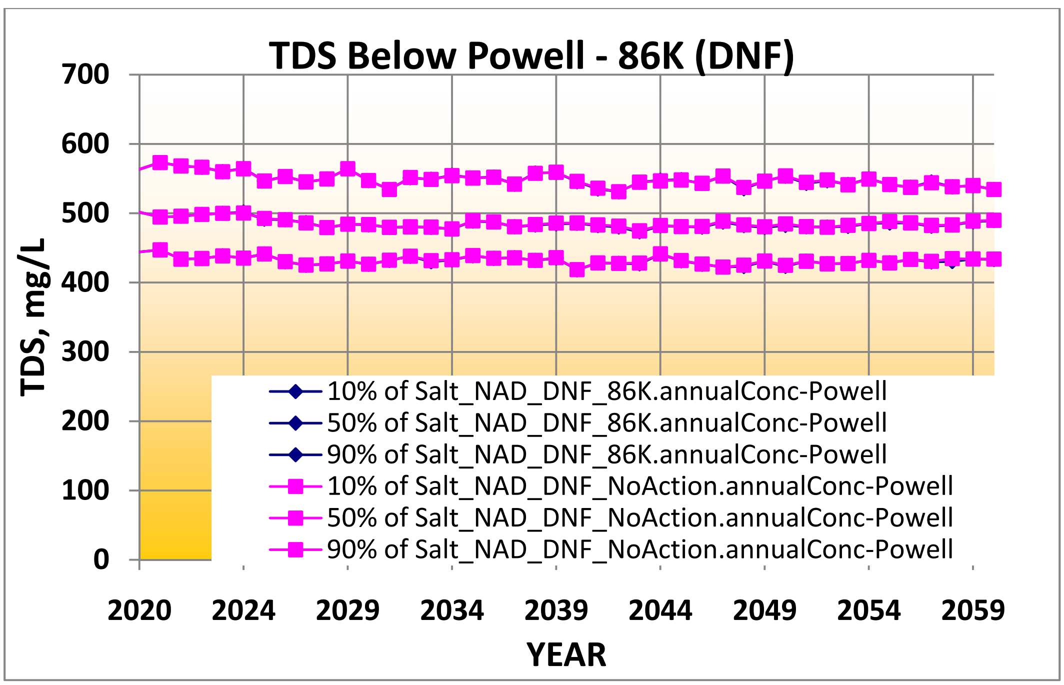

Figure E-4: CRSS DNF results – TDS below Lake Powell, 86K Pipeline Alternative, 2020-2060

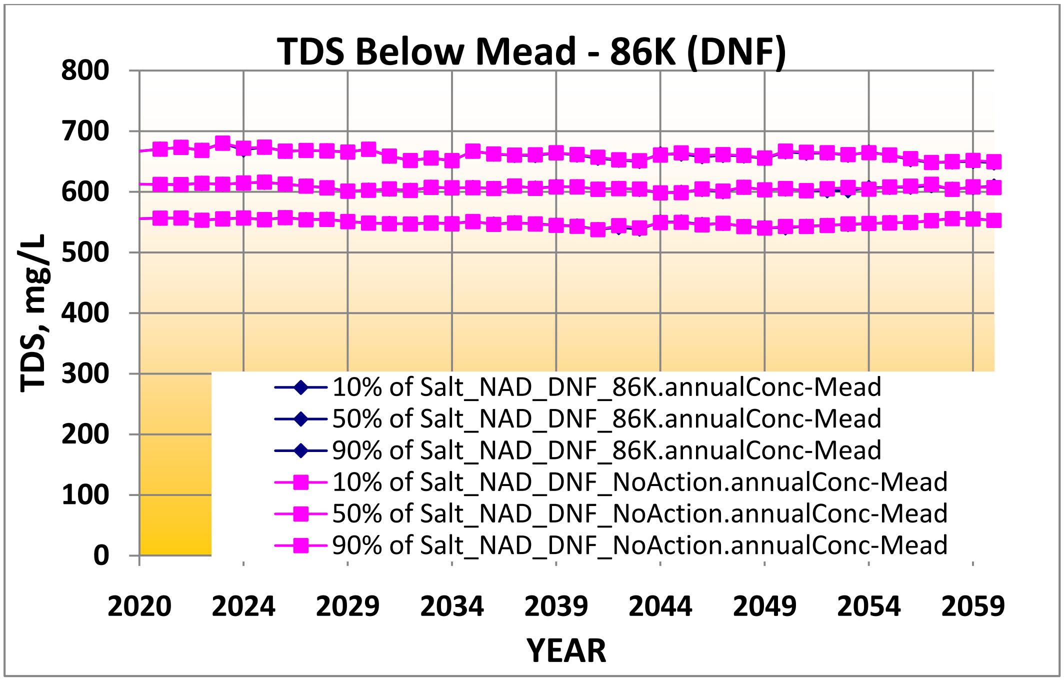

Figure E-5: CRSS DNF results – TDS below Lake Mead, 86K Pipeline Alternative, 2020-2060

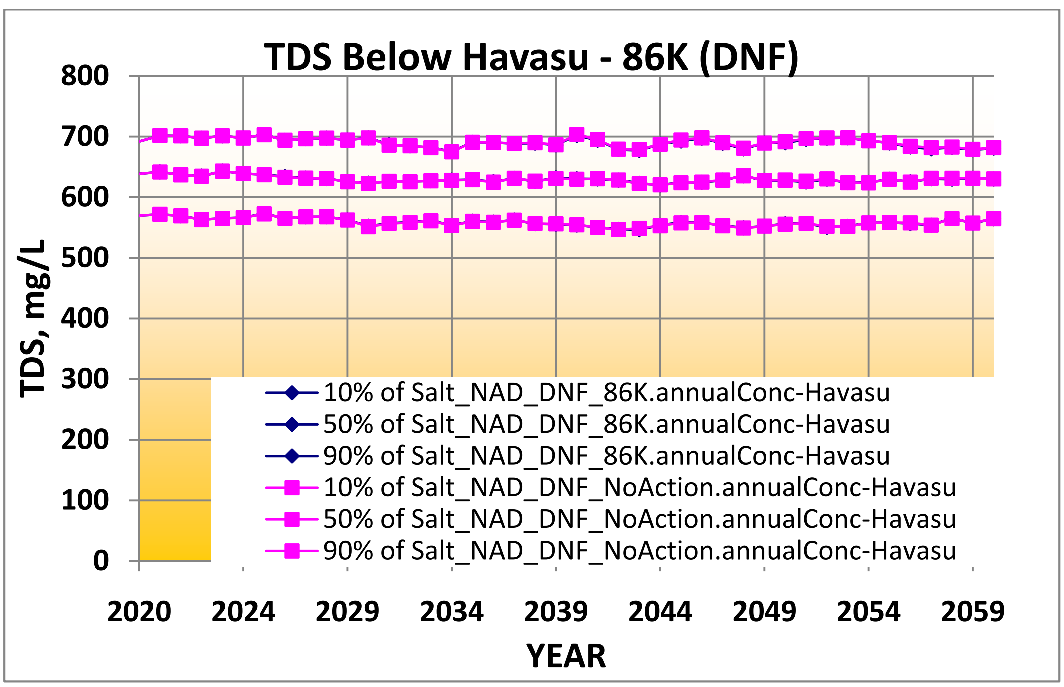

Figure E-6: CRSS DNF results – TDS below Lake Havasu, 86K Pipeline Alternative, 2020-2060

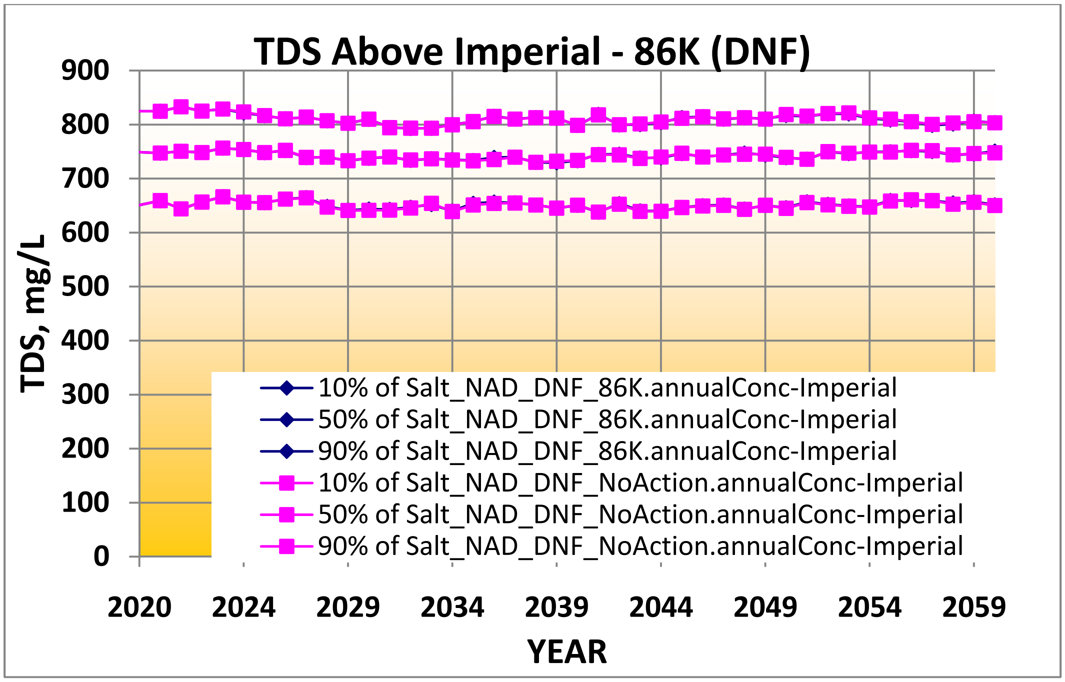

Figure E-7: CRSS DNF results – TDS above Imperial, 86K Pipeline Alternative, 2020-2060

The next four graphs present the results of the 86K pipeline alternative for the NPC hydrology scenario. Figure E-8 is TDS below Lake Powell, Figure E-9 is TDS below Lake Mead, Figure E-10 is TDS below Lake Havasu, and Figure E-11 is TDS above Imperial Reservoir & Dam. As can be seen in each graph, there is no visual difference between the 86K pipeline and no action alternatives for the 90th, 50th, and 10th statistical percentiles. The NPC hydrology results for the 100K pipeline alternative also do not show any difference from the no action alternative.

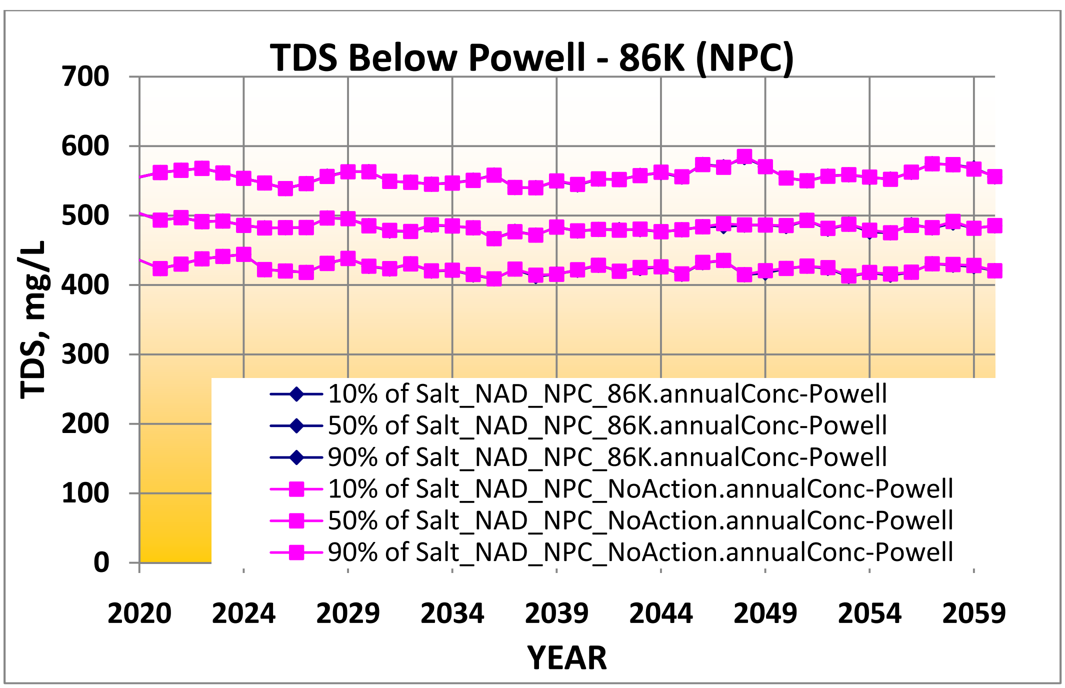

Figure E-8: CRSS NPC results – TDS below Lake Powell, 86K Pipeline Alternative, 2020-2060

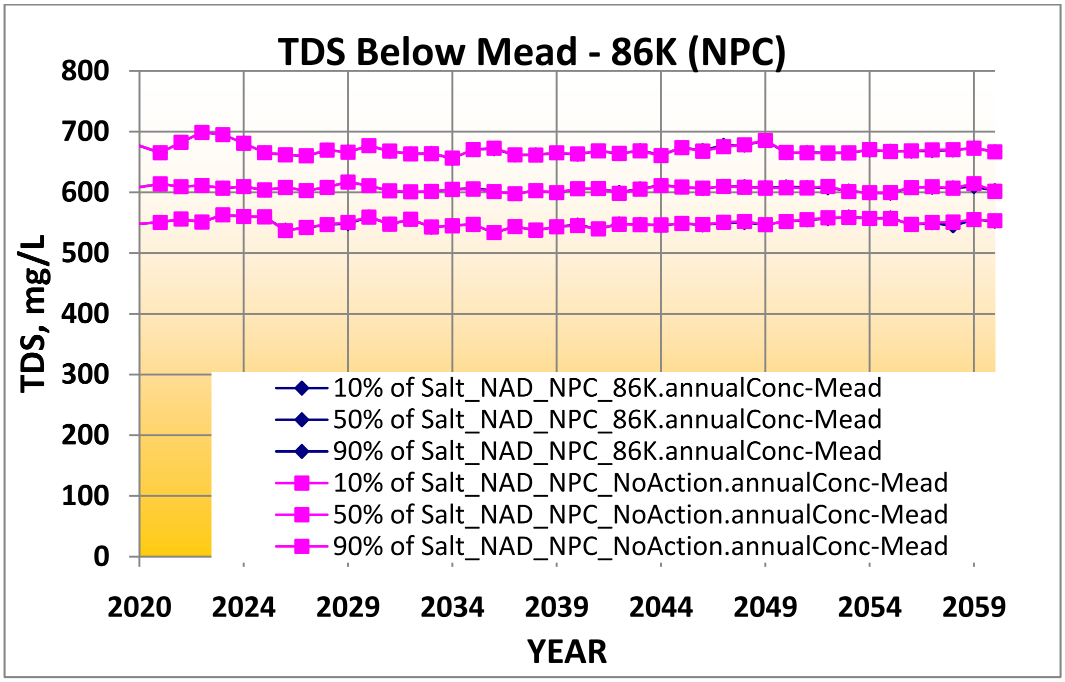

Figure E-9: CRSS NPC results – TDS below Lake Mead, 86K Pipeline Alternative, 2020-2060

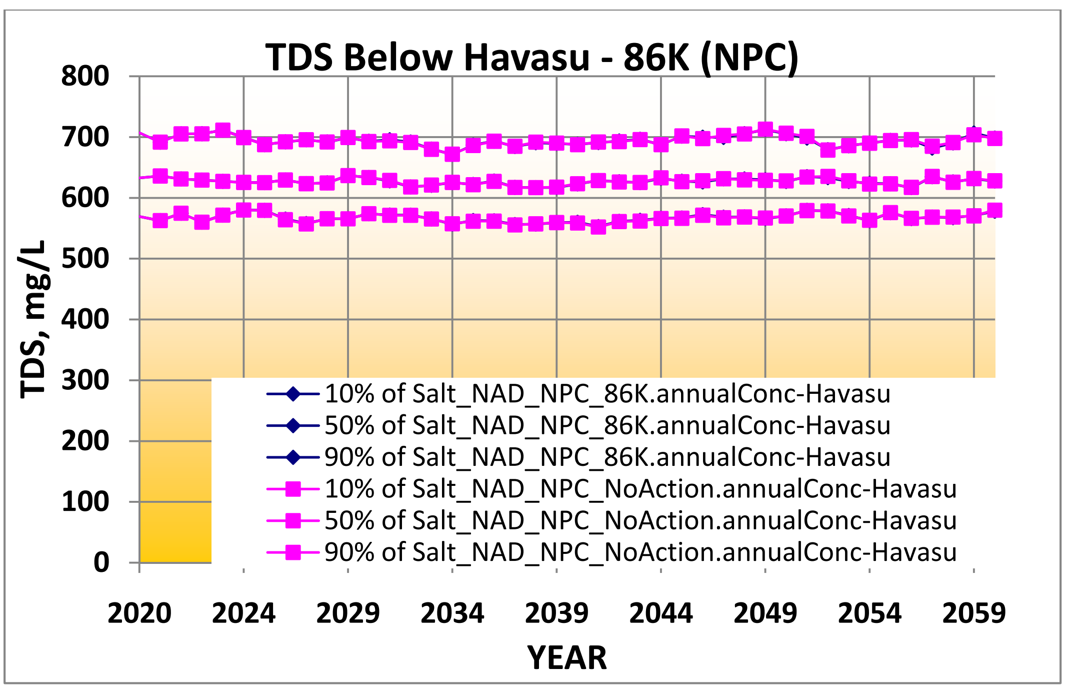

Figure E-10: CRSS NPC results – TDS below Lake Havasu, 86K Pipeline Alternative, 2020-2060

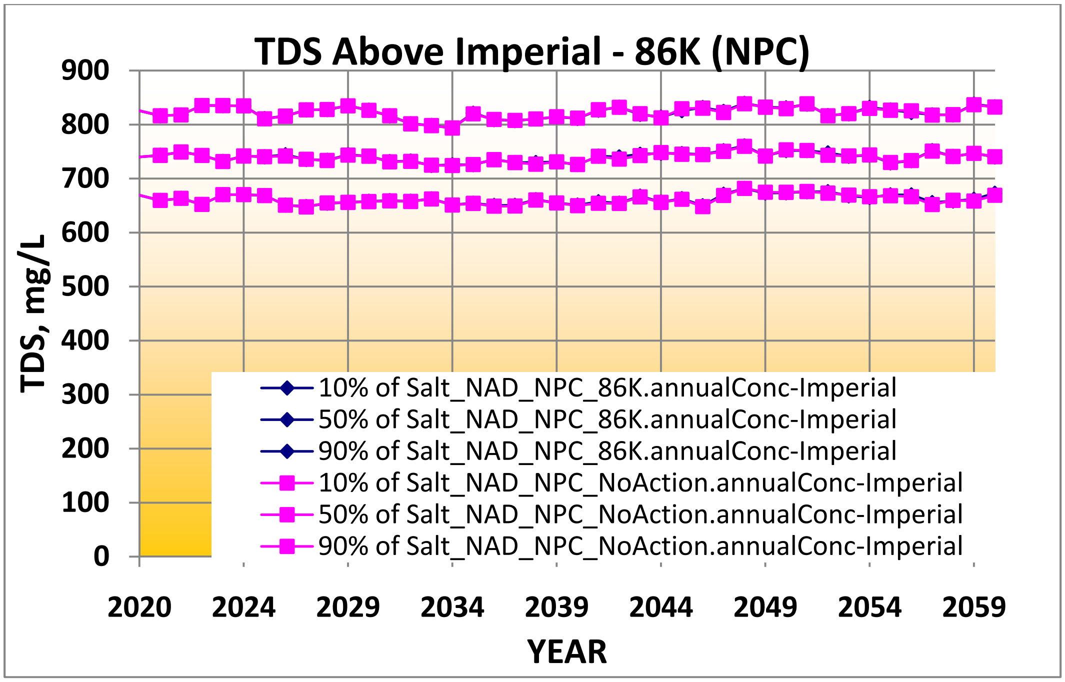

Figure E-11: CRSS NPC results – TDS above Imperial, 86K Pipeline Alternative, 2020-2060

F. Shortage Criteria EIS Modeling Results – Release Temperatures

Glen Canyon Dam release temperatures for varying reservoir pool elevations were analyzed in the "Colorado River Interim Guidelines for Lower Basin Shortages and Coordinated Operations for Lake Powell and Lake Mead, Final Environmental Impact Statement" or Shortage Criteria EIS (U.S. Department of the Interior, 2007). The results from the Shortage Criteria EIS present another method of evaluating the effects of the proposed Lake Powell Pipeline on release temperatures from Glen Canyon Dam.

F.1 Development of Release Temperatures for Shortage Criteria EIS

The Shortage Criteria EIS analysis approximated dam release temperatures based on reservoir pool elevations. Modeled scenarios of varying reservoir pool elevations were used to supplement historic observed data. Tables 4.5-2 and 4.5-3 of the Shortage Criteria EIS give the temperature range of dam releases at the 90th, 50th, and 10th percentile reservoir pool elevation of each alternative for the months of July and October, respectively. July was selected because it was typically the warmest month pre-dam. October was selected because release temperatures are typically warmest during this month. Both months were considered significant for the biological resources analysis of the Shortage Criteria EIS. Temperature ranges can be quite large at a given pool elevation because of the influence of several factors on release temperatures, most notably hydrology of the Upper Colorado River Basin and the resulting volume of spring runoff inflow to Lake Powell.

F.2 Using Shortage EIS Results to Estimate Release Temperatures

The CRSS hydrology modeling for the proposed Lake Powell Pipeline used two different future inflow hydrology datasets, Direct Natural Flow (DNF) and Nonparametric Paleo-conditioned (NPC) inflows (Grantz, 2010). As discussed in Section D.1.1 the water quality models are limited to simulating traces from results of the DNF hydrology input models. Using results from the Shortage EIS allows for additional analysis of the hydrology results from the NPC input models. The analysis gives a range of release temperatures based on reservoir pool elevations. There is not any consideration of the effects the withdrawal of warmer, upper layer water through the pipeline have on release temperatures.

Following the same methods used in the Shortage Criteria EIS, the 86K pipeline and 100K pipeline alternatives were compared with the no action alternative for the 90th, 50th, and 10th percentile reservoir pool elevations for the months of July and October. The 90th, 50th, and 10th percentile reservoir pool elevations are determined from cumulative distribution frequency (CDF) plots of reservoir pool elevation plotted against percent exceedance. The CDF plots use percent exceedance which is equal to one minus percentile. The CDF plots and data can be viewed in Attachments D, E, F, & G.

The ranges of release temperatures for a particular reservoir pool elevation are estimated from historic and modeled release temperatures for the months of July and October. Figure F-1 is a graph of release temperatures versus reservoir pool elevation for the month of July. Figure F-2 is a graph of release temperatures versus reservoir pool elevations for the month of October. The data shown in these graphs does not cover every possible scenario of reservoir pool elevation, hydrology, dam operations and other factors. The lack of data is taken into consideration when estimating the upper and lower bounds of possible release temperatures.

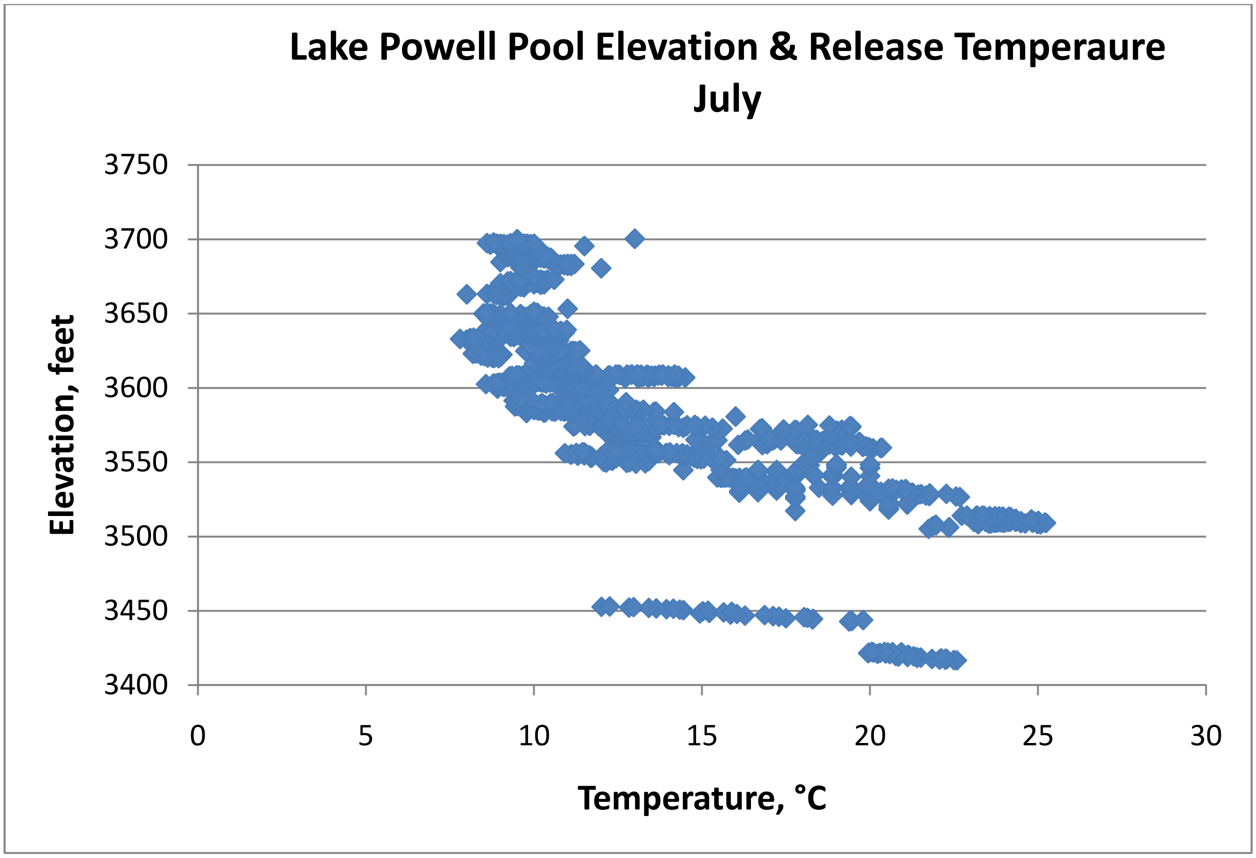

Figure F-1: Lake Powell July Release Temperatures, Historic & Modeled

Data points below elevation 3,500 feet should be ignored since the predicted 90th, 50th, and 10th percentile pool elevations do not drop to that level. The data for these graphs as well as for each month of the year are available in Attachment H.

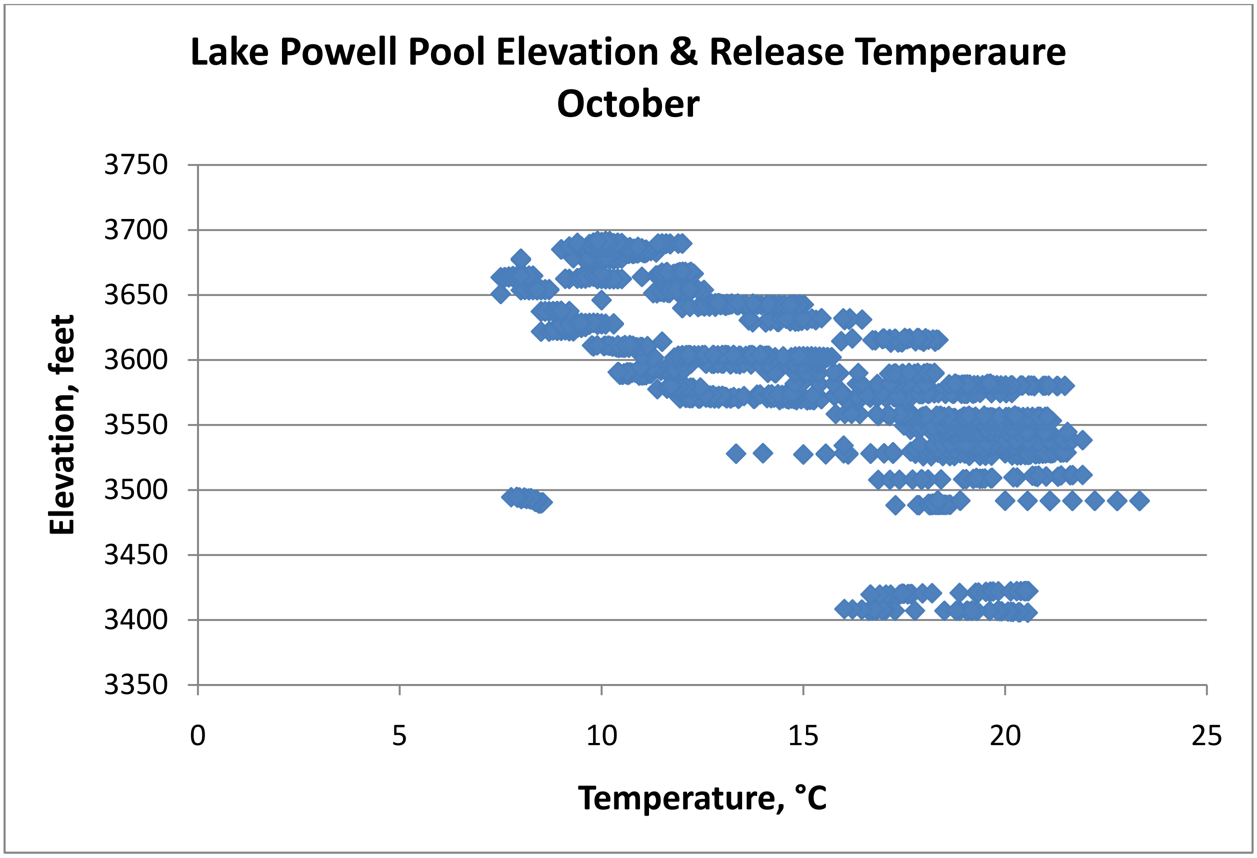

Figure F-2 Lake Powell October Release Temperatures, Historic & Modeled

F.2.1 86K Pipeline Alternative

The CRSS results (DNF & NPC) for the 86K pipeline and the no action alternatives were evaluated for the period when the pipeline reaches full capacity which is 2043-2060. The 90th, 50th, and 10th percentile elevations for July and October were determined from the DNF 86K pipeline scenario CDF which is found in Attachment D. Temperature ranges corresponding to the three elevation percentiles for the months of July and October were estimated using the data shown in Figure F-1 and Figure F-2. The 90th, 50th, and 10th percentile elevations and corresponding estimates of temperature ranges are for the DNF 86K pipeline and no action alternatives are shown in Table F-1. Estimated temperature ranges differ slightly from the ranges estimated for the Shortage Criteria EIS due to a more conservative interpretation of the data and graphs.

Table F-1: No Action & 86K Pipeline DNF Pool Elevations & Release Temperatures

Scenario	Month	90th		50th		10th	
		Elev, ft	Temp, °C	Elev, ft	Temp, °C	Elev, ft	Temp, °C
No Action – DNF	July	3700.00	8.5 – 11	3678.71	8 – 11.5	3615.12	8 – 14
	October	3691.41	8.5 – 12	3673.83	7.5 – 12.5	3606.85	9.5 – 19
86K – DNF	July	3700.00	8.5 – 11	3675.94	8 – 11.5	3609.21	8 – 14
	October	3691.31	8.5 – 12	3669.67	7.5 – 12.5	3599.83	9.5 – 19

The 90th, 50th, and 10th percentile elevations for the 86K pipeline and no action scenarios from the CRSS – NPC simulation are shown in Table F-2. These elevations were determined from the NPC 86K pipeline scenario CDF which is found in Attachment E.

Table F-2: No Action & 86K Pipeline NPC Pool Elevations & Release Temperatures

Scenario	Month	90th		50th		10th	
		Elev, ft	Temp, °C	Elev, ft	Temp, °C	Elev, ft	Temp, °C
No Action – NPC	July	3700.00	8.5 – 11	3680.73	8 – 11.5	3550.98	11 – 21
	October	3691.36	8.5 – 12	3675.6	7.5 – 12.5	3537.55	13 – 22
86K – NPC	July	3700.00	8.5 – 11	3678.63	8 – 11.5	3542.09	11.5 – 22
	October	3691.19	8.5 – 12	3673.7	7.5 – 12.5	3527.64	13 – 22

Differences in temperature releases between the 86K pipeline and no action alternatives are unlikely to be apparent unless the reservoir is significantly drawn down and the differences in pool elevations are near 10 feet or greater. The CRSS results for the NPC hydrology datasets have greater reductions in pool elevations for the 10th percentile and differences in release temperatures are more likely to be apparent. Even so, the estimated temperature ranges at the 10th percentile pool elevations for the 86K pipeline and no action alternatives differ by just 1°C in July and do not differ significantly in October. These results are consistent with release temperature results of the CE-QUAL-W2 modeling.

F.2.2 100K Pipeline Alternative

The CRSS results (DNF & NPC) for the 100K pipeline and the no action alternatives were evaluated for the period when the pipeline reaches full capacity which is 2046-2060. This is a different time period of evaluation than was used in the 86K pipeline analysis and as a result the no action alternative pool elevations in the two sections are slightly different. The 90th, 50th, and 10th percentile elevations for July and October were determined from the DNF 100K pipeline scenario CDF which is found in Attachment F. Temperature ranges corresponding to the three elevation percentiles for the months of July and October were estimated using the data shown in Figure F-1 and Figure F-2. The 90th, 50th, and 10th percentile elevations and corresponding estimates of temperature ranges are for the DNF 100K pipeline and no action alternatives are shown in Table F-3. Estimated temperature ranges differ slightly from the ranges estimated for the Shortage Criteria EIS due to a more conservative interpretation of the data and graphs.

Table F-3: No Action & 100K Pipeline DNF Pool Elevations & Release Temperatures

Scenario	Month	90th		50th		10th	
		Elev, ft	Temp, °C	Elev, ft	Temp, °C	Elev, ft	Temp, °C
No Action – DNF	July	3700.00	8.5 – 11	3679.49	8 – 11.5	3616.38	8 – 14
	October	3691.33	8.5 – 12	3674.54	7.5 – 12.5	3607.29	9.5 – 19
86K – DNF	July	3700.00	8.5 – 11	3675.81	8 – 11.5	3609.07	8 – 14
	October	3691.21	8.5 – 12	3669.10	7.5 – 12.5	3601.14	9.5 – 19

The 90th, 50th, and 10th percentile elevations for the 100K pipeline and no action scenarios from the CRSS – NPC simulation are shown in Table F-4. These elevations were determined from the NPC 100K pipeline scenario CDF which is found in Attachment G.

Table F-4: No Action & 100K Pipeline NPC Pool Elevations & Release Temperatures

Scenario	Month	90th		50th		10th	
		Elev, ft	Temp, °C	Elev, ft	Temp, °C	Elev, ft	Temp, °C
No Action – NPC	July	3700.00	8.5 – 11	3681.59	8 – 11.5	3543.12	11.5 – 22
	October	3691.57	8.5 – 12	3676.54	7.5 – 12.5	3533.20	13 – 22
86K – NPC	July	3700.00	8.5 – 11	3679.48	8 – 11.5	3536.56	12 – 23
	October	3691.38	8.5 – 12	3674.33	7.5 – 12.5	3523.49	13 – 22

Differences in temperature releases between the 100K pipeline and no action alternatives are unlikely to be apparent unless the reservoir is significantly drawn down and the differences in pool elevations are near 10 feet or greater. The CRSS results for the NPC hydrology datasets have greater reductions in pool elevations for the 10th percentile and differences in release temperatures are more likely to be apparent. Even so, the estimated temperature ranges at the 10th percentile pool elevations for the 100K pipeline and no action alternatives differ by just 1°C in July and do not differ in October. Again, these results are consistent with release temperature results of the CE-QUAL-W2 modeling.

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