Lake Powell Pipeline

Draft Study Report 5
Groundwater Resources

March 2011

Draft Groundwater Resources Technical Report
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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 Groundwater Resources 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

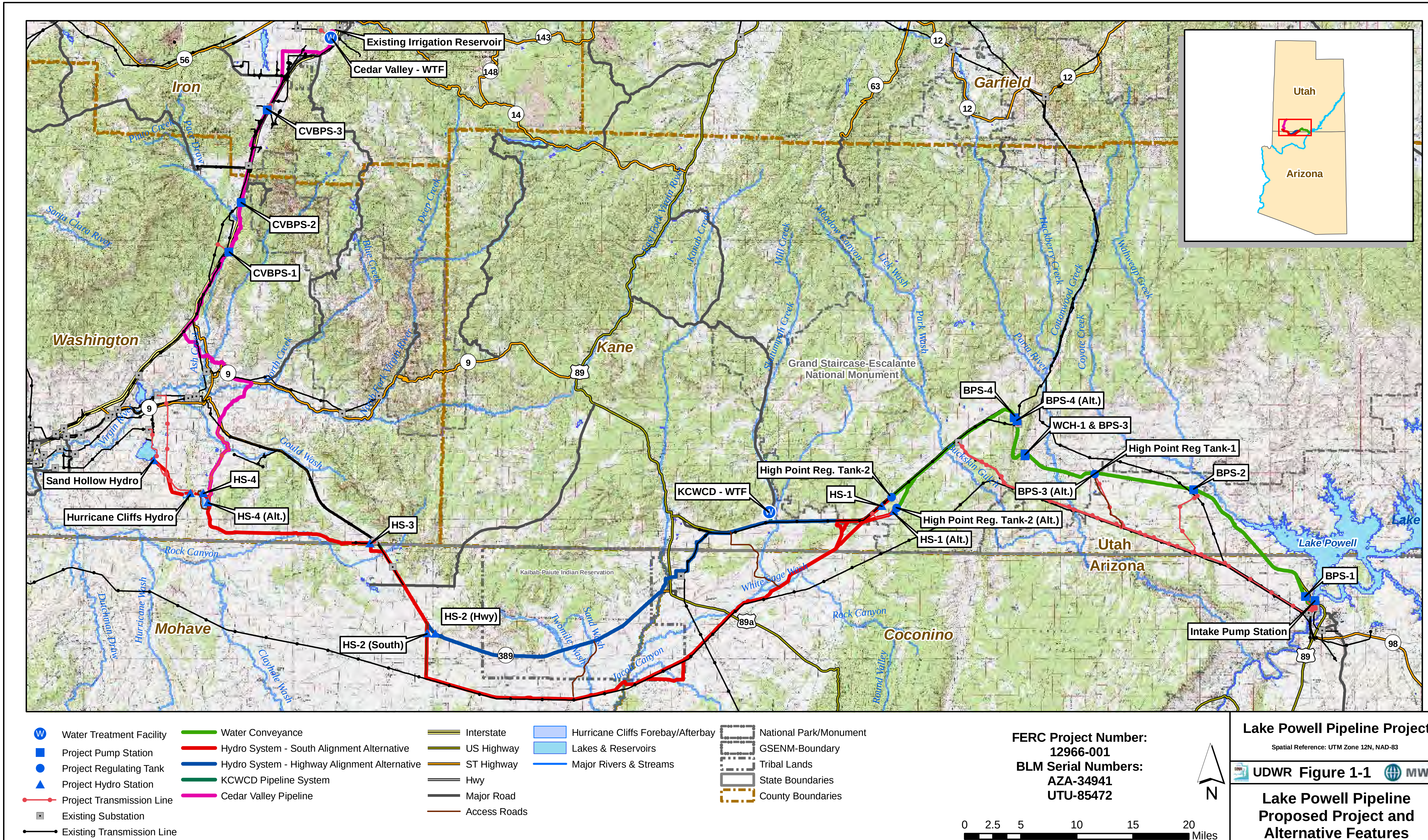


Figure 1-1

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

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

N

0 0.5 1 2 3 4 Miles

Lake Powell Pipeline Project

Spatial Reference: UTM Zone 12N, NAD-83

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.

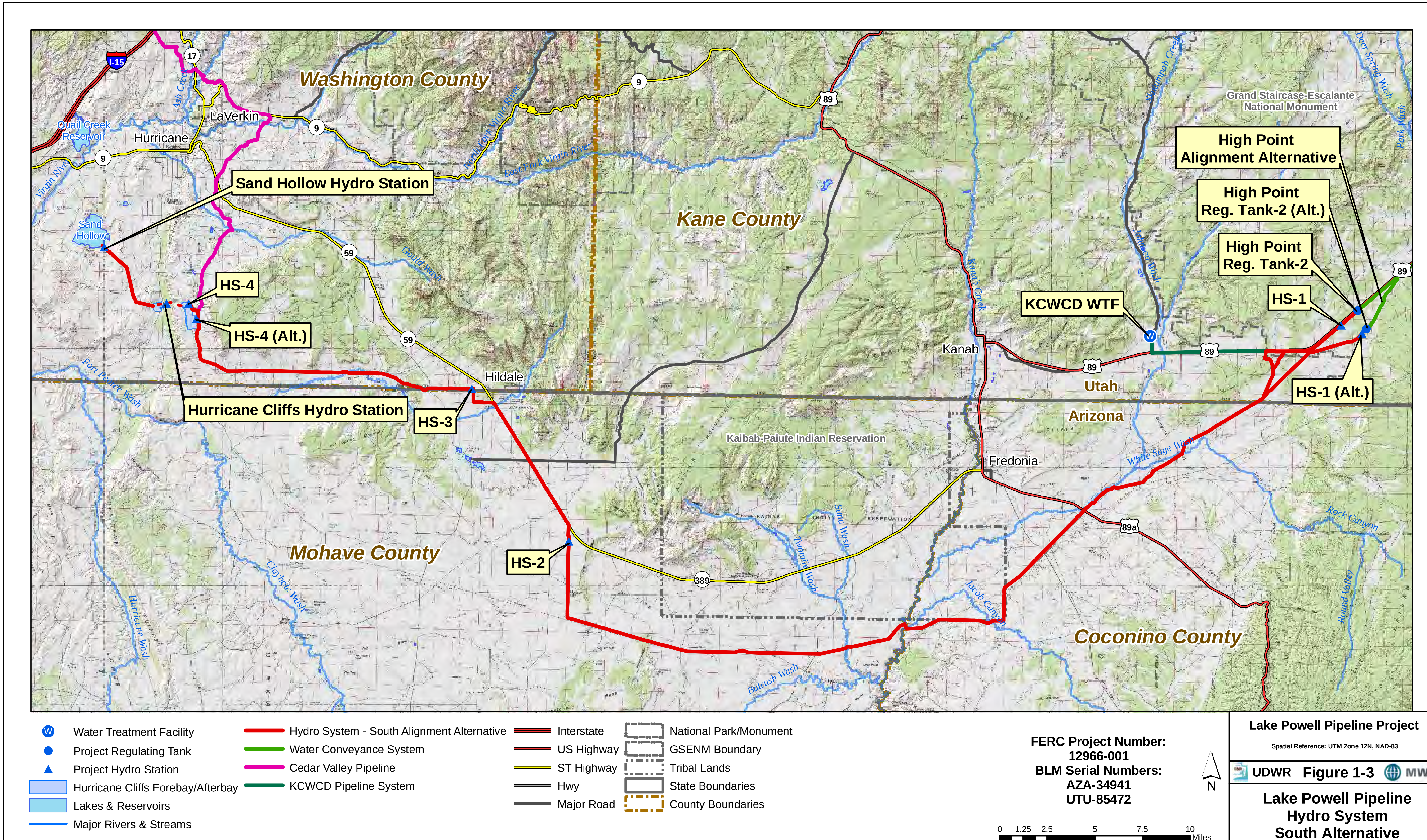
The High Point Alignment Alternative would diverge south from U.S. 89 parallel to the K4020 road and continue outside of the Congressionally-designated utility corridor to a buried regulating tank (High Point Regulating Tank-2 (Alt.) at ground level elevation 5,630 feet MSL, which would be the topographic 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
Kaibab-Paiute Indian Reservation
LaVerkin
Hurricane
Hildale
Kanab
Fredonia
Utah
Arizona
Quail Creek Reservoir
Sand Hollow
Sand Hollow Hydro Station
HS-4
HS-4 (Alt.)
Hurricane Cliffs Hydro Station
HS-3
HS-2
KCWCD WTF
HS-1
HS-1 (Alt.)
High Point Alignment Alternative
High Point Reg. Tank-2 (Alt.)
High Point Reg. Tank-2
Virgin River
Ash Creek
North Fork Virgin River
East Fork Virgin River
Gould Wash
Fort Pearce Wash
Clayhole Wash
Hurricane Wash
Kanab Creek
Johnson Wash
Sand Wash
Twomile Wash
Jacob Canyon
Bulrush Wash
White Sage Wash
Rock Canyon
Round Valley
Deer Spring Wash
Park Wash
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
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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 1-3
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.

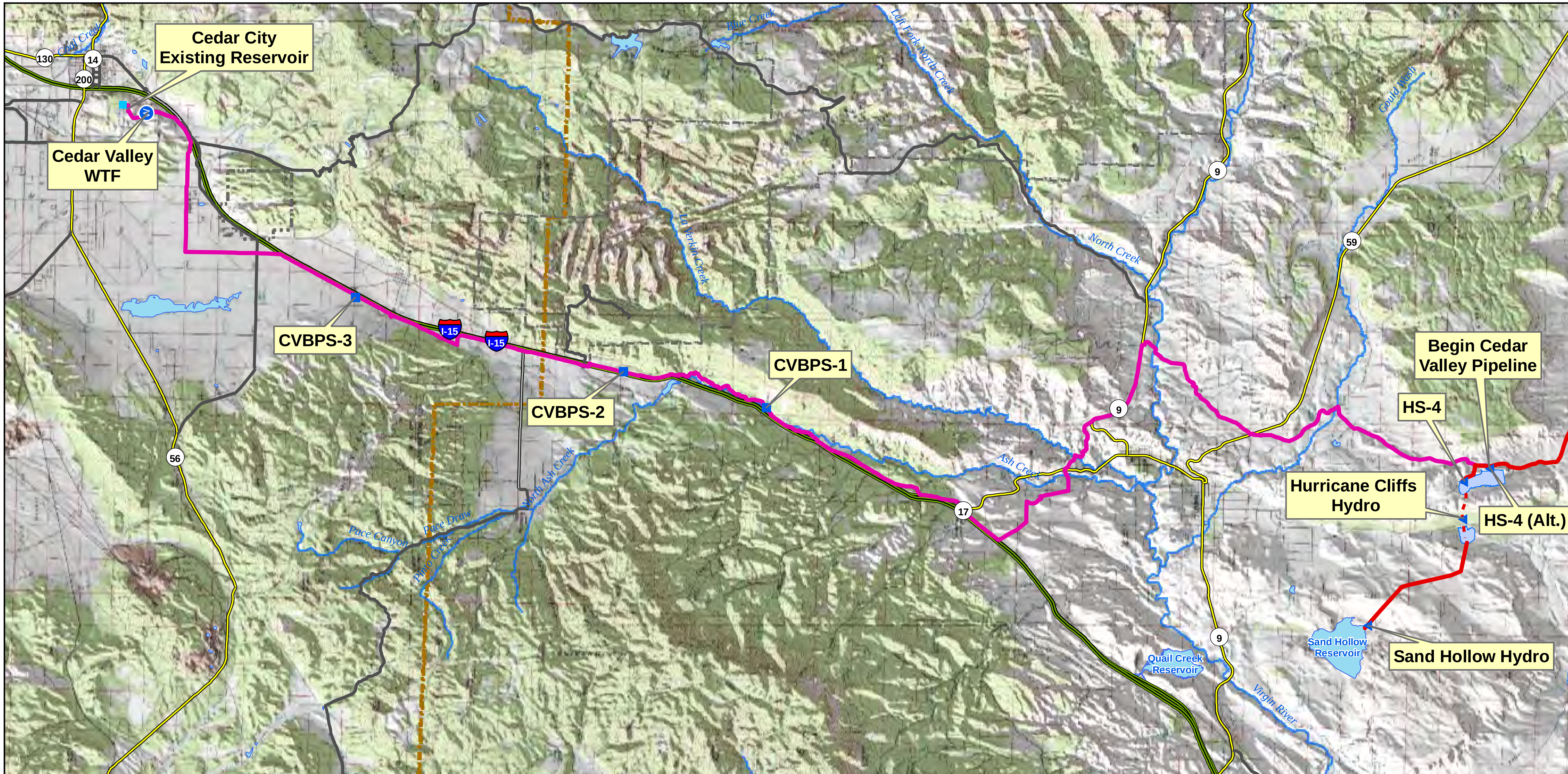
The penstock alignment would continue through White Sage Wash and then parallel to the Navajo-McCullough Transmission Line, crossing U.S. 89 Alt. and Forest Highway 22 toward the southeast corner of the Kaibab Indian Reservation. The penstock alignment would run parallel to and south of the south boundary 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.

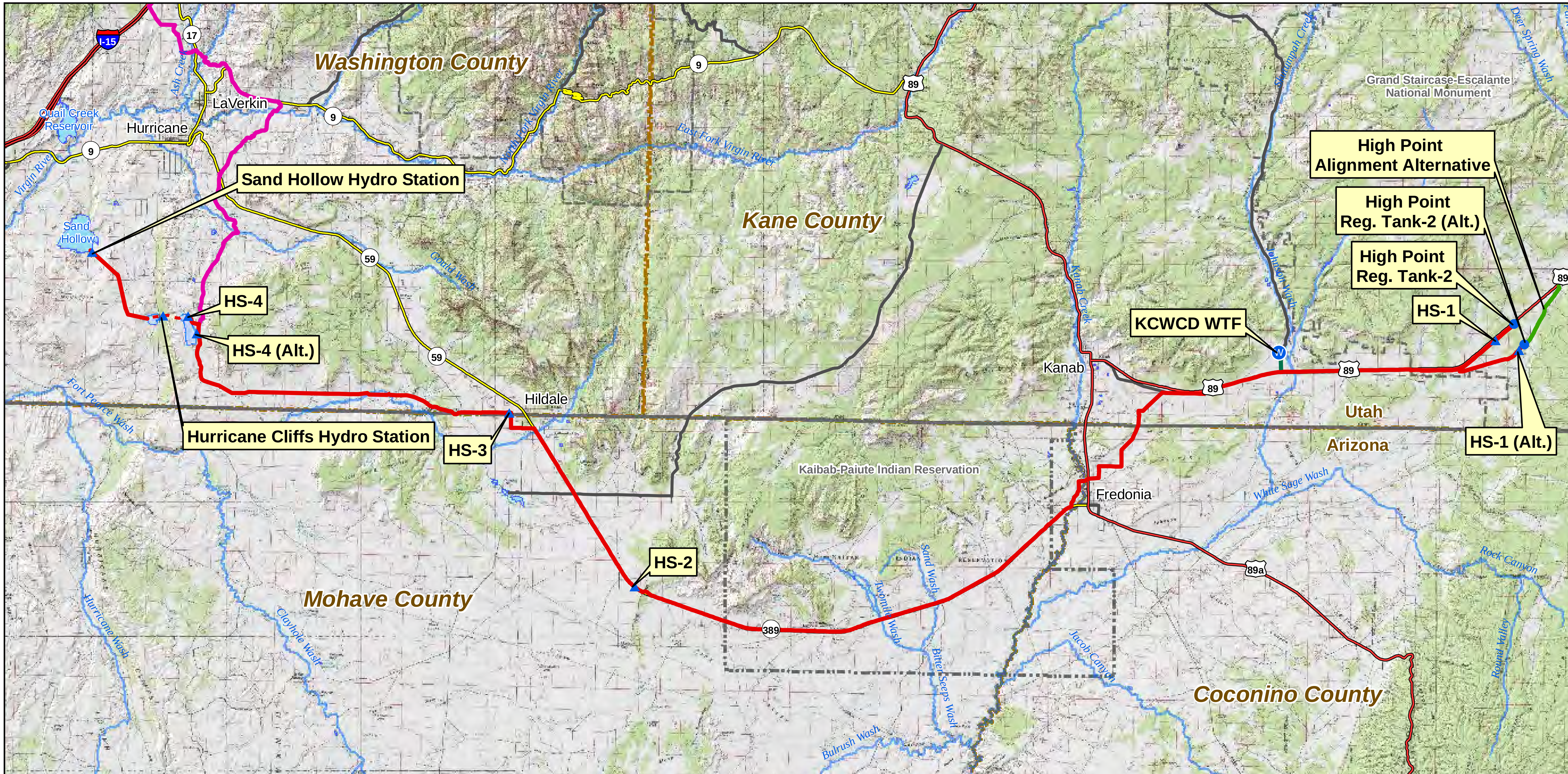
The **Hydro System** would convey the Lake Powell water from the regulating tank at the high point at ground elevation 5,695 feet MSL for about 80 miles through a buried 69-inch diameter penstock in Kane and Washington counties, Utah and Coconino and Mohave counties, Arizona to Sand Hollow Reservoir 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.



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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BLM Serial Numbers:
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UTU-85472

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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 1-5** 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).

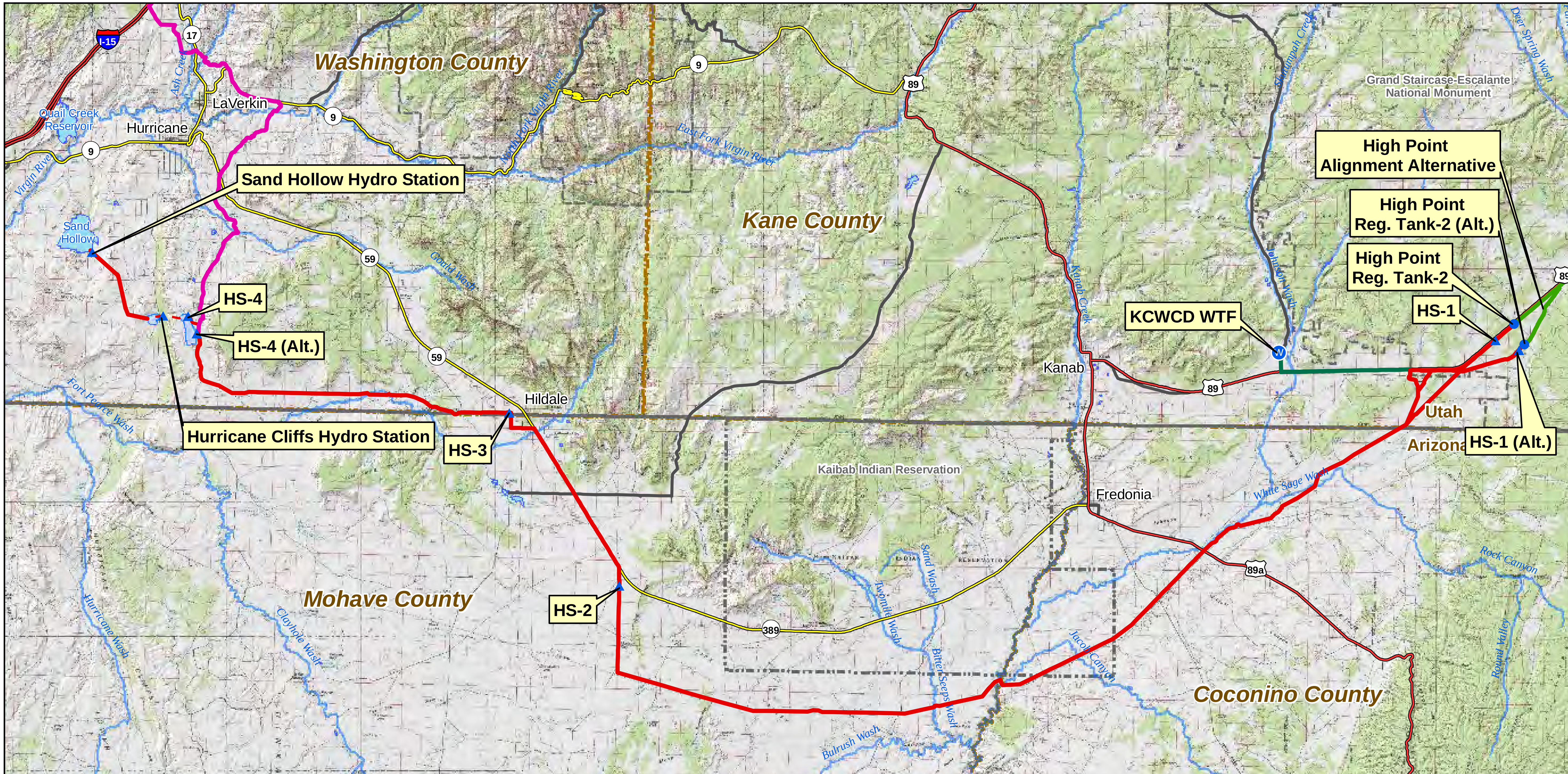
The proposed new **BPS-1 Transmission Line** would begin at the new switch station located on the south side of U.S. 89 and parallel the LPP Water Conveyance System alignment to the BPS-1 substation west of U.S. 89. This 69 kV transmission line would be about 1 mile long in Coconino County, Arizona (Figure 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
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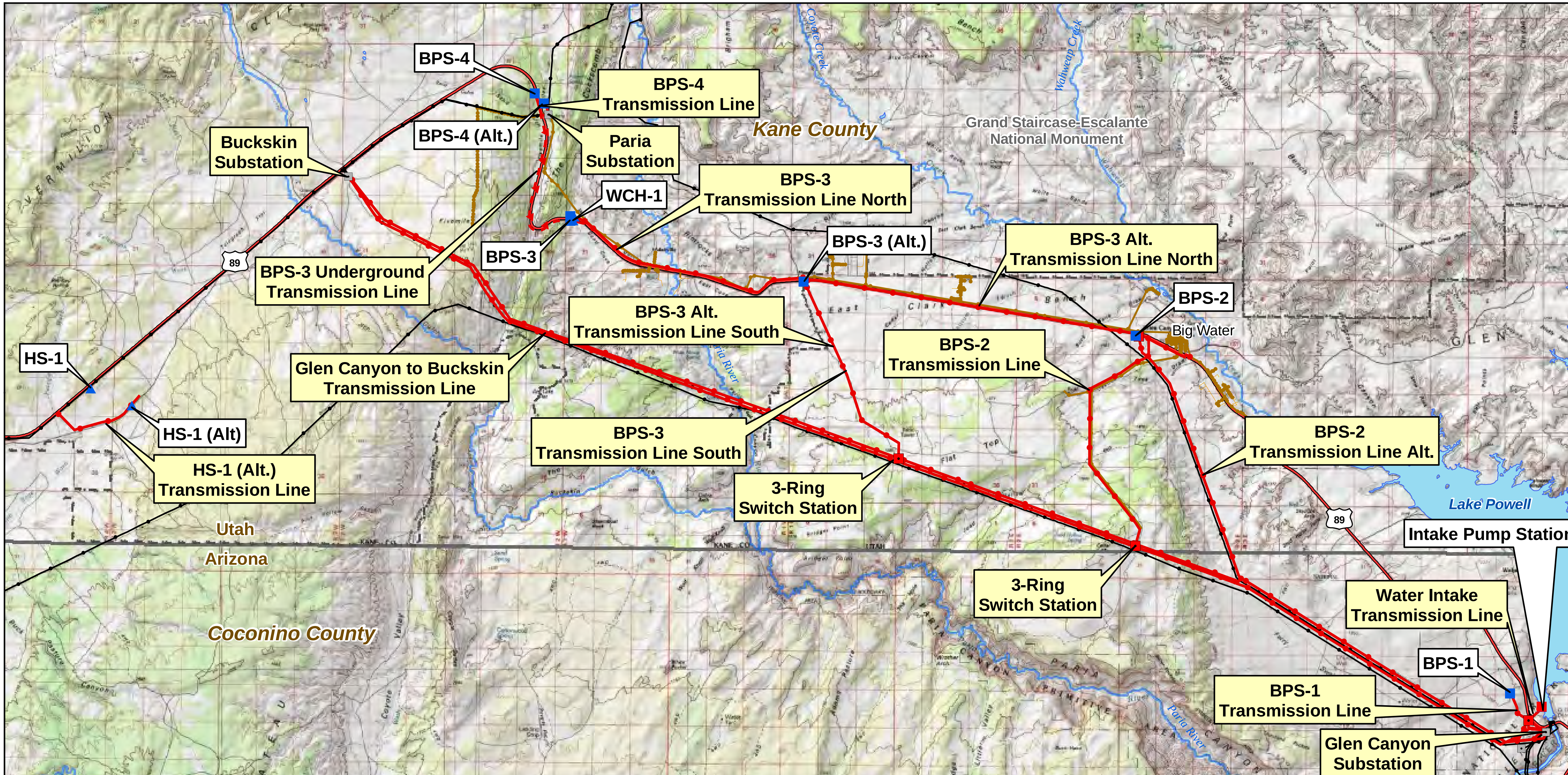
0 1.25 2.5 5 7.5 10 Miles

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
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0 0.5 1 2 3 4 Miles

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Lake Powell Pipeline Project

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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).

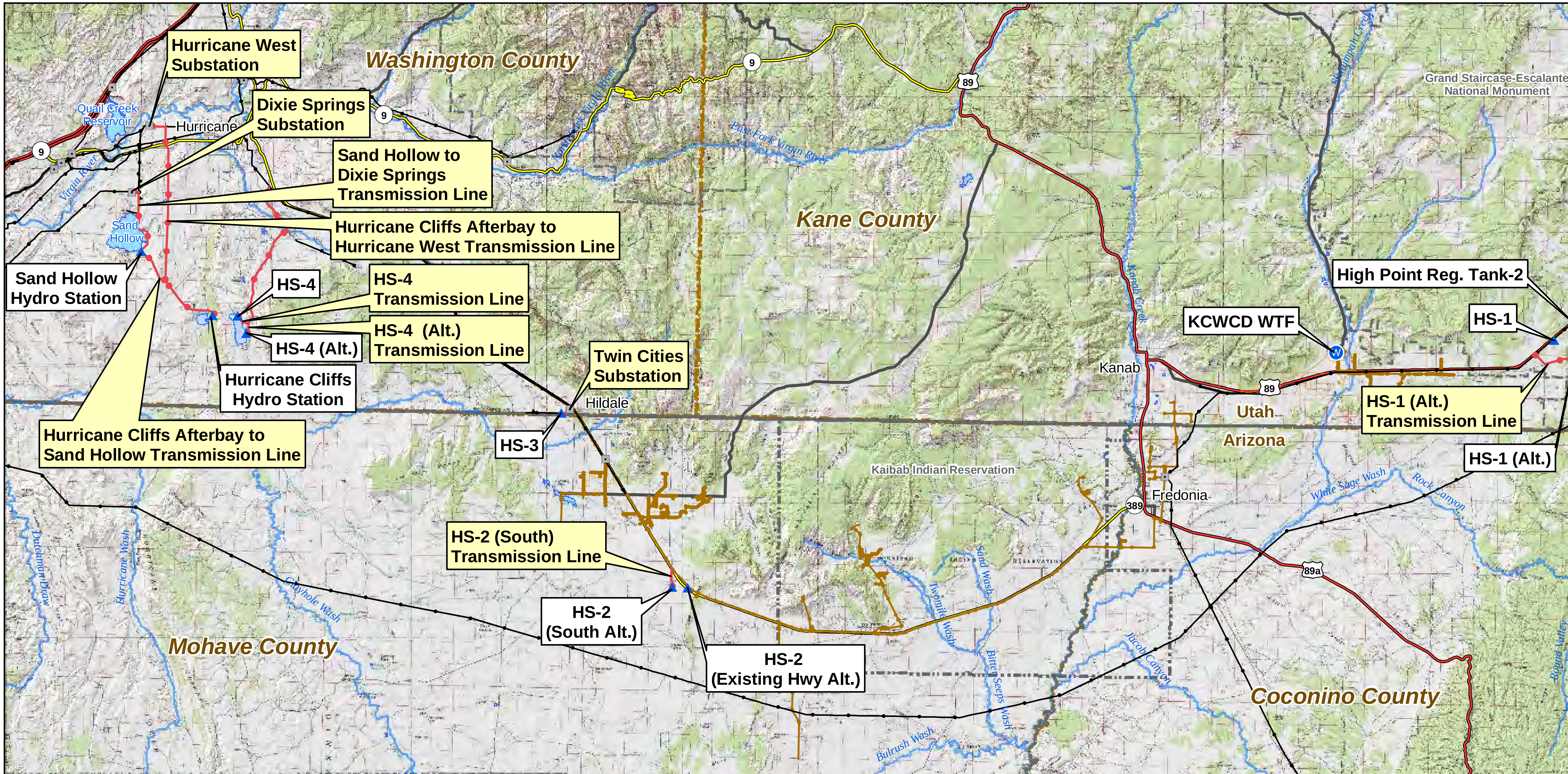
The proposed new **Hurricane Cliffs Afterbay to Sand Hollow Transmission Line** would consist of a new 69 kV transmission line from the Hurricane Cliffs peaking power plant and substation, and run northwest to the Sand Hollow Hydro Station substation. This new 69 kV transmission line would be about 4.9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

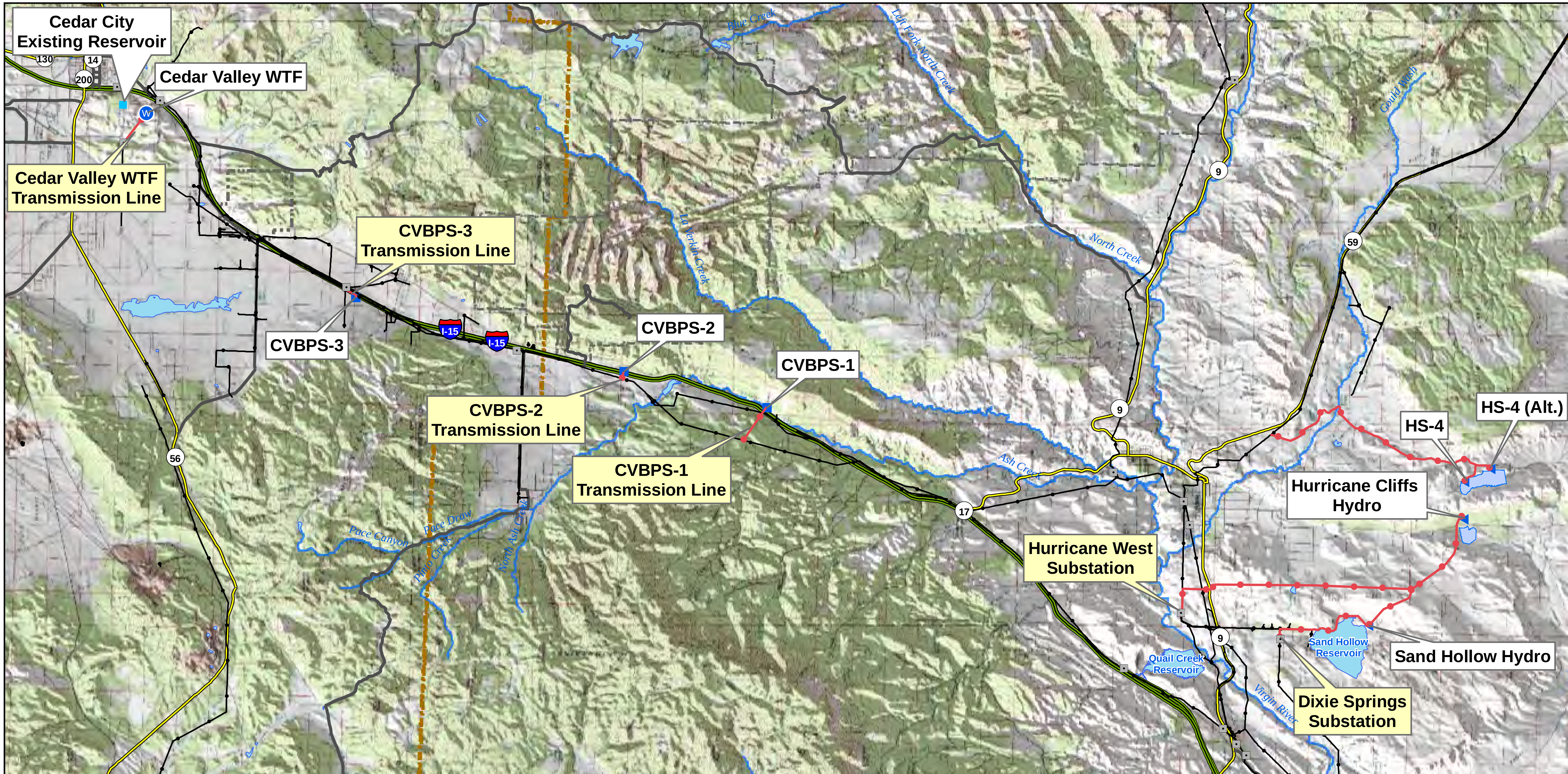
N

Lake Powell Pipeline Project

Spatial Reference: UTM Zone 12N, NAD-83

UDWR **Figure 1-8** MWH

Lake Powell Pipeline Transmission Line Alternatives West



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

N

0 1 2 4 6 8 Miles

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 Purposes of Study

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

1.5.1 Identified Issues

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

- Groundwater levels at the water intake site
- Groundwater levels at locations where the pipeline would cross streams
- Groundwater levels at the forebay and afterbay reservoirs
- Groundwater levels and trends associated with existing recharge at Sand Hollow Reservoir
- Groundwater quality and trends associated with existing recharge at Sand Hollow Reservoir
- Groundwater levels along the Cedar Valley Pipeline, particularly at stream crossings
- Groundwater levels and trends near proposed recharge basins in southwestern Cedar Valley
- Projected groundwater level changes associated with recharge of Lake Powell water at Sand Hollow Reservoir and southwestern Cedar Valley
- Projected groundwater quality changes associated with recharge of Lake Powell water at Sand Hollow Reservoir and southwestern Cedar Valley
- Identification of groundwater production wells within the projected recharge spheres of influence on water quantity and quality at Sand Hollow Reservoir and southwestern Cedar Valley
- Projections of surface water and groundwater interactions at the Virgin River, lower Quichapa Creek, and Quichapa Lake

1.5.2 Impact Topics

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

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

Chapter 2
Methodology

2.1 General

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

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

2.2 Assumptions

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

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

2.3 Data Used

The information that was reviewed for this study included the following maps, documents, and databases. The complete references are found in Chapter 8:

- Arizona Department of Water Resources (ADWR) Well Registry
- Cedar City Engineer 2007. Cedar City 2006 Water Report: Report to the Mayor and City Council, Cedar City, Utah
- HAL (Hansen, Allen & Luce) 2005. Washington County Water Conservancy District, Petition for Classification of the Navajo/Kayenta and Upper Ash Creek Aquifers, Final Report
- MWH 2009. Lake Powell Pipeline Phase I Preliminary Engineering and Environmental Studies Task 5 - Develop and Analyze Alternatives. Revised Technical Memorandum 5.13C, Aquifer Recharge Issues
- Reclamation (U.S. Bureau of Reclamation) 2007. Unpublished water quality sampling data for Wahweap Sampling Station, Lake Powell, Wahweap Sampling Station
- UAC R317 2007. Utah Administrative Code, Rule Title 317, Water Quality
- USGS (U.S. Geological Survey) 1985. Study and Interpretation of the Chemical Characteristics of Natural Water: U.S. Geological Survey Water-Supply Paper 2554
- USGS 1999. User's Guide to PHREEQC (Version 2) – A Computer Program for Speciation, Batch-Reaction, One-Dimensional Transport, and Inverse Geochemical Calculations. D.L. Parkhurst and C.A.J. Apel. USGS Water-Resource Investigations Report 99-4259
- USGS 2000. Geohydrology and Numerical Simulation of Ground-Water Flow in the Central Virgin River Basin of Iron and Washington Counties, Utah: Utah Department of Natural Resources Technical Publication No. 116
- USGS 2002. Selected Hydrologic Data for Cedar Valley, Iron County, Southwestern Utah, 1930-2001: U.S. Geological Survey Open-File Report No. 01-419
- USGS 2005a. Pre- and Post-Reservoir Ground-Water Conditions and Assessment of Artificial Recharge at Sand Hollow, Washington County, Utah, 1995-2005: U.S. Geological Survey Scientific Investigations Report 2005-5185
- USGS 2005b. Hydrology and Simulation of Ground-Water Flow in Cedar Valley, Iron County, Utah: U.S. Geological Survey Scientific Investigations Report 2005-5170
- USGS 2007. Assessment of Artificial Recharge at Sand Hollow Reservoir, Washington County, Utah, Updated to Conditions Through 2006: U.S. Geological Survey Scientific Investigations Report 2007-5023
- USGS 2009. 2009. Assessment of Artificial Recharge at Sand Hollow Reservoir, Washington County, Utah, Updated to Conditions Through 2007: U.S. Geological Survey Scientific Investigations Report 2009-5050
- USGS 2010a. National Water Information System (NWIS) database.
- USGS 2010b. Personal communication with Victor Heilweil, USGS, pertaining to ongoing research of geochemical effects of recharge at Sand Hollow Reservoir
- Utah Department of Environmental Quality, Division of Water Quality (DEQ-DWQ) 2007. Utah Ground Water Quality Protection Program, Aquifer Classification Maps for Utah's Groundwater.
- Utah Division of Water Rights (UDWRi) Well Drilling Database
- Washington County Water Conservancy District (WCWCD) 2005. Geology Along the Route of the Lake Powell Water Pipeline, Utah and Arizona: Report WCWCD-02

2.4 Impact Analysis Methodology

2.4.1 Pipeline Impacts

2.4.1.1 Stream Channel Crossings

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

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

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

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

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

Table 2-1 Dewatering Probability Categories		
Anticipated Depth to Groundwater (ft)	**Probability of Dewatering Requirement During Construction**	**Typical Crossings Encountered**
0 to 16	High	Perennial streams
16 to 30	Medium	Seasonal low-flow streams and dry washes with riparian/phreatophyte vegetation
> 30	Low	Dry washes or ephemeral streams

2.4.1.2 Groundwater Well Locations and Water Level Measurement Records

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

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

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

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

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

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

2.4.2 Unlined Forebay and Afterbay Recharge Impacts

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

2.4.3 Groundwater – Surface Water Interactions

Interactions between groundwater and surface water were evaluated by identifying locations where groundwater recharge associated with the Project could affect surface water discharge rates or water quality. This was accomplished by reviewing topographic and geologic maps, as well as USGS reports relevant to this issue.

2.4.4 Water Quality Impacts

2.4.4.1 Data Review and Modeling

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

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

2.4.4.2 Recharge Evaluation

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

Chapter 3
Affected Environment (Baseline Conditions)

3.1 Impact Area

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

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

3.2 Overview of Baseline Conditions

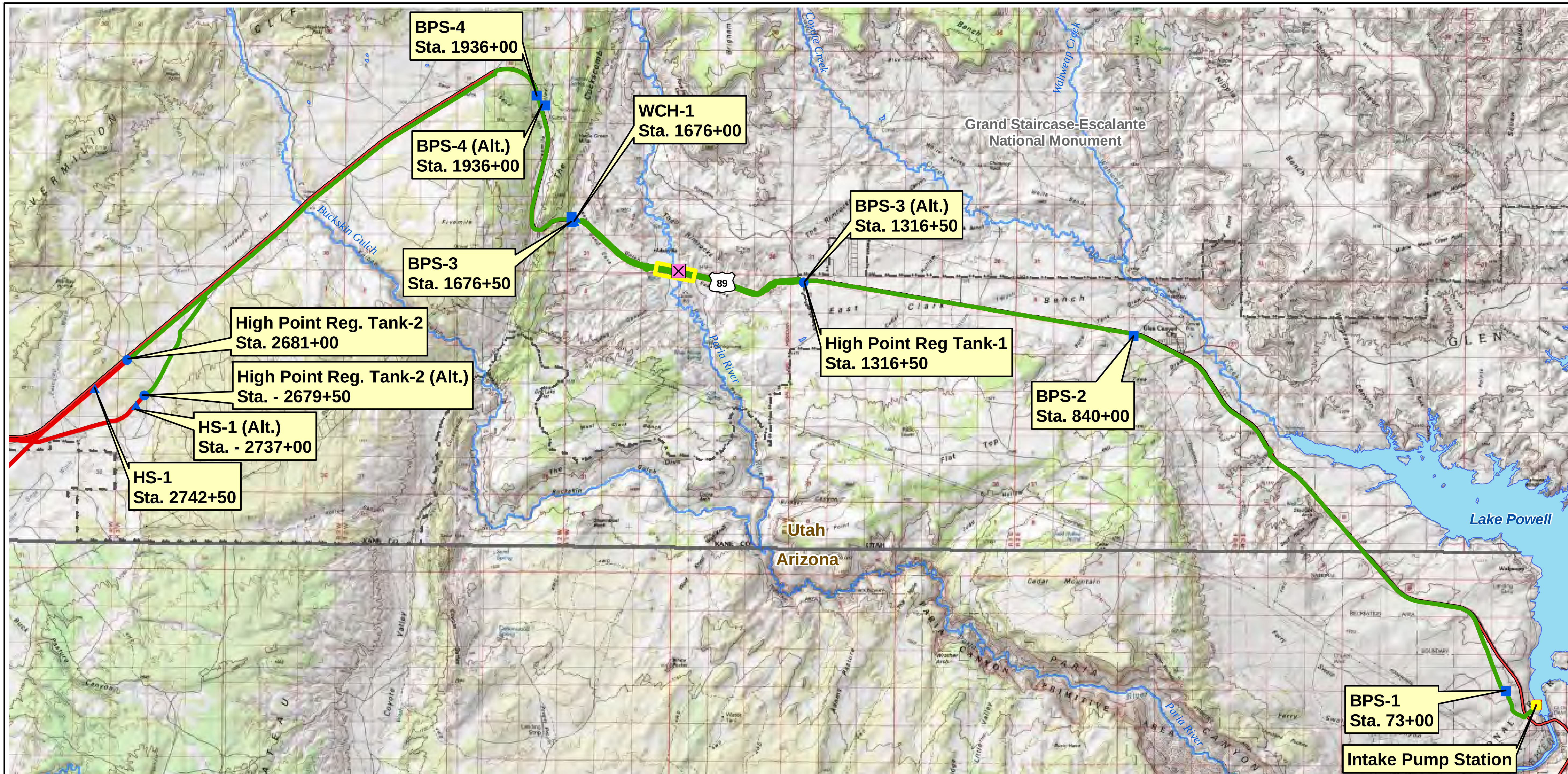
3.2.1 Lake Powell Pipeline

3.2.1.1 Shallow Groundwater

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

Table 3-1
LPP Stream Channel Crossings

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



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

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

N

0 0.5 1 2 3 4 Miles

Lake Powell Pipeline Project

1:175,000 Scale

Spatial Reference: UTM Zone 12N, NAD-83

UDWR **Figure 3-1** MWH

Lake Powell Pipeline
Potential Shallow
Groundwater Locations
Water Conveyance System

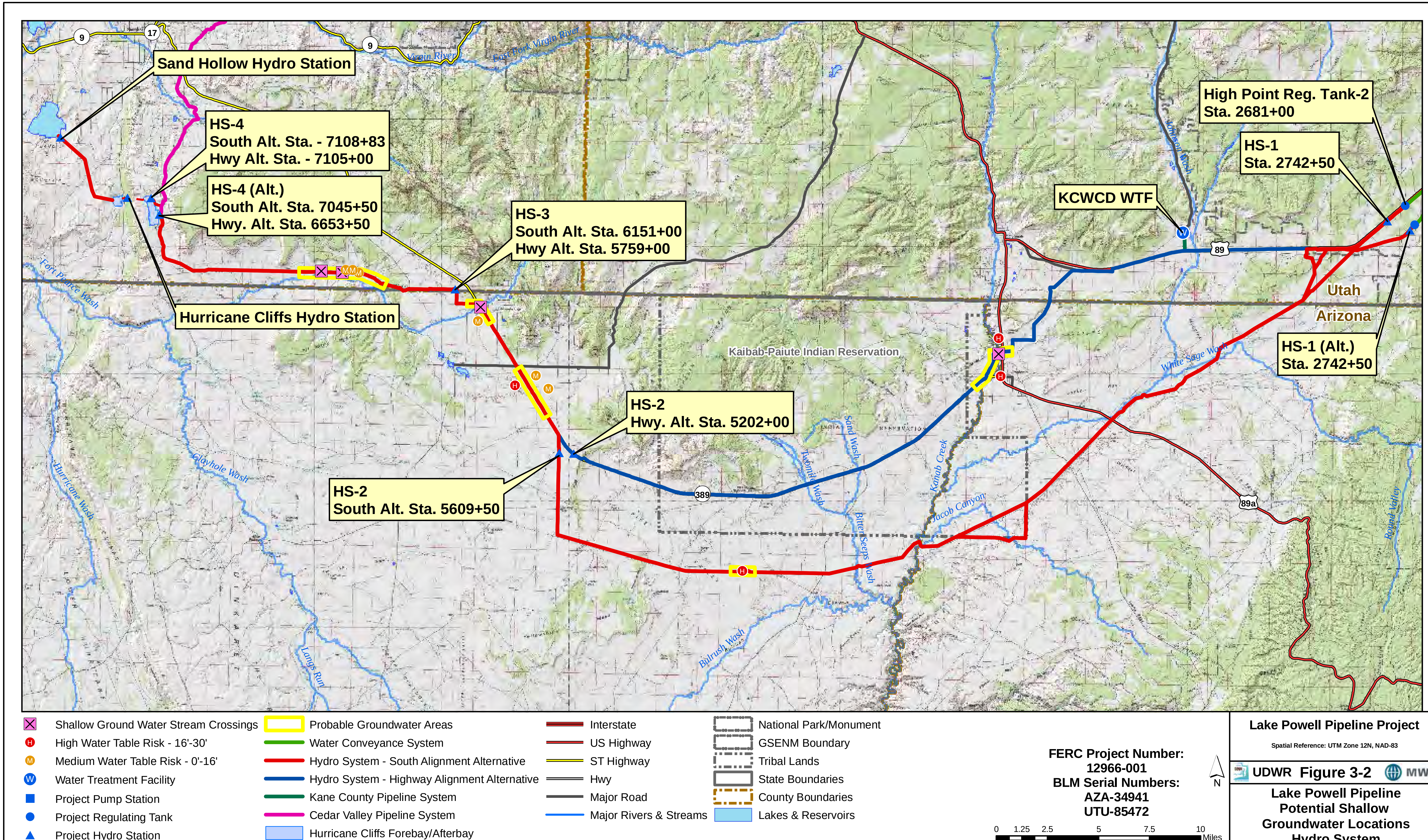


Figure 3-2
Lake Powell Pipeline Potential Shallow Groundwater Locations Hydro System

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

3.2.1.2 Forebay and Afterbay Recharge

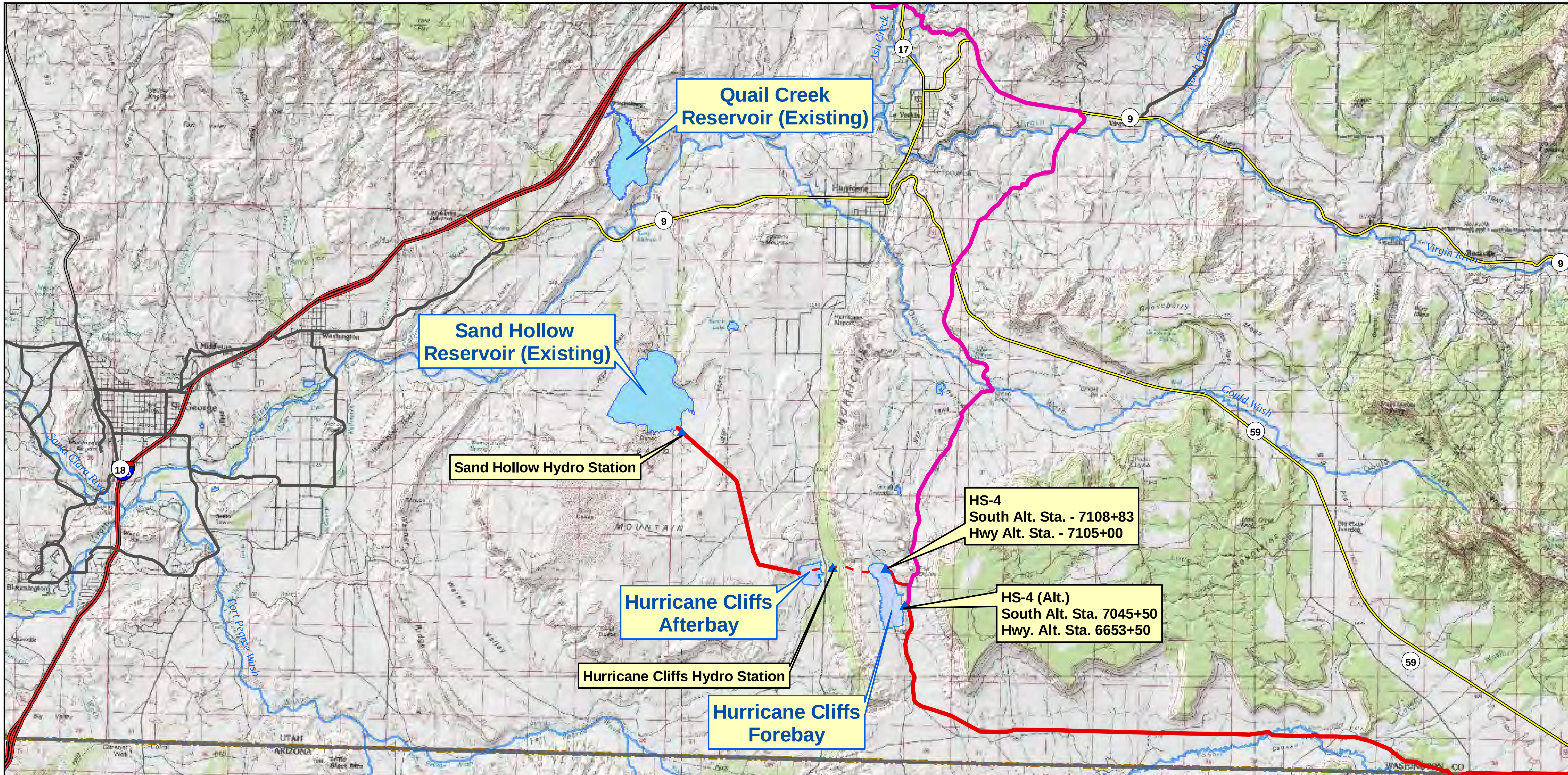
Three open-air reservoirs could be constructed as part of the Project, including the Hurricane Cliffs Hydrostation Forebay (Forebay), the Hydropower Peaking Reservoir, and the Hurricane Cliffs Hydrostation Afterbay (Afterbay). All three reservoirs are located near the Hurricane Cliffs, as shown in Figure 3-3. Of these, only the Hurricane Cliffs Hydrostation Afterbay would not be lined to prevent substantial seepage.

The Forebay would be located above the Hurricane Cliffs. Underlying strata includes the Lower Red Member of the Moenkopi Formation, the Timpoweap Member of the Moenkopi Formation, the Harrisburg Member of the Kaibab Formation, and the Fossil Mountain Member of the Kaibab Formation, as well as some basalt flows. Vertical fractures within these formations could result in relatively high infiltration rates, and discharge to the face of Hurricane Cliffs would be a concern. However, the Forebay may be partially lined to prevent substantial amounts of seepage and reduce the possibility of discharge to the face of the cliffs. Furthermore, the strata dip gently toward the east, away from the cliffs, and zones of little or no fractures present within the formations would tend to direct seepage from the Forebay away from the cliffs rather than toward it.

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

3.2.1.3 Groundwater – Surface Water Interactions

Only one location within the Project has the potential to be affected by groundwater-surface water interactions. This would be at Sand Hollow Reservoir and the nearby Virgin River. Recharge from the existing Sand Hollow Reservoir, which began filling in 2002, affects groundwater levels near Sand Hollow Reservoir by causing mounding of the groundwater table. This mound now extends from the underlying water table to the bottom of the reservoir, and therefore cannot get much larger. Some of the recharge is recovered by production wells. Flow within the Navajo Sandstone aquifer system underlying Sand Hollow Reservoir is northward and westward, and intercepts the Virgin River both north and west of the reservoir. Ongoing studies by the USGS (USGS 2005; 2007; 2009; 2010) suggest that the water levels within the aquifer are no longer changing substantially as a result of recharge from Sand Hollow Reservoir. Therefore rates of discharge to the Virgin River are assumed to be approximately stabilized and are unlikely to change substantially as a result of recharge from the reservoir, regardless of the source of water filling the reservoir.



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

FERC Project Number:
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BLM Serial Numbers:
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UTU-85472

N

0 0.5 1 2 3 4 Miles

Lake Powell Pipeline Project

Spatial Reference: UTM Zone 12N, NAD-83

UDWR **Figure 3-3** MWH

Lake Powell Pipeline Project Reservoirs

3.2.1.4 Water Quality

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

Water quality at Sand Hollow Reservoir has been characterized by ongoing USGS investigations (USGS 2005; 2007; 2009; 2010). The effects of recharge using Virgin River water, which is very similar in concentrations of Total Dissolved Solids and most individual constituents to Lake Powell water, have been documented by the USGS. Current recharge at Sand Hollow Reservoir has resulted in a trend toward higher TDS, caused in part by the higher TDS of Virgin River water as it blends with underlying groundwater, as well as a probable leaching effect of salts within the soil. This leaching appears to be diminishing, because groundwater quality near the reservoir appears to be improving after an initial increase in TDS. If current trends continue, groundwater underlying Sand Hollow Reservoir will become similar to the recharge water. A more extensive discussion is provided in the Recharge Technical Report, included in Appendix A.

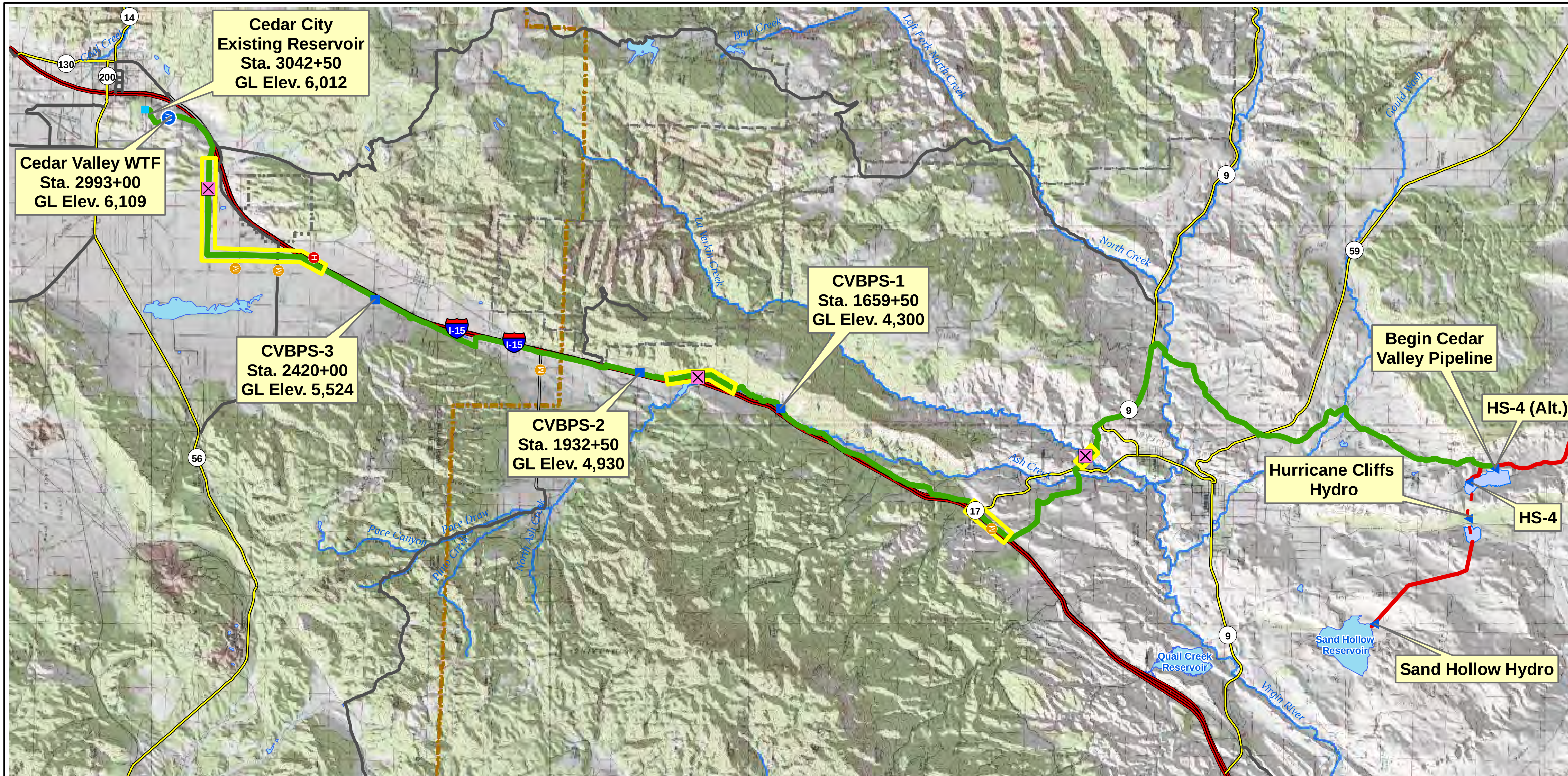
3.2.2 Cedar Valley Pipeline

3.2.2.1 Shallow Groundwater

3.2.2.1.1 Stream Channel Crossings. The potential to encounter groundwater along most of the Project alignments is low, because most of the alignments are located across areas where groundwater has been historically recorded at low levels, often with few water production wells. Table 3-2 presents stream crossings and washes along the alignments and the estimated probability of encountering groundwater during construction, requiring dewatering. Estimated depths to groundwater were obtained from relevant well water level measurements where available, which are discussed in greater detail in Section 3.2.2.1.2. If no direct information was found for determining depth to groundwater at channel crossings, it was assumed that crossings where stream flow occurs much of the year would be at high risk, crossings of infrequent, intermittent-flowing streams would be at medium risk, and crossings of normally-dry washes would be at low risk. The locations where stream channel crossings present a medium to high risk of encountering groundwater during construction of the CVP are shown in Figure 3-4.

Table 3-2
CVP Stream Channel Crossings

Stream Channel	Probability of Encountering Groundwater	Rationale
Gould Wash	Low	Measured water table is >30 feet in well
Virgin River	Low	Above-grade canyon crossing
LaVerkin Creek	High	Stream flows much of the year
Lower Ash Creek	Low	Above-grade canyon crossing
Upper Ash Creek	High	Stream flows much of the year
Camp Creek	High	Stream flows much of the year
Kanarra Creek	High	Stream flows much of the year
Shurtz Creek	Medium	Stream flows intermittently; measured water table is <30 ft in well



High Water Table Risk - 16'-30'	Cedar Valley Pipeline	Interstate	Hurricane Cliffs Forebay/Afterbay
Medium Water Table Risk - 0'-16'	Hydro System Lake Powell Pipeline	US Highway	Lakes & Reservoirs
Shallow Ground Water Stream Crossings	Hurricane Cliffs Pressure Tunnel	ST Highway	Major Rivers & Streams
Probable Groundwater Areas		Hwy	National Park/Monument
Water Treatment Facility		Major Road	County Boundaries
Project Pump Station			Tribal Lands
Project Hydro Station			

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

0 1.25 2.5 5 7.5 10 Miles

N

Lake Powell Pipeline Project

Spatial Reference: UTM Zone 12N, NAD-83

UDWR **Figure 3-4** MWH

Cedar Valley Pipeline System
Potential Shallow
Groundwater Locations
Shallow Ground Water Risk

Stream channel crossings at LaVerkin Creek, upper Ash Creek, Kanarra Creek and possibly Shurtz Creek are locations of probable shallow groundwater. Less likely locations include Gould Wash and Camp Creek. Groundwater is unlikely to be encountered at the remaining stream channels within the depth that would be excavated for pipeline construction.

3.2.2.2 Unlined Forebay and Afterbay Recharge

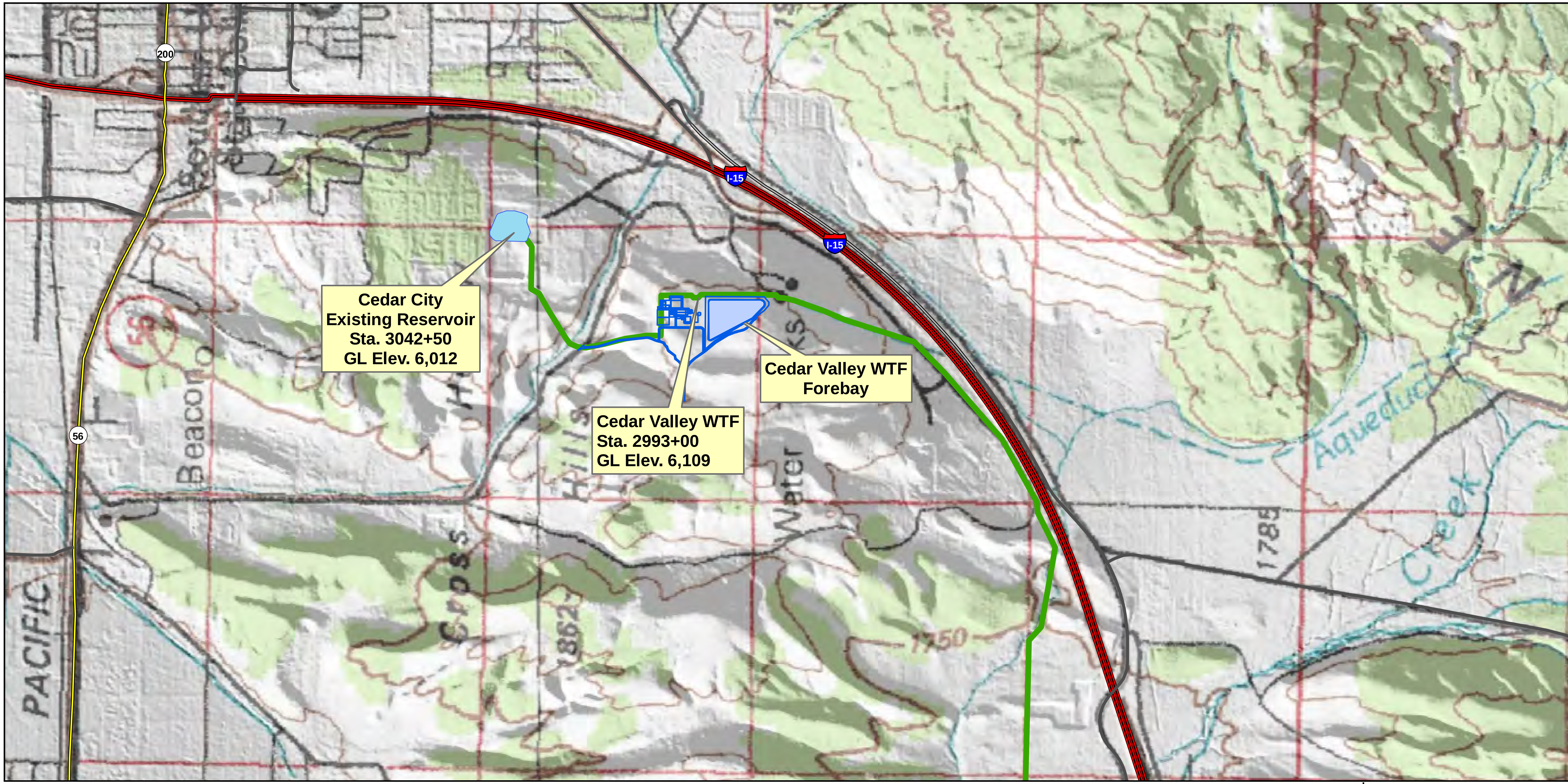
There are no unlined forebays or afterbays that would be part of the CVP Alternative. A lined forebay just upstream of the Cedar Valley Water Treatment Facility (WTF) and an existing terminal reservoir in Cedar City are shown in Figure 3-5. The existing reservoir is lined to prevent excessive seepage, and the proposed WTF forebay would be lined as well. Therefore, there should be only limited seepage from these reservoirs that could reach groundwater.

3.2.2.3 Groundwater – Surface Water Interactions

Aquifer recharge in the Cedar Valley was previously considered a component of the CVP Alternative. Therefore evaluation of potential groundwater-surface water interactions was included in the Study Plan. Evaluation of recharge effects was considered and is documented in a Technical Report, included in Appendix A. Partially as a result of the evaluation of the feasibility of recharge, that option was eliminated from the CVP Alternative. No recharge would occur as part of the CVP Alternative, therefore no groundwater-surface water interactions would occur.

3.2.2.4 Water Quality

Aquifer recharge in the Cedar Valley was previously considered a component of the CVP Alternative. Therefore, evaluation of water quality impacts was included in the Study Plan. Evaluation of recharge effects was considered and is documented in a Technical Report, included in Appendix A. Partially as a result of the evaluation of the feasibility of recharge, that option was eliminated from the CVP Alternative. No recharge would occur as part of the CVP Alternative, therefore groundwater quality would not be affected.



Cedar City Existing Reservoir
Cedar Valley WTF
Project Pump Station
Project Hydro Station
Cedar Valley Pipeline
Interstate
US Highway
ST Highway
Hwy
Major Road
Cedar Valley Forebay
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 1,500 3,000 4,500 Feet

N

Lake Powell Pipeline Project

Spatial Reference: UTM Zone 12N, NAD-83

UDWR **Figure 3-5** MWH

Cedar Valley Pipeline
Project Reservoirs

Chapter 4
Environmental Consequences (Impacts)

4.1 Significance Criteria

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

4.1.1 Shallow Groundwater

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

4.1.2 Groundwater Recharge

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

4.1.3 Groundwater-Surface Water Interactions

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

4.1.4 Water Quality

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

4.2 Potential Impacts Eliminated From Further Analysis

No impacts were eliminated from further analysis.

4.3 South Alternative Impacts

4.3.1 Construction Impacts

4.3.1.1 Shallow Groundwater

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

4.3.1.2 Groundwater Recharge

No impacts would occur.

4.3.1.3 Groundwater-Surface Water Interactions

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

4.3.1.4 Water Quality

BMPs would be utilized during construction to prevent accidental releases of fuel or chemicals and to minimize disposal of turbid water that could affect groundwater quality. Therefore, no significant construction impacts would occur.

4.3.2 Operational Impacts

4.3.2.1 Shallow Groundwater

No impacts would occur.

4.3.2.2 Groundwater Recharge

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

Recharge at Sand Hollow Reservoir from LPP water would continue the hydraulic recharge conditions similar to baseline conditions where recharge of Virgin River water occurs. Therefore no significant impacts would occur.

4.3.2.3 Groundwater-Surface Water Interactions

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

4.3.2.4 Water Quality

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

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

4.4 Existing Highway Alternative Impacts

4.4.1 Construction Impacts

4.4.1.1 Shallow Groundwater

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

4.4.1.2 Groundwater Recharge

No impacts would occur.

4.4.1.3 Groundwater-Surface Water Interactions

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

4.4.1.4 Water Quality

BMPs would be utilized during construction to prevent accidental releases of fuel or chemicals and to minimize disposal of turbid water that could affect groundwater quality. Therefore, no significant construction impacts would occur.

4.4.2 Operational Impacts

4.4.2.1 Shallow Groundwater

No impacts would occur.

4.4.2.2 Groundwater Recharge

No impacts would occur.

4.4.2.3 Groundwater-Surface Water Interactions

No impacts would occur.

4.4.2.4 Water Quality

No impacts would occur.

4.5 Southeast Corner Alternative Impacts

4.5.1 Construction Impacts

4.5.1.1 Shallow Groundwater

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

4.5.1.2 Groundwater Recharge

No impacts would occur.

4.5.1.3 Groundwater-Surface Water Interactions

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

4.5.1.4 Water Quality

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

4.5.2 Operational Impacts

4.5.2.1 Shallow Groundwater

No impacts would occur.

4.5.2.2 Groundwater Recharge

No impacts would occur.

4.5.2.3 Groundwater-Surface Water Interactions

No impacts would occur.

4.5.2.4 Water Quality

No impacts would occur.

4.6 Cedar Valley Pipeline Impacts

4.6.1 Construction Impacts

4.6.1.1 Shallow Groundwater

Shallow groundwater would be encountered at LaVerkin Creek, upper Ash Creek, southeast of New Harmony near I-15, and possibly in the vicinity of Shurtz Creek. Although possible, it is unlikely that shallow groundwater would be encountered elsewhere. BMPs would be utilized to limit drawdown during water to the minimum drawdown necessary for safe and effective construction. BMPs would be utilized to prevent groundwater migration along trench bedding where shallow groundwater is encountered. Drawdown would be temporary, no longer than necessary for construction purposes, which would not cause long-term or extensive depletion of groundwater levels or available supplies. Disposal of dewatered groundwater would be performed using BMPs to prevent surface erosion. Therefore, no significant impacts are expected to occur.

4.6.1.2 Groundwater Recharge

No impacts would occur.

4.6.1.3 Groundwater-Surface Water Interactions

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

4.6.1.4 Water Quality

BMPs would be utilized during construction to prevent accidental releases of fuel or chemicals and to minimize disposal of turbid water that could affect groundwater quality. Therefore, no significant construction impacts would occur.

4.6.2 Operational Impacts

4.6.2.1 Shallow Groundwater

No impacts would occur.

4.6.2.2 Groundwater Recharge

No impacts would occur.

4.6.2.3 Groundwater-Surface Water Interactions

No impacts would occur.

4.6.2.4 Water Quality

No impacts would occur.

4.7 No Lake Powell Water Alternative

4.7.1 WCWCD No Lake Powell Water Alternative

4.7.1.1 Shallow Groundwater

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

4.7.1.2 Groundwater Recharge

The No Lake Powell Water Alternative would virtually eliminate outside lawn and landscape watering. Currently, most of the water used for this purpose originates from surface water, primarily the Virgin River. A severe restriction on watering would reduce the amount of groundwater recharge. This would be a significant long term impact.

4.7.1.3 Groundwater-Surface Water Interactions

No impacts would occur.

4.7.1.4 Water Quality

No impacts would occur.

4.7.2 CICWCD No Lake Powell Water Alternative

4.7.2.1 Shallow Groundwater

Continued overpumping of groundwater in the Cedar Valley would continue to result in depletion of the groundwater resource. Projected demands indicate that groundwater resource supply would begin to diminish. Availability of groundwater resources would continue to diminish as growth continued, and water use would be extensively curtailed. This would be a significant long term impact.

4.7.2.2 Groundwater Recharge

The No Lake Powell Water Alternative would virtually eliminate outside lawn and landscape watering. A severe restriction on outdoor watering would reduce the amount of groundwater recharge. This would be a significant long-term impact.

4.7.2.3 Groundwater-Surface Water Interactions

No impacts would occur.

4.7.2.4 Water Quality

No impacts would occur.

4.7.3 KCWCD No Lake Powell Water Alternative

4.7.3.1 Shallow Groundwater

No impacts would occur.

4.7.3.2 Groundwater Recharge

No impacts would occur.

4.7.3.3 Groundwater-Surface Water Interactions

No impacts would occur.

4.7.3.4 Water Quality

No impacts would occur.

4.8 No Action Alternative

4.8.1 WCWCD No Action Alternative

4.8.1.1 Shallow Groundwater

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

4.8.1.2 Groundwater Recharge

No impacts would occur.

4.8.1.3 Groundwater-Surface Water Interactions

No impacts would occur.

4.8.1.4 Water Quality

No impacts would occur.

4.8.2 CICWCD No Action Alternative

4.8.2.1 Shallow Groundwater

Continued overpumping of groundwater in the Cedar Valley would continue to result in depletion of the groundwater resource. Projected demands indicate that groundwater resource supply would begin to diminish. Availability of groundwater resources would continue to diminish as growth continued, and water use would be extensively curtailed. This would be a significant long term impact.

4.8.2.2 Groundwater Recharge

No impacts would occur.

4.8.2.3 Groundwater-Surface Water Interactions

No impacts would occur.

4.8.2.4 Water Quality

No impacts would occur.

4.8.3 KCWCD No Action Alternative

4.8.3.1 Shallow Groundwater

No impacts would occur.

4.8.3.2 Groundwater Recharge

No impacts would occur.

4.8.3.3 Groundwater-Surface Water Interactions

No impacts would occur.

4.8.3.4 Water Quality

No impacts would occur.

Chapter 5
Mitigation and Monitoring

5.1 South Alternative

5.1.1 Mitigation

No mitigation of impacts would be required if Best Management Practices (BMPs) are followed and design and construction activities include appropriate restrictions based on identified risks. A list of anticipated BMPs that would be implemented during construction are provided in Appendix C.

5.1.2 Monitoring

No monitoring would be required.

5.2 Existing Highway Pipeline Alternative

5.2.1 Mitigation

No mitigation of impacts would be required if BMPs are followed and design and construction activities include appropriate restrictions based on identified risks. A list of anticipated BMPs that would be implemented during construction are provided in Appendix C.

5.2.2 Monitoring

No monitoring would be required.

5.3 Southeast Corner Alternative

5.3.1 Mitigation

No mitigation of impacts would be required if BMPs are followed and design and construction activities include appropriate restrictions based on identified risks. A list of anticipated BMPs that would be implemented during construction are provided in Appendix C.

5.3.2 Monitoring

No monitoring would be required.

5.4 Cedar Valley Pipeline

5.4.1 Mitigation

No mitigation of impacts would be required if BMPs are followed and design and construction activities include appropriate restrictions based on identified risks. A list of anticipated BMPs that would be implemented during construction are provided in Appendix C.

5.4.2 Monitoring

No monitoring would be required.

5.5 No Lake Powell Water Alternative

5.5.1 Mitigation

Alternative water supplies, combined with extensive water conservation measures, would be necessary to restrict increased groundwater demands from population growth.

5.4.2 Monitoring

Groundwater levels would require regular monitoring to determine continued trends and rates of depletion to maintain adequate groundwater supply for future growth.

5.6 No Action Alternative

5.6.1 Mitigation

Alternative water supplies, combined with extensive water conservation measures, would be necessary to restrict increased groundwater demands from population growth.

5.6.2 Monitoring

Groundwater levels would require regular monitoring to determine continued trends and rates of depletion to maintain adequate groundwater supply for future growth.

Chapter 6
Unavoidable Adverse Impacts

6.1 South Alternative

No unavoidable adverse impacts associated would occur.

6.2 Existing Highway Pipeline Alternative

No unavoidable adverse impacts would occur.

6.3 Southeast Corner Line Alternative

No unavoidable adverse impacts would occur.

6.4 Cedar Valley Pipeline

No unavoidable adverse impacts would occur.

6.5 No Lake Powell Water Alternative

Depletion of groundwater supplies would result in reduced availability of water and higher pumping costs. Economic and population growth would eventually be limited by high cost of water and depletion of groundwater resources. Agricultural irrigation ultimately would not exist. Subsidence of land because of overpumping of the Cedar Valley Aquifer probably would worsen.

6.6 No Action Alternative

Depletion of groundwater supplies would result in reduced availability of water and higher pumping costs. Economic and population growth would eventually be limited by high cost of water and depletion of groundwater resources. Agricultural irrigation ultimately would not exist. Subsidence of land because of overpumping of the Cedar Valley Aquifer probably would worsen.

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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Glossary

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

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

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

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

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

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

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

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

Abbreviations and Acronyms

ADWR	Arizona Department of Water Resources
BMP	Best Management Practice
BPS	Booster Pump Station
CBPS	Cedar Booster Pump Station
CICWCD	Central Iron County Water Conservancy District
CVP	Cedar Valley Pipeline
DEQ	Department of Environmental Quality
DWQ	Division of Water Quality
FERC	Federal Energy Regulatory Commission
GIS	Geographical Information System
GOPB	Governor's Office of Planning and Budget
GPCD	Gallons Per Capita Per Day
GSENM	Grand Staircase-Escalante National Monument
HAL	Hansen, Allen & Luce
HPRT	High Point Regulating Tank
HS	Hydro Station
IPS	Intake Pump Station
KCWCD	Kane County Water Conservancy District
LPP	Lake Powell Pipeline
M&I	Municipal and Industrial
MSL	Mean Sea Level
NWIS	National Water Information System
RO	Reverse Osmosis
SHR	Sand Hollow Reservoir

SITLA	School and Institutional Trust Land Administration
UDWR	Utah Division of Water Resources
USGS	U.S. Geological Survey
WCWCD	Washington County Water Conservancy District
WTF	Water Treatment Facility

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Appendix A
Revised Technical Memorandum 5.13C
Aquifer Recharge Issues

Lake Powell Pipeline Phase I - Preliminary Engineering and Environmental Studies

Task 5 - Develop and Analyze Alternatives

Revised Technical Memorandum 5.13C Aquifer Recharge Issues

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May 2009

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TM 5.13C PUMP STATION FEATURES

5.13C.1 INTRODUCTION

The proposed Lake Powell Pipeline (LPP) would provide a new water supply of approximately 100,000 af/yr to southwest Utah communities including St. George, the Cedar Valley, and possibly Kanab, as well as surrounding areas. About 80,000 af/yr would be delivered to the Washington County Water Conservancy District (WCWCD) service area. The remaining 20,000 af/yr would be pumped from the St. George metropolitan area for delivery to the Central Iron County Water Conservancy District (CICWCD) for use in the Cedar Valley and surrounding areas.

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

5.13C.2 PROPOSED PROJECT

5.13C.2.1 General

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

Water delivered to the CICWCD would be pumped from a pipeline diversion upstream of a hydroelectric facility forebay at the top of the Hurricane Cliffs into a pipeline that would convey water to the Cedar Valley. Delivery of the CICWCD water would occur by discharge of raw water to a terminal point in Cedar Valley, which could include one or more of the following facilities: a municipal water treatment plant; a water treatment plant for treatment prior to recharge via injection wells; a reservoir; a surface irrigation water distribution system; or a series of groundwater recharge basins. Aquifer recharge options include infiltration basins as well as injection wells and/or Aquifer Storage and Recovery (ASR) wells. If injection or ASR wells are used to accomplish recharge, conventional water treatment (filtration and disinfection) probably would be required prior to injection to meet regulatory requirements and to avoid or mitigate against fouling of the well screens, filter packs, or surrounding aquifer from mineral precipitation, suspended solids, or biomaterials.

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

WTP treated water transmission system, downstream of the WTP, for distribution to potable water users. All of these facilities are owned and operated by the WCWCD.

5.13C.3 EXISTING CONDITIONS

5.13C.3.1 Water Supply

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

5.13C.3.1.1 Surface Water

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

5.13C.3.1.1.1 Quail Creek Reservoir

Quail Creek Reservoir is owned and operated by WCWCD. The reservoir is supplied with water that gravity flows from Quail Creek, but most of the water in the reservoir is diverted from the nearby Virgin River. It has a full-pool surface area of 590 acres and a capacity of 40,325 acre-feet. The Quail Creek watershed area covers 592,577 acres and has an annual average inflow of 22,000 acre-feet. The maximum depth of the reservoir is 190 feet, and the water is contained by two dams. The reservoir provides drinking water to the St. George metropolitan area and is treated at an on-site water treatment plant. Minimum stream flows and excess flows are released to the Virgin River downstream of the larger of the two dams (UGS 1999; Utah DEQ-DWQ 2007a).

5.13C.3.1.1.2 Sand Hollow Reservoir

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

5.13C.3.1.1.3 Lake Powell

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

5.13C.3.1.2 Groundwater

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

5.13C.3.1.2.1 Navajo Sandstone Aquifer

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

Sand Hollow Reservoir was filled with water pumped from the Virgin River starting in 2002 and completed in 2005. The rate of seepage from the reservoir that has recharged the underlying Navajo Aquifer has declined from 2002, when the reservoir began filling, to 2006 (USGS 2007). A number of production wells near the reservoir are benefiting from recharge because the hydraulic influence of recharge from the reservoir is raising water table elevations, thereby providing more hydraulic head to reduce pumping lift requirements. The groundwater is pumped from the wells, owned and operated by the WCWCD, for use in St. George and nearby communities west of the reservoir.

5.13C.3.1.2.2 Cedar Valley Aquifer System

Groundwater in the Cedar Valley is the primary source of water for Cedar City and other communities in the valley. Groundwater is pumped from the alluvial aquifer, which consists of subunits of unconfined, semiconfined, and confined production zones associated with alternating layers of coarse-grained material (sand and gravel) with fine-grained sediments (clay and silt). The fine-grained layers create zones of confined pressure that result in artesian conditions, primarily toward the middle of the valley. The lateral continuity of confining layers is not well understood but is generally not thought to be complete across the valley floor, because the artesian aquifer units appear to be somewhat hydraulically connected. Perching of unconfined groundwater occurs on clay layers above the aquifer as well. The source material for the alluvial system is derived from erosion and deposition of rocks of the uplifted mountains and highlands to the east and west of the valley floor, primarily from the eastern highlands associated with the uplifted Hurricane Cliffs and fault system. Coarse-grained sediments eroded from the uplifted rocks are generally deposited near the valley margins, and finer-grained sediments are typically deposited further out into the valley, although some fine-grained deposits can be found throughout much of the valley. Thus, the silt and clay layers that create artesian aquifer conditions near the middle of the valley are generally not found, or are less extensive, near the eastern margin of the valley floor.

Recharge to this aquifer occurs from direct precipitation, from overland runoff from adjacent highlands and mountains surrounding the valley, from irrigation using surface and groundwater, and from streamflow losses on Coal Creek and Shurtz Creek, which flow westward out of the Hurricane Cliffs, and other smaller streamflows. Rediversion of streamflow for irrigation also contributes to recharge in the valley. Much of the water used for potable purposes originates from a wellfield near Quichapa Lake and from wells between Cedar City and the City of Enoch (Cedar City Engineer 2007). Additional pumping from the aquifer is used for domestic purposes and for irrigation.

5.13C.4 GROUNDWATER QUALITY STANDARDS

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

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

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

TDS = Total Dissolved Solids

Table 5.13C.2 – Utah Numerical Groundwater Quality Standards

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

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

Parameter Description	Value
Vinyl chloride	0.002
Xylenes (Total)	10
Other Organic Chemicals	
Five Haloacetic Acids (HAA5) [Monochloroacetic acid; Dichloroacetic acid; Trichloroacetic acid; Bromoacetic acid; Dibromoacetic acid]	0.06
Total Trihalomethanes (TTHM)	0.08
Radionuclides	
Radium-226 + Radium-228	5pCi/l
Gross alpha, including Radium-226 but excluding Radon and Uranium	15pCi/l
Uranium	0.030 mg/l
Beta particle and photon radioactivity	4 millirem/year a

Notes:

a Except for the radionuclides listed below, the concentration of man-made radionuclides causing four millirem total body or organ dose equivalents shall be calculated on the basis of a two liter per day drinking water intake using the 168 hour data listed in "Maximum Permissible Body Burden and Maximum Permissible Concentration Exposure", NBS Handbook 69 as amended August 1962, U.S. Department of Commerce. If two or more radionuclides are present, the sum of their annual dose equivalent to the total body or to any organ shall not exceed four millirem/year. Average annual concentrations assumed to produce a total body or organ dose of four millirem/year:

Radionuclide Critical Organ Concentration

Tritium Total Body 20,000 pCi/L

Strontium-90 Bone Marrow 8 pCi/L

b A permit specific ground water quality standard for any pollutant not specified above may be established by the State at a level that will protect public health and the environment. This permit limit may be based on U.S. Environmental Protection Agency maximum contaminant level goals, health advisories, risk based contaminant levels, standards established by other regulatory agencies and other relevant information.

5.13C.4.1 Class IA Protection Levels

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

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

5.13C.4.2 Class II Protection Levels

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

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

5.13C.4.3 Class III Protection Levels

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

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

5.13C.5 AQUIFER CLASSIFICATIONS

Within the LPP project vicinity, two aquifers have been classified. These include the Cedar Valley aquifer system in the vicinity of Cedar City and the Navajo/Kayenta Aquifer in the St. George area of Washington County. The portion of the Navajo/Kayenta Aquifer associated with Sand Hollow

Reservoir is in the Navajo Sandstone, therefore the aquifer is referred to herein as the Navajo Sandstone Aquifer.

5.13C.5.1 Navajo Sandstone Aquifer

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

5.13C.5.2 Cedar Valley Aquifer

For classification purposes, the Cedar Valley aquifer system has been subdivided into three areas. Most of the aquifer has been designated Class IA. The area around Cedar City from the eastern edge of the valley to about four miles west, five miles north, and six miles south of Cedar City is designated as Class II. A relatively small area north of Cedar City and south of Enoch, mostly west of Interstate 15, is designated as Class III (Utah DEQ-DWQ 2007c). The designated aquifer classification areas are shown in **Figure 5.13C.2**.

5.13C.6 SURFACE WATER QUALITY

5.13C.6.1 Lake Powell

Lake Powell water quality has been monitored at various locations. The U.S. Geological Survey (USGS) water quality sampling location nearest to the LPP intake pump station is at Wahweap Bay, just south of the Utah-Arizona state boundary at 2.4 miles from Glen Canyon Dam and 2.1 miles from the proposed intake site. Sample data used for this evaluation were taken at various depths throughout the water column at approximately monthly or bi-monthly intervals from June 1995 to March 2004 for laboratory analyses. Profile sampling (field parameters, including temperature, pH, electrical conductivity, dissolved oxygen (DO), turbidity, oxygen reduction potential (ORP) and total dissolved solids (TDS) were collected for various depths at approximately monthly intervals from January 2002 to March 2007. Not all samples were analyzed at each sampling event, but enough samples were collected to provide some characterization. The average, minimum, and maximum concentrations determined from sampling at the Wahweap Bay sampling site are presented in Table 5.13C-3. Samples collected from various water depths have been placed into groups (0-5 meter (m), 5-50 m, 50-100 m, >100 m). Concentrations shown in **Table 5.13C.3** are presented in mg/L unless otherwise noted.

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

Parameter	Depth (m)	Average	Minimum	Maximum	Remarks
Temperature (ºC)	0-5	17.3	8.3	27.4	
	5-50	12.6	7.3	27.0	
	50-100	8.0	6.5	11.0	
	>100	7.7	6.4	8.7	
	Overall	10.7	6.4	27.4	
pH (S.U.)	0-5	8.1	7.5	9.0	a) Single day, 4/7/04; all other sample events >6.9
	5-50	7.7	2.1a	9.1	
	50-100	7.4	2.2a	8.1	
	>100	7.5	6.2	8.0	
	Overall	7.6	2.1a	9.1	
Conductivity (µS)	0-5	786	650	892	
	5-50	806	569	1018	
	50-100	949	716	1074	
	>100	987	880	1084	
	Overall	878	569	1084	
Dissolved Oxygen	0-5	8.1	5.9	10.7	
	5-50	6.5	1.7	12.1	
	50-100	4.3	1.9	8.2	
	>100	4.2	0.5	8.4	
	Overall	5.6	0.5	12.1	
Turbidity (NTU)	0-5	2.3	0b	34.2	b) Turbidity recorded at 0 NTU - uncommon in natural surface waters; presumably <0.1 NTU
	5-50	2.5	0b	16.4	
	50-100	3.7	0b	17.9	
	>100	3.9	0b	20.3	
	Overall	3.1	0	34.2	
TDS (field)	0-5	517	434	612	
	5-50	526	364	652	
	50-100	611	458	717	
	>100	638	563	717	
	Overall	569	364	717	
TSS (lab)	0-5	4.1	4.0	7.8	
	5-50	4.1	4.0	5.8	
	50-100	4.2	3.9	14.2	
	>100	5.9	4.0	15.3	
	Overall	4.3	3.9	15.3	
Ca	0-5	56.8	45.4	69.4	
	5-50	60.7	47.3	79.5	
	50-100	64.3	45.5	82.6	
	>100	74.7	53.3	95.9	
	Overall	64.3	45.4	95.9	

Parameter	Depth (m)	Average	Minimum	Maximum	Remarks
Mg	0-5	20.0	15.8	23.4	
	5-50	20.5	15.0	24.6	
	50-100	21.3	15.8	27.9	
	>100	24.7	17.9	29.5	
	Overall	21.7	15.0	29.5	
Na	0-5	54.4	39.4	69.0	
	5-50	57.2	41.0	76.4	
	50-100	60.2	39.8	85.7	
	>100	74.4	46.3	97.5	
	Overall	61.7	39.4	97.5	
K	0-5	2.6	1.0	7.0	
	5-50	2.5	1.0	4.0	
	50-100	2.3	1.0	4.3	
	>100	2.7	1.0	4.7	
	Overall	2.5	1.0	7.0	
CO3	0-5	0.8	0.0	2.2	
	5-50	0.9	0.0	1.8	
	50-100	0.7	0.0	1.0	
	>100	0.8	0.0	1.0	
	Overall	0.8	0.0	2.2	
HCO3	0-5	152	116	182	
	5-50	160	127	209	
	50-100	163	133	186	
	>100	178	141	214	
	Overall	163	116	214	
Alkalinity	0-5	126	95	164	
	5-50	132	113	171	
	50-100	136	109	184	
	>100	147	115	239	
	Overall	135	95	239	
Cl	0-5	35.0	26.4	51.8	
	5-50	38.1	24.9	59.2	
	50-100	42.6	25.6	74.8	
	>100	58.5	31.8	81.9	
	Overall	43.8	24.9	81.9	
SO4	0-5	176	140	221	
	5-50	184	124	232	
	50-100	190	136	272	
	>100	228	170	292	
	Overall	195	124	292	
SiO2	0-5	7.5	6.2	8.8	
	5-50	7.7	6.4	8.7	
	50-100	8.4	7.0	9.4	
	>100	8.5	7.1	9.9	
	Overall	8.1	6.2	9.9	

Parameter	Depth (m)	Average	Minimum	Maximum	Remarks
Fe	0-5	0.0042	0.004	0.0106	
	5-50	0.004	0.004	0.0042	
	50-100	0.004	0.004	0.0059	
	>100	0.0041	0.004	0.0087	
	Overall	0.0041	0.004	0.0106	
Total P as P	0-5	0.0	0.0	0.1	
	5-50	0.0	0.0	0.1	
	50-100	0.0	0.0	0.1	
	>100	0.0	0.0	0.1	
	Overall	0.0	0.0	0.1	
O-phosphate as P	0-5	0.0	0.0	0.0	
	5-50	0.0	0.0	0.5	
	50-100	0.0	0.0	0.0	
	>100	0.0	0.0	0.1	
	Overall	0.0	0.0	0.5	
NH3 as N	0-5	0.0	0.0	0.2	
	5-50	0.0	0.0	0.1	
	50-100	0.0	0.0	0.3	
	>100	0.0	0.0	0.2	
	Overall	0.0	0.0	0.3	
NO2+NO3 as N	0-5	0.1	0.0	0.4	
	5-50	0.2	0.0	0.4	
	50-100	0.3	0.0	0.5	
	>100	0.4	0.2	0.5	
	Overall	0.3	0.0	0.5	
TKN as N	0-5	0.2	0.1	0.9	
	5-50	0.2	0.1	0.9	
	50-100	0.3	0.1	6.3	
	>100	0.2	0.1	0.6	
	Overall	0.2	0.1	6.3	

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

5.13C.6.2 Sand Hollow Reservoir

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

5.13C.7 GROUNDWATER QUALITY

5.13C.7.1 St. George Metropolitan Area

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

5.13C.7.1.1.1 Groundwater Near Sand Hollow Reservoir

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

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

A cluster of samples collected from wells north of the current location of the Sand Hollow Reservoir, south and east of the Virgin River and west of the City of Hurricane, have higher TDS (greater than 500 mg/L); samples from these wells tend to be warmer than at other locations, with some samples measured at greater than 20ºC. The warmer, higher TDS concentration wells are generally of the calcium-sodium-sulfate type and are believed to represent a blending with deeper geothermal groundwater migrating up into the Navajo Aquifer through faults and fractures associated with the Hurricane Fault Zone a few miles to the west (USGS 2000).

Sampling of monitoring and production wells in the immediate vicinity of Sand Hollow Reservoir was conducted by the USGS as part of a study of the effects of artificial recharge of Virgin River water on the Navajo Aquifer in Sand Hollow. The locations of these wells are shown in **Figure 5.13C.3**. Sampling began at some locations between 1999 and 2001, before construction and filling of the reservoir with Virgin River water. Periodic or one-time sampling of selected wells occurred up through 2006, and reflects the effects, if any, caused by aquifer recharge. Analytical results of this sampling, as well as samples collected from the Virgin River and from Sand Hollow Reservoir, are shown in **Table 5.13C.4**. A complete discussion of this study is provided by Heilweiland others (USGS 2005a) and by Heilweil and Susong (USGS 2007).

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

Map Number	Well Name	Date Sampled	Specific Conductance (µS)	pH (standard units)	Total Dissolved Solids (mg/L)
5	WD 10	10/12/2001 1	375	7.8	202
		09/13/2001	365	7.8	-
		05/07/2003	350	7.8	-
		10/13/2003	350	7.7	-
6	Well 4	08/29/2001	480	8.0	-
		09/11/2002	495	8.1	297
		10/15/2003	475	7.9	-
8	WD 4	04/02/1999	355	8.2	-
		12/18/2002	350	7.7	205
		01/19/2006	345	8.0	-
9	WD 6	05/15/2001	130	7.6	88
		08/28/2001	185	7.7	-
		09/09/2002	290	7.7	167
		12/17/2002	400	7.6	-
		03/19/2003	425	7.5	251
		05/07/2003	450	7.5	276
		06/09/2003	390	7.8	-
		08/04/2003	350	7.5	234
		10/06/2003	400	7.6	239
		01/08/2004	300	7/7	172
		05/03/2004	700	7.4	446
		02/09/2005	445	7.9	269
		04/05/2005	460	7.6	-
		01/19/2006	684	7.6	-
10	Well 8	10/08/2002	550	7.5	323
		10/09/2003	430	7.6	242
		09/21/2004	530	7/7	312
28	North Dam 3A	10/08/2002	4,430	8.0	3,020
		12/18/2002	2,830	8.0	1,890

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

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

Map Number	Well Name	Date Sampled	Specific Conductance (µS)	pH (standard units)	Total Dissolved Solids (mg/L)
RES 3	Reservoir	09/10/2002	1,000	8.8	669
		03/20/2003	830	8.2	525
		06/10/2003	850	8.2	-
		08/06/2003	920	7.6	568
		10/07/2003	910	8.4	569
		01/08/2004	870	8.4	523
		05/05/2004	710	8.2	442
		09/22/2004	765	8.5	-
		02/10/2005	855	8.4	546
		01/18/2006	815	8.5	-

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

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

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

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

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

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

5.13C.7.1.1.2 Groundwater Near Quail Creek Reservoir

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

5.13C.7.2 Cedar Valley Groundwater Quality

The aquifer system in the Cedar Valley occurs primarily in unconsolidated, somewhat cemented sediments associated with erosion, transport and deposition of upthrown blocks of crust rock, typical of Basin and Range intermontane valleys. Sediments in the valley floor are derived from erosion of the mountains east and west of the valley, with most sediments originating in the mountains to the east (Hurricane Cliffs). Sediments tend to be coarser near the margins of the valley, particularly on the eastern margin, and finer grained and more layered toward the center of the valley. As a result, both confined and unconfined aquifer conditions exist in the valley and tend to be more pronounced toward the center of the valley floor. In general, three primary aquifers have been identified, including an upper, unconfined aquifer and two deeper aquifers that behave as confined or semiconfined systems.

Recharge to the upper, unconfined aquifer occurs both as direct precipitation and from losing streams originating in the mountains, primarily in the higher elevations associated with the Hurricane Cliffs and Markagunt Plateau on the east, with Coal Creek near Cedar City being the largest single source of recharge from a losing stream as it crosses the alluvial fan near the mouth of Cedar Canyon and as streamflow is diverted for irrigation in the valley. Recharge also occurs due to losses from Shurtz Creek and other smaller streams as they flow out of the highlands across alluvial fans and other coarse valley margin sediments on the east side of the valley. Irrigation derived both from pumping of deeper groundwater and from surface water diversions also provides recharge to the upper, unconfined aquifer. Recharge to the deeper, confined or semiconfined aquifers, from which most groundwater pumping takes place, is believed to occur primarily from infiltration of streamflow and precipitation along the eastern valley margin, and to a lesser extent from bedrock discharge at depth associated with deep circulating groundwater in the mountains. In many locations, groundwater quality is influenced by the water quality of streams that flow from the eastern mountains westward into the valleys and recharge the aquifers; also of importance is the geochemical nature of the porous media through which groundwater flows. Some limited recharge to the shallow, unconfined aquifer system also occurs from surface flow from streams originating in the Harmony Mountains and the Black Mountains, located west and north, respectively, of the Cedar Valley (USGS 2005b). These mountains are smaller in aerial extent and of lower elevation than the highland areas east of the valley, therefore they contribute somewhat less to recharge of the valley aquifer system.

A collection of water quality data reported by Howells, Mason, and Slaugh (USGS 2002) includes measurements of specific conductance, TDS, temperature, and other parameters in surface and groundwater samples from many locations in the Cedar Valley at irregular sampling intervals between 1961 and 2001. The water quality data sets provided in that report are too large to be included herein. The data presented by the USGS (2002) as well as other studies are summarized in USGS (2005b).

Specific conductance measurements in Coal Creek, a major source of recharge for groundwater, are generally less than 500 µS; the estimated TDS concentration of Coal Creek water is calculated to be less than 325 mg/L. The water is classified as a calcium-magnesium-bicarbonate type. Shurtz Creek, which flows westward into the valley from Cedar Mountain about five miles southwest of Coal Creek, is another surface source of recharge but is substantially smaller than Coal Creek. Shurtz Creek water is a calcium-bicarbonate-sulfate type water (USGS 2005b).

Groundwater quality varies considerably throughout the Cedar Valley. At Cedar City, high TDS concentrations (greater than 1,500 mg/L in the alluvial fan near the mouth of Cedar Canyon, greater than 1,000 mg/L in other parts of Cedar City) cause groundwater to be unsuitable for potable use. Cedar City obtains its groundwater supply primarily from wells west of Quichapa Lake in the south central part of the valley, and from an area north of Cedar City and south of the City of Enoch area (USGS 2005b; Cedar City Engineer 2007). Springs in Shurtz Canyon and other springs located in mountain canyons east of the valley also are used for potable water. Most of the wells and springs used by Cedar City for potable purposes report average TDS concentrations between 110 and 280 mg/L, with combined average annual concentrations between 165 and 217 mg/L from 1998 to 2006. These potable water sources are from a wellfield west of Quichapa Lake, two wells south of the City of Enoch, and springs in Shurtz Canyon and Cedar Canyon, as well as Spillsbury Spring in Quichapa Canyon, located in the Harmony Mountains southwest of the Quichapa Wellfield. High TDS concentrations are reported for groundwater samples from two production wells just north of Cedar City, with TDS at or greater than 1,000 mg/L in one well and at or greater than 2,000 mg/L in the other well in samples collected from 2003 to 2006 (Cedar City Engineer 2007).

Cedar Valley aquifers have been classified under the State Groundwater Quality Classification System. The classified areas include a classification of IA (Pristine Aquifer) for most of the valley on the north and west sides from Kanarraville in the south to the Black Mountains in the north. Most of the area in the southeast part of the valley, from a few miles south of the City of Enoch to Kanarraville Creek, is classified as Class II (Drinking Water Aquifer). Class II designation also is applied to a small area northwest of the City of Enoch near Rush Lake, as well as a very small area at Mud Spring Wash about 15 miles northwest of Enoch. Class III (Limited Use Aquifer) is assigned to a portion of the valley in the north central part of Cedar City and continuing northward to about two miles south of the City of Enoch. Groundwater in the Class II and III aquifer systems tends to be high in TDS, calcium, magnesium, bicarbonate, sulfate, and total hardness. The primary origin of these elevated concentrations in groundwater appears to be leaching of alluvial sediments and of binding cement precipitates from the matrix of sediments overlying the aquifer in the vicinity of recharge.

5.13C.8 COMPATIBILITY OF LAKE POWELL WATER WITH GROUNDWATER

5.13C.8.1 General Regulatory Issues

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

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

5.13C.8.2 Navajo Sandstone Aquifer

Recharge of water from Lake Powell to the Navajo Sandstone Aquifer underlying the Sand Hollow area would result in a blend of water types that would affect the existing groundwater quality. The effects may be similar to what is currently occurring as a result of recharging Virgin River water because water quality in the Virgin River is reasonably similar to Lake Powell water quality, although TDS concentrations in Lake Powell may be marginally higher. In general, groundwater quality would tend to become more like the recharge source water. The current water quality in the Navajo Sandstone Aquifer near Sand Hollow Reservoir is in transition, as the blended waters tend toward an eventual equilibrium, although changes in the rate of recharge are anticipated as well as rates of groundwater pumping; as a result, water quality concentrations of TDS, pH, hardness, and other parameters may tend to shift upward or downward over time within a range of upper and lower concentrations depending on recharge and well pumping rates. Ultimately, groundwater constituent concentrations would tend to be higher for most parameters than currently occurs, with groundwater nearest the reservoir exhibiting the highest constituent concentrations and groundwater furthest away from the reservoir exhibiting the lowest constituent concentrations. Further away from the reservoir, the effects of recharge on groundwater quality may be negligible as the water quality of current recharge sources (primarily direct precipitation) are greater than the effects of recharge from the bed of Sand Hollow Reservoir.

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

Preliminary modeling of the potential for precipitation or dissolution of minerals was performed by MWH for blending of Lake Powell water with groundwater in the Navajo Sandstone Aquifer using the USGS PHREEQC modeling program (USGS 1999). Average concentrations of water from sampling at Wahweap Bay in Lake Powell at a depth of 50 to 100 meters were used for this modeling, because this depth likely would correspond to the depths of pump station intakes on Lake Powell. It is important to note that other water quality data have been used for evaluating Lake Powell water in addition the data presented herein; the Wahweap Bay data were selected for PHREEQC modeling because of the depth-differential results available. A simulated blending of this water with water from Well WD-RJ (No. 32 on **Figure 5.13C.3**), near Sand Hollow Reservoir and within the anticipated lateral range of influence, was performed to predict the likelihood of precipitation or dissolution of minerals. Blending was modeled at ratios of groundwater to Lake Powell water of 90 percent to 10 percent, 50 percent to 50 percent, and 10 percent to 90 percent, respectively. The resulting minerals projected by the blending would be expected to precipitate if the change in saturation index from existing groundwater conditions projected by the model for each associated mineral is positive, and conversely, the minerals would be expected to dissolve if the change in projected saturation index from existing groundwater conditions is negative. Large saturation index values, either negative or positive, are more likely to result in dissolution or precipitation than smaller values. Note that the probability of either dissolution or precipitation and the resulting impacts on aquifer permeability and water quality depend on many factors, including the concentrations of the parameters involved in the reactions, the presence or absence of associated minerals in the aquifer matrix, variations in rates of recharge, and other factors. Thus, a high saturation index, either positive or negative, does not mean that the associated reaction would occur, rather that the potential for the reaction exists.

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

5.13C.8.3 Cedar Valley Aquifer

Recharge of water from Lake Powell to the Cedar Valley aquifer system will result in a blend of water types that would affect the existing groundwater quality. The location, or locations, of recharge would influence the extent of change. Four general locations were considered for recharge locations in the Cedar Valley. These included the gravel pit areas north of Cedar City, the mouth of Coal Creek Canyon just east of Cedar City, the area between the mouth of Shurtz Creek Canyon and Hamilton's Fort, and near the mouth of Quichapa Canyon southwest of Quichapa Lake. These locations are shown in **Figure 5.13C.4**. A brief discussion of the viability of each of these sites for recharge by means of surface infiltration basins is provided hereafter.

The possible recharge location southwest of Cedar City, near Quichapa Lake, would result in recharge of groundwater in a part of the aquifer system that has been designated as Class IA. Recharge at the Quichapa Canyon site would most likely result in an increase in TDS and the concentrations of several other constituents, with the greatest changes occurring closest to the point of recharge and diminishing impacts further from the recharge basin. A benefit of recharging at this location is its relative proximity to a production wellfield used to supply water to Cedar City. Water quality impacts on water pumped from the wellfield are not known; however, it is likely that the blending of Lake Powell water with existing groundwater would dilute the increased TDS concentration and other constituents before pumping occurred, thereby diminishing the effects of recharge on wellfield water quality. The expected blend of LPP water and groundwater would result in pumped water quality between about 200 and 500 mg/L TDS. Conversely, its location in a Class IA portion of the aquifer system would mean that some degradation of water quality would occur near the point of recharge., but would probably still meet the requirements for a Class IA aquifer.

Recharge near the airport north of Cedar City would occur in Class II or possibly Class III designated aquifer areas. Recharge would occur in groundwater that is higher in TDS than Lake Powell water. This would have the benefit of diluting the TDS in groundwater, possibly improving its quality. However, the resulting blend of LPP water and Class II groundwater may not be considered aesthetically acceptable for drinking water, since most groundwater currently used for drinking water in the community is considerably better quality than the blended water would be.

Recharge through the alluvial fan near the mouth of Cedar Canyon would occur in a Class II designated aquifer area. This area is believed to be a source of recharge for groundwater in the valley due to losses from Coal Creek, so a recharge basin or basins at this site has a higher probability of success, although measurements of streamflow losses suggest that the potential for recharge in this area is limited (USGS 2005b).

The quality of Coal Creek water with an estimated TDS of less than 325 μS/cm is substantially better than the underlying groundwater. Groundwater specific conductance was measured at 2,190 to 2,220 μS/cm (estimated TDS of 1,424 to 1,443 mg/L using the method of Hem) in water samples collected from a well near the mouth of Cedar Canyon in 1999 and 2000 (USGS 1985; 2002d). The presence of high TDS groundwater in this area appears to be largely the result of leaching of cements and minerals in vadose zone soils from recharge associated with seepage losses from Coal Creek. Recharge by surface basins near the mouth of Cedar Canyon may result in a similar leaching process and could degrade the quality of Lake Powell water before it reaches groundwater.

Groundwater data are limited near the mouth of Shurtz Creek; the closest well to this potential recharge area for which extensive groundwater quality data are available is in the vicinity of Hamiltons Fort. Specific conductance for a sample collected from this well in 2000 was 1,140 µS/cm, or about 740 mg/L TDS (USGS 2002d). This is within the area designated as a Class II aquifer system. Shurtz Creek is a likely source of groundwater recharge at this site (USGS 2005b). Water quality data for Shurtz Creek were derived from a sample collected in 1999 (USGS 2002d); specific conductance was measured at 510 µS/cm, for an estimated 330 mg/L TDS. This suggests that some degradation of water quality occurs due to leaching of sediments and matrix cements by surface water recharge to groundwater, although groundwater quality at the location of the well water samples at Hamiltons Fort also may be influenced by recharge from another area or areas. If leaching of minerals occurs, it is less extensive than at the Coal Creek alluvial fan site, which is consistent with the lower flow rates in Shurtz Creek and the resulting lower potential for recharge and associated leaching.

Modeling of mineralization potential was performed using the USGS PHREEQC program, with water quality from one well closest to each of the four potential recharge locations for which adequate water quality data were available based on USGS characterization (USGS 2005b). These wells were as follows (identifying numbers include corresponding township (south), range (west), section and third-level quarter-section, following USGS convention):

1. Near mouth of Quichapa Canyon: Well C-37-12-5acc-2
2. Airport area: Well C-36-115aca-1
3. Near mouth of Cedar Canyon: Well C-36-11-11bac-1
4. Between Mouth of Shurtz Creek Canyon and Hamiltons Fort: Well C-36-11-31abc-1

Simulations were completed using water quality from each of these four wells, blended with average water quality concentrations from Lake Powell's Wahweap Bay water at 50-100 m depth. This location was chosen because it is likely to have the greatest potential for reaction as a result of blending because of the greater differences between concentrations of Lake Powell water and existing groundwater quality. Ratios of groundwater to Lake Powell water used for blending were 90 percent to 10 percent, 50 percent to 50 percent, and 10 percent to 90 percent, respectively.

The model results for all four locations indicate that the potential for increased mineral precipitation as a result of blending Lake Powell water with existing groundwater is small and is generally limited to minerals associated with iron oxide. Iron concentrations in both Lake Powell water and groundwater are relatively low, therefore iron precipitation is not likely to be a concern for reducing aquifer permeability. Moderately high negative saturation indices in blended waters for sulfur, sulfides and gypsiferous minerals at all locations suggests the potential for increased concentrations of sulfate in the aquifer, although the change in saturation indices for these minerals before and after blending is generally small to moderate, indicating that a large change from current conditions as a result of blending waters is not likely. The potential exists for some leaching of sulfur-based cement precipitates and minerals in the vadose zone from infiltration of Lake Powell water in recharge basins, but the negative saturation indices for sulfur-based minerals Lake Powell water are moderate and do not suggest that Lake Powell water would more aggressively leach these minerals from vadose zone sediments compared to natural recharge sources.

5.13C.8.4 Additional Evaluation Needs

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

The means and capacity of future recharge facilities in Cedar Valley need to be further developed. If construction of a reservoir or reservoirs will be necessary, this would require further evaluation for feasibility and impacts.

5.13C.9 CAPACITY FOR CEDAR VALLEY RECHARGE BASIN INFILTRATION

5.13C.9.1 Recharge Basin Evaluation Source Information

In order to use Lake Powell water for recharge of the Cedar Valley, a recharge basin system will need to be constructed. The Cedar Valley Recharge Basins (CVRB) should be located at a site where surface soil and subsurface alluvial deposits are favorable to allowing infiltration from the surface to the water table.

Each of the four sites was evaluated for the potential for effective recharge using infiltration basins. The following sources of data and information were used in performing these evaluations:

- Well driller reports and (if available) associated geologic logs from the Utah Department of Natural Resources, Division of Water Rights (UDWRi 2009)
- Soils maps from the Natural Resources Conservation Service (NRCS 2009)
- Geologic mapping from the Utah Geological Survey (UGS 2006)

- Aerial photos from Google Earth (Google Earth 2009)
- Groundwater quality classification mapping (UDEQ-DWQ 2007c)
- Reports and studies by the U.S. Geological Survey (USGS 2002; 2005b)
- Site photographs
- Preliminary field observations.

5.13C.9.2 Recharge Basin Evaluation Criteria

In evaluating each site, consideration was given to the capacity for water infiltrating from the surface by means of recharge basins would be able to flow vertically from the surface to the water table and, secondarily, to zones of recharge for confined or semiconfined aquifers used for groundwater production. Another important factor in evaluating each site was the potential impact on groundwater quality that recharge at a given site would be likely to have. Also, the potential for unintended creation of surface seeps, springs, or other surface water discharges must be considered.

Ideally, a candidate site for recharge from the surface by infiltration basins would meet all of the following criteria:

- Permeable, uncemented, coarse-grained surface soils, or at least a fine-grained surface layer thin enough that it could be readily removed during construction of recharge basins
- Coarse-grained, permeable, uncemented subsurface materials between the land surface and the water table
- Coarse-grained, permeable, uncemented materials vertically situated along the lateral margin of confining layers to enable downward migration of recharge water into confined aquifer zones further out into the valley, allowing recharge of confined aquifer production zones
- Sufficient depth to the water table to allow for mounding at the water table interface without causing saturated conditions at the surface or resulting in seeps and springs at nearby topographic lows
- Groundwater that could be recharged by Lake Powell water without substantial degradation of water quality
- Reasonably level terrain over the area of recharge basins
- Existing access roads in proximity to the recharge basins
- Reasonably close proximity to existing production wells and/or infrastructure, or the capacity to develop these features

- No nearby existing or potential contaminant sources
- Sufficient available, undeveloped land to construct and operate the basins.

At a minimum, a successful recharge location would meet the requirement for coarse, permeable soils from the surface to the water table. If fine-grained, low permeability sediments are present, they must be no more than a few feet thick and laterally discontinuous to allow a pathway for downward vertical migration, even if that flow pathway is tortuous. The impact on groundwater quality must be acceptable both to UDEQ-DWQ and to the anticipated water users, meaning that regulatory requirements are met and aesthetic changes are moderate and gradual if water is to be used for potable purposes, and any impacts on irrigation water quality are not detrimental to crops. The site cannot be contaminated or be close to potential contaminant sources.

5.13C.9.3 Quichapa Creek Canyon Mouth Recharge Location Evaluation

NRCS soils maps and field observations show that the soils near the mouth of Quichapa Canyon include areas of low permeability surface soils and areas where soils are moderately permeable. Flow from Quichapa Creek passes through an excavated pond of roughly ½ acre in area and some 10 to 12 feet deep or more, and a visual comparison of the rate of inflow and outflow shows that some infiltration is occurring at the pond.

A review of UDWRi driller reports (well logs) and a limited available number of geologic logs suggests that the site near Quichapa Creek Canyon may not meet the minimum requirement for unencumbered vertical flow from the surface to the water table; most well logs indicate the presence of one or more layers of silt or clay from near the surface to the water table. Some well logs indicate only moderate thicknesses of clay or silt in the subsurface above the water table, but most indicate the presence of one or more layers of clay or silt that are several feet thick. Thus, water infiltrating at the surface may not recharge the aquifer, and may perch on a confining clay layer in the vadose zone. There is a risk that perched water would flow laterally on top of the confining layer and discharge to Quichapa Lake. Although this site would be favorable in other respects because of its proximity to an existing production wellfield operated by Cedar City, the apparent limited ability to infiltrate water from the surface to the water table may put limitations on the feasibility of recharge to the aquifer at this location.

It should be noted that well driller reports/logs can be unreliable for the purposes of interpreting subsurface geologic conditions due to the inherent uncertainty of records kept by drillers, who are generally not trained geologists, whose objectives are primarily to drill and construct wells rather than gather geologic information, and who may be limited in their ability to collect and describe samples because of the methods of drilling and sampling available to them. Although the drillers' reports generally suggest unfavorable conditions at this site, conclusive results could only be obtained by core drilling and inspection by a qualified geologist, followed by pilot testing.

5.13C.9.4 Airport Area Gravel Pits Location Evaluation

UDWRi well logs suggest that the alluvial material overlying the water table in much of this area does not have substantial thicknesses of laterally continuous silt or clay below the first three to six feet and that most of the material from the surface to the water table consists of sand, gravel, and cobbles with minor silt. The presence of gravel pits in this area tends to verify the information in the well logs, and inspection of cut banks in the gravel pits show that the upper 50 feet or so of material is silty sand, silty sandy gravel, and cobbles or boulders. Surface soils are generally suitable, or are thin enough that they could be removed during construction of recharge basins. The water table is greater than 60 feet in most places, so the depth to groundwater would probably be adequate for mounding at the water table, although the depth to groundwater from the floor of the gravel pits is probably much less. However, greater mounding could be allowed in the gravel pits because lateral flow would facilitate recharge as well and the absence of nearby areas of lower elevation would prevent surface discharge. There is generally limited relief.

Cementation is evident from observation of very steep to vertical or even overhanging cuts in the gravel pits that are several tens of feet high, much steeper than the normal angle of repose for unconsolidated granular alluvium. This suggests that permeability is probably less than would be the case for similar but uncemented materials. Anecdotal reports of diverting flood flows from Coal Creek into the gravel pits indicate that the gravels can infiltrate water, although no details are available about the actual rate of recharge or other factors.

As shown in **Figure 13C.3**, groundwater quality in this area is lower than elsewhere in the valley. It is classified as a Class II aquifer system near the gravel pits and Class III north and east of the airport and along I-15. TDS for groundwater sampled near the airport is from 735 mg/L to 1,060 mg/L (USGS 2002) and is generally higher to the east and north. Water recharged to this area would blend with water of technically acceptable but aesthetically marginal drinking water quality relative to existing drinking water supplies in this area. Although the recharged water would blend with lower quality groundwater and probably would improve the overall water quality, the resulting blended water would still be of relatively low quality for potable purposes and may not be suitable for some agricultural uses. Therefore this location may not be desirable for recharge if another suitable location is available.

5.13C.9.5 Cedar Canyon Mouth Location Evaluation

As noted previously, an important source of groundwater recharge in the Cedar Valley occurs from streamflow losses from Coal Creek as it flows across through the alluvial fan near the mouth of Cedar Canyon. Well logs are inconclusive but suggest that surface recharge basin or basins at this site could achieve some aquifer recharge. However, the apparent leaching that results in degradation of recharged water from Coal Creek into the underlying aquifer would likely occur with water recharged from basins. As at the gravel pits, cementation is apparent in vertical or overhanging cut banks along the creek near the mouth of the canyon, suggesting that the permeability of these materials is reduced due to cement precipitates in the particle matrix. Therefore this location is questionable as a recharge location, although further investigation may be warranted to evaluate the probability of leaching from recharge basins. This site is largely developed as part of Cedar City, so there may be limits on the availability of land for recharge basins.

5.13C.9.6 Shurtz Creek Canyon Mouth Location Evaluation

Seepage from Shurtz Creek along the eastern margin of the Cedar Valley has been identified as a source of recharge for the valley aquifer system, primarily due to infiltration of surface flow through the alluvial fan near the mouth of the canyon as the creek flows across the fan (USGS 2005b). Shurtz Creek is an intermittent stream that flows largely in response to snowmelt runoff and storm runoff. It is believed to be a losing stream from the mouth of the canyon to its terminus at Quichapa Lake, when flowing.

There are few UDWRi well logs in this vicinity, and these do not all correlate well with one another regarding subsurface conditions. The most complete and reliable well log was prepared by the Utah Geological Survey for a well drilled in 1998 about one mile east of Hamiltons Fort, near the junction of Kolob Road and the frontage road just after it crosses to the southeast side of I-15. This well log indicates that five to six feet of silt and clay is underlain by sand, gravel, and cobbles with minor amounts of fines from the surface to the water table. The material is identified as "calcareous", probably in reference to cementation of the soil matrix associated with calcium carbonate precipitates. Other well logs located near Hamiltons Fort and about a mile further northeast between I-15 and the valley floor margin are less complete, being completed by drillers rather than a geologist, but suggest possibly favorable conditions for surface recharge. However, some other well logs in the vicinity indicate the presence of silt and/or clay layers of non-specific depth or thickness, conditions which may or may not be favorable for surface recharge.

Field observations revealed the presence of a layer of sandy silt to silty sand at the surface to a depth of five feet or more. Exposed bank slopes within the channel of Shurtz Creek, nearby Hicks Creek, and in road cuts near the canyon show that this is underlain by alternating layers of coarse-grained and finer grained sediments within the upper 15 to 20 feet. The steep to vertical and occasionally overhanging slopes in many bank cuts demonstrate significant cementation of soils both within the overlying silt or silty sand as well as within the underlying coarse-grained sediments to at least 20 feet depth and probably more.

Surface soil maps and field observations show that poorly sorted, mostly coarse alluvium exists at the surface on alluvial fans at the mouth of the canyon and at some locations further out into the valley; however, field inspection shows that a matrix of fine-grained sediments and probably some cementation is in the matrix of much of these coarse alluvial sediments. Just beyond the alluvial fans on flatter ground, the surface soils are mostly silt and/or clay. Some well logs suggest that coarser-grained sediments underlie these fine-grained surface deposits at depths of five feet or more.

Depth to groundwater near Hamiltons Fort appears to be between roughly 60 and 100 feet. A well log located near the mouth of Shurtz Creek Canyon shows sand, gravel, cobble, and minor fines from the surface to bedrock at 38 feet without encountering groundwater; recharge near this well could conceivably work if groundwater infiltrated to the contact between alluvium and bedrock and then flowed westward along the contact into the aquifer (this is likely one way that natural groundwater recharge occurs along the eastern margin of the valley). However, with only 38 feet from the surface to bedrock, the risk of saturation mounding up to the bottoms of the recharge basins and/or stream channel is increased, which would make recharge less effective. Relatively little level space between canyon walls is available for recharge facilities in this area.

This area is largely undeveloped and is owned by both public and private parties, although marked plats and encroaching infrastructure, as well as realtor signage, indicate that some of the area is being targeted for urban development. Near the north end of Kolob Road is a small motorcycle track and some industrial buildings of unknown use, apparently not currently in service. There is no obvious evidence of potential contamination when observed from the road or from aerial photos.

Groundwater in this area is within a Class II aquifer system. TDS is higher than Lake Powell water but within drinking water parameters; USGS sampling (USGS 2002) found that TDS is approximately 740 mg/L in this area, whereas Lake Powell water is typically less than 500 mg/L. Recharge at this site using Lake Powell water would probably result in improved groundwater quality that would be acceptable for potable and irrigation use, although of lower water quality than many groundwater users in Cedar Valley are accustomed to.

5.13C.9.7 Evaluation and Recommendations for Proposed Recharge Location

No single proposed location appears to be clearly suitable for surface recharge using basins. Each site has advantages and disadvantages; however, some locations are known to have limitations that suggest they would not be favorable for surface basin recharge. A summary of advantages and disadvantages for each site is presented in **Table 5.13C.5** below.

TABLE 5.13C.5
POTENTIAL RECHARGE LOCATIONS
ADVANTAGES AND DISADVANTAGES

Criterion	Quichapa Creek Canyon Mouth	Airport Area	Cedar Canyon Mouth	Shurtz Creek Canyon Mouth
Permeable surface or shallow subsurface soils	Y[b]	Y	Y	Y[b]
Permeable sediments from surface to water table[a]	U[c]	Y	Y	U[c]
Little or no cementation of soils	N	N	N	N
Avenue for recharge of deeper confined zones	U	N	Y	Y
Water table mounding unlikely to reach bottom of recharge basin or land surface[a]	U[d]	U[e]	Y[d]	Y[d]
Unlikely to degrade groundwater quality beyond regulatory limits[a]	Y	Y	Y	Y
Blended groundwater quality acceptable for primary uses (municipal, irrigation)[a]	Y	U	U	Y
Generally level terrain	Y	Y	Y	Y

Accessible with minimal construction	Y	Y	Y	Y
Close to production wells and/or infrastructure	Y	N	N	N
No known potential contaminant sources[a]	Y	U	Y	Y
Adequate undeveloped land area[a]	Y	Y	N	Y

Y = yes; N = no; U = unknown

a) Required feature for successful recharge.

b) Surface soils are moderately permeable in selected locations only.

c) Subsurface conditions are variable based on location.

d) Mounding from recharge could reach basins and/or stream channel if basins are too close to mouth of canyon due to shallow bedrock, or if a flow-inhibiting clay layer retards vertical flow.

e) If recharge occurs in excavated gravel pits, mounding might rise to bottom of deeper pits due to reduced depth to water table.

As shown in **Table 5.13C.5** above, all of the sites considered have certain limitations. Although no site can be conclusively eliminated from consideration based on available data and information, it appears that space limitations at the mouth of Cedar Canyon would make this site difficult to convert from developed urban land to recharge basins. The gravel pit areas near the airport may be the most favorable for achieving recharge, but the groundwater quality in this area is marginal for municipal purposes; blending with Lake Powell water would improve groundwater quality but may be aesthetically unacceptable and could result in problems with scaling due to high hardness. For these reasons, the Cedar Canyon and Airport Area sites do not appear to be good candidates for recharge.

The Quichapa Creek Canyon mouth location would be advantageous in many respects, particularly its position relative to the Quichapa wellfield. However, several well logs in this vicinity indicate the presence of one or more layers of silt or clay that, if laterally continuous, would not be favorable to vertical downward flow from the surface to the water table. This would be a “fatal flaw” that would eliminate this site, if the confining layers are laterally continuous in the area. As noted previously, some infiltration is occurring at this site now at a pond through which Quichapa Creek flows, but it is not known whether the recharge water is reaching the aquifer or is perching on confining layers. Additional characterization, including borehole coring and possibly pilot testing, at this site would be necessary to determine whether recharge basins are a viable option. If coring results do not eliminate the site from further consideration, in-situ infiltration testing should be performed with monitoring of vadose zone moisture from the surface to the water table.

The Shurtz Creek Canyon site, defined broadly as the area from the mouth of Shurtz Creek Canyon west to Hamiltons Fort, northeast on the valley floor between I-15 and the mountains to the southern limits of Cedar City, and south to Hicks Creek and the Paiute Indian Reservation, appears to have potential for surface recharge using infiltration basins. Surface soils throughout most of the area include fine sand and silt, which is not conducive to infiltration, but the thickness of this layer appears to be from five to ten feet in some areas and probably could be removed as part of construction of the recharge basins. Subsurface conditions are not well understood; it appears that silt or clay layers are present in some locations but not others, suggesting that the confining layers are not laterally continuous. As at other sites, soil cementation is extensive and could limit recharge, although the depth of cementation is not known. Additional study of this area would be neccessary to better characterize surface and subsurface conditions and determine whether basin recharge at this location is feasible. Characterization would include coring from the surface to the water table, in-situ infiltration testing, and vadose zone moisture monitoring during infiltration testing.

It should be noted that recharge also probably could be accomplished nearly anywhere in the aquifer system by means of injection wells and/or Aquifer Storage and Recovery (ASR) wells. However, it is likely that these methods would require conventional water treatment (sand filtration and disinfection at a minimum) of water prior to injection to comply with State Underground Injection Control (UIC) requirements. A conventional water treatment plant with a capacity of 18 to 20 MGD (approximately 20,000 acre-ft/yr) may cost $30 to $40 million. ASR or injection wellfields could cost several million dollars more. This option probably would be much more expensive than surface recharge basin infiltration but may be viable if no suitable location can be found for surface recharge.

A workshop conducted on April 29, 2009 by the Central Iron County Water Conservancy District (CICWCD) was used to present various CVP terminus options to members of the CICWCD Board of Directors and representatives from Cedar City and the City of Enoch. Terminus options included basin recharge at the Quichapa Lake, Shurtz Creek, and Coal Creek sites, as well as treatment and injection at Quichapa Lake, construction of one or more surface reservoirs, and construction of a water treatment plant for direct use of Lake Powell water. After an evaluation of the advantages and disadvantages of these options was presented, the CICWCD Board and community representatives generally preferred construction of a water treatment plant for direct use of Lake Powell water, rather than aquifer recharge or reservoir construction. Therefore at the time of this writing, it appears that aquifer recharge will be eliminated from further consideration for the CVP terminus.

5.13C.10 CASE STUDY: TUCSON, ARIZONA, CENTRAL ARIZONA PROJECT

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

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

The difference in pH between CAP water (7.6) and previously used ground water (7.9) as well as other water quality parameters such as dissolved oxygen (DO) and TDS/hardness were contributing factors to the release of the corrosion by-products from the pipe interiors. The CAP water reacted with both potable distribution system mains and with customer plumbing. The CAP water's higher mineral content was not believed to be a primary factor in the problems that developed. Other possible causes of problems included the sudden introduction of CAP water without gradual blending, reversals in flow direction in the distribution system, increases in flow velocities, and changes in water pressure. The changes resulted in release of corrosion by-products and in some instances, pipe failure from excessive pitting. Subsequent complaints about the water quality resulted in discontinued use of the direct distribution of CAP water to residents (City of Tucson 2008). Numerous lawsuits were served on the City by various customers and interest groups.

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

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

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

5.13C.9 SUMMARY

Aquifer recharge using Lake Powell water appears to be technically feasible for groundwater at Sand Hollow Reservoir, but the feasibility of recharge in the Cedar Valley is less certain unless performed using injection or ASR wells. Current proposals for recharge include infiltration from the existing Sand Hollow Reservoir; Recharge basins were originally proposed in Cedar Valley, but the locations considered for recharge basins may not be suitable as a result of subsurface confining layers, extensive soil cementation, and/or poor groundwater quality in some locations. Currently, CICWCD and local community decision makers for the Cedar Vally generally prefer the option of treatment and direct use of Lake Powell water rather than aquifer recharge. Injection wells and/or ASR wells may be feasible but would require treatment prior to use. Recharge in the KCWCD service area is anticipated to be only incidental from the surface water impoundment currently under construction, therefore aquifer recharge at this location is not considered in this memorandum.

It is anticipated that recharge of Lake Powell water will result in increased TDS concentrations and possibly other constituents, but that the requirements of the Utah Department of Environmental Quality can probably be met under the terms of a Permit by Rule if numerical groundwater standards for the designated aquifer classes can be achieved. Concerns about aesthetic effects of potential increases in TDS concentrations and those of other constituents should be considered in final selection of the recharge processes and locations. Considerations pertaining to determining final recharge locations should consider the permeability of underlying materials as well as the proximity to production wells, balancing the hydraulic head benefits of locating recharge facilities near wells and the aesthetic benefits of locating recharge facilities further from wells, allowing greater blending with existing groundwater.

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

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Appendix B
List of Well Logs
Arizona and Utah

APPENDIX B

WELL LOGS REVIEWED TO ESTIMATE DEPTHS TO GROUNDWATER

UTAH WELLS

Well ID Number	Township	Range	Section	Water Level (ft below surface)	Borehole Depth (ft)	Open Intervals Depth (ft)	Notes
A44491	43S	3E	32	278	875	NA	First water 635-645 ft
A17209	43S	2E	10	273	450	330-450	First water 280 ft
A28959	43S	2E	11	210	610	320	First water 320 ft
A73567	43S	2E	13	201	625	315-625	First water 294 ft
A30515	43S	2E	13	322	605	NA	First water 412 ft
A30515	43S	2E	13	230	661	NA	First water 356 ft
A31224	42S	2E	14	247	537	NA	First water 243 ft
A21880	43S	1E	1	460	520	NA	First water 470 ft
A13091	43S	1E	2	470	778	NA	First water 495 ft
A13092	43S	1E	2	485	782	NA	First water 485 ft
A14116	43S	1E	2	490	620	NA	First water 490 ft
NA	43S	1W	3	148	302	275-300	First water 180 ft
A44751	43S	1W	3	312	645	610-525	First water 270 ft
A36382	43S	1W	4	300	695	NA	Water level before casing 112 ft
A24022	42S	2W	2	DRY	500	NA	Dry hole
A69823	42S	2W	2	DRY	500	NA	Dry hole
A28444	42S	2W	2	DRY	500	NA	Dry hole
A39863	43S	3W	3	60	404	NA	First water 60 ft
A18984	43S	4W	29	85	140	NA	First water 90 ft
A27205	43S	4W	30	35.5	140	93-98	First water 85 ft
A18080	43S	4W	32	DRY	381	NA	Dry hole
A18567	43S	4W	32	65	140	80-140	First water 45 ft
A23579	43S	4W	32	DRY	400	NA	Dry hole
A10923	43S	11W	28	50	150	NA	First water 90 ft
A38025	43S	11W	28	53	105	77-87	First water 45 ft
A58606	43S	11W	28	42	120	48-105	First water 45 ft
A10923	43S	11W	31	47	95	NA	First water 50 ft
A38025	43S	11W	32	DRY	110	NA	Dry hole
A18148	43S	11W	33	54	120	61-65	
NA	43S	11W	33	85	170	36-170	First water 85 ft
NA	43S	11W	33	54	150	80-97	First water 45 ft
A33363	43S	11W	34	65	80	70-75	First water 65 ft
A32848	43S	11W	36	51	100	NA	
A50221	43S	12W	34	26	80	NA	First water >55 ft
A27850	43S	13W	5	500	530	NA	First water 503 ft
A32318	42S	13W	5	18	54	NA	
A13293	42S	13W	18	66	258	NA	First water 66 ft
A13843	42S	13W	18	60	194	NA	First water 66 ft
A24194	42S	13W	18	65	1005	120-340 &&	First water 65 ft; multiple open intervals deeper
A25994	42S	13W	19	214	965	135-295 &&	First water >223 ft; multiple open intervals deeper
A8103	42S	13W	20	337	410	NA	
01-81-004-M-05	42S	13W	30	117	134	117-122	Monitoring well
A16498	42S	13W	30	155	450	52-450	
A12214	42S	13W	30	112	600	NA	First water 150 ft
A12892	42S	13W	12	35	165	16-165	First water 45 ft
A26729	40S	13W	2	288	329	299-329	First water 310 ft
A25492	40S	13W	2	301	400	334-344	
A18464	40S	13W	2	483	680	440-680	
A20074	40S	13W	11	210	600	520-540, 560-580	First water >440 ft
A17497	40S	13W	22	220	360	320-340	
A20659	40S	13W	27	245	300	260-300	First water 245 ft
A20559	40S	13W	28	28	600	220-420	First water >25 ft
A20559-2	40S	13W	28	55	600	50-170 &&	Multiple open intervals deeper
A18419	40S	13W	28	31	600	110-230 &&	Multiple open intervals deeper
A22558	38S	12W	4	265	300	260-300	
A26905	38S	12W	5	338	540	145-540	First water 360 ft
A12029	38S	12W	9	11	135	11-40	
A16635	38S	12W	20	38	220	62-190	First water 45 ft
93-81-001-P-02	38S	12W	29	95	520	400-440, 480-520	First water 111 ft
A5865	38S	12W	29	28	196	28-38 &&	Multiple open intervals deeper
A36782	38S	12W	29	105	206	106-206	First water 105 ft
A20013	38S	12W	32	21	216	40-54 &&	First water 40 ft; multiple open intervals deeper
A15093	37S	12W	2	82	602	576-596	First water 50 ft
A6512	37S	12W	2	77	280	272-280	First water 140 ft

A22759	37S	12W	2	65	542	531-536	First water 340 ft
A21503	37S	12W	11	25	365	25-?	Bottom of perforated interval not recorded
A21503	37S	12W	11	30	480	120-160 &&	Multiple open intervals deeper
A23897	37S	12W	14	42	236	50-216	First water 41 ft
A12052	37S	12W	14	13	160	50-65 &&	First water 18 ft; multiple open intervals deeper
A14142	37S	12W	14	37	206	NA	First water 48 ft
A18838	37S	12W	22	41	225	141-142 &&	First water 65 ft; multiple open intervals deeper
A17836	37S	12W	22	35	262	35-39 &&	First water 35 ft; multiple open intervals deeper
A36128	37S	12W	28	99	576	160-242 &&	First water 99 ft; multiple open intervals deeper
A14786	37S	12W	33	200	305	265-305	
A17542	37S	12W	33	200	300	280-300	First water 240 ft
A23354	37S	12W	33	224	355	240-266	First water 230 ft
A24547	36S	12W	25	72	145	NA	First water 106 ft
A17784	36S	12W	35	130	545	438-438, 542-545	First water 35 ft
A27779	36S	12W	35	25	253	NA	First water 28 ft
A23170	36S	12W	36	104	307	108-113 &&	First water 107 ft; multiple open intervals deeper
A18827	36S	11W	30	176	610	220-360, 430-600	First water 220 ft
A20180	36S	11W	32	290	400	240-280, 360-400	First water >61 ft

ARIZONA WELLS

Well ID Number	Township	Range	Section	Water Level (ft below surface)	Borehole Depth (ft)	Open Intervals Depth (ft)	Notes
55-532252	41N	2W	8	16	30	10-30	Monitoring well
55-532251	41N	2W	8	16	30	10-30	Monitoring well
55-540991	41N	2W	20	12	20	8 - 20	Extraction well
55-542897	41N	2W	20	15	20	8 - 20	Monitoring well
55-578528	41N	2W	21	12	40	7-32	Monitoring well
55-598254	41N	2W	21	12	25	24-25	Monitoring well
55-578530	41N	2W	21	28	34	9-29	Monitoring well
55-578526	41N	2W	21	29	34	9-29	Monitoring well
55-578527	41N	2W	21	29	34	9-29	Monitoring well
55-578529	41N	2W	21	35	40	10-35	Monitoring well
55-598252	41N	2W	21	12	25	24-25	Monitoring well
55-598251	41N	2W	21	12	25	24-25	Monitoring well
55-578524	41N	2W	21	33	34	8-33	Monitoring well
55-598253	41N	2W	21	12	25	24-25	Monitoring well
55-578525	41N	2W	21	12	33	4-33	Monitoring well
55-585328	41N	2W	21	12	25	24-25	Monitoring well
55-585329	41N	2W	21	12	33	8-33	Monitoring well
55-624436	39N	5W	5	55	60	NA	
55-515691	40N	6W	3	220	305	NA	
55-570376	41N	6W	6	23	52	30-45	Monitoring well
55-589008	41N	6W	6	40	100	18-100	
55-911846	41N	6W	17	DRY	1000	NA	Dry hole
55-591707	41N	6W	20	38	60	NA	First water >25 ft
55-569437	41N	6W	20	15	85	53-69	
55-212466	41N	6W	21	28	90	NA	First water 20 ft
55-518316	41N	6W	27	20	82	71-79	
55-591676	41N	6W	27	32	68	slotted 20-68	First water 43 ft
55-216955	41N	6W	27	33	65	NA	First water 40 ft
55-212556	41N	6W	28	30	60	NA	First water 30 ft
55-513374	41N	7W	1	270	700	620-670	
55-515954	41N	7W	1	130	425	325-425	
55-516701	41N	7W	1	143	400		First water 290 ft
55-526232	42N	7W	33	45	80	60-80'	First water 50 ft
55-087471	42N	7W	34	77	154		
55-218502	42N	7W	34	152	223	120-220	First water >77 ft
55-548006	42N	7W	35	245	400	320-330	First water >270 ft
55-809380	42N	7W	35	255	398	200-398	
55-219680	42N	7W	35	236	352	232-352	First water >187 ft
55-218777	42N	7W	35	243	407	227-407	
55-218505	42N	7W	35	210	404		First water >173 ft
55-219673	42N	7W	35	182	262	182-262	First water >165 ft

Appendix C
Best Management Practices for Trenching and Dewatering

APPENDIX C
BMPs for Groundwater Resource Protection

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

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

TABLE C-1
CONSTRUCTION SITE BMPS

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

		result of construction activity. Runoff and contaminants from staging area will be prevented from entering the stream by the use of secondary containment structures. Directional drilling may be used in geologically sensitive locations to minimize potential for groundwater contamination. All drilling fluids will be captured and accounted for during drilling activities.
6	Stormwater	In addition to other BMPs specified in this document, infiltration trenches for storm water percolation will be used as applicable.
7	Instream sediment control	All instream work should be performed in dry conditions. If this is not possible, all structures will be protected during periods of high discharge. Turbidity should be minimized by using instream water barriers, diversions or settling ponds to limit the disturbed area. All equipment should be kept out of stream channels and dry river beds.
8	Waste management	All waste generated by the construction project should be handled, stored and disposed of under prevailing codes and regulations. Secondary containment structures should be used where applicable.