National Park Service

Hydroanalysis Modeling Report

Glen Canyon National Recreation Area Locations for Hite Launch Ramp

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Prepared by:

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Acronyms and Abbreviations

Acronym	Definition
2D	two-dimensional
cfs	cubic feet per second
fps	feet per second
GLCA	Glen Canyon National Recreation Area
NPS	National Park Service
STA	Station
USGS	U.S. Geological Survey

DISCLAIMER: If using a screen reader, adjustment to your default settings may be required.

Chapter 1 – Introduction

In support of Glen Canyon National Recreation Area (GLCA) 318878 to provide sustainable small boat access to the Colorado River in the Hite District, Contract Number (No.) 140P2023D0006, Task Order No. 140P2024F0155, Subtask 11 for the National Park Service (NPS) Glen Canyon National Recreation Area, Jacobs conducted field reconnaissance, analyzed existing data, and developed a hydrodynamic model to describe hydraulic conditions for the Colorado River at a proposed new river access ramp located along the left (south) riverbank downstream of the Hite Bridge (Utah State Route 95). Since 1999, the water level of Lake Powell has declined between 100 and 150 feet, and the river through the project area has transitioned from a lake environment back to free-flowing conditions, including rapid and dynamic changes as the river erodes through more than 100 feet of lacustrine sediment deposited in the pre-dam river channel. Because of the lower water levels, the existing Hite boat ramp, located on the left riverbank approximately 2.7 miles downstream of the Hite Bridge, no longer reaches the water.

In March 2022, Jacobs prepared a technical report titled, Identification of Potential Locations for Launch Ramps in Lake Powell Hite Launch Ramp Feasibility Study (Jacobs 2022), which evaluated five potential ramp locations based on data available at that time. On July 26, 2023, the NPS and Jacobs completed a value analysis study (Kirk Value Planners and Jacobs, 2023), which selected a preferred location for a new river access ramp. Since the completion of these two reports, river conditions have continued to change in the project area.

Forecasting future conditions of the Colorado River and Lake Powell in the project area is intractable due to watershed-scale uncertainties in future hydrologic (precipitation, drought) conditions, water withdrawals, and water allocation policy decisions, as well as reach-scale uncertainties in evolving bathymetry of the riverbanks and bed and the resulting water surface elevations. The period of record for nearby U.S. Geological Survey (USGS) gages is relatively limited (less than 10 years) and influenced by the dynamic river conditions. USGS measurements of discharge, river bathymetry, and water surface elevations are useful for documenting recent trends, but extrapolation of those trends is subject to great uncertainty.

This hydraulic modeling technical memorandum documents the observed trends in riverbed elevation and water surface elevation. Interpretation of these data helped inform the selection of the design water surface elevation by Jacobs and the NPS for the proposed boat ramp. (Design decisions upslope of the water surface – road and ramp slopes, widths, and surface materials – were developed separately by Jacobs, with input from NPS.) To describe hydraulic conditions (water surface elevation, depth, velocity) for existing and probable future conditions at the new ramp location, Jacobs developed a two-dimensional hydraulic model. This hydraulic modeling technical

memorandum documents the currently available (2024 and 2025) data, interpretation, modeling approach, and key findings and recommendations.

Chapter 2 – Field Reconnaissance

Three members of Jacobs' hydraulics and geomorphology team visited the project location. One member visited alone on March 28, 2024, while in the area on a personal trip. Access was limited to the area near the highway bridge. On that day, the water surface elevation at the USGS gage (USGS 09328990) was approximately 3,572 feet (Figure 1). Two visited together on June 18, 2024, and met with NPS staff to look at the proposed upstream ramp location and the existing Hite ramp. On that day, the water surface elevation at the USGS gage was approximately 3,586 feet (Figure 2).

Figure 1. Proposed Ramp Location (March 28, 2024)

Figure 1. View from right (north) bank across Colorado River toward proposed ramp location (red arrow) on March 28, 2024. The discharge at the USGS Gypsum gage was 7,560 cfs, and the water surface elevation at the USGS Hite gage was 3,572 feet NAVD 88.

Figure 2. Proposed Ramp Location (June 18, 2024)

Figure 2. View from right (north) bank across Colorado River toward proposed ramp location (red arrow) on June 18, 2024. The discharge at the USGS Gypsum gage was 36,000 cfs, and the water surface elevation at the USGS Hite gage was 3,586 feet NAVD 88.

Chapter 3 – Data Analysis

A desktop study was conducted to synthesize available data related to river conditions at the proposed boat ramp.

3.01 Primary Data Sources

The following data sources were identified and reviewed:

- Colorado River water levels recorded at USGS gage (USGS 09328990 COLORADO RIVER AB DIRTY DEVIL RIVER NR HITE, UT; https://waterdata.usgs.gov/nwis/uv?site_no=09328990&legacy=1); period of record: December 15, 2016, to January 16, 2025. (This gage was discontinued in January 2025 due to lack of a funding cooperator.)
- Colorado River discharge measurements collected at USGS gage (USGS 09328960 COLORADO RIVER AT GYPSUM CANYON NEAR HITE, UT; https://waterdata.usgs.gov/nwis/uv?site_no=09328960&legacy=1); period of record: June 29, 2023, to current
- Lake Powell water level data (https://waterdata.usgs.gov/monitoring-location/09379900/#dataTypeId=continuous-62614-0&period=P7D&showMedian=true; https://graphs.water-data.com/lakepowell/); period of record: 1963 to present
- Pre-dam 1959 topographic survey (digitized 10-foot contours above river water surface [no bathymetry] at time of survey; https://www.sciencebase.gov/catalog/item/60a58d8ad34ea221ce48cce3; Jones and Root, 2021)
- Repeat bathymetric cross section survey data collected by USGS near Hite Bridge (2017 to 2024)
- Bathymetric and topographic survey data collected by Jacobs in May 2024
- Personal communications with USGS Grand Canyon Monitoring and Research Center staff (Paul Grams, Scott Hynek, and Chris Wilkowske) from spring 2022 to spring 2025

Analysis of the available data are included in the subsections below. Key findings are summarized at the end of the technical memorandum.

3.02 Water Surface and Channel Bed Elevations

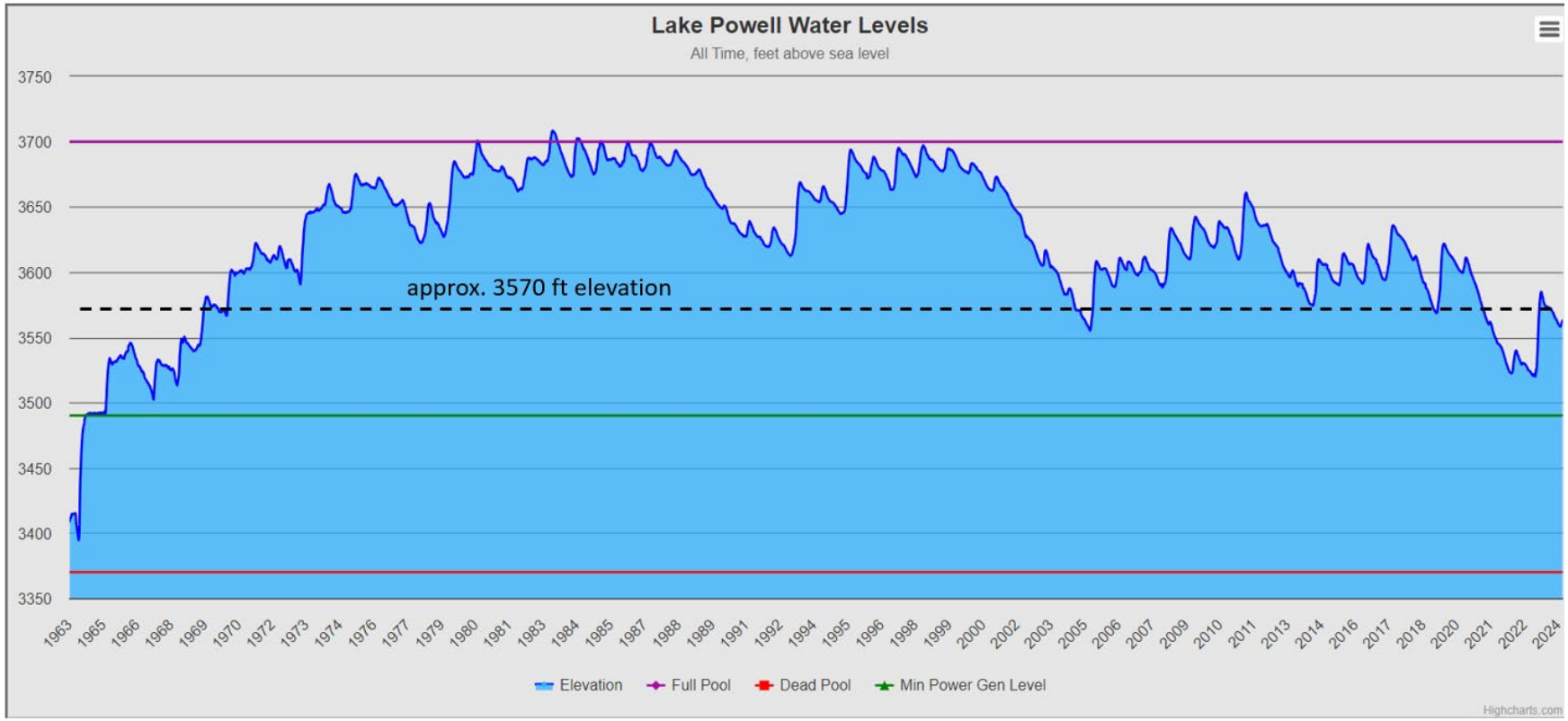
3.02.1 Lake Powell Water Surface Elevations – Historical Data

The water level of Lake Powell has been continuously monitored since the completion of construction of Glen Canyon Dam in 1964 (Figure 3). Water levels increased until reaching full pool (3,700 feet) in 1980. Water levels began declining around 1999 and continued through 2005, reaching a low of approximately 3,555 feet. After 2005, water levels experienced intermittent periods of recovery and decline, and, in 2023, the water level declined to its lowest recorded level, approximately 3,525 feet. Over the 43 years from 1980 to 2023, the water level in Lake Powell dropped 175 feet, an average annual decline of 4 feet.

3.02.1 Lake Powell Water Surface Elevations – Projections

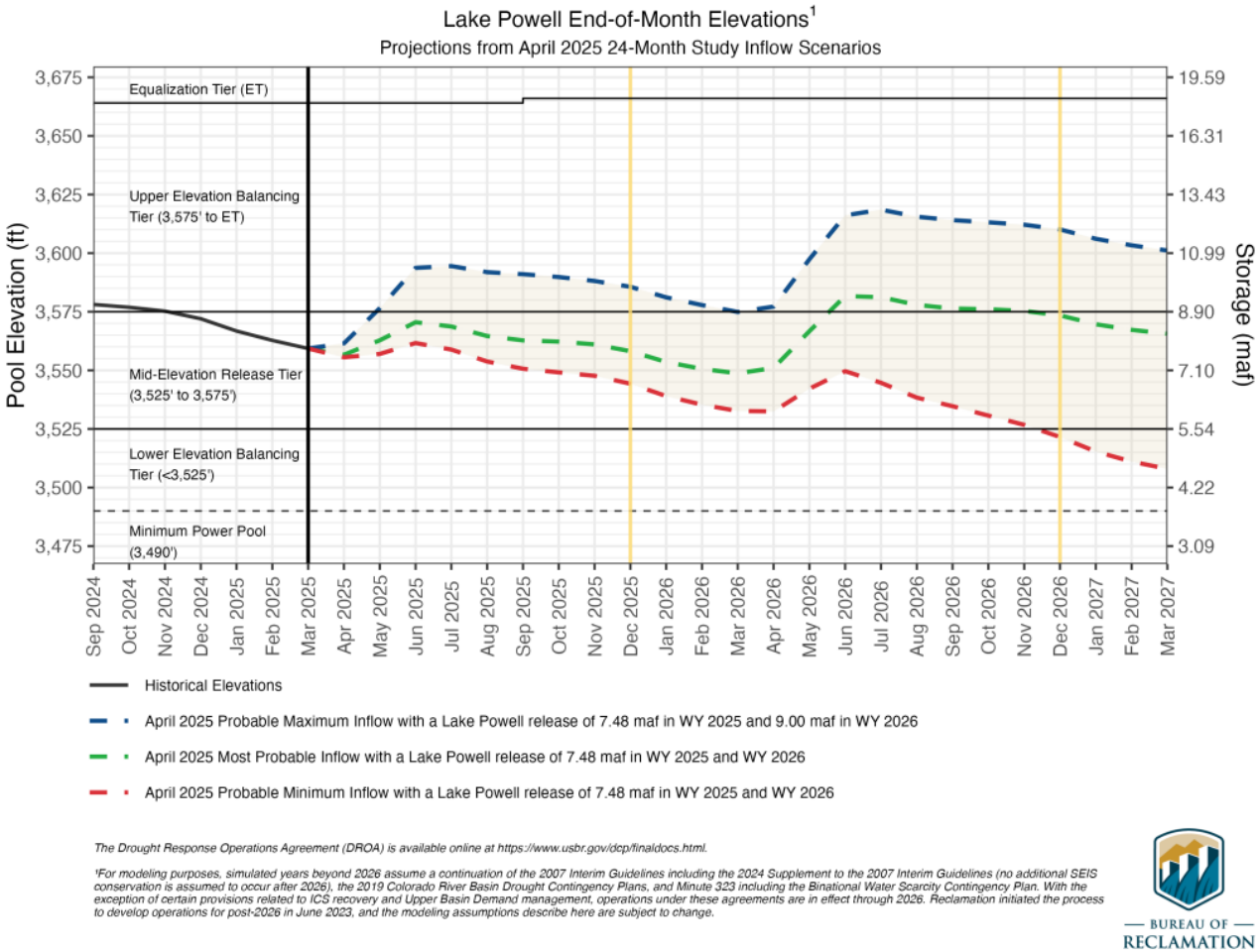
The Bureau of Reclamation projects Lake Powell water levels 24 months into the future on a rolling basis. In recent years (e.g., December 2020 projection), actual (measured) water levels were as much as 20 feet lower than the projected “probable minimum inflow” water levels. The most recent projection (April 2025) shows a continually declining trend and probable minimum inflow water surface elevation (red dashed line) of approximately 3510 feet by March 2027 (Figure 4).

Figure 3. Lake Powell Water Levels 1964 to 2024



Source: https://graphs.water-data.com/lakepowell/

Figure 4. Lake Power 24-month Water Level Projections (April 2025 to March 2027)



Sources: https:/www.usbr.gov/uc/water/crsp/cs/gcd.html; https://www.usbr.gov/uc/water/crsp/studies/images/PowellElevations.pdf

3.02.2 Project Area

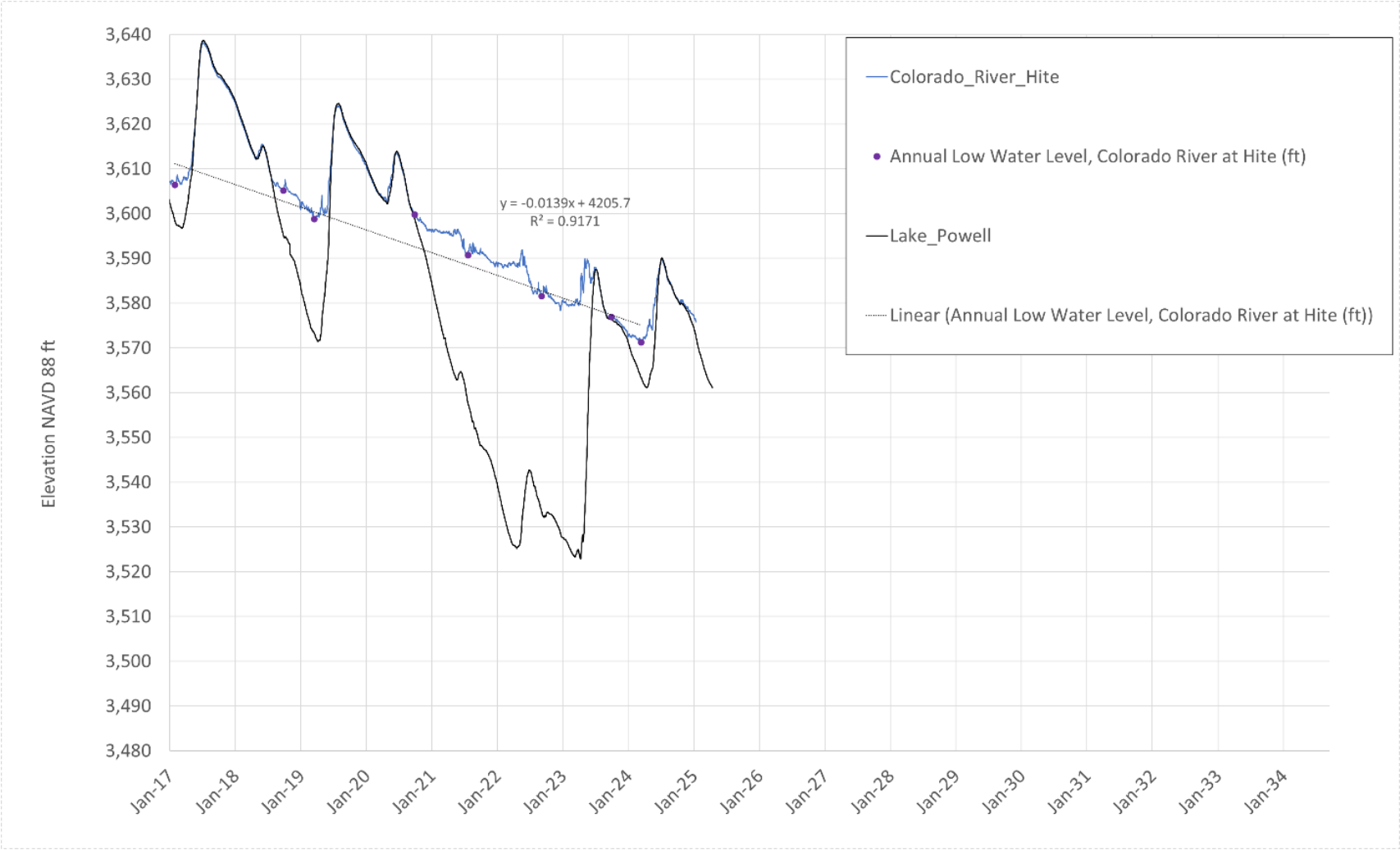
The USGS began recording water levels in the Colorado River at the Hite Bridge (Route 95) in late 2016 at USGS gage 09328990. In a typical water year, water levels increase during spring runoff and then decline through summer and winter. This expected trend is observed in the mean daily discharge data. However, the annual low-water elevation has continually declined as well, and, recently, spring runoff has not produced enough flow to notably elevate seasonal water levels.

During the 7 years between 2017 and 2024 (the most recent available data), the annual low-water elevation has declined 35 feet from approximately 3606 feet to 3571 feet, an average of 5 feet annually (Figure 5), similar to the water surface elevation decline rate observed for Lake Powell since 1980 (Section 3.2.1). While these values are similar and redundancy is helpful when considering trends, the factors affecting each are related, but not identical.

Specifically, in addition to other factors, the water surface elevation through the free-flowing river reach at the project area is primarily influenced by the channel bed elevation (when the site is unaffected by backwater from Lake Powell). As water levels in Lake Powell have declined, the upstream extent of the backwater effect has shifted downstream, at least for some duration of each year, thereby returning the river to free-flowing conditions. The first documented observation of free-flowing conditions at the Hite Bridge was recorded by the USGS in 2017.

Figure 5 shows the historical water levels in Lake Powell and the Colorado River at Hite Bridge, as measured at USGS gage 09328990. When the water surface elevation lines converge, conditions at Hite are backwatered by Glen Canyon Dam (Lake), and when the lines diverge, the river is free-flowing at Hite. Notably, since approximately January 2021, when the river has been in mostly free-flow conditions, the annual rate of decline of the water surface elevation (purple dots) has remained very consistent (trendline with an R^2 value greater than 0.9). (Note: annual low-water values are based on the water year, which starts October 1, not the calendar year.)

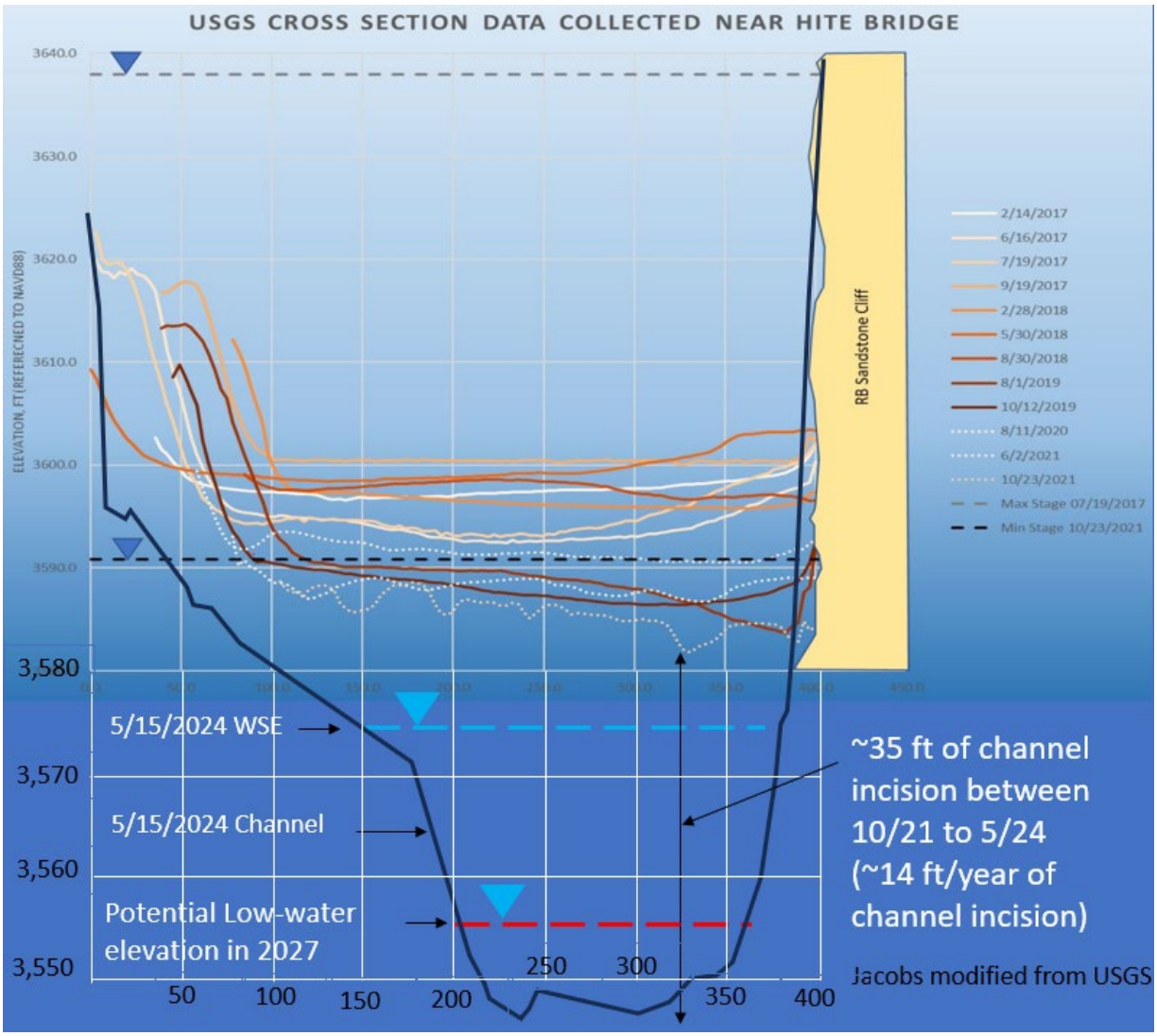
Figure 5. Historical Water Surface Elevations – Colorado River at Hite and Lake Powell



When the river is free-flowing, the river erodes lacustrine (unconsolidated fine) sediments deposited over the past 60 years, and the channel incises. When backwater conditions return, the river shifts back to being a depositional environment. Despite the river in the project area experiencing both erosion and deposition, the net channel change since 2017 has been strongly erosional. The USGS has been conducting repeat bathymetric surveys of a cross section located near their gage (09328990) at the Hite Bridge since February 2017 (USGS unpublished data, 2022). Twelve surveys were conducted by the USGS between February 2017 and October 2021 (Figure 6). During those 4.5 years, the minimum river channel elevation at the repeat cross section incised approximately 18 feet over 4.5 years, an average of 4 feet annually.

No additional bathymetric data were available until Jacobs' survey subcontractor (Center Line Surveying, Inc. DBA Survey Systems [SSI]) conducted a bathymetric survey of the project area on May 15, 2024. Results of the survey showed that the channel thalweg (lowest point of the channel bed) at the Hite Bridge has incised roughly 35 feet since October 2021, an average of 14 feet annually (Figure 6). The accelerated rate of erosion is likely due to 3 years of free-flowing river conditions between 2020 and 2023, a condition likely to persist based on Reclamation's 24-month forecast of Lake Powell water surface elevations (Section 3.2.2).

Figure 6. Repeat Bathymetric Cross Sections near the Hite Bridge



Source: USGS unpublished data (2017 to 2021) shared with Jacobs in March 2022 and modified by Jacobs with more recent data

If the current trend continues and water levels in Lake Powell remain low or decline more than projected, free-flowing conditions are likely to continue, and the river at Hite will continue to incise. If backwater conditions return, channel incision would cease and likely aggrade until free-flowing conditions return (at least seasonally). As noted previously, river bed and water surface elevations at Hite are influenced by watershed- and reach-scale factors that cannot be predicted.

3.03 Ramp Design Implications and Considerations

Historical water level data show a wide range of elevations at Hite, and recent decades have shown a general decline with periods of intermittent recovery. These conditions complicate the determination and selection of a water level design elevation for a river

access ramp. The existing Hite ramp is not usable when the river level is below 3,650 feet (Lake Powell water data 2025).

A new ramp at Hite would need to be sustainable, safe, and operable over a wide range of water levels. Despite the uncertainties, several data points related to water levels can be used to help bound the selection of a ramp design elevation:

- The existing Hite ramp is usable at water levels above 3,650 feet.
- The minimum power pool elevation at Glen Canyon Dam is 3,490 feet.
- The pre-dam water surface elevation in 1959 near Hite was 3,475 feet (per pre-dam survey).
- The minimum dead pool elevation at Glen Canyon Dam is 3,370 feet.

Assuming future hydrologic and water use conditions upstream of Hite are comparable to those in the 1950s and Lake Powell drops below the minimum power pool, the pre-dam river elevation at Hite (3,475 feet) is a reasonable lowest bound estimate for how far river levels could drop if the river continues to erode through the historic lake deposits. However, the duration of time until the river reaches that level is unknown. The change could continue to happen relatively gradually, even though the elevations of the riverbed and the water level do not move in unison. For example, the most recent bathymetric survey shows the bed elevation dropping faster than the water levels, average annual rates of 14 and 4 feet, respectively. Or, less likely but possible, the change could happen over a short period of time, such as one or more spring runoffs, if more erodible bed material is encountered, resulting in a headcut propagating upstream, as had been observed elsewhere on the Colorado River and San Juan rivers (Grams and Tusso 2023).

Another useful data point is the depth of accumulated sediment at Hite since construction of the dam. Differencing the digital elevation models derived from the 1959 pre-dam topographic survey and the 2024 light detection and ranging (LiDAR) survey produces a sediment thickness map. Figure 7a and 7b show the accumulated sediment thickness since the completion of the dam in 1964. Depths greater than 100 feet of deposition are present throughout the project reach, and the actual depths are even greater because the pre-dam surface is based on the water level in 1959, not the actual channel bed.

Figure 7a. Lacustrine Sediment Thickness (feet) Accumulated between 1959 (Pre-dam) and 2024 in the Project Area

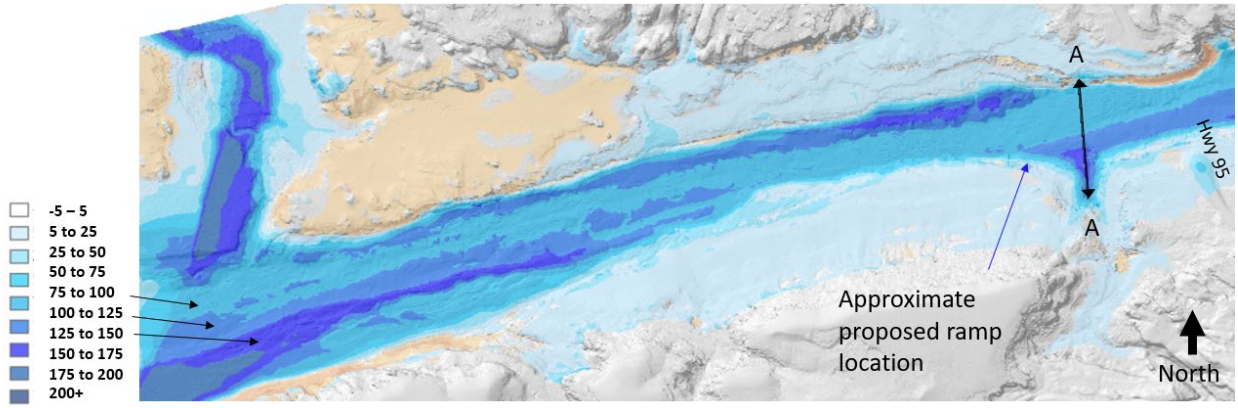
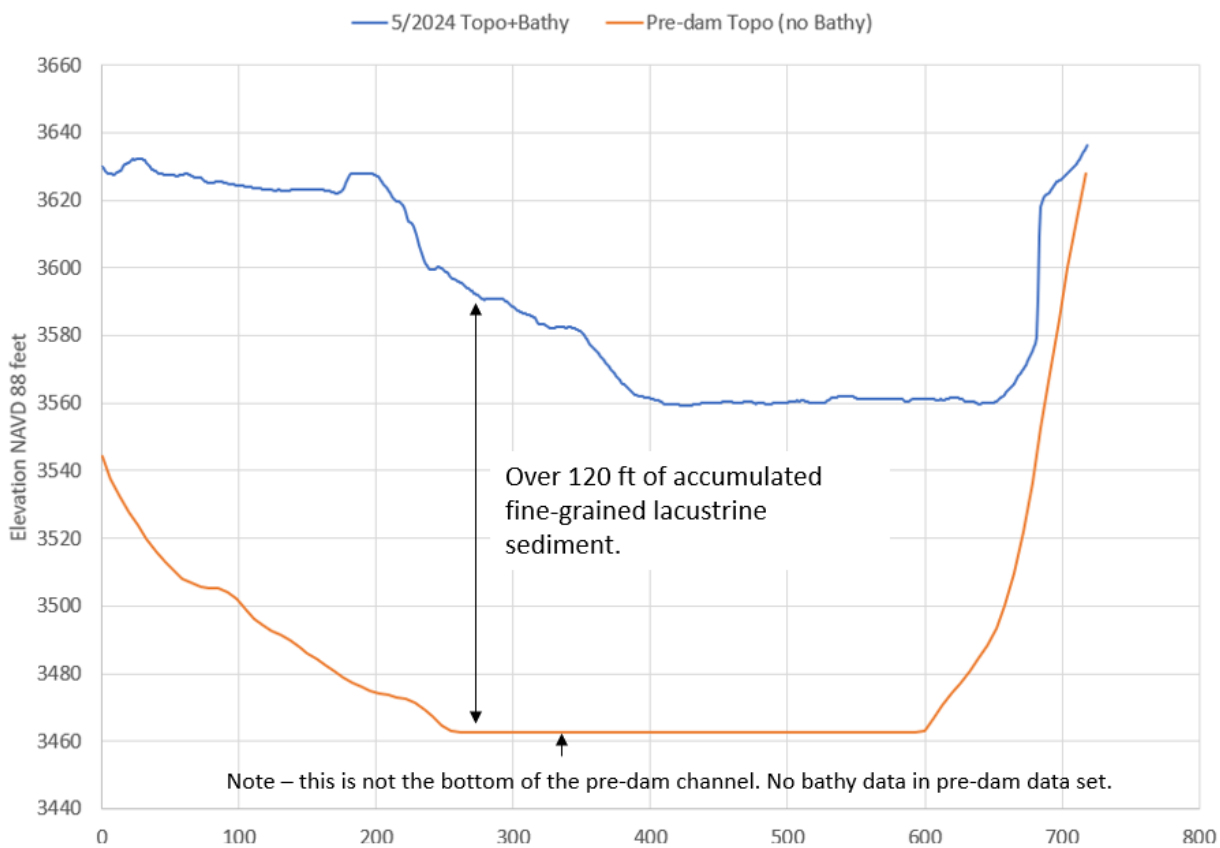


Figure 7b. Comparison of Cross Section Geometry (Looking Downstream) through Section A-A shown on Figure 7a between 1959 (Pre-dam) and 2024 in the Project Area (Hite Bridge Shown at Left End)

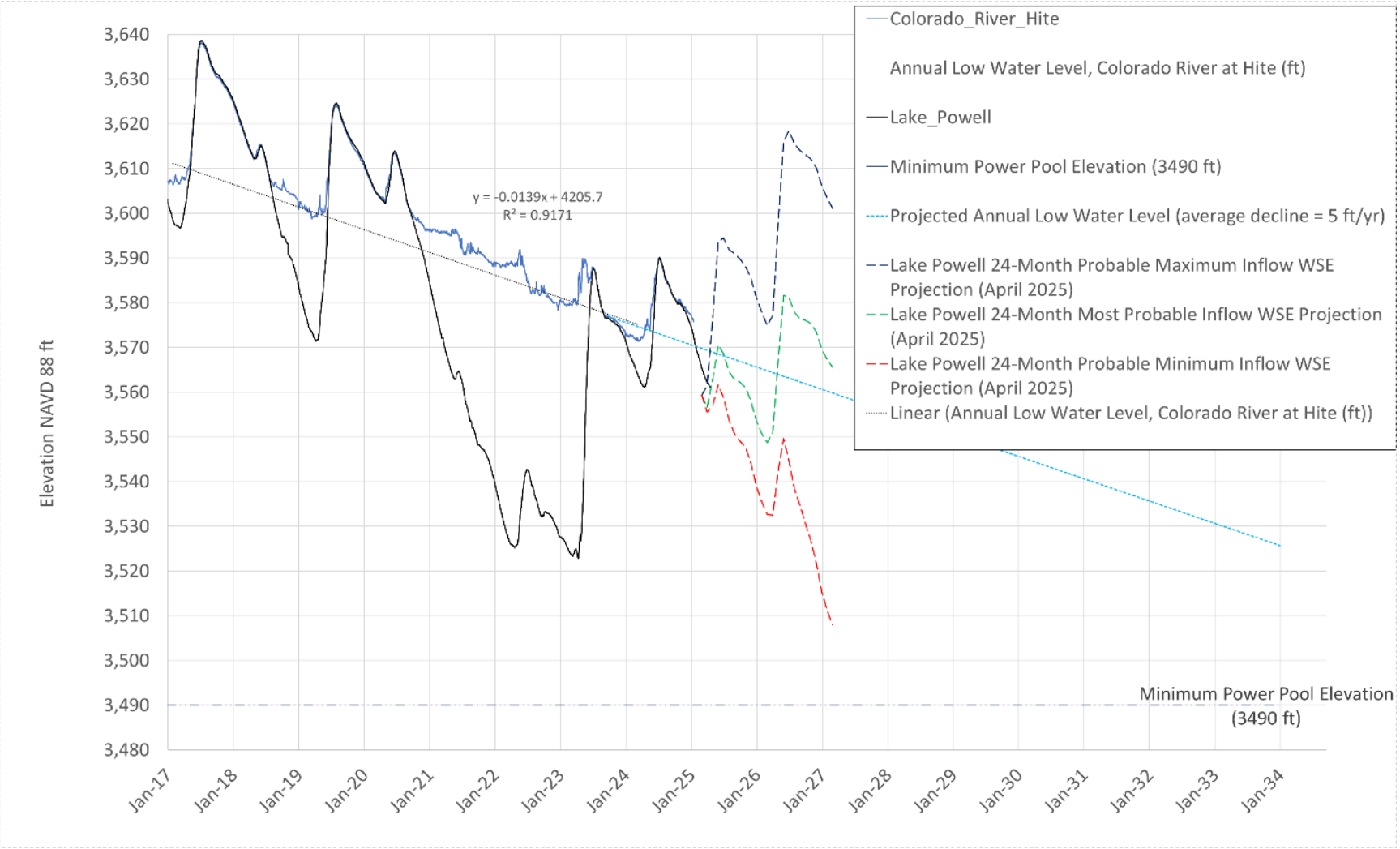


Near the proposed ramp location, lacustrine sediment deposits are likely greater than 100 feet thick (Figure 7b) because the pre-dam topography does not include bathymetry

of the channel. During the field reconnaissance, these lacustrine sediments were visually characterized as silt and fine sand, which are low strength and highly mobile sediments. When the Colorado River is free-flowing, these lacustrine deposits are easily eroded. The eroding channel bed combined with the potential future reduction in Colorado River flows together affect the water surface elevations.

Figure 8 shows historical (identical to Figure 5) and projected water levels in Lake Powell and the Colorado River at Hite Bridge. Historical data suggest that the water surface elevation is declining 5 feet per year on average. If a uniform rate is assumed into the future (light blue dashed line), the annual low flow trendline would extend below the proposed bottom of ramp design elevation of 3,529 feet in 2033 (8 years from 2025). Notably, the Bureau of Reclamation's recent (April 2025) 24-month projection of water surface elevations in Lake Powell (future probable minimum inflow; red dashed line) suggests the reservoir water surface elevation could be 3508 feet in March 2027, 21 feet below the proposed ramp.

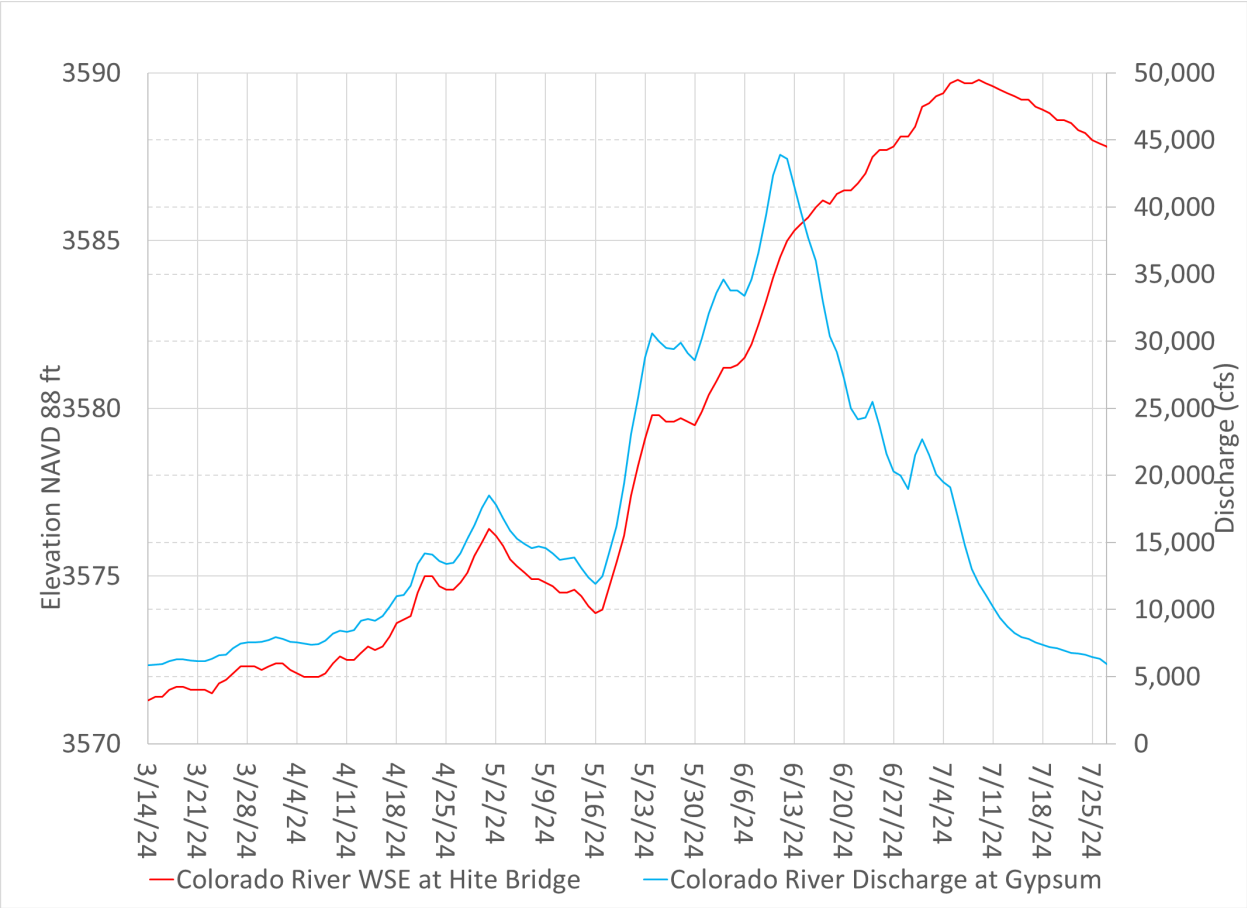
Figure 8. Historical and Projected Water Surface Elevations – Colorado River at Hite and Lake Powell



3.04 River Discharge

Recent and real-time Colorado River discharge data for the project area are based on the Gypsum gage (09328960), located approximately 30 miles upstream and with a short period of record (began recording discharge July 1, 2023). The only spring runoff data currently available are from spring 2024 (Figure 9), when flows increased from approximately 6,000 cubic feet per second (cfs) in March to approximately 30,000 cfs in May to a peak spring flow of 44,200 cfs on June 11, 2024. The river water surface elevation at the Hite Bridge generally tracked consistently with the upstream discharge data during the ascending hydrograph (Figure 9), suggesting the Gypsum discharge data as an appropriate upstream boundary for hydraulic modeling at Hite.

Figure 9. Example Comparison of Colorado River Discharge (Gypsum) And Water Surface Elevation (Hite) during the 2024 Spring Runoff



Based on the gage data between fall 2023 and winter 2024, the average flow rate at Gypsum was 6,300 cfs, and flows remained relatively constant. Therefore, 6,300 cfs is chosen as a representative typical low flow for the modeling and design. Based on the 2024 spring runoff hydrograph currently available, 30,000 cfs is chosen as a typical spring flow and assumed representative of current hydrologic conditions in the project area.

However, due to the very short period of record, neither of these “design” flows has statistical significance due to the lack of available data. For example, neither can be considered to represent an “X-year recurrence interval flow, or X-percent exceedance” which would be based on flow frequency analysis using a period of record at least 20 years long. Despite this limitation, both flows are measured at a relatively nearby gaging station, represent recent conditions, and are the best available information to provide the upstream boundary condition for the hydraulic model. Worth noting, use of the Gypsum discharge data assumes no tributary inflows between the gage and the project area.

Chapter 4 – Model Development

A two-dimensional (2D) hydraulic model was developed to evaluate water depths and velocities at the proposed ramp location. The flow field predicted by the model near the ramp also provides context to understand where erosion and deposition may occur. The selected hydraulic modeling software is Hydrologic Engineering Center's River Analysis System, developed by the U.S. Army Corps of Engineers. The subsections below describe the model development process, data inputs, and model results for existing and probable future conditions.

4.01 Design Criteria

Two primary design criteria are the focus of the probable future conditions modeling: depth and velocity. Specifically, a minimum depth of 3.5 feet is required at low flow, and a maximum velocity of 7 feet per second (fps) (5 miles per hour) is required at high flow at the ramp (and approaching the ramp). The depth criteria are based on feedback from NPS about launching J-boats (Jacobs, 2022), and the velocity criteria are based on feedback from listening sessions hosted by NPS in 2021, including documents provided by the boating community (e.g., Returning Rapids Project 2021).

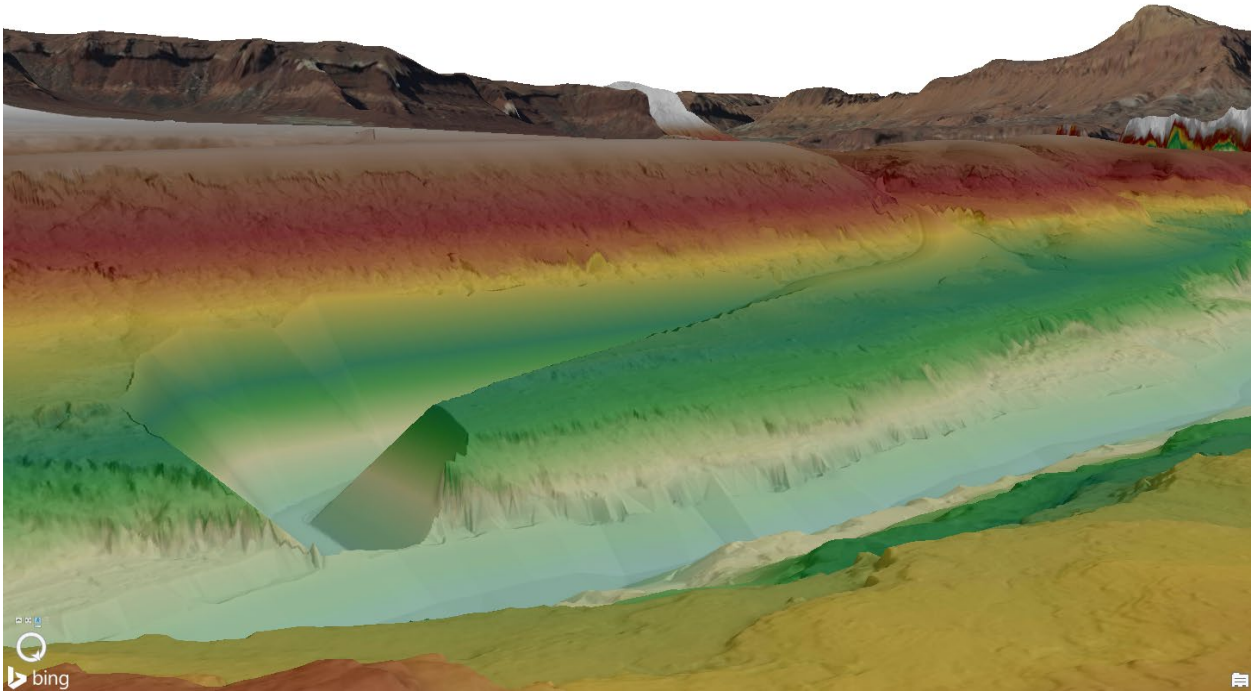
The proposed design surface was developed by Jacobs based on input from NPS on ramp slopes and includes these ramp criteria:

- Bottom of ramp elevation: 3,529 feet
- Ramp width: 35 feet
- Lower approach ramp slope: 2 percent
- Upper approach ramp slope: 16 percent

The upper approach ramp slope of 16 percent approximates the upper limit of the ramp angle range (9 degrees) requested by the boating community (Returning Rapids Project, 2021). The 16 percent grade is needed due to the steep terrain in the area and was carried forward from the Conceptual Plans (Jacobs 2022). However, the lower approach ramp slope is flatter than the requested lower limit of the ramp angle range (6 degrees or 10.5 percent; Returning Rapids Project, 2021). The 2 percent ramp was selected as a minimum slope to get to the edge of the rock river channel section without increasing excavation while maintaining a positive slope. This 2 percent ramp section is expected to pose operational and hazard challenges due to the low gradient. A minimum safe operable water level (3539 feet) can be calculated based on a 4-foot minimum depth for the trailer and the vehicle located on the lowest portion of the 16 percent ramp (3535 feet + 4 feet). Below 3539 feet, tow vehicles could unknowingly back onto the submerged 2 percent portion of the ramp and immediately be in more than 3.5 feet of water, flooding the engine and/or floating the vehicle.

Figure 10 shows the resulting probable future conditions surface, described in the following sections, from a similar perspective as Figures 1 and 2 (Section 2).

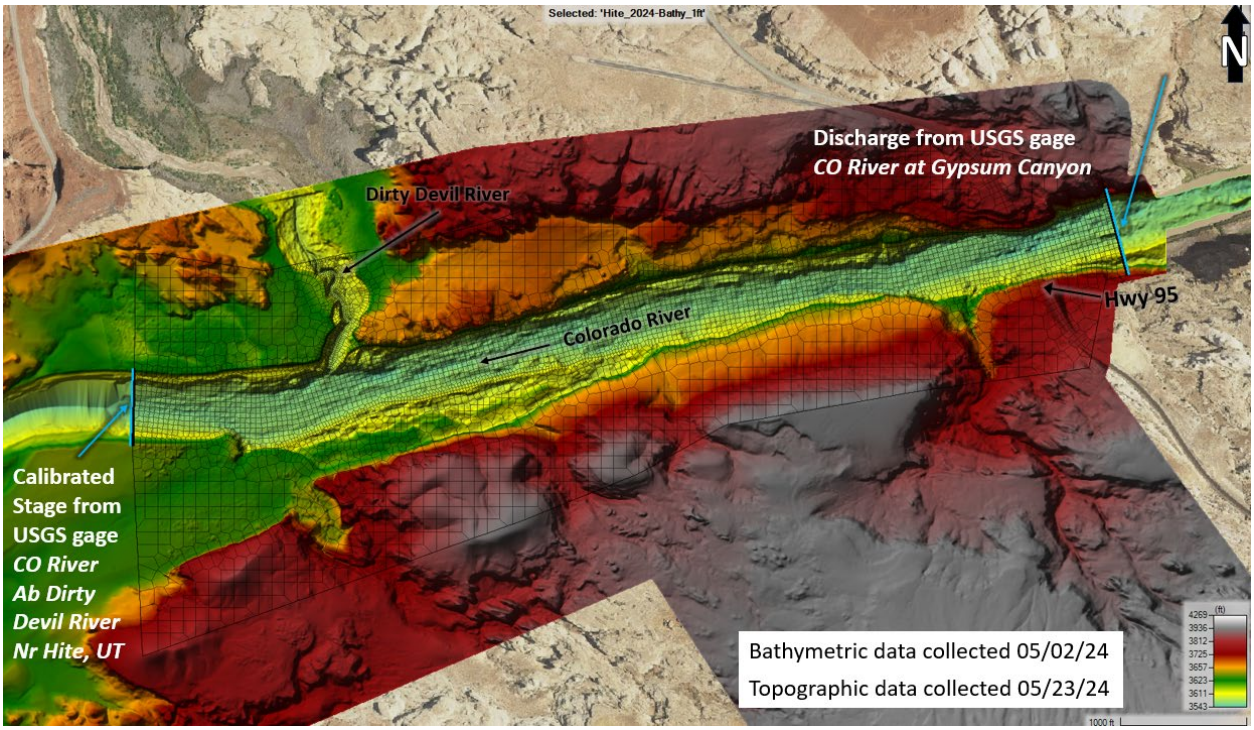
Figure 10. Probable Future Conditions Surface Oblique View from Right (Northern) Bank across Colorado River Toward Proposed Ramp Location



4.02 Model Domain

The model extent, or model domain, extends from just upstream of Route 95 and downstream to below the Dirty Devil tributary. The boundary of the model domain is shown on Figure 11 with the existing conditions terrain. The approximately 1.5-mile-long project reach covers 393 acres and is represented by 4,960 2D grid cells in the existing conditions model and 5,487 2D grid cells in the probable future conditions model. The grid scale is 40 by 40 feet for the main channel, 15 by 15 feet for the Dirty Devil River channel, 25 by 25 feet for the Dirty Devil River floodplain, 15 by 15 feet for the proposed ramp, 50 by 50 feet for high-ground refinements, and 100 by 100 feet for the floodplain areas.

Figure 11. Existing Conditions Model Domain and Boundary Condition Definitions



The model surface for existing conditions was relatively straightforward to develop by merging bathymetric data collected on May 2, 2024, by SSI and topographic data collected on May 23, 2024, by Jacobs' survey crew. The surface can be considered representative of riverbank and bed conditions in May 2024. However, the development of the model surface for probable future conditions required multiple assumptions, and these assumptions have a large influence on the modeled results. The probable future conditions surface assumes the following about the river bed and banks:

- The rate of bed erosion in the future will be similar to the rate of bed erosion measured during the past 7 years.
- Only bed erosion (net change over bed surface in the project area) and no bed deposition or bank slumping will occur in the future. For example, the future conditions surface does not account for a mud-slump scenario such as that which occurred approximately 5 miles upstream of the project area in October 2024 (NPS 2024).
- The roughness of the riverbanks and bed will be similar to the current roughness.
- The shape of the future riverbanks will be similar to the shape of the riverbanks exposed in recent years. Specifically, the slope of the riverbank will remain relatively constant as the bed continues to erode.

- Along the left (south) bank at the boat ramp, the future bed elevation will be approximately 3529 feet, 35 feet below the 2024 bed elevation.

Based on these assumptions, the probable future conditions bathymetric and topographic surface was developed using the following steps:

- Use the existing conditions surface to identify the toes of each side slope at the channel bed.
- Starting at these existing toes, extend the riverbank side slopes down at 50 percent (2H:1V) to mimic the existing side slopes of exposed sediments in the topographic surface.
- Within these extended riverbanks, lower the existing conditions bed surface by 35 feet, the distance from the toe of the existing 2024 bathymetry (approximately 3564 feet) to the toe of the boat ramp (approximately 3,529 feet).
- Connect the lowered side slope elevations points to define the surface of the lowered bed.

This approach to defining the probable future conditions surface resulted in narrowing of the channel bed by approximately 140 feet. The existing conditions and probable future conditions surfaces are shown on Figure 12, and four example cross sections with the "downward extensions" of the existing riverbank side slopes are shown on Figure 14.

Figure 12. Comparison of Existing and Probable Future Conditions Model Surfaces

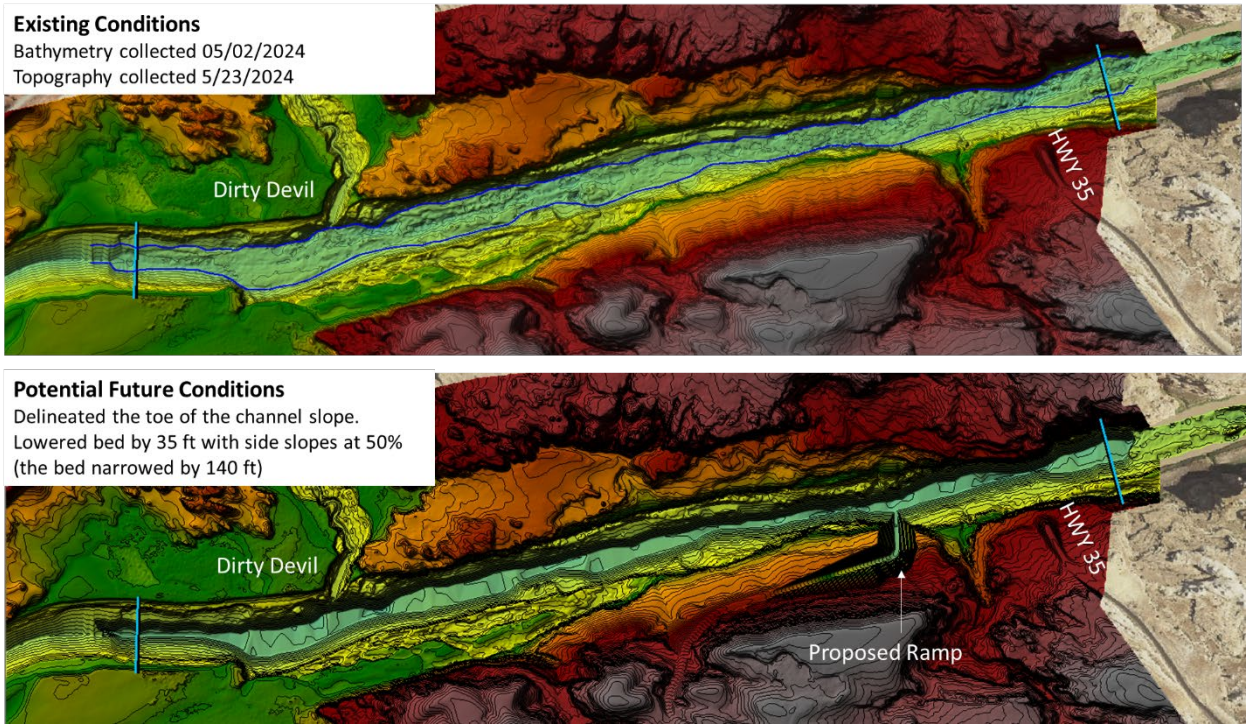


Figure 13. Four Example Cross Sections Comparing Existing and Probable Future Conditions

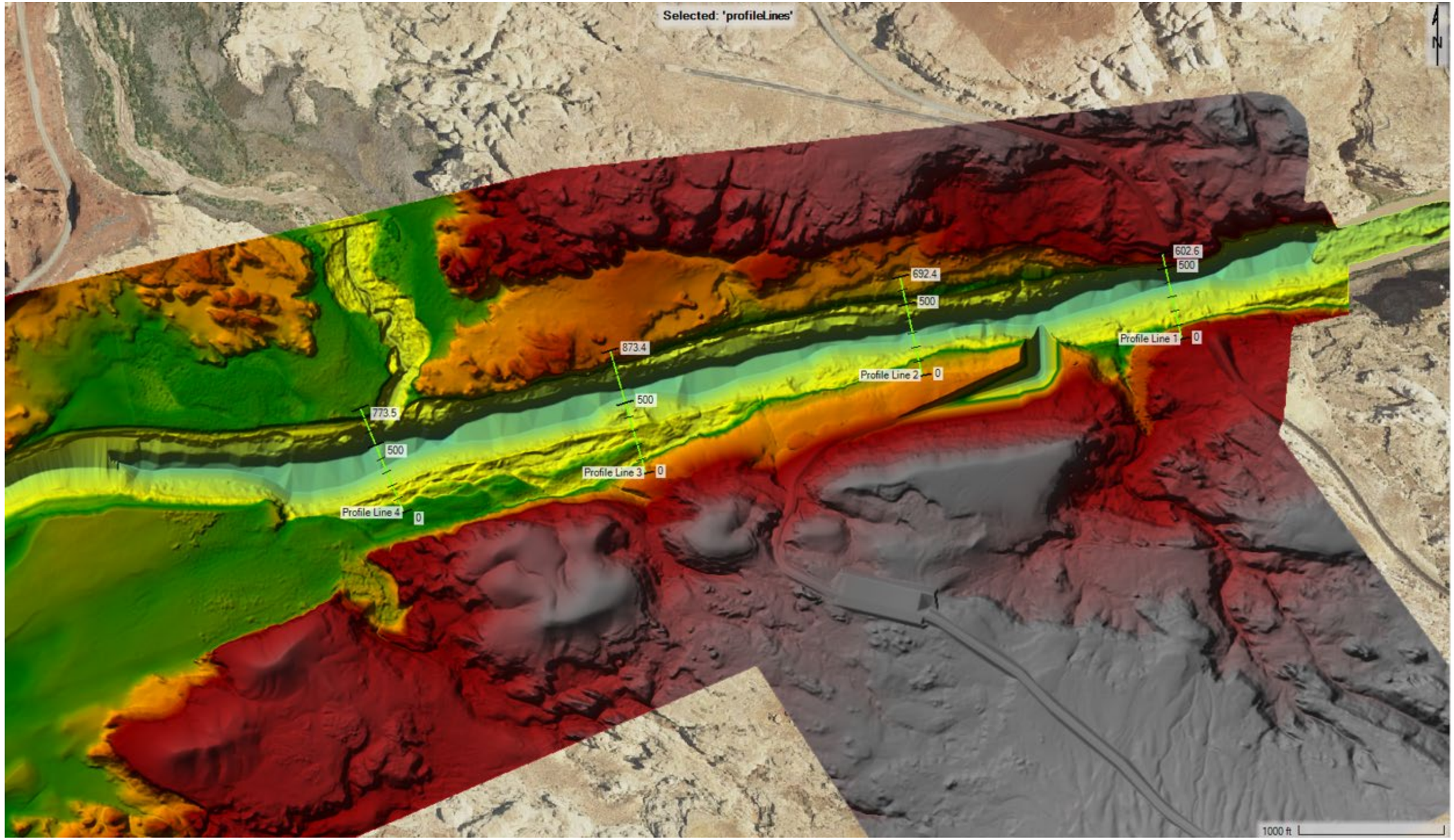
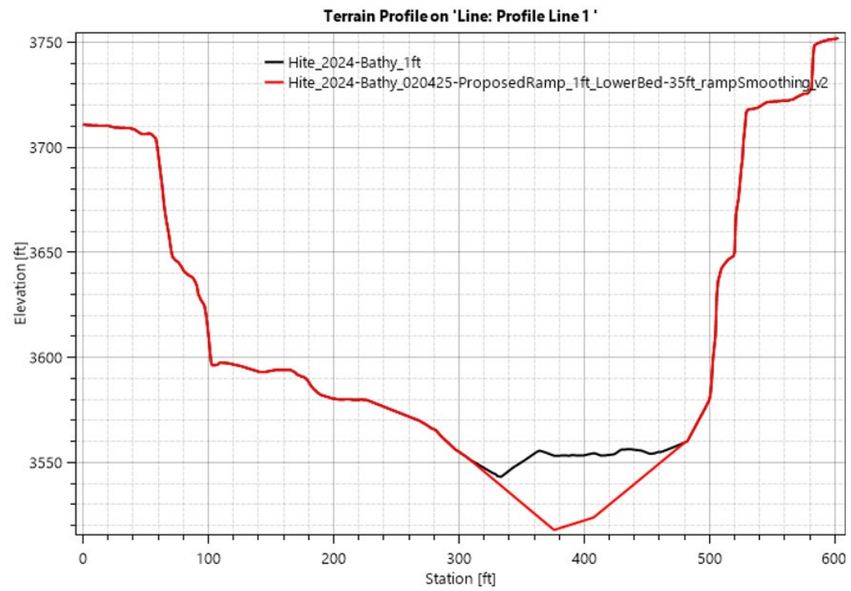
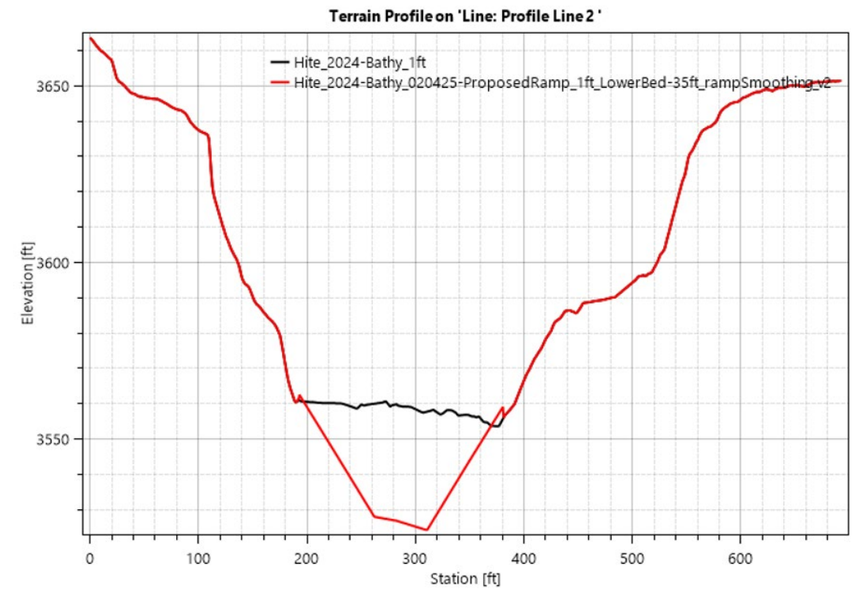
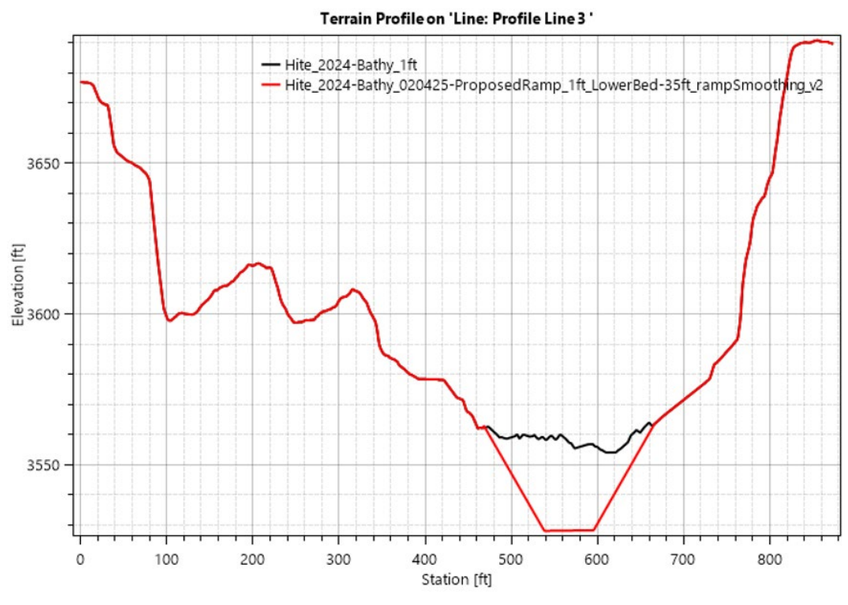
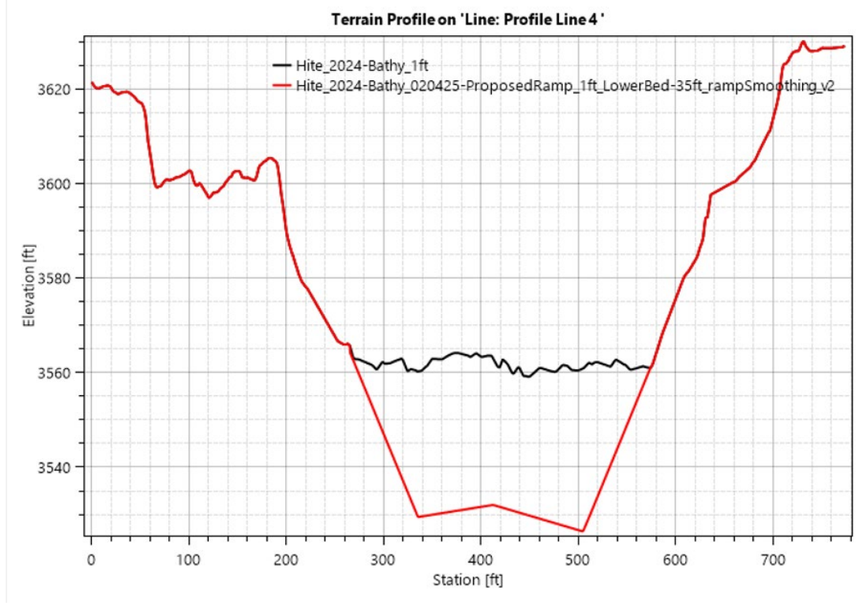


Figure 14. Terrain Profiles







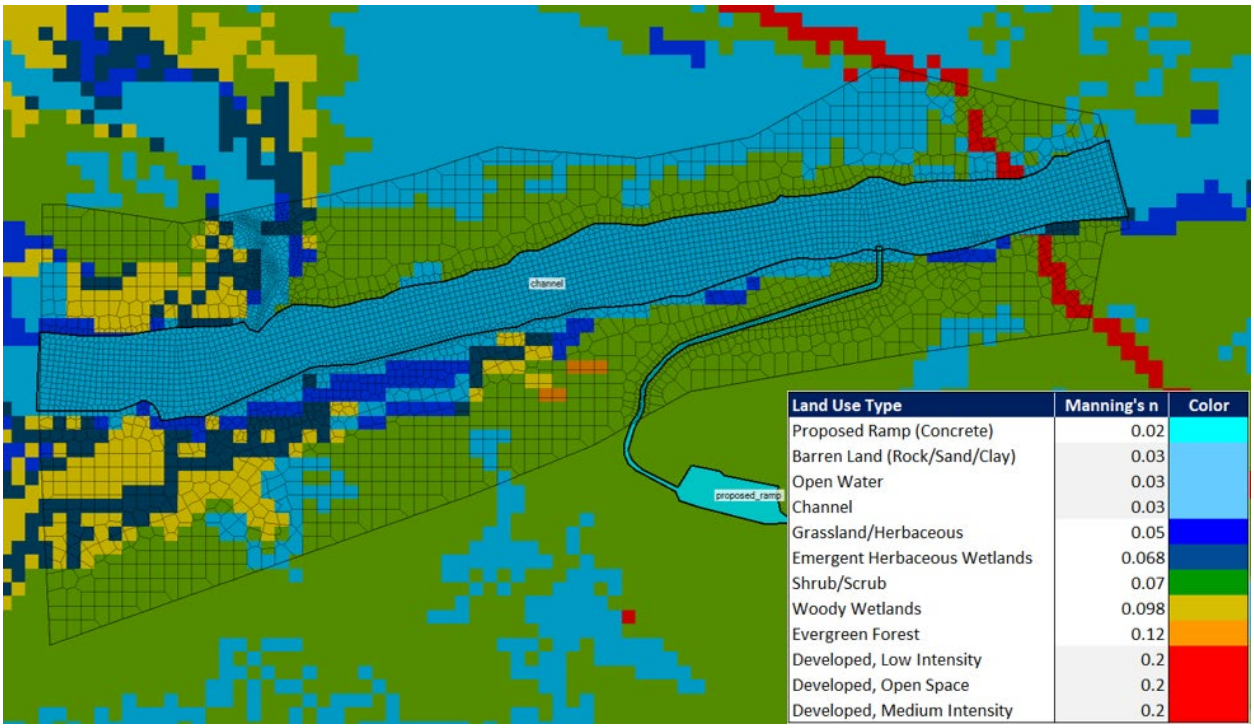


An important hydraulic implication of these assumptions underlies the probable future conditions model results: Initially, for a given water surface elevation, the lower the channel scours, the narrower the channel width, and the smaller the cross section area; together, these conditions result in a deeper (higher relative water surface) channel. However, as the riverbank deposits continue to slump (as has been documented upstream and downstream of the proposed ramp location), the water surface elevation will decline at a faster rate due to the relatively faster rate of channel widening (width returning to the pre-dam canyon walls). This uncertainty underscores how relatively small and gradual or episodic changes in cross section shape and bed elevation create large changes in water surface elevation in this dynamic river canyon.

4.03 Hydraulic Roughness

Water flowing in a riverine environment experiences two forms of flow resistance: form drag and skin friction. Both types of resistance affect hydraulic conditions such as water level, velocity, and shear stress, and correspondingly the energy that is available to transport sediment. Factors such as vegetation, planform geometry, bedforms, bed and bank particle sizes, and flow depth all contribute to the overall flow resistance. The project reach is a relatively straight (low planform drag) sand-bed channel with modest vegetation. The primary flow resistance factors are drag on the bed created by the presence of dunes on the channel bed, which are typically dynamic, and drag from vegetation when water levels are high enough to interact with the vegetation and jagged rock surfaces. Skin friction contributes to flow resistance, but to a lesser extent than drag forces. Due to a lack of available calibration data, engineering judgement was used to estimate the total combined flow resistance in the form of the Guackler-Manning's roughness coefficient (n-values). Figure 15 shows the spatial distribution of selected n-values used in the hydraulic model.

Figure 15. Probable Future Conditions Surface Roughness Values (Manning's n)



Land Use Type	Manning's n	Color
Proposed Ramp (Concrete)	0.02	
Barren Land (Rock/Sand/Clay)	0.03	
Open Water	0.03	
Channel	0.03	
Grassland/Herbaceous	0.05	
Emergent Herbaceous Wetlands	0.068	
Shrub/Scrub	0.07	
Woody Wetlands	0.098	
Evergreen Forest	0.12	
Developed, Low Intensity	0.2	
Developed, Open Space	0.2	
Developed, Medium Intensity	0.2	

4.04 Boundary Conditions

The hydraulic model includes two boundary conditions:

1. Prescribed flows as the upstream boundary condition
2. Prescribed water levels as the downstream boundary

The model computes hydraulic conditions at the individual grid scale between these two defined boundaries. During model development, the entire flow record at Gypsum (USGS 09328960) was used to calibrate the model (July 1, 2023, to June 1, 2024).

The two design flows described in Section 3.3 were selected to characterize typical conditions at the ramp. For the upstream boundary, a steady-state flow of 6,300 cfs was selected to characterize the low flow period that occurs in summer, fall, and winter, and a steady-state flow of 30,000 cfs was selected to characterize a typical spring flow. The downstream boundary condition was defined as "normal depth" for the design flows using an adjusted version of the USGS water level data (USGS gage 09328990) collected at the Hite Bridge (refer to Section 4.3).

A normal depth boundary condition requires an estimate of the reach-scale water surface slope, which under normal flow conditions is approximately equal to the reach-scale slope of the channel bed. Given the rapidly changing channel dynamics and relatively short length of the survey, it is difficult to get a reliable estimate of the slope of the bed. Therefore, instead of using the channel bed slope to estimate the normal slope,

Jacobs used water surface slopes identified through the calibration process (refer to section 4.e for details). Model results at this location are highly sensitive to the normal slope assignment, and it remains an uncertain variable in predicting hydraulic conditions.

Similar to the important assumptions associated with the proposed conditions modeled surface, the probable future conditions model results assume that future typical flow conditions will be similar to the selected design flow from the 2024 measured data.

4.05 Model Calibration

Model calibration refers to the process of adjusting some model inputs to align modeled results with measured data. The typical model calibration process requires known boundary conditions. At this site, the upstream boundary condition, river flow, is moderately uncertain for three primary reasons:

1. The relatively long distance (30 miles) between the gage and project area
2. Failure to account for tributary inflows and accretion flows
3. An unknown downstream water level (within the model domain). Given these constraints, a typical model calibration process cannot be performed

Therefore, the calibration approach involved a water level translation, rather than roughness calibration, where the water levels recorded at Hite Bridge are adjusted (lowered) before they are assigned as the downstream boundary. Iterative model runs and adjustments were made until the model-predicted water levels at Hite Bridge approximately matched the observations at the USGS gage. Figure 16 shows two iterations of model calibration. Run #2 was selected as the best fit calibration.

While the available data are imperfect for a typical calibration process, the results do provide some insight about the expected water surface slopes based on the assumed channel roughness. The water surface slope is relatively flat at low flows and increases at higher flows. The increase in slope is likely due to bedforms (e.g., dunes) height increasing at higher flows. Figure 17 shows the resulting water surface slopes over the duration of the calibration period and the values used for proposed condition modeling.

Figure 16. Existing Conditions Model Calibration Results

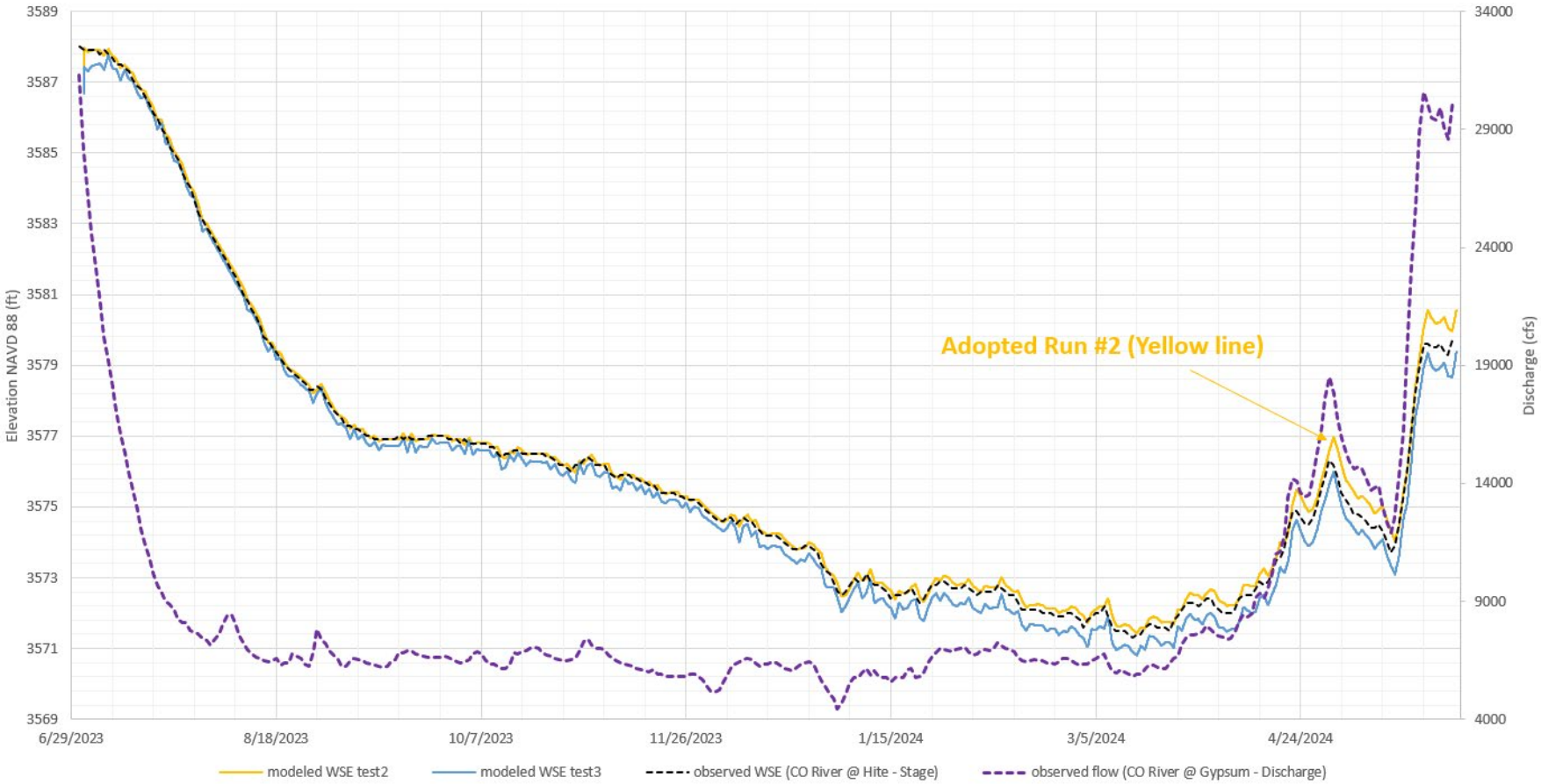
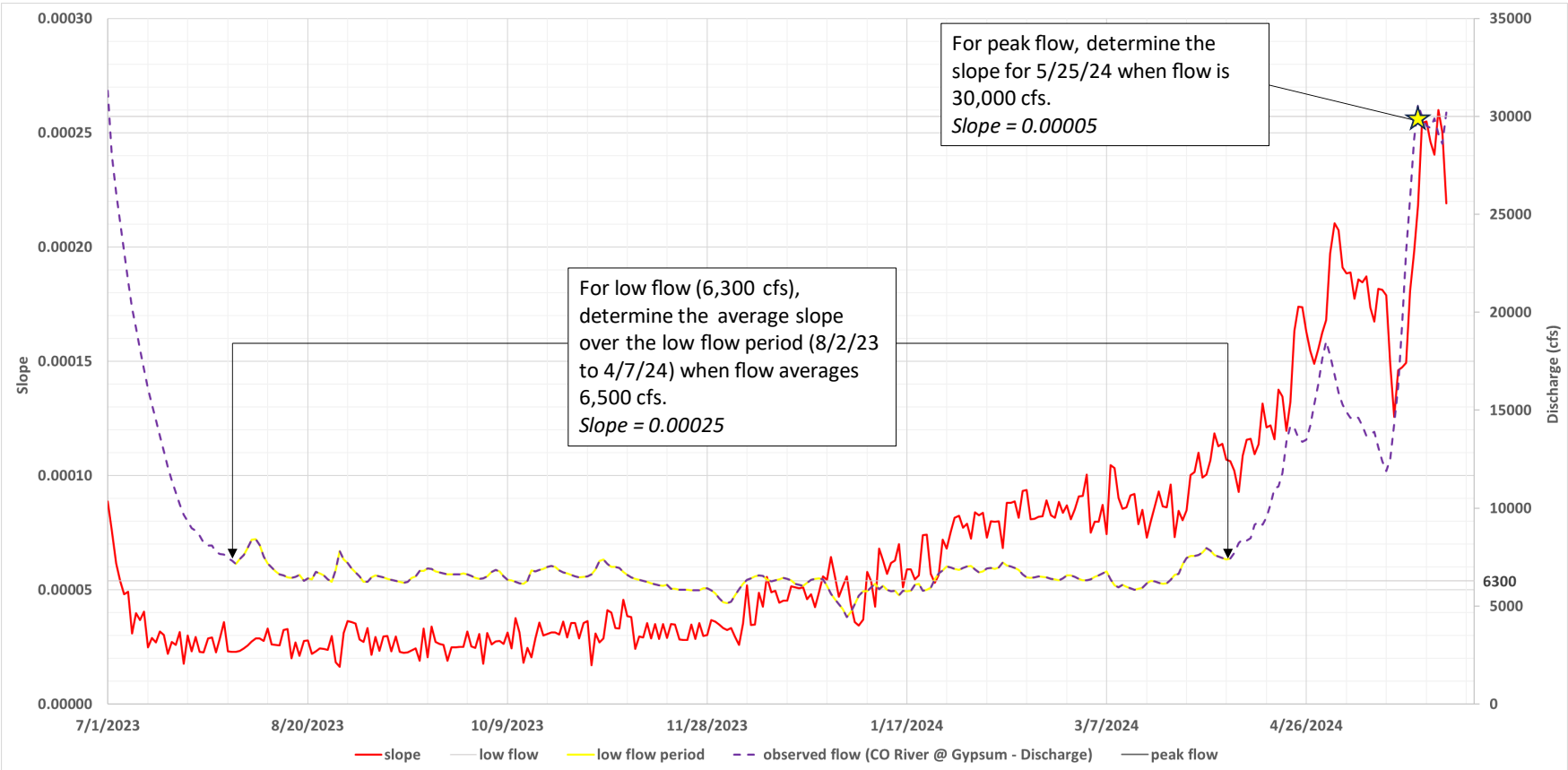


Figure 17. Calibrated Water Surface Slope over the Project Reach



Chapter 5 – Probable Future Conditions Model Results

Multiple uncertainties related to future geomorphic, hydrologic, and hydraulic conditions underlie the probable future conditions model results presented in this report. Working with the assumptions and modeling approach described in previous sections, results for water surface elevation, depth, and velocity data are presented in the following subsections for the two flow scenarios described in Section 3.4, high flow (30,000 cfs) and low flow (6,300 cfs).

5.01 Water Surface Elevation

The probable future conditions model results suggest the low flow (6,300 cfs) water surface elevation would be approximately 3,557 feet, and the high flow (30,000 cfs) elevation would be 3,569 feet (Figure 18). For these two flows, the design boat ramp elevation (3,529 feet) would be inundated 28 feet and 40 feet deep, respectively, and the water's edge would intercept the 16 percent ramp approximately 400 feet and 485 feet upslope of the bottom of the ramp (STA 79+66 in the computer-aided design [CAD] design file [not shown] and Station (STA) 1125 on Figure 18), respectively.

5.01 Depth

The probable future conditions model results suggest the low flow (6,300 cfs) depth across the channel would range from 28 feet to 35 feet (Figure 19), and the high flow (30,000 cfs) depth would range from 40 feet to 47 feet (Figure 20). Depth conditions at the ramp would be the same as those described above for water surface elevation. These results meet the minimum depth criteria of 3.5 feet (Section 4.1) for both low and high flow conditions.

Figure 18. Comparison of Existing and Probable Future Conditions Modeled Water Surface Elevations at 6,300 cfs and 30,000 cfs

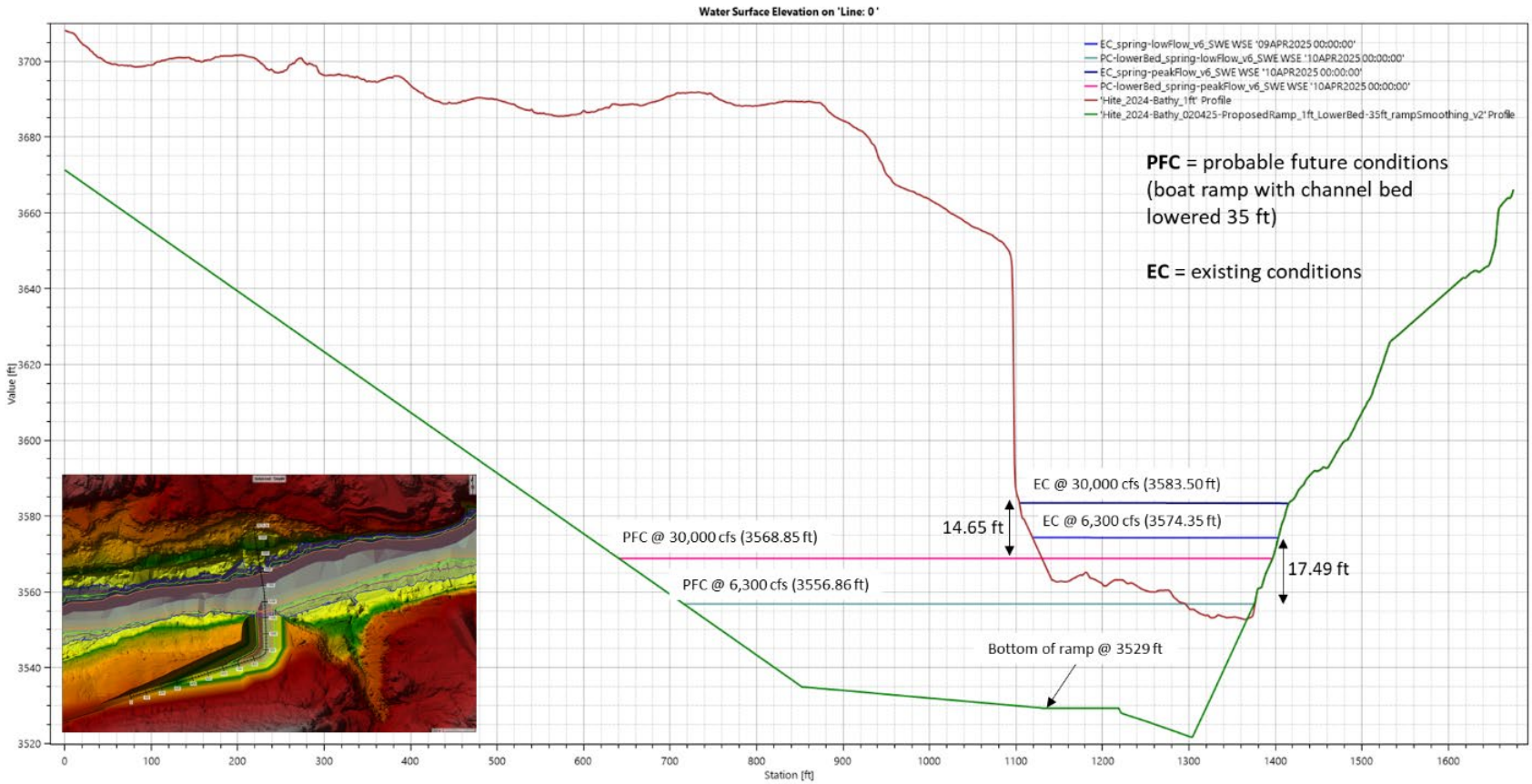


Figure 19. Plan View of Probable Future Conditions Depth Contours at 6,300 cfs

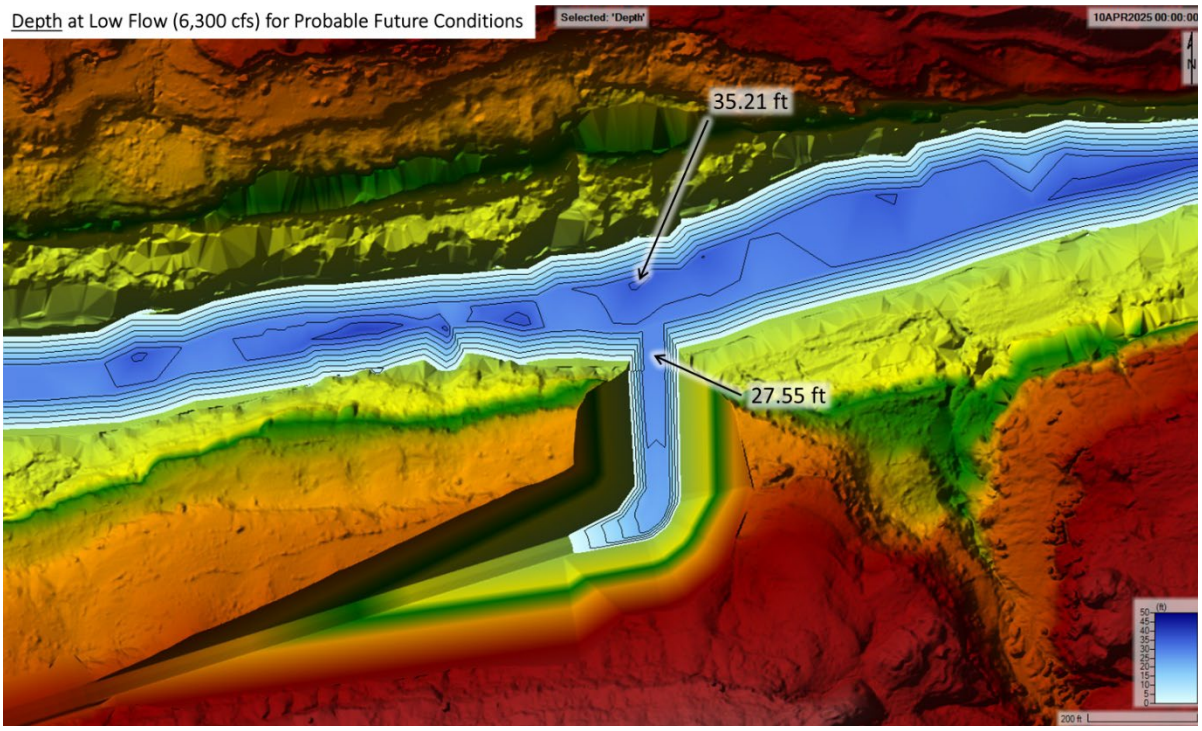
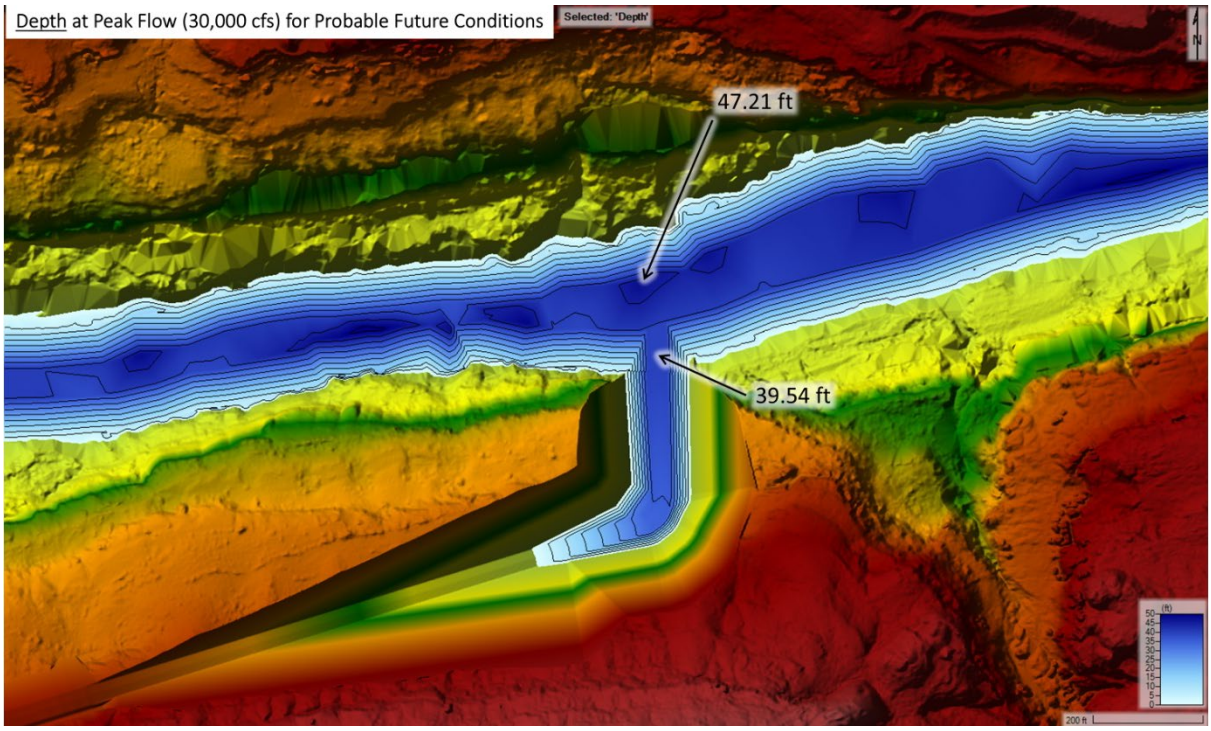


Figure 20. Plan View of Probable Future Conditions Depth Contours at 30,000 cfs



5.02 Velocity

The probable future conditions model results suggest the low flow (6,300 cfs) velocity across the channel width would approach approximately 2 fps (Figures 21 and 22), and the high flow (30,000 cfs) velocity across the channel width would approach approximately 5 fps. For these two flows, within the ramp area itself, the velocity would be less than 1 fps. Near the bottom of the ramp (STA 79+66), the velocity would be approximately 1 fps and 2 fps at the low and high flows, respectively. The velocities upstream of the ramp are also manageable for boat approaching the ramp. Figures 20 and 21 show the results in plan view and in section for low flow, and Figures 23 and 24 show the results for high flow.

Figure 21. Plan View of Probable Future Conditions Velocity at 6,300 cfs

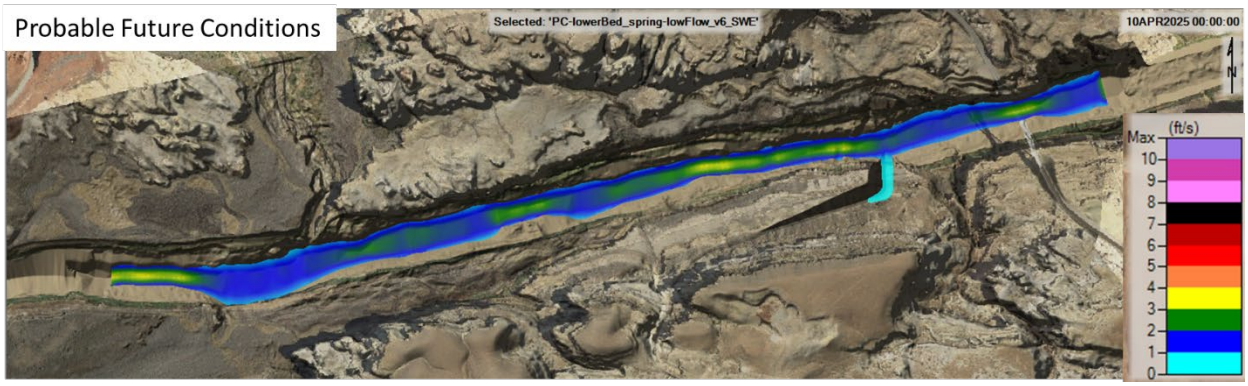


Figure 22. Section View at Boat Ramp of Probable Future Conditions Velocity at 6,300 cfs

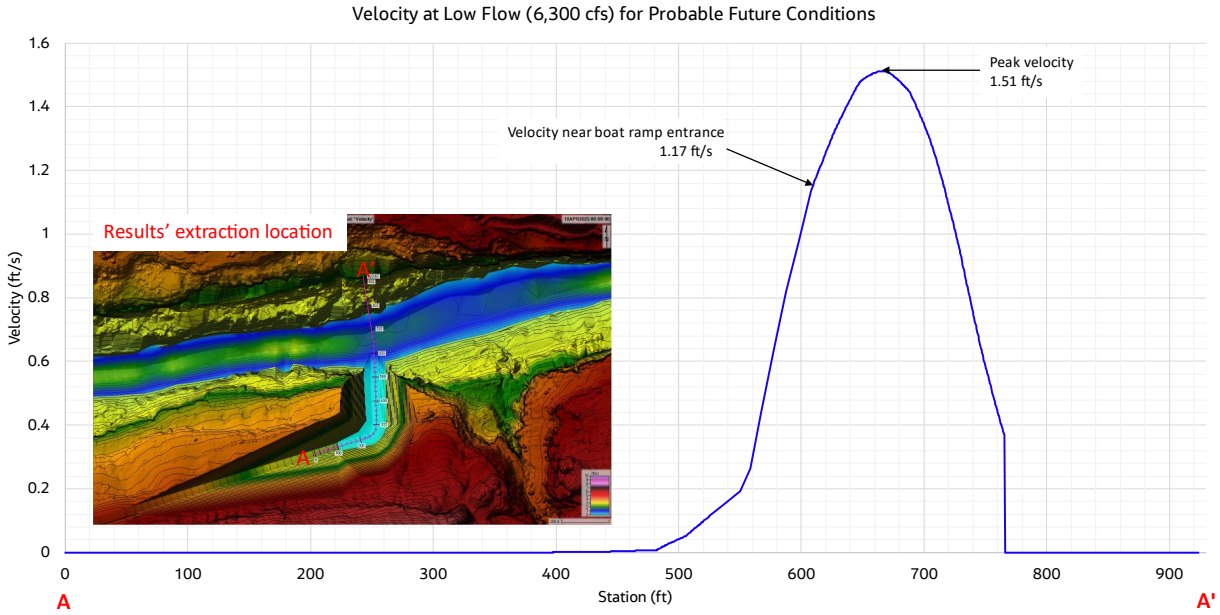


Figure 23. Plan View of Probable Future Conditions Velocity at 30,000 cfs

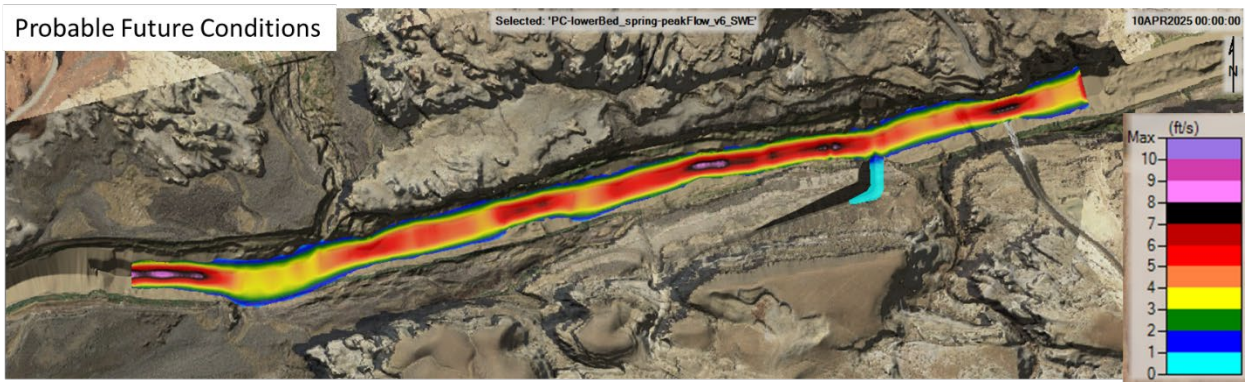
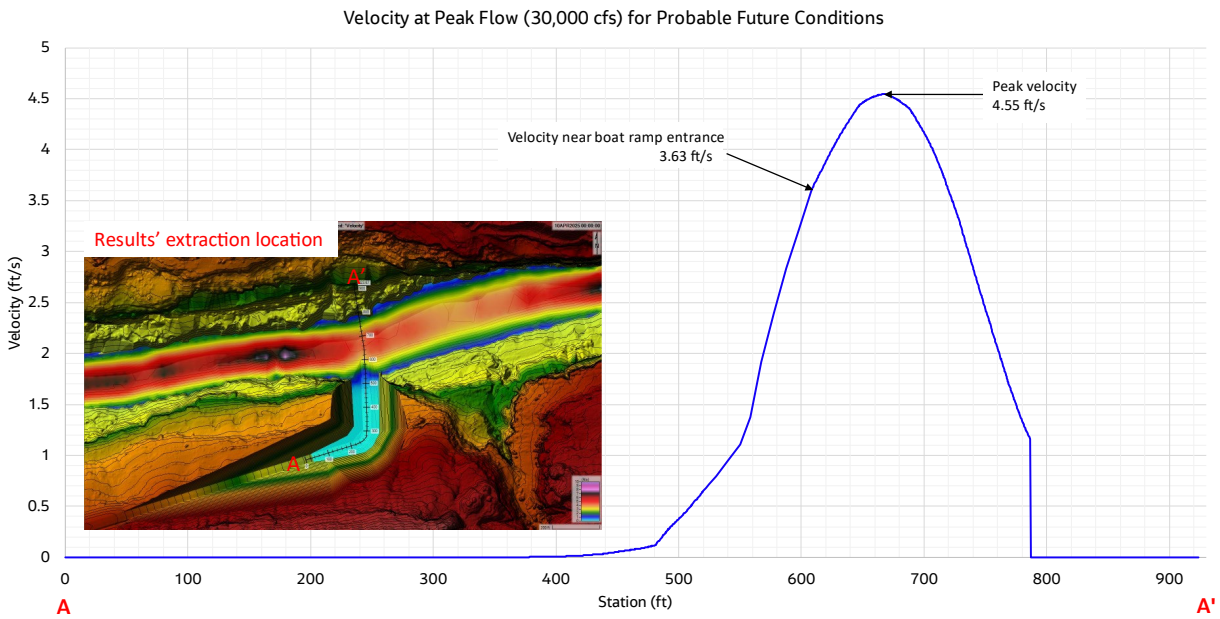
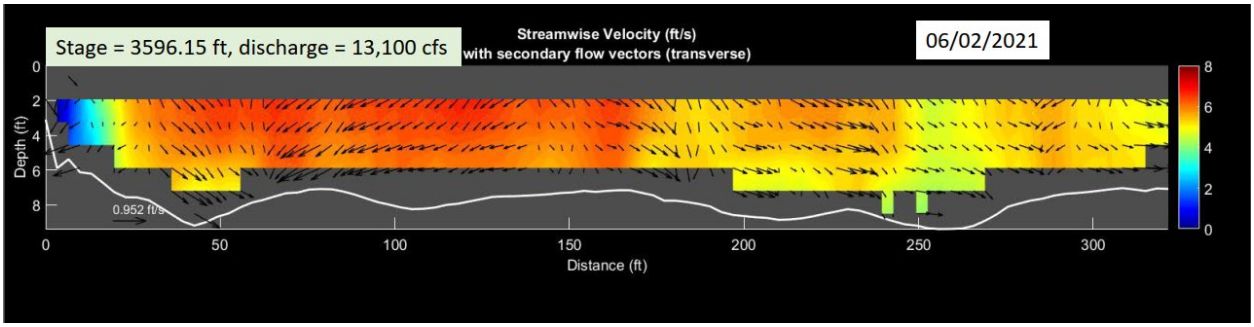


Figure 24. Section View at Boat Ramp of Probable Future Conditions Velocity at 30,000 cfs



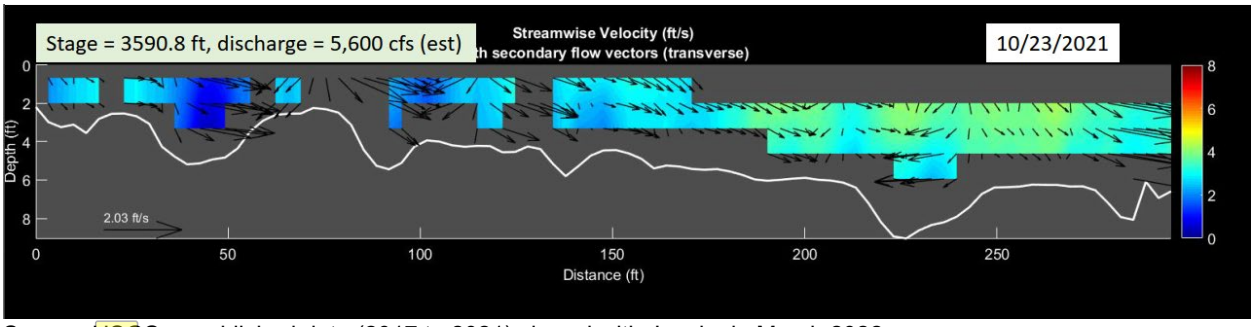
Although these model results meet the maximum velocity criteria of 7 fps (Section 4.1) for both low and high flow conditions, these results are unexpected; higher velocities would be expected. For a given flow (discharge), a reduction in channel width and associated cross section area is expected to increase velocity. However, as noted in the model calibration discussion, the model is sensitive to the prescribed downstream normal depth slope which is variable, and the future condition is uncertain. The probable future conditions could be more similar to the existing conditions which suggest the low flow (6,300 cfs) velocity along the riverbank would be approximately 3 fps and the high flow (30,000 cfs) velocity would be approximately 5 fps. Notably, field measurements of velocity collected by the USGS at two different discharges during free-flowing river conditions in 2023 show mid-channel velocities approaching 5 fps at 5,600 cfs (Figure 25) and 8 fps at 13,100 cfs (Figure 26). Together, the modeling results and field measurements suggest velocities at the ramp should be less than the 7 fps criteria for boat retrieval.

Figure 25. Field-Measured Velocity during Free-flowing River Conditions (June 2, 2021) near Hite Bridge Showing Mid-channel Velocities Approaching 8 fps at a Discharge of 13,100 cfs



Source: USGS unpublished data (2017 to 2021) shared with Jacobs in March 2022

Figure 26. Field-measured Velocity During Free-flowing River Conditions (October 23, 2021) near Hite Bridge Showing Mid-channel Velocities Approaching 5 fps at an Estimated Discharge of 5,600 cfs



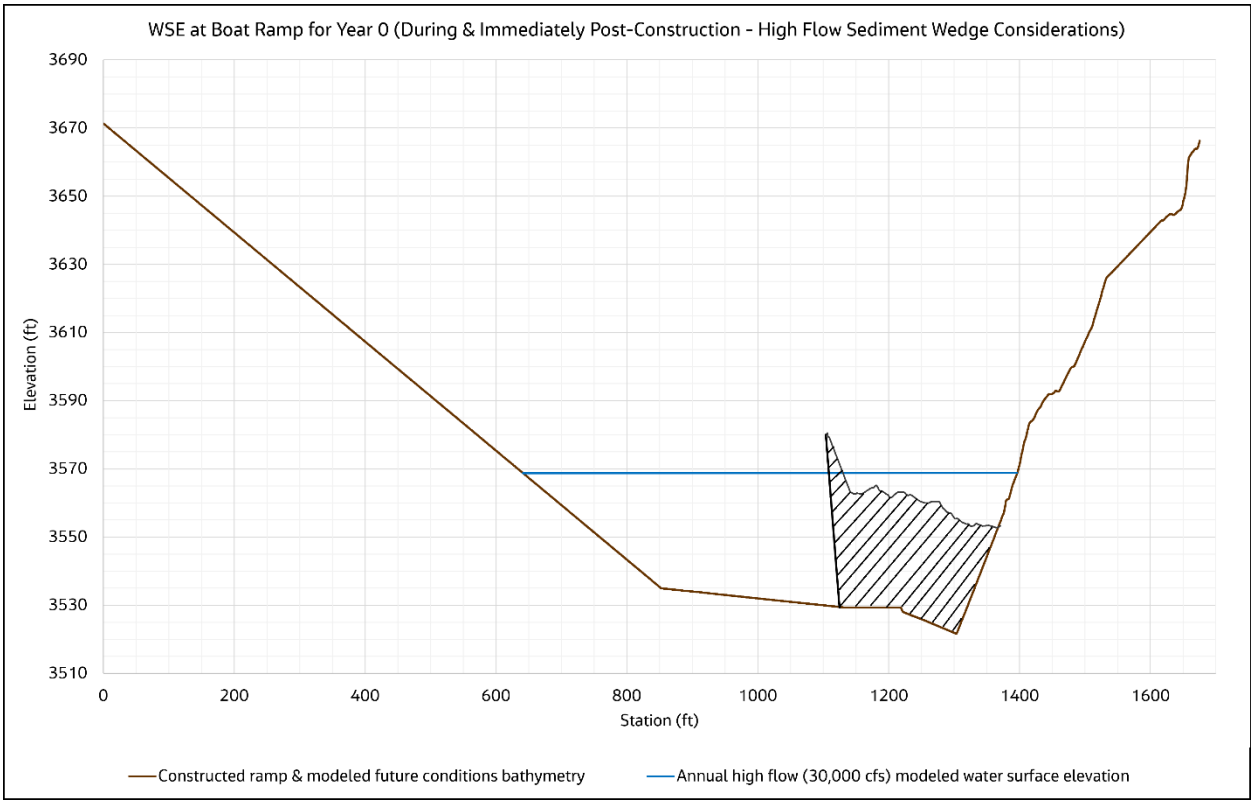
Source: USGS unpublished data (2017 to 2021) shared with Jacobs in March 2022

Chapter 6 – Construction, Operations, and Maintenance Considerations

Findings from the probable future conditions hydraulic modeling provide context to inform construction and future maintenance. Due to the depths of excavation (both the water depth and sediment depth), extensive efforts will be required to isolate the work area. Short-duration high flows may occur as a result of fall thunderstorms or winter rain-on-snow events, but low-water levels will typically start in September, with lowest levels from December to March. Lowest water surface elevations measured in 2024 at the Hite Bridge gage (USGS gage 09328990) were approximately 3,572 feet. This is more than 40 feet above the bottom of the proposed ramp elevation (3,529 feet) at a location currently (May 2024) occupied by more than 50 feet of sediment. As bedrock is blasted to create the new ramp, water and sediment will need to be managed to isolate the work area.

During and immediately following construction and for an unknown future duration, the new ramp will create a “hole,” with sediment perched above it, as the bedrock is blasted away (Figure 27). The model surface does not account for this interim condition when much of the river bed (remaining outside the construction work area) would be higher than the ramp. The construction approach will require managing sediment to prevent it from entering the work area.

Figure 27. Schematic Cross Section of Boat Ramp Facing Downstream Showing Annotated Modeled High Flow (30,000 cfs) Water Surface Elevation Inundation on 16 Percent Ramp and Remaining Sediment Wedge (Black Hatched Area) in River Channel, during and Following Blasting of the Ramp



As water levels decline through the summer and fall, sediment (a slippery silty sand) would need to be removed from the above water portion of the ramp surface to avoid creating a slippery condition for boat retrieval on the steep ramp. The extent and depth of this sediment removal maintenance would be expected to decline through time, as the river continues to erode and water levels move down the ramp. However, until then, maintenance may be required multiple times each year (after high flows), presumably requiring heavy equipment and potentially pumping of water from the river.

Eventually, as the river recedes, the boat ramp will create an alcove with a recirculating eddy, and suspended sand and coarse silt are expected to deposit on the ramp. The Colorado River transports a high volume of sediment, and any depositional zone, like the ramp, could accumulate significant amounts of sediment, especially during high flows. Figures 28 and 29 show the model-predicted eddy and low velocity zone at the ramp.

Figure 28. Velocity Flow Lines and Magnitudes at 6,300 cfs

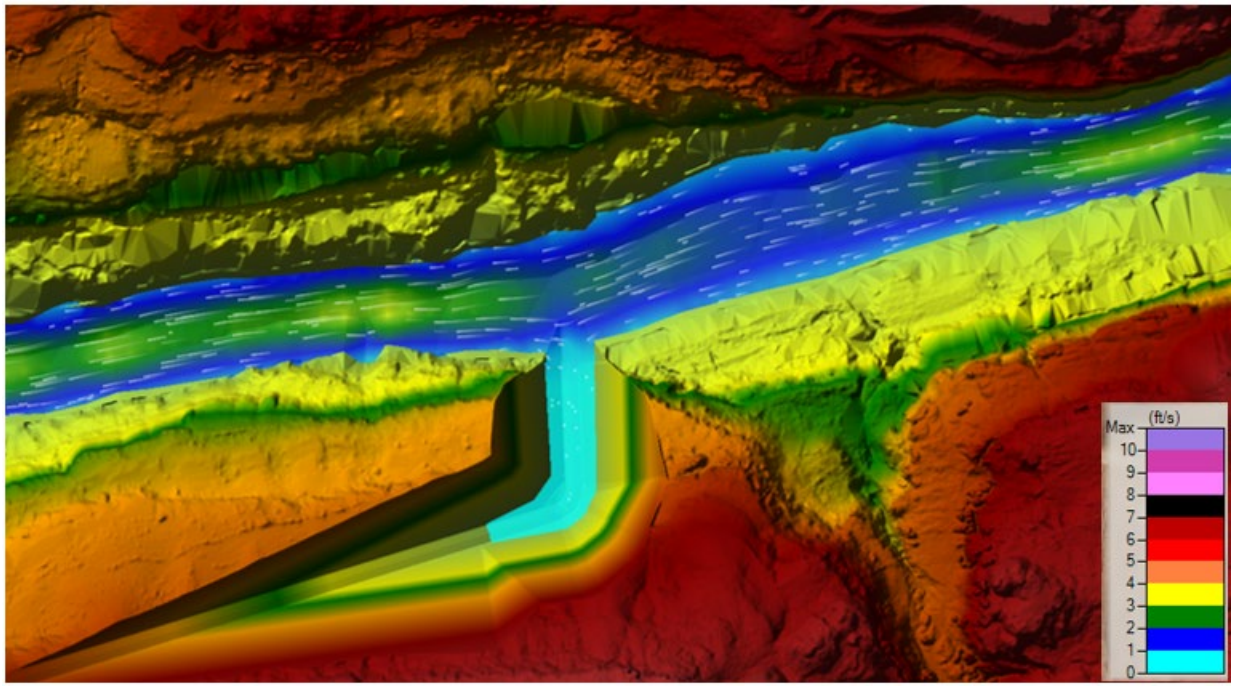
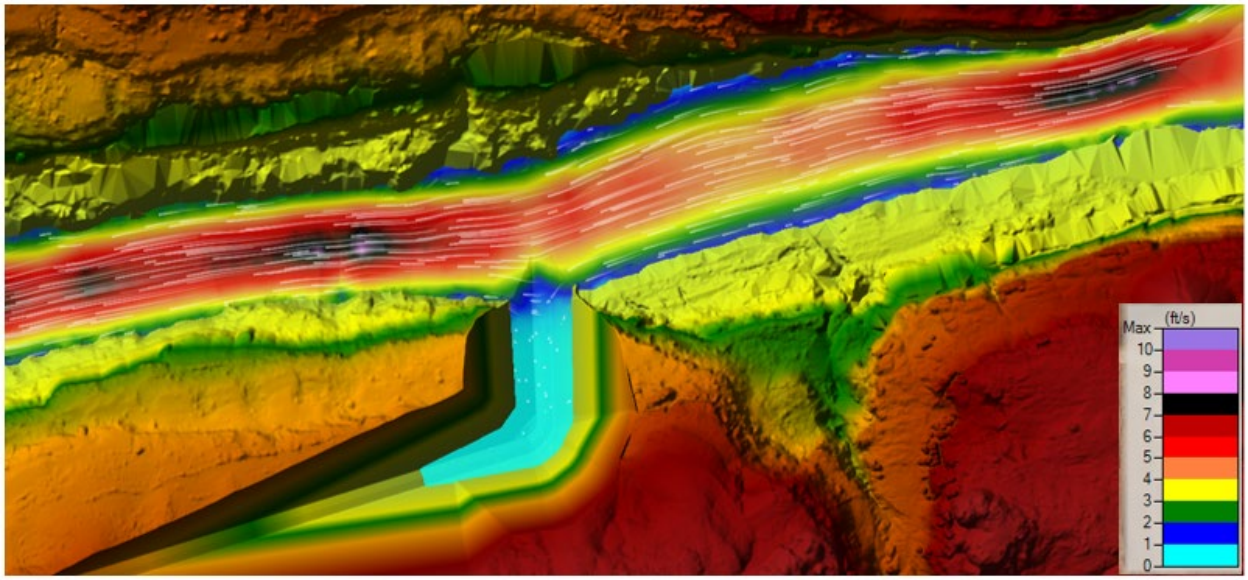


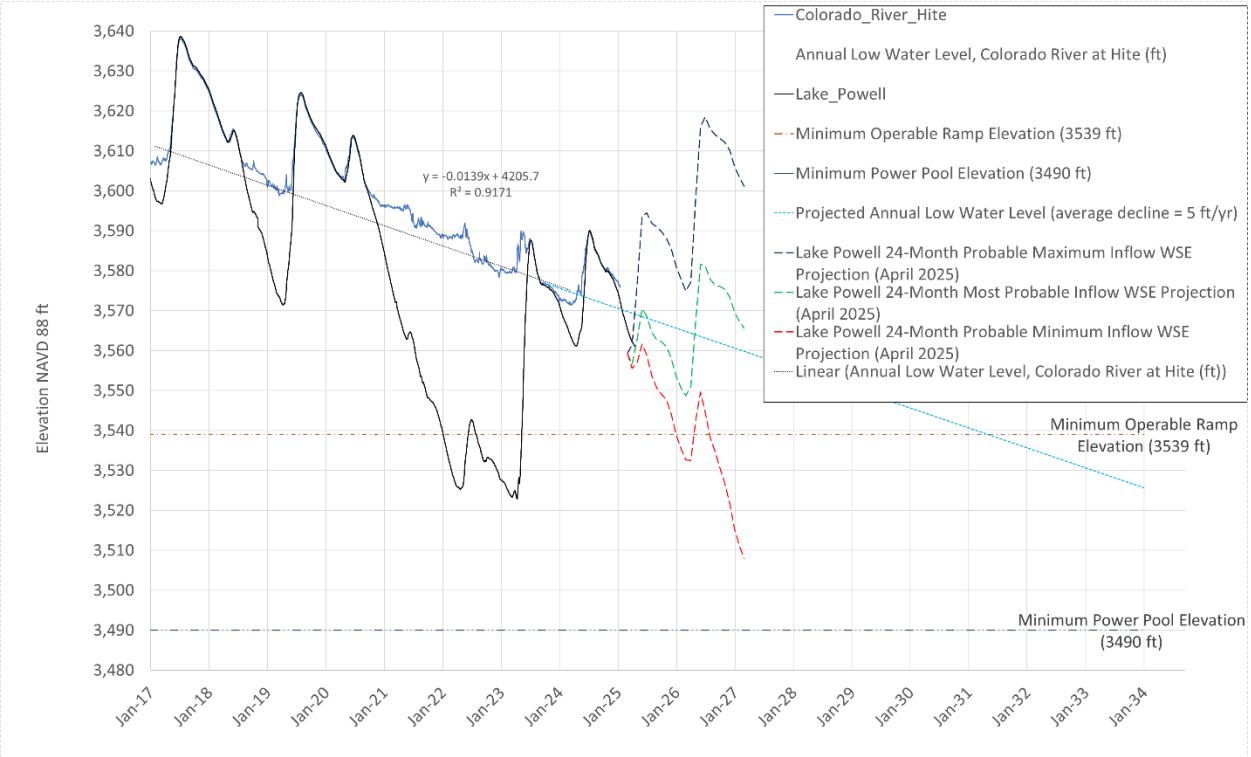
Figure 29. Velocity Flow Lines and Magnitudes at 30,000 cfs



Also, the ramp would likely become inoperable when water levels drop below 3,539 feet, 4 feet above the point of transition from 16 percent slope to 2 percent slope because boats are unretrievable on a 2 percent slope without submerging the towing vehicle to dangerous levels (Figure 30). When the water surface intercepts the 16 percent ramp, some 2-wheel drive vehicles will be precluded from retrieving boats

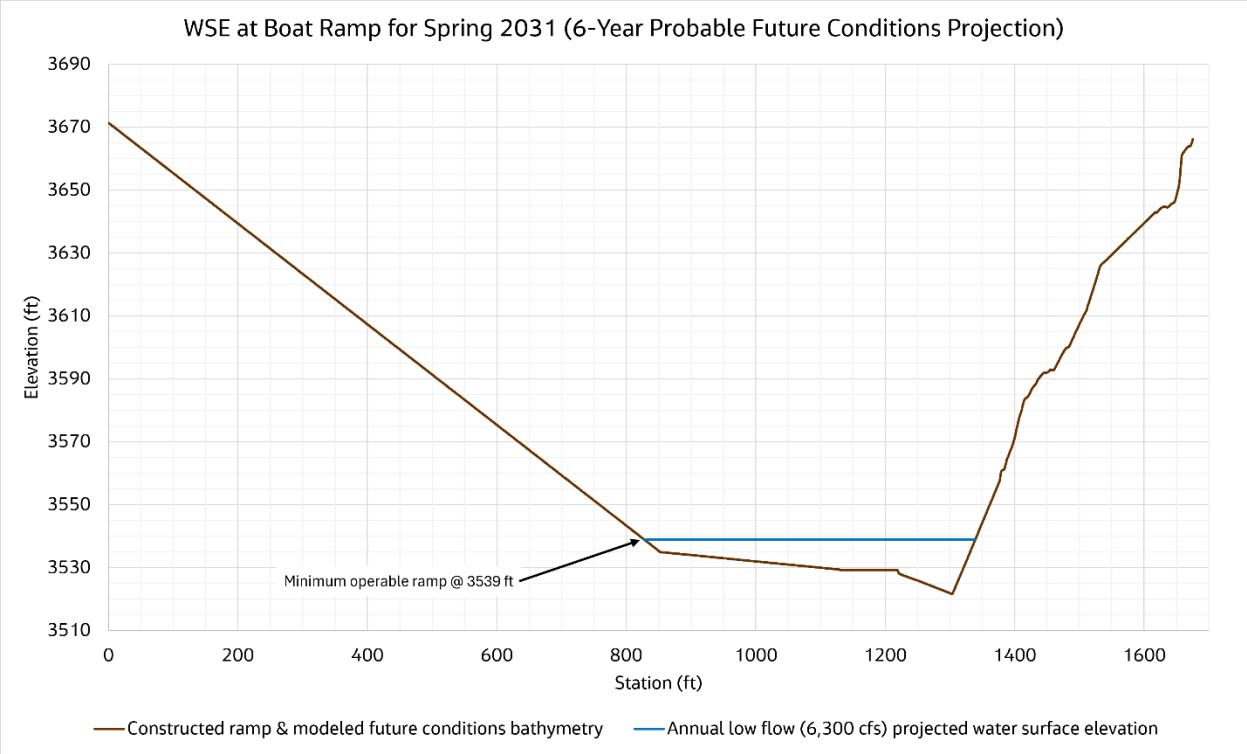
(Warning signs should be posted.) From an access perspective, without a turn-around loop near the bottom of the ramp, vehicles hauling trailers will have to back down the long steep grade with a short trailer which will create challenges for some users and pose a safety risk for pedestrians walking up the ramp to the parking area and restrooms and to oncoming traffic.

Figure 30. Historical and Projected Water Surface Elevations Relative to Minimum Operable Ramp Elevation



Based on the water surface elevation projections and ramp design and use considerations described previously, the ramp could become inoperable by spring 2031 (Figures 30 and 31). This projection is independent of the timing of construction, but it does assume the annual low flow water level will continue to decline at an average rate of 5 feet per year.

Figure 31. Projected Low Flow Water Surface in spring 2031 (6-year Projection from 2025 Data) Relative to Minimum Operable Ramp Elevation



Chapter 7 – Key Assumptions and Findings

Describing future conditions along this dynamic reach of the Colorado River requires making assumptions about many unknown factors. These assumptions and the findings of the hydraulic modeling provide context to characterize potential future conditions and how they may affect the construction, operations, and maintenance of the new boat ramp, as summarized below.

7.01 Key Assumptions

- River flows in the vicinity of the project area will remain like those over the past 5+ years.
- Water surface elevations in the vicinity of the project area will remain above the minimum power pool elevation of 3,490 feet.
- If Lake Powell is operated below the minimum power pool elevation, water surface elevations in the vicinity of the project may return to the pre-dam river elevation of 3,475 feet (1959 survey).
- Changes to the river channel in the vicinity of the project area over the past 5+ years will continue at a relatively constant rate, specifically the riverbanks and bed will continue to erode, and with a cross section shape that narrows through time.

7.02 Key Findings

This section provides findings from the study.

7.02.1 Conditions and Trends

- Lacustrine sediment deposits in the project area are likely greater than 100 feet thick.
- Initially, for a given water surface elevation, the lower the channel scours, the narrower the channel shape, and the higher the relative water surface elevation. However, as the riverbank deposits continue to slump (as has been documented upstream and downstream of the proposed ramp location), the water surface elevation will decline at a faster rate due to the relatively faster rate of channel widening (width returning to the pre-dam canyon walls). This uncertainty underscores how relatively small and gradual or episodic changes in cross section shape and bed elevation create large changes in water surface elevation in this dynamic river canyon.
- Based on USGS and Reclamation gage measurements, the annual low-water elevation in the project area has been dropping approximately 4 feet per year, the same rate of decline in water surface observed for Lake Powell.

- Based on USGS and Jacobs bathymetric surveys, the bed elevation in the project area has incised 4 feet per year between February 2017 and October 2021, and it incised 14 feet per year from October 2021 to May 2024 (35 feet total).
- During the immediate post-construction period (first several years), the proposed ramp design appears to meet the depth and velocity criteria at both low flow (6,300 cfs in summer, fall, and winter) and high flow (30,000 cfs in spring).
- Starting in 6 years (2031), when projected low flow water levels drop below 3,539 feet, the ramp would not be operational at low flows.
- As the riverbank deposits continue to slump (as has been documented upstream and downstream of the proposed ramp location), the water surface elevation will decline at a faster rate due to the relatively faster rate of channel widening (width returning to the pre-dam canyon walls).

7.02.2 Construction, Operations, and Maintenance

- Low-water conditions would be expected to last approximately 4 months each year, and, for existing conditions, water depths during low flows adjacent to the construction work area would likely exceed 10 feet.
- During and immediately following construction and for an unknown future duration, the new ramp would be in a “hole.” As water levels decline through the summer and fall, sediment (a slippery silty sand) would need to be removed from the ramp surface to prevent vehicles from losing traction and being stranded on the ramp. The extent of this annual maintenance would be expected to decline through time, as the river bed continues to erode and water levels move down the ramp.
- Immediately following construction and for an unknown future duration, when the water surface intercepts the 16 percent ramp, most two-wheel drive vehicles will be precluded from retrieving boats. Warning signs should be posted.
- In the future, the ramp would likely become inoperable when water levels drop below 3,539 feet, 4 feet above the inflection from 16 percent slope to 2 percent slope because small boats are unretrievable on a 2 percent slope. (The towing vehicle would be too submerged before the trailer has 4 feet of depth for boat retrieval, risking flooding the engine and potentially floating the vehicle – a significant risk to the public.) Closure notices should be provided online, at the new ramp, and at upstream (launch) boat ramps to give users advance notice of the ramp closure.
- Without a turn-around loop near the bottom of the ramp, vehicles hauling trailers will have to back down the steep grade, on a curve, with a short trailer. This could create driving challenges for some users and pose a safety risk for pedestrians walking up the ramp to the parking area and restrooms.

Chapter 8 – References

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