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JORDAN RIVER HYDRAULIC STUDY

SALT LAKE COUNTY

July 2019

BOWEN COLLINS & ASSOCIATES

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CHAPTER 1
INTRODUCTION

INTRODUCTION

The Jordan River is about 50 miles long and flows from Utah Lake in Utah County, to the Great Salt Lake in Salt Lake County. Discharges in the Jordan River are highly regulated by reservoirs on streams upstream of Utah Lake, by pumps and a regulating structure at its headwaters at the Utah Lake outlet, and by multiple diversions and pump stations between Turner Dam on the Utah/Salt Lake County line and the Great Salt Lake. The Jordan River has 16 major tributaries, 11 drain areas east of the river (one of which is in Utah County), and 5 drain areas west of the river. The river receives most of the urban storm water runoff generated in the Salt Lake Valley.

Rivers are one of the most dynamic landforms on earth. Erosion and sedimentation often results in changes in river profiles as well as lateral channel migration. Before being influenced by the activities of man (i.e., farming, development, flood control, channel relocation, dredging, flow regulation, etc.), the Jordan River used to be a natural river whose releases were naturally regulated by the stage of Utah Lake. The river channel was very sinuous and had a fairly wide floodplain. Then a regulating structure, in the form of a pumping station, was constructed at the Utah Lake outlet that would generally control releases into the river to match the needs of downstream irrigators. In addition, the Surplus Canal was also constructed to reduce flooding potential in Salt Lake City, north of 2100 South Street, by diverting most of the water contained in the Joran River upstream of 2100 South into the Surplus Canal. This allows the Lower Jordan River the ability to accommodate inflows from Parley’s Creek, Emigration Creek, Red Butte Creek, and City Creek, as well as urban runoff.

Between 1952 and 1958, some time after the 1952 flood on the Jordan River, a project was completed in the south end of the Salt Lake Valley that widened and straightened the channel. Removing most of the meanders in the natural stream resulted in an increase of slopes and velocities. Although that action may have reduced the floodplain associated with the river, it also caused some lateral stability issues and the river channel is still experiencing some lateral migration, in an effort to regain some of its original sinuosity.

In addition to the man-made impacts to the river mentioned above, development pressure has increased significantly in or near the floodplain in the last 40 years. Flood Insurance Rate Maps (FIRMs) developed by FEMA have been published and are used by communities in Salt Lake County to help regulate and protect development from flood hazards. In addition, Salt Lake County has established a “meander corridor” based on the results of “The Jordan River Stability Study,” prepared by CH2M Hill to help protect development near the river from lateral migration hazards.

The current effective FIRMs for the Jordan River in Salt Lake County were developed using hydraulic computer models from two studies. The FIRMs for the Lower Jordan River (downstream of the Surplus Canal Diversion) were developed using a hydraulic model that used channel geometry data that was collected in the early 1980s. Between 2100 South and Turner Dam at the Salt Lake / Utah County line, the FIRMs are based on a hydraulic model that used cross section data collected in that late 1980s, supplemented with between 65 and 70 cross sections that were surveyed in the early 1990s.

PURPOSE OF STUDY

Since most of the Flood Insurance Study work was completed for the reach of the Jordan River that is located in Salt Lake County more than 30 years ago, a lot of development has occurred near the river. FEMA has approved a hydrology-based Conditional Letters of Map Revision (CLOMR) to revise the magnitude of the one-percent-chance annual flood (100-year flood) between the river's confluence with Little Cottonwood Creek and the Great Salt Lake. A number of natural and man-made changes have occurred along the Jordan River in Salt Lake County. In an effort to define how these changes have impacted the Jordan River floodplain, Salt Lake County (the County) retained Bowen, Collins and Associates (BC&A) to complete a new hydraulic analysis of the 40-mile reach of the Jordan River between Burnham Dam and Turner Dam. This study area is illustrated on Figure 1, included in Volume II. All figures referenced in this report are in Volume II. The major objectives of this study are to:

1. Develop a GIS inventory of all bridges, diversions, and other hydraulic structures on or along this reach of the Jordan River.
2. Develop an updated, calibrated hydraulic model of this reach of the Jordan River in accordance with FEMA standards and guidelines.
3. Utilize the new hydraulic model and information obtained through field observations to identify areas that may need maintenance or improvements to protect property and existing infrastructure.
4. Utilize the hydraulic model to develop an updated map that accurately defines the boundaries of the 100-year floodplain for planning and management purposes.

This report summarizes the work performed to accomplish these objectives.

BACKGROUND

River Alignment Movement

The Jordan River is a dynamic land feature that is constantly changing. The Jordan River Stability Study completed in the early 1980's showed previous alignments of the Jordan River. Some of those alignments are shown in Figure 1. The Jordan River Stability Study demonstrated that the Jordan River channel has experienced significant lateral migration. That study also identified a meander corridor (also identified on Figure 1) that should be used to limit development along the Jordan River.

RELATED STUDIES

The following related studies and information were reviewed to obtain relevant information to help accomplish the study objectives:

- 1987 Jordan River Survey Monuments 2100 South to 14600 South prepared by CH2M Hill
- Jordan River Stability Study by CH2M Hill
- Floodplain work maps prepared as part of the 1994 FEMA Flood Insurance Study (FIS) for the Jordan River
- 2009 FEMA Flood Insurance Study Report
- GIS data from the FEMA National Flood Hazard Layer
- Jordan River/Surplus Canal CLOMR
- Lower Jordan River Hydrology Study / CLOMR
- Hydraulics Study Figure for the Surplus Canal and the Lower Jordan River prepared by Michael Baker International, Inc.
- Lower Jordan River Levee Evaluation by CH2M
- U.S. Army Corps of Engineers National Levee Database (https://levees.sec.usace.army.mil/)

The results of the work associated with completing these tasks are presented in this report. Questions associated with this report may be addressed Craig Bagley P.E., CFM, who served as project manager, Kameron Ballentine, P.E./project engineer, or Ben Kirk/staff engineer.

CHAPTER 2
REVIEW OF EXISTING CONDITIONS

GENERAL ASSESSMENT OF JORDAN RIVER

A general assessment of the 40-mile reach of the Jordan River between Turner Dam and Burnham Dam in Salt Lake County was performed as part of this study. This assessment included collecting and reviewing existing data, performing field survey work and reconnaissance, and comparing information from the current effective FIS to current conditions. The primary purpose of this work was to compile a detailed inventory of bridges and hydraulic structures on the Jordan River, collect information needed to develop a hydraulic model of the study reach of the river, perform an general visual assessment of the river channel condition, and identify relevant changes that have occurred in the study area over the last 35 years that could potentially impact the floodplain an associated base flood elevations published by FEMA.

Topography and Aerial Photography

Topographic and aerial photographic mapping along the Jordan River were obtained from the Utah Automated Geographic Reference Center (AGRC). The aerial photography used for this study is 2018 High Resolution Imagery. Topographic data was obtained from the bare earth LiDAR 2013-14 data with 0.5-foot contours. The 2018 aerial photography from AGRC were used for the backgrounds on most of the Figures in this report.

Field Survey

A considerable amount of field survey work was performed to collect geometric data on the river channel and hydraulic structures for use in developing a new hydraulic model of the study reach of the Jordan River. Approximately 746 channel cross sections were manually surveyed, including the channel areas inundated by flowing water. The field survey generally collected topographic and bathymetric data that extended from the top of left bank to the top of right.

Digital topographic mapping data was used in conjunction with GIS technology to extend the surveyed channel cross sections across the historical floodplain. New cross sections were generally surveyed at 500-foot intervals. Locations of the new surveyed channel cross sections are shown in Figure 2-1.

Survey data was also collected at each of the 93 structures that cross the Jordan River in the study area. Structures that were surveyed included:

- Bridges
- Check structures
- Irrigation diversion structures

The following pertinent data were collected at each structure: high cord elevation, low chord elevation, channel invert, deck elevation, and structure width.

VISUAL ASSESSMENT

A visual assessment of the Jordan River was performed for the river reach located between I-215 in North Salt Lake and 14600 South. The purpose of the visual assessment was to observe general conditions, identify potential problems and maintenance issues, take photographs, and document the visual condition of existing embankments that could impound water during a large flood event. General observations noted during the visual assessment are summarized below.

General Observations

The visual assessment / field reconnaissance work was performed in August 2018. Discharge in the river during that time was relatively low. Major observations are listed below.

- **Earthen Embankments and Levees**. The current effective FEMA Flood Insurance Rate Maps (FIRMs) have some areas designated as "Shaded Zone X Behind a Levee." However, since that study was published, the requirements for FEMA levee accreditation have changed, making it more difficult to certify that levees meet minimum FEMA levee design criteria. It is believed that the levees in the river reach between 2100 South and 3000 South can be accredited by FEMA. However, other earthen embankments along the Lower Jordan River (below the Surplus Canal Diversion) do not meet minimum FEMA levee standards due to vegetation on the embankments, pipe penetrations (unless a flex/tide valve is installed), and having less than the minimum required freeboard.
- **Bank Erosion**. River banks in some areas have experienced erosion and the bank slope is nearly vertical. In some areas, the vertical banks range from 5-10 feet in height. However, these vertical banks and the associated bank instability are not currently near development. The biggest current concerns associated with erosion are a power pole on the inside of the bank near 1300 South, as shown below in Photo 1, and the tall vertical bank where the river is cutting into a hill on the west bank just upstream of the 12600 South Bridge over the river (see Photo 2).

Photo 1: Erosion near a power pole on inside of bank at approximately 1300 South

Photo 2: Tall vertical bank just upstream of the bridge at 12600 South

- **Vegetation on River Banks**. Vegetation on the channel banks of the river throughout the study area contain dense vegetation that is well established. Much of the vegetation on the banks are invasive species (Russian Olive and Tamarisk) and there are more established trees on the banks of the Lower Jordan River than there are upstream of 2100 South. There are also intermittent trees, including some with exposed roots, or dead branches that are in or near the water (see Photo 3 below). It is believed that the bank vegetation upstream of 2100 south is generally denser than it was when the current effective model and floodplain were developed in the 1990s.

Photo 3: Thick vegetation, fallen trees, and sediment bar at approximately 3900 South.

- **Potential for Debris Plugging.** Although most of the bridges and hydraulic structures in the study reach are wide and designed to provide freeboard during a 100-year flood, some structures have piers that could potentially collect debris and restrict flow in the river. This is especially true on the Lower Jordan River where there are several railroad crossings and other structures with multiple piers, as shown below in Photos 4 and 5. There is also an abandoned bridge structure with multiple piers at about 2700 North that should be removed to reduce the potential for flooding associated with debris plugging. (See Photo 6).

Photo 4: Piers on railroad bridge at approximately 100 South could collect debris

Photo 5: A diversion structure with a canoe passage feature near South Temple has piers that could potentially capture debris

Photo 6: Abandoned bridge structure at about 2700 North should be removed

- **Sedimentation.** Another potential problem that was a focus of the field reconnaissance was to identify areas where sediment deposition could increase flood or erosion potential. Sedimentation problems are common near tributary confluences and near irrigation diversions. The only location where significant sediment deposition has occurred is in the tailwater area immediately upstream of the Joint Diversion Structure (see Photo 7 below). Since there is not development near this area, this problem is not a major concern. It is also recommended that the County continue to monitor and remove sediment deposits between 3700 South and 4200 South (see Photo 3 above).

Photo 7: Sediment deposition upstream of the Joint Diversion

COMPARING HISTORICAL DATA TO CURRENT CONDITIONS

In addition to identifying potential problems identified in the field, some 1987 channel survey data and some information from the current effective FIS were compared to current conditions to identify potential problems with lateral channel migration, erosion, and deposition. This evaluation is summarized below.

- **Resurvey of Monumented Channel Cross Sections.** In 1987 Salt Lake County sponsored a project where 39 survey monuments were established along the Jordan River between 2100 South and 14700 South. Those survey monuments were to be used to help document changes in profile and location of the Jordan River. As part of this study, 9 of those 39 cross sections were resurveyed between 2100 South and 14700 South. The results of the 2018 survey were compared to the 1987 survey data. The cross section comparisons are included in Appendix A. As the cross-section comparison figures indicate, there has been very little change on cross sections on the river between 2100 South and 4800 South. However, south of 4800 South, there are signs of some head cutting, bank improvements, sediment deposition, and lateral bank migration. It should be noted that the 9 cross sections that were resurveyed, were selected primarily for ease of access. The locations of those cross sections are shown in Figure 2-1.
- **Lateral Channel Migration**. The Jordan River Stability Report prepared by CH2M Hill performed an analysis using historical aerial photographs between 1937 and 1990 that showed how the approximate centerline of the Jordan River had changed. A figure from that report is included in Appendix B to generally summarize that analysis. As part of this study, the approximate centerline of the river from the current effective FIS was obtained

from the National Flood Hazard Layer database on FEMA's website and compared to the centerline of the river from a 2018 aerial photographs. The results of that analysis are presented in Figure 2-1. The information in Figure 2-1 shows two important things. First, the reach of the Jordan River in the portion of the study area north of about 10400 South has been quite stable over the last 30 to 35 years, with only minor changes. South of 10400 South, the river channel has experienced some significant lateral migration as it continues to regain some of the sinuosity that was lost when the river was straightened in the 1950s. The increased sinuosity has likely resulted in a lower slope gradient and could have an impact on the hydraulic and floodplain analyses. That issue will be addressed in Chapter 3.

- **Development Encroachment.** Significant development has occurred along the Jordan River corridor in the project area since the work associated with the current effective FIS on the Jordan River was completed. This can be seen by comparing development conditions on the aerial photographic base map on the FIS work maps included in Appendix C to the aerial that shown on the 2018 base mapping included in Figure 2-1.

Figure 2-1 summarizes the data and key observations discussed in this chapter, including:

- An inventory of bridges, diversions, and other hydraulic structures along the river
- Locations of levees or earthen embankments that could impound water during a large runoff event
- Locations of new surveyed cross sections
- Locations of monumented 1987 cross sections that were resurveyed as part of this study
- Areas where the channel has moved laterally since the current FIS was completed.
- The Jordan River Meander Corridor boundaries.

CHAPTER 3
HYDRAULIC ANALYSES

A hydraulic computer model of the Jordan River from Turner Dam to the Burnham Dam was developed utilizing topographic data, survey data, aerial photographs, and other data discussed in Chapter 2. The model was developed to estimate the capacity of the channel as well as delineate the 100-year floodplain. Version 4.1.0 of the HEC-RAS computer program developed by the United States Army Corps of Engineers was used to perform the hydraulic modeling. Geo-HECRAS was utilized to create a HEC-RAS geometry file. This chapter describes how the hydraulic model was developed and summarizes the results of the hydraulic analysis.

MODEL DEVELOPMENT

This section outlines the general methodology and approach used to complete the hydraulic modeling tasks for this project. The hydraulic analysis associated with this study was limited to only the 100-year flood. No floodway analysis was performed.

The hydraulic modeling performed as part of this study utilized a steady-state analysis. Such an analysis provides the most conservative results.

Basic Information

Data acquisition and hydraulic model development tasks were completed in accordance with FEMA Guidelines and Specifications.

Stream Layout and Cross-section Locations

The Jordan River centerline location was digitized using ArcGIS software and the 2018 High Resolution Orthophotography (HRO) Utah's Automated Geographic Reference Center (ARGC) website. River channel cross sections were surveyed and entered into the hydraulic model at intervals of about 500 feet. Generally, field survey work was performed to collect detailed channel geometry data from top of left bank to top of right bank. The geometry data for the over bank areas for the cross sections were collected by extending the cross section limits across the overbank and floodplain limits using the digital 2013-14 LiDAR data and GIS tools. Survey data of hydraulic structures were used to develop the geometry data for hydraulic structures on the river. The model contains 746 cross sections and 93 structures.

Manning's "n" Values and Expansion/Contraction Coefficients

Values for channel overbank roughness coefficients, or Manning's "n" coefficients, were estimated based on field observations, aerial photography, published roughness coefficient information, and engineering judgment. As a general rule, Manning's "n" values were selected that would result in subcritical flow conditions. The Manning's "n" values used for the overbank ranged between 0.040 and 0.100, and between 0.030 and 0.045 for the main channel. These Manning's "n" values are within an acceptable range that reflect the channel conditions and are close to the values used in FEMA's current effective model.

Boundary Conditions

The study reach of the Jordan River was divided into two segments for modeling purposes. The Lower Jordan River segment extends from Burnham Dam to the Surplus Canal diversion. The other segment extends from the Surplus Canal Diversion to Turner Dam. The downstream boundary conditions for the new hydraulic model for the Lower Jordan River were set such that the downstream water surface would be calculated based on the normal depth using an estimated slope of the energy grade line. The first cross section on the model for the main channel is located below Burnham Dam. For the purposes of this study, and by request from the County, it was assumed that the gates at Burnham Dam were closed. However, hydraulic analysis for this study did not use the 100-year base flood elevation of the Great Salt Lake as a boundary condition. The FIS Report for Salt Lake County designates the Great Salt Lake Floodplain as Zone A (general flooding). The FIS Report for Davis County reports a still-water base flood elevation for the Great Salt Lake of 4215 feet, and the regulatory floodplain as Zone AE with a base flood elevation of 4218 feet, which accounts for wave run-up. The regulatory base flood elevation decreases to 4217 feet upstream of I-215.

The downstream water surface elevation (4234.3 feet) at the Surplus Canal Diversion was defined using information from the Surplus Canal hydraulic model developed for Salt Lake County by Bowen, Collins & Associates as part of the 2012 Detailed Surplus Canal Study.

HYDROLOGIC ANALYSIS

Salt Lake County recently obtained two hydrology-based CLOMRs that revise flow rates along the Jordan River that FEMA used in the current effective FIS (see Appendix D for the FIS Summary of Discharges, and Appendices E and F for the approved revisions to the hydrology). These changes are summarized in Table 3-1.

Table 3-1
Summary of 100-Year Current Effective and Revised Discharges along Jordan River

Location Along Jordan River	Current Effective FIS 100-Year Discharge (cfs)	Revised 100-Year Discharge (cfs)
At Jordan Narrows	3000	3000[1]
At 9000 South	2790	2790[1]
At 5800 South	2850	2850[1]
At Little Cottonwood Creek Confluence	3740	3280[1]
At Big Cottonwood Creek Confluence	4535	3360[1]
At Mill Creek Confluence	4700	3400[1]
Downstream of Surplus Canal Diversion	250	208[2]
At 1300 South	1010	787[2]
At 900 South (UP Bridge)	1095	797[2]
At 800 South (Indiana Ave	1405	814[2]
At 500 South	1530	833[2]
At 400 South	1585	836[2]
At North Temple	1790	992[2]
At 500 North	1765	992[2]
At 700 North	1370	992[2]
At Rose Park Golf Course Bridge	1200	992[2]

[1]Based on Jordan River/Surplus Canal CLOMR (see Appendix E)
[2]Based on Lower Jordan River Hydrology Study (see Appendix F)

MODEL RESULTS

The following sections summarize the results of the hydraulic analysis and compares the results from this study with those from FEMA's current effective FIS and FIRMs.

Model Calibration

In order to calibrate the model, flow measurements and water surface elevations were collected. This data was also backchecked using Salt Lake County stream gage data. This calibration processed is described below.

Flow measurements were collected at three bridge crossings during a significant rainfall event on April 16, 2019 using an Acoustic Doppler Current Profiler (ADCP). The water surface elevation at each monitoring point was measured simultaneously by measuring down from a known survey point at each bridge. Three locations to measure flow were selected where a bridge was available with a known low chord, and where there was minimal bank vegetation that would not negatively affect the depth measurements from the ADCP. Two of these locations were specifically selected because they were near existing active Salt Lake County stream gage locations (500 North and 4800 South). The other location (Brooklyn Avenue at approximately 1050 South) was selected because significant flow enters the Jordan River upstream of this point at the Three Creeks

Confluence (Red Butte Creek, Emigration Creek, and Parleys Creek). This adds another data point to the Lower Jordan River to be able to better calibrate. Appendix G includes the measurement locations and detailed results. Table 3-2 summarizes the results of the flow monitoring efforts.

Table 3-2
Model Calibration Using ADCP

Monitoring Location	Correlating Cross Section in Model	Flow Measurement Date (mm/dd/yy)	ADCP Flow (cfs)	Known Bridge Elevation (ft)	Measure Down (ft)	River WSE (ft)	Required Manning's n to Calibrate Model
500 North	47648	04/16/19	402	4225.73	8.07	4217.66	0.039
1050 South	64308	04/16/19	221	4232.68	9.53	4223.15	0.045
4700 South	106928	04/16/19	739	4259.90	12.54	4247.36	0.035

The discharge and water surface elevations in Table 3-2 were reviewed and considered to be reasonable. Manning's "n" values in the model were adjusted to calibrate the hydraulic model so that the computed water surface elevations matched the observed water surface elevations using the observed discharge rates. The revised discharge rates in Table 3-1 were then used in the calibrated model to compute and update the base flood elevations in the portion of the model between 4800 South and Burnham Dam. These calibration efforts resulted in computed water surface elevations that are between 0 and 2 feet lower than those published in the current effective FEMA Flood Insurance Study downstream of 4800 South. The reach of the Jordan River upstream of Little Cottonwood Creek confluence near 4800 South has not experienced a discharge event large enough to calibrate the model since this study began because discharge in that reach of river is associated with releases from Utah Lake. Utah Lake has not had an unregulated discharge for many years because its level has been below "Compromise Elevation" due to drought.

In an effort to further calibrate the hydraulic model flow rates and water surface elevation data were obtained from Salt Lake County's Jordan River gages located at 9000 South, 4800 South, and 500 North (https://rain-flow.slco.org/list.php). Discharge and water surface data from this website from recent peak storm events were compared to the calibrated model output to see how the model results compared to gage data. The data comparison is summarized in Table 3-3.

Table 3-3
Comparison of Calibrated Output to Salt Lake County Stream Gage Data

Gage Location	Correlating Cross Section in Model	Peak Flow Gage Date	Flow (cfs)	Gage Elevation (ft)	Gage Water Depth (ft)	Gage WSE (ft)	Calibrated Model WSE (ft)	Difference in WSE (ft)	Comment
500 North	47648	10/10/18	745	4212.8	7.15	4219.95	4219.99	-0.04	Keep Manning's n of 0.039
4800 South	107213	10/10/18	1120	4244.45	3.73	4248.18	4248.49	-0.31	Keep Manning's n of 0.035[1]
9000 South	142049	6/19/11	1804	4293.4	6.12	4299.52	4299.48	0.04	Keep Manning's n of 0.035

[1] To match the gage data, Manning;s "n" would need to be reduced to 0.030 between 3300 South and 4800 South

Based on the results summarized in Table 3-3, the calibrated model seems reliable and is further validated by the Salt Lake County stream gage data. The gage data at 500 North almost exactly matches the data collected using the ADCP. Although calibration data at 4800 South does not exactly match, the comparative water surface elevations are within a few inches. However, to be conservative, a Manning's "n" of 0.035 was maintained upstream of 3300 South, with the section between 2100 South and 3300 South having a Manning's "n" of 0.030. The gage data at 9000 South seems to support this assumption since the required Manning's "n" to calibrate at 9000 South is also 0.035. The vegetation upstream of 9000 South is thicker. Since no data is available to calibrate this reach of the river, it was assumed that the Manning's "n" for the channel from 9000 South to Turner Dam is 0.040. There is also no data available downstream of 500 North. This reach was assumed to have a Manning's "n" of 0.035.

It is recommended that more flow monitoring and model calibration be performed. There should be an opportunity to collect some valuable data this year since the Jordan River tributaries currently have above-normal snowpack and significant runoff is anticipated. Utah Lake is also near compromise level, which could allow for further calibration data for the Upper Jordan River.

Base Flood Elevations

The hydraulic computer model was used to compute water surface elevations associated with the revised 100-year discharges listed in Table 3-1 at each of the new cross sections. That information was used to develop a hydraulic profile. The model results were then compared to the base flood elevations published in the current effective FIS Report. As expected, in areas where flow rates were reduced (north of 4800 South), the computed 100-year (base flood) elevations are generally lower than those published in the current effective FIS Report. In areas south of 4800 South, where the base flood discharge rates did not change, the new hydraulic analysis indicates that there are areas where the computed base flood elevations have increased between 1 and 2 feet. This increase can mostly be attributed to the fact that the existing channel has a milder slope that is the result of the lateral channel migration that has occurred over the last 35 years. As shown in the Manning's Equation below, as the slope of the channel decreases due to sinuosity, channel conveyance capacity also decreases (flow depth would increase). The formula also indicates that as Manning's "n" increases, channel flow capacity decreases (and flow depth increases).

Manning's Equation: $Q = \left(\frac{1.49}{n}\right) AR^{0.667} S^{0.5}$

Where Q = flow rate (cfs)
n = manning's roughness coefficient
A = flow area (ft^2)
R = hydraulic radius (ft)
S = slope (ft/ft)

Recent field data indicates that the general gradient of the area between 10600 South and 12600 South has decreased from 0.00140 ft/ft to 0.00127 ft/ft (approximately 13 percent) during the last 35 years, with some localized areas decreasing by as much as 25 percent. This is a significant change that needs to be considered before additional development occurs in the study area. If this trend continues, the extent of the floodplains could continue to grow and existing residential structures end up in the expanded floodplain. Homes and developing properties should be constructed at least 3 feet higher than the values published in the current effective FIS or at least 1.5 feet higher than the elevations computed in this study. This is a reminder that rivers are naturally dynamic in nature and some conservative, prudent decisions should be made when planning for future changes and long-term development.

Freeboard at Low Chords of Bridges

The updated model was used to evaluate the freeboard between the computed water surface associated with the revised 100-year discharges listed in Table 3-1 and the surveyed elevations of the low chords of the 87 bridge structures that cross the river in the study area. Five bridges were found to have water impounded on the low chord. This is an undesirable condition as it can cause pressurized flow under the bridges and floating debris can impact the bridge structures and potentially cause structural damage. A summary of the hydraulic model information for the bridges that have submerged low chords associated with the updated 100-year discharges is presented in Table 3-4.

Table 3-4
Bridges with Submerged Low Chords During a 100-Year Flood

Bridge Location	Estimated Water Impounded on Low Chord (Feet)
3900 South	1.6
500 South	0.6
300 South	0.5
700 North	0.1
1000 North	0.1

It is recommended that Salt Lake County work with UDOT and Salt Lake City to monitor debris at these bridges during large runoff events and take measures to protect the bridges from being damaged by floating debris. When these bridges are replaced in the future, the design should provide minimum freeboard to better protect the bridge structures.

Current Effective Floodplain

The current effective FEMA floodplain data as published on FEMA's National Flood Hazard Layer database is shown on Figure 3-1. That figure is included for reference only.

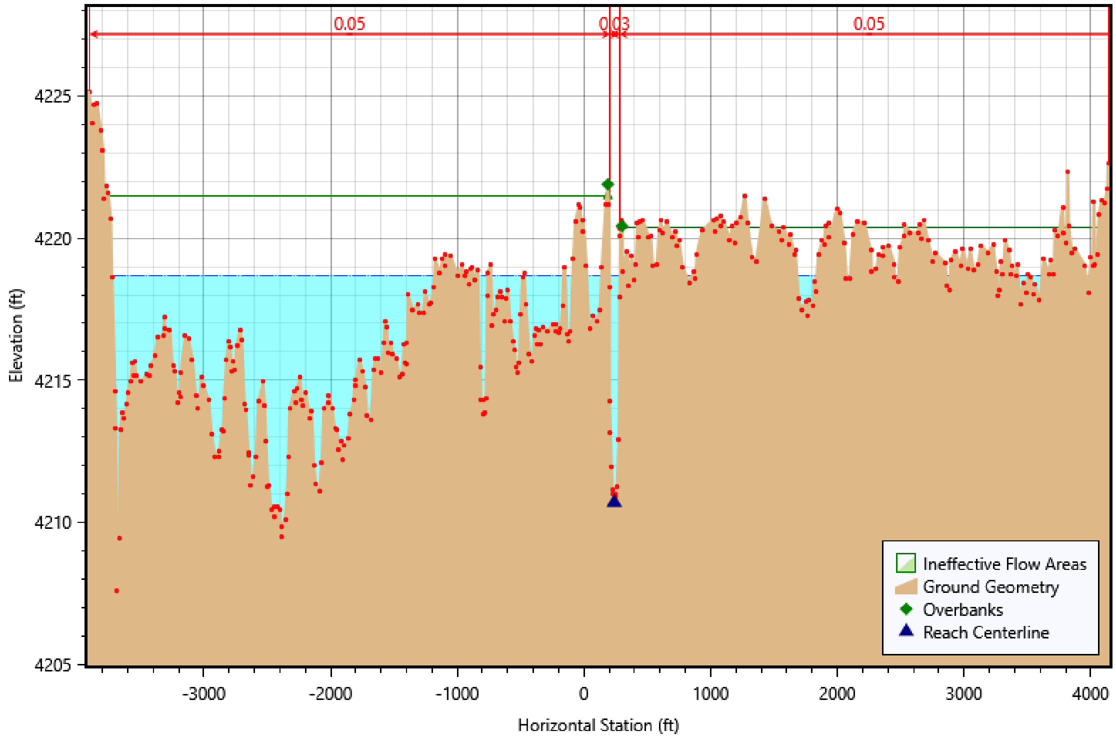
Updated Floodplain Delineation

An updated floodplain was developed from the Turner Dam to I-215 in North Salt Lake. The updated extents of the 100-year floodplain were digitally delineated from Turner Dam to I-15 in North Salt Lake using a digital ground surface created using the 2013-14 LIDAR data. The floodplain was not delineated North of I-215 since the flooding source is primarily lacustrine. The surface created from the LiDAR data was used in conjunction with GeoHECRAS to generate approximate inundation areas where the elevations of the overbanks and nearby ground surfaces are lower than the computed water surface in the main channel (with the exception of the left overbank between North Temple and I-215). This approach is conservative in that not all the inundated area shown on the figure will flood. Rather, it shows all areas that have potential for flooding since they are lower than the water surface in the main channel and could become inundated should earthen embankments fail and/or storm drains fail to flow properly due to backwater from the river. The results of the updated 100-year floodplain are presented in Figure 3-2. The results of the updated 100-year floodplain are compared with the current effective floodplain on Figure 3-3.

In areas where the base flood elevations increased (south of 4800 South), the floodplain extents also increased. The updated 100-year floodplain between 4800 South and North Temple show that the floodplain extents defined on the current effective FIRM have generally decreased because the base flood discharge has been reduced. However, in some areas in that same reach the updated floodplain extents are slightly larger, due to the use of more refined and accurate terrain data and the use of new computer technology that allows more for accurate floodplain delineation.

The updated floodplain extents in the river reach from North Temple to the north I-215 crossing shows a significant increase in the 100-year floodplain extents. This area generally has earthen embankments on both sides of the river that were considered to be effective flood deterrents when the work associated with the effective FIS was completed. Although those embankments may adequately function during the 100-year flood event, they are not certified as levees and cannot be considered as an effective flood control measure when mapping the floodplain for a FEMA-sponsored study. The extents of the 100-year floodplain shown on Figure 3-2 were developed using current FEMA protocol for nonaccredited levees. Therefore, the flood extents of the updated floodplain are larger than those on the current effective FIRMs.

Graphic 1 contains an image of a channel cross section extracted from the HEC-RAS model. This particular cross section is near 1100 North and is approximately 1.5 miles wide. The model was set to make both overbanks ineffective flow areas, meaning it only calculates the water surface based on the flow area inside the main channel. However, the image demonstrates that the 100-year water surface in the channel is higher than almost the entire area in the left overbank, and higher some of the roads in the right overbank. It should be noted that, depending on the flood duration and storm hydrograph, this may cause storm drain pipes to backup and result in local flooding, mostly in the streets, east of the river. Most of the area west of the Jordan River in Salt Lake City drains to other storm water management facilities.



Graphic 1
Modeled Channel Cross Section Near 1100 North

A separate hydraulic model was developed for the left overbank area along the Lower Jordan River to better estimate the floodplain depth and extent if floodwater is routed in the overbank. If the left embankment or levee were to fail, it is estimated that no more than half of the water would leave the channel. Therefore, only 500 cfs was routed through the left overbank model for this analysis (about half of the revised 100-year discharge). The updated 100-year floodplain shown on Figure 3-2 reflects the results of this analysis. Although the model results showed that the depths in the left overbank decreased compared to what is shown in the image above, the floodplain extents were similar.

Bank Overtopping

There are a few areas where the hydraulic model predicts that water will overtop an earthen embankment during a one-percent-annual-chance flood (100-year flood). The depth of flooding in these areas may be related to the downstream boundary conditions used in the hydraulic model at Burnham Dam. It appears that some of these inundated areas were designed to flood during extreme runoff events. The biggest area is along the west side of the river from the Regional Athletic Complex to the Jordan River OHV State Recreation Area (approximately 9,000 feet of the west bank that is overtopped). This area is not a concern since it only consists of grass and fields, with no habitable structures. Other areas where the banks may experience overtopping include a reach that is about 700 feet long on the east bank near Riverview Avenue and Catherine Street; an area that is about 600 feet long on the east bank near Riverside Park between 700 North and 800 North; and an area that is about 200 feet long on the east bank near Constitution Park at about 300 North and 1350 West. Although flooding in these areas initially impacts open, undeveloped areas, nearby buildings could potentially flood or be placed in a floodplain if not protected by a FEMA-certified levee. It is recommended the limits of areas that can be allowed to be temporarily flooded be defined and that certified levees be constructed at the allowable flood limits.

Baker Study

A valley analysis was performed by Michael Baker International in 2012 (see Appendix H). That analysis included both the Jordan River and Surplus Canal, beginning at 2100 South and continuing to 3300 North. The results include a wide floodplain and an extremely wide floodway ranging up to a mile wide. The Baker analysis used the current effective flow rates. Therefore, it is understandable that the floodplain extents associated with their analysis would be larger than the results associated with this study. The results of the analysis associated with this study indicate that the Lower Jordan River channel has capacity to convey the 100-year discharges through most developed areas if the existing levees function properly. However, if water were to leave the channel due to a failed embankment on the west bank, it would flow overland and would have a hydraulic grade line lower than that of the main river channel. Any flow in the west overbank should be modeled separate from the water in the main river channel. The existing flow patterns should also be carefully considered when performing an updated floodway analysis.

It is recommended that the earthen embankments or levees along the Lower Jordan River between North Temple and I-215 be improved so that they can be accredited by FEMA. When this area is updated to reflect FEMA standards, most of the area will be reclassified as Zone AE. A study that analyzed some options for levees in the area was completed in 2009 (see Appendix I). Although some items discussed in the study have since changed, especially pricing, much of what was studied still applies today. We recommend that a similar study be conducted to update the results. The results may show that it is cheaper to obtain levee certification than the cumulative flood insurance costs residents will have to pay due to the changes in flood hazard designation.

CHAPTER 4
RECOMMENDATIONS

This chapter summarizes the recommendations that were developed as work associated with this study was being performed. These recommendations have been divided into two categories: administrative/institutional recommendations; and capital project recommendations.

ADMINISTRATIVE/INSTITUTIONAL RECOMMENDATIONS

1. **Mitigate Lateral Erosion/Channel Migration Hazards Near Development.** Rivers are one of the most dynamic landforms on earth. Therefore, it is recommended that Salt Lake County continue to work with Cities and developers to ensure that erosion hazard mitigation measures are designed and implemented during the design and construction phases of any development adjacent to the Jordan River. This will help protect future development near the river from being damaged by lateral erosion hazards. In addition, the following 2 specific recommendations are made to address lateral erosion hazard issues that were observed in the field:

   a. Work with the utility owner to monitor bank erosion near an existing power pole located on the steep bank of the river near 1300 South. This pole may need to be relocated or the bank around the pole may need to be stabilized to prevent the river from eroding away the soil that currently supports the pole.

   b. Armor and stabilize the west bank of the river just upstream of the 12600 South Bridge at the base of an existing hill where the river migration has cut into the hill and created a large vertical bank that may have destabilized the adjacent hillside. Such a project may include relocating a short section of the river eastward, away from the hillside. Completing this project would reduce the sediment load in the river and help prevent an emergency response project if the hillside were to collapse into the river.

2. **Work with Communities to Implement More Stringent Requirements for Base Floor Elevations in New Development along the River in the South End of the Salt Lake Valley.** Results of this study indicate that lateral channel migration that has occurred since the current-effective FEMA Flood Insurance Study was completed has increased river sinuosity and decreased channel slope and conveyance capacity. This means that the base flood elevation may have increased between one and two feet in some areas. In areas where channel migration is likely to continue to occur, it is recommended that ordinances or institutional requirements be put in place that will require the base floor elevations of new structures to be at least 3 feet higher than the current base flood elevations published by FEMA, or at least 1.5 feet higher than the base flood elevations computed by this study.

3. **Monitor Debris Accumulation and Associated Hazards at the 5 Bridges that will have Submerged Low Chords during High Runoff Events.** The bridges are located at: 3900 South, 500 South, 300 South, 700 North, and 1000 North. Debris should also be monitored at the UP&L Diversion.

4. **Work to Ensure Proper Hydraulic Modeling Procedures are Used to Develop Updated FEMA Flood Hazard/Risk Maps for the Floodplain Associated with the Lower Jordan River.** In the near future, the FEMA Flood Insurance Rate Maps will be updated for the Lower

Jordan River. When it is time to perform that analysis, Salt Lake County and Salt Lake City personnel should meet with FEMA representatives and the Study Contractor to discuss how to accurately map the floodplain outside the main river channel. The following items are presented for consideration in planning and performing the associated floodplain analysis:

a. Determine if the base flood event is related to a cloudburst event or a snowmelt event.

b. Consider effects that the Surplus Canal will have on the base flood hydrograph during a large runoff event. It may be more appropriate to utilize a dynamic model with a runoff hydrograph rather than steady state model.

c. Consider routing floodwater existing in the Lower Jordan River channel in a separate model that will route water in the overbanks independent of the water in the main river channel. The hydraulic grade line in the overbanks will likely be different than that of the main channel.

d. When modeling the overbank flooding, estimate how much water can realistically leave the main channel, since the existing earthen embankments or levees will only allow a portion of the water to leave the channel if they fail.

e. When modeling the floodplain west of the Lower Jordan River, consider the natural topography and the extent of some of the topographic high points. If water leaves the river, is it physically possible for some of the water to flood all of the area between the river and I-215.

f. Consider the effectiveness and capacity of the existing storm drain facilities that currently serves the area west of the Lower Jordan River and the fact that river has been moved from its original position.

g. Realize that accurately mapping the floodplain west of the Jordan River will be technically difficult.

h. Account for the Surplus Canal levees when mapping the floodplain associated with the Lower Jordan River.

i. Utilize FEMA's Levee Analysis and Mapping Procedure (LAMP) in working to develop the study and analysis process that will best meet the needs of the communities.

j. Determine how to best account for newly determined Great Salt Lake base flood elevations with regard to designing levee improvements and updating the floodplain mapping on the Lower Jordan River. The published base flood elevations on the Lower Jordan River just upstream of the I-215 bridge crossing are 4215.5 feet from the Salt Lake County FIS and 4217 from the Davis County FIS. The Davis County elevations account for wave runup from the Great Salt Lake.

CAPITAL PROJECT RECOMMENDATIONS

1. **Remove the Abandoned Bridge Structure at 2700 North.** Remnants of an abandoned bridge that includes multiple piers is located at about 2700 North on the Lower Jordan River. This abandoned structure is prone to plug with floating debris during a large runoff event and is in a location that is difficult to monitor. This structure should be removed to mitigate the hazards associated with debris plugging. The estimated cost for this project is $30,000.

2. **Continue Work to Obtain FEMA Accreditation of the Existing Levees Between the Mill Creek Confluence and the Surplus Canal Diversion.**

3. **Collect Water Surface Elevation Data that can be Used to Calibrate the Portion of the Hydraulic Model Upstream of 2100 South.** Discharges in the river in the segment of the river upstream of the Little Cottonwood Creek confluence is largely controlled by releases from Utah Lake. It has been years since the water surface in Utah Lake has reached compromise elevation where the regulating gates are opened. The next time the gates are opened to provide significant flow in the river, some data should be collected to calibrate the upper reach of the model. Data was collected to calibrate the model for the reach of the Lower Jordan River as part of this study. The estimated cost to perform this task is $7,500.

4. **Continue to Monitor and Remove Sediment in the Jordan River near the Confluences of Little Cottonwood Creek, Big Cottonwood Creek, and Mill Creek.**

5. **Plan and Fund a Method to Improve the Levees on the Lower Jordan River so they will Meet FEMA Accreditation Criteria.** The existing earthen embankments along the Lower Jordan River have functioned adequately in the past. However, they do not meet minimum FEMA levee accreditation criteria. This means that hundreds of structures could be placed in a FEMA floodplain when the existing Flood Insurance Rate Maps are updated. Existing levee deficiencies include: woody vegetation on the embankments or levees; inadequate freeboard; and lack of data on the earthen fill. With homes and businesses constructed so close to the river and the desire to maintain trees along the river to maintain a desirable riverine environment, it will be difficult and expensive to construct needed improvements. The needed improvements would make it optional, not almost mandatory, for the owners of structures near the river to purchase flood insurance. It is recommended that a new feasibility/planning study be completed to evaluate the costs and benefits of making the needed levee improvements. It is estimated that such a study would cost between $200,000 and $300,000. The Lower Jordan River Levee Evaluation Study prepared by CH2M HILL in 2009 (see Appendix I) estimated the cost for levee improvements and certification to be approximately $14 million. However, this cost estimate was only for the west bank between Redwood Road and North Temple. By using the same cost per linear foot, and scaling the price using the ENR Index, it is estimated that the 2019 cost to improve and certify levees on both river banks between I-215 and North Temple would be between $50 million to $60 million.

6. **Construct FEMA-Certified Levees Adjacent to Areas That May Have Been Designed to Flood.** There are four significant overbank areas along the Lower Jordan River where the hydraulic model shows water would overtop the bank or existing earthen embankment and inundate a park or open area during a 100-year flood event. These areas approximately include:

    a. 9000 feet along the west bank from the Regional Athletic Complex to the Jordan River OHV State Recreation Area in the Rose Park area
    b. 700 feet along the east bank at Riverview Avenue and Catherine Street
    c. 600 feet along the east bank at Riverside Park between 700 North and 800 North
    d. 200 feet along the east bank at Constitution Park near 300 North and 1350 North

It is recommended that these areas be reviewed to determine if they can be flooded in an extreme runoff event. After areas of allowable flooding are defined, FEMA-certified levees should be constructed at the allowable flood limits to protect existing or future development and to limit the extents of new 100-year flood hazards. The estimated cost to construct levees in these areas is between $1 million and $10 million, depending on what is deemed necessary. However, these costs are already incorporated into the cost estimate to improve both banks between I-215 and North Temple.

BOWEN COLLINS
& ASSOCIATES