Appendix D

Investigation & Analysis

Skull Valley Watershed Project
Tooele County, Utah

Investigation and Analysis Report

Final

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Prepared for:

United States Department of Agriculture
Natural Resources Conservation Service

Tooele County

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1.0 Introduction

The purpose of this Investigation and Analysis (I&A) Report is to present information that supports the formulation, evaluation, and conclusions of the Watershed Plan and Environmental Assessment (Plan-EA) for the Skull Valley Watershed Project (Project), located within the Skull Valley Watershed in Tooele County, Utah. The report is required and must be included as an appendix to the Plan-EA.

The procedures, techniques, assumptions, scope, and intensity of the investigations for each subject are described in sufficient detail so that a reader not familiar with the project areas or their issues can form an opinion on the adequacy of the Plan-EA. This report supplements information contained in the Plan-EA and is not intended to replace or duplicate information contained therein.

The planning studies presented in this I&A Report are based on standard methods and procedures used and approved for use by the United States Department of Agriculture Natural Resources Conservation Service (NRCS). The following information summarizes the investigation and analysis for the key planning studies conducted in the preparation of the Plan-EA. Additional information relevant to each section provided in this report is available upon request as part of the administrative record for the project. Requests for additional information can be submitted to the following address:

NRCS
Wallace F. Bennett Federal Building
125 S State St., Room 4010
Salt Lake City, UT 84138-1100

1.1 Project Location

The Project is located between Highway 196 and the Stansbury Mountains within the Skull Valley Goshute Reservation (Reservation) at latitude 40.398758°/ longitude -112.721906°. Improvements are being proposed within and approximate 92.3-acre area on the Reservation (refer to Map B1 in Appendix B of the Plan-EA).

2.0 Watershed Boundary Development

The watershed boundary was developed by reviewing 12-digit Hydrologic Unit Code (HUC 12) sub-watershed boundaries. Key boundaries to include within the new watershed boundary consisted of the Reservation boundary, drainage areas used for hydrologic analysis, flood inundation areas identified during the hydraulic analysis, and any areas potentially impacted by alternative measures. The key boundaries were imported into a Geographical Information Systems mapping program and were found to intersect four HUC 12 sub-watersheds. The outer boundary of the four HUC 12 watersheds was used to develop the proposed Skull Valley Watershed Boundary. The areas of each sub-watershed were calculated using a GIS mapping system and added together to determine the total area for the Skull Valley Watershed of 107,558 acres. Refer to Section 1.2 of the Plan-EA for a list of the HUC 12 sub-watershed names and numbers, acres associated with each, and map depicting the Skull Valley Watershed boundary.

3.0 Hydraulic and Hydrology Analysis

Information in this section is summarized from a hydrology technical memorandum (TM) and hydraulics TM completed for the Project (Bowen Collins & Associates [BC&A] 2020 and 2022a). These TMs are included in Appendix E of the Plan-EA.

3.1 Data Sources

Data sources used to complete the hydrologic and hydraulic analysis are included in Table 3-1. Topographic datum and coordinate system used for analysis included North American Vertical Datum 1988 (vertical datum), North American Datum of 1983 (geodetic datum), and State Plane Utah Central (coordinate system).

Table 3-1. Data Sources

Data	Source	Description
2018 Bare Earth LiDAR Topography	USGS 3D Elevation (UGRC 2018)	1-meter resolution bare-earth DTM data set of project vicinity. Data was used to generate the hydraulic model and to verify drainage basin extents/parameters.
Aerial Imagery	USDA National Agricultural Imagery Program (NAIP)	1-meter pixel aerial imagery was used to determine existing land uses for hydraulic models.
Field Survey	BC&A Field Reconnaissance	Field reconnaissance was completed by BC&A to confirm site conditions, drainage paths, landcover, hydraulic structures, and damaged facilities.
Soil Data	Web Soil Survey (NRCS 2020)	Soils Survey Geographic Database (SSURGO) mapping data was used to determine hydrologic soil type for hydrologic models.
Land Cover Data	National Land Cover Dataset (NLCD) (USGS 2011 and 2016)	Surface cover characteristics for hydrologic models were determined from land cover.
Rainfall Data	NOAA Atlas 14 (NOAA 2006)	Used to develop design rainfall depths.

3.2 Hydrology Model

A flood frequency analysis, regression analysis, and development of a rainfall-runoff model were performed and compared to an NRCS hydrology study (NRCS 2013) and a USACE hydrology study (USACE 2019) to determine the recommended hydrology for design. The rainfall-runoff model was selected as the best fit analysis method to support the Project. This rainfall-runoff model resulted in higher runoff rates when compared to the regression and flood frequency analysis and were consistent with the results of the USACE and NRCS analysis, providing conservative values for design.

Drainage basin boundaries were developed for the rainfall-runoff model using Aquaveo's Watershed Modeling System (WMS) software. Basin delineations for the analysis stopped approximately at the start of the alluvial fans west of the Stansbury Mountains, with the assumption that little to no runoff is generated from rainfall on the coarse-grained alluvial fan deposits. The drainage areas include the Indian Hickman Canyon drainage area (5.61 mi^2) and the Foothills Drainage Basin (1.61 mi^2) (Figure 3-1).

Runoff Curve Numbers (CN) were estimated for each drainage area based on soil type and land cover determined by inspection of aerial imagery, filed observations, NLCD (USGS 2011 and 2016) and hydrologic soil groups from the SSURGO (NRCS 2020). A composite CN number of 67 was calculated using GIS software on a weighted area basis.

The lag time was calculated for each drainage area using the National Engineering Handbook (NEH) watershed lag method (NRCS 2010). The longest flow length and average drainage area slope parameters were calculated using GIS software. Parameters and results of the lag time (L) and time of concentration (Tc) calculated for each basin are included in Table 3-2. Flow paths for Tc can be seen in Figure 3-1.

Table 3-2. Drainage Basin Lag and Time of Concentration Summary

Drainage Basin	Area (acres)	CN	Longest Flow Length (ft)	Average Watershed Land Slope	L (min)	Tc (min)	Average Flow Travel Velocity (ft/s)
Indian Hickman Canyon	3,590	67	29,530	55.7	55	92	5.3
Foothills	1,028	67	10,399	34.3	16	26	3.4

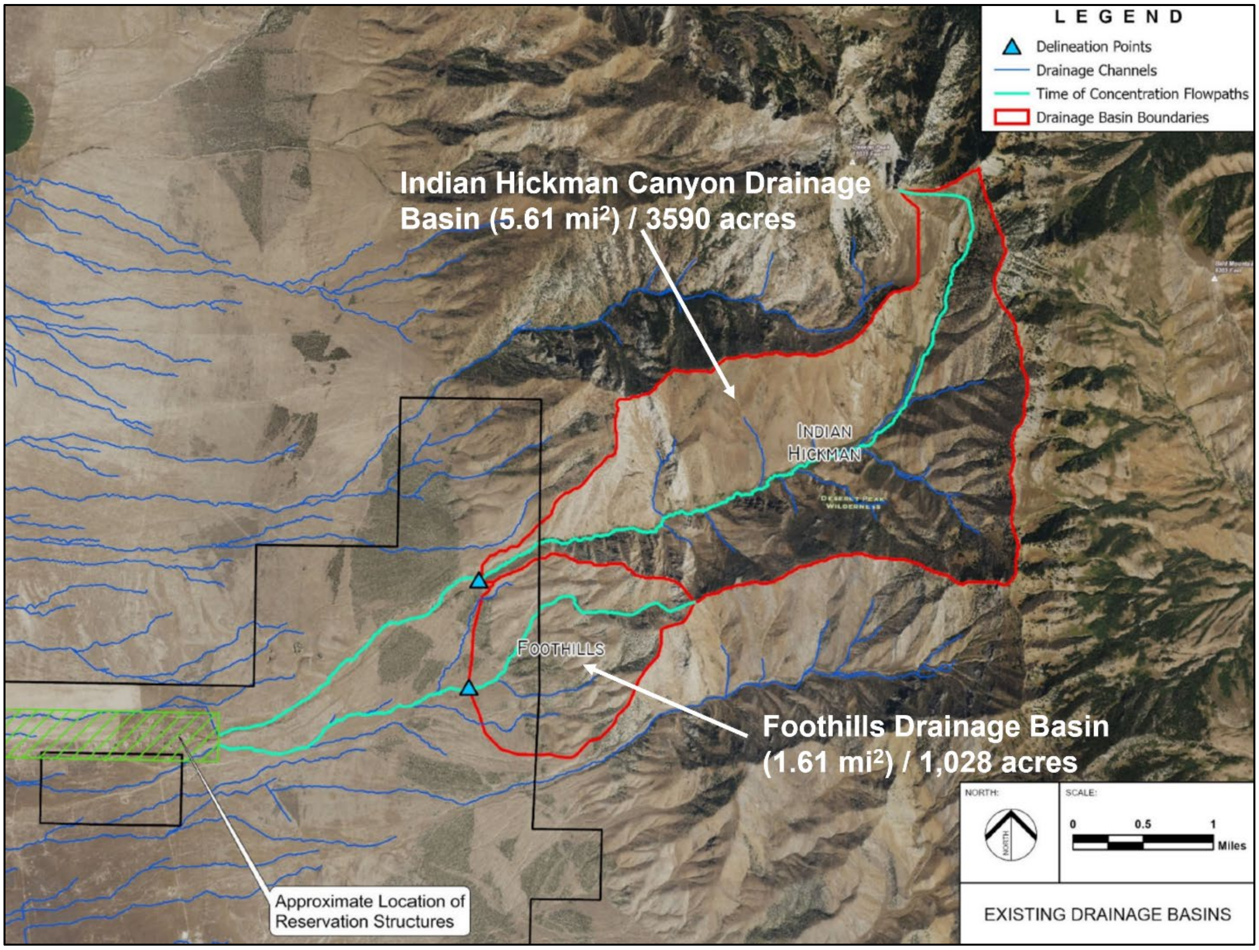


Figure 3-1. Drainage Areas

Design storm depths were obtained from the National Oceanic and Atmospheric Administration (NOAA) Precipitation Frequency Data Server (PFDS) and included NOAA Atlas 14 total storm depths for various recurrence intervals. Point storm depth estimates for recurrence intervals from 1 to 500 years were obtained from the NOAA PFDS and adjusted for an areal reduction factor using the procedure described in NOAA Technical Report 24 (NOAA 1980). The areal reduction factor was calculated at 0.98 based on 16.5 mi^2 generalized storm area. NOAA Atlas 14-point storm depths and areal adjusted depths are provided in Table 3-3.

Rainfall distributions were created from the areal reduced storm depths using NRCS WInTR-20 software and the procedures described in NEH 630.04 (NRCS 2010). Design hydrographs for each basin were created using the USACE HEC-HMS software and computed based on the standard Soil Conservation Service (SCS) Unit Hydrograph method. The design peak discharges calculated for the drainage basins for each recurrence interval are provided in Table 3-4. In addition, a combined hydrograph of the drainage areas was developed to determine a combined flow just upstream of the Reservation. This was performed based on the alluvial system and potential for sudden change in flow path that could combine the flow paths during future events. The two hydrographs for the basins were routed in the HEC-HMS model using the Muskingum-Cunge flood routing method from the NEH 630.1703 (NRCS 2021). HEC-HMS peak discharges for the combined flow are included in Table 3-4.

Table 3-3. Design Storm Depths

Item	Recurrence Interval (year)								
	1	2	5	10	25	50	100	200	500
NOA Atlas 14 Point Depth (in)	1.84	2.28	2.78	3.19	3.75	4.18	4.62	5.08	5.70
Areal Adjusted Depth (in)	1.80	2.23	2.72	3.13	3.68	4.10	4.53	4.98	5.59

Table 3-4. HEC-HMS Peak Discharge Results

Drainage Basin	Peak Flow by Recurrence Interval (cfs)								
	1	2	5	10	25	50	100	200	500
Indian Hickman Canyon	40	120	330	580	1,010	1,420	1,920	2,520	3,510
Foothills	10	40	130	230	410	580	800	1,050	1,470
Combined Flow	50	150	420	730	1,280	1,800	2,440	3,210	4,490

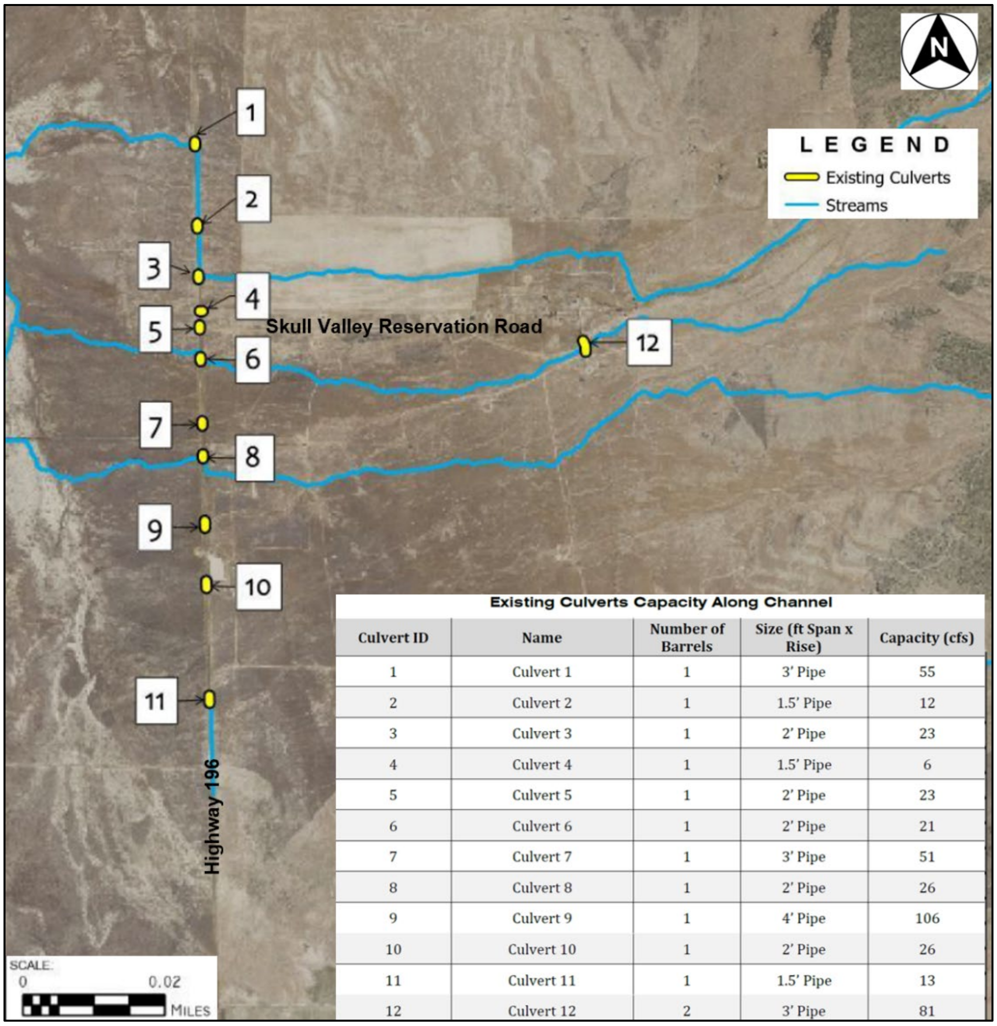
3.3 Hydraulic Modeling

3.3.1 Existing Conditions

Hydraulic modeling was performed using HEC-RAS software (version 5.0.7) to evaluate existing and alternative flood conditions. Since major overland flooding occurs throughout the alluvial fan floodplain, it was determined that the best modeling approach would be a two-dimensional (2D) flow analysis. The runoff hydrographs for the drainage areas were input for unsteady flow into the existing conditions hydraulic model for the 5 through 500-year frequency floods. The 1- and 2-year frequency floods were not modeled due to very low runoff values.

The modeling surface was developed using 1-meter resolution LiDAR data (Utah Geospatial Resource Center [UGRC] 2018). The model included a 20-foot by 20-foot cell size and break lines were added to align the cell faces with natural breaks in the underlying terrain. A Manning's roughness coefficient (n-value) was assigned to each cell by subdividing the floodplain area into various surface roughness subareas based on land use (verified through aerial imagery). N-values used in the model include 0.045 (channel), 0.06 (overbank), and 0.02 (road). Twelve culverts were modeled assuming they were 100% open and consisting of concrete box or concrete pipe (n=0.015), or corrugated metal (n=0.024). Culvert sizes were based on UDOT data, USACE data (USACE 2019), and field investigations conducted by BC&A. The Federal Highway Administration software (HY-8 version 7.60) was used to assess the existing culvert capacities.

Culvert locations and capacities are included in Figure 3-2 below. Upstream and downstream boundary conditions were set with the inflow hydrographs near the mouth of each canyon and the area west of Highway 196 as the outflow.



Existing Culverts Capacity Along Channel

Culvert ID	Name	Number of Barrels	Size (ft Span x Rise)	Capacity (cfs)
1	Culvert 1	1	3' Pipe	55
2	Culvert 2	1	1.5' Pipe	12
3	Culvert 3	1	2' Pipe	23
4	Culvert 4	1	1.5' Pipe	6
5	Culvert 5	1	2' Pipe	23
6	Culvert 6	1	2' Pipe	21
7	Culvert 7	1	3' Pipe	51
8	Culvert 8	1	2' Pipe	26
9	Culvert 9	1	4' Pipe	106
10	Culvert 10	1	2' Pipe	26
11	Culvert 11	1	1.5' Pipe	13
12	Culvert 12	2	3' Pipe	81

Figure 3-2. Existing Culverts and Capacity

3.3.2 Alternative Conditions

The Action Alternatives (Berm and Channel Improvements Full Riprap Alternative and Berm and Channel Improvements Reduced Riprap Alternative) were designed to manage runoff from the 24-hour, 100-year design storm to protect the developed Reservation community. It consists of constructing berms and conveyance channel improvements to divert flood flows north and south around the developed Reservation community. The hydraulic model used for the existing condition analysis was modified to include berms/walls to analyze the alternative conditions and develop inundation maps.

3.3.3 Flood Modeling Results

The model output was imported into a GIS mapping program to support flood analysis. Flood inundation extents and depths were overlain with Reservation structures and roads to determine flood impacts. Results of the features and acres of land inundated for the 5- through 500-year frequency floods are provided in the Plan-EA and were used to support damage reduction benefit calculations for the economic analysis. The 100- and 500-year flood maps depicting the existing (No Action) and Action Alternative flooding are provided in Appendix C of the Plan-EA.

4.0 Engineering

4.1 Alternatives Evaluation

Several alternatives were developed by the engineering team to protect the Reservation from flooding for up to an including a 100-year flood. These alternatives were developed in enough detail to identify approximate measures and costs to evaluate rationality for implementation. The process of formulating alternatives for the project followed procedures outlined in the National Watershed Program Manual (NRCS 2015a); National Watershed Program Handbook (NRCS 2014); Principles, Requirements, and Guidelines for Water and Land Related Resources Implementation Studies (PR&G) (Council of Environmental Quality [CEQ] 2013 & 2014); and other NRCS watershed planning policy.

Alternatives were eliminated from more detailed study/design if they were considered infeasible, had exorbitant costs, did not meet the purpose and need, or other critical factors. Two Action Alternative were determined reasonable to include in detailed study/design, which were the Berm and Channel Improvements Full Riprap Alternative and the Berm and Channel Improvements Reduced Riprap Alternative. Refer to Section 5.4 of the Plan-EA for the eliminated alternative descriptions and justification, and refer to the PR&G Analysis Report (included in Appendix E of the Plan-EA) for the alternative selection decision-making process.

The Action Alternatives include measures to protect the Reservation from flooding by installing flood diversion berms and flood conveyance channels, resulting in rerouting flood flows around the developed Reservation community. Both Action Alternatives include armoring of the bank/berm on the Reservation side only of newly constructed berm segments with flood conveyance channels at the toe of the berm. The Berm and Channel Improvements Reduced Riprap Alternative also only armors the banks on the Reservation side of the remaining channel segments, while the Berm and Channel Improvement Full Riprap Alternative armors both banks of those segments. The reduced riprap alternative was developed in consideration of the existing alluvial fan system, which has common and natural channel migration with associated sediment deposition patterns that shape the fan. The reduced riprap alternative provides protection to the developed Reservation community while allowing the remaining fan system to continue its natural migration and sediment deposition patterns in areas of the alluvial fan where there is no existing or proposed development. Refer to Section 5.5 for a detailed description of the Action Alternatives.

The No Action Alternative was also evaluated as a baseline for comparison of the Action Alternatives. The No Action Alternative considers the actions that would take place if no federal action or federal funding were provided. The sponsors would leave the drainages “as-is” with no improvements for flood control for the No Action Alternative. O&M activities would be performed which included sediment/debris removal and culvert maintenance, along with an anticipated replacement of a culvert.

4.2 Design Criteria

Conceptual designs were developed for the Action Alternatives included in detailed study to support the environmental analysis in the Plan-EA (refer to Appendix E of the Plan-EA). Design criteria used in conceptual design included:

- NRCS Code 356 Conservation Practice Standard Dike and Levee (NRCS 2022a)
- NRCS Code 362 Conservation Practice Standard Diversions (NRCS 2022b)
- NRCS Code 582 Conservation Practice Standard Open Channel (NRCS 2015b)

An Excel spreadsheet utilizing the Manning's equation (solving for normal depth) and the existing conditions 2D HEC-RAS model were used to size the proposed berms and flood conveyance channels. Design considered the factors listed below.

- The locations of berms should be placed so existing channel alignment is maintained as much as possible. If there are possibilities of shortening the berm lengths, that will be evaluated in final design.
- The channels and berms would be designed to have a 100-year water surface elevation at or below the berm landside toe. The berms system would not impound or hold back water and is not required to meet FEMA 65.10 for levees.
- All berm and channel embankments should be designed to allow for a minimum 2 feet of freeboard during the design storm.
- Riprap armoring protection is recommended through the entire reach of improved berm and channel, at a minimum of 2 feet above the 100-year flood water surface elevation and should be buried below ground to protect from channel migration toward the Reservation.

Hydraulic design criteria for the berms and channel improvements are included in Table 4-1.

Table 4-1. Hydraulic Design Criteria

Type	Flow Rate (cfs)	N-Value	Channel Bottom Width (ft)	Flood Depth (ft)	Channel Slope (%)	Side Slope (m:1)	Average Velocity (ft/s)
North Channel/Berm	150	0.045	5 to 25	0.9 to 1.1	2.37 to 6.13	3	5.0 to 7.1
South Channel/Berm[1]	1,200	0.045	5 to 75	1.6 to 2.5	1.32 to 5.27	3	6.6 to 10.0
South Channel/Berm[2]	2,200	0.045	25 to 75	2.6 to 4.5	3.07 to 4.15	3	10.8 to 14.4

1 – This section of channel includes flow from the Indian Hickman drainage area

2 – This section of channel includes combined flow from the Indian Hickman and foothills drainage areas.

Velocities along the proposed berm and flood conveyance channels range from 5.0 to 14.4 ft/s (Table 4-1) and armoring or other stabilization measures were determined to be necessary to protect from channel migration toward the Reservation. Five different methods were used to calculate riprap sizing for armoring and are listed below. The USACE method was chosen out of the five methods for calculating the concept design riprap sizing.

- UDFCD Method: Based primarily on mean channel velocity, longitudinal channel slope, and specific gravity of rock

- HEC-11 Method: Based on average channel depth, mean channel velocity, specific gravity of rock, and angle of response.
- HEC-15 Method: Based on maximum channel depth and is sensitive to angle of repose.
- Isbash Method: Accounts for velocity and unit weights of riprap and fluid
- Minnesota TN 3 Method: Based only off of average channel velocity.
- USACE Method: Based on local channel depth, average channel velocity, water surface top width, radius of river bends, specific gravity of rock and angle of repose.

4.3 Cost Estimates

The Cost estimates for the Action Alternatives were computed using 2022 dollars. Costs account for estimated quantities of material and labor. O&M costs were determined over a 100-year Project life. The No Action Alternative does not have installation costs. The detailed costs for the Action Alternatives are and No Action Alternative are included as an Appendix in the PR&G Report in Appendix E of the Plan-EA.

5.0 Cultural

Cultural surveys were conducted and a Cultural Resource Assessment prepared (Certus Environmental Solutions, LLC 2021). A file search and archival review was conducted on October 17, 2020 for a ½-mile buffer around the Project area and included a detailed review of the Utah Division of State History Sego and HUB databases, historical topographic maps/aerial photos, historic General Land Office maps, URARA rock art data, and Utah statewide historic contexts. The field work was performed on October 28, 2020 by Principal Investigator, Sheri Murray Ellis. The field survey included walking parallel transects spaced no more than 15 meters apart on 132 acres of land. Results of the survey are incorporated into the Plan-EA. A copy of the cultural survey could not be included in Appendix E because it contains sensitive location information on cultural and historical resources.

6.0 Aquatic Resource Delineation

An aquatic resource delineation was completed and a report prepared to identify jurisdictional waters of the U.S. (BC&A 2022b). The delineation was conducted in accordance with the USACE Wetlands Delineation Manual (USACE 1987) and the Arid West Supplement (USACE 2008). A total of 162 acres were surveyed on October 28, 2020 by BC&A biologist, Merissa Davis. National Wetlands Inventory data from the U.S. Fish and Wildlife Service and NRCS hydric soil data was reviewed prior to performing field work. Results of the survey are incorporated into the Plan-EA and a copy of the report is provided in Appendix E of the Plan-EA.

7.0 Decision-Making Process

The decision-making process for this Project followed the PR&G (CEQ 2013 and 2014), and the National Planning Procedures Handbook (NRCS 2021). The PR&G followed an eight-step evaluation process and NRCS planning followed a nine-step process. The PR&G eight-step planning process completed for the Project is documented in the PR&G Analysis Report included in Appendix E of the Plan-EA. A summary of the NRCS nine-step planning process completed for the Project is provided in Section 1.1.1 of the Plan-EA.

8.0 PR&G Evaluation and Economics

The PR&G evaluation process includes guiding principles to assist in decision making and weighing tradeoffs of Project alternatives, and the use of an ecosystem services framework to describe the comprehensive set of benefits that people receive from nature characterized as ecological goods and services provided by a healthy, functioning environment. The PR&G analysis for the Project is documented in the PR&G Analysis Report included in Appendix E of the Plan-EA.

The National Watershed Program Manual (NRCS 2015) was used as a reference for the economic analysis, along with PR&G (CEQ 2013 and 2014), NRCS Department Manual (DM) 95000-013 (USDA 2017), and the NRCS Decision Memorandum for PR&G (NRCS 2018). The economic analysis was completed by Long Watershed Planning Economics, LLC who has over 20 years of experience. The analysis included the Future with Federal Investment (FWFI) alternatives and the Future Without Federal Investment (FWOFI) alternative or the No Action Alternative.

The economic evaluation used a quantification and valuation of flood damages with and without the project measures by flooding depth for each modeled storm event. Monetary economic benefits due to project action identified for the analysis included flood prevention to buildings. Flood damage reduction benefits were assessed based on the equivalent annual damage reduction expected through implementation of the FWFI Alternatives as compared with the FWOFI baseline.

Average annual flood damages were calculated using the cumulative probability method as specified in the URB1 manual (SCS 1990). The 2- through 500-year storm events, modeled by BC&A in HEC-RAS, were used to determine flood damages. Inundated structures were classified into one of three categories: inundated less than 1 foot, inundated 1 to 3 feet, or inundated greater than 3 feet, for each storm event.

Structure depth-damage functions were collected from the USACE to use for each type of structure (USACE 2004). A depth damage function for one story homes without a basement was used for residences and the appropriate depth-damage function was used for other structures.

The period of analysis for all alternatives is 101 years. All costs and benefits over the evaluation period were discounted to a net present value, then annualized over the period of analysis using the 2023 Federal Water Resources Discount Rate of 2.5%. Refer to Section 3.5 of the PR&G Analysis Report included in Appendix E for calculated benefits and costs.

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