

Appendix D

Investigation and Analysis Report



Investigation and Analysis Report for Santa Clara Watershed Project 05-05 2023 (9:30 PM)

Appendix D

Santa Clara Watershed

Washington County, Utah

The purpose of the Investigation and Analysis Report is to present information that supports the formulation, evaluation, and conclusions of the proposed Santa Clara Watershed Plan- Environmental Assessment (Plan-EA). 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 watersheds/dams or their deficiencies or 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.

March 2024

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D.1 Introduction

The planning studies presented in this Investigation and Analysis Report (I&A Report) are based on standard methods, procedures, and computer programs used and approved for use by the U.S. Department of Agriculture (USDA) Natural Resources Conservation Service (NRCS). The following information provides a summary of the investigation and analysis for the key planning studies in the preparation of the Plan-EA for the proposed Santa Clara Watershed Project. Additional information relevant to each of the sections 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:

USDA-NRCS

Wallace F. Bennett Federal Building

125 South State Street, Room 4010

Salt Lake City, Utah 84138-1100

Washington County is proposing to repair or install a series of new detention basins in Dammeron Valley and Diamond Valley in Washington County, Utah and to provide armoring along the Santa Clara River on Shivwits land near Ivins, Utah. The basins and armoring will provide flood protection to the local communities and Shivwits Tribe farming area.

The project includes the construction of three detention basins on dry washes to the east of Dammeron Valley; the rerouting of existing flows to an adjacent-routed channel on the south end of Dammeron Valley; the re-establishment of three existing detention basins in Diamond Valley; the armoring and protection along an existing channel in Diamond Valley; armoring portions of the south bank of the Santa Clara River just west of the Shivwits tribal community near the Shem dam; repair of two stormwater drainage ditches; and the installation of an irrigation pipeline. The detention basins will include uncontrolled low-level outlets, and the dams will be earthen structures with principal spillways. The purpose of the basins is to detain peak flows during large storm events protecting downstream infrastructure. Due to homes located immediately downstream, these dams are classified as High Hazard.

Note on Vertical Datum: All elevations provided in this I&A Report for current conditions are in the Utah Coordinate System of 1983, South Zone.

D.2 Sedimentation

The proposed locations of the sediment basins are subject to flash floods and debris flows. Initial estimates of sediment accumulation have been developed for preliminary design of the project. Sedimentation was estimated using historical data conveyed by the Diamond Valley Water Manager and the following three methods:

- 1968 Pacific Southwest Inter-Agency Committee Sediment Yield Classification Procedure
- 1973 USDA Soil Conservation Service Sediment Yield Rate Map

- 1982 Strand and Pemberton method developed for the semiarid climate of the southwestern United States

To our knowledge, written records providing indication for sediment accumulation at the existing Diamond Valley sites are not available. Based on verbal reports from Mr. John Crazier (personal communication, 2022), who has lived in Diamond Valley for about 30 years and is the current Water Manager for the Diamond Valley Acres Water Company, we understand that sediment accumulation in the existing detention basins has not significantly reduced the basin capacities. We understand that soil materials have been borrowed from the Diamond Valley 1 and 2 sites periodically, but the primary purpose of the borrow work was to obtain materials for use at other sites. The borrow has not been considered necessary to remove accumulated sediments.

D.2.1 Sediment Yield Classification Procedure

The Pacific Southwest Inter-Agency Committee developed a sediment yield classification procedure that estimates sediment yield as a function of nine individual drainage basin characteristics. Each characteristic is given a subjective numerical rating based on observation and experience. Sediment yield per unit area of the drainage basin is estimated based on the category determined by the sum of the classification ratings.

Based on the analyses performed, the estimated average annual sediment yields within the project area will be 0.2–0.5 acre-feet/ mile².

D.2.3 Estimated Sediment Yield Rate Map

An estimated sediment yield rate map for the State of Utah was prepared by the USDA Soil Conservation Service in 1973. This map is a general area map with cautions that it is not to be used for specific sites since large variations may occur in the delineated areas. The Dammeron Valley sites are in an area mapped as Yield Class 3 (0.5–1.0 acre-feet/ mile² per year) and Yield Class 5 (0.1–0.2 acre-feet/ mile² per year). The Diamond Valley sites are in an area mapped as Yield Class 3 (0.5–1.0 acre-feet/ mile² per year) and Yield Class 4 (0.2–0.5 acre-feet/ mile² per year).

D.2.4 Strand and Pemberton Method

An empirical method to estimate sediment yield within the semiarid western United States was developed by Stand and Pemberton in 1982. The estimated sediment yield is calculated using the following equation:

$$Q = 1.84A_d^{-0.24}$$

Where Q = annual sediment yield, acre-feet/ mi²

A_d = drainage area, square miles

This method results in estimated annual average sediment yield rates between 1.4 and 2.5 acre-feet/ mile². The sediment yield rates calculated using this method are significantly higher than the rates estimated by the methods described above.

D.2.5 Recommended Sediment Yield

Based upon the analyses performed, we recommend that the design of the Dammeron Valley detention basins assumes the average annual sediment yield will be 0.5 acre-feet/mile². This value is the upper value estimated using the Sediment Yield Classification Procedure, which considered site-specific characteristics of the Dammeron Valley project drainage basins. The sediment yield rates calculated using the Strand and Pemberton method are significantly higher than the rates estimated by the other two methods described above and, in our opinion, are less credible than those estimated using site-specific data.

Actual sediment accumulation within detention basins is dependent upon the volume of sediment transported (sediment yield), the characteristics of the sediment load, the flow velocity through the detention basin, and other factors. The detention basins planned for this project will have low-level un-gated principal spillways. Gravel and sand particles will likely be retained within the basins; however, fine clay particles will likely remain in suspension and be transported through the basin spillways.

The existing alluvial materials within the proposed basin footprints are likely representative of the sediment materials which will accumulate within the basins during the life of the facilities. As described in Section 4 of this report, the existing overburden soils at the Dammeron Valley sites were predominantly granular soils. Laboratory testing performed on samples obtained from the Dammeron Valley sites had an average of 32 percent fines passing a No. 200 sieve. Since it is likely that the majority of the fines will not be deposited within the detention basins, a trap efficiency of 70 percent is recommended for the Dammeron Valley detention basins.

Based on our analyses and reported historical sediment accumulation, we recommend that an annual sediment yield of 0.25 acre-feet/mile² be assumed for the Diamond Valley 1 and 2 detention basins.

The Diamond Valley 3 basin has been in place for at least 30 years. From aerial photos, it appears that the area at the Diamond Valley 3 basin where sediments have accumulated is about 0.35 acre. Assuming an average sediment depth of 5 feet results in a total estimated sediment accumulation of 1.8 acre-feet.

The materials at the Diamond Valley sites had more fine-grained soils compared to the Dammeron Valley sites. Laboratory testing performed on samples obtained from the Diamond Valley sites, neglecting the existing embankment soils, had an average of 54 percent fines passing a No. 200 sieve. A trap efficiency of 50 percent is recommended for the Diamond 1 and 2 Detention Basins.

The Diamond 3 Detention Basin will function as a diversion structure, and outflows from the basin will be approximately equal to inflows during design storm events. The Diamond 3 Detention Basin will be designed assuming that 25 percent of the sediment load will be trapped in the basin, 25 percent will be trapped in the Diamond 2 Detention Basin, and 50 percent will be transported through the basins without being trapped.

Based on the analyses described above, design of the detention basins assumes the following sediment accumulation rates.

Table D-1. Design Sediment Accumulation

Site	Approx. Drainage Basin Area (mile ²)	Estimated Average Annual Sediment Accumulation (acre-feet)	Estimated 50-year Sediment Accumulation (acre-feet)
Dammeron 1	0.28	0.11	5.5
Dammeron 2	3.6	1.4	70
Dammeron 3	0.73	0.27	14
Diamond 1	0.90	0.11	5.5
Diamond 2	0.93	0.15	7.5*
Diamond 3	0.60	0.04	2.0

Table D-1 Footnote:

*Includes 2 acre-feet from the Diamond 3 drainage area.

D.3 Flooding and Risk Analysis

Hydrologic and hydraulic analyses have been performed for the Dammeron Valley and Diamond Valley detention basins (**Attachments 7 and 8**). Inundation maps have been prepared based on these analyses (**Attachment 9**). For Dammeron Valley, the inundation areas during a breach of each dam are summarized below, extending down through the community, agricultural land, and a state highway before ultimately draining through natural and improved drainage corridors into the Santa Clara River approximately 11 miles downstream. The areas shown below are the inundation boundaries upstream of the state highway, which are the areas with any form of development or improvements.

- Dammeron 1: 154 ac
- Dammeron 2: 156 ac
- Dammeron 3: 157 ac

For Diamond Valley, the inundation areas during a breach of each dam are summarized below, extending through the community and into a primary drainage corridor through the community before ultimately draining through natural and improved drainage corridors into the Santa Clara River approximately 4 miles downstream. The areas shown below are the inundation boundaries upstream of the state highway and down approximately 1,000 feet from what is currently the furthest south development.

- Diamond 1: 203 ac
- Diamond 2: 247 ac
- Diamond 3: 214 ac

The hazard classification of all the detention basin dams is “high.” The total population at risk is estimated to be 260 for Dammeron Valley and 488 for Diamond Valley, which is the maximum loss of life in the event of a dam failure.

D.4 Geology

D.4.1 Regional Geology

The project area is located near the southwestern corner of Utah and is within the transition zone between the Basin and Range Physiographic Province to the west and the Colorado Plateau Province to the east. The Basin and Range province is typified by a series of northerly trending uplifted mountain ranges and down dropped valleys (horsts and grabens) created by normal faulting resulting from extensional forces. The Colorado Plateau to the east is an area of much greater stability with significantly less seismic activity.

The transitional zone is an area of relatively complex geology with bedrock varying in age from the Proterozoic (greater than 542 million years ago [mya]), as seen in the Beaver Dam Mountains to the west, to younger Quaternary age (less than 0.5 mya) basalt flows. Most of the colorful red-rock scenery is found in the Triassic and Jurassic age sedimentary deposits. The region owes the majority of its present-day structure to geological events younger than ~100 mya (later Cretaceous).

The region went through a period of compressional activity that pushed and compressed western Utah toward eastern Utah, generating folds and overthrust faulting. Periods of compressional activity occurred during the Sevier Orogeny (~100 mya) and Laramide Orogeny (70 mya). During the Tertiary period (Oligocene–early Miocene), a large igneous intrusion pushed up into the southwestern Utah overlying bedrock as a large, shallow, mushroom-shaped intrusion (20.5 mya). This created an uplifted dome where the overlying fractured rock more readily eroded away, leaving behind the Pine Valley Mountains. The Pine Valley laccolith is the largest laccolith in America (Cook 1957, 1960b; Biek et al., 2007). During this time, compressional forces began to be replaced by extensional forces resulting in volcanism and Basin and Range faulting.

The transition zone is broken up by numerous northerly trending faults. This zone of faults makes up the southern end of the Intermountain Seismic Belt (ISB), which trends from western Montana into northern Arizona (Smith and Arabasz 1991). This relatively narrow belt generates a significant amount of seismic activity with numerous active and potentially active faults. The ISB within southwestern Utah is generally considered to be constrained on the east side by the Hurricane fault zone and on the west side by the Gunlock and Grand Wash fault zone. The Gunlock Fault, Washington Fault, and Hurricane Fault are located about 5.5 miles west, 14 miles southeast, and 20 miles east of the project area, respectively.

Dammeron and Diamond Valleys are located southwest of the Pine Valley mountains and east of the Gunlock Fault. Several basalt flows and cinder cones are present within the vicinity of the project area. Volcanism in the region is inactive; however, seismic activity continues. Since 1962, Basin and Range extensional faulting has generated 5 earthquakes with magnitudes of at least 5

within 50 miles of the project area.¹ The second largest earthquake recorded in Utah since 1850, which occurred in Pine Valley in November 1902, had an estimated magnitude of 6.3. The Pine Valley earthquake epicenter was about 8.5 miles northeast of Dammeron Valley.

D.4.2 Dammeron Valley

The topography in the Dammeron Valley area generally slopes towards the southwest. The topography at the proposed dam alignments slopes down towards the drainage channels at a rate of between about 5 and 20 percent. The drainage channel grades within the proposed detention basin are generally less than about 5 percent.

The surficial geology for the proposed Dammeron Valley detention basins, as mapped by R. F. Biek et. Al.,² is shown on the geologic maps included in **Attachment 1**. The western portion of the Dammeron 1 detention basin and dam is located in an area mapped as Quaternary alluvial and eolian deposits (Qae), consisting of gravel, sand, and silt deposited in small channels and alluvial flats, with some windblown deposits. The Cretaceous age Cedar Mountain Formation (Kcm) is mapped near the right abutment of the dam alignment. Cedar Mountain Formation bedrock may underlie the alluvium on the western side of the planned detention basin.

The southeastern portion of the Dammeron 1 detention basin and the majority of the dam is within an area mapped as Quaternary age Dammeron³ Valley East lava flow and cinder cone (Qbde). The thickness of the lava flow is generally 10 to 20 feet thick. The lava flow deposits were encountered in test holes performed for the detention basin and are shown on the logs as basalt deposits.

As shown in **Attachment 1**, Dammeron 2 Detention Basin is in an area mapped as Quaternary age Dammeron Valley and Saddle Mountain lava flows and cinder cones (Qbde and Qbsm). As stated above, the Dammeron Valley lava flow deposit is typically 10 to 20 feet thick. The Saddle Mountain deposit is typically 20 to 40 feet thick.

The northern end of the proposed Dammeron 3 detention basin and dam is in an area mapped as Dammeron Valley lava flow and cinder cone deposits. The central portion of the dam and basin is in an area mapped as Quaternary alluvium and colluvium (Qac). Fingers of the Jurassic Age Co-op Creek Limestone Member of the Carmel Formation (Jcc) are mapped near the south end of the proposed alignment. The Jcc formation consists of limestone and may also contain calcareous shale, platy limestone, fine-grained sandstone, and some gypsiferous mudstone and siltstone.

¹ *Utah Earthquakes (1850–2016) and Quaternary Faults*, Bowman, S.D. and Arabasz, W.J.; Utah Geological Survey Map 277, 2017.

² *Geologic Map of the St. George and East Part of the Clover Mountains 30'x60' Quadrangles, Washington and Iron Counties, Utah*; Biek, R. F. et al.; 2009.

³ Spelling of the lava flow as shown on the geologic map.

D.4.3 Diamond Valley

The existing Diamond 1 and 2 detention basins are retained by dams with maximum heights of about 10 and 15 feet, respectively. It appears that about 10 feet of native soil materials have been excavated from within the Diamond 1 basin to increase the storage capacity. It is our understanding that the existing Diamond 3 site also functions as a small detention basin. It appears that the Diamond 3 basin was constructed by creating a small berm using materials excavated from within the basin.

The planned Diamond 3 dam will direct flows towards the Diamond 2 detention basin. Outflows from the Diamond 2 detention basin currently flow within a man-made channel in a westerly direction to the Diamond 1 detention basin. It is our understanding that the existing Diamond 1 basin does not currently have an outflow channel.

The Diamond Valley community is built predominately on alluvial valley fill deposits. Along the north and east sides of the study area are hills of Jurassic to Cretaceous age bedrock which appears to dip down gently toward the northeast at about 3 degrees.

As shown in **Attachment 1**, the existing Diamond 1 Detention Basin is in an area mapped as Quaternary alluvial and eolian deposits (Qae), consisting of gravel, sand, and silt deposited in small channels and alluvial flats. The east side of the basin is near the mapped boundary of the Jurassic age Sinawava Member of the Temple Cap Sandstone (Jts) formation, which contains mudstone, siltstone, and silty sandstone materials.

Diamond 2 Detention Basin is within an old faulted wash. The majority of the existing dam footprint and basin are in an area mapped as Holocene to upper Pleistocene age alluvial and colluvial deposits (Qac), described as clay to boulder-sized sediment. The material underlying the upper portion of the existing dam abutments and upper portion of the basin is mapped as Co-op Creek Limestone (Jcc). The fault line which trends northeast/southwest through the center of the dam and basin is the Wide Canyon Fault. This fault is listed on the Utah Quaternary Fault and Fold Database, but it is not listed on the U.S. Geological Survey (USGS) Quaternary Fault and Fold Database. The fault is believed to be more than 750,000 years old and is not considered to be active.

The proposed Diamond 3 Detention Basin is in an area mapped similarly to the Diamond 2 site, with Co-op Creek Limestone mapped near both abutments and alluvial and colluvial deposits mapped in the center of the dam and basin.

The Utah Geologic Survey published a series of Geologic Hazard maps for the St. George–Hurricane Metropolitan Area in 2008. Most of the project area is beyond the northern limit of the 2008 study area; however, Diamond 3 Detention Basin is within the study area. The hazard map shows the area as having a high risk for flooding associated with flash floods and debris flows, and reducing this risk is the primary purpose of the proposed project. Rockfall hazard, with rock debris usually less than 1.5 feet in size, is shown as moderate due to the existing relatively steep slopes in the Diamond 3 basin area. Soils in this area are classified by the NRCS as having a low susceptibility for expansive volumetric changes. The bedrock units are classified as having a moderate shrink/swell susceptibility, with collapse potential which can be greater than 3 percent. While the soils in this area are not mapped as having a significant amount of gypsum, the bedrock

unit surrounding the area does contain some medium-thin beds and veins of gypsum which could also be found in the alluvial material.

The area is mapped as being surrounded by hard bedrock on the geologic hazard maps, while the bottom of the basin is mapped as having buried bedrock likely more than 10 feet deep. The map identifies the alluvial deposits (Qac) as being susceptible to hazards associated with piping and erosion of the soil.

D.4.4 Geologic Hazards

The Dammeron Valley and Diamond Valley areas are subject to flash flooding and debris flows, and reducing the risk of these hazards is the primary purpose of the Santa Clara Watershed project. In addition to flooding and debris flow, the potential geologic hazards which appear to pose the greatest risk to the proposed detention basins are surface and internal erosion. Based on the results of geotechnical investigations performed during this study, the risk of inadequate debris basin performance due to soil or rock volumetric changes (shrinkage, collapse, or swell) and dissolution of soluble minerals (gypsum) appears to be low.

A probabilistic seismic hazard analysis was performed using the USGS Dynamic: Conterminous U.S. Unified Hazard Tool. The Peak Ground Acceleration in the project area for Site Class B/C boundary conditions is 0.30 gram for an earthquake event having a return period of 5,000 years.

The potential for liquefaction to result in significant strength loss beneath the detention basin dams is low since 1) it is unlikely that the foundation soils will be saturated during an earthquake event and 2) Standard Penetration Test (SPT) testing indicated that native soil deposits are generally in a state dense enough to prevent strength loss by liquefaction.

D.5 Subsurface Soil and Water

D.5.1 Field and Laboratory Testing Procedures

Subsurface investigations for the project were performed at the locations shown in **Attachment 2**. Test hole logs and sample photos are included in **Attachment 3**. The test hole numbers shown on the site plan and logs have the prefixes DA1, DA2, and DA3 (Dammeron Valley 1, 2, and 3) and DI1, DI2, and DI3 (Diamond Valley 1, 2, and 3) to indicate the basin where the hole was performed. The test holes were numbered in accordance with NRCS standards, with test holes XXX-1 through 99 performed along the proposed dam alignment and test holes XXX-101 through 199 performed within the proposed detention basins to investigate potential borrow areas.

Investigations performed for this study assumed that earth fill materials would be obtained from within the proposed detention basins or from previously developed commercial sources. We envision that the majority of the materials to be used for construction of detention dams will be obtained from within the basins, and processed filter and drain materials will be obtained from commercial sources. Riprap may be obtained from a combination of available materials within the basins or commercial sources.

The borings were drilled using a CME 55 rotary drill rig. A tri-cone rock bit, and HW or NW casing, with water as the drilling fluid, were used to advance the borings through overburden materials. Drilling and sampling were performed using NWJ drilling rods.

Disturbed samples were obtained within overburden materials by driving a 2- or 2.5-inch outside diameter split spoon sampling tube through a distance of 18 inches using a 140-pound weight dropped from a distance of 30 inches. The sampler size is indicated on the boring logs. Based on energy evaluations conducted approximately annually in general accordance with ASTM D4633, the automatic trip hammer used for sampling with the CME-55 drill rig delivers an average energy greater than 80 percent of the theoretical maximum energy.

The number of hammer blows required to drive the sampling spoon through each 6 inches of penetration is shown on the boring logs. The sum of the last two blow counts, which represents the number of blows recorded while driving the sampling spoon through 12 inches, is defined as the penetration value, N .

Penetration values corrected for sampler size, overburden, and hammer energy provide a good indication of the in-place density of sandy soils; however, they only provide an indication of the relative stiffness of cohesive material, since the penetration resistance of materials of this type is a function of moisture content. Considerable care must be exercised when interpreting the penetration value in gravelly type soils, particularly where the size of the granular particles exceeds the inside diameter of the sampling spoon. The penetration value generally provides a good indication of the in-place density of gravelly-type material if the spoon can be driven through the full 18 inches with reasonable sample recovery.

Corrections applied to the blow counts to determine the corrected standard penetration, $(N_1)_{60}$ values, shown on the boring logs were as follows:

- Sampler size correction for 2.5-inch OD sampler (where applicable): multiply by 0.938
- Hammer energy correction from 80 percent hammer energy ratio to 60 percent standard energy ratio: multiply by 1.33
- Overburden correction: multiply by $C_N = (P_a / \sigma'_v)^{0.5} \leq 1.7$

where: P_a = atmospheric pressure, approximated as 2000 per square foot (psf),

σ'_v = effective vertical stress, calculated using assumed average total soil unit weights of 120 pcf, and hydrostatic pore pressure calculated from the measured or estimated groundwater level.

The SPT corrections listed above are basic corrections based on generalized interpretations and assumptions. Different and/or additional corrections may be appropriate for specific design applications.

Relatively undisturbed samples were obtained at select locations by pushing a thin-walled sampling tube into the subsurface material using the hydraulic pressure on the drill rig. The locations at which the undisturbed samples were obtained are shown on the boring logs.

Miniature vane shear and pocket penetrometer tests were performed on some of the cohesive samples retrieved from the borings. Miniature vane shear tests, which provide an indication of undrained shear strength, were generally performed on samples with strengths less than about

1,000 psf. Pocket penetrometer tests, which provide an indication of the unconfined compressive strength, were performed on some of the stiffer samples obtained.

Each sample obtained in the field was classified according to the Unified Soil Classification System. The symbol designating soil type according to this system is presented on the boring logs. A description of the Unified Soil Classification System is included in **Attachment 4**, and the meanings of the various symbols shown on the logs can be obtained from this figure.

Bedrock materials encountered within the borings were continuously cored using an NQ wireline system. The percentage of the core run recovered and the Rock Quality Designation (RQD) values measured during the subsurface investigations are shown on the boring logs. The RQD is the percentage of intact core pieces at least 4 inches in length recovered from a single core run. A correlation of rock quality with RQD values is provided in Attachment 3.

Constant head open-hole permeability testing was performed within subsurface materials during the investigations. The tests were performed by drilling ahead of the casing, filling the casing with water, and recording the rate at which water was added to maintain the water level at the top of the casing. Permeability values were calculated using the methods described in *Design of Small Dams* (USBR 1987).

Test pits were excavated using a John Deere 160 excavator operated by Probitas Inc. The test pits were excavated to depths between 10 and 15 feet below the existing ground surface except where excavation was impractical due to the presence of bedrock or dense gravelly materials.

Laboratory testing was performed in accordance with ASTM International standards, except that tests to determine water soluble solids were performed in accordance with a Bureau of Reclamation standard since ASTM does not have a comparable test method. Tests performed during the investigations include:

- Moisture Content (ASTM D2216)
- Sieve Analysis (ASTM C117, C136)
- Atterberg Limits (ASTM D4318)
- Unconfined Compression (ASTM D7012)
- Dispersive Clay (Pinhole, ASTM D4647)
- Consolidation (ASTM D2435)
- Direct Shear (ASTM D3080)
- Moisture Density Relationship (Proctor, ASTM D698)
- Permeability (ASTM D5084)
- Water Soluble Solids (USBR 5450)

The results of the laboratory testing are included in **Attachment 4**.

D.5.2 Subsurface Conditions

As shown on the test hole logs, cobbles and boulders were encountered in many of the test holes. The test results discussed below do not generally include the cobble and boulder size fractions of the materials. Estimates of the sizes and fractions of the cobbles and boulders are shown on test pit logs.

D.5.2.1 Dammeron 1 Detention Basin

The Dammeron 1 Detention Basin dam alignment was investigated by drilling Boring DA1-1 near the bottom of the drainage channel to a depth of 30 feet below the existing ground surface, excavating Test Pit DA1-2 within the left abutment area, and excavating Test Pit DA1-3 within the right abutment area. Test Pits DA1-101 through -103 were excavated within the proposed basin to investigate potential borrow materials.

Basalt rock was encountered about 6 and 3 feet below the ground surface in DA1-1 and DA1-2, respectfully. Bedrock was not encountered within the other test holes performed at this site.

Recovery, which was between 19 and 100 percent, and RQD values, which were between 0 and 57 percent, measured from the basalt core obtained from Boring DA1-1 indicate the rock quality is very poor to fair and is highly fractured and/or fissured. The hydraulic conductivity values calculated from the permeability tests were between 210 and 3,300 feet/year. Basalt deposits are generally highly fractured and fissured due to the volcanic deposition and cooling process. In our experience, the hydraulic conductivity values are relatively low to moderate compared to other basalt deposits. It appears likely that many of the fractures/ fissures at this site are infilled with soil or other mineral deposits. Laboratory testing performed on samples of the basalt are summarized below.

Table D-2. DA1 Site Basalt Rock Properties

Soil Property	No. of Tests	Range	Average
Dry Unit Weight (pcf)	2	136.3–139.1	137.7
Moisture Content (%)	2	0.4–0.5	0.5
Unconfined Compressive Strength (psi)	2	4,840–8,730	6,785
In-Situ Hydraulic Conductivity (feet/year)	5	210–3,300	1,400

The overburden soils encountered in the test holes at this site were predominantly mixtures of sands and gravels with low to medium plastic fines; however, deposits of fat clay (CH) several feet thick were encountered in Test Pits DA1-101 and 102. Laboratory testing performed on samples of overburden are summarized below.

Table D-3. DA1 Site Overburden Material Properties

Soil Property	No. of Tests	Range	Average
(Fat Clay Samples) Moisture Content (%)	2	15.0–19.5	17.3
(Fat Clay Samples) Liquid Limit (%)	2	53–55	54
(Fat Clay Samples) Plasticity Index (%)	2	27–34	31
(Fat Clay Samples) Gravel Content (%)	2	1–2	2
(Fat Clay Samples) Sand Content (%)	2	7–22	15
(Fat Clay Samples) Silt/ Clay Content (%)	2	77–91	84
(Fat Clay Samples) Dispersive Clay	2	Non-Dispersive (ND-1 & ND-2)	N/A
(Sand and Gravel Samples) Moisture Content (%)	5	2.6–14.4	8.2
(Sand and Gravel Samples) Liquid Limit (%)	4	24–62	38
	1	Non-plastic	N/A
(Sand and Gravel Samples) Plasticity Index (%)	4	4–37	15
(Sand and Gravel Samples) Gravel Content (%)	5	6–41	23
(Sand and Gravel Samples) Sand Content (%)	5	37–60	52
(Sand and Gravel Samples) Silt/ Clay Content (%)	5	16–40	25
(Sand and Gravel Samples) Water Soluble Solids (%)	3	0.27–1.15	0.57
(Sand and Gravel Samples) Dispersive Clay	2	Non-Dispersive (ND-1)	N/A
(Sand and Gravel Samples) In-Situ Hydraulic Conductivity (feet/ year)	2	32–650	340
(Sand and Gravel Samples) Laboratory Hydraulic Conductivity—Remolded and Compacted Sample (cm/ sec)	2	2.62×10^{-8} – 1.09×10^{-5}	5.5×10^{-6}

Soil Property	No. of Tests	Range	Average
(Sand and Gravel Samples) Moisture Density Relationship—Standard	2	102.3–106.6	104.5
(Sand and Gravel Samples) Maximum Laboratory Density (pcf)	2	16.3–20.8	18.6
(Sand and Gravel Samples) Optimum Moisture Content	2	24.5–28.0	26.3
(Sand and Gravel Samples) Direct Shear Friction Angle—Remolded and Compacted Sample Cohesion	2	4.5–7.2	5.9

D.5.2.2 Dammeron 2 Detention Basin

The Dammeron 2 Detention Basin dam alignment was investigated by drilling Boring DA2-1 near the bottom of the drainage channel to a depth of 30 feet below the existing ground surface, excavating Test Pit DA2-2 within the left abutment area, and excavating Test Pit DA2-3 within the right abutment area. Test Pits DA2-101 through -106 were excavated within the proposed basin to investigate potential borrow materials.

The overburden soils encountered in the test holes along the dam alignment were predominantly mixtures of sands and gravels with non-plastic fines. Laboratory testing performed on samples of overburden are summarized below.

Table D-4. DA2 Site Material Properties

Soil Property	No. of Tests	Range	Average
Moisture Content (%)	3	6.1–14.4	10.0
Liquid Limit (%)	1	33	33
	4	Non-plastic	N/ A
Plasticity Index (%)	1	13	13
Gravel Content (%)	5	17–46	37
Sand Content (%)	5	31–53	45
Silt/ Clay Content (%)	5	4–39	18
Water Soluble Solids (%)	1	0.1	0.1

Soil Property	No. of Tests	Range	Average
Dispersive Clay	1	Non-Dispersive (ND-1)	N/ A
In-Situ Hydraulic Conductivity (feet/ year)	5	52–520	270
Maximum Laboratory Density (pcf)	2	84.3–100.2	92.3
Optimum Moisture Content	2	20.2–32.5	26.4
Moisture Density Relationship—Standard Maximum Laboratory Density (pcf)	2	81.1–100.2	90.7
Optimum Moisture Content	2	20.2–35.1	27.7

Basalt rock was encountered 22 feet below the ground surface in DA2-1. Bedrock was not encountered within the other test holes performed along the dam alignment; however, basalt rock was encountered within 2 feet of the ground surface within all six test pits excavated within the proposed basin.

Recovery, which was between 28 and 100 percent, and RQD values, which were between 0 and 92 percent, measured from the basalt core obtained from Boring DA2-1 indicate the rock is relatively intact to highly fractured and/or fissured. A hydraulic conductivity test was performed within the zone between 20 and 27 feet below the ground surface. The hydraulic conductivity of the zone could not be determined because the flow into the formation exceeded the capacity of the pumping equipment being used (17.7 gallon/ minute).

The basalt core obtained from a depth of 25 feet in Boring DA2-1 had a moisture content of 0.7 percent, dry unit weight of 170.2 pcf, and unconfined compressive strength of 14,630 psi.

D.5.2.3 Dammeron 3 Detention Basin

The Dammeron 3 Detention Basin dam alignment was investigated by drilling Boring DA3-1 near the bottom of the drainage channel to a depth of 32.5 feet below the existing ground surface and excavating Test Pits DA3-2 through -5 along the proposed detention basin dam alignment. Test Pits DA3-101 through -107 were excavated within the proposed basin to investigate potential borrow materials.

The overburden soils encountered in the test holes were predominantly mixtures of sands and gravels with low to medium plastic fines. Clay layers up to about 4 feet thick were encountered at the ground surface in several of the test pits. Laboratory testing performed on samples of overburden are summarized below.

Table D-5. DA3 Site Material Properties

Soil Property	No. of Tests	Range	Average
Moisture Content (%)	14	2.6–10.1	6.4
Liquid Limit (%)	10	20–57	33
	8	Non-plastic	N/ A
Plasticity Index (%)	10	4–34	15
Gravel Content (%)	18	1–60	25
Sand Content (%)	18	2–71	43
Silt/ Clay Content (%)	18	5–97	32
Water Soluble Solids (%)	8	0.1–2.96	0.66
Dispersive Clay	5	Non-Dispersive (ND-1)	N/ A
	1	Dispersive (D-1)	N/ A
In-Situ Hydraulic Conductivity (feet/ year)	6	0–850	110
Laboratory Hydraulic Conductivity—Remolded and Compacted Sample (cm/ sec)	2	6.91×10^{-7} – 5.23×10^{-5}	2.65×10^{-5}
Maximum Laboratory Density (pcf)	8	96.8–128.7	110.5
Optimum Moisture Content	8	8.7–20.6	14.7
Direct Shear Friction Angle—Remolded and Compacted Sample Cohesion	2	28.0–29.7	28.9
		0–1.9	1.0
Swell Potential from Consolidation Test	1	0.1%	0.1%

D.5.2.4 Diamond 1 Detention Basin

The Diamond 1 Detention Basin dam alignment was investigated by drilling Borings DI1-1 and -2 through the existing embankment. There are no known drawings from construction of the existing detention basin, and the project conceptual design includes removing and reconstructing the existing embankment. It is likely that the reconstructed embankment will be slightly upstream of the existing embankment due to property constraints.

The soil materials encountered at the site predominantly consisted of sandy and clayey soils. Laboratory testing performed on samples from this site are summarized below.

Table D-6. DI1 Site Material Properties

Soil Property	No. of Tests	Range	Average
Moisture Content (%)	7	8.4–13.8	11.2
In-Situ Dry Unit Weight (pcf)	4	101.7–124.3	111.8
Liquid Limit (%)	6	17–28	24
	1	Non-plastic	N/A
Plasticity Index (%)	6	3–12	8
Gravel Content (%)	7	0–1	0
Sand Content (%)	7	17–64	42
Silt/ Clay Content (%)	7	35–83	58
Water Soluble Solids (%)	2	0.36–0.39	0.38
Dispersive Clay	2	Non-Dispersive (ND-2)	N/A
In-Situ Hydraulic Conductivity (feet/ year)	10	5–780	230
Swell/ Collapse Potential from Consolidation Test	2	<0.1%	<0.1%

D.5.2.5 Diamond 2 Detention Basin

There are no known drawings from construction of the existing Diamond 2 Detention Basin, and the project conceptual design includes removing the existing embankment and constructing a new embankment upstream of the existing. Moving the embankment is envisioned due to property constraints. The Diamond 2 Detention Basin dam alignment was investigated by drilling Boring DI2-1 through the existing embankment, drilling DI2-2 at the assumed alignment of the new embankment, and drilling DI2-101 within the detention basin.

The soil materials encountered at the site predominantly consisted of clayey materials; however, gravelly materials were encountered within Boring DI2-101. Laboratory testing performed on samples from this site are summarized below.

Table D-7. DI2 Site Material Properties

Soil Property	No. of Tests	Range	Average
(Clayey Samples) Moisture Content (%)	7	8.0–26.6	14.8
(Clayey Samples) In-Situ Dry Unit Weight (pcf)	1	100.7	100.7
(Clayey Samples) Liquid Limit (%)	7	24–30	26
(Clayey Samples) Plasticity Index (%)	7	9–15	11
(Clayey Samples) Gravel Content (%)	7	0–10	5
(Clayey Samples) Sand Content (%)	7	42–51	45
(Clayey Samples) Silt/ Clay Content (%)	7	46–56	50
(Clayey Samples) Water Soluble Solids (%)	1	0.35	0.35
(Clayey Samples) Dispersive Clay	2	Non-Dispersive (ND-1)	N/ A
(Clayey Samples) In-Situ Hydraulic Conductivity (feet/ year)	6	42–6,400	1,400
(Gravel Sample) Moisture Content (%)	1	8.7	8.7
(Gravel Sample) Liquid Limit (%)	1	Non-plastic	N/ A
(Gravel Sample) Gravel Content (%)	1	65	65
(Gravel Sample) Sand Content (%)	1	25	25
(Gravel Sample) Silt/ Clay Content (%)	1	10	10
(Gravel Sample) Water Soluble Solids (%)	1	0.09	0.09

D.5.2.6 Diamond 3 Detention Basin

The proposed Diamond 3 Detention Basin dam alignment was investigated by drilling Boring DI3-1. The soil materials encountered at the site consisted predominantly of clayey materials. Laboratory testing performed on samples from this site are summarized below.

Table D-8. DI3 Site Material Properties

Soil Property	No. of Tests	Range	Average
Moisture Content (%)	2	15.1–24.0	19.6
In-Situ Dry Unit Weight (pcf)	1	98.8	98.8
Liquid Limit (%)	2	32–34	33
Plasticity Index (%)	2	18	18
Gravel Content (%)	2	0–35	18
Sand Content (%)	2	29–35	32
Silt/ Clay Content (%)	2	36–65	51
Swell/ Collapse Potential from Consolidation Test	1	<0.1%	<0.1%
In-Situ Hydraulic Conductivity (feet/year)	6	5–4,800	2,300

Mr. John Cazier reported that a detention basin was constructed at this site by the Bureau of Land Management (BLM) at least 30 years ago. From site observations, it appears that the detention basin was created by constructing a berm a few feet high using soils excavated from within the basin. The relatively high hydraulic conductivity values within the upper 15 feet of Boring DI3-1 may, in part, be due to the presence of recently (less than 100 years) deposited sediments. However, from site topography and observations, it is unlikely that the recent sediments are 15 feet deep.

D.5.3 Groundwater

Groundwater was not encountered within any of the test holes performed for this study, except that water was measured 28 feet below the ground surface in Boring DA1-1. The water measured in Boring DA1-1 may have been influenced by drill water used during the drilling work.

D.6 Geotechnical Analysis

D.6.1 Available Borrow Materials

Earthfill materials generally having 20 to 80 percent plastic fines are available for use as borrow from the Dammeron 1 Detention Basin site. Fat clay was encountered in the lower portion of Test Pits DA1-101 and -102. Use of the fat clay for construction of dam embankments is not recommended. About 20,000 yd³ of earthfill generally having 20 to 80 percent passing a No. 200 sieve is available for use from the DA1 site. Processing the earthfill materials to remove cobbles and boulders will be required during construction of embankments.

Basalt rock, which was not practicable to excavate, was encountered within the test pits performed within the Dammeron 2 Detention Basin site. Assuming the basalt is at least 10 feet thick, we estimate that 85,000 yd³ of basalt is available to borrow for use as riprap or rockfill within the DA2 detention basin site. Assuming that blasting will be required to efficiently borrow the basalt materials, we recommend that all rock needed for construction of the project be borrowed and stockpiled prior to DA2 Detention Basin foundation treatment or embankment construction. We recommend that the limits of the basalt borrow area be at least 100 feet from the planned footprint of the dam embankment. Investigations to evaluate the quantity and quality of the basalt should be performed during final design. Basalt deposits in southwestern Utah are generally suitable for use as riprap.

Earthfill materials, which are predominantly gravelly soils, are available for use as borrow from the Dammeron 3 Detention Basin site. About 200,000 yd³ of gravelly soil is available to be borrowed from within the DA3 site. Processing the materials to remove cobbles and boulders will be required during embankment construction.

The existing embankment fill at the Diamond 1 and 2 Detention Basin sites, which is predominantly clayey and sandy soil, is suitable for re-use during construction of the embankments. Native deposits encountered within the existing foundations was also predominantly clayey and sandy, and it is likely that additional earthfill materials can be borrowed from within the basins for use as embankment fill. The results of the investigations indicate that less processing to remove oversize rocks will be required at the Diamond Valley sites compared to the Dammeron Valley sites.

D.6.2 Foundation Treatment

D.6.2.1 Dammeron Valley Sites

Basalt and other fractured rock within the dam embankment footprints should be treated to prevent internal erosion caused by soil particles migrating into open bedrock features under hydraulic gradients. The risk of internal erosion is reduced where gravelly soils are present on top of the rock materials since investigations at the Dammeron Valley sites indicate few, if any, open bedrock features are large enough to allow movement of gravel size particles. If particle movement begins to occur in areas where gravelly soils are present, the gravel will likely collect near the top of the openings. Sand will nest on the gravelly matrix, then finer particles will nest on the sand.

Conceptual design cross sections for the Dammeron Valley Detention Basins are included in **Attachment 5**. A conceptual cross section for areas where the bedrock is more than 10 feet below the existing ground surface, less than 10 feet below the existing ground surface, and an alternative section are included in the attachment.

In areas where the bedrock is at least 10 feet below the native ground surface, a keyway trench beneath the dam centerline is recommended. The keyway trench depth should be equal to the maximum height of the dam divided by 5, i.e., the trench depth is 6 feet for a dam with a maximum height of 30 feet. The keyway trench should have side slopes no steeper than 1H:1V with a base width of at least 15 feet.

In areas where the bedrock is within 10 feet of the existing ground surface, the conceptual design assumes that overburden soils will be removed beneath the center and upstream portions of the dam. For conceptual design, we have assumed that a 4-inch-thick layer of unreinforced concrete

will be constructed on top of the bedrock to mitigate the potential for internal erosion into open rock features. This cross section has been assumed for the western two-thirds of the DA1 dam and southern one-half of the DA3 dam.

D.6.2.2 Diamond Valley Sites

The alternative cross section shown in **Attachment 6** has been used for conceptual design of the Diamond Valley Detention Basin dams. Hydraulic conductivity test results indicate that the native soils at the DI1 and DI2 sites are relatively impervious. A 3-foot-deep keyway has been included in the conceptual designs for these detention basin dams.

Soils classified as lean clay were encountered within the upper 14 feet at the Diamond 3 Detention Basin site. The hydraulic conductivities within the upper 15 feet were between 2,500 and 4,800 feet/year, which are significantly higher than values typically calculated for lean clay soils. The hydraulic conductivities may be an indication of recently deposited soil and/or fissures within the clay deposits. Additional foundation investigations at this site should be performed during final design. Assuming the detention basin dam will be about 15 feet high at this site, an 8-foot-deep keyway has been assumed beneath the DI3 detention basin dam for preliminary design. This recommended conceptual design keyway depth is about 50 percent of the planned dam height.

D.6.3 Embankment Design

Considering the foundation conditions and available borrow materials at these sites, earth-fill-type embankments are planned at the Dammeron and Diamond Valley sites. The conceptual design embankment cross sections have low-permeable soil cores and granular shells. The low-permeable core will likely be constructed using clayey materials having 20 to 80 percent passing a No. 200 sieve and a dry unit weight of at least 90 pcf. Shell materials will likely be granular soils having 5 to 50 percent passing a No. 200 sieve with a dry unit weight of at least 90 pcf. Many of the samples tested from the Dammeron Valley sites had 20 to 50 percent plastic fines passing a No. 200 sieve and can likely be used for either embankment zone.

Materials sampled from Test Pit DA2-2, located on the southeast side of the proposed Dammeron 2 Detention Basin dam, appeared to be of volcanic origin. The moisture-density relationship test (Proctor) performed in the laboratory on a sample obtained from a depth of 6 feet resulted in a maximum dry density of 84.3 pcf and optimum moisture of 32.5 percent. The material was classified as sand with gravel (SP). The test results indicate high water absorption potential. The embankment design will likely require use of the higher quality materials available from the project area, which will have better strength characteristics compared to lighter materials.

The conceptual design of the Dammeron Valley embankments has 3H:1V (Horizontal:Vertical) upstream and downstream slopes with a toe drain beneath the downstream embankment toe. This cross section is expected to perform satisfactorily for the proposed detention basins. For these detention basins, which will not have a normal storage, it is very unlikely that steady-state reservoir full seepage conditions will ever develop during the life of the facility.

The Diamond Valley detention embankments have been conceptually designed with 2H:1V downstream slopes and internal chimneys (**Attachment 5**, Alternative Cross Section). The steeper downstream slopes are necessary due to property boundaries at the Diamond Valley sites.

Toe drains, as shown in **Attachment 5**, have been included in the conceptual dam designs. The toe drain will improve the safety of the dams by reducing the risk of saturation within embankment and near-surface foundation materials. The toe drain installed beneath the downstream toe will connect to an outfall which daylights downstream of the dams.

Embankments have been designed with crest widths that meet NRCS and State of Utah requirements.

D.7 Water Quality

There is no permanent pool or perennial stream associated with the detention basins being installed with this project. The lower elevations of the drainage course appear to be intermittent while the higher reaches appear ephemeral. There are no culinary uses or habitat uses to be associated with the water discharged through the dams. The detention basins will serve as temporary storage facilities during large storm events that will release the flows at a controlled rate to protect downstream communities. As discussed in **Section D.2**, the detention basins are situated in areas that will likely produce large sediment volumes during intense rainfalls. Water storage within the detention basins will allow sediment to settle out of the water before leaving continuing downstream, thus improving downstream water quality conditions.

For the Shivwits community, the project will include the armoring of channels that will prevent further erosion. The channel armoring will include armoring the Santa Clara Riverbank and the discharge points from two diversion channels into the river. The armoring will inhibit sedimentation, thus improving downstream water quality conditions.

D.8 Hydrologic Analysis

The hydrologic and hydraulic analyses performed for the project (**Attachments 7 and 8**) includes the identification of general and local design floods per State of Utah and NRCS requirements in development of the low-level outlet and primary spillway. The design floods include the 100-year storm, Spillway Evaluation Hydrographs, the Principal Spillway Hydrograph (PSH), the Auxiliary Spillway Hydrograph (ASH), and the Freeboard Hydrograph (FBH). The results are included in **Tables D-9 through D-5** and include results for the flows attenuated through the detention basins.

Table D-9. Design Flood Information, Dammeron 1 Detention Basin

Design Flood	Peak Inflow	Peak Storage	Peak Water Elev.	Peak Outflow
100-Year Storm	252	26	4691.5	5
PSH	298	33	4692.4	223
ASH-Local	475	31	4692.2	152
ASH-General	149	30	4692.0	100
FBH-Local	1,312	46	4694.4	1,199

Design Flood	Peak Inflow	Peak Storage	Peak Water Elev.	Peak Outflow
FBH-General	406	36	4692.9	404

Table D-10. Design Flood Information, Dammeron 2/3 Detention Basin

Design Flood	Peak Inflow	Peak Storage	Peak Water Elev.	Peak Outflow
100-Year Storm	1,155	390	4697.0	25
PSH	2,832	445	4698.4	2,103
ASH-Local	2,733	429	4698.0	1,263
ASH-General	1,815	426	4697.9	1,127
FBH-Local	7,766	525	4700.2	6,986
FBH-General	5,274	491	4699.6	5,229

Table D-11. Design Flood Information, Diamond 1 Detention Basin

Design Flood	Peak Inflow	Peak Storage	Peak Water Elev.	Peak Outflow
100-Year Storm	677	61	4556.0	130
PSH	847	73	4557.9	1,224
ASH-Local	1,183	74	4558.0	1,341
ASH-General	440	72	4557.4	820
FBH-Local	3,344	86	4560.0	3,461
FBH-General	1,214	75	4558.3	1,593

Table D-12. Design Flood Information, Diamond 2 Detention Basin

Design Flood	Peak Inflow	Peak Storage	Peak Water Elev.	Peak Outflow
100-Year Storm	670	27	4600.0	5
PSH	860	39	4601.4	614

Design Flood	Peak Inflow	Peak Storage	Peak Water Elev.	Peak Outflow
ASH-Local	1,120	40	4601.8	859
ASH-General	434	37	4600.7	191
FBH-Local	3,275	47	4604.0	2,931
FBH-General	1,201	40	4601.9	958

Table D-13. Design Flood Information, Diamond 3 Detention Basin

Design Flood	Peak Inflow	Peak Storage	Peak Water Elev.	Peak Outflow
100-Year Storm	500	14	4607.0	5
PSH	608	24	4608.4	467
ASH-Local	893	25	4608.9	741
ASH-General	306	23	4607.7	167
FBH-Local	2,446	31	4611.0	2,228
FBH-General	816	25	4608.8	678

The spillway and top-of-dam parameters were sized and selected to route the flows most efficiently through the detention basins based on these hydrologic criteria. The total required freeboard was calculated and included the determination of the maximum wave runoff during different scenarios combining 50-mile-per-hour (mph) and 100-mph winds with storm events. Based on Dam Safety and TR-60 requirements, the spillway and top-of-dam parameters for each detention basin are shown in Table D-14.

Table D-14. Detention Basin Freeboard and Top of Dam Summary

Detention Basin	Spillway Crest Elevation	Spillway Width	Freeboard Requirement	Top-of-Dam Elevation
Dammeron 1	4691.5	90	3.0	4694.5
Dammeron 2/3	4697.0	450	3.2	4700.2
Diamond 1	4556.0	150	4.0	4560.0
Diamond 2	4600.0	130	4.0	4604.0

Detention Basin	Spillway Crest Elevation	Spillway Width	Freeboard Requirement	Top-of-Dam Elevation
Diamond 3	4607.0	100	4.0	4611.0

D.9 Auxiliary Spillway Suitability and Integrity Analysis

Integrity design erosion analyses for the auxiliary spillways while passing the freeboard design hydrograph storm events were performed using the NRCS SITES computer program (version 2015.1.8). NRCS requires that the spillway be designed to not breach during passage of the freeboard storm.

Investigations performed as part of the study indicated that silty sands and clays were most prominent at the proposed detention basin locations. Based upon a review of erosion parameters for silty sands and clays included in the SITES program Help menu, a head cut index ranging between 0.05 and 0.2 with diameters ranging between 0.003 and 0.19 inch was used. The results of the SITES analyses are illustrated in **Attachment 6**, and it will be noted that the estimated erosion as a result of the freeboard storms does not result in a spillway breach. The results of the analysis indicate that NRCS auxiliary spillway integrity requirements are satisfied.

D.10 Design Criteria

NRCS TR-60, Earth Dams and Reservoirs, and Utah State Rule R655-11, Requirements for the Design, Construction, and Abandonment of Dams, will be the governing design criteria for the proposed detention basins. In cases where the requirements of the two design criteria are different, the more conservative will be used for design.

D.11 Economic Evaluation

D.11.1 Summary of Requirements and Guidelines

The NRCS National Watershed Program Manual (NWPM) was used as a reference for the economic analysis along with three other documents: the National Resource Economics Handbook, Part 611 Water Resources Handbook for Economics, USDA/NRCS, July 1998; Principles and Guidelines for Water- and Land-Related Resources Implementation Studies (P&G), December 1983; and Guidance for Conducting Analyses under the Principles, Requirements, and Guidelines for Water- and Land-Related Resources Implementation Studies and Federal Water Resource Investments (PR&G), DM 9500-013. The latter includes requirements set forth in the Council on Environmental Quality Principles and Requirements for Federal Investments in Water Resources (P&R) and Interagency Guidelines. DM 9500-013 provides guidance on completing a PR&G analysis, including steps in the planning and evaluation process, differences between project- and programmatic-level evaluations, direction on incorporating an ecosystem services framework, and techniques for economic analysis.

According to the P&G, the alternative that maximizes net economic benefits is referred to as the National Efficiency Evaluation (NEE) alternative and will be the preferred alternative. In addition to P&G requirements, PR&G requires that public benefits (monetary and non-monetary) be maximized relative to cost. Furthermore, there is not a hierarchal relationship among the

economic, social, or environmental goals, regardless of whether they can be monetized. Agency policy allows for the use of social effect goals to make the case for flood control activities, even if the associated benefit-cost (B/C) ratio is less than 1:1. This is due to the difficulty in monetizing the value of life and quality of life, which is laden with subjective value judgments. Threat to human life and quality factors can therefore be used to outweigh purely economic considerations when appropriate. PR&G allows a wide range of alternatives to illustrate the range of potential tradeoffs among environmental, economic, and social goals.

The Federal Objective, as set forth in the Water Resources Development Act of 2007, specifies that Federal water resources investments shall reflect national priorities, encourage economic development, and protect the environment by (1) seeking to maximize sustainable economic development; (2) seeking to avoid the unwise use of floodplains and flood-prone areas and minimizing adverse impacts and vulnerabilities in any case in which a floodplain or flood-prone area must be used; and (3) protecting and restoring the functions of natural systems and mitigating any unavoidable damage to natural systems.

The guiding principles in P&G and PR&G constitute the concepts that should consider when analyzing Federal investments in water resources and the P&G and PR&G General Requirements are topics that agencies must consider when analyzing Federal investments in water resources. The following Principles constitute the overarching concepts the Federal government seeks to promote through Federal investments in water resources now and into the foreseeable future.

D.11.1.1 Healthy and Resilient Ecosystems.

Federal investments in water resources should protect and restore the functions of ecosystems and mitigate any unavoidable damage to these natural systems.

D.11.1.1 Sustainable Economic Development.

Federal investments in water resources should encourage sustainable economic development.

D.11.1.1 Floodplains.

Federal investments in water resources should avoid the unwise use of floodplains and flood-prone areas and minimize adverse impacts and vulnerabilities in any case in which a floodplain or flood-prone area must be used.

D.11.1.1 Public Safety.

Threats to people, including both loss of life and injury from natural events, should be assessed in the determination of existing and future conditions and, ultimately, in the decision-making process.

D.11.1.1 Environmental Justice.

Environmental justice is the fair treatment and meaningful involvement of all people, regardless of race, color, national origin, or income, with respect to the development, implementation, and enforcement of environmental laws, regulations, and policies. Agencies should ensure that Federal actions identify any disproportionately high and adverse public safety, human health, or environmental burdens of projects on minority, Tribal, and low-income populations.

D.11.1.1 Watershed Approach.

A watershed approach to analysis and decision-making facilitates evaluation of a more complete range of potential solutions and is more likely to identify the best means to achieve multiple goals over the entire watershed.

D.11.2 Alternatives Evaluated

According to the P&G and the NWPM, “Flood Prevention” was the purpose analyzed for the Santa Clara Watershed Plan-EA. **Table D-15**, Comparison of NEE Benefits and Costs Santa Clara Watershed Project, contains a summary of the average annual project costs and benefits. The Excel Workbook “SantaClaraFloodDamagesBenefitsData.xml,” with associated sheets within the workbook, provides the detail for the complete economic analysis. The project area contained two sub-basins: Dammeron Valley and Diamond Valley. Incremental analysis was conducted considering each sub-basin and flood control structures.

Table D-15. Comparison of Annual NEE Benefits and Costs Santa Clara Watershed Project (Dollars)¹

–	Average Annual Costs ³	Average Annual Benefits ²	Benefit Cost Ratio	Net Benefits
Dammeron Alt 1	\$358,669	\$1,340,704	3.74	\$982,035
Diamond Alt 1	\$307,083	\$2,396,173	7.80	\$2,089,090
Shivwits Alt 1	\$37,990	\$10,171	0.27	-\$27,819
Grand Total	\$703,742	\$3,747,048	5.32	\$3,043,306

Footnote for Table D-15:

¹Discount rate 2.5 percent with a 51-year period of analysis. Price base 2022.

²Taken from **Table 8-4**.

³Taken from **Tables 8-5 and 8-6**.

As described in the General Plan-EA, the main purpose of the watershed plan is to reduce the average annual flood damages within the watershed. Additional purposes considered include reducing erosion and sediment damages and protecting recreation opportunities and wildlife. While only flood damage-related benefits were quantified, other types of benefits serving the project purposes were still considered qualitatively when evaluating the costs and benefits of project alternatives.

According to PR&G, after preliminary consideration, agencies may remove from detailed study those alternatives that do not achieve the Federal Objective and Guiding Principles. In addition, alternatives that may at first appear reasonable but clearly become unreasonable because of cost, logistics, existing technology, social, or environmental reasons may also be eliminated from further analysis. These alternatives should be briefly discussed to indicate that they were considered, and the analysis should document the reason(s) why they were eliminated (e.g., they do not achieve the Federal Objective and Guiding Principles).

In general, the NEE alternative was developed in accordance with PR&G by evaluating economic, social, and environmental impacts from flood damage reduction in the rural community. Given the emphasis placed on the construction of flood control structures by the local steering committee to provide flood mitigation, the geographic extents of evaluated alternatives are limited to the area in which one or more of the proposed structural alternatives would have an estimated impact to the 500-year flood depth. The annual benefits of the project alternatives are based on the estimated reduction in average annual floodwater damages with proposed flood control measures in place compared to future conditions without mitigative action (No Action Alternative).

Alternatives considered included the No Action Alternative, nonstructural alternatives, the locally preferred alternative, and the NEE Alternative. Alternatives were compared against the No Action Alternative, which involved projecting existing resources and conditions into the future to establish a benchmark against which alternatives were evaluated. Tradeoffs between alternatives with respect to environmental, economic, and social goals were identified.

Both structural and nonstructural alternatives were evaluated for this planning study. However, nonstructural alternatives were eliminated from detailed study by the planning team due to exorbitant cost compared to the potential benefits. One structural alternative was eliminated because the monetary benefits were well below the costs. Following are summaries of eliminated alternatives, which propose to mitigate damages from the 100-year flood.

- **Alternative 2. Relocation**—The alternative to relocate the residences, improvements, structures, and other land value uses to a location outside of the floodplain has been analyzed. There are 69 residences and 0 commercial businesses in the 100-year floodplain. Costs for such relocation include the purchase of new property for the relocated items; the logistical, labor, and material costs associated with relocating and constructing new facilities; and the demolition and cleanup of the existing improvements and structures. Costs to complete this have been estimated at two times the current assessed value of the properties. Relocating the affected properties in Dammeron Valley and Diamond Valley would require costs about \$145 million. Further, the demolition and cleanup of the existing properties and the development of properties elsewhere create a larger impact on the environment and communities. This alternative is economically and culturally unreasonable and does not provide any additional flood protection benefit.
- **Alternative 3. Floodproofing**—To protect areas that would be affected by flooding, individual properties could be floodproofed or floodwalls could be constructed within the floodplain boundary. The area protected by the dam includes portions of the communities of Dammeron Valley and Diamond Valley. Floodproofed structures would include 69 residences and 0 commercial businesses. Floodwalls would be required along roadways as well as developed areas throughout the floodplain. Floodproofing structures and several miles of floodwalls with dozens of penetrations would be required at a cost of over \$15 million. This alternative is unreasonable because the cost is higher than the cost of the structural alternative considered for final analysis, there are no additional flood protection benefits, and the community and environmental impacts are significantly greater.

Along with the No Action Alternative, one alternative proposing construction of several flood control structures for three project areas, Dammeron Valley, Diamond Valley, and Shivwits Area, was identified and evaluated in detail. The project consists of eight separate dam structures across six debris basins and tributaries. The debris basins have individual uncontrolled low-level outlets

that are designed to convey low flows that can be adequately conveyed in downstream drainage facilities. Principal spillways for each detention basin will be used to safely convey large storm events without causing damage to the dam structures. Shivwits Area includes the repair and flood proofing an irrigation canal and delivery system.

In both Dammeron and Diamond Valley, each of the flood control structures works in conjunction with each other, and the omission of any item within the alternative (i.e., omitting any one of the three detention basins in each area) would render the remaining options ineffective. As such, the alternatives for Dammeron Valley and Diamond Valley are inclusive of all items as a single alternative for each area.

- Alternative 1. Dammeron—Dammeron Valley alternative includes three new detention basins and one channel intended to route a fourth drainage area. Dam structure 1 (max dam height: 33.5 feet) for one detention basin (26 acre-feet capacity). Two detention basins, dam structures 2 and 3, each have individual dam structures (max dam height: 38 feet), but as water levels rise, the two basins combine into a single body of water with one spillway (390 acre-feet capacity). Storm events will be attenuated through the three detention basins collected upstream of the community. The limited and attenuated flows will be safely routed through the community, across the downstream highway, and into existing drainage corridors. The property where the dam would be located is privately owned and includes some BLM land.
- Alternative 1. Diamond—Diamond Valley involves four dam structures and three detention basins and the armoring of an existing channel. The detention basins exist but need dredging and rehabilitation. The spillway for Diamond 3 includes an existing bypass channel that conveys flows to Diamond 2, and the spillway for Diamond 2 includes an existing bypass channel that conveys flows to Diamond 1. Diamond 1 is currently a sump basin with no outlet. Each of the detention basins will be dredged and the existing dam structures will be rehabilitated. Due to site constraints, Diamond 1 will require two separate dam structures (max dam height: 12 feet) to reach the required capacity (61 acre-feet capacity). The low-level outlet being proposed on Diamond 1 with this project will drain a portion of the sump basin, but the lower elevations of the detention basin will continue as a sump. Flows leaving Diamond 1 will be conveyed through new pipe to a nearby existing drainage corridor that has capacity to safely receive the flows. Diamond 2 will require a single dam structure (max dam height: 19 feet) to reach the required capacity (27 acre-feet capacity). Diamond 3 will require a single dam structure (max dam height: 15 feet) to reach the required capacity (14 acre-feet capacity). The property where the dam would be located is privately owned and includes some BLM land.
- Alternative 1. Shivwits—Shivwits site includes construction of approximately 2,225 linear feet of rock rip-rap bank protection along the Santa Clara River. The armoring is to prevent stream erosion threatening the historic Shivwits school/meeting house and two Civil Conservation Corps rock-lined ditches. The armoring will also protect approximately 30 acres of cultivated fields. The plan also includes the installation of approximately 5,800 linear feet of 8-inch pipe to provide irrigation to the cultivated acres.

The preferred alternative will allow the sponsors to protect property and infrastructure while maximizing public benefits. Average annual monetary benefits of this alternative are estimated to

be \$3,747,048. The estimated average annual cost is \$703,742, resulting in an annual net benefit of \$3,043,306.

D.11.3 Environmental and Social Benefits

Environmental and social benefits were not monetized but are further explained for each alternative studied in detail in the Environmental Consequences Section of the Plan-EA.

Environmentally adverse impacts will be minimized during construction. Long-term, there would only be negligible adverse impacts anticipated from any of the evaluated alternatives. The region is arid with sparse trees along the banks of intermittently dry streams.

Socially, the threat of loss of life or property may be minimized with reduced flood depths at buildings and roads. The annual average daily traffic on county major collector and rural roads near the project area was about 900 vehicles to almost 12,000 vehicles per day (Utah Department of Transportation 2020).

Incidental recreation after construction will continue and is expected to have minimal benefits from the structural alternatives through enhancement of wildlife and scenic improvement. Waterbodies developed from the impoundments would likely attract wildlife for short periods of time, but not significantly increase hunting, fishing, and general outdoor activity in the vicinity of the dams.

The Shivwits portion of the project is located on the Shivwits Band of Paiutes tribal land. There are cultural, social, environmental, and economic benefits by bringing irrigation water back to the project area (personnel communication, Karma Grayman, Shivwits Band, 2023). The tribe could use the area for irrigated pasture, alfalfa hay, or native corn species and melons. Based on the lack of data for non-market crops and the high likelihood of growing alfalfa the first few years after flood control, the income from growing alfalfa was used in the economic analysis.

- **Cultural:** The Shivwits Band will be able to revive traditional agricultural practices and grow native corn species, along with melons, which they have not done for decades (Travis Duran, personal communication, 2023). This will help to restore some of their traditional ecological knowledge and they will be able to pass it down to younger generations. Without the pipeline, the fields remain dry and will not support these traditional crops. In addition, by installing rip rap at the end of the historic rock lined ditch, we will be preserving components of the historic Shivwits Indian School (42WS5621), which is eligible for the National Register of Historic Places, and it has also served as a gathering place for Shivwits Band meetings, was home to many Shivwits Band members from the 1900s to 1950s, and was the location of Funeral Cry Ceremonies for the people. The area will also be used to educate tribal school youth about traditional agriculture and the cultural importance of the school.
- **Social:** By being able to grow traditional native plants and restore the field to agricultural practices, the Shivwits Band will also restore traditional gatherings to this aream such as the Bear Dance, which was practiced once a year in this area of land (Travis Duran, personal communication, 2023). In addition, with these traditional gatherings, younger generations will be able to learn about the significant historic of the Shivwits Indian School and the experiences of their ancestors. The school served as a day school for Shivwits Paiute

Indians from the late 19th century to early 20th century during extremely dire times, and later served as a meetinghouse. By bringing agriculture back to the area and revitalizing it as a traditional gathering area, new traditions will be built and strengthen the Shivwits community and bring younger generations to this area.

- **Environmental**: Converting it to a piped irrigation system will increase irrigation efficiency (Travis Duran, personal communication, 2023).
- **Economics**: The Shivwits Band will be able to employ Band members on this plot of land during planting and harvesting seasons and teach them about the gathering of native corn and melons and traditions associated with them (Travis Duran, personal communication, 2023).

D.11.4 Period of Analysis

The Period of Analysis used was 51 years (including 1 year for design and construction). Floods from the 2, 5, 10, 25, 50, 100, 200, and 500-year storm events were analyzed to estimate average annual flood-related damages.

A net present value analysis was conducted to compare the costs of project alternatives. Average annual values were also estimated. All costs of installation, operation, and maintenance were based on 2022 prices. The costs associated with designing and implementing all structural measures were assumed to be implemented over a 1-year period immediately preceding operation. The alternative with a 51-year period of analysis yielded the highest net benefits using the mandated 2.5 percent discount rate for all federal water resource projects for fiscal year 23 to discount and amortize the anticipated streams of costs and benefits.

D.11.5 Economic Analysis and Documentation

A customized Excel worksheet using Federal Emergency Management Agency (FEMA) depth-damage curves and locally obtained data was used to evaluate benefits and costs of alternatives. Each project alternative, storm event, and flood damage category were included in the worksheet to estimate average annual damages. Alternative cost estimates provided by the project engineers were also included in the worksheet. Economic data and results were linked in the worksheet to create the required P&G tables for the final project report.

D.11.6 Rural Community and Agricultural Damages

The stream of monetary benefits was described in average annual equivalent terms. The average annual expected benefits were the difference between the No Action Alternative and each project Alternative. The expected average annual damages for each alternative, storm event (eight events), and damage category below were estimated with the following equation:

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$$\sum_{i=1}^8 (PFED_{i-1} + FED_i)/2 * (PPFE_{i-1} - PFE_i)$$

*PFED_{i-1} - Previous Flood Event Damages**FED_i - Flood Event Damages**PPFE_{i-1} - Probability of Previous Flood Event**PFE_i - Probability of Flood Event*

D.11.6.1 Structure, Content, and Vehicle Damages

Structure, building content, and vehicle damages for each storm event and project alternative were estimated based on structures identified from aerial imagery, property data provided by the Washington County, Utah tax assessor, and water depths obtained from hydraulic simulation of the evaluated storm events. Areas flooded and flood depths with and without project were estimated by Alpha Engineering, St. George, Utah. Building types, contents, and the typical number of vehicles and vehicle values associated with impacted buildings were estimated using interpolation of flood depth-damage curves developed by FEMA. The percent damage factor was multiplied by each building structure and vehicle dollar value to estimate flood damages. Total value of structures on impacted properties is shown below. This value does not include land values, only structure values.

Watershed Project Number and Value of Structures Summary

<u>Dammeron</u>	<u>Number</u>	<u>Value</u>
Total Structures:	25	\$18,434,275
Residences and Apts:	27	\$18,434,275
<u>Diamond</u>	<u>Number</u>	<u>Value</u>
Total Structures:	42	\$26,772,085
Residences and Apts:	42	\$26,772,085

There are no commercial businesses, public properties, or critical facilities in the impacted project area. Structure and content values were estimated as a percentage (about 75 percent structure and 60 percent content damages at 10-feet flood depth in a 1-story, no basement home) of assessed property values. Estimated floodwater depths (where damage occurs) for various storms (including the 500-year storm) for each structure were based on the results of the hydrology and hydraulics simulation modeling. Floodwater data was then used with water depth to damage functions to estimate structural and content damages based on the ground elevation of each

structure. A similar analysis was conducted for vehicles located at the property within the floodplain area. Damage to vehicles was estimated to begin at 0.5 foot of flood depth. Each affected property was estimated to have a minimum of two vehicles. The vehicle value was estimated to be \$7,500/vehicle.

D.11.6.2 Road Damages

Road damages for each storm event and project alternative were estimated. Road location, flood depth, and road surface area impacted by floodwater were identified. Areas flooded, flood depths, and monetary damages with and without project were estimated by Alpha Engineering, St. George, Utah. The cost of road repair or replacement was estimated. There were no road damages estimated if the flood depth was less than 0.1 foot. If flood depth was between 0.1 and 0.5 foot, flood damages were estimated to be half the road repair or replacement cost. If flood depth was greater than 0.5 foot, flood damages were estimated to be the total road repair replacement cost.

For the economic analysis, there are approximately 12 associated roadways within Dammeron Valley and 6 roadways in Diamond Valley project areas affected by storms up to and including the 500-year storm event.

D.11.6.3 Bridge & Culvert Damages

For the economic analysis, there were no identified culverts and bridges (stream crossings) affected by storms up to and including the 500-year event.

D.11.6.4 Other Damages

No additional “Other Damages” (emergency aid, clean-up, sewer, debris removal, etc.) were provided or estimated by local county officials.

D.11.6.5 Crop Damages

Crop damages from each storm event and project alternative were estimated. About 4 acres of vineyard were flooded in the Dammeron sub-basin. Areas flooded and flood depths with and without project were estimated by Alpha Engineering, St. George, Utah, and the local NRCS Field Agronomist provided crop production data. Five-year average crop yields and prices were estimated using crop budget data published by University of California-Davis and National Agricultural Statistics Service information. Acreage of damages associated with each crop type was estimated by the project GIS specialist. Crop Percent damage factors for flood inundation were obtained from NRCS, and estimated for depths of less than 1 foot, 1 to 3 feet, and greater than 3 feet.

The “Seasonal Damage Factor” represents the probability that the flood event occurs during the crop growing/harvest season, and then is multiplied by the crop damage factor. The Seasonal (crop) Damage Factor was estimated as: $[0.5 \text{ times (Harvest Starts minus Plant Starts), plus } 0.5 \text{ times (Harvest Ends minus Harvesting Starts)}]$, divided by 365 Days. The Average Crop Value per acre was estimated as The Average Unit Price times Average Yield.

Damageable Value per Acre (per Flood Depth). The dollar crop damages per flood event were estimated by the sum of the Seasonal Damage Factor, the Inundation Factor, and the Average

Crop Value per Acre. The flood event losses were estimated as the sum of Damage Value per Acre times Acres Flooded for each flood event.

The Shivwits Band of Paiutes tribal land could be flooded, and about 30 acres are no longer farmed because of flood damage to ditches, pipeline and sprinklers, and continued flooding, that made farming unfeasible. With flood control measures, the Shivwits Band will be able to farm the field again and employ Band members in crop production and teach tribal members about growing native corn and melons and traditions associated with them (Travis Duran, personal communication, 2023). For the economic analysis, we assumed the Shivwits field would be in alfalfa hay production. The Without Project flood damages are the complete loss of income from the hay land and were estimated as Net Income from Extension Service Crop Budgets (Utah State University). Net Returns was defined as “price” times “yield” minus annual “crop production costs” (excluding owner unpaid labor, management, equity, and risk). Crop costs were updated to the current year using the Producer Prices Received Index. Crop prices and yields were the previous ten-year averages. The Net Returns per acre were weighted to account for a 10-year Alfalfa-Oat crop rotation. The benefit is the Net Income from hayland that is restored to crop production.

D.11.6.6 Other Agricultural Damages

There were no other pasture, range, livestock, or confined animal feeding operation damages identified within the project area affected by storms up to and including the 500-year event.

D.11.6.7 Recreation

Based on evidence found at the site and information from local residences, the dam sites and upstream and downstream waterways (on private property and BLM land) are used by some people for recreational purposes. The flood control structures are not intended to store water for recreation. Incidental recreational activities, such as hunting and hiking/walking, are expected to be minimal. Since there is no official or unofficial count of usage, estimated annual visitor-days is not available. Therefore, incidental recreation impacts were not evaluated.

D.11.6.8 Scour and Sediment Damages

Flood erosion scour and sediment deposition damages from each storm event and project alternative were estimated. Areas and quantity of scour and sediment with and without project were estimated by Alpha Engineering, St. George, Utah. Erosion-scour was defined as soil loss greater than 6 inches. Up to about 90 acres of rural and residential land were identified with significant erosion-scour in the flooded area. Damages were estimated as the cost per acre to replace lost soil on eroded areas. Sediment deposition damages were estimated to be up to about 1,000 cubic yards in the flooded area. Damages were estimated as the cost to remove sediment from deposition areas.

As reflected in the table below, current average annual floodwater damages without the project (present condition) are \$3,848,341. Floodwater damages with the project (Alternative 1) dams were estimated to be \$101,293.

Table D-16. Summary of Annual Expected Damages (Dollars)¹

Category	Present Condition	Alternative¹
(Structure, Contents, & Vehicles) Dammeron	\$1,372,698	\$40,080
(Structure, Contents, & Vehicles) Diamond	\$2,453,856	\$61,031
(Structure, Contents, & Vehicles) Shivwits	\$0	\$0
(Roads and Culverts) Dammeron	\$1,583	\$0
(Roads and Culverts) Diamond	\$599	\$0
(Roads and Culverts) Shivwits	\$0	\$0
(Crop-Flood) Dammeron	\$359	\$3
(Crop-Flood) Diamond	\$0	\$0
(Crop-Flood) Shivwits	\$10,171	\$0
(Scour) Dammeron	\$5,859	\$99
(Scour) Diamond	\$2,372	\$39
(Scour) Shivwits	\$0	\$0
(Sediment) Dammeron	\$422	\$34
(Sediment) Diamond	\$422	\$6
(Sediment) Shivwits	\$0	\$0
Total	\$3,848,341	\$101,293

Footnote for Table D-16:

¹Price base: 2022. Calculated using FY 2022 Water Resources Discount Rate (2.50 percent), annualized over 50 years, and 51-year period of analysis. Prepared March 2023.

D.11.7 Watershed Project Costs

Project costs for flood control dams and channel work were estimated by Alpha Engineering, St. George, Utah in September 2022. Installation and operation and maintenance costs for each activity are described in detail in the cost tabs in the economic analysis Excel worksheet.

All costs were allocated to the flood prevention purpose according to the procedure in the National Resource Economics Handbook, Part 611 Water Resources Handbook for Economics, Chapter 6 Costs and Cost Allocation (NRCS 2014b). Work Plan-EA tables were constructed based on the calculated cost allocated to flood prevention. Within this purpose, the costs were shared between NRCS and the local and state entities as specified in the NWPM. In this case, cost share for flood prevention is 100 percent federal and 0 percent local. Within these guidelines, engineering is 100 percent federal and operation, maintenance, and replacement is 100 percent local. See Work Plan Table 2 in the Plan-EA for the results of the cost allocation/cost-sharing process.

All costs were amortized at the fiscal year 2023 Federal Water Resource Discount of 2.50 percent for 51 years. Average Annual Costs are computed as the sum of the amortized construction cost and the annual operation and maintenance cost. Engineers estimate that each of the structures would last 50 years, the life of the project.

All project costs were estimated by project engineers and converted to Present Values by discounting each cost to the beginning of the period of analysis using the applicable project discount rate. Installation expenditures before the project is installed were brought forward to the end of the period of installation by charging compound interest at the project discount rate from the date the costs are incurred. Finally, the project discount rate was used to convert the present values to average annual equivalent terms. All estimated values and damages were assessed within a customized Excel template.

Table D-17. Watershed Project Annual Cost Summary (Dollars)¹

Evaluation Unit	Amortization of Installation Cost	Operation, Maintenance, & Replacement	Total
Dammeron Valley ¹	\$281,800	\$76,869	\$358,669
Diamond Valley ¹	\$222,300	\$84,783	\$307,083
Shivwits Site ¹	\$37,500	\$490	\$37,990
Grand Total	\$541,600	\$162,142	\$703,742

Footnote for Table D-17:

¹Discount rate 2.50 percent with a 51-year period of analysis. Price base 2022.

D.11.8 Watershed Project Benefits and Costs

As reflected in the table below, current average annual benefits are \$3,747,048 and the average annual costs are \$703,742. The net annual benefits with and without benefits that the project would provide to downstream properties is \$3,043,306.

As reflected below, both Dammeron Valley and Diamond Valley had a B/C ratio greater than 1.0. The Shivwits area had a B/C ratio of less than 1.0 at .27. All three geographic areas, under Alternative 1, produce a B/C ratio of 5.32.

Table D-18. Watershed Project Benefit-Cost Summary (Dollars)¹

Evaluation Unit	Average Annual Costs³	Average Annual Benefits²	Benefit Cost Ratio	Net Benefits
Dammeron Valley ¹	\$358,669	\$1,340,704	3.74	\$982,036
Diamond Valley ¹	\$307,083	\$2,396,173	7.80	\$2,089,089
Shivwits Site ¹	\$37,990	\$10,171	0.27	-\$27,819
Grand Total	\$703,742	\$3,747,048	5.32	\$3,043,306

Footnote for Table D-18:

¹Discount rate 2.50 percent with a 51-year period of analysis. Price base 2022.

²From **Tables D-24** through **D-28**.

³From **Table D-23**.

D.11.9 Final Tables

All tables, for all alternatives, are displayed below. The following tables show cost-share percentages and amounts for watershed project plan implementation.

Table D-19. Alternative 1 Cost-Share Summary—Dammeron

Works of Improvement	%³	NRCS	%³	Sponsors	Total
Cost-shareable: Construction Costs	100%	\$6,896,688	0%	\$0	\$6,896,688
Cost-shareable: Engineering Technical Assistance Costs⁴	100%	\$551,735	0%	\$0	\$551,735
Cost-shareable: Project Admin. Costs¹	100%	\$275,868	0%	\$0	\$275,868

Works of Improvement	%³	NRCS	%³	Sponsors	Total
Subtotal: Cost-Share Costs	—	\$7,724,290	—	\$0	\$7,724,290
Non-cost shareable: Construction Costs	0%	\$0	100%	\$6,000	\$6,000
Non-cost shareable: Engineering Costs	0%	\$0	100%	\$600	\$600
Non-cost shareable: Real Property Landrights⁵	0%	\$0	100%	\$65,000	\$65,000
Non-cost shareable: Mitigation	0%	\$0	100%	\$0	\$0
Non-cost shareable: Permits	0%	\$0	100%	\$800	\$800
Non-cost shareable: Project Admin. Costs¹	0%	\$0	100%	\$0	\$0
Subtotal: Non-Cost-Share Costs	—	\$0	—	\$72,400	\$72,400
TOTAL	99%	\$7,724,290	1%	\$72,400	\$7,796,690

Footnote for Table D-19:

¹The sponsors and NRCS will each bear the costs of project administration that each incurs.

²If actual non-cost-shareable item expenditures vary from these figures, the responsible party will bear the change.

³As per NWPM Section 500.42 and Figure 500-E2, PL-566 cost share rates depend on the authorized purposes of the particular watershed plan. For flood prevention measures, PL-566 pays 100 percent of construction and engineering. Installation of compensatory mitigation is considered part of the construction of the flood control measure (per text between Figures 500-E1 and 500-E2). Real property rights acquisition is 100 percent sponsor cost for most PL-566 activities. However, acquisition of property rights for mitigation and recreation may be cost-shared (see referenced sections).

⁴Cost-shareable at 100 percent NRCS if Sponsor hires engineering for structure design. Not cost-shareable if sponsor's engineering is for elements required for real property rights (road improvements, power line modification, livestock water supply line, etc.).

⁵Construction elements required to satisfy real property rights are also 100 percent Sponsor cost.

Table D-20. Alternative 1 Cost-Share Summary—Diamond

Works of Improvement	%³	NRCS	%³	Sponsors	Total
Cost-shareable: Construction Costs	100%	\$5,473,508	0%	\$0	\$5,473,508
Cost-shareable: Engineering Technical Assistance Costs⁴	100%	\$437,881	0%	\$0	\$437,881
Cost-shareable: Project Admin. Costs¹	100%	\$218,940	0%	\$0	\$218,940
Subtotal: Cost-Share Costs	—	\$6,130,328	—	\$0	\$6,130,328
Non-cost shareable: Construction Costs	0%	\$0	100%	\$6,000	\$6,000
Non-cost shareable: Engineering Costs	0%	\$0	100%	\$600	\$600
Non-cost shareable: Real Property Landrights⁵	0%	\$0	100%	\$65,000	\$65,000
Non-cost shareable: Mitigation	0%	\$0	100%	\$0	\$0
Non-cost shareable: Permits	0%	\$0	100%	\$800	\$800
Non-cost shareable: Project Admin. Costs¹	0%	\$0	100%	\$0	\$0
Subtotal: Non-Cost- Share Costs	—	\$0	—	\$72,400	\$72,400
TOTAL	99%	\$6,130,328	1%	\$72,400	\$6,202,728

Footnote for Table D-20:

¹The sponsors and NRCS will each bear the costs of project administration that each incurs.²If actual non-cost-shareable item expenditures vary from these figures, the responsible party will bear the change.³As per NWPM Section 500.42 and Figure 500-E2, PL-566 cost-share rates depend on the authorized purposes of the particular watershed plan. For flood prevention measures, PL-566 pays 100 percent of construction and engineering. Installation of compensatory mitigation is considered part of the construction of the flood control measure (per text between Figures 500-E1 and 500-E2). Real property rights acquisition

is 100 percent sponsor cost for most PL-566 activities. However, acquisition of property rights for mitigation and recreation may be cost-shared (see referenced sections).

⁴Cost-shareable at 100 percent NRCS if Sponsor hires engineering for structure design. Not cost-shareable if sponsor's engineering is for elements required for real property rights (road improvements, power line modification, livestock water supply line, etc.).

⁵Construction elements required to satisfy real property rights are also 100 percent Sponsor cost.

Table D-21. Alternative 1 Cost-Share Summary—Shivwits

Works of Improvement	%³	NRCS	%³	Sponsors	Total
Cost-shareable: Construction Costs	100%	\$728,925	0%	\$0	\$728,925
Cost-shareable: Engineering Technical Assistance Costs⁴	100%	\$30,000	0%	\$0	\$30,000
Cost-shareable: Project Admin. Costs¹	100%	\$10,000	0%	\$0	\$10,000
Subtotal: Cost-Share Costs	—	\$768,925	—	\$0	\$768,925
Non-cost shareable: Construction Costs	0%	\$0	100%	\$6,000	\$6,000
Non-cost shareable: Engineering Costs	0%	\$0	100%	\$600	\$600
Non-cost shareable: Real Property Landrights⁵	0%	\$0	100%	\$65,000	\$65,000
Non-cost shareable: Mitigation	0%	\$0	100%	\$0	\$0
Non-cost shareable: Permits	0%	\$0	100%	\$800	\$800
Non-cost shareable: Project Admin. Costs¹	0%	\$0	100%	\$0	\$0
Subtotal: Non-Cost- Share Costs	—	\$0	—	\$72,400	\$72,400
TOTAL	74%	\$768,925	26%	\$268,975	\$841,325

Footnote for Table D-21:

¹The sponsors and NRCS will each bear the costs of project administration that each incurs.

²If actual non-cost-sharable item expenditures vary from these figures, the responsible party will bear the change.

³As per NWPM Section 500.42 and Figure 500-E2, PL-566 cost-share rates depend on the authorized purposes of the particular watershed plan. For flood prevention measures, PL-566 pays 100 percent of construction and engineering. Installation of compensatory mitigation is considered part of the construction of the flood control measure (per text between Figures 500-E1 and 500-E2). Real property rights acquisition is 100 percent sponsor cost for most PL-566 activities. However, acquisition of property rights for mitigation and recreation may be cost-shared (see referenced sections).

⁴Cost-sharable at 100 percent NRCS if Sponsor hires engineering for structure design. Not cost-shareable if sponsor's engineering is for elements required for real property rights (road improvements, power line modification, livestock water supply line, etc.).

⁵Construction elements required to satisfy real property rights are also 100 percent Sponsor cost.

Table D-22. Estimated Installation Cost for Alternatives¹

Installation Cost Items	PL-83-566 Funds	Other Funds	Total
Dammeron Alt 1	\$7,724,290	\$72,400	\$7,796,690
Diamond Alt 1	\$6,130,328	\$22,500	\$6,152,828
Shivwits Alt 1	\$768,925	\$268,975	\$1,037,900
Total Project	\$14,623,543	\$363,875	\$14,987,418

Footnote for Table D-22:

¹Price base 2022.

Table D-23. Estimated Cost Distribution for Alternatives¹

Installation Cost Items ²	(PL-83-566) Construction Costs	(PL-83-566) Engineering Technical Assistance Costs	(PL-83-566) Project Admin. Costs	Total PL-83-566 Costs	(Other Funds) Construction Costs	(Other Funds) Engineering Costs	(Other Funds) Real Property Land Rights	(Other Funds) Permits	(Other Funds) Mitigation	(Other Funds) Project Admin. Costs	(Other Funds) Total Other Funds	(Other Funds) Total Project Cost	Amortized Costs, FY2022 Rate	Annual OM&R	Total Annual Costs
Dammeron Alt 1	\$6,896,688	\$551,735	\$275,868	\$7,724,290	\$6,000	\$600	\$65,000	\$800	\$0	\$0	\$72,400	\$7,796,690	\$281,800	\$76,869	\$358,669
Diamond Alt 1	\$5,473,508	\$437,881	\$218,940	\$6,130,328	\$20,000	\$2,000	\$0	\$500	\$0	\$0	\$22,500	\$6,152,828	\$222,300	\$84,783	\$307,083
Shivwits Alt 1	\$728,925	\$30,000	\$10,000	\$768,925	\$268,475	\$0	\$0	\$500	\$0	\$0	\$268,975	\$1,037,900	\$37,500	\$490	\$37,990
Total Project	\$13,099,120	\$1,019,616	\$504,808	\$14,623,543	\$294,475	\$2,600	\$65,000	\$1,800	\$0	\$0	\$363,875	\$14,987,418	\$541,600	\$162,142	\$703,742

Footnote for Table D-23:

¹Discount rate 2.50 percent with a 51-year period of analysis. Price base 2022.

²All costs towards the Project Purpose of Flood Prevention.

Table D-24. Estimated Average Annual Costs for Alternatives¹

Evaluation Unit	Amortization of Installation Cost	Operation, Maintenance, & Replacement	Total
Dammeron Alt 1	\$281,800	\$76,869	\$358,669
Diamond Alt 1	\$222,300	\$84,783	\$307,083
Shivwits Alt 1	\$37,500	\$490	\$37,990
Grand Total	\$541,600	\$162,142	\$703,742

Footnote for Table D-24

¹Discount rate 2.50 percent with a 51-year period of analysis. Price base 2022.²From Table D-22.**Table D-25. Estimated Average Annual Flood Damage Reduction Benefits Alternative 1—Dammeron**

Dammeron Alt 1 Item	Average Annual Damages without Project—Ag Related	Average Annual Damages without Project—Non-Ag Related	Average Annual Damages with Project—Ag Related	Average Annual Damages with Project—Non-Ag Related	Average Annual Benefits—Ag Related	Average Annual Benefits—Non-Ag Related
(Floodwater Damage) Structures, Contents, Vehicles	—	\$1,372,698	—	\$40,080	\$0	\$1,332,617
(Floodwater Damage) Roads	—	\$1,583	—	—	\$0	\$1,583
(Floodwater Damage) Crop and Pasture	\$359	—	\$3	—	\$356	\$0
(Floodwater Damage) Subtotal	\$359	\$1,374,281	\$3	\$40,080	\$356	\$1,334,201

Dammeron Alt 1 Item	Average Annual Damages without Project— Ag Related	Average Annual Damages without Project— Non-Ag Related	Average Annual Damages with Project— Ag Related	Average Annual Damages with Project— Non-Ag Related	Average Annual Benefits— Ag Related	Average Annual Benefits— Non-Ag Related
(Sediment/ Erosion Damage) Sediment Deposition	—	\$422	—	\$34	\$0	\$388
(Sediment/ Erosion Damage) Flood Plain Scour	—	\$5,859	—	\$99	\$0	\$5,760
(Sediment/ Erosion Damage) Road and Bridge	—	\$0	—	\$0	\$0	\$0
(Sediment/ Erosion Damage) Urban	—	\$0	—	\$0	\$0	\$0
(Sediment/ Erosion Damage) Subtotal	—	\$6,281	—	\$133	\$0	\$6,148
Indirect Damage	\$0	\$0	\$0	\$0	\$0	\$0
Grand Total	\$359	\$1,380,562	\$3	\$40,214	\$356	\$1,340,348

Footnote D-25:

¹Discount rate 2.50 percent with a 51-year period of analysis. Price base 2022.

Table D-26. Estimated Average Annual Flood Damage Reduction Benefits Alternative 1—Diamond

Diamond Alt 1 Item	Average Annual Damages without Project— Ag Related	Average Annual Damages without Project— Non-Ag Related	Average Annual Damages with Project— Ag Related	Average Annual Damages with Project— Non-Ag Related	Average Annual Benefits— Ag Related	Average Annual Benefits— Non-Ag Related
(Floodwater Damage) Structures, Contents, Vehicles	—	\$2,453,856	—	\$61,031	\$0	\$2,392,824
(Floodwater Damage) Roads	—	\$599	—	—	\$0	\$599
(Floodwater Damage) Crop and Pasture	—	—	—	—	\$0	\$0
(Floodwater Damage) Subtotal	—	\$2,454,454	—	\$61,031	\$0	\$2,393,423
(Sediment/ Erosion Damage) Sediment Deposition	—	\$422	—	\$6	\$0	\$416
(Sediment/ Erosion Damage) Flood Plain Scour	—	\$2,372	—	\$39	\$0	\$2,333
(Sediment/ Erosion Damage) Road and Bridge	—	\$0	—	\$0	\$0	\$0

Diamond Alt 1 Item	Average Annual Damages without Project— Ag Related	Average Annual Damages without Project— Non-Ag Related	Average Annual Damages with Project— Ag Related	Average Annual Damages with Project— Non-Ag Related	Average Annual Benefits— Ag Related	Average Annual Benefits— Non-Ag Related
(Sediment/ Erosion Damage) Urban	—	\$0	—	\$0	\$0	\$0
(Sediment/ Erosion Damage) Subtotal	—	\$2,794	—	\$45	\$0	\$2,750
Indirect Damage	\$0	\$0	\$0	\$0	\$0	\$0
Grand Total	\$0	\$2,457,24 9	\$0	\$61,076	\$0	\$2,396,17 3

Footnote for D-26:

¹Discount rate 2.50 percent with a 51-year period of analysis. Price base 2022.

**Table D-27. Estimated Average Annual Flood Damage Reduction Benefits Alternative 1—
Shivwits**

Shivwits Alt 1	Average Annual Damages without Project— Ag Related	Average Annual Damages without Project— Non-Ag Related	Average Annual Damages with Project— Ag Related	Average Annual Damage s with Project —Non- Ag Related	Average Annual Benefits —Ag Related	Average Annual Benefits —Non- Ag Related
(Floodwater Damage) Structures, Contents, Vehicles	—	—	—	—	\$0	\$0
(Floodwater Damage) Roads	—	—	—	—	\$0	\$0

Shivwits Alt 1	Average Annual Damages without Project—Ag Related	Average Annual Damages without Project—Non-Ag Related	Average Annual Damages with Project—Ag Related	Average Annual Damages with Project—Non-Ag Related	Average Annual Benefits—Ag Related	Average Annual Benefits—Non-Ag Related
(Floodwater Damage) Crop and Pasture	\$10,171	—	\$0	—	\$10,171	\$0
(Floodwater Damage) Subtotal	\$10,171	—	\$0	—	\$10,171	\$0
(Sediment/ Erosion Damage) Sediment Deposition	—	—	—	—	\$0	\$0
(Sediment/ Erosion Damage) Flood Plain Scour	—	—	—	—	\$0	\$0
(Sediment/ Erosion Damage) Road and Bridge	—	—	—	—	\$0	\$0
(Sediment/ Erosion Damage) Urban	—	—	—	—	\$0	\$0
(Sediment/ Erosion Damage) Subtotal	\$0	—	\$0	—	\$0	\$0
Indirect Damage	\$0	\$0	\$0	\$0	\$0	\$0
Grand Total	\$10,171	\$0	\$0	\$0	\$10,171	\$0

Footnote for Table D-27:

¹Discount rate 2.50 percent with a 51-year period of analysis. Price base 2022.

**Table D-28. Estimated Average Annual Flood Damage Reduction Benefits Alternative 1—
Dammeron, Diamond, and Shivwits**

Dammeron, Diamond & Shivwits Alt 1	Average Annual Damages without Project— Ag Related	Average Annual Damages without Project— Non-Ag Related	Average Annual Damages with Project— Ag Related	Average Annual Damages with Project— Non-Ag Related	Average Annual Benefits— Ag Related	Average Annual Benefits— Non-Ag Related
(Floodwater Damage) Structures, Contents, Vehicles	\$0	\$3,826,55 ₃	\$0	\$101,112	\$0	\$3,725,44 ₂
(Floodwater Damage) Roads	\$0	\$2,182	\$0	\$0	\$0	\$2,182
(Floodwater Damage) Crop and Pasture	\$10,531	\$0	\$3	\$0	\$10,528	\$0
(Floodwater Damage) Subtotal	\$10,531	\$3,828,73 ₅	\$3	\$101,112	\$10,528	\$3,727,62 ₄
(Sediment/ Erosion Damage) Sediment Deposition	\$0	\$844	\$0	\$40	\$0	\$804
(Sediment/ Erosion Damage) Flood Plain Scour	\$0	\$8,231	\$0	\$138	\$0	\$8,093
(Sediment/ Erosion Damage) Road and Bridge	\$0	\$0	\$0	\$0	\$0	\$0

Dammeron, Diamond & Shivwits Alt 1	Average Annual Damages without Project— Ag Related	Average Annual Damages without Project— Non-Ag Related	Average Annual Damages with Project— Ag Related	Average Annual Damages with Project— Non-Ag Related	Average Annual Benefits— Ag Related	Average Annual Benefits— Non-Ag Related
(Sediment/ Erosion Damage) Urban	\$0	\$0	\$0	\$0	\$0	\$0
(Sediment/ Erosion Damage) Subtotal	\$0	\$9,076	\$0	\$178	\$0	\$8,897
Indirect Damage	\$0	\$0	\$0	\$0	\$0	\$0
Grand Total	\$10,531	\$3,837,811	\$3	\$101,290	\$10,528	\$3,736,521

Footnote for Table D-28:

¹Discount rate 2.50 percent with a 51-year period of analysis. Price base 2022.

Table D-29. Estimated Average Annual Flood Damage Reduction Benefits Santa Clara Watershed Project

Item	Estimated Average Annual Damage without Project (No Action Alternative)	Estimated Average Annual Damage with Project (Preferred Alternative)	Damage Reduction Benefit
(Floodwater Damage) Structures, Contents, Vehicles	\$3,826,553	\$101,112	\$3,725,442
(Floodwater Damage) Roads	\$2,182	\$0	\$2,182
(Floodwater Damage) Crop and Pasture	\$10,531	\$3	\$10,528
(Floodwater Damage) Subtotal	\$3,839,266	\$101,115	\$3,738,151

Item	Estimated Average Annual Damage without Project (No Action Alternative)	Estimated Average Annual Damage with Project (Preferred Alternative)	Damage Reduction Benefit
(Sediment/ Erosion Damage) Sediment Deposition	\$844	\$40	\$804
(Sediment/ Erosion Damage) Flood Plain Scour	\$8,231	\$138	\$8,093
(Sediment/ Erosion Damage) Road and Bridge	\$0	\$0	\$0
(Sediment/ Erosion Damage) Urban	\$0	\$0	\$0
(Sediment/ Erosion Damage) Subtotal	\$9,076	\$178	\$8,897
Total	\$3,848,341	\$101,293	\$3,747,048

Footnote for Table D-29:

¹ Price base: 2022. Calculated using FY 2022 Water Resources Discount Rate (2.50 percent), annualized over 50 years, and 51-year period of analysis. Prepared March 2023.

Table D-30. Comparison of Benefits and Costs

—	Average Annual Costs ³	Average Annual Benefits ²	Benefit Cost Ratio	Net Benefits
Dammeron Alt 1	\$358,669	\$1,340,704	3.74	\$982,036
Diamond Alt 1	\$307,083	\$2,396,173	7.80	\$2,089,089
Shivwits Alt 1	\$37,990	\$10,171	0.27	-\$27,819
Grand Total	\$703,742	\$3,747,048	5.32	\$3,043,306

Footnote for Table D-30:

¹Discount rate 2.50 percent with a 51-year period of analysis. Price base 2022.

²From **Tables D-24** through **D-28**.

³From **Table D-23**.