

Appendix D. Investigation and Analysis Report

Appendix D.1. Design Criteria

Three governing documents were identified to establish design criteria: NRCS Technical Release 210-60 (TR-60), Utah Administrative Code R655-11, and the NRCS National Engineering Handbook. Additional NRCS documents were also referenced and are presented in a comprehensive list in *TM001 – Design Criteria*.

Appendix D.2. Hydrology

A hydrologic analysis was conducted to support the design of culverts, channels, debris basins, water and sediment basins, and canal capacities. This analysis considered Utah Dam Safety and NRCS design storms, as well as frequency storms to size and design various flood infrastructure improvements and support the economic analysis. Subwatersheds were delineated and hydrologic modeling parameters were estimated utilizing the best available GIS data, which included surface, land cover, soils, gridded precipitation, and other hydrology data. A summary of the sub-watershed areas is provided in Table D-1. Refer to *TM002 – Hydrology* for more information, including a drainage map showing the selected subwatershed.

Table D-1. Subwatershed Hydrologic Modeling Parameters

Hydrologic Modeling Parameters	Flat Canyon Subwatershed
Drainage Basin Area (mi ²)	16.5
SCS Curve Number (CN AMC II)	68.5
Longest Watercourse Length (mi)	9.1
Lag Time (hrs)	1.35

The proposed debris basin is located upstream of agricultural, residential, and commercial properties. Based on the obvious risk to property and life, as well as the required storage volume and dam heights, a high hazard classification was assumed per Utah Dam Safety and NRCS criteria. During final design of the project, dam breach analyses and flood inundation modeling will be needed to confirm this risk level and support emergency action plans.

The design storms for the debris basin included the development of the Utah Dam Safety Inflow Design Flood (IDF), which was adopted as the NRCS Freeboard Hydrograph (FBH). The NRCS Principal Spillway Hydrograph (PSH) and Auxiliary Spillway Hydrograph (ASH) were also evaluated. A hydrologic model was built using the Hydrologic Engineering Center Hydrologic Modeling System (HEC-HMS, Version 4.3) from the U.S. Army Corps of Engineers (USACE). Design storms were routed through the reservoirs, accounting for the 100-year sediment accumulation volumes. Controlling design storms included the 6-hour Spillway Evaluation Flood (SEF), which was adopted as the IDF and FBH. The debris basin storage and principal spillway capacity were designed to contain the 100-year 24-hour storm and PSH without initiating the auxiliary spillway, reducing the discharging peak flows to a manageable level.

Frequency storm events were evaluated from the 2-year up to the 500-year event with the SCS Type II distribution, as well as a distribution from NOAA Atlas 14, for comparison purposes in developing a reasonably conservative design. The storms developed using the SCS Type II distribution were found to result in similar runoff volumes but higher, more-conservative peak flows when compared to the NOAA Atlas 14 distribution. Considering the characteristics of the steep semi-arid watersheds' historic high runoff events, the Type II distribution was used in the sizing of the proposed project measures and the economic analysis. Also, where the volumes of these different storm distributions are relatively close (e.g., within 2% for Flat Canyon), the effect on the sizing of proposed debris basin and downstream

measures is minimal. This is due to the nature of how a storm is routed through a debris basin, where a storm fills the debris basin volume and slowly releases water downstream. Therefore, the volume of a storm as a significant influence on the sizing of debris basin and downstream improvements as compared to the peak flow of a storm.

The parameters for the principal and auxiliary spillways of the proposed debris basin were input directly into the hydrologic model. For the 30 percent design level, a simple orifice element was used to simulate the principal spillway outlet and a broad-crested weir was used to simulate the emergency spillway. The design drawings included in *TM007 – Design Drawings* include details showing the design concept for the principal and emergency spillway designs assumed in the analysis, design, and cost estimating. The debris basin volume, spillway capacity, and height are provided in Table D-2. Refer to Structural Table 7-4 of the EA for an additional overall summary of the design parameters of the debris basin.

Table D-2. Debris Basin Design Volumes and Depths

Debris Basin Design Measurements	Flat Canyon Subwatershed
Volume at Emergency Spillway Crest (ac-ft)	827
Volume at Dam Crest (ac-ft)	1120
100-year Sediment Volume (ac-ft)	359
100-year Water Storage Volume (ac-ft)	468
Depth to Emergency Spillway Crest (ft) ¹	55.0
Depth to Dam Crest (ft) ¹	65.0
Depth to 100-year Sediment Volume (ft) ¹	34.7
Total Height of Dam (ft)²	73.0

Limiting downstream capacities were established based on downstream storm water conveyance capacities, which included culverts, channels, and the Sevier Valley and Richfield canals. Provided that the outflow from the debris basin does not exceed these limiting capacities, the existing downstream conveyance system will have adequate capacity to safely convey runoff without flooding. These limiting discharge flows were used to size the debris basin volume and spillway size and are summarized in Table D-3.

Table D-3. Limiting Downstream Capacities

Subwatershed	Limiting Capacity (cfs)	Notes
Flat Canyon	200	Sevier Valley Canal and Richfield Canal Excess Capacity

The controlling Utah Dam Safety SEP and 100-year design storms, as well as the NRCS FBH, ASH, and PSH storms, were routed through the proposed debris basin to determine the critical events. The 6-hour local SEP controlled the design of all Utah Dam Safety storms and was therefore adopted as the IDF and the NRCS FBH. The 100-year storm with an AMC II condition and the PSH were used to size the principal spillway based on the criteria that the emergency spillway should not be engaged during these events and the downstream peak flow cannot exceed the limiting capacities summarized in Table D-4. The controlling storms and corresponding flows and depths are shown in Table D-5.

Table D-4. Hydrologic Modeling Results for the Debris Basin Controlling Design Storms

Parameters	Distribution	Flat Canyon Subwatershed
Peak Inflow (cfs)	IDF/FBH (6-hour SEF)	6826.5
Peak Outflow (cfs)	IDF/FBH (6-hour SEF)	3666.5
Peak Water Surface Depth (ft)*	IDF/FBH (6-hour SEF)	64.5
Freeboard to Dam Crest (ft)	IDF/FBH (6-hour SEF)	0.5
Peak Inflow (cfs)	100-year 24-hour (NOAA Distribution)	519.8
Peak Outflow (cfs)	100-year 24-hour (NOAA Distribution)	178.3
Peak Water Surface Depth (ft)*	100-year 24-hour (NOAA Distribution)	46.4
Freeboard to Emergency Spillway Crest (ft)	100-year 24-hour (NOAA Distribution)	8.6
Peak Inflow (cfs)	100-year 24-hour (SCS Distribution)	1145.3
Peak Outflow (cfs)	100-year 24-hour (SCS Distribution)	182.2
Peak Water Surface Depth (ft)*	100-year 24-hour (SCS Distribution)	46.9
Freeboard to Emergency Spillway Crest (ft)	100-year 24-hour (SCS Distribution)	8.1
Peak Inflow (cfs)	PSH (10-day)	605.4
Peak Outflow (cfs)	PSH (10-day)	232.7
Peak Water Surface Depth (ft)*	PSH (10-day)	54.6
Freeboard to Emergency Spillway Crest (ft)	PSH (10-day)	0.4

*Depths are relative to upstream toe of dam to represent true depth of sediment or water.

Appendix D.3. Sedimentation

A sedimentation analysis was completed to predict both the submerged and aerated sediment loads resulting from the analyzed subwatersheds. Because the proposed debris basins are considered dry dams per TR-60, none of the sediment is considered submerged. In other words, the total sediment is equal to the aerated sediment. Therefore, whenever sediment is referenced throughout the analysis, it refers to aerated sediment or total sediment. The estimated sediment load rates from the analysis were used in estimating sediment load volumes over time for the debris basins (dry dams) and other hydraulic structures proposed in the Watershed Plan. All debris basins have been designed to provide capacity for 100-years of sediment accumulation.

In the late 1980s, two debris basins were constructed at the outlets of Dairy Canyon and Cottonwood Canyon. These basins are contiguous with the other subwatersheds being studied as part of the Watershed Plan and have been in operation and collecting sediment for more than 30 years. The existing sediment pool elevations were surveyed to help calibrate the different methods used in estimating sediment loads.

The yield rates from the calibrated Pacific Southwest Inter-Agency Committee (1968) method were used for design. The final design sedimentation rates for each basin are presented in Table D-5. Refer to *TM003 – Sedimentation* for additional information on the sedimentation analysis, including an overview map of each subwatershed with each corresponding sedimentation rate and loading rate.

Table D-5. Design Sedimentation Rates for Each Subwatershed

Subwatershed	Sedimentation Rate (ac-ft/mi ² /yr)	Deposition Rate (ac-ft/yr)	100 Years of Sediment (ac-ft)
Flat Canyon	0.21*	3.59	359

*A watershed area of 16.5 square miles was used in place of the total 17.1 square miles because the watershed area above the proposed location of the Flat Canyon basin is only 16.5 square miles and not the total area analyzed in the sedimentation.

Appendix D.4. Hydraulics

A hydraulic analysis was performed to complete flood modeling to support the economic analysis and determine existing and proposed flood channel capacities. The flood modeling supported the economic analysis by showing the existing and proposed flooding conditions as a result of proposed project measures. The USACE River Analysis System (HEC-RAS 5.0.6) was used to create a combined one-dimensional (1D) and two-dimensional (2D) flood model.

. The storm events that were modeled for existing and proposed conditions in Flat Canyon for the 500-, 200-, 100-, 50-, 25-, 10-, 5-, and 2-year storm events. This resulted in 16 different scenarios. Refer to *TM004 – Hydraulics* for a detailed explanation on the flood modeling for Flat Canyon as well as a map showing the inundation areas for each event.

The existing south flood channel was evaluated to determine its general condition, hydraulic capacities, and road-crossing capacities. These factors were evaluated to determine the necessary improvements that would be required for the channel after proposed project measures are implemented. The channel would be designed to convey a portion of the attenuated 100-year flow from the Flat Canyon debris basin. A summary of the items that are proposed in upgrading the south flood channel are presented below. Sheet PL-01 of *TM007 – Design Drawings* shows an exhibit that also describes each of these project elements:

- Reconstruct the overshot structure to allow storm flows to be directed into the flood channel while allowing for a set maximum flow rate to enter the Sevier Valley Canal during the 100-year event.
- Construct a rock chute and stilling basin to help dissipate energy downstream of the overshot structure.
- Upgrade and armor the existing open channel.
- Construct a splitter structure to allow a set maximum flow rate to enter the Richfield Canal and the remaining flow to enter a closed conduit inlet structure.
- Install closed conduit pipe from the splitter structure to an outlet structure east of Highway 118.
- Install a pipe outlet structure to discharge into an overland flow area with containment berms that would convey flows to the Sevier River.

The existing Willow Creek flood channel was also evaluated to determine its general condition, hydraulic capacities, and road-crossing capacities. These factors were evaluated to determine the necessary improvements that would be required for the channel after proposed project measures were implemented. This channel would be designed to convey a portion of the floodwaters from Flat Canyon to the Sevier River. This system is referred to as the North Flood Channel. A summary of the items that are proposed as part of the north flood channel are presented below. Sheet PL-04 of *TM007 – Design Drawings* shows an exhibit that also describes each of these project elements:

- Construct an emergency canal overflow structure allowing floodwater to exit the Sevier Valley Canal into the existing channel;
- Construct a rock chute and stilling basin to help dissipate energy downstream of the emergency canal overflow structure;

- Upgrade existing open channel and associated culverts and road crossings between the Sevier Valley Canal and the Richfield Canal;
- Install riprap bank protection at the confluence with the Richfield Canal to prevent erosion;
- Construct an emergency overflow and pipe inlet structure with trash rack in the Richfield Canal to allow floodwater to exit the canal and enter the proposed storm water pipe; and
- Install storm water pipe to convey flows from the Richfield Canal to an overshoot over the Vermillion Canal and then to the Sevier River.

TM004 – Hydraulics provides more specific design information regarding flood modeling and channel improvements for these items.

Appendix D.5. Geotechnical

A geotechnical investigation was conducted by AECOM Technical Services, Inc. (AECOM), which consisted of field exploration, laboratory testing of soils, field surveying, and engineering analyses. The borings and pits were logged in the field. The collected soil samples were used for laboratory testing. The laboratory testing program included classifying on-site soils, assessing physical and engineering properties, and performing particle-size gradations (mechanical and hydrometer), analyzing Atterberg limits, and evaluating moisture/density relationships (modified proctor).

Based on geotechnical analysis, Flat Canyon is a suitable locations for a debris basin. While further analysis will be required before final design, a list of the key recommendations is disclosed in *TM005 – Geotechnical*.

Appendix D.6. Economics

Whether the proposed project alternative is economically feasible is determined by comparing the average annual benefits to the average annual costs. If the average annual benefits for the proposed project alternative exceed the average annual costs, then the proposed project alternative is considered economically feasible. The economic analysis considers the no-action scenario (hereafter without-project scenario) as the baseline condition, which does not have any benefits or costs associated with it. Changes resulting from implementation of a with-project scenario (single project element or combination of elements) in relation to the without-project scenario would be measured as a cost or a benefit. An economic analysis was performed to quantify the benefits and costs of each project element. The following summarizes the results of the economic analysis. Additional detail on the economic analysis can be found in *TM006 – Economics*.

Benefits and costs over the period of analysis were annualized to allow for a direct comparison of average annual benefits to average annual costs. The benefits and costs were evaluated using a 2025 price level over a 102-year period of analysis (2 years of construction and 100-year project life), amortized using a discount rate of 3 percent. The benefit categories represent damage reduction from future flooding. The analysis uses inundation models for eight flood recurrence intervals, which are the 50-percent- (2-year), 20-percent- (5-year), 10-percent- (10-year), 4-percent (25-year), 2-percent- (50-year), 1-percent- (100-year), 0.5-percent- (200-year), and 0.2-percent- (500-year) annual-probability flood events, to estimate future damages from flooding within the study area. Average annual benefits were compared to the average annual costs to generate a benefit-cost ratio for each project element and an aggregate benefit-cost ratio of the with-project scenario.

The benefit categories evaluated include flood damage reduction to residential and nonresidential structures (e.g., residential, commercial, religious facility, government), contents, automobiles, and agriculture, and debris removal). Table D-6 lists the number of structures protected for the proposed project alternative at the 0.2-percent-annual-probability flood event.

Table D-6. Number of Residential and Nonresidential Structures Protected by Project Element (0.2-percent-annual-probability flood event)

Project Element	Structure Inundated – Without-Project Scenario	Structures Inundated – With-Project Scenario	Structures Protected
With Project Alternative	947	0	947

The proposed project alternative would also result in a reduction in inundation of agricultural lands. Therefore, agricultural benefits, which include crop damages avoided and reduced damage from sedimentation in the canals, were monetized. Table D-7 lists the area of agricultural land protected for the proposed project alternative at the 1-percent-annual-probability flood event.

Table D-7. Acres of Agricultural Land Protected by Project Element (1-percent-annual-probability flood event)

Project Element	1-Percent-Annual Probability			0.2-Percent-Annual Probability		
	Agricultural Land Inundated - Without-project	Agricultural Land Inundated – With-project	Agricultural Land Protected	Agricultural Land Inundated - Without-project	Agricultural Land Inundated – With-project	Agricultural Land Protected
With Project Alternative	2,540	0	2,540	2,820	0	2,820

Note: Acreage inundated is rounded to the nearest ten.

Table D-8 shows the total average annual damages avoided for the proposed project alternative.

Table D-8. Total Damages Avoided by Project Element

Project Element	Average Annual Structure Damages Avoided	Average Annual Agricultural Damages Avoided	Total Average Annual Benefits
With Project Alternative	\$1,492,000	\$265,000	\$1,757,000

Notes: 2021 price level, 2.75 percent discount rate, and a 102-year period of analysis. Benefits are rounded to the nearest thousand.

The total project costs presented in Table D-9 were used the economic analysis. The project lifespan for the proposed project alternative was assumed to be 100 years. Construction costs and average annual operations and maintenance (O&M) costs were estimated to determine an average annual cost for the proposed project alternative (Table D-9).

Table D-9. Average Annual Costs by Project Element

Project Element	Total Implementation Costs	Average Annual O&M	Average Annual Costs
With Project Alternative	\$20,629,000	\$12,000	\$685,000

Notes: 2021 price level, 2.75 percent discount rate, and a 102-year period of analysis. Average annual cost includes interest during construction. Costs are rounded to the nearest thousand.

Table D-10 summarizes the average annual benefit and average annual costs for the proposed project alternative, which were used to calculate the benefit-cost ratio the proposed project alternative. The benefit-cost ratio is 2.6:1.0.

Table D-10. Benefit-Cost Analysis Summary

Project Element	Average Annual Benefits	Average Annual Costs	Benefit-Cost Ratio	Net Benefits
With Project Alternative	\$1,757,000	\$685,000	2.6:1.0	\$1,072,000

Notes: 2021 base year, amortized using a 2.75 percent discount rate and a 102-year period of analysis.

Appendix D.7. 30 Percent Drawings

The proposed alternative was evaluated to approximately a 30 percent design level. Design drawings were generated to help communicate the geospatial locations and conceptual design details of the project elements, approximate disturbance areas, and aid in cost estimating. *TM007 – Design Drawings* contains a full set of 30 percent design drawings.

Appendix D.8. Introduction

The information presented in this Investigation and Analysis Report is based on standard methods, procedures, and computer programs used and approved for use by the NRCS. The following information gives a summary of the investigation and analysis for the key planning studies in the preparation of the proposed Richfield-West Sevier Watershed project. The information in this section is summarized from technical memos (TM) prepared for this project, which are provided in Appendix E. Requests for additional information can be submitted to the following address:

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

Appendix D.9. Probable Cost

The cost of each project element was evaluated, and a probable cost was determined. These costs were determined by a combination of 30 percent design quantities, past and present unit costs, and engineering experience. *TM008 – Probable Costs* contains detailed quantities, unit cost, and total project element costs.

Appendix D.10. Hazard Classification

The proposed debris basin located at Flat Canyon was evaluated to determine a recommended hazard classification. Based on the dam breach analysis of the debris basin, a high hazard classification is recommended. *TM009 – Hazard Classifications* contains detailed description of the hazard classification analysis.

Appendix D.11. Statement of Limitations

This document represents Jones & DeMille Engineering's professional judgment based on the information available at the time of its completion and as appropriate for the project scope of work. Services performed in developing the content of this document have been conducted in a manner consistent with that level and skill ordinarily exercised by members of the engineering profession currently practicing under similar conditions. No warranty, express or implied, is made.

Appendix D.12. References

Natural Resources Conservation Service (NRCS). 2019. Technical Release 210-60: Earth Dams and Reservoirs. Conservation Engineering Division. March 2019.

Pacific Southwest Inter-Agency Committee. 1968. Pacific Southwest Inter-agency Committee Report of the Water Management Subcommittee on Factors Affecting Sediment Yield in the Pacific Southwest Area and Selection and Evaluation of Measures for Reduction of Erosion and Sediment Yield. Pacific Southwest Inter-Agency Committee. October.