Nacimiento-Fergusson Road

CA ERFO 22S01(1)

Final Hydraulics Report

In Partnership With:

Los Padres National Forest

Federal Highway Administration
Central Federal Lands Highway Division

January 2023

Signature Sheet

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Executive Summary

Hydrologic and hydraulic analyses were conducted for the CA ERFO 22S01(1) Nacimiento-Fergusson Road project. The project section of NFSR 22S01 was impacted by the Dolan Fire in late 2020. Following the fire, a high precipitation event occurred within the burn area in January 2021 resulting in significant impacts to the road. Along NFSR 22S01, sixteen sites were evaluated for ERFO improvements. Three sites were determined to be ineligible under the ERFO program and eight of the remaining thirteen sites included hydraulic features that were evaluated in this report.

For these eight crossings, the peak flow values were estimated using available USGS regression equations for California, a gage comparison with a nearby USGS stream gage, and an NRCS rainfall-runoff model conducted using HEC-HMS. The USGS regional regression equations were selected as the most appropriate peak flow rates for the project site. Additionally, a multiplier of 1.5 was added to the selected peak flow rates to account for the increased flows associated with the Dolan Fire.

The hydraulic design criteria were developed in accordance with the Federal Lands Highway (FLH) for culvert design and low water crossings. Per the FLH PDDM, culverts are designed to the 25-year storm event. For the culverted crossings, a HW/D ratio of 1.0 was targeted in order to account for the higher debris flow associated with the burned watershed. Site 6 has a significantly higher sediment supply upstream of the crossing and therefore a HW/D ratio of 0.8 or less was targeted for this location. For all seven sites, culvert replacements were determined that will adequately pass the 25-year storm event. In addition, a potential low water crossing was evaluated and determined to be unsuitable for Site 6 (further detail provided in the report). Finally, an additional culvert was evaluated for Site 16 to intercept excess ditch flows and reduce the potential for impacts to the proposed wall at this site.

Using the survey information and preliminary pipe recommendations, culvert recommendations were determined using site-specific HY-8 models. Due to the high sediment loads associated with the project site, single barrel culverts are recommended as they transfer sediment more efficiently. The proposed replacement culverts, inlet and outlet configuration, and stability requirements at all eight sites evaluated in this report are provided in the following recommendations table.

Site Recommendations

Site	Capacity						Stability					
	25-Year Design Flow (cfs)	Diameter (in)	Structure Type	Modeled Pipe Slope (ft/ft)	Inlet & Outlet Configuration	HW/D Ratio	Pipe Anchors (C602-50)	Culvert Rundown (C602-50)	Riprap Apron (shaped per C251-50)			
									Riprap Class	Length (ft)	Width (ft)	Thickness (ft)
Site 2	187.7	72	CMP	0.086	Concrete Headwalls (601-5)	0.91	No	No	5	24	24	3
Site 3	40.1	48	CMP	0.321	Metal End Sections (602-4)	0.57	Yes	No	3	12	12	2
Site 4	10.4	24	CMP	0.338	Metal End Sections (602-4)	0.78	Yes	No	3	4	6	2
Site 6	133.8	72	CMP	0.094	Concrete Headwalls (601-5)	0.72	No	No	5	24	24	3
Site 10	6.0	24	CMP	0.267	Metal End Sections (602-4)	0.53	Yes	Yes	No riprap apron is recommended at this location.			
Site 11	66.3	48	CMP	0.076	Metal End Sections (602-4)	0.99	No	No	5	16	10	3
Site 12	16.8	36	CMP	0.214	Inlet: Concrete Headwall (601-5) Outlet: Metal End Section (602-4)	0.56	No	No	3	6	9	2
Site 16	8.1	24	CMP	0.190	Metal End Sections (602-4)	0.70	No	Yes	No riprap apron is recommended at this location.			

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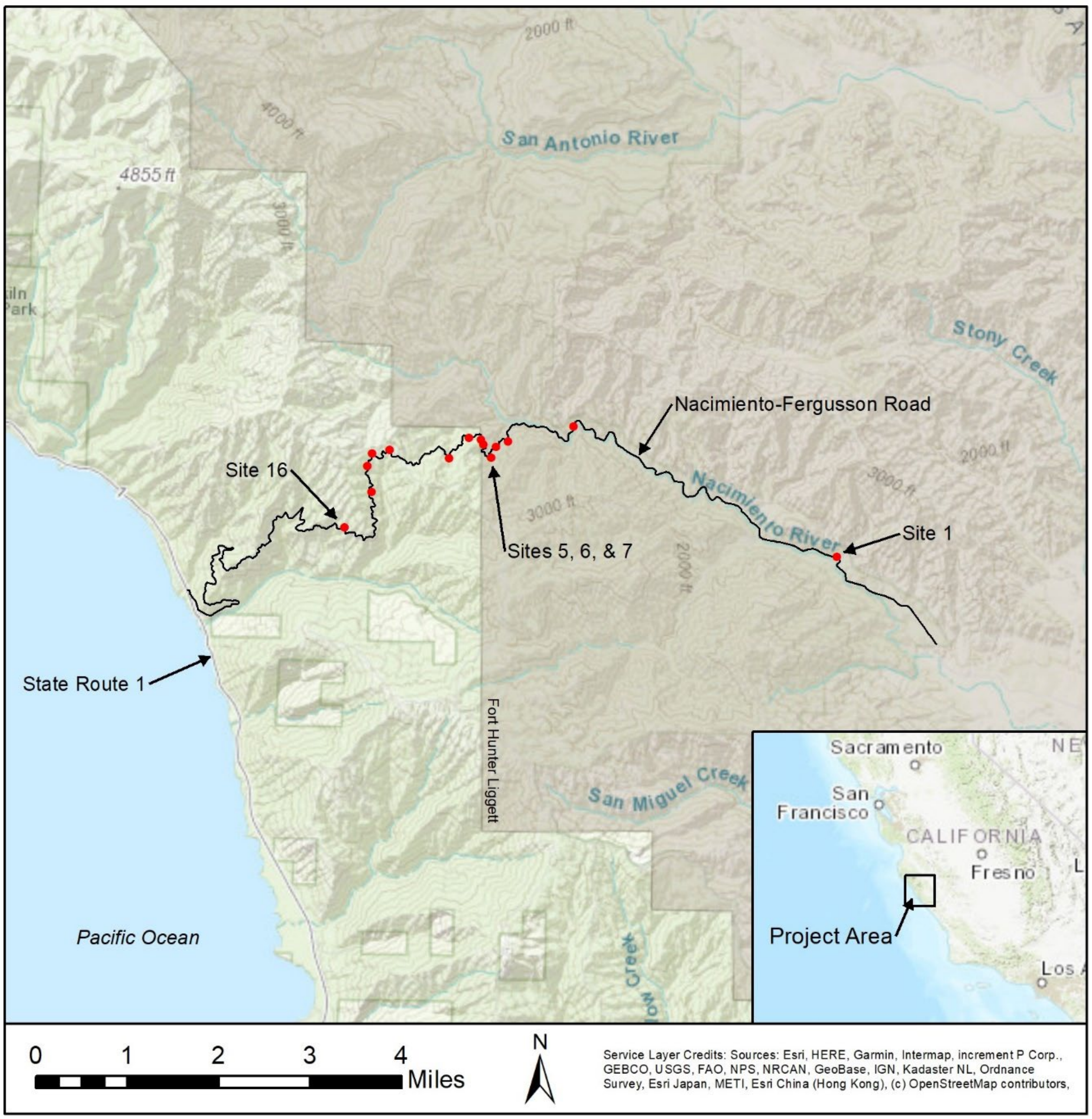
1 Project Background Information

1.1 Project Information

Nacimiento-Fergusson Road (National Forest System Route 22S01) is located in Monterey County, CA and connects Fort Hunter Liggett to California State Route 1. The project section of NFSR 22S01 was impacted by the Dolan Fire in late 2020. Following the fire, a high precipitation event occurred within the burn area in January 2021 resulting in significant impacts to the road. Along NFSR 22S01, 16 sites were evaluated for ERFO funding during the scoping site visit on September 8th, 2021. The site locations are presented in Figure 1 below with Site 1 on the eastern end of NFSR 22S01 near the Ponderosa Campground and Sites 2 through 16 continuing west in numerical order. Due to their close proximity, Sites 5, 6, & 7 were depicted as one location. Of the 16 sites, Sites 1, 7, and 9 were determined to be ineligible for ERFO improvements.

Figure 1: Project Location Map



1.2 EXISTING DRAINAGE FEATURES & SITE SELECTION

Of the sites assessed, Sites 2 through 4, Site 6, Sites 10 through 12, and Site 16 include hydraulic features that will be evaluated in this report. A summary of the sites is included in Table 1 below.

Table 1: Existing Site Summary

Site	Existing Condition	Recommendation
1	Existing bridge structure in functioning condition. Significant sediment load from upstream.	• **Not eligible for ERFO funds.** • **No recommended hydraulics work proposed.**
2	**Existing 48" CMP** Culvert in poor condition with a buried inlet and floating outlet. Significant sediment supply upstream.	• Evaluate drainage basin to determine peak flow rates to existing culvert. • Evaluate existing pipe capacity. • **Provide minimum replacement pipe size if necessary (may leave in place if adequately sized).**
3	**Existing 24" CMP** Culvert in poor condition with a buried inlet and floating outlet and not functioning.	• Evaluate drainage basin to determine peak flow rates to existing culvert. • **Provide minimum replacement pipe size.**
4	**Assumed 12"-18" CMP** Existing ditch relief culvert inlet is buried. Flow from the northeast overwhelmed the inlet and caused the embankment on the northwest side to erode.	• Evaluate drainage basin to determine peak flow rates to existing culvert. • **Provide minimum replacement pipe size.**
5	Excess flow associated with the Site 6 drainage overwhelmed the road and caused the embankment to erode.	• No hydraulic features are present on the site. • **No recommended hydraulics work proposed.**
6	**Assumed Buried Culvert** Existing culvert not identified in the field but identified in Google Street view. Pipe has completely failed and is overwhelmed with sediment from upstream.	• Evaluate drainage basin to determine peak flow rates to existing culvert. • **Provide minimum replacement pipe size.** • **Evaluate potential for low water crossing.**
7	Excess storm flow from the road to the northwest has caused the embankment on the eastern side of the road to erode. No hydraulic features are present on the site.	• **Not eligible for ERFO funds.** • **No recommended hydraulics work proposed.**
8	Excess storm flow from the road to the north as well as flow from the western slope has caused the embankment on the eastern side of the road to erode.	• No hydraulic features are present on the site. • **No recommended hydraulics work proposed.**
9	Excess storm flow from the road to the north as well as flow from the western slope has caused the embankment on the eastern side of the road to erode.	• **Not eligible for ERFO funds.** • **No recommended hydraulics work proposed.**
10	**Existing 12" CMP** Existing ditch relief culvert. Inlet is completely buried and approximately 10-20 feet of pipe is floating at the outlet due to embankment erosion.	• Evaluate drainage basin to determine peak flow rates to existing culvert. • **Provide minimum replacement pipe size.**

11	**Assumed Buried Culvert** Flow from the road to the northwest likely overwhelmed the existing culvert causing the embankment to fail on the northern side of the road. An existing half pipe culvert rundown was identified laying in the channel. The rundown is no longer functioning.	• Evaluate drainage basin to determine peak flow rates to existing culvert. • **Provide minimum replacement pipe size.**
12	**Assumed Buried Culvert** No culvert was located during the scoping site visit but a culvert delineator and inlet basin were identified in available Google Street view. Once culvert was filled with sediment, the road was overwhelmed causing the downslope embankment to fail.	• Evaluate drainage basin to determine peak flow rates to existing culvert. • **Provide minimum replacement pipe size.**
13	Embankment failure on the western side of the road. There is an existing 36" CMP to the north of Site 13 but this crossing had no impact on the bank failure. Existing culvert is clean, in good condition, and functioning. Flow from road to the east overwhelmed the road causing the embankment to fail prior to reaching the existing culvert.	• No hydraulic features are present on the site. • **No recommended hydraulics work proposed.**
14	Embankment to the east has eroded due to excessive storm flows from the north. No hydraulic structures present at this location.	• Minor ditch conditioning recommended along the western side of the road. • **No recommended hydraulics work proposed.**
15	Flow from the road to the north spilled across the road and eroded the embankment to the southeast. No hydraulics structures present at this site. Ditches are generally clean. Road was just overwhelmed with flow.	• No hydraulic features are present on the site. • **No recommended hydraulics work proposed.**
16	Ex. 18" CMP with drop inlet structure at inlet and culvert rundown at outlet. The existing pipe, inlet, and outlet are all in good condition and functioning. Flood flows from the road to the south cut across the road and erode the fill slope on the western side of the road.	• Existing pipe is functioning and did not contribute to the bank failure. • **Additional ditch relief culvert would improve drainage and protect the proposed wall. Evaluate additional ditch relief culvert.**

1.3 Flood Insurance Study

According to the FEMA Map Service Center, Sites 1 through 16 are all designated as areas of minimal flood hazard (Zone X) and therefore not within a special flood hazard area (SFHA). Because all sites are located outside of the SFHA, no coordination with FEMA is required.

2 HYDRAULIC DESIGN CRITERIA

The Federal Lands Highway Project Development and Design Manual (PDDM) (Federal Lands Highway 2012) establishes the hydraulic design criteria for NFSR 22S01. The project section of NFSR 22S01 will be returned to its pre-flood condition under the ERFO program and therefore design speed and average daily traffic (ADT) were not provided. Due to the winding and remote nature of the road, NFSR 22S01 is assumed that the design speed is well below 45-mph with low ADT. Additionally, the road is not designated as a critical access road. Therefore, NFSR 22S01 will be considered a low-standard road for hydraulic design purposes and will be evaluated against the design criteria provided in Table 2 below.

Table 2: PDDM Hydraulic Design Criteria

Low-Standard Roadway	**Design Frequency**	**Check Frequency**	**Design Criteria**
Roadway Culverts	25-Year	Overtopping	New: AHW ≤ bottom of aggregate base layer
			Existing: AHW ≤ shoulder hinge point
			Where D ≤ 48", HW/D ≤ 1.5 & Where D > 48", HW/D ≤ 1.2
			Heavy debris or sediment load concerns: 0.8 ≤ HW/D ≤ 1.0
			Crossing is stable at the design flood
			Minimum pipe size: 24 in. or equivalent

Due to the high sediment loads associated with the burned watershed, a HW/D ratio of 1.0 or less will be utilized for all culvert replacements at Sites 2-4, 10-12, and 16 while Site 6 will be designed with a HW/D ratio of 0.8 or less to accommodate the extreme volume of sediment upstream of the crossing.

3 HYDROLOGIC ANALYSIS

3.1 HYDROLOGIC SETTING AND TOPOGRAPHIC DATA

The project sites along NFSR 22S01 are split between two major basins. Sites 1 through 11 are located within the San Miguel Creek-Nacimiento River Subwatershed (HUC12: 180600050601) while Sites 12 through 16 are located within the Limekiln Creek-Frontal Pacific Ocean Subwatershed (HUC12: 180600060305).

NFSR 22S01 cuts through the Santa Lucia Mountain Range which is characterized by northwest-trending, steep-sided, sharp-crested ridges. All associated watersheds flow either directly or indirectly to the Pacific Ocean. The topography is comprised of rapidly incising stream networks and highly unstable slopes. Stream channels and hillslopes are very steep with the average hillslope gradients exceeding 60% in some areas. Elevations rise rapidly from the coast and represent a range of elevations of 200-ft to nearly 5,900-ft. This elevation results in a rain shadow effect as storms move over the range. Mean annual precipitation throughout the area ranges from 48-in near the coast, to 23-in further inland. For this reason, the basin associated with Site 2 receives significantly less precipitation than the other more westward basins studied.

The contributing basins for each crossing selected for analysis were delineated using a 10-m raster digital elevation model (DEM) obtained from the USGS National Map as shown in Figure 2. General basin characteristics are provided in Table 3. Mean annual precipitation data was obtained from the PRISM Data Explorer using 30-year normal precipitation depths from 1991-2020 sampled from an 800-m cell most closely representative of each basin (PRISM Climate Group 2022).

Figure 2: Basin Delineations

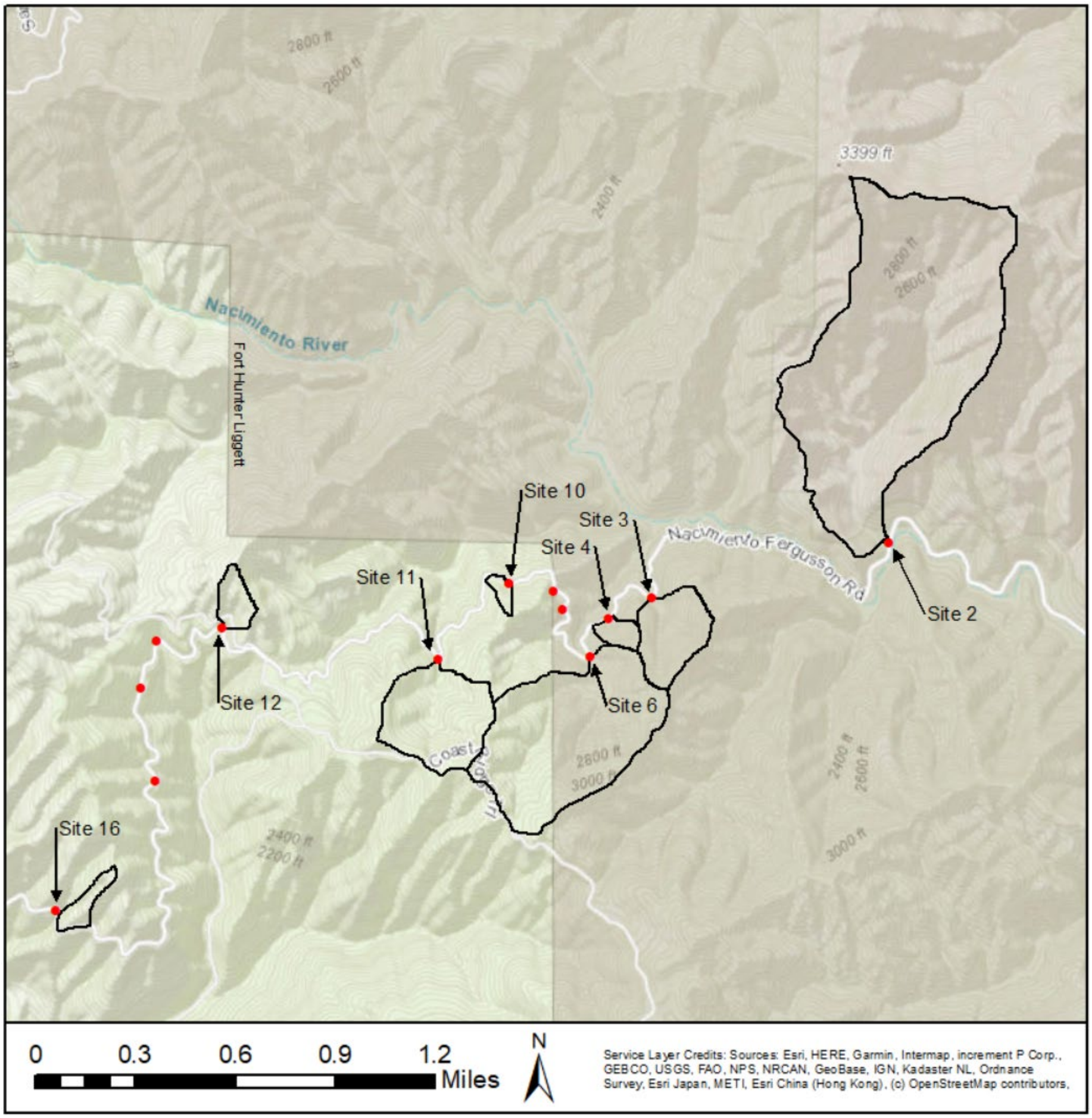


Table 3: General Basin Characteristics

Site	Drainage Area (ac)	Mean Basin Elevation (ft)	Mean Basin Slope (%)	Mean Annual Precip (in)
2	286.7	2,459	62	34.6
3	30.3	2,443	76	44.9
4	6.1	2,330	66	44.9
6	126.7	2,761	59	44.9
10	3.4	2,500	56	43.0
11	53.1	2,881	54	45.9
12	9.9	2,973	56	47.5
16	7.7	2,230	56	43.7

3.2 Dolan Fire Burn Area Emergency Response (BAER) Report

The Dolan Fire first started on August 18, 2020 and was at 98% containment as of the release of the BAER report on October 13, 2020 (USDA Forest Service 2020). The associated BAER report outlines the extent the fire including areas burned, burn severity, and road impacts as well as the anticipated watershed response and recovery. Within the fire perimeter, approximately 8.5% was unburned, 36% had a low burn severity, 45% had a moderate burn severity, and 10% had a high burn severity. Approximately 125,000-ac was impacted. Existing soils within the area were already highly erodible and following the fire, nearly 96% of the burn area is now classified as having a severe soil erosion hazard rating. The predicted unburned, pre-fire sediment load is 2.5 tons per acre while the post-fire load is predicted to be 31.5 tons per acre.

Anticipated vegetative recovery for this region is extremely variable depending on precipitation but on average recovery is rapid, often exceeding 60% ground cover in one growing season. However, severe debris flows are likely to linger for 2-3 years with post-burn erosion and runoff rates approaching pre-burn levels within 5-7 years. Increases in runoff across the burn area are expected to be 130% to 375% compared to normal. For the Nacimiento River basin, which most closely corresponds to the project sites, peak flows are anticipated to experience a 354% increase over normal. Aside from this prediction, no additional information is provided on hydrologic response.

Considering that the proposed ERFO drainage improvements outlined in this report will not be constructed until 2023, three complete growing seasons will have occurred within the watershed. Based on the BAER report, the majority of the more severe debris flows will have already occurred and recovery will likely be well underway. The major flood event associated with the January 2021 storm will also have likely stripped away the majority of the hydrophobic soil layers further working towards a pre-fire equilibrium. For this reason, an increase of 354% (3.54 multiplier) is likely no longer applicable by the time drainage improvements are made. While no indication is made in the report as to the flow rates 3 years after the fire, if pre-burn flow rates are likely to be achieved after 7 years with the bulk of the more severe flow rates occurring within the first 2-3 years, flow rates will likely be approaching pre-burn levels. Assuming approximately 80% of the watershed recovery will have occurred within the first 3 years, peak flow rates will likely be much closer to pre-burn rates.

Therefore, using the logic outlined above, a multiplier of 1.5 (reflecting 80% recovery) will be applied to the final peak flow rates defined in Section 3.6. This is supported by the post-fire runoff modifier equation which results in a multiplier of 1.55 based on burn severity within the watershed (Moscow Forestry Sciences Laboratory 2009). Sections 3.3 through 3.5 will assume pre-fire peak flow conditions for comparison purposes. The multiplier will be applied once the most appropriate hydrologic method is selected.

3.3 Regression Equation Estimates

The applicable regression equation for the project basins defined in Section 3.1 are detailed in the USGS Scientific Investigations Report 2012-5113. Per the report documents, the project area lies within the Central Coast (Region 4) hydrologic region which relates peak discharge to drainage area and mean annual precipitation. According to the study, 114 basins were used in the development of the regression equations and include drainage areas between 0.11 and 4,600 square miles and mean annual precipitation depths between 7 and 46 inches. All basins fall within the range of precipitation values but only the basin areas associated with Sites 2 and 6 fall within the range of drainage areas used for the development of the regression equations. Peak flow estimates for all seven basins are provided in Table 4 using the Central Coast regression equations. Because the basins associated with Sites 3-4, 10-12, and 16 fall below the minimum applicable drainage area, error associated with these flow rates is unknown but may still be useful for flow rate determination. Flow rates with variables outside of the range of prediction are *italicized* in Table 4.

Table 4: Regression Equation Peak Flow Rates

Return Period (years)	Annual Exceedance Probability (%)	Site 2 Peak Flow (cfs)	Site 3 Peak Flow (cfs)	Site 4 Peak Flow (cfs)	Site 6 Peak Flow (cfs)	Site 10 Peak Flow (cfs)	Site 11 Peak Flow (cfs)	Site 12 Peak Flow (cfs)	Site 16 Peak Flow (cfs)
2	50	21.6	*6.2*	*1.6*	21.0	*0.8*	*10.6*	*2.7*	*1.8*
5	20	53.4	*13.2*	*3.4*	44.5	*1.9*	*22.2*	*5.7*	*3.9*
10	10	83.7	*19.3*	*5.0*	64.6	*2.8*	*32.1*	*8.2*	*5.8*
25	4	125.1	*26.7*	*6.9*	89.2	*4.0*	*44.2*	*11.2*	*8.1*
50	2	159.6	*32.6*	*8.5*	108.4	*4.9*	*53.6*	*13.6*	*10.0*
100	1	189.8	*37.2*	*9.7*	123.8	*5.7*	*61.0*	*15.4*	*11.5*

3.4 AVAILABLE HYDROLOGIC DATA

Per the USGS National Water Information System (NWIS), there are no active or inactive USGS peak streamflow stations within the study area. The USGS Report 2012-5113, detailed in Section 3.3 above, provides a summary of the gage stations used in the development of the regression equations as well as an area weighted comparison equation (Equation 13 in the report) for computing peak flows at an ungaged site based on information from a gaged site. Use of Equation 13 is applicable for computing flow at ungaged locations along the same gaged stream when the drainage area for the ungaged site is equal to 0.5 to 1.5 times the drainage area of the gaged site. While the requirement for the ungaged and gaged sites to be along the same stream is not met for the NFSR 22S01 sites, it may still be useful for flow rate determination.

To identify a gage within the Central Coast region that may be comparable to the NFSR 22S01 sites, gages were sorted first by drainage area and then mean annual precipitation. One gage was identified that somewhat closely matched the characteristics of the NFSR 22S01 sites. The selected gage for comparison (USGS station 11142800) is an inactive stream gage located along Rat Creek approximately 10-mi northwest of the project site where the channel crosses below California State Route 1. Available gage information is provided below in Table 5.

Table 5: Gage Information

Station Name (Number)	Rat Creek near Lucia CA (USGS 11142800)
Latitude/Longitude	36.0922° / 121.6175°
Drainage Area	0.82 mi^2
Mean Annual Precipitation	32.9 inches
Period of Record	1961 - 1973

Using the previously mentioned Equation 13, the flow rates provided in Table 6 were computed.

Table 6: Peak Flow Rates based on Gage Comparison

Return Period (years)	Annual Exceedance Probability (%)	Site 2 Peak Flow (cfs)	Site 3 Peak Flow (cfs)	Site 4 Peak Flow (cfs)	Site 6 Peak Flow (cfs)	Site 10 Peak Flow (cfs)	Site 11 Peak Flow (cfs)	Site 12 Peak Flow (cfs)
2	50	*21.0*	*9.7*	*2.6*	*28.2*	*1.3*	*16.0*	*4.4*
5	20	*51.9*	*21.3*	*5.7*	*61.0*	*3.2*	*34.5*	*9.5*
10	10	*81.2*	*31.4*	*8.4*	*89.2*	*4.8*	*50.4*	*13.8*
25	4	*121.4*	*43.4*	*11.6*	*123.0*	*6.8*	*69.3*	*18.8*
50	2	*155.0*	*52.7*	*14.2*	*148.9*	*8.3*	*83.5*	*22.7*
100	1	*184.4*	*59.7*	*16.1*	*169.3*	*9.5*	*94.5*	*25.5*

3.5 RAINFALL-RUNOFF MODEL ESTIMATES

Rainfall-runoff modeling using HEC-HMS version 4.9 (U.S. Army Corps of Engineers 2022) was conducted to compare the peak flow estimates from the regression equations as described in the following sections. Hydraulic model parameters and results are provided in Appendix A.

3.5.1 Precipitation

The point precipitation values for the project basins were obtained from NOAA Atlas 14, Volume 6, Version 2 (Perica, et al. 2014) using the Precipitation Frequency Data Server (NOAA 2011). Sampling from the basin centroids for Sites 3-12 resulted in very similar point precipitation depths (within 0.1-in for all return periods) and therefore the same precipitation depths were applied across those basins. The precipitation values below were assumed to represent the precipitation over the entire basin area. The point precipitation values for a duration of 24 hours at various return periods are shown in Table 7.

Table 7: NOAA Atlas 14 24-Hour Precipitation

Return Period (years)	Annual Exceedance Probability (%)	Site 2 Precipitation (in)	Sites 3 - 12 Precipitation (in)
2	50	4.93	5.49
5	20	6.26	6.93
10	10	7.37	8.15
25	4	8.94	9.85
50	2	10.2	11.2
100	1	11.5	12.6

3.5.2 Basin Characteristics

The NRCS curve number (CN) method (Natural Resources Conservation Service 1997) was used to estimate runoff. SSURGO soil information (Natural Resources Conservation Service 2015) is available for the project basins and was used for this assessment. Land cover was obtained from the 2019 National Land Cover Dataset (Multi-Resolution Land Characteristics Consortium 2019). Time of concentration was estimated by the NRCS TR-55 methodology. The minimum time of concentration used was 5-min. Lag time is computed as 60% of the time of concentration (minimum of 3-min).

The project basins included hydrologic soil groups (HSG) B and D. Land cover for the basins consisted of primarily Grassland/Herbaceous and Evergreen Forest and to a much lesser extent, Developed/Open Space, Mixed Forest, and Woody Wetlands.

A summary of basin parameters is shown below in Table 8.

Table 8: Basin Parameters (NRCS Method)

Basin Parameter	Site 2	Site 3	Site 4	Site 6	Site 10	Site 11	Site 12
Drainage Area (sq. mi.)	0.448	0.047	0.010	0.198	0.005	0.083	0.015
Composite Curve Number (CN)	76.4	61.0	59.3	59.4	57.7	57.7	62.2
Lag Time (min)	12.6	3.0	3.0	6.9	3.0	4.0	3.0

3.5.3 Results

The hydrologic computations were evaluated using a 24-hr storm distribution derived from the NOAA Atlas 14 rainfall data with the peak intensity occurring at the 12-hr position. A TP-40 area reduction incorporated into the rainfall distribution.

Table 9: Rainfall-Runoff Peak Flow Rates

Return Period (years)	Annual Exceedance Probability (%)	Site 2 Peak Flow (cfs)	Site 3 Peak Flow (cfs)	Site 4 Peak Flow (cfs)	Site 6 Peak Flow (cfs)	Site 10 Peak Flow (cfs)	Site 11 Peak Flow (cfs)	Site 12 Peak Flow (cfs)
2	50	263	29	6	82	3	37	10
5	20	375	47	9	136	4	64	16
10	10	471	64	13	185	6	89	21
25	4	603	87	18	257	8	126	29
50	2	708	107	22	315	10	156	35
100	1	820	128	26	379	13	189	42

3.6 Recommended Design Flows

The peak flow results of the rainfall-runoff model are significantly higher (between 2 and 10 times) than that of the regression equation and gage comparison peak flows. For example, the rainfall-runoff model 2-year peak flow for Site 2 was 263-cfs as compared to 21.6- and 21.0-cfs for the regression equation and gage comparison results, respectively. The same comparison of the 100-year event resulted in 820-, 189.8-, and 184.4-cfs for the rainfall-runoff model, regression equations, and gage comparison, respectively.

Further review of the basins used in the development of the Central Coast regression equations indicated that of the 11 basins below 1-mi^2, the maximum 2-year peak flow was 12-cfs. The maximum 100-year peak flow of those same 11 basins was 281-cfs. The first basin to exceed the rainfall-runoff model peak flows for Site 2 had a drainage area of 9.3-mi^2 or over 20 times the basin area of Site 2. Additionally, review of the available Google Street view imagery taken before the fire in January 2012 did not indicate any significant capacity issues that the higher flows associated with the rainfall runoff model would suggest. For these reasons, it is assumed that the rainfall-runoff model is significantly overestimating the peak flow rates along Nacimiento-Fergusson Road.

The gage comparison results are in pretty close agreement with the regression equations which is likely due to the regression equation flows being utilized in Equation 13. For the gage comparison, the gaged drainage area is outside the range of comparison for all sites except Site 2. Additionally, mean annual precipitation at the selected gage is below that experienced by all project sites. While only two of the seven basins fall within the minimum drainage area outlined in USGS Report 2012-5113, the regression equations were selected as the most appropriate peak flow rates for use in the hydraulic calculations.

Therefore, Table 10 presents the regression equation peak flow rates as the recommended design flows along with the recommended 1.5 multiplier outlined in Section 3.2 which takes into account the increased peak flow rates associated with the Dolan Fire in the fall of 2020. Site 16 was not evaluated using a rainfall runoff model or gage analysis as it was added once the initial hydrologic analyses were complete and the USGS regression equations were selected as the best method. For this reason, Site 16 was only evaluated using the regression equations.

Table 10: Recommended Design Flows

Return Period (years)	Annual Exceedance Probability (%)	Site 2 Peak Flow (cfs)	Site 3 Peak Flow (cfs)	Site 4 Peak Flow (cfs)	Site 6 Peak Flow (cfs)	Site 10 Peak Flow (cfs)	Site 11 Peak Flow (cfs)	Site 12 Peak Flow (cfs)	Site 16 Peak Flow (cfs)
2	50	32.4	9.3	2.4	31.5	1.2	15.9	4.1	1.8
5	20	80.1	19.8	5.1	66.8	2.9	33.3	8.6	3.9
10	10	125.6	29.0	7.5	96.9	4.2	48.2	12.3	5.8
25	4	187.7	40.1	10.4	133.8	6.0	66.3	16.8	8.1
50	2	239.4	48.9	12.8	162.6	7.4	80.4	20.4	10.0
100	1	284.7	55.8	14.6	185.7	8.6	91.5	23.1	11.5

4 Hydraulic Analysis

As detailed in Table 1, Sites 2-4, Site 6, and Sites 10-12 include existing culverted crossings to be evaluated for replacement. All sites were evaluated for replacement culverts while Site 6 was evaluated for both a culvert and potential low water crossing. The existing Site 16 culvert was unimpacted by the January 2021 storm but an additional ditch relief culvert was evaluated to protect the proposed wall at this location.

4.1 Low Water Crossing Alternative (Site 6)

As discussed at the scoping site visit and in the preliminary recommendations report, Site 6 was considered for a potential low water crossing due to the high sediment loads upstream. The primary concern with this option was the 13-ft elevation difference between the existing road surface and channel below. To create a stable low water crossing in this location would require a combination of lowering the road grade around the existing curve and installing a riprap ramp down to the existing stream bed. Preliminary riprap sizing indicates that a riprap ramp with a slope simply matching the existing stream bed grade (10%) will require a Class 10 particle size to remain stable. To cover the elevation difference between the road and the stream bed below, the riprap ramp will be significantly steeper and therefore the riprap size required effectively renders a low water crossing impractical in this location.

Additionally, due to the sediment supply upstream, converting this site to a low water crossing will result in sediment, rock, and debris being deposited across the road surface following any flow event. During the scoping site visit, large cobbles and some boulders were identified in the sediment supply upstream. Based on the material observed, any flow event as the potential to make the road impassable until it can be cleared and thus requiring a higher level of maintenance over the life of the crossing.

Lastly, based on the survey information at this site, the road continues downhill to the east from the crossing itself. To prevent flood flows from continuing down the road, the low water crossing would require the road grade to be dropped locally by probably 2-3-ft and thus significantly expanding the road work required at this location.

For these reasons, a low water crossing was determined to be impractical in this location. Instead, a culverted crossing is recommended. To account for the significant sediment supply upstream, it is recommended that the pipe be oversized to reduce the maintenance effort at this site. Therefore, a HW/D ratio of 0.8 is recommended to allow for the sediment to pass through the crossing and require less frequent maintenance.

4.2 Culvert Capacity Design

To model the culverted crossings, a site specific HY-8 (Federal Highway Administration 2021) model was developed for each site to determine the required pipe diameter that will convey the 25-year design flows provided in Table 10. Because the existing pipes are no longer functioning (or not present for Site 16), it is assumed that all existing culverts will be replaced to meet the design criteria outlined in Section 2. For this reason, the existing pipes were not modeled. Using the site survey collected by CFL in August 2021, existing pipe inverts and pipe lengths (where available) along with surveyed outlet channel characteristics were used to determine the proposed pipe dimensions and slopes. Due to the high sediment loads associated with the project site, only single barrel culverts are recommended as they transfer sediment more efficiently. Required pipe sizes for each site are provided in Table 11 below. HY-8 model development and outputs are provided in Appendix B.

4.3 Culvert Stability Design

Due to the steep slopes associated with the project site, the seven crossings require more detailed consideration for stability. The standard outlet protection detail (C251-50 – Placed Riprap at Culvert Outlets) applies to pipes 48-in or less and on slopes below 10%. Due to pipe size for Sites 2 and 6 and pipe slopes for the remaining sites, C251-50 is not applicable at these locations. Therefore, outlet protection has been evaluated per HEC-14 (Federal Highway Administration 2006) for these four sites. Outlet protection was evaluated using the Hydraulic Toolbox's Riprap Analysis tool for culvert outlet protection. For tailwater depths, the Manning's equation was used to determine normal depth for the surveyed channel downstream. For Site 2, the value of 0.4D was used for tailwater as there is no defined channel at this outlet. Hydraulic Toolbox model development and outputs are provided in Appendix B.

For Sites 10 and 16, the proposed culverts will discharge to excessively steep slopes. Due to the outlet slopes, culvert rundowns are recommended. Due to the difficulty in placing riprap at the outlet of the proposed Site 16 culvert rundown, an apron is not recommended.

5 Recommendations

Based on the design criteria defined in Section 2, the design flows outlined in Table 10, and hydraulic models described in Section 4.2, single barrel metal culverts recommendations were determined at each of the eight sites and are provided in Table 11 below. Per the PDDM, pipe anchors are recommended for metal pipes placed at slopes exceeding 25%. For this reason, the proposed culverts at Sites 3, 4, and 10 should be installed with anchors to prevent joint separation.

Additionally, per the PDDM, for the design of new structures, flared end sections are recommended for pipes 48-in and smaller. For larger pipes, a headwall end treatment is recommended. Beveled edges should be used on all headwalls. Several culverts have buried inlets with significant sediment stored upstream. For this reason, significant excavation and grading may be required to install the replacement structure and provide a flow path to the inlet.

Table 11: Proposed Culvert Recommendations

Site	25-Year Design Flow (cfs)	Diameter (in)	Structure Type	Modeled Pipe Slope (ft/ft)	Inlet & Outlet Configuration	HW/D Ratio	Pipe Anchors (C602-50)
Site 2	187.7	72	CMP	0.086	Concrete Headwall (601-5)	0.91	No
Site 3	40.1	48	CMP	0.321	Metal End Section (602-4)	0.57	Yes
Site 4	10.4	24	CMP	0.338	Metal End Section (602-4)	0.78	Yes
Site 6	133.8	72	CMP	0.094	Concrete Headwall (601-5)	0.72	No
Site 10	6.0	24	CMP	0.267	Metal End Section (602-4)	0.53	Yes
Site 11	66.3	48	CMP	0.076	Metal End Section (602-4)	0.99	No
Site 12	16.8	36	CMP	0.214	Inlet: Concrete Headwall (601-5) Outlet: Metal End Section (602-4)	0.56	No
Site 16	8.1	24	CMP	0.190	Metal End Section (602-4)	0.70	No

5.1 OUTLET PROTECTION

Results of the outlet protection analysis described in Section 4.3 are provided in Table 12 below. For Sites 10 and 16, the proposed culverts will discharge to excessively steep slopes. Due to the lower flow rates at these crossings and lack of a defined channel downslope, it is recommended that a culvert rundown be installed at the outlet per C602-50 and discharge at least 20ft from the edge of pavement. For Sites 10 and 16, a riprap apron is not recommended due to constructability issues at this outlet. The rundowns extend far enough from the road edge such that it will not impact the embankment.

Table 12: Proposed Outlet Recommendations

Site	Culvert Rundown (C602-50)	Riprap Apron (shaped per C251-50)			
		Riprap Class	Length (ft)	Width (ft)	Thickness (ft)
Site 2	No	5	24	24	3
Site 3	No	3	12	12	2
Site 4	No	2 (or 3)[1]	4	6	2
Site 6	No	5	24	24	3
Site 10	Yes	No riprap apron is recommended at this location.			
Site 11	No	4 (or 5)[1]	16	10	3
Site 12	No	2 (or 3)[1]	6	9	2
Site 16	Yes	No riprap apron is recommended at this location.			

[1] If it is more cost effective to increase riprap classes and reduce the different types of materials then consider providing Class 3 in place of Class 2 and Class 5 in place of Class 4.

5.2 Site-Specific Discussion

Following the 70% field review, several hydraulic design changes are recommended as discussed below. These recommendations are reflected in the tables above.

Site 2: The original outlet protection recommendation for this site was a Class 4 Apron, 36ft-L, 36ft-W, 3ft-T. The apron recommendation was revised based on the updated pipe slope, 70% field review, and to reduce Waters of the United States (WOUS) impacts. For these reasons, a Class 5 apron is recommended with the dimensions stated in Table 12.

Site 3: The hydraulically adequate structure based on the design criteria for this crossing is a 42-in CMP. Considering the depth of this structure (greater than 10-ft), the proposed pipe in this location is recommended to be upsized to 48-in to allow for potential lining in the future. Similar to Site 2, culvert outlet protection was revised based on the updated pipe slope and size, 70% field review, and to reduce WOUS impacts. The updated recommendation is a Class 3 apron with the dimensions stated in Table 12.

Site 4: The original design called for a culvert rundown in this location. Following the 70% field review, the rundown was determined to be unnecessary and should be replaced with a riprap apron. The standard apron dimensions were reduced to minimize impacts to the WOUS. Apron class and thickness were updated based on the revised pipe slopes. Apron details are provided in Table 12.

Site 6: The original outlet protection recommendation for this site was a Class 5 Apron, 36ft-L, 36ft-W, 3.5ft-T. The apron recommendation was revised based on the updated pipe slope, 70% field review, and to reduce Waters of the United States (WOUS) impacts. For these reasons, a Class 5 apron is recommended with the dimensions stated in Table 12. In addition, it is recommended to shift the inlet towards the right bank (looking downstream) if possible and/or extend the wingwall to the toe of slope so as to prevent bypass flows from the channel above.

Site 10: The proposed culvert at Site 10 should be installed with a culvert rundown to extend the discharge point farther away from the roadway embankment and toe of the proposed wall. Due to constructability issues associated with the steep slopes at the outlet, a riprap apron is not recommended. A metal end section should still be installed at the outlet to assist with flow expansion.

Site 11: The original outlet protection recommendation for this site was a Class 5 Apron, 24ft-L, 24ft-W, 3.5ft-T. The apron recommendation was revised based on the updated pipe slope, 70% field review, and to reduce Waters of the United States (WOUS) impacts. For these reasons, a Class 4 apron is recommended with the dimensions stated in Table 12.

Site 12: The original design called for a culvert rundown in this location. Following the 70% field review, the rundown was determined to be unnecessary and should be replaced with a riprap apron. Additionally, the existing pipe was uncovered during the field review and was identified as a 36-in CMP. While the hydraulically adequate pipe size is a 30-in, the crossing should be replaced in kind. For the inlet, a headwall is recommended to better accommodate ditch flow draining the roadway surface. The standard apron dimensions were adjusted based on the revised pipe slopes and to minimize impacts to the WOUS. Apron details are provided in Table 12.

Site 16: An additional culvert is recommended above the proposed wall to reduce the potential for flows from impacting the wall structure. A culvert rundown is proposed in this location to discharge flows away from the road embankment. Due to constructability issues associated with the steep slopes at the outlet, a riprap apron is not recommended. A metal end section should still be installed at the outlet to assist with flow expansion.

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Appendix A

Hydrologic Analysis

Precipitation Frequency Data Server Information

Site 2:

NOAA Atlas 14, Volume 6, Version 2
Location name: Jolon, California, USA*
Latitude: 36.0224°, Longitude: -121.4189°
Elevation: 2310.84 ft**
* source: ESRI Maps
** source: USGS

POINT PRECIPITATION FREQUENCY ESTIMATES

Sanja Perica, Sarah Dietz, Sarah Heim, Lillian Hiner, Kazungu Maitaria, Deborah Martin, Sandra Pavlovic, Ishani Roy, Carl Trypaluk, Dale Unruh, Fenglin Yan, Michael Yekta, Tan Zhao, Geoffrey Bonnin, Daniel Brewer, Li-Chuan Chen, Tye Parzybok, John Yarchoan

NOAA, National Weather Service, Silver Spring, Maryland

PF tabular | PF graphical | Maps & aerials

PF tabular

PDS-based point precipitation frequency estimates with 90% confidence intervals (in inches)[1]

Duration	Average recurrence interval (years)									
	1	2	5	10	25	50	100	200	500	1000
5-min	0.220 (0.197-0.248)	0.271 (0.243-0.306)	0.339 (0.302-0.383)	0.395 (0.348-0.452)	0.472 (0.396-0.569)	0.534 (0.434-0.663)	0.599 (0.470-0.771)	0.669 (0.504-0.897)	0.772 (0.548-1.10)	0.858 (0.581-1.28)
10-min	0.315 (0.283-0.355)	0.389 (0.348-0.439)	0.485 (0.433-0.550)	0.566 (0.499-0.649)	0.677 (0.567-0.815)	0.765 (0.622-0.951)	0.858 (0.673-1.11)	0.959 (0.723-1.29)	1.11 (0.786-1.57)	1.23 (0.833-1.83)
15-min	0.381 (0.342-0.429)	0.470 (0.421-0.531)	0.587 (0.524-0.665)	0.684 (0.603-0.784)	0.818 (0.686-0.986)	0.925 (0.752-1.15)	1.04 (0.814-1.34)	1.16 (0.874-1.56)	1.34 (0.950-1.90)	1.49 (1.01-2.22)
30-min	0.520 (0.466-0.585)	0.641 (0.574-0.723)	0.800 (0.713-0.905)	0.932 (0.821-1.07)	1.12 (0.934-1.34)	1.26 (1.02-1.57)	1.41 (1.11-1.82)	1.58 (1.19-2.12)	1.82 (1.29-2.59)	2.03 (1.37-3.02)
60-min	0.735 (0.660-0.827)	0.907 (0.812-1.02)	1.13 (1.01-1.28)	1.32 (1.16-1.51)	1.58 (1.32-1.90)	1.78 (1.45-2.22)	2.00 (1.57-2.57)	2.24 (1.69-3.00)	2.58 (1.83-3.66)	2.87 (1.94-4.28)
2-hr	1.14 (1.02-1.28)	1.39 (1.24-1.56)	1.71 (1.53-1.94)	1.99 (1.76-2.28)	2.39 (2.00-2.88)	2.71 (2.20-3.36)	3.05 (2.40-3.93)	3.44 (2.59-4.61)	4.00 (2.85-5.69)	4.49 (3.04-6.70)
3-hr	1.48 (1.33-1.66)	1.79 (1.60-2.02)	2.21 (1.97-2.50)	2.57 (2.26-2.94)	3.08 (2.58-3.71)	3.50 (2.84-4.34)	3.95 (3.10-5.09)	4.45 (3.36-5.97)	5.21 (3.70-7.40)	5.86 (3.97-8.74)
6-hr	2.17 (1.94-2.44)	2.63 (2.35-2.96)	3.26 (2.90-3.69)	3.79 (3.34-4.35)	4.56 (3.82-5.49)	5.18 (4.22-6.44)	5.86 (4.60-7.55)	6.61 (4.98-8.86)	7.71 (5.48-11.0)	8.65 (5.86-12.9)
12-hr	2.94 (2.64-3.31)	3.62 (3.24-4.08)	4.54 (4.05-5.14)	5.31 (4.68-6.09)	6.40 (5.37-7.71)	7.28 (5.92-9.04)	8.20 (6.43-10.6)	9.20 (6.93-12.3)	10.6 (7.56-15.1)	11.8 (8.00-17.6)
24-hr	3.94 (3.65-4.34)	4.93 (4.57-5.43)	6.26 (5.78-6.91)	7.37 (6.77-8.20)	8.94 (7.97-10.2)	10.2 (8.91-11.8)	11.5 (9.85-13.6)	12.9 (10.8-15.6)	14.8 (12.0-18.7)	16.4 (12.8-21.3)
2-day	4.83 (4.47-5.31)	6.08 (5.63-6.71)	7.77 (7.18-8.58)	9.19 (8.43-10.2)	11.2 (9.98-12.8)	12.8 (11.2-14.9)	14.4 (12.4-17.2)	16.2 (13.6-19.7)	18.7 (15.1-23.6)	20.7 (16.3-27.0)
3-day	5.37 (4.98-5.91)	6.80 (6.30-7.49)	8.71 (8.04-9.62)	10.3 (9.46-11.5)	12.6 (11.2-14.4)	14.4 (12.6-16.8)	16.3 (14.0-19.4)	18.3 (15.4-22.3)	21.2 (17.2-26.8)	23.5 (18.5-30.6)
4-day	5.93 (5.50-6.53)	7.53 (6.97-8.29)	9.64 (8.91-10.7)	11.4 (10.5-12.7)	14.0 (12.5-16.0)	16.0 (14.0-18.6)	18.1 (15.5-21.5)	20.4 (17.1-24.8)	23.6 (19.1-29.8)	26.2 (20.6-34.0)
7-day	7.07 (6.55-7.78)	8.99 (8.33-9.91)	11.5 (10.7-12.7)	13.7 (12.5-15.2)	16.6 (14.8-19.0)	19.0 (16.7-22.1)	21.5 (18.5-25.6)	24.2 (20.2-29.4)	27.9 (22.6-35.2)	31.0 (24.3-40.3)
10-day	7.83 (7.26-8.62)	9.97 (9.24-11.0)	12.8 (11.8-14.1)	15.1 (13.9-16.8)	18.3 (16.4-21.0)	20.9 (18.3-24.4)	23.6 (20.3-28.1)	26.5 (22.2-32.2)	30.5 (24.7-38.5)	33.8 (26.5-43.9)
20-day	10.2 (9.49-11.3)	13.1 (12.1-14.4)	16.7 (15.4-18.4)	19.6 (18.0-21.8)	23.6 (21.1-27.0)	26.7 (23.4-31.1)	29.9 (25.6-35.5)	33.2 (27.8-40.4)	37.9 (30.7-47.9)	41.7 (32.7-54.2)
30-day	12.5 (11.6-13.8)	16.0 (14.8-17.6)	20.4 (18.8-22.5)	23.9 (21.9-26.5)	28.4 (25.4-32.5)	32.0 (28.0-37.2)	35.5 (30.5-42.3)	39.3 (32.9-47.8)	44.5 (36.0-56.1)	48.7 (38.2-63.3)
45-day	15.4 (14.2-16.9)	19.6 (18.1-21.6)	24.7 (22.8-27.3)	28.8 (26.4-32.0)	34.0 (30.3-38.8)	37.8 (33.1-44.0)	41.7 (35.8-49.6)	45.7 (38.3-55.6)	51.1 (41.4-64.5)	55.5 (43.6-72.2)
60-day	17.9 (16.6-19.7)	22.7 (21.0-25.0)	28.4 (26.3-31.4)	32.9 (30.1-36.5)	38.5 (34.3-44.0)	42.6 (37.3-49.5)	46.6 (40.0-55.4)	50.7 (42.5-61.7)	56.2 (45.5-71.0)	60.6 (47.6-78.8)

[1] Precipitation frequency (PF) estimates in this table are based on frequency analysis of partial duration series (PDS).

Numbers in parenthesis are PF estimates at lower and upper bounds of the 90% confidence interval. The probability that precipitation frequency estimates (for a given duration and average recurrence interval) will be greater than the upper bound (or less than the lower bound) is 5%. Estimates at upper bounds are not checked against probable maximum precipitation (PMP) estimates and may be higher than currently valid PMP values.

Please refer to NOAA Atlas 14 document for more information.

Sites 3-16:

NOAA Atlas 14, Volume 6, Version 2
Location name: Big Sur, California, USA*
Latitude: 36.0074°, Longitude: -121.4372°
Elevation: 2576.4 ft**
* source: ESRI Maps
** source: USGS

POINT PRECIPITATION FREQUENCY ESTIMATES

Sanja Perica, Sarah Dietz, Sarah Heim, Lillian Hiner, Kazungu Maitaria, Deborah Martin, Sandra Pavlovic, Ishani Roy, Carl Trypaluk, Dale Unruh, Fenglin Yan, Michael Yekta, Tan Zhao, Geoffrey Bonnin, Daniel Brewer, Li-Chuan Chen, Tye Parzybok, John Yarchoan

NOAA, National Weather Service, Silver Spring, Maryland

PF_tabular | PF_graphical | Maps_&_aerials

PF tabular

PDS-based point precipitation frequency estimates with 90% confidence intervals (in inches)[1]

Duration	Average recurrence interval (years)									
	1	2	5	10	25	50	100	200	500	1000
5-min	0.252 (0.226-0.283)	0.306 (0.275-0.345)	0.378 (0.338-0.428)	0.439 (0.387-0.502)	0.523 (0.439-0.629)	0.590 (0.480-0.733)	0.662 (0.520-0.852)	0.741 (0.559-0.993)	0.857 (0.609-1.22)	0.956 (0.647-1.43)
10-min	0.361 (0.324-0.406)	0.439 (0.394-0.495)	0.542 (0.484-0.613)	0.629 (0.555-0.720)	0.749 (0.629-0.902)	0.846 (0.689-1.05)	0.949 (0.745-1.22)	1.06 (0.801-1.42)	1.23 (0.873-1.75)	1.37 (0.928-2.04)
15-min	0.437 (0.392-0.491)	0.531 (0.476-0.598)	0.655 (0.585-0.742)	0.760 (0.671-0.871)	0.906 (0.760-1.09)	1.02 (0.833-1.27)	1.15 (0.901-1.48)	1.29 (0.969-1.72)	1.49 (1.06-2.11)	1.66 (1.12-2.47)
30-min	0.587 (0.527-0.660)	0.714 (0.640-0.805)	0.882 (0.787-0.997)	1.02 (0.902-1.17)	1.22 (1.02-1.47)	1.38 (1.12-1.71)	1.54 (1.21-1.99)	1.73 (1.30-2.32)	2.00 (1.42-2.84)	2.23 (1.51-3.32)
60-min	0.833 (0.749-0.937)	1.01 (0.909-1.14)	1.25 (1.12-1.42)	1.45 (1.28-1.66)	1.73 (1.45-2.08)	1.95 (1.59-2.43)	2.19 (1.72-2.82)	2.45 (1.85-3.29)	2.84 (2.02-4.03)	3.16 (2.14-4.72)
2-hr	1.28 (1.15-1.44)	1.54 (1.38-1.74)	1.89 (1.69-2.14)	2.19 (1.94-2.51)	2.62 (2.20-3.16)	2.98 (2.42-3.70)	3.37 (2.64-4.33)	3.80 (2.86-5.09)	4.45 (3.16-6.32)	5.01 (3.40-7.48)
3-hr	1.66 (1.49-1.87)	1.99 (1.78-2.24)	2.44 (2.18-2.76)	2.83 (2.49-3.24)	3.39 (2.84-4.08)	3.85 (3.13-4.78)	4.36 (3.43-5.62)	4.94 (3.72-6.61)	5.81 (4.13-8.25)	6.57 (4.45-9.80)
6-hr	2.43 (2.18-2.73)	2.92 (2.62-3.29)	3.60 (3.22-4.08)	4.18 (3.69-4.79)	5.03 (4.22-6.06)	5.73 (4.66-7.12)	6.50 (5.10-8.36)	7.35 (5.54-9.84)	8.61 (6.12-12.2)	9.71 (6.58-14.5)
12-hr	3.32 (2.98-3.73)	4.05 (3.63-4.56)	5.04 (4.50-5.70)	5.89 (5.19-6.75)	7.09 (5.95-8.53)	8.06 (6.56-10.0)	9.09 (7.13-11.7)	10.2 (7.69-13.7)	11.8 (8.40-16.8)	13.2 (8.91-19.6)
24-hr	4.42 (4.09-4.86)	5.49 (5.09-6.05)	6.93 (6.41-7.66)	8.15 (7.48-9.06)	9.85 (8.78-11.3)	11.2 (9.81-13.0)	12.6 (10.8-15.0)	14.1 (11.8-17.2)	16.3 (13.1-20.5)	18.0 (14.1-23.4)
2-day	5.38 (4.99-5.92)	6.75 (6.25-7.44)	8.58 (7.93-9.48)	10.1 (9.29-11.3)	12.3 (11.0-14.1)	14.0 (12.3-16.4)	15.9 (13.6-18.9)	17.8 (14.9-21.7)	20.6 (16.6-25.9)	22.8 (17.9-29.6)
3-day	5.99 (5.56-6.60)	7.55 (6.99-8.32)	9.63 (8.90-10.6)	11.4 (10.5-12.7)	13.9 (12.4-15.9)	15.9 (13.9-18.5)	18.0 (15.4-21.4)	20.2 (17.0-24.6)	23.4 (18.9-29.6)	26.0 (20.4-33.8)
4-day	6.62 (6.14-7.29)	8.36 (7.74-9.22)	10.7 (9.86-11.8)	12.6 (11.6-14.1)	15.4 (13.8-17.6)	17.7 (15.5-20.6)	20.0 (17.2-23.8)	22.5 (18.9-27.4)	26.1 (21.1-32.9)	29.0 (22.7-37.7)
7-day	7.93 (7.35-8.73)	10.0 (9.29-11.1)	12.8 (11.8-14.1)	15.1 (13.9-16.8)	18.4 (16.4-21.0)	21.0 (18.4-24.5)	23.8 (20.4-28.3)	26.7 (22.4-32.6)	30.9 (25.0-39.0)	34.4 (27.0-44.7)
10-day	8.85 (8.20-9.74)	11.2 (10.4-12.3)	14.3 (13.2-15.8)	16.8 (15.4-18.7)	20.4 (18.2-23.3)	23.2 (20.4-27.1)	26.2 (22.5-31.2)	29.4 (24.7-35.9)	34.0 (27.5-42.9)	37.7 (29.6-49.0)
20-day	11.8 (10.9-13.0)	14.9 (13.8-16.5)	19.0 (17.5-21.0)	22.3 (20.4-24.8)	26.7 (23.8-30.5)	30.1 (26.4-35.1)	33.7 (28.9-40.1)	37.5 (31.4-45.6)	42.8 (34.6-54.0)	47.1 (37.0-61.3)
30-day	14.5 (13.4-16.0)	18.4 (17.1-20.3)	23.3 (21.6-25.8)	27.2 (25.0-30.3)	32.4 (28.9-37.0)	36.3 (31.8-42.3)	40.4 (34.6-48.0)	44.6 (37.4-54.3)	50.4 (40.8-63.7)	55.2 (43.4-71.8)
45-day	17.8 (16.5-19.6)	22.5 (20.9-24.8)	28.4 (26.2-31.3)	32.9 (30.2-36.6)	38.7 (34.5-44.3)	43.0 (37.7-50.1)	47.4 (40.6-56.3)	51.8 (43.4-63.1)	58.0 (46.9-73.2)	62.9 (49.4-81.8)
60-day	20.5 (19.0-22.6)	26.0 (24.0-28.6)	32.5 (30.0-35.9)	37.4 (34.4-41.6)	43.7 (39.0-50.0)	48.2 (42.3-56.1)	52.6 (45.2-62.6)	57.2 (48.0-69.7)	63.4 (51.3-80.0)	68.3 (53.6-88.8)

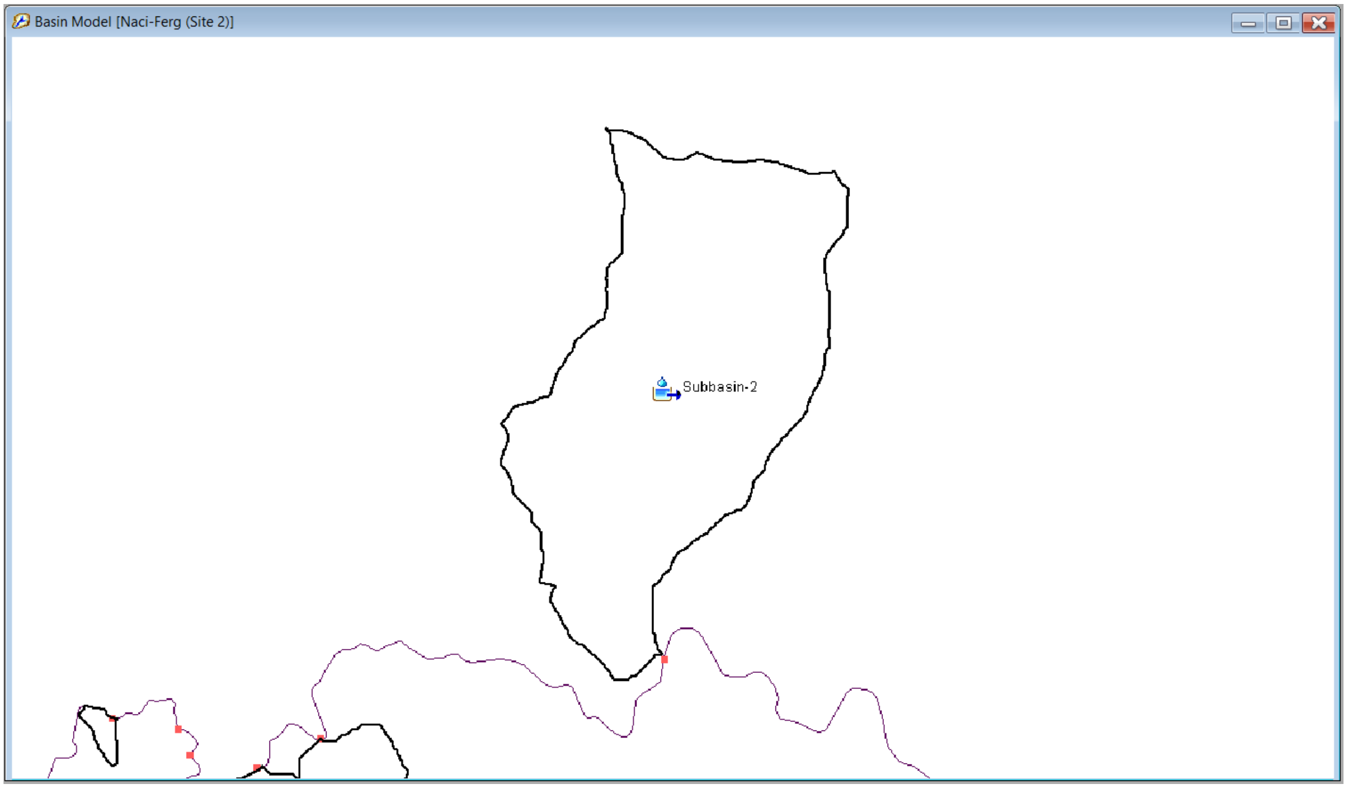
[1] Precipitation frequency (PF) estimates in this table are based on frequency analysis of partial duration series (PDS).

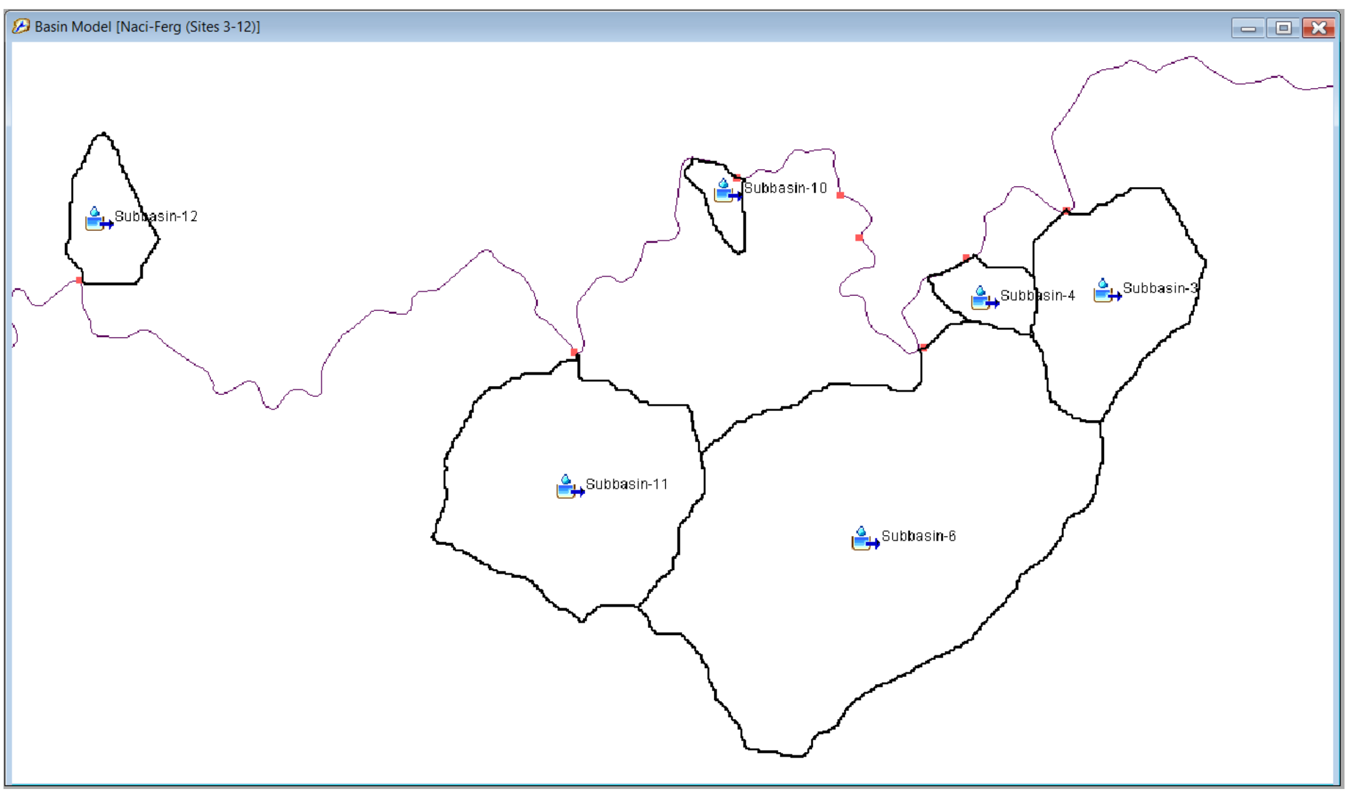
Numbers in parenthesis are PF estimates at lower and upper bounds of the 90% confidence interval. The probability that precipitation frequency estimates (for a given duration and average recurrence interval) will be greater than the upper bound (or less than the lower bound) is 5%. Estimates at upper bounds are not checked against probable maximum precipitation (PMP) estimates and may be higher than currently valid PMP values.

Please refer to NOAA Atlas 14 document for more information.

HEC-HMS Information

Nacimiento-Fergusson Road Basin Model:





Nacimiento-Fergusson Road Input Parameters:

Subbasin Areas:

Subbasin Area [Naci-Ferg (Site 2)]

Subbasin	Area (MI2)
Subbasin-2	0.448

Subbasin Area [Naci-Ferg (Sites 3-12)]

Subbasin	Area (MI2)
Subbasin-3	0.047
Subbasin-4	0.01
Subbasin-6	0.198
Subbasin-10	0.005
Subbasin-11	0.083
Subbasin-12	0.015

Curve Numbers:

Curve Number Loss [Naci-Ferg (Site 2)]

Subbasin	Initial Abstraction (IN)	Curve Number	Impervious (%)
Subbasin-2		76.4	0.0

Curve Number Loss [Naci-Ferg (Sites 3-12)]

Subbasin	Initial Abstraction (IN)	Curve Number	Impervious (%)
Subbasin-3		61	0.0
Subbasin-4		59.3	0.0
Subbasin-6		59.4	0.0
Subbasin-10		57.7	0.0
Subbasin-11		57.7	0.0
Subbasin-12		62.2	0.0

Lag Times:

SCS Transform[Naci-Ferg (Site 2)]

Subbasin	Graph Type	Lag Time (MIN)
Subbasin-2	Standard (PRF 484)	12.6

SCS Transform[Naci-Ferg (Sites 3-12)]

Subbasin	Graph Type	Lag Time (MIN)
Subbasin-3	Standard (PRF 484)	3
Subbasin-4	Standard (PRF 484)	3
Subbasin-6	Standard (PRF 484)	6.9
Subbasin-10	Standard (PRF 484)	3
Subbasin-11	Standard (PRF 484)	4
Subbasin-12	Standard (PRF 484)	3

Meteorologic Models:

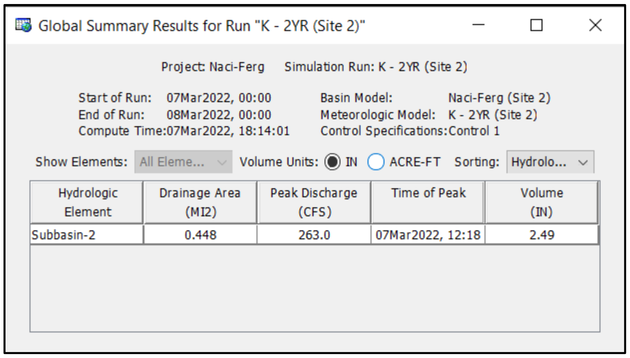
Note: Only 2yr shown. Precipitation depths vary based on return period. Storm area for TP-40 reduction is equal to sum of basin areas.

Frequency Storm

	K - 2YR (Site 2)	A - 2YR (Sites 3-12)
Met Name:	K - 2YR (Site 2)	A - 2YR (Sites 3-12)
Storm Type:	HYDRO35 TP40 TP49	HYDRO35 TP40 TP49
Annual-Partial Conversion:	--None--	--None--
Annual-Partial Ratio:	1.00	1.00
Storm Duration:	1 Day	1 Day
Intensity Duration:	5 Minutes	5 Minutes
Intensity Position:	50 Percent	50 Percent
Area Reduction:	TP40	TP40
*Storm Area (MI2)	0.448	0.358
Curve:	Uniform For All Subbasins	Uniform For All Subbasins

Duration	Depth (IN) (Site 2)	Depth (IN) (Sites 3-12)
5 Minutes	0.271	0.306
15 Minutes	0.470	0.531
1 Hour	0.907	1.010
2 Hours	1.390	1.540
3 Hours	1.790	1.990
6 Hours	2.630	2.920
12 Hours	3.620	4.050
1 Day	4.930	5.490
2 Days		
4 Days		
7 Days		
10 Days		

Nacimiento-Fergusson Road Results (Site 2):

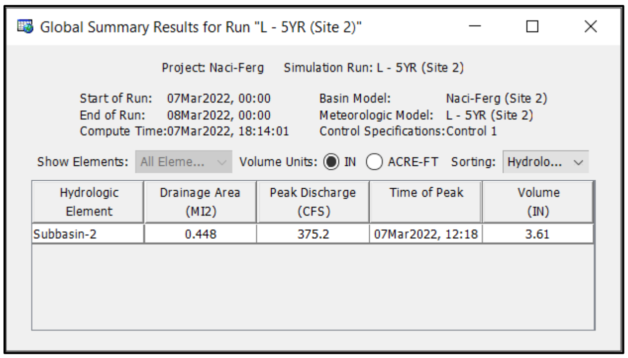

Global Summary Results for Run "K - 2YR (Site 2)"

Project: Naci-Ferg Simulation Run: K - 2YR (Site 2)

Start of Run: 07Mar2022, 00:00 Basin Model: Naci-Ferg (Site 2)
End of Run: 08Mar2022, 00:00 Meteorologic Model: K - 2YR (Site 2)
Compute Time: 07Mar2022, 18:14:01 Control Specifications: Control 1

Show Elements: All Eleme... Volume Units: IN ACRE-FT Sorting: Hydrolo...

Hydrologic Element	Drainage Area (MI2)	Peak Discharge (CFS)	Time of Peak	Volume (IN)
Subbasin-2	0.448	263.0	07Mar2022, 12:18	2.49

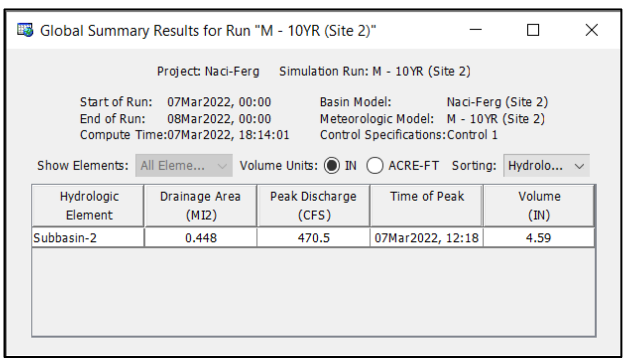

Global Summary Results for Run "L - 5YR (Site 2)"

Project: Naci-Ferg Simulation Run: L - 5YR (Site 2)

Start of Run: 07Mar2022, 00:00 Basin Model: Naci-Ferg (Site 2)
End of Run: 08Mar2022, 00:00 Meteorologic Model: L - 5YR (Site 2)
Compute Time: 07Mar2022, 18:14:01 Control Specifications: Control 1

Show Elements: All Eleme... Volume Units: IN ACRE-FT Sorting: Hydrolo...

Hydrologic Element	Drainage Area (MI2)	Peak Discharge (CFS)	Time of Peak	Volume (IN)
Subbasin-2	0.448	375.2	07Mar2022, 12:18	3.61

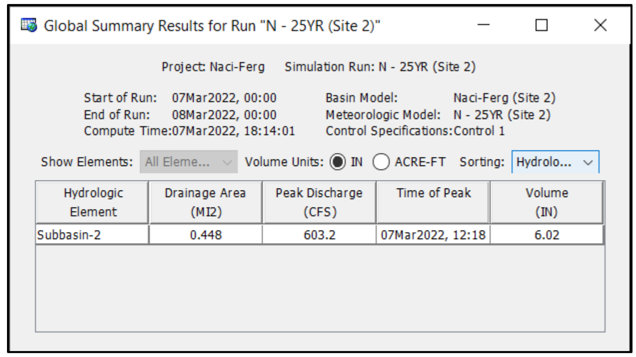

Global Summary Results for Run "M - 10YR (Site 2)"

Project: Naci-Ferg Simulation Run: M - 10YR (Site 2)

Start of Run: 07Mar2022, 00:00 Basin Model: Naci-Ferg (Site 2)
End of Run: 08Mar2022, 00:00 Meteorologic Model: M - 10YR (Site 2)
Compute Time: 07Mar2022, 18:14:01 Control Specifications: Control 1

Show Elements: All Eleme... Volume Units: IN ACRE-FT Sorting: Hydrolo...

Hydrologic Element	Drainage Area (MI2)	Peak Discharge (CFS)	Time of Peak	Volume (IN)
Subbasin-2	0.448	470.5	07Mar2022, 12:18	4.59

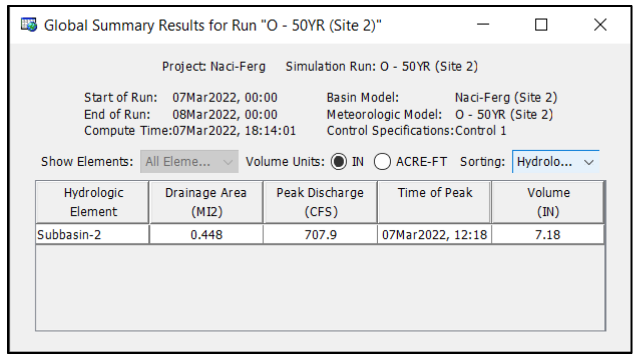

Global Summary Results for Run "N - 25YR (Site 2)"

Project: Naci-Ferg Simulation Run: N - 25YR (Site 2)

Start of Run: 07Mar2022, 00:00 Basin Model: Naci-Ferg (Site 2)
End of Run: 08Mar2022, 00:00 Meteorologic Model: N - 25YR (Site 2)
Compute Time: 07Mar2022, 18:14:01 Control Specifications: Control 1

Show Elements: All Eleme... Volume Units: IN ACRE-FT Sorting: Hydrolo...

Hydrologic Element	Drainage Area (MI2)	Peak Discharge (CFS)	Time of Peak	Volume (IN)
Subbasin-2	0.448	603.2	07Mar2022, 12:18	6.02

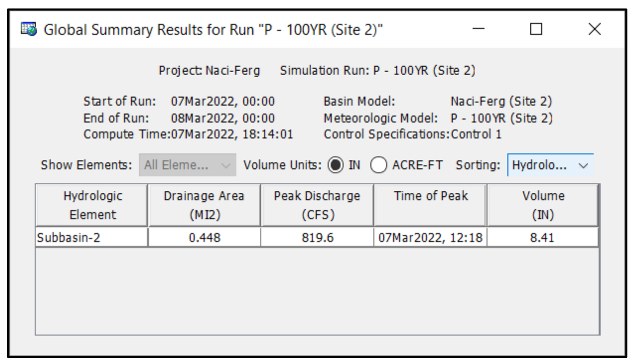

Global Summary Results for Run "O - 50YR (Site 2)"

Project: Naci-Ferg Simulation Run: O - 50YR (Site 2)

Start of Run: 07Mar2022, 00:00 Basin Model: Naci-Ferg (Site 2)
End of Run: 08Mar2022, 00:00 Meteorologic Model: O - 50YR (Site 2)
Compute Time: 07Mar2022, 18:14:01 Control Specifications: Control 1

Show Elements: All Eleme... Volume Units: IN ACRE-FT Sorting: Hydrolo...

Hydrologic Element	Drainage Area (MI2)	Peak Discharge (CFS)	Time of Peak	Volume (IN)
Subbasin-2	0.448	707.9	07Mar2022, 12:18	7.18


Global Summary Results for Run "P - 100YR (Site 2)"

Project: Naci-Ferg Simulation Run: P - 100YR (Site 2)

Start of Run: 07Mar2022, 00:00 Basin Model: Naci-Ferg (Site 2)
End of Run: 08Mar2022, 00:00 Meteorologic Model: P - 100YR (Site 2)
Compute Time: 07Mar2022, 18:14:01 Control Specifications: Control 1

Show Elements: All Eleme... Volume Units: IN ACRE-FT Sorting: Hydrolo...

Hydrologic Element	Drainage Area (MI2)	Peak Discharge (CFS)	Time of Peak	Volume (IN)
Subbasin-2	0.448	819.6	07Mar2022, 12:18	8.41

Nacimiento-Fergusson Road Results (Sites 3-12):

Global Summary Results for Run "A - 2YR (Sites 3-12)"

Project: Naci-Ferg   Simulation Run: A - 2YR (Sites 3-12)

Start of Run: 07Mar2022, 00:00   Basin Model: Naci-Ferg (Sites 3-12)
End of Run: 08Mar2022, 00:00   Meteorologic Model: A - 2YR (Sites 3-12)
Compute Time: 07Mar2022, 18:13:59   Control Specifications: Control 1

Show Elements: All Eleme...   Volume Units: IN ACRE-FT   Sorting: Hydrolo...

Hydrologic Element	Drainage Area (MI2)	Peak Discharge (CFS)	Time of Peak	Volume (IN)
Subbasin-3	0.047	29.1	07Mar2022, 12:06	1.67
Subbasin-4	0.010	5.6	07Mar2022, 12:06	1.54
Subbasin-6	0.198	81.9	07Mar2022, 12:12	1.54
Subbasin-10	0.005	2.5	07Mar2022, 12:06	1.42
Subbasin-11	0.083	37.4	07Mar2022, 12:06	1.42
Subbasin-12	0.015	9.9	07Mar2022, 12:06	1.76

Global Summary Results for Run "B - 5YR (Sites 3-12)"

Project: Naci-Ferg   Simulation Run: B - 5YR (Sites 3-12)

Start of Run: 07Mar2022, 00:00   Basin Model: Naci-Ferg (Sites 3-12)
End of Run: 08Mar2022, 00:00   Meteorologic Model: B - 5YR (Sites 3-12)
Compute Time: 07Mar2022, 18:13:59   Control Specifications: Control 1

Show Elements: All Eleme...   Volume Units: IN ACRE-FT   Sorting: Hydrolo...

Hydrologic Element	Drainage Area (MI2)	Peak Discharge (CFS)	Time of Peak	Volume (IN)
Subbasin-3	0.047	47.2	07Mar2022, 12:06	2.64
Subbasin-4	0.010	9.3	07Mar2022, 12:06	2.48
Subbasin-6	0.198	135.9	07Mar2022, 12:12	2.48
Subbasin-10	0.005	4.3	07Mar2022, 12:06	2.32
Subbasin-11	0.083	64.4	07Mar2022, 12:06	2.32
Subbasin-12	0.015	15.8	07Mar2022, 12:06	2.76

Global Summary Results for Run "C - 10YR (Sites 3-12)"

Project: Naci-Ferg   Simulation Run: C - 10YR (Sites 3-12)

Start of Run: 07Mar2022, 00:00   Basin Model: Naci-Ferg (Sites 3-12)
End of Run: 08Mar2022, 00:00   Meteorologic Model: C - 10YR (Sites 3-12)
Compute Time: 07Mar2022, 18:14:00   Control Specifications: Control 1

Show Elements: All Eleme...   Volume Units: IN ACRE-FT   Sorting: Hydrolo...

Hydrologic Element	Drainage Area (MI2)	Peak Discharge (CFS)	Time of Peak	Volume (IN)
Subbasin-3	0.047	63.5	07Mar2022, 12:06	3.55
Subbasin-4	0.010	12.7	07Mar2022, 12:06	3.35
Subbasin-6	0.198	185.0	07Mar2022, 12:12	3.36
Subbasin-10	0.005	6.0	07Mar2022, 12:06	3.18
Subbasin-11	0.083	89.3	07Mar2022, 12:06	3.17
Subbasin-12	0.015	21.1	07Mar2022, 12:06	3.68

Global Summary Results for Run "D - 25YR (Sites 3-12)"

Project: Naci-Ferg   Simulation Run: D - 25YR (Sites 3-12)

Start of Run: 07Mar2022, 00:00   Basin Model: Naci-Ferg (Sites 3-12)
End of Run: 08Mar2022, 00:00   Meteorologic Model: D - 25YR (Sites 3-12)
Compute Time: 07Mar2022, 18:14:00   Control Specifications: Control 1

Show Elements: All Eleme...   Volume Units: IN ACRE-FT   Sorting: Hydrolo...

Hydrologic Element	Drainage Area (MI2)	Peak Discharge (CFS)	Time of Peak	Volume (IN)
Subbasin-3	0.047	87.2	07Mar2022, 12:06	4.89
Subbasin-4	0.010	17.7	07Mar2022, 12:06	4.67
Subbasin-6	0.198	256.6	07Mar2022, 12:12	4.67
Subbasin-10	0.005	8.4	07Mar2022, 12:06	4.46
Subbasin-11	0.083	125.7	07Mar2022, 12:06	4.45
Subbasin-12	0.015	28.8	07Mar2022, 12:06	5.05

Global Summary Results for Run "E - 50YR (Sites 3-12)"

Project: Naci-Ferg   Simulation Run: E - 50YR (Sites 3-12)

Start of Run: 07Mar2022, 00:00   Basin Model: Naci-Ferg (Sites 3-12)
End of Run: 08Mar2022, 00:00   Meteorologic Model: E - 50YR (Sites 3-12)
Compute Time: 07Mar2022, 18:14:00   Control Specifications: Control 1

Show Elements: All Eleme...   Volume Units: IN ACRE-FT   Sorting: Hydrolo...

Hydrologic Element	Drainage Area (MI2)	Peak Discharge (CFS)	Time of Peak	Volume (IN)
Subbasin-3	0.047	106.5	07Mar2022, 12:06	6.01
Subbasin-4	0.010	21.7	07Mar2022, 12:06	5.77
Subbasin-6	0.198	314.9	07Mar2022, 12:12	5.77
Subbasin-10	0.005	10.4	07Mar2022, 12:06	5.53
Subbasin-11	0.083	155.7	07Mar2022, 12:06	5.53
Subbasin-12	0.015	35.0	07Mar2022, 12:06	6.19

Global Summary Results for Run "F - 100YR (Sites 3-12)"

Project: Naci-Ferg   Simulation Run: F - 100YR (Sites 3-12)

Start of Run: 07Mar2022, 00:00   Basin Model: Naci-Ferg (Sites 3-12)
End of Run: 08Mar2022, 00:00   Meteorologic Model: F - 100YR (Sites 3-12)
Compute Time: 07Mar2022, 18:14:00   Control Specifications: Control 1

Show Elements: All Eleme...   Volume Units: IN ACRE-FT   Sorting: Hydrolo...

Hydrologic Element	Drainage Area (MI2)	Peak Discharge (CFS)	Time of Peak	Volume (IN)
Subbasin-3	0.047	127.6	07Mar2022, 12:06	7.21
Subbasin-4	0.010	26.1	07Mar2022, 12:06	6.95
Subbasin-6	0.198	379.2	07Mar2022, 12:12	6.94
Subbasin-10	0.005	12.6	07Mar2022, 12:06	6.69
Subbasin-11	0.083	188.7	07Mar2022, 12:06	6.69
Subbasin-12	0.015	41.7	07Mar2022, 12:06	7.40

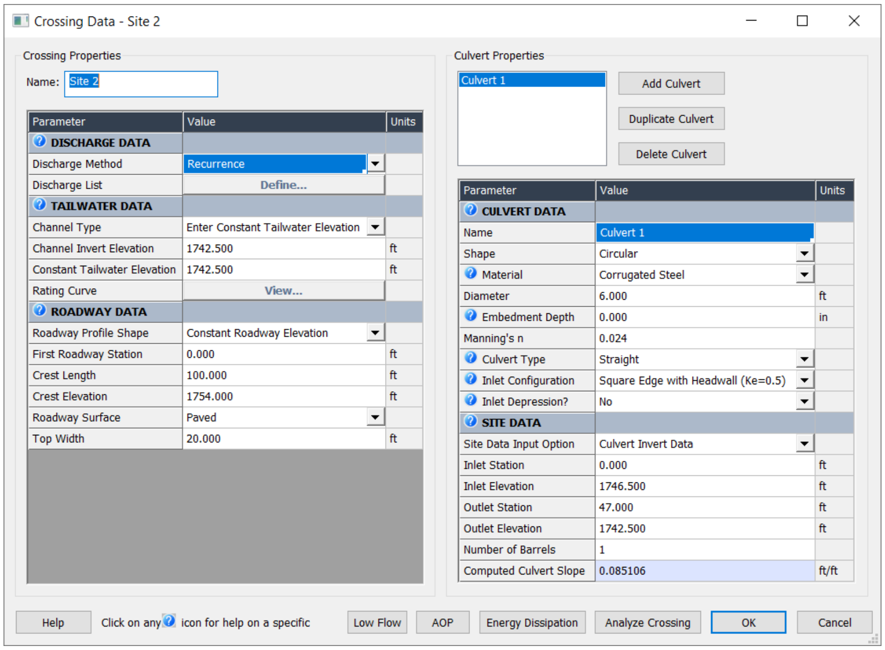
Appendix B

Hydraulic Analysis

HY-8 Culvert Analyses

Site 2 (72" CMP with Headwalls):

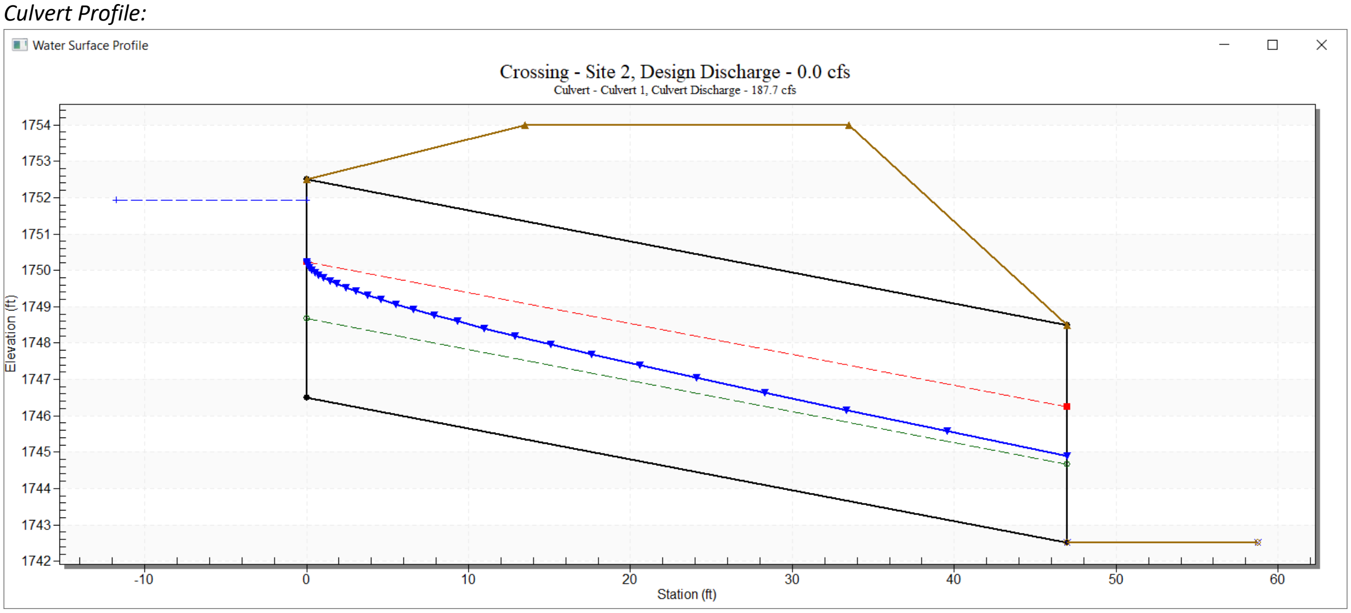
Crossing Data:



Culvert Summary Table:

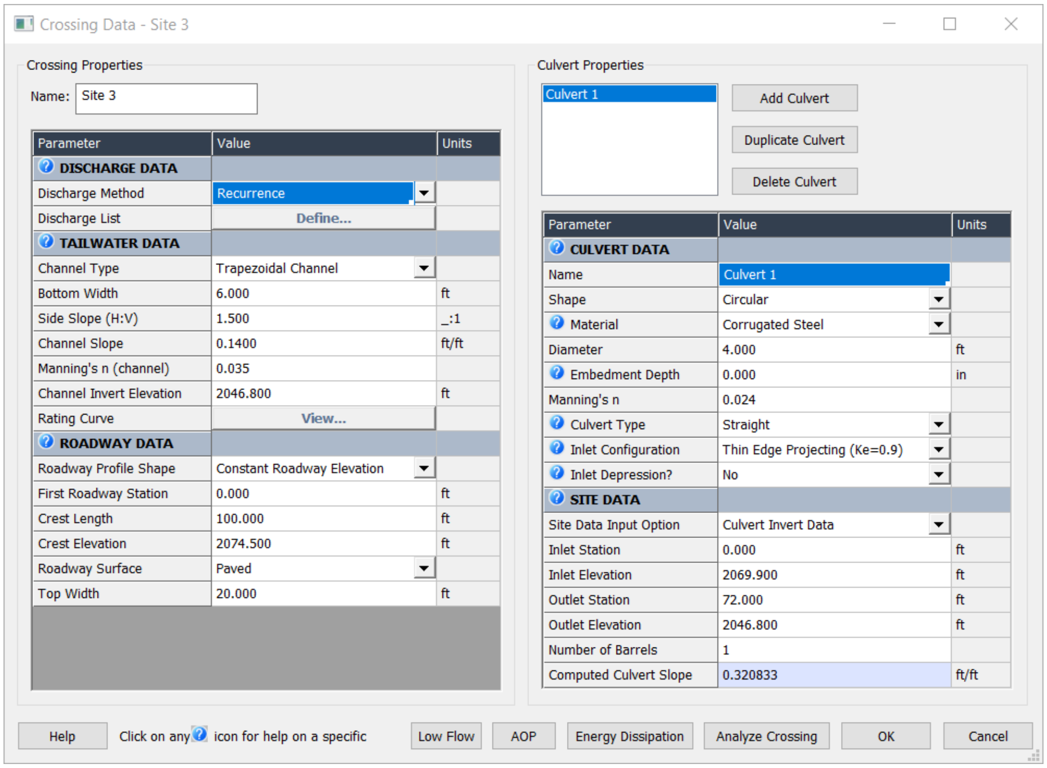
Discharge Names	Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Controlling Depth		Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
				Inlet (ft)	Outlet (ft)							
2 year	32.40	32.40	1748.41	1.91	-2.46	1-S2n	0.90	1.50	0.91	0.00	11.96	0.00
5 year	80.10	80.10	1749.61	3.11	-1.36	1-S2n	1.40	2.40	1.47	0.00	14.87	0.00
10 year	125.60	125.60	1750.63	4.13	-0.37	1-S2n	1.76	3.03	1.89	0.00	16.42	0.00
25 year	187.70	187.70	1751.94	5.44	1.08	1-S2n	2.17	3.74	2.39	0.00	17.84	0.00
50 year	239.40	239.40	1753.10	6.60	2.42	5-S2n	2.48	4.24	2.77	0.00	18.75	0.00
100 year	284.70	278.35	1754.08	7.58	4.23	5-S2n	2.69	4.57	3.04	0.00	19.36	0.00

Culvert Profile:



Site 3 (42" CMP with Flared End Sections):

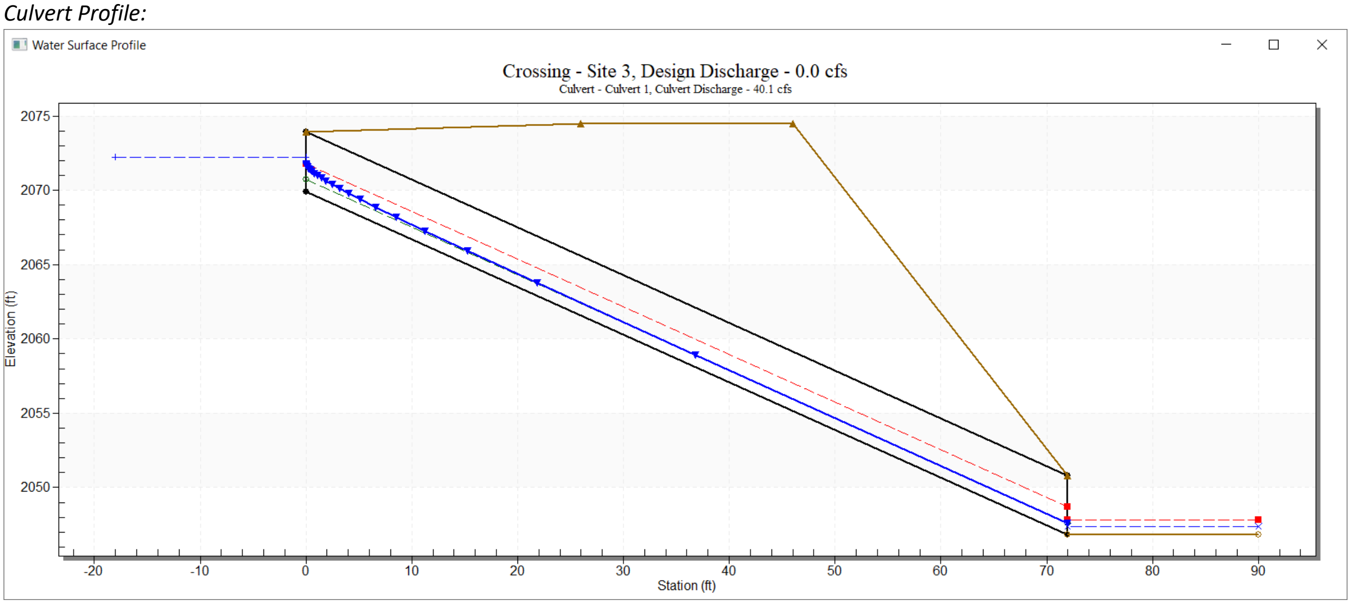
Crossing Data:



Culvert Summary Table:

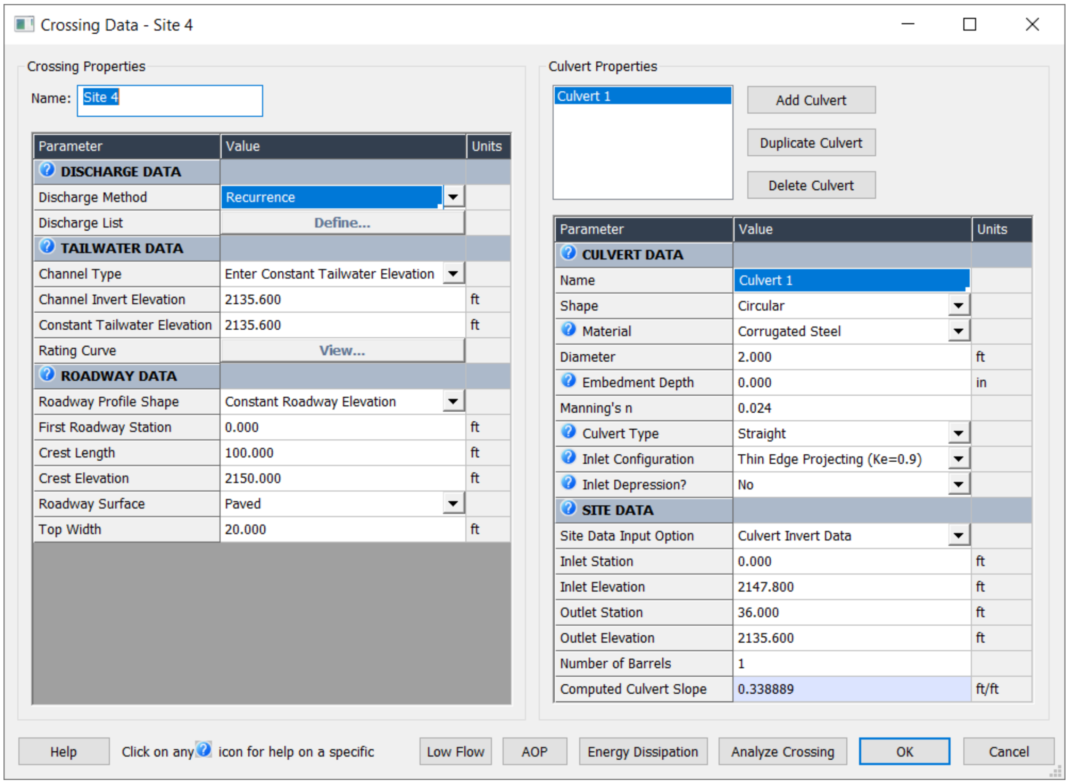
Discharge Names	Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Controlling Depth Inlet (ft)	Controlling Depth Outlet (ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
2 year	9.30	9.30	2070.92	1.02	-22.19	1-S2n	0.40	0.89	0.40	0.25	14.17	5.92
5 year	19.80	19.80	2071.41	1.51	-21.67	1-S2n	0.57	1.31	0.59	0.39	17.16	7.79
10 year	29.00	29.00	2071.74	1.84	-21.24	1-S2n	0.69	1.60	0.69	0.48	19.89	8.91
25 year	40.10	40.10	2072.19	2.29	-20.71	1-S2n	0.81	1.89	0.81	0.59	21.85	9.96
50 year	48.90	48.90	2072.58	2.68	-20.26	1-S2n	0.90	2.10	0.90	0.66	23.07	10.65
100 year	55.80	55.80	2072.89	2.99	-19.88	1-S2n	0.96	2.25	0.98	0.71	23.27	11.12

Culvert Profile:



Site 4 (24" CMP with Flared End Sections):

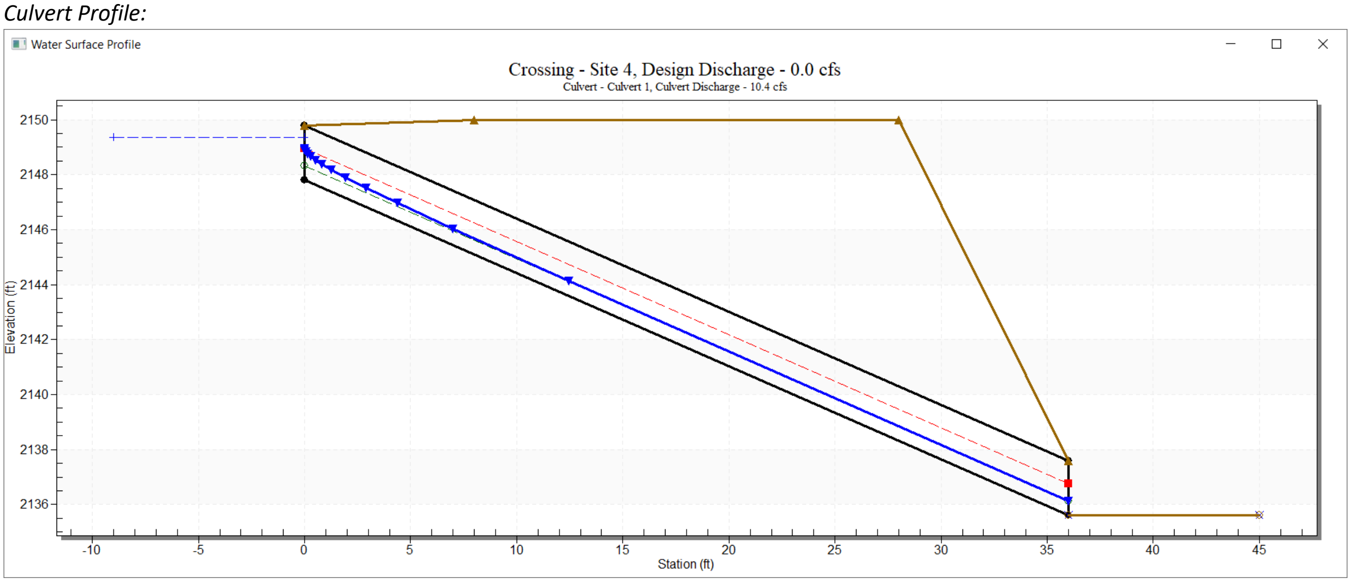
Crossing Data:



Culvert Summary Table:

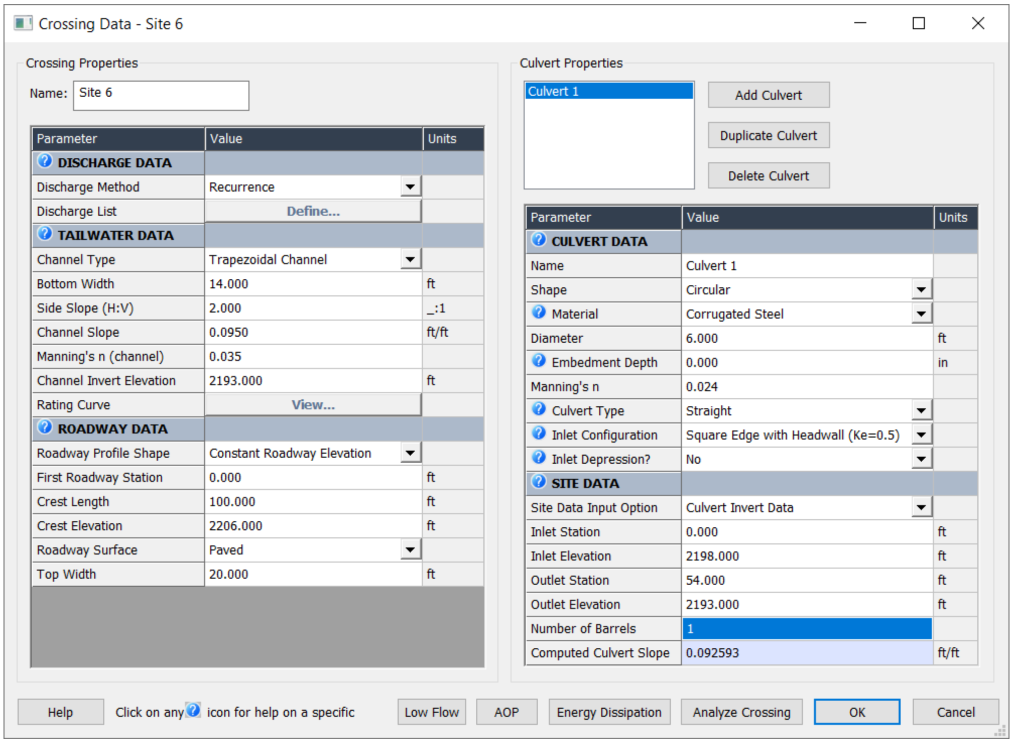
Discharge Names	Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Controlling Depth Inlet (ft)	Controlling Depth Outlet (ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
2 year	2.40	2.40	2148.41	0.61	-11.63	1-S2n	0.25	0.54	0.25	0.00	10.55	0.00
5 year	5.10	5.10	2148.71	0.91	-11.26	1-S2n	0.36	0.80	0.37	0.00	12.71	0.00
10 year	7.50	7.50	2148.98	1.18	-10.92	1-S2n	0.44	0.97	0.45	0.00	14.36	0.00
25 year	10.40	10.40	2149.35	1.55	-10.45	1-S2n	0.52	1.15	0.52	0.00	15.93	0.00
50 year	12.80	12.80	2149.67	1.87	-10.01	1-S2n	0.57	1.29	0.57	0.00	17.22	0.00
100 year	14.60	14.60	2149.93	2.13	-9.65	5-S2n	0.61	1.38	0.61	0.00	17.87	0.00

Culvert Profile:



Site 6 (72" CMP with Headwalls):

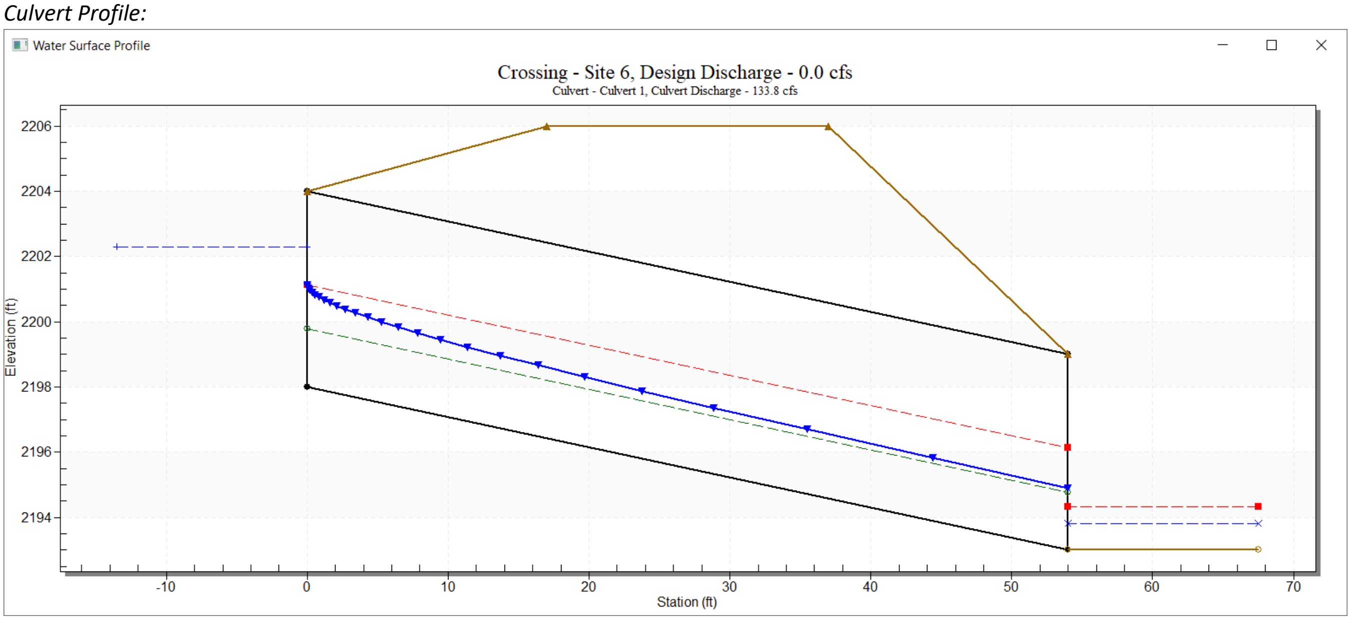
Crossing Data:



Culvert Summary Table:

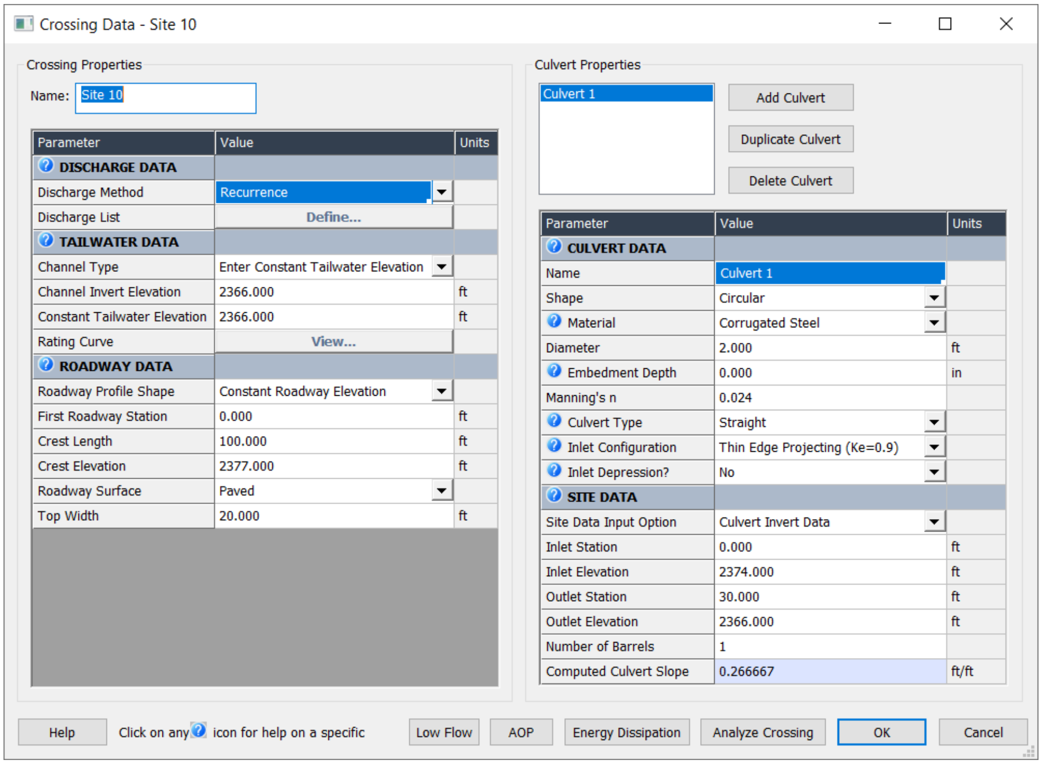
Discharge Names	Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Controlling Depth Inlet (ft)	Controlling Depth Outlet (ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
2 year	31.5	31.5	2199.87	1.87	-3.48	1-S2n	0.86	1.48	0.86	0.35	12.54	6.21
5 year	66.8	66.8	2200.79	2.79	-2.64	1-S2n	1.25	2.18	1.29	0.54	14.91	8.2
10 year	96.9	96.9	2201.48	3.48	-1.98	1-S2n	1.51	2.65	1.58	0.67	16.23	9.38
25 year	133.8	133.8	2202.28	4.28	-1.16	1-S2n	1.78	3.13	1.9	0.81	17.44	10.52
50 year	162.6	162.6	2202.89	4.89	-0.49	1-S2n	1.97	3.47	2.12	0.91	18.18	11.26
100 year	185.7	185.7	2203.37	5.37	0.08	1-S2n	2.11	3.72	2.3	0.99	18.66	11.79

Culvert Profile:



Site 10 (24” CMP with Flared End Sections):

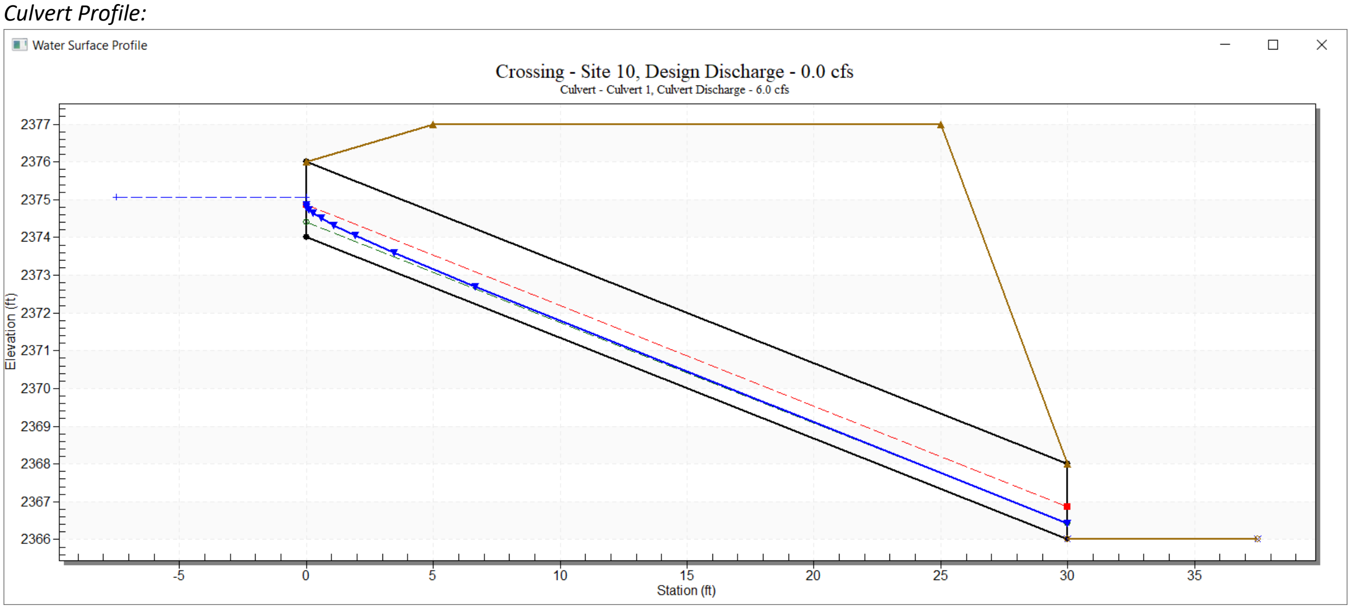
Crossing Data:



Culvert Summary Table:

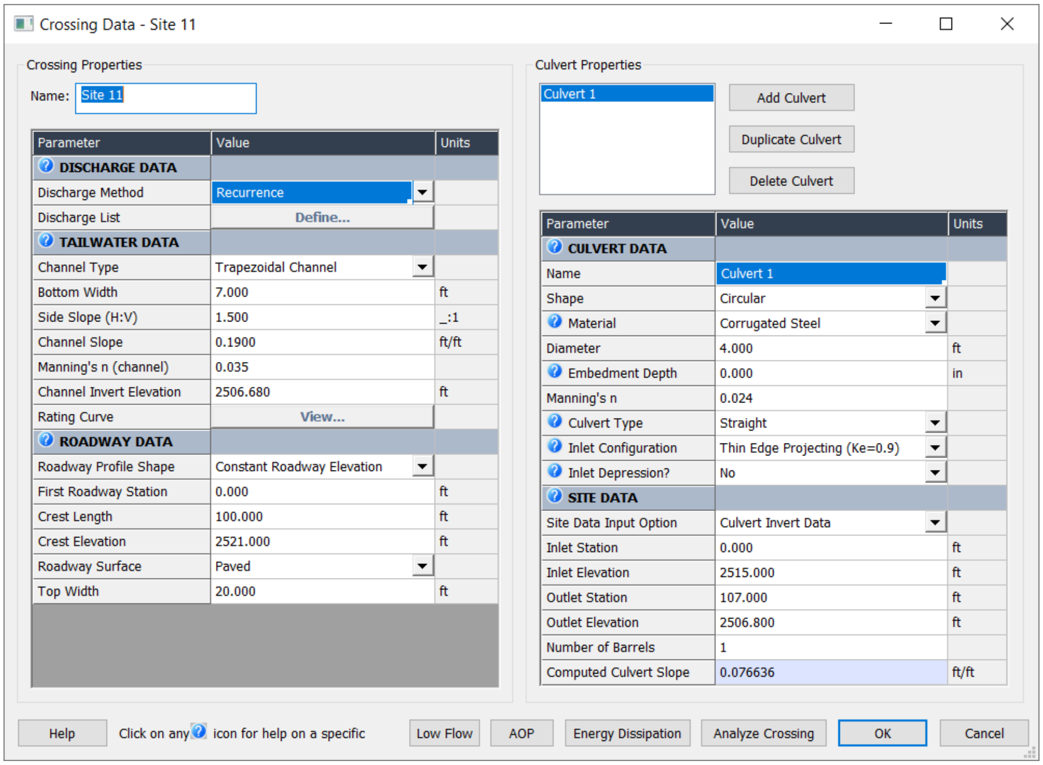
Discharge Names	Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Controlling Depth Inlet (ft)	Controlling Depth Outlet (ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
2 year	1.20	1.20	2374.45	0.45	-7.61	1-S2n	0.19	0.38	0.19	0.00	7.92	0.00
5 year	2.90	2.90	2374.71	0.71	-7.36	1-S2n	0.29	0.59	0.29	0.00	10.27	0.00
10 year	4.20	4.20	2374.86	0.86	-7.19	1-S2n	0.35	0.72	0.35	0.00	11.45	0.00
25 year	6.00	6.00	2375.06	1.06	-6.95	1-S2n	0.42	0.87	0.42	0.00	12.71	0.00
50 year	7.40	7.40	2375.24	1.24	-6.76	1-S2n	0.46	0.97	0.46	0.00	13.50	0.00
100 year	8.60	8.60	2375.39	1.39	-6.58	1-S2n	0.50	1.05	0.50	0.00	14.11	0.00

Culvert Profile:



Site 11 (48” CMP with Flared End Sections):

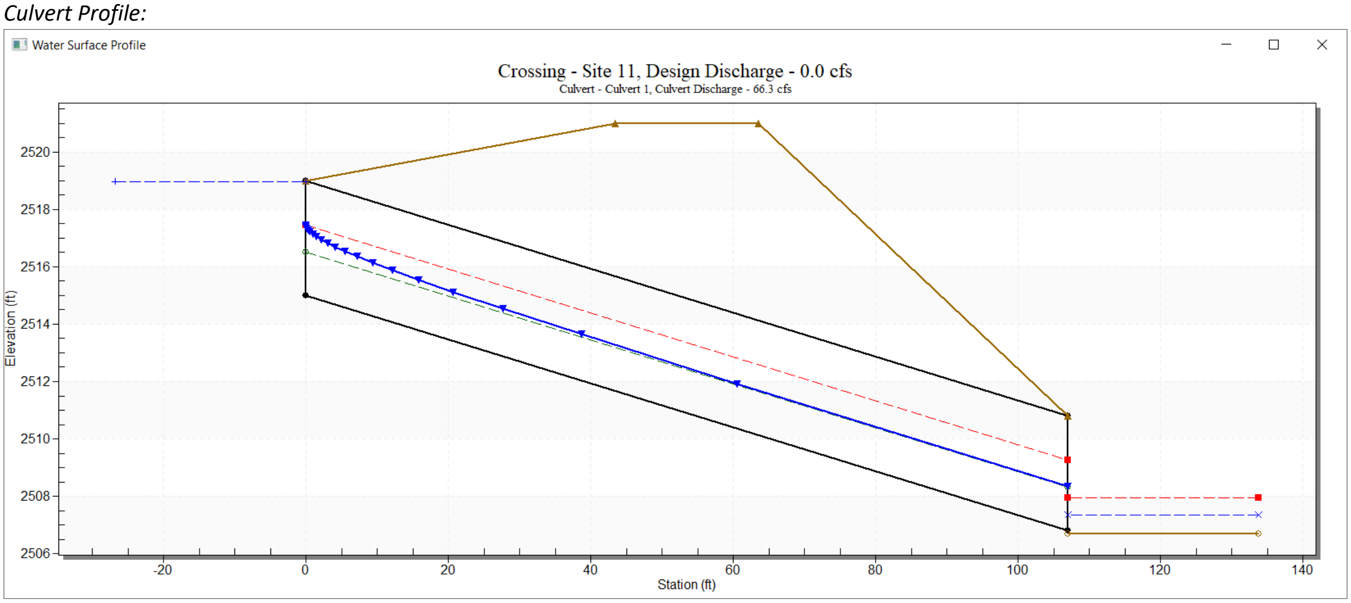
Crossing Data:



Culvert Summary Table:

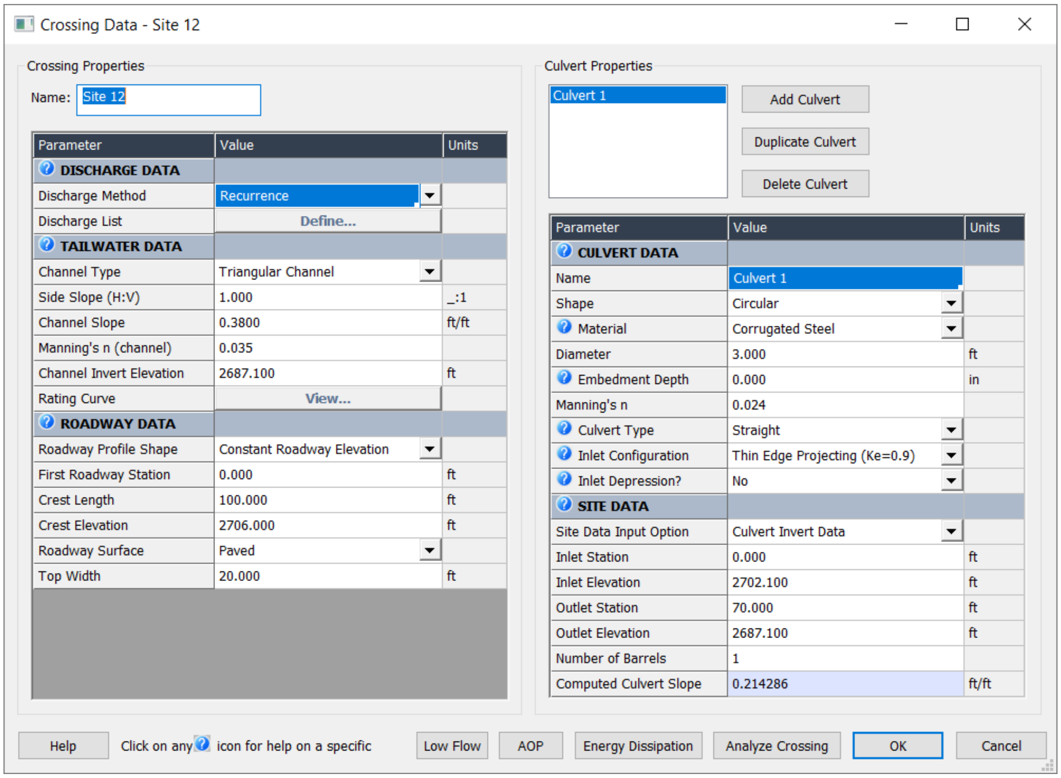
Discharge Names	Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Controlling Depth Inlet (ft)	Controlling Depth Outlet (ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
2 year	15.90	15.90	2516.62	1.62	-6.94	1-S2n	0.73	1.17	0.72	0.28	10.29	7.57
5 year	33.30	33.30	2517.47	2.47	-6.08	1-S2n	1.06	1.71	1.06	0.44	12.46	9.91
10 year	48.20	48.20	2518.14	3.14	-5.28	1-S2n	1.28	2.08	1.28	0.55	13.84	11.28
25 year	66.30	66.30	2518.96	3.96	-4.15	1-S2n	1.52	2.46	1.54	0.66	14.83	12.59
50 year	80.40	80.40	2519.67	4.67	-3.14	5-S2n	1.69	2.72	1.69	0.74	15.92	13.44
100 year	91.50	91.50	2520.30	5.30	-2.26	5-S2n	1.82	2.90	1.85	0.80	16.13	14.04

Culvert Profile:



Site 12 (30" CMP with Flared End Sections):

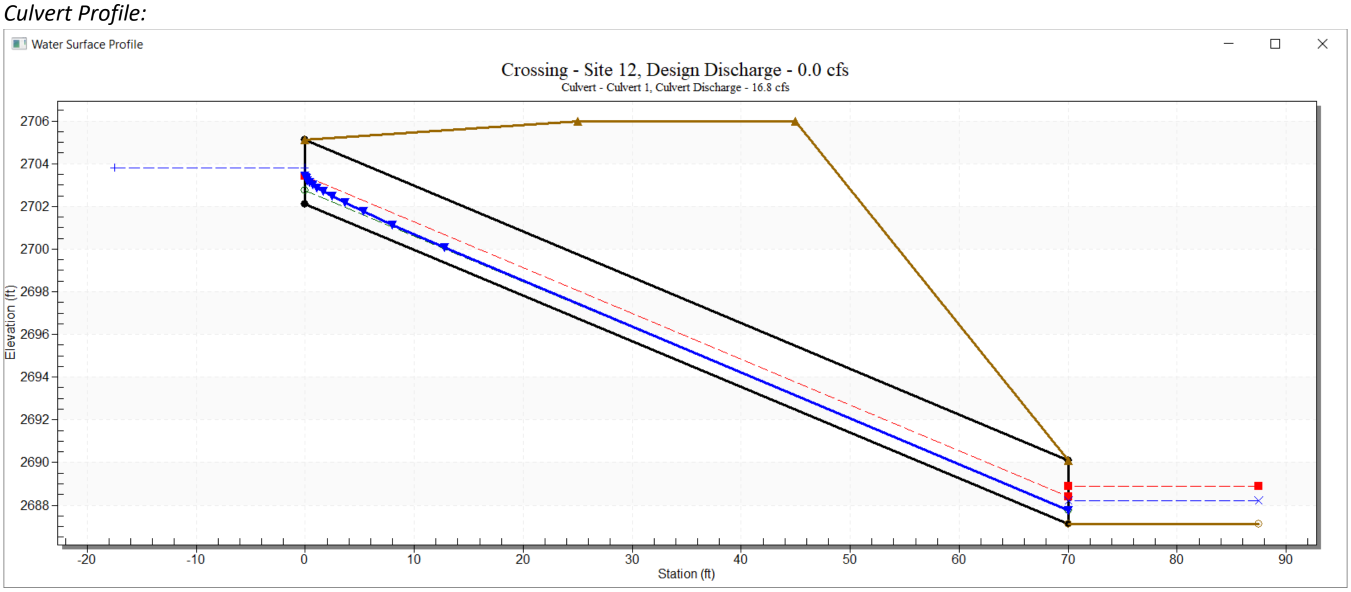
Crossing Data:



Culvert Summary Table:

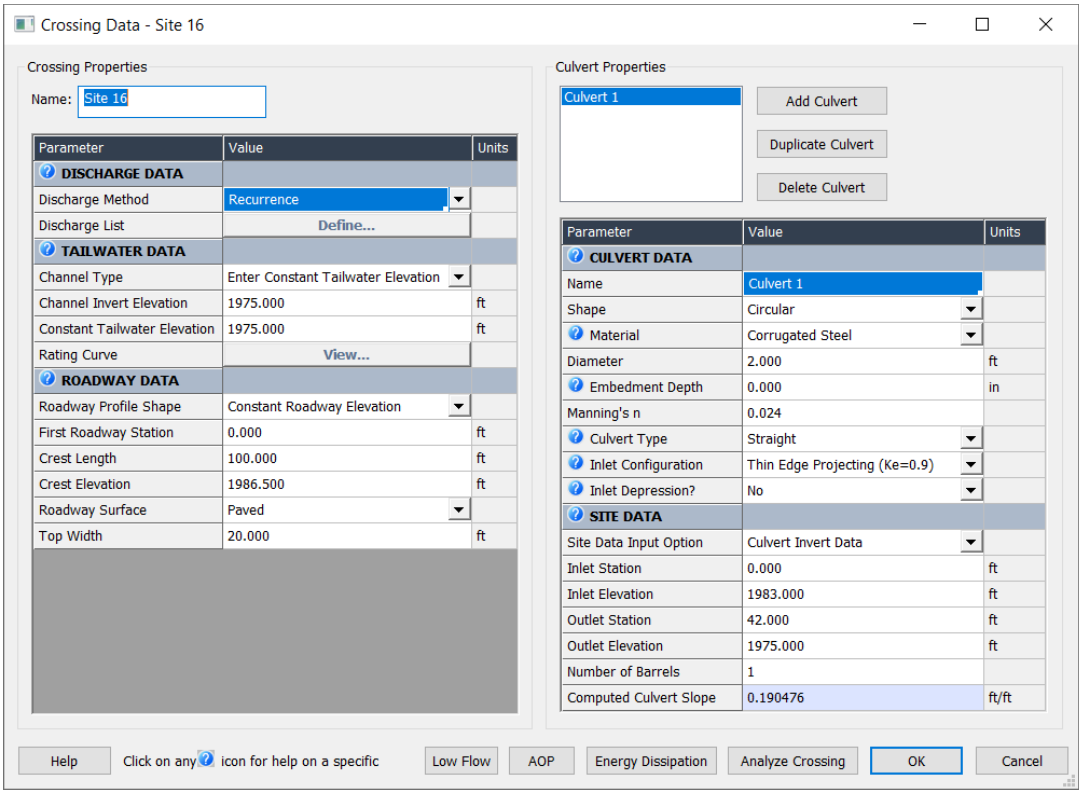
Discharge Names	Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Controlling Depth Inlet (ft)	Controlling Depth Outlet (ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
2 year	4.10	4.10	2702.88	0.78	-14.33	1-S2n	0.32	0.63	0.32	0.65	10.02	9.79
5 year	8.60	8.60	2703.25	1.15	-13.99	1-S2n	0.46	0.93	0.46	0.85	12.45	11.78
10 year	12.30	12.30	2703.49	1.39	-13.71	1-S2n	0.55	1.11	0.55	0.98	13.86	12.89
25 year	16.80	16.80	2703.78	1.68	-13.37	1-S2n	0.64	1.31	0.64	1.10	15.19	13.93
50 year	20.40	20.40	2704.04	1.94	-13.08	1-S2n	0.71	1.45	0.71	1.18	16.06	14.62
100 year	23.10	23.10	2704.22	2.12	-12.85	1-S2n	0.75	1.55	0.75	1.24	16.65	15.08

Culvert Profile:



Site 16 (24" CMP with Flared End Sections):

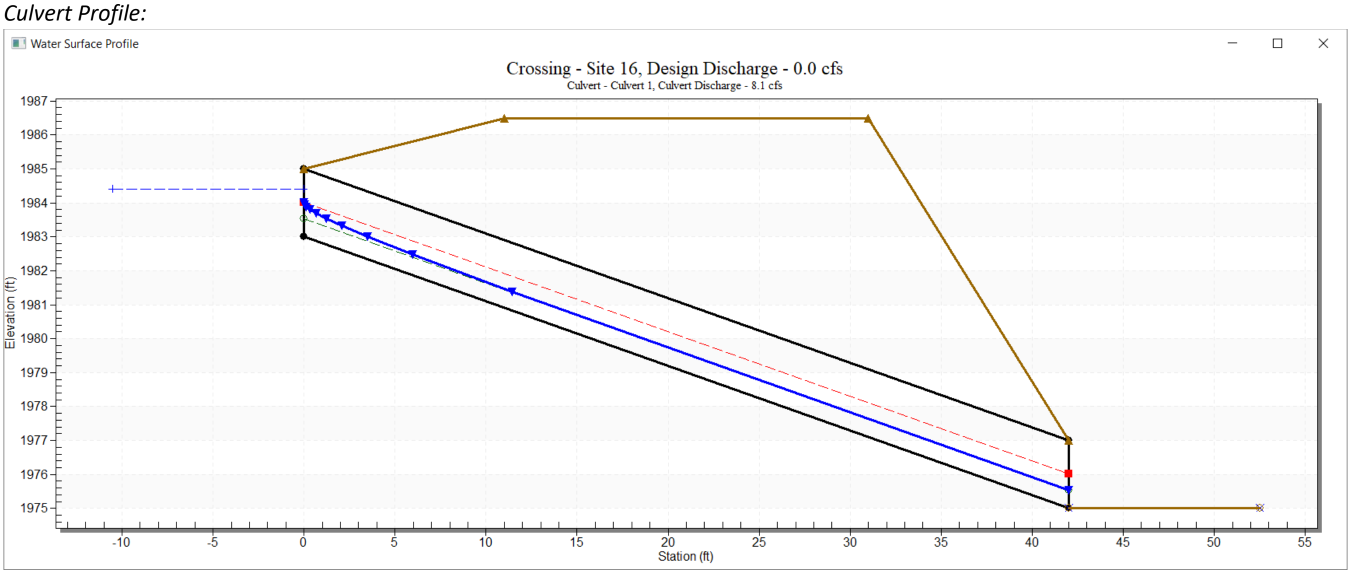
Crossing Data:



Culvert Summary Table:

Discharge Names	Total Discharge (cfs)	Culvert Discharge (cfs)	Headwater Elevation (ft)	Controlling Depth Inlet (ft)	Controlling Depth Outlet (ft)	Flow Type	Normal Depth (ft)	Critical Depth (ft)	Outlet Depth (ft)	Tailwater Depth (ft)	Outlet Velocity (ft/s)	Tailwater Velocity (ft/s)
2 year	1.80	1.80	1983.58	0.58	-7.52	1-S2n	0.25	0.46	0.25	0.00	7.91	0.00
5 year	3.90	3.90	1983.88	0.88	-7.22	1-S2n	0.36	0.69	0.36	0.00	9.94	0.00
10 year	5.80	5.80	1984.11	1.11	-6.95	1-S2n	0.44	0.85	0.44	0.00	11.18	0.00
25 year	8.10	8.10	1984.40	1.40	-6.60	1-S2n	0.53	1.01	0.53	0.00	12.25	0.00
50 year	10.00	10.00	1984.64	1.64	-6.29	1-S2n	0.58	1.13	0.58	0.00	13.07	0.00
100 year	11.50	11.50	1984.84	1.84	-6.01	1-S2n	0.63	1.22	0.64	0.00	13.26	0.00

Culvert Profile:



Hydraulic Toolbox – Riprap Analysis

Site 2:

Site 2 - Outlet Protection

Structure type: Culvert Outlet Protection | Geotextile/Granular Filter Design...

Parameter	Value	Units	Notes
Channel Parameters			
Select Channel	Site 2 - Pipe Analysis		
	Channel Calculator...		
Design Flow	187.700	cfs	
Channel Depth	2.167	ft	
Slope	0.086	ft/ft	
Bottom Width	0.000	ft	
Area	9.207	ft^2	
Top Width	5.764	ft	
Wetted Perimeter	7.738	ft	
Hydraulic Radius	1.190	ft	
Input Parameters			
	Transfer Values From Channel Calcu...		
Flow	187.700	cfs	
Culvert Diameter	6.000	ft	
Normal Depth in Culvert	2.167	ft	
Tailwater Depth	2.400	ft	If tailwater is unknown, use 0.4D
Flow Type	supercritical		
Results			
D50	16.276	in	
D50	1.356	ft	The sizing equation assumes a rock s.g.=2.65. If s.g. is not 2.65, rock size (D...
Riprap Shape	Riprap shape should be angular		
Riprap Class			
Riprap Class Name	CLASS V		
Riprap Class Order	5		
D15	13.00	in	This value is an 'average' of the size fraction range for the selected riprap class
D50	18.50	in	This value is an 'average' of the size fraction range for the selected riprap class
D85	25.50	in	This value is an 'average' of the size fraction range for the selected riprap class
D100	36.00	in	This value is an 'average' of the size fraction range for the selected riprap class
Layout			
Apron Length	36.000	ft	
Apron Thickness	3.392	ft	
Apron Width (at apron end)	36.251	ft	
Computation Variables			
Tailwater Depth Used in Computations	2.400	ft	
Culvert Diameter Used in Calculations	4.084	ft	

OK | Cancel

Site 3:

Site 3 - Outlet Protection

Structure type: Culvert Outlet Protection | Geotextile/Granular Filter Design...

Parameter	Value	Units	Notes
Channel Parameters			
Select Channel	Site 3 - Pipe Analysis		
	Channel Calculator...		
Design Flow	40.100	cfs	
Channel Depth	0.815	ft	
Slope	0.321	ft/ft	
Bottom Width	0.000	ft	
Area	1.838	ft^2	
Top Width	3.222	ft	
Wetted Perimeter	3.747	ft	
Hydraulic Radius	0.490	ft	
Input Parameters			
	Transfer Values From Channel Calcu...		
Flow	40.100	cfs	
Culvert Diameter	4.000	ft	
Normal Depth in Culvert	0.815	ft	
Tailwater Depth	0.585	ft	If tailwater is unknown, use 0.4D
Flow Type	supercritical		
Results			
D50	10.479	in	
D50	0.873	ft	The sizing equation assumes a rock s.g.=2.65. If s.g. is not 2.65, rock size (D...
Riprap Shape	Riprap shape should be angular		
Riprap Class			
Riprap Class Name	CLASS III		
Riprap Class Order	3		
D15	9.00	in	This value is an 'average' of the size fraction range for the selected riprap class
D50	12.50	in	This value is an 'average' of the size fraction range for the selected riprap class
D85	17.00	in	This value is an 'average' of the size fraction range for the selected riprap class
D100	24.00	in	This value is an 'average' of the size fraction range for the selected riprap class
Layout			
Apron Length	16.000	ft	
Apron Thickness	3.438	ft	
Apron Width (at apron end)	17.889	ft	
Computation Variables			
Tailwater Depth Used in Computations	0.963	ft	
Culvert Diameter Used in Calculations	2.408	ft	

OK | Cancel

Site 4:

Site 4 - Outlet Protection

Structure type: Culvert Outlet Protection

Geotextile/Granular Filter Design...

Parameter	Value	Units	Notes
Channel Parameters			
Select Channel	Site 4 - Pipe Analysis		
	Channel Calculator...		
Design Flow	10.400	cfs	
Channel Depth	0.516	ft	
Slope	0.338	ft/ft	
Bottom Width	0.000	ft	
Area	0.643	ft^2	
Top Width	1.750	ft	
Wetted Perimeter	2.132	ft	
Hydraulic Radius	0.301	ft	
Input Parameters			
	Transfer Values From Channel Calcu...		
Flow	10.400	cfs	
Culvert Diameter	2.000	ft	
Normal Depth in Culvert	0.516	ft	
Tailwater Depth	0.659	ft	If tailwater is unknown, use 0.4D
Flow Type	supercritical		
Results			
D50	6.017	in	
D50	0.501	ft	The sizing equation assumes a rock s.g.=2.65. If s.g. is not 2.65, rock size (D...
Riprap Shape	Riprap shape should be angular		
Riprap Class			
Riprap Class Name	CLASS I		
Riprap Class Order	1		
D15	4.50	in	This value is an 'average' of the size fraction range for the selected riprap class
D50	6.50	in	This value is an 'average' of the size fraction range for the selected riprap class
D85	9.00	in	This value is an 'average' of the size fraction range for the selected riprap class
D100	12.00	in	This value is an 'average' of the size fraction range for the selected riprap class
Layout			
Apron Length	8.000	ft	
Apron Thickness	1.896	ft	
Apron Width (at apron end)	9.108	ft	
Computation Variables			
Tailwater Depth Used in Computations	0.659	ft	
Culvert Diameter Used in Calculations	1.258	ft	

OK Cancel

Site 6:

Site 6 - Outlet Protection

Structure type: Culvert Outlet Protection

Geotextile/Granular Filter Design...

Parameter	Value	Units	Notes
Channel Parameters			
Select Channel	Site 6 - Pipe Analysis		
	Channel Calculator...		
Design Flow	133.800	cfs	
Channel Depth	1.773	ft	
Slope	0.094	ft/ft	
Bottom Width	0.000	ft	
Area	6.987	ft^2	
Top Width	5.475	ft	
Wetted Perimeter	6.897	ft	
Hydraulic Radius	1.013	ft	
Input Parameters			
	Transfer Values From Channel Calcu...		
Flow	133.800	cfs	
Culvert Diameter	6.000	ft	
Normal Depth in Culvert	1.773	ft	
Tailwater Depth	0.814	ft	If tailwater is unknown, use 0.4D
Flow Type	supercritical		
Results			
D50	17.090	in	
D50	1.424	ft	The sizing equation assumes a rock s.g.=2.65. If s.g. is not 2.65, rock size (D...
Riprap Shape	Riprap shape should be angular		
Riprap Class			
Riprap Class Name	CLASS V		
Riprap Class Order	5		
D15	13.00	in	This value is an 'average' of the size fraction range for the selected riprap class
D50	18.50	in	This value is an 'average' of the size fraction range for the selected riprap class
D85	25.50	in	This value is an 'average' of the size fraction range for the selected riprap class
D100	36.00	in	This value is an 'average' of the size fraction range for the selected riprap class
Layout			
Apron Length	36.000	ft	
Apron Thickness	3.392	ft	
Apron Width (at apron end)	35.660	ft	
Computation Variables			
Tailwater Depth Used in Computations	1.555	ft	
Culvert Diameter Used in Calculations	3.887	ft	

OK Cancel

Site 10:

Site 10 - Outlet Protection

Structure type: Culvert Outlet Protection

Geotextile/Granular Filter Design...

Parameter	Value	Units	Notes
Channel Parameters			
Select Channel	Site 10 - Pipe Analysis		
	Channel Calculator...		
Design Flow	6.000	cfs	
Channel Depth	0.416	ft	
Slope	0.267	ft/ft	
Bottom Width	0.000	ft	
Area	0.473	ft^2	
Top Width	1.623	ft	
Wetted Perimeter	1.894	ft	
Hydraulic Radius	0.250	ft	
Input Parameters			
	Transfer Values From Channel Calcu...		
Flow	6.000	cfs	
Culvert Diameter	2.000	ft	
Normal Depth in Culvert	0.416	ft	
Tailwater Depth	0.659	ft	If tailwater is unknown, use 0.4D
Flow Type	supercritical		
Results			
D50	3.051	in	
D50	0.254	ft	The sizing equation assumes a rock s.g.=2.65. If s.g. is not 2.65, rock size (D...
Riprap Shape	Riprap shape should be angular		
Riprap Class			
Riprap Class Name	CLASS I		
Riprap Class Order	1		
D15	4.50	in	This value is an 'average' of the size fraction range for the selected riprap class
D50	6.50	in	This value is an 'average' of the size fraction range for the selected riprap class
D85	9.00	in	This value is an 'average' of the size fraction range for the selected riprap class
D100	12.00	in	This value is an 'average' of the size fraction range for the selected riprap class
Layout			
Apron Length	8.000	ft	
Apron Thickness	1.896	ft	
Apron Width (at apron end)	8.957	ft	
Computation Variables			
Tailwater Depth Used in Computations	0.659	ft	
Culvert Diameter Used in Calculations	1.208	ft	

OK Cancel

Site 11:

Site 11 - Outlet Protection

Structure type: Culvert Outlet Protection

Geotextile/Granular Filter Design...

Parameter	Value	Units	Notes
Channel Parameters			
Select Channel	Site 11 - Pipe Analysis		
	Channel Calculator...		
Design Flow	66.300	cfs	
Channel Depth	1.527	ft	
Slope	0.076	ft/ft	
Bottom Width	0.000	ft	
Area	4.408	ft^2	
Top Width	3.886	ft	
Wetted Perimeter	5.327	ft	
Hydraulic Radius	0.827	ft	
Input Parameters			
	Transfer Values From Channel Calcu...		
Flow	66.300	cfs	
Culvert Diameter	4.000	ft	
Normal Depth in Culvert	1.527	ft	
Tailwater Depth	0.659	ft	If tailwater is unknown, use 0.4D
Flow Type	supercritical		
Results			
D50	14.853	in	
D50	1.238	ft	The sizing equation assumes a rock s.g.=2.65. If s.g. is not 2.65, rock size (D...
Riprap Shape	Riprap shape should be angular		
Riprap Class			
Riprap Class Name	CLASS IV		
Riprap Class Order	4		
D15	10.50	in	This value is an 'average' of the size fraction range for the selected riprap class
D50	15.50	in	This value is an 'average' of the size fraction range for the selected riprap class
D85	21.00	in	This value is an 'average' of the size fraction range for the selected riprap class
D100	30.00	in	This value is an 'average' of the size fraction range for the selected riprap class
Layout			
Apron Length	24.000	ft	
Apron Thickness	2.842	ft	
Apron Width (at apron end)	24.290	ft	
Computation Variables			
Tailwater Depth Used in Computations	1.105	ft	
Culvert Diameter Used in Calculations	2.763	ft	

OK Cancel

Site 12:

Site 12 - Outlet Protection

Structure type: Culvert Outlet Protection | Geotextile/Granular Filter Design...

Parameter	Value	Units	Notes
Channel Parameters			
Select Channel	Site 12 - Pipe Analysis		
	Channel Calculator...		
Design Flow	16.800	cfs	
Channel Depth	0.642	ft	
Slope	0.214	ft/ft	
Bottom Width	0.000	ft	
Area	1.110	ft^2	
Top Width	2.461	ft	
Wetted Perimeter	2.887	ft	
Hydraulic Radius	0.384	ft	
Input Parameters			
	Transfer Values From Channel Calcu...		
Flow	16.800	cfs	
Culvert Diameter	3.000	ft	
Normal Depth in Culvert	0.642	ft	
Tailwater Depth	0.659	ft	If tailwater is unknown, use 0.4D
Flow Type	supercritical		
Results			
D50	6.301	in	
D50	0.525	ft	The sizing equation assumes a rock s.g.=2.65. If s.g. is not 2.65, rock size (D...
Riprap Shape	Riprap shape should be angular		
Riprap Class			
Riprap Class Name	CLASS I		
Riprap Class Order	1		
D15	4.50	in	This value is an 'average' of the size fraction range for the selected riprap class
D50	6.50	in	This value is an 'average' of the size fraction range for the selected riprap class
D85	9.00	in	This value is an 'average' of the size fraction range for the selected riprap class
D100	12.00	in	This value is an 'average' of the size fraction range for the selected riprap class
Layout			
Apron Length	12.000	ft	
Apron Thickness	1.896	ft	
Apron Width (at apron end)	13.464	ft	
Computation Variables			
Tailwater Depth Used in Computations	0.728	ft	
Culvert Diameter Used in Calculations	1.821	ft	

OK | Cancel

Site 16:

Site 16 - Outlet Protection

Structure type: Culvert Outlet Protection | Geotextile/Granular Filter Design...

Parameter	Value	Units	Notes
Channel Parameters			
Select Channel	Site 16 - Pipe Analysis		
	Channel Calculator...		
Design Flow	8.100	cfs	
Channel Depth	0.526	ft	
Slope	0.190	ft/ft	
Bottom Width	0.000	ft	
Area	0.660	ft^2	
Top Width	1.762	ft	
Wetted Perimeter	2.155	ft	
Hydraulic Radius	0.306	ft	
Input Parameters			
	Transfer Values From Channel Calcu...		
Flow	10.400	cfs	
Culvert Diameter	2.000	ft	
Normal Depth in Culvert	0.516	ft	
Tailwater Depth	0.659	ft	If tailwater is unknown, use 0.4D
Flow Type	supercritical		
Results			
D50	6.017	in	
D50	0.501	ft	The sizing equation assumes a rock s.g.=2.65. If s.g. is not 2.65, rock size (D...
Riprap Shape	Riprap shape should be angular		
Riprap Class			
Riprap Class Name	CLASS I		
Riprap Class Order	1		
D15	4.50	in	This value is an 'average' of the size fraction range for the selected riprap class
D50	6.50	in	This value is an 'average' of the size fraction range for the selected riprap class
D85	9.00	in	This value is an 'average' of the size fraction range for the selected riprap class
D100	12.00	in	This value is an 'average' of the size fraction range for the selected riprap class
Layout			
Apron Length	8.000	ft	
Apron Thickness	1.896	ft	
Apron Width (at apron end)	9.108	ft	
Computation Variables			
Tailwater Depth Used in Computations	0.659	ft	
Culvert Diameter Used in Calculations	1.258	ft	

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