



**Final Supplemental Watershed Plan No. 1 - Environmental
Assessment**

United States
Department of
Agriculture

Central Sonoma Watershed - Matanzas Creek Dam Rehabilitation Project
Sonoma County, California

Natural
Resources
Conservation
Service

Sponsoring Local Organization: Sonoma County Water Agency
Lead Agency: Natural Resources Conservation Service (NRCS)

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Appendix D - TM005 - Existing Hydrology Analysis



TM005 – Existing Hydrology Analysis

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1.0 Introduction

Matanzas Creek Dam (CA00794) is an earthen embankment dam located in Sonoma Water, California. Construction of the dam was proposed as a result of the original Central Sonoma Watershed Plan developed in 1958 under the National Resources Conservation Service (NRCS) PL-566 program. The dam was designed by the NRCS and constructed in 1964 as a flood control structure. Sonoma Water Agency (Sonoma Water) currently owns, operates, and maintains the dam.

In 2016, HDR and Kleinfelder completed a dam assessment for the NRCS, which evaluated the dam based on Technical Release 210-60 (TR-60) design criteria. It was determined that Matanzas Creek Dam is out of compliance with TR-60 criteria due to its inability to route the principal spillway hydrograph without activating the earthen auxiliary spillway (HDR; Kleinfelder, 2016).

1.1 Purpose and Scope

Jones & DeMille Engineering (JDE) and AECOM have contracted with the NRCS to develop a supplemental watershed plan and environmental document that focuses on bringing Matanzas Creek Dam into compliance with NRCS and California Division of Safety of Dams (CA DSOD) standards. This report focuses on the hydrologic analysis of the watershed and the hydraulic performance of the existing dam. The spillway stability and integrity analysis is provided in *TM006 – Spillway Stability and Integrity* (JDE, 2023a).

1.2 NRCS Criteria

NRCS Technical Release 210-60 (TR-60) (NRCS, 2019a) establishes minimum requirements for earth dams. The criteria as it relates to hydrology and hydraulic performance is summarized below.

The Principal Spillway Hydrograph (PSH) is used to size the principal spillway (including the outlet structure, conduit, etc.) and to establish the elevation of the auxiliary spillway crest. For a High Hazard class dam, the PSH is a 100-year 10-day duration storm which must be passed through the primary spillway without engaging the auxiliary spillway. This storm is routed through the reservoir with the starting pool elevation set at the principal spillway crest and low-level outlet assumed to be plugged or closed. In addition, the peak routed flood pool volume during the PSH must draw down by 85 percent in 10 days or less. The precipitation depths for this storm are taken from NOAA Atlas 14 and the distributions are developed following the procedures outlined in National Engineering Handbook – Design Hydrographs (Section 4, Chapter 21) (NRCS, 2019).

The Auxiliary Spillway Hydrograph (ASH), also referred to as the Stability Design Hydrograph (SDH), is used to size the auxiliary spillway and evaluate the erodibility/stability of the spillway. The hydrograph is developed by applying an equation from TR-60 Figure 2-2 (NRCS, 2019a) to estimate the precipitation depth for both the 6-hour and 24-hour duration storm. For a High Hazard class dam, this precipitation equation is $P_{100} + 0.262 * (PMP - P_{100})$, where P_{100} is the 100-yr precipitation depth and PMP is the probable maximum precipitation depth. Hydrometeorological Report No. 58/59 (HMR 58/59) was used to determine the PMP depth and temporal distribution (NOAA, 1999).

The Freeboard Hydrograph (FBH) is also used to size the auxiliary spillway. Similar to the ASH/SDH, the hydrograph is developed by applying an equation from TR-60 Figure 2-2 (NRCS, 2019a) to estimate the precipitation depth for both the 6-hour and 24-hour duration storm. For a High Hazard dam, the auxiliary spillway is required to pass 100% of the PMP without overtopping the crest of the dam or breaching the auxiliary spillway.

The capacity of the auxiliary spillway is evaluated by routing the FBH with no residual freeboard and the ASH/SDH with freeboard. The minimum residual freeboard was estimated following guidance found in

NRCS Technical Release No. 69 – Riprap for Slope Protection against Wave Action (TR-69) (NRCS, 1983). Per this criterion, the maximum calculated wave run-up and wind setup heights were determined to ensure adequate freeboard. The calculated freeboard was added to the peak water surface elevation during the ASH/SDH and compared with the dam crest elevation to determine if adequate freeboard was available.

1.3 CA DSOD Criteria

CA DSOD establishes minimum hydrologic requirements for dams in *DSOD Inspection and Reevaluation Protocols* (CA DSOD, 2018). Dams with extremely high downstream hazard potential are designed for the PMP, as determined by HMR 58/59. Design storms typically consider the 72-hour storm event, but the 6-hour storm event should be considered for smaller watersheds (CA DSOD, 2018). For Matanzas Creek Dam, both storm durations were evaluated. Note that the CA DSOD design storm is equivalent to the NRCS FBH criterion (require to pass 100% of the PMP). Although the 72-hour duration storm is not required per NRCS criteria, the storm was also evaluated per TR-60 guidelines. Therefore, the NRCS evaluation of the 6-hour and 72-hour FBH storm events were used to satisfy the CA DSOD criteria.

The minimum total freeboard (also referred to as the normal freeboard), defined by CA DSOD as the distance from the lowest point of the dam crest to the auxiliary spillway crest, is 4 feet for dams built across natural flow paths. For dams subject to high seismic loads, which includes Matanzas Creek Dam, the minimum total freeboard is 5 feet plus 5 percent of the dam height. This results in the minimum total freeboard of 9.75 feet (5 feet plus 0.05 times 95 feet). Note that the dam currently has 15 feet of total freeboard available. The minimum residual freeboard, defined as the distance from the lowest point of the dam crest to the maximum reservoir elevation when routing the design storm, is 1.5 feet. Residual freeboard must also account for wind and wave runup during the design storm (CA DSOD, 2018); therefore, TR-69 will also be used to determine if the minimum residual freeboard for CA DSOD criteria.

For reservoirs with less than 5,000 acre-feet of storage capacity, the low-level outlet system must be able to drain half of the reservoir's capacity in 7 to 10 days and its full capacity 20 to 30 days (specific time is determined by CA DSOD and is based on various dam parameters) (CA DSOD, 2018).

2.0 Previous Hydrologic Studies

Several previous hydrologic studies have been completed for Matanzas Creek Dam. Reviewing previous studies was pertinent to completing this hydrologic analysis and understanding the results. A summary of the more relevant studies and findings is provided below.

In 2016, HDR and Kleinfelder completed a dam assessment (HDR; Kleinfelder, 2016) for the NRCS which evaluated the dam based on TR-60 (similar to those described in Section 1.2), but it was the 2005 version of TR-60 which has since been superseded by the more recent 2019 version. The 2016 dam assessment determined that Matanzas Creek Dam meets the 10-day PSH drawdown requirement and that the dam will not be overtopped during the 6-hour or the 72-hour FBH event. However, the assessment determined that Matanzas Creek Dam cannot route the PSH through its existing principal spillway without operating the auxiliary spillway; therefore, the dam was determined to be out of compliance with TR-60 requirements. The report recommended that the principal spillway be upsized to meet the PSH requirements.

In regard to the PSH the original design report completed by Woodward, Clyde, Sherard and Associates (WCS) in 1960, the report states that “an exception to the Watershed Work Plan was made in that a 24 hour storm was used in the design rather than a 72-hour storm.” Furthermore, the design report states the

design criteria for the principal spillway, "...consists of a 1 percent frequency storm for a 24 hour duration" (WCS, 1960). This finding may partially explain why Matanzas Creek Dam does not meet current TR-60 criteria for the PSH. However, it should be noted that the data and methodology for creating the PSH has changed over the years – so even though an exception was granted previously it was for a different older version of the PSH. Regarding the auxiliary spillway and dam crest design criteria, the design report states the crest elevation was determined with an 8.5-hour storm duration (WCS, 1960), which also differs to current TR-60 criteria. This, however, did not prevent the dam from meeting TR-60 criteria in the 2016 dam assessment.

In 2017, ESA completed hydrologic and hydraulic models of the Santa Rosa Creek watershed for Sonoma Water (ESA, 2017a; 2017b). The analysis considered two storm events, referred to as the New Year's Eve 2005 rainfall event and a storm event that occurred on January 20-21, 2010, as means to calibrate the models. The methods and procedures of the calibration are described in ESA's reports (ESA, 2017a; 2017b). For two of the stream gages, the hydrologic calibration successfully brought the percent difference within $\pm 1\%$. However, the stream gage that is representative of Matanzas Creek (which is located downstream of Matanzas Creek Dam) had a -14.1% difference on the hydrologic model for the New Year's Eve 2005 rainfall event. ESA provided a technical memorandum to Sonoma Water that presents potential causes of the calibrated percent difference for Matanzas Creek (ESA, 2015). The findings presented in ESA's memo are as follows:

- Observed flow at the Matanzas Creek stream gages is primarily driven by flow from Matanzas Creek Dam (other watersheds contribute to the stream gage).
- Rainfall and loss characteristics could be a potential cause of percent differences in the calibration, but not to the extent of explaining a 500 cfs difference when rain stops after 8:00 am.
- Matanzas Creek Dam's stage-discharge rating curve may be inaccurate.
- The stage-discharge rating curve on the Matanzas Creek stream gage may be inaccurate.

Sonoma Water provided ESA's hydrologic and hydraulic models of Santa Rosa Creek watershed to JDE for completion of this project. Also, since completion of the 2017 ESA reports, Sonoma Water has installed several new stream gages in the surrounding watersheds and a new stage gage for the reservoir of Matanzas Creek Dam. JDE utilized the received models and the new rainfall and stage gage data for further calibration of the Matanzas Creek watershed, which will be described further in Section 4.6.

3.0 Site Description

3.1 Matanzas Creek Dam and Appurtenant Structures

Matanzas Creek Dam is an earthen embankment dam that was constructed in 1964 for flood control. The dam has a crest length of approximately 685 feet, a crest top width of 24 feet, and a total height of approximately 95 feet. The embankment has a 3:1 upstream slope with one wave berm that is 10 feet in width. The downstream face of the dam has a 2.5:1 slope and two stability berms that are also both 10 feet wide.

The principal spillway of the dam is cast-in-place reinforced concrete 10-feet by 10-feet intake structure. The intake riser is surrounded by a concrete structure with anti-vortex walls and several large trash racks. The intake reduces down to a 5.25-feet by 5.25-feet reinforced concrete conduit that runs through the embankment to the outlet structure and stilling basin. The outlet structure consists of reinforced concrete walls, spillway, and a stilling basin that features chute blocks, baffle blocks, and a concrete cutoff wall (similar to a USBR Type III stilling basin). The dam also features a low-level outlet consisting of a trash rack, slide gate, and 18-inch pipe which discharges into the 5.25-feet by 5.25-feet concrete conduit.

The auxiliary spillway of the dam is a vegetated earthen spillway that wraps around the right abutment of the embankment. The auxiliary spillway operates as a broad-crested weir with a weir length of 200 feet and 2:1 side slopes. The crest of the spillway includes a concrete cut-off wall that extends 10 feet below the ground surface.

A summary of parameters for Matanzas Creek Dam is provided in Table 3-1. Elevations from the as-built drawings were presumed to be in the NGVD 29 vertical datum. NOAA's Coordinate Conversion and Transformation Tool calculates a datum shift of +2.9 feet to convert to the NAVD 88 vertical datum for the project area; however, survey data completed for this project showed a localized datum shift of +2.63 feet (previously explained in *TM001 – Existing Conditions Assessment*, JDE & AECOM, 2023). Therefore, elevations converted from NGVD 29 to NAVD 88 used a datum shift of +2.63 feet.

Table 3-1. Matanzas Creek Dam Parameters

General Data				
Name of Dam	Matanzas Creek Dam (NID: CA00794)			
Latitude / Longitude	38.4063° N 122.6520° W			
Dam Owner/Operator	Sonoma Water Water Agency			
Year Completed	1964			
Embankment Type	Earthen			
Purpose(s)	Flood Control			
Hazard Classification	High (NRCS); Extremely High (CA DSOD)			
Intended Design Life	50 years			
Drainage Area	11.45	acre-feet (JDE 2021)		
Dam Height	95	feet		
Embankment Length	685	feet		
Embankment Top Width	24	feet		
Embankment Upstream Slope	3:1	H:V		
Embankment Downstream Slope	2.5:1	H:V		
Spillway Dimensions				
Auxiliary Spillway Width	200	feet	Open Channel, Earthen	
Principal Spillway Intake	10 ft x 10 ft		Reinforced Concrete	
Principal Spillway Conduit	5.25 ft x 5.25 ft		Reinforced Concrete	
Low-Level Drawdown Diameter	18	inch	Steel Pipe	
Elevations				
	As-Builts (NGVD 29)		JDE 2021 (NAVD 88)	
Top of Dam	425	feet	427.63	feet
Auxiliary Spillway Crest	410	feet	412.63	feet
Principal Spillway Crest	375	feet	377.63	feet
Low-Level Drawdown Invert	350.8	feet	354.5	feet
Storage				
	As-Builts Data		JDE 2021	
Top of Dam	2,650	ac-ft	2,671	ac-ft
Auxiliary Spillway Crest	1,520	ac-ft	1,444.8	ac-ft
Principal Spillway Crest	245	ac-ft	88.9	ac-ft
Sediment Storage Capacity	245	ac-ft	88.9	ac-ft

3.2 Watershed Description

3.2.1 Topographic Data

The best available topographic data for the dam's watershed is a 2013 3-feet resolution LiDAR surface received from Sonoma Water. The 2013 LiDAR was used to determine the watershed boundary,

elevations, slopes, longest flow paths, etc. The watershed for Matanzas Creek Dam is shown on Exhibit 4 in Appendix A.

A tour of the watershed was completed during the January 2021 site visit to confirm watershed attributes such as the delineated watershed boundary, drainage features, land cover types, soil conditions, development, etc.

Note that the delineated watershed boundary from the 2013 LiDAR data resulted in an area of 11.45 square miles, which is less than the previously determined area of 11.5 square miles (ESA, 2017b).

3.2.2 Land Cover

Land cover was evaluated with a vegetation and habitat map developed by Sonoma Water. Sonoma Water's vegetation map represented the state of landscape in 2013 and adheres to the National Vegetation Classification System (Sonoma Water, 2020). Examples of the land cover classifications include urban and developed areas, major roads, water, woodland and forest vegetation, shrubland vegetation, herbaceous vegetation, orchards, groves, vineyards, cropland, etc.

In addition to Sonoma Water's data, the land cover for the watershed was reevaluated by manually mapping the land cover types with 2020 aerial imagery obtained from the National Agricultural Imagery Program (NAIP) and a machine learning process utilizing ArcGIS Pro software. The Image Classification Wizard tool was used to classify land cover types for the entire watershed based on identifying a sample of land cover types by the color and shape of pixel groupings.

After comparing the 2013 vegetation map and the 2020 NAIP aerial imagery, it was determined that very minimal changes to the landscape had occurred through the years. Furthermore, the manually mapping of land cover was comparable to Sonoma Water's vegetation map, minus minor inaccuracies of orchards, vineyards, and crops produced from the Image Classification Wizard tool. Therefore, it was determined that the 2013 vegetation map provided a more accurate mapping of land cover throughout the watershed and therefore was used for further hydrologic analysis.

The land cover classifications from the 2013 vegetation map were reclassified to appropriate land cover classifications defined in the National Engineering Handbook (NEH) Part 630 Chapters 8 (NRCS, 2002) and 9 (NRCS, 2004a). The summary of land cover classifications and their areas within with delineated watershed are shown in Table 3-2. The chosen hydrologic condition for each land cover was based on aerial imagery and observations made while touring the watershed.

3.2.2.1 Future Land Cover Conditions

Future land development within the watershed should be considered throughout the design life of the dam. After coordination with Sonoma Water for available forecast information of land development, it was determined that there was minimal anticipated build-out expected within the watershed. However, to be conservative, the possible development of residential districts in replacement of the existing orchards and vineyards was considered. However, it should be noted that the CN for an orchard or vineyard in good hydrologic condition is equivalent to a CN for a ½ acre residential lot, which is the likely smallest size of lot that would be considered for land development within the watershed (note that most existing residential lots within the watershed are larger than ½ acre). Therefore, it was determined that any possible land development would result in minimal change to the overall CN for the watershed. To be conservative, however, the future conditions considered at one percent increase of imperviousness in the watershed, which is equivalent to approximately 73 acres or 24 miles of road development.

Table 3-2. Land Cover Data

Land Cover Type – 2013 Vegetation Map	Reassigned Land Cover Type – NEH Part 630	Hydrologic Condition	Area (acres)	Area (sq. mi.)
Developed	Residential – 1/8 Acre	Not Applicable	240.0	0.37
Forest Silver	Woods	Good	3,115.2	4.87
Herbaceous	Herbaceous	Fair	3,050.8	4.77
Major Roads	Impervious Areas	Not Applicable	30.9	0.05
Non-native Shrub	Desert Shrub	Fair	82.9	0.13
Orchard or Grove	Woods-grass	Fair	769.4	1.20
Perennial Agriculture	Row Crops – SR	Poor	1.3	0.00
Shrub	Desert Shrub	Fair	6.5	0.01
Vineyard	Woods-grass	Fair	1.3	0.00
Water	Open Water	Not Applicable	28.1	0.04
Total Area:			7,326.4	11.45

3.2.3 Soil Characteristics

Soil Survey Geographic Database (SSURGO) soil data was downloaded from the NRCS’s Web Soil Survey (NRCS, 2019b). The obtained soil data for the watershed was last updated by the NRCS in 2020. The soil data includes the hydrologic soil group (typically classified as A, B, C, D) for the soils located within the delineated watershed, which is shown on Exhibit 4 in Appendix A. The majority of soils within the watershed were classified as C or D. The hydrologic soil group in conjunction with the land cover data were used to determine the curve numbers (CN) for the watershed. A summary of the soil groups and their areas are shown in Table 3-3. Note that the received SSURGO soil data had small areas with unclassified hydrologic soil groups. For these areas, the unclassified soil group was assigned based on surrounding soils groups.

Table 3-3. Soil Characteristics

Hydrologic Soil Group	Area (acres)	Area (sq. mi.)
A	0	0
B	34.0	0.05
C	4,951.4	7.74
D	2,341.0	3.66
Total Area:	7,326.4	11.45

4.0 Hydrologic Analysis

4.1 Precipitation

The required precipitation values to meet both NRCS and CA DSOD criteria was previously described in Sections 1.2 and 1.3. The summary of determined precipitation values to meet these criteria are provided in Table 4-1, and the calculations for the PMP values per HMR 58/59 are provided in Appendix B. Note that Table 4-1 includes the precipitation values determined during the 2016 dam assessment for comparison purposes only.

The temporal distributions for the general and local storms followed HMR 58/59 guidelines. The 24-hour and 72-hour general storms were developed with a center-peaking distributions and the 6-hour local storm was developed with a front-peaking temporal distribution (see Appendix B).

Table 4-1. Precipitation Values (High Hazard)

Storm Event	Agency Criteria	Precipitation Notation	Precip. Values ¹ (inches)	
			2016 Dam Assessment	2021 JDE
100-year Precipitation ²				
6-hour	NRCS	P100 _{6-hr}	4.7	4.77
24-hour	NRCS	P100 _{24-hr}	10.3	10.47
Principal Spillway Hydrograph (PSH)				
100-year 10-day	NRCS	P100 _{10-day}	24.7	24.92
Freeboard Hydrograph (FBH) ³				
6-hour	NRCS; CA DSOD	PMP _{6-hr}	6.6	6.57
24-hour	NRCS	PMP _{24-hr}	NA ⁴	24.45
72-hour	NRCS; CA DSOD	PMP _{72-hr}	41.5	41.60
Auxiliary Spillway Hydrograph (ASH/SDH)				
6-hour	NRCS	P100 _{6-hr} + 0.26(PMP _{6-hr} - P100 _{6-hr})	5.2	5.24
24-hour	NRCS	P100 _{24-hr} + 0.26(PMP _{24-hr} - P100 _{24-hr})	NA ⁴	14.11

¹2016 Dam Assessment (HDR/Kleinfelder, 2016) precipitation values are listed for comparison purposes only. The 2021 JDE values were used in this analysis.

²100-year precipitation depths per NOAA Atlas 14. Values were used to determine the ASH/SDH precipitation depths.

³PMP precipitation depths per HMR 58/59.

⁴24-hour storm duration not evaluated in the 2016 Dam Assessment (HDR/Kleinfelder, 2016).

4.2 Loss and Transform Methods

Rainfall losses were based on the SCS CN method, per NEH Part 630 Chapters 9 (NRCS, 2004a) and 10 (NRCS, 2004b). The CNs were determined based off the assumption of a normally saturated watershed, or Antecedent Runoff Condition Type II (ARCI). Table 4-2 displays the CNs based on the land cover, hydrologic condition, and hydrologic soil group, and Exhibit 4 in Appendix A shows the spatial distribution of land cover and soil groups throughout the watershed.

The Lag Time (Lg) of the watershed was calculated using the SCS Velocity Method and the SCS Watershed Lag Method, as described in NEH Part 630 Chapter 15 (NRCS, 2010). The Velocity Method consists of flow path segments broken up into sheet flow, shallow concentrated flow, and opened channel flow. Each segment requires the length and slope as well as the land cover type, flow type, and typical open channel geometry depending on the segment type. The Watershed Lag Method uses an empirical equation which requires the watersheds watercourse length, average basin slope, CN, and area. These parameters were delineated and estimated using topographic data, aerial imagery, and based on field visits. It was determined that the SCS Watershed Lag Method produced a reasonable Lg based on ESA's hydrologic report and their calibration of the watershed.

A comparison of CN and lag time for Matanzas Creek Dam's watershed for this analysis and previous studies is shown in Table 4-3.

Table 4-2. SCS Curve Numbers (ARCII)

Land Cover	Hydrologic Condition	Hydrologic Soil Group			
		A	B	C	D
Residential – 1/8 Acre	Not Applicable	77	85	90	92
Woods	Good	30	55	70	77
Herbaceous	Fair	62	71	81	89
Impervious Areas	Not Applicable	98	98	98	98
Desert Shrub	Fair	55	72	81	86
Woods-grass	Fair	43	65	76	82
Row Crops – SR	Poor	72	81	88	91
Woods-grass	Fair	43	65	76	82
Open Water	Not Applicable	100	100	100	100

Table 4-3. Comparison of CN and Lag Time (Pre-Calibrated)

Parameter	2016 Dam Assessment (HDR; Kleinfelder, 2016)	2017 Hydrologic Report (ESA, 2017b)	2021 JDE
Curve Number (ARCII)	84	79.7	81
Lag time (hr)	0.8	1.80	1.55

4.3 Flood Routing

The NRCS and CA DSOD hydrologic criteria were analyzed using SITES (Version 2005.1.8), which was developed by the U.S. Department of Agriculture in cooperation with Kansas State University (USDA, 2014). All routed storms assumed that the initial reservoir stage was equal to the principal spillway crest (377.63 feet) and that the low-level outlet was closed. Note that the principal spillway crest for the dam is equivalent to the designed sediment pool elevation, and it is the lowest uncontrolled spillway.

4.3.1 Stage-Storage

The reservoir stage-area and stage-storage curves were developed in ArcGIS Pro for Matanzas Creek Dam using the 2013 3-feet LiDAR surface in conjunction with the 2020 LiDAR data and sediment removal records, as previously described in *TM001 – Existing Conditions Assessment* (JDE & AECOM, 2023). The as-built and existing condition stage-area and stage-storage curves for the dam is shown in Table 4-4 and Figure 4-1.

4.3.2 Stage-Discharge

Rating curves for the principal and auxiliary spillways were evaluated and compared with the rating curves found on the as-builts for Matanzas Creek Dam.

The rating curve for the earthen (grass-lined; Manning’s $n = 0.03$) auxiliary spillway was developed in HEC-RAS with the 2013-LiDAR terrain data. The rating curve for the principal spillway was developed per TR-210-29 (NRCS, 1965) guidelines. During the calibration analysis of the watershed (see Section 4.6), it was determined that the existing principal spillway has an approximate average of 200 cfs more capacity than what was developed on the as-builts. ESA also found the principal spillway to have more capacity in their calibration efforts (ESA, 2017b). The developed rating curves for the spillways are compared with rating curves shown on the as-builts in Figure 4-2. The tabular data and procedures to develop the stage-discharge relationships are provided in Appendix B.

Table 4-4. Stage-Storage and Stage-Area

Elevation (NVGD 29) (ft)	Elevation (NAVD 88) (ft)	As-built		2013 LiDAR		Notes
		Storage Capacity (ac-ft)	Storage Area (ac)	Storage Capacity (ac-ft)	Storage Area (ac)	
335	337.63	0	0	0.00	0.00	
340	342.63	10	0.5	0.00	0.00	
350	352.63	20	2.5	0.01	0.01	
360	362.63	70	7	4.48	1.81	
370	372.63	170	12	43.18	7.41	
375	377.63	245	15	88.91	10.82	Principal Spillway Crest
380	382.63	330	19	154.45	15.65	
390	392.63	580	31	414.00	36.78	
400	402.63	975	46	856.01	51.29	
410	412.63	1520	61	1444.78	66.96	Auxiliary Spillway Crest
420	422.63	2225	81	2201.72	85.11	
425	427.63	2650	92	2671.03	110.15	Dam Crest
427.37	430	2851	97	2893.48	122.03	Extrapolated
430.37	433	3106	104	3175.07	137.05	Extrapolated

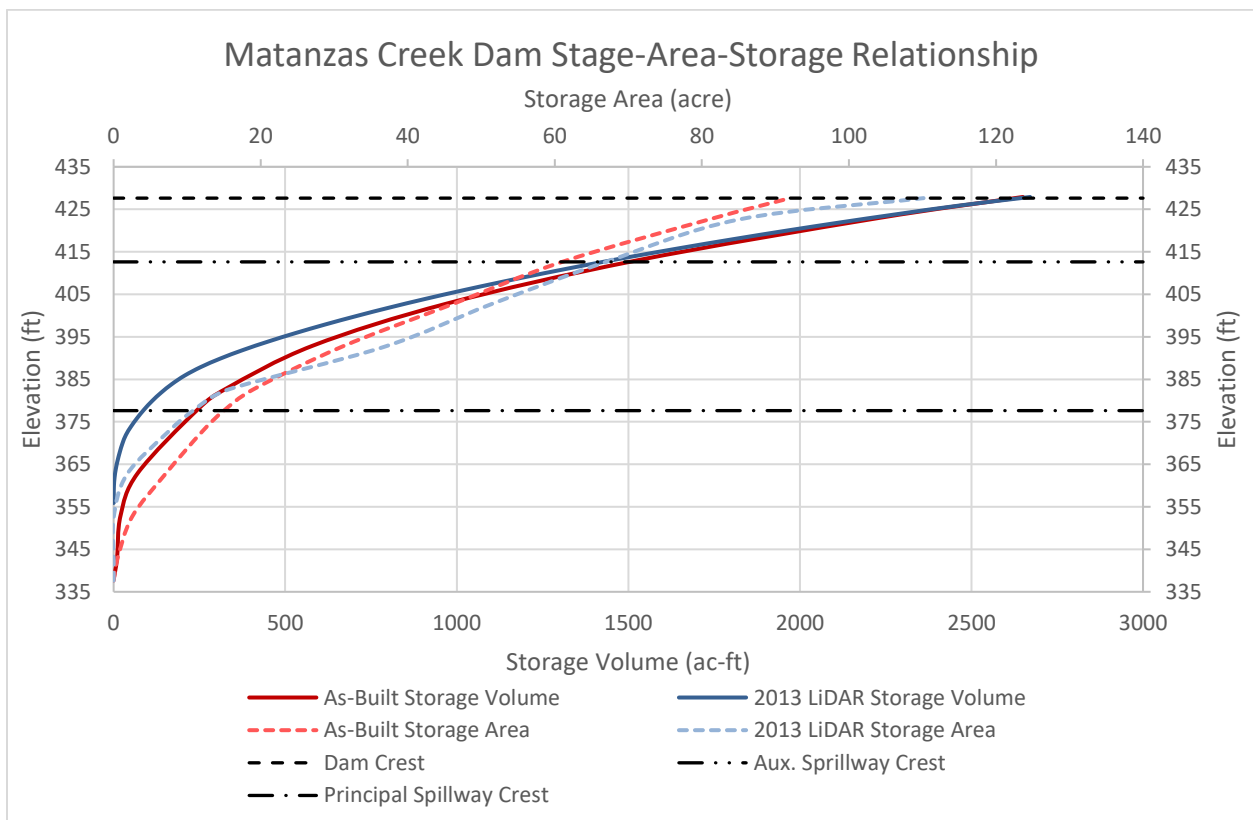


Figure 4-1. Stage-Area and Stage-Storage Curves

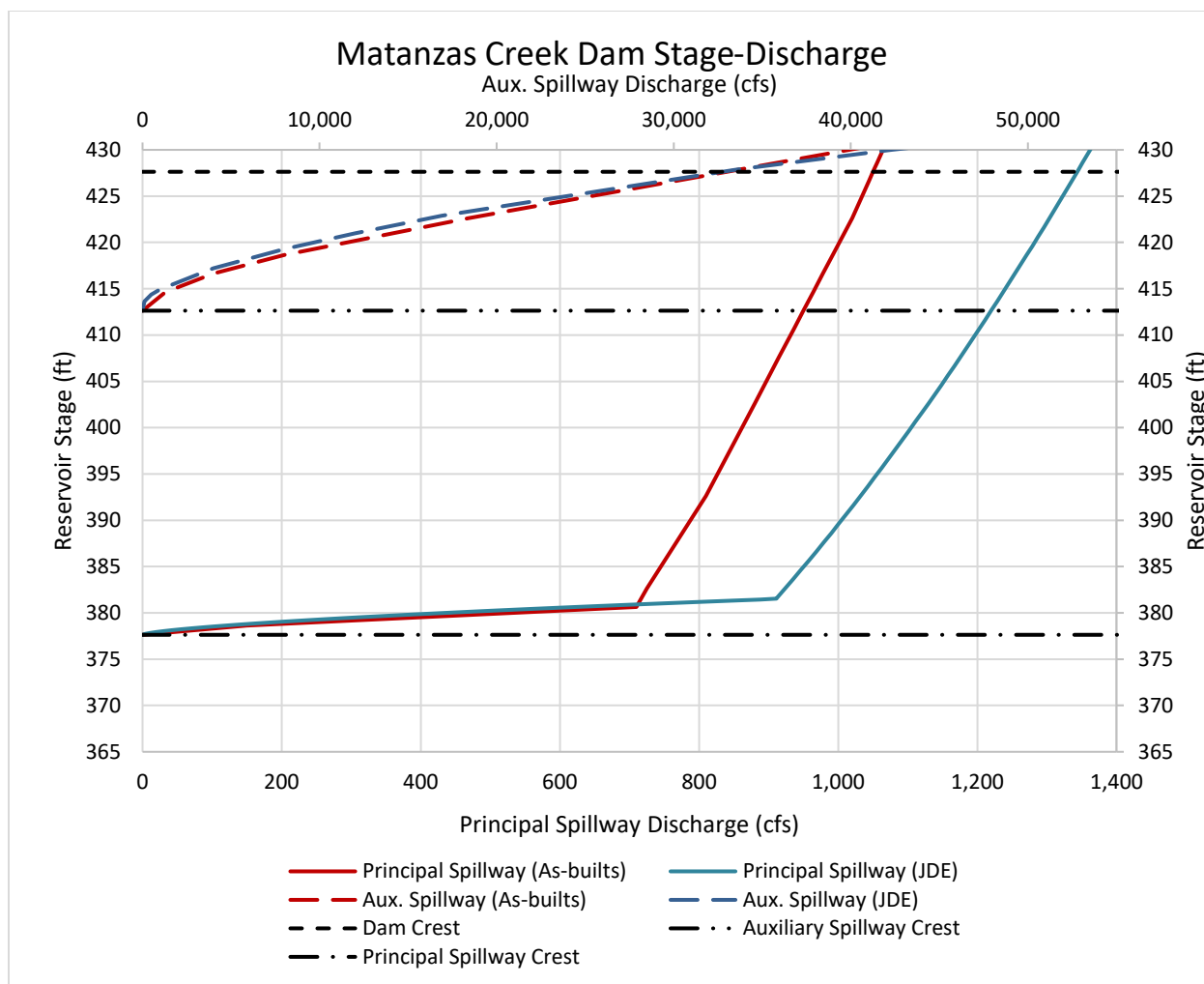


Figure 4-2. Stage-Discharge Curve

4.4 Unit Hydrographs

SITES typically uses the SCS Unit Hydrograph as the transform method. The HEC-HMS model of the Central Sonoma Watershed received by Sonoma Water (further explained in Section 4.6), however, uses the Snyder Unit Hydrograph as the transform method. Since the results of this hydrologic analysis and the completed calibration of the model will need to be used for the Central Sonoma Watershed and the flood-frequency analysis in *TM008 – Frequency Flood Routing* (JDE, 2023b), the Snyder Unit Hydrograph transform method was used in SITES for the TR-60 hydrologic analysis.

The hydrographs for the TR-60 storm criteria were developed in the HEC-HMS model used to calibrate the watershed (see Section 4.6). These hydrographs were then imported into SITES to complete the flood routing and evaluation of the dam. The produced hydrographs are provided in Appendix B.

4.5 Freeboard

NRCS TR-69 (NRCS, 1983) was used to determine the minimum freeboard required for the ASH/SDH storm event. The maximum wind speed data recorded at the Santa Rosa Airport (nearest available wind speed gage to the dam) was approximately 54 miles per hour (mph). The maximum wind speed for the project location per Figure 4 in TR-69 is approximately 85 mph. The U.S. Bureau of Reclamation

recommends using a 100 mph wind speed (USBR, 1987), which is a simple but conservative approach. The freeboard required was evaluated for each wind speed, but to be conservative, an overland windspeed of 100 mph was used to determine the required freeboard. With an effective fetch length of 0.25 miles, Matanzas Creek Dam requires a minimum of 2.1 feet of freeboard for the ASH/SDH storm event.

As previously discussed in Section 1.3, the CA DSOD minimum total freeboard for Matanzas Creek Dam is 9.75 feet since the dam is subject to high seismic loads. Matanzas Creek Dam currently has 15 feet of total freeboard and therefore meets this criterion. The minimum residual freeboard for the dam when routing the design storm per CA DSOD criteria is 2.1 feet, as determined from TR-69 guidelines.

Wave-runup calculations per TR-69 guidelines are provided in Appendix B.

4.6 Calibration

4.6.1 Hydrologic Model

Sonoma Water provided JDE with a calibrated hydrologic model from the Santa Rosa Creek Climate Plan which was based on the 2017 study by ESA (ESA, 2017b). The model contains the entire Santa Rosa Creek Watershed. In previous studies it was noted that the calibration for Matanzas Creek required an increased CN in order to minimize differences between modeled and observed flows. This was based on the precipitation data that was available at the time. Additional precipitation gages have been installed in the years since the previous studies were completed. The calibration for this study utilizes the additional precipitation and stream flow data and will focus on the calibration for the Matanzas Creek watershed. As such only the subbasins upstream of the USGS 11466170 stream gage on Matanzas Creek were modeled and calibrated. The Matanzas and Spring Creek subbasins and parameters were extracted from the model provided by Sonoma Water. Sonoma Water further improved the ESA calibrated model by adjusting Lg values and baseflow parameters in the Matanzas and Spring Creek subbasins. All the parameters from the received model were left unchanged aside from Elevation-Area-Discharge data for Matanzas Creek Dam based on the 2021 JDE analysis (refer to Sections 4.3.1 and 4.3.2 for the updated data). All modeling and calibration were done in HEC-HMS version 4.8 (USACE, 2019). New meteorological models were created for the calibration event using the rainfall data from seven gages that will be discussed subsequently. Two meteorological model methods were used in HEC-HMS: Gage Weights and Inverse Distance Weighting (IDW).

4.6.2 Calibration Event

The rainfall event that was used to calibrate the model was the storm that occurred on February 25-28, 2019. The observed peak flow for Matanzas Creek just upstream of the confluence with Santa Rosa Creek was 2,020 cfs (see Figure 4-3).

4.6.3 Calibration Data

The previous study utilized four rain gages for calibrating the hydrologic model (ESA, 2017b). A total of 21 rain gages were shown on the Sonoma Onerain website in the vicinity of the project that had precipitation data for the February 2019 rainfall event (Sonoma Water, 2021). The list of gages was refined and narrowed down to seven gages, based on the Thiessen Polygon analysis. The seven rain gages below were used for the calibration rainfall. An exhibit showing all the rainfall gages is included in Appendix A. The cumulative rainfall for all seven gages for February 2019 is shown in Figure 4-4.

Precipitation Data:

1. Matanzas Creek at Bennet Valley Road

2. Matanzas Reservoir 40200
3. Enterprise Road 40221
4. Spring Creek at Diversion 40203
5. Spring Lake 40204
6. Santa Rosa Downtown Culverts 40222
7. McCrea Trail 40211

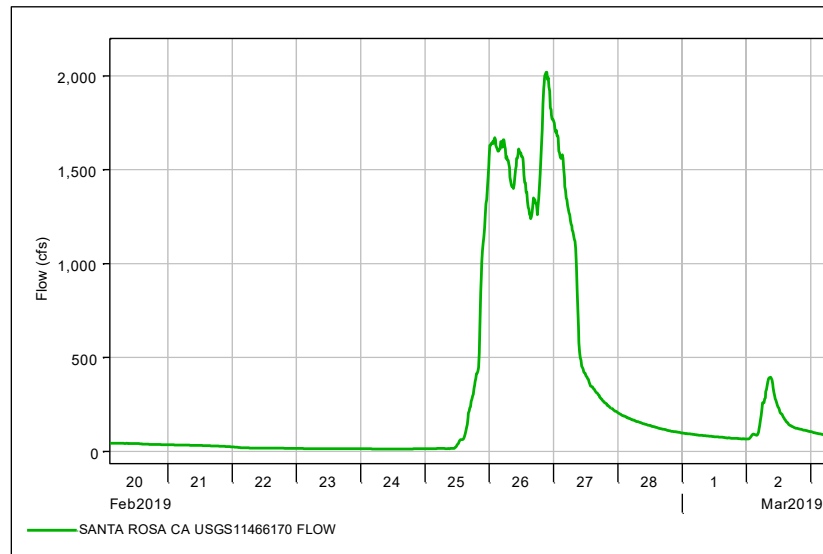


Figure 4-3. USGS 11466170 Stream Flow Data for February 20 - Mar 3, 2019

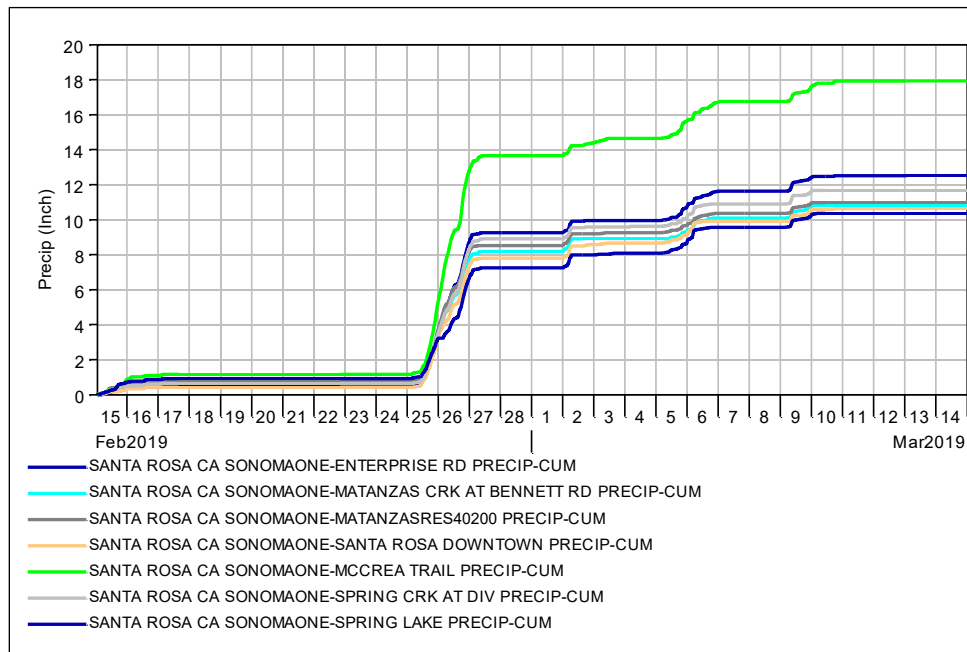


Figure 4-4. Cumulative Rainfall Data for February 2019

In addition to the rainfall data, streamflow and stage data were utilized. The gages with data available are shown below. Sonoma Water was able to obtain stage data for Matanzas Reservoir that was not available publicly.

Stream Flow & Stage:

1. USGS 11466170 MATANZAS C A SANTA ROSA CA – Flow, Stage
2. USGS 11466150 MATANZAS C RES OUTFLOW NR SANTA ROSA CA – Flow, Stage (limited)
3. Matanzas Creek at Bennet Valley Road – Stage
4. USGS Matanzas Reservoir – Stage
5. Spring Creek at Diversion 40203 - Stage

4.6.4 Spatial and Temporal Distribution of Calibration Rainfall

Thiessen Polygon (Depth Weighting/Area of Influence/Calibration gages):

Thiessen Polygons were developed for all 21 gages using GIS tools. Based on the resulting polygons, the list of gages was narrowed down to six initially, but a 7th (McCrea Trail) was added at the request of Sonoma Water. After adding the McCrea Trail gage, it was determined that the gage had no influence on the Thiessen polygons developed for the Matanzas Creek Dam watershed. The polygons were used to determine the area of influence and area weight for each rain gage. This information was utilized in the Gage Weights Meteorological Model in HEC-HMS. See Exhibit 1 in Appendix A.

Mean Annual Precipitation (MAP)

The mean annual precipitation data for the project area was determined using the dataset developed by the PRISM climate group at Oregon State University. The MAP is the 30-year normal precipitation data for the period of 1981-2010. The MAP was determined for each subbasin centroid and each precipitation gage location. The ratio of the MAP was used to adjust for regional or elevation bias in the precipitation data. This information was input into the indexing options in the precipitation methods in HEC-HMS. See Exhibit 2 in Appendix A.

Temporal Weighting:

This distance between each subbasin centroid and the precipitation gage location was calculated. The inverse distance was calculated for each gage and subbasin centroid combination. This information was used to determine which precipitation gage would be used for the temporal distribution of rainfall at each subbasin. Essentially, the closest gage to the subbasin centroid was assigned a temporal weight of 1. This information was used for the time weight in the Gage Weights Meteorological Model in HEC-HMS. See Exhibit 3 in Appendix A.

4.6.5 Calibration

The model was calibrated to the observed flows at the gage on Matanzas Creek upstream of Santa Rosa Creek. Initial parameters that were revised include the baseflow and reservoir water surface elevation at the beginning of the simulation. Several parameters were looked at to optimize the model including CN, Lg, and peaking coefficient. The Lg and peaking coefficient were adjusted but it was determined those parameters had a lesser impact as the previous calibration appeared to be spot on regarding the transform parameters. The initial values for the subbasin CN's were high with most of the values in the upper 80's and 90's. With the additional rainfall data, especially in the upper watershed, it was apparent that CN's could be decreased. A CN scale factor for all subbasins was optimized to calibrate to the observed flows.

The other parameter that had the most significant impact was the Stage-Storage-Discharge relationship for Matanzas Reservoir.

4.6.6 Results & Recommended Parameters

The goal of the calibration was to consider the combination of peak flow and volume as opposed to just the peak flow. Using this approach results in a hydrograph that matches the overall shape of the storm well and yields a peak flow that is slightly more conservative than the observed flow. The results and error statistics are shown in Table 4-5. The error statistics suggest very good model performance per Moriasi, et. al,(2007). The observed and simulated hydrographs for the February 2019 event are shown in Figure 4-5. Based on the results, it is recommended that the CN for all subbasins in Matanzas and Spring Creeks from the calibrated ESA hydrologic model be decreased by approximately 20%. For the Matanzas Reservoir subbasin this is a decrease in the CN from 89.4 (calibrated CN from ESA report) to 71.4. The CN of 71.4 should be considered for ARC II conditions (average soil antecedent runoff conditions). It is also recommended to use the Lg developed by ESA (1.8 hours) due to the results of the calibrated model and observed flow data.

Table 4-5. Matanzas Creek U/S of Santa Rosa Creek - Comparison between Observed and Simulated Hydrographs for February 2019 Event

Parameter	Observed	Simulated	Difference		Error Statistics			CN Scale Factor
			cfs	%	RMSE Std Dev	% Bias	Nash-Sutcliffe	
Peak Flow (cfs)	2,020	2,377	357	17.7	0.2	-0.14	0.944	0.80
Discharge Vol. (in)	5.2	5.19	-0.01	-0.19				

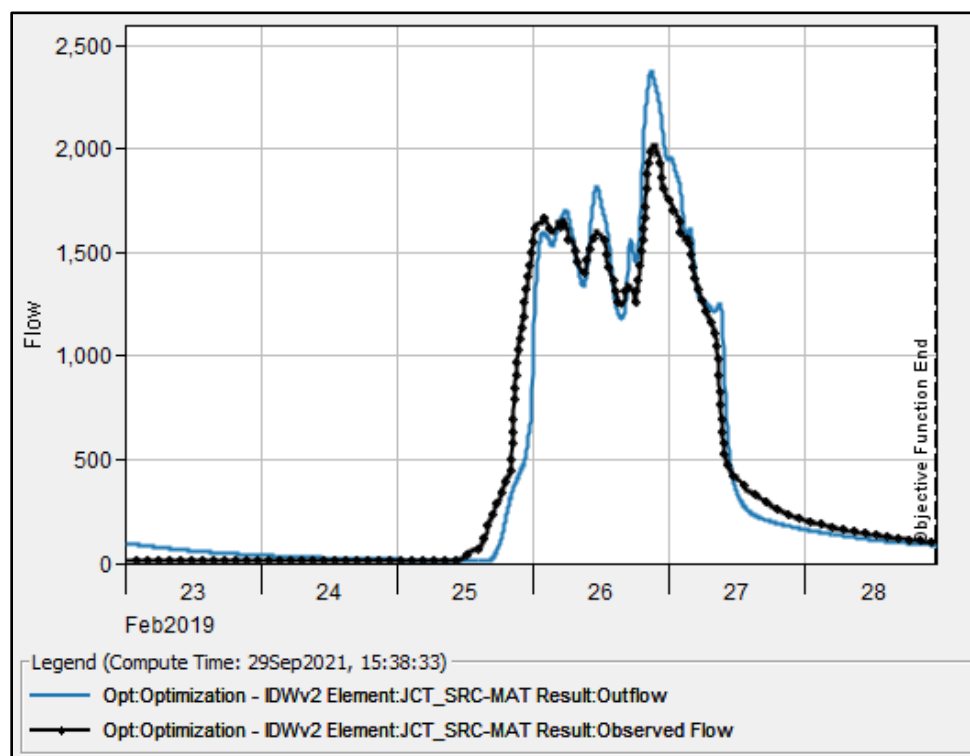


Figure 4-5. Matanzas Creek U/S of Santa Rosa Creek – Observed and Simulated Hydrographs

To further verify the calibration, the New Year's Eve 2005 rainfall event that ESA's hydrologic study calibration was based on was further analyzed. The USGS 11466170 stream gage recorded a peak flow of approximately 3,700 cfs on December 31, 2005. After completing a Bulletin 17-B analysis on the USGS 11466170 stream gauge, it was determined that the New Year's Event 2005 rainfall event was approximately a 25-year storm event (actual percent probability for this storm event was calculated as 4.3%, see Appendix B). Reservoir water surface elevation data for Matanzas Creek Dam was not available for the 2005 storm event; however, it was observed that the reservoir pool came close to the auxiliary spillway crest (see Figure 4-6). The calibrated parameters described in this report were used to route the NOAA Atlas 14 precipitation data for the 25-year 24-hour storm event (8.53 inches). In result, the maximum reservoir water surface elevation was 412.0 feet (approximately 7.5 inches below the existing auxiliary spillway crest). Therefore, it was confirmed that the calibrated parameters described in this document are reasonable.

In summary, the recommended hydrologic parameters for Matanzas Creek Dam are a watershed area of 11.45 square miles, an ARC II CN of 71.4, a Lg of 1.8 hours, and a time of concentration of 2.4 hours. Also, as previously described in Section 3.2.2, an additional 1% imperviousness should be considered for future watershed conditions.



Figure 4-6. Matanzas Creek Dam reservoir water surface elevation after New Year's Eve 2005 rainfall event. Dam crest located in the background; auxiliary spillway crest located several feet to the right of the shown access road. Photo courtesy of Sonoma Water.

5.0 Results

The Matanzas Creek Dam modeling results for the PSH, the ASH/SDH, and the FBH for the 6-hr local storm and the 24-hr and 72-hr general storms are shown in Table 5-1. Since the future condition of the dam's watershed is the governing evaluation, only the future condition results are shown in Table 5-1. The complete SITES model output for both existing and future conditions is provided in Appendix B.

The results of the model show that Matanzas Creek Dam meets all of CA DSOD hydrology and hydraulic criteria and the majority of NRCS criteria with the exception of two items: (1) the dam cannot pass the

PSH without activating the auxiliary spillway and (2) the dam does not have sufficient sediment storage for a 50-year design life. A summary of NRCS and CA DSOD criteria for Matanzas Creek Dam is listed in

Table 5-2. A drawdown analysis was also completed to evaluate the CA DSOD criteria. Assuming the existing outlet works (auxiliary spillway, principal spillway, and low-level outlet) are in good working condition and clear of debris, the days required to drain the reservoir full storage and half storage is 2.3 and 2.1 days, respectively.

With an estimated annual sediment deposition rate of 3.8 acre-feet (see *TM001 – Existing Conditions Assessment*, JDE & AECOM, 2023), Matanzas Creek Dam has sufficient sediment storage for approximately 23.4 years (88.9 ac-ft of storage up to the principal spillway crest divided by 3.8 acre-feet per year) if further sediment removal was discontinued by Sonoma Water.

Table 5-1. SITES Modeling Results for Future Conditions

Parameter	100-yr 10-day PSH (Future)	6-hr Local ASH/SDH & FBH (Future)	24-hr General ASH/SDH & FBH (Future)	72-hr General FBH (Future)
Agency Criteria	NRCS	NRCS; CA DSOD (FBH)	NRCS	CA DSOD
Watershed Runoff Curve Number	71.4	71.4	71.4	71.4
Watershed Drainage Area (sq. mi.)	11.45	11.45	11.45	11.45
Lag Time (hrs)	1.8	1.8	1.8	1.8
Time of Concentration (hrs)	2.4	2.4	2.4	2.4
Initial Reservoir Elevation (ft)	377.63	377.63	377.63	377.63
Initial Reservoir Storage (ac-ft)	89	89	89	89
Rainfall Duration (hrs)		6	24	72
SDH Rainfall Total (in)		5.24	14.11	
SDH Inflow Peak (cfs)		5,723.2	8,173.4	
SDH Outflow Peak (cfs)		1,150.7	6,932	
SDH Maximum WS (ft)		404.88	417.96	
SDH AS Max. Head (ft)		0.00	5.33	
FBH Rainfall Total (in)		6.57	24.45	41.6
FBH Inflow Peak (cfs)		8,429.2	15,714.2	18,348.2
FBH Outflow Peak (cfs)		1640	15,292	18042
FBH Maximum WS (ft)		413.66	421.73	422.77
FBH AS Max. Head (ft)		1.03	9.10	10.14
PSH Drawdown (days)	5.52			
PS Discharge at AS Crest (cfs)	1,280.7	1,219.9	1,219.9	1,219.9
AS Crest (ft)	419.82	412.63	412.63	412.63
Storage, AS Crest (ac-ft)	1,971.5	1,444.8	1,444.8	1,444.8

Table 5-2. Evaluation of NRCS and CA DSOD Criteria for Matanzas Creek Dam

Agency Criteria	Assessment Results (Future Conditions)
NRCS (TR-60)	
PSH routed without operating earthen auxiliary spillway?	No
Meets 10-day PSH drawdown requirements?	Yes
6-hour FBH contained without overtopping?	Yes
24-hour FBH contained without overtopping?	Yes
Route the ASH/SDH through primary and auxiliary spillways without encroaching on required freeboard (2.1 feet)?	Yes
Sufficient sediment storage capacity for 50-year design life?	No
CA DSOD	
6-hour PMP contained without encroaching on required residual freeboard (2.1 feet)?	Yes
72-hour PMP contained without encroaching on required residual freeboard (2.1 feet)?	Yes
Minimum total freeboard of 9.75 feet?	Yes
Outlet works capable of draining half of the reservoir capacity in 7 or 10 days?	Yes
Outlet works capable of draining the full reservoir capacity in 20 or 30 days?	Yes

6.0 Summary

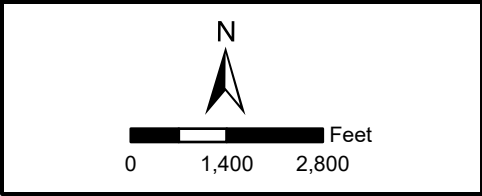
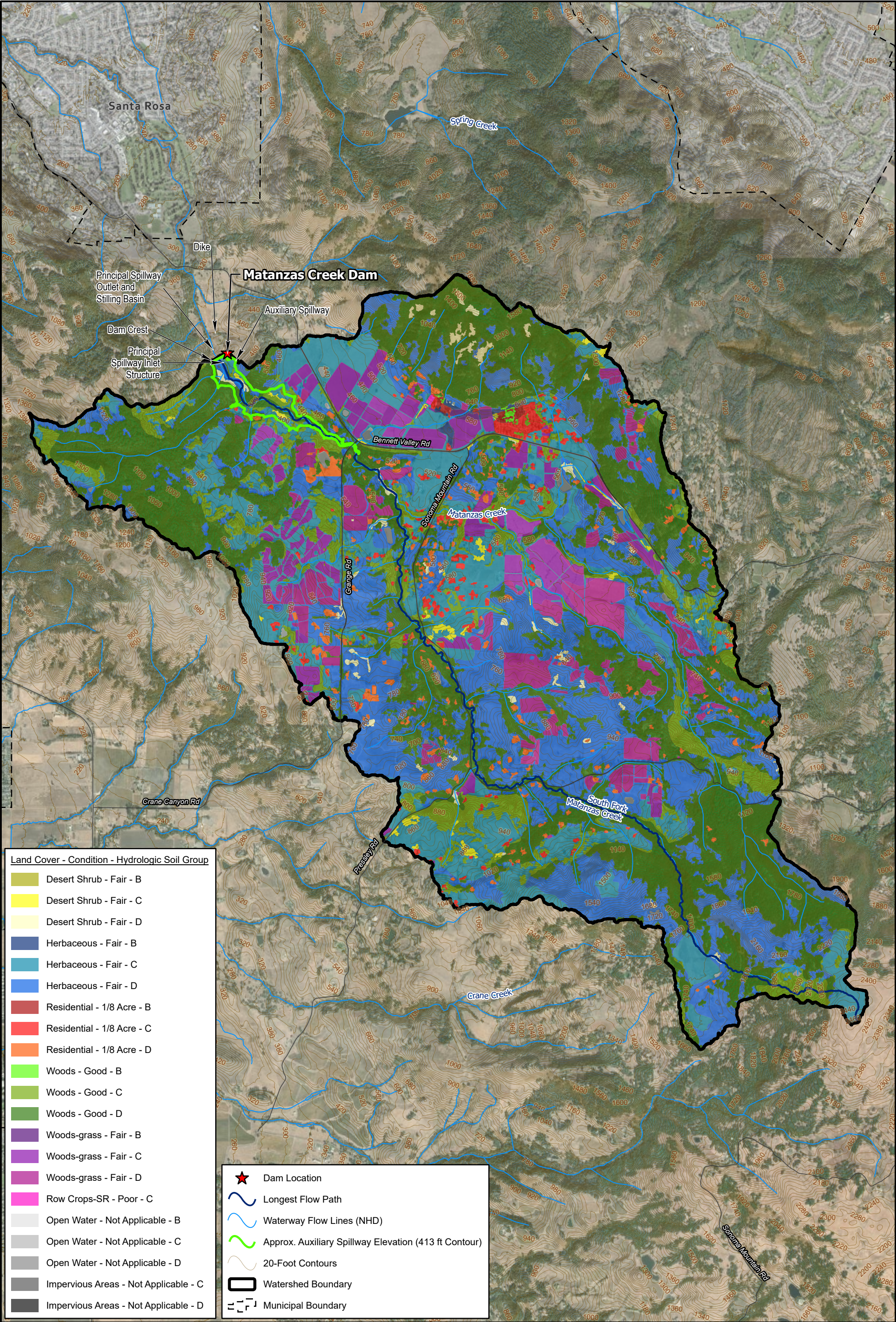
JDE has completed a hydrologic analysis for Matanzas Creek Dam according to NRCS and CA DSOD criteria. Based on the results of this hydrologic analysis, Matanzas Creek Dam does not meet two NRCS TR-60 criteria. First, the dam cannot route the PSH without operating the auxiliary spillway. Second, the dam does not have sufficient sediment storage capacity for a 50-year design life if further sediment removal projects were discontinued by Sonoma Water. However, based on further direction from the NRCS, continued removal of sediment is acceptable per TR-60 criteria. Therefore, existing sediment storage capacity may be acceptable pending on an approved sediment removal agreement with Sonoma Water. Matanzas Creek Dam is currently in compliance with CA DSOD criteria. Note that this document does not address geological or seismic criteria.

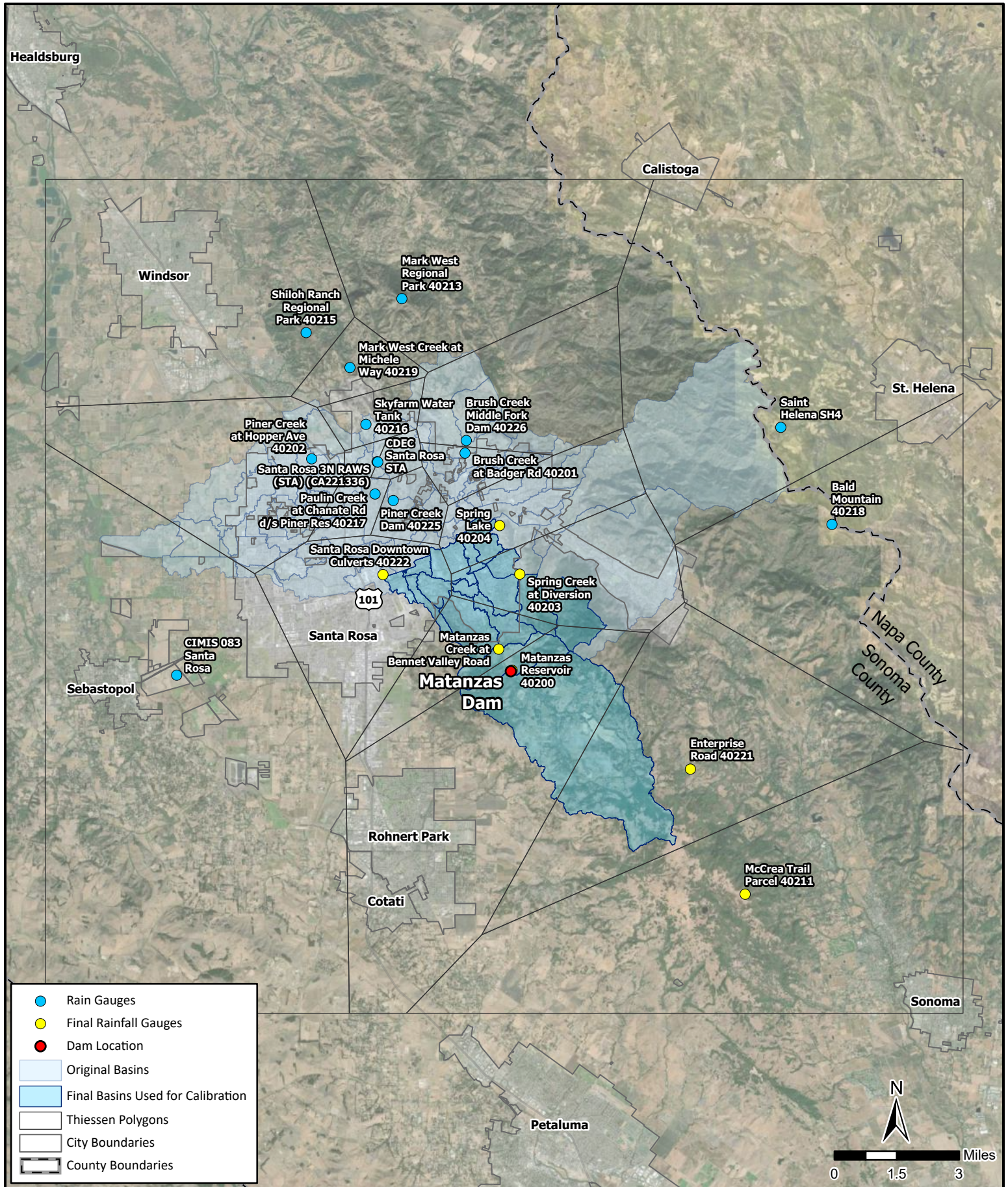
7.0 References

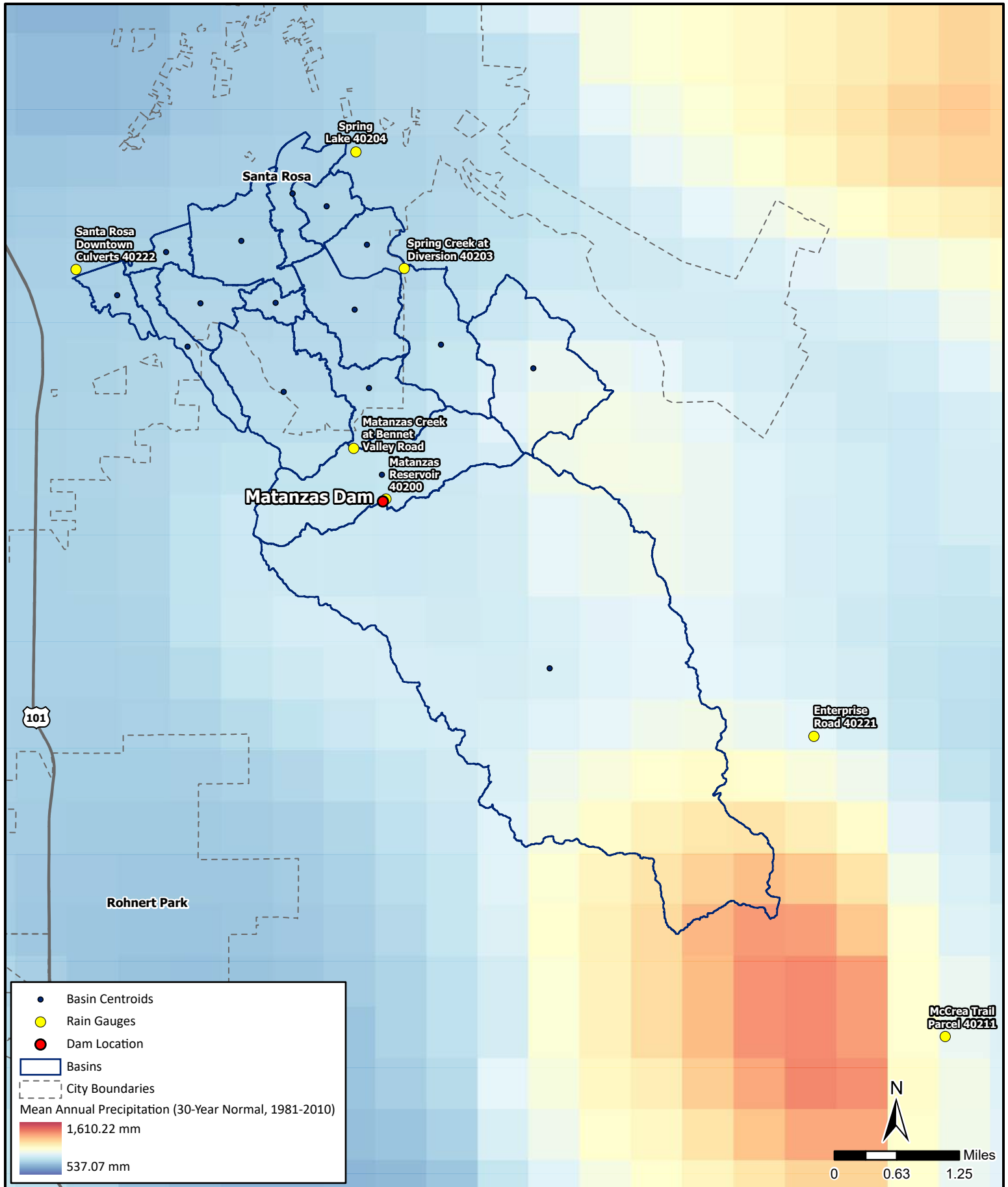
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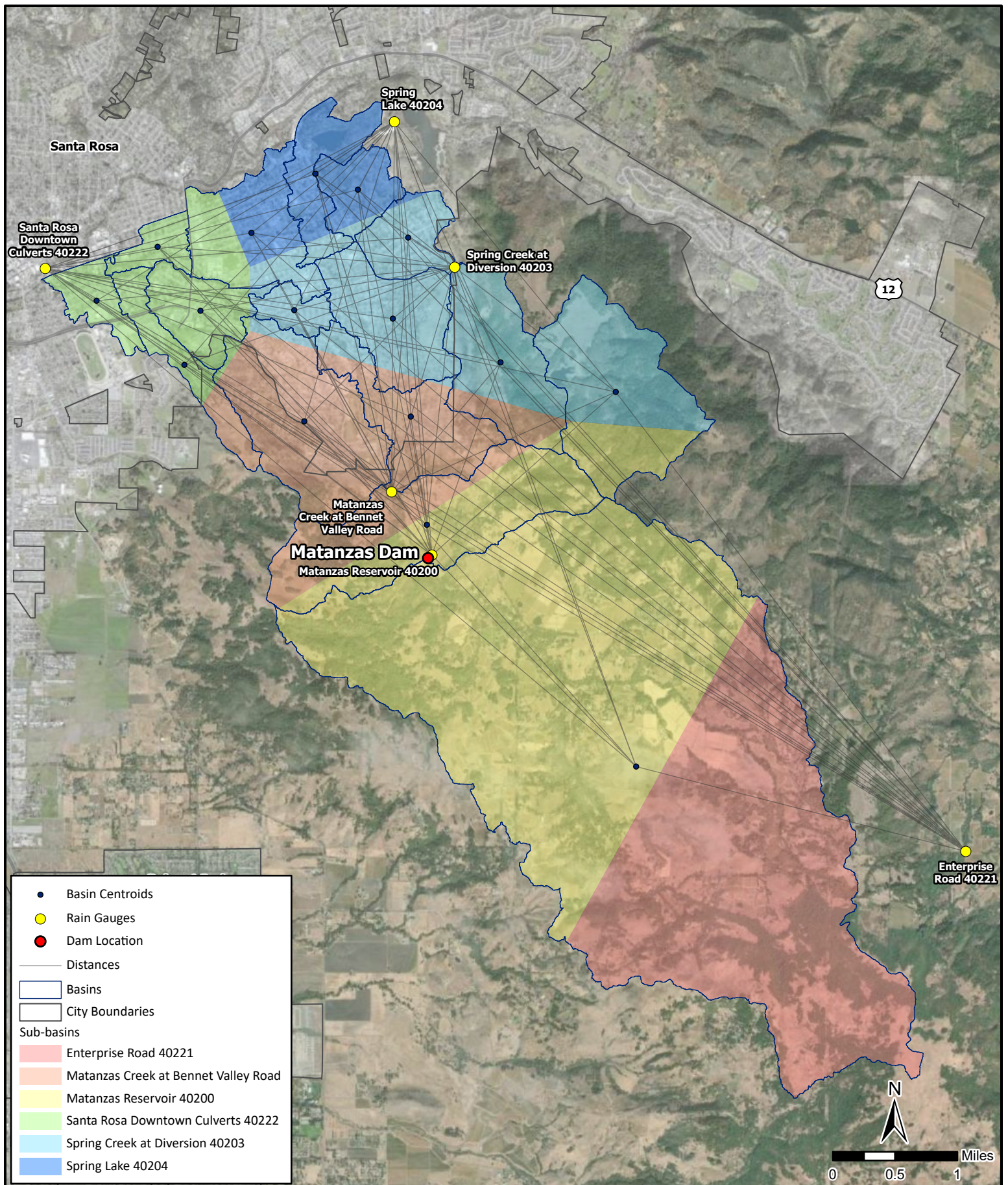
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Appendix A. Exhibits









Appendix B. Calculations

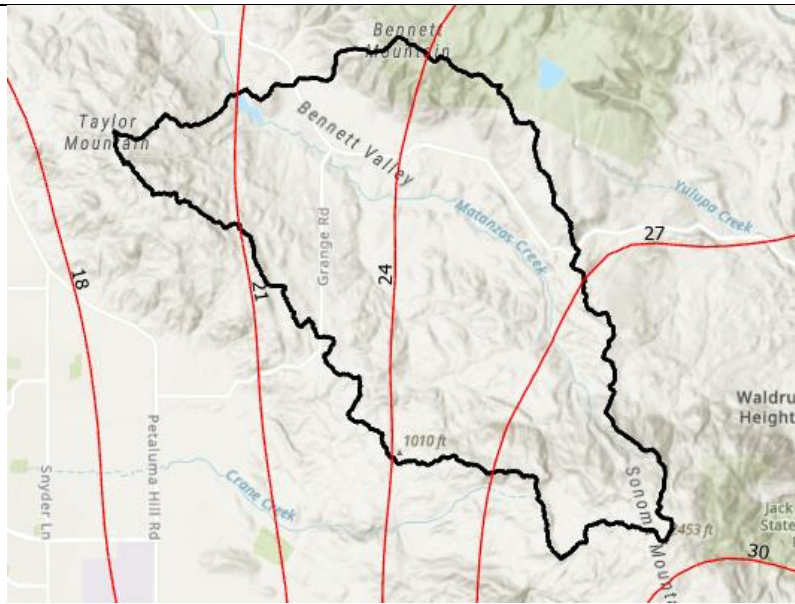
B.1. Precipitation Data: HMR 58/59



CALCULATION COVER SHEET



Project Name:	Matanzas Creek Dam – Supplemental Watershed Plan-ED									
Project Number:	2006-048									
Title of Calculations:	Design Storms: Precipitation Depths and Distributions									
Calculations By:	Hayden C.	Date: 6/19/2021								
Reviewed By:	K. Curtis	Date: 7/20/2021								
Number of pages (Including cover sheet): 13										
DESCRIPTION & PURPOSE										
The purpose of this analysis is determine the precipitation depths and temporal distributions to be used for NRCS and CA DSOD design storms for inflow hydrology.										
REFERENCES / DATA										
References: • NOAA, Hydrometeorological Report No. 58. October 1998. • NOAA, Hydrometeorological Report No. 59. February 1999. • NOAA, Precipitation Frequency Data Server: Atlas 14 Point Precipitation Frequency Estimates. 2017. • NRCS, Technical Release 210-60 – Earth Dams and Reservoirs, March 2019. • NRCS, National Engineering Handbook: Part 630 – Hydrology, Chapter 4 – Storm Rainfall Depth and Distribution, August 2019. • NRCS, National Engineering Handbook: Part 630 – Hydrology, Chapter 16 – Hydrographs, March 2007. • NRCS, National Engineering Handbook: Part 630 – Hydrology, Chapter 21 – Design Hydrographs, May 2019. Data: • HMR 58/59 • NOAA Atlas 14										
DESIGN CRITERIA / ANALYSIS / METHODS / ASSUMPTIONS										
The steps and procedures found in this document follow the guidelines listed in HMR 58/59. <u>Steps completed for 24-hour and 72-hour General Storms</u> Step 1 & 2: Drainage Outline and User Decision <table border="1"><tr><td rowspan="2">Matanzas Creek Dam Watershed Area:</td><td>11.45</td><td>sq. mi.</td></tr><tr><td>7326.4</td><td>ac</td></tr><tr><td>PMP Value Required:</td><td colspan="2">All-Season</td></tr></table>			Matanzas Creek Dam Watershed Area:	11.45	sq. mi.	7326.4	ac	PMP Value Required:	All-Season	
Matanzas Creek Dam Watershed Area:	11.45	sq. mi.								
	7326.4	ac								
PMP Value Required:	All-Season									



Step 3: All-Season Index PMP Estimate

Iso-Area (in)	Area (acres)	% Area	Iso x % Area (in)
18	42.7	0.6%	0.1
21	1453.2	19.8%	4.2
24	3312.0	45.2%	10.8
27	2201.3	30.0%	8.1
30	317.3	4.3%	1.3

Weighted Average General Storm 10 sq. mi 24-hr PMP (in) = **24.5** $\Sigma(\text{Iso} \times \% \text{ Area})$

Step 4: Seasonal Index PMP Estimate (not needed since we are using all-season PMP)

Step 5 & 6: Depth-Duration Relationship and Aerial Reduction Factors

Region for Matanzas Creek Dam:	Midcoastal
PMP from Step 3 (in):	24.5
Watershed Area (sq. mi.):	11.45

<---Since > 10 sq. mi., area reduction is needed

Table 2.1. All-season depth-duration ratios for California regions.						
Region	Duration					
	1	6	12	24	48	72
Northwest	0.10	0.40	0.73	1.00	1.49	1.77
Northeast	0.16	0.52	0.69	1.00	1.40	1.55
Midcoastal	0.13	0.45	0.74	1.00	1.45	1.70
C. Valley	0.13	0.42	0.65	1.00	1.48	1.75
Sierra	0.14	0.42	0.65	1.00	1.56	1.76
Southwest	0.14	0.48	0.76	1.00	1.41	1.59
Southeast	0.30	0.60	0.86	1.00	1.17	1.28

<i>Midcoastal</i>						
Area (mi ²)	1 hr	6 hr	12 hr	24 hr	48 hr	72 hr
10	100.00	100.00	100.00	100.00	100.00	100.00
50	87.50	88.75	90.00	91.00	92.00	93.00
100	81.75	83.75	85.50	87.00	88.50	90.00
200	75.75	78.25	80.50	82.50	84.50	86.25
500	67.50	71.00	73.50	76.00	78.50	80.50
1000	60.75	65.50	68.00	70.50	73.00	75.50
2000	53.00	58.50	61.50	64.00	67.00	70.00
5000	38.00	44.50	48.50	52.00	55.00	59.00

Column 1: Duration of storm

Column 2: Depth duration ratio shown in Table 2.1 for Midcoastal region

Column 3: Interpolated area reduction factor shown in Table 2.3 for Midcoastal region

Column 4: Adjusted PMP values for Matanzas Creek Watershed (24.5 in x Column 2 x Column 3)

Duration (hr)	Table 2.1 Ratio	Table 2.3 Factor	Adjusted PMP (in)
1	2	3	4
1	0.13	0.995	3.2
6	0.45	0.996	11.0
12	0.74	0.996	18.1
24	1.00	0.997	24.5
48	1.45	0.997	35.5
72	1.70	0.997	41.6

24-hour and 72-hour TR-60 Precipitation Depths for Matanzas Creek Dam

Storm Duration (hr)	PMP Storm Type	P ₁₀₀ (in)	PMP (in)	SDH/ASH (in)	FBH (in)
		1	2	3	4
24	General	10.47	24.45	14.11	24.45
72	General	15.99	41.60	24.45	41.60

1) NOAA Atlas 14 for 100-year precip.

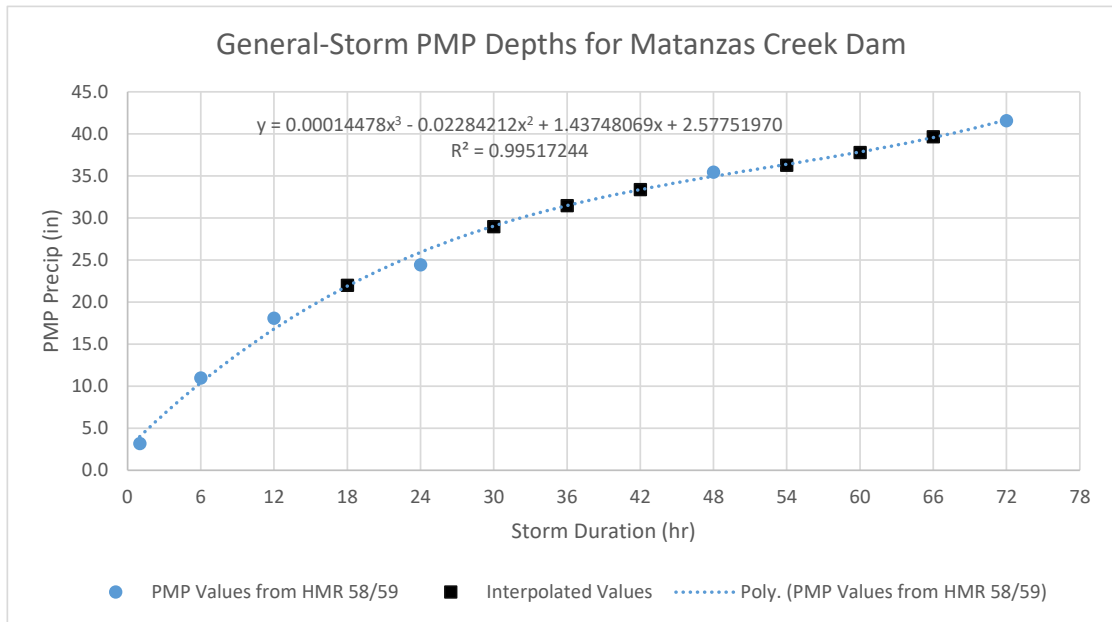
2) HMR 58/59 (Column 4 in Step 6)

3) For High Hazard dam; $P_{100} + 0.26(PMP - P_{100})$

4) For High Hazard dam; PMP

Step 7: Incremental Estimates

(See graph and table on next page)



Duration (hr)	6-hr Cumulative PMP Depths (in)	6-hr Incremental PMP Depths (in)
0	0	0
1	3.2	3.2
6	11.0	7.8
12	18.1	7.1
18	22.0	3.9
24	24.5	2.5
30	29	4.5
36	31.5	2.5
42	33.4	1.9
48	35.5	2.1
54	36.3	0.8
60	37.8	1.5
66	39.7	1.9
72	41.6	1.9
Total:		41.6

a 0.0001448
b -0.0228421
c 1.4374807
d 2.5775197

= Interpolated PMP values for other 6-hr incremental storm durations

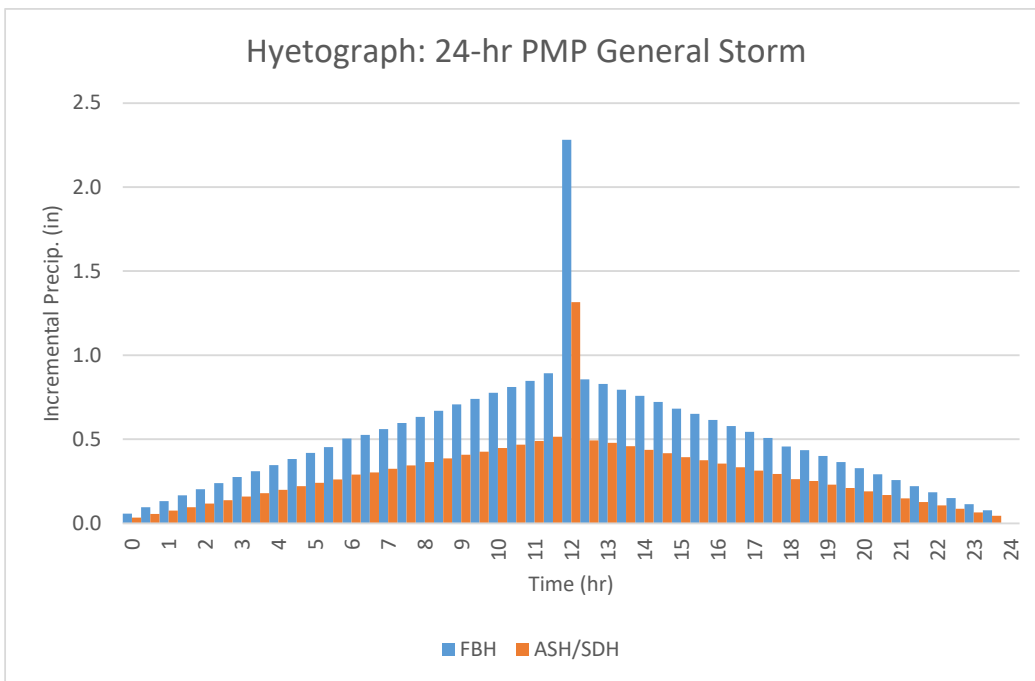
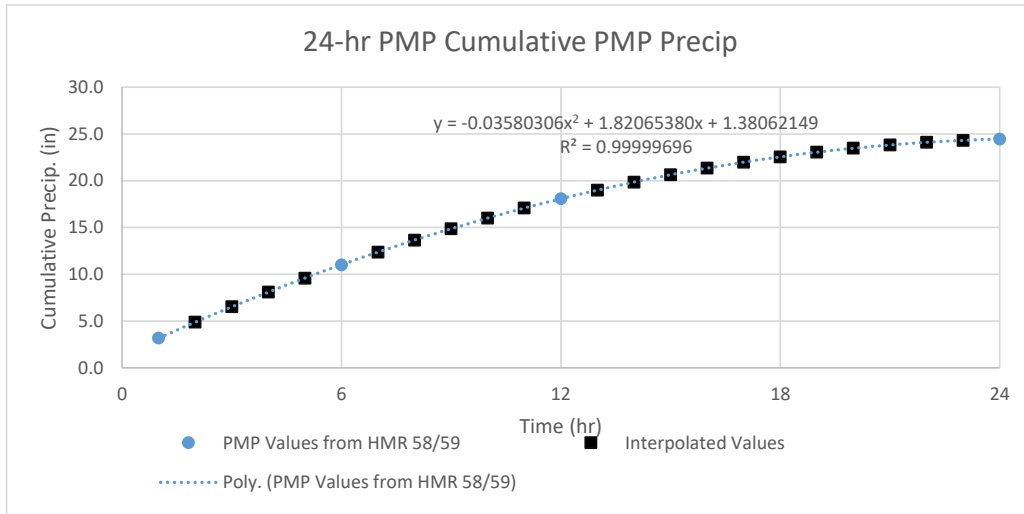
Step 8: Temporal Distribution (24-hour General Storm)

24-hr General Storm

Duration (hr)	Cumulative PMP Depths (in)	Incremental PMP Depths (in)	Rank	Hyetograph PMP (in)	Unitless	Rainfall Distribution	Hyetograph SDH (in)
0	0	0	49	0.1	0.0024	0.0000	0.03
0.5	2.3	2.3	1	0.1	0.0039	0.0024	0.06
1	3.2	0.9	2	0.1	0.0054	0.0063	0.08
1.5	4.0	0.9	3	0.2	0.0068	0.0117	0.10
2	4.9	0.8	4	0.2	0.0083	0.0185	0.12
2.5	5.7	0.8	5	0.2	0.0098	0.0268	0.14
3	6.5	0.8	6	0.3	0.0112	0.0366	0.16
3.5	7.3	0.8	7	0.3	0.0127	0.0478	0.18
4	8.1	0.8	8	0.3	0.0142	0.0605	0.20
4.5	8.8	0.8	9	0.4	0.0156	0.0747	0.22
5	9.6	0.7	10	0.4	0.0171	0.0903	0.24
5.5	10.3	0.7	11	0.5	0.0186	0.1074	0.26
6	11.0	0.7	13	0.5	0.0206	0.1260	0.29
6.5	11.7	0.7	12	0.5	0.0215	0.1466	0.30
7	12.4	0.7	14	0.6	0.0230	0.1681	0.32
7.5	13.0	0.7	15	0.6	0.0244	0.1911	0.34
8	13.7	0.6	16	0.6	0.0259	0.2155	0.37
8.5	14.3	0.6	17	0.7	0.0273	0.2414	0.39
9	14.9	0.6	18	0.7	0.0290	0.2687	0.41
9.5	15.4	0.6	19	0.7	0.0303	0.2977	0.43
10	16.0	0.6	20	0.8	0.0317	0.3279	0.45
10.5	16.6	0.5	21	0.8	0.0332	0.3597	0.47
11	17.1	0.5	22	0.8	0.0347	0.3929	0.49
11.5	17.6	0.5	23	0.9	0.0365	0.4275	0.51
12	18.1	0.5	24	2.3	0.0933	0.4641	1.32
12.5	18.5	0.5	25	0.9	0.0350	0.5574	0.49
13	19.0	0.5	26	0.8	0.0339	0.5924	0.48
13.5	19.4	0.4	27	0.8	0.0325	0.6263	0.46
14	19.9	0.4	28	0.8	0.0310	0.6588	0.44
14.5	20.3	0.4	29	0.7	0.0295	0.6898	0.42
15	20.6	0.4	30	0.7	0.0279	0.7194	0.39
15.5	21.0	0.4	31	0.7	0.0266	0.7473	0.38
16	21.3	0.3	32	0.6	0.0251	0.7739	0.35
16.5	21.7	0.3	33	0.6	0.0237	0.7991	0.33
17	22.0	0.3	34	0.5	0.0222	0.8227	0.31
17.5	22.3	0.3	35	0.5	0.0208	0.8450	0.29
18	22.6	0.3	36	0.5	0.0187	0.8657	0.26
18.5	22.8	0.3	37	0.4	0.0178	0.8844	0.25
19	23.0	0.2	38	0.4	0.0164	0.9022	0.23
19.5	23.3	0.2	39	0.4	0.0149	0.9186	0.21
20	23.5	0.2	40	0.3	0.0134	0.9335	0.19
20.5	23.7	0.2	41	0.3	0.0120	0.9469	0.17
21	23.8	0.2	42	0.3	0.0105	0.9589	0.15
21.5	24.0	0.1	43	0.2	0.0090	0.9694	0.13
22	24.1	0.1	44	0.2	0.0076	0.9785	0.11
22.5	24.2	0.1	45	0.1	0.0061	0.9860	0.09
23	24.3	0.1	46	0.1	0.0047	0.9922	0.07
23.5	24.4	0.1	47	0.1	0.0032	0.9968	0.04
24	24.5	0.1	48	0.0	0.0000	1.0000	0.00
Total:		24.5		24.5	1.0000		14.11

= interpolated PMP values

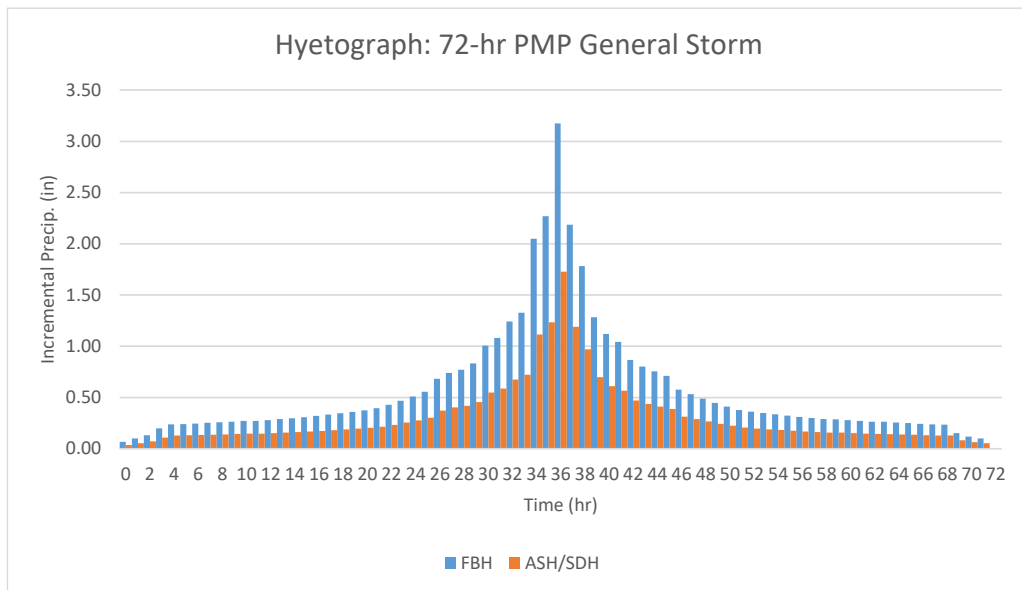
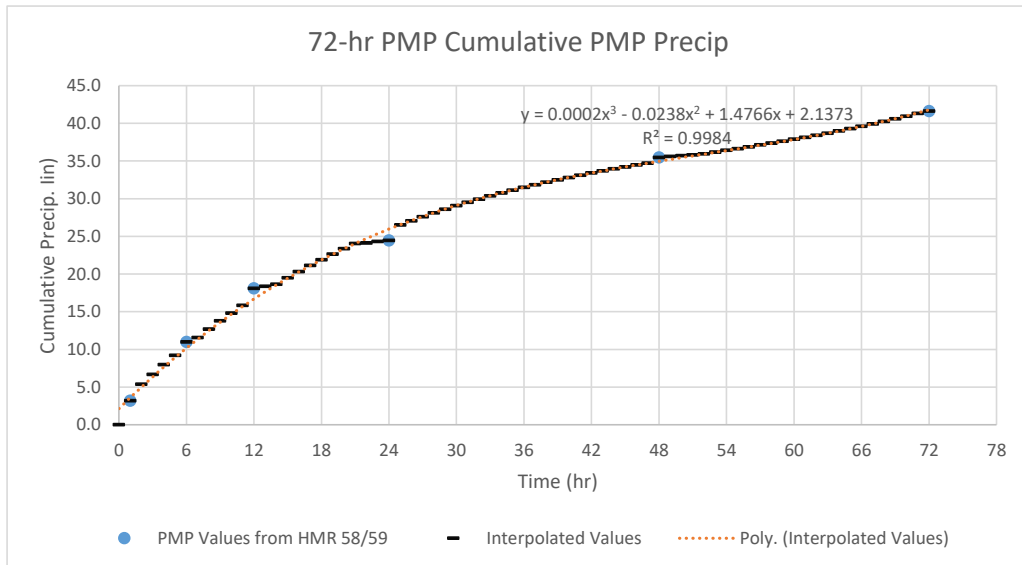
a -0.035803064
b 1.820653802
c 1.38062149



Step 8: Temporal Distribution (72-hour General Storm)

Duration (hr)	Cumulative PMP Depths (in)	Incremental PMP Depths (in)	Rank	Rank (Center Peak)	Hyetograph PMP (in)	Unitless	Rainfall Distribution	Hyetograph SDH (in)
0	0.0	0	73	72.0	0.07	0.0016	0.00	0.04
1	3.2	3.2	1	70.0	0.10	0.0024	0.00	0.05
2	5.4	2.2	3	68.0	0.13	0.0032	0.00	0.07
3	6.7	1.3	6	66.0	0.20	0.0048	0.01	0.11
4	8.0	1.3	7	64.0	0.24	0.0057	0.01	0.13
5	9.2	1.2	8	62.0	0.24	0.0058	0.02	0.13
6	11.0	1.8	5	60.0	0.25	0.0059	0.02	0.13
7	11.6	0.6	21	58.0	0.25	0.0061	0.03	0.14
8	12.7	1.1	9	56.0	0.26	0.0062	0.04	0.14
9	13.8	1.1	10	54.0	0.26	0.0063	0.04	0.14
10	14.8	1.0	11	52.0	0.27	0.0065	0.05	0.15
11	15.8	1.0	12	50.0	0.27	0.0065	0.05	0.15
12	18.1	2.3	2	48.0	0.28	0.0067	0.06	0.15
13	18.4	0.3	55	46.0	0.29	0.0069	0.07	0.16
14	18.6	0.3	50	44.0	0.30	0.0072	0.07	0.16
15	19.5	0.9	13	42.0	0.31	0.0074	0.08	0.17
16	20.3	0.8	14	40.0	0.32	0.0077	0.09	0.17
17	21.1	0.8	15	38.0	0.33	0.0080	0.10	0.18
18	21.9	0.8	16	36.0	0.35	0.0083	0.11	0.19
19	22.6	0.7	18	34.0	0.36	0.0087	0.11	0.20
20	23.3	0.7	19	32.0	0.38	0.0090	0.12	0.20
21	24.0	0.7	20	30.0	0.39	0.0095	0.13	0.21
22	24.1	0.1	72	28.0	0.43	0.0103	0.14	0.23
23	24.3	0.2	66	26.0	0.47	0.0112	0.15	0.25
24	24.5	0.2	67	24.0	0.51	0.0123	0.16	0.28
25	26.5	2.0	4	22.0	0.55	0.0133	0.17	0.30
26	27.1	0.6	22	20.0	0.68	0.0164	0.19	0.37
27	27.6	0.5	23	18.0	0.74	0.0178	0.20	0.40
28	28.1	0.5	24	16.0	0.77	0.0185	0.22	0.42
29	28.6	0.5	25	14.0	0.83	0.0200	0.24	0.45
30	29.1	0.5	26	12.0	1.01	0.0242	0.26	0.55
31	29.5	0.4	27	10.0	1.08	0.0260	0.28	0.59
32	29.9	0.4	28	8.0	1.24	0.0298	0.31	0.68
33	30.3	0.4	29	6.0	1.33	0.0319	0.34	0.72
34	30.7	0.4	30	4.0	2.05	0.0493	0.37	1.12
35	31.1	0.4	31	2.0	2.27	0.0545	0.42	1.24
36	31.5	0.4	33	1.0	3.17	0.0763	0.48	1.73
37	31.8	0.3	35	3.0	2.19	0.0526	0.55	1.19
38	32.2	0.3	37	5.0	1.78	0.0428	0.61	0.97
39	32.5	0.3	39	7.0	1.28	0.0308	0.65	0.70
40	32.8	0.3	41	9.0	1.12	0.0269	0.68	0.61
41	33.1	0.3	43	11.0	1.04	0.0251	0.71	0.57
42	33.4	0.3	45	13.0	0.87	0.0208	0.73	0.47
43	33.7	0.3	48	15.0	0.80	0.0193	0.75	0.44
44	33.9	0.3	51	17.0	0.76	0.0182	0.77	0.41
45	34.2	0.3	53	19.0	0.71	0.0171	0.79	0.39
46	34.5	0.3	56	21.0	0.58	0.0139	0.81	0.31
47	34.7	0.3	58	23.0	0.53	0.0128	0.82	0.29
48	35.5	0.8	17	25.0	0.49	0.0117	0.83	0.27
49	35.6	0.1	68	27.0	0.45	0.0108	0.84	0.24
50	35.7	0.1	70	29.0	0.41	0.0099	0.86	0.22
51	35.8	0.1	71	31.0	0.38	0.0091	0.87	0.21
52	35.9	0.1	69	33.0	0.36	0.0087	0.87	0.20
53	36.2	0.2	65	35.0	0.35	0.0084	0.88	0.19
54	36.4	0.2	64	37.0	0.34	0.0081	0.89	0.18
55	36.6	0.2	63	39.0	0.32	0.0078	0.90	0.18
56	36.9	0.2	62	41.0	0.31	0.0075	0.91	0.17
57	37.1	0.2	61	43.0	0.30	0.0072	0.91	0.16
58	37.4	0.2	60	45.0	0.29	0.0070	0.92	0.16
59	37.6	0.3	59	47.0	0.29	0.0069	0.93	0.16
60	37.9	0.3	57	49.0	0.28	0.0067	0.94	0.15
61	38.1	0.3	54	51.0	0.27	0.0065	0.94	0.15
62	38.4	0.3	52	53.0	0.26	0.0064	0.95	0.14
63	38.7	0.3	49	55.0	0.26	0.0063	0.96	0.14
64	39.0	0.3	47	57.0	0.26	0.0062	0.96	0.14
65	39.3	0.3	44	59.0	0.25	0.0060	0.97	0.14
66	39.6	0.3	42	61.0	0.24	0.0058	0.97	0.13
67	39.9	0.3	40	63.0	0.24	0.0057	0.98	0.13
68	40.2	0.3	38	65.0	0.24	0.0057	0.99	0.13
69	40.6	0.3	36	67.0	0.15	0.0036	0.99	0.08
70	40.9	0.4	34	69.0	0.12	0.0028	0.99	0.06
71	41.3	0.4	32	71.0	0.10	0.0024	1.00	0.05
72	41.6	0.3	46	73.0	0.00	0.0000	1.00	0.00
Total:		41.6			41.60	1.0000		22.65
= interpolated PMP values								

a	0.00014
b	-0.02284
c	1.43748
d	2.57752



Steps completed 6-hr Local Storm

Step 1: 1-hr, 1 sq. mi. local-storm PMP

Estimate 1-hr 1 sq. mi PMP from Figure 2.21:

5.55 in

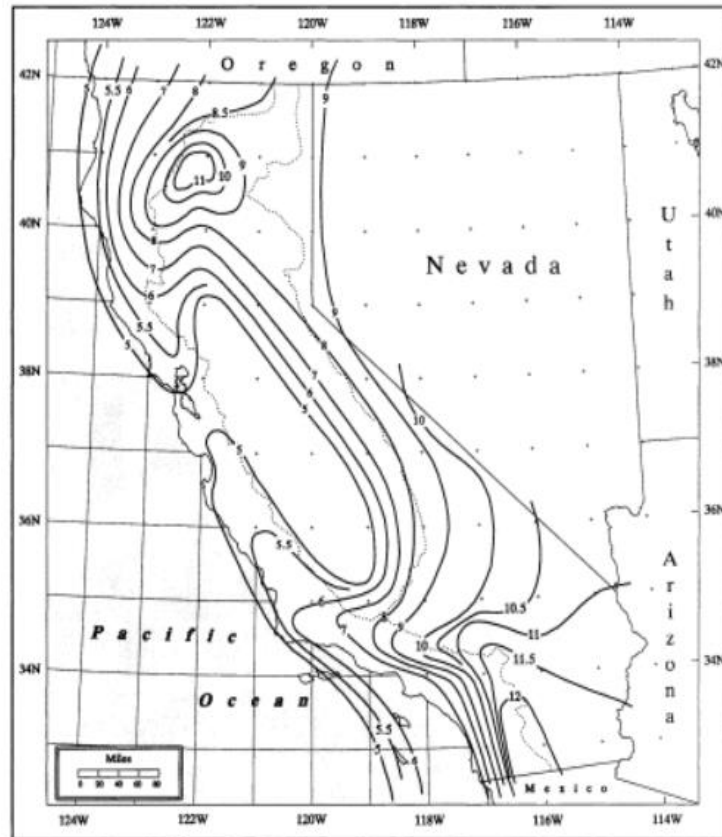


Figure 2.21. California local-storm PMP precipitation estimates for 1 mi², 1 hour (inches).

Step 2: Adjustment for Mean Drainage Elevation

Note: No adjustment for elevation is needed since the mean elevation of the drainage basin is less than 6,000 feet.

Steps 3 & 4: Adjustment for Duration and Basin Area

Based on Figure 2.24, the depth-duration relation for watershed is 1.3 (Group C). Adjustments for duration are shown below, which use factors shown in Table 2.10. Calculations of steps 3 and 4 are shown in the table for steps 5 and 6.

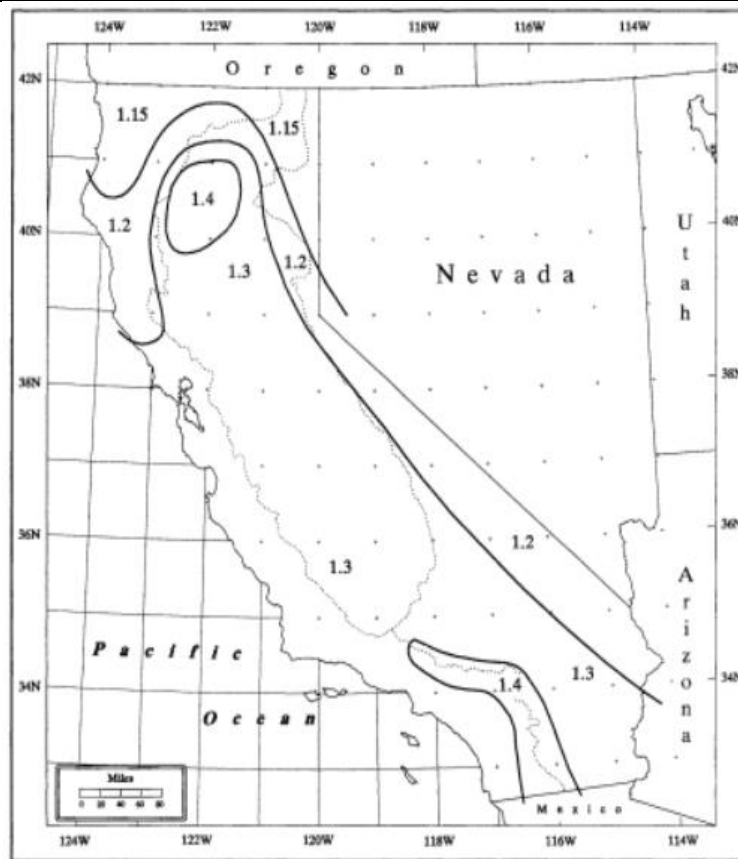
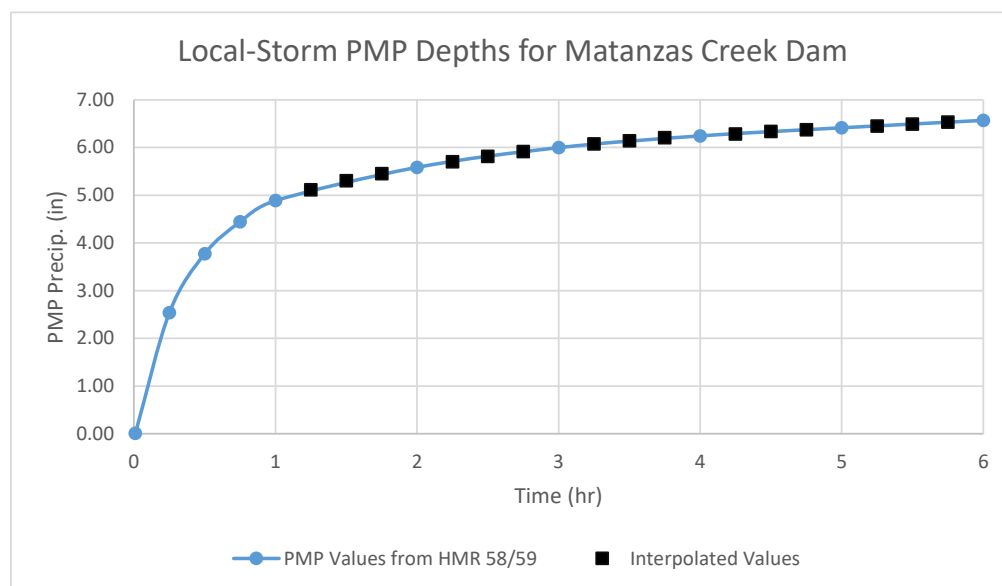


Figure 2.24. California local-storm PMP 6-hour to 1-hour ratios for 1 mi². For use with Figure 2.23; A = 1.15, B = 1.2, C = 1.3, D = 1.4.

Table 2.10. Depth-duration relations (percent of 1-hour amount) for 1-mi² PMP for California local storms.

Relationship Designator (see Figure 2.23)				
Duration (hours)	A	B	C	D
0	0	0	0	0
1/4	55	55	55	55
1/2	79	79	79	79
3/4	91	91	91	91
1	100	100	100	100
2	109.5	110.5	114	117
3	112	116	120	126
4	114	118	125	132
5	114.5	119	128	137
6	115	120	130	140

Steps 5 & 6: PMP Estimates for Basin & Incremental Amounts and Temporal Distribution



Duration (hr)	Depth-Duration Factor	Basin Area Factor ¹	Cumulative PMP (in)	Incremental PMP (in)
0.01	0	0	0.01	0
0.25	0.55	0.83	2.53	2.52
0.5	0.79	0.86	3.77	1.24
0.75	0.91	0.88	4.44	0.67
1	1	0.88	4.88	0.44
2	1.14	0.882	5.58	0.70
3	1.2	0.9	5.99	0.41
4	1.25	0.90	6.24	0.25
5	1.28	0.90	6.41	0.17
6	1.3	0.91	6.57	0.16

¹Values determined from Figures 2.25 to 2.28

= interpolated values

Storm Duration (hr)	PMP Storm Type	P ₁₀₀ (in)	PMP (in)	SDH/ASH (in)	FBH (in)
		1	2	3	4
6	Local	4.77	6.57	5.24	6.57

1) NOAA Atlas 14 for 100-year precip.

2) HMR 58/59 (Column 4 in Step 6)

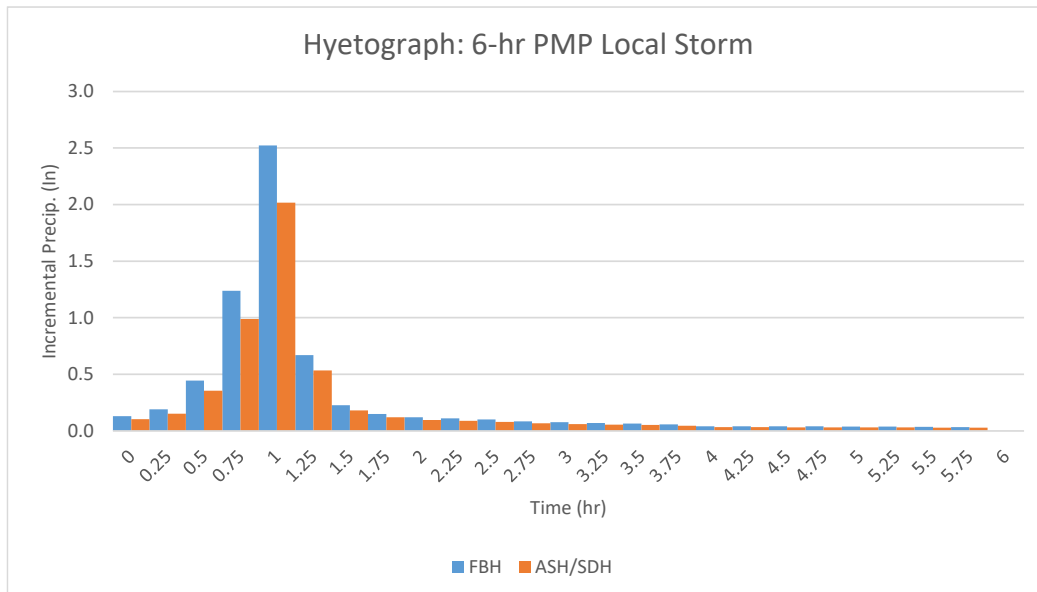
3) For High Hazard dam; $P_{100} + 0.26(PMP - P_{100})$

4) For High Hazard dam; PMP

Note: For the temporal distribution, a front-peaking distribution (first hour peaking distribution) was used (see table and hyetograph on next page)

6-hr Local Storm

Duration (hr)	Cumulative PMP Depths (in)	Incremental PMP Depths (in)	Rank	Rank (First-Hour Peak)	Hyetograph 6-hr PMP (in)	Unitless	Rainfall Distribution	Hyetograph 6-hr SDH (in)
0	0.01	0.00	25	8	0.130	0.0199	0.0000	0.10
0.25	2.53	2.52	1	6	0.190	0.0290	0.0199	0.15
0.5	3.77	1.24	2	4	0.445	0.0678	0.0489	0.36
0.75	4.44	0.67	3	2	1.237	0.1887	0.1167	0.99
1	4.88	0.44	4	1	2.524	0.3849	0.3054	2.02
1.25	5.11	0.23	5	3	0.669	0.1020	0.6904	0.53
1.5	5.30	0.19	6	5	0.226	0.0345	0.7924	0.18
1.75	5.45	0.15	7	7	0.150	0.0229	0.8268	0.12
2	5.58	0.13	8	9	0.120	0.0182	0.8497	0.10
2.25	5.70	0.12	9	10	0.110	0.0168	0.8680	0.09
2.5	5.81	0.11	10	11	0.100	0.0153	0.8847	0.08
2.75	5.91	0.10	11	12	0.084	0.0128	0.9000	0.07
3	5.99	0.08	12	13	0.076	0.0116	0.9128	0.06
3.25	6.07	0.08	13	14	0.070	0.0107	0.9244	0.06
3.5	6.14	0.07	14	15	0.065	0.0099	0.9351	0.05
3.75	6.205	0.065	15	16	0.056	0.0085	0.9450	0.04
4	6.240	0.035	23	17	0.041	0.0062	0.9535	0.03
4.25	6.279	0.039	20	18	0.040	0.0061	0.9598	0.03
4.5	6.335	0.056	16	19	0.039	0.0060	0.9659	0.03
4.75	6.369	0.034	24	20	0.039	0.0059	0.9718	0.03
5	6.410	0.041	17	21	0.039	0.0059	0.9778	0.03
5.25	6.449	0.039	19	22	0.038	0.0058	0.9837	0.03
5.5	6.489	0.040	18	23	0.035	0.0053	0.9895	0.03
5.75	6.527	0.038	22	24	0.034	0.0052	0.9948	0.03
6	6.566	0.039	21	25	0.000	0.0000	1.0000	0.00
Total:		6.56			6.56	1		5.24



Summary of TR-60 and CA DSOD Criteria Precipitation

Storm Duration (hr)	PMP Storm Type	P ₁₀₀ (in)	PMP (in)	SDH/ASH (in)	FBH (in)
		1	2	3	4
6	Local	4.77	6.57	5.24	6.57
24	General	10.47	24.45	14.11	24.45
72	General	15.99	41.60	24.45	41.60

- 1) NOAA Atlas 14 for 100-year precip.
- 2) HMR 58/59 (Column 4 in Step 6)
- 3) For High Hazard dam; $P_{100} + 0.26(PMP - P_{100})$
- 4) For High Hazard dam; PMP

B.2. Stage-Discharge Curve

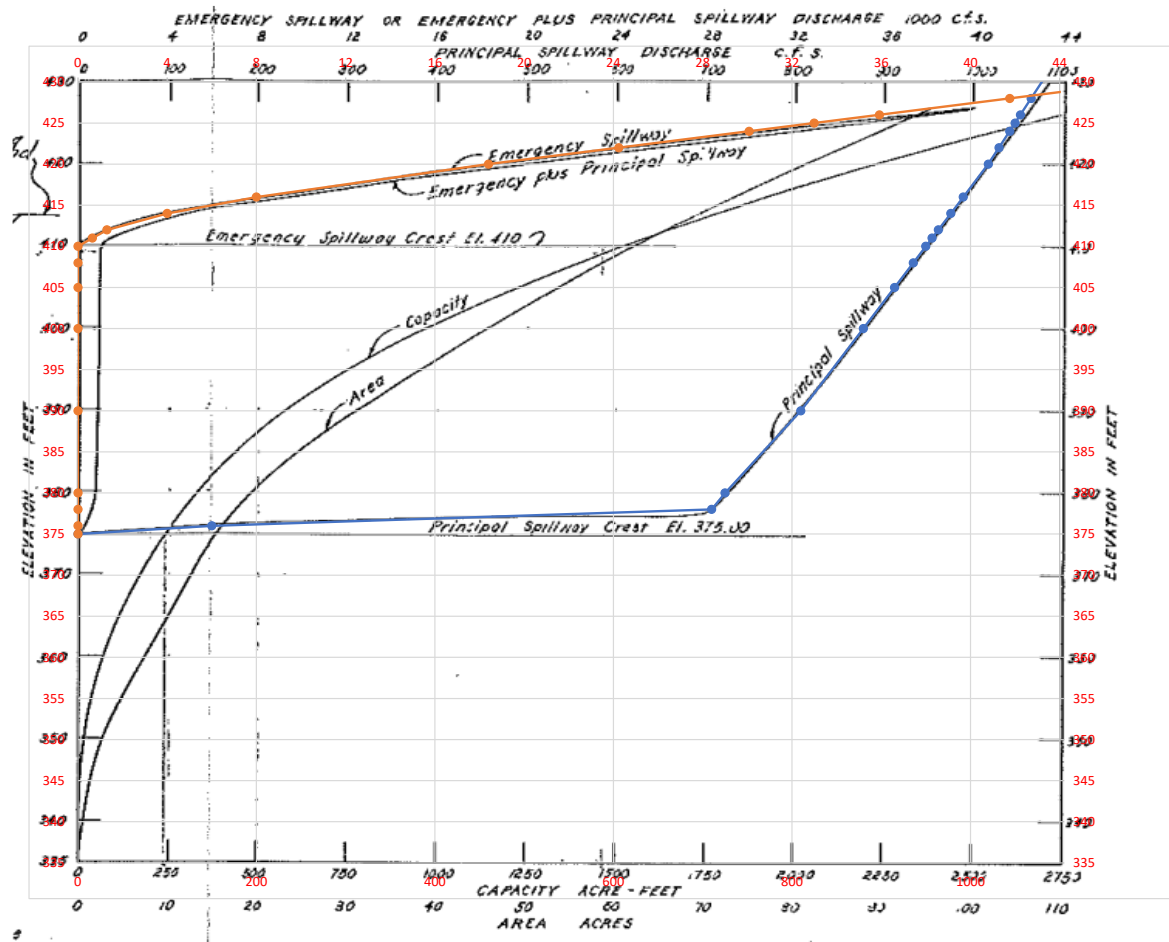


CALCULATION COVER SHEET

Shaping
the Quality
of Life

Project Name:	Matanzas Creek Dam – Supplemental Watershed Plan-ED	
Project Number:	2006-048	
Title of Calculations:	Stage-Discharge Curves	
Calculations By:	Hayden C.	Date: 5/6/2021
Reviewed By:	Ricky A.	Date: 8/3/2021
Number of pages (Including cover sheet): 9		
DESCRIPTION & PURPOSE		
Stage-discharge curves for Matanzas Creek Dam are found on the as-built drawings (also shown in this document). Per the scope of work, the stage-discharge curves of the dam were to be verified. Also, previous studies identified there may be a source of error in the dam's stage-discharge curves (ESA, 2015). This document outlines the methods and procedures to evaluate the stage-discharge curves for the dam and compare the data with the as-built drawings.		
REFERENCES / DATA		
References: • ESA, "Santa Rosa Creek Hydrologic Model Calibration," April 2015 • HDR/Kleinfelder, "California Dam Assessment for Matanzas Creek Dam Sonoma County, CA," NRCS, April 2016. • NRCS, Technical Release 29 – Hydraulics of Two-Way Covered Risers, June 1965. • NRCS, Technical Release 210-60 – Earth Dams and Reservoirs, March 2019. • USGS, 1976. Hydraulic Model Investigation of Marsh Creek Dam Spillway In Contra Costa County, California. ARS-NC-35. Data: • As-built drawings – stage-storage curves • Previous analyses of stage-storage curves (HDR/Kleinfelder and ESA)		
DESIGN CRITERIA / ANALYSIS / METHODS / ASSUMPTIONS		
The following general steps were followed to verify the stage-discharge curves for Matanzas Creek Dam: 1. Develop stage-discharge curves from as-built drawings 2. Evaluate principal spillway discharge rating curving using NRCS TR-29 (spreadsheet and SITES), and then calibrate the rating curve with the February 25-28, 2019 storm event (USGS 11466170) 3. Evaluate auxiliary spillway discharge rating curving using HEC-RAS and 2013 LiDAR 3-feet resolution surface 4. Compare the developed rating curves with as-built drawings 5. Determine final rating curves to be used for evaluating the dam per TR-60 criteria		

Data from As-Built Drawings

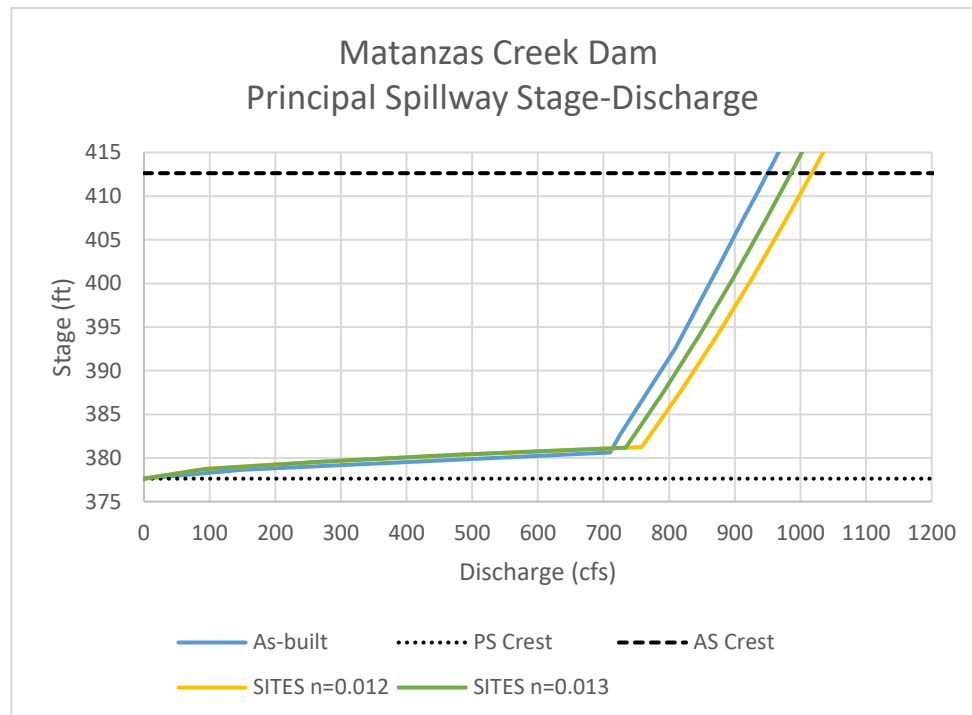


NGVD26 Elevation ft	NAVD88 Elevation ft	PS Flow cfs	AS Flow cfs	Total Flow cfs	AS Flow 1000 cfs	Total Flow 1000 cfs
375	377.63	0	0	0	0	0
376	378.63	150	0	150	0	0.15
378	380.63	710	0	710	0	0.71
380	382.63	725	0	725	0	0.725
390	392.63	810	0	810	0	0.81
400	402.63	880	0	880	0	0.88
405	407.63	915	0	915	0	0.915
408	410.63	936	0	936	0	0.936
410	412.63	950	0	950	0	0.95
411	413.63	957	650	1607	0.65	1.607
412	414.63	964	1300	2264	1.3	2.264
414	416.63	978	4000	4978	4	4.978
416	418.63	992	8000	8992	8	8.992
420	422.63	1020	18400	19420	18.4	19.42
422	424.63	1032	24240	25272	24.24	25.272
424	426.63	1044	30080	31124	30.08	31.124
425	427.63	1050	33000	34050	33	34.05
426	428.63	1056	35920	36976	35.92	36.976
428	430.63	1068	41760	42828	41.76	42.828
433	435.63	1098	56360	57458	56.36	57.458

Principal Spillway Rating Curve (TR-29 and SITES)

The NRCS 'laDropInlet.xls Ver.1.02' spreadsheet and SITES program (both of which follow TR-29 guidelines) was used to evaluate the principal spillway rating curve. Manning's n values (surface roughness) of 0.012 and 0.013 (default value in SITES) for the existing principal spillway conduit were considered. These values were consistent with site observations and CCTV inspection of the conduit.

Comparison of the principal spillway results is shown below. Overall, the SITES evaluation (TR-29) of the spillway shows the spillway may be slightly more efficient than what the as-builts suggest.

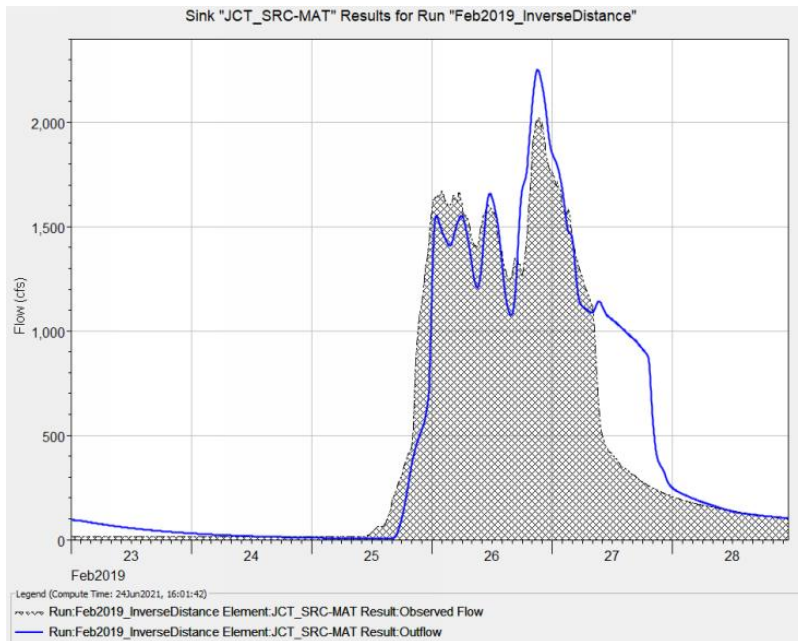


Calibration of Rating Curve: February 25-28, 2019 storm event

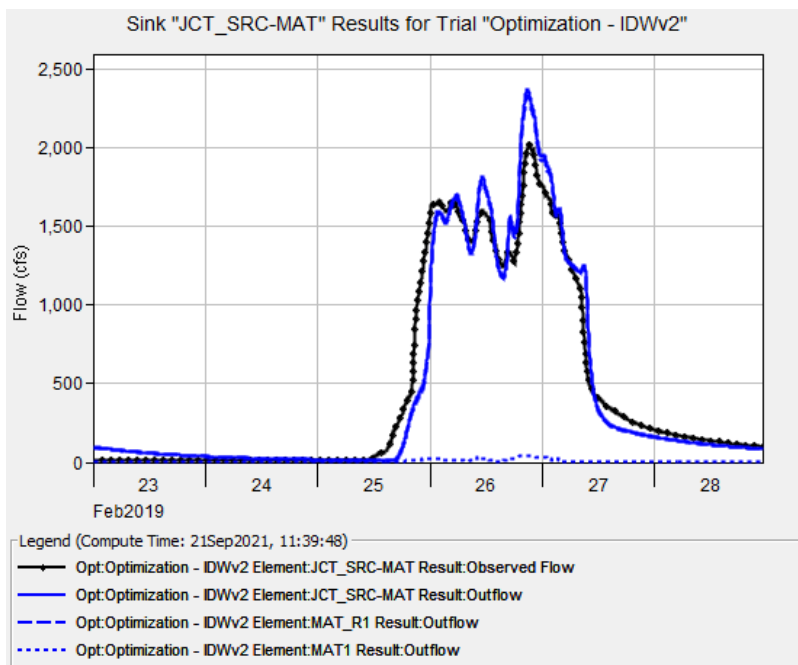
After using the rating curve shown above during the HEC-HMS calibration of USGS 11466170 stream gage, it was determined that the principal spillway's capacity was greater. Therefore, the following parameters were adjusted in the NRCS 'laDropInlet.xls Ver.1.02' spreadsheet:

- Weir discharge coefficient, $C = 3.33$
- Barrel Orifice Coefficient, $C_d = 0.97$
- Entrance Coefficient, $K_e = 0.34$ (USGS, 1976 – study of drop inlet spillway of March Creek Dam in Contra Costa County, California).
- Manning's roughness, $n = 0.010$
- For the calibration storm event, it was determined that the low-level inlet was open during the storm event. The 18-inch low-level outlet was modeled as orifice flow ($C_d = 0.82$) partially blocked by debris (48%) to match the observed reservoir pool data after it dropped below the principal spillway crest. However, note that this low-level outlet rating curve will not be included during the PSH, ASH, or FBH storm events, per TR-60 criteria.

The below figures shows the difference of the pre-calibrated rating curve and the calibrated rating curve. The final tabular and graphical rating curve for the principal spillway is provided on pages 8-9.



Calibration results with pre-calibrated rating curve



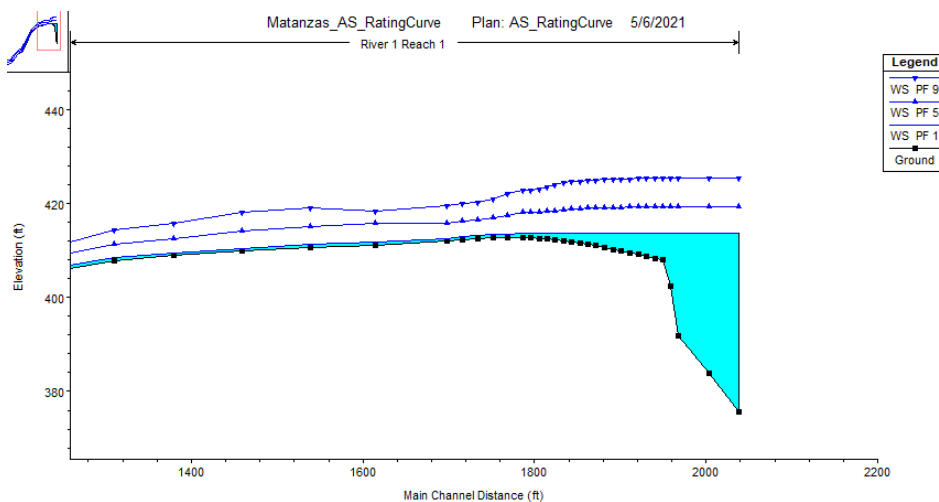
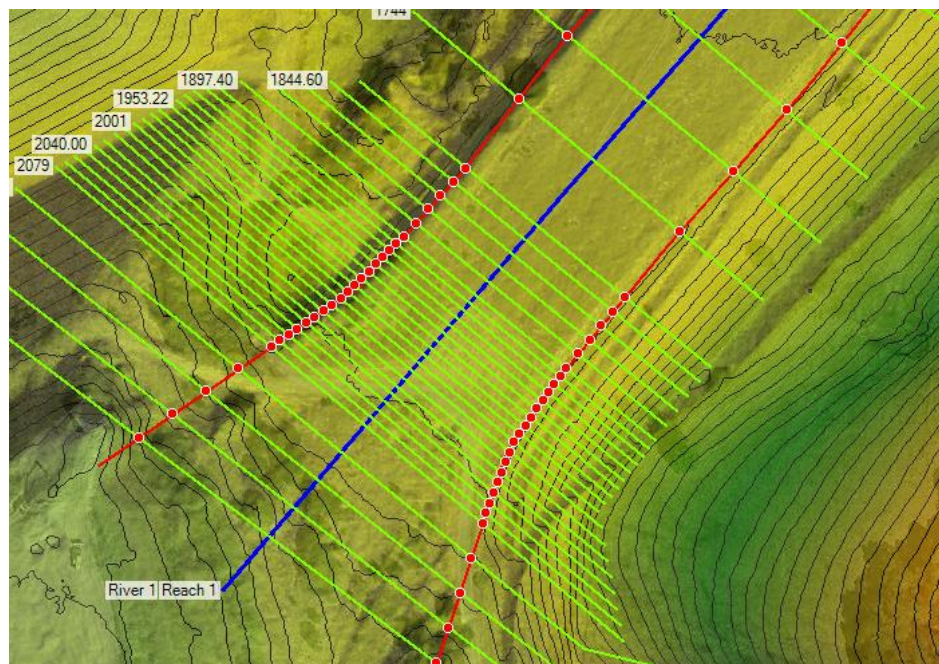
Calibration results with post-calibrated rating curve

Auxiliary Spillway Rating Curve (HEC-RAS)

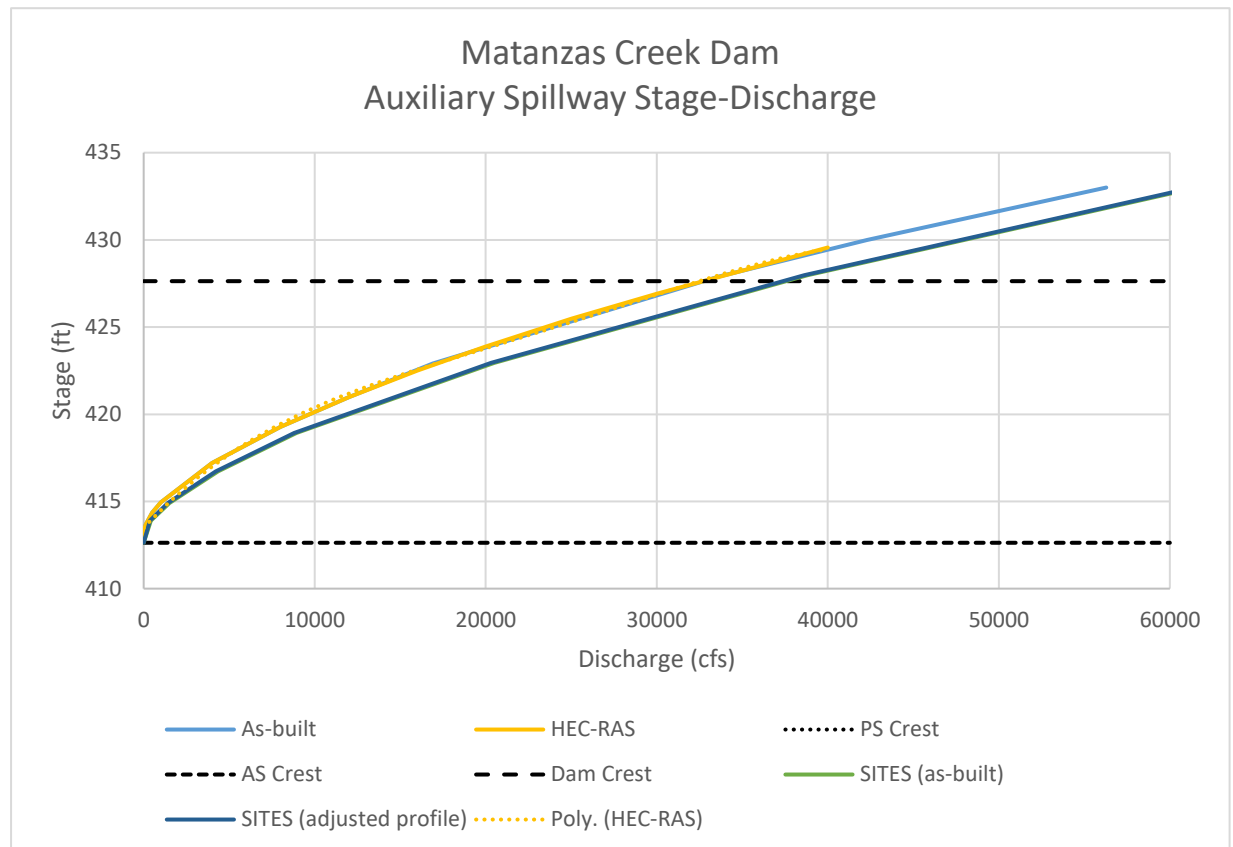
A 1D steady-state HEC-RAS (v5.0.7) model was utilized to evaluate rating curve of the existing conditions of the auxiliary spillway. The existing spillway has a “crest” that consists of a concrete cutoff wall that is flush with the existing ground. In general, the auxiliary spillway is a gradual open channel, so a 1D HEC-RAS model was determined appropriate for the evaluate. The 2013 3-foot resolution LiDAR was used to accurately model the spillway channel. The spillway is grass-lined (Manning’s $n = 0.03$).

An appropriate number of cross-sections were applied to capture the reservoir elevation surface elevation for a given steady-state flow. The geometry of the model and profile of select runs are shown below.

SITES was also used to evaluate the capacity of the spillway.



The comparison of the as-built drawings, HEC-RAS, and SITES ratings curves are shown below. In general, the HEC-RAS model displayed similar results to the as-built drawing data. The HEC-RAS model's rating curve was slightly less efficient than the as-builts and was therefore used in an effort to be conservative on the hydraulic evaluation of the existing dam.

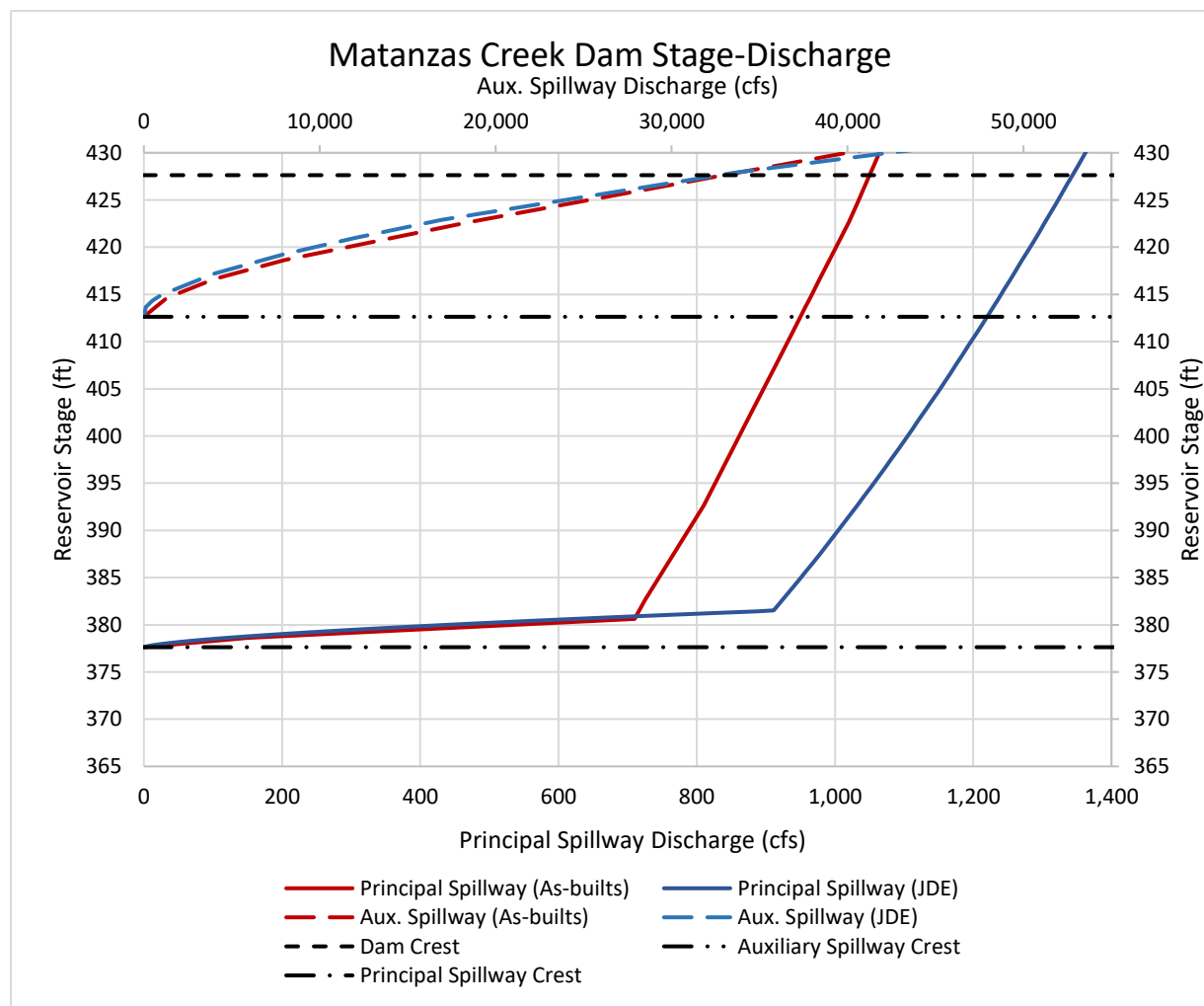


Selected Stage-Discharge Rating Curves for Matanzas Creek Dam

The principal spillway rating curve produced from calibrated HEC-HMS model was selected for the analysis of TM005 and other analyses of this project. The calibrated rating curve is similar, though slightly less efficient, than that developed by ESA during their calibration efforts (ESA, 2017b).

The selected rating curve of auxiliary spillway for this project was the curve produced by HEC-RAS. The results agreed with the as-built drawing rating curve, and the curve is based on an accurate LiDAR surface of the existing spillway.

The comparison of as-built drawing and selected stage-discharge curves for Matanzas Creek Dam is shown below. Tabular data is shown on the next page. The larger table of data is the fully developed rating curves, but the reduced tabular data used in SITES is also provided (SITES only allows 20 columns of tabular data).



NAVD 88 Elevation ft	Storage ac-ft	Principal Discharge cfs	Auxiliary Discharge cfs	Total Discharge cfs	NAVD 88 Elevation ft	Storage ac-ft	Principal Discharge cfs	Auxiliary Discharge cfs	Total Discharge cfs
0.00	0.00	0.00	0.00	0.00	381.63	138.90	912.38	0.00	912.38
354.50	0.06	0.00	0.00	0.00	382.63	154.45	923.90	0.00	923.90
356.00	0.13	0.00	0.00	0.00	383.63	170.00	935.28	0.00	935.28
358.00	0.36	0.00	0.00	0.00	384.63	188.66	946.52	0.00	946.52
360.00	1.09	0.00	0.00	0.00	385.63	207.33	957.63	0.00	957.63
362.00	3.34	0.00	0.00	0.00	386.63	230.83	968.62	0.00	968.62
364.00	7.26	0.00	0.00	0.00	387.63	254.34	979.48	0.00	979.48
366.00	12.72	0.00	0.00	0.00	388.63	282.89	990.22	0.00	990.22
368.00	19.40	0.00	0.00	0.00	389.63	311.43	1000.84	0.00	1000.84
370.00	27.47	0.00	0.00	0.00	390.63	344.27	1011.35	0.00	1011.35
372.00	38.43	0.00	0.00	0.00	391.63	377.11	1021.76	0.00	1021.76
374.00	54.04	0.00	0.00	0.00	392.63	414.00	1032.06	0.00	1032.06
376.00	72.45	0.00	0.00	0.00	393.63	450.90	1042.26	0.00	1042.26
377.63	88.91	0.00	0.00	0.00	394.63	490.87	1052.36	0.00	1052.36
377.73	90.08	3.79	0.00	3.79	395.63	530.83	1062.36	0.00	1062.36
377.83	91.24	10.72	0.00	10.72	396.63	573.70	1072.27	0.00	1072.27
377.93	92.40	19.70	0.00	19.70	397.63	616.57	1082.09	0.00	1082.09
378.03	93.56	30.33	0.00	30.33	398.63	662.29	1091.82	0.00	1091.82
378.13	94.72	42.38	0.00	42.38	399.63	708.00	1101.47	0.00	1101.47
378.23	95.88	55.72	0.00	55.72	400.63	756.37	1111.03	0.00	1111.03
378.33	97.04	70.21	0.00	70.21	401.63	804.73	1120.51	0.00	1120.51
378.43	98.20	85.78	0.00	85.78	402.63	856.01	1129.91	0.00	1129.91
378.53	99.37	102.36	0.00	102.36	403.63	907.30	1139.23	0.00	1139.23
378.63	100.53	119.88	0.00	119.88	404.63	961.62	1148.48	0.00	1148.48
378.73	101.69	138.30	0.00	138.30	405.63	1015.95	1157.65	0.00	1157.65
378.83	102.85	157.59	0.00	157.59	406.63	1073.14	1166.75	0.00	1166.75
378.93	104.01	177.69	0.00	177.69	407.63	1130.33	1175.78	0.00	1175.78
379.03	105.17	198.58	0.00	198.58	408.63	1190.54	1184.75	0.00	1184.75
379.13	106.33	220.23	0.00	220.23	409.63	1250.76	1193.64	0.00	1193.64
379.23	107.49	242.62	0.00	242.62	410.63	1314.25	1202.47	0.00	1202.47
379.33	108.66	265.72	0.00	265.72	411.63	1377.74	1211.23	0.00	1211.23
379.43	109.82	289.50	0.00	289.50	412.63	1444.78	1219.94	0.00	1219.94
379.53	110.98	313.96	0.00	313.96	413.63	1511.81	1228.58	390.01	1618.59
379.63	112.14	339.07	0.00	339.07	414.63	1582.26	1237.15	1014.17	2251.32
379.73	113.48	364.82	0.00	364.82	415.63	1652.71	1245.68	2153.52	3399.20
379.83	114.82	391.18	0.00	391.18	416.63	1726.57	1254.14	3508.10	4762.24
379.93	116.15	418.16	0.00	418.16	417.63	1800.43	1262.54	5077.90	6340.44
380.03	117.49	445.72	0.00	445.72	418.63	1877.63	1270.89	6862.91	8133.81
380.13	118.83	473.87	0.00	473.87	419.63	1954.84	1279.19	8863.15	10142.34
380.23	120.17	502.58	0.00	502.58	420.63	2035.76	1287.43	11078.61	12366.04
380.33	121.51	531.85	0.00	531.85	421.63	2116.67	1295.62	13509.28	14804.90
380.43	122.84	561.67	0.00	561.67	422.63	2201.72	1303.76	16155.18	17458.94
380.53	124.18	592.03	0.00	592.03	423.63	2286.77	1311.85	19016.30	20328.14
380.63	125.52	622.91	0.00	622.91	424.63	2376.48	1319.89	22092.63	23412.52
380.73	126.86	654.32	0.00	654.32	425.63	2466.19	1327.88	25384.19	26712.06
380.83	128.20	686.23	0.00	686.23	426.63	2568.61	1335.82	28890.96	30226.78
380.93	129.53	718.65	0.00	718.65	427.63	2671.03	1343.71	32612.96	33956.67
381.03	130.87	751.56	0.00	751.56	428.63	2764.89	1351.56	36550.18	37901.74
381.13	132.21	784.96	0.00	784.96	429.63	2858.75	1359.37	40702.61	42061.98
381.23	133.55	818.84	0.00	818.84	430.63	2952.62	1367.12	45070.27	46437.39
381.33	134.89	853.20	0.00	853.20	431.63	3046.48	1374.84	49653.14	51027.98
381.43	136.22	888.02	0.00	888.02	432.63	3140.34	1382.51	54451.24	55833.75
381.53	137.56	911.22	0.00	911.22					

Note that the total discharge on the previous page is representative of the principal spillway and auxiliary spillway discharge only. Discharge values with elevations above the dam crest do not include flows overtopping the dam.

Below is the reduced tabular data of the rating curves that was used for the NRCS SITES software (SITES limits the data entry to 20 rows):

NAVD 88 Elevation ft	Storage ac-ft	Principal Discharge cfs	Auxiliary Discharge cfs
377.63	88.91	0.00	0.00
378.13	94.72	42.38	0.00
378.63	100.53	119.88	0.00
379.13	106.33	220.23	0.00
379.63	112.14	339.07	0.00
380.63	125.52	622.91	0.00
381.43	136.22	888.02	0.00
381.53	137.56	911.22	0.00
385.63	207.33	957.63	0.00
400.63	756.37	1111.03	0.00
405.63	1015.95	1157.65	0.00
412.63	1444.78	1219.94	0.00
413.63	1511.81	1228.58	390.01
414.63	1582.26	1237.15	1014.17
415.63	1652.71	1245.68	2153.52
416.63	1726.57	1254.14	3508.10
418.63	1877.63	1270.89	6862.91
420.63	2035.76	1287.43	11078.61
423.63	2286.77	1311.85	19016.30
427.63	2671.03	1343.71	32612.96

B.3. Hydrographs



CALCULATION COVER SHEET



Project Name:	Matanzas Creek Dam – Supplemental Watershed Plan-ED	
Project Number:	2006-048	
Title of Calculations:	Hydrographs per TR-60 criteria used in SITES	
Calculations By:	Hayden C.	Date: 6/19/2021
Reviewed By:	K. Curtis	Date: 7/20/2021
Number of pages (Including cover sheet): 14		
DESCRIPTION & PURPOSE		
The HEC-HMS model for the broader Central Sonoma Watershed (received from Sonoma County) uses the Snyder Unit Hydrograph transform method. This model was used for calibrating Matanzas Creek Dam with surrounding precipitation and stream gauges. This document provides the hydrographs per TR-60 that were used as input for the SITES evaluation of the dam (SITES typically uses the SCS Unit Hydrograph transform method).		
REFERENCES / DATA		
References: • CA DSOD, Division of Safety of Dams Inspection and Reevaluation Protocols, September 2018. • NRCS, Technical Release 210-60 – Earth Dams and Reservoirs, March 2019. • NRCS, National Engineering Handbook (NEH) Part 630 • NOAA, Hydrometeorological Report No. 58 and 59, October 1998 and February 1999		
DESIGN CRITERIA / ANALYSIS / METHODS / ASSUMPTIONS		
The hydrographs and results presented in this document were produced in HEC-HMS v4.8. The hydrographs were used in SITES for evaluating Matanzas Creek Dam with TR-60 criteria. Below is a summary of input for the watershed: • Matanzas Creek Dam Watershed Area = 11.45 sq. mi. • Loss Method: SCS Curve Number ○ Calibrated CN (Existing and Future) = 71.4 ○ Future Imperviousness increase = 1% • Transform Method: Snyder Unit Hydrograph ○ Standard Lag = 1.8 hours ○ Peaking Coefficient = 0.75 • Precipitation Data (see Table 4-1 in report or “Design Storms: Precipitation Depths and Distributions” in Appendix B)		

6-Hour Local Storms

Existing Condition ASH/SDH:

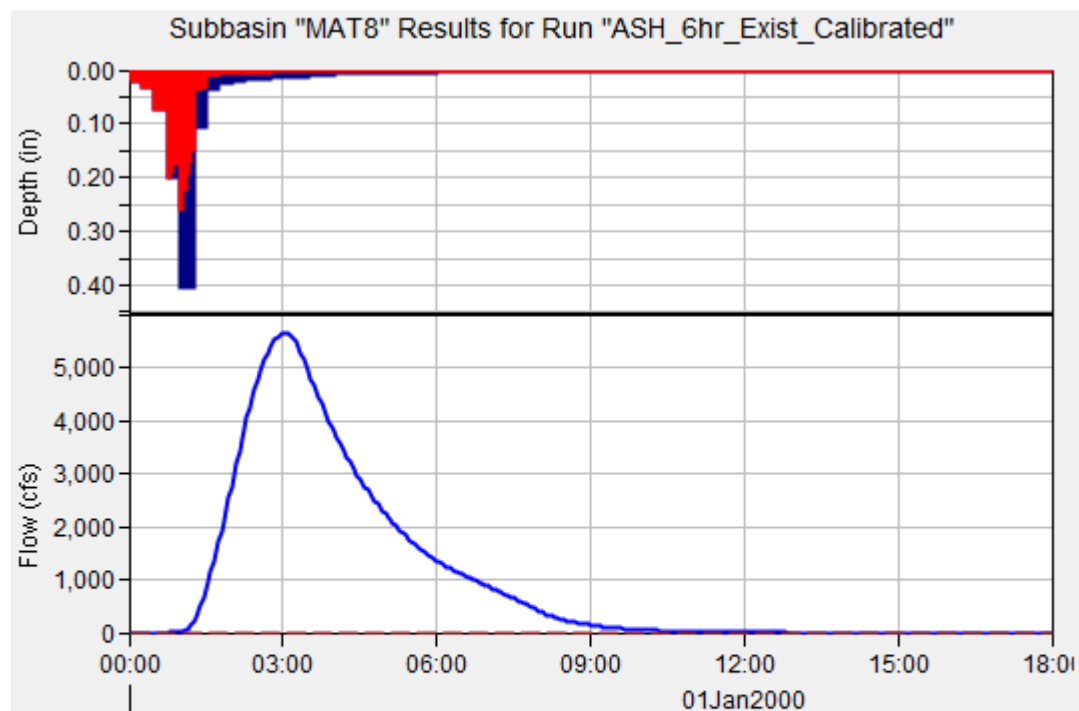
Project: Matanzas_MAT8Only Simulation Run: ASH_6hr_Exist_Calibrated
Subbasin: MAT8

Start of Run: 01Jan2000, 00:00 Basin Model: Matanzas_Exist_Calibrated
End of Run: 01Jan2000, 18:00 Meteorologic Model: ASH_6hr_LS_HMR58
Compute Time: 29Sep2021, 17:27:45 Control Specifications: 6hr_LS

Volume Units: ☒ IN ☐ ACRE-FT

Computed Results

Peak Discharge:	5648.7 (CFS)	Date/Time of Peak Discharge:	01Jan2000, 03:03
Precipitation Volume:	5.24 (IN)	Direct Runoff Volume:	2.33 (IN)
Loss Volume:	2.91 (IN)	Baseflow Volume:	0.00 (IN)
Excess Volume:	2.33 (IN)	Discharge Volume:	2.33 (IN)



Legend (Compute Time: 29Sep2021, 17:27:45)

- Run: ASH_6hr_Exist_Calibrated Element: MAT8 Result: Precipitation
- Run: ASH_6hr_Exist_Calibrated Element: MAT8 Result: Precipitation Loss
- Run: ASH_6hr_Exist_Calibrated Element: MAT8 Result: Outflow
- Run: ASH_6hr_Exist_Calibrated Element: MAT8 Result: Baseflow

Future Condition ASH/SDH:

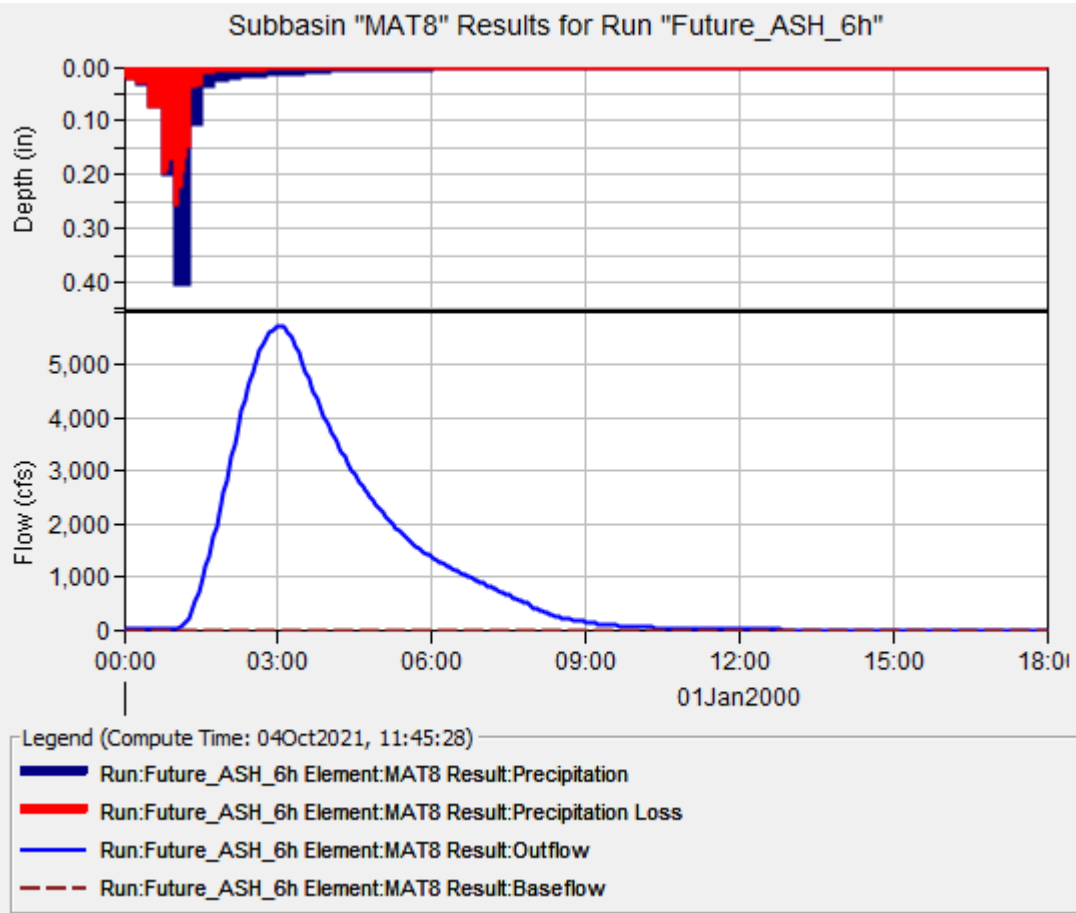
Project: Matanzas_MAT8Only Simulation Run: Future_ASH_6h
Subbasin: MAT8

Start of Run: 01Jan2000, 00:00 Basin Model: Matanzas_Future_Calib_1%imp
End of Run: 01Jan2000, 18:00 Meteorologic Model: ASH_6hr_LS_HMR58
Compute Time: 04Oct2021, 11:45:28 Control Specifications: 6hr_LS

Volume Units: ☒ IN ☐ ACRE-FT

Computed Results

Peak Discharge:	5723.2 (CFS)	Date/Time of Peak Discharge:	01Jan2000, 03:03
Precipitation Volume:	5.24 (IN)	Direct Runoff Volume:	2.36 (IN)
Loss Volume:	2.88 (IN)	Baseflow Volume:	0.00 (IN)
Excess Volume:	2.36 (IN)	Discharge Volume:	2.36 (IN)



Existing Condition FBH:

Project: Matanzas_MAT8Only Simulation Run: FBH_6hr_Exist_Calibrated
Subbasin: MAT8

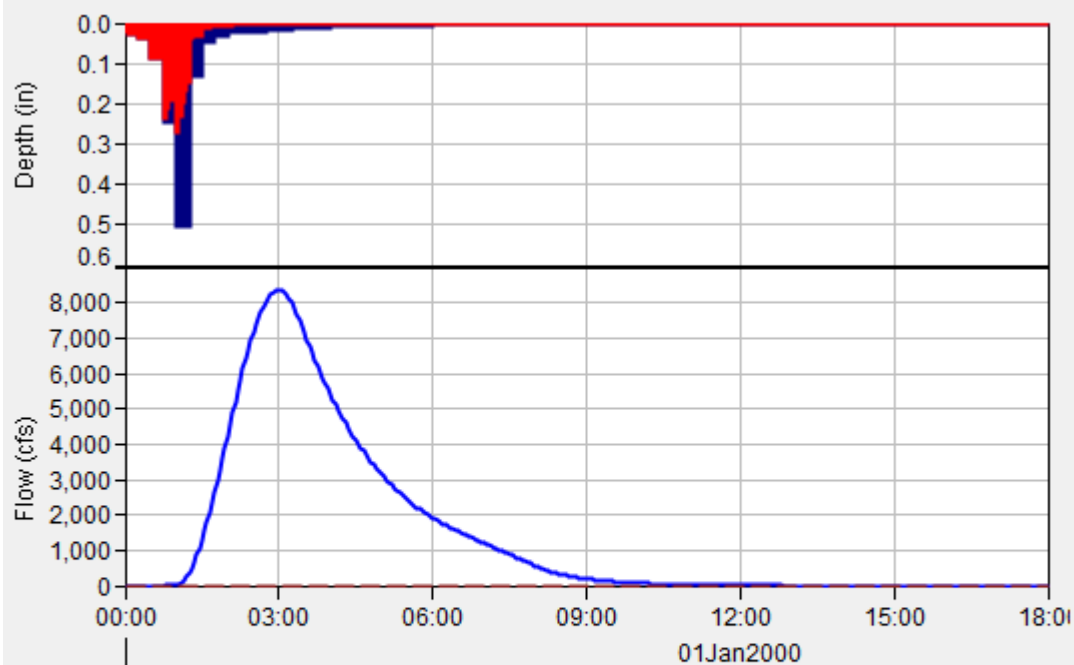
Start of Run: 01Jan2000, 00:00 Basin Model: Matanzas_Exist_Calibrated
End of Run: 01Jan2000, 18:00 Meteorologic Model: FBH_6hr_LS_HMR58
Compute Time: 29Sep2021, 17:27:46 Control Specifications: 6hr_LS

Volume Units: ☒ IN ☐ ACRE-FT

Computed Results

Peak Discharge:	8347.0 (CFS)	Date/Time of Peak Discharge:	01Jan2000, 03:00
Precipitation Volume:	6.56 (IN)	Direct Runoff Volume:	3.39 (IN)
Loss Volume:	3.16 (IN)	Baseflow Volume:	0.00 (IN)
Excess Volume:	3.39 (IN)	Discharge Volume:	3.39 (IN)

Subbasin "MAT8" Results for Run "FBH_6hr_Exist_Calibrated"



Legend (Compute Time: 29Sep2021, 17:27:46)

- Run:FBH_6hr_Exist_Calibrated Element:MAT8 Result:Precipitation
- Run:FBH_6hr_Exist_Calibrated Element:MAT8 Result:Precipitation Loss
- Run:FBH_6hr_Exist_Calibrated Element:MAT8 Result:Outflow
- Run:FBH_6hr_Exist_Calibrated Element:MAT8 Result:Baseflow

Future Conditions FBH:

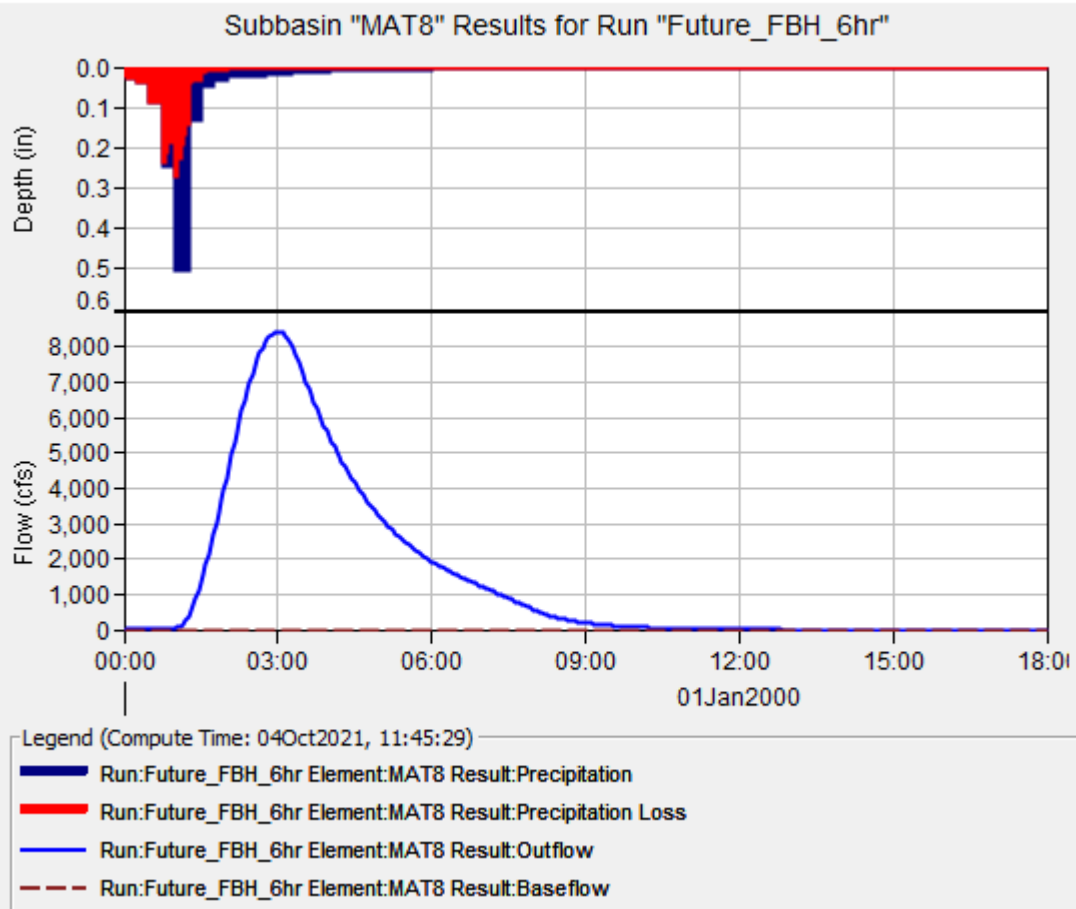
Project: Matanzas_MAT8Only Simulation Run: Future_FBH_6hr
Subbasin: MAT8

Start of Run: 01Jan2000, 00:00 Basin Model: Matanzas_Future_Calib_1%imp
End of Run: 01Jan2000, 18:00 Meteorologic Model: FBH_6hr_LS_HMR58
Compute Time: 04Oct2021, 11:45:29 Control Specifications: 6hr_LS

Volume Units: ☒ IN ☐ ACRE-FT

Computed Results

Peak Discharge:	8429.2 (CFS)	Date/Time of Peak Discharge:	01Jan2000, 03:00
Precipitation Volume:	6.56 (IN)	Direct Runoff Volume:	3.43 (IN)
Loss Volume:	3.13 (IN)	Baseflow Volume:	0.00 (IN)
Excess Volume:	3.43 (IN)	Discharge Volume:	3.43 (IN)



24-Hour General Storms

Existing Condition ASH/SDH:

Project: Matanzas_MAT8Only Simulation Run: ASH_24hr_Exist_Calibrated
Subbasin: MAT8

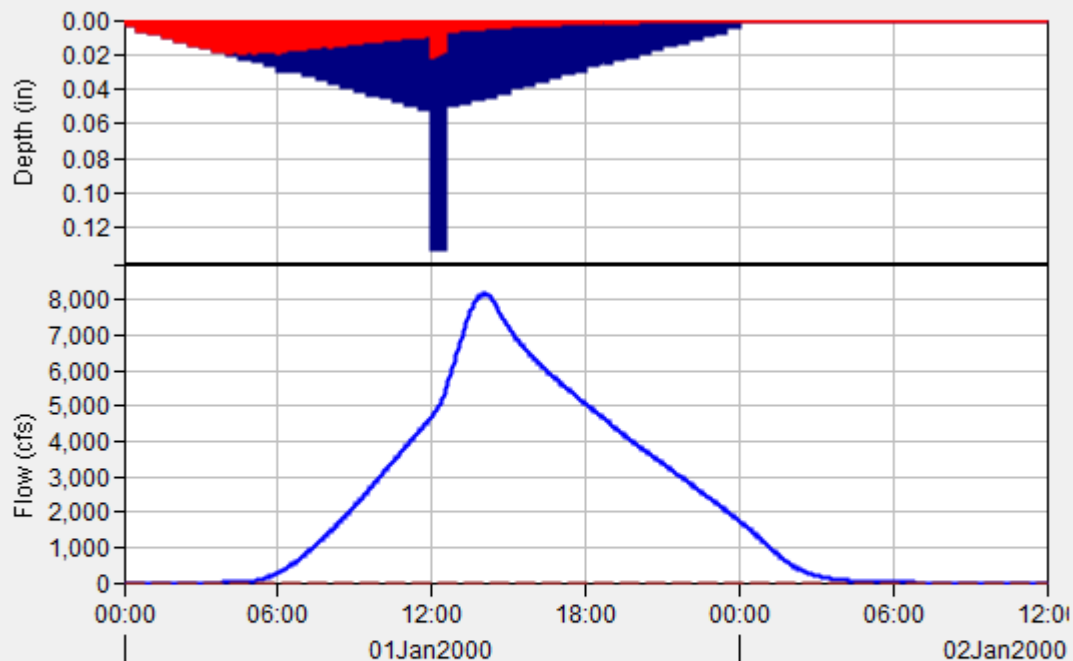
Start of Run: 01Jan2000, 00:00 Basin Model: Matanzas_Exist_Calibrated
End of Run: 02Jan2000, 12:00 Meteorologic Model: ASH_24hr_GS_HMR58
Compute Time: 29Sep2021, 17:27:45 Control Specifications: 24hr_GS

Volume Units: ☒ IN ☐ ACRE-FT

Computed Results

Peak Discharge:	8157.6 (CFS)	Date/Time of Peak Discharge:	01Jan2000, 14:03
Precipitation Volume:	14.12 (IN)	Direct Runoff Volume:	10.24 (IN)
Loss Volume:	3.88 (IN)	Baseflow Volume:	0.00 (IN)
Excess Volume:	10.24 (IN)	Discharge Volume:	10.24 (IN)

Subbasin "MAT8" Results for Run "ASH_24hr_Exist_Calibrated"



Legend (Compute Time: 29Sep2021, 17:27:45)

- Run:ASH_24hr_Exist_Calibrated Element:MAT8 Result:Precipitation
- Run:ASH_24hr_Exist_Calibrated Element:MAT8 Result:Precipitation Loss
- Run:ASH_24hr_Exist_Calibrated Element:MAT8 Result:Outflow
- Run:ASH_24hr_Exist_Calibrated Element:MAT8 Result:Baseflow

Future Condition ASH/SDH:

Project: Matanzas_MAT8Only Simulation Run: Future_ASH_24hr
Subbasin: MAT8

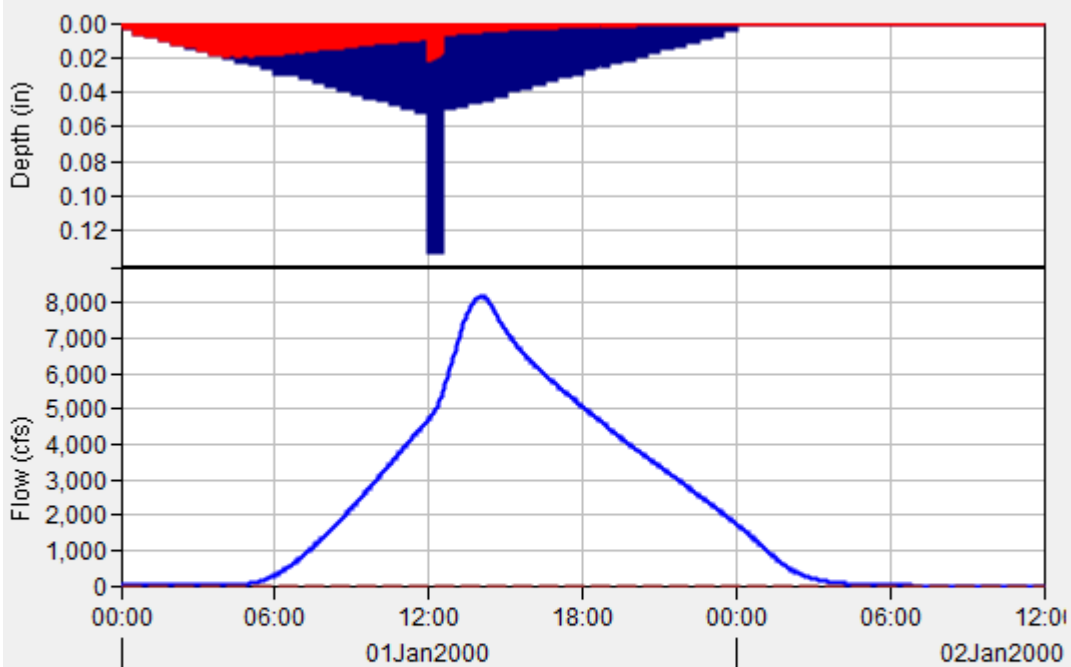
Start of Run: 01Jan2000, 00:00 Basin Model: Matanzas_Future_Calib_1%imp
End of Run: 02Jan2000, 12:00 Meteorologic Model: ASH_24hr_GS_HMR58
Compute Time: 04Oct2021, 11:51:20 Control Specifications: 24hr_GS

Volume Units: ☒ IN ☐ ACRE-FT

Computed Results

Peak Discharge:	8173.4 (CFS)	Date/Time of Peak Discharge:	01Jan2000, 14:03
Precipitation Volume:	14.12 (IN)	Direct Runoff Volume:	10.28 (IN)
Loss Volume:	3.84 (IN)	Baseflow Volume:	0.00 (IN)
Excess Volume:	10.28 (IN)	Discharge Volume:	10.28 (IN)

Subbasin "MAT8" Results for Run "Future_ASH_24hr"



Legend (Compute Time: 04Oct2021, 11:51:20)

- Run:Future_ASH_24hr Element:MAT8 Result:Precipitation
- Run:Future_ASH_24hr Element:MAT8 Result:Precipitation Loss
- Run:Future_ASH_24hr Element:MAT8 Result:Outflow
- Run:Future_ASH_24hr Element:MAT8 Result:Baseflow

Existing Condition FBH:

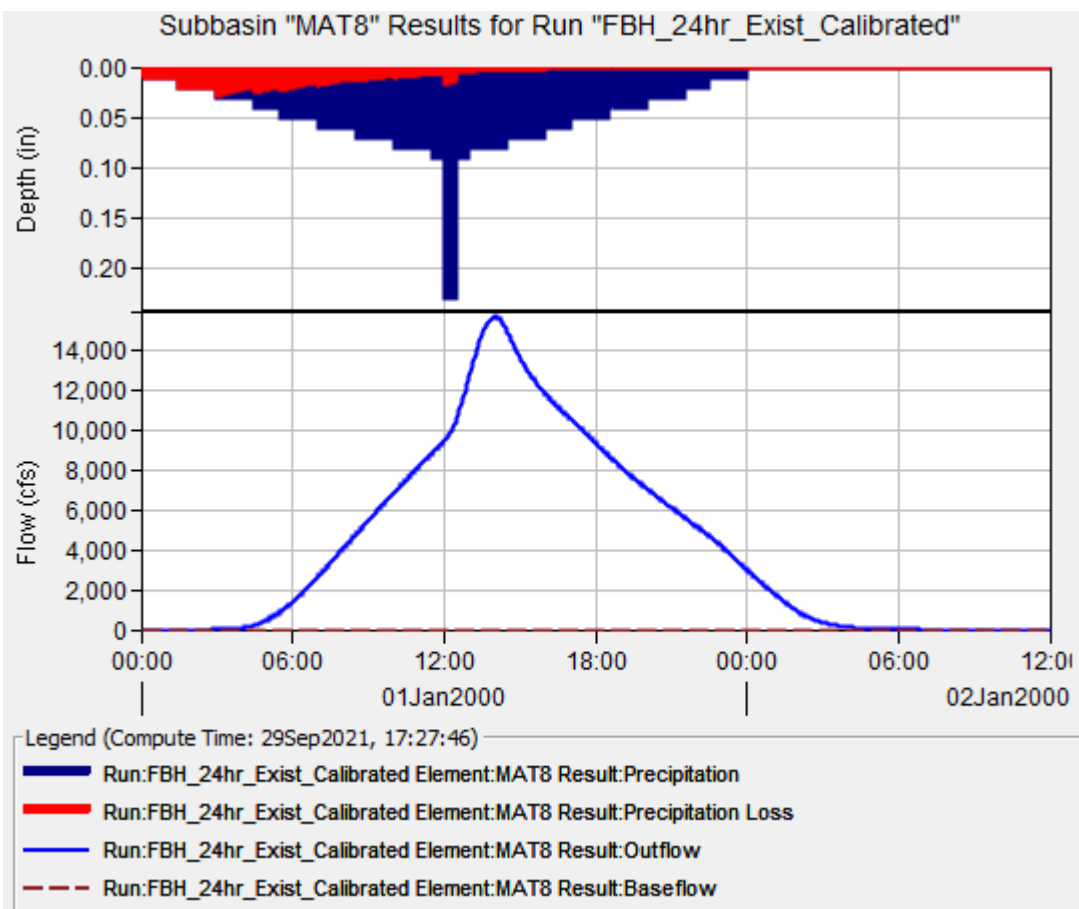
Project: Matanzas_MAT8Only Simulation Run: FBH_24hr_Exist_Calibrated
Subbasin: MAT8

Start of Run: 01Jan2000, 00:00 Basin Model: Matanzas_Exist_Calibrated
End of Run: 02Jan2000, 12:00 Meteorologic Model: FBH_24hr_GS_HMR58
Compute Time: 29Sep2021, 17:27:46 Control Specifications: 24hr_GS

Volume Units: ☒ IN ☐ ACRE-FT

Computed Results

Peak Discharge:	15701.8 (CFS)	Date/Time of Peak Discharge:	01Jan2000, 14:03
Precipitation Volume:	24.50 (IN)	Direct Runoff Volume:	20.27 (IN)
Loss Volume:	4.23 (IN)	Baseflow Volume:	0.00 (IN)
Excess Volume:	20.27 (IN)	Discharge Volume:	20.27 (IN)



Future Conditions FBH:

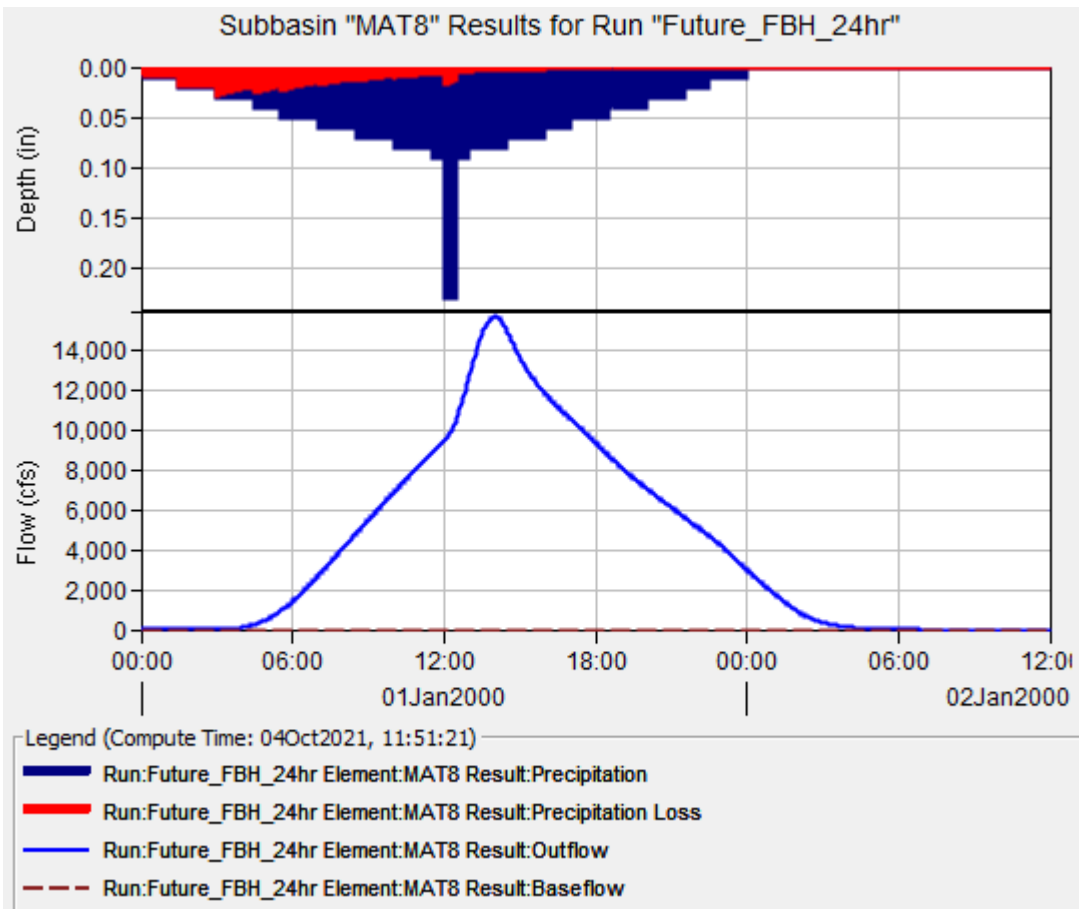
Project: Matanzas_MAT8Only Simulation Run: Future_FBH_24hr
Subbasin: MAT8

Start of Run: 01Jan2000, 00:00 Basin Model: Matanzas_Future_Calib_1%imp
End of Run: 02Jan2000, 12:00 Meteorologic Model: FBH_24hr_GS_HMR58
Compute Time: 04Oct2021, 11:51:21 Control Specifications: 24hr_GS

Volume Units: ☒ IN ☐ ACRE-FT

Computed Results

Peak Discharge:	15714.2 (CFS)	Date/Time of Peak Discharge:	01Jan2000, 14:03
Precipitation Volume:	24.50 (IN)	Direct Runoff Volume:	20.31 (IN)
Loss Volume:	4.19 (IN)	Baseflow Volume:	0.00 (IN)
Excess Volume:	20.31 (IN)	Discharge Volume:	20.31 (IN)



72-Hour General Storms

Existing Condition ASH/SDH:

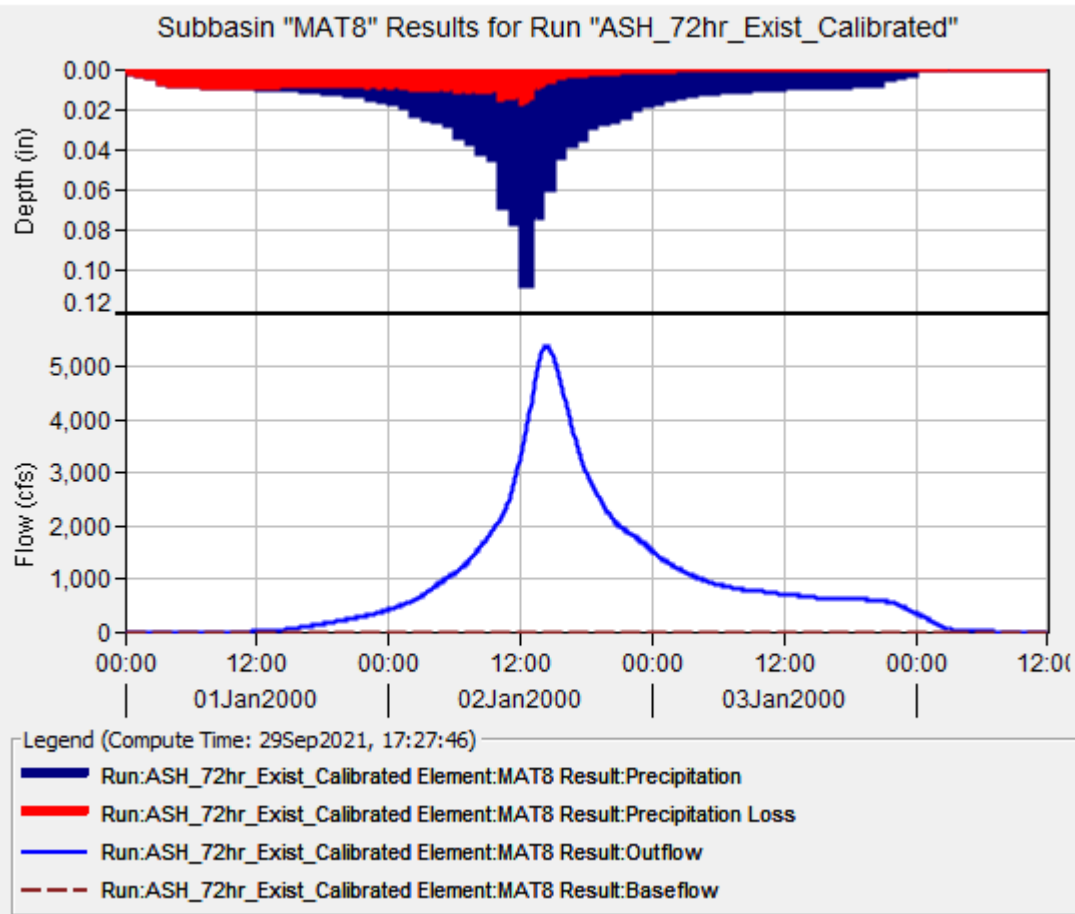
Project: Matanzas_MAT8Only Simulation Run: ASH_72hr_Exist_Calibrated
Subbasin: MAT8

Start of Run: 01Jan2000, 00:00 Basin Model: Matanzas_Exist_Calibrated
End of Run: 04Jan2000, 12:00 Meteorologic Model: ASH_72hr_GS_HMR58
Compute Time: 29Sep2021, 17:27:46 Control Specifications: 72hr_GS

Volume Units: ☒ IN ☐ ACRE-FT

Computed Results

Peak Discharge:	5382.1 (CFS)	Date/Time of Peak Discharge:	02Jan2000, 14:24
Precipitation Volume:	14.09 (IN)	Direct Runoff Volume:	10.21 (IN)
Loss Volume:	3.88 (IN)	Baseflow Volume:	0.00 (IN)
Excess Volume:	10.21 (IN)	Discharge Volume:	10.21 (IN)



Future Condition ASH/SDH:

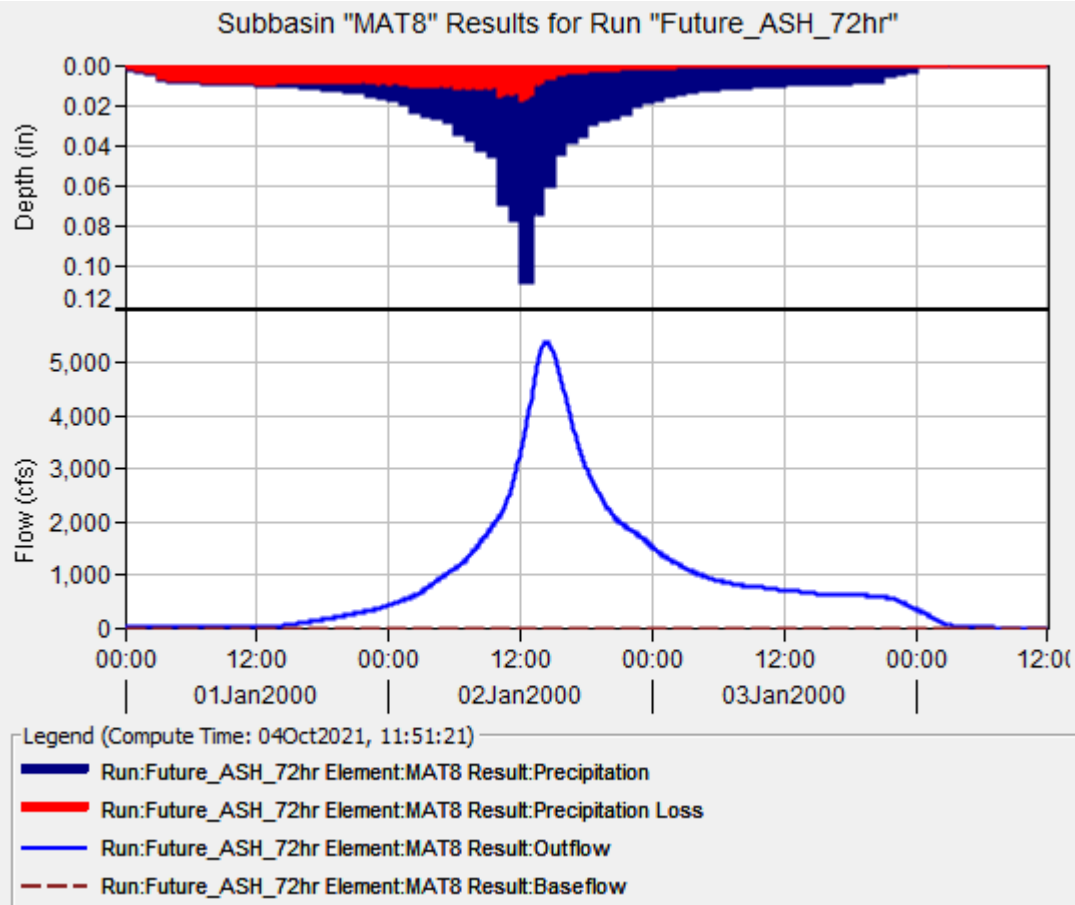
Project: Matanzas_MAT8Only Simulation Run: Future_ASH_72hr
Subbasin: MAT8

Start of Run: 01Jan2000, 00:00 Basin Model: Matanzas_Future_Calib_1%imp
End of Run: 04Jan2000, 12:00 Meteorologic Model: ASH_72hr_GS_HMR58
Compute Time: 04Oct2021, 11:51:21 Control Specifications: 72hr_GS

Volume Units: ☒ IN ☐ ACRE-FT

Computed Results

Peak Discharge:	5391.9 (CFS)	Date/Time of Peak Discharge:	02Jan2000, 14:18
Precipitation Volume:	14.09 (IN)	Direct Runoff Volume:	10.25 (IN)
Loss Volume:	3.84 (IN)	Baseflow Volume:	0.00 (IN)
Excess Volume:	10.25 (IN)	Discharge Volume:	10.25 (IN)



Existing Condition FBH:

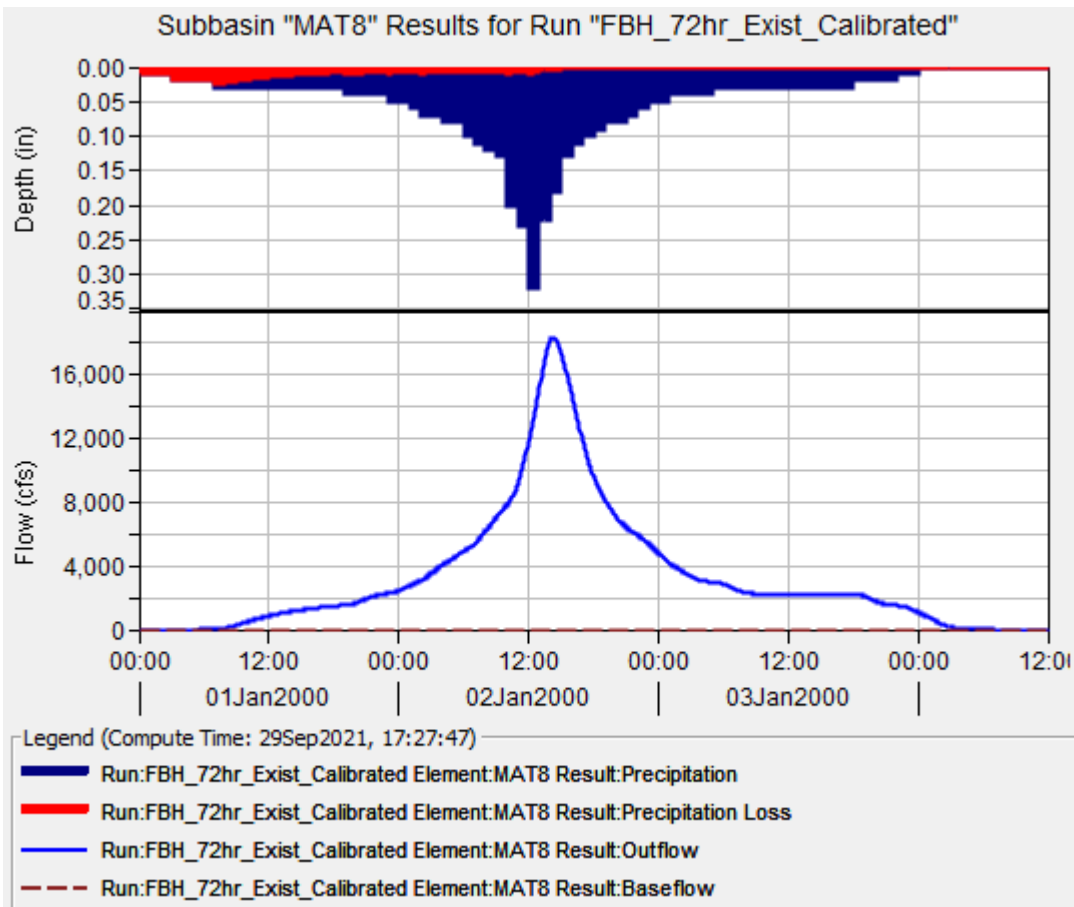
Project: Matanzas_MAT8Only Simulation Run: FBH_72hr_Exist_Calibrated
Subbasin: MAT8

Start of Run: 01Jan2000, 00:00 Basin Model: Matanzas_Exist_Calibrated
End of Run: 04Jan2000, 12:00 Meteorologic Model: FBH_72hr_GS_HMR58
Compute Time: 29Sep2021, 17:27:47 Control Specifications: 72hr_GS

Volume Units: ☒ IN ☐ ACRE-FT

Computed Results

Peak Discharge:	18342.8 (CFS)	Date/Time of Peak Discharge:	02Jan2000, 14:18
Precipitation Volume:	41.70 (IN)	Direct Runoff Volume:	37.25 (IN)
Loss Volume:	4.45 (IN)	Baseflow Volume:	0.00 (IN)
Excess Volume:	37.25 (IN)	Discharge Volume:	37.25 (IN)



Future Conditions FBH:

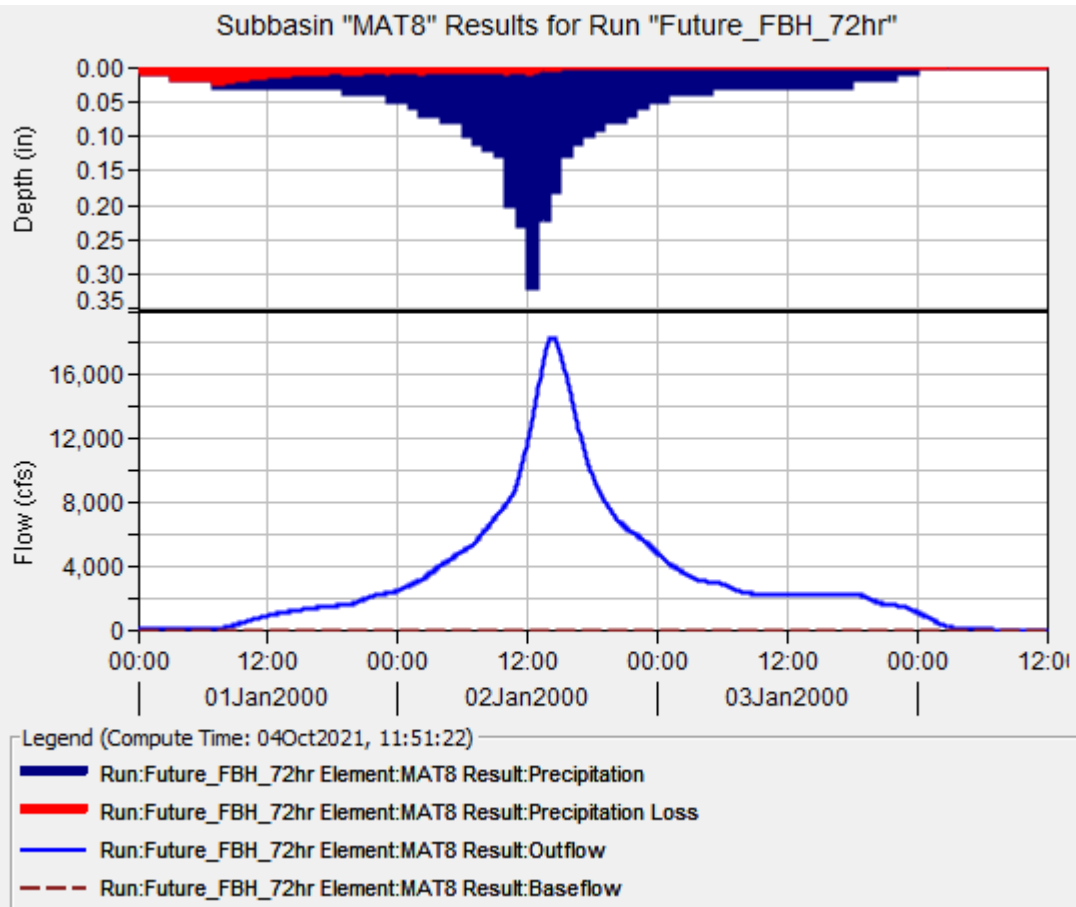
Project: Matanzas_MAT8Only Simulation Run: Future_FBH_72hr
Subbasin: MAT8

Start of Run: 01Jan2000, 00:00 Basin Model: Matanzas_Future_Calib_1%imp
End of Run: 04Jan2000, 12:00 Meteorologic Model: FBH_72hr_GS_HMR58
Compute Time: 04Oct2021, 11:51:22 Control Specifications: 72hr_GS

Volume Units: ☒ IN ☐ ACRE-FT

Computed Results

Peak Discharge:	18348.2 (CFS)	Date/Time of Peak Discharge:	02Jan2000, 14:18
Precipitation Volume:	41.70 (IN)	Direct Runoff Volume:	37.30 (IN)
Loss Volume:	4.40 (IN)	Baseflow Volume:	0.00 (IN)
Excess Volume:	37.30 (IN)	Discharge Volume:	37.30 (IN)



Summary Table

Parameter Description	ASH/SDH		FBH	
	Existing	Future	Existing	Future
6-Hour Local Storm				
Peak Discharge (cfs)	5,648.7	5,723.2	8,347.0	8,429.2
Precipitation Volume (in)	5.24	5.24	6.56	6.56
Loss Volume (in)	2.91	2.88	3.16	3.13
Excess Volume (in)	2.33	2.36	3.39	3.43
24-Hour General Storm				
Peak Discharge (cfs)	8,157.6	8,173.4	15,701.8	15,714.2
Precipitation Volume (in)	14.12	14.12	24.50	24.50
Loss Volume (in)	3.88	3.84	4.23	4.19
Excess Volume (in)	10.24	10.28	20.27	20.31
72-Hour General Storm				
Peak Discharge (cfs)	5,382.1	5,391.9	18,342.8	18,348.2
Precipitation Volume (in)	14.09	14.09	41.70	41.70
Loss Volume (in)	3.88	3.84	4.45	4.40
Excess Volume (in)	10.21	10.25	37.25	37.30

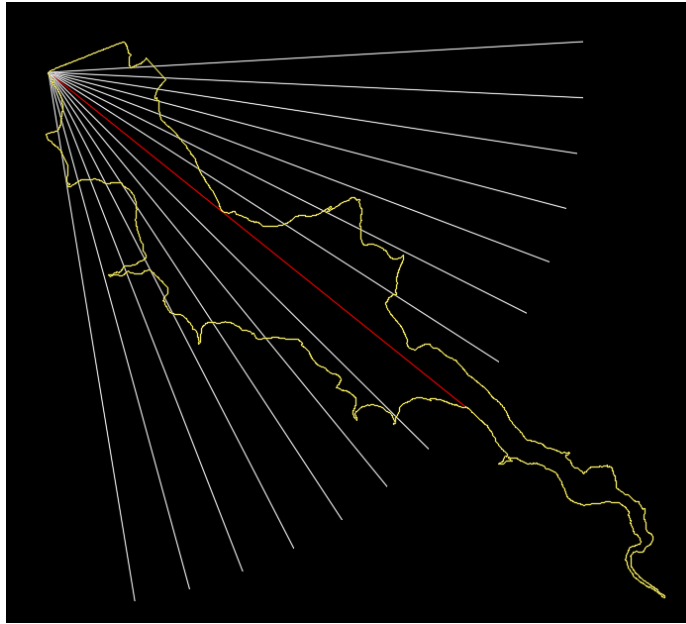
B.4. Residual Freeboard (TR-69)



CALCULATION COVER SHEET

Shaping
the Quality
of Life

Project Name:	Matanzas Creek Dam – Supplemental Watershed Plan-ED	
Project Number:	2006-048	
Title of Calculations:	Required Freeboard for Wind Speed and Wave Action	
Calculations By:	Hayden C.	Date: 6/19/2021
Reviewed By:	K. Curtis	Date: 7/20/2021
Number of pages (Including cover sheet): 4		
DESCRIPTION & PURPOSE		
Determine the minimum required freeboard for the Matanzas Creek Dam auxiliary spillway hydrograph per TR-60. TR-69 guidelines were followed to calculate the freeboard for wind speed and wave action.		
REFERENCES / DATA		
References: • CA DSOD, Division of Safety of Dams Inspection and Reevaluation Protocols, September 2018. • NRCS, Technical Release 210-60 – Earth Dams and Reservoirs, March 2019. • NRCS, Technical Release 69 – Riprap for Slope Protection Against Action, May 1983. • USBR, Design of Small Dams, Third Edition, 1987. Data: • Data from TR-69 Figures and Tables • NOAA Climate Data Online Search – Santa Rosa Airport (Station USW00023213)		
DESIGN CRITERIA / ANALYSIS / METHODS / ASSUMPTIONS		
The steps and procedures found in this document follow the guidelines listed in NRCS TR-69. <u>Effective Fetch Length</u> Fetch lengths were determined with the longest possible fetch during the ASH/SDH peak reservoir elevation being the center fetch and the other fetch lengths being at 6 degree increments. See next page for fetch length calculations.		



1	2	3	4	5	6
No.	α	$\cos \alpha$	$\cos^2 \alpha$	Distance (ft)	Col. 4 x 5
1	42	0.743	0.552	793.4	438.2
2	36	0.809	0.655	875.1	572.8
3	30	0.866	0.750	830.8	623.1
4	24	0.914	0.835	858.5	716.5
5	18	0.951	0.905	895.5	810.0
6	12	0.978	0.957	1104.8	1057.0
7	6	0.995	0.989	1345.2	1330.5
8	0	1.000	1.000	4014.9	4014.9
9	6	0.995	0.989	3673.0	3632.9
10	12	0.978	0.957	2577.0	2465.6
11	18	0.951	0.905	2241.6	2027.5
12	24	0.914	0.835	137.3	114.6
13	30	0.866	0.750	48.9	36.7
14	36	0.809	0.655	24.8	16.2
15	42	0.743	0.552	18.6	10.3
Sum	-	13.511	-	19439.4	17866.7

Effective Fetch (Col. 6/3) 1322.39 ft
Effective Fetch 0.25 mi

Required Freeboard Calculation: Using Santa Rosa Airport Wind Speed Data

NOAA wind speed for Santa Rosa Airport was considered for use at Matanzas Creek Dam. A safety factor was estimated to account for regional differences and to be conservative.

NOAA max 5-sec wind speed at Santa Rosa Airport: 53.9 mph

Safety Factor 1.3

Design Wind Speed: 70.07 mph

Wind Setup + Wave Runup Calculation

Description	Variable	Quantity	Units	Notes
Max Fastest Mile Velocity	V	85	mph	See TR 69 figure 4
Effective Fetch Length	Fe	0.25	mi	Fetch Length
Effective Fetch Length	Fe	1322	ft	
Dam Face Slope	S	19.8	deg	3:1 Slope
Overland Wind Speed	UL	70.1	mph	See TR 69 figure 5 (maximum = Max Fastest Mile Velocity (V))
Overland Wind Speed	UL	102.8	ft/s	
Wind Ratio	Uw/UL	1.05	-	See TR 69 figure 7
Overwater Wind Speed	Uw	73.6	mph	
Overwater Wind Speed	Uw	107.9	ft/s	
Average Water Depth Along Fetch	D	42.39	ft	2013 LiDAR and SITES Results
Wind Setup	S	0.02	ft	See TR 69 figure 13
Wave Height	Hs	1.64	ft	See TR 69 figure 2
Wave Length	L	24.10	ft	See TR 69 figure 11
Wave Runup	R	1.46	ft	
Wind Setup + Wave Runup	S + R	1.48	ft	Final Required Freeboard

Required Freeboard Calculation: Using Maximum Wind Speed from Per Figure 4 of TR-69

Wind Setup + Wave Runup Calculation

Description	Variable	Quantity	Units	Notes
Max Fastest Mile Velocity	V	85	mph	See TR 69 figure 4
Effective Fetch Length	Fe	0.25	mi	Fetch Length
Effective Fetch Length	Fe	1322	ft	
Dam Face Slope	S	19.8	deg	3:1 Slope
Overland Wind Speed	UL	85.0	mph	See TR 69 figure 5 (maximum = Max Fastest Mile Velocity (V))
Overland Wind Speed	UL	124.7	ft/s	
Wind Ratio	Uw/UL	1.05	-	See TR 69 figure 7
Overwater Wind Speed	Uw	89.3	mph	
Overwater Wind Speed	Uw	130.9	ft/s	
Average Water Depth Along Fetch	D	42.39	ft	2013 LiDAR and SITES Results
Wind Setup	S	0.03	ft	See TR 69 figure 13
Wave Height	Hs	2.02	ft	See TR 69 figure 2
Wave Length	L	28.56	ft	See TR 69 figure 11
Wave Runup	R	1.77	ft	
Wind Setup + Wave Runup	S + R	1.81	ft	Final Required Freeboard

Required Freeboard Calculation: USBR recommendation of 100 mph wind speed

Wind Setup + Wave Runup Calculation

Description	Variable	Quantity	Units	Notes
Max Fastest Mile Velocity	V	85	mph	See TR 69 figure 4
Effective Fetch Length	Fe	0.25	mi	Fetch Length
Effective Fetch Length	Fe	1322	ft	
Dam Face Slope	S	19.8	deg	3:1 Slope
Overland Wind Speed	UL	100.0	mph	See TR 69 figure 5 (maximum = Max Fastest Mile Velocity (V))
Overland Wind Speed	UL	146.7	ft/s	
Wind Ratio	Uw/UL	1.05	-	See TR 69 figure 7
Overwater Wind Speed	Uw	105.0	mph	
Overwater Wind Speed	Uw	154.0	ft/s	
Average Water Depth Along Fetch	D	42.39	ft	2013 LiDAR and SITES Results
Wind Setup	S	0.05	ft	See TR 69 figure 13
Wave Height	Hs	2.39	ft	See TR 69 figure 2
Wave Length	L	32.96	ft	See TR 69 figure 11
Wave Runup	R	2.09	ft	
Wind Setup + Wave Runup	S + R	2.13	ft	<i>Final Required Freeboard</i>

Final Required Freeboard for Matanzas Creek Dam = **2.1 feet**

B.5. Calibration

CALCULATION SUMMARY

Project Name:	Matanzas Creek Dam – Watershed Plan-EA	
Project Number:	2006-048	
Title of Calculations:	Hydrologic Model Calibration	
Calculations By:	K. Curtis	Date: 07/21/2021
Reviewed By:	R. Anderson	Date: 08/03/2021
Number of pages (Including cover sheet): 16		

DESCRIPTION & PURPOSE

The purpose of this analysis is to summarize the methodology and results of the hydrologic model calibration for the Matanzas Creek Dam as part of the Watershed Plan-EA. A calibrated model from ESA & Sonoma County was provided. The Matanzas and Spring Creek tributaries were extracted from the model and calibrated using new precipitation data. This summary outlines the data used for calibration, and methods utilized in calibrated the HEC-HMS model.

REFERENCES / DATA

References:

- Sonoma County Real-time Rainfall, River-Stream, and Reservoir Data
www.sonoma.onerain.com
- USGS National Water Information System
<https://maps.waterdata.usgs.gov/mapper/index.html>
- ESA hydrology report and calibration memo
- ESA model SRC Climate Adaptation Model
- HMS Tutorials

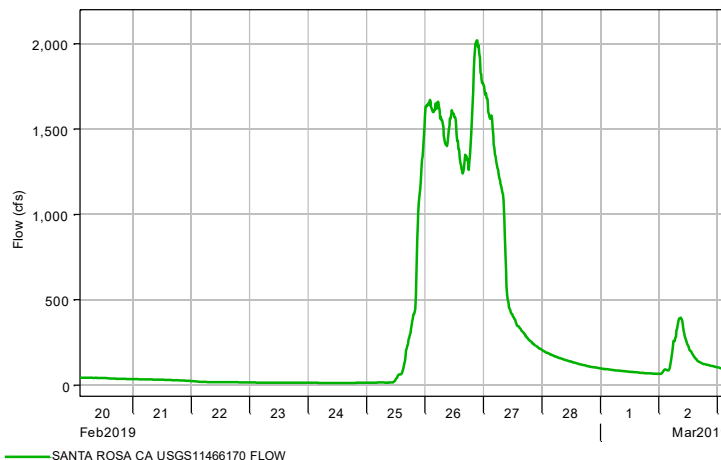
Data:

- Precipitation Depths – Sonoma Onerain
- Stream Flow Data – USGS NWIS, Sonoma Onerain
- Stage/Elevation Data - USGS NWIS, Sonoma Onerain

DESIGN CRITERIA / ANALYSIS / METHODS / ASSUMPTIONS

Calibration Storm Event:

- February 25-28, 2019
- Peak Flow at USGS 11466170 Matanzas Creek – 2020 cfs



CALCULATION SUMMARY

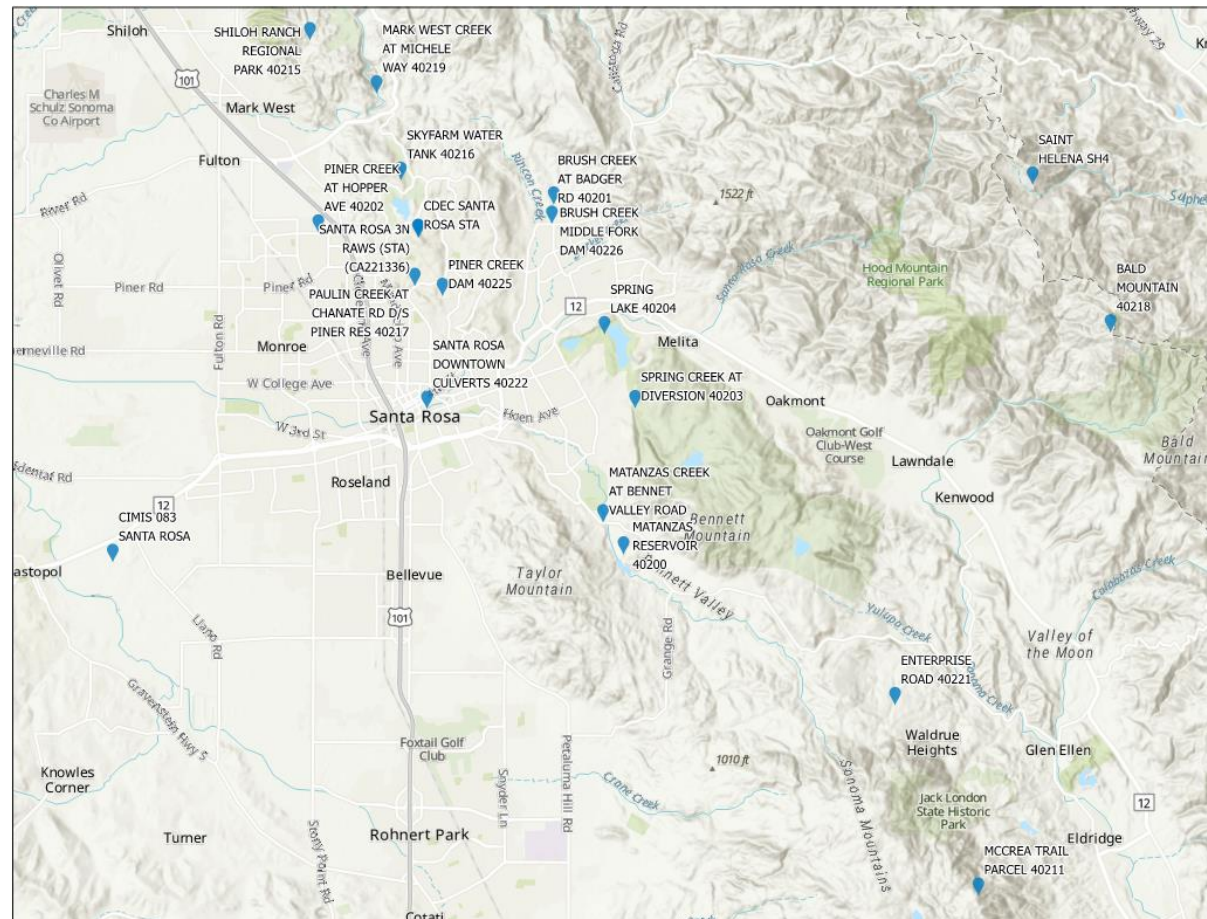
Project Name:	Matanzas Creek Dam – Watershed Plan-EA	
Project Number:	2006-048	
Title of Calculations:	Hydrologic Model Calibration	
Calculations By:	K. Curtis	Date: 07/21/2021
Reviewed By:	R. Anderson	Date: 08/03/2021
Number of pages (Including cover sheet): 16		

Gages:

Precipitation

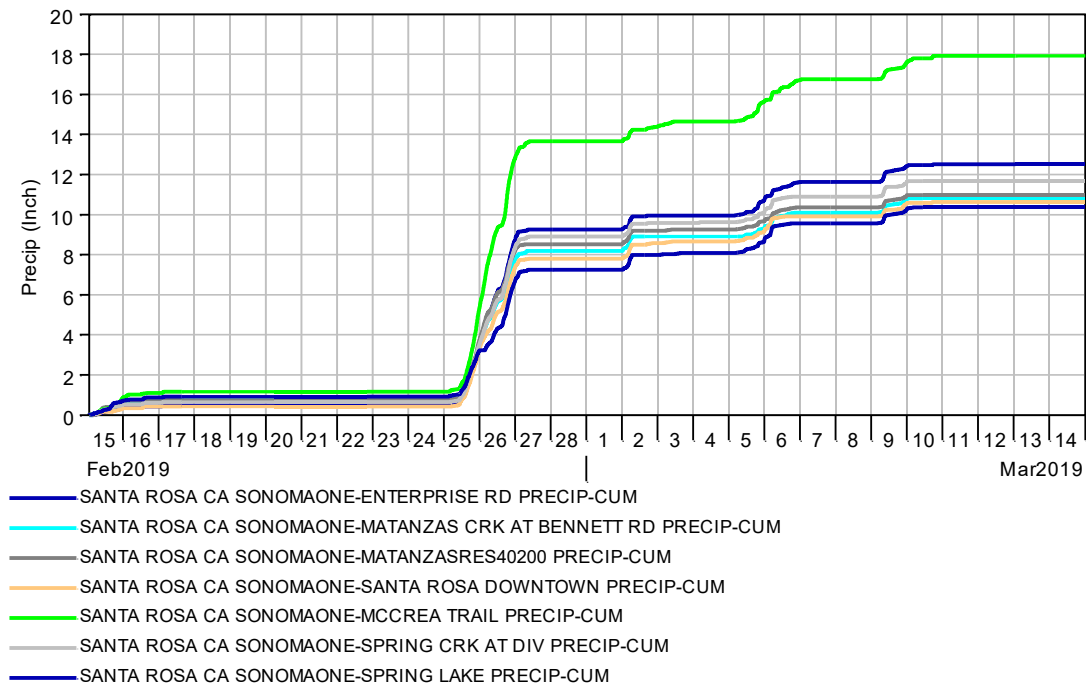
1. Matanzas Creek at Bennet Valley Road
2. Matanzas Reservoir 40200
3. Enterprise Road 40221
4. Spring Creek at Diversion 40203
5. Spring Lake 40204
6. Santa Rosa Downtown Culverts 40222
7. McCrea Trail 40211

There were 21 gages on Sonoma Onerain Website that had precipitation data for the February 2019 rainfall event within reasonable distance of the project area. That list of gages was refined, based on the Thiessen Polygon analysis. The above 7 rain gages were used from the calibration model and the calibration rainfall.



CALCULATION SUMMARY

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Reviewed By:	R. Anderson	Date: 08/03/2021
Number of pages (Including cover sheet): 16		



Stream Flow & Stage

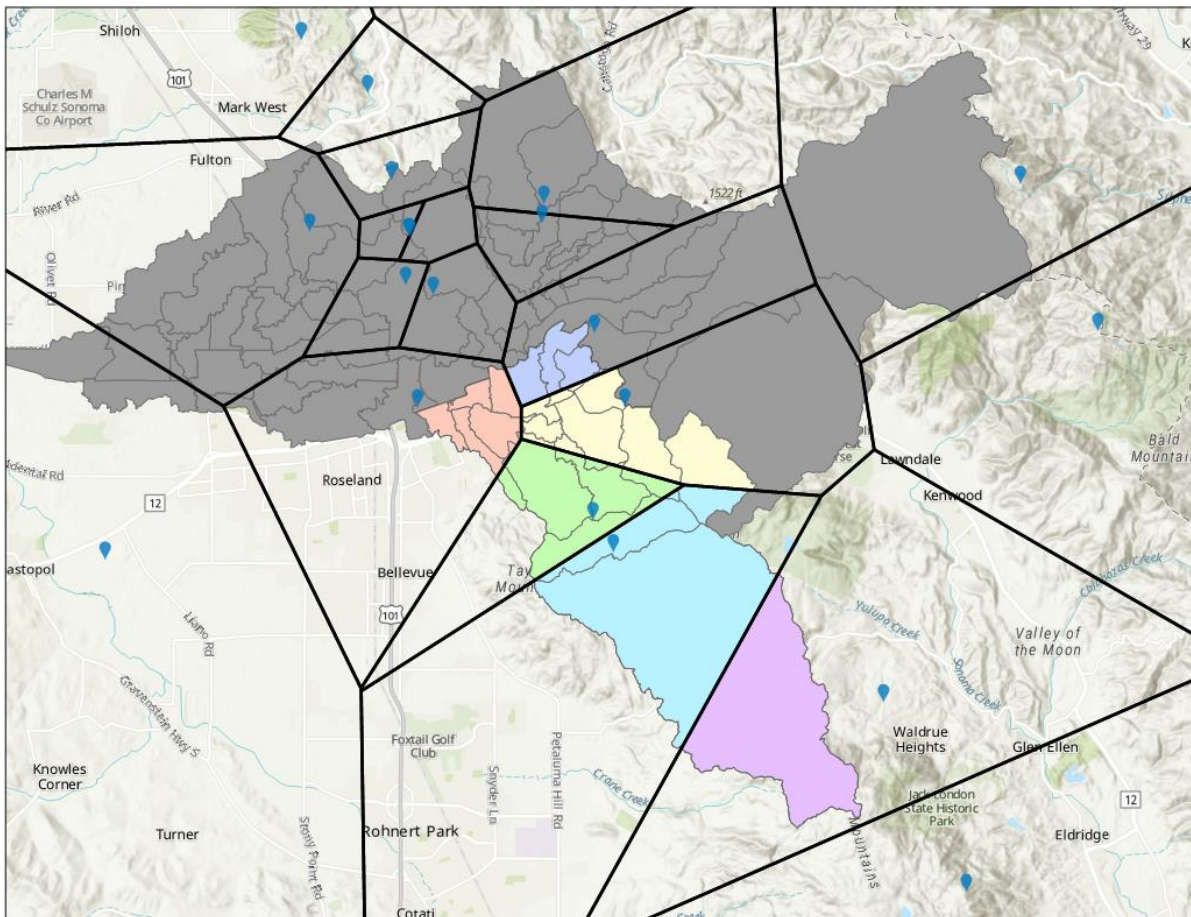
1. USGS 11466170 MATANZAS C A SANTA ROSA CA – Flow, Stage
2. USGS 11466150 MATANZAS C RES OUTFLOW NR SANTA ROSA CA – Flow, Stage (limited)
3. Matanzas Creek at Bennet Valley Road – Stage
4. USGS Matanzas Reservoir – Stage
5. Spring Creek at Diversion 40203 - Stage

CALCULATION SUMMARY

Project Name:	Matanzas Creek Dam – Watershed Plan-EA	
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Reviewed By:	R. Anderson	Date: 08/03/2021
Number of pages (Including cover sheet): 16		

Thiessen Polygon (Depth Weighting/Area of Influence/Calibration gages):

Thiessen Polygons were developed for all 21 gages using GIS. Based on the resulting polygons, the list of gages was narrowed down to 6 initially, but a 7th (McCrea Trail) was added at the request of Sonoma County. The polygons were used to determine the area of influence for each rain gage. This information was utilized in the Gage Weights Meteorological Model in HEC-HMS.



CALCULATION SUMMARY

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Number of pages (Including cover sheet): 16			

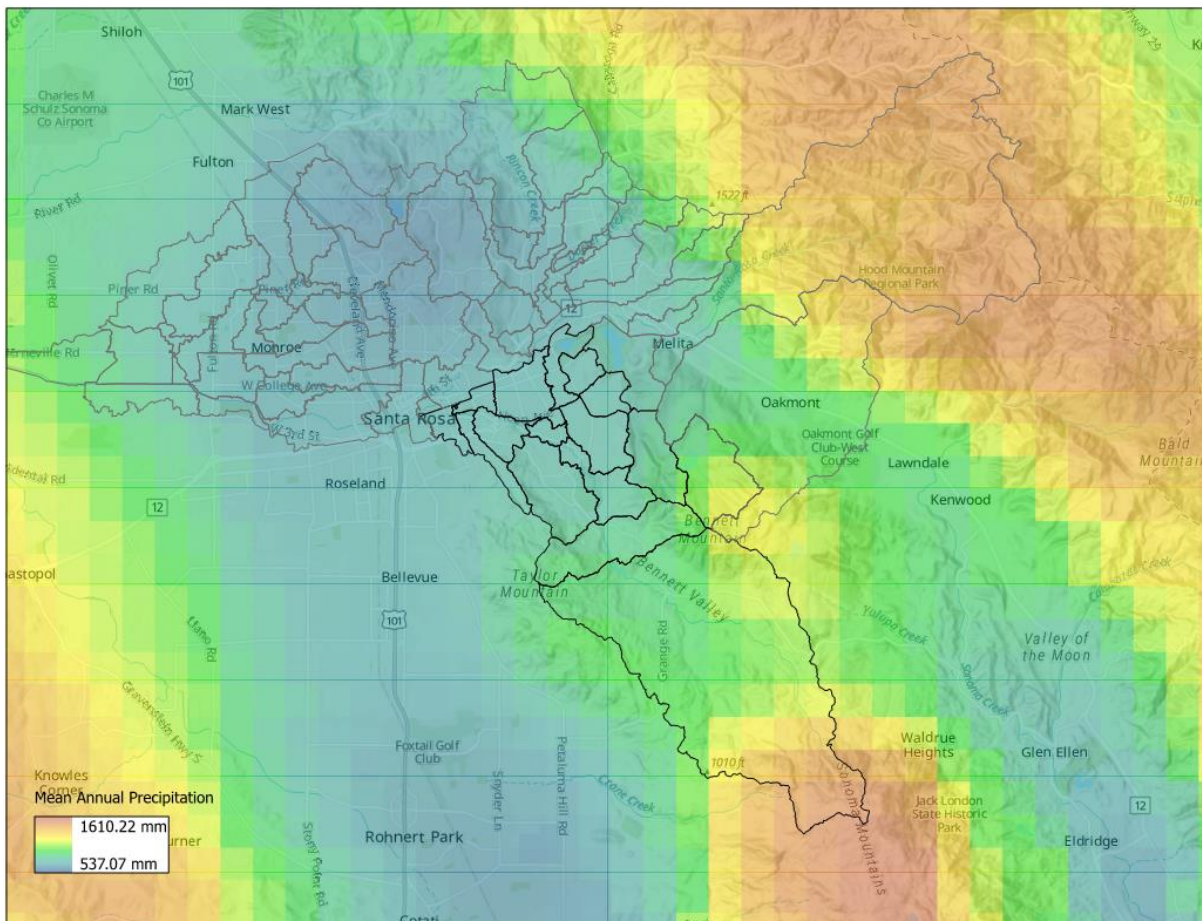
Watershed	Parameter	Thiessen Polygon Weighting						
		Gages						
		Matanzas Crk at Bennett	Matanzas Resvr	Enterprise Rd	Spring Creek at Div	Spring Lake	Santa Rosa Downtown	McCrea Trail
SPRG1	Area (acre)						123.73	
	Weight	0.00	0.00	0.00	0.00	0.00	1.00	0.00
SPRG2	Area (acre)				94.06	235.99	181.76	
	Weight	0.00	0.00	0.00	0.18	0.46	0.36	0.00
SPRG3	Area (acre)				38.02	259.21		
	Weight	0.00	0.00	0.00	0.13	0.87	0.00	0.00
SPRG4	Area (acre)				15.81	197.26		
	Weight	0.00	0.00	0.00	0.07	0.93	0.00	0.00
SPRG5	Area (acre)				239.16	8.72		
	Weight	0.00	0.00	0.00	0.96	0.04	0.00	0.00
SPRG6	Area (acre)	32.94			479.82			
	Weight	0.06	0.00	0.00	0.94	0.00	0.00	0.00
SPRG7	Area (acre)	124.86	16.26		455.14			
	Weight	0.21	0.03	0.00	0.76	0.00	0.00	0.00
MAT1	Area (acre)						167.65	
	Weight	0.00	0.00	0.00	0.00	0.00	1.00	0.00
MAT2	Area (acre)	85.15					162.83	
	Weight	0.34	0.00	0.00	0.00	0.00	0.66	0.00
MAT3	Area (acre)				11.67		283.16	
	Weight	0.00	0.00	0.00	0.04	0.00	0.96	0.00
MAT4	Area (acre)				114.90		0.24	
	Weight	0.00	0.00	0.00	1.00	0.00	0.00	0.00
MAT5	Area (acre)	815.47			35.41		22.26	
	Weight	0.93	0.00	0.00	0.04	0.00	0.03	0.00
MAT6	Area (acre)	429.82			61.36			
	Weight	0.88	0.00	0.00	0.12	0.00	0.00	0.00
MAT7	Area (acre)	422.91	627.46					
	Weight	0.40	0.60	0.00	0.00	0.00	0.00	0.00
MAT8	Area (acre)	0.33	4089.92	3274.75				
	Weight	0.00	0.56	0.44	0.00	0.00	0.00	0.00
LAKEILS	Area (acre)	0.66	253.30		614.79			
	Weight	0.0008	0.29	0.00	0.71	0.00	0.00	0.00

CALCULATION SUMMARY

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Number of pages (Including cover sheet): 16		

Mean Annual Precipitation (MAP)

The mean annual precipitation data for the project area was determined using the dataset developed by the PRISM climate group at Oregon State University. The MAP is the 30-year normal precipitation data for the period of 1981-2010. The MAP was determined for each subbasin centroid and each precipitation gage location. The ratio of the MAP was used to adjust for regional or elevation bias in the precipitation data. This information was input into the indexing options in the precipitation methods in HEC-HMS.



CALCULATION SUMMARY

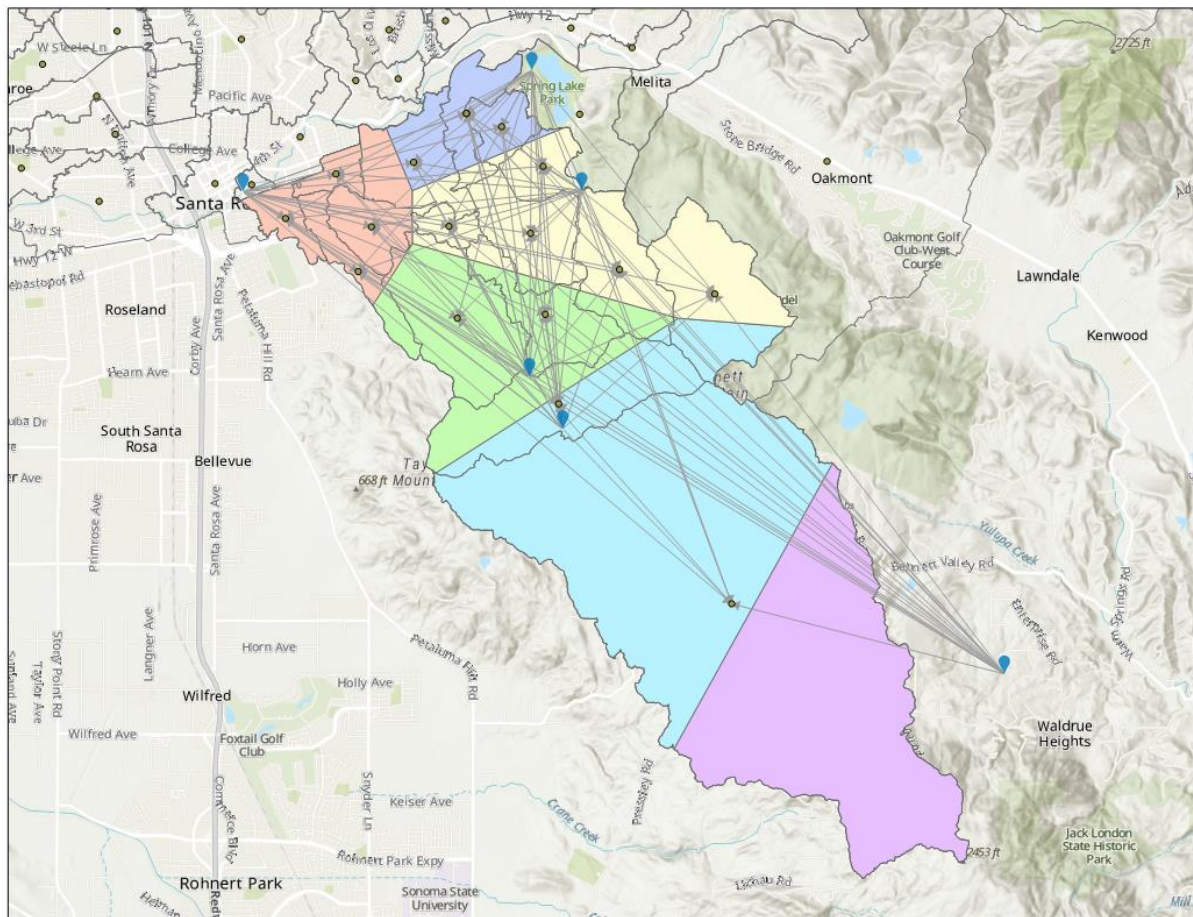
Project Name:	Matanzas Creek Dam – Watershed Plan-EA							
Project Number:	2006-048							
Title of Calculations:	Hydrologic Model Calibration							
Calculations By:	K. Curtis				Date: 07/21/2021			
Reviewed By:	R. Anderson				Date: 08/03/2021			
Number of pages (Including cover sheet): 16								
		876.75	896.83	955.89	836.83	826.94	817.89	981.98
	MAP Weighting							
Watershed	Parameter	Gages						
		Matanzas Crk at Bennett	Matanzas Resvr	Enterprise Rd	Spring Creek at Div	Spring Lake	Santa Rosa Downtown	McCrea Trail
SPRG1	MAP - Subbasin	823.48						
	Ratio	0.94	0.92	0.86	0.98	1.00	1.01	0.84
SPRG2	MAP - Subbasin	829.57						
	Ratio	0.95	0.93	0.87	0.99	1.00	1.01	0.84
SPRG3	MAP - Subbasin	826.56						
	Ratio	0.94	0.92	0.86	0.99	1.00	1.01	0.84
SPRG4	MAP - Subbasin	832.41						
	Ratio	0.95	0.93	0.87	0.99	1.01	1.02	0.85
SPRG5	MAP - Subbasin	839.67						
	Ratio	0.96	0.94	0.88	1.00	1.02	1.03	0.86
SPRG6	MAP - Subbasin	841.42						
	Ratio	0.96	0.94	0.88	1.01	1.02	1.03	0.86
SPRG7	MAP - Subbasin	886.79						
	Ratio	1.01	0.99	0.93	1.06	1.07	1.08	0.90
MAT1	MAP - Subbasin	822.66						
	Ratio	0.94	0.92	0.86	0.98	0.99	1.01	0.84
MAT2	MAP - Subbasin	841.75						
	Ratio	0.96	0.94	0.88	1.01	1.02	1.03	0.86
MAT3	MAP - Subbasin	834.65						
	Ratio	0.95	0.93	0.87	1.00	1.01	1.02	0.85
MAT4	MAP - Subbasin	838.71						
	Ratio	0.96	0.94	0.88	1.00	1.01	1.03	0.85
MAT5	MAP - Subbasin	855.84						
	Ratio	0.98	0.95	0.90	1.02	1.03	1.05	0.87
MAT6	MAP - Subbasin	841.86						
	Ratio	0.96	0.94	0.88	1.01	1.02	1.03	0.86
MAT7	MAP - Subbasin	880.84						
	Ratio	1.00	0.98	0.92	1.05	1.07	1.08	0.90
MAT8	MAP - Subbasin	927.10						
	Ratio	1.06	1.03	0.97	1.11	1.12	1.13	0.94
LAKEILS	MAP - Subbasin	978.36						
	Ratio	1.12	1.09	1.02	1.17	1.18	1.20	1.00

CALCULATION SUMMARY

Project Name:	Matanzas Creek Dam – Watershed Plan-EA	
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Temporal Weighting:

This distance between each subbasin centroid and the precipitation gage location was calculated. The inverse distance was calculated for each. More or less this information was used to determine which precipitation gage would be used for the temporal distribution of rainfall at each subbasin. Essentially the closest gage to the subbasin centroid was assigned a temporal weight of 1. This information was used in the Gage Weights Meteorological Model in HEC-HMS.





CALCULATION SUMMARY



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Project Number:	2006-048	
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Calculations By:	K. Curtis	Date: 07/21/2021
Reviewed By:	R. Anderson	Date: 08/03/2021
Number of pages (Including cover sheet): 16		

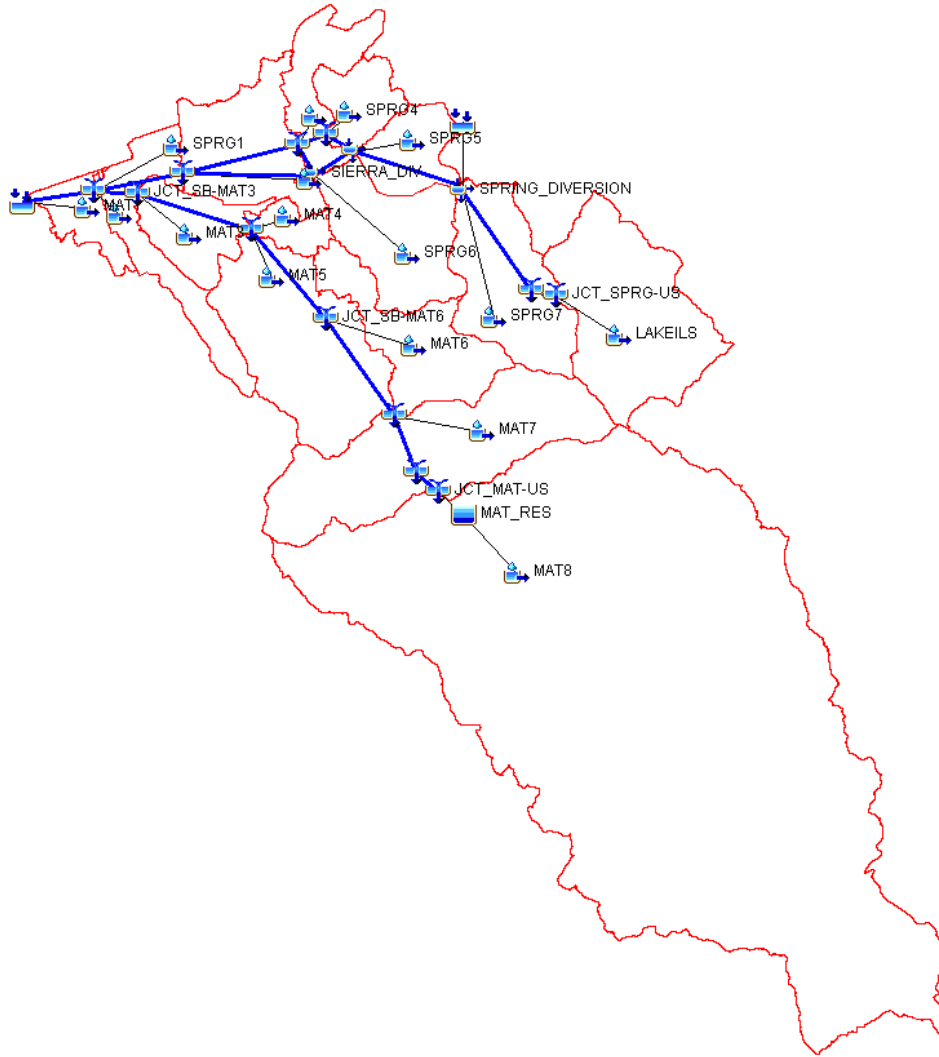
Inverse Distance Weighting						
Parameter	Gages					
	Matanzas Crk at Bennett	Matanzas Resvr	Enterprise Rd	Spring Creek at Div	Spring Lake	Santa Rosa Downtown
ID (ft ⁻¹)	6.96E-05	5.72E-05	2.34E-05	7.92E-05	8.81E-05	2.06E-04
TW	0.13	0.11	0.04	0.15	0.17	0.39
ID (ft ⁻¹)	8.01E-05	6.39E-05	2.50E-05	1.14E-04	1.30E-04	1.13E-04
TW	0.15	0.12	0.05	0.22	0.25	0.21
ID (ft ⁻¹)	7.21E-05	5.92E-05	2.51E-05	1.41E-04	2.49E-04	8.24E-05
TW	0.11	0.09	0.04	0.22	0.40	0.13
ID (ft ⁻¹)	7.76E-05	6.33E-05	2.63E-05	1.90E-04	3.06E-04	7.32E-05
TW	0.11	0.09	0.04	0.26	0.42	0.10
ID (ft ⁻¹)	9.26E-05	7.41E-05	2.84E-05	4.27E-04	2.02E-04	6.48E-05
TW	0.10	0.08	0.03	0.48	0.23	0.07
ID (ft ⁻¹)	1.36E-04	9.85E-05	3.02E-05	2.93E-04	1.20E-04	6.72E-05
TW	0.18	0.13	0.04	0.39	0.16	0.09
ID (ft ⁻¹)	1.39E-04	1.15E-04	3.50E-05	2.23E-04	8.97E-05	5.07E-05
TW	0.21	0.18	0.05	0.34	0.14	0.08
ID (ft ⁻¹)	6.71E-05	5.60E-05	2.29E-05	6.56E-05	6.79E-05	3.90E-04
TW	0.10	0.08	0.03	0.10	0.10	0.58
ID (ft ⁻¹)	9.71E-05	7.56E-05	2.56E-05	8.21E-05	7.34E-05	1.39E-04
TW	0.20	0.15	0.05	0.17	0.15	0.28
ID (ft ⁻¹)	8.96E-05	7.01E-05	2.52E-05	9.14E-05	8.71E-05	1.47E-04
TW	0.18	0.14	0.05	0.18	0.17	0.29
ID (ft ⁻¹)	1.14E-04	8.40E-05	2.74E-05	1.42E-04	1.11E-04	9.34E-05
TW	0.20	0.15	0.05	0.25	0.19	0.16
ID (ft ⁻¹)	2.10E-04	1.28E-04	2.99E-05	1.10E-04	7.54E-05	7.84E-05
TW	0.33	0.20	0.05	0.17	0.12	0.12
ID (ft ⁻¹)	3.04E-04	1.68E-04	3.35E-05	1.52E-04	7.99E-05	5.98E-05
TW	0.38	0.21	0.04	0.19	0.10	0.08
ID (ft ⁻¹)	4.89E-04	7.68E-04	3.74E-05	9.11E-05	5.84E-05	5.13E-05
TW	0.33	0.51	0.03	0.06	0.04	0.03
ID (ft ⁻¹)	6.41594E-05	8.03E-05	6.92958E-05	4.4418E-05	3.43E-05	3.053E-05
TW	0.20	0.25	0.21	0.14	0.11	0.09
ID (ft ⁻¹)	9.61204E-05	9.6E-05	4.08443E-05	0.00011584	6.76E-05	4.0413E-05
TW	0.21	0.21	0.09	0.25	0.15	0.09

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HMS Model Methods (Gage Weights/IDW)

Utilized existing model from Sonoma County (SRC Climate Adaption Model). Extracted the subbasins for Matanzas Creek and Spring Creek with the outlet at the USGS stream gage on Matanzas Creek above the junction with Santa Rosa Creek. All the parameters for the existing model were left unchanged aside from Elevation-Area-Discharge data for Matanzas Reservoir based on the 2021 JDE Analysis.





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New Meteorological models were created for the Feb 2019 event using the rainfall data from the 7 gages listed previously. Two meteorological model methods were used in HEC-HMS: Gage Weights and Inverse Distance Weighting (IDW). The gage weights method used the area weight from the Thiessen polygons, time weight from the temporal weighting/Inverse distance, and Indexing from MAP ratio. The IDW used the latitude and longitude coordinates for each subbasin centroid and gage location along with indexing from the MAP ratio. The results from the two methods appeared to be the same.

Calibration Parameters

Calibrated Parameter-SCS CN Scale Factor for all subbasins

Method-Univariate

Goal-minimization

Objective Statistic-Used all of the minimization statistics for comparison, First Lag Autocorrelation yielded the best results

Snyder's parameters (i.e., lag time and peaking coefficient) were adjusted but it was determined those parameters had a lesser impact. CN and Stage-Storage-Discharge had the most significant impact on the calibration.

Proposed Parameters and Error Statistics

20% reduction in the CN for all subbasins

Objective Statistic	Simulated			Observed		
	Discharge Volume (in)	Peak Flow (cfs)	Time of Peak	Discharge Volume (in)	Peak Flow (cfs)	Time of Peak
First Lag Autocorrelation	5.19	2,377.3	20:45	5.2	2,020	21:15
Mean of Absolute Residuals	5	2,343.4	20:45	5.2	2,020	21:15
Mean of Squared Residuals	5.11	2,343.4	20:45	5.2	2,020	21:15
Sum of Absolute Residuals	5	2,343.4	20:45	5.2	2,020	21:15
Sum of Squared Residuals	5.11	2,363.5	20:45	5.2	2,020	21:15

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Objective Statistic	Volume - Error Statistics		Peak Flow - Error Statistics	
	Difference	Percent Difference	Difference	Percent Difference
First Lag Autocorrelation	-0.01	-0.19%	357.3	17.7%
Mean of Absolute Residuals	-0.2	-3.8%	323.4	16.0%
Mean of Squared Residuals	-0.09	-1.7%	323.4	16.0%
Sum of Absolute Residuals	-0.2	-3.8%	323.4	16.0%
Sum of Squared Residuals	-0.09	-1.7%	343.5	17.0%

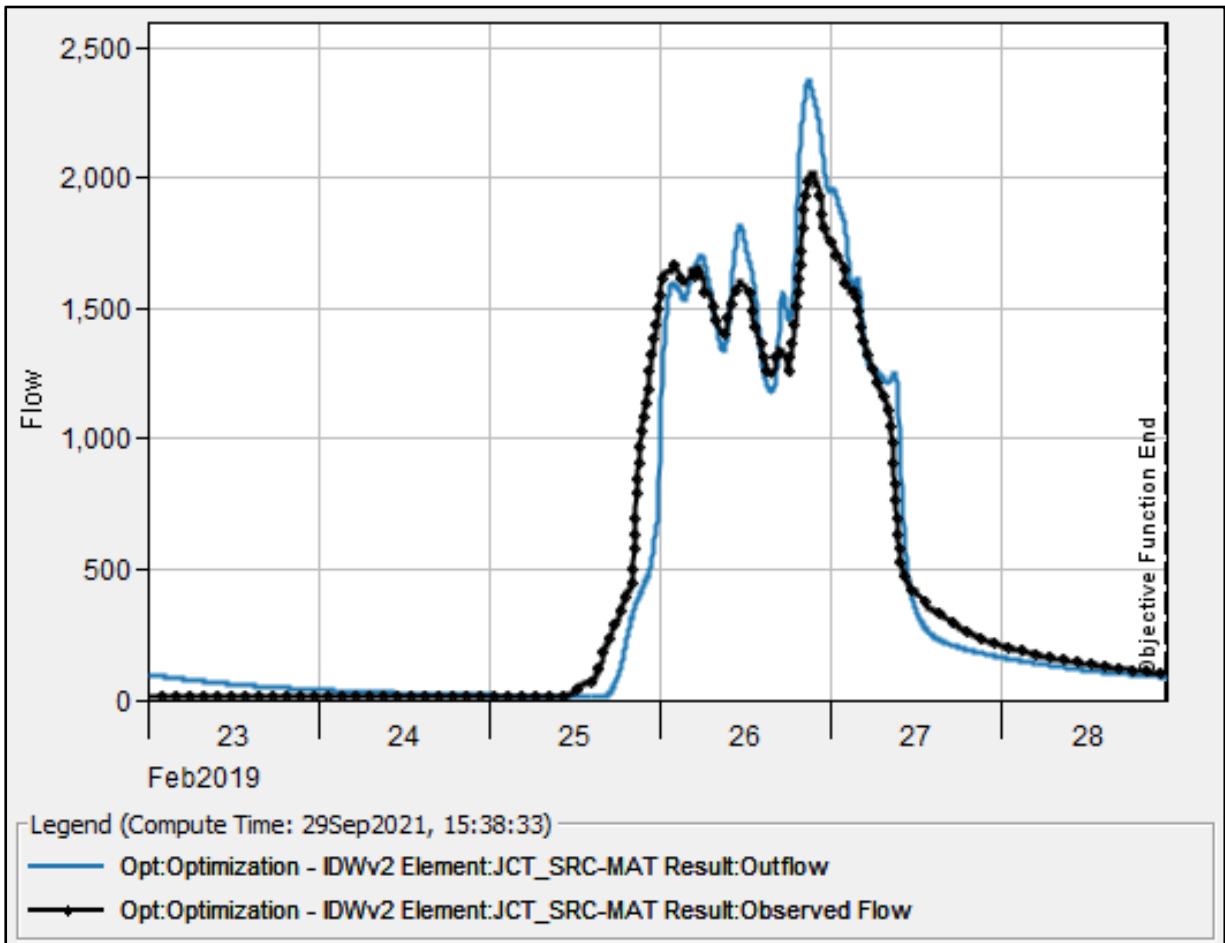
Objective Statistic	Error Statistics			Optimized CN Scale Factor - All Subbasins
	RMSE Std Dev	% Bias	Nash-Sutcliffe	
First Lag Autocorrelation	0.2	-0.14	0.944	0.799
Mean of Absolute Residuals	0.2	-3.68	0.938	0.777
Mean of Squared Residuals	0.2	-1.6	0.943	0.786
Sum of Absolute Residuals	0.2	-3.68	0.938	0.777
Sum of Squared Residuals	0.2	-1.6	0.943	0.786

Performance Rating	RSR	NSE	PBIAS (%)		
			Streamflow	Sediment	N, P
Very good	$0.00 \leq RSR \leq 0.50$	$0.75 < NSE \leq 1.00$	$PBIAS < \pm 10$	$PBIAS < \pm 15$	$PBIAS < \pm 25$
Good	$0.50 < RSR \leq 0.60$	$0.65 < NSE \leq 0.75$	$\pm 10 \leq PBIAS < \pm 15$	$\pm 15 \leq PBIAS < \pm 30$	$\pm 25 \leq PBIAS < \pm 40$
Satisfactory	$0.60 < RSR \leq 0.70$	$0.50 < NSE \leq 0.65$	$\pm 15 \leq PBIAS < \pm 25$	$\pm 30 \leq PBIAS < \pm 55$	$\pm 40 \leq PBIAS < \pm 70$
Unsatisfactory	$RSR > 0.70$	$NSE \leq 0.50$	$PBIAS \geq \pm 25$	$PBIAS \geq \pm 55$	$PBIAS \geq \pm 70$

Moriasi, et. al, 2007 developed a performance rating table based on commonly used statistical measures to evaluate model performance.

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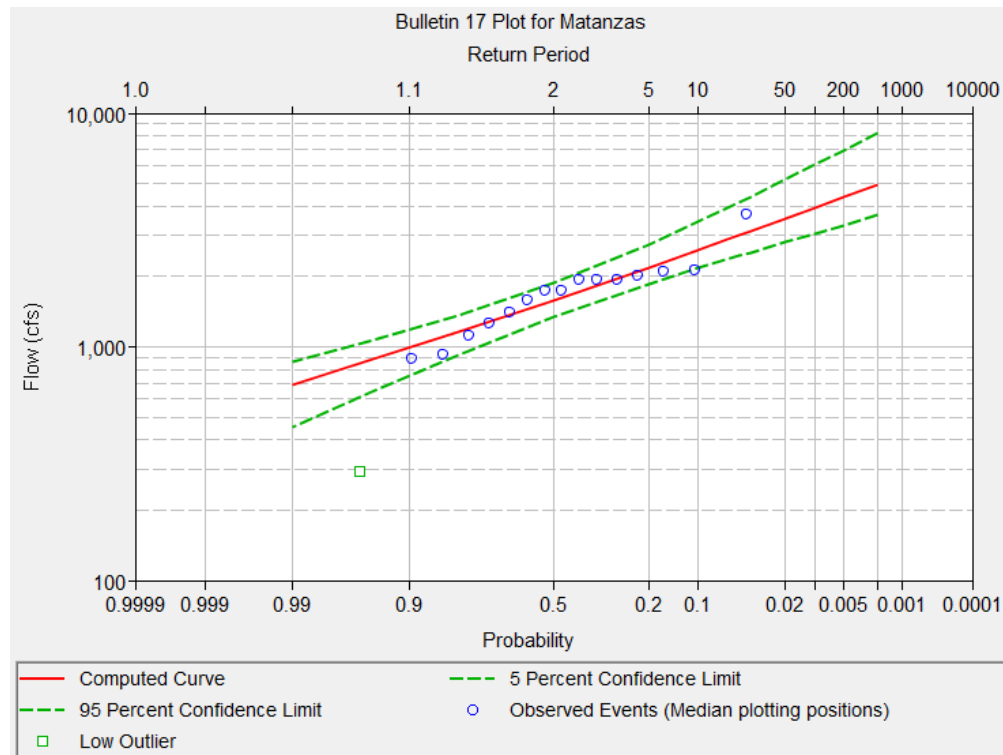
First Lag Autocorrelation; CN for MAT 71.4, 20% reduction in all CN's. Goal was to calibrate to a combination of peak flow and volume as opposed to just the peak flow. Using that approach results in a hydrograph that matches the overall shape of the storm fairly well and yields a peak flow that is slightly more conservative than the observed. The main difference is the receding limb or the portion of the hydrograph where flow is attributed to the draining of Matanzas reservoir.

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Verify Calibrated Parameters with New Year's Eve 2005 Storm Event

HEC-SSP Version 2.2 was used to conduct a Bulletin 17-B analysis for the USGS 11466170 stream gage. It is noted that the highest recorded peak flow occurred on December 31, 2005, which is the New Year's Eve 2005 storm event that ESA calibrated their hydrologic model to. Results of the Bulletin 17-B analysis (see below) show that the 2005 rainfall event was approximately a 25-year storm event (calculated percent probability was 4.3%).



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Order	FREQ	FLOW Comput...	FLOW 5 Perce...	FLOW 95 Perc...	FLOW Observ...	t
Label		Comput...	5 Perce...	95 Perc...	Observe...	t
Units	Percent	CFS			CFS	
Type	PROB	LOG			LOG	
1	0.200	4922.6	8253.0	3669.7		
2	0.500	4351.3	6945.2	3325.1		
3	1.000	3933.4	6034.4	3065.2		
4	2.000	3525.5	5185.7	2803.9		
5	4.000	3124.7	4393.8	2538.0		
6	4.268				3700.0	
7	5.000	2996.5	4150.1	2450.7		
8	10.000	2597.7	3424.2	2169.9		
9	10.366				2130.0	
10	16.463				2080.0	
11	20.000	2189.6	2739.1	1863.2		
12	22.561				2020.0	
13	28.659				1940.0	
14	34.756				1940.0	
15	40.854				1920.0	
16	46.951				1730.0	
17	50.000	1589.0	1867.8	1350.2		
18	53.049				1730.0	
19	59.146				1580.0	
20	65.244				1390.0	
21	71.341				1260.0	
22	77.439				1110.0	
23	80.000	1162.5	1366.5	928.4		
24	83.537				925.0	
25	89.634				891.0	
26	95.000	869.2	1059.4	632.0		
27	95.732					
28	99.000	683.0	868.2	454.0		

Reservoir stage data for the 2005 storm event was not available. However, it was observed by Sonoma County that the reservoir stage nearly reached the auxiliary spillway crest (see photo below). It is unclear how long the photo was taken after the peak reservoir stage, but it can be observed that the reservoir stage is within a couple feet of the auxiliary spillway crest.

NOAA Atlas 14 precipitation data was used to determine the precipitation depth of 8.53 inches for the 25-year 24-hour duration storm event. A CA-1 rainfall distribution was used to route the rainfall through the calibrated model (CN = 71.4, etc.). It was determined that the peak reservoir stage was 412 feet (approximately 7.5 inches below the auxiliary spillway crest). Therefore, it was determined that the calibrated CN and other parameters were reasonable.

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Dam crest for Matanzas Creek Dam is shown in the background. Auxiliary spillway crest is located several feet to the right of the shown access road. Photo courtesy of Sonoma Water.

B.6. SITES Output

	ASH&FBH_E xist_72hr	ASH&FBH_ Exist_24hr	ASH&FBH_ Exist_6hr	PSH_Exist	ASH&FBH_ Future_6hr	ASH&FBH_F uture_24hr	ASH&FBH_F uture_72hr	PSH_Future
Site Identification	S1	S1	S1	S1	S1	S1	S1	S1
Watershed Runoff Curve Number	N/A	N/A	N/A	71.	N/A	N/A	N/A	72.
Total Watershed Drainage Area (Sq.Miles)	11.45	11.45	11.45	11.45	11.45	11.45	11.45	11.45
Watershed Time of Concentration (Hours)	N/A	N/A	N/A	2.40	N/A	N/A	N/A	2.40
SDH Rainfall Total (Inches)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
SDH Rainfall Duration (Hours)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
FBH or Storm Rainfall Total (Inches)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
FBH or Storm Rainfall Duration (Hours)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
SDH Inflow Peak (CFS)	5382.1	8157.6	5648.7	N/A	5723.2	8173.4	5391.9	N/A
FBH or Storm Inflow Peak (CFS)	18342.8	15701.8	8347.0	N/A	8429.2	15714.2	18348.2	N/A
Initial Reservoir Elevation (Feet)	377.63	377.63	377.63	377.63	377.63	377.63	377.63	377.63
Maximum WS SDH (Feet)	415.99	417.94	404.59	N/A	404.88	417.96	416.00	N/A
Maximum WS FBH or Storm (Feet)	422.77	421.73	413.52	N/A	413.66	421.73	422.77	N/A
Storage at Max. WS FBH or Storm (Acre-Ft)	2214.8	2127.8	1504.4	N/A	1513.9	2127.8	2214.8	N/A
Top Dam (Feet)	422.77	421.73	415.63	N/A	415.63	421.73	422.77	N/A
Storage, Top Dam (Acre-Ft)	2215.0	2128.0	1653.0	N/A	1653.0	2128.0	2215.0	N/A
Emb. Yardage (CY)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
PSH Drawdown (Days)	N/A	N/A	N/A	5.52	N/A	N/A	N/A	5.52
378 Drawdown (Days)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
PS Crest (Feet)	377.63	377.63	377.63	377.63	377.63	377.63	377.63	377.63
PS Number of Conduits	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
PS Conduit Diameter (Inches)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
PS Conduit Height (Feet)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
PS Conduit Width (Feet)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
PS Conduit Area (Sq. Feet)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Storage, PS Crest (Acre-Ft)	89.	89.	89.	89.	89.	89.	89.	89.
PS Discharge at AS Crest (CFS)	1219.9	1219.9	1219.9	1278.5	1219.9	1219.9	1219.9	1280.7
PS Discharge for SDH (CFS)	1248.7	1265.1	1147.9	N/A	1150.7	1265.3	1248.8	N/A
PS Discharge FBH or Storm (CFS)	1304.8	1296.4	1227.6	N/A	1228.9	1296.4	1304.8	N/A
AS Crest (Feet)	412.63	412.63	412.63	419.55	412.63	412.63	412.63	419.82
Storage, AS Crest (Acre-Ft)	1444.8	1444.8	1444.8	1950.2	1444.8	1444.8	1444.8	1971.5
AS Width (Feet)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
AS Exit Slope (%)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
AS Ret. Curve Index	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
AS Veg. Cover Factor	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
AS Maintenance Code	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
AS Max. Head SDH (Feet)	3.36	5.31	0.00	N/A	0.00	5.33	3.37	N/A
AS Peak Discharge SDH/Storm (CFS)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
AS Exit Velocity SDH or Storm (Ft/S)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
AS Stress SDH or Storm (Lb./Sq.Ft.)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Hp FBH or Storm (Feet)	10.14	9.10	0.89	N/A	1.03	9.10	10.14	N/A
AS Peak Discharge FBH/Storm (CFS)	16732.	13983.	347.	N/A	411.	13996.	16737.	N/A
AS Integ. Dist. FBH or Storm (Feet)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Oe/B FBH or Storm (Acre-Ft/Ft)	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Uncontrolled Drainage Area (Sq.Miles)	11.45	11.45	11.45	11.45	11.45	11.45	11.45	11.45
Number of Errors	0	0	0	0	0	0	0	0