Drainage Analysis Report

Rainbow Pond and Downstream Channel

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1.0 Introduction

The Southern Sandoval County Arroyo Flood Control Authority (SSCAFCA) has identified the Rainbow Pond as a critical flood control facility in the Calabacillas Watershed Park Management Plan (CAWMP), dated February 2015. The proposed Rainbow Pond (see Figure 1) will be located in the Rainbow Watershed, which flows into the Calabacillas Arroyo.

This report documents the hydrologic, hydraulic and scour analyses required for the design of the Rainbow Pond and its downstream infrastructure. The Rainbow Pond is required to receive and attenuate the 1% Annual Chance storm (100-year recurrence interval). The proposed pond will then convey a metered discharge, significantly less than the 100-year storm, through a proposed trapezoidal channel that will discharge to the existing Rainbow Tributary channel located south of Vancouver Rd. SE between Atlantic Rd. SE and Brazos Dr. SE in Rio Rancho, NM. The proposed project elements include construction of a pond embankment and outlet works, an approximately 1500-foot long trapezoidal channel, and reinforced concrete box culverts (RCBC) for 3 roadway crossings between the proposed pond and the existing Rainbow Tributary.

Hydrologic and Hydraulic Modeling for Rainbow Tributary Final Report, a previous study conducted by CH2M Hill, dated March 2017, was utilized to support SSCAFCA's analyses and is discussed later in this report.

2.0 Project Location

The project is in southwestern Rio Rancho, New Mexico. The closest major cross streets are Southern Blvd. and Rainbow Blvd. More specifically, the proposed pond location is between 3rd and 5th Streets just north of Inca Rd. (see Figure 1). The proposed channel and culverts shown in Figure 1 are indicated in yellow and pink respectively. The proposed pond's contributing area is approximately 1 square mile with elevations ranging from 5840-ft at the headwater to 5670-ft at the proposed pond location (1.5-2% slope). The watershed upstream of the pond is approximately 30% developed, with residential houses mostly in ½-acre lots. Directly north (upstream) and south (downstream) of the proposed pond location between the 3rd and the 5th Streets is currently undeveloped. Immediately south of Tulip Rd. is an existing developed residential area surrounded by multi-family housing between Tulip Rd. and Vancouver Rd. and approximately ¼-acre lots below Vancouver Rd.

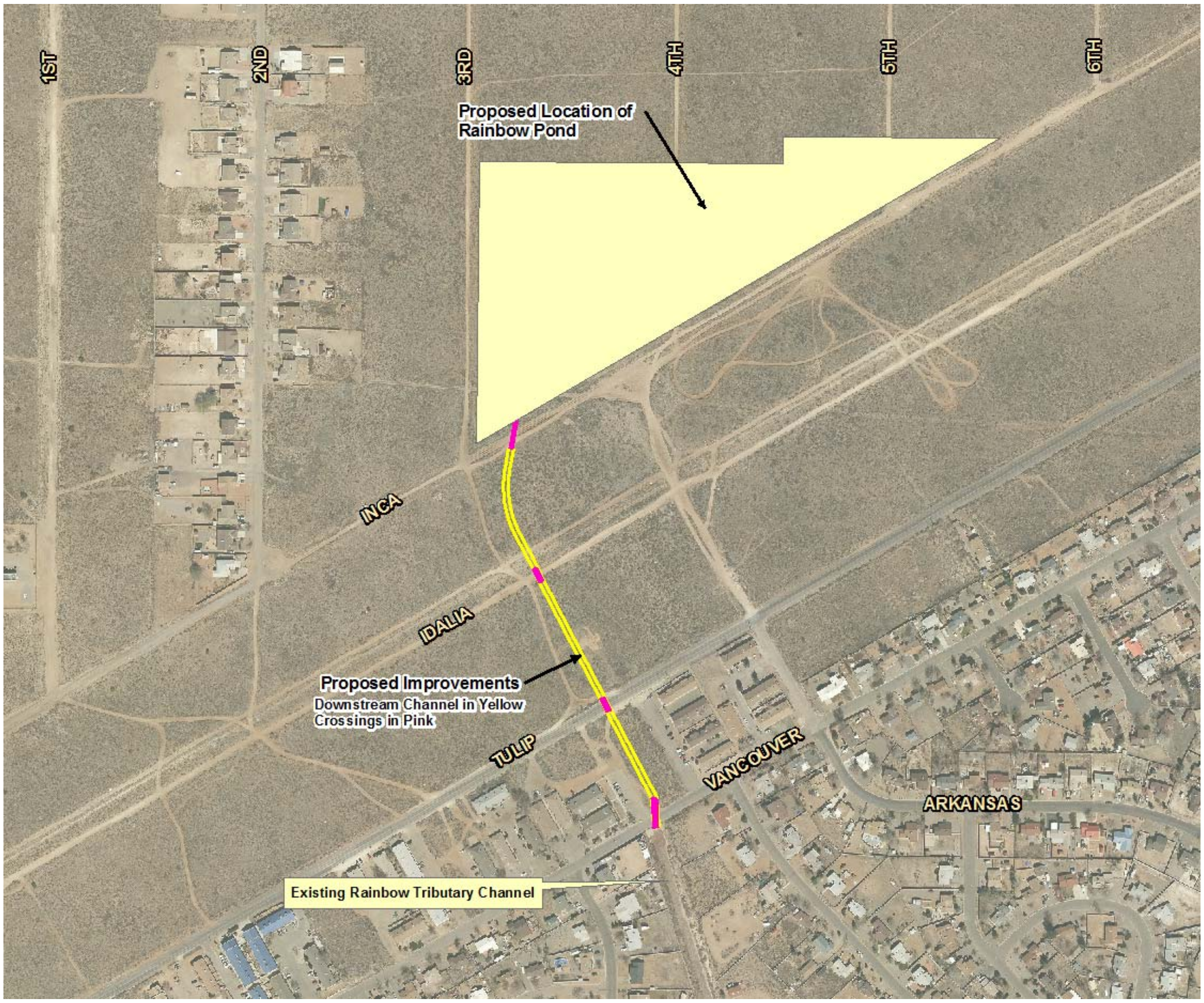

Figure 1 - Proposed Pond Location

There is not a significant change in grade in the project area. There is a gradual slope from north to south and from west to east, and a sag in terrain between 4^{th} and 5^{th} Streets.

Utility crossings have been identified along the proposed channel alignment at several locations. These utilities have been both horizontally and vertically located and provisions will be made during the construction plan design process to either relocate or otherwise mitigate these conflicts. The proposed channel and culvert hydraulics presented herein account for the locations of these utilities and detailed elevation information will be provided in the future construction plan set. The found utilities include: a telecommunications cable line in Inca Rd., two natural gas high-pressure transmission lines (16" and 20" diameter) along Idalia Rd., and City of Rio Rancho (CORR) gravity water and sewer lines in Vancouver Rd.

3.0 USACE Permitting

Action No. SPA-2016-00030 was assigned to this project. It was determined that a Department of the Army permit is not required for this project based on an approved jurisdictional determination (JD), dated January 14, 2016, that there are no waters of the United States on the project site since the site consists entirely of uplands.

4.0 Floodplain Status

The proposed pond and downstream infrastructure are located within two Flood Insurance Rate Map (FIRM) panels: 35043C1888D and 35043C2101D, both effective as of 3/18/2008 (see Figure 2). The proposed Rainbow Pond is located within an *"Area of Minimal Flood Hazard"* (unshaded Zone X), as identified on FIRM panel 35043C1888D. The proposed channel and culverts from downstream of the Inca Rd. crossing to the downstream of the Vancouver Rd. crossing is identified as the *"Calabacillas Arroyo Tributary"* (aka Rainbow Tributary) and is mapped as Flood Zone A on Panel 35043C1888D. The location where the proposed channel/culvert will discharge into the existing Rainbow Tributary channel (immediately downstream of Vancouver Rd.) is within an "*Area of Minimal Flood Hazard"* (unshaded Zone X), as identified on FIRM panel 35043C2101D. Portions of the proposed project located within the unshaded Zone X are outside of the Special Flood Hazard Area (SFHA) and are not subject to 44 CFR *Insurance and Hazard Mitigation* requirements. Portions of the proposed project are located within a Zone A SFHA and this report serves as documentation that the requirements of 44 CFR 60.3 are satisfied.

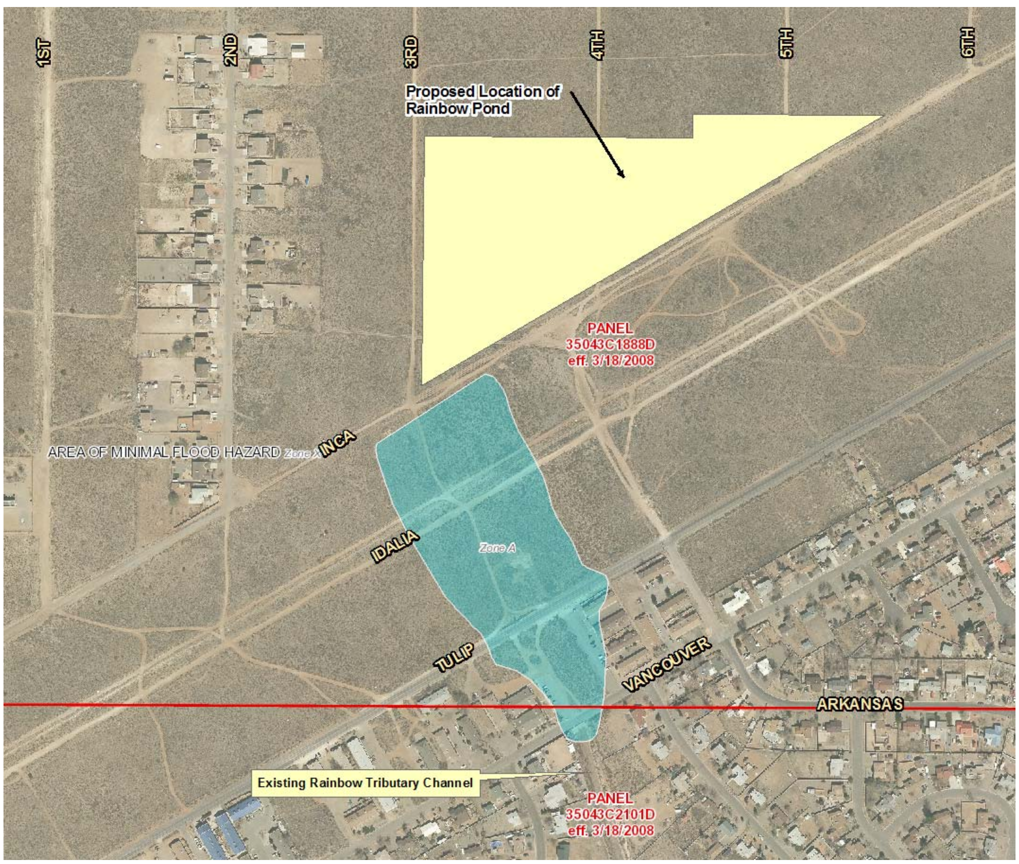

Figure 2 - FEMA Floodplain and FIRM Panel Information

This project will maintain the flood carrying capacity of the existing watercourse and will provide a more robust storm water conveyance that will be easier to operate and maintain. SSCAFCA will provide all available project information, including this report, to the CORR floodplain manager for all applicable permitting prior to constructing this project.

It is important to note that once constructed, the proposed Rainbow Pond and downstream infrastructure will significantly reduce the area of inundation currently shown on the FIRM. The proposed improvements will be built on SSCAFCA's fee simple real property and other public rights-a-way and will not alter the ultimate point of discharge for this watercourse (no diversions) or create new areas of ponding upstream of the proposed Rainbow Pond. This project is designed to provide a positive impact to the surrounding properties by attenuating the 100-year peak discharge through the construction of the proposed Rainbow Pond.

SSCAFCA will provide a FEMA Letter of Map Revision at a later date (post-construction), which will include the Rainbow Pond and downstream channel.

5.0 SSCAFCA Pond & Channel Minimum Design Requirements

Based on Section 3.C and 5.H of SSCAFCA Development Process Manual, a selected design must satisfy these elements:

Channel (subcritical flow):

- Froude number less than 0.7 for any significant length of the reach.
- Freeboard, defined as the vertical distance between the 100-year WSEL and the top of the pond embankment, will comply with Section 3.C.4 and will be reflected in the construction plans.
- Channel side slopes will be armored (lined), allowing for a side slope design between 2:1 and 6:1, per Section 3.C.5.c.
- Channel access road and ramps will be provided in accordance with Section 3.C.5.d & e.
- Street crossings (proposed concrete box culverts) will be sized to convey the 100-year storm (Section 3.C.5.f).

Pond:

- A primary spillway needs to be designed at minimum to convey flows from the 100-year fully developed condition (Section 5.H.1).
- The size of the outlet pipe must be equal to or larger than 24-in in diameter. The velocity needs to be 2 fps or greater when flowing at quarter full (Section 5.H.3a).
- All runoff must be discharged within 24 hours or less (Section 5.H.8).
- A minimum of 1 foot of freeboard (for the 100-year storm) is required for all ponds (Section 5.H 10).
- Pond must have sufficient storage of 100-year runoff and the sediment coming from the 100-year storm (Section 5.H.11).

6.0 Hydrology and Hydraulic 2D Analysis (CH2M Hill)

Due to the flat slopes and incised, intersecting dirt roads that bisect this watershed, CH2M Hill was contracted by SSCAFCA to conduct a two-dimensional (2D) hydraulic model (using HEC-RAS 5.0) to better define flow paths, flow quantities, and inundation limits to assist in the siting of the proposed Rainbow Pond. 2D hydraulic models utilize high-resolution terrain data such as LiDAR as the base topography for flow routing and allows for flow to move laterally in any direction to define various hydraulic parameters and extents.

In support of the hydraulic analysis, CH2M Hill also refined the 100-year storm hydrology using the Hydrologic Modeling System developed by the Army Corps of Engineers (HEC-HMS). The hydrology was further investigated and refined for the existing condition and the future fully-developed condition to support the identification of excess runoff for spatial distribution within the HEC-RAS 2D hydraulic analysis.

CH2M Hill's Report is included for reference (digital format only) in Appendix A.

6.1 Summary of Existing and DEVEX Conditions Hydrology (CH2M Hill)

SSCAFCA typically requires analysis of three different hydrologic scenarios to evaluate existing and future hydrologic scenarios: Existing, DEVEX, and Ultimate Conditions. These scenarios are defined as follows:

- Existing Conditions – Hydrology representing existing development and drainage infrastructure as of the date of the report (CAWMP effective date).
- DEVEX Conditions – Hydrology representing a fully developed watershed, assuming existing platting, and only incorporating currently existing drainage infrastructure.
- Ultimate Conditions – Hydrology representing a fully developed watershed including all existing drainage facilities along with anticipated future drainage infrastructure.

CH2M Hill's hydrologic analyses considered only two hydrologic scenarios – Existing and DEVEX Conditions. As discussed in Section 7.1.1, the 100-year Ultimate Conditions scenario was developed by SSCAFCA using CH2M Hill's DEVEX model as the basis to evaluate the proposed Rainbow Pond.

The Rainbow Tributary is a sub-watershed of the Calabacillas Watershed. The HEC-HMS model from SSCAFCA's CAWMP was utilized by CH2M Hill to extract and refine the Rainbow Tributary basin for a much more detailed hydrologic analysis. The original CAWMP model delineated the Rainbow Tributary basin into 4 subbasins. CH2M Hill further delineated these 4 subbasins into 20, based on field reconnaissance, aerial imagery, and LiDAR information showing several incised unpaved roads that bisect the Rainbow Tributary, creating man-made hydrologic boundaries.

The Rainbow Tributary basin boundary was refined based on LiDAR information for a small eastern portion of the basin, resulting in an 8-acre reduction in area from the total area defined in the CAWMP. The resulting drainage area is 0.956 square miles at the pond location (HEC-HMS junction RA_103D.J).

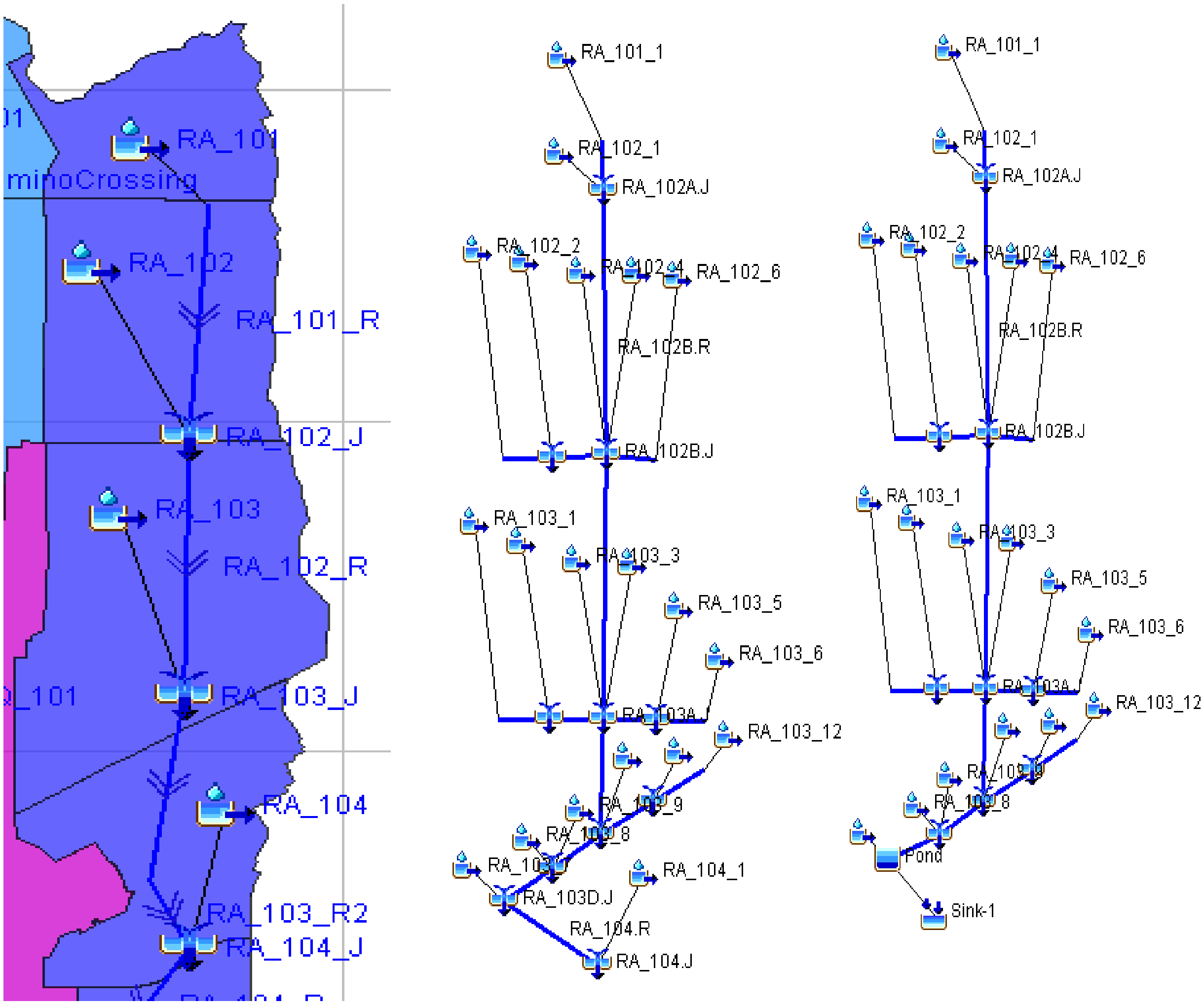

Figure 3 - Comparison of HEC-HMS Models
The Rainbow Watershed in CAWMP on the left, CH2M Hill's DEVEX Conditions in the center, and SSCAFCA Ultimate Conditions on the right.

The 100-year_NoReduction hyetograph from SSCAFCA's CAWMP model was input as the precipitation data, and gage information of Zone 4 of the CAWMP was entered in the HEC-HMS model. The calculated time of concentration and the excess precipitation are summarized in Section 3 of the CH2M Hill report.

Table 1 - CH2M Hill's HEC-HMS Results at the Proposed Pond Location (RA_103D.J)

Hydrologic Scenario	100-year Peak Flow, (ft^3/s)	100-year Volume, (ac-ft)
Existing Conditions	661	40.2
DEVEX Conditions	1070	78.5

6.2 Summary of Hydraulic 2D Analysis (CH2M Hill)

CH2M Hill's HEC-RAS 2D results were reviewed by SSCAFCA and were used solely to verify flow paths and confirm the siting for the proposed pond, see Figure 4.

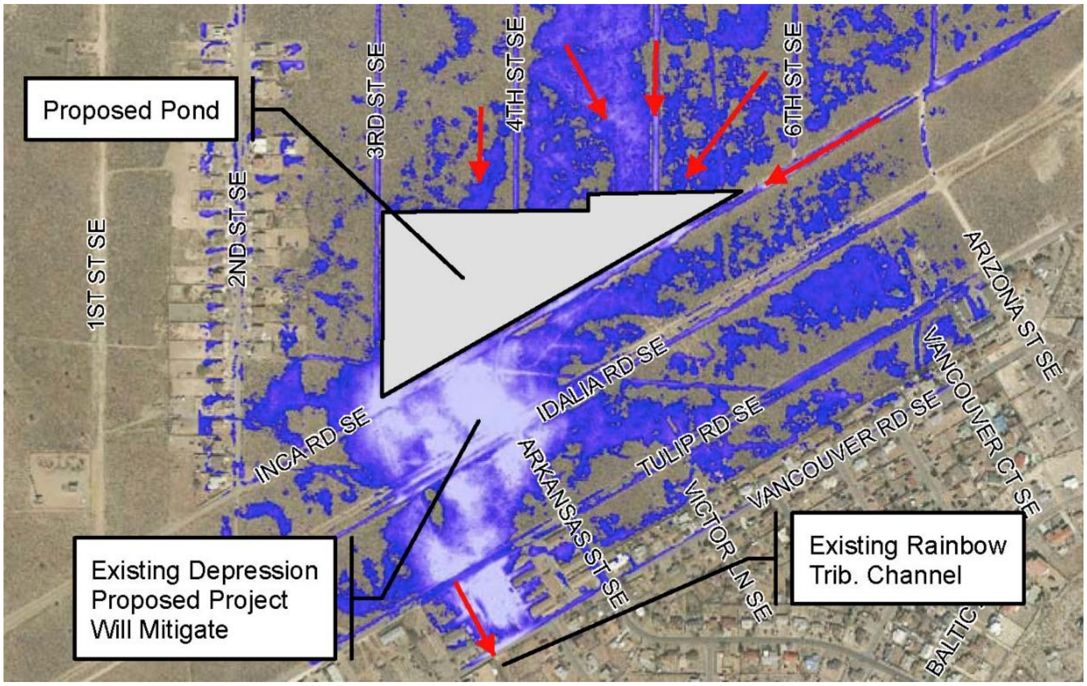

Figure 4 - CH2M Hill HEC-RAS 2D Model DEVEX Inundation Limits Shown in Blue

In summary, when comparing the HEC-HMS and HEC-RAS 2D model results, some discrepancies of peak flow and volume were found.

Table 2 - Comparison of CH2M Hill's peak flow and volume results at proposed pond location (SECT_104_1.5)

Model	Existing Conditions Q100 (cfs)	DEVEX Conditions Q100 (cfs)	Existing Conditions Vol100 (ac-ft)	DEVEX Conditions Vol100 (ac-ft)
HEC-HMS CAWMP	723	1144	40.9	79.7
HEC-HMS CH2M	661	1070	40.2	78.5
HEC-RAS 2D	272	478	33.9	70.8

These discrepancies are likely caused by attenuation of runoff in localized depressions and the resulting storage within the watershed that does not ultimately leave the basin.

CH2M Hill's peak flow and volume results and comparisons between HEC-HMS and HEC-RAS 2D are provided for informational purposes only. More details on CH2M Hill's 100-year hydraulic and hydrologic analyses can be found in Section 5 of the CH2M Hill Report, see Appendix A.

The inundation results of the 2D hydraulic model were provided to the City of Rio Rancho as "best available information" to supplement the FEMA FIRM floodplain mapping. It is recommended that proposed development within the areas identified by the 2D model to become inundated be flagged for mitigation prior to building permit issuance.

7.0 Hydrology & Hydraulic Analysis (SSCAFCA)

SSCAFCA utilized the results from CH2M Hill's DEVEX Conditions hydrologic analysis to determine the size and location of the proposed pond and to design a conveyance system to connect the proposed pond to the existing Rainbow Tributary channel. Additionally, SSCAFCA developed a 500-year storm hydrologic model and to size the proposed pond's emergency spillway and confirm that the model showed no overtopping of the pond embankment under the 500-year storm scenario.

All models developed for this project are in the NAD 1983, *State Plane New Mexico Central FIPS 3002 feet* coordinate system (modified to incorporate local survey ground parameters & scale factors) and use the NAVD 88 vertical datum.

7.1 SSCAFCA Hydrologic Analysis

HEC-HMS version 4.2.1 was used for all hydrologic modelling prepared by SSCAFCA.

7.1.1 100-year Hydrology - Ultimate Conditions

A 100-year Ultimate Conditions HEC-HMS model was created by SSCAFCA using CH2M Hill's DEVEX model as the basis. A reservoir was added to represent the proposed Rainbow Pond at RA_103D.J. All elements downstream of the proposed pond location were removed from CH2M Hill's model, as they would no longer be applicable in SSCAFCA's proposed Ultimate Conditions model.

HY-8 version 7.50 was used to generate a stage-discharge relationship for the proposed pond's primary spillway (see Section 7.2.1). This information was added to the HEC-HMS model to route the upstream hydrograph through the proposed pond and develop the pond's peak discharge, see Figure 5 below.

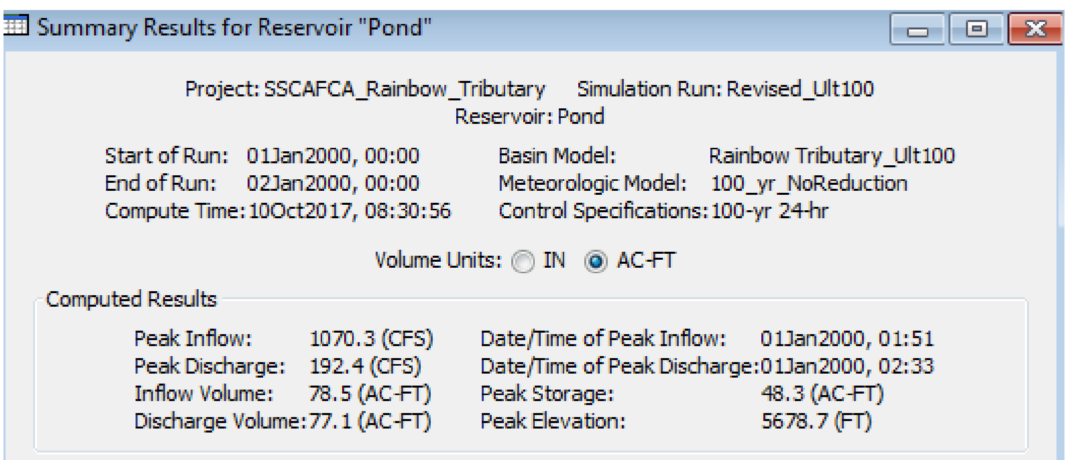

Figure 5 – SSCAFCA's HEC-HMS Results – 100-year Ultimate Conditions

7.1.2 500-year Hydrology - Ultimate Conditions

SSCAFCA developed a 500-year model in HEC-HMS in order to design an emergency spillway for the proposed pond and verify in the model that the upstream hydrograph for the 500-year storm could be routed through the proposed pond, primary spillway and emergency spillway without overtopping the embankment. This model used the 100-year Ultimate Conditions model as the basis and adjusted the following parameters for the 500-year scenario:

- SSCAFCA obtained the design rainfall from NOAA Atlas 14: https://hdsc.nws.noaa.gov/hdsc/pfds/pfds_map_cont.html?bkmrk=nm
- A 24-hour distribution curve was created using rainfall distribution equations F-1 through F-6 in SSCAFCA DPM Section 2 Hydrology F.2.3. Temporal Distribution.
- Depth-area reduction factor of 1.0 was chosen based on SSCAFCA DPM Section 2 F.2.2 Depth-Area-Reduction.

As discussed in Section 7.2.2, the weir equation and HEC-HMS were used to determine the emergency spillway geometry and maximum water surface elevation (WSEL), ensuring that no overtopping of the embankment occurred under the 500-year storm event.

7.2 SSCAFCA Hydraulic Analysis

7.2.1 Pond Primary Spillway

The proposed Rainbow Pond's primary spillway invert will be located at the pond bottom (elevation 5670.57 ft). Stage-storage information for the proposed pond was extracted from AutoCAD Civil3D for the proposed pond design and inserted into HEC-HMS. See Appendix B for pond grading plan used to develop the stage-storage information.

HY-8 and HEC-HMS were utilized in conjunction to iteratively size the primary spillway. After several iterations, a two-cell 3'x3' RCBC was selected for the primary spillway. The HY-8 analysis considered variable tailwater in its calculations based on the geometry and roughness of the downstream channel. The CBC rating curve developed in HY-8 was input into HEC-HMS as a part of the stage-discharge table for the proposed pond and the HEC-HMS model was run to verify that the emergency spillway (Section 7.2.2) was not activated during the 100-year storm and that adequate pond freeboard was maintained. See Appendix B for HY-8 and HEC-HMS results.

Table 3 - Stage-Discharge-Storage Table for Proposed Pond

WSEL (ft)	Primary Spillway Discharge (cfs)	Cumulative Storage (ac-ft)
5670.57	0	0.0
5671.97	25	6.9
5672.79	50	11.1
5673.49	75	15.0
5674.13	100	18.6
5674.92	125	23.3
5676.26	150	31.7
5677.62	175	40.8
5678.7 (100-year Peak WSEL)	192.4	48.55
5678.8 (Emergency Spillway Elevation)	195	49.3
5680.2 (500-year Peak WSEL)	215	59.1
5680.5 (Top of Pond Embankment)	220.9	62.3

7.2.2 Pond Emergency Spillway

The weir equation, $Q = C \cdot L \cdot H^{3/2}$, with a discharge coefficient of 2.65 and HEC-HMS were utilized in conjunction to iteratively size the emergency spillway. After several iterations, a 100-foot long weir was selected for the emergency spillway and the proposed geometry, when confirmed in HEC-HMS, resulted in a 500-year WSEL of 5680.2 ft.

The weir coefficient was evaluated by researching *Open Channel Hydraulics, Chow, 1959*, and *Handbook of Hydraulics, King & Brater, Sixth Edition, 1976*. Chow describes that a broad-crested weir coefficient of 2.65 is at the lower end of the range for actual observed C values. Chow (Energy & Momentum Principles section) states, "…the practical range of the coefficient to H3/2 obtained by actual observations is from 3.05 to 2.67." King & Brater suggests that, when comparing Head to Weir Breadth, the weir coefficient tends to converge on a value of approximately 2.63 as head and breadth increase. The selected weir coefficient of 2.65 is a widely accepted value for similar broad crested weir applications. This coefficient yields a peak discharge on the lower end of the spectrum of reasonable values given that the range of broad-crested weir coefficients have been shown to range from approximately 3.0 to 2.6.

7.2.3 Downstream Channel & Roadway Crossings

HEC-RAS version 5.0.3 1-Dimensional model was used as the hydraulic model to verify hydraulics for the proposed channel and roadway crossings downstream of the proposed pond. The following assumptions were made to model in HEC-RAS:

- The proposed channel bottom will be 14-ft wide.
- The proposed channel side slopes will be 2.5 horizontal: 1 vertical.
- Surface treatments for the proposed channel will include native soil bottom with riprap side slopes.

HEC-geoRAS is an ArcGIS extension, which allows creating spatial features necessary for hydraulic analysis in a GIS environment such as the stream centerline, banks, flow paths, cross sections, and bridges. Once these features are digitized, this tool can be utilized to assign elevations to the features based on provided terrain data and create a geometric import file for HEC-RAS.

Based on local design and topographic constraints, the proposed channel geometry and culvert crossings were drafted in AutoCAD Civil3D and extracted for use in the ArcGIS environment. The proposed surface data generated in AutoCAD was brought into ArcGIS, clipped to include only the area of interest, and converted from a TIFF format to a Triangular Irregular Network (TIN) to be processed in HEC-geoRAS. The resulting TIN was used to digitize the required hydraulic model elements described above. The channel centerline was extended approximately 500-ft into the existing Rainbow Tributary channel (downstream of Vancouver Rd. SE) in order to define the downstream boundary condition.

The elevation data for the proposed pond and channel was based on a 1-foot resolution local survey completed by WHPacific. The data set uses the NGVD 88 vertical datum and are based on NM State Plane Central (Feet) coordinate system.

Cross sections were placed perpendicular to the flow. The 3 road crossings were also modeled. The proposed channel geometry will be trapezoidal and it is estimated that the channel bottom will be native soil and the 2.5 horizontal: 1 vertical side slopes will be riprap lined. Native soils in the project area consist primarily of fine sand, so the channel design has incorporated armored side slopes and a very flat longitudinal slope in order to reduce flow velocities. Manning's Roughness values of 0.030 for the channel and 0.045 for the overbanks were assigned. At cross section 1456, Manning's n of 0.013 was utilized for a concrete drop approach.

After the proposed channel discharges into the existing Rainbow Tributary channel, the vegetation changes to a sandy channel bottom with weeds and light brush on the overbanks. For the existing Rainbow Tributary channel cross sections, the Manning's Roughness values were changed to 0.035 for the channel and 0.050 for the overbanks. The following picture depicts the condition of the existing Rainbow Tributary channel:

Figure 6 - Existing Rainbow Tributary Channel - XS3 Looking Upstream to Vancouver Rd.

A peak discharge of 192.4 cfs (see Figure 5) was applied at the beginning cross section (XS 1806). For the downstream boundary condition, normal depth (based on the energy slope between the two most downstream cross sections) was utilized.

The default setting for flow regime in HEC-RAS is subcritical flow, however, based on trial runs of the model, it was found that the flow is likely to be supercritical when exiting the Vancouver Rd. culvert. When both subcritical and supercritical flows are anticipated in the model, it is beneficial to run the model in the mixed flow regime. The proposed channel model was run in the mixed flow regime in order to properly reflect critical flow conditions and model hydraulic jumps associated with the proposed riprap basins at each culvert outfall (see Section 8).

The mixed flow regime requires both upstream and downstream boundary conditions to be specified. Similar to the downstream boundary condition, the energy slope of the first two upstream cross sections was utilized as the upstream boundary condition.

For each of the proposed roadway crossings, the following culvert information was entered in the Bridge Culvert Data section of HEC-RAS:

Table 4 - Summary of HEC-RAS Bridge/Culvert Input Parameters

Roadway Crossing	Upstream Invert Elevation (ft)	Downstream Invert Elevation (ft)	Culvert Length (ft)	Bridge/Culvert Type	Cell Size (WxH)	Manning's Roughness Structure
Idalia Rd.	5667.30	5667.12	40	3-cell RCBC	4'x 3'	0.013
Tulip Rd.	5665.47	5664.91	40	3-cell RCBC	4'x 3'	0.013
Vancouver Rd.	5661.08	5659.93	84	3-cell RCBC	4'x 3'	0.013

The Vancouver Rd. crossing is skewed at an approximate angle of 27 degrees. The model is reflective of the skew at the upstream side of the crossing. The downstream side is parallel to the alignment of the channel, and the skew was not modeled. Energy and momentum methods for low flow methods and pressure and/or weir method for the high flow methods were selected to account for potentially submerged inlets at each roadway crossing.

Table 5 - Summary of HEC-RAS Roadway Crossing Results & Recommendations

Crossing Name	Upstream Invert Elevation (ft)	Upstream WSEL (ft)	Outlet Velocity (ft/s)	Recommended Roadway/Deck Elevation (ft)*
Idalia Rd.	5667.30	5670.42	7.36	5671.42
Tulip Rd.	5665.47	5668.57	10.42	5669.57
Vancouver Rd.	5661.08	5664.13	11.01	5665.13

* Recommended roadway elevation is one foot above the upstream WSEL.

A review of the HEC-RAS results raised a concern over the culvert outlet velocities being high and the need for erosion protection. High velocity at the culvert outlets creates scour and undermining of the structure toe, which may damage the structure. Scour analysis was conducted to determine the extent of the potential scour and design countermeasures to minimize the erosion.

8.0 Scour

The 100-year hydrology and hydraulics results provided the input parameters used in the scour calculations for this project.

Scour analysis and countermeasure design were based on the Federal Highway Administration Hydraulic Engineering Circular No.14, (HEC-14) Hydraulic Design of Energy Dissipaters for Culverts and Channels, Third Edition, dated July 2006; Hydraulic Engineering Circular No. 23 (HEC-23), Bridge Scour and Stream Instability Countermeasures, Second Edition, dated March 2001; and the SSCAFCA Sediment and Erosion Design Guide dated November 2008.

8.1 Analysis

Due to the highly-erosive nature of the soils within the project area and the high culvert exit velocities, scour analyses were conducted to assess concerns for:

1. Undermining of the downstream toe of culverts (culvert outlet scour); and
2. Erosion of the upstream left side slope at the Vancouver crossing (flow impinging at an angle).

Culvert Outlet Scour: HEC-14 was used to determine the size of the riprap required at each roadway crossing. A D_{50} of **10-in** is recommended for the crossing at Inca Rd. A D_{50} of **6-in** is recommended for the crossings at Idalia Rd, Tulip Rd. and Vancouver Rd.

Flow Impinging at an Angle: As flow approaches the Vancouver Rd. crossing, it will be impinging on the left side slope at an angle of approximately 27 degrees. HEC-23 was used to determine a scour depth of **6.4-ft** at this location.

Dimensions for the proposed scour countermeasure elements are presented in Table 6 below. Detailed results from these analyses are documented in Appendix C.

The reader will notice that the riprap size determined in the actual calculations may differ from the recommended riprap size presented in Table 6. The recommended riprap size is determined based on local rock availability and widely-used riprap specifications, which are limited in the D_{50} sizes. In no circumstance was a smaller riprap size recommended than was used in the scour calculations. Although a larger D_{50} may be recommended than was used in the scour calculations, the dimensions of the recommended riprap basins were not modified for the larger riprap size, reflecting a more conservative approach to the design.

8.2 Countermeasure Design

As previously mentioned, the proposed crossings were designed to accommodate the 100-year event. All scour calculations and designs were also based on the 100-year event.

Riprap Basins are recommended for the roadway crossings at Inca Rd., Tulip Rd., and Vancouver Rd. and a Riprap Apron is recommended at the Idalia Rd. crossing. Additionally, all proposed channel side slopes will be armored with riprap to 1-ft above the 100-year WSEL (top of channel) along the entire channel.

8.2.1 Culvert Outlet Scour

Based on the above guidance and equations, the countermeasure for the crossings are sized as follows:

Table 6 - Roadway Crossing Scour Countermeasure Design Parameters

Roadway Crossing	Calculated D_{50} (ft)	Recom-mended D_{50} (ft)	Scour Hole, hs (ft)	Dissipator Pool Length, Ls (ft)	Apron Length (ft)	Culvert Exit Velocity (ft/s)	Basin Exit Velocity, Vc (ft/s)
Inca Rd.	0.8	0.8	1.6	16	8	10.69*	5.2
Idalia Rd.	0.23	0.5	-	-	12	7.36	-
Tulip Rd.	0.35	0.5	0.73	12	4	10.42	4.6
Vancouver Rd.	0.4	0.5	0.86	12	4	11.01	4.9

*Culvert exit velocity for Inca Rd was computed based on the continuity equation. Flow per a culvert cell (96.2 cfs) was divided by the area of one cell (3*3=9 sq ft) to obtain the velocity. The velocities listed for other crossings are from HEC-RAS summary output table.

At the Idalia Rd. crossing, it was determined that a riprap basin was not applicable (requirements in the basin design calculations were not satisfied, very small scour hole, small D_{50}, etc.), so a riprap apron was determined to be a more appropriate countermeasure. Equation 10.4 in HEC-14 was utilized to estimate the size of rock required for the 100-year flow. The riprap apron dimensions were computed utilizing equations listed on page 10-19 of the HEC-14 document. See Appendix C for detailed scour calculations.

The Vancouver Rd. crossing will discharge into the existing Rainbow Tributary channel, which is a constructed channel that includes mature natural vegetation and grade control structures. At the time of the writing of this report, the channel was in a stable condition.

8.2.2 Scour with Flow Impinging at Angle - Vancouver Rd. Crossing

The upstream side of the Vancouver Rd. crossing is bent westward by approximately 27 degrees and it is expected that redirection of flow will occur at the left side slope before the inlet. The scour depth computed for the side slope is 6.4-ft, based on HEC-23 Equation 4.4 on page 4.8. This will be mitigated by extending the riprap slope protection to 7-ft below the channel invert at this location.

Detailed scour calculations are documented in Appendix C.

9.0 Conclusion

Based on the results of the analyses described in this report, the following is recommended:

- The pond's invert elevation is 5670.57 ft, which is also the upstream invert of the primary spillway.
- The primary spillway for the proposed pond includes a 251-ft long, 2-cell 3'W x 3'H RCBC.
- The proposed pond will impound 48.55 acre-feet during the 100-year storm.
- The emergency spillway elevation is 5678.8 ft, which is one tenth higher than the 100-year WSEL.
- The elevation of the top of pond embankment is 5680.5 ft, which provides more than 1.5-ft of freeboard for the 100-year event.
- The crossing structure for each roadway (Idalia Rd., Tulip Rd., and Vancouver Rd.) is a 3-cell 4'W x 3'H RCBC with straight headwalls on the upstream and the downstream sides.
- A concrete drop approach, creating a drop of 1.3-ft of elevation over 10'1" span, will be constructed at the upstream side of the proposed Idalia Rd crossing.
- The proposed channel, downstream of the primary spillway outlet, will be trapezoidal in shape with a 14-ft wide bottom, 2.5H:1V side slopes, native soil on the channel bottom and riprap armoring on the side slopes.
- For scour protection, the following countermeasures are recommended:
  Inca Rd: 16-ft long riprap energy dissipator, rock size (D_{50}) = 10-in
  Idalia Rd: 12-ft long riprap apron only, 1.5-ft deep, rock size (D_{50}) =6-in
  Tulip Rd: 12-ft long riprap energy dissipator, rock size (D_{50}) = 6-in
  Vancouver Rd: 12-ft long riprap energy dissipator, rock size (D_{50}) = 6-in

The analyses and results presented in this report do not consider back-to-back storm events.

The design of the proposed pond and outlet channel did not incorporate any basins or contributing areas south of Inca Rd. This area is located within an existing playa and development within the area between Inca Rd and Vancouver Rd should consider the effects of storm water ponding and include provisions to mitigate flooding of permanent structures. Consultation with the City of Rio Rancho Floodplain Administrator is strongly recommended.

A geotechnical report was completed for this project and should be incorporated in the final design of construction plans and provided as supplemental information during the bidding/construction phase.

During construction plan set preparation, the engineer should ensure that all scour countermeasure elements are designed as provided in the referenced documents used in the analysis discussed above. This should include, but is not limited to: rock thickness, key-in locations, granular bedding or filter fabric installation, etc.