International Falcon Reservoir HUC-8 Watershed, Texas
Base Level Engineering (BLE) Results

MAS No. FY20-CTP-FRP-MAST #5 T.O. No. 11

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Executive Summary

The Texas Water Development Board (TWDB) contracted Halff Associates (Halff) to complete a Base Level Engineering (BLE) analysis for the HUC-08 watershed No. 13080003 – International Falcon Reservoir in South Texas, to support the U.S. Department of Homeland Security's Federal Emergency Management Agency's (FEMA) Discovery process and validation of effective Zone A Special Flood Hazard Areas (SFHAs). The BLE process involves using best available data and incorporating automated techniques with standard 2-dimensional (2D) model development procedures to produce regulatory-quality flood hazard boundaries for the 1-percent annual chance event as well as estimates of flood hazard boundaries for multiple recurrence intervals.

The source digital terrain data used for surface model development in support of hydrologic and hydraulic analysis as well as mapping activities were leveraged from various local, State, and Federal partners. Details regarding the different datasets used are provided below in Section 2.1.

Precipitation depths for this study were established using NOAA Atlas 14 rainfall. An average precipitation depth was computed for the study area. The Hydrologic Engineering Center's (HEC) Hydrologic Modeling System (HMS) was used to develop a simplified hydrologic model to compute excess rainfall which was then used in a rain-on-grid, 2D hydraulic model using HEC-RAS. The hydraulic model was used to compute flood depths and peak water surface elevations within the study area.

The stream mile network that was validated for this watershed was compiled using FEMA's Community Needs Management Strategy (CNMS) inventory. CNMS is an inventory of flood hazard studies and flood hazard mapping needs for areas where a study is needed. This data is helpful for community officials in analyzing and depicting flood hazards to enhance the understanding of flood risks. Communities may use this information to make informed decisions on their planning and flood mitigation efforts. Table ES-1.1 lists the stream miles associated with this validation analysis.

Table ES-1.1: Summary of Stream Miles

Source	International Falcon Reservoir Stream Miles
CNMS	4,905

The full inventory of Zone A studies in the watershed were classified in CNMS. Total miles validated in CNMS are summarized in Table ES-1.2.

Table ES-1.2: Aggregated Zone A Validation Results

Validation Status	Status Type	Total Miles
VALID	BEING STUDIED	690.9
UNVERIFIED	BEING STUDIED	426.2

01 Introduction

Recent innovations and efficiencies in floodplain mapping have allowed the U.S. Department of Homeland Security's Federal Emergency Management Agency (FEMA) to develop a process called Base Level Engineering (BLE), which can be used to address current program challenges, including the validation of Zone A studies and the availability of flood risk data in the early stages of a flood risk project. The BLE process involves using best available data and incorporating automated techniques with standard 2-dimensional (2D) model development procedures to produce flood hazard boundaries for the 1-percent annual chance event as well as estimates of flood hazard boundaries for multiple recurrence intervals. The cost for developing the data and estimates resulting from the BLE process is lower than standard flood production costs. The BLE results may be used for eventual production of regulatory and non-regulatory products.

As described in Title 42 of the Code of Federal Regulations, Chapter III, Section 4101(e), once every five years, FEMA must evaluate whether the information on Flood Insurance Rate Maps (FIRMs) reflects the current risks in flood-prone areas. FEMA makes this determination of flood hazard data validity by examining flood study attributes and change characteristics, as specified in the Validation Checklist of the CNMS Technical Reference. The CNMS Validation Checklist provides a series of critical and secondary checks to determine the validity of flood hazard areas studied by detailed methods (e.g., Zone AE, AH, or AO). While the critical and secondary elements in CNMS provide a comprehensive method of evaluating the validity of Zone AE studies, a cost-effective approach for evaluating Zone A studies has been lacking.

In addition to the need for Zone A validation guidance, FEMA standards require flood risk data to be provided in the early stages of a flood risk project. FEMA Program Standard SID #29 requires that during Discovery, data must be identified that illustrates potential changes in flood elevation and mapping that may result from the proposed project scope. If available data does not clearly illustrate the likely changes, an analysis is required that estimates the likely changes. This data and any associated analyses should be shared, and results should be discussed with stakeholders.

An important goal of the BLE process is the scalability of the results. Scalability means that the results of a BLE analysis can not only be used for CNMS evaluations of Zone A studies but can also be leveraged throughout the Risk Mapping, Assessment and Planning (Risk MAP) program. The data resulting from a BLE analysis can be updated as needed and used for the eventual production of regulatory and non-regulatory products, outreach and risk communication, and MT-1 processing. Leveraging this data outside the Risk MAP program may also be valuable to external stakeholders.

The Texas Water Development Board (TWDB) contracted Halff Associates (Halff) to complete a BLE analysis for the International Falcon Reservoir Watershed in South Texas to support FEMA's Discovery process and validation of effective Zone A Special Flood Hazard Areas (SFHA). The study extents include portions of Zapata, Jim Hogg, Starr, and Webb Counties, and include the following communities: The Cities of Mirando and Laredo, and the Census-Designated Places of Lopeno, San Ygnacio, Guerra, and Zapata. The study area consists of seven HUC-10 basins on the United States side: Retama Creek – San Jacinto Creek, Dolores Creek, Salamoneno Creek, Los Tanques Creek – Villa Creek, Cavasara Creek – Rio Grande, Arroyo Veleno – Falcon Reservoir, and Arroyo del Tigre Grande – Falcon Reservoir. Figure 1.1 shows the orientation of the International Falcon Reservoir HUC-8 basin with respect to the Texas counties and Mexico.

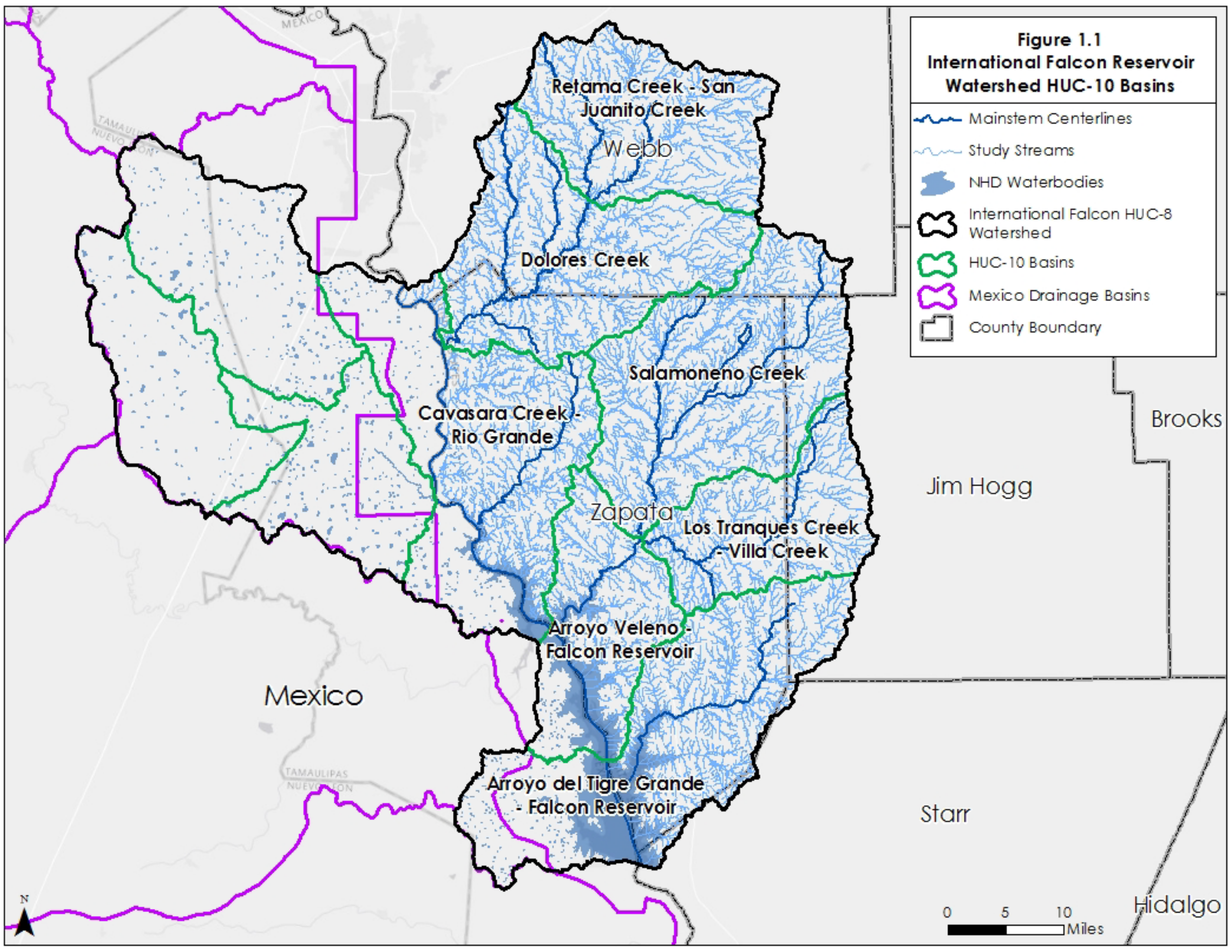

Figure 1.1: International Falcon Reservoir Watershed

02 2D BLE Modeling Inputs and Controls

Section 2 presents fundamental components required to execute a 2D hydraulic engineering analysis for the International Falcon Reservoir Watershed. Inputs such as elevation data, hydrology used to develop rain-on-grid data and inflow hydrographs, and hydraulic analyses and requisite model parameters are defined herein. HEC-RAS, Version 6.1 rain-on-grid utility was applied in the production of the 2D BLE products produced for this watershed.

2.1 Topographic Data

A high-resolution Digital Elevation Model (DEM) is a fundamental component for 2D engineering analyses by providing a detailed representation of the ground surface for hydraulic routing through the model area. As such, DEMs were developed for the International Falcon Reservoir BLE project by leveraging available high-resolution gridded elevation data derived from Light Detection and Ranging (LiDAR) collections throughout the entire State of Texas. The 10-foot DEM developed to support the 2D BLE modeling and analysis, within the International Falcon Reservoir Watershed, was executed using the following steps:

1. Available elevation data for the project area were inventoried and collected.
2. Leveraged elevation data were evaluated and prioritized based on source vertical accuracy, year of collection, and resolution.
3. Seamless DEMs were processed using GIS.
4. Quality was assured using quantitative and qualitative assessment.

Documentation regarding leveraged data including coverage, accuracy, acquisition dates, and source contact/agency are presented in the figures, tables and text within the following sections. All vertical accuracy specifications were obtained from the metadata or survey reports provided with the leverage datasets. All available metadata, survey reports, and other leverage documentation are included in the FEMA Data Capture Technical Reference compliant submittal content for the International Falcon Reservoir Watershed.

2.1.1 Inventory

An inventory of existing topographic data was conducted for the International Falcon Reservoir BLE project footprint. Figure 2.1 depicts the datasets identified for leverage across the project area. FEMA, National Oceanic and Atmospheric Administration (NOAA), U.S. Geological Survey (USGS), and other State and Federal agencies were queried to build the inventory with the most current and available data sources.

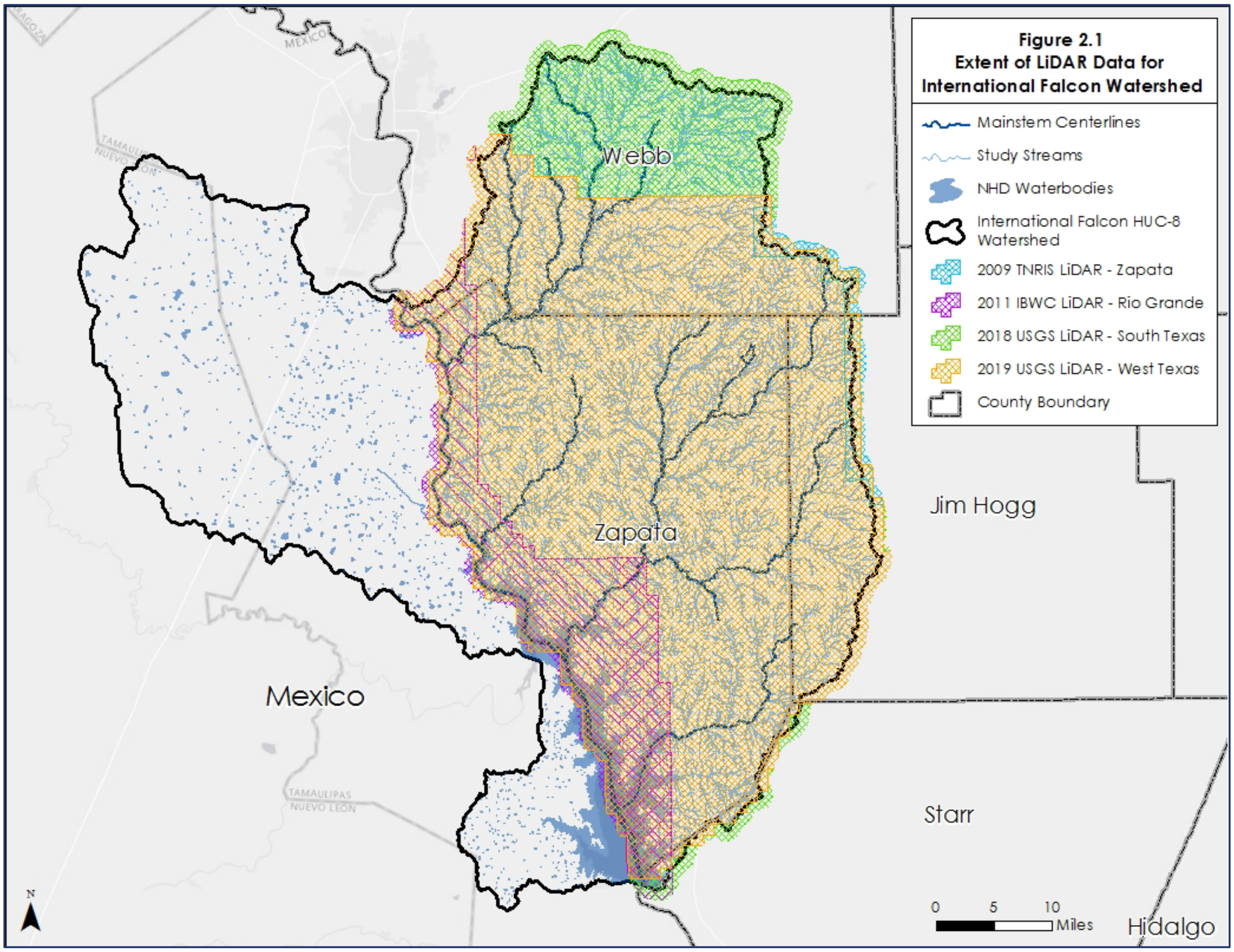

Figure 2.1: International Falcon Reservoir Watershed BLE Source Terrain Data

2.1.2 Evaluation

A data coverage assessment was conducted to check for data gaps, extent, accuracy, and completeness. A review of related documentation, reports, indexes, and metadata associated with the leveraged datasets ensured each dataset meets FEMA accuracy requirements for topographic data. Decisions to leverage or exclude a dataset (or portion of it), were based generally on the following criteria coupled with engineering judgment:

- Data meets FEMA vertical accuracy standards (Table 2.1)
- Date of origination
- Data density and coverage

Table 2.1 depicts the Risk Map SID #43 vertical accuracy requirements based on flood risk and terrain slope within the floodplain being mapped.

Table 2.1: FEMA Vertical Accuracy Requirements for Leveraged Data

Level of Flood Risk	Typical Slopes	Specification Level	Vertical Accuracy*	LiDAR Nominal Pulse Spacing (NPS)
High (Deciles 1,2,3)	Flattest	Highest	24.5 cm / 36.3 cm	≤ 2 meters
High (Deciles 1,2,3)	Rolling or Hilly	High	49.0 cm / 72.6 cm	≤ 2 meters
High (Deciles 2,3,4,5)	Hilly	Medium	98.0 cm / 145 cm	≤ 3.5 meters
Medium (Deciles 3,4,5,6,7)	Flattest	High	49.0 cm / 72.6 cm	≤ 2 meters
Medium (Deciles 3,4,5,6,7)	Rolling	Medium	98.0 cm / 145 cm	≤ 3.5 meters
Medium (Deciles 3,4,5,6,7)	Hilly	Low	147 cm / 218 cm	≤ 5 meters
Low (Deciles 7,8,9,10)	All	Low	147 cm / 218 cm	≤ 5 meters

*Vertical Accuracy at 95% Confidence Level (FVA or NVA)/(CVA or VVA)

Table 2.2 depicts the complete list of source elevation data and attributes leveraged for the International Falcon Reservoir Watershed BLE project. All datasets used for hydraulic analyses and mapping meet the highest specification level defined in Table 2.1. Further explanation of the Table ES-1.1 datasets can be referenced in section 2.1.2.1.

Table 2.2: Source Topographic Data Available for the International Falcon Reservoir Watershed

Year	Description	Data Type	RMSE	Source/Owner
2009	Zapata	Airborne LiDAR	0.00116m	TNRIS
2011	IBWC	Airborne LiDAR	0.03m	IBWC
2018	USGS	Airborne LiDAR	0.009m	USGS
2018	Mexico	Airborne LiDAR	Best Available	Mexico
2019	USGS	Airborne LiDAR	Less than 10 cm	USGS

2.1.2.1 International Falcon Reservoir Watershed Source Terrain Data

The source elevation data for the International Falcon Reservoir Watershed are DEMs derived from USGS, IBWC and TNRIS LiDAR data. Preprocessed bare-earth hydro-enforced DEMs from the acquiring entity (via USGS, IBWC, and TNRIS) were projected and adjusted as needed into one seamless DEM. Bare-earth LiDAR data are typically made by filtering non-ground returns (e.g. buildings, vegetation, etc.) from the processed LiDAR returns with hydro-lines and other LiDAR derived break lines enforced. Figure 2.1 depicts the extent of the data defined in Table 2.2. Brief descriptions of each LiDAR source are provided below. For more detailed information, please see the attached LiDAR project report for each individual project.

2009 TNRIS Zapata LiDAR – The 2009 TNRIS Zapata LiDAR was acquired in October of 2009. The measured RMSE was documented as 0.00116m Non-Vegetative Accuracy. The reported Z (vertical) Accuracy meets the 19.6 cm or better Non-Vegetated Vertical Accuracy at 95% confidence level using RMSE(z) x 1.9600 as defined by the National Standards for Spatial Data Accuracy (NSSDA) and was assessed and reported following National Digital Elevation Program (NDEP)/ASRPS Guidelines.

2011 IBWC LiDAR – The 2011 IBWC LiDAR was acquired from December 2010 to August 2011. The measured RMSE was documented at 0.03m Non-Vegetated Accuracy.

2018 Mexico – The best available LiDAR for Mexico is from 2018 and was used in the digital elevation model. Project and LiDAR quality specifics can be found at the Spanish Language site at the link provided: https://www.inegi.org.mx/temas/relieve/continental/#Mapa

2018 USGS South Texas LiDAR – The 2018 South Texas LiDAR was acquired from 2018-2019. The measured RMSE was documented at 0.0090 m Non-Vegetative Accuracy. The reported Z (vertical) Accuracy meets the 19.6 cm or better Non-Vegetated Vertical Accuracy at 95% confidence level using RMSE(z) x 1.9600 as defined by the National Standards for Spatial Data Accuracy (NSSDA) and was assessed and reported following National Digital Elevation Program (NDEP)/ASRPS Guidelines.

2019 USGS West Texas LiDAR – The 2019 USGS West Texas LiDAR was acquired from February 2019 to April 2019. The measured RMSE was documented at less than 10 cm. The reported Z (vertical) Accuracy meets the 19.6 cm or better Non-Vegetated Vertical Accuracy at 95% confidence level using RMSE(z) x 1.9600 as defined by the National Standards for Spatial Data Accuracy (NSSDA) and was assessed and reported following National Digital Elevation Program (NDEP)/ASRPS Guidelines.

2.1.3 Data Development Methodology

The source topographic data were processed for an area covering the International Falcon Reservoir Watershed and contributing drainage areas for the International Falcon Reservoir BLE modeling efforts. The topographic data for International Falcon Reservoir Watershed was projected horizontally, as needed, to North American Datum of 1983 (NAD83), State Plane Coordinate System (SPCS) Texas South in feet (4205-SPC83). All topographic data were adjusted vertically, as needed, to NAVD88 in feet. Halff used a combination of ArcGIS and other software tools to apply any vertical datum shifts and/or any horizontal projection transformations to the topographic data.

2.1.4 DEM QA/QC

DEMs developed for use in the International Falcon Reservoir Watershed BLE analysis were developed using a controlled process, evaluated, and assured by a topographic data development team and were evaluated and assured by the engineering team to meet the quality standards of the project. Quality assurance during the data development process includes, but is not limited to the following QC checks:

- Horizontal Projection Check
- Vertical Datum Check
- Resolution Check
- Format Check
- Seamless Data Check to ensure the DEM files are consistent and seamless along source data edges

The quality control after the development process by the topographic data development team included visual observations using hillshade, contouring, color rendering, and/or other visual aids to review and identify potential impactful anomalies within the DEM surface. This QC step included, but were not limited to the following QC checks:

- Seamless Data Check to ensure no voids along the edges and between the prioritized datasets
- NoData Value Check to ensure no null values
- Manual Elevation Check using hillshade rasters to find erroneous elevation issues
- Unit Consistency Check
- Legacy Cell Value Anomalies

Quality assurance conducted after the seamless DEM development conducted by the engineering team included visual and automated assessments to identify potentially impactful anomalies or slope changes that may adversely impact hydraulic computations.

The final DEM data developed for the International Falcon Reservoir Watershed are assured to meet FEMA standards and present a representative surface developed from leveraged elevation data for the purposes of this BLE project.

2.2 2D BLE Methods

The following sections describe the 2D computational mesh and program setting considerations, followed by discussion and tabulation of hydrologic and hydraulic engineering methods and model inputs.

2.2.1 2D Computational Mesh and Settings

The HEC-RAS 2D computational mesh defines the extents of the 2D flow and can affect the accuracy of the 2D calculations. A denser mesh may provide more accurate results, but it can dramatically increase model run times. The original 2D mesh for the model was established as evenly spaced cells at approximately 200 feet. The mesh was further refined by placing breaklines along roads, berms, ridges, and other high ground that can impede the flow as well as stream centerlines to allow flow conveyance. To reduce model run times, the International Falcon Reservoir HUC-8 was bisected into North and South study areas, and a separate RAS model was created for each. The North model included the following HUC-10 basins: Retama Creek – San Juanito Creek, Dolores Creek, Cavasara Creek – Rio Grande; and the South model included the following HUC-10 basins: Salamoneno Creek, Los Tanques Creek – Villa Creek, Arroyo Veleno – Falcon Reservoir, and Arroyo del Tigre Grande – Falcon Reservoir.

The HEC-RAS 2D computational mesh was created for International Falcon Reservoir Watershed based on the USGS HUC boundaries using ArcGIS toolsets, such as smoothing and simplification routines, significantly reducing the need for manual edits to mesh cells within HEC-RAS. The 2D mesh consists of 830,094 cells in the North model and 905,810 cells in the South model, with a 200-foot nominal mesh cell size. Factors that result in either larger or smaller cell sizes included:

- Proximity to the edge of the 2D mesh
- Presence of breaklines
- Refinement of mesh for significant flood control features (levees, dams, etc.)

To ensure the entire International Falcon Reservoir Watershed, including adjacent flows, was represented, a 1-mile buffer was initially added to the HUC boundaries for each model's 2D computational mesh area. This buffer was expanded where the two models tied-in to each other at the Rio Grande to create a larger overlap, allowing for flows to be transferred seamlessly from the North model to the South model. The mesh was further extended into Mexico as needed to capture the entire flood extents of the Rio Grande.

A 30-second base time step was used in both HEC-RAS models, applying the Diffusion Wave (simplified Full Momentum) equations. Variable time step was applied based on a time series of dividers to adjust the base time step to alleviate velocity spikes without significantly increasing the run times.

2.2.2 Model and Boundary Condition Setup

Using HEC-RAS rain-on-grid modeling requires establishing a 2D computational mesh boundary as discussed previously, and often requires defining inflow boundary conditions in addition to excess precipitation applied to the mesh. For the International Falcon Reservoir Watershed, inflow hydrographs from San Ambrosia – Santa Isabel Watershed and from the Mexico side of the International Falcon Reservoir Watershed were used, along with excess precipitation applied to the mesh. Figure 2.2 shows the 2D computational mesh for the International Falcon Reservoir Watershed.

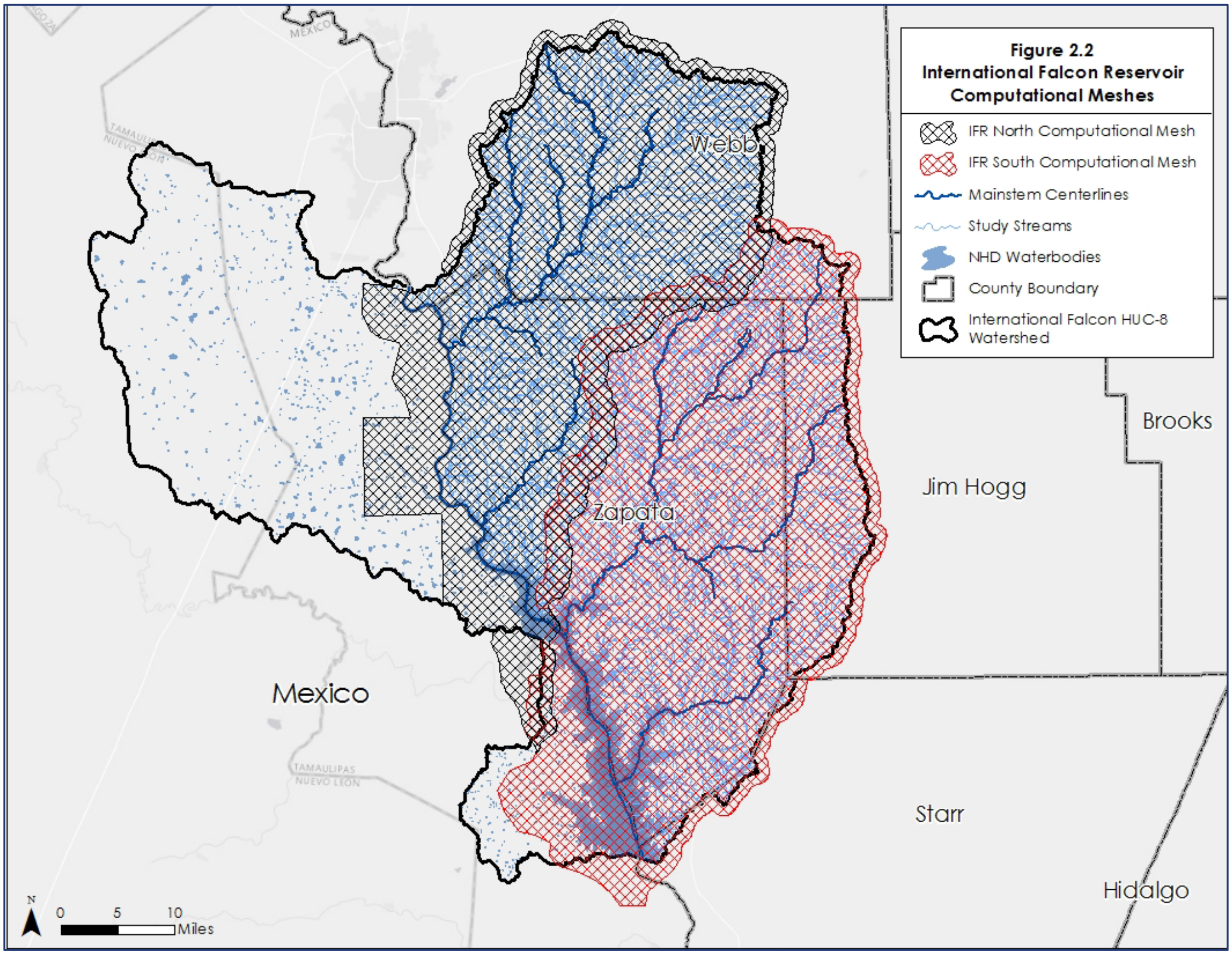

Figure 2.2: HEC-RAS 2D Computational Mesh

Figure 2.3 shows the inflow boundary condition locations for the International Falcon Reservoir Watershed. The development of the inflow hydrographs, and excess precipitation hyetographs for the 2D mesh, is described in the following Section 2.2.3.1.1.

A flow hydrograph representing outflow from the upstream San Ambrosia – Santa Isabel RAS model was used for the boundary condition along the Rio Grande. The remaining boundaries on the U.S side were defined as continuous boundaries to allow drainage from adjacent basins to leave the model area freely. Normal depth was used for non-unique outflow boundary conditions using approximate energy grade-line slopes estimated from the LiDAR terrain data.

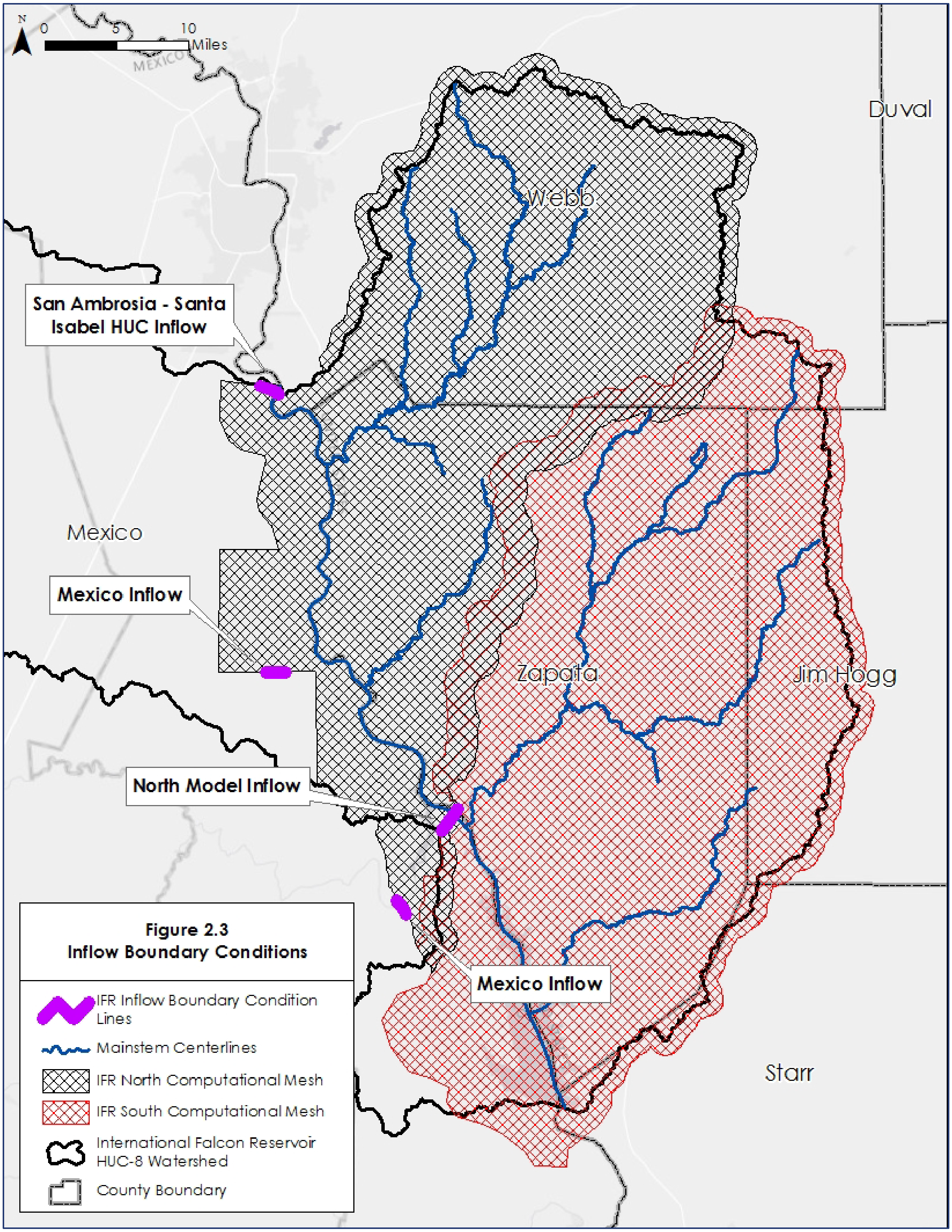

Figure 2.3: HEC-RAS 2D Computational Mesh and Inflow Boundary Conditions for International Falcon Reservoir Watershed

2.2.3 Hydrology

The International Falcon Reservoir Watershed contains the Rio Grande with contributing drainage area from both the United States and Mexico, with the greater portion from Mexico. The following sections discuss the approach for the hydrologic modeling in the United States and in Mexico.

2.2.3.1 United States Hydrology

HEC-HMS, Version 4.3, was used for the development of excess precipitation hyetographs which were applied to the 2D mesh in the United States. Precipitation frequency data published in NOAA Atlas 14, Volume 11 Version 2.0 (NOAA, 2018) were used for this study. These data were obtained from NOAA's Precipitation Frequency Data Server (PFDS) (http://hdsc.nws.noaa.gov/hdsc/pfds/index.html). The 10-, 4-, 2-, 1-, and 0.2-percent annual chance 24-hour precipitation depths for the watershed were determined by area-weighted intersection of gridded PFDS data within the study area. Excess precipitation for the 2D mesh was developed as described in Section 2.2.3.1.1.

Inflow hydrograph boundary conditions to for the 2D mesh were derived from the upstream model for the San Ambrosia – Santa Isabel Watershed hydraulic model and from the Mexico hydrology model (discussed in Section 2.2.3.3).

There are no known USGS and IBWC gages within the model area with more than 20-years of combined flow record for use in model validation.

2.2.3.1.1 Excess Precipitation for 2D Computational Mesh

HEC-HMS version 4.3 was used to apply the SCS Curve Number method to calculate losses and define excess precipitation for each watershed. Temporal distributions of point rainfall totals were defined using frequency storm distributions. The plus and minus standard error for the 1-percent annual chance precipitation depths were determined as the upper and lower 84% confidence limits on the nominal 1-percent depth, assuming a normal distribution of the logarithms for the precipitation depths.

In addition to recurrence interval precipitation estimates, NOAA Atlas 14 provides 90% confidence intervals of reported precipitation values. On a normal distribution curve, 90% confidence intervals (i.e. the upper and lower 95% confidence limits) correspond to +/- 1.645 standard deviations. The 1% plus and minus events are defined to be one standard deviation above and below the 1% event.

Curve Numbers were computed by intersecting the National Land Cover Dataset (NLCD) 2016 coverage and NRCS soils data based on the matrix presented in Table 2.3. A portion of the modeled area was outside the coverage of the NLCD, and these areas were assumed to be NLCD classification of 11 (open water) since they were located in and near the Rio Grande. Additionally, along the Rio Grande at the northern end of the International Falcon Reservoir Watershed, there were small portions of the soil data that did not have an assigned hydrologic soil group. All missing soil group data was assigned a value of "B" based on the patterns seen throughout the remainder of the data.

Table 2.3: Land Use-Soils-CN Matrix for Computing Initial Curve Numbers

LU_GridCode	NLCD LU Description	Hydrologic Soil Group			
		A	B	C	D
11	Open Water	99	99	99	99
21	Developed Open Space	49	69	79	84
22	Developed Low Intensity	61	75	83	87
23	Developed Medium Intensity	81	88	91	93
24	Developed High Intensity	89	92	94	95
31	Barren Land	39	61	74	80
41	Deciduous Forest	30	55	70	77
42	Evergreen Forest	30	55	70	77
43	Mixed Forest	30	55	70	77
52	Shrub Scrub	30	48	65	73
71	Herbaceous	49	62	74	85
81	Hay Pasture	39	61	74	84
82	Cultivated Crops	51	67	76	80
90	Woody Wetlands	72	80	87	93
95	Emergent Herbaceous Wetlands	72	80	87	93

The time of concentration (in hours) for the study area was approximated as the square root of the drainage area (in square miles). Time of concentration was multiplied by 0.6 to compute the lag time. The lag time does not impact the excess rainfall hyetograph, so it was not necessary to compute a more accurate basin travel time. The table below shows the curve number and lag time values used in this study.

Table 2.4: U.S. Rainfall-Runoff Parameters (Curve Number, Lag Time)

Sub-basin Description	CN	Lag Time (min)
International Falcon Reservoir - North	67	1,023
International Falcon Reservoir - South	64	1,134

NRCS rainfall-runoff methods were used to define excess precipitation applied to the 2D mesh, including curve numbers for defining rainfall losses and lag time for transforming the runoff temporally. No routing was considered in the rainfall-runoff modeling. Frequency storm distributions were used for defining temporal distributions of point rainfall totals. Weighted average rainfall depths were calculated for the 10-, 4-, 2-, 1-, and 0.2-percent ACEs. The weighted average rainfall depths for 1-percent plus and 1-percent minus rasters were also calculated using the upper and lower confidence intervals for the 1-percent event. These steps were performed for durations of 5-min, 15-min, 1-hr, 2-hr, 3-hr, 6-hr, 12-hr, and 24-hr. The weighted average rainfall depths were used to determine the excess precipitation in the HEC-HMS model. Areal reduction was not applied to the US portion of the watershed based on the sensitivity analysis described in Section 2.3.1.1. Table 2.5 provides the rainfall depths for a 24-hour storm duration used for determining excess precipitation.

Table 2.5: Precipitation Rainfall Depths for Estimating Excess Precipitation for HEC-RAS 2D Computational Mesh

Sub-basin Description	Percent Annual Chance Exceedance	Rainfall Duration (in)							
		5 min	**15 min**	**1 hr**	**2 hr**	**3 hr**	**6 hr**	**12 hr**	**24 hr**
International Falcon Reservoir	10%	0.79	1.58	2.90	3.61	4.03	4.71	5.27	5.85
	4%	0.97	1.95	3.58	4.52	5.09	6.00	6.74	7.49
	2%	1.12	2.24	4.12	5.25	5.95	7.07	8.00	8.92
	1%	1.28	2.55	4.70	6.05	6.91	8.28	9.41	10.52
	1% minus	0.98	1.96	3.62	4.68	5.36	6.46	7.38	8.29
	1% plus	1.57	3.14	5.79	7.43	8.46	10.10	11.44	12.74
	0.2%	1.68	3.34	6.26	8.29	9.61	11.68	13.29	14.77

Figure 2.4 and Figure 2.5 show the hyetographs applied to the 2D computational mesh.

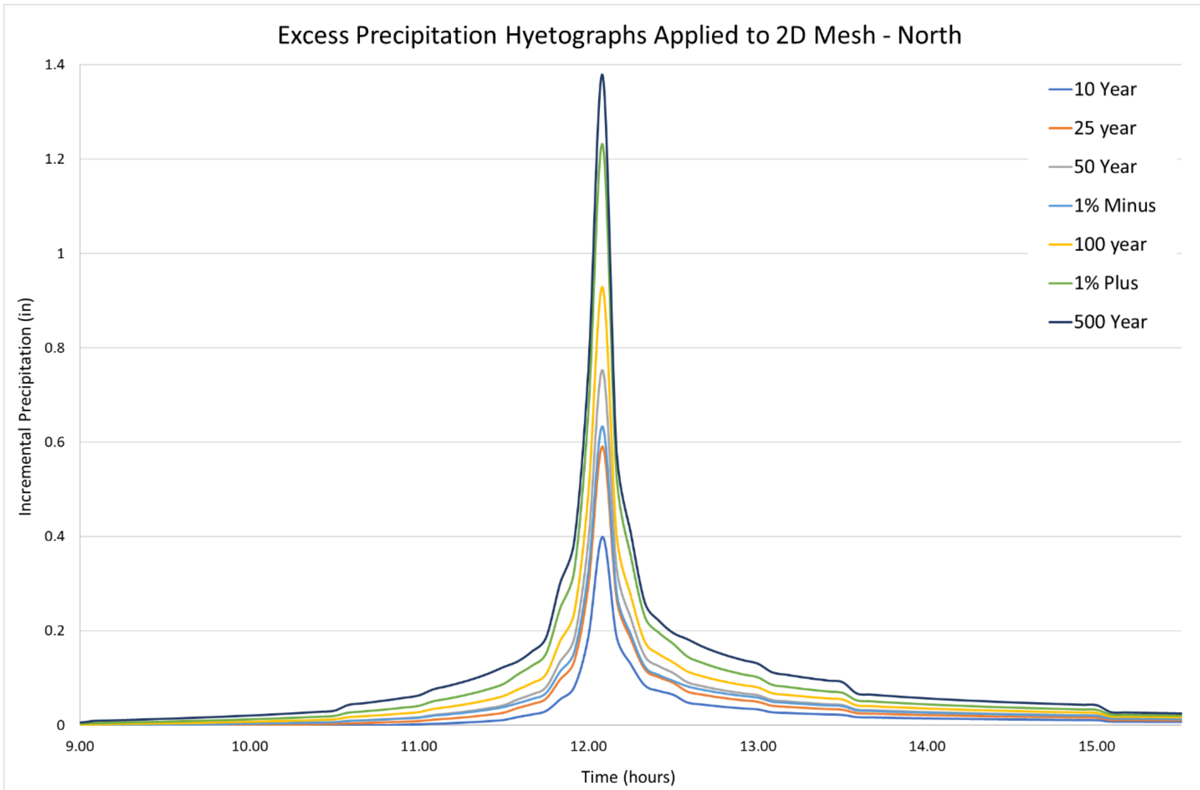

Figure 2.4: Excess Precipitation Hyetographs Applied to the Computational Mesh in International Falcon Reservoir - North

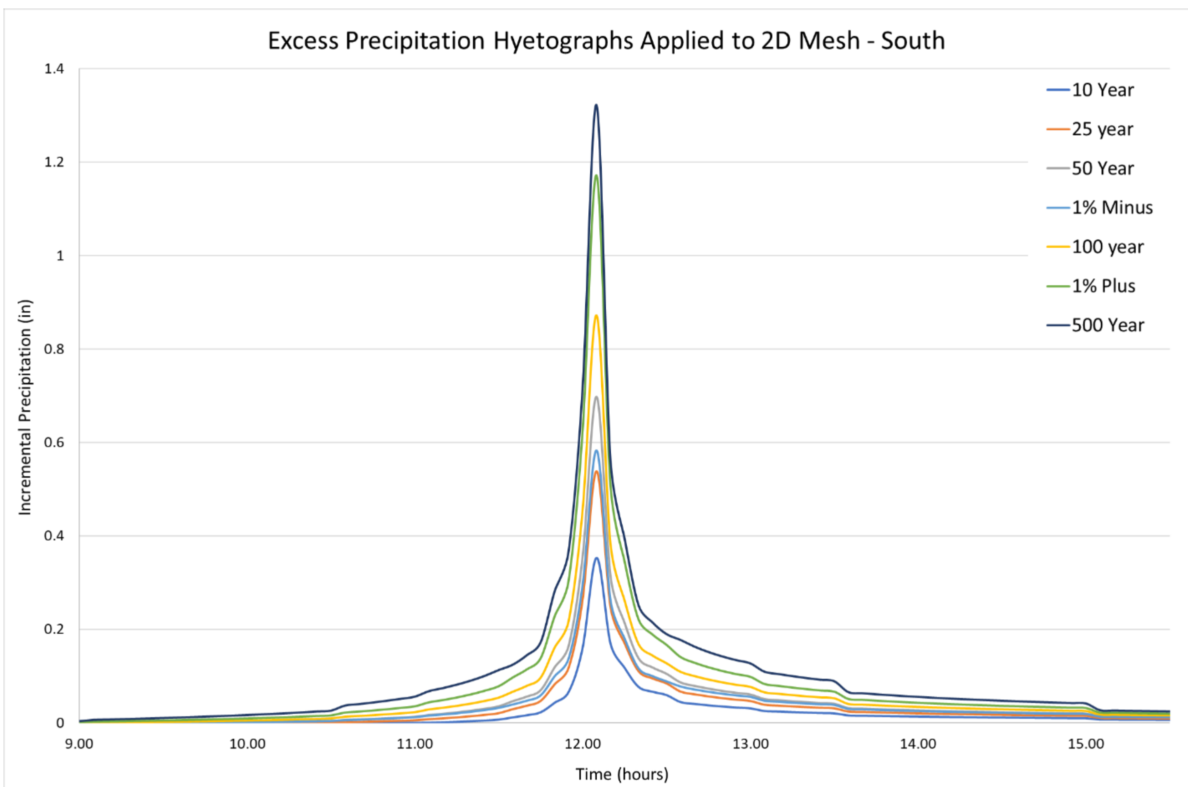

Figure 2.5: Excess Precipitation Hyetographs Applied to the Computational Mesh in International Falcon Reservoir - South

2.2.3.2 Mexico Hydrology

HEC-HMS, Version 4.3 was used to develop the inflow hydrographs applied to the 2D mesh for the contributing drainage area from Mexico. The hydrology in Mexico utilized drainage areas obtained from the *Instituto Nacional de Estadística, Geografía y Informatica* (INEGI) website, specifically, the "*Simulador de Flujos de Agua de Cuencas Hidrograficas*". These basins were merged or adjusted based on location and engineering judgement.

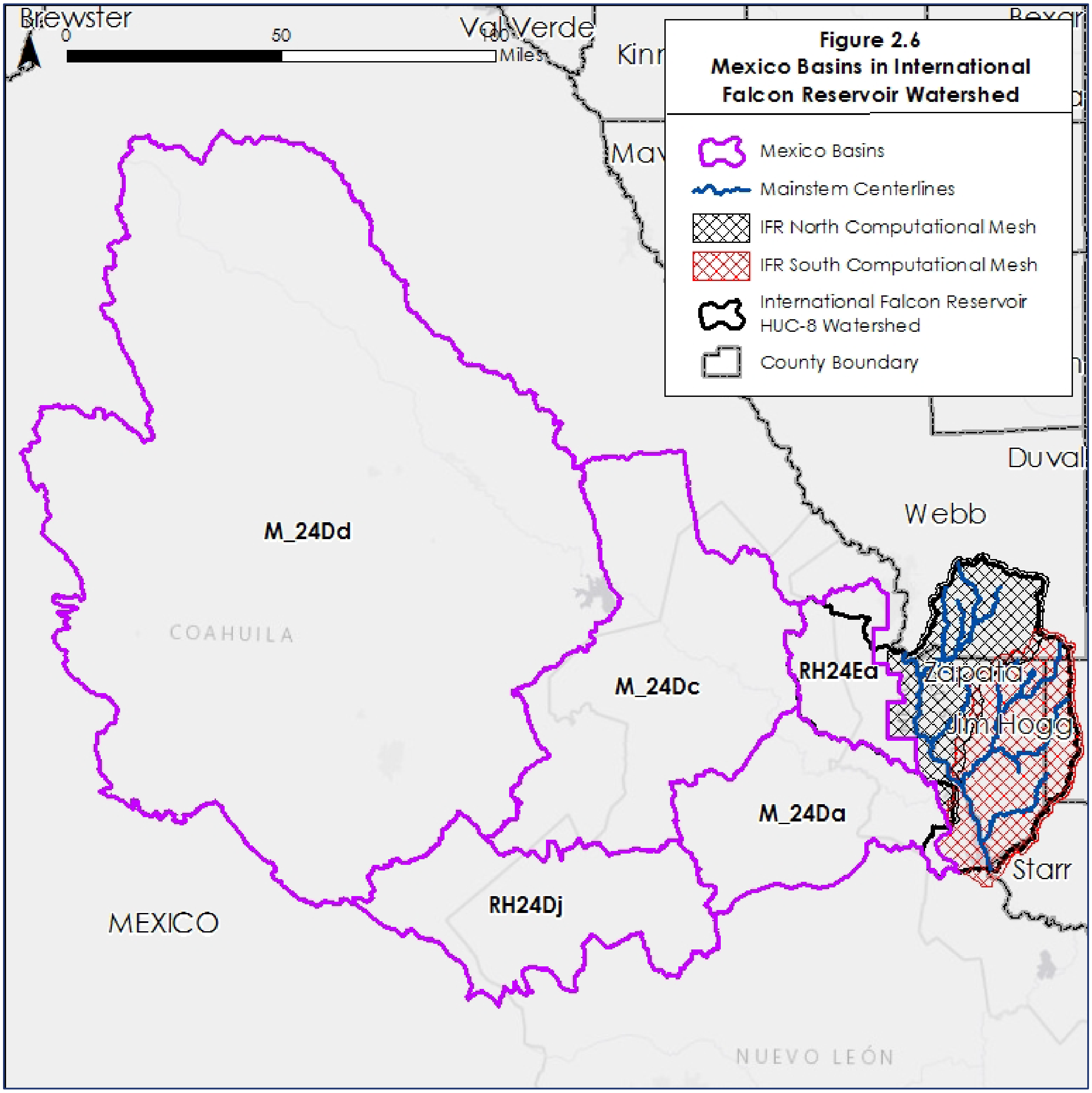

Figure 2.6: Mexico Basins in International Falcon Reservoir Watershed

Mexico land use data was based on the North American Land Change Monitoring System (NALCMS) 2015 land cover 30-meter resolution map. The NALCMS land cover categories were converted to NLCD codes according to Table 2.6 below.

Table 2.6: Mexico Landcover

NALCMS 2015 Land Cover Values and Description		NLCD Code	NLCD Description
Value 1	Temperate or sub-polar needleleaf forest	42	Evergreen Forest
Value 2	Sub-polar taiga needleleaf forest	42	Evergreen Forest
Value 3	Tropical or sub-tropical broadleaf evergreen forest	42	Evergreen Forest
Value 4	Tropical or sub-tropical broadleaf deciduous forest	41	Deciduous Forest
Value 5	Temperate or sub-polar broadleaf deciduous forest	41	Deciduous Forest
Value 6	Mixed forest	43	Mixed Forest
Value 7	Tropical or sub-tropical shrubland	52	Shrub Scrub
Value 8	Temperate or sub-polar shrubland	52	Shrub Scrub
Value 9	Tropical or sub-tropical grassland	71	Herbaceous
Value 10	Temperate or sub-polar grassland	71	Herbaceous
Value 14	Wetland	95	Emergent Herbaceous Wetlands
Value 15	Cropland	82	Cultivated Crops
Value 16	Barren lands	31	Barren Land
Value 17	Urban	23	Developed Medium Intensity
Value 18	Water	11	Open Water

The time of concentration for the Mexico sub-basins was calculated using velocity-based methods. The flow was split into five major categories: overland flow, shallow concentrated flow, channel – mountainous, channel – hills, and channel – plains. Each of the channel sections were drawn and had an estimated slope. The velocities for channel sections were calculated using the open channel sections in Bentley's FlowMaster software. Table 2.7 shows the curve number and lag time values used in this study.

Table 2.7: Mexico Rainfall-Runoff Parameters (Curve Number, Lag Time)

Sub-basin Description	CN	Lag Time (min)
M_24Da	71	4,492
M_24Dc	70	2,058
M_24Dd	70	8,206
RH24Ea	71	1,894
RH24Dj	70	1,493

Precipitation data for Mexico was obtained from Centro Nacional de Prevencíon de Desastres in Mexico (http://www.atlasnacionalderiesgos.gob.mx/portal/fenomenos). Isohyets were available for the 24-hr storm event and treated like contours to create a precipitation raster. Rainfall depths were available only for 1-hour and 24-hour storm durations, so depths for the other durations (5-min, 15-min, 2-hr, 3-hr, 6-hr, and 12-hr) were computed based on average ratios established from the depth-durations in the U.S.

hydrology. Additionally, rainfall depths were not available for the 4-percent, 1-percent plus, and 1-percent minus frequency events, so depths were interpolated based on ratios established from the U.S. hydrology.

Areal reduction was applied to the Mexico subbasins using the USGS areal reduction curves (USGS WRI Report 99-4267). Areal reduction was applied to the Mexico basins and not the US basins in order to align with the gage analyses on the Rio Grande and to ensure that the International Falcon Reservoir stage did not exceed the top of the dam in the 0.2-percent storm event.

2.2.3.2.1 Don Martin Reservoir

Don Martin Lake is a large reservoir in Coahuila, Mexico that sits on Rio Salado, which is a tributary to the Rio Grande. The reservoir was constructed in the 1930s for flood control and irrigation purposes. The reservoir was modeled in HEC-HMS with an elevation-discharge rating curve. This rating curve was produced based on historical stage-storage data and a stage-discharge curve that was built using the weir equation. Dam information was obtained from *Estadisticas del Agua en Mexico* (2010, http://www.conagua.gob.mx/conagua07/contenido/documentos/capitulo_4.pdf).

The dam consists of 26 radial gates for the primary service spillway. Each gate is 25 feet wide and 14.5 feet high, resulting in a total weir length of 650 feet. The crest elevation of the gates is 844.42 feet, which was conservatively assumed to be the initial water surface elevation in the reservoir. The maximum emergency level is at 858.92 feet, and the top of dam is at 872.05 feet.

2.2.3.3 Rainfall-Runoff Hydrograph Boundary Conditions

This section discusses the drainage areas for which inflow hydrographs, developed from rainfall-runoff modeling, were used as boundary conditions to the 2D computational mesh. The following figures show the inflow hydrographs for each contributing flooding source applied to the 2D computational mesh. Figure 2.7 includes the San Ambrosia – Santa Isabel drainage area contributing inflow hydrographs to International Falcon Reservoir. Figure 2.8 and Figure 2.9 include the Mexico drainage area contributing inflow hydrographs to International Falcon Reservoir.

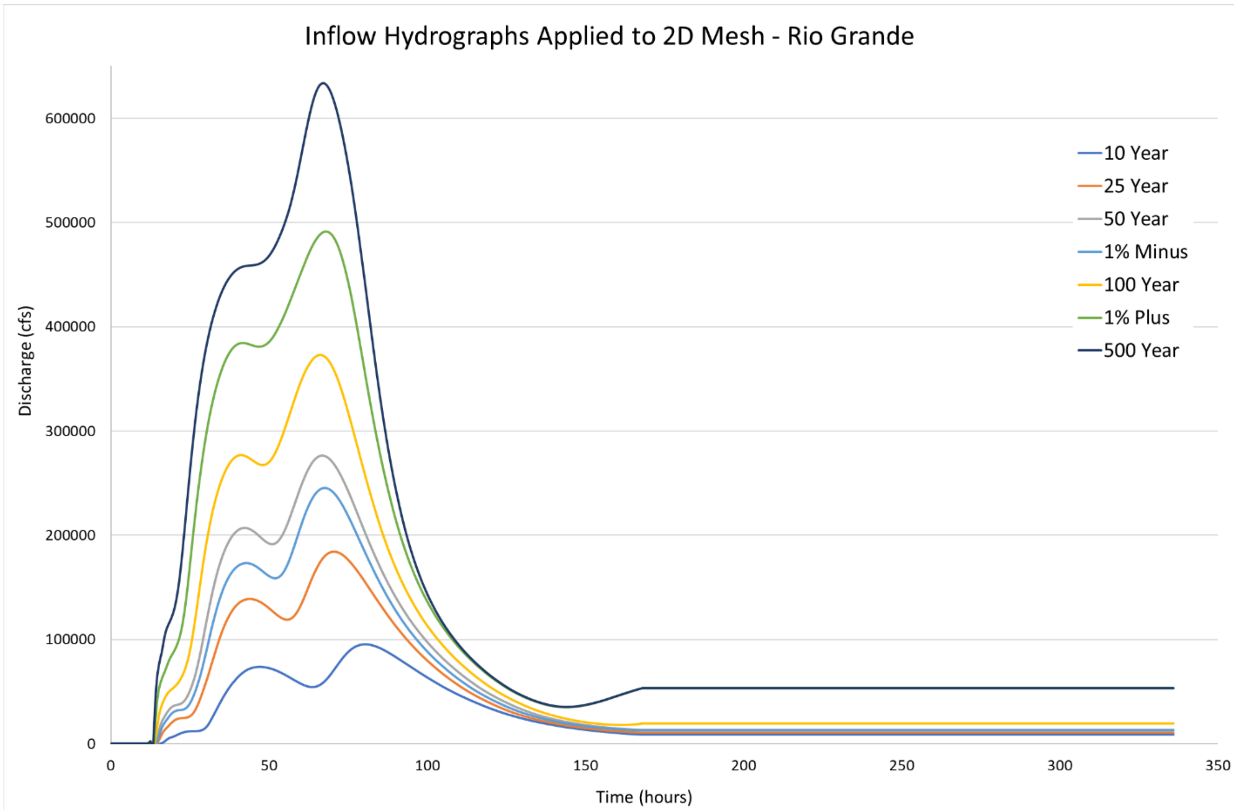

Figure 2.7: San Ambrosia – Santa Isabel Watershed – Rio Grande Contributing Drainage Area Inflow Hydrographs

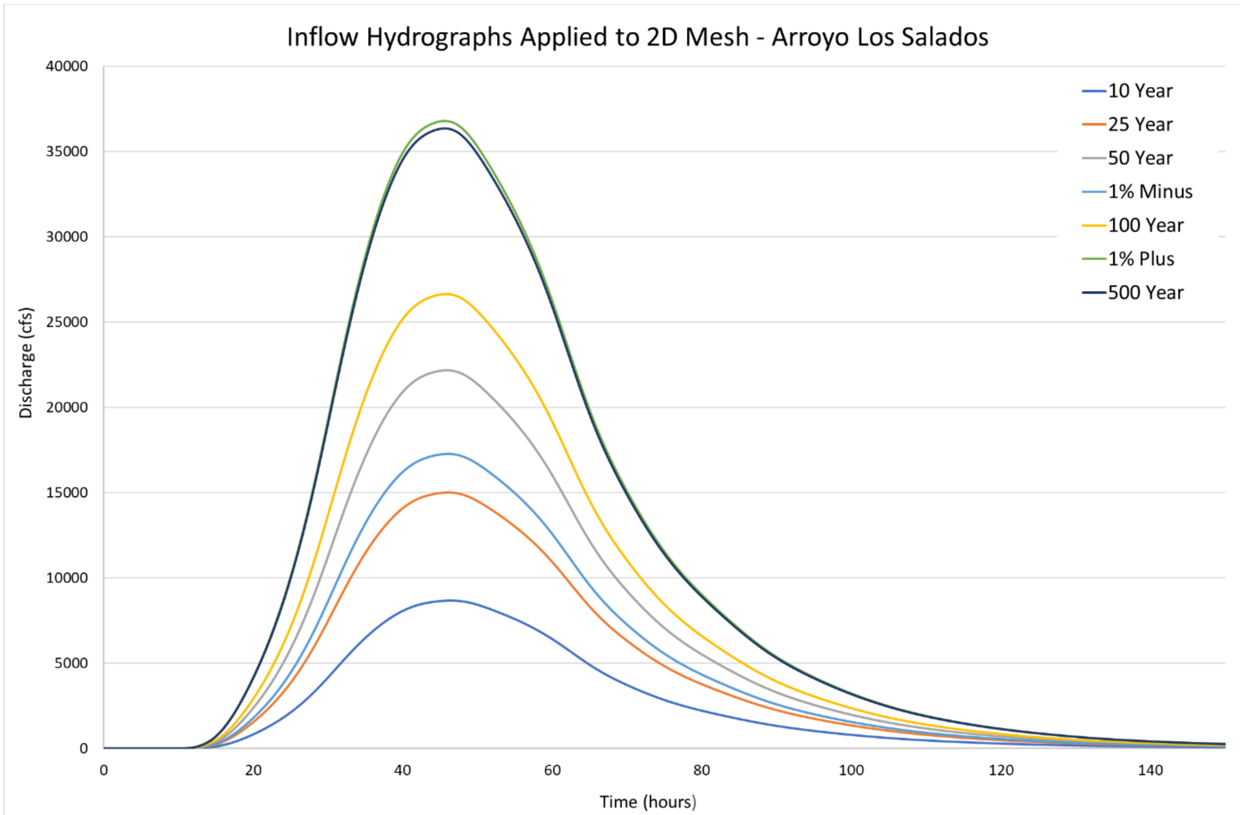

Figure 2.8: RH24Ea Basin – Arroyo Los Salados Contributing Drainage Area Inflow Hydrographs

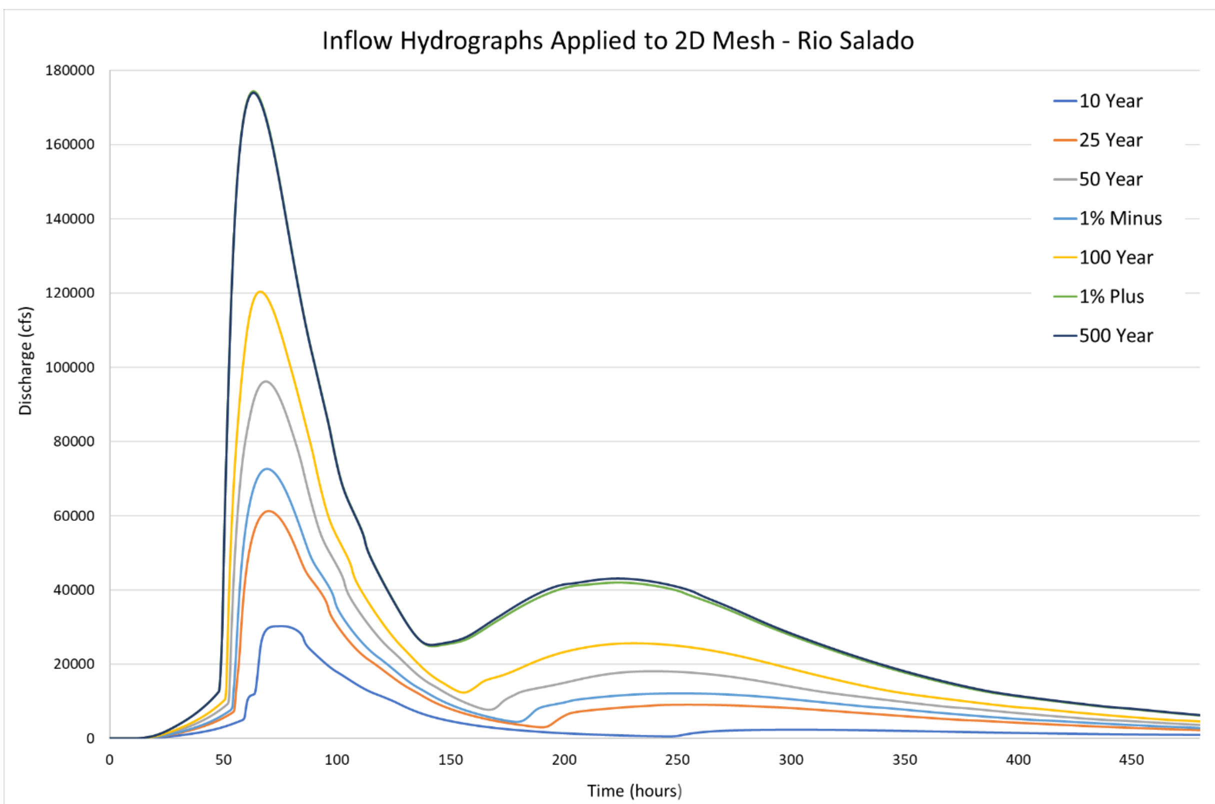

Figure 2.9: Rio Salado Junction 1 – Rio Salado Contributing Drainage Area Inflow Hydrographs

2.2.4 Hydraulics

This section describes the remaining hydraulic modeling considerations, including implementation of Manning's roughness values, breaklines, and hydraulic structures within the 2D computational mesh.

2.2.4.1 Roughness Coefficients

A Manning's n roughness coverage was developed for the 2D computational mesh using typical values for roughness for given NLCD land classifications. In several areas, the channel section land use indicated a Manning's n-value inappropriate for channel conveyance. A 20-foot buffer zone was created by automated processes around each stream centerline to create a main channel roughness zone. The channel roughness zone was given a Manning's n value of 0.045, obtained from the HEC-RAS User's Manual, to ensure the channel 2D cells have appropriate conveyance. The table below shows a typical land use-roughness matrix used in defining the roughness coverage for the study area.

Table 2.8: NLCD 2016-Manning's N Roughness Matrix

NLCD Classification	Manning's N	Minimum	Normal	Maximum
Open Water	0.030	0.025	0.038	0.050
Developed, Open Space	0.040	0.030	0.040	0.050
Developed, Low Intensity	0.060	0.060	0.090	0.120
Developed, Medium Intensity	0.080	0.080	0.120	0.160
Developed, High Intensity	0.120	0.120	0.160	0.200
Barren Land	0.030	0.023	0.025	0.030
Deciduous Forest	0.120	0.100	0.150	0.200
Evergreen Forest	0.120	0.080	0.120	0.160
Mixed Forest	0.120	0.080	0.140	0.200
Scrub/Shrub	0.060	0.070	0.115	0.160
Grassland/Herbaceous	0.030	0.025	0.038	0.050
Pasture/Hay	0.040	0.025	0.038	0.050
Cultivated Crops	0.040	0.020	0.035	0.050
Woody Wetlands	0.100	0.045	0.098	0.150
Emergent Herbaceous Wetland	0.080	0.050	0.068	0.085
Main Channel[1]	0.045			

Source: HEC-RAS 2D Modeling User's Manual

[1] Clean, winding, some pools and shoals, some weeds and stones, lower stages, more ineffective slopes and sections

2.2.4.2 Breaklines

Breaklines align grid cell faces and were used within the 2D mesh area to define prominent features including road embankments and hydraulic structures as well as stream centerlines. Road embankments were identified in ArcGIS and imported into HEC-RAS as breaklines to ensure that water was not routed past roads until it was deep enough to overtop the road. County, interstate, state recognized, and U.S. roads were incorporated for road breaklines from the ESRI North America Detailed Streets layer. The stream centerlines were input as breaklines to ensure cells lined up perpendicular to the stream and to capture stream conveyance. Stream centerlines were simplified to speed up editing and run times in HEC-RAS. Levees from the National Levee Inventory, and railroads from the TIGER Railroads layer were also incorporated. Additionally, several private dams and embankments were added as breaklines to better represent flow patterns through and around these structures.

2.2.4.2.1 Roads

Culvert crossings specifically were identified by intersections of the stream centerlines and road lines by automated processes and were modeled by burning channels through the embankment in the DEM to prevent unnecessary impoundment of water. This approach was used for most hydraulic structures because it could be implemented in ArcGIS on a large scale with much less effort than alternative methods. Since this an automated process, it was not possible to isolate specific culverts to burn through the DEM, thus conservative assumptions on width of opening were applied to not overestimate the release of water through the crossing.

Culvert crossings that were not processed out of the terrain data were modeled by offsetting breaklines adjacent to the road embankment to align grid cells around the embankment and allow water to be routed across the embankment without creating artificial backwater. This approach was used for most hydraulic structures because it could be implemented in ArcGIS on a large scale with much less effort than alternative methods. An example of the offset breakline approach is shown below.

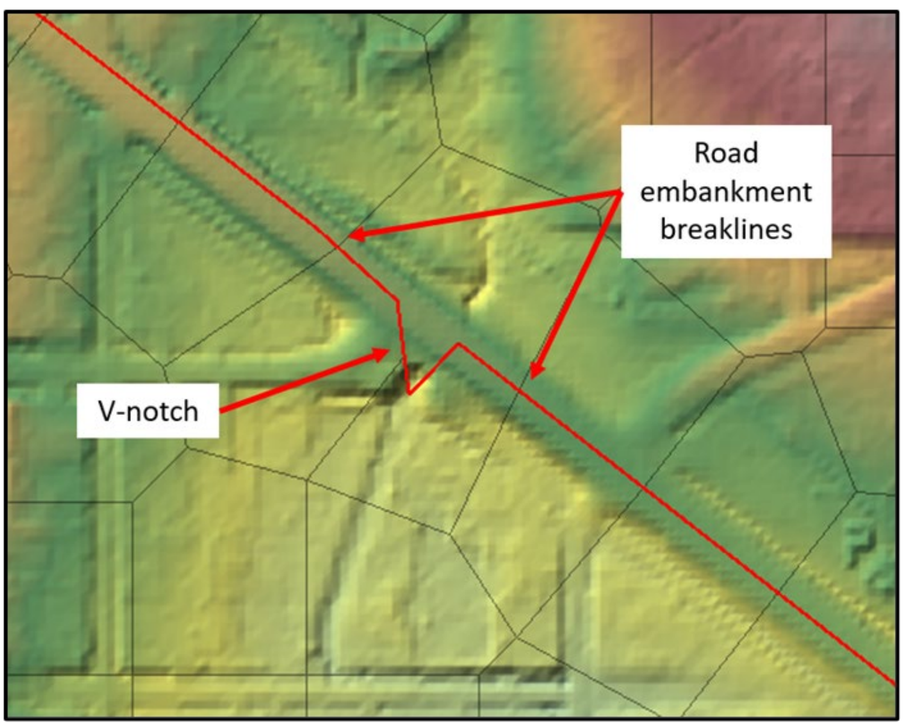

Figure 2.10: V-notch Breakline Approach at Bridge Crossing

2.2.4.3 Initial Conditions

Initial conditions were not used in the International Falcon Reservoir 2D BLE model.

2.2.5 Special Assumptions

Due to the large size and long computation times of the International Falcon Reservoir HUC, it was deemed necessary to split the HUC-8 into North and South RAS models. The models were split approximately 1,000 feet upstream of the confluence of the Rio Grande and the Rio Grande tributary from Mexico. There were some differences in the North and South models such as necessary boundary conditions, but nominal mesh cell size and landuse n-values remained constant between the two models. A flow hydrograph along the Rio Grande was used to transfer flow from the North model to the South model, assuming normal depth conditions. Then, a stage hydrograph was generated from the South model and applied at the downstream end of the North model to ensure a tie-in between the two half-HUCs. Figure 2.11 below shows the two model boundaries with respective buffers used in the RAS models.

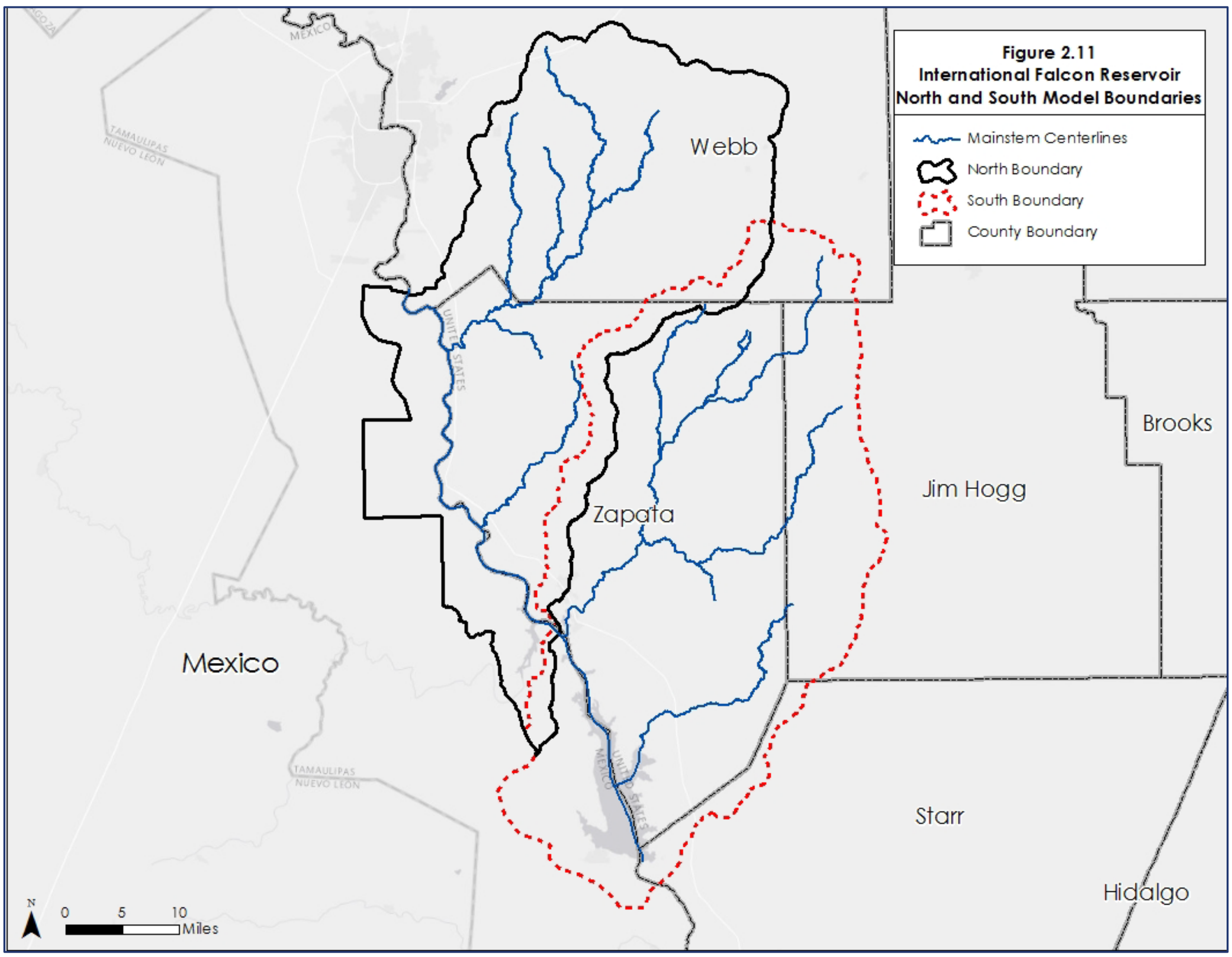

Figure 2.11 : International Falcon Reservoir Model Boundaries

2.2.5.1 International Falcon Reservoir

The International Falcon Reservoir is on the Rio Grande, located on the downstream end of the International Falcon Reservoir Watershed, immediately upstream of the Los Olmos Watershed. The International Falcon Dam was constructed in 1954 as a major flood control reservoir, and is operated by the International Boundary and Water Commission (IBWC). The dam provides significant flood protection for the region and thus required a more detailed modeling approach than typically used in BLE. Data for the dam was obtained from the IBWC. To model the dam structure in HEC-RAS, 2D connection lines were used for each dam outflow structure. Figure 2.12 provides a schematic of the 2D connection setup in HEC-RAS. The spillway was drawn this way to increase model stability and decrease drawdown effects at the spillway.

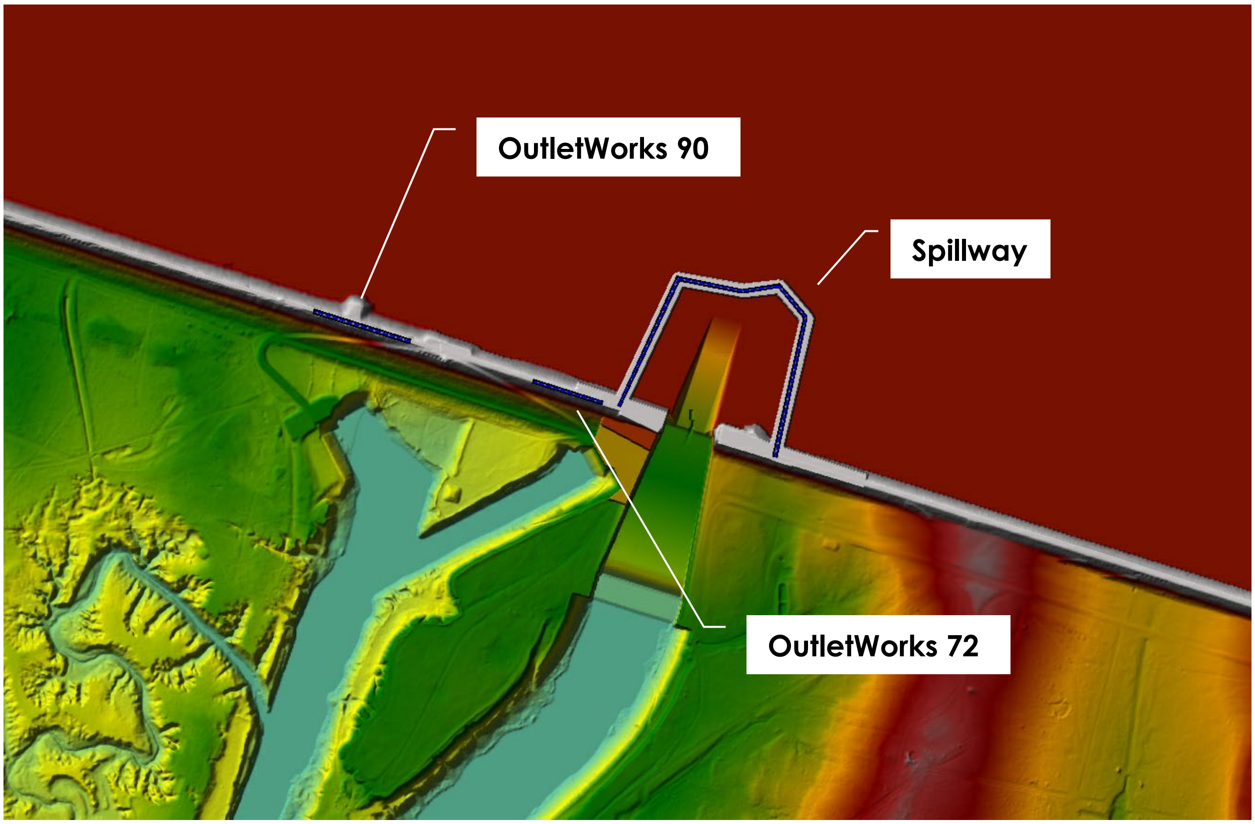

Figure 2.12 : International Falcon Reservoir Dam SA /2D Connection Alignments

Due to limited information and the high-level modeling approached used for BLE, additional information was not acquired for the gate operations of these structures. Future detailed studies in this area may consider coordination with the IBWC to represent the spillway discharges more accurately.

A static reservoir elevation of 285.75 ft was assumed and built into the terrain model. This elevation was selected because it was the highest water surface elevation measured in the reservoir in the last ten years, which provides a conservative estimate of the lake's initial storage. All discharge rating curves (described below) thus begin at elevation 285.75 ft. The top of dam is at elevation 323.0 ft-msl. Table 2.9 lists important design elevations within the dam.

Table 2.9: Important Dam Design Elevations

Description	Elevation (ft msl)
Dam top	323.0
Maximum water surface	314.2
Top of normal flood control pool, top of gates	306.7
Top of conservation pool	301.2
Assumed minimum water surface (HEC-RAS)	285.75
Primary spillway crest elevation, bottom of gates	256.7
Minimum pool level since storage began	235.0
Lowest water outlet for downstream use	203.33

The dam consists of a 350-foot-wide concrete ogee-crested service spillway at crest elevation 256.7 ft-msl. The service spillway is controlled by six fixed wheel gates, each 50 feet tall and 50 feet wide. The service spillway was modeled using a discharge rating curve obtained from the United States Bureau of Reclamation's *Hydraulic Model Studies of Falcon Dam – Hydraulic Laboratory Report No. Hyd. 276* (1950). Figure 2.13 shows the discharge-elevation curve used to model the service spillway. Multiple iterations on dam release capacity were run to test the sensitivity of the resulting peak reservoir elevation. Targets were to see a 1-percent storm elevation peak near the top of the flood control pool (306.7 ft) and a 0.2-percent storm elevation peak near the maximum water surface elevation (314.2 ft) and below the dam top (323.0 ft). Based on these iterations, gates were set to pass 90% of the full design capacity (all gates fully open). The resulting peak reservoir elevations at the dam are 305.1 ft in the 1-percent storm and 317.8 ft in the 0.2-percent storm.

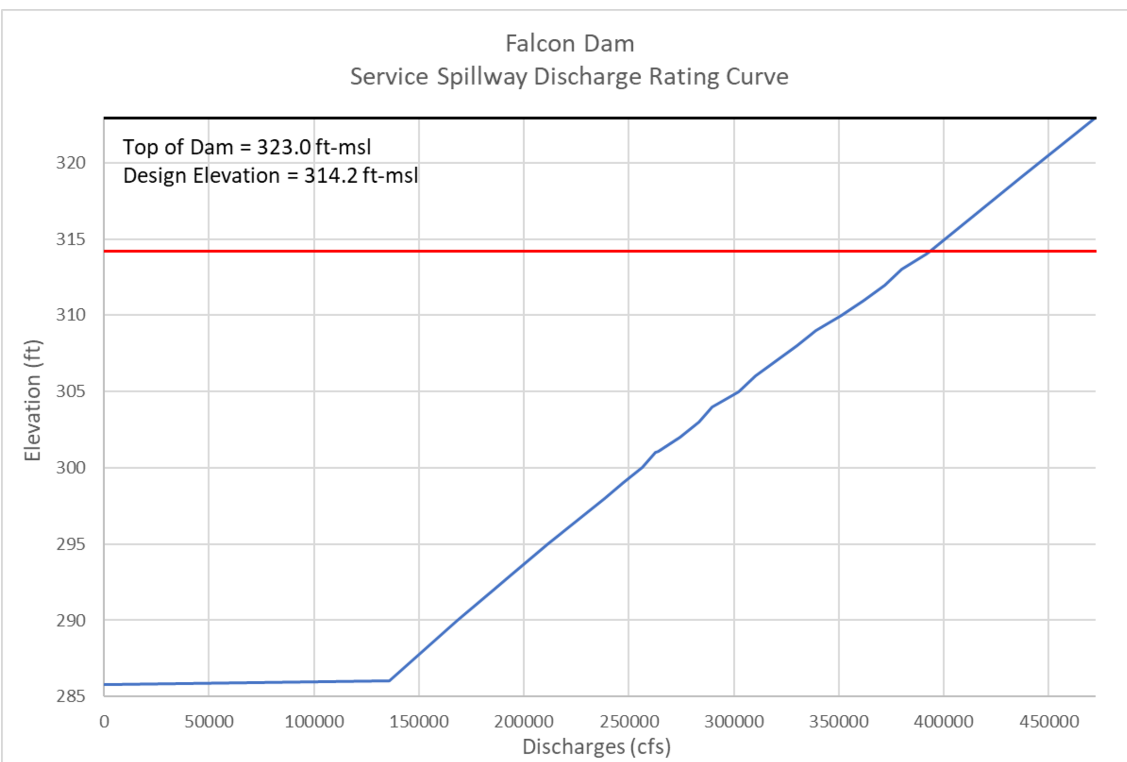

Figure 2.13 : Falcon Dam Service Spillway Discharge Rating Curve

The dam also consists of two outlet works structures. One structure consists of two 90-inch hollow-jet valves, and the other structure consists of two 72-inch hollow-jet valves. Figure 2.14 and Figure 2.15 show the discharge-elevation curves (obtained from the *Falcon Dam* report) used to model the two outlet works structures.

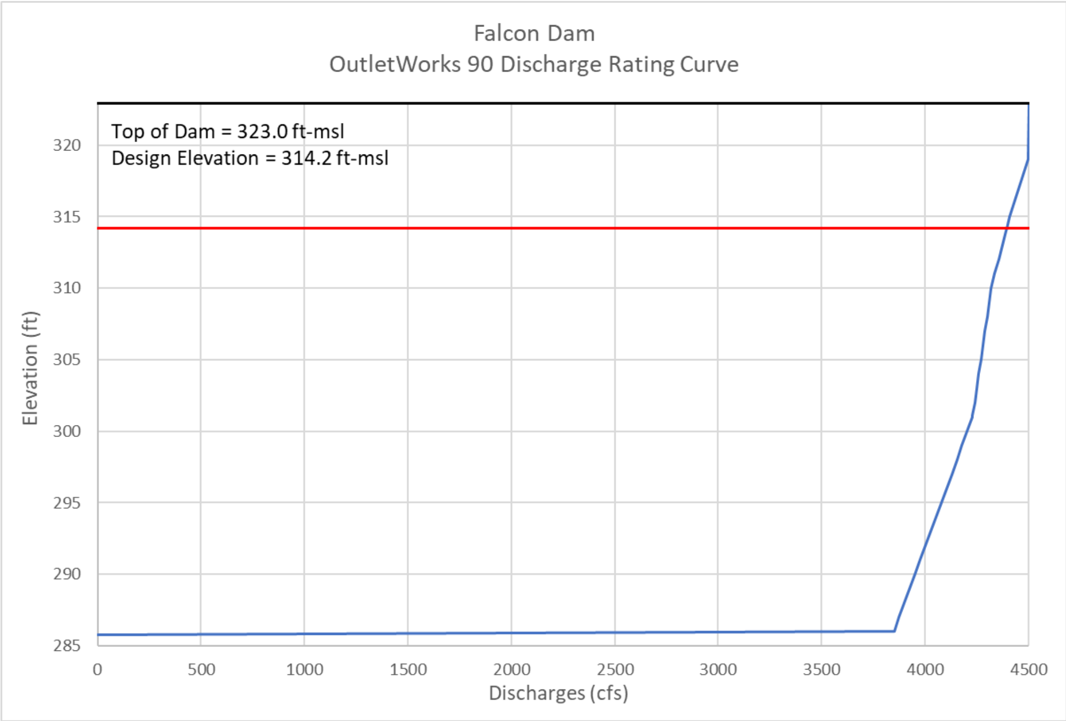

Figure 2.14 : Falcon Dam Outlet Works 90 Discharge Rating Curve

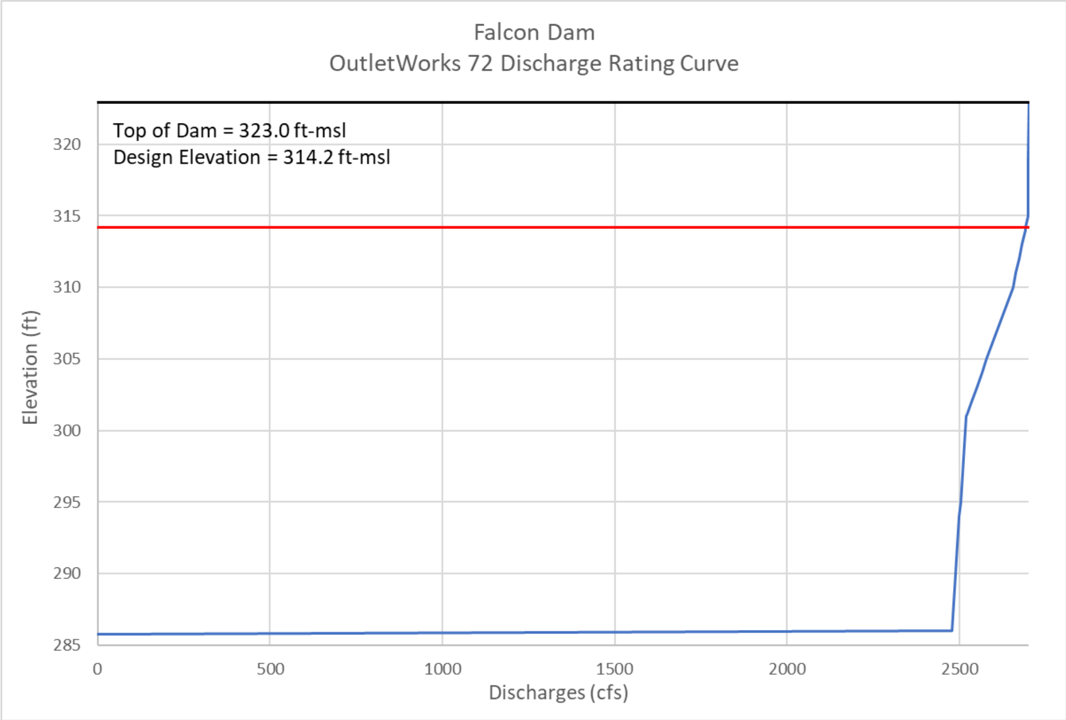

Figure 2.15 : Falcon Dam Outlet Works 72 Discharge Rating Curve

2.3 Model Results

The 2D BLE results for the study produced flood risk mapping that compared reasonably well with the effective SFHA in most cases and provides additional estimated flood risk in areas that do not currently have an SFHA mapped. Additionally, the application of rain-on-grid modeling allowed for the identification of localized flood risk beyond the extents of the traditional SFHAs. Table 2.10 shows a comparison of some of the effective BFE data with the model results. In general, differences are within 1.0 ft, with the largest difference at 1.6 ft (San Juanito Creek Tributary). The differences can be attributed to the effective study date (which is 2008 in the International Falcon Reservoir Watershed), the availability of newer digital topography, the change in rainfall data, and the 2D nature of this BLE study. While there are differences in water surface elevation, the modeled flood extents align well to the effective mapping.

While the results provide context for flood risk communication as part of the Discovery process, and are scalable, the results require further analysis to be used for regulatory purposes. The validity of the 2D BLE results should be verified through community work map meetings before being applied as a regulatory product.

Table 2.10: Effective and Model BFE Comparison

Stream	Comparison Point Effective Station	Effective BFE (feet)	Model BFE (feet)	Difference (feet)
San Juanito Creek Tributary	36700	529.5	530.3	0.8
San Juanito Creek Tributary	37643	531.8	531.0	-0.8
San Juanito Creek Tributary	37683	531.9	531.0	-0.9
San Juanito Creek Tributary	38766	535.0	535.5	0.5
San Juanito Creek Tributary	41329	537.1	535.6	-1.5
San Juanito Creek Tributary	42190	537.3	535.7	-1.6
San Juanito Creek Tributary	42656	537.5	535.9	-1.6
San Juanito Creek Tributary	42698	537.5	535.9	-1.6
San Juanito Creek Tributary	43472	538.3	537.0	-1.3
San Juanito Creek Tributary	44320	541.0	539.5	-1.5
San Juanito Creek Tributary	45848	542.5	541.1	-1.4
San Juanito Creek Tributary	47121	543.4	543.7	0.3
San Juanito Creek Tributary	48540	545.0	545.0	0.0
San Juanito Creek Tributary	50496	547.2	548.4	1.2
San Juanito Creek Tributary	51715	550.7	551.1	0.4
San Juanito Creek Tributary	53607	553.8	554.1	0.3
San Juanito Creek Tributary	54452	555.1	555.5	0.4
San Juanito Creek Tributary	54507	555.1	555.6	0.5
San Juanito Creek Tributary	55211	556.3	557.0	0.7
San Juanito Creek Tributary	56648	559.0	559.4	0.4
San Juanito Creek Tributary	57774	561.1	561.6	0.5
San Juanito Creek Tributary 1	1690	536.1	535.7	-0.4
San Juanito Creek Tributary 1	3640	536.4	536.4	0.0
San Juanito Creek Tributary 1	4664	537.3	538.1	0.8
San Juanito Creek Tributary 1	5337	538.4	539.9	1.5

Stream	Comparison Point Effective Station	Effective BFE (feet)	Model BFE (feet)	Difference (feet)
San Juanito Creek Tributary 1	6629	540.6	541.7	1.1
San Juanito Creek Tributary 1	7424	542.2	543.1	0.9
San Juanito Creek Tributary 1	9018	544.8	545.2	0.4
San Juanito Creek Tributary 1	10747	547.2	547.7	0.5
San Juanito Creek Tributary 1	11835	549.5	549.8	0.3
San Juanito Creek Tributary 1	13472	553.3	552.8	-0.5
San Juanito Creek Tributary 1	14399	555.9	555.3	-0.6
San Juanito Creek Tributary 1	15247	558.1	557.8	-0.3
San Juanito Creek Tributary 1	16337	560.6	559.8	-0.8
San Juanito Creek Tributary 2	3690	546.8	546.7	-0.1
San Juanito Creek Tributary 2	4189	548.7	547.9	-0.8
San Juanito Creek Tributary 2	4780	550.2	549.7	-0.5
San Juanito Creek Tributary 2	5650	553.3	552.2	-1.1
San Juanito Creek Tributary 2	7013	558.8	557.7	-1.2
San Juanito Creek Tributary 2	7514	561.0	560.4	-0.6
San Juanito Creek Tributary 2	8342	565.9	564.6	-1.3
San Juanito Creek Tributary 2	9005	568.9	568.1	-0.8
San Juanito Creek Tributary 2	9530	571.7	570.9	-0.8
San Juanito Creek Tributary 2	10091	576.5	575.5	-1.0
San Juanito Creek Tributary 3	4450	547.9	547.1	-0.8
San Juanito Creek Tributary 3	4864	549.1	548.1	-1.0
San Juanito Creek Tributary 3	5587	551.1	549.7	-1.4
San Juanito Creek Tributary 3	6777	554.7	553.9	-0.8
San Juanito Creek Tributary 3	7968	558.2	557.1	-1.1
San Juanito Creek Tributary 3	9051	560.8	560.8	0.0
San Juanito Creek Tributary 3	9677	563.5	563.1	-0.4
San Juanito Creek Tributary 3	10419	568.2	566.7	-1.5
San Juanito Creek Tributary 3	11053	571.5	572.0	0.5
San Juanito Creek Tributary 3	11616	575.6	574.6	-1.0
San Juanito Creek Tributary 4	1355	536.9	536.4	-0.5
San Juanito Creek Tributary 4	2642	538.1	538.2	0.1
San Juanito Creek Tributary 4	3723	539.5	539.7	0.2
San Juanito Creek Tributary 4	4501	541.1	541.6	0.5
San Juanito Creek Tributary 4	5661	544.2	544.9	0.7
San Juanito Creek Tributary 4	6820	547.3	547.5	0.2
San Juanito Creek Tributary 4	7960	549.9	549.5	-0.4
San Juanito Creek Tributary 5	2042	559.6	558.8	-0.8
San Juanito Creek Tributary 5	6798	575.0	573.5	-1.5

2.3.1.1 Model Validation & Sensitivity Analysis

There were no known USGS and IBWC gages within the model area with more than 20-years of combined flow record for use in calibration and validation. Flow comparisons in the downstream HUC-8, Los Olmos, were used to validate the modeled dam releases from International Falcon Reservoir. As discussed in Section 2.2.5.1, the dam's design elevations were also used to determine the dam release capacity.

2.4 Challenges

Major challenges included a lack of peak streamflow records in the HUC-8, though sufficient data in the downstream HUC-8 was available to provide confidence in the results.

The Mexico hydrology was established using best available soils and land use data as well as topographic information. Runoff estimates were not able to be validated for the Mexico hydrology.

Road structures have not been added to the BLE model despite evidence of cross structures which allow the streams to convey water through numerous structures. In these locations, the model may be overestimating the water surface elevation upstream of the road until the road is overtopped and underestimating the water surface elevation downstream of the road.

Modeling of the International Falcon Dam in HEC-RAS was a major challenge in this BLE study. Multiple iterations were performed to stabilize the model and complete the model validation on the downstream HUC. Due to limited information on the dam and the high-level modeling approach used for BLE, additional information was not acquired for the dam operations of this flood control structure.

HEC-RAS, Version 6.1, has an apparent bug that was identified in reviewing isolated areas of flooding. In these areas, the lower frequency events (ex. 10-percent) showed higher water surface elevations than the higher frequency events (ex. 0.2-percent). This was reviewed in multiple versions of HEC-RAS and was confirmed to occur in Version 5.7, 6.1 and 6.2. It is unknown why this may occur; however, the model does not experience instabilities and the mainstem floodplains have not shown this occurring when reviewing profile lines. In review of the model setup, stability and results, the flood extent results appear appropriate and impacts due to the bug are likely negligible.

HEC-RAS, Version 6.1 has a known error in the rain on mesh interpolation of flood depths between adjacent cells in the overbank area. This error produces artificially higher depths of flooding on the flood fringe referred to as cupping. Since this is a known issue in HEC-RAS and HEC is working on a solution, effort to remove these errors from the flood extents was not performed. Figure 2.12 below provides an example of cupping for reference. Once a solution is provided by HEC, it may be possible to update mapping to reduce and/or remove the cupping effects on the fringe of the floodplains.

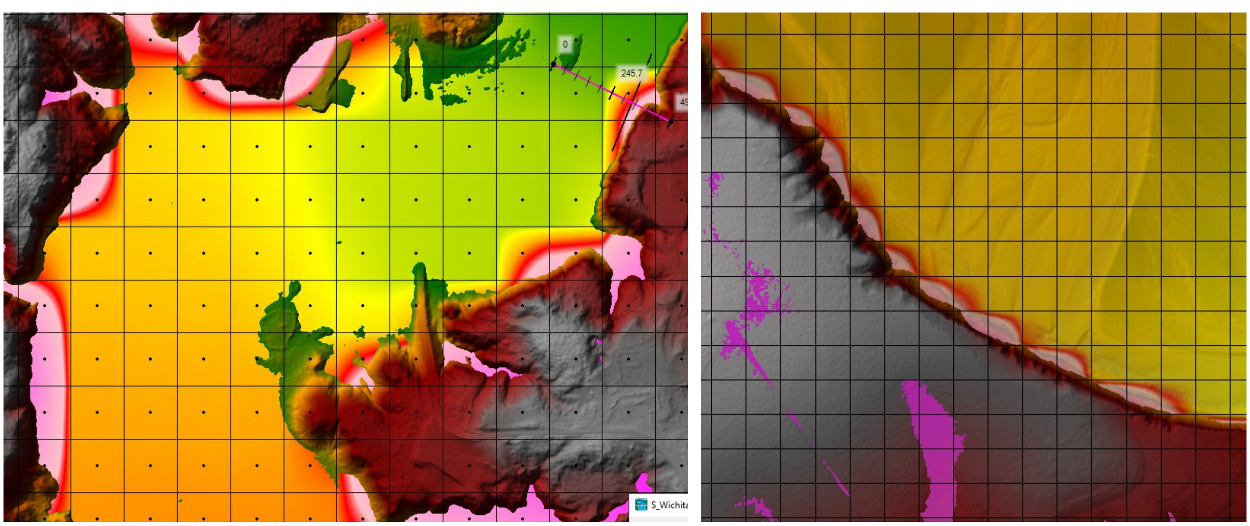

Figure 2.16: Cupping Examples

2.5 Recommendations

This study provides significant information useful for flood identification and communication among those affected. The study is highly scalable, and stakeholder input and further analysis would enhance the product and inform implementation of regulatory flood hazard areas. In addition, the validity of the 2D BLE results should be verified through community work map meetings before being applied as a regulatory product.

03 Floodplain Mapping and Effective Zone A Validation

The following sections provide a synopsis of how raw modeled depths were translated into SFHAs. In addition to developing a new SFHA, the BLE model data was leveraged to validate the effective zone A studies within the project footprint. The results of the validation effort can be found below in Section 3.2.

3.1 Special Flood Hazard Area

3.1.1 Model Outputs

The floodplains are derived from the raw modeled depth grids using the maximum value. These depth grids are exported from HEC-RAS as TIFF format rasters with an interpolated rendering that slope values at the center and along the faces/edges of the computational mesh cells. Using GIS, the TIFF rasters are post processed into a 10-percent non-regulatory feature class, 1-percent ACE SFHAs, and 0.2-percent shaded X polygons.

3.1.2 Methodology

The use of 2D modeling methods results in water surface elevation values at every cell in the model's computational meshes. In order to represent the desired model results and eliminate extraneous disconnected cells, post processing of the depth grids is required. For the purposes of the International Falcon Reservoir BLE study, floodplain mapping delineation was completed using connected raster cells at the extent of the CNMS mapped and unmapped features in the project footprint. Converting the raster data to polygon features enabled an intersection of modeled results to the CNMS and effective zones to create the SFHA and 0.2-percent shaded X features. Because the new mapping, based on gridded engineering, retains the blocky shape of a raster, a simplification process was applied using GIS to smooth the boundaries using a 10-foot smoothing threshold. These processes remove unnecessary points, bends, and angles while preserving the natural shape of the polygon. Furthermore, small voids, or "holes" inside of the floodplain were aggregated with the larger surrounding polygons to merge them and make the floodplain complete. In alignment with the TWDB's 2D BLE Guidelines (May 2022) floodplain polygons were cleaned against the criteria provided below in Table 3.1 which provides thresholds for mapping removal based on depth and area of flood risk.

Table 3.1: Mapping Threshold Matrix

Area (ac)	Depth (ft)
< 0.33	-
0.33 - 0.5	< 0.33
0.5 - 1.0	< 0.25
1.0 - 2.0	<0.1

For example, if flooding polygons were disconnected from a flooding source and less than two acres in area and 0.1 feet of depth, the polygon was removed from the SFHA. These edits align to the mapping standards adopted by the TWDB and those required by FEMA.

In addition to the SFHA, all other flooding associated with the 1- and 0.2-percent raw results were retained as "on the shelf" data that may be leveraged for future needs and analysis. This information is available in the included Supplemental Data associated with this study.

3.1.3 Flood Hazard Area Layer

Special Flood Hazard Areas (SFHA), as noted above, were developed to at least the extent of the CNMS features and up to 0.1 square mile drainage area and effective zone A study locations. The Regional CNMS database, National Flood Hazard Layer, and paper inventory were used as reference data to ensure extent of the BLE results represents appropriate current flooding extent coverage, at a minimum.

The 0.2-percent flood areas were produced using the same methods as the 1-percent SFHA. After both layers were developed, a union of the two products was performed to develop the deliverable format EBFE_FLD_HAZ_AR.

3.1.4 Mapping Considerations

3.1.4.1 Ponds

Numerous ponds exist throughout the International Falcon Reservoir Watershed. Due to the nature of 2D BLE and the large mesh cells used for modeling, the entire extent of smaller, isolated ponding areas is not always fully mapped in the raw model output. To identify flood risk in these areas, the pond footprints were merged in by automated processes using the best available National Hydrography Dataset. This dataset has its own limitations in that it is not current to current topography or LiDAR and may not align completely to the present-day pond footprints. However, it was used as the best available at the time of the study. A nominal depth of 0.1-foot was used for any areas merged into the floodplain that were not in the raw model results and the water surface elevation was interpolated. The water surface elevations in these areas should not be considered correct and would require further study to refine the correct water surface elevation based on detailed modeling.

3.1.4.2 Mapping Tie-Ins

Watershed tie-ins required manual review and coordination between HUCs to ensure tie-ins could be met within the required 0.5-feet FEMA requirement. For International Falcon Reservoir, significant tie-ins occur at the upstream boundary with San Ambrosia – Santa Isabel, between the half HUCs of International Falcon Reservoir and downstream with Los Olmos.

For the tie-in with San Ambrosia – Santa Isabel, a raster difference was created in ArcGIS based on the raw depth and WSE grids to manually establish the tie-in location for the 10-, 1-, and 0.2-percent ACE floodplain extents. Each difference grid was reviewed to determine a tie-in location with WSE difference no greater than plus/minus 0.5-feet. The two International Falcon Reservoir half HUCs were modeled using a stage hydrograph, which ensured a tie-in could be established within the lake. Therefore, no manual adjustments to the grids were required for this location. Since the tie-in with Los Olmos is at the International Falcon Reservoir Dam, no effort was needed to assure mapping tie-ins in this area.

Minor fringe watershed tie-ins to adjacent HUCs were checked to ensure they met the 0.5-foot tie-in requirement. These areas were modeled using overlapping meshes between adjacent HUCs and then clipped to the USGS HUC boundaries. These HUC boundaries resulted in minor discrepancies in the mapping extent and water surface elevations, however, no differences exceeded the 0.5-foot mapping tolerance.

3.1.4.3 Centerline Alignment

After completion of the FLD_HAZ_AR, the S_WTR_LNs (centerlines) were reviewed for containment within the 1-percent ACE floodplain. Any centerlines that were 50 feet or greater in length outside of the 1-percent floodplain extent were realigned for containment.

3.2 Validation of Effective Zone A SFHA

The following summarizes the results of the CNMS validation assessments for the effective Zone A studies in the International Falcon Reservoir Watershed.

3.2.1 Initial Assessment A1 – Significant Topography Update Check

The significant topography update check determines whether a topographic data source is available that is significantly better than what was used for the effective Zone A modeling and mapping. For this study of the International Falcon Reservoir Watershed the topographic data source for the BLE analysis was derived from the best available LiDAR data, as discussed in Section 2.1. This elevation data provides quality LiDAR data coverage for the entire study area, therefore, this check is set to PASS.

3.2.2 Initial Assessment A2 – Check for Significant Hydrology Changes

The significant hydrology changes check determines whether new regression equations have become available from the USGS since the date of the effective Zone A study. If newer regression equations exist for the area of interest, then an engineer must determine whether these regression equations would significantly affect the 1-percent ACE flow. It is unknown if regression methods were used in the effective studies, therefore, this element was set to FAIL for newly added streams and left PASS if already attributed as such in previous CNMS.

3.2.3 Initial Assessment A3 – Check for Significant Development

The significant development check, using the National Urban Change Indicator (NUCI) dataset, assesses increased urbanization in the study watershed. If the percentage of urban area within a HUC-12 watershed containing the effective Zone A study is 15 percent or more and has increased by 50 percent or more since the effective analysis, the study would fail this check. The check for significant development in the International Falcon Reservoir Watershed was completed by evaluating percentage of urban change at the HUC-12 level. The entire watershed is classified as rural and all reaches were set to PASS for this assessment.

Table 3.2 presents the summarized results of checks A1 through A3.

Table 3.2: A1-A3 Validation Results

Assessment Checks	Pass / Fail	Notes
A1 – Topography	Pass	LiDAR significantly better than effective USGS topo source/Effective mapping leveraged LiDAR data.
A2 – Hydrology	Pass/Fail	Effective hydrology methods are unknown
A3- Development	Pass	Less than 15% of study area is under urban cover/>50% increase in urban area in an urban HUC-12

3.2.4 Validation Check A4 – Check of Studies Backed by Technical Data

Zone A studies that pass all initial assessment checks described above may be categorized as “Valid” in the CNMS Inventory only if the effective Zone A study is supported by modeling or sound engineering judgment and all regulatory products are in agreement. If the effective Zone A study passes all initial assessment checks, but is not supported by modeling, or if the original engineering method used is unsupported or undocumented, a comparison of the BLE results and effective Zone A’s is performed. Due to lack of documentation of the original engineering methods in the International Falcon Reservoir

Watershed, check A4 has been marked as FAIL for most parts of this study and left as PASS if it was already identified as such in previous CNMS.

3.2.5 Validation Check A5 – Comparison of BLE and Effective Zone A

The effective Zone A comparison was performed at the full extent of the International Falcon Reservoir Watershed. The validation of the effective Zone A boundaries using 2D flood hazard products differ from the standard 1D methods due to the lack of cross sections and their use with standard FBS methodology. For this 2D study, the effective A zone boundaries were compiled using the National Flood Hazard Layer and Core Logic effective digital uplift product. These data were dissolved to one continuous A-zone layer, which then had test points placed along its perimeter at least every 200 feet.

For each test point, a 75-foot buffer polygon was created. Using this buffer, the minimum and maximum values of the DEM were extracted, as a proxy for the effective base flood elevation. The minimum value of the 1% minus raster, and the maximum value of the 1% plus raster are also extracted. These 1% plus maximum and 1% minus minimum values are products of the new 2D BLE study and act as the vertical tolerance. The test point passes if the DEM maximum value is less than or equal to the 1% plus maximum value and the DEM minimum value is greater than or equal to the 1% minus minimum value. This can be visualized as a short 75-foot radius cylinder, with a height of 1% plus maximum – 1% minus minimum. This test verifies that at least one point from the ground surface (i.e. proxy BFE) falls both vertically and horizontally within this range.

3.2.6 Validation Results

All 1,117.2 total miles of available CNMS features representing the effective Zone A studies were categorized as shown in Table 3.3 and illustrated in Figure 3.1 below.

Table 3.4Table 3.4 summarizes the validation results based on the individual HUC-12 watersheds within International Falcon Reservoir Watershed.

Table 3.3: Aggregated Zone A Validation Results

Validation Status	Status Type	Total Miles
VALID	BEING STUDIED	690.9
UNVERIFIED	BEING STUDIED	426.2

Table 3.4: HUC-12 Zone A Validation Results

HUC-12 Watershed		Total FBS Points	Fail	Pass	%Pass	BLE Comparison Pass? (>85%)
Watershed Name	Watershed Number					
Headwaters San Juanito Creek	130800030101	1,387	641	746	53.8	FAIL
Burrito Tank	130800030102	1,863	1,161	702	37.7	FAIL
Lobo Creek-San Juanito Creek	130800030103	1,515	702	813	53.7	FAIL
Headwaters Reiser Creek	130800030104	1,891	1,146	745	39.4	FAIL
Reiser Creek-Retama Creek	130800030105	1,055	667	388	36.8	FAIL
Ryo Creek	130800030106	1,301	906	395	30.4	FAIL
Retama Creek-San Juanito Creek	130800030107	627	430	197	31.4	FAIL
Upper Agua Azul Creek	130800030201	782	530	252	32.2	FAIL
Lower Agua Azul Creek	130800030202	893	659	234	26.2	FAIL
Los Lasos Tank-Cerrito Creek	130800030203	671	415	256	38.2	FAIL
Cerrito Creek-San Juanito Creek	130800030204	863	635	228	26.4	FAIL
El Jaral Creek	130800030205	1,648	900	748	45.4	FAIL
Upper Blancas Creek	130800030206	972	413	559	57.5	FAIL
Lower Blancas Creek	130800030207	1,611	944	667	41.4	FAIL
Upper Dolores Creek	130800030208	1,201	506	695	57.9	FAIL
Middle Dolores Creek	130800030209	1,320	742	578	43.8	FAIL
Lower Dolores Creek	130800030210	2,168	1,468	700	32.3	FAIL
Mendez Hills-Rio Grande	130800030601	756	747	9	1.2	FAIL
Arroyo Salado	130800030602	2,269	1,064	1,205	53.1	FAIL
El Derramadero-Rio Grande	130800030603	600	581	19	3.2	FAIL
El Grullo Creek-Falcon Reservoir	130800030604	2,063	1,340	723	35.0	FAIL
Arroyo Blanco-Cavasara Creek	130800030605	1,568	902	666	42.5	FAIL
Las Palomas Creek-Falcon Reservoir	130800030606	2,344	1,254	1,090	46.5	FAIL
Chapote Creek-Falcon Reservoir	130800030608	2,105	1,182	923	43.8	FAIL
Chargos Creek	130800030701	1,188	520	668	56.2	FAIL
Mulato Creek	130800030702	1,245	658	587	47.1	FAIL
Las Ovejas Creek-Salamoneno Creek	130800030703	1,783	970	813	45.6	FAIL
Headwaters Arroyo Grande	130800030704	643	469	174	27.1	FAIL
Arroyo Grande	130800030705	1,487	827	660	44.4	FAIL
Lower Taquache Creek	130800030706	635	448	187	29.4	FAIL
Headwaters Escobas Creek	130800030707	555	301	254	45.8	FAIL
Escobas Creek-Salamoneno Creek	130800030708	1,414	947	467	33.0	FAIL
130800030309-Salamoneno Creek	130800030709	383	264	119	31.1	FAIL
Arroyo Blanco-Salamoneno Creek	130800030710	527	379	148	28.1	FAIL
Los Tanques Creek	130800030801	818	711	107	13.1	FAIL
Colorado Oil Field	130800030802	114	111	3	2.6	FAIL
Los Tanques Creek-Arroyo Huisache	130800030803	982	848	134	13.6	FAIL
Fandango Creek	130800030804	524	363	161	30.7	FAIL

HUC-12 Watershed		Total FBS Points	Fail	Pass	%Pass	BLE Comparison Pass? (>85%)
Watershed Name	Watershed Number					
Upper Villa Creek	130800030805	1,194	800	394	33.0	FAIL
Lower Villa Creek	130800030806	708	458	250	35.3	FAIL
Canada Honda	130800030901	878	510	368	41.9	FAIL
Arroyo Varal-Arroyo Veleno	130800030902	1,025	693	332	32.4	FAIL
Arroyo Cabeza de Vaca-Falcon Reservoir	130800030903	2,797	1,433	1,364	48.8	FAIL
Arroyo Loma Blanca-Falcon Reservoir	130800030904	2,242	1,239	1,003	44.7	FAIL
Chico Creek	130800031001	737	628	109	14.8	FAIL
Headwaters San Juan Creek	130800031002	850	666	184	21.6	FAIL
Arroyo Charco Redondo	130800031003	1,030	774	256	24.9	FAIL
Mexia Creek-San Juan Creek	130800031004	976	847	129	13.2	FAIL
Arroyo del Tigre Grande	130800031005	1,559	1,085	474	30.4	FAIL
Arroyo Melones-Falcon Reservoir	130800031006	993	469	524	52.8	FAIL
Arroyo del Tigre Chiquita	130800031007	1,590	741	849	53.4	FAIL
Arroyo Tinajas-Falcon Reservoir	130800031011	1,625	838	787	48.4	FAIL

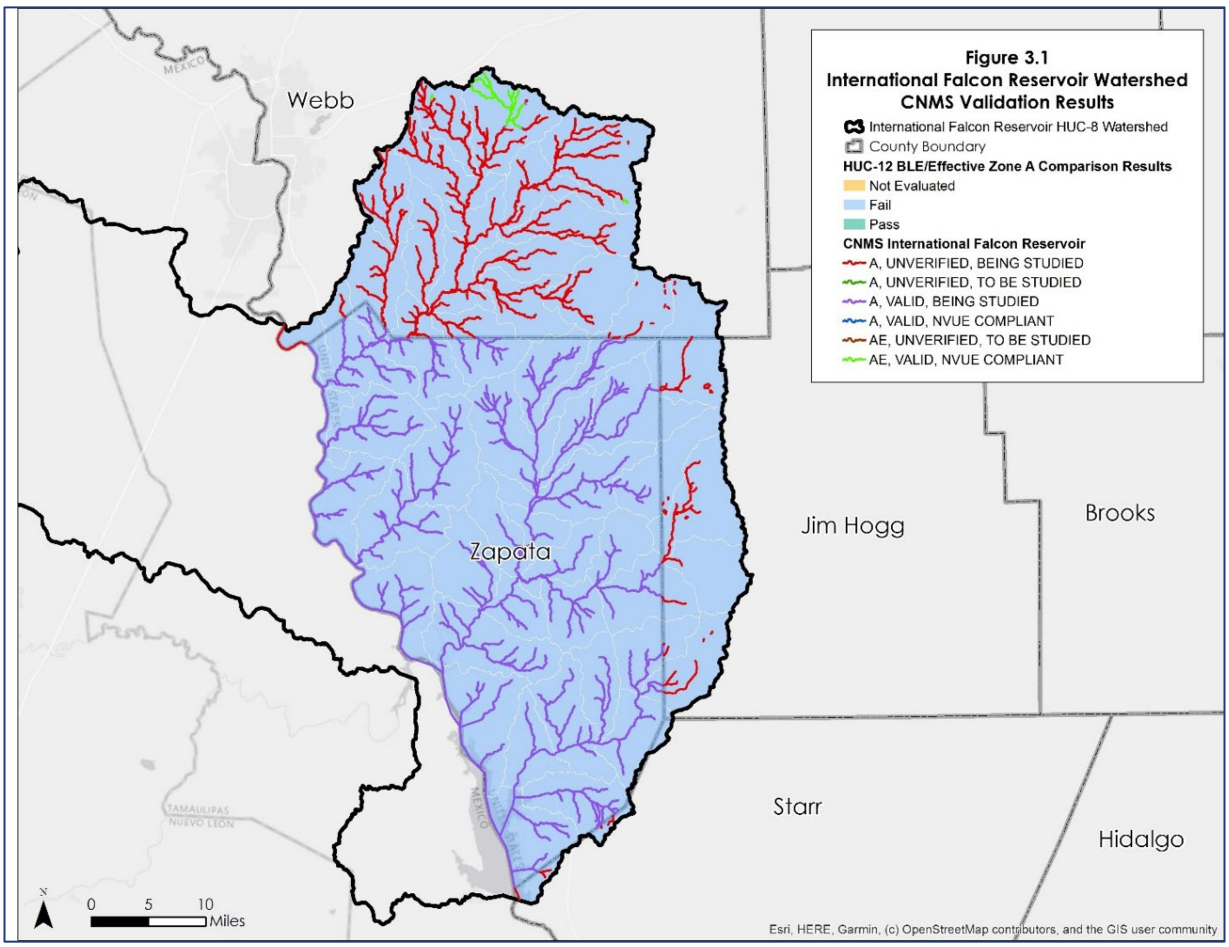

Figure 3.1: International Falcon Reservoir Watershed CNMS Validation Results

3.3 Flood Risk Analysis

A flood risk analysis was performed for this project. The updated 1-percent ACE depth grid was used to calculate the potential flood losses. The loss results are stored in the S_FRAC_AR spatial file within the FRD geodatabase. All results are reported in whole dollar values.

Hazus Version 5.1 (SP02) was used for the basic and refined loss analysis.

The losses are reported via census blocks. It is important to note that Hazus Version 5.1 (SP02) uses dasymetric census blocks. Dasymetric mapping removes undeveloped areas (such as areas covered by bodies of water, wetlands, or forests) from the census blocks, changing their shape and reducing their size in these areas. For more information on dasymetric data visit FEMA's Media Library for the Hazus-MH Data Inventories: Dasymetric vs. Homogenous, or Hazus 3.0 Dasymetric Data Overview.

Hazus analysis was performed by county within the project watershed extents for the 1-percent return period to ensure proper model processing. A summary of results per county for the 1-percent ACE scenario is shown in Table 3.5.

Table 3.5: Hazus 5.1 (SP02) Results for 1-percent-annual-chance (100 year) scenario for International Falcon Reservoir Watershed, Texas

County	Full Replacement – Total Loss	Dollar Exposure (Replacement Value) - Buildings	Dollar Exposure (Replacement Value) - Contents
Jim Hogg	$707,000.00	$13,025,000.00	$6,998,000.00
Starr	$210,000.00	$22,773,000.00	$21,794,000.00
Webb	$10,127,000.00	$83,791,000.00	$46,256,000.00
Zapata	$102,833,000.00	$619,242,000.00	$371,816,000.00
Total	**$113,877,000.00**	**$738,831,000.00**	**$446,864,000.00**

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