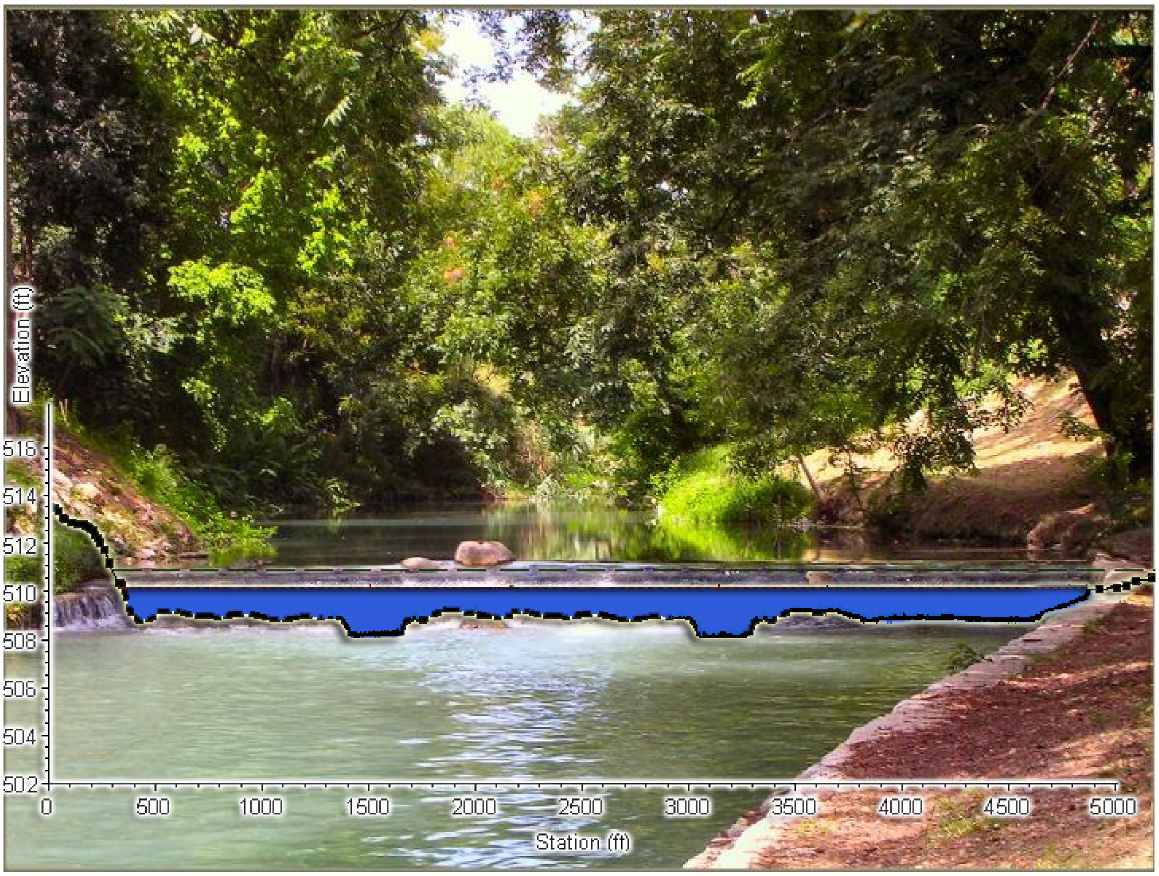
San Antonio River Basin
Regional Modeling Standards for Hydrology and Hydraulic Modeling

REVISION September 2013



SAN ANTONIO RIVER AUTHORITY
Leaders in Watershed Solutions

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GLOSSARY

Annual Chance (AC): The probability that a storm of a given size or larger will occur within a one-year period. The AC is equal to one divided by the return period (e.g., the 100 year floodplain is also the 1% AC floodplain).

Design Hydrology Model: Detailed hydrology model used for the purposes of project design and analysis. The size of basins/drainage areas is not restricted by the limitations set for the regional hydrology models.

Digital Flood Insurance Rate Map (DFIRM): A digital version of the flood insurance rate map, referencing the 1% AC floodplain.

Drainage Basins: Subdivisions of the sub-watershed and/or watershed areas.

Federal Emergency Management Agency (FEMA): FEMA is responsible for coordinating the Federal response to floods, earthquakes, hurricanes, and other natural or man-made disasters and providing disaster assistance to States, communities and individuals. FEMA is responsible for administering the NFIP and administering programs that provide assistance for mitigating future damages from natural hazards.

Flood Insurance Rate Map (FIRM): Maps used to identify the location of FEMA Special Flood Hazard Areas (SFHA).

Floodplain: a nearly flat plain along the course of a stream that is naturally subjected to flooding. Area of inundation from flow greater than the daily average.

Hydraulic models: Computerized representations of rivers/creeks, storm drains, and other water conveyance systems. These are the tools used to determine the depth and velocity of storm water. These computerized models are calibrated using observed information after flood events. These are needed to develop maps that show flood prone areas.

Hydrology models: Computerized representations of watersheds. These are the tools used to determine the amount and effects runoff and estimate peak flows. These computerized models are calibrated using observed information after flood events. These are needed to develop maps that show flood prone areas.

National Flood Insurance Program (NFIP): A national program which most cities and all counties within the SARB are participants, this federal program is tasked with 3 major components: Identify and map flood prone communities, require that communities adopt and enforce floodplain management regulations, and enable interested persons to purchase insurance against loss resulting from physical damage to or loss of real property or personal property resulting from flooding. In order to assess and manage the flood risk, a national standard was adopted, the 1% annual chance flood.

Regional Modeling: A drainage basin meets regional criteria when the basin area is 1 square mile or greater. Drainage basins less than 1 square mile are considered local drainage.

River Basin: The San Antonio River Basin (SARB).

Sub-watershed: Smaller watersheds tributary to either the main streams in the major watersheds or to the San Antonio and Medina Rivers. Examples include the Rosillo Creek, Medio Creek, Charco Creek, and Marcelinas Creek sub-watersheds.

Watershed: Major watersheds within the SARB. These include the Salado Creek, Leon Creek, Cibolo Creek, Upper San Antonio River, Lower San Antonio River, and Medina River watersheds (Figure 1).

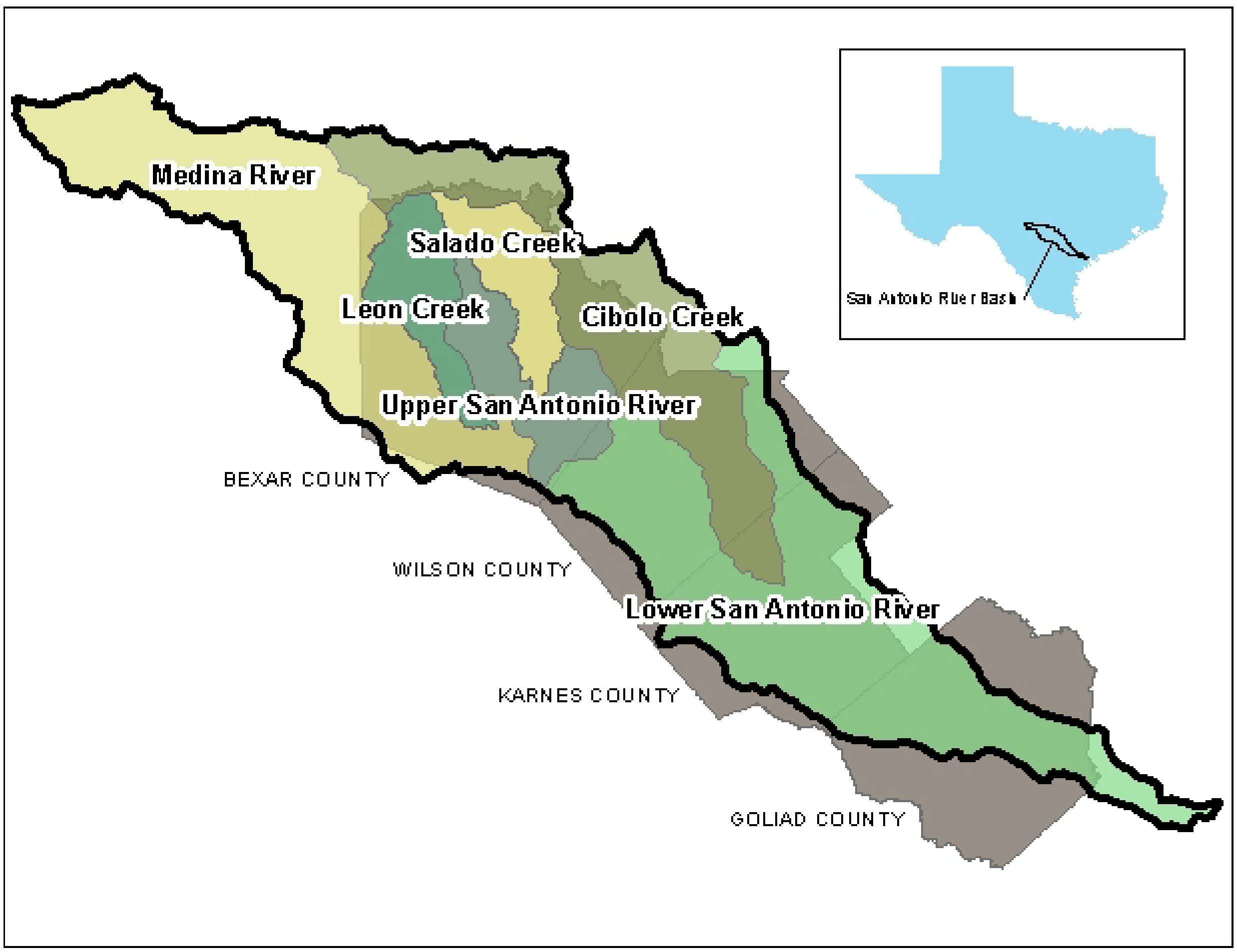


Figure 1- San Antonio River Basin and Major Watersheds

1.0 INTRODUCTION AND GENERAL GUIDELINES

The San Antonio River Basin Regional Modeling Standards for Hydrology and Hydraulic Modeling was developed in 2006 in support of regional flood studies that were prepared as part of the Federal Emergency Management Agency's (FEMA) Flood Map Modernization (Map Mod) program. These standards serve to provide consistent methodology for regional Hydrology and Hydraulic (H&H) modeling in the San Antonio River Basin (SARB).

The Federal Emergency Management Agency (FEMA) issued *Guidelines and Specifications for Flood Hazard Mapping Partners* (FEMA, 2003a) including appendices which were updated several times. Currently, FEMA is transitioning from the previous guidelines and specifications to *Data Capture Standards Technical References* as part of FEMA's Risk Mapping, Assessment & Planning (Risk MAP) program that began in 2009 upon the completion of the Map Mod program. All regional H&H modeling, including revisions to existing regional models developed as part of Map Mod, and new H&H models, will conform to the most current FEMA technical references and standards.

The information included herein provides additional standards and guidelines specific to the San Antonio River Basin. These standards apply to all topographic, planimetric, survey, coefficient, and parameter data used to create or update regional hydrology and hydraulic (H&H) models. Deviation from these standards may be accepted when accompanied by documentation and justification.

1.1 BACKGROUND

As part of FEMA's Map Mod program, the regulatory floodplains shown on the Flood Insurance Rate Maps (FIRMs) within the SARB were digitized and, in many cases, restudied between 2003 and 2010 to produce the Digital Flood Insurance Rate Maps (DFIRMs) and DFIRM geospatial data for Bexar, Wilson, Karnes and Goliad Counties. Hydrologic models were developed for each watershed and hydraulic models were developed for major streams.

The H&H models supporting the geospatial documentation files and Technical Support Data Notebooks (TSDNs) are maintained by SARA. The TSDNs document details about the development of the DFIRM H&H models and geospatial data and should be used as resources when working with the DFIRM H&H models and geospatial data.

1.2 MODEL UPDATES

The DFIRM H&H models and geospatial data on file with SARA shall be used as the basis for floodplain mapping and impact assessments within the SARB. All new models and modifications to existing models shall conform to the relevant standards and documentation requirements. Inclusion of future conditions may be added to existing models due to changes in political jurisdiction or Special Flood Hazard Area (SFHA) classification.

Hydrology Models

When modifying a regional DFIRM hydrology model, distinction shall be made between the models used to develop Flood Insurance Study (FIS) peak flows and design hydrology models used to capture details of a proposed project.

Regional hydrology models should not be truncated and the software version should not be changed without sufficient justification. Model changes should reflect changes in land use, routing, watershed response, and regional detention or diversion projects. Sub-basins shall not be divided except in cases of regional detention or diversion projects. Sub-basin delineation should only be updated with more detailed topographic data when the change in area causes a change in peak flow greater than +/- 5% of the FIS peak flow.

Design hydrology models should be a truncated version of the regional model that can be modified as necessary to represent pre- and post-project conditions. Truncation should occur at FIS nodes (the junction used to develop FIS peak flows). The entire regional model sub-basin(s) containing the main project area should be represented in the design hydrology model[1], but inflow hydrographs from the regional model may be used to represent upstream areas. The difference between the pre- and post-project conditions peak flows at FIS nodes will be used to measure the impacts of the project. If peak flows change by more than +/- 5%, the project is considered to have an impact on hydrology.

Once the hydrologic impacts of the project have been documented via the design hydrology model, sub-basin impervious cover parameters should be modified in the regional model to reproduce the relative impact of the project as documented in the design hydrology model. The lag time should also be modified if the project impacts the time of concentration sub-parameters. If the resulting peak flows vary more than +/- 5% from the FIS peak flows, the FIS should be updated. Whether or not the FIS is updated, the revised regional model should be submitted to SARA to be used as the "best available model" for subsequent studies.

Hydraulic Models

Regional DFIRM hydraulic models can be truncated and updated to a more recent analysis software version. They may also be converted to an alternative software package with sufficient justification and documentation. Any changes to the effective model structure or software version will require a comparison between the effective and duplicate effective models in the project study documentation. The duplicate effective model must be calibrated in accordance with FEMA's

[1] If the project area is located primarily in one sub-basin with a small area crossing into an adjacent sub-basin and if the area pertaining to the adjacent sub-basin is less than 2% of the sub-basin's total area, it is not necessary to include the entire adjacent sub-basin in the design model.

submittal requirements as outlined in *Instructions for Completing the Application Forms for Conditional Letters of Map Revision and Letters of Map Revision* (FEMA, 2013). The use of an alternative modeling platform requires an explanation in the documentation on why the effective modeling platform was inappropriate for the model reach and why the proposed modeling platform should be used.

1.3 NAMING CONVENTIONS

The Unites States Geological Survey (USGS) Hydrologic Unit Code (HUC) numbering system was adopted during DFIRM development in the SARB to establish unique watershed names for regional hydrology models. The SARB was originally divided into four categorized as shown in Table 1.

12100301	Upper San Antonio River
12100302	Medina River
12100303	Lower San Antonio River
12100304	Cibolo Creek

Table 1 - HUC Numbering System

The HUC is defined by a series of two-number codes that define the level of detail for the catchment under study. Thus, the 8-digit HUC for the Upper San Antonio River can be broken down as follows:

12 : Region : Texas-Gulf Region
10 : Sub-Region : Central Texas Coastal
03 : Account Unit : The SARB
01 : Cataloging Unit : The Upper San Antonio River

The SARB HUC numbering system was increased to a 12-digit or 14-digit number in order to capture the level of detail needed for regional modeling. The 12-digit HUC was primarily used in rural areas of the basin. The 14-digit HUC was used primarily in urban areas. A 12-digit HUC is obtained by adding four digits to the original 8-digit HUC. The first two digits represent the watershed and the other two represent the sub-watershed. The 14-digit HUC is obtained by adding an additional two digits to the 12-digit HUC to represent individual drainage basins. Figure 2 lists the hydrologic unit breakdown for 12 and 14-digit HUCs. More information can be found in the *Federal Standards and Procedures for the National Watershed Boundary Dataset* (USGS, 2012).

14-digit	12	: Region	Texas Gulf Region	12-digit
	10	: Sub Region	Central-Texas Coastal	
	03	: Account Unit	The SARB	
	01	: Cataloging Unit	The Upper San Antonio River	
	01	: Watershed	Salado Creek	
	06	: Sub Watershed	Rosillo Creek	
	02	: Drainage Basin	Rosillo Creek Drainage Basin RC2	

Figure 2 - HUC Numbering Example

The HUC numbering system begins at the top of the watershed, increases in the downstream direction and ranges from 01 to 99 as shown in Figure 3.

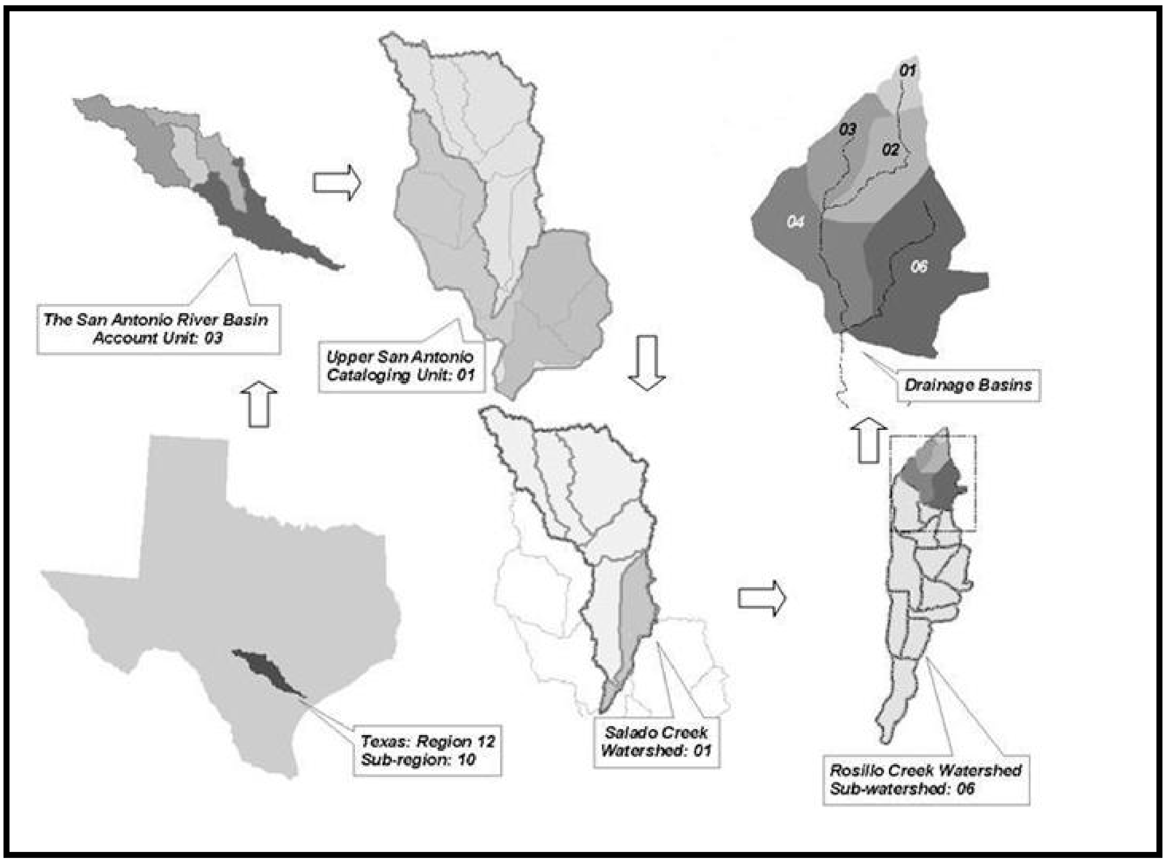


Figure 3 - Drainage Basin Numbering

For a comprehensive listing of current drainage basin delineations and numbering, please contact SARA. Please note that the regional hydrology models for Leon Creek and the Upper San Antonio River (LMMP) do not follow the HUC naming convention. These two models were originally developed by the United States Army Corps of Engineers (USACE). If sub-basin renaming is necessary within these models, coordination with SARA is requested.

1.4 REGULATORY DESIGN EVENTS

The 1% annual chance (AC) existing conditions and the 1% AC future condition events are the primary regulatory events for communities in the SARB. All models should include the 10%, 4%, 2%, 1%, and 0.2% AC existing conditions storm simulations. Studies within Bexar County shall include the 1% AC future conditions event in addition to those listed previously. Other communities must request the 1% future conditions event to be included in studies under their jurisdiction, if desired.

1.4.1 Existing Conditions

Existing conditions model runs are used to evaluate the impacts of the current development state in the watershed, establish a baseline for design of regional flood control facilities, and forecast flooding.

In certain cases, the regulatory entity may require the use of more frequent design events for purposes other than FEMA FIRM development. Other purposes could include stream morphology, infrastructure, or regional storm-water facility design where smaller events may be critical to the performance of the design. Smaller events may include, but are not limited to, 20%, 25%, 50%, or 100% AC storm events.

1.4.2 Future Conditions

The 1% AC future conditions event is sometimes used to delineate the 1% AC future conditions floodplain to be mapped in lieu of the 0.2% AC floodplain on FEMA FIRM panels.

Future conditions should reflect the communities' planned fully-developed scenario for the watershed under study. The City of San Antonio (COSA) Unified Development Code (UDC) requires the inclusion of the 4% AC ultimate development (future conditions) event plus freeboard (if higher than the 1% AC event without freeboard) for the design of concrete or grass-lined channels. Higher frequency future conditions events may be used for design at the discretion of the regulatory entity.

2.0 SUPPORTING DATA

Quality supporting data for the development of numerical models is essential. Data typically used for model development includes, but is not limited to, topographic data for watershed delineation and cross section geometry; survey data for hydraulic structures; and land use and soil data for the determination of loss rates.

2.1 DFIRM GEOSPATIAL DATA

Geospatial data was developed as part of the 2010 DFIRM process and are available through SARA. Additionally, revised data associated with Letters of Map Revisions (LOMRs) are also available through SARA or FEMA. These data include FEMA SFHA boundaries, sub-basin delineation boundaries, hydraulic model cross sections, and effective stream centerlines. Twelve-digit sub-basins are available for the entire SARB, and 14-digit are available for the majority of the SARB. These data will serve as the standards for the SARB.

2.2 TERRAIN DATA

Watershed modeling studies must use the best available topographic data for the area to be modeled and must meet the minimum standards outlined below. Data produced to a higher accuracy standard than minimum standards may be necessary or desirable for certain projects.

All topographic data used for hydraulic modeling and mapping must follow the FEMA standards as described in Table A-2 in the *Guidelines and Specifications for Flood Hazard Mapping Partners Appendix A: Guidance for Aerial Mapping and Surveying* (FEMA, 2003) or the most current FEMA *Data Capture Standard Technical Reference*. Vertical control should be established in project areas so that the digital surface model can be processed to meet the vertical standard.

A combination of 2003 aerial photogrammetry, 2003 Light Detection And Ranging (LiDAR) data, and survey was used to develop the 2010 DFIRM H&H models. When modifying existing models, topographic data for effective models may need to be replaced, or at least augmented by, as-built drawings if changes have occurred to the channel geometry since the effective date of the model. Additionally, new models and updates shall use a combination of the most recent LiDAR and survey data. If a study area extends beyond the coverage of LiDAR data, USGS topographic data should be used to supplement the LiDAR data.

2.2.1 Aerial Photogrammetry and LiDAR

Watershed delineation in Bexar County was performed using 2003 aerial photogrammetry (5-foot accuracy) supplemented by field or plan drawing verification. In Wilson, Karnes, and Goliad

Counties, watershed delineation was performed using 2003 LiDAR. For the 2010 DFIRM hydraulic models, the generalized topographic data was supplemented with survey.

LiDAR data developed in 2010 (or more recent) in cooperation with the Texas Water Development Board (TWDB) and available through SARA will be considered the minimum acceptable standard for new models and models updates. The LiDAR data is accompanied by 3D breaklines of water features for use in developing surface TINs. One foot contours have been developed from LiDAR for some areas of the basin.

2.2.2 Surveys

Surveys for hydrologic modeling would primarily be recorded to define the inflow and outflow characteristics of flood control facilities. Some survey, or at least a reference to storm sewer plans, may be required to define drainage basin boundaries (especially in flat areas if detailed topographic data is not available).

Channel cross sections for hydraulic models should be surveyed at significant bends or locations where there are significant geometric changes so that the corresponding head losses will not be missed. Photographs should be provided for surveyed cross-sections (see Figure 4 for examples). These photographs should show the condition of the ground and vegetation (roughness) in the channel and overbanks in the vicinity of the cross-section. Surveyed channel cross-sections are required to establish the channel bathymetry where water obstructs LiDAR data collection or where channel features are smaller than the LiDAR horizontal resolution.

Figure 4 - Example Cross Section Photographs

Upstream

Downstream

Horizontal and vertical controls should be established using the Texas Department of Transportation (TXDOT) High Accuracy Reference Network control monuments.

A standard system of survey codes helps to streamline the integration of survey data into the models and provides more consistency between survey contractors. Survey data should conform to the most current FEMA *Data Capture Standard Technical Reference*.

2.2.3 USGS Topographic Data

USGS topographic data at 10' contour intervals will be the minimum acceptable standard for manual watershed delineation outside LiDAR coverage areas. Regional automated watershed delineation should use data from the USGS National Elevation Dataset (NED). This dataset provides seamless coverage over the entire SARB and will eliminate most problems related to edge-matching of multiple files. A 100-foot digital elevation model (DEM) grid will be considered a minimum standard for all new work. Where available, more detailed data shall be used.

2.3 LAND USE

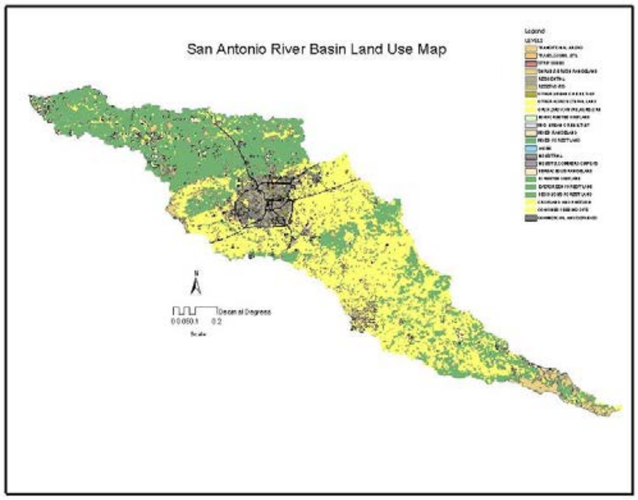
Land use is a key component in the determination of loss rates for hydrologic modeling. Its use is complicated by changes in the state of development in urban areas and in agricultural practices in rural areas over time. Land use data is available in some form for the entire SARB. The resolution and accuracy of this data can vary substantially.

When updated land use data is submitted to support changes to a regional hydrologic model, it should meet the geospatial data standards presented in Appendix E to allow SARA to maintain a land cover data set consistent with the data incorporated into the regional models.

2.3.1 Existing Conditions

The existing conditions land use information used in the SARB DFIRM remapping effort included two primary components. The first was specific to Bexar County and the City of San Antonio (COSA). Within Bexar County, parcel and zoning data developed from tax information and aerial photography flights of the County were used to define the existing conditions land use as of 2005. The second component was USGS 1992 National Land Cover Data (NLCD) (Figure 5). The NLCD was used to define existing conditions land use in the SARB outside of Bexar County.

Figure 5 - San Antonio River Basin Land Use Map (2005)



Studies that develop new models or update existing models should use current parcel, zoning and aerial orthophotography data where available. Within Bexar County, parcel and zoning data is updated annually by the Bexar County Appraisal District. Aerial orthophotography is updated biennially and maintained by the City of San Antonio. Outside of Bexar County, aerial orthophotography is available from the Texas Natural Resources Information System (TNRIS) at http://www.tnris.org.

If local land use information is not available, the most recent version of the USGS land cover data set may be used. A detailed description of this data is available on the USGS national mapping web site at http://landcover.usgs.gov/usgslandcover.php. Any detailed data developed in the future by other municipalities within the watershed should be used to supplement the USGS data. This is especially important in urbanized areas.

2.3.2 Future Conditions

Future conditions land use data is required to generate parameters for future conditions models. COSA has developed an ultimate conditions land use set using zoning information for the City and its extraterritorial jurisdiction. This data set was used to represent future conditions land use over most of Bexar County.

Outside of Bexar County, the creation of a future conditions land use set was based on the USGS land use data modified based on population projections for the year 2060 developed for the Texas Water Development Board (TWDB) Region L Water Plan.

Updates to the future conditions land use data should incorporate any additional data available from cities, counties, or other administrative entities within study area if available. If a study extends beyond the future conditions land use information available from local entities, the recommended approach for development of this data is to start with the USGS land cover as the base dataset and modify it using population projections developed for TWDB water use planning studies in the region assuming a 50 year planning horizon.

2.4 SOILS

Soils data is a key component in the development of loss rate parameters for hydrologic modeling. The Natural Resources Conservation Service (NRCS), formerly known as the Soil Conservation Service (SCS), is the primary supplier of this information. The NRCS is currently in the process of converting their soil survey information into digital format. Much of this data is already available. The digital data is produced in SSURGO (Soil Survey Geographic) format, designed for use in GIS software. Field mapping methods using national standards are used to construct the soil maps in the SSURGO database. Mapping scales generally range from 1:12,000 to 1:63,360. SSURGO is the most detailed level of soil mapping developed by the NRCS. The SSURGO data are organized by USGS 7.5 minute quadrangles within each county and are digital versions of the original soil survey maps. Additional information regarding SSURGO data can be found at http://soils.usda.gov/.

2.5 INFRASTRUCTURE DATA

When possible, all major structures in the stream reach to be modeled should be surveyed. The survey data shall conform to the most current FEMA *Data Capture Standards Technical Reference* and the following:

- Flood Control Structures
  - Storage-elevation relationships must be defined with topographic data that have a minimum contour interval of 2 feet (1.2 ft vertical accuracy). Where an established volume and surface area relationship exists, it shall be used and verified against other available topographic information above the level pool elevation.
  - Studies involving SARA dams should obtain the current rating curve from SARA.
  - The outlet and spillway elevations should be surveyed or taken from as-built plans.
- Bridges and Culverts
  - Cross-sections should be surveyed at the upstream and downstream toe of the road embankment to define the bridge/culvert opening. When the channel geometry is consistent through the opening, one representative cross-section may be surveyed upstream and copied downstream. The survey cross-sections must identify all significant features of the bridge/culvert geometry (top of abutment, toe of slope, limits of riprap, etc.)
  - Flow lines (and centerlines if different) should be surveyed for each culvert barrel.

- A cross-section should be surveyed along the centerline of the road over the bridge/culvert. If the centerline is not the highest point, the highest point must be identified and surveyed along with the centerline.
- Any walls or bridge rails along the edges of the road should be surveyed (begin and end points and top elevations).
- The low chord (top of bridge opening – often the bottom of the bridge beams and sometimes low-hanging utility lines) of the bridge shall be surveyed at both ends for flat bridge decks and at multiple points as needed to define sloping bridge decks or low chords with discontinuities (steps). The low chord shall be surveyed both on the upstream and the downstream side of the bridge.

- Dams/Weirs
  - Cross-sections should be surveyed immediately upstream and downstream of the dam or weir.
  - A cross-section should be surveyed along the top of the dam or weir, capturing the highest elevations that form the dam/weir, and the shape of the weir.
  - The flow line elevation at the upstream and downstream end of any low-flow outfall should be surveyed.
  - Sufficient surveying should be performed to fully define any weir opening in the structure.

- Adequate field notes must be provided to describe the size and shape of any surveyed opening, weir or spillway. A sketch of the surveyed structure should also be provided. Any siltation or blockage of culvert or bridge openings should be noted and shown in a sketch and photograph. The width of the roadway and any shoulder (paved or grass lined) should be indicated in the notes.

- Photographs must be provided for any surveyed structure. At a minimum, photographs should be taken of the upstream and downstream faces of the structure and looking upstream and downstream from the structure. Photographs should include a description and either a date stamp or the date included with the description.

- Standardized field codes and comments as outlined in the most current FEMA *Data Capture Standards Technical Reference* should be used for all surveys associated with modeling projects.

- If sufficiently accurate as-built plans are available for a structure, they may be used in place of field survey. The use of any as-built drawings must be approved by the reviewing entity on a case-by-case basis before they are used to develop the model. The datum used to establish the elevations for the plans should be noted and elevations must be adjusted to match the modeling standards described in this document.

2.6 PRECIPITATION DATA

Precipitation values will be based on the USGS publication *Atlas of Depth-Duration Frequency of Precipitation Annual Maxima for Texas* (Asquith & Roussel, 2004). This publication includes additional years of data since the publications of the traditionally-used TP-40 (Hershfield, 1961) and Hydro-35 (Frederick, Myers, & Auciello, 1977) publications. The values for Bandera, Bexar, Karnes, Goliad, and Wilson counties are included in Table 2 through Table 6.

For historical events, NEXRAD data is available from the National Oceanic and Atmospheric Administration (NOAA), National Climatic Data Center. Rain gauge data for the Edwards Aquifer recharge and contributing zones is available from the Edwards Aquifer Authority.

Table 2 - USGS Adjusted IDF Rainfall Values for Bandera County

Total Rainfall for Frequency (Inches)

Duration	100% AC	50% AC	20% AC	10% AC	4% AC	2% AC	1% AC	0.2% AC
5 minute	0.42	0.51	0.67	0.78	0.89	0.97	1.14	1.48
15 minute	0.82	0.97	1.21	1.50	1.80	2.05	2.30	3.00
30 minute	1.14	1.38	1.80	2.10	2.40	2.63	3.08	4.00
1 hour	1.45	1.79	2.40	2.79	3.31	3.90	4.40	5.90
2 hour	1.76	2.20	2.99	3.60	4.40	5.20	5.90	8.30
3 hour	1.94	2.44	3.34	4.00	4.95	5.80	6.55	9.60
6 hour	2.25	2.85	3.93	4.80	6.00	7.00	7.90	11.10
12 hour	2.56	3.26	4.53	5.50	6.60	7.70	9.00	12.50
24 hour	2.88	3.67	5.12	6.10	7.60	9.00	10.30	14.00
2-day	3.19	4.08	5.71	6.90	9.00	10.00	11.50	14.70
3-day	3.37	4.32	6.06	7.40	9.40	10.70	12.00	15.40
4-day	3.50	4.49	6.31	7.80	9.75	10.85	12.50	15.90
5-day	3.60	4.62	6.50	8.20	10.10	11.00	13.00	16.40
7-day	3.75	4.82	6.79	9.00	11.00	11.50	14.00	18.00

Table 3 - USGS Adjusted IDF Rainfall Values for Bexar County

Total Rainfall for Frequency (Inches)

Duration	100% AC	50% AC	20% AC	10% AC	4% AC	2% AC	1% AC	0.2% AC
5 minute	0.54	0.61	0.70	0.78	0.93	1.04	1.13	1.52
15 minute	1.00	1.15	1.37	1.60	1.80	2.10	2.50	3.30
30 minute	1.46	1.64	1.90	2.12	2.50	2.80	3.05	4.60
1 hour	1.81	2.07	2.46	2.76	3.32	3.85	4.35	6.30
2 hour	2.22	2.57	3.11	3.55	4.35	5.10	5.80	8.10
3 hour	2.41	2.80	3.42	3.95	4.90	5.70	6.60	9.40
6 hour	2.86	3.31	4.01	4.60	5.70	6.50	7.50	10.60
12 hour	3.26	3.78	4.60	5.40	6.40	7.50	8.80	12.40
24 hour	3.85	4.44	5.36	6.00	7.50	9.00	10.00	13.70
2-day	4.28	4.94	5.97	6.70	8.50	9.90	11.20	15.00
3-day	4.52	5.20	6.26	7.10	9.00	10.50	12.00	15.60
4-day	4.95	5.66	6.76	7.55	9.45	10.95	12.45	16.05
5-day	5.39	6.13	7.26	8.00	9.90	11.40	12.90	16.50
7-day	5.57	6.36	7.60	8.50	10.50	11.80	13.80	17.80

Table 4 - USGS Adjusted IDF Rainfall Values for Wilson County

Total Rainfall for Frequency (Inches)

Duration	100% AC	50% AC	20% AC	10% AC	4% AC	2% AC	1% AC	0.2% AC
5 minute	0.50	0.55	0.71	0.83	0.96	1.11	1.20	1.55
15 minute	0.91	1.08	1.43	1.65	2.00	2.30	2.60	3.40
30 minute	1.35	1.49	1.93	2.23	2.60	3.00	3.25	4.20
1 hour	1.67	1.82	2.39	2.79	3.38	3.85	4.38	5.80
2 hour	1.94	2.25	3.00	3.50	4.30	5.00	5.70	7.75
3 hour	2.10	2.36	3.30	3.95	4.90	5.70	6.50	9.30
6 hour	2.45	2.65	3.80	4.50	5.50	6.40	7.20	10.50
12 hour	2.78	3.00	4.35	5.10	6.40	7.40	8.50	12.00
24 hour	3.25	3.55	4.88	5.90	7.40	8.80	9.95	13.10
2-day	3.52	4.00	5.43	6.50	8.00	9.70	10.70	14.00
3-day	3.72	4.10	5.70	7.00	8.50	10.50	11.50	14.80
4-day	3.86	4.31	5.98	7.40	8.95	11.00	12.00	15.45
5-day	3.98	4.53	6.25	7.80	9.40	11.50	12.50	16.10
7-day	4.14	4.85	6.80	8.30	10.00	11.80	13.00	17.00

Table 5 - USGS Adjusted IDF Rainfall Values for Karnes County

Total Rainfall for Frequency (Inches)

Duration	100% AC	50% AC	20% AC	10% AC	4% AC	2% AC	1% AC	0.2% AC
5 minute	0.51	0.57	0.73	0.84	0.98	1.11	1.22	1.55
15 minute	1.04	1.11	1.43	1.62	1.98	2.29	2.50	3.20
30 minute	1.38	1.53	1.98	2.28	2.66	3.00	3.30	4.20
1 hour	1.73	1.82	2.40	2.80	3.38	3.85	4.35	5.80
2 hour	1.96	2.25	2.99	3.55	4.20	4.90	5.50	7.50
3 hour	2.15	2.36	3.29	3.90	4.80	5.65	6.50	8.80
6 hour	2.48	2.59	3.60	4.40	5.50	6.40	7.30	10.30
12 hour	2.80	3.05	4.37	5.05	6.40	7.50	8.60	12.00
24 hour	3.28	3.53	4.90	6.00	7.30	8.80	9.90	13.20
2-day	3.41	4.00	5.55	6.70	8.20	9.60	11.00	14.20
3-day	3.59	4.25	5.90	7.10	8.60	10.10	11.80	14.80
4-day	3.72	4.45	6.28	7.50	9.05	10.55	12.15	15.45
5-day	3.82	4.65	6.65	7.90	9.50	11.00	12.50	16.10
7-day	3.97	4.90	6.90	8.20	10.00	11.60	12.60	16.60

Table 6 - USGS Adjusted IDF Rainfall Values for Goliad County

Total Rainfall for Frequency (Inches)

Duration	100% AC	50% AC	20% AC	10% AC	4% AC	2% AC	1% AC	0.2% AC
5 minute	0.53	0.58	0.75	0.85	1.00	1.12	1.25	1.55
15 minute	1.07	1.12	1.44	1.60	1.95	2.20	2.50	3.00
30 minute	1.43	1.58	2.03	2.30	2.70	3.04	3.38	4.20
1 hour	1.79	1.85	2.45	2.85	3.40	3.80	4.40	5.75
2 hour	2.05	2.33	3.10	3.60	4.30	4.90	5.50	7.60
3 hour	2.22	2.45	3.33	3.97	4.85	5.65	6.55	9.20
6 hour	2.52	2.74	3.80	4.60	5.70	6.60	7.80	11.20
12 hour	2.80	3.18	4.40	5.25	6.60	8.00	9.30	13.00
24 hour	3.37	3.80	5.40	6.50	8.00	9.50	11.40	15.00
2-day	3.56	4.35	6.15	7.90	9.50	11.00	12.70	16.70
3-day	3.75	4.70	6.60	8.30	10.50	12.00	13.30	17.30
4-day	3.89	4.92	6.93	8.55	10.75	12.25	13.65	17.65
5-day	4.00	5.13	7.25	8.80	11.00	12.50	14.00	18.00
7-day	4.16	5.45	7.73	9.20	11.20	13.00	14.50	18.80

2.7 STREAM FLOW AND STAGE DATA

Stream flow and stage data is available from the USGS for flood frequency analysis and/or model calibration. Table 7 list flow gaging stations that are available in the SARB as of February 2013.

Table 7 - San Antonio River Basin USGS Gauges

Gauge #	Gauge Location
08177700	Olmos Creek at Dresden Dr, San Antonio, TX
08178000	San Antonio River at San Antonio, TX
08178050	San Antonio River at Mitchell St, San Antonio, TX
08178504	San Pedro Creek at Probandt St at San Antonio, TX
08178565	San Antonio River at Loop 410 at San Antonio, TX
08178585	Salado Creek at Wilderness Rd, San Antonio, TX
08178593	Salado Creek at Blanco Rd. San Antonio, TX
08178700	Salado Creek at Loop 410 at San Antonio, TX
08178800	Salado Creek at Loop 13 at San Antonio, TX
0817887350	Medina River at Patterson Rd at Medina, TX
08178880	Medina River at Bandera, TX
08180586	San Geronimo Ck nr Helotes, TX
08180700	Medina River near Macdona, TX
08180720	Medina River near Von Ormy, TX
08180800	Medina River near Somerset, TX
08181400	Helotes Creek at Helotes, TX
08181435	Leon Creek at Loop 410 at San Antonio, TX
08181480	Leon Creek at IH 35 at San Antonio, TX
08181500	Medina River at San Antonio, TX
08181800	San Antonio River near Elmendorf, TX
08183200	San Antonio River near Floresville, TX
08183500	San Antonio River near Falls City, TX
08183890	Cibolo Creek at Cibolo Nature Center near Boerne, TX
08183900	Cibolo Creek near Boerne, TX
08184050	Cibolo Creek at Smithson Valley Rd near Bulverde, TX
08185000	Cibolo Creek at Selma, TX
08185065	Cibolo Creek near Saint Hedwig, TX
08185100	Martinez Creek near Saint Hedwig, TX
08185500	Cibolo Creek at Sutherlands Springs, TX
08186000	Cibolo Creek near Falls City, TX
08186500	Ecleto Creek near Runge, TX
08188060	San Antonio River at SH 72 near Runge, TX
08188500	San Antonio River at Goliad, TX
08188570	San Antonio River near McFaddin, TX

Historical data may also be available for the gauge stations listed in Table 8 which are no longer active. Stage data may also be available from the City of San Antonio flood warning network and surveyed high water marks.

Table 8 - San Antonio River Basin Inactive USGS Gauge Locations

Gauge #	Gauge Location
08180000	Medina Canal near Rio Medina, TX
08180001	Medina Canal Diver below Siphon 2 near Rio Medina,
08180003	Medina Canal at FM 2676 near Rio Medina, TX
08180008	Medina Canal at Kelly Rd near Macdona, TX
08180500	USGS Medina River near Rio Medina, TX
08180942	Laurel Canyon Creek near Helotes, TX
08183850	Cibolo Creek at IH 10 above Boerne, TX

3.0 HYDROLOGIC MODELING

3.1 APPROACH

3.1.1 Permitted Methods

FEMA Guidelines and Specifications recommend three general hydrologic methods for determining peak flows: statistical analysis of stream gauge data, regression equations, and the use of hydrologic models. Due to the limited availability of gauge data in the SARB, hydrologic models are the most commonly used method. Other methods to determine peak flows may be employed if acceptable to the local floodplain administrator, SARA staff, and FEMA. The Rational Method is intended for local drainage only (less than 200 acres) and shall not be used for regional modeling.

3.1.1.1 Flood Frequency Analysis

Flood frequency analysis of stream gauge data should be used to determine peak flows when at least 10 years of data is available. One must be careful when selecting a gauge site and utilizing the site data for flood frequency analysis. Consideration to how this data was determined, whether by direct measure or interpolation must be taken into account. Gauges with less than 10 years of data are not sufficient for flood frequency analysis but may be used for calibration.

Watershed changes and backwater conditions will impact analysis. Watershed changes include, but are not limited to, urbanization, detention facilities, transportation infrastructure, etc. Backwater can cause the same water surface elevation to represent more than one flow during a storm event, creating a looped rating curve.

When performing a flood frequency analysis, the Pearson Type III distribution with log transformation (Log-Pearson Type III) should be used. See the publication *Guidelines for Determining Flood Flow Frequency - Bulletin #17B* (USGS, 1976; Rev. 1981) for guidance.

PeakFQ and HEC-SSP are statistical flood frequency analysis software packages available for use. FEMA's *Hydrologic Models Meeting the Minimum Requirement of National Flood Insurance Program* provides a complete list of accepted statistical models.

If a flood frequency analysis is performed, the gauge numbers and source information should be documented.

3.1.1.2 Regression Equations

Regression equations may be acceptable depending on the scope of the hydrologic modeling task. They are not recommended for areas with changing land use or flood detention structures or where flood hydrographs are required for hydraulic analysis.

FEMA recommends the use of statewide regression equations. TXDOT recommends regional regression equations. If regression equations are used, document the selection process for the equation(s).

3.1.1.3 Hydrologic Model

Because many streams in the SARB have limited or no gauge data, contain sub-watersheds with flood control structures, and experience frequently-changing development conditions hydrologic modeling will probably be the most common method for determining peak flows.

3.1.2 Level of Detail

The regional hydrologic models are statistical models based on statistical precipitation data (not historical events). As such, the precision of the estimated peak flows is limited. The following guidelines for rounding should be applied when reporting peak flows:

- If the peak flow is less than 1,000 cfs, round to the nearest whole cfs.
- If the peak flow is between 1,000 and 10,000 cfs, round to the nearest 10 cfs.
- If the peak flow is between 10,000 and 100,000 cfs, round to the nearest 100 cfs.
- If the peak flow is greater than 100,000 cfs, round to the nearest 1,000 cfs.

3.1.3 Software Selection

The peak flows for the 2005 remapping effort were developed using Hydraulic Engineering Center Hydrological Modeling System (HEC-HMS) version 2.2.2, 3.0 or 3.1.0, depending on the watershed. Software updates and patches occur regularly as this software continues to be developed. More recent versions are considered acceptable. The current version of this free software can be found at http://www.hec.usace.army.mil/software/hec-hms/. See the HEC-HMS user and technical reference manuals for capabilities and limitations.

The use of alternate modeling software is also acceptable as long as the software is included on FEMA's *Hydrologic Models Meeting the Minimum Requirement of National Flood Insurance Program* list. The only exception is HEC-1 which is not acceptable for use in the SARB. If the study is proposing to use an alternate method to the effective model method, the study must establish why the effective method is inappropriate and explain why the proposed alternate is more appropriate.

3.1.4 Time Step

The calculation time interval in hydrologic modeling is an important consideration and must be carefully weighed for the modeling scale. The regional nature of the proposed modeling system lends itself to the use of a longer time step than is used for more detailed studies. It is recommended that the time step for computation be a minimum of 5 minutes. This time step will provide a balance of computational efficiency and accuracy for the length of routing reaches and drainage-basin lag times that are most likely to be considered in the regional scale models.

Smaller time steps may be necessary in order to ensure computational stability of short routing reaches, to model drainage basins with a short lag time, or to update the regional models with detailed studies using smaller sub-basins. If a smaller time step causes excessively long computation times, the study area may be separated from the main watershed model for use with the smaller time step. The results from the sub-model should then be incorporated into the main model.

Adjusting the time step of a hydrologic model will impact the number of steps/subreaches in the Modified Puls and Muskingum routing methods. See Sections 3.6.1, 3.6.3 and 4.3.3 for guidance.

3.2 SCENARIOS

When performing a hydrologic analysis, all of the modeling scenarios should be included in a single model file. The scenarios may include the following:

- Duplicate Effective – This scenario is used when updating the software version or changing software. The topographic, land use, soil, and structural information included in the input data must match the effective hydrology model.
- Corrected Effective – This scenario is used to correct errors in the effective/duplicate effective modeling configuration, but does not include updates to modeling parameters due to man-made changes since the effective model was adopted.
- Existing Conditions (Pre Project) – This scenario is based on the duplicate effective or corrected effective scenario and will include non-project-related updates to reflect existing topographic, land use, soil, and structural changes to the hydrologic landscape.
- Proposed Conditions (Post Project) – This scenario updates the Existing Conditions model with project-related parameters for the phase being constructed that impact land use, time of concentration, unit hydrograph or routing.
- Future Conditions (Ultimate Development) – This scenario addresses planned development by applying anticipated changes in land use for the study basin (Section 1.4.2). The Future Conditions scenario shall include all future phases of a planned project.

3.3 SUB-BASIN DELINEATION

The sub-basin delineation target for DFIRM was approximately 1.5 square miles in urban areas and approximately 3 square miles in rural areas not likely to urbanize in the foreseeable future. Smaller sub-basins may be required to adequately represent special features (confluences, diversion tunnels, detention facilities, etc.) within the study area. Smaller sub-basins may also be required to provide boundary flow conditions at the upstream ends of hydraulic model reaches. The recommended minimum sub-basin area is approximately 1 square mile, which corresponds with the lower limits for FEMA floodplain modeling. The modeler should gradually work his/her way downstream, ensuring that the rate-of-increase in computed peak discharge (from one node to the next) allows for a stable backwater computation.

3.4 RUNOFF METHOD AND LOSSES

3.4.1 Runoff Method

The runoff method used in HEC-HMS will depend on the focus of the study. Runoff in HMS is typically calculated through a loss model and unit hydrograph model. Hydrology models are also require an assumed initial moisture condition. The soil moisture standard for the SARB for most hydrology studies is Antecedent Moisture Condition II. If long-term or period-of-record simulations are being performed, a continuous moisture accounting methodology shall be used. Continuous moisture accounting is typically used to evaluate long-term flow conditions for erosion and sediment transport studies, or to more accurately simulate historical events that lasted more than one day. HMS provides several options for continuous moisture accounting. The study should fully document the reasoning for the selection of a particular method.

3.4.2 Curve Number

The SCS Curve Number (CN) loss model shall be used to simulate surface storage and infiltration losses for single-event models. The CN method is a simple, widely-accepted method that uses readily-available information to develop model parameters. The method uses four elements: 1) hydrologic soil group, 2) type of land use, 3) antecedent moisture condition, and 4) percent impervious cover. The CN shall be based on the hydrologic soil group, antecedent moisture conditions, and natural land cover for undeveloped areas. For developed areas, a separate percent impervious cover parameter shall be used in conjunction with the CN. Composite curve numbers should be rounded to the nearest whole number. The CN values listed in Table 9 have been adopted as a representative base set for the SARB. These CNs are based on the assumption that ground cover is in good condition (>75% cover).

Table 9 - Base Curve Numbers

Cover Description	Hydrologic Condition	Curve Number for Hydrologic Soil Group			
		A	B	C	D
Open space (lawns, parks, golf courses, cemeteries, etc.)	Good	39	61	74	80
Meadow (continuous grass, protected from grazing and generally mowed for hay)		30	58	71	78
Brush (brush-weed-grass mixture with brush the major element)	Good	30	48	65	73
Woods	Good	30	55	70	77

An expanded set of CNs can be developed using the USGS National Land Use/Land Cover (NLCD) data described in Section 2.3.1. This data set uses a modified form of the Anderson Land Use classification system to define 21 land use categories. In order to be useful, each of these classifications must be associated with a CN. The recommended associations between land use and CN are listed in Table 10.

Note: The NLCD classification for quarries/strip mines/gravel pits is not adequately covered by any category. These areas, especially in the karst portions of the watershed, will tend to hold significant amounts of water or allow for rapid infiltration rather than increased runoff. If the area is freely draining, the same CNs for transitional areas should be used. If the area tends to hold water, an appropriately low curve number should be selected or the area should be excluded as a non-contributing or disconnected drainage area.

Adjustments can be made to reflect more appropriate antecedent moisture conditions using Table 11. Any adjustments to the antecedent moisture condition must be documented in the study report.

Table 10 - National Land Cover, Land Use Classifications and Corresponding TR-55 Classifications

	NLCD Class	NRCS TR-55 Class	Hydrologic Condition
11	Open Water	NA – Assume 98 for all	
12	Perennial Ice/Snow	NA	
21	Low Intensity Residential	Open space with COSA impervious percentage for ¼ to 1 acre Res.	Good
22	High Intensity Residential	Open space with COSA impervious percentage for ⅛ acre Res.	Good
23	Commercial/Industrial/ Transportation	Open space with COSA impervious percentage from 72–95%	Good
31	Bare Rock/Sand/Clay	Newly graded areas	
32	Quarries/Strip Mines/Gravel Pits	Special – refer to text	
33	Transitional	Newly graded areas	
41	Deciduous Forest	Woods	Fair
42	Evergreen Forest	Woods	Fair
43	Mixed Forest	Woods	Fair
51	Shrubland	Brush	Fair
61	Orchards/Vineyards/Other	Woods – grass combination	Good
71	Grasslands/Herbaceous	Meadow	
81	Pasture/Hay	Pasture	Fair
82	Row Crops	Row crops (SR+CR)	Good
83	Small Grains	Small grain (SR+CR)	Good
84	Fallow	Fallow	Good
85	Urban/Recreational Grasses	Open Space	Good
91	Woody Wetlands	Woods	Good
92	Emergent Herbaceous Wetlands	Meadow	

Table 11 - Variation of Curve Number with Antecedent Moisture Condition

CN for Condition II	CN for Condition I	CN for Condition III	CN for Condition II	CN for Condition I	CN for Condition III
100	100	100	61	41	78
99	97	100	60	40	78
98	94	99	59	39	77
97	91	99	58	38	76
96	89	99	57	37	75
95	87	98	56	36	75
94	85	98	55	35	74
93	83	98	54	34	73
92	81	97	53	33	72
91	80	97	52	32	71
90	78	96	51	31	70
89	76	96	50	31	70
88	75	95	49	30	69
87	73	95	48	29	68
86	72	94	47	28	67
85	70	94	46	27	66
84	68	93	45	26	65
83	67	93	44	25	64
82	66	92	43	25	63
81	64	92	42	24	62
80	63	91	41	23	61
79	62	91	40	22	60
78	60	90	39	21	59
77	59	89	38	21	58
76	58	89	37	20	57
75	57	88	36	19	56
74	55	88	35	18	55
73	54	87	34	18	54
72	53	86	33	17	53
71	52	86	32	16	52
70	51	85	31	16	51
69	50	84	30	15	50
68	48	84			
67	47	83	25	12	43
66	46	82	20	9	37
65	45	82	15	6	30
64	44	81	10	4	22
63	43	80	5	2	13
62	42	79	0	0	0

3.4.3 Impervious Cover

Recommended impervious cover percentages for existing development and zoning within the SARB are listed in Table 12.

Table 12 - Percent Impervious Cover by Land Use

	Land Use Category	Zoning District	Average Percent Impervious Cover
Residential	1/8 acre Residential Lots, or Garden or Townhouse apartments	R-4, R-5, RM-4, RM-5; TND/TOD Use Patterns	65-85%
	1/4 acre Residential Lots	R-6, RM-6	38%
	1/3 acre Residential Lots	R-15	30%
	1/2 acre Residential Lots	R-20	25%
	1 acre Residential Lots	RP, RE	20%
Industrial		L, I-1, I-2	72-85%
Business or Commercial		NC, O, C	85-95%
Densely developed (apartments)		MF	65-85%
Streets, Roads, and Parking Areas			98%

3.5 UNIT HYDROGRAPH

3.5.1 Method Selection

The selection of a unit hydrograph method is based on topography, purpose, and software limitations. The SARB contains a wide range of topographic conditions from the steep slopes of the Edwards Plateau to the moderate slopes in the San Antonio area to the flat slopes toward the Gulf Coast, and the unit hydrograph method needs to be able to account for this variation.

The COSA UDC recommends the use of the SCS dimensionless unit hydrograph[2], but the implementation of the SCS unit hydrograph method in HEC-HMS has limitations. In HEC-HMS, the SCS methodology includes a hard-wired shape factor of 484. The factor has been known to vary from about 600 in steep terrain to 100 in very flat terrain (NRCS, 2007). While the SCS method may be appropriate for the moderately sloping areas that cover San Antonio and Bexar County south of the Edwards Plateau, it is not as applicable for the steeply sloping areas in the upper portions of the basin or the flat areas toward the coast. Other methods such as the Snyder and Modified Clark unit hydrograph methods provide additional variables that allow the user to adjust the shape of the hydrograph to more closely match observed conditions.

Because of the limitations of the SCS dimensionless unit hydrograph, the Snyder unit hydrograph is the recommended unit hydrograph methodology for consistency across the entire SARB. In areas appropriate for the application of the SCS method (moderate topography) either Snyder or SCS methodology may be used. Existing models may retain the SCS methodology.

[2] The UDC allows for the use of other methods with approval.

The Modified Clark (ModClark) methodology may also be used in cases where a gridded representation of the watershed is appropriate and has been defined. The ModClark method is typically used in conjunction with radar data.

3.5.2 Time of Concentration

Time of concentration (T_C) and/or lag time (typically 0.6* T_C) are used to describe the relationship between the center of mass of the precipitation and the center of mass of the runoff hydrograph at the outlet of a sub-basin. An expanded version of the TR-55 (NRCS, 1986) and Snyder's methodologies for calculation of the time of concentration were used to develop most of the DFIRM regional hydrology models[3]. When updating or modifying a DFIRM hydrology model, the same T_C methodology should be used unless sufficient justification, with associated evidence and documentation, can be presented by the study to support the use of an alternate method. Design hydrology models may also use the Seelye chart to estimate the overland flow portion of T_C as outlined in the COSA UDC.

The TR-55 methodology separates the movement of water through the drainage basin into three components. These components and the resources for calculation of each are listed below.

1. Overland (sheet) flow (OF)
    a. Acceptable range = 5 < OF < 20 minutes
    b. Use Manning's kinematic solution (TR-55 Equation 3-3)

$$T_t = \frac{0.007\ (nL)^{0.8}}{(P_2)^{0.5}\, S^{0.4}}$$

    Where:

    T_t = travel time (hr),
    n = Manning's roughness coefficient for sheet flow (Table 13),
    L = flow length (ft),
    P_2 = 2-year, 24-hour rainfall (in), and
    S = slope of land surface (ft/ft).

    c. Maximum length = 300 feet with a most-likely length of 100 feet when used in overland flow computations for unpaved areas. (Thomas, 1986)

[3] The Medina and Cibolo Creek hydrology models used the Snyder method for lag time as described below in Section 3.5.4.

Table 13 - Manning's Roughness Coefficients for Sheet Flow (Depth ≤ 0.1 ft)

Surface Description	n
Smooth surfaces (concrete, asphalt, gravel, or bare soil	0.011
Fallow (no residue)	0.05
Cultivated soils:	
Residue cover ≤ 20%	0.06
Residue cover ≥ 20%	0.17
Grass:	
Short-grass prairie	0.15
Dense grasses	0.24
Bermudagrass	0.41
Range (natural)	0.13
Woods:	
Light underbrush	0.40
Dense underbrush	0.80

Source: Table 3-1 TR-55 (NRCS, 1986)

2. Shallow concentrated flow
   a. Use Manning's equation for defined swales, bar ditches and street sections

$$V = \frac{1.49}{n} R^{2/3} S^{1/2}$$

   Where:

   V = velocity,
   n = Manning's roughness coefficient for open channel flow,
   R = hydraulic radius,
   S = channel slope, and
   1.49 is a conversion factor for English units.

   b. Use Figure 3-1 from TR-55 where the geometric section is not defined
3. Channel flow
   a. Existing computer model where available
   b. Manning's equation otherwise

The Snyder lag time (T_{lag}) is calculated using the following equation:

$$T_{lag} = CC_t\left(\frac{LL_c}{\sqrt{S}}\right)^N$$

where

C_t = basin coefficient;
L = length of the main stream from the outlet to the divide;
L_c = length along the main stream from the outlet to a point nearest the watershed centroid;
C = a conversion constant (0.75 for SI and 1.00 for foot-pound system),
S = overall slope of longest watercourse from point of concentration to the boundary of drainage basin; and
N = an exponent, commonly taken as 0.33.

The estimated value for T_{lag} should be rounded to the nearest minute. The parameter C_t is best found via calibration, as it is not a physically based parameter. This parameter has been found to vary from 0.4 in mountainous areas to 8.0 along the Gulf of Mexico.

3.5.3 SCS Unit Hydrograph

The SCS Unit Hydrograph method requires two parameters, lag time (T_{lag}) and a shape factor (also called a peak rate factor). The lag time for a drainage basin is typically calculated as a fraction of the time of concentration for the basin. An estimate of T_{lag} as 60% of T_c based on studies by the NRCS is commonly used (used in CoSA UDC). Various studies have estimated T_{lag} as 50–75% of T_c. A value of 0.6 T_c should be used as the initial estimate for T_{lag}. However, this variation should be considered during calibration of models. The estimated value for T_{lag} should be rounded to the nearest minute.

The peak rate factor can range from 100 in flat, swampy areas to 600 in steep areas. In HEC-HMS, the peak rate factor is fixed at a value of 484.

3.5.4 Snyder Unit Hydrograph

The Snyder unit hydrograph requires two parameters, lag time and peaking coefficient (similar function to the 484 shape factor coefficient in SCS unit hydrograph) to define the shape of the hydrograph.

The peaking coefficient (C_p) is also generally determined based on calibration to measured events. The hydrology TSDNs provide additional information on peaking coefficients for each regional hydrology model. Larger values of C_p are associated with smaller values of C_t (USACE HEC, 2000).

3.5.5 Modified Clark Unit Hydrograph

The Modified Clark unit hydrograph uses gridded rainfall data. It requires two input parameters: time of concentration and storage coefficient. Additional information can be found in *Runoff Simulation Using Radar Rainfall Data* (USACE HEC, 1996) and the HEC-HMS *Technical Reference Manual* (USACE HEC, 2000).

3.6 ROUTING

The channel routing methodology selected for HMS modeling will be based on the availability of hydraulic models within the watershed. If hydraulic models are available, the Modified Puls routing technique should be applied. For channels without available hydraulic models, the selection of the routing method will be based on the anticipated effects of storage. If overbank/channel storage is not significant, the Muskingum-Cunge eight-point cross section method should be used. If the effects of overbank/channel storage are anticipated to be significant, the Muskingum routing method should be used.

The order of preference for routing procedures to be used in the SARB models is as follows:

1. Modified Puls based on hydraulic modeling,
2. Muskingum-Cunge with 8-point cross section,
3. Muskingum

The number of routing steps within a routing reach must be set for each of these methods in order to ensure the computational stability of the model. The number of steps should be based on an estimate of the flow or travel time as described in the HEC-HMS manuals and the model time-step.

3.6.1 Modified Puls

The storage-discharge relationship for Modified Puls routing is to be based on the finalized hydraulic models for the watershed. These models must be configured for execution over a range of flow that brackets the minimum (0 cfs) and maximum flows (greater of 0.2% AC existing or 1% AC ultimate condition). At least eight different flow values (not including 0) distributed proportionally over this range should be used to develop the routing data. The resulting storage-discharge curves should be checked for discontinuities prior to use in the hydrologic models. Such discontinuities or sharp breaks in the curve are likely to cause computational instabilities in the hydrologic model.

3.6.2 Muskingum Cunge

The Muskingum-Cunge 8-point cross section should be based on the best available topographic or as-built plan data for the subject reach. Manning's n-values should be determined in a similar fashion to those for hydraulic models.

3.6.3 Muskingum

The Muskingum routing method requires the input of two parameters. These are the travel time through the reach (K) and a dimensionless weighting factor (X) related to the character of the channel.

The travel time can be estimated as $K = L/V_w$. The USACE Engineering Manual EM 1110-2-1417 (USACE, 1994) suggests estimating the flood wave velocity (V_w) as 1.33–1.67 times the average velocity, which may be estimated with Manning's equation and representative cross section geometric information.

The X coefficient is related to the type of channel and condition of flow in the channel. Table 14 provides guidelines for this coefficient. These are intended to serve as a starting point and may be modified during calibration.

Table 14 - Guidelines for Initial Values of the Muskingum X Coefficient

Type of Channel		X Coefficient
Natural with Overbank Flow	Flat	0.1
	Moderate	0.2
	Steep	0.3
Regular Grass Lined Ditch		0.4
Culverts or Concrete Channels		0.5

3.7 STORAGE AND DIVERSIONS

Before modeling a detention facility, its storage capacity and significance to the watershed should be considered. Regional models should include major storage and diversion structures such as regional detention basins, NRCS flood control structures, and larger dams and reservoirs. Development-level detention ponds used for storm water quality or quantity management should be included in the design hydrology model with impacts to the regional model reflected in the impervious cover and/or lag time parameters.

Storage and diversions should be modeled based on the best available information from as-built design plans or field surveys. Some facilities may need to be analyzed independently of the overall hydrologic model. The results of the external analysis shall then be input into the regional model. Such facilities would include Medina Dam and certain off-channel regional detention facilities that have complex inflow and outflow relationships. The standard methodology available within HMS should be used for all other structures and diversions. Only volume above the normal pool elevation of a facility should be included in storage estimates. Results for NRCS structures should be compared with existing NRCS SITES models where available. SARA should be consulted prior to altering the storage/diversion curves for existing tunnels or SARA's NRCS dams.

3.8 RAINFALL

Rainfall is the driving factor behind all of the processes simulated in H&H models. Hydrologic analysis for floodplain mapping is based around design storms rather than specific historic events. A reasonable hypothetical representation of rainfall is key to the production of good design storm simulations. These aspects include the spatial and temporal distributions of the rainfall, the duration of the rainfall, and the total amount of rainfall.

3.8.1 Duration

A 24-hour design storm is sufficient for most watershed level evaluations. However, modeling watersheds with longer response times such as the entire SARB will require a longer design storm. All models should be checked to insure that the peak flow has passed the mouth of the basin prior to the end of the simulation. (The outfall hydrograph should have reached the falling limb near the baseflow.)

3.8.2 Precipitation

The total rainfall volume is selected from the tables in Section 2.6 based on design storm event, storm duration, and county in which the study is located.

3.8.3 Distribution

The temporal distribution of the design storm rainfall is assigned in HEC-HMS using the USER HYETOGRAPH storm simulation type. The DFIRM hyetographs are stored in a HEC-Data Storage System (DSS) file which is available with the HMS model provided by SARA. They were developed to address the temporal and spatial distribution of rainfall within the SARB. A corrected set of hyetographs was produced in October 2012 and are recommended for use; however, their incorporation into new analyses will require close review for potential impacts outside the study area.

The nature of the spatial distribution for synthetic rainfall will be determined by the scale of the modeling to be performed. Two different approaches will be used depending on whether river basin scale or watershed scale modeling is being considered.

1. Watershed Scale Modeling – The traditional modeling approach of using uniformly distributed rainfall across the entire watershed will be used at this scale. The use of point rainfall totals is appropriate for areas less than 10 square miles. All ramodeling for drainage areas greater than 10 square miles in the SARB will apply areal reduction factors (ARF) to the rainfall to represent equivalent average values over the contributing watershed area.

The DFIRM hyetographs in the HEC-DSS file were developed to facilitate the adoption of the USGS rainfall values (Asquith & Roussel, 2004). A new set of areal reduction curves were developed for the SARB and can be found in Appendix C. For a detailed description of the process please refer to Technical paper 2, Appendix D. These areal reduction curves were used in Bexar, Karnes, and Wilson Counties. Goliad County used areal reduction factors developed for coastal areas as noted in the Hydrology TSDN for Goliad County. The hyetographs have to be stored and referenced outside of HEC-HMS because the integrated method of computing areal reduction is based on the reduction curves in TP-40. The TP-40 areal reduction factors will produce excessive runoff compared to the runoff resulting from application of the new aerial reduction factors.

2. River Basin Scale Modeling – The simulation of uniformly distributed rainfall across the entire SARB is not a reasonable approach. Storm cells that produce heavy rainfalls are typically concentrated over smaller areas with bands of lighter rainfall extending out from the highest intensity portions of the storm. These storms can be more realistically simulated with an ellipsoidal distribution used by the method for determination of probable maximum precipitation as described in HMR-52 (NOAA, 1982). In a few cases, the river basin scale modeling may be used on watersheds that, due to topographic conditions, are long and slender in shape such as Cibolo Creek and Ecleto Creek. For discussion on ellipsoidal positioning please refer to Appendix C.

For information about which approach is used in a particular regional model, refer to its Hydrology TSDN.

3.9 BASEFLOW AND INFLOW HYDROGRAPHS

In some cases, a model will need to account for flow from areas beyond the model limits or from baseflow.

The DFIRM regional hydrology models did not account for baseflow. Baseflow in the modeled stream segments was less than 5% of the peak flow for the design storm events. If a study is performed in which the baseflow is greater than 5% of the peak flow for the design storm event, the baseflow should be included in the analysis, and the source of baseflow data should be documented.

Flow from areas beyond the model limits is represented using inflow hydrographs. Several of the regional hydrology models include inflow hydrographs from adjoining regional models as documented in the hydrology TSDNs. Inflow hydrographs may also be used in design hydrology models to represent upstream areas truncated from the regional models. When inflow hydrographs are used, methodologies and simulation timing in the source model and the analysis model must be consistent.

3.10 DOCUMENTATION

3.10.1 Model Metadata

Each model developed for the SARB must be thoroughly documented. This documentation should be in a form similar to the metadata required for geospatial data. It will include documentation of the source of the model, the spatial extents, the methodologies used in the modeling, and any significant differences from previous models in the area. A summary of the additional information to be included in the modeling metadata is listed below.

1. Common Information
   a. Responsible Engineer
   b. Major Watershed
   c. Brief Description (<250 characters)
   d. Description of any unusual features
   e. Purpose of study
   f. Extents of modeling
   g. General differences from preceding models
   h. Date completed by engineer
   i. Date of jurisdictional review
   j. Date of SARA review
   k. File Name
2. Hydrology Specific Information
   a. Design storm description
   b. Unit hydrograph methodology description
   c. Routing methodology description
   d. Source model for Modified Puls routing data
   e. Source of soils data
   f. Source of land use data
   g. Development condition

These items should serve as the minimum requirements for documentation of the models in the SARB. This information will be stored in a linked database and maintained by SARA so that it can be accessed to determine the source of data within the modeling geodatabase. This is in addition to the documentation of the modeling process required by FEMA for update of FIRMs.

3.10.2 Geospatial Documentation

If the following elements are created or modified:

- Sub-basins,
- Reaches,
- Junctions, or
- Locations of modeled structures,

The supporting geospatial files are requested by SARA in the format outlined in Appendix E. The data should only be submitted for the elements being modified within the study area.

4.0 HYDRAULIC MODELING

Hydraulic modeling is used both to calculate the extent of the floodplain and to evaluate the impact of structures and any changes made to a channel. It is important that the hydraulic modeling methodology used for the SARB be consistent for all models. Any elements of the hydraulic modeling application that are not specifically listed below (ineffective flow areas, blocked obstructions, levees, etc.) are to be based on generally accepted engineering principles.

4.1 APPROACH

4.1.1 Model Type

The 2010 DFIRM remapping study was conducted using one-dimensional steady state analysis. Unsteady state and two-dimensional modeling techniques are acceptable; however, if modifications to a DFIRM hydraulic model include changing model type, supporting documentation must include an explanation of why the existing modeling approach is inappropriate.

4.1.1.1 One-dimensional steady state

One-dimensional steady state models represent flow in one direction: from upstream to downstream. Hydrologic input does not vary with time. This is the primary model type used for floodplain mapping and analysis in the SARB.

4.1.1.2 One-dimensional unsteady state

Currently, unsteady flow modeling may be useful for certain situations such as offline storage that are difficult to model with the combination of a steady flow hydraulic model and a hydrologic model. Applications of the unsteady flow option within HEC-RAS should be based on the guidelines in the HEC-RAS manuals and in the UNET model (original basis for the unsteady flow capabilities in RAS) documentation.

4.1.1.3 Two-dimensional unsteady state

Two-dimensional models can simulate flow in multiple directions and are therefore useful for modeling flat areas and complex drainage patterns. Two-dimensional model surfaces can be developed to represent the entire study area or can be linked to one-dimensional model features.

4.1.2 Software Selection

The hydraulic modeling software selected as the standard for use in DFIRM models was the USACE Hydraulic Engineering Center – River Analysis System (HEC-RAS) version HEC-RAS v. 3.0.0.

Software updates and patches occur regularly, as this software continues to be developed. More recent versions are considered acceptable. Current version of this free software can be found at http://www.hec.usace.army.mil/software/hec-ras/. For capabilities and limitations please refer to the HEC-RAS user and technical reference manual.

The use of other hydraulic modeling software is also acceptable depending on the modeling task, as long as the software is included on FEMA's *Hydrologic Models Meeting the Minimum Requirement of National Flood Insurance Program*.

4.2 SCENARIOS

When preparing a model for submittal, the appropriate scenarios should be included in a single model file. The scenarios may include but are not limited to:

- Duplicate Effective – This scenario is used when updating the software version or changing software. The topographic and structural information included in the input data must match the effective hydraulic model.
- Corrected Effective – This scenario is used to correct errors in the effective/duplicate effective modeling configuration and natural changes in topography, but does not include updates to modeling parameters due to man-made structures since the effective model was adopted.
- Existing Conditions (Pre Project) – This scenario is based on the duplicate effective or corrected effective scenario and will include non-project-related updates to reflect existing topographic, and structural changes to the hydrologic landscape.
- Proposed Conditions (Post Project) – This scenario updates the Existing Conditions model with project-related parameters for the phase being constructed that impact channel or overbank geometry.
- Future Conditions (Ultimate Development) – This scenario applies the future conditions hydrology to the proposed conditions hydraulic geometry to calculate future conditions water surface elevations for regulatory purposes.

4.3 OPEN CHANNEL RIVERINE MODELS

4.3.1 Cross Sections

In accordance with FEMA criteria, "cross sections must be placed perpendicular to flood flow and extend beyond the 0.2 percent annual chance floodplain boundaries on either side of the stream (2009)." The US Army Corps of Engineers *Engineering Manual 1110-2-1416 Appendix D* (USACE, 1993) and the USGS publication *Computation of Water-Surface Profiles in Open Channels* (Davidian, 1984) provide additional guidance for good practice in the placement of cross sections.

4.3.1.1 Spacing

The primary issue in hydraulic modeling is often the density of cross sections within the modeled stream reach. The appropriate model cross section density will be determined based on the level of development and the location of critical structures within the reach. For all modeling within cities and other urbanized portions (including areas of projected urbanization) the maximum modeling cross section spacing will not exceed 500 feet. For areas of Bexar County and other portions of the SARB that are likely to remain predominantly rural, the maximum modeling cross section spacing will not exceed 1,000 feet. The modeling cross section spacing should be reduced as necessary in order to model significant features and steeper channel slopes. Cross-sections in the vicinity of bridges, culverts, and weirs should be located as described in the HEC-RAS manuals.

4.3.1.2 Reach Lengths

During the development of a model reach lengths are assigned to the channel, left overbank, and right overbank areas of each cross section representing the distance to the respective portions of the next downstream cross section and affecting the volume within the modeled reach. When modifying an existing model to add or remove a cross section or structure, the downstream reach lengths should be checked, and the volume within the model should be checked. The overall stream length for the study area should not change without justification.

4.3.1.3 Head Losses

Table 15 lists guidelines for the base Manning's n-values to be used. These values also may be adjusted slightly based on calibration procedures for the model. The actual values used for modeling should be adjusted based on site reconnaissance or aerial photography. Roughness values will typically be higher in overbanks with similar vegetation to the adjacent channel due to shallower depths in the overbank.

Table 15 - Manning's Roughness Coefficients

Channel Description	Manning's n-values		
	Average	Minimum	Maximum
Concrete Lined Channel	0.015	0.010	0.020
Grass Lined Channel with regular maintenance	0.035	0.030	0.040
Gravel or Outcropping Stone Channel with limited vegetation	0.045	0.040	0.050
Grass Lined Channel without recent maintenance	0.050	0.045	0.055
Vegetated Channel with trees, little or no underbrush	0.055	0.050	0.060
Natural Channel with trees, moderate underbrush	0.075	0.070	0.080
Natural Channel with trees, dense underbrush	0.090	0.085	0.095
Natural Channel with dense trees, and dense underbrush	0.100	0.100	0.100 (or higher with justification)

Overbank Description	Average	Minimum	Maximum
Pasture	.045	0.035	0.055
Trees, little or no underbrush, scattered structures	0.070	0.060	0.075
Dense vegetation, multiple fences and structures	0.085	0.075	0.100 (or higher with justification)

Manning's n-values for situations not covered in the table shall be based on generally accepted engineering principles. The USGS publication, *Guide for Selecting Manning's Roughness Coefficients for Natural Channels and Flood Plains* (Arcement & Schneider, 1989) may be used as a guide for the selection of roughness coefficients within the ranges listed in Table 15.

Manning's n-values may be developed from a number of sources. Several modeling interfaces provide options for the initial estimation of n-values from land use. Roughness coefficients derived in this manner should be regarded as an initial estimate and should be verified by evaluations in the field, or, at a minimum, from evaluation of aerial photography.

Eddy losses (contraction and expansion coefficients) and energy losses through bridges are addressed in Section C.3.3 in Appendix C of Guidelines and Specifications (FEMA, 2009).

4.3.1.4 Ineffective Flow Areas and Blocked Obstructions

Techniques for modeling non-conveyance areas are discussed in the HEC-RAS manual and Section C.3.3 in Appendix C of Guidelines and Specifications (FEMA, 2009). Special care should be taken when producing floodplain maps where these techniques have been used to ensure water surface profiles carried into ineffective areas are not mapped erroneously.

4.3.2 Structures

The guidelines outlined in the HEC-RAS technical manual should be followed to the extent possible for all structures. This includes the proper location of cross sections upstream and downstream of the structure. Structures should be modeled based on the most reasonable available computation procedure within HEC-RAS (in-line weirs, culverts or bridges). Certain types of culverts, weirs and inline dams may need to be modeled as bridges. This should be addressed on a case-by-case basis.

4.3.2.1 Bridges and Culverts

The HEC-RAS bridge modeling routines provide multiple computation options for low flow and two computational options for high flow. The single most appropriate high and low flow options should be selected for the final version of the model.

4.3.2.2 Other Inline Structures

There are a number of stream reaches in the SARB with inline weirs/dams. The HEC-RAS manual provides guidance for selecting modeling options. The flow area in the cross sections upstream of the weirs should account for the normal pool of the structure.

4.3.2.3 Levees and Lateral Structures

Lateral structures can be used to track flow leaving the main stream at a spill location or into an offline detention pond. When using this feature in a steady state model, the flow balance between the flow leaving and the flow continuing downstream may be determined using the Optimization feature as described in the HEC-RAS manual. **Please note:** the flow adjustment should then be entered as a flow change in the hydrologic input data (HEC-RAS flow file), at which point the Optimization feature should no longer be used.

4.3.3 Storage

Storage in hydraulic models can be divided into two types – reservoir storage and channel storage. It is handled differently between steady and unsteady state models.

In steady state models, reservoir storage is related to lateral and inline structures (above). Offline reservoirs are connected to the main channel using one of various lateral connection options as described in the HEC-RAS manual. Flow leaving the channel is optimized by balancing the water surface elevations between the reservoir and the channel when the optimization feature is used.

Inline reservoir storage is not accounted for in a steady state hydraulic model. Cross section information needs to account for any impacts to flow area caused by the dam, and the hydrology model should be used to estimate impacts to peak flows.

While steady state models do not account for channel storage impacts to peak flows, they can be used to develop the storage-discharge relationships used for the Modified Puls hydrologic routing method (Section 5.6.1). For the DFIRM hydrology models where Modified Puls was used, reach definitions (upstream and downstream cross sections), flow tables, and routing step calculations are provided in the hydrology TSDNs for each regional hydrology model. The flow tables were developed using a range of flows from zero to the greater of the 0.2% AC existing or 1% AC ultimate peak flows. The tables include a sufficient number of increments to estimate a storage rating curve for each routing reach. The number of steps for each reach was calculated by dividing the reach length in feet by the product of the average velocity in feet per second and the hydrologic model time step in minutes. If a project impacts the channel geometry for a routing reach, the storage-discharge function and parameters need to be updated to reflect the changes.

4.3.4 River Reaches and Junctions

The river reach should follow the primary flowpath for the 1% AC storm event, usually the stream centerline. Appendix C of the Guidelines and Specifications (FEMA, 2009) addresses how to handle when the 1% AC storm event follows a different flowpath than the stream centerline (profile baseline), split flow, and diverted flow.

Where multiple reaches are combined at a junction, analysis options are described in the HEC-RAS manual.

4.3.5 Boundary Conditions

Boundary condition requirements depend on whether the model is steady or unsteady, whether the model limits are mid-stream or at a confluence, and the likelihood of coincident peaks at a confluence. Section C.3.3 in Appendix C of the Guidelines and Specifications (FEMA, 2009) provides guidance for selecting the appropriate boundary conditions for floodplain mapping.

In many cases, boundary conditions will need to be established for truncated DFIRM hydraulic models. For steady state truncated DFIRM hydraulic models, the downstream boundary condition should be set to a known water surface elevation, using the results of the original DFIRM hydraulic model to select the known water surface elevations.

4.3.6 Hydrologic Input

4.3.6.1 Steady State

When modifying the hydrologic input in a regional hydraulic model, it is generally recommended to maintain the existing flow change locations. However, modifications are acceptable with justification.

Flows used in the hydraulic model are generally the peak flows extracted from elements of the hydrology model for a given storm. The hydrology model provides flows at the downstream end of headwater basins, at junctions, and at the downstream end of routing reaches (e.g., modified puls reaches). In general, the flows used within the HEC-RAS model should either be extracted from a headwater basin or from the downstream end of a routing reach, unless a major tributary brings flow into a reach.

For headwater basins, the peak flow input will be entered at one-third the channel distance upstream from the computation flow point as shown in Figure 6. This location is the farthest upstream that a hydraulic model should extend into a headwater basin.

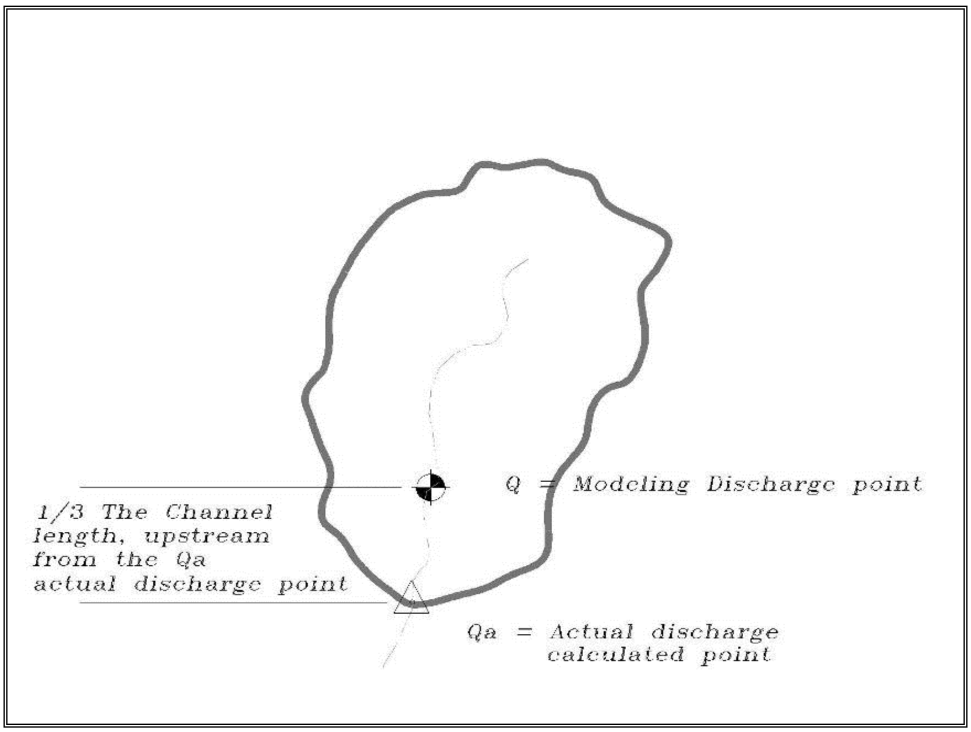


Figure 4 – Headwater Basin Modeling Discharge Point

Moving downstream, flow change locations should be located at the end of reach segments and at confluences. If the peak flow increases more than 5% between flow change locations other than confluences, interpolated flows should be added to provide a smoother transition. The interpolation method may be weighted based on contributing drainage area or reach length depending on the nature of the drainage area between flow change locations.

If the flow calculation point falls on a road, the flow should be entered at the approach cross section to the bridge rather than between the actual bridge sections.

4.3.6.2 Unsteady State

{*This section to be completed with next revision of the modeling standards.*}

4.4 TWO-DIMENSIONAL MODELS

Often the hydraulics of a study reach is complex, where flow mixing is occurring and there are lateral flow connections. In such cases, a two dimensional (2D) model may be considered. 2D models are most applicable when terrain is flat, floodplains are broad, water moves in two or more directions, and/or where flow is hydraulically disconnected between the main channel and the floodplain (FEMA, 2009).

2D dynamic modeling is intended for use when one-dimensional (1D) modeling is inappropriate for the study reach. A modeling approach is inappropriate when the theoretical assumptions of the 1D approach are violated by the flow conditions of the project. Engineering studies intending to use 2D models must document why the traditional 1D approach cannot be used and why a 2D model is required to comply with the scope of the study.

Multi-dimensional model software is typically classified using two of four terms that describe the mathematical solver methodology. A model is described as being either implicit or explicit and as being either finite element or finite difference. Each of the preceding classifications has data requirements and solution behaviors that present unique challenges; therefore, all stages of 2D model development, including the type of mathematical approach used by the model and the reasoning behind the model's selection for a study must be fully documented.

2D models being submitted for FEMA map changes must adhere to the requirements in Section C.3.3.3 of Appendix C: Guidance for Riverine Flooding Analysis and Mapping (FEMA, 2009).

4.4.1 Domain Extents and Orientation

The domain extents of a 2D model must cover the entire project area and extend beyond the project far enough area to allow a solution for the floodplain without piling up water at the boundary or encountering any other boundary effect. The domain must also extend upstream and downstream far enough to tie in with water surface elevations of effective water surface models outside the project area within half a foot.

Grid orientation options can be used to align the computation grid with the project stream network. Orienting the grid provides the user with an opportunity to fine tune or optimize the model solver. If this option is used, however, the orientation of the X-axis should be kept between 90^o and -90^o of east.

4.4.2 2D Terrain

Model cell elevations can be derived from many sources. Whether a model can use a particular source format varies among software developers. The results from a 2D model are very sensitive to the quality of the underlying terrain model. Extra care should be used to ensure that the model terrain is the highest quality available for the scale of the study.

4.4.2.1 Elevation

If the model cell elevations are determined from point elevation data, the cell elevations should represent an average of the points within a given cell.

If the cell elevations are determined from a grid or triangulated irregular network (TIN), the individual cell elevations should represent an average of the underlying TIN or grid elevations.

The resulting computational domain should be reviewed carefully to ensure that elevation transitions smoothly throughout the domain. Abrupt changes in elevation will cause model instability.

4.4.2.2 Roughness

Experience is crucial in selecting roughness values for 2D flows. Published guidance is not readily available outside software reference manuals. Some 2D modelers have found that roughness values tend to be higher than those used for 1D models. The project engineer should use observed flows and/or high water marks whenever available to calibrate the roughness values. If observed data is not available a sensitivity analysis, in conjunction with software documentation, should be used to determine reasonable roughness values.

4.4.3 Non-conveyance Areas

Non-conveyance areas should be set to reflect natural conditions as closely as possible. Techniques such as turning off cells, using high roughness or elevation values, and using thin walls to simulate non-conveyance areas for project design purposes is acceptable. However, removing elements from computation should not be used when developing BFEs for mapping (FEMA, 2009).

4.4.4 2D Hydraulic Structures

Most 2D software products include bridge, weir or culvert routines. However, bridges and culverts should be modeled externally to verify that the 2D results represent the hydraulic structure performance correctly and the differences should be documented accordingly.

4.4.4.1 Rating Curve Method

If the 2D model software being used requires a rating curve to represent the performance of a hydraulic structure, the project engineer should select an appropriate calculator and document the derivation technique used to create the rating curve. The study must also include an explanation of how the hydraulic structure is tied to the vertical datum, how the structure is aligned relative to the stream, and a list of the cells associated with the structure.

4.4.4.2 1D/2D Interface Method

Modeling software that relies on 1D/2D hybrid methods to represent hydraulic structures often uses abstract representations rather than physical geometry parameters for hydraulic structures. When these methods are used, the study should document how the model represents hydraulic structures in the study area. The performance of the hydraulic structures in 1D/2D models should also be compared to external software solutions for verification.

4.4.5 Boundary Conditions

2D models are dynamic models that minimally require upstream and downstream boundary conditions. The downstream boundary condition should consist of a stage-time hydrograph or rating curve. The upstream boundary condition should consist of a flow-time hydrograph. The modeler should also be aware that additional boundary conditions are required anywhere water enters or leaves the domain. No boundary condition should be used to restrict water from entering or leaving the domain without justification. All boundary conditions should be fully documented.

4.4.6 Hydrologic Input

If the 2D model is being used to support a FEMA map change, the study must maintain all flow change location peak flows used in the effective model unless the study is changing the effective hydrology.

4.4.6.1 Lumped Flow Routing (External Rainfall-Runoff)

Lumped flow routing models, like HEC-HMS, produce a hydrograph at junction points along a stream centerline. Routing losses are included at each junction; therefore, 2D models using lumped flow model output should be built in a manner to not include additional routing losses between junction locations if the model area encompasses more than one output node; to do so would double-count routing losses and produce erroneous results.

Hydrographs from external sources should be assigned across several domain elements, rather than assigning the entire inflow hydrograph to a single domain element, to minimize surging.

4.4.6.2 Distributed Flow Routing (Internal Rainfall-Runoff)

Some 2D software applications provide unit hyetograph and frequency storm routines that calculate watershed runoff and apply the resulting hydrographs to 2D domain elements or to nodes along a 1D/2D reach. The use of this method will be considered a change to the effective hydrology for regulatory purposes in the SARB. Proposals to use this method must be approved by the local community Floodplain Administrator, include aerial reduction if the contributing area is greater than 10 square miles, and fully document why the effective hydrology method was inappropriate.

4.4.6.3 2D Rainfall

2D rainfall applies a hyetograph to a polygon that covers all, or a portion of, the model computational domain to produce runoff. The use of 2D rainfall must be coordinated with the local community Floodplain Administrator. Studies proposing 2D rainfall must present justification to obtain approval. If 2D rainfall is approved, the project engineer must incorporate aerial reduction in the model if the drainage area at the outlet is greater than 10 square miles. The use of 2D rainfall will be considered a change to the effective hydrology for regulatory purposes in the SARB. A discussion as to why the effective hydrology method was inappropriate must be included in the study.

4.4.7 Initial Conditions

Two common methods to establish initial conditions have been encountered in 2D software packages. The first method enables the user to manually set initial conditions throughout the system. The second method requires a warm-up run to establish initial water surface elevations and other initial conditions. All initial conditions and the methods used to derive them shall be thoroughly documented in the study.

4.4.7.1 Antecedent Soil Moisture

In cases where the input hydrology was taken from an external hydrology model, the hydrographs will have already taken infiltration losses into effect; therefore, infiltration loses should not be used in the 2D models to avoid double-counting flow losses.

If the input hydrology does not include infiltration loses, as in the case of 2D rainfall, including losses in the 2D model is required and the methodology must be fully documented. The set of submitted model runs should include a sufficiently long warm-up run that establishes starting soil moisture conditions for the mapping run unless the software provides for the setting of initial soil moisture by other means. The target level for soil moisture and the rationale for the selected soil moisture level must also be documented.

4.4.8 Cell Size and Time Step

Cell size should be set appropriately for the project terrain. Cells should be large enough to accurately represent the floodplain being studied and ensure a smooth transition in terrain elevation. Consideration of the balance between the required detail needed to describe the flood plain terrain and model computational efficiency is important. Cell size should not be set to remove specific structures or lots from the floodplain. Channels should have at least 3 to 4 cells across major flow paths.

Cell size and time step are closely interrelated in 2D modeling. The Courant Number, C, is a good check to determine the adequacy of these two parameters in relation to one another. One form of the relationship is shown below:

$$C = \frac{\Delta t}{\Delta x}(\sqrt{2gH})$$

Where,

Δt = time step
Δx = grid size
g = gravitational acceleration
H = water depth

Software using implicit solvers should have the cell size and time step set so that the Courant Number is between 5 & 10 (typically closer to 5). Software using explicit solvers should have the cell size and time step set so that the Courant Number is less than 1. The project engineer should also consult software documentation for guidance.

4.4.9 Simulation Options and Tolerances

There are many options to set operational tolerances and other parameters for any 2D model and they are all set at default values. The project engineer should review the model defaults to ensure they are reasonable. Refer to the reference manual for the particular software being used simulation option and tolerance guidance. The threshold parameter for determining whether a model cell is wet or dry should be set at 0.01 foot in the SARB. Other thresholds can be used if approved by the community Floodplain Administrator. The rationale behind using other thresholds should be fully documented in the study report.

4.4.10 Stability and Continuity Criteria

Instability in a dynamic model appears in the result hydrographs as rapid variations between high and low values with time or spikes of excessively high or low values. Sometimes it's referred to as "bouncing", "searching" or "spiking." It is the result of the model failing to converge properly and should be reduced or eliminated whenever possible. A model that runs perfectly without any instability produces smooth, continuous hydrographs. Instability in the fringes of a hydrograph at the beginning or end of a run may be acceptable if the study can establish that the instability does not impact the overall accuracy of the model; however, instability at the hydrograph peak should always be resolved.

Continuity, on the other hand, is a measure of how well the model accounts for the inflow volume versus the outflow volume. 2D model continuity should be within 1%. 1D/2D model continuity should be within 5%.

4.5 COMBINING 1D AND 2D MODELS

1D/2D hybrid models do well in areas where stream channels are well defined and the channel flow satisfies 1D modeling assumptions, but flow in the overbanks has significant lateral movement that no longer satisfies 1D modeling assumptions.

Cross section placement will generally follow 1D practice guidelines. The difference between 1D and 1D/2D models lies in cross section length. Cross sections for 1D/2D models typically only represent the channel from left bank station to right bank station. However, cross sections may be extended into part of the overbanks where 1D modeling assumptions remain valid and the transition to 2D would occur at the point where 1D assumptions are no longer satisfied. In either case, the project engineer must remain cognizant of where the transition from 1D to 2D occurs to ensure the model solution represents natural flow conditions.

4.6 FLOODWAYS

If floodways are to be calculated for an area, the standard methodologies outlined in the HEC-RAS hydraulic reference manual (USACE HEC, 2002) and the FEMA *Guidelines and Specifications for Flood Hazard Mapping Partners* (FEMA, 2009) publication should be followed. More recent versions of these publications may be used as they become available. Floodways should be determined using steady state, one-dimensional hydraulic models.

4.7 DOCUMENTATION

4.7.1 Model Metadata

In addition to the basic modeling standards described in the preceding sections, each model developed for the San Antonio River Basin must be thoroughly documented. This documentation should be in a form similar to the metadata required for geospatial data. It will include documentation of the source of the model, the spatial extents, the methodologies used in the modeling, and any significant differences from previous models in the area. A summary of the additional information to be included in the modeling metadata is listed below.

1. Common Information
    - a. Responsible Engineer
    - b. Major Watershed
    - c. Brief Description (<250 characters)
    - d. Description of any unusual features
    - e. Purpose of study
    - f. Extents of modeling
    - g. General differences from preceding models
    - h. Date completed by engineer
    - i. Date of jurisdictional review
    - j. Date of SARA review
    - k. File Name
2. Hydraulic Specific Information
    - a. Steady or unsteady flow simulation
    - b. Flow regime for model
    - c. Source of flows
    - d. Description of boundary conditions
    - e. Source of topographic data
    - f. Coordinate system and datum's for topographic data
    - g. Source of roughness data

These items should serve as the minimum requirements for documentation of the models in the SARB. This information will be stored in a linked database and maintained by SARA so that it can be accessed to determine the source of data within the modeling geodatabase. This is in addition to the documentation of the modeling process required by FEMA for update of FIRM maps.

4.7.2 Geospatial Documentation

If the following elements are created or modified:

- Cross sections,
- Stream centerlines, or
- Structures,

The supporting geospatial files are requested by SARA in the format outlined in Appendix E. The data should only be submitted for the elements being modified within the study area.

5.0 CALIBRATION DATA

Calibration is vital for the development of accurate hydrologic and hydraulic models. All models accepted for use in the SARB should be as extensively calibrated as available measured data allows. Additional measured data should be collected when possible to augment the available calibration data sets. Measured rainfall and flows must be used for calibration/verification of models if available. Measured high water marks and stage measurements made at appropriately equipped flood warning sites should also be used when available.

Peak flows should be calibrated to within 10% of observed flows and the timing of the peak should match within 30 minutes (or less for small watersheds). Hydraulic models should be calibrated to within 0.5 feet of measured stage information. It may not always be possible to achieve this level of calibration based on the quality of the available observed data or due to unknown issues (channel blockage, etc.) during an event. The model may still be accepted, but the calibration issues should be documented.

Adequate hydrologic model calibration consists of two primary components. These are the matching of measured peak flows and the matching of the timing of the observed peaks. The initial estimates of model parameters (CN, percent of impervious cover, lag time and routing coefficients) should be adjusted in order to minimize the differences between measured and simulated events. In general, the parameters that are based on measured physical data, such as the percent impervious cover and the soil types, should be used less for calibration, and varied less when used for calibration, than those that are based on calculated or assumed conditions (e.g., lag time and routing coefficients). Antecedent moisture conditions must also be considered in the adjustment of loss rate parameters during the calibration process.

The primary calibration parameter in a hydraulic model is the Manning's roughness coefficient. Most of the other elements of the model are based as closely as possible on the measured real-world geometry of the stream and any structures along that stream. The Manning's roughness coefficients listed in Table 13 serve as an initial estimate for the channel roughness and may be adjusted upward or downward. These should probably be adjusted by no more than 0.005. Table 13 also provides a range of n-values for overbank areas. The roughness coefficient may be adjusted within these ranges during calibration. During calibration, the presence and behavior of ineffective areas, blocked obstructions, lateral structures, and storage areas can be reviewed, and changes may be appropriate if the model does not adequately represent the actual flow characteristics.

Calibration should be performed based on a minimum of three historical events when sufficient data is available. The models should also be verified and the calibration adjusted after significant new flooding events occur. The calibration events should be significant events (equivalent to the 50% AC or larger design storm) preferably with large events (4% AC or greater) when sufficient data is available. A fairly recent set of floods events should be chosen to reflect recent land use changes. If the storm occurred more than five years in the past, the model should be adjusted to account for the subsequent changes in land use. This is especially important in the San Antonio area. More recent events will also allow for the use of radar rainfall data.

Rainfall data from NEXRAD radar should be ground-truthed and then used to provide better representations of the areal distribution of measured precipitation. If radar rainfall data is not readily available for a particular event, precipitation data from rain gauges should be distributed over the modeled watershed based on either the Thiessen polygon or Isohyetal methods.

Stage measurements from USGS, Edwards Aquifer Authority, or COSA flood-warning sites and surveyed high water marks can be used to guide the calibration of the hydraulic model. It is important to remember that most stage data will be available near existing structures and that these parts of a stream system are most susceptible to debris blockage. If modeled results are significantly different from the observed data at a structure, debris blockage is a possible cause that should be investigated to the highest extent possible. High water marks are often surveyed by the USGS or other entities after significant flooding events. These may provide data in areas other than near structures.

Hydraulic models can be used to estimate peak flows based on such stage or high water mark information. A calibrated hydrologic model may be used to estimate the flow at locations for which flow is not directly measured. Calibration of a set of hydrologic and hydraulic models is a linked process and some iteration between the two may be required.

In addition to calibration based on measured historical events, the design storm flows should be checked for reasonableness. Flood frequency analyses at all available USGS gauges within the study area should be performed with up-to-date data. The current version of the USGS PEAKFQ application (Flynn, Kirby, & Hummel, 2006) should be used to perform these analyses. Calculated flood frequencies should then be used as a check of the hypothetical design storms used in the modeling system. Alternatively, USGS regional regression equations (Asquith & Slade, 1996) or TXDOT regression equations (TXDOT, 2001) may also be used as a check for design storms where appropriate.

6.0 FLOODPLAIN MAPPING

6.1 BASE MAP

Base map data sets will serve two purposes for this project — as input for modeling parameters and as the foundation for floodplain mapping.

The map data used to develop input parameters will include land use information as described in Section 2.2.3 and soils data as described in Section 2.4.

To define cross sections and produce the floodplain, the ground surface will be defined using a combination of survey data and aerial photogrammetry/LiDAR or USGS topographic data as outlined in Section 2.2. The surface model must meet the FEMA vertical accuracy standards as described in Table A-2 in the *Guidelines and Specifications for Flood Hazard Mapping Partners Appendix A: Guidance for Aerial Mapping and Surveying* (FEMA, 2003b) or the most current FEMA *Data Capture Standards Technical Reference*.

Aerial orthophotography will be the standard base map to provide context for exhibits. Information about accepted sources of aerial orthophotography is included in Section 2.3.1.

6.2 FLOODPLAIN

Floodplain mapping and the development of associated documentation will be based on FEMA standards. These standards are outlined in the *Guidelines and Specifications for Flood Hazard Mapping Partners* (FEMA, 2003a), available at the FEMA web site (http://www.fema.gov/) or the most current FEMA *Data Capture Standards Technical Reference*. These include, but are not limited to the existing conditions 1% AC and 0.2% AC.

FEMA allows for the display of the future (ultimate) condition, 1% AC floodplain on FIRM panels. The guidelines described in the FEMA publication *Modernizing FEMA's Flood Hazard Mapping Program: Recommendations for Using Future Conditions Hydrology for the National Flood Insurance Program* (FEMA, 2001) and formalized in recent changes to the Code of Federal Regulation (44 CFR 59 and 64) may be used for the display of future condition floodplains on FIRM panels for the region.

6.3 GEOSPATIAL DOCUMENTATION

The following geospatial files are required in support of a Letter of Map Change:

- Floodplain (area and line formats)
- Base Flood Elevations
- CLOMR/LOMR Boundary

The following geospatial files are also requested if the base map information was modified as part of the analysis:

- Land Use
- Contours (if produced for mapping included with the Letter of Map Change submittal)

Specific requirements for the geospatial documentation files are provided in Appendix E. The data should only be submitted for the elements being modified within the study area.

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APPENDIX A: MAPS OF MODEL DETAIL

San Antonio River Basin DFIRM Streams

SAN ANTONIO RIVER AUTHORITY

This map displays the San Antonio River Basin DFIRM Streams.

0 1.25 2.5 5 Miles

Published on December 07, 2007

Created By: JoseF

APPENDIX B: DRAINAGE BASIN DELINEATION MAPS

SAN ANTONIO RIVER AUTHORITY

This map displays the Bexar Couty Sub-Watersheds.

Published on December 07, 2007
Created By: JoseF

APPENDIX C: DEVELOPMENT OF DESIGN RAINFALL INFORMATION

An employee-owned company

March 3, 2005

Mr. Nefi Garza, P.E.
San Antonio River Authority
100 East Guenther Street
San Antonio, Texas 78204

RE: **Project # 441184.02 and 441184.04**
General Hydrologic and Hydraulic Modeling Tasks: Development of Design Rainfall Information

Dear Nefi:

The following is a brief report summarizing the design rainfall information to be used for the San Antonio River Basin. The report describes proposed guidance for the use of point rainfall versus an elliptical distribution, a proposed methodology for the determination of point rainfall totals for various durations at any location in the River Basin, and proposed rainfall totals based on the new USGS report. The use of HEC-1 instead of HEC-HMS in order to facilitate areal reduction based simulations is also discussed.

Point Rainfall and Ellipsoidal Distribution
Point rainfall is recommended for use in the design storm simulations for all watersheds tributary to the Medina and Lower San Antonio Rivers. An ellipsoidal rainfall distribution should be used for the Medina River downstream of Medina Lake and the San Antonio River downstream of the confluence with the Medina River. It may also be advisable to use the ellipsoidal distribution for the lower portion of the Cibolo Creek watershed below Interstate Highway 10 East given the size and elongated shape of the watershed.

The use of point rainfall to define the design for the tributary watersheds of the major streams is reasonable given the size of these watersheds The San Antonio River upstream of the confluence with the Medina River is one of the largest at 372 square miles (this area includes the 223 square mile Salado Creek watershed. This approach, when used with the areal reduction techniques in either HEC-1 or HEC-HMS, will likely produce more conservative flows than would be produced by the proposed ellipsoidal approach. The ellipsoidal approach provides a greater reduction in rainfall with increasing areas as opposed to the areal reduction curves used by the models (basically the curves from TP-40).

The added complication of the ellipsoidal approach is not warranted for use in modeling of the tributary systems. While the ellipsoidal approach has been made as simple as possible, it still requires the evaluation of two storm orientations centered at multiple points within the subject watershed. The critical centering is also likely to be different for points within the watershed. As a result, the ellipsoidal approach is more appropriate for large basin-scale modeling, preferably with more generalized models than those used for the tributary watersheds.

Determination of Point Rainfall within the San Antonio River Basin

Point rainfall totals for the relevant design events have been developed for the five counties that comprise a majority of the San Antonio River Basin. These five counties from upstream to downstream are Bandera, Bexar, Wilson, Karnes and Goliad. It is recommended that the rainfall developed for these five counties be used to define the design rainfall for all drainage basins (defined by hydrologic unit) predominantly within each county. Refer to Figure 1 for the hydrologic units associated with each county.

The proposed methodology is a compromise approach that allows major variations in rainfall characteristics to be represented across the Basin, while remaining consistent and simple to apply for the majority of smaller watershed studies. As shown on Figure 1, most of the area to be studied as part of the Bexar County FEMA restudy would use the rainfall totals for Bexar County under the proposed methodology. The Bandera rainfall totals would be used for modeling of the Medina River upstream of Medina Lake. The Bandera rainfalls should be used with the ellipsoidal distribution simulation of flows along the Medina downstream of the dam.

Development of Point Rainfall Totals from USGS Report

The rainfall totals developed for the five counties are based on the USGS report "Atlas of Depth-Duration Frequency of Precipitation Annual Maxima for Texas" (Scientific Investigations Report 2004-5041). Rainfall totals for the 10-, 25-, 50-, 100- and 500-year events for durations of 5, 15, and 30 minutes; 1, 2, 3, 6, 12 and 24 hours; and 2, 3, 5 and 7 day durations were read from the atlas maps provided in the USGS report. This rainfall information is intended to be used for both the Frequency Distribution hyetograph and for determination of the rainfall totals and hyetographs shapes to be used with ellipsoidal storms.

Three values were determined for each recurrence and duration combination for each of the five counties. The three values consisted of the minimum and maximum rainfall totals at any point within a county and a representative value for the county. The representative values were determined based on an interpretation of the average rainfall total across a particular county. These values were tabulated and then graphed for each recurrence interval event in each county. The resultant graphs provided an initial estimate of the IDF curves and minimum and maximum boundary ranges for each of the IDF curve ordinates.

The initial IDF curve values were evaluated and revised as necessary in order to provide smooth curves for use in hydrologic modeling. The representative values determined from the atlas maps were adjusted as appropriate in order to smooth the curves. In most cases, the adjusted values fell within the minimum and maximum bounding ranges determined for the county. In a few cases, the values had to be adjusted above or below the bounding range in order to produce a smooth curve. This approach was discussed with William Asquith, author of the USGS report. He agreed in principle to the approach as described above. The resulting rainfall tables (Tables 1-5) and graphs (Figures 2-6) are attached at the end of this report. The preliminary and final tables and graphs are included in the spreadsheet on the CD attached with this report.

The 5-minute rainfall values called for in the Frequency Distribution hyetograph method (both HEC-HMS and HEC-1) are not available in the USGS report (15-minute is the smallest reported duration). The 5-minute values listed in the final table were developed under the assumption that the 5-minute rainfall total would be approximately 37% of the 30-minute total. This approach is based on the guidance provided in Table 3 in TP-40. The table states that the 5- and 15-minute rainfall can be estimated as 37% and 72% of the 30-minute rainfall respectively. Guidance for the determination of the 5-minute rainfall was also provided by Craig Lofton of the USACE. He stated that the Corps typically uses a value between 46 and 50 percent of the 15-minute rainfall total. Based on the TP-40 approach, the 5-minute rainfall value for the 100-year event in Bexar County is 1.13 inches. This equates to 45% of the 15-minute rainfall determined from the USGS report, which falls just outside of the range used by the Corps. The ratio is the same as that obtained in consideration of the UDC 5- and 15-minute rainfall totals.

Comparison to Other Data Sets

The rainfall data developed as described above was compared with both the existing rainfall totals in the CoSA UDC, the TxDOT IDF curve equations with coefficients for the subject counties (derived from TP-40), Hydro-35 and TP-40. The results of these comparisons for the Bexar County 100-year event are shown in Table 6. The comparison is shown graphically in Figure 7. Equations in the form used for the TxDOT IDF curves also were fit to the unadjusted USGS rainfall totals. Equations for Bexar County were fit to both the full set of rainfall totals through the 7-day duration and from the 5-minute through 24-hour durations.

Table 6: Summary of IDF Rainfall Values for the Bexar County 100-Year Event

	100-Year Rainfall Totals					
Duration	UDC	TxDOT	**USGS Adjusted**	USGS Fitted (All)	USGS Fitted (24-Hour)	TP-40
5 minute	0.87	1.21	**1.13**	0.94	1.00	1.24
15 minute	1.91	2.40	**2.50**	2.17	2.24	2.41
30 minute		3.30	**3.05**	3.29	3.33	3.35
1 hour	4.25	4.26	**4.35**	4.52	4.50	4.27
2 hour	5.57	5.28	**5.80**	5.74	5.67	5.28
3 hour	6.23	5.92	**6.60**	6.42	6.35	5.86
6 hour	7.13	7.11	**7.50**	7.56	7.51	7.10
12 hour	8.05	8.46	**8.80**	8.69	8.72	8.55
24 hour	9.91	10.02	**10.00**	9.88	10.01	9.90

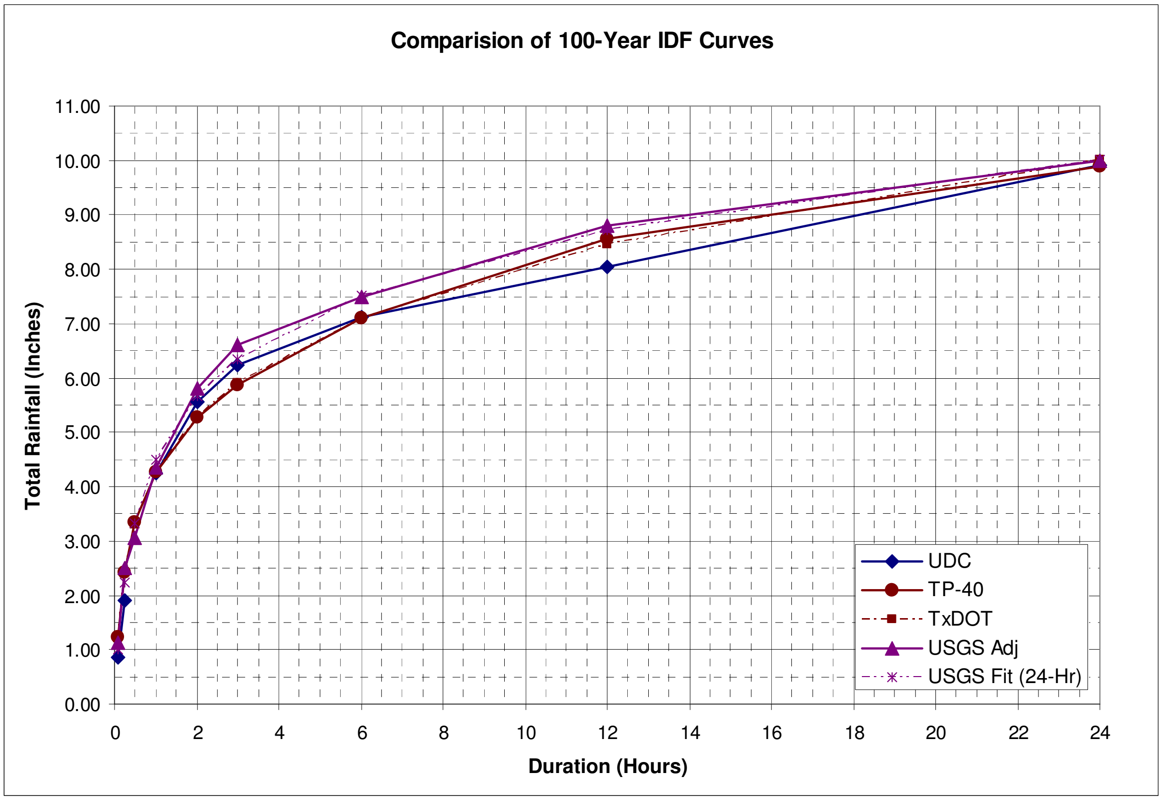


Figure 7: Comparison of IDF Curves for Bexar County

As can be seen in the table and figure, the most significant differences between the adjusted USGS values and the UDC values are in the 5- and 15-minute durations. The 1-hour through 24-hour values are also higher. However, the difference in the short duration events produce the largest difference in computed flows. The various IDF data sets were tested with a preliminary HEC-HMS model for the Salado Creek watershed. A HEC-HMS meteorologic model with the frequency storm distribution was developed for each version of the IDF curves. The results from the various meteorologic models produced total flows at the mouth that ranged from 2% to 6% higher with the USGS adjusted values producing the highest flows.

The differences were slightly more pronounced when looking at the individual drainage basins. All of the other IDF values produced substantially higher flows for drainage basins with short lag times. This is a result of the large relative differences between the UDC and other 5- and 15-minute rainfall values. In the case of the USGS fitted values, the difference in flows varies between 4 and 6 percent for drainage basins with lag times greater than 30 minutes. The differences tend to increase as the lag time decreases with a flow increase of approximately 30 percent for lag times around 15-minutes.

The 5- and 15-minute UDC values appear to be based directly on the Hydro-35 National Weather Service Publication. Both TP-40 and the USGS report indicate a significantly higher 15-minute rainfall than that derived from Hydro-35. This fact along with the 30-minute rainfall from the USGS report yield correspondingly higher 5-minute rainfalls. Even the equations fitted to the USGS values produce significantly higher 5- and 15-minute rainfalls.

The USGS fitted values are recommended for use in hydrologic modeling for the Bexar County FEMA Restudy and for the Regional Watershed Modeling System. However, everyone should be aware that these values will, in general, produce higher flows than those produced by the UDC rainfall values.

Ellipsoidal Rainfall Distribution

The assumption of a single point rainfall begins to break down when considering larger and larger areas. Ellipsoidal storm distributions are recommended for determination of flows along major streams with large watershed areas (greater than approximately 500 square miles) or very elongated shapes (Cibolo Creek). For the San Antonio River Basin, such streams would be the Medina River below Medina Dam, The San Antonio River below the confluence with the Medina River and Cibolo Creek below IH10 East. Point rainfall values would still be used to determine the FEMA and design flows for all other tributaries. The ellipsoidal analysis would be focused on the development of FEMA and design flows along the main stems of the three mentioned streams.

The size and shape of the elliptical storms to be used were developed based on HMR-52 guidance. Two storm orientations were considered for the River Basin, one at 220 degrees and the other at 320 degrees (see Figures 8 and 9 below). These orientations were based on the guidance in HMR-52 and on analysis of isohyetal maps from recent, large rainfall events. These two orientations correspond to the major storm patterns typical of the area (large fronts moving from the southwest and tropical storms moving from the southeast). The values of the elliptical isohyets are derived from the maximum point rainfall for a given design storm based on the location of the center of the storm. If the storm is centered over the Bexar County areas as described above, the Bexar County value would be used as the rainfall total for the central 10-square mile ellipse. The rainfall values for the outer isohyets are then reduced according to areal reductions factor based on the area of the isohyets. The methodology used for the areal reduction was based on the USGS Water-Resources Investigations Report 99-4267, "Areal-Reduction Factors for the Precipitation of the 1-Day Design Storm in Texas."

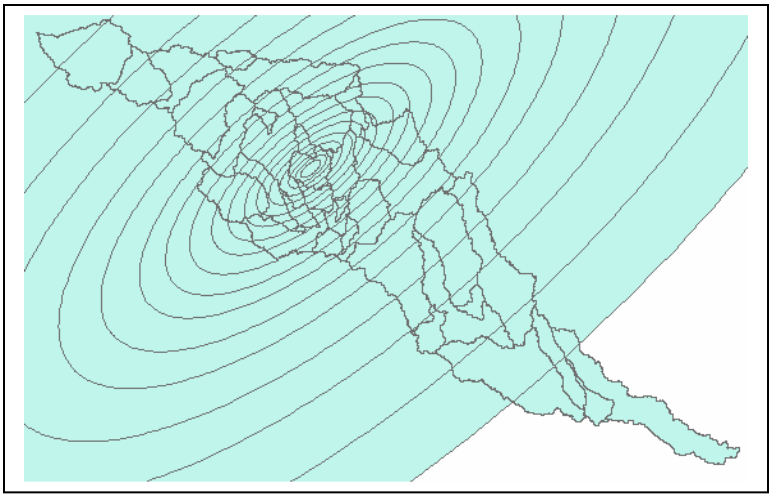


Figure 8: Ellipsoidal Orientation at 220 Degrees

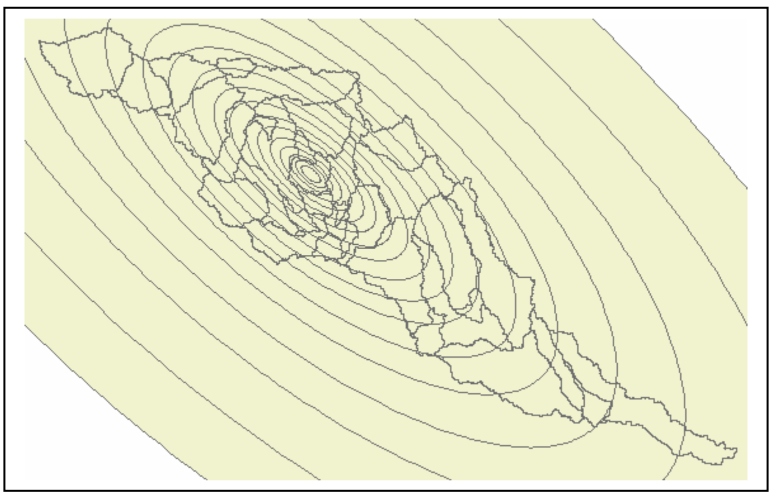


Figure 9: Ellipsoidal Orientation at 320 Degrees

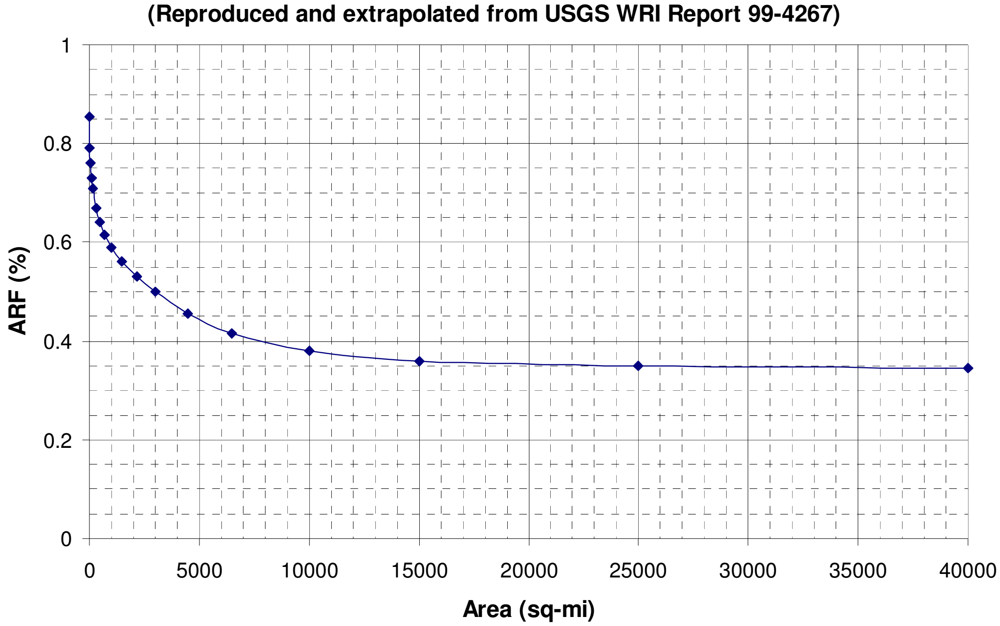
Areal reduction is an important consideration in the use of both point rainfall and an ellipsoidal distribution. Recent work by Halff Associates on the Lower Colorado River Basin (Lower Colorado River FEMA Study) has shown that the areal reduction curves from TP-40 (equivalent to those used in HEC-1 and HEC-HMS), when applied to an ellipsoidal storm distribution, generate flows considerably higher than is reasonable based on statistical analysis of gage records. The maximum areal reduction in the 100-year event based on the TP-40 curves is about 90%. This would mean that for a rainfall centered on the upper Medina River, the rainfall at Goliad would still be 90% of the maximum rainfall. In order to address this overly conservative assumption, areal reduction curves from the USGS study are recommended for use in determining the rainfall values associated with each ellipse. These curves yield a maximum areal reduction to 34.5% of the centroidal point rainfall for the outermost ellipse (40,000 square miles). Refer to Table 7 and Figure 10 for a full summary of the areal reduction factors for the ellipsoidal storms.

Table 7: Areal Reduction Curve (Reproduced and extrapolated from USGS WRI Report 99-4267)

Ellipse	Area (sq mi)	Base ARF for Area	Reduction Factors for Ellipses
A	10	0.855	1.000
B	25	0.79	0.823
C	50	0.76	0.775
D	100	0.73	0.745
E	175	0.71	0.720
F	300	0.67	0.690
G	450	0.64	0.655
H	700	0.615	0.628
I	1000	0.59	0.603
J	1500	0.56	0.575
K	2150	0.53	0.545
L	3000	0.5	0.515
M	4500	0.455	0.478
N	6500	0.415	0.435
O	10000	0.38	0.398
P	15000	0.36	0.370
Q	25000	0.35	0.355
R	40000	0.345	0.348

Note: Curve extrapolated for ellipsoidal areas O, P, Q and R

Figure 10: Areal Reduction Curve
(Reproduced and extrapolated from USGS WRI Report 99-4267)



In order to apply the ellipsoidal rainfall to a watershed, the ellipsoidal storm pattern must be used to calculate weighted rainfall for each drainage basin. The ellipsoidal storm patterns were initially created in CAD and then converted to shape files, one for the 220 degree orientation and one for the 320 degree orientation. GIS tools were then used to create appropriate attributes for the ellipsoid bands. The bands of the ellipsoids were attributed with the average value of the bounding isohyetal lines. In order to calculate the weighted rainfall for each drainage basin in a watershed, the ellipsoid shape file must be shifted to the appropriate centering point and then intersected with the shape file representing the drainage basins in the model. The weighted average storm rainfall for each of the watersheds may then be calculated for a given storm centering and orientation option.

The steps described above generate a weighted average rainfall total for each drainage basin in a model that must then be distributed over a hyetograph. A set of unit hyetographs was developed with the HMS model based on the frequency storm distribution and the Bexar County IDF values described in the preceding section. The ordinates of the resulting balanced hyetographs were divided by the total rainfall in order to obtain unit hyetographs. These unit hyetographs were developed for 24-hour, 2-day, 4-day and 7-day durations. The selection of the duration for use in a given analysis is dependent on the contributing watershed area at the point of interest. For the upper portions of the Medina and Cibolo, the 24-hour or 2-day durations may be adequate. For the San Antonio River between the confluence with the Medina and the confluence with the Cibolo, the 2- or 4-day duration would be more appropriate. Points below the confluence with Cibolo Creek should use either the 4- or 7-day duration. The duration used is dependant on the travel time of the peak from the upper portion of the water shed. In all cases, the simulation time should be approximately twice the rainfall duration in order to simulate the full runoff response of the watershed.

The weighted, total rainfall values calculated from the intersection of the basin watersheds with the storm centered ellipsoid, are distributed over these unit hyetographs to provide the necessary areally reduced precipitation for the model. This results in a separate hyetograph for each drainage basin that must then be assigned to a gage within HMS. Given the potential number of drainage basins and the number of centerings that must be analyzed, this process would be very tedious if done by hand. In order to automate this task, an application was created to distribute the calculated average precipitation values (manipulated in a spreadsheet and saved to a comma separated variable file) over the appropriate unit hyetograph. The resulting hyetographs for each drainage basin in the model are written out to a text file that is formatted for batch-mode entry into DSS. An external DSS rainfall input file containing the incremental hyetograph for each of the drainage basins may then be created for each of the storm centering options using the USACE DSSTS executable DOS program with the batch input files created by the application.

A gage must then be created in HMS for each drainage basin. Each of these gages must point to the directory containing the external DSS rainfall input files for the storm centering option. The various storm centering options may then evaluated by simply performing a find and replace routine in the HMS gage file to replace the previous storm centering DSS file with the current storm centering DSS file of interest. The HMS model may then be executed and the global summary table with peak flows copied and pasted into an excel file for evaluation.

Potential Use of HEC-1 Instead of HEC-HMS

The use of the HEC-1 model in place of HEC-HMS has been discussed in previous meetings. There are two primary advantages that have been put forth for this approach. The first is that detailed HEC-1 models already exist for portions of the Bexar County study area. Some of these models are quite complex and could be difficult to translate to HEC-HMS. The second is that HEC-1 offers the capability for consistent areal reduction whereas HEC-HMS will required significantly more runs or additional post processing in order to generate appropriate, areally reduced flows at all points within a watershed. The second factor is the more persuasive argument. However, models that are created or remain in HEC-1 will not be directly compatible with the RWMS. These models will need to be converted at some point in order to be integrated into the system. Ideally, version 3 of HEC-HMS will be soon become available and will eliminate the problems of consistent areal reduction in HMS. It is our recommendation that all hydrologic models, with the possible exception of the complex upper San Antonio River watershed, be created in HEC-HMS. This will facilitate integration into the RWMS and will also make the models easier to update in future studies.

If you have any questions or comments, please do not hesitate to contact me at (512) 342-3295.

Sincerely,

Karl McArthur, P.E.
Senior Water Resources Engineer

Attachments

cc: Tony Trollope, Duke Altman, Saul Nuccitelli, PBS&J
William Burmeister, Steve Gonzales, SARA

APPENDIX D: DEVELOPMENT OF AN ALTERNATIVE STORM HYETOGRAPH METHOD FOR AREAL REDUCTION

1965-2005

40 YEARS OF EXCELLENCE

BEXAR COUNTY MAP MODERNIZATION

Development of an Alternative Storm Hyetograph Method for Areal Reduction

SEPTEMBER 2005

PAPE-DAWSON ENGINEERS, INC.

555 East Ramsey | San Antonio, Texas 78216 | Phone: 210.375.9000 | Fax: 210.375.9010 | info@pape-dawson.com

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Written By

Wayne Tschirhart, Troy Dorman, Shiva Sandrana, Robin Buske

Overview

As part of the Regional Watershed Modeling System (RWMS), new adjusted rainfall developed by PBS&J and based on a recent USGS study for the Texas Department of Transportation was adopted for use in hydrologic models. PBS&J also proposed an ellipsoidal rainfall distribution for areal reduction to be applied to specific watersheds in the San Antonio River Basin. Development of both the adjusted rainfall and ellipsoidal distribution are documented in the RWMS technical memorandum titled "Snyder Hydrograph Guidelines", hereafter referred to as PBS&J-2005. The updated rainfall and ellipsoid areal reduction was tested using the San Antonio River (SAR) LMMP model. Analysis of the model output showed a 20% increase in flow using the new rainfall values with no other model changes. The increase was the result of an up to 30% increase in rainfall at short durations (<15min). Application of the ellipsoidal distribution reduced flows in the SAR basin to reasonable values but created a discontinuity at the junction of the San Antonio River and Medina River A new methodology was investigated to incorporate new USGS based Areal Reduction Factors (ARF) to replace the TP-40 based methodology hard-wired into HEC-1 and HEC-HMS. This paper presents a methodology to apply ellipsoidal areal reduction factors to the 24-hour storm used in the SAR basin tributary models.

The Upper San Antonio River Basin Test

The original LMMP study model (HEC-1) that is currently being used in the DFIRM process was selected for testing the impact of the adjusted rainfall rates. The watershed is approximately 134.5 square miles and the SAR USGS gauge at Loop 410 was selected as the point of interest to allow comparison with a gauged event. The accepted LMMP study model (HEC-1) produced a flow of 86,437 cfs using the rainfall rates supplied by the City of San Antonio Unified Development Code (UDC). For testing purposes, the model was updated with only the new precipitation. The updated model produced a flow of 106,917 cfs for the 1% annual chance event, which included TP-40 areal reduction by HEC-1. This flow was considered unreasonable since the highest recorded flow at Loop 410 was 79,400 cfs during the October 1998 flood.

As part of the analysis of the SAR below the confluence with the Medina River, the ellipsoidal rainfall distribution method was applied by intersecting ellipsoid patterns provided by PBS&J with the SAR basin delineation in GIS to obtain a single weighted areal reduction factor for each major basin. The 330 Degree pattern produced the highest average rainfall for the major watersheds. The 1% annual chance frequency rainfall depths were distributed via a unit hyetograph to produce incremental hyetographs for each return period. The hyetographs were entered into HEC-1 and the model was run. The 1% annual chance flow at Loop 410 was reduced to 67,430 cfs, a 22% decrease from the accepted LMMP model. This is consistent with the 74.5 percent ARF suggested by the PBS&J report. Recognizing that the new rainfall dataset would most likely produce excessive flows throughout the study area, an alternate method was required to produce consistent flows as area increases down basin.

Areal Reduction Using the Frequency Storm Meteorological Model

Areal reduction in the tributary sub-basins using HMS was performed by setting storm size threshold values in the HMS meteorological model (Figure 1). The threshold values were determined by evaluating points of interest within each watershed model. Multiple threshold values were run and the results for each were exported to a spreadsheet provided by PBS&J (Figure 2). Table 1 contains selected model results from the current study Martinez B model. This approach parallels the areal reduction approach built into HEC-1 but does not create a hydrograph at every computation point in the model.

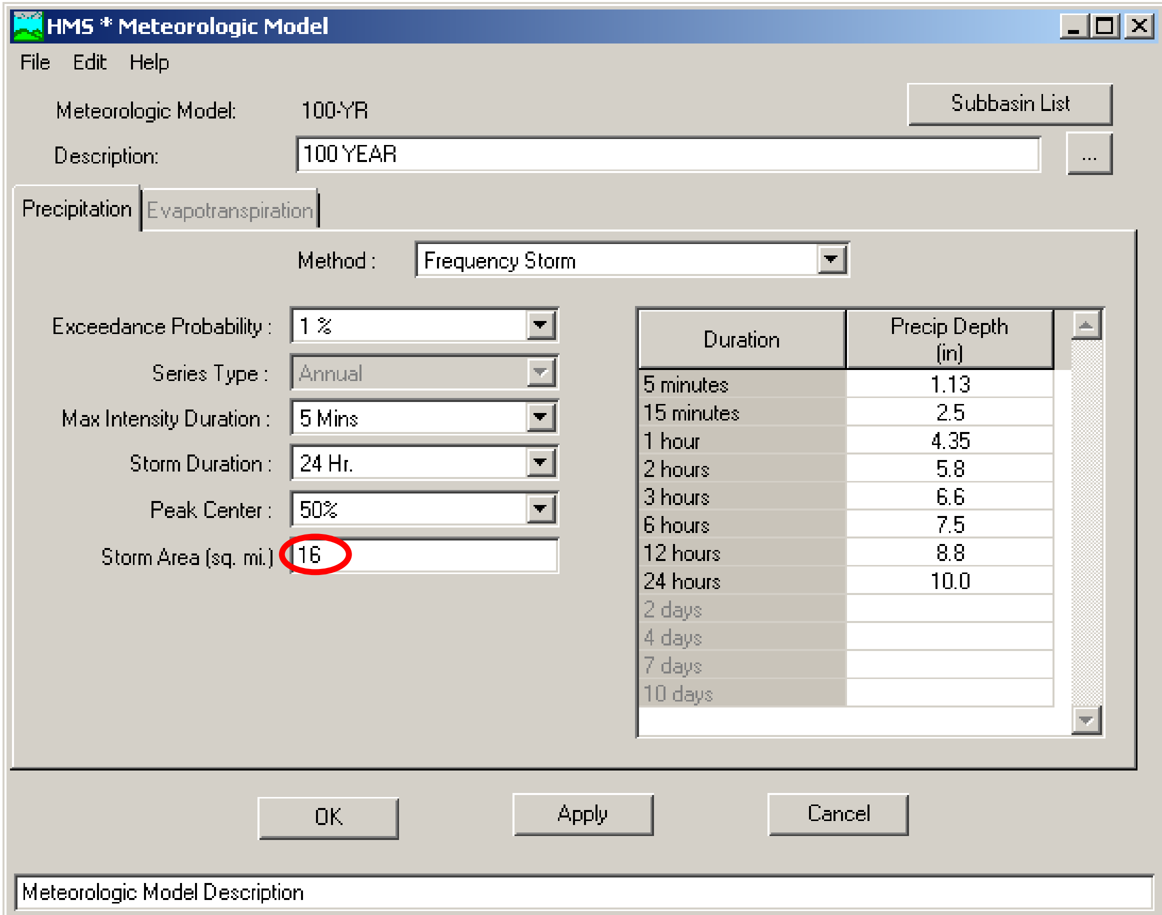


Figure 1 - HMS Model With Reduction Threshold Set At 16 Miles

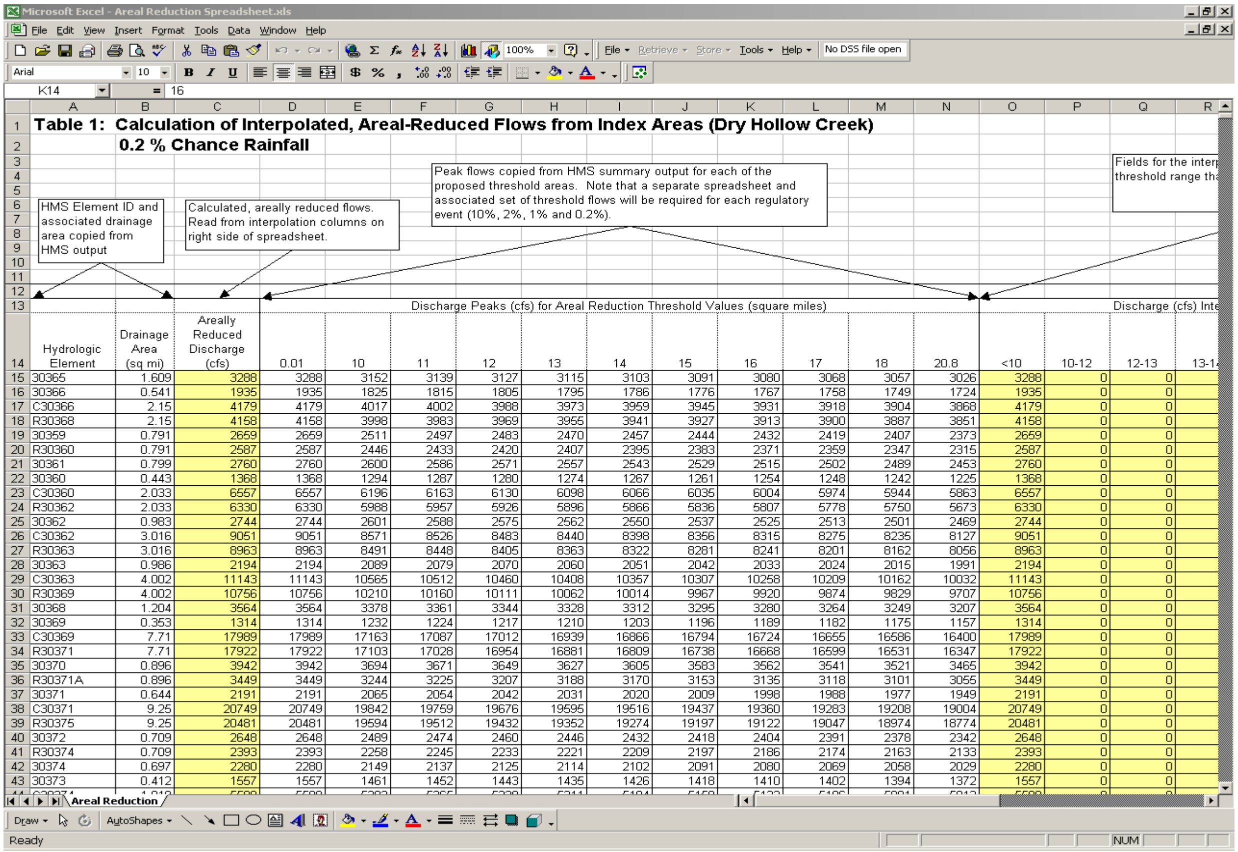


Table 1: Calculation of Interpolated, Areal-Reduced Flows from Index Areas (Dry Hollow Creek)
0.2 % Chance Rainfall

			Discharge Peaks (cfs) for Areal Reduction Threshold Values (square miles)												Discharge (cfs) Inte		
Hydrologic Element	Drainage Area (sq mi)	Areally Reduced Discharge (cfs)	0.01	10	11	12	13	14	15	16	17	18	20.8	<10	10-12	12-13	13-1
30365	1.609	3288	3288	3152	3139	3127	3115	3103	3091	3080	3068	3057	3026	3288	0	0	
30366	0.541	1935	1935	1825	1815	1805	1795	1786	1776	1767	1758	1749	1724	1935	0	0	
C30366	2.15	4179	4179	4017	4002	3988	3973	3959	3945	3931	3918	3904	3868	4179	0	0	
R30368	2.15	4158	4158	3998	3983	3969	3955	3941	3927	3913	3900	3887	3851	4158	0	0	
30359	0.791	2659	2659	2511	2497	2483	2470	2457	2444	2432	2419	2407	2373	2659	0	0	
R30360	0.791	2587	2587	2446	2433	2420	2407	2395	2383	2371	2359	2347	2315	2587	0	0	
30361	0.799	2760	2760	2600	2586	2571	2557	2543	2529	2515	2502	2489	2453	2760	0	0	
30360	0.443	1368	1368	1294	1287	1280	1274	1267	1261	1254	1248	1242	1225	1368	0	0	
C30360	2.033	6557	6557	6196	6163	6130	6098	6066	6035	6004	5974	5944	5863	6557	0	0	
R30362	2.033	6330	6330	5988	5957	5926	5896	5866	5836	5807	5778	5750	5673	6330	0	0	
30362	0.983	2744	2744	2601	2588	2575	2562	2550	2537	2525	2513	2501	2469	2744	0	0	
C30362	3.016	9051	9051	8571	8526	8483	8440	8398	8356	8315	8275	8235	8127	9051	0	0	
R30363	3.016	8963	8963	8491	8448	8405	8363	8322	8281	8241	8201	8162	8056	8963	0	0	
30363	0.986	2194	2194	2089	2079	2070	2060	2051	2042	2033	2024	2015	1991	2194	0	0	
C30363	4.002	11143	11143	10565	10512	10460	10408	10357	10307	10258	10209	10162	10032	11143	0	0	
R30369	4.002	10756	10756	10210	10160	10111	10062	10014	9967	9920	9874	9829	9707	10756	0	0	
30368	1.204	3564	3564	3378	3361	3344	3328	3312	3295	3280	3264	3249	3207	3564	0	0	
30369	0.353	1314	1314	1232	1224	1217	1210	1203	1196	1189	1182	1175	1157	1314	0	0	
C30369	7.71	17989	17989	17163	17087	17012	16939	16866	16794	16724	16655	16586	16400	17989	0	0	
R30371	7.71	17922	17922	17103	17028	16954	16881	16809	16738	16668	16599	16531	16347	17922	0	0	
30370	0.896	3942	3942	3694	3671	3649	3627	3605	3583	3562	3541	3521	3465	3942	0	0	
R30371A	0.896	3449	3449	3244	3225	3207	3188	3170	3153	3135	3118	3101	3055	3449	0	0	
30371	0.644	2191	2191	2065	2054	2042	2031	2020	2009	1998	1988	1977	1949	2191	0	0	
C30371	9.25	20749	20749	19842	19759	19676	19595	19516	19437	19360	19283	19208	19004	20749	0	0	
R30375	9.25	20481	20481	19594	19512	19432	19352	19274	19197	19122	19047	18974	18774	20481	0	0	
30372	0.709	2648	2648	2489	2474	2460	2446	2432	2418	2404	2391	2378	2342	2648	0	0	
R30374	0.709	2393	2393	2258	2245	2233	2221	2209	2197	2186	2174	2163	2133	2393	0	0	
30374	0.697	2280	2280	2149	2137	2125	2114	2102	2091	2080	2069	2058	2029	2280	0	0	
30373	0.412	1557	1557	1461	1452	1443	1435	1426	1418	1410	1402	1394	1372	1557	0	0	

Figure 2 - Areal Reduction Spreadsheet Example.

Watershed	Model Point	Drainage Area	FIS	Current Study
E. Fk E. Br. Salitrillo	30109	0.93 mi^2	1,100 cfs	1,909 cfs
E. Br. Salitrillo	30110	1.3 mi^2	2,750 cfs	2,830 cfs
E. Salitrillo	30101	1.0 mi^2	2,851 cfs	3,125 cfs
	C30103	1.6 mi^2	3,126 cfs	4,968 cfs
	C30108	5.5 mi^2	5,820 cfs	7,639 cfs
	C30113	12.9 mi^2	10,740 cfs	14,107 cfs
Martinez Cr. B	C30162	9.5 mi^2	2,600 cfs	4,775 cfs
	C30170	14.0 mi^2	8,400 cfs	10,546 cfs
W. Salitrillo	C30116	2.2 mi^2	5,080 cfs	5,120 cfs
	C30118	3.8 mi^2	1,580 cfs	2,327 cfs

Table 1 – Selected Martinez B 1% Annual Chance Model Results vs. Existing FIS.

The interest in testing the ellipsoid areal reduction factors on the SAR tributaries centers around the asymptotic limit of TP-40 areal reduction for 24-hour storms, which is around 8%. The general consensus believes that an 8% reduction is too conservative and a greater reduction should be applied in this region of Texas (USGS WRI 99-4267). Application of the full HMR-52 ellipsoid areal reduction method to the SAR tributaries is neither practical nor recommended, since most are fairly small. This investigation was conducted to test alternative methods to reduce flows in the SAR tributaries using ellipsoid areal reduction factors without the GIS procedure.

Alternative 1: Areal Reduction Using IDF Equations

The RWMS recommends a 24-hour storm with a 6-minute computation interval for SARB watershed models. PBS&J-2005 contains a letter dated March 3, 2005 that mentions the development of 24-hr, 2-day, 4-day, and 7-day unit hyetographs; however, Pape-Dawson only received the 2 to 7-day hyetographs and the tributary models use a 24-hr storm. Several approaches were examined to scale the 2-day hyetograph to 24-hours, but they were abandoned since IDF equations are non-linear and time is one of the variables. It became evident that the most prudent approach was to develop a new unit hyetograph for the 24-hour storm.

The Bexar County TXDOT IDF equation was selected as the starting point of development. The equation was used to calculate 24-hr, 15-min Depth-Duration-Frequency (DDF) curves for the 10, 4, 2, 1, and 0.2 percent annual chance storms. The alternating block method was used to build incremental and cumulative hyetographs for each storm. The cumulative hyetographs are shown in Figure 3. Since the curves are very close, they were averaged and the average hyetograph was normalized to produce a 24-hr, 15-minute unit hyetograph.

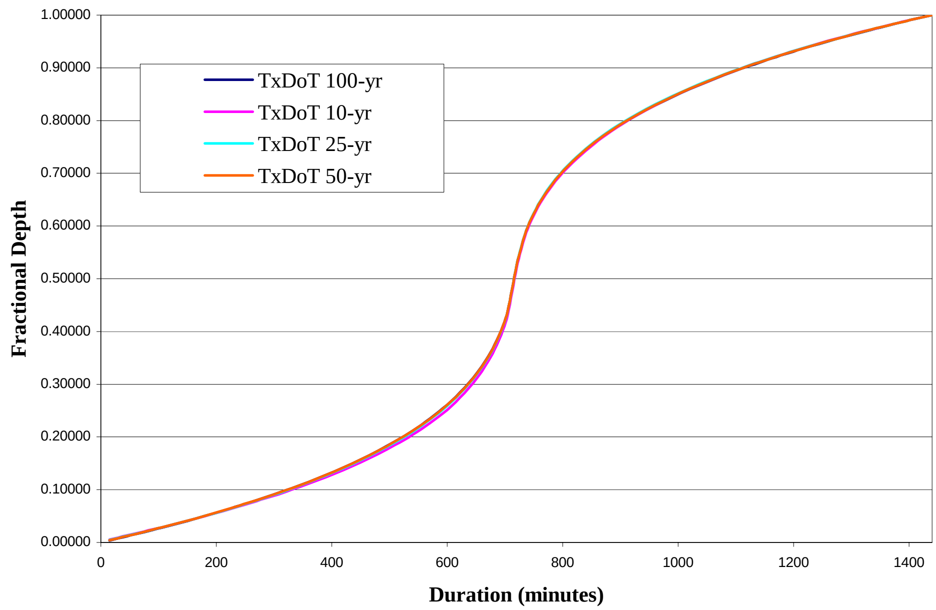


Figure 3 – Cumulative Hyetographs For Bexar County.

A 2-day unit hyetograph was also developed to compare with the PBS&J version (Figure 4). In order to maintain an equivalent peak rainfall duration, the Bexar County IDF equation was adjusted to more-or-less match the shape of the PBS&J unit 2-day hyetograph.

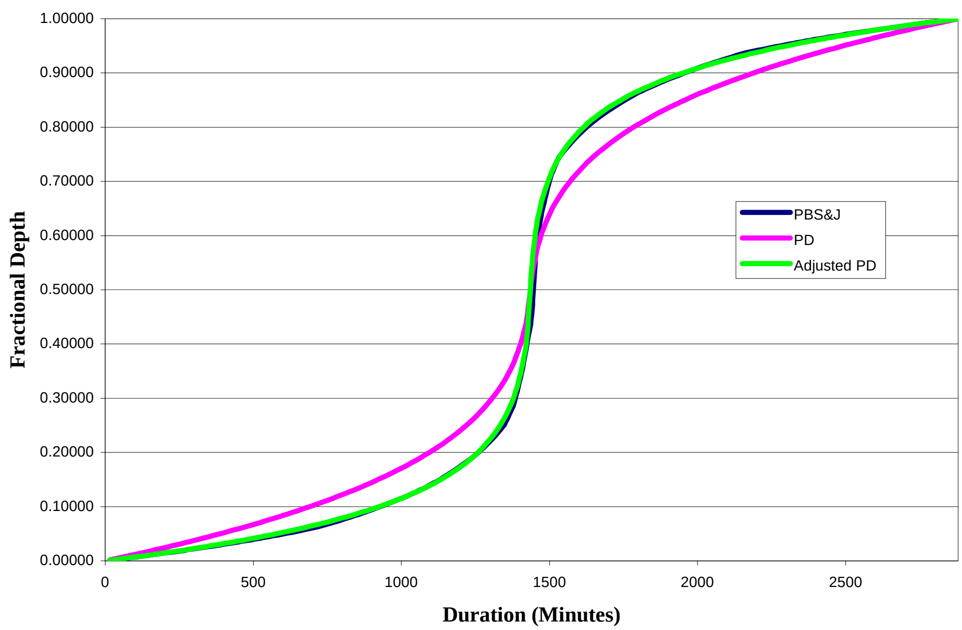


Figure 4 – Pape-Dawson Curves vs. PBS&J Curve.

A new 24-hr, 15-minute unit hyetograph was then produced with the adjusted equation and imported into DSS using the new Excel DSS Add-in from the HEC. Once the unit hyetograph was in DSS, the areal reduction factors for ellipses (Table 7 of PBS&J-2005) were applied to get a design hyetograph for each storm and reduction threshold value. The ellipsoid areal reduction factors were interpolated by applying a smooth graph line in Excel and reading them from the graph. This proved to be more accurate than linear interpolation as Figure 5 shows. The new hyetographs were entered into HMS as gauges, the user-defined

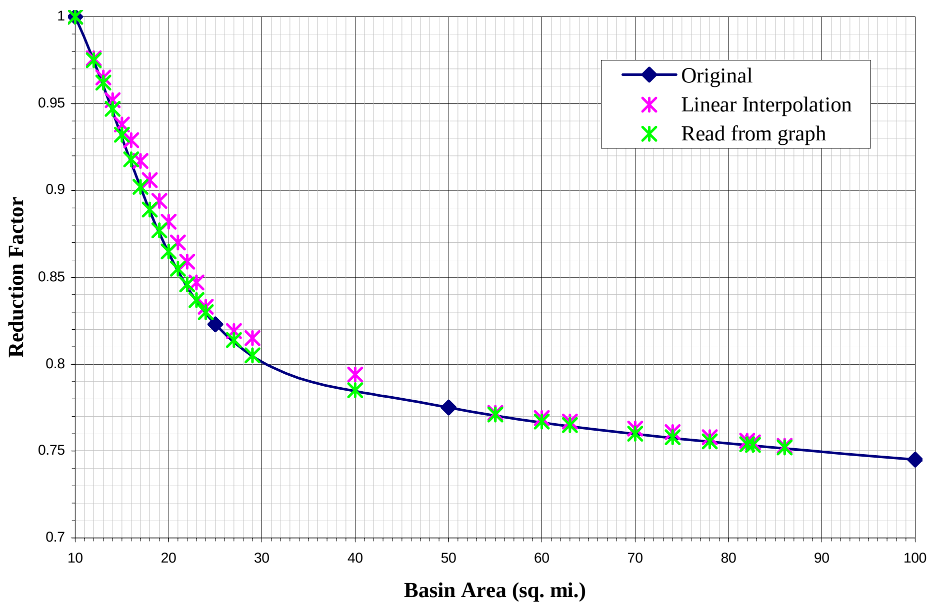


Figure 5 - ARF Interpolation

hyetograph meteorological model was applied, the model was run, and the output was entered into the reduction spreadsheet to obtain reduced flows. Table 2 compares the results between the current study model and the IDF-based model for the Martinez B drainage basin. The flow reductions were fairly severe across the board. The flows from basins of

Watershed	Model Point	Drainage Area	Current 1% chance	15-min PD 1% chance	% Diff.
E. Fk E. Br. Salitrillo	30109	0.93 mi^2	1,909 cfs	1,482 cfs	-29 %
E. Br. Salitrillo	30110	1.3 mi^2	2,830 cfs	2,171 cfs	-30 %
E. Salitrillo	30101	1.0 mi^2	3,125 cfs	2,149 cfs	-45 %
	C30103	1.6 mi^2	4,968 cfs	3,441 cfs	-44 %
	C30104	1.7 mi^2	5,062 cfs	3,509 cfs	-44 %
	C30108	5.5 mi^2	7,639 cfs	6,033 cfs	-27 %
	C30113	12.9 mi^2	14,107 cfs	8,588 cfs	-64 %
Martinez Cr. B	C30162	9.5 mi^2	4,775 cfs	3,745 cfs	-28 %
	C30170	14.0 mi^2	10,546 cfs	7,567 cfs	-39 %
W. Salitrillo	C30116	2.2 mi^2	5,120 cfs	3,857 cfs	-33 %
	C30118	3.8 mi^2	2,327 cfs	1,842 cfs	-26 %

Table 2 – Comparison Of HMS Model Output For Alternative 1.

10 mi^2 or less should have matched, or been very close to, the current study model since the ellipsoid areal reduction factor is 1.0 for 10 mi^2 or less. An examination of the model output revealed that HMS equally distributed the 15-min peak rainfall total of 1.41 inches over three 6-min intervals. This functionally decreased the rainfall depth, causing a respective decrease in runoff. To get a more valid comparison, a 6-minute unit hyetograph was developed from the same IDF equation to match the model computation interval, but DSS would not accept a 6-minute dataset from any source outside of HMS. It was necessary to change the recommended computation interval from 6 minutes to 5 minutes to get the new hyetographs into DSS. After the necessary changes were made, a new model run was performed. The comparisons from that run are shown in Table 3. The decreased time interval clearly made a

Watershed	Model Point	Drainage Area	Current 1% chance	5-min PD 1% chance	% Diff.
E. Fk E. Br. Salitrillo	30109	0.93 mi^2	1,909 cfs	1,645 cfs	-16%
E. Br. Salitrillo	30110	1.3 mi^2	2,830 cfs	2,428 cfs	-17%
E. Salitrillo	30101	1.0 mi^2	3,125 cfs	2,535 cfs	-23 %
	C30103	1.6 mi^2	4,968 cfs	4,021 cfs	-24 %
	C30104	1.7 mi^2	5,062 cfs	4,116 cfs	-23 %
	C30108	5.5 mi^2	7,639 cfs	6,652 cfs	-15 %
	C30113	12.9 mi^2	14,107 cfs	12,437 cfs	-13 %
Martinez Cr. B	C30162	9.5 mi^2	4,775 cfs	4,150 cfs	-15 %
	C30170	14.0 mi^2	10,546 cfs	9,093 cfs	-16 %
W. Salitrillo	C30116	2.2 mi^2	5,120 cfs	4,354 cfs	-18 %
	C30118	3.8 mi^2	2,327 cfs	2,025 cfs	-15 %

Table 3 – Comparison Of HMS Model Output Using A 5-Minute Hyetograph.

significant improvement, but the results were still not within an acceptable range of the current study model because the maximum 1% annual chance, 5-minute precipitation depth was only 0.75 inches. The new rainfall data provided by PBS&J set the 1% chance, 5-min rainfall total at 1.13 inches.

Alternative 2: Areal Reduction Using HMS Hyetographs

The second alternative was a slight modification to the first. Instead of creating new hyetographs from IDF curves, the hyetographs were extracted from HMS frequency-storm runs with the storm size set at 0.01 square miles. This was done to ensure that the unreduced peak rainfall totals matched the HMS frequency-storm peak totals for each storm. That way, the flow from the smaller drainage basins would match the current study model and the larger basins would see a reduction. The hyetographs were put into Excel, normalized and

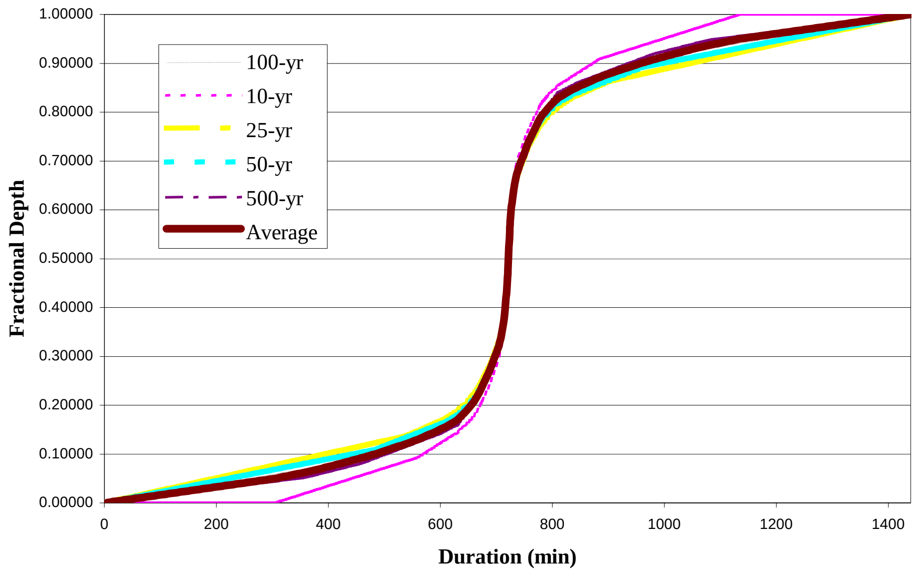


Figure 6 - Unit Frequency Storm Hyetographs From HMS.

plotted (Figure 6). An average unit hyetograph was calculated, the new 1% annual chance, 24-hr rainfall totals were distributed over it, and the peak 5-minute values were compared. The results are listed in Table 4. The differences were significant enough to justify dropping

Frequency	HMS	Unit Hyetograph	% Difference
10%	0.78 in	0.71 in	-9.9
4%	0.93 in	0.89 in	-4.5
2%	1.04 in	1.07 in	2.8
1%	1.13 in	1.19 in	5.0
0.2%	1.52 in	1.63 in	6.8

Table 4 - Peak Rainfall Total Comparison.

the unit hyetograph approach and applying the ellipsoid areal reduction factors to the individual HMS frequency storm hyetographs. The extracted hyetographs were written to

DSS from Excel as the 10-mile hyetographs for each frequency. The reduction factors for each threshold value were applied to the 10-mile hyetograph and entered into DSS. The HMS model was modified to accept the new hyetographs and was run. Table 5 compares the

Watershed	Model Point	Drainage Area	Current 1% chance	HMS 1% chance	% Diff.
E. Fk E. Br. Salitrillo	30109	0.93 mi^2	1,909 cfs	1,925 cfs	1%
E. Br. Salitrillo	30110	1.3 mi^2	2,830 cfs	2,856 cfs	1%
E. Salitrillo	30101	1.0 mi^2	3,125 cfs	3,175 cfs	2%
	C30103	1.6 mi^2	4,968 cfs	5,048 cfs	2%
	C30104	1.7 mi^2	5,062 cfs	5,154 cfs	2%
	C30108	5.5 mi^2	7,639 cfs	7,714 cfs	1%
	C30113	12.9 mi^2	14,107 cfs	14,377 cfs	2%
Martinez Cr. B	C30162	9.5 mi^2	4,775 cfs	4,832 cfs	1%
	C30170	14.0 mi^2	10,546 cfs	10,622 cfs	1%
W. Salitrillo	C30116	2.2 mi^2	5,120 cfs	5,202 cfs	2%
	C30118	3.8 mi^2	2,327 cfs	2,345 cfs	1%

Table 5 – Comparison Of HMS Model Output For Alternative 2.

Alternative 2 output with the current study model. The 10 mi^2 flows were within 1-2% of the frequency-storm model 10 mi^2 flows and the flows for drainage areas greater than 10 mi^2 were reduced to reasonable values, compared to previous model runs. Figure 7 shows a comparison of all model points between the two models. The ellipsoid areal reduction factors applied to the HMS frequency storm hyetographs produced the desired results. The flows out

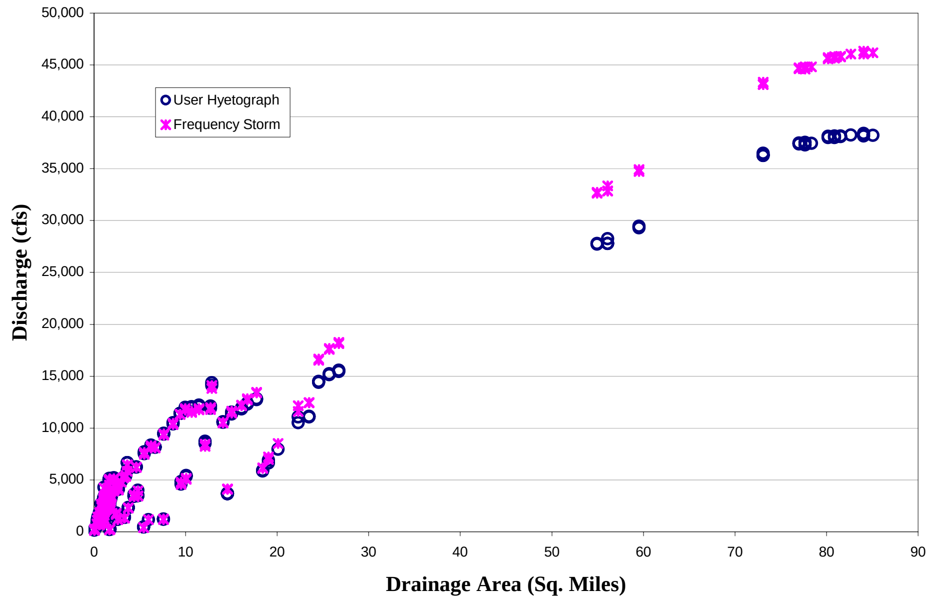


Figure 7 - Comparison Of Current Model With Alternative 2 Model.

of drainage basins 10 mi^2 or less were not reduced and received the full point rainfall. The flows out of drainage basins larger than 10 mi^2 were reduced in proportion to their size. The maximum flow reduction was 21%, which reasonably agrees with the 22% reduction observed with the LMMP model test. The Alternative 2 method is proposed for use to perform areal reduction that is consistent with the new rainfall data that has been adopted.

Conclusions

The approach described in this report provides a workable solution to incorporating the USGS adjusted rainfall rates into the RWMS while maintaining consistency with existing local standards. This approach has the advantages of allowing the conversion of legacy HEC-1 models to HMS and standardizing the hydrologic methods across the entire study area.

San Antonio River Authority
White Paper – Modify Hydrology Models
Rev. 2

July 12, 2007

Process to Obtain Peak Discharge Data and Update or Modify Hydrology Models

The purpose of this document is to outline the process of obtaining peak discharge data and modifying/updating the Digital Flood Insurance Rate Map (DFIRM) hydrology models. Over the period in time in which the hydrology models were developed for the San Antonio River Basin (SARB), several different HEC-HMS versions were used (2.2.2, 3.0 and 3.1.0). This outline is based on HEC-HMS version 3.1.0 since it is the most current version and is compatible with the previous versions.

Items that are necessary to obtain peak discharges and update/modify the DFRIM hydrology models include:

- Complete HEC-HMS model of the watershed of interest saved on local hard drive
- Copy of the "Calculation of Interpolated Areal-Reduced Flows from Index Areas" Excel spreadsheet
- Copy of the San Antonio River Basin Regional Modeling Standards for Hydrology and Hydraulic Modeling
- Copy of the hydrology Technical Support Data Notebook (TSDN) that includes in watershed of interest

All of these items can be found on the Bexar Regional Watershed Management website located at www.sara-gis-tx.org/website/dfirm/.

Obtaining Peak Discharge Data

The quickest way to find peak discharges used for the DFIRM is through the watershed-specific hydrology TSDN. The TSDN includes a watershed schematic map in the appendices. The map shows the calculation node and sub-watershed structure of the HEC-HMS model. Each calculation node is identified by an alpha-numeric label. The labels are typically coded in a way that clearly identifies which sub-watershed(s) are associated with the nodes. Peak discharges for the different frequency storm events for each node can be found in the aerial reduction spreadsheet once the node(s) of interest are identified using the schematic map. Discharges can be obtained from the spreadsheet without having to rerun the model under most circumstances.

If the HEC-HMS model must be rerun to obtain peak discharge data, the following paragraphs describe the process to obtain the correct flows. It must be noted that the flow results of any single model run cannot be used because of the areal reduction method employed for the DFIRM project. The flows must be taken from the "Calculation of Interpolated, Areal-Reduced Flows from Index Areas" Excel spreadsheet. Therefore, one must save a copy of the model and the areal reduction spreadsheet for the model being used on the local hard drive; furthermore, the "Read Only" property of the spreadsheet and model files must be cleared before proceeding. The spreadsheet can be found on the CD-ROM/DVD located in the appendix of the TSDN. Furthermore, to avoid any path issues, the models should be saved in C:\hmsproj*model name*\. Some models use gridded precipitation files and any changes in the path will require the user to manually re-establish all of the paths for the DSS and grid cell parameter files.

Once the "Read Only" property has been cleared, open the model in HEC-HMS. If a warning or error message pops up that says data was not found or data was not able to be opened as indicated, the file paths of the support files that make up a HEC-HMS model will require editing or the support files will need to be placed in the same file structure. The paths can be changed by opening the individual model files using a text editor such as Notepad or WordPad.

A HEC-HMS model contains three components. They are the basin model, the meteorological model, and the control specification. After the HEC-HMS project is open, a basin model can be viewed by selecting the basin name under the "Basin Models" directory. Normally there are several basin models that represent different scenarios such as existing conditions, future conditions, proposed conditions, and possibly calibration; however, the model scenarios could have been developed as separate projects just as well. Figure 2 shows the HEC-HMS project menu screen for Leon Creek as an example.

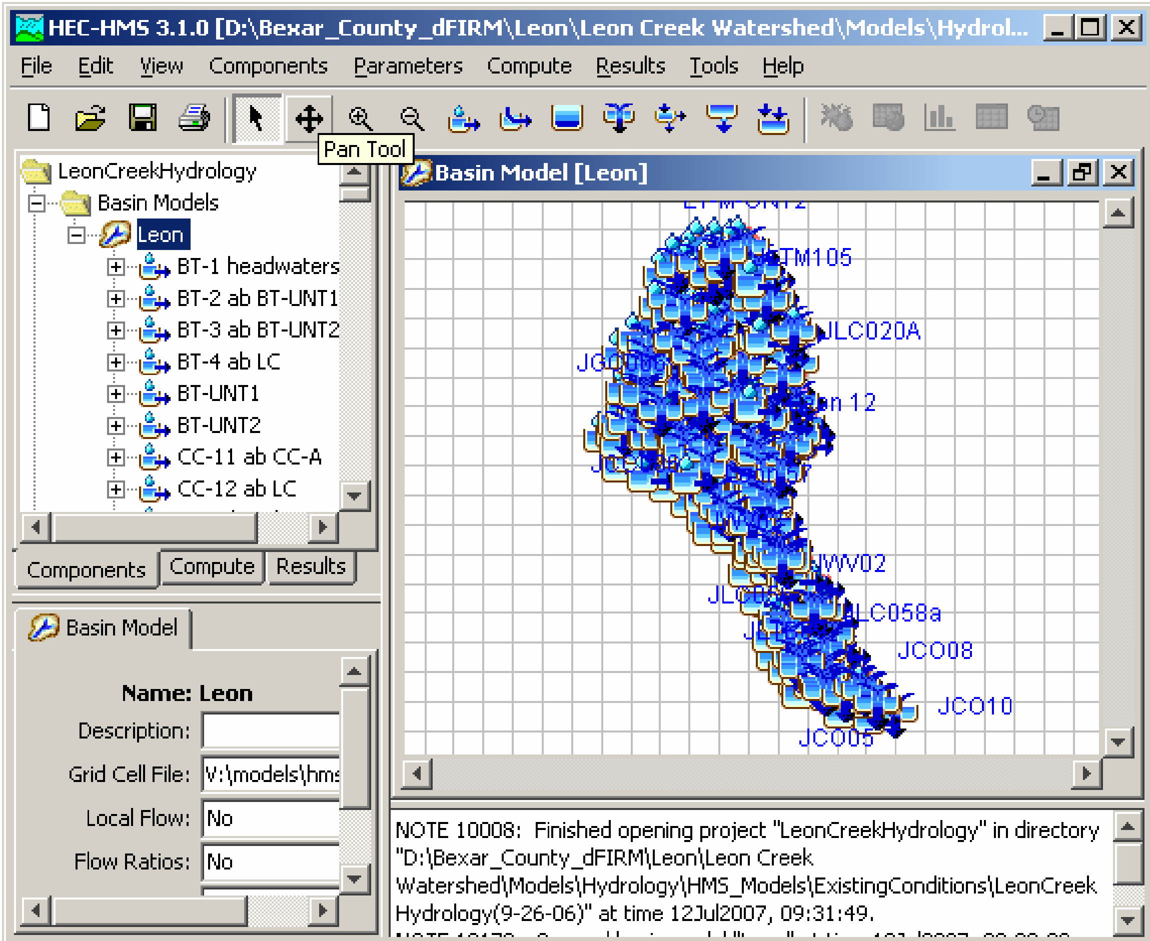


Figure 2

Selecting the basin name will bring up the model schematic, which is comprised of junction nodes, routing reaches and sub-watersheds. The parameters of a model element can be viewed by selecting the element ID and looking in the pane on the bottom left.

The configured model runs are located on the "Compute" tab under the "Simulation Run" folder (see Figure 3). How the desired discharges are obtained will depend on the rainfall simulation methodology employed for the watershed of interest. Point rainfall, ellipsoidal, point/ellipsoidal rainfall combination and the frequency storm are four possible rainfall simulation methodologies used in the hydrologic analysis of watersheds within Bexar, Wilson, Karnes and Goliad counties.

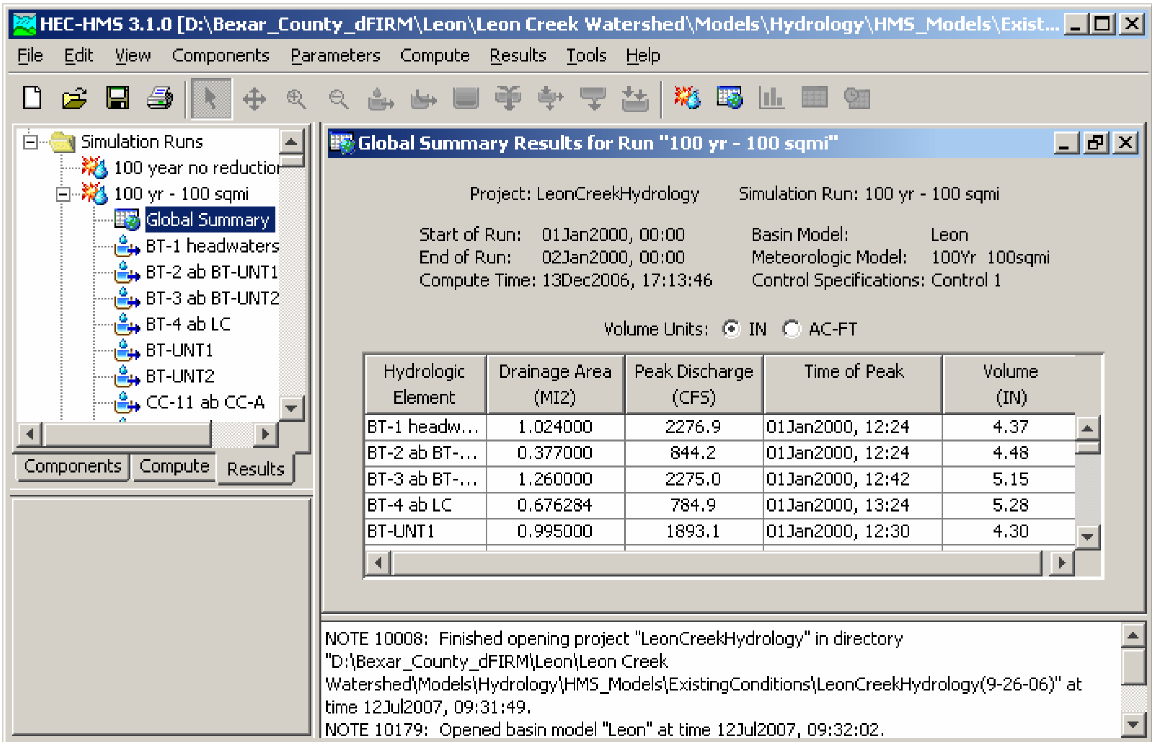
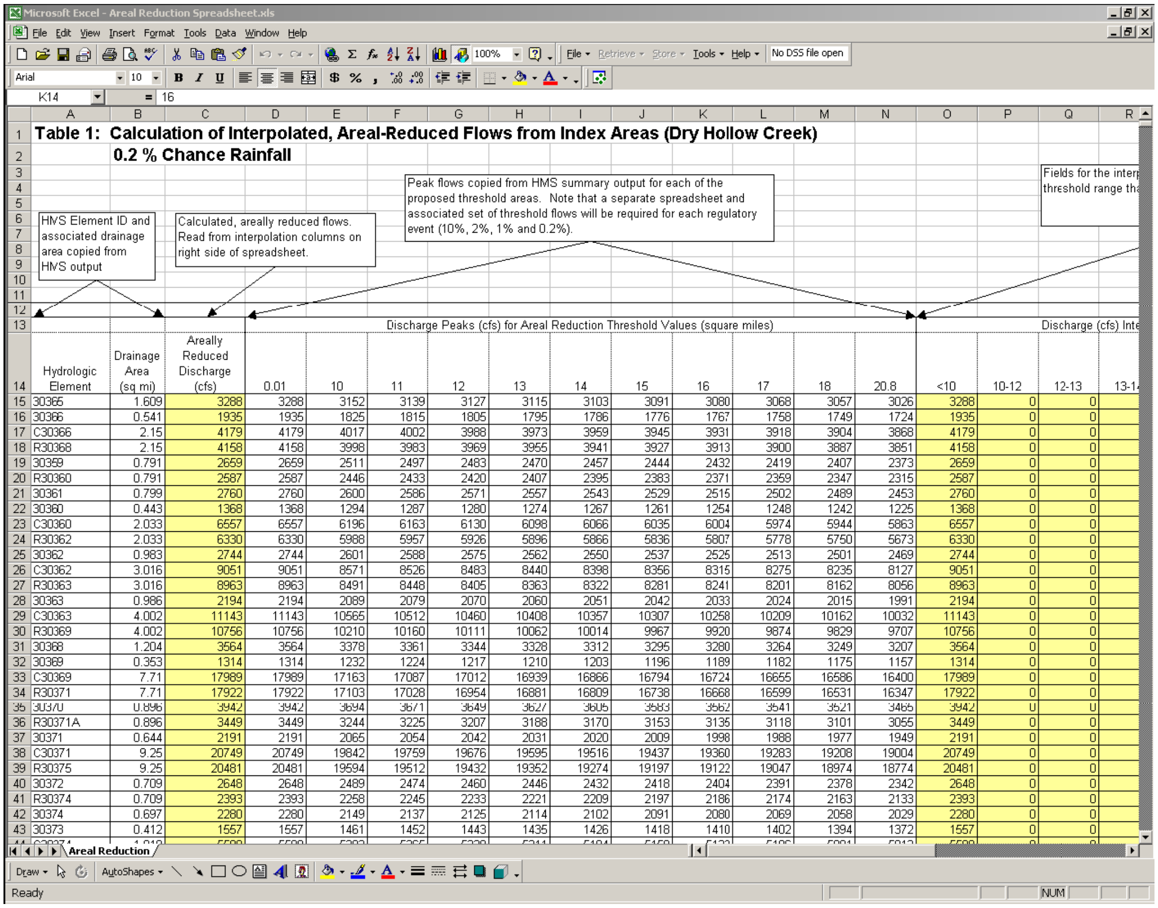


Figure 3

If the point rainfall methodology was used, several simulation runs for each storm frequency will need to be performed. The different model runs are necessary to convert the point rainfall into area-averaged rainfall (including areal reduction) for sub-watersheds larger than 10 square miles. All simulations need to be run for all locations within the chosen watershed. To perform a model run, simply highlight the appropriate run, right click, and select "Compute." For the Leon Creek example, the user would have to perform seven model runs to obtain the 100-year peak discharge data for any given calculation node.

After computing all simulations, select the "Results" tab and chose one of the simulations for the desired storm frequency. Select the "Global Summary" and copy the "Discharge Peak," "Hydrologic Element" and "Basin Area" columns individually (see Figure 3) and paste them in the appropriate columns in the areal reduction spreadsheet (Figure 4). Each model run applies a different areal reduction factor for index storm sizes selected by the original modelers. Therefore, the discharge values must be inserted into the column that corresponds to the model run's storm size, i.e. 100 sq mi.



			Discharge Peaks (cfs) for Areal Reduction Threshold Values (square miles)											Discharge (cfs) Inte		
Hydrologic Element	Drainage Area (sq mi)	Areally Reduced Discharge (cfs)	0.01	10	11	12	13	14	15	16	17	18	20.8	<10	10-12	12-13
30365	1.609	3288	3288	3152	3139	3127	3115	3103	3091	3080	3068	3057	3026	3288	0	0
30366	0.541	1935	1935	1825	1815	1805	1795	1786	1776	1767	1758	1749	1724	1935	0	0
C30366	2.15	4179	4179	4017	4002	3988	3973	3959	3945	3931	3918	3904	3868	4179	0	0
R30368	2.15	4158	4158	3998	3983	3969	3955	3941	3927	3913	3900	3887	3851	4158	0	0
30359	0.791	2659	2659	2511	2497	2483	2470	2457	2444	2432	2419	2407	2373	2659	0	0
R30360	0.791	2587	2587	2446	2433	2420	2407	2395	2383	2371	2359	2347	2315	2587	0	0
30361	0.799	2760	2760	2600	2586	2571	2557	2543	2529	2515	2502	2489	2453	2760	0	0
30360	0.443	1368	1368	1294	1287	1280	1274	1267	1261	1254	1248	1242	1225	1368	0	0
C30360	2.033	6557	6557	6196	6163	6130	6098	6066	6035	6004	5974	5944	5863	6557	0	0
R30362	2.033	6330	6330	5988	5957	5926	5896	5866	5836	5807	5778	5750	5673	6330	0	0
30362	0.983	2744	2744	2601	2588	2575	2562	2550	2537	2525	2513	2501	2469	2744	0	0
C30362	3.016	9051	9051	8571	8526	8483	8440	8398	8356	8315	8275	8235	8127	9051	0	0
R30363	3.016	8963	8963	8491	8448	8405	8363	8322	8281	8241	8201	8162	8056	8963	0	0
30363	0.986	2194	2194	2089	2079	2070	2060	2051	2042	2033	2024	2015	1991	2194	0	0
C30363	4.002	11143	11143	10565	10512	10460	10408	10357	10307	10258	10209	10162	10032	11143	0	0
R30369	4.002	10756	10756	10210	10160	10111	10062	10014	9967	9920	9874	9829	9707	10756	0	0
30368	1.204	3564	3564	3378	3361	3344	3328	3312	3295	3280	3264	3249	3207	3564	0	0
30369	0.353	1314	1314	1232	1224	1217	1210	1203	1196	1189	1182	1175	1157	1314	0	0
C30369	7.71	17989	17989	17163	17087	17012	16939	16866	16794	16724	16655	16586	16400	17989	0	0
R30371	7.71	17922	17922	17103	17028	16954	16881	16809	16738	16668	16599	16531	16347	17922	0	0
30370	0.896	3942	3942	3694	3671	3649	3627	3605	3583	3562	3541	3521	3465	3942	0	0
R30371A	0.896	3449	3449	3244	3225	3207	3188	3170	3153	3135	3118	3101	3055	3449	0	0
30371	0.644	2191	2191	2065	2054	2042	2031	2020	2009	1998	1988	1977	1949	2191	0	0
C30371	9.25	20749	20749	19842	19759	19676	19595	19516	19437	19360	19283	19208	19004	20749	0	0
R30375	9.25	20481	20481	19594	19512	19432	19352	19274	19197	19122	19047	18974	18774	20481	0	0
30372	0.709	2648	2648	2489	2474	2460	2446	2432	2418	2404	2391	2378	2342	2648	0	0
R30374	0.709	2393	2393	2258	2245	2233	2221	2209	2197	2186	2174	2163	2133	2393	0	0
30374	0.697	2280	2280	2149	2137	2125	2114	2102	2091	2080	2069	2058	2029	2280	0	0
30373	0.412	1557	1557	1461	1452	1443	1435	1426	1418	1410	1402	1394	1372	1557	0	0

Figure 4

This process must be repeated for all simulations for a given frequency in order to obtain the peak discharges for the entire watershed. Note that only the peak discharge information will need to be copied from the HEC-HMS model to the areal reduction spreadsheet for the remaining simulations. After this process is complete, the peak discharge for a given node can be found under the column titled "Areally Reduced Discharge" within the excel spreadsheet.

If the ellipsoidal methodology is used, several simulations for a given storm frequency may exist due to the optimal storm positioning that is necessary to produce peak discharge results along a creek or river system. In order to determine which simulations produces peak discharges at the different nodal locations, it is necessary to refer to documentation within the model or the hydrology TSDN. Once this is determined, the peak discharge information can be accessed directly by selecting the 'Global Summary' for the appropriate simulation under the 'Results' tab (after running the simulation). Note that this peak discharge information is only applicable for the specific node in which the simulation is intended. Since the area reduction has been included in the simulation itself, there is no need to interpolate the results as is necessary with the point rainfall methodology.

The point /ellipsoidal rainfall methodology is only utilized to obtain peak discharge rates for the Lower San Antonio River. The storm simulation titled '"Wilson County centered over Wilson, Karnes and Goliad counties" was the storm simulation chosen to produce appropriate peak discharge results. As with the ellipsoidal rainfall methodology, peak discharge results can be accessed directly from the model without interpolation after running the simulation. Also, this single storm simulation provides correct peak discharge information at all nodal locations along the Lower San Antonio River (unlike the ellipsoidal rainfall methodology).

The frequency storm methodology is only utilized to obtain peak discharge rates for the Upper Cibolo Creek. All area reductions are performed automatically during the HEC-HMS model simulation. Peak discharge information for all nodal locations along the creek can be accessed directly through a single storm simulation within the model.

The hydrology TSDN details which storm simulation methodology is used for a particular watershed and contains additional information on each methodology.

Modifying/ Updating the DFIRM Model

After a hydrology model has been developed, it must be maintained to reflect the continual changes of a development within the watershed. An important tool for the development and modification of the DFIRM hydrology models is ArcGIS (Figure 5). Much of the parameter input used in hydrology modeling can be spatially related and calculated in ArcGIS. Once parameter changes have been determined using the many tools available in ArcGIS, they can be easily updated in the hydrology model.

Included in the appendix of the hydrology TSDN is a CD-ROM/DVD containing shapefiles that contain HEC-HMS parameter data for each watershed. This spatial parameter data includes curve number, impervious cover and sub-basin area. These shapefiles can be modified to reflect watershed changes. After modifications are complete, HEC-HMS parameter inputs can be recalculated. Other HEC-HMS parameter input not formatted for ArcGIS must be calculated by other means.

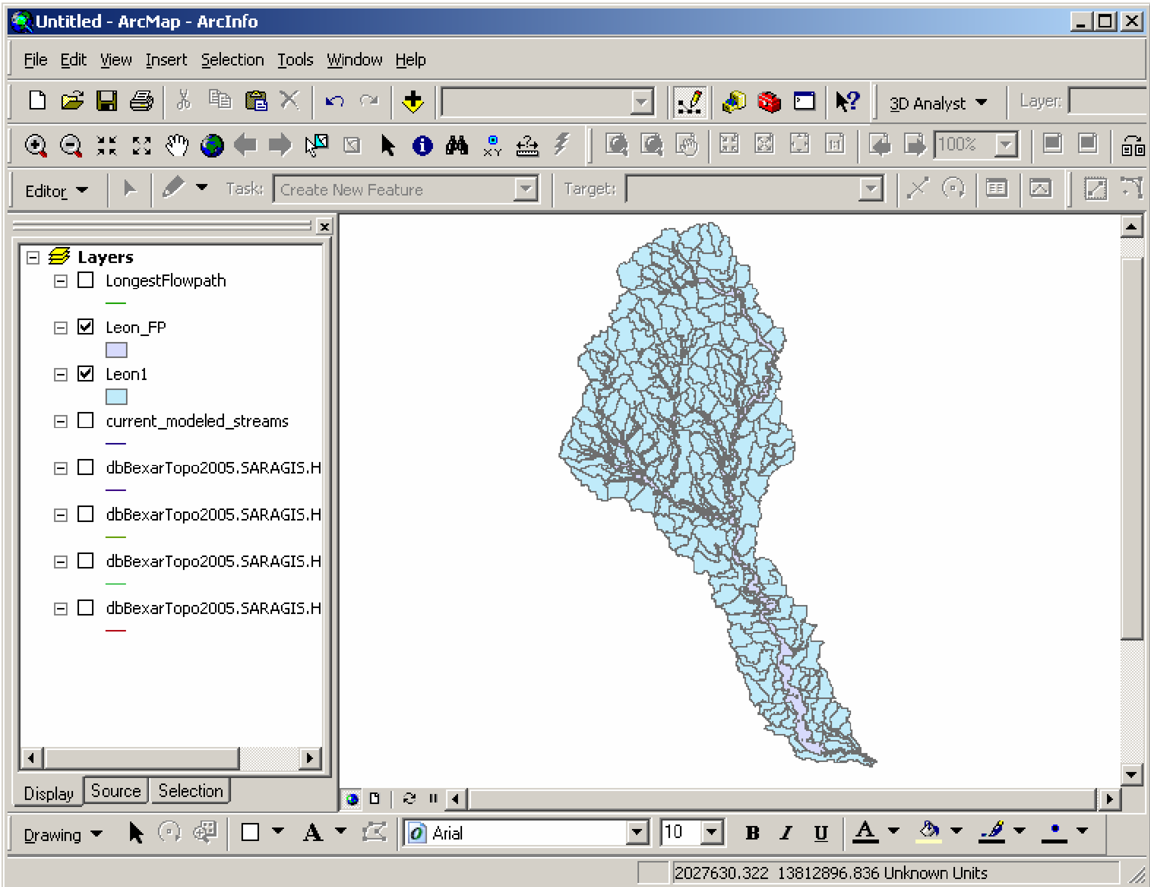


Figure 5

Parameter input can be updated within the HEC-HMS model by selecting the "Parameters" menu and choosing the appropriate category. In order to obtain the discharge results due to a parameter change, one will need to run all simulations for each storm frequency as outlined in the previous section.

This document generally describes the process of obtaining peak discharge data and modifying/updating the DFIRM hydrology models. Additional information pertaining to the methodology and parameters used to model the watersheds within Bexar, Wilson, Karnes and Goliad counties can be found in the watershed specific hydrology TSDN. Supplemental information relating to the use of HEC-HMS hydrologic modeling software can be found in the HEC-HMS User Manual and Technical Reference Manual.

APPENDIX E: GEOSPATIAL DATA GUIDELINES

E.1. COORDINATE SYSTEM AND DATUM

The standard coordinate system will be Texas State Plane, South Central Zone (in grid format). The standard horizontal datum will be North American Datum of 1983 (NAD83), and the standard vertical datum will be the North American Vertical Datum of 1988 (NAVD88). The standard unit will be feet.

- Projected Coordinate System: NAD_1983_StatePlane_Texas_South_Central_FIPS_4204_Feet
- Projection: Lambert_Conformal_Conic
- False_Easting: 1968500.00000000
- False_Northing: 13123333.33333333
- Central_Meridian: -99.00000000
- Standard_Parallel_1: 28.38333333
- Standard_Parallel_2: 30.28333333
- Latitude_Of_Origin: 27.83333333
- Linear Unit: Foot_US

- Geographic Coordinate System: GCS_North_American_1983
- Datum: D_North_American_1983
- Prime Meridian: Greenwich
- Angular Unit: Degree

E.2. SOFTWARE

Geospatial data submittals should be compatible with the ESRI software suite. Most CADD software is able to export layers into a suitable shapefile format. A variety of free software is available to facilitate the population of the data fields required in Section A.4. Examples include but are not limited to:

- Quantum GIS (http://www.qgis.org)
- Geographic Resources Analysis Support System (http://grass.osgeo.org/)
- System for Automated Geoscientific Analyses (http://www.saga-gis.org/).

Please note the availability of these resources may change without notice.

E.3. METADATA STANDARDS

In order to provide the greatest compatibility with standards already in use, facilitate data sharing efforts and take advantage of tried and true metadata specifications, it is recommended the use of the Federal Geographic Data Committee (FGDC) Content Standard for Digital Geospatial Metadata (FGDC-STD-001-1998) as its metadata standard.

The FGDC Metadata standard specifies data elements and groups of data elements to provide documentation for spatial data. It also specifies the order in which those elements appear in the metadata file as well as which elements are required (referred to as "core" elements) and which are considered optional.

For the purposes of this project, the FGDC required elements will be considered the minimum metadata requirements but it is strongly recommended that any available optional elements be included whenever possible. The FGDC required items are:

1. Description
2. Keywords
3. Citation
4. Extent
5. Time period of content
6. Status
7. Access and use constraints
8. Metadata contact
9. Horizontal accuracy statements.
10. Vertical accuracy statements.

The FGDC data elements and detailed specification can be found at:
http://www.fgdc.gov/metadata/documents/workbook_0501_bmk.pdf

E.4. TOPOLOGY

Care should be taken in the development of line and polygon geospatial data types to ensure feature edges and vertices snap to those of adjoining features. Common topology errors to avoid are provided in Table 1. When polygon shapefiles are prepared using CADD software, closed polylines should be used.

Table 1 - Common Polygon Topology Errors

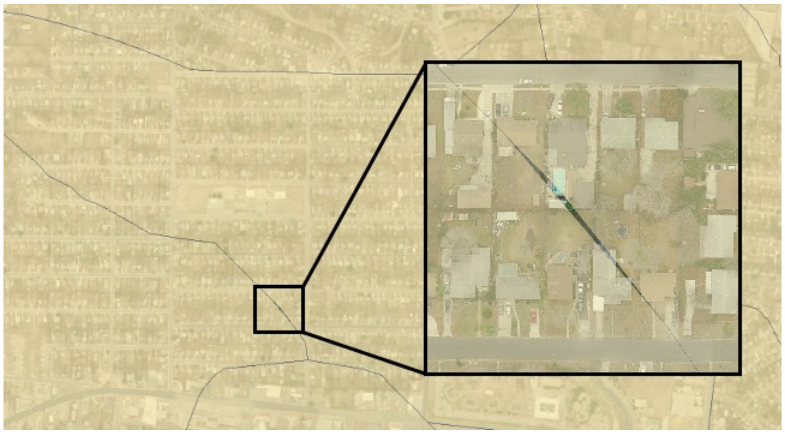
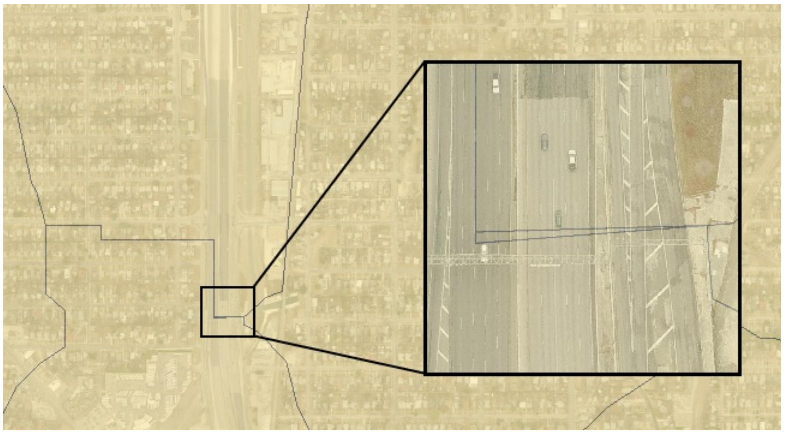
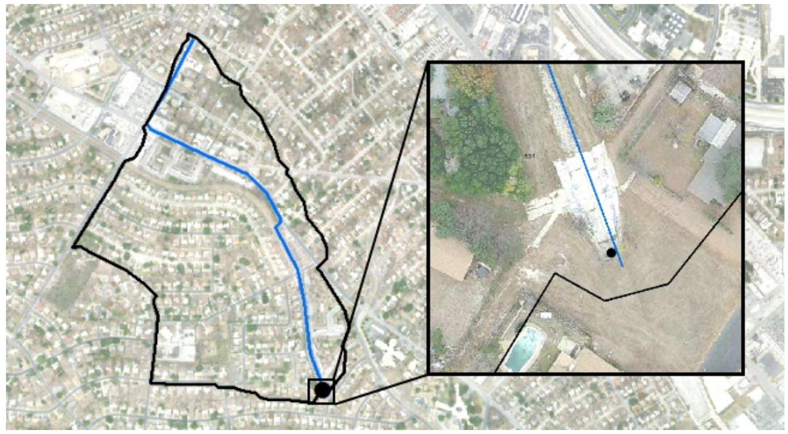
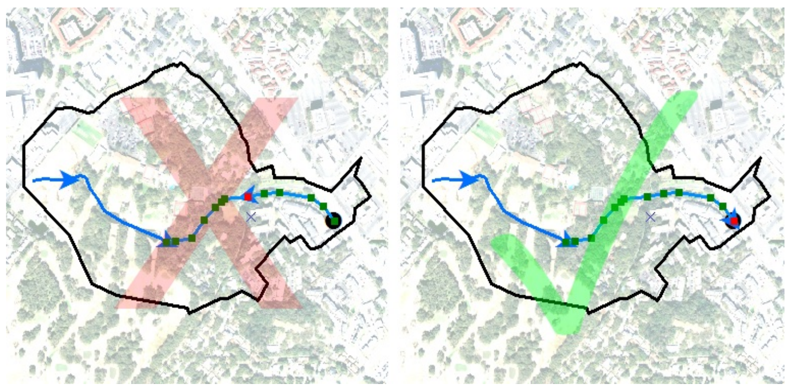
Overlap: one or more sides of a polygon extend over the boundary of an adjacent polygon.	
Gap: the sides of adjacent polygons do not touch.	
Sliver: a small polygon	

Table 2 - Common Polyline Topology Errors

Dangling Node: a node on a line or polygon feature that is supposed to intersect a point or a node on another feature but doesn't.	
Line Double-Back: a line segment drawn over itself	

E.5. SHAPEFILE CONTENT REQUIREMENTS

The tables in the next few pages present the feature attributes required for each of the shapefiles listed in the Geospatial Documentation Guidelines for Hydrology (Section 3.10.2), Hydraulics (Section 4.8.2), and Mapping (Section 6.3) which included:

- Base Flood Elevations (CLOMR/LOMR submittal)
- CLOMR/LOMR Boundaries (CLOMR/LOMR submittal)
- Cross Sections (Regional hydraulic model update)
- Floodplains (Polygon) (CLOMR/LOMR submittal)
- Floodplains (Line) (CLOMR/LOMR submittal)
- Junctions (Regional hydrology model update)
- Land Use (Regional hydrology model update)
- Reaches (Regional hydrology model update)
- Stream Centerlines (Regional hydraulic model update)
- Structures (Regional hydraulic model update)
- Sub-basins (Regional hydrology model update)

These files are only requested if the information is being modified as a result of the study. The data submitted does not need to extend beyond the study area.

The floodplain line features should match their corresponding floodplain polygon feature outlines. An example is provided in Figure 1. The floodplain polygon should have features covering the area inside the CLOMR/LOMR boundary, including Zone X for areas outside other floodplain zones.

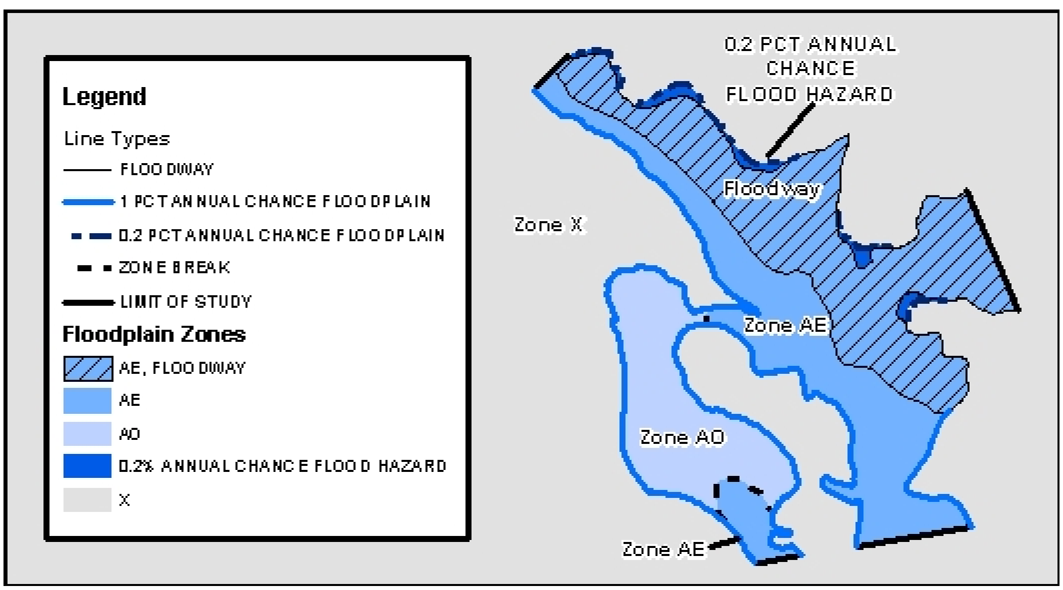


Figure 1 - Floodplain Zones and Line Types

Base Flood Elevations
Feature Name: S_BFE
Geometry Type: Polyline

Field Name	Type	Length/ Precision	Scale	Field Description	Values
OBJECTID	Double	11		An automatically generated unique identifier.	
BFE_LN_ID	Text	25		Unique feature identifier.	(Leave field empty)
ELEV	Double	Default	2	Base Flood Elevation. The rounded, whole elevation of the 1-percent-annual-chance flood.	
LEN_UNIT	Text	11		Measurement system used for the BFEs.	CENTIMETERS, FEET, INCHES, KILOMETERS, METERS, MILES, MILES
V_DATUM	Text	17		Vertical datum. The vertical datum indicates the reference surface from which the flood elevations are measured.	MSL, NAVD88, NGVD29, LOCAL TIDAL DATUM, MLLW, MLW
SOURCE_CIT	Text	11		(Leave field empty.)	(Leave field empty.)

CLOMR/LOMR Boundary

Feature Name: S_LOMR
Geometry Type: Polyline

Field Name	Type	Length/ Precision	Scale	Field Description	Values
OBJECTID	Double	11		An automatically generated unique identifier.	
DFIRM_ID	Text	15		Study Identifier. For a single-jurisdiction flood risk project, the value is composed of the two-digit State FIPS code and the four-digit FEMA CID code (e.g., 480001). For a countywide flood risk project, the value is composed of the two-digit State FIPS code, the three-digit county FIPS code, and the letter "C" (e.g., 48107C). Within each FIRM Database, the DFIRM_ID value will be identical.	(Same value as effective DFIRM.)
EFF_DATE	Date	Default	0	Effective Date. Effective date of the LOMR.	(Leave field empty.)
CASE_NO	Text	13		Case Number. This is the case number of the LOMR that is assigned by FEMA. The case number is used to track the LOMR's supporting documentation and will be generated following submittal.	(Leave field empty.)
SCALE	Text	5		Map Scale. This is the denominator of the effective LOMR scale as a ratio. For example, 24000 is the denominator for a 1″ = 2000′ map.	STANDARD 1″=500′/STANDARD 1″=1000′/STANDARD 1′=2000′
STATUS	Text	12		Status of the LOMR. This will be generated following submittal with one of the following values : SUPERSEDED, REVALIDATED, INCORPORATED, REDETERMINED, EFFECTIVE.	(Leave field empty.)
SOURCE_CIT	Text	11		(Leave field empty)	(Leave field empty.)

Cross Sections
Feature Name: S_XS
Geometry Type: Polyline

Field Name	Type	Length/ Precision	Scale	Field Description	Values
OBJECTID				An automatically generated unique identifier.	
XS_LN_ID	Text	25		Unique feature identifier.	(Leave field empty)
XS_LTR	Text	12		Cross Section Letter - The letter or number that is assigned to the cross section on the hardcopy FIRM and in the FIS report. This field is populated when the cross section is lettered in the Effective FEMA cross section.	(Same value as effective FEMA cross section or leave field empty)
START_ID	Text	25		Station Start Identification - Describes the origin for the measurements in the STREAM_STN field.	(Same value as adjacent effective FEMA cross section or leave field empty)
STREAM_STN	Double	Default		Stream Station - The measurement along the stream centerline or profile baseline to the cross section location.	
XS_LN_TYP	Text	24		Cross-Section Line Type – Based on whether the cross section has a letter assigned in the XS_LTR field (LETTERED) or not (NOT LETTERED). Lettered cross sections are shown on the hardcopy FIRM.	LETTERED, NOT LETTERED
WTR_NM	Text	100		Surface Water Feature Name. This is the formal name of the stream or water body.	(Same value as WTR_NM in Stream Centerline/S_WTR_LN)
WSEL_REG	Double	Default		Modeled Water Surface Elevation for the 1-Percent-Annual-Chance Flood Event. This the modeled water-surface elevation for the 1-percent-annual-chance flood event in the stream channel at this cross section. In the case of levee(s) associated with a cross section, it is assumed that the levee(s) holds.	(Value from hydraulic model, rounded to two decimal places)
LEN_UNIT	Text	11		Water-Surface and Streambed Elevation Units. This unit indicates the measurement system used for the water-surface and streambed elevations.	CENTIMETERS, FEET, INCHES, KILOMETERS, METERS, MILES, MILES
V_DATUM	Text	17		Vertical Datum. The vertical datum indicates the reference surface from which the flood and streambed elevations are measured.	MSL, NAVD88, NGVD29, LOCAL TIDAL DATUM, MLLW, MLW
SOURCE_CIT	Text	11		(Leave field empty)	(Leave field empty)

Floodplain

Feature Name: S_FLD_HAZ_AR

Geometry Type: Polygon

Field Name	Type	Length/ Precision	Scale	Field Description	Values
OBJECTID	Double	11		An automatically generated unique identifier.	
FLD_AR_ID	Text	25		Unique feature identifier.	(Leave field empty)
FLD_ZONE	Text	55		Flood Zone - the flood zone designation used by FEMA to designate the SFHAs and for insurance rating purposes.	A, AE, AH, AO, AR, A99, B, C, D, V, VE, X, 0.2 PCT ANNUAL CHANCE FLOOD HAZARD, 1 PCT ANNUAL CHANCE FLOOD HAZARD CONTAINED IN CHANNEL, 1 PCT FUTURE CONDITIONS
FLOODWAY	Text	8		Floodway Area - populated if the area is within a regulatory floodway.	FLOODWAY, Null
SFHA_TF	Text	1		Special Flood Hazard Area. If the area is within a SFHA this field would be true. This field will be true for any area coded as an A or V flood zone area. It should be false for any X or D flood areas.	T, F, U (True, False, Unknown)
STATIC_BFE	Double	Default	2	Static Base Flood Elevation. This field will be populated for areas that have been determined to have a constant Base Flood Elevation (BFE) over a flood zone such as a lake or coastal zone where the BFE applies to the entire polygon. The BFE value will be shown beneath the zone label.	
V_DATUM	Text	17		Vertical Datum - indicates the reference surface from which the flood elevations are measured. This field is only populated if the STATIC_BFE field is populated.	MSL, NAVD88, NGVD29, LOCAL TIDAL DATUM, MLLW, MLW
DEPTH	Double	Default	2	Depth. This is the depth for Zone AO areas. This value is shown beneath the zone label on the FIRM. This field is only populated if a depth is shown on the FIRM.	
LEN_UNIT	Text	11		Length Units - indicates the measurement system used for the BFEs and/or depths. This field is only populated if the STATIC_BFE or DEPTH field is populated.	CENTIMETERS, FEET, INCHES, KILOMETERS, METERS, MILES
VELOCITY	Double	Default	2	Velocity - the velocity measurement of the flood flow in the area. Normally this is applicable to alluvial fan areas (certain Zone AO areas). This value is shown beneath the zone label on the FIRM. This field is only populated when a velocity is associated with the flood zone area.	
VEL_UNIT	Text	17		Velocity Unit - the unit of measurement for the velocity. This field is populated when the VELOCITY field is populated.	CENTIMETERS/HOUR, FEET/SECOND, INCHES/HOUR, METERS/SECOND

SOURCE_CIT	Text	11		(Leave field empty)	(Leave field empty)

Floodplain

Feature Name: S_FLD_HAZ_LN

Geometry Type: Polyline

Field Name	Type	Length/ Precision	Scale	Field Description	Values
OBJECTID	Double	11		An automatically generated unique identifier.	
DFIRM_ID	Text	6		Study Identifier. For a single-jurisdiction flood risk project, the value is composed of the two-digit State FIPS code and the four-digit FEMA CID code (e.g., 480001). For a countywide flood risk project, the value is composed of the two-digit State FIPS code, the three-digit county FIPS code, and the letter "C" (e.g., 48107C). Within each FIRM Database, the DFIRM_ID value will be identical.	(Same value as effective DFIRM.)
FLD_LN_ID	Text	25		Unique feature identifier	(Leave field empty)
LN_TYP	Text	45		Line Type. These line types describe the flood boundary and may be used to indicate how the feature must be depicted on the hardcopy FIRM. An example is provided in Figure 1 on page 5 of this appendix.	SFHA/FLOOD ZONE BOUNDARY, LIMIT OF DETAILED STUDY/LIMIT OF STUDY, OTHER BOUNDARY
SOURCE_CIT	Text	11		(Leave field empty)	(Leave field empty)

Junctions

Feature Name: S_HydroNode
Geometry Type: Points

Field Name	Type	Length/ Precision	Scale	Field Description	Values
OBJECTID	Double	11		An automatically generated unique identifier.	
NodeID	Text	25		Unique feature identifier	(Leave field empty)
NodeName	Text	254		Hydrologic node name and description of node location	
IsPourPt	Text	1		Sub-basin pour point (outlet). This field will be true for any point that represents a sub-basin outlet. It should be false for other points, which represent confluences.	T, F, U (True, False, Unknown)
SOURCE_CIT	Text	11		(Leave field empty)	(Leave field empty)

Land Use

Feature Name: LandUse
Geometry Type: Polygon

Field Name	Type	Length/ Precision	Scale	Field Description	Values
OBJECTID	Double	11		An automatically generated unique identifier.	
SARBCODE	Text	2		Land Use Code	See Table 10 in Section 3.4.2.
AREA	Double	Default		Area of land use polygons in acres.	

Reaches

Feature Name: S_HydroLink

Geometry Type: Points

Field Name	Type	Length/ Precision	Scale	Field Description	Values
OBJECTID	Double	11		An automatically generated unique identifier.	
LinkID	Long			Unique feature identifier	(Leave field empty)
WTR_NM_LID	Long			Surface Water Feature Name. This is the name of the surface water feature represented by the hydrologic reach link.	(Same value as WTR_NM in Stream Centerline/S_WTR_LN if corresponding to a mapped stream.)
LinkName	Text	254		Secondary feature identifier or group name. Populate field or (Leave field empty).	
UpNodeID	Text	25		Upstream Node. This is the node ID at the upstream end of the reach.	
DownNodeID	Text	25		Downstream Node. This is the node ID at the downstream end of the reach.	
SOURCE_CIT	Text	11		(Leave field empty.)	(Leave field empty)

Stream Centerline

Feature Name: S_WTR_LN
Geometry Type: Polyline

Field Name	Type	Length/ Precision	Scale	Field Description	Values
OBJECTID	Double	11		An automatically generated unique identifier.	
WTR_LN_ID	Text	25		Unique feature identifier	(Leave field empty)
WATER_TYP	Text	25		Surface Water Feature Type. The type value describes the kind of watercourse represented.	AREA OF COMPLEX CHANNELS/OVERFLOWS, STREAM CENTERLINE, OPEN WATER AREA, WETLANDS, MANMADE WATER FEATURE, GLACIAL FEATURE, COASTLINE/ISLAND SHORELINE, INTERMITTENT RIVER/STREAM/WASH
CHAN_REP	Text	6		Channel Representation. Single means linear water features represented by a centerline. Double means linear water features represented by shorelines or channel banks.	SINGLE, DOUBLE
WTR_NM	Text	100		Surface Water Feature Name. This is the formal name of the surface water feature, as it will appear on the hardcopy FIRM.	
SOURCE_CIT	Text	11		(Leave field empty)	(Leave field empty)

Structures
Feature Name: S_GEN_STRUCT
Geometry Type: Points

Field Name	Type	Length/ Precision	Scale	Field Description	Values
OBJECTID	Double	11		An automatically generated unique identifier.	
STRUCT_ID	Text	25		Unique feature identifier.	(Leave field empty)
STRUCT_TYP	Text	25		Structure Type. These are hydraulic structures within the flood risk project area.	BRIDGE, CANAL, CHANNEL, CULVERT, DAM, DIKE, DROP STRUCTURE, ENERGY DISSIPATER, FLUME, GATE, LEVEE, PUMP STATION, SIDE WEIR STRUCTURE, STORM SEWER, UTILITY CROSSING, WEIR, WING WALL, FLOODWALL, PIPELINE, RETAINING WALL, SIPHON, OTHER/MISC STRUCTURE
STRUCT_NM	Text	50		Structure Name. This is the proper name of the feature and/or the related transportation feature name as shown on the FIRM and/or the flood profile. If the flood profile has the proper structure name and no related transportation name, this field stores the proper name (e.g., Hoover Dam). If the flood profile has the related transportation name and no proper name, this field stores the related transportation name (e.g., Main Street). If the flood profile has the proper name and the transportation name, this field stores both names (e.g., Hoover Dam / Main Street). If structure has no proper name and no related transportation name, this field is left blank; this field should not store the structure type (e.g., dam).	
WTR_NM	Text	100		Surface Water Feature Name. This is the formal name of the surface-water feature associated with the structure, as it will appear on the hardcopy FIRM.	(Same value as WTR_NM in Stream Centerline/S_WTR_LN)
SOURCE_CIT	Text	11		(Leave field empty.)	(Leave field empty)

Sub-basins

Feature Name: S_HydroBasin

Geometry Type: Polygon

Field Name	Type	Length/ Precision	Scale	Field Description	Values
OBJECTID	Double	11		An automatically generated unique identifier.	
BasinID	Text	25		Unique feature identifier.	(Leave field empty)
BasinName	Text	254		Name of sub-basin.	
WTR_NM_LID	Text	100		Surface Water Feature Name. This is the name of the primary flooding source drained by the sub-basin.	
NodeID	Text	25		Node Identification. The node is associated with the sub-basin.	
Shape_Area	Double	Default		Area of sub-basin in acres.	
SOURCE_CIT	Text	11		(Leave field empty.)	(Leave field empty)