Texas Water Development Board Final Report: Contract Number 1600012035

Development of a Flood Warning Tool Set for Medina River, Bandera County, Texas

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Bandera County River Authority and Groundwater District

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Acronyms

Bandera County River Authority and Groundwater District, (BCRAGD)

Texas Water Development Board, (TWDB)

Hydrologic Engineering Center-River Analysis System (HEC-RAS)

USGS Flood Inundation Mapping Program (FIMP)

Flood Inundation Maps (FIMS)

Flood Early Warning Systems (FEWS)

National Weather Service (NWS) Advanced Hydrologic Prediction Service (AHPS)

Geostationary Operational Environmental Satellite (GOES)

USGS National Water Information Center (NWIS)

USGS Data-Collection Platform (DCP)

U.S. Army Corps of Engineers (USACE)

USGS Scientific Investigations Report (SIR)

Abstract

Floods are the leading cause of natural disaster losses in the United States. Although loss of life to floods during the past half century have declined, in part because of improved warning systems, economic losses have continued to rise with increased urbanization in flood hazard areas throughout the nation (U.S. Geological Survey, 2006).

On June 1, 2016 the Bandera County River Authority and Groundwater District, (BCRAGD) applied for, and received, a funding grant from the Texas Water Development Board, (TWDB). A contract was entered into by both the BCRAGD and TWDB on December 27, 2017 to contract with the U.S. Geological Survey (USGS) for development of a flood warning tool set for the Medina River, Bandera County, Texas.

The study area encompassed a 23-mile reach of the Medina River from the confluence of Winans Creek to English Crossing Road above Medina Lake (fig. 1). The USGS developed a Hydrologic Engineering Center-River Analysis System (HEC-RAS) model, which applied data from existing streamflow-gaging stations and installed two additional 'stage only' streamflow-gaging stations along the headwaters of the North and West Prongs of the Medina River. A flood atlas, consisting of a library of flood-inundation maps for a range of streamflow conditions, was developed and will be included on the USGS Flood Inundation Mapping Program (FIMP) website. The Flood Inundation Maps (FIMS) depict estimates of the areal extent and depth of flooding corresponding to selected water levels (stages) at the USGS streamflow-gaging station 08178880 Medina River at Bandera, Texas.

Introduction

Over the past 30 years, the average statistics show annual flood losses in the United States at about $8 billion and nearly 100 fatalities per year. Bandera County is in the Texas Hill Country region, where high intensity rain rates and steep terrain frequently contribute to flash flooding (Caran and Baker, 1986). The recent 2015 Memorial Day floods within the region were a painful reminder of just how susceptible the Hill Country is to flash flooding.

While floods are impossible to prevent completely, and there is no way to completely guarantee protection of life and property, many federal, state, and local agencies have demonstrated that the loss of life, injuries, and property damage can be greatly reduced with Flood Early Warning Systems (FEWS) in place.

The USGS - FEWS of the Medina River provides near real-time hydrologic data, available on the internet and many other social media web-based outlets. A user can view data of river stage, flow, or rainfall in real-time, directly from the streamflow-gaging station using the internet and can quickly access the specific flood map corresponding to the present river stage conditions. The flood atlas consists of a set of digital flood-inundation extent polygons and water depth grid maps derived from the gage height (river stage value) providing the user with corresponding inundation estimates and digital map overlays. Pre-defined user set thresholds can be established for each available hydrologic monitored condition at the streamflow-gaging station, providing the user with email or text alerts when conditions reach or exceed a user pre-defined threshold. This allows for critical information to be provided to the user preceding significant flooding conditions.

The National Weather Service (NWS) Advanced Hydrologic Prediction Service (AHPS), using hydrologic simulation models, (including forecast prediction streamflow rates) are primarily based on USGS streamflow real-time hydrologic data throughout the United States. This includes Bandera County at USGS streamflow-gaging station 08178880 Medina River at Bandera, Texas (National Weather Service, 2018; U.S. Geological Survey, 2018a).

Problem

Because of the risk of future flash flooding in Bandera County, there is a significant need for a flood early warning tool set to enhance the communication of potential flood risk, providing emergency managers and the general public critical information necessary to better mitigate the impacts of flooding.

Objectives and Scopes

To help inform emergency managers and other water resource decision makers about flooding events, the USGS, in cooperation with BCRAGD, established a flood early warning tool set of the Medina River in Bandera County. The tool set includes a monitoring network of the USGS continuous streamflow-gaging stations and development of a HEC-RAS hydraulic simulation model (U.S. Army Corps of Engineers, 2016 a, b). Flood inundation maps were created and are made available to view in the USGS Flood Inundation Mapper (USGS FIM) website (U.S. Geological Survey, 2018b). A 3-year study area included a 23-mile reach of the Medina River from Winans Creek to English Crossing Road (fig. 1).

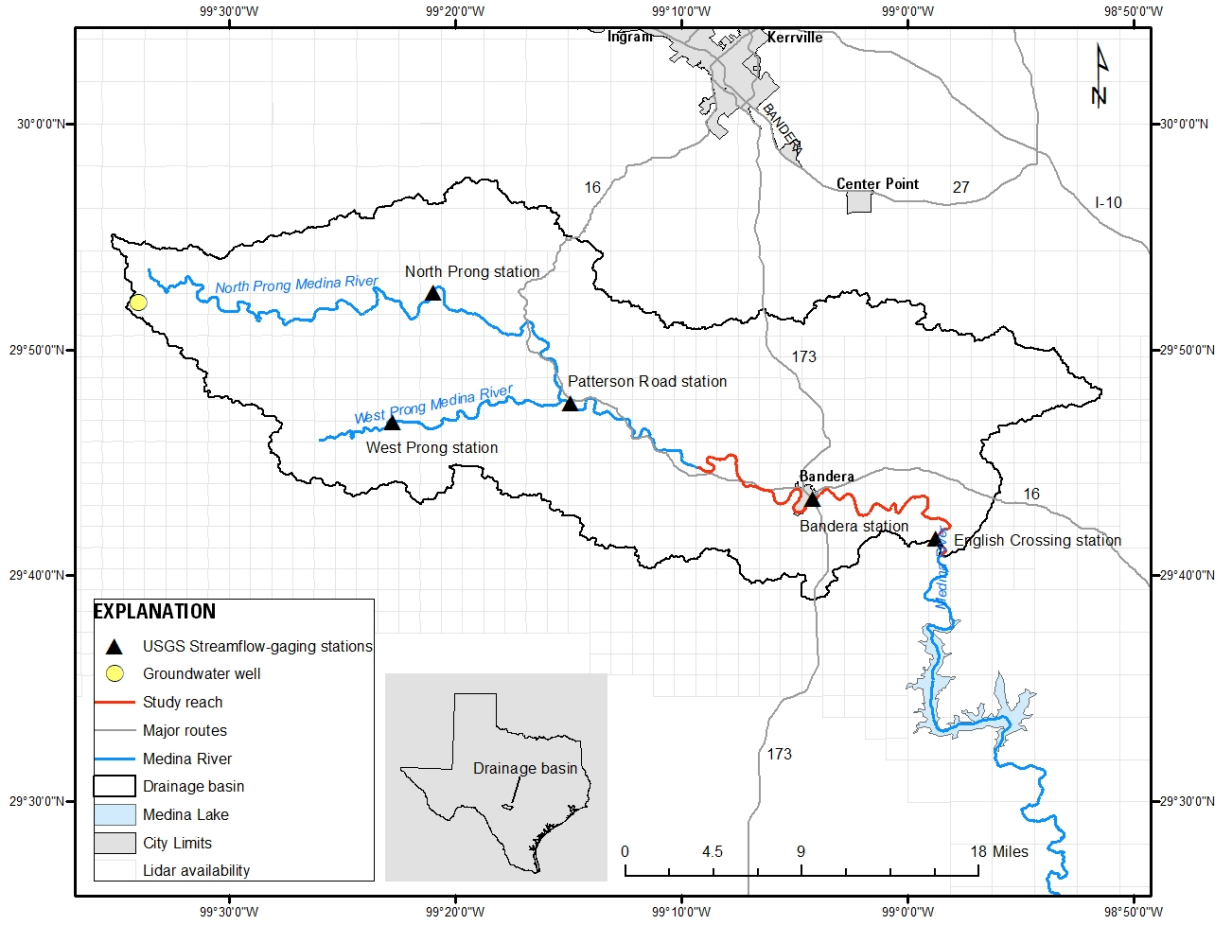

Figure 1. Study area map with the USGS streamflow-gaging stations.

Establishment of Streamflow-Gaging Network (Locations)

Prior to this study, three existing USGS streamflow-gaging stations were in operation within the study reach of the Medina River (table 1): 0817887350 Medina River at Patterson Road at Medina, Texas. (fig. 2, herein after Patterson Road station); 08178880 Medina River at Bandera, Texas. (fig. 3, herein after Bandera station); and 08178980 Medina River above English Crossing near Pipe Creek, Texas. (fig. 4, herein after English Crossing station).

USGS installed two additional stage-only streamflow-gaging stations and included precipitation collection monitors, near the headwaters of the North and West Prongs of the Medina River for flood early warning purposes: 08178861 North Prong Medina River at Brewington Creek near Medina, Texas. (fig. 5, herein after North Prong station); and 08178871 West Prong Medina River at Carpenter Creek Road near Medina, Texas. (fig. 6, herein after West Prong station). These two additional streamflow-gaging stations are located above the confluence of the existing USGS streamflow-gaging station, Patterson Road station at Medina, Texas.

Figure 2. USGS streamflow-gaging station 0817887350 Patterson Road at Medina, Texas.

Figure 3. USGS streamflow-gaging station 08178880 Medina River at Bandera, Texas.

Figure 4. USGS streamflow-gaging station 08178980 Medina River above English Crossing Road near Pipe Creek, Texas.

Figure 5. USGS streamflow-gaging station 08178861 North Prong Medina River at Brewington Creek near Medina, Texas.

Figure 6. USGS streamflow-gaging station 08178871 West Prong Medina River at Carpenter Creek Road near Medina, Texas.

Table 1. U.S. Geological Survey streamflow-gaging stations in the study area includes a 23-mile reach in the Medina River.

	Station number	Station name	Latitude and longitude	Data collected	Period of data collection	Changes made during this study period
1	08178861	North Prong Medina River at Brewington Creek near Medina, Texas.	29.87533, -99.3488	Gage height Precipitation	October 12, 2017–present January 6, 2019–present	New installation
2	08178871	West Prong Medina River at Carpenter Creek Road near Medina, Texas.	29.78014, -99.3793	Gage height Precipitation	August 3, 2017–present January 6, 2019–present	New installation
3	0817887350	Medina River at Patterson Road at Medina, Texas.	29.79389, -99.2486	Discharge Gage height Precipitation	November 2, 2011–present November 2, 2011–present January 6, 2019–present	Added precipitation
4	08178880	Medina River at Bandera, Texas.	29.72384, -99.0700	Discharge Gage height	May 28, 1987–present October 1, 2007–present	--
5	08178980	Medina River above English Crossing near Pipe Creek, Texas.	29.69439, -98.9793	Discharge Gage height Precipitation	May 10, 2017–present May 10, 2017–present January 6, 2019–present	Added precipitation

Streamflow-Gaging Operations

The streamflow-gaging stations continuously measure and record data, including discharge, gage height, and precipitation every 15 minutes. The data is then transmitted every hour by way of a Geostationary Operational Environmental Satellite (GOES) to the USGS National Water Information Center (NWIS) database, and then made available to users over the internet (U.S. Geological Survey, 2018b). The type of data recorded in each streamflow-gaging station is summarized in Table 1.

The USGS streamflow-gaging station equipment used for the Medina River flood early warning system consists of a compressed air pressure differential type system in which, an orifice tubing is installed beneath the water surface and contained within the streamgage. A constant air pressure is pumped through the orifice line into the stream. The air pressure value is monitored as the water level increases or decreases above the tubing orifice location and the continual air pressure will change proportionately. The relative difference of air pressure is converted digitally using an electronic processor which is connected to a USGS Data-Collection Platform (DCP).

Data verifications are performed daily by USGS personnel and are continually reviewed electronically by USGS designed software. Routine on-site field inspections and equipment calibrations are completed by USGS personnel on a 6 to 8-week schedule and more often during weather related events.

Obstacles and Lessons Learned

There were minimal obstacles encountered during the streamflow-gaging station installation process which were resolved in a timely fashion, regarding preferred location of each streamflow-gaging station. Landowner, County, or State Right of Way access agreements were obtained for the streamflow-gaging station infrastructure and appurtenance to be installed.

Although there were no negative concerns, lessons learned during the selection of streamflow-gaging station locations and pre-construction of each new streamflow-gaging station is to continue ensuring a scientific scrutiny. Alternative field location reconnaissances are adequately identified, and landowner access agreements are requested as soon as possible.

Development of Flood Atlas

The USGS has standardized the procedures for creating FIMS for flood-prone communities (U.S. Geological Survey, 2018b). Tasks specific to the development of the FIMS for Bandera, Texas were as follows:

- collect and compile topographic and bathymetric data for selected cross sections and geometric data for structures and bridges along the study area
- estimate energy-loss factors (roughness coefficients) in the stream channel and flood-plain and determination of steady-flow data
- compute water-surface profiles using the U.S. Army Corps of Engineers (USACE) HEC-RAS) computer program (U.S. Army Corps of Engineers, 2016a,b),
- produce estimated FIMS for a range of river stages using the HEC-RAS computer program and Esri, Inc. ArcGIS (Esri, Inc., 2018), and
- prepare FIMS both as shapefile polygons that depict the areal extent of flood-inundation and as depth grids that provide the depth of floodwaters, for display on a USGS flood-inundation mapping application (U.S. Geological Survey, 2018b).

Further detailed discussion regarding the HEC-RAS model development, calibration process, and simulated results can be found in the USGS Scientific Investigations Report (Choi and Engel, 2019). The HEC-RAS estimated flood-inundation extent polygons, flood depths grids, and study limit lines are available in a companion Science Base data release (Engel and Choi, 2019).

The USGS - FIMP website (https://water.usgs.gov/osw/flood_inundation) will provide USGS flood-inundation study information to the public. The website links to the FIMP application that presents map libraries and provides detailed information on flood-inundation extents and gage heights for modeled sites will be found at (https://wimcloud.usgs.gov/apps/FIM/FloodInundationMapper.html).

In addition, BCRAGD developed an internal operations Flood Plan that includes BCRAGD office and employee responsibilities during a flood event. The BCRAGD Flood Plan is attached to this report as a separate document for information purposes.

Summary

The study area encompassed a 23-mile reach of the Medina River from the confluence of Winans Creek to English Crossing Road above Medina Lake. The USGS developed a HEC-RAS model, which applied data from existing streamflow-gaging stations and the newly installed two additional 'stage only' streamflow-gaging stations along the headwaters of the North and West Prongs of the Medina River. A flood atlas, comprised of a library of digital flood maps, was developed and will be available on the USGS - FIMP website for public awareness. The results of the investigation and model documentation will be published in a USGS - SIR upon completion and approval of a formal USGS report, currently in review.

The flood inundation maps depict estimates of the areal extent and depth of flooding corresponding to selected water levels (stages) at the USGS streamflow-gaging station 08178880 Medina River at Bandera, Texas. A calibrated hydraulic model applied 29 water-surface profiles for flood stages at 1-foot (ft) intervals referenced to the Bandera station gage datum and ranging from 10 ft or near stream-bank full to 38 ft, which exceeds the Major Flood Stage of the NWS – AHPS of 24 ft.

In addition to incorporating these data sets, emergency managers and general public can access real-time data of the additional USGS streamflow-gaging stations installed within the study area as well as the existing gaging stations. The selected gaging station and user defined data can be linked to the USGS WaterAlert notifications system (http://water.usgs.gov/wateralert/). The WaterAlert service sends e-mail or phone text messages when selected streamflow-gaging station parameters, such as streamflow or gage height (stage) meets or exceeds user-definable thresholds.

These flood-inundation maps, in conjunction with the water-alert system and real-time stream data are intended to assist emergency managers during flooding events with a tool to efficiently guide the general public in taking individual safety precautions and further reduce or avoid property losses.

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Attachment:

Bandera County River Authority and Groundwater District – Flood Plan May 2019 (BCRAGD internal referenced document, for informational purposes only)