Report P5A Flood Data Services

Prepared for Project 0-7095-01 Flood Assessment System for TxDOT (FAST)

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Introduction

Task 5 in the FAST project agreement describes the development of Flood Data Services to support the FAST map applications. These services include a (1) representation of flooded road segments and (2) a representation of bridges with flood warnings indicating water is approaching or impacting the low chord of the bridge.

As shown on the left in Figure 1, in previous research (TxDOT Project 0-7095), two prototype websites were developed to independently demonstrate flood warnings for bridges and the locations of roads predicted to flood. For this project (TxDOT Project 0-7095-1), the goal is to transform these prototypes into operational agnostic application programming interfaces (API) and feature layers. Ultimately, these geospatial layers and services will be used to create real-time web maps and dashboards, as shown on the right in Figure 1.

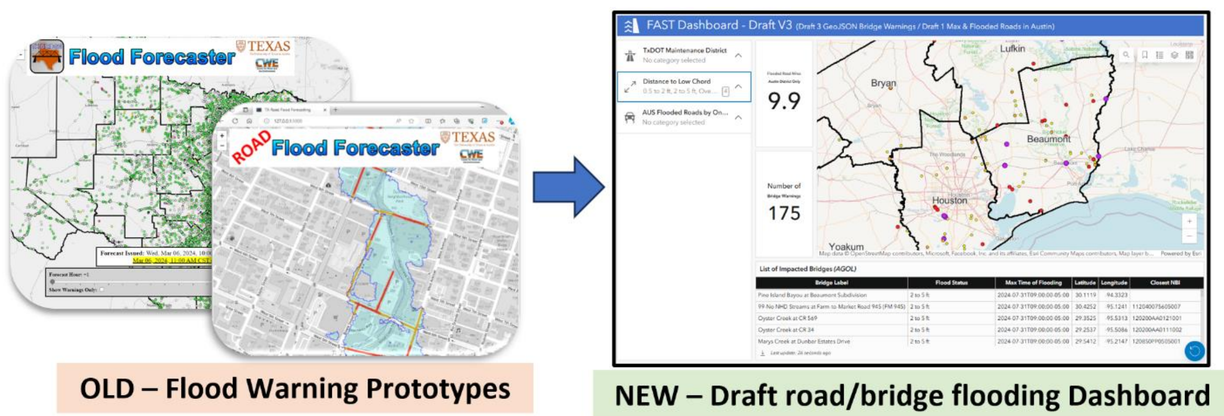


Figure 1. Transforming prototype web sites into services for dashboard creation

Data Sources and Preparation

To create the feature layers and graphics for flood warnings, the data preparation for bridge and road services is detailed in the subsequent sections.

Bridges

Bridge warnings are represented as point locations in a map attributed with an indication of warning status. For example, Figure 2 indicates that a forecast flow is projected to be within (2 to 5) feet from the low chord of the bridge.

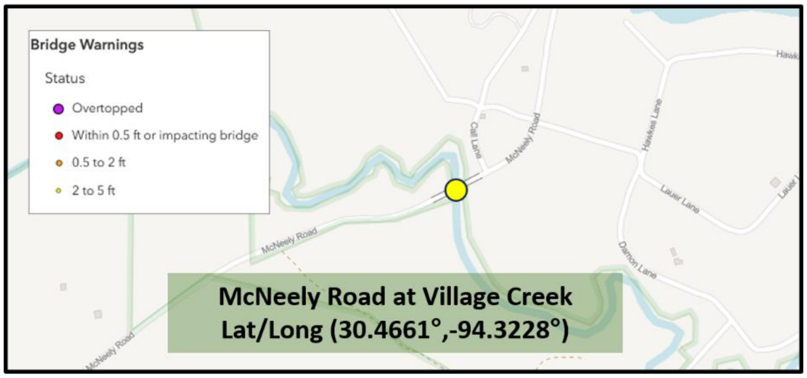


Figure 2. Sample bridge warning point where McNeely Road crosses Village Creek

For bridges, a SQLite database (from TX-Bridge, as detailed in Report P5B of Project 0-7095) was programmatically created using statewide LiDAR point clouds. This database contains information on bridge locations, cross-sectional geometry, and hydraulic rating curves. However, not all the extracted bridges are suitable for flood prediction.

To identify bridges suitable for flood prediction, the following filters were applied:

- Minimum water conveyance area beneath the bridge must be at least one (1) square foot.
- Bridge cannot be more than 200 feet from a river.
- Bridge must have a low chord elevation.
- Bridge must have a hydraulic rating curve corresponding to a National Water Model flow.

With these filters applied, bridge warning points are computed for the remaining bridges. If the warnings are positive, they are broadcasted in a geospatial feature layer.

Roads

Road flooding is represented as vector line segments in a map attributed with flood depth and time of flooding. The source of the road lines is the TxDOT Roadway Inventory as downloaded from the TxDOT Open Data Portal (https://gis-txdot.opendata.arcgis.com/).

In the current phase of the project, road flooding is computed using Height Above Nearest Drainage (HAND) grids, Figure 3. HAND includes rating curves that relate streamflow to water depth, as well as catchments (local watersheds) where the hydraulic computations for deriving these rating curves occur.

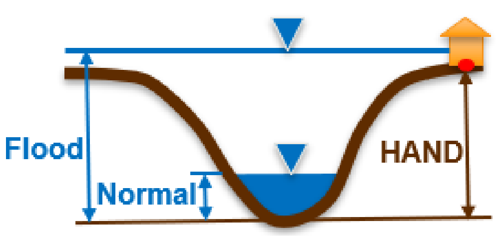


Figure 3. Conceptual diagram of Height Above Nearest Drainage (HAND). Flooding occurs when the water depth exceeds the HAND value at a given location.

HAND is derived from hydro-conditioned digital elevation models (DEMs), Figure 4, which often do not accurately represent road and bridge elevations where they cross streams. To correct the HAND grids and remove artificial depressions, a 1-meter road DEM is created from LiDAR data and compared with the DEM used to compute HAND. This comparison helps determine the necessary adjustments to the HAND grid to accurately represent roads. For more details on this process, including tutorial visit: https://www.caee.utexas.edu/prof/maidment/RoadElevationModel.htm.

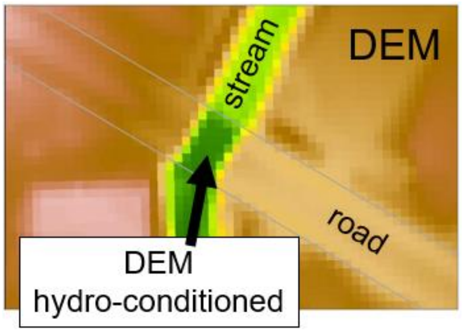
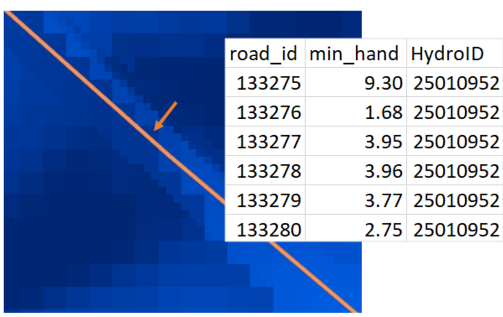


Figure 4. Example of hydroconditioned DEM

The flow rate at which a segment is subject to flooding is precomputed by intersecting the TxDOT roadways with the HAND catchments (watersheds). The team assigns a unique identifier (road_id) to each segment and computes the minimum HAND value for each road segment. This represents the lowest part of the road segment with respect to the nearest stream that would flood the road. If the water level in the stream exceeds the minimum HAND value for the road, then the road will flood. The result of this analysis is a table storing the minimum HAND per road, Figure 5. This precomputed layer is termed the "road flooding susceptibility" data.



road_id	min_hand	HydroID
133275	9.30	25010952
133276	1.68	25010952
133277	3.95	25010952
133278	3.96	25010952
133279	3.77	25010952
133280	2.75	25010952

Figure 5. Minimum HAND per road segment. In the screenshot the road is the orange line. In the HAND grid (blue grid cells), one can see the road represented as the lighter colored cells, and a stream with darker cells running from the bottom-left to the top-right.

Backend Services

Once the static data for the bridge and "road flooding susceptibility" tables are established, they are combined with real-time streamflow data to assess which bridges and roads are likely to be inundated within the next 18 hours, Figure 6. This process is supported by a backend service hosted by KISTERS, which provides periodic hourly updates to support bridge warnings and flood computation for roads. The service integrates the National Water Model (NWM) short-range forecasts with bridge definitions and performs the necessary calculations for the Bridge Warning service.

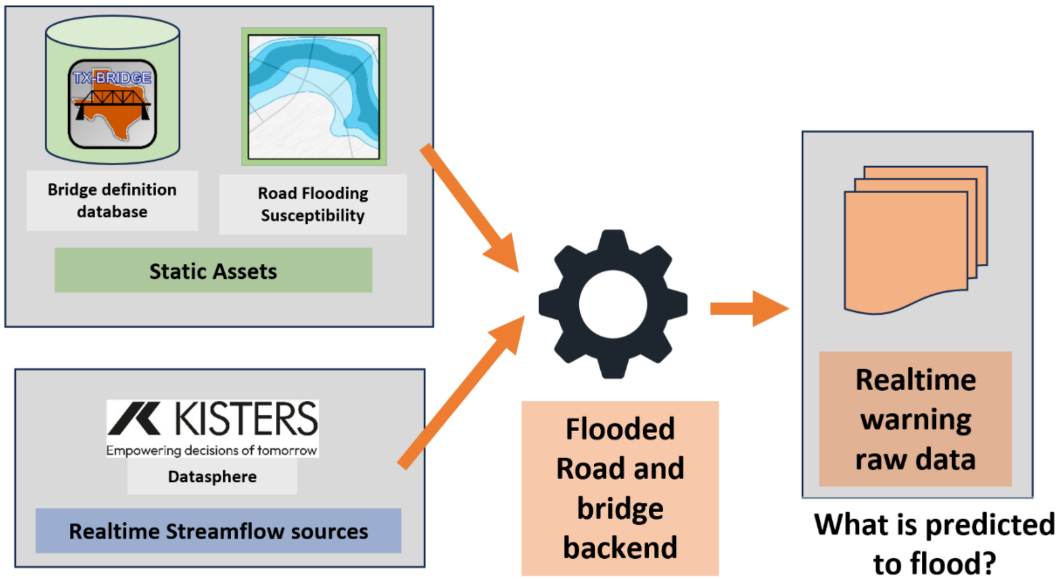


Figure 6. Overview of KISTERS backend data services for computing real time flood warning data

The KISTERS service is currently providing hourly updates on real-time raw data, which includes:

- Current short-range stream flows for Texas: Streamflow Data (NetCDF)
- Bridge forecast data: Feather Format and GeoJSON Format

Bridge Cross Section Service

When a user clicks on a bridge to open a pop-up with additional details, they can follow a link within the pop-up to access a time-enabled cross-section of the bridge, displaying water levels throughout the forecast period. This feature relies on a service that integrates the static bridge definition database with streamflow data. KISTERS has deployed a service that fulfills these requests, rendering the information "on-demand", Figure 7.

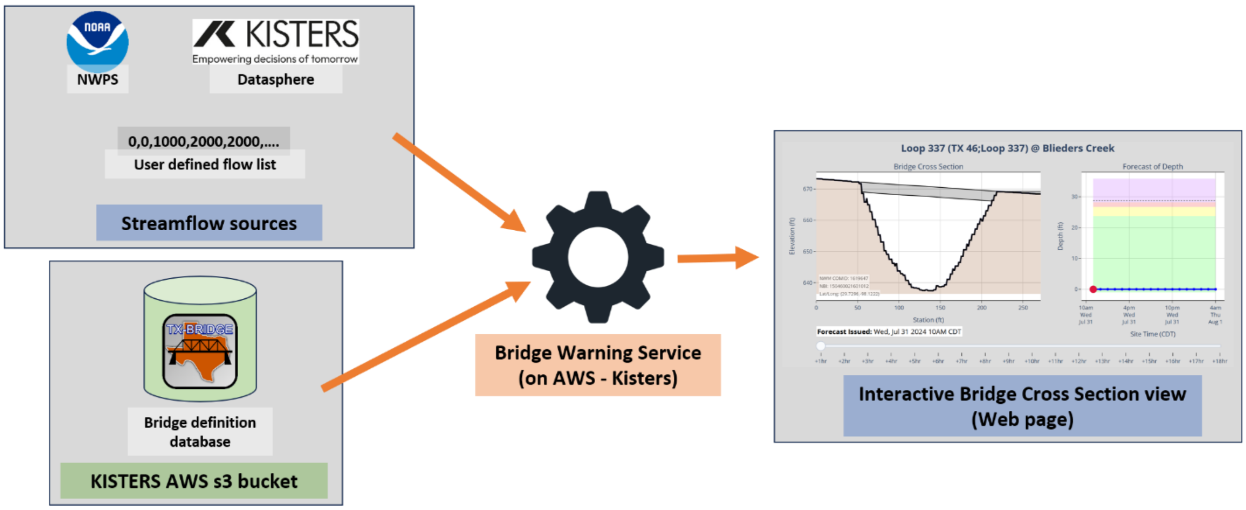


Figure 7. Schematic of the functionality of KISTERS' Bridge Cross Section Web Service

Example URL: https://bridges.txdot.kisters.cloud/xs/?uuid=00a1d8c7-2ead-4fc4-ae9c-928146a4460c&source=datasphere&product=short_range

Each bridge is assigned a unique identifier (UUID), and its hydraulic rating curve and cross-section geometry are precomputed and stored in the bridge definition database. Streamflow data can be sourced from (1) NOAA's National Water Prediction Service, (2) KISTERS' Datasphere, or (3) a user-defined list of eighteen flows. The user-defined list feature is provided to facilitate the future capability of plotting historical data.

Bridge Cross Sections API

The Bridge Warning Service is a RESTful API which was built in python using the FastAPI framework and plotly for graphic generation. FastAPI integrates with Swagger by default. Swagger is a framework for API design and documentation that helps future developers and consume RESTful web services. This service's documentation is currently exposed through KISTERS Bridge Warnings - Swagger UI . This interface documents how to build URLs to retrieve bridge cross sections, Figure 8.

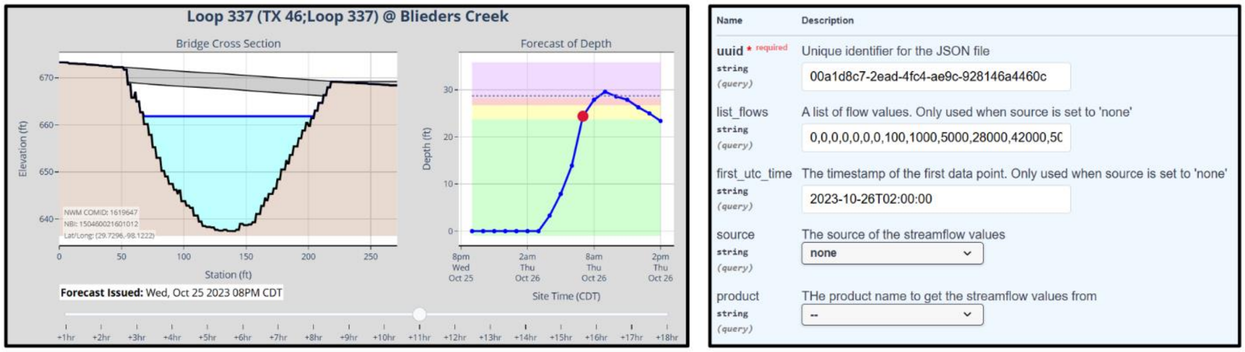


Figure 8. Swagger User Interface for the creation of a bridge cross section with user provided flows and user provided time for first hour

Example URL: https://bridges.txdot.kisters.cloud/xs/?uuid=00a1d8c7-2ead-4fc4-ae9c-928146a4460c&list_flows=0,0,0,0,0,0,0,100,1000,5000,28000,42000,50000,45000,42000,35000,30000,25000&first_utc_time=2023-10-26T02:00:00

Hosted Feature Layers and Web Maps

KISTERS provides real-time flood prediction data, updated hourly. From this raw data, there is a need to create and serve geospatial layers for bridge warnings (points) and flooded roads (lines). TxDOT has requested that these layers be made available through a 'data agnostic API'. This API should offer a consistent interface for interacting with various spatial data sources, including GIS, spatial databases, and web services. The team is exploring options such as ArcGIS Online (AGOL), GeoServer, and GeoJSON for serving these data. The immediate objective is to integrate these layers into a web map and dashboard.

A Draft real-time flooding dashboard, as shown in Figure 9, using the flood data services detailed in this write-up is currently functional with a limited data coverage at: https://www.arcgis.com/apps/dashboards/fd411771ec834f8994d40bc18459c002

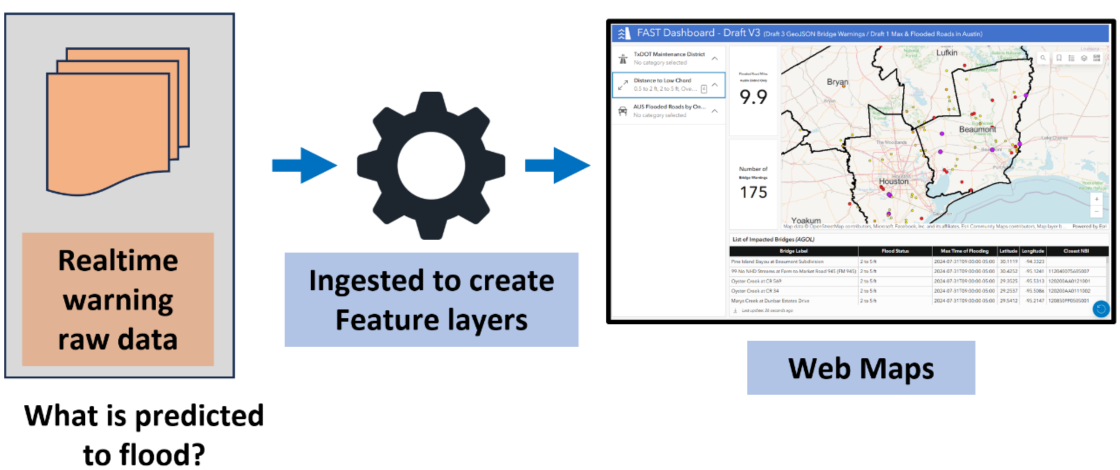


Figure 9. Conversion of raw real-time flood warning data into feature layers and web maps