City of Billings Case Study: Complex Floodplain Issues

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In 1937, a major flood of Yellowstone River tributaries devastated Billings, Montana. Despite the vulnerability of the community that this event revealed, the floodplain was not accurately delineated for decades. The reason for this delay in mapping was due to two factors: 1) lack of available funding and 2) exceedingly complex flow patterns in the developed floodplain. Recently, however, a rapidly expanding population and an increasing rate of development highlighted the critical need for an accurate floodplain delineation. The City of Billings recognized that only with an accurate floodplain map could they effectively manage the risk to their citizens.

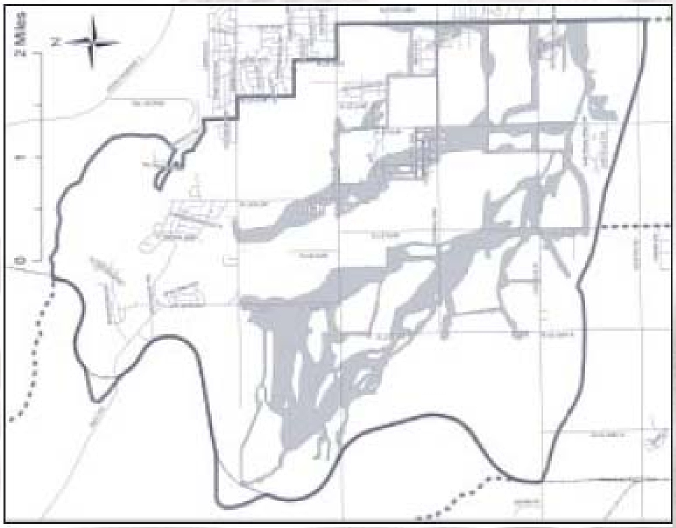
Funding for the mapping project finally came through in 2005, and PBS&J was hired to delineate the 100-year floodplain for the area west of Billings. It became clear almost immediately, however, that the complexity of this mapping exercise would require an innovative modeling approach. Conventional one-dimensional flow modeling would not accurately delineate the floodplain in the project area.

A typical floodplain study. For the majority of floodplain studies, one-dimensional hydraulic modeling is appropriate and provides a clear picture of the area impacted by a flooding event. Typical studies involve determining the peak flow for a specific reach of stream, computing the water surface elevation for each cross section, and using topographic maps to delineate the floodplain. Most often, HEC-RAC – a one dimensional, open-channel flow, hydraulic computer model – is issued to determine water surface elevations and is the industry standard for floodplain delineation projects. Developed by the US Army Corps of Engineers, this free tool is accepted by FEMA and is appropriate for most situations.

The City of Billings. The floodplain in the vicinity of Billings, however, is not a typical situation. First, the prevalence of manmade structures like ditches, bridges, and canals complicated the hydraulic model. Second, Billings lies on extremely flat terrain without distinct channels, making it very challenging to determine where or how far flood water will spread. This lack of a distinct natural flow pattern and the frequent splitting of flows by manmade structures eliminated HEC-RAS as an option. It was immediately clear to the PBS&J engineers and hydrologists that HEC-RAS would not be capable of accurately characterizing the reality of the situation.

PBS&J's approach. The PBS&J team needed a far more accurate picture than the HEC-RAS could provide so they used a two-dimensional hydraulic model called xpswmm to delineate the floodplain. The team ultimately selected xpswmm because it captured and utilized more of the critical factors at play in Billings in its algorithms than other two-dimensional models that were evaluated.

Rather than considering only the maximum peak flow for all channels like one-dimensional modeling, xpswmm routes flow input from each sub-basin through the flow network. This accounts for factors like temporary storage within a channel or along the channel sides that decrease peak flow. Also, routing in xpswmm reflects the time required for flood waters from each sub-basin to reach a particular point, resulting in off-set flow peaks. With these factors and complexities built into the model, PBS&J could create a far more realistic picture of the floodplain.



The team also had to account for Billings' existing infrastructure such as culverts, bridges and roadways that could act as dams in the event of a flood, influencing the water's route. These impacts needed to be precisely reflected in the model and were beyond the capabilities of one-dimensional modeling, which assumes water is flowing in one direction. PBS&J's model accounted for water flowing laterally away from the streams/channels, which was key to understanding the effects of Billings' infrastructure on flood waters and the complications arising from the flow of water outside of designated channels and/or very flat areas.

Finally, the PBS&J team incorporated LiDAR (Light Detection and Ranging) data into the model. This data was acquired at a fine scale – a two-meter grid with one-foot contour elevations, resulting in a level of accuracy that allowed the team to truly understand and demonstrate where water would flow and even the velocity and depth of that flow.

Boiling it down, the project area was so large, flat, and had so many existing structures that the PBS&J team needed to compute the hydrology in a stepwise procedure to capture it. They did this by running the model through small time steps. This "real-time" model was so extensive and intensive that it took 11 hours to run completely.

Challenges. While a superior tool for this complicated project, the xpswmm was not without its challenges. First, the PBS&J team needed to manage the huge amount of data that the model requires. The LiDAR data, for example, included coordinates at two-meter intervals over the entire project grid, resulting in so much data that the model initially could not handle it. The team had to run it through a post processor to maintain the required level of accuracy while reducing the number of physical points. Even after doing this, PBS&J needed to upgrade its hardware so the model could be run on computers powerful enough to process this amount of data.

Benefits. The benefits of using xpswmm and PBS&J's approach extended beyond having an accurate floodplain model for an exceedingly complex area. The project also involved extensive data compilation and surveying so that road crossings, canal crossings and other critical points in the project area are now compiled in detailed GIS data layers. Culverts, for example, have their location, invert elevations, size and shape, and even construction materials detailed in a GIS layer. That's a useful product for the city and county to use in managing ongoing culvert maintenance. In general, these layers can be overlaid on any other kind of map, which Billings can use in evaluating ownership lots and for future planning efforts.

Results. The final product of PBS&J's work was a highly accurate floodplain map for the Billings area that wouldn't have been possible using traditional methods. This map is critical for Billings in planning for future development as it outlines what areas are at risk in the event of a flood. It is now clear what specific mitigation measures should be taken in certain areas, like requiring homes or buildings to be elevated to limit property damage. Additionally, physical changes can be introduced to the landscape to route or store water appropriately.

The challenges encountered in designating Billings' floodplains may arise for other quickly developing areas, particularly those where flat topography complicates flood flow predictions – a common occurrence where formerly agricultural lands are being converted to a suburban setting on a city's developing fringes. In these areas, traditional modeling methods may not be sufficient. As was the case with Billings, generating meaningful data for use in mitigating the dangers and damages caused by floods may require a unique approach.

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