New Inundation Layers for the *Coastal Resilience* tool
Summary Memo, September 2014
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Background:
GIS layers depicting the inundation of Puget Sound river deltas under various climate change scenarios were produced by USGS and Peter Horne during the initial development of the Puget Sound Coastal Resilience web tool. These layers were produced using a USGS GIS model that ran tidal water across a DEM derived from the best available sources of LiDAR elevation data. In the model, as water hits an elevation obstacle, it ceases to flow towards any areas behind the obstacle, and in this way the model was able to show the protective effects of levee systems. Using this data also allowed the site to evaluate the risk of overtopping of the levee systems under the "Levee Freeboard" tool. The inundation layers were eventually moved to TNC's global *Coastal Resilience* website from the USGS development site on Western Washington University's server.

Subsequent assessment of the inundation layers revealed that the DEM included some inaccuracies in the elevation of a few places in the levee system. As a result, some of the inundation layers incorrectly showed areas getting flooded under conditions when they would not actually flood. In addition, some recent dike removal restoration projects were not reflected in the LiDAR and therefore the inundation layers showed these places as still protected from flooding.

New Inundation Layers:
Western Washington University generated new inundation layers for the Nooksack, Skagit, Stillaguamish, Snohomish and Nisqually Rivers. We used the new levee layer previously created by WWU, along with the DEMs for each delta to identify errors in how well the DEM captured the levee system. In collaboration with Eric Grossman at USGS we corrected the levee portion of the GIS model so that 2010 MHHW tidal flooding would be correctly illustrated. When the model correctly represented current conditions, it was re-run to generate new inundation scenarios for all future conditions.

The new inundation layers were provided to TNC in a GIS geodatabase. Figure 1 illustrates the original 2010 MHHW layers and the new corrected layers. The Skagit system had the most error, with several thousand acres of area originally shown as flooded under 2010 MHHW conditions. This was mostly due to the poor quality of elevation data available for the Padilla and Samish parts of the system. There were 16 areas of error detected in the five rivers. Most of the flooding errors were due to areas that were incorrectly shown as flooded. However six of the errors in the Stillaguamish and Snohomish systems were due to places shown as dry that should have flooded. These were generally places where restoration projects have removed levees.

Recommendations:

Sea Level Rise Inundation Scenarios

In the menu of the web tool, coastal inundation scenarios are currently listed under the heading "Inundation Scenarios". We suggest that this be renamed to something like "Sea Level Rise Inundation Scenarios". This may help to clarify that the scenarios show the effect of sea level rise on coastal flooding for the river deltas, but they do not incorporate river floods or climate change impacts on river flows. Now that TNC is adding layers to certain sites that describe river flooding risks, it may be important to clearly indicate which scenarios show just SLR impacts and which include other kinds of flood drivers such as river flows.

Add a Caveat Statement to Inundation Maps

The GIS model used to derive the inundation maps assumes that as soon as a levee is overtopped, all areas protected by the levee will flood to the elevation of the high water level. In reality, the area and depth of flooding will depend on how much water flows over the levee, whether the levee breaches to allow more flooding, and how long the flooding continues. If a levee breach does not occur, flooding due to high tidal water is likely to happen only during the few hours of a high tide. Since we cannot guess the likelihood of a breach, the length of time of overtopping, the size of the area that would be overtopped, or the total volume of water that would flow across the dike, the model takes the simplistic approach of mapping all areas that would be vulnerable to flooding if a dike could no longer prevent flow. As a result the inundation layers show the "worst case" scenario.

For example, on the Snohomish River, the 2010 HOW (highest observed water) scenario shows much of the lower tidal Snohomish floodplain as being flooded. In reality, very little of that area would likely be flooded because there may be only a few small dips in the levee where some water would seep over the levee during the period of maximum water level. Some areas may get a little wet under these conditions but it is unlikely that the whole area would flood. Further analysis of the LiDAR DEM or ground-based RTK-GPS data could be used to identify the low spots and their elevation relative to the rest of the levee system, which would allow a more detailed analysis of the likely scale of flood risk.

Since the inundation scenarios show the "worst case" flood outcome, we suggest adding the following notice, or similar language, to all inundation layers:

> *"Important: When an inundation map indicates that an area protected by a levee has been flooded, it shows the worst case scenario, assuming that all low areas behind the levee will get flooded. When these areas are shown as flooded, it means that there is at least one spot in the levee system that is lower than the high water line. In an actual event, the area that gets flooded would depend on the width of the low spot, how long the water level remains above the low spot on the levee, and the total volume of water that passes over the levee at that spot."*

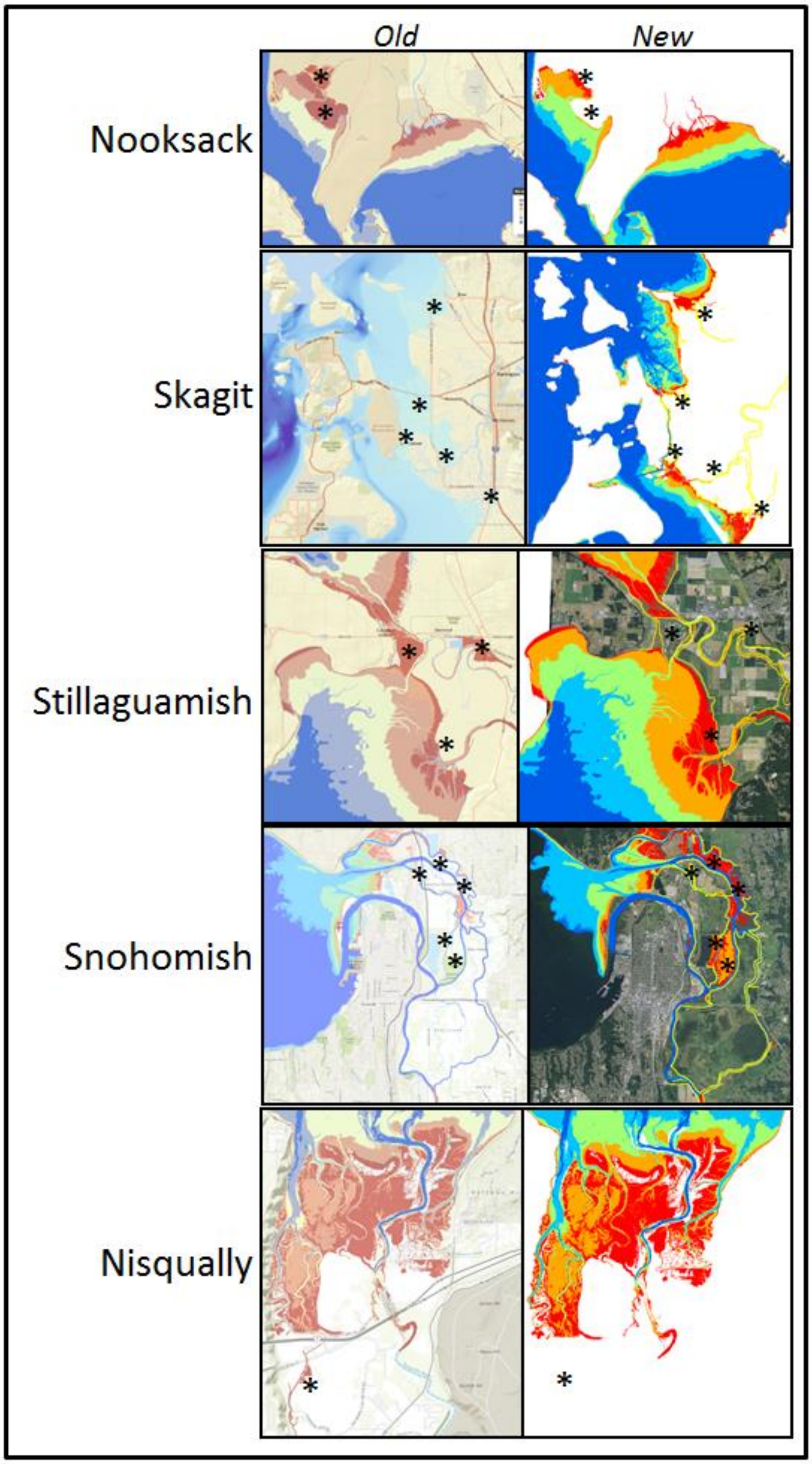

Figure 1. *Maps showing the errors in the original 2010 MHHW inundation maps (left column) and the corrected inundation maps (right column). The stars indicate places where inundation was incorrectly shown in the earlier maps. Errors included places that incorrectly flooded, as well as restoration areas that should have flooded but did not.*