Mitigating Total Flood Impacts through Intentional Flooding in Agricultural Land along the Lower Nooksack River

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Association of State Floodplain Managers Conference 2014

Abstract: The purpose of this study is to examine the flooding patterns within the Nooksack River Basin in Whatcom County, Washington, in order to design and recommend changes to flood management strategies. Focusing on Reach 2 and Reach 3, defined by the Lower Nooksack River Comprehensive Flood Hazard Management Plan, flooding occurs predominantly in agricultural land, as well as urban land within portions of Ferndale. In order to mitigate this flooding, the proposed strategy consists of intentionally flooding designated areas and storing floodwaters. By analyzing the example hydrograph of the November 30th, 1995 flood event, we observe approximately 9,200 cfs exceeded the flood flow corresponding to Ferndale's levee gauge height of 19 feet. In order to accommodate and redistribute these flows to prevent damage downstream, a conceptual storage layout is presented as an example of how storage areas could be chosen. Approximately 4,670 acre-feet of land could be used to store floodwaters in the conceptual storage scenario. This study recognizes that peak flow reduction depends on the capacity of chosen storage areas, and a more detailed study would be required to determine the most feasible layout. This strategy offers benefits such as relief of levee breaching, stored water that could be used during drier seasons, reduced risk of crop loss, and replenishment of nutrients and groundwater to surrounding aquifers. Funding for infrastructure modifications can come from shifting City of Ferndale flood capital investment upstream, which will still mitigate downstream by reducing total flow. Compensation for intentionally flooded lands can be sourced from an agricultural risk co-op, with dues and pay-outs reflecting level of loss avoided. This study highlights the idea that accommodating the floodwaters by directing the flow course to designated land is a safe and cost effective method to mitigate floods compared to using traditional levee systems.

Introduction

The Nooksack River Basin is located in Whatcom County, situated in the northwest corner of Washington State. The 950 square mile basin begins in the North Cascades around Mount Baker in three branches. Heavy precipitation and snowpack storage, combined with steep mountain topography, contribute to flow characteristics of the upper basin. The branches converge at the town of Deming and flow westward through Lynden, Ferndale, and Bellingham, discharging into Bellingham Bay (Whatcom 1999). The region south of Deming is a flat, broad floodplain adjacent to the Nooksack.

The Lower Nooksack River extends from the upstream town of Deming and ends at the alluvial fan in Bellingham Bay. Flooding in this region has impacts on upstream agricultural areas and downstream urban areas. This study seeks to minimize impacts of flooding in the town of Ferndale by improving flood management practices on upstream agricultural land. A vicinity map of the Nooksack River basin is provided below in Figure 1.

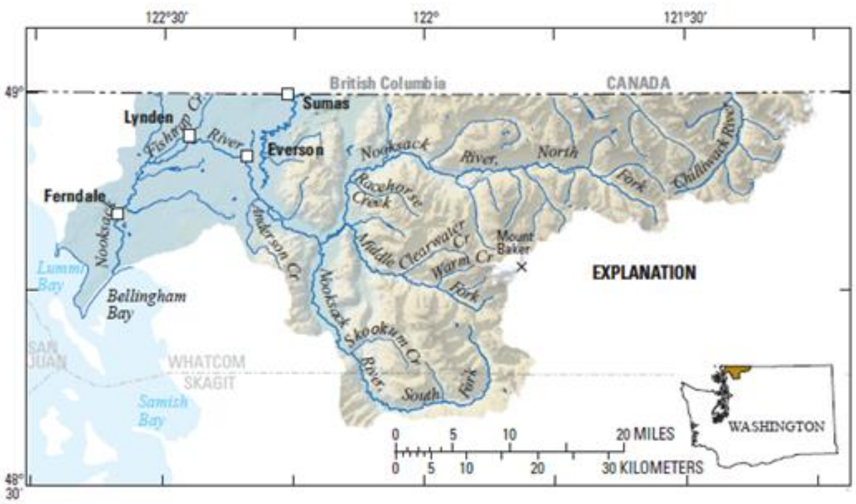

Figure 1: Nooksack River vicinity map (USGS 2013)

Historically, the floodplain of the Lower Nooksack contained old growth forests, which distributed water throughout the basin, dissipated energy, and provided storage capacity during flooding events. As development occurred, old growth forests were replaced with agricultural vegetation and small growth forests. Development of agricultural land resulted in increased peak flows and took away the natural floodplain ability to distribute waters throughout the basin and dissipate energy (Whatcom 1999).

Current flood management infrastructure includes a levee system along the Nooksack River and in the town of Ferndale. Although this infrastructure has some success in protecting against flooding, an increase in flood frequency and expected development on the Nooksack River around Ferndale call for the need to improve the current system.

Change

Location

The Lower Nooksack is divided into four reaches by the Lower Nooksack River Comprehensive Flood Hazard Management Plan (CFHMP). The focus of this project lies within Reach 2 and Reach 3. Along this stretch approximately 43% of parcels in the floodplain are predominately agricultural (Whatcom 1999). Reach 3 occupies the area between the Everson Bridge and the Guide Meridian Bridge. Over time, levees have been built along both river banks for a majority of the reach by an assortment of agencies, both public and private. There was not a common standard for design and maintenance between the different agencies, which led to the creation of levees with different protection levels ranging from less than the 5-year flood to more than the 10-year flood (Whatcom 1999). Without the necessary coordination, Reach 3 experiences flooding in random patterns that become hard to predict.

Reach 2 occupies the area from the Guide Meridian Bridge to the portion of Interstate 5, located in Ferndale. This portion of the reach is lined with levees on both sides of the bank that overtop and cause farmlands upstream to flood consistently when high flows occur. Reach 2 ends with areas of Ferndale that lie within the 100-year floodplain (Whatcom 1999). The addition of levees within Reach 2 and Reach 3 have acted to protect the surrounding farmland, but have also changed the characteristics of the river, restricting the natural morphology. As humans try to control natural phenomena to accommodate human lifestyle, climate change is beginning to prove that new methods need to be implemented.

Climate Change Projections in the Pacific Northwest

The projected change in temperature and precipitation in the Global Climate Models (GCMs) will continue to impact the Pacific Northwest region. According to the recent Climate Change report by the Climate Change Group at the University of Washington, the lower Nooksack basin will suffer a shift from being a transitional watershed, characterized by winter precipitation and snowpack, to a rain dominant watershed under 2020s, 2040s and 2080s climate change scenarios. For transient basins, a relatively small increase in temperature can significantly increase the fraction of winter precipitation falling as rain and decrease the amount of water stored in snowpack (Alan et. al. 2013; Littell et. al. 2009).

Frequency

With future climate projections predicting a greater proportion of winter precipitation falling as rain, rather than snow, winter flood risk will intensify for warmer transient basins. The ratio of the 21st century compared to the 20th century for both the 20-year flood and 100-year flood are projected to be around 0.9 to 1.5. The ratio is projected to increase from the 2020's to the 2080's. Higher flood magnitudes indicate more intense flooding in the future (Alan et. al. 2013).

Land Use

The Nooksack Water Resource Inventory Area (WRIA 1) is expecting a small shift towards urban development. Comparison of land use in 2003 and projected future land use in 2017 indicates a 3% increase in city land use. Urbanization will increase the impermeable area within the watershed and lead to faster and higher peak flow, which will worsen flooding. The impermeable urban area will also decrease infiltration that contributes to groundwater and decreases baseflow.

Severity

The CFHMP estimates flood flows for the 10, 50, and 100-year flood at Ferndale as shown below in Table 1.

Table 1: Magnitude of flood flows at the City of Ferndale (Whatcom 1999)

Flood Event	River Flow (cfs)
10-Year Flood	40,000
50-Year Flood	55,800
100-Year Flood	63,000

Impacts

Flooding in the Nooksack basin causes human, natural, and societal impacts. Development continues to occur within the 100-year floodplain, increasing the risk for property damage, injury, or even loss of life.

Through the course of several flooding events, sediment and debris have accumulated in the ditches that run parallel to the river, which normally provide drainage to the farmlands. This accumulation causes tributaries such as Bertrand Creek and Fishtrap Creek in Reach 2 to experience water back-up during flood events, resulting in levee breaches onto undrainable farmland (Cooper 2013). If farmland is unable to drain, cropped areas that are vulnerable to inundation will be damaged.

The construction of levees has restricted channel morphology, creating narrower waterways. Reducing the width of the river increases the flow velocity. Bridges, such as the Guide Meridian Bridge, are supported on piles. The increase in flow velocity increases the risk of scour around the piles, which decreases the structural integrity of the bridges (Whatcom 1999). Bridges are very important for this area, especially the I-5 Bridge, which enables transportation for residents and truck freight. The closure of the I-5 Bridge would result in catastrophic financial loss.

Strategy

Our mitigation strategy is predicated on intentionally spilling water out of the channel during high flows and into land that has less entrenched capital. Spilled water will be temporarily detained on agricultural land, providing opportunity to benefit from floodwaters as opposed to incurring losses downstream.

Peak Flow Reduction

Water that would normally contribute to peak flood flows would be spilled in predetermined areas by modifying the present levee system, to reduce peak flood flows at the City of Ferndale. This concept can be illustrated by looking at a hydrograph of flood flows for the historical flood event at the City of Ferndale on November 30th, 1995. The maximum recorded flow for this flood event was 41,200 cfs, exceeding the 10-year flow of 40,000 cfs as listed in Table 1. The National Weather Service defines the flood level in the City of Ferndale at a gauge height of 19 feet, corresponding to a flow of approximately 32,000 cfs (NWS 2013). The peak flow of the 1995 flood by this definition exceeds the minimum level of flooding. The hydrograph of the 1995 flood is included in Figure 2, accompanied by the defined minimum flood level.

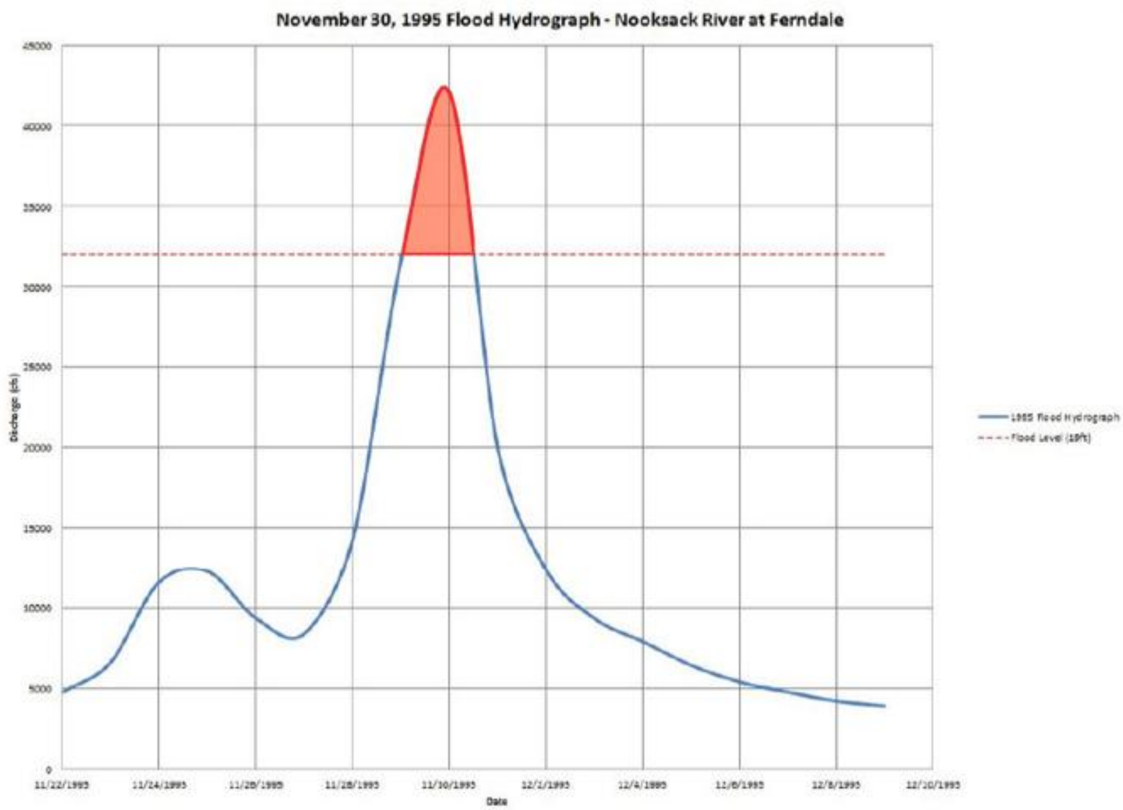

Figure 2: November 30, 1995 Flood Hydrograph - Nooksack River at Ferndale (USGS 2013)

By detaining water in upland agricultural areas, floodwaters that exceed the minimum flood level at the City of Ferndale can be redistributed to alternative areas of the hydrograph, or eliminated if stored and used, or infiltrated. The shaded region in Figure 2 represents the volume of water that can be redistributed to bring peak flows at Ferndale below flood levels.

Floodwater Storage Location

This study recognizes that peak flow reduction depends on the capacity of chosen storage areas, and a more detailed study would be required to determine the most feasible layout. Conceptual areas picked to hold flood waters were chosen to best match available land and natural topography of the floodplain.

USGS topographic maps of Lynden and the Nooksack River were used to determine possible areas of agricultural land in Reach 3 that could be used to store floodwaters in natural depressions adjacent to the river known as Mormon and Scott's Ditches. The elevation of the reconnection points to the Nooksack River were chosen as points where floodgates could be constructed to control storage levels. A maximum storage level behind the floodgate was assumed to be 5 feet, limiting the delineated storage area to a 5 foot topographical increase in elevation upstream in the ditches. This effectively created storage areas with an average depth of 2.5 feet, delineated in Figure 3 below. Floodgates would require the construction of small levees at the downstream end of storage extending to the sides as necessary, as shown in the figure by the bold blue lines. Upland storage of Scott's Ditch, shown in yellow, is also possible, but would require levee construction to contain water in the floodplain around Scott's Ditch, displayed by the yellow bold line.

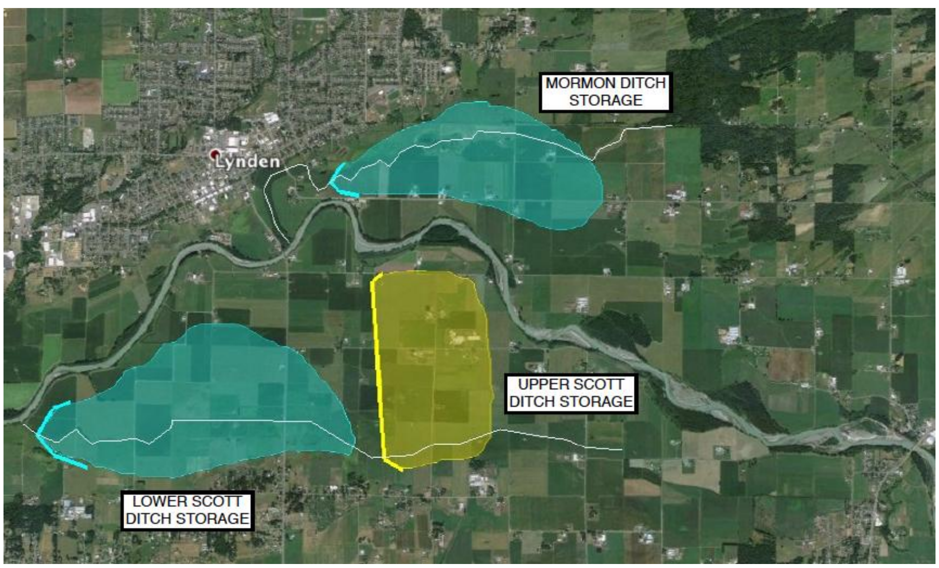

Figure 3: Reach 3 conceptual storage areas (shaded) and infrastructure locations (bold lines) (Google Earth)

Altogether, these conceptual storage sites hold approximately 4670 acre-feet of storage. This amount of storage effectively redistributes the peak flow of the flood hydrograph. In referencing Figure 2, peak flow in this scenario at the City of Ferndale is reduced to 36,500 cfs.

Independent of chosen storage locations, this strategy presents the opportunity of rotating areas of storage between flood seasons. The primary storage location can be rotated from year to year, with the advantage of routing and detaining flood waters in areas with a greater known flood risk.

Benefits

The most obvious and direct benefit of utilizing storage areas is to reduce the severity of the flood downstream. In terms of the 1995 flood, the application of the 3 storage areas reduces the peak flow at Ferndale by 13%. By predetermining flood areas, the amount of floodwater remaining in the channel would be decreased and be less destructive for levees in Reach 2 and Reach 3, lowering levee maintenance cost and preventing damage at Ferndale. The portion deducted from the budget for both downstream infrastructure and levee maintenance can be used to pay for the loss of flooding those areas.

Intentionally flooding and storing water on predetermined areas reduces risk of crop loss and associated damages. Farmlands outside spill and storage areas could plant regular crops with lower risk of loss. For those whose farmland would be flooded, it would be possible to accommodate by leaving land fallow, using flood resistant crops, or choosing crops with minimal loss when flooded. Storing the floodwaters provides opportunity for regional aquifer recharge and offers a greater supply of water during the summer low flow months for agricultural and municipal use.

Funding Strategy for Remediation

Funding for the remediation discussed above would be separated into two primary sources- flood infrastructure, and loss compensation/risk sharing. With respect to infrastructure, the City of Ferndale would be the primary actor. Our suggestion is that money allocated for improving and maintaining levees be spent on creating pathways to spill water at a lower flood level upstream. Increasing the proportion of this funding to expand into upstream projects may prove to be a short-term constraint on arterial flooding during heavy precipitation, but will ultimately mitigate low-frequency, high-cost impact scenarios brought on by riverine flooding.

The second component of funding pertains to balancing compensation of landowners for intentionally flooded areas. Our suggestion is the creation of an agricultural risk co-op encompassing land owners impacted by intentionally redistributed flood water. All landowners do not have the same land or agricultural value attributed to their parcel. Therefore, part of our assumption is that a parcel-specific modulation could be designed. Intentional flooding would favor land that could more feasibly be left fallow or sustain flood-resistant crops.

Rotational flooding schedules would be used to determine which areas receive water allowed through levee gates, such that impacts annualized over the return period in the rotation schedule is minimized for any given single landowner. Compensation for losses that exceed null-loss for flooded crop area that partially recovers would follow the same exposed-value based modulation used for calculating how much each co-op member pays into the total fund.

Conclusion

Under current conditions, the lower Nooksack basin experiences levee breaches, causing flood damage to agricultural and urban land. By designating specific areas that can be intentionally flooded in order to store the floodwaters, the floodwater can be used in a beneficial manner and areas downstream can be protected. This also provides opportunity for replenishment of natural aquifers and irrigation during the drier season. With intentional flooding, construction and maintenance cost of levees is decreased, offering funds to create and manage the storage. Overall, accommodating the floodwaters by directing the flow course to designated land is a safe and cost effective method to mitigate floods compared to using traditional levee systems.

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