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Modification of Existing Dams

Measure 1 – Upper Baker Dam

Upper Baker Dam is located at River Mile (RM) 9.3 on the Baker River tributary to the Skagit River, which comes into the Skagit River (RM 56.5) just upstream of the Concrete Gage. The drainage area above Upper Baker Dam is 215 square miles which is roughly 7% of the drainage area for the Skagit River near Mount Vernon and typically contributes roughly 12% of the peak flow seen on the Skagit River. The Corps of Engineers currently has the authorization for flood control space that maximizes at 74,000 acre-feet on November 15th of the flood season. With the existing flood control space, Upper Baker Dam outflow's current contribution to the 100-year flow is 9,000 cfs which represents 4% of the total flow. These measures are designed to reduce the flow contribution coming from Upper Baker Dam with additional storage, timing, and minimum outflow adjustments.

The major potential advantage of Measure 1 is the reduction in flood flows during more frequent, smaller flood events. Potential disadvantages include increased flood flows during large events, impacts to endangered species, and hydropower losses. In addition, design must meet new Corps HQ structure and design requirements. Resolution of designation of FERC Probable Maximum Flood would be required for the HQ to approve this measure. Finally, the measure only reduces flows from 15% of total inflow to mainstem.

Measure 1A – Upper Baker Dam – 74K Storage – 0 cfs Outflow

This measure reduces the minimum flow released from Upper Baker Dam from 5,000 cfs to 0 cfs. The flood storage remains the same at 74,000 acre-feet and the flood control follows what is set in the Water Control Manual. This measure reduces the outflow at the dam for flood events up through a 25-year event but fills up the storage quicker and causes more flow to be released at larger flood events such as the 100-year. The benefits are seen because of the higher frequency of the lower events. Considerations for further Study:

- A more detailed analysis of possible structural modifications at the dam (necessary to meet Corps safety requirements) will be developed based on HQ guidance.
- This measure reduces flood flows for more frequent events (less than a 50-year event) but causes the storage to fill up prematurely in larger flood events, which causes increases in flows. Areas that normally do not see flooding until the larger flood events such as Sedro-Woolley have negative benefits because of this while most of the other areas see a benefit.
- These estimates of benefits and costs should be considered preliminary and are provided for the purpose of initial screening of management measures.
- Corps Headquarters will need to determine whether the dam meets current Corps operation and design requirements. If the dam does not meet criteria, Headquarters will need to identify what dam modifications are required and these costs will be attributed to the measure. This effort cannot be initiated until FERC determines what modifications may be required to the dam for Puget Sound Energy (PSE) to meet FERC requirements.
- This measure has the potential to increase flooding for Sedro-Wooley in major events. This would need to be mitigated.
- Costs to structurally modify the dam have not been determined or included in this evaluation. Dam maintenance and operation costs attributed to additional flood storage would be a 100% local cost.
- Costs of measure are based strictly on hydropower loss from change in operations of the dam. Power loss compensation would be a 100% local cost.
- Potential environmental impacts have not been evaluated. Need to assure that this measure would not impact critical in-stream flows (i.e. spawning beds and fish stranding).

Measure 1B – Upper Baker Dam – 85K Storage – 0 cfs Outflow

This measure reduces the minimum flow released from Upper Baker Dam from 5,000 cfs to 0 cfs and increases the flood storage from 74,000 acre-feet to 85,000 acre-feet. The flood control follows what is

set in the Water Control Manual. This measure reduces the outflow at the dam for all flood events up to a 75-year event and then is similar to existing conditions.
Considerations for further Study:

- This measure reduces flood flows for more frequent events (less than a 100-year event) but causes the storage to fill up prematurely in larger flood events, which causes increases in flows. Areas that normally do not see flooding until the larger flood events such as Sedro-Woolley have negative benefits because of this while most of the other areas see a benefit.
- These estimates of benefits and costs should be considered preliminary and are provided for the purpose of initial screening of management measures.
- Need determination of whether dam meets Probable Maximum Flood criteria and, if not, what would be necessary to meet the criteria.
- Corps Headquarters will need to determine whether the dam meets current Corps operation and design requirements. If the dam does not meet criteria, Headquarters will need to identify what dam modifications are required and these costs will be attributed to the measure. This effort cannot be initiated until FERC determines what modifications may be required to the dam for Puget Sound Energy (PSE) to meet FERC requirements.
- Measure has the potential to increase flooding for Sedro-Wooley in major events. This would need to be mitigated.
- Costs to structurally modify the dam have not been determined or included in this evaluation. Dam maintenance and operation costs attributed to additional flood storage would be a 100% local cost.
- Costs of measure are based strictly on hydropower loss from change in operations of the dam. Power loss compensation would be a 100% local cost.
- Potential environmental impacts have not been evaluated. Need to assure that this measure would not impact critical in-stream flows (i.e. spawning beds and fish stranding).

Measure 1C – Upper Baker Dam – 100K Storage – 0 cfs Outflow

This measure reduces the minimum flow released from Upper Baker Dam from 5,000 cfs to 0 cfs and increases the flood storage from 74,000 acre-feet to 100,000 acre-feet. The flood control follows what is set in the Water Control Manual. This measure reduces the outflow at the dam for all flood events.

Considerations for further Study:

- This measure reduces flows for all events greater than a 2-year flood at all locations.

- These estimates of benefits and costs should be considered preliminary and are provided for the purpose of initial screening of management measures.
- Corps Headquarters will need to determine whether the dam meets current Corps operation and design requirements. If the dam does not meet criteria, Headquarters will need to identify what dam modifications are required and these costs will be attributed to the measure. This effort cannot be initiated until FERC determines what modifications may be required to the dam for Puget Sound Energy (PSE) to meet FERC requirements.
- Costs to structurally modify the dam have not been determined or included in this evaluation. Dam maintenance and operation costs attributed to additional flood storage would be a 100% local cost.

- Costs of measure are based strictly on hydropower loss from change in operations of the dam. Power loss compensation would be a 100% local cost.
- Potential environmental impacts have not been evaluated. Need to assure that this measure would not impact critical in-stream flows (i.e. spawning beds and fish stranding).

Measure 1D – Upper Baker Dam – 110K Storage – 0 cfs Outflow

This measure reduces the minimum flow released from Upper Baker Dam from 5,000 cfs to 0 cfs and increases the flood storage from 74,000 acre-feet to 110,000 acre-feet. The flood control follows what is set in the Water Control manual. This measure reduces the outflow at the dam for all flood events but is only marginally better than 100K storage even in large events.

Considerations for further Study:

- This measure reduces flows for all events greater than a 2-year event at all locations.
- These estimates of benefits and costs should be considered preliminary and are provided for the purpose of initial screening of management measures.
- Corps Headquarters will need to determine whether the dam meets current Corps operation and design requirements. If the dam does not meet criteria, Headquarters will need to identify what dam modifications are required and these costs will be attributed to the measure. This effort cannot be initiated until FERC determines what modifications may be required to the dam for Puget Sound Energy (PSE) to meet FERC requirements.
- Costs to structurally modify the dam have not been determined or included in this evaluation.
- Dam maintenance and operation costs attributed to additional flood storage would be a 100% local cost.

- Costs of measure are based strictly on hydropower loss from change in operations of the dam. Power loss compensation would be a 100% local cost.
- Potential environmental impacts have not been evaluated. Need to assure that this measure would not impact critical in-stream flows (i.e. spawning beds and fish stranding).

Measure 2 – Lower Baker Dam

Lower Baker Dam is located at River Mile (RM) 1.2 on the Baker River tributary to the Skagit River, which comes into the Skagit River (RM 56.5) just upstream of the Concrete Gage. The drainage area above Lower Baker Dam is 297 square miles, of which, 82 square miles is between Upper and Lower Baker Dams which is an additional 3% of the drainage area and 15% combined for the Skagit River near Mount Vernon. With the existing flood control space and flow releases at Upper Baker Dam, Lower Baker Dam's combined existing outflow contribution to the 100-year flow is 16,500 cfs which represents 7.3% of the total flow (7,500 cfs is the runoff between Upper and Lower Baker Dam and 9,000 cfs is the release from Upper Baker). These measures are designed to reduce the flow contribution coming from Lower Baker Dam with storage and outflow adjustments.

The major advantage of this measure is that implementation can be carried out on an informal basis by Puget Sound Energy in appropriate flood events (case-by-case basis). Potential disadvantages include limited storage capacity, limited outflow capacity, and hydropower losses. In addition, new Corps HQ structure and design requirements must be met. Finally, the flood forecasting technology currently available does not allow for the sufficiently precise prediction of storm timing and magnitude that would be required for this project to be Federally authorized.

Measure 2A 1&2 – Lower Baker Dam – 15K Storage – 0 cfs Outflow

This measure would initiate flood control at Lower Baker Dam. This measure would set aside 15,000 acre-feet of storage for floods. In this evaluation, there is no way to maintain any storage by the time the peak flow occurs at Concrete using any conventional methods of flood control even for smaller events such as the 5-year and 10-year. This result is caused by two limitations. There is limited outflow capacity to maintain the storage (can only release 4000 cfs below the spillway crest), and the limited storage fills up with the excess inflow.

To define what is conventional, it is generally recognized that a set plan and storage needs to be in place before any flood occurs because, otherwise, the plan requires a very good understanding of the weather and its hydrologic response to act appropriately. An example of a set plan is what the Corps has with Upper Baker and that is that the Corps shuts flows down to minimum flows 3 hours before the unregulated (natural (without dam flow)) Skagit River near Concrete flow reaches 90,000 cfs and then reduces flows to 0 cfs until the flood peak passes and then begin to evacuate pool.

Considerations for further Study:

- Corps Headquarters will need to determine whether the dam meets current Corps operation and design requirements. If the dam does not meet criteria, Headquarters will need to identify what dam modifications are required and these costs will be attributed to the measure. This effort cannot be initiated until FERC determines what modifications may be required to the dam for Puget Sound Energy (PSE) to meet FERC requirements.
- Operation, as described, would require that the National Weather Service (NWS) could, with 90%+ certainty, forecast upcoming flood events' time, magnitude and duration to be sufficiently reliable for Corps authorization. Based on discussions with NWS, this is impossible.
- Costs to structurally modify the dam have not been determined or included in this evaluation. Dam maintenance and operation costs attributed to additional flood storage would be a 100% local cost.
- Costs of implementation of this measure are based strictly on hydropower loss from change in operations of the dam. Power loss compensation would be a 100% local cost.
- Potential environmental impacts have not been evaluated. Assurance that this measure would not impact critical in-stream flows (i.e. spawning beds and fish stranding) is needed.

Measure 2B 1&2 – Lower Baker Dam – 29K Storage – 0 cfs Outflow

This measure would initiate flood control at Lower Baker Dam. This measure would set aside 29,000 acre-feet of storage for floods. In this evaluation, there is no way to maintain any storage by the time the peak flow occurs at Concrete using any conventional methods of flood control even for smaller events such as the 5-year and 10-year. This result is caused by two limitations. There is limited outflow capacity to maintain the storage (can only release 4000 cfs below the spillway crest), and the limited storage fills up with the excess inflow.

To define what is conventional, it is generally recognized that a set plan and storage needs to be in place before any flood occurs because, otherwise, the plan requires a very good understanding of the weather and its hydrologic response to act appropriately. An example of a set plan is what we have with Upper Baker and that is that we shut flows down to minimum flows 3 hours before the unregulated (natural (without dam flow)) Skagit River near Concrete flow reaches 90,000 cfs and then reduce flows to 0 cfs until the flood peak passes and then begin to evacuate pool.

Considerations for further Study:

- Corps Headquarters will need to determine whether the dam meets current Corps operation and design requirements. If the dam does not meet criteria, Headquarters will need to identify what dam modifications are required and these costs will be attributed to the measure. This effort cannot be initiated until FERC determines what modifications may be required to the dam for Puget Sound Energy (PSE) to meet FERC requirements.

- Operation, as described, would require that the National Weather Service (NWS) could, with 90%+ certainty, forecast upcoming flood events' time, magnitude and duration to be sufficiently reliable for Corps authorization. Based on discussions with NWS, this is impossible.

- Costs to structurally modify the dam have not been determined or included in this evaluation. Dam maintenance and operation costs attributed to additional flood storage would be a 100% local cost.

- Power loss compensation would be a 100% local cost.

- Potential environmental impacts have not been evaluated. Assurance is needed that this measure would not impact critical in-stream flows (i.e. spawning beds and fish stranding).

Measure 2C 1&2 – Lower Baker Dam – 45K Storage – 0 cfs Outflow

This measure would initiate flood control at Lower Baker Dam. This measure would set aside 45,000 acre-feet of storage for floods. In this evaluation, there is no way to maintain any storage by the time the peak flow occurs at Concrete using any conventional methods of flood control even for smaller events such as the 5-year and 10-year. This result is caused by two limitations. There is limited outflow capacity to maintain the storage (can only release 4000 cfs below the spillway crest), and the limited storage fills up with the excess inflow.

To define what is conventional, it is generally recognized that a set plan and storage needs to be in place before any flood occurs because, otherwise, the plan requires a very good understanding of the weather and its hydrologic response to act appropriately. An example of a set plan is what we have with Upper Baker and that is that we shut flows down to minimum flows 3 hours before the unregulated (natural (without dam flow)) Skagit River near Concrete flow reaches 90,000 cfs and then reduce flows to 0 cfs until the flood peak passes and then begin to evacuate pool.

Considerations for further Study:

- Corps Headquarters will need to determine whether the dam meets current Corps operation and design requirements. If the dam does not meet criteria, Headquarters will need to identify what dam modifications are required and these costs will be attributed to the measure. This effort cannot be initiated until FERC determines what modifications may be required to the dam for Puget Sound Energy (PSE) to meet FERC requirements.
- Operation, as described, would require that the National Weather Service (NWS) could, with 90%+ certainty, forecast upcoming flood events' time, magnitude and duration to be sufficiently reliable for Corps authorization. Based on discussions with NWS, this is impossible.
- Costs to structurally modify the dam have not been determined or included in this evaluation. Dam maintenance and operation costs attributed to additional flood storage would be a 100% local cost.
- Power loss compensation would be a 100% local cost.
- Potential environmental impacts have not been evaluated. Assurance is needed that this measure would not impact critical in-stream flows (i.e. spawning beds and fish stranding).

Measure 3 – Ross Dam

Ross Dam is located at River Mile (RM) 105.20 on the Skagit River, which is just upstream of Newhalem. The drainage area above Ross Dam is 999 square miles which is roughly 32% of the drainage area for the Skagit River near Mount Vernon and would typically contribute roughly 18% of the peak flow seen on the Skagit River if there was no flood control. The Corps of Engineers currently has the authorization for flood control space that maximizes at 120,000 acre-feet on December 1st of the flood season. With the existing flood control space, Ross Dam outflow's current contribution to the 100-year flow is 10,500 cfs which represents 4.7% of the total flow. These measures are designed to reduce the flow contribution coming from Ross Dam with additional storage, timing, and minimum outflow adjustments.

The potential advantage of this measure is the reduction of flows for events greater than the 10-year event. Potential disadvantages include impacts to endangered species, hydropower losses, and impacts to Seattle City Light facilities. In addition, the measure would require re-opening of the FERC license, and might require negotiations with Canada.

Measure 3A – Ross Dam – 150K Storage – 0 cfs Outflow

This measure increases the flood storage set aside from 120,000 acre-feet to 150,000 acre-feet and sets the minimum flow released from Ross Dam to 0 cfs. The flood control follows what is set in the Water Control manual. This measure reduces the outflow at the dam for flood events greater than or equal to a 25-year event. This measure reduces flows for all events greater than a 10-year event at all locations.

Considerations for further Study:

- Seattle Public Utilities (SPU) is not supportive of modifying the operation or structure of their dams. Modifications could require a reopening of their FERC license and could impact their launch and other facilities. Increases in pool elevation would require international negotiations with Canada.
- Cost attributable to any changes in operation or maintenance, or hydropower losses would be funded 100% by the local sponsor.

- The estimate of benefits should be considered preliminary and are provided for the purpose of initial screening of management measures.
- Environmental impacts of modifications have not been identified.

Measure 3B – Ross Dam – 180K Storage – 0 cfs Outflow

This measure increases the flood storage set aside from 120,000 acre-feet to 180,000 acre-feet and sets the minimum flow released from Ross Dam to 0 cfs. The flood control follows what is set in the Water Control manual. This measure reduces the outflow at the dam for flood events greater than or equal to a 25-year event. This measure reduces flows for all events greater than a 10-year event at all locations.

Considerations for further Study:

- Seattle Public Utilities (SPU) is not supportive of modifying the operation or structure of their dams. Modifications could require a reopening of their FERC license and could impact their launch and other facilities. Increases in pool elevation would require international negotiations with Canada.
- Cost attributable to any changes in operation or maintenance, or hydropower losses would be funded 100% by the local sponsor.
- Benefit estimates should be considered preliminary and are provided for the purpose of initial screening of management measures.
- Environmental impacts of modifications have not been identified.

Measure 4 – Nookachamps Storage

This measure attempted to follow the design and modeling provided by PIE in 2006. This design is a levee structure on the left bank from the Highway 9 bridge just downstream of Sedro-Woolley (River Mile (RM) 22.7) to the BNSF Bridge at the beginning of the three bridge corridor (RM 17.56). There is a gate at the upstream end that would control when the water entered into the storage area. The design of this measure has a gate that is 15 feet high and 300 feet wide and has an invert of 35 feet NGVD 29. The gate opens when the flow through the 3 bridge corridor approaches 140,000 cfs.

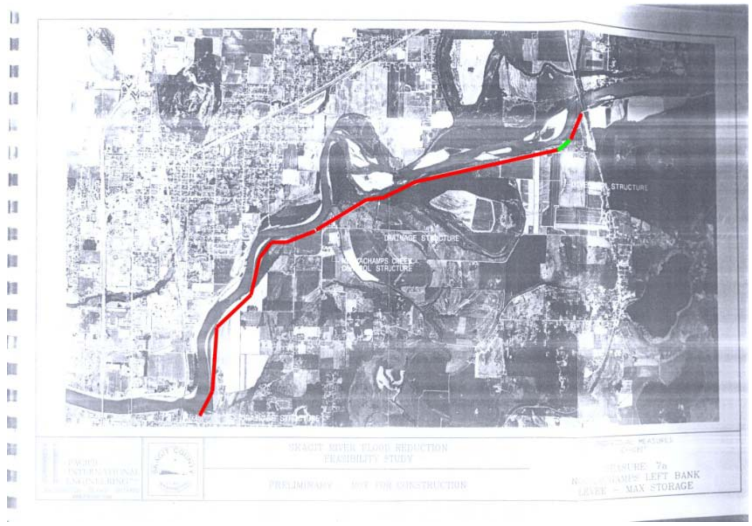


Table 8 presents damages by reach in the without-project condition, with Measure 4 in place, and damages prevented (benefits), calculated using HEC-FDA flood damage analysis software.

Measure 5 – Hart's Slough Storage

This measure attempted to follow the design and modeling provided by PIE in 2006. This design is a levee structure on the left bank from the Highway 9 bridge just downstream of Sedro-Woolley (River Mile (RM) 22.7) to the start of the levee system at RM 21.6. There is a gate at the upstream end that would control when the water entered into the storage area. The design of this measure has a gate that is 15 feet high and 170 feet wide and has an invert of 35 feet NGVD 29. The gate opens when the flow through the 3 bridge corridor approaches 140,000 cfs.

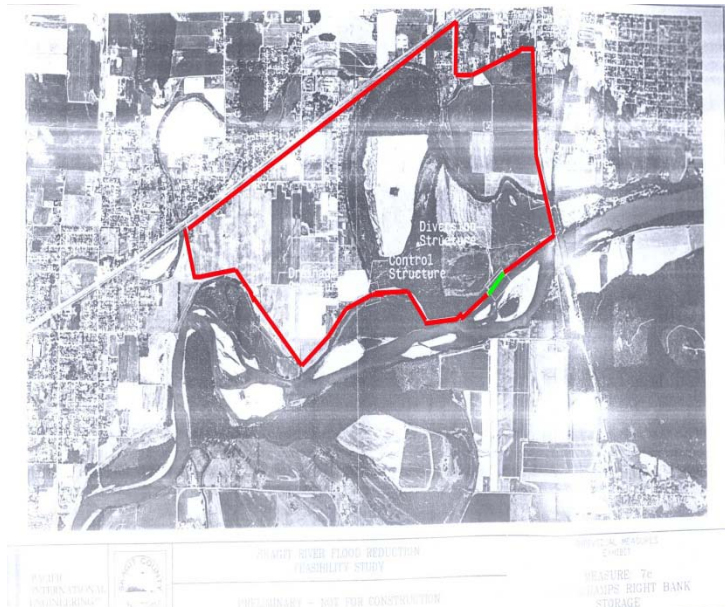
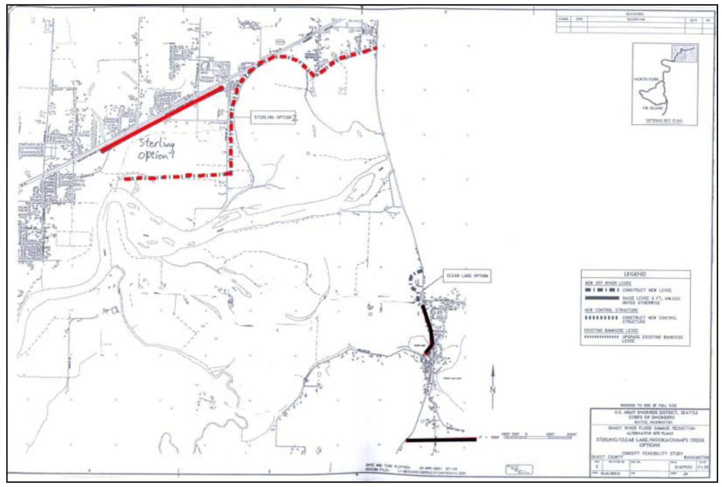


Table 9 presents damages by reach in the without-project condition, with Measure 5 in place, and damages prevented (benefits), calculated using HEC-FDA flood damage analysis software.

Measure 6 – Sterling Levee

This levee is designed to plug up the low spot in the Highway 20 and railroad that is found on the right bank at roughly RM 21.9 where the ground elevation dips to 39.9 feet NGVD 29. This elevation corresponds to roughly a 10-year flood elevation so any floods larger than a 10-year flood (125,000 cfs) allows water to overflow in this area and eventually makes its way into Burlington. This area has been flood fought in the past but this measure would make the structure more permanent.



There were two designs for this levee developed in 2001 that are shown in the picture above. One of them ties in the levee at the upstream side at Sedro-Woolley and the downstream side at the existing levee system. It also encompasses most of the houses that are found in this area. The other design raises the ground elevation for the low spot only to match what is upstream and downstream.

Major potential advantages for this measure are that it will be considered in conjunction with a large levee system during alternatives analysis, and that the addition of an optional setback would have less environmental impacts. Potential disadvantages include a lack of significant flood protection as a stand-alone project, lack of completed environmental impacts analysis, possibility of relocation requirements with the setback option, and that sub-measure 6B is limited to protection between 10- and 20-year events.

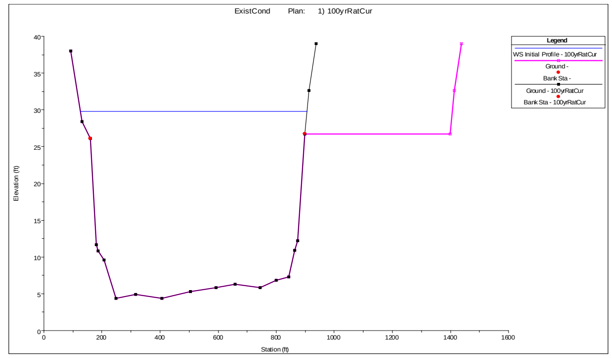
Considerations for further Study:

- This measure will be considered in conjunction with a larger levee system during alternatives analysis. It does not provide significant flood protection as a stand-alone project.
- This measure does not represent protection by itself, but is tied to the protection downstream. There is some benefit to filling in the low spot (not yet quantified). However, in the analysis, the results would only appear for events above a 10-year, and below a 20-year probability. In the levee failure analysis that has been completed, additional levees fail beyond a 20-year event, making it difficult to distinguish between the flooding caused by overtopping, and the flooding

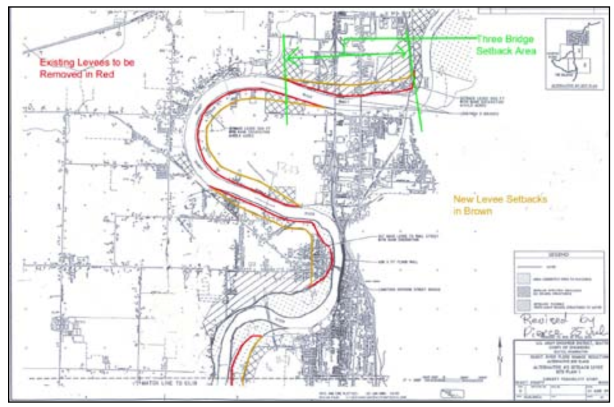
caused by other levee failures that contribute water to this same area. A detailed analysis of only this levee is possible, but may not be pragmatic. Unless the Sterling Levee is the only other chosen measure, the analysis may not be warranted. It is best at this time to tie this levee to Measure 15 - Improve Levee System – Right Bank.

- The environmental impacts of this measure have not been evaluated.

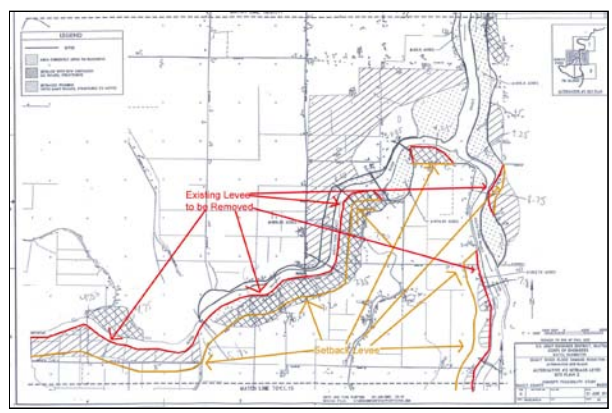
Measure 7 – Levee Setback - Downstream of 3-Bridge Corridor



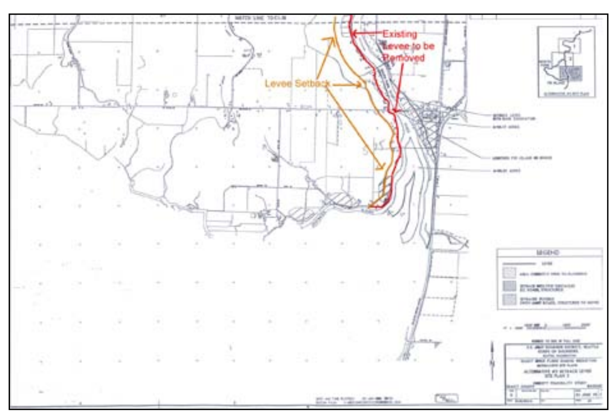
This setback is designed to improve the levee system's ability to move more water downstream by giving the river more area to move downstream. This setback starts just downstream of the I-5 bridge (RM 16.8) and extends out both the North and South Forks. The setback starts below the three-bridge area to see what the benefit is without having to expensively rebuild the three bridges. The Mount Vernon Bridge would still need to be set back as well as the North Fork and South Fork bridges. The picture shows the existing cross section with the black dots and the revised setback cross section in pink. The next three pictures show the plan view with the setback including everywhere but the area in green.



This measure is a 500 foot setback on the Mainstem from RM 16.8 to the Forks, the North Fork from the Mainstem to its mouth, and the South Fork from the Mainstem to its mouth. The setback starts at the top of bank elevation and the levee is moved back 500 feet from where it currently is. The setback alternates which side of the bank it is on based on a preliminary look at where the real estate would be cheaper to obtain. This layout is as follows:



<u>Mainstem</u>
Left Bank – RM 16.8 to 13.8
Right Bank – RM 13.8 to 11.7
Left Bank – RM 11.7 to Forks
<u>North Fork</u>
Left Bank – RM 9.25 to mouth



<u>South Fork</u>
Left Bank – RM 9.25 to 7.8

Right Bank – RM 7.8 to mouth

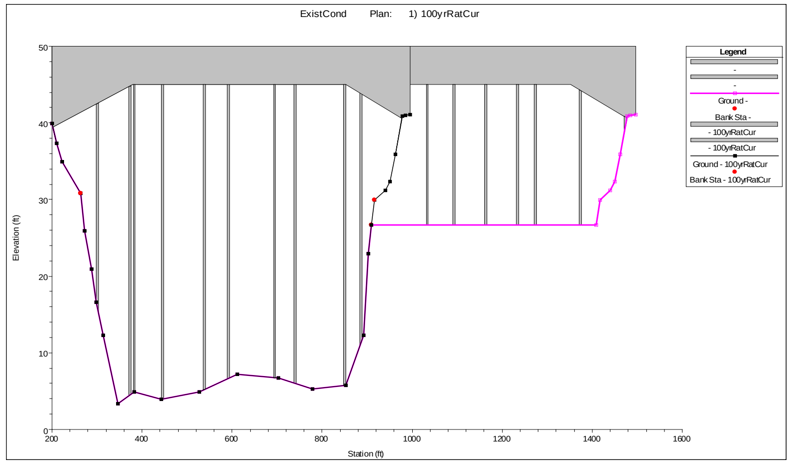
Potential advantages of this measure include the reduction of induced flooding and required levee height, as well as the minimization of environmental impact and the provision of riparian improvement opportunities. Potential disadvantages include the necessary modifications to bridges (Mount Vernon, North Fork, and South Fork), the difficulty of raising a levee on only one side of the river (induced flooding), increased sediment transport, increased localized flooding, impacts to agricultural land, and potential toxic contamination. Also, the measure will require purchasing of property (relocation) and replacement of existing infrastructure (i.e. West Mount Vernon).

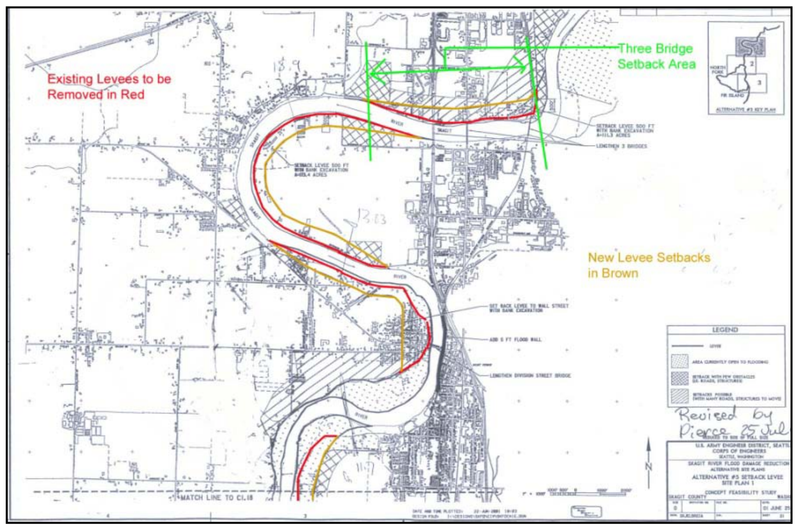
Consideration for further study:

- At this time, this measure has only been run with the levee setback elevations being the same as the existing levee elevations. This is partly because the improvement alternates from one side of the river to the other. It would be difficult to raise one side and not the other, particularly when it is not connected all the way from upstream to downstream. Running a setback levee all on the same side will alter the costs of the measure.
- Environmental impacts have not been evaluated. However, setting back levees generally minimizes environmental impact.

Measure 8 – Levee Setback – Three Bridge Corridor Only

This setback is designed to improve the levee system's ability to move more water downstream past the three bridge corridor by giving the river more area to move in this area. This setback starts at the BNSF RR bridge (RM 17.56) and ends just downstream of the I-5 bridge (RM 16.8). This setback is designed to determine the benefit of the setback just at the three bridge area. This involves the replacement of the BNSF RR bridge, the Riverside bridge, and the I-5 Bridge. The picture below shows the existing cross section with the black dots and the revised setback cross section in pink. The next picture below shows the plan view of the setback in the green area.





This measure is a 500 foot setback on the Mainstem right bank from RM 17.56 to 16.8. The setback starts at the top of bank elevation and the levee is moved back 500 feet from where it currently is. The setback alternates which side of the bank it is on based on a preliminary look at where the real estate would be cheaper to obtain. This layout is as follows:

<u>Mainstem</u>
Right Bank – RM 17.56 to 16.8

Potential advantages of this measure include the reduction of flooding upstream of the 3-Bridge Corridor, minimization of environmental impact, opportunities for riparian improvements, and indirect reduction of debris management issues through bridge modifications. Potential disadvantages include the necessity of bridge modifications, Hwy 99 abutments replacements, the possibility of worsening downstream flooding, and the real estate purchasing requirements for setbacks (relocations, road/infrastructure replacement). In addition, bridge modifications would be the responsibility of

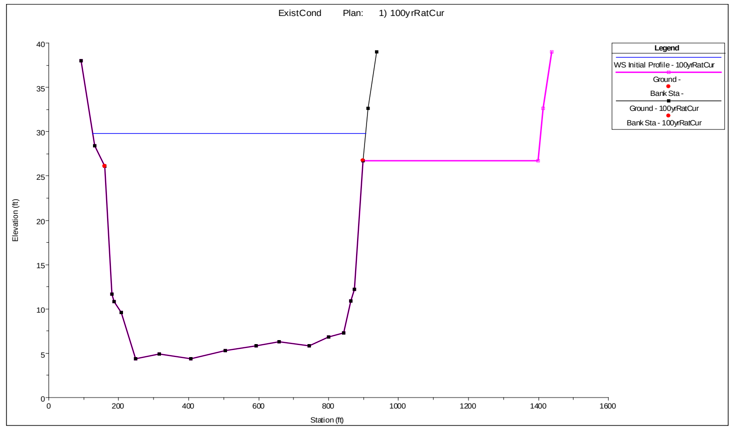
WSDOT and BNRR, but a Corps project must "stand on its own". It would be invalid to assume that bridges would be modified in time for the Corps project.

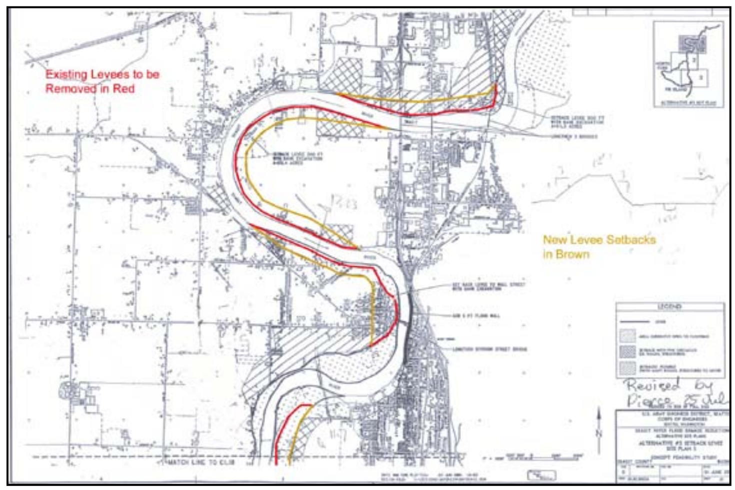
Consideration for further study:

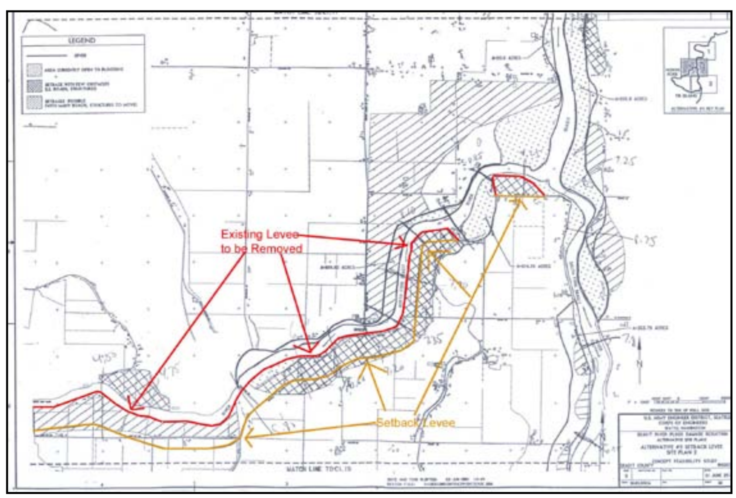
- Elimination of river constriction will require significant modifications to the three bridges.
- At this time, this measure has only been run with the levee setback elevations being the same as the existing levee elevations. This is partly because the improvement alternates from one side of the river to the other. It would be difficult to raise one side and not the other, particularly when it is not connected all the way from upstream to downstream. Running one side only will alter the costs of the measure.
- Environmental impacts have not been evaluated. However, setting back levees generally minimizes environmental impact.

Measure 10 – Setback Levees Mainstem and North Fork Only

This setback is designed to improve the levee system's ability to move more water downstream by giving the river more area to move downstream. This setback starts at the beginning of the three bridge corridor at the BNSF Bridge (RM 17.56) to where the mainstem splits into the North and South Forks and then extends out the North Fork. The setback only extends down the North Fork to see whether the North Fork is the main downstream constriction of the two forks. This requires setting back 5 bridges. The picture below shows the existing cross section with the black dots and the revised setback cross section in pink. The next 2 pictures below show the plan view of the setback.







This measure is a 500 foot setback on the Mainstem from RM 17.56 to the Forks and the North Fork from the mainstem to its mouth. The setback starts at the top of bank elevation and the levee is moved back 500 feet from where it currently is. The setback alternates which side of the bank it is on based on a preliminary look at where the real estate would be cheaper to obtain. This layout is as follows:

<u>Mainstem</u>

Left Bank – RM 17.56 to 13.8

Right Bank – RM 13.8 to 11.7

Left Bank – RM 11.7 to Forks

North Fork
Left Bank – RM 9.25 to mouth

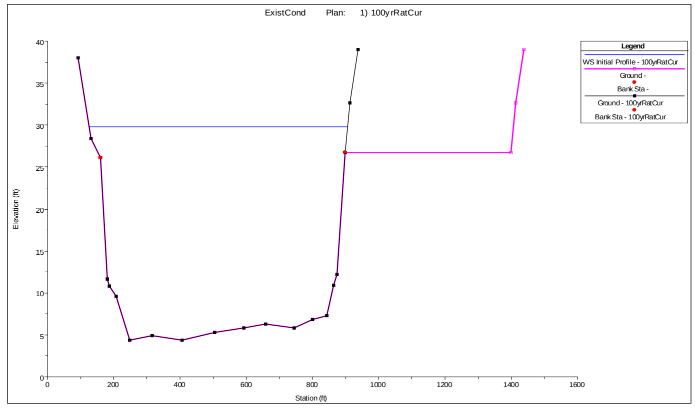
Potential advantages of this measure include the reduction of induced flooding, the minimization of environmental impacts, and the opportunity for riparian improvements. Potential disadvantages include the required setback of five bridges, increased sediment transport, localized erosion, relocation requirement, and the difficulty in raising a levee on only one side of the river. In addition, Corps policy does not support projects that encourage development in rural areas. Lastly, large property purchases and infrastructure replacement would be necessary.

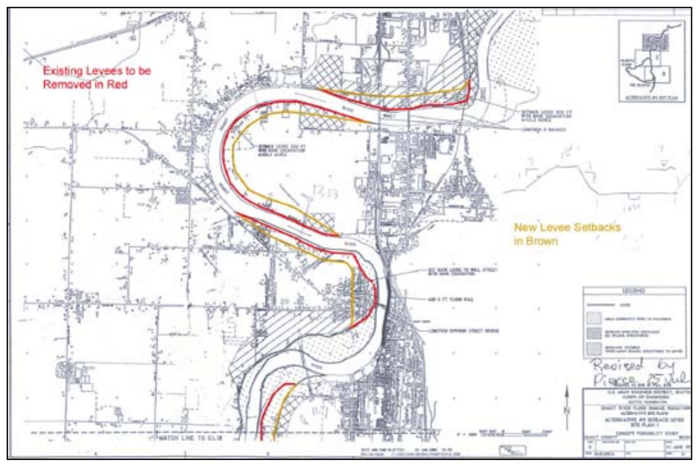
Consideration for further study:

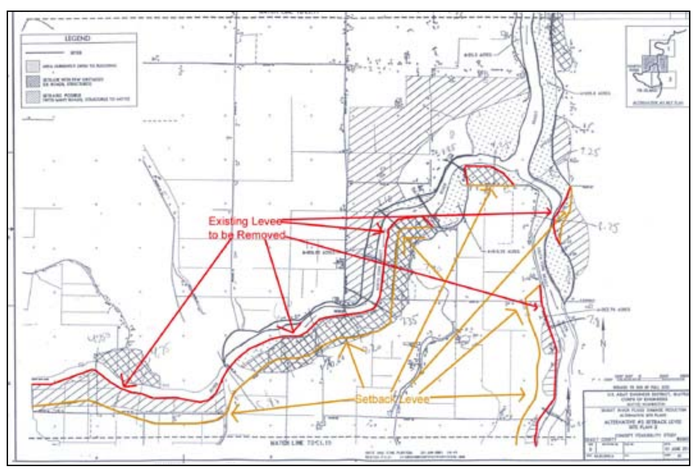
- At this time, this measure has just been run with the levee setback elevations as the same as the existing levee elevations. This is partly because the improvement alternates from one side of the river to the other. It would be difficult to raise one side and not the other, particularly when it is not connected all the way from upstream to downstream. Running it with a levee only on one side will alter the costs of the measure.
- Environmental impacts have not been evaluated. However, setting back levees generally minimizes environmental impact.

Measure 13 – Setback Levees – Entire System

This setback is designed to improve the levee system's ability to move more water downstream by giving the river more area to move downstream. This setback starts at the beginning of the three bridge corridor at the BNSF Bridge (RM 17.56) to where the mainstem splits into the North and South Forks and then extends out both the North Fork and South Fork Skagit River. This requires setting back 5 bridges. The picture below shows the existing cross section with the black dots and the revised setback cross section in pink. The next 3 pictures below show the plan view of the setback.







This measure is a 500 foot setback on the Mainstem from RM 17.56 to the Forks, the North Fork from the mainstem to its mouth, and the South Fork from the mainstem to its mouth. The setback starts at the top of bank elevation and the levee is moved back 500 feet from where it currently is. The setback alternates which side of the bank it is on based on a preliminary look at where the real estate would be cheaper to obtain. This layout is as follows:

<u>Mainstem</u>

Left Bank – RM 17.56 to 13.8

Right Bank – RM 13.8 to 11.7

Left Bank – RM 11.7 to Forks

<u>North Fork</u>

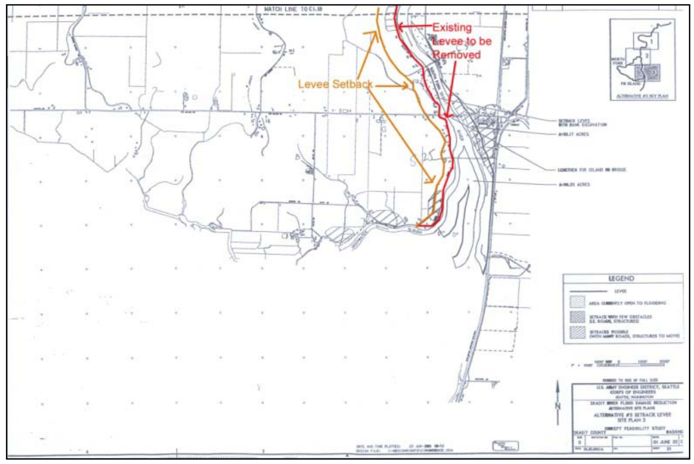
Left Bank – RM 9.25 to mouth

<u>South Fork</u>

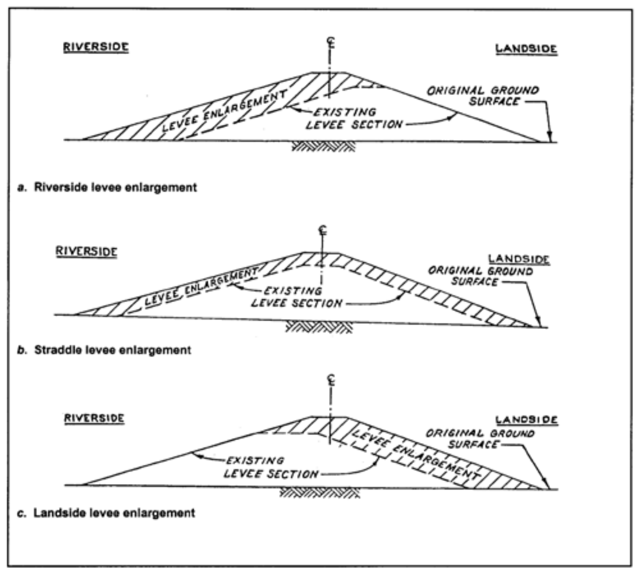
Left Bank – RM 9.25 to 7.8

Right Bank – RM 7.8 to mouth

Potential advantages of this measure include the reduction of induced flooding, the minimization of environmental impacts, and the opportunity for riparian improvements. Potential disadvantages include Corps policy on not supporting encouragement of rural development, setback of 5 bridges, increased sediment transport, increased localized erosion, and the difficulty in raising a levee on only one side of the river. In addition, the measure would require property purchased for a wider levee footprint and replacing large portion of existing infrastructure.



Considerations for further study:



a. Riverside levee enlargement

b. Straddle levee enlargement

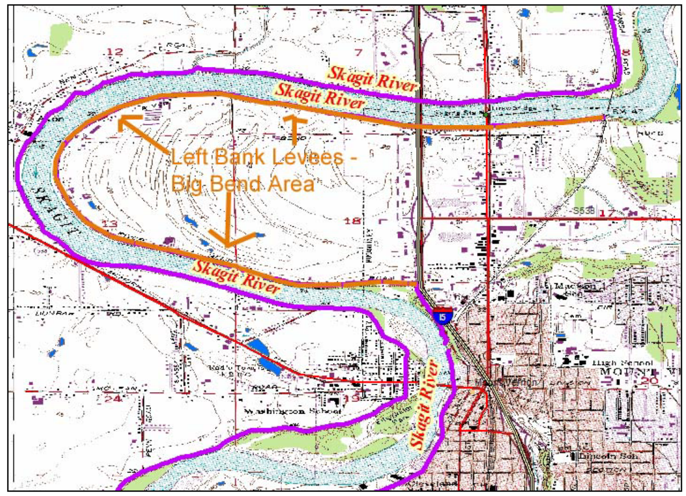
c. Landside levee enlargement

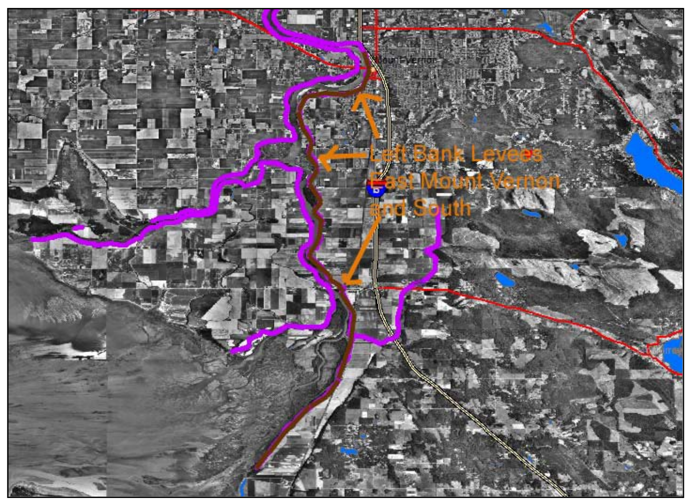
- At this time, this measure has only been run with the levee setback elevations at the same elevation as the existing levee elevations. This is partly because the improvement alternates from one side of the river to the other. It would be difficult to raise one side and not the other, particularly when it is not connected all the way from upstream to downstream. Running a setback levee with it all on one same side will alter the costs of the measure.
- Environmental impacts have not been evaluated. However, setting back levees generally minimizes environmental impact.

Measure 14 – Improve Levee System – Left Bank

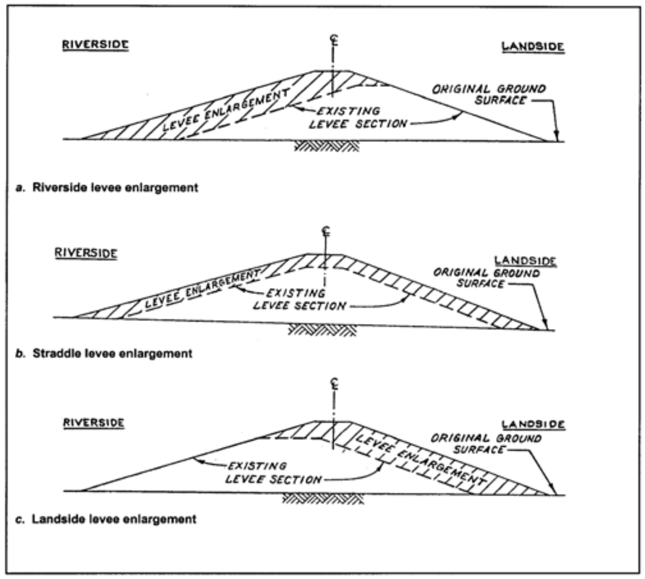
This improvement of existing levee measure is evaluating the benefits of raising the left bank levee system that protects the North Mount Vernon area (RM 17.56 to RM 13.1) as well as from East Mount Vernon south to Stanwood (RM 13.1 to the mouth of the South Fork).

The major potential advantage of this measure is the minimal change in footprint versus a setback levee. Potential disadvantages include violation of Corps policy and Executive Order 11988, requirement to improve entire system, mitigation requirement for environmental impacts, increased sedimentation and localized erosion, and the difficulty in raising a levee on only one side of the river.



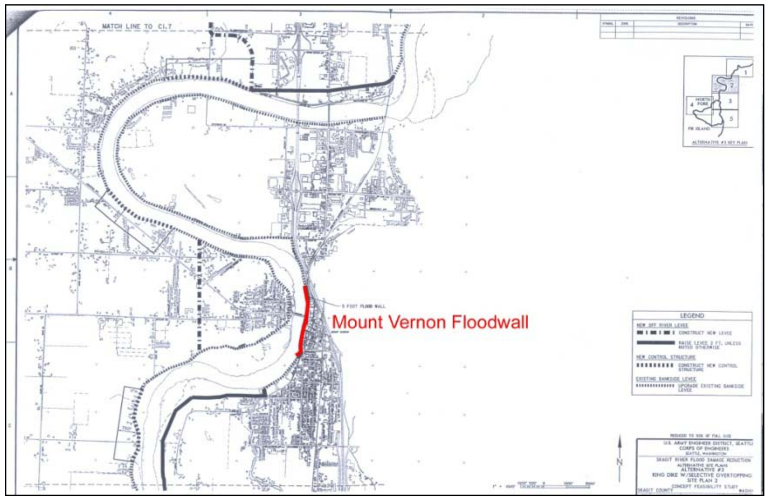


Measure 15 – Improve Levee System – Right Bank



The improve right bank existing levee measure is evaluating the benefits of raising the levee system that protects the right bank of the Skagit River from Highway 9 (RM 22.7) to the mouth of the North Fork Skagit River. The right bank existing levee system on the Mainstem starts at RM 20.9 and is continuous through the North Fork right bank except for minor sections on the right bank of the North Fork where there are parts that are tied to high ground. The costs for this design are derived from PIE's Interim Evaluation of Measures Report (April 2006) by combining elements Sterling Levee (page 105), Right bank Levee Highway 9 (Rhodes Road) to BNSF Bridge (page 111), 3a – DD12 Right Bank River Bend Setback Levee (page 131), 3b - River Bend Setback Levee (page 131), 5b - Mount Vernon Right Bank Levee (page 191), 5c - Mount Vernon Right Bank Levee (page 191), 10b – DD1 – Right Bank Levee RM 12 to Fork (page 191), and North Fork Right Bank Levee (page 247).

Measure 16 – Mount Vernon Floodwall



The Mount Vernon Floodwall is a design to reduce damages to downtown East Mount Vernon by building a floodwall to eliminate the low spot that is currently sandbagged during floods. This evaluation has similar challenges as the Sterling Levee in that it is difficult to quantify damages

The Mount Vernon Floodwall is designed to plug up the low spot on the left bank at East Mount Vernon (RM 12.96) to RM 12.4. This area is currently sandbagged during floods and has a rough ground elevation of 28 to 29 feet NGVD 29 which corresponds to roughly a 10-year water surface (120,000 cfs). Floods larger than a 10-year flood, therefore, could allow water to overflow into downtown East Mount Vernon if the area was not sandbagged. This measure would make the structure more permanent.

The design for this floodwall developed in 2001 is shown in the picture above. The design raises the ground elevation for the low spot only to match what is upstream and downstream.

Potential advantages of this measure include a permanent feature to reduce damages in East Mount Vernon (replace annual flood fighting), and the minimization of impacts to structures adjacent to the river, compared to a levee. Potential disadvantages include lack of significant flood protection as a stand-alone project, impacts to commercial structures (i.e. parking), restriction of public access to the river, and the need to assess impacts on historic buildings.

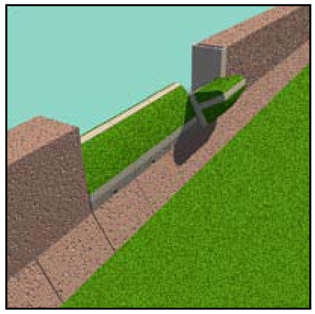
Considerations for further study:

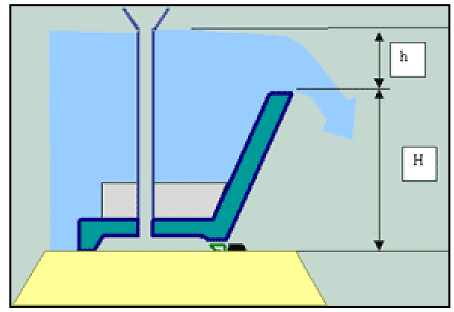
- This measure could impact Mount Vernon commercial structures near the river. Possible induced flooding will need to be evaluated and mitigated.
- The challenge with this measure is that it does not represent protection by itself, but is tied to the protection upstream and downstream. There is a benefit to filling in the low spot but, in the analysis, the results would only appear between a 10-year event and a 25-year event. In the levee failure analysis that was completed, some additional levees fail beyond a 25-year event and so it becomes difficult to distinguish the flooding being caused by this overtopping and the

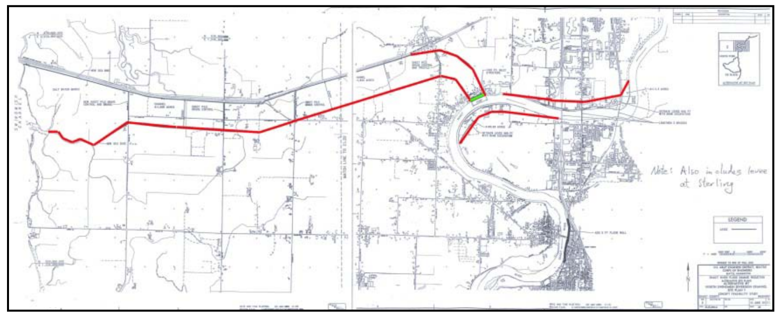
flooding caused by levees failing that contribute water to this same area. This analysis can be done but would take some extensive analysis that may not be worth it unless we plan to only do the Mount Vernon Floodwall at a minimal protection level and not do anything else. It is best at this time to extend this floodwall and make it a ring dike as is done in Measure 35 – East Mount Vernon Ring Dike.

Measure 17 - Swinomish Bypass

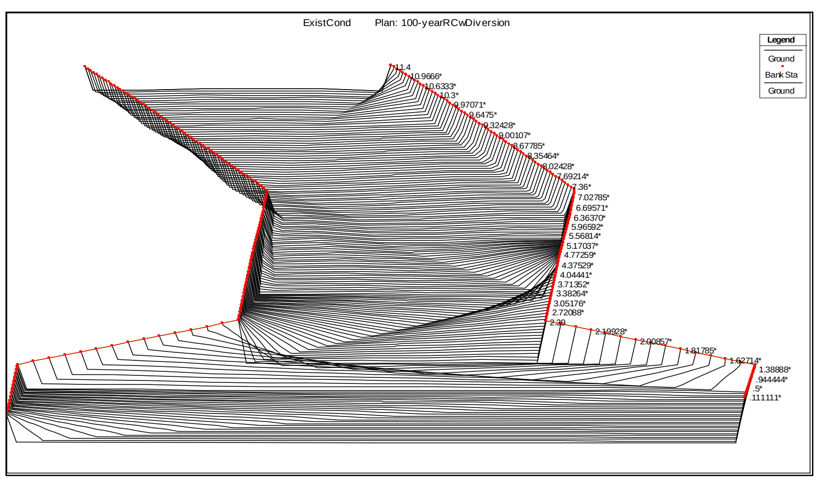
The Swinomish Bypass is a design to divert water out to the Swinomish Channel to Padilla Bay through a fusegate "designed fail" system where the levee would fail at a specific elevation and location and then this overflow would be leveed in down to the Swinomish Channel. The Bypass would be 6.7 miles long. This also requires a setback of the levee in the three-bridge corridor to get the flow through to the bypass.







The Swinomish Bypass design diverts water at the end of the first river bend past the three bridge corridor (RM 15.9). The fuseplugs would be designed to start failing at a water surface of 34.5 feet NGVD 29. They fail in 200 foot increments with the second failing at 34.7 feet NGVD 29 and the third at 34.9 feet NGVD 29. This measure maxes out at 600 feet wide. The 34.5 feet elevation is the elevation of the 25-year existing condition water surface in the average levee failure condition. The water that spills out is contained in a 2000 foot wide corridor with levees on both sides and expanding to 5000 feet for the last 1.5 miles down by the Swinomish Channel. No excavation is done in this measure on the route to the Swinomish Channel. The design currently is for the area to be maintained during the winter in a way that keeps the roughness of the channel down. The setback of the levee in the three-bridge corridor is 500 feet.



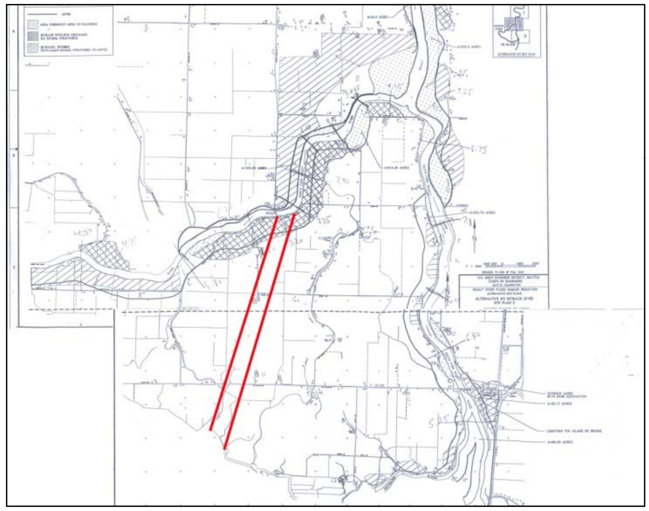
Potential advantages of this measure include the lack of catastrophic failure risk, and the added potential for recreation and/or environmental features. Potential disadvantages include sediment deposition into Padilla Bay (a marine sanctuary), localized erosion, impacts to Swinomish Slough, impacts to agricultural land, and required evaluation of setting weir elevation to a 5 to 10-year event. In addition, benefits will not be fully realized until 3 bridges are replaced.

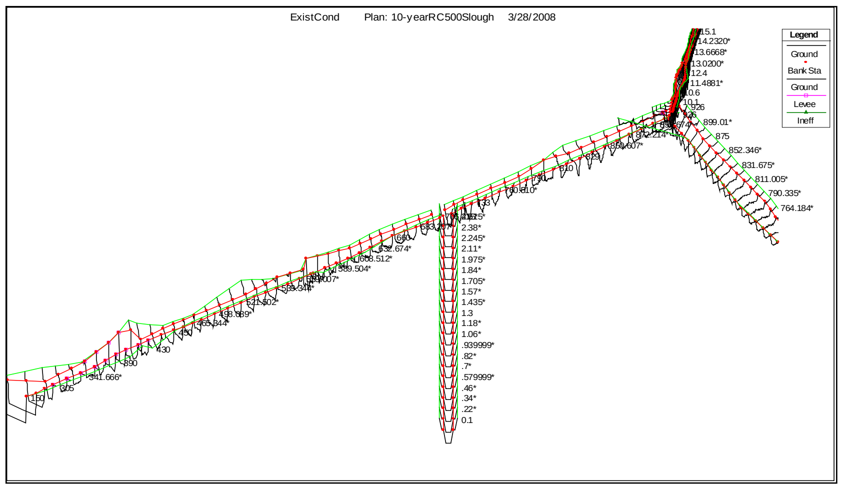
Considerations for further study:

- This measure does not realize its full benefit because the bypass does not become effective until water is already high enough on the levees that it can cause failures. The economic analysis sees these river stages and equates the damages that can be seen when failures occur. It is also unlikely that necessary freeboard (to make the levee system certifiable) will be available if we wait this late to have the levee fail into the diversion. We probably want to look at allowing this diversion to become effective several feet lower.
- Environmental impacts have not been evaluated. Potential concerns include impacts to the Swinomish Channel and Padilla Bay.

Measure 18 – Fir Island Bypass

The Fir Island Bypass is a design to divert water from the North Fork Skagit River out to Skagit Bay. This is an excavated channel from a location on the North Fork Skagit River to Skagit Bay. This design is to help with overcoming the limited capacity of the North Fork Skagit River to convey flow to Skagit Bay. The location chosen is done to minimize movement of known residences, creation of new bridges, and length of the bypass. The bypass is 2.7 miles long and would require new bridges on Moore Road and Fir Island Road.





Potential advantages of this measure include a lack of catastrophic failure risk, the potential for environmental or recreational features, added environmental complexity to delta, no induced flooding, reduced flooding in Mount Vernon, and has a wider channel with levees as an option. Potential disadvantages of this measure include diversion of sediment to the central portion of the Skagit Bay shoreline, impacts to agricultural land, infrastructure improvement requirements, lack of economic justification as a stand-alone project, relocation requirements, and potential impacts to eelgrass beds.

Measure 18A – Fir Island Bypass – 500 feet

The Fir Island Bypass is a design to divert water from the North Fork Skagit River out to Skagit Bay at RM 7.2 of the North Fork. The bypass channel starts with a thalweg elevation that mimics RM 7.2 of the North Fork (-10 feet NGVD 29) and exits into Skagit Bay with a thalweg elevation of -20 feet NGVD 29. This measure's bypass is 500 feet wide. The design currently is for the area to be maintained during the winter in a way that keeps the roughness of the channel down.

Considerations for further study:

- There is a potential concern to the loss of farmland.
- Design would require replacement of bridge(s).
- There is a potential benefit from creating fresh water flow to the Skagit Estuary.

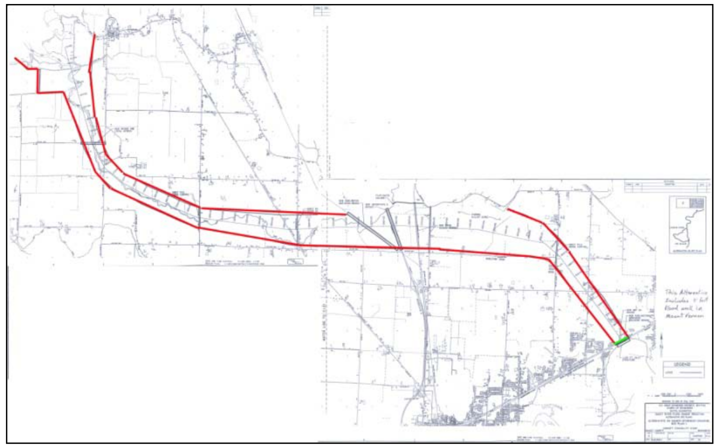
Measure 18B – Fir Island Bypass – 1500 feet

The Fir Island Bypass is a design to divert water from the North Fork Skagit River out to Skagit Bay at RM 7.2 of the North Fork. The bypass channel starts with a thalweg elevation that mimics RM 7.2 of the North Fork (-10 feet NGVD 29) and exits into Skagit Bay with a thalweg elevation of -20 feet NGVD 29. This measure's bypass is 1500 feet wide. The design currently is for the area to be maintained during the winter in a way that keeps the roughness of the channel down.

Considerations for further study:

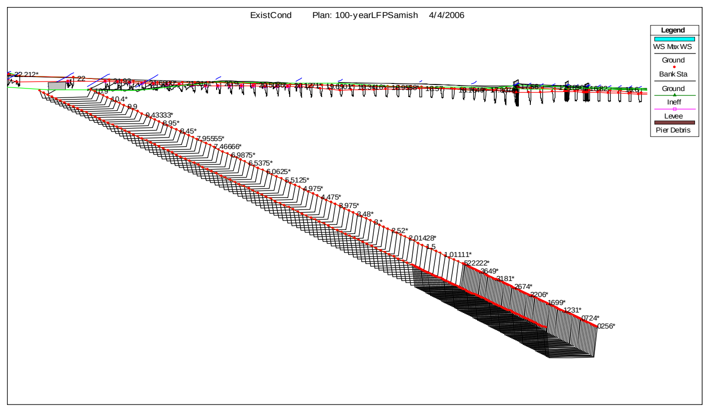
- There is a potential concern to the loss of farmland.
- Design would require replacement of bridge(s).
- There is a potential benefit from creating fresh water flow to the Skagit Estuary.

Measure 19 – Samish Bypass



The Samish Bypass is a design to divert water out of the system before the river reaches the three bridge corridor. This bypass takes water out of the system at the northernmost point of Hart's Slough at RM 22.0.

The bypass goes north of the city of Burlington and follows the Samish River out to Samish Bay. This route is roughly 11 miles long and would require 9 bridges (Collins Road, District Line Road, Sheen Road, Burlington Alder Road, I-5, BNRR, Chuckanut Drive, Thomas Road, Farm to Market Road).



The Samish Bypass design diverts water at the northernmost point of Hart's Slough at RM 22.0 into a 1500 foot wide corridor with levees on both sides. No excavation is done in this measure on the route to Samish Bay. The entrance to the corridor is at 40.5 feet NGVD 29 which would start taking in water at floods slightly larger than a 10-year flood. The design currently is for the area to be maintained during the winter in a way that keeps the roughness of the channel down.

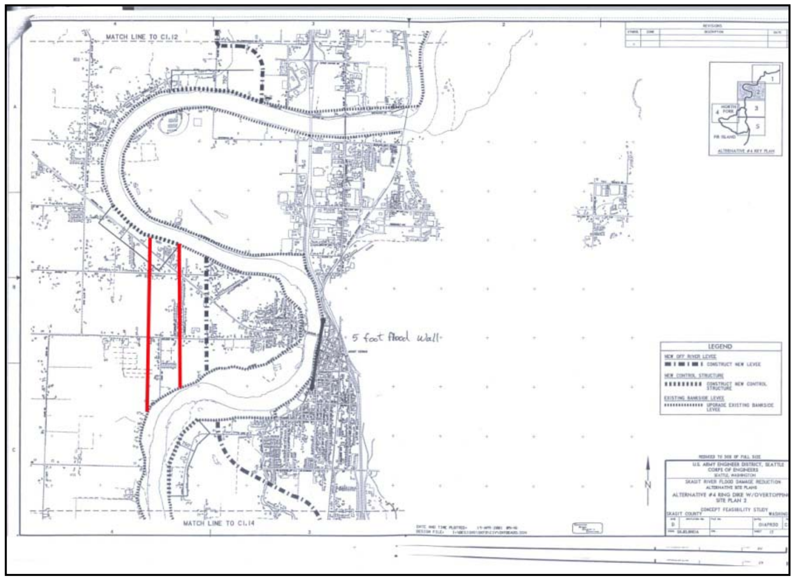
Potential Advantages of this measure include lack of catastrophic failure risk, potential for added recreation and/or environmental features, and removal of water upstream of the 3-bridge corridor. Potential disadvantages of this measure include the required construction (9 bridges, levees, excavation), weir height evaluation requirement, Samish basin impact analysis requirement, environmental impact analsyis requirement, impacts from cross-basin fish mixing, impacts to agricultural land, and diversion of fine sediments to Samish Bay during flood events.

Considerations for future study:

- This is the only measure that removes flow from the Skagit upstream of the Three Bridge Corridor. This measure will need to evaluate induced flooding to the Samish River system.
- This measure has challenges in showing major benefits because the bypass does not become effective until water is already high enough on the levees that it can cause failures. The economic analysis sees these river stages and equates the damages that can be seen when failures occur. The initial bypass grade is not very favorable to move a lot of flow. To make it more effective, a lot of excavation in this upper reach is probably necessary.
- Environmental impacts have not been evaluated. A potential issue is the cross basin mixing of the Skagit and Samish Rivers and resulting impacts on fish.

Measure 20 – Mount Vernon Bypass

The Mount Vernon Bypass is a design to overcome the constriction of the Skagit River at the Division Street Bridge. This increases conveyance in this area by creating an additional channel from upstream of West Mount Vernon at RM 14.0 to downstream at RM 11.2 (see picture below). This bypass is 1 mile long and requires two bridges at Highway 536 (Memorial Highway) and McLean Road.



Potential advantages of this measure include reduction of flood elevations near Mount Vernon, elimination of catastrophic failure risk, potential for added recreation and/or environmental features, minimization of environmental impact, and opportunity for riparian improvements. Potential disadvantages include infrastructure modification requirements, relocation requirements, loss of urban land, downstream sediment deposition, erosion, and possible levee improvements downstream of outlet. In addition, the measure may need to be combined with another to minimize the impacts to Fir Island.

Measure 20A – Mount Vernon Bypass – 500 feet

The Mount Vernon Bypass is an excavated channel that has a thalweg that is in between the thalwegs seen on the Skagit River at RM 14.0 and that of the Skagit River at RM 11.2 downstream (-5 feet NGVD 29). This measure's bypass is 500 feet wide.

Considerations for future study:

- These benefits should be considered preliminary and are provided for the purpose of initial screening of management measures.
- Environmental impacts have not been evaluated.
- Costs have not been evaluated.

Measure 20B – Mount Vernon Bypass – 1500 feet

The Mount Vernon Bypass is an excavated channel that has a thalweg that is in between the thalwegs seen on the Skagit River at RM 14.0 and that of the Skagit River at RM 11.2 downstream (-5 feet NGVD 29). This measure's bypass is 1500 feet wide.

Considerations for future study:

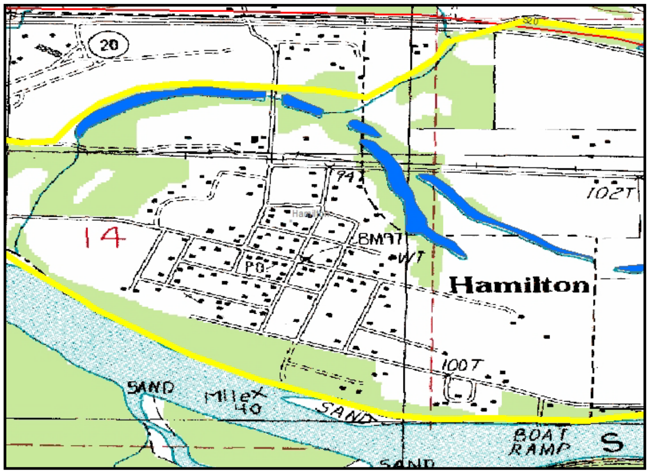
- These estimates of benefits and costs should be considered preliminary and are provided for the purpose of initial screening of management measures.
- Environmental impacts have not been evaluated.
- Costs have not been evaluated.

Measure 25 – Nonstructural Measures

Non-structural measures will be further evaluated in future analysis. Prerequisites to the evaluation of non-structural measures are as follows. The new hydraulic analysis must be completed, including the new levee failure analysis, followed by generation of alternatives. These prerequisites will better define the areas where non-structural measures might be practicable. Examples of non-structural measures that may be evaluated include: flood proofing, relocations, landscape features, and flood warning evacuation systems.

Potential advantages of these measures include minimal environmental impacts, and increased public safety and awareness. The major potential disadvantage is that these measures allow residual damages.

Measure 26 – Hamilton Relocation



Hamilton is being considered for nonstructural flood damage reduction and relocation. A Section 205 study completed by the Corps in the 1980's indicated that a structural solution for Hamilton is not feasible. This evaluation will take place following the non-structural measures' prerequisites identified in Section 6.5.1.49. Analysis will likely involve a benefit-cost analysis that evaluates mulitiple project alternatives such as: prioritizing the lowest lying properties, the properties with the lowest relocation cost, or the highest value properties. A flood model would be used to compare the average annual damages to a property with the cost of moving that property.

The Corps previously completed an evaluation of protecting Hamilton from flooding. No alternative was economically justified under this evaluation. The Corps, at the request of the State, will consider relocating Hamilton based on potential increased environmental benefits. The Corps will coordinate this with ongoing local efforts.

Potential advantages of this measure include the possible justification of the project on environmental grounds, the removal of structures and infrastructure from the floodway, increased public safety, and coordination with state, local, and private entities. Potential disadvantages include the possibility that environmental benefits may not economically justified, and that relocation costs are high.

Measure 27 – Debris Management

This measure is to look at different ways woody debris can be handled to avoid blockages and other situations that jeopardize the flood protection system. The existing condition assumes that in larger floods that the BNSF Bridge will collect debris in a way similar to the way it did in 1995. This condition can be seen below.

Potential advantages of this measure include the reduction of flow constriction at bridges, reduced pressure on bridges, and reduction of the risk associated with debris removal during flood events (including life safety). Potential disadvantages include loss of large woody debris that is valuable as fish habitat, and that current environmental regulation do not allow for the permanent removal of debris.

Considerations for further analysis:

- For this measure, it is assumed that the blockage at the BNSF Bridge could be prevented by some measure. Currently, we do not have a feasible plan to implement this measure and to determine what the costs are.
- No evaluation of environmental impacts has been conducted to date.
- There are potential issues in the permitting required for debris removal.

Measure 28 – Sedro-Woolley Ring Dike

This measure is to build a levee to protect Sedro-Woolley from flooding from the Skagit River.

Measure 29 – Sedro-Woolley Sewage Treatment Plant Ring Dike

These measures look at improving the levee around the Sedro-Woolley Sewage Treatment Plant to reduce damages. The outline of the levee is in light green below. This schematic and costs are partially derived from page 91 of PIE's Interim Evaluation of Measures.

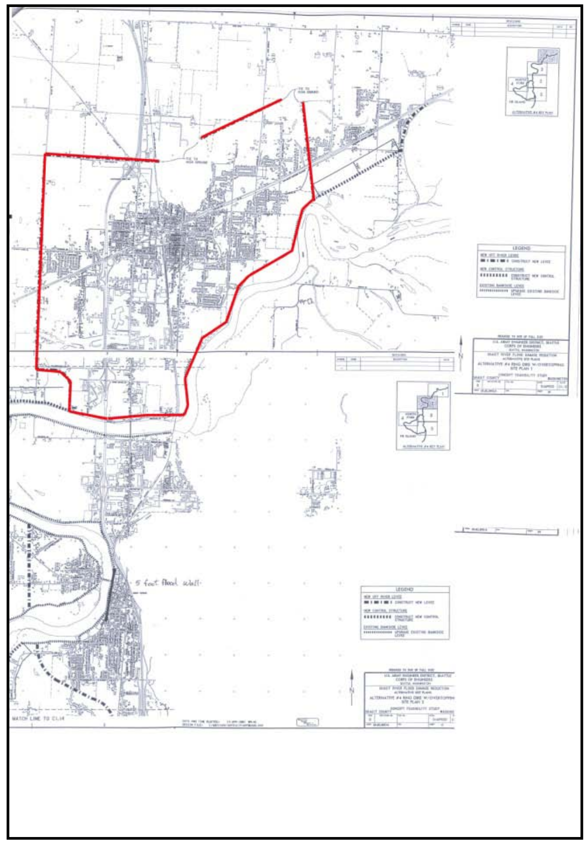
Potential advantages of this measure include increased protection of the sewage treatment plant, and the reduction of contamination risk. Potential disadvantages include a lack of certainty as to whether flooding is significant enough to justify improvement to the dike, and the requirement of and extensive pumping system.

Measure 30 - Sedro-Woolley Hospital Ring Dike

These measures look at building a ring dike around the Sedro-Woolley Hospital to reduce damages. This levee would protect the area in the blue hatched lines below. Potential advantages of this measure include added protection of the hospital building, and the improved life safety of hospital patients. Potential disadvantages include the necessity of barricades at the entrances/exits to maintain egress and ingress, dangers associated with temporary loss of access to a hospital, and the required extensive pumping system.

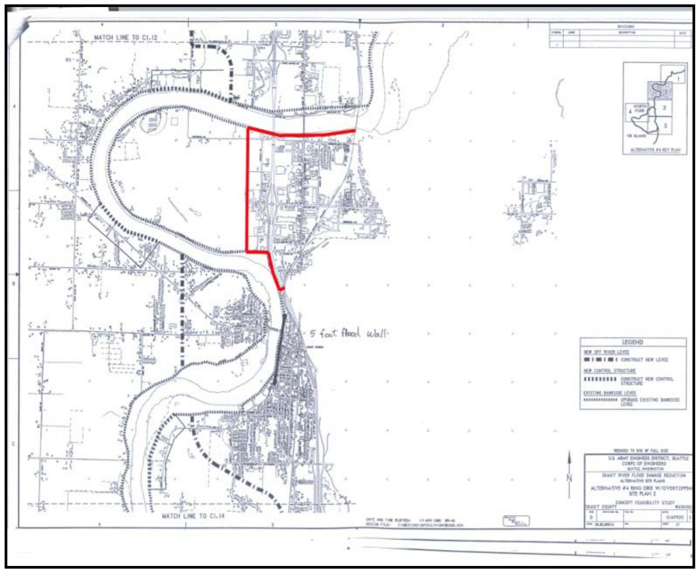
Measure 31 – Burlington Ring Dike

These measures look at surrounding the city of Burlington with a levee to reduce damages. The outline of the levee is in red below. The levee follows the existing right bank levee of the Skagit River starting at RM 20.9 to RM 16.6, then heads north to McCorquadale Road and then goes west on that road, then heads North on Pulser Road to Josh Wilson Road where it heads east to high ground just past the Burlington Northern Railroad. On the other side of the high ground it heads Northeast to another area of high ground before it heads south to connect to the Skagit River levee at RM 20.9. This design path is done to limit the length and cost of the levee while also following Executive Order 11988 which requires the Federal government "to avoid direct or indirect support of floodplain development wherever there is a practicable alternative". This means that the levee can not target protecting undeveloped areas.



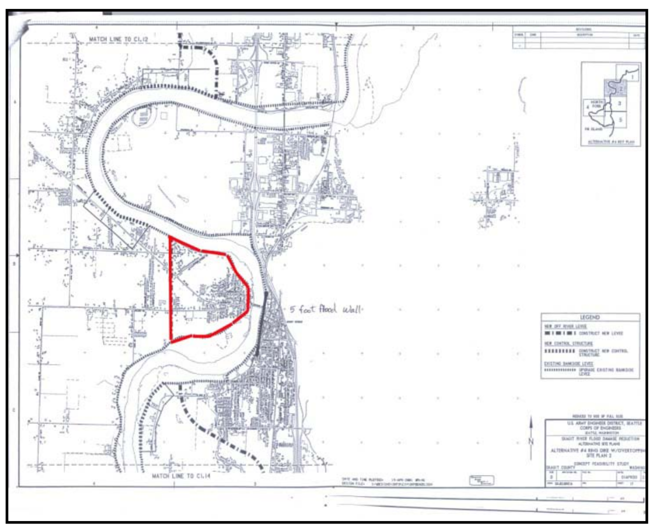
Measure 32 – North Mount Vernon Ring Dike

These measures look at surrounding the northern part of the city of Mount Vernon with a levee to reduce damages. The outline of the levee is in red below. The levee follows the existing left bank levee of the Skagit River starting at RM 17.56 to RM 16.6, then heads directly south until it ties back into the levee system at RM 13.1 and then ties into the high ground of I-5 just north of East Mount Vernon. This design path is done to limit the length and cost of the levee while also following Executive Order 11988 which requires the Federal government "to avoid direct or indirect support of floodplain development wherever there is a practicable alternative". This means that the levee can not target protecting undeveloped areas. The costs for this design are derived from PIE's Interim Evaluation of Measures Report (April 2006) by combining elements 3c – DD17 Left Bank Levee – BNSF to I-5 (PIE Report page 131), and 6a – Big Bend Cutoff Levee (PIE Report page 185).



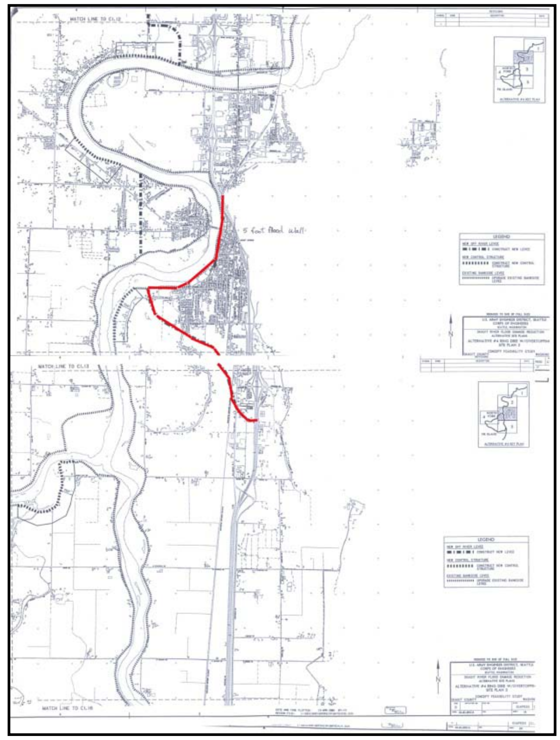
Measure 33 – West Mount Vernon Ring Dike

These measures look at surrounding the western part of the city of Mount Vernon with a levee to reduce damages. The outline of the levee is in red below. The levee follows the existing right bank levee of the Skagit River starting at RM 13.83 to RM 11.7, and then completes the ring by connecting the levee at RM 13.83 and RM 11.7 roughly 4000 feet west of the Division Street Bridge. This design path is done to limit the length and cost of the levee while also following Executive Order 11988 which requires the Federal government "to avoid direct or indirect support of floodplain development wherever there is a practicable alternative". This means that the levee can not target protecting undeveloped areas.



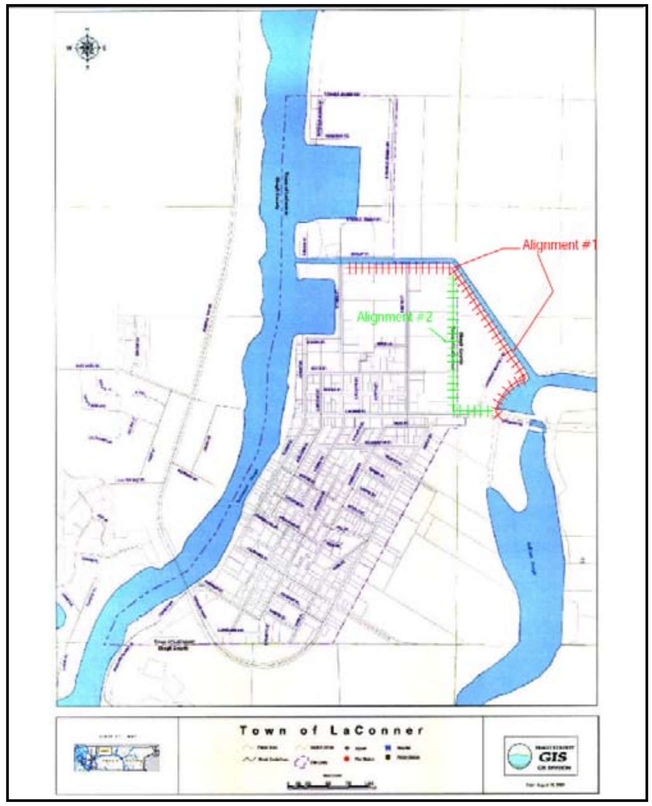
Measure 34 – East Mount Vernon Ring Dike

These measures look at surrounding the northern part of the city of Mount Vernon with a levee to reduce damages. The outline of the levee is in red below. The levee follows the existing left bank levee of the Skagit River starting at RM 13.1, which ties into the high ground of I-5 just north of East Mount Vernon, and goes to RM 11.7. At RM 11.7, it then follows the outline of the housing developments on the south side of East Mount Vernon until it reaches high ground which is at I-5 just south of the Anderson Road exit. This design path is done to limit the length and cost of the levee while also following Executive Order 11988 which requires the Federal government "to avoid direct or indirect support of floodplain development wherever there is a practicable alternative". This means that the levee can not target protecting undeveloped areas.



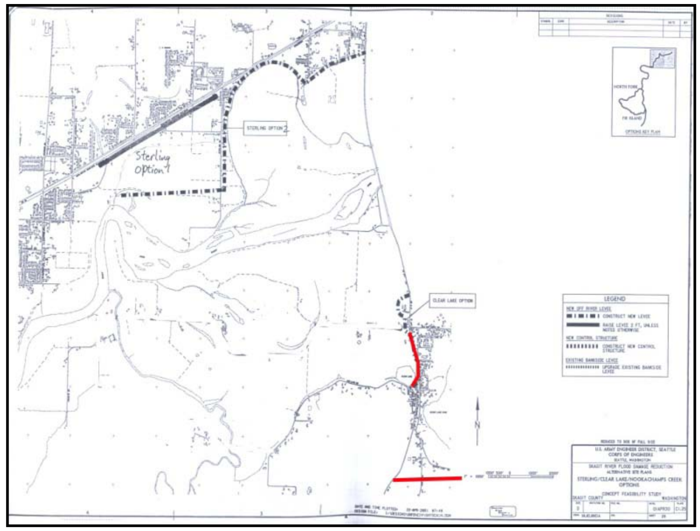
Measure 35 – La Conner Ring Dike

The picture below comes from a design that was displayed in the city of La Conner's Emergency Response Plan put together by Northwest Hydraulic Consultants Inc. in February 2003. The ring dike may need to be greatly expanded as the proposed alignments tie into other levees that may not be built to appropriate standards. More study is necessary to better define the alignment and costs. The City of LaConner has requested the Corps initiate a Section 205 flood study to address this potential project.



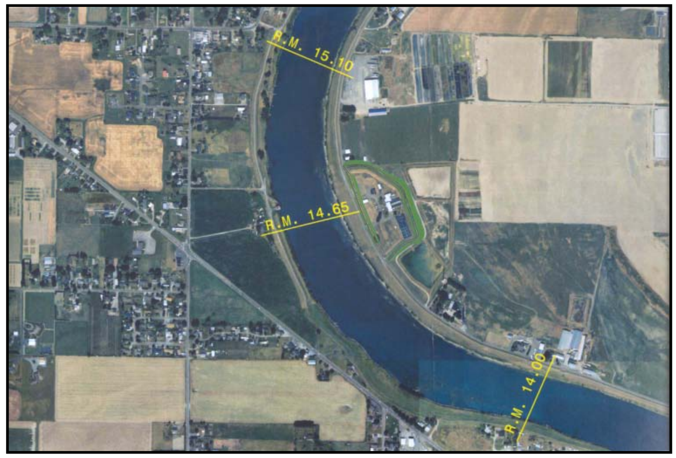
Measure 36 – Clear Lake Ring Dike

This measure addresses flood damages in the Clear Lake area. The picture below shows a preliminary design alignment for a ring dike of the Clear Lake area developed in 2001.



Measure 37 – Anacortes Water Treatment Plant Ring Dike

These measures will look at building a ring dike around the Anacortes Water Treatment Plant to reduce damages. The ring dike is displayed below in green. These measures will be evaluated during future studies.



Potential advantages of this measure include increased protection of the water treatment plant, and protection of water quality. The major potential disadvantage of this measure is the requirement of an extensive pumping system.

Measure 38 – 3-Bridge Corridor Modifications

This measures will consider modifying the BNRR, I-5, and Burlington Boulevard bridges and setting back levees. Other measures/alternatives will likely be considered with and without this measure to ensure that the analysis is capturing all possible benefits from reduced damages to Burlington.

Potential advantages of this measure include increased width of the channel in the 3-bridge corridor, leading to increased hydraulic capacity that can sustain larger flows.

The high expense of bridge modifications may not be justified in the alternatives analysis, but including it as a possibility will ensure that no opportunity for maximizing benefits is overlooked. In addition, running each of the identified alternatives with and without these modifications will provide information about what projects will be affordable. In reality, while bridge modifications are a measure under consideration for Federal authorization, bridge modification may need to be completed outside of the Federal authority.

This measure is currently under evaluation for hydraulic effect, costs, and potential benefits.