M E M O R A N D U M

Date: **01/03/2017**

To: **Will Hall, Surface Water Utility Director - Surface Water Management**
Linda Neunzig, Snohomish County Agricultural Coordinator - Office of Economic Development

CC: **Brett Gaddis, Senior Habitat Specialist - Surface Water Management**
Dave Lucas, Public Works Supervisor III - Floodplain Services, Surface Water Management
Erik Stockdale, Special Projects Coordinator - Surface Water Management

From: **Aaron Kopp, PE, Water Resources Engineer - Floodplain Services, Surface Water Management**

Subject: **Skykomish River Geomorphic Assessment and Conceptual Alternatives, RM 10 to 13**

Executive Summary

Background

At the request of Linda Neunzig, Snohomish County Agricultural Coordinator, Surface Water Management staff reviewed local landowner's thoughts on ways to protect their properties from increasing river migration and/or bank erosion. An alternative approach is also presented for consideration by the landowners. This memo documents the existing geomorphic condition of the Skykomish River reach between RM 10 and 13 (Reach) and presents two conceptual alternatives for reducing the present rate of bank erosion. Alternative 1 consists of suggestions by local landowners along the Reach. A list of protective measures in Alternative 1 is provided in Appendix A and mapped in Appendix E. Alternative 2 consists of a reach-scale design which generally proposes the use of large wood material to provide the required environmental mitigation for bank stabilization projects.

Existing Conditions

In order to evaluate the existing conditions and the proposed project elements in each alternative, a geomorphic assessment was conducted to describe the current channel form and the river processes responsible for creating and maintaining that form. The dominant reach-scale processes are lateral channel migration and sediment deposition. The storage of gravel and cobble sediment within the side bars and forested mid-channel bars causes the main and side channels to migrate laterally and erode streambanks. The most severe instances of local bank erosion within the Reach are being driven by these reach-scale processes. Bank armoring and reduced vegetation cover are contributing factors for the rates of erosion. Continued channel aggradation may lead to the river changing course across the low elevations of the floodplain. Mapping of the Reach and RM 10 to 13 is provided in Appendix B.

Recommendations

Recommended actions are proposed in Alternative 2, which includes measures from Alternative 1. The proposed strategy in Alternative 2 provides bank protection at a local scale, where it is needed most, and addresses the reach-scale geomorphic processes needed for bank protection to be effective in the long term. Engineered logjams could be utilized within the Reach to reduce lateral channel migration and the possibility of changing points and angle of attack by the river along the streambanks.

Conclusions

Any approaches proposed should address the reach scale processes during design to reduce future rates of erosion while also managing the avulsion and erosion risk to other properties within the Reach. If riprap revetment solutions are used without additional types of structures to help address the larger reach-scale processes, the design life may be limited to the short term and the design could increase erosion downstream. Maps of Alternative 2 are provided in Appendices F, G, H and I.

Large wood structures (engineered log jams, flood fencing and large wood revetments) can be designed to achieve the same results as riprap revetments. The application of large wood structures instead of riprap would significantly decrease the amount of habitat mitigation and environmental permitting required for bank stabilization projects. Both large wood and riprap alternatives would reduce flood hazards and increase agricultural viability, however a large wood alternative would also help restore salmon populations which would be much more likely to receive funding at the State and Federal levels, a key aspect of implementation.

Scope

At the request of Linda Neunzig, Snohomish County Agricultural Coordinator, Surface Water Management staff reviewed local landowner's thoughts on ways to protect their properties from increasing river migration and/or bank erosion. Additionally, an alternative approach is presented for consideration by the landowners. This memo documents the existing geomorphic condition of the Skykomish River reach between RM 10 and 13 (Reach) and presents two conceptual alternatives for reducing the present rate of bank erosion. Alternative 1 consists of suggestions by local landowners along the Reach and is included as Appendix A. Alternative 2 consists of a reach-scale design which generally proposes the use of large wood material to provide the required environmental mitigation for bank stabilization projects. The information in this memo is presented in four sections: geomorphic assessment, conceptual alternatives, recommendations, and conclusions. A site map of the Reach is provided as Appendix B.

Geomorphic Assessment

Geomorphic processes are the natural mechanisms of weathering, erosion and deposition that result in the modification of the surficial materials and landforms at the earth's surface (British Columbia Ministry of Environment, 2016). In order to evaluate the existing conditions and the proposed improvements in each alternative, an assessment was conducted to describe the geomorphic processes responsible for creating and maintaining channel form. Because of the complexity or river changes through time and locations, it is helpful to categorize river processes into those occurring at the landscape, watershed, reach, and local scale. A figure of landscape, watershed, and reach-scales is presented in figure 1.

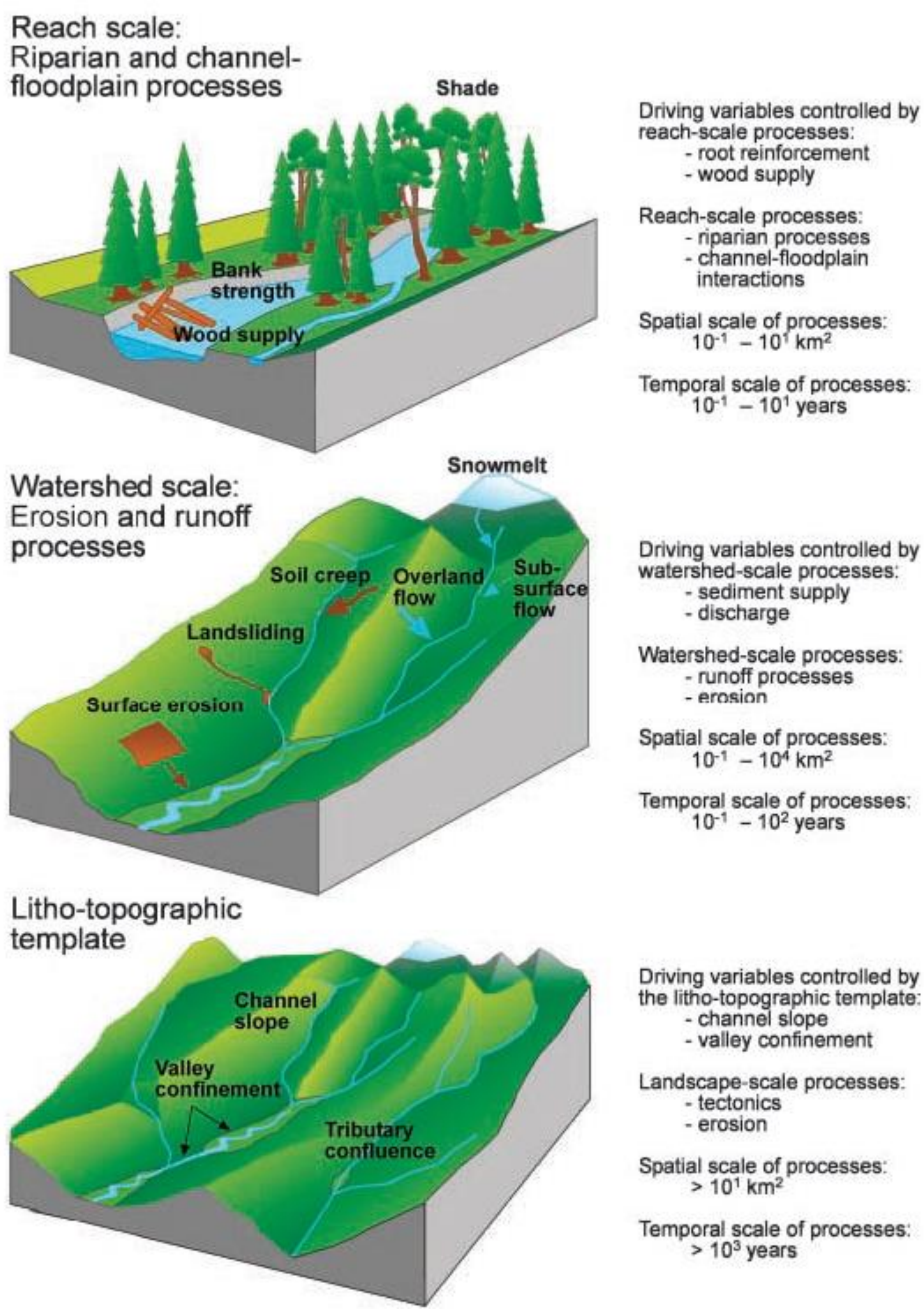

Figure 1 – Landscape, Watershed, and Reach Spatial Scales (Beechie et al., 2010)

The landscape, or litho-topographic, scale is based on the geology, topography, and valley form. Channel slope and valley confinement are the most important elements at the landscape scale. The Reach occurs just downstream of the boundary between the geologic provinces of the steeper North Cascade Mountains and the flatter Puget Sound Lowlands (WA DNR, 2017). The change in channel slope at this boundary can be seen near RM 15 in Figure 2. The Skykomish River has a broad alluvial valley downstream of RM 22 and the city of Gold Bar. Reductions in channel slope and a widening of the valley floor typically result in sediment deposition.

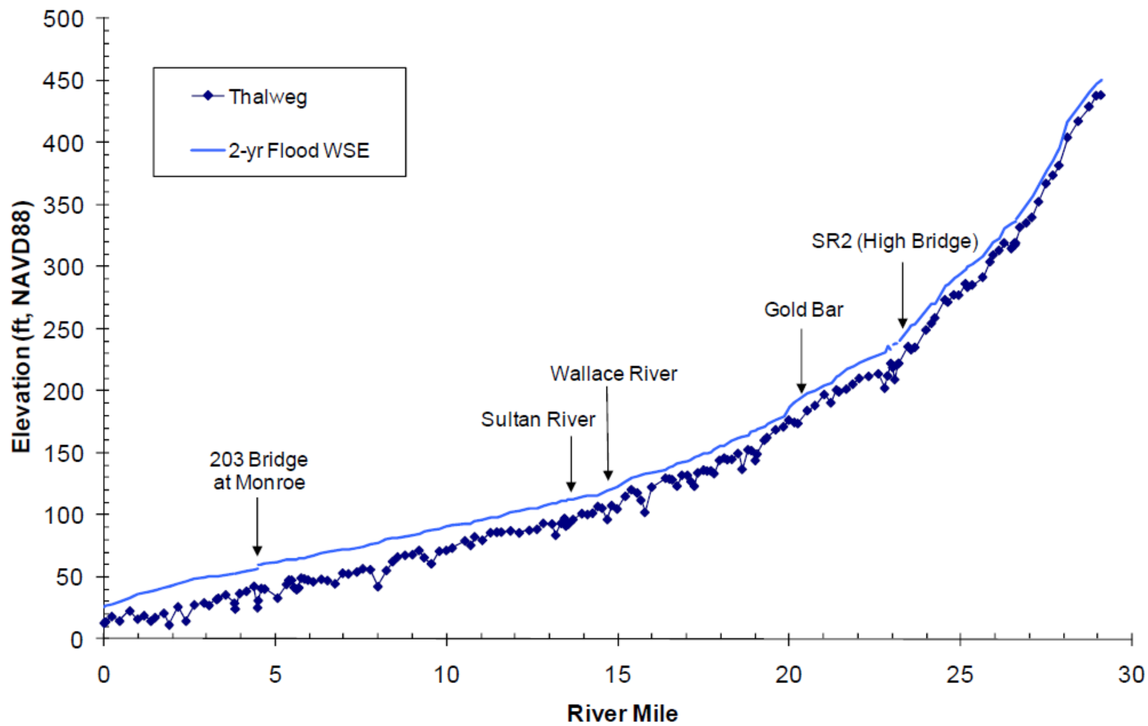

Figure 2 –River Slope (DeVries, 2010)

At the watershed scale, the discharges of both sediment and water are the important elements. These materials result from erosion in the upper portions of the basin. The river carries the sediment downstream and deposits it as the channel flattens. This occurs in the Reach from RM 10 to 13.

At the reach scale, the riparian and channel-floodplain interactions are the dominant processes. The primary variables in these processes include wood in the channel, bank reinforcement, channel migration, bank erosion, and sediment deposition.

The local scale is a subset of the reach-scale. Examples of local scales would be individual side channel bends, gravel bars, or stream bank segments. Local scale processes can include scour holes, bank failure, and bar formation. Local scale features change more frequently than other scales if they do not work with processes occurring at the larger scales of the reach, watershed, and landscape. Previous constructed projects within the Reach occurred mostly at the local scale.

The most severe instances of local bank erosion within the Reach are caused by processes occurring at a watershed scale. The dominant reach-scale processes of lateral channel migration and sediment deposition are a result of the more sediment entering the Reach than is being transported out of the Reach. The storage of gravel and cobble sediment within the side bars and forested mid-channel bars causes the main and side channels to migrate laterally and erode finer-grained streambanks. Bank armoring and reduced vegetation cover are contributing factors for the rates of erosion. Continued channel aggradation may lead to the river changing course across the low elevations of the floodplain.

A planning-level channel migration zone (pCMZ) was delineated within the Reach to provide a record of past channel migration and a baseline for evaluating future channel migration. A channel migration zone reflects the activity and locations of past channel migration and also depicts the potential area that the channel could occupy in the future. Abandoned channel meanders, erosional scallops, and scroll bars are geomorphic features that indicate the previous lateral extent of a river. These features and others were used to delineate the pCMZ as outlined in Washington State Department of Ecology Publication, no. 14-06-025. Mapping of the pCMZ is provided in Appendix C. Potential avulsion risks were also delineated within the pCMZ.

Avulsions alter channel form by cutting new channels across the floodplain. Aggrading reaches of rivers have a greater tendency to overtop their banks than degrading reaches and this leads to a higher avulsion risk. Allowing lateral channel migration to sort and store sediment within reaches tends to decrease the avulsion risk. An avulsion prior to 1947 opened up the side channel inlet near the Bahnmiller property. Currently, avulsion risks are present along the southeast corner of the Bahnmiller property and in between the channels that run along the west and east sides of the Groeneveld agricultural field.

The floodplains are comprised of loam soils that provide little resistance to erosion. Forested riparian areas on lower banks can provide additional erosion protection along banks in the Reach. Knotweed in the Reach further exacerbates the sparse riparian bank conditions because it tends to shade out other plants, has poor root structure, and emits toxins to poison nearby plants and trees.

Bank conditions within the Reach that provide greater resistance to erosion include low banks reinforced by the roots of woody plants, historic riprap revetments, natural log jams, and valley wall bedrock. These features are mapped in Appendix D.

For the purpose of this analysis, the Reach was described as three sub-reaches, one for each of the meander bends at approximately river miles (RM) 13, 12, and 11 (Appendix D).

The meander at RM 13 has limited potential to store sediment. The lateral channel migration is limited by the riprap and bedrock on the outside of the bend. Sediment deposition occurs on the floodplain of the inside bend during flood flows. During flood events the water routes through the forested floodplain in the southwest direction. Several side channels and inactive channels are present within the forested inside portion of the meander bend. Potential avulsion pathways exist between the forested inside portion of the meander bend and the higher terrace upon which the Groeneveld farm buildings are located.

The meander at RM 12 also has limited potential to store sediment. Lateral channel migration is limited due to the riprap along the outside of the bend. Portions of riprap have been dislodged from the revetment and are now lying in the channel several feet away from the bank. The downstream end of the outside meander between RM 11.5 and RM 11.7 is not laterally constrained or eroding. Along the inside bend, a chute channel has formed with a sediment barrier on its upstream end.

The meander at RM 11 has several locations of sediment deposition. The primary locations of sediment deposition are a point bar on the southeast side of the island at RM 11 and side bars within the side channel along the north side of the island at RM 11. Based on historic aerial photography the side channel has been widening over the last several decades. This process is likely to continue into the near future. The rate of channel widening could increase if a chute cutoff occurs across the narrowest portion of the island at RM 10.5.

Review of Conceptual Alternatives

Conceptual Alternative 1

Local landowners proposed fourteen measures to stabilize river channel banks within the reach. Alternative 1 stabilization measures are described in the following paragraphs and summarized in Table 1. The locations of the measures are presented in Appendix E.

Table 1. Summary of Alternative 1 Bank Stabilization Measures

Location #	Alternative 1 Bank Stabilization Measures
1	Lower berm at choke point
2	Punch through weir and overflow area
3	Anchor logs that float in
4	Revegetate the bank opposite measure #2 with medicinal herbs
5	Add additional flood fence and planting
6	Maintain flood fence where broken
7	Fix flood fence
8	Construct groin to narrow channel at big washout
9	Remove log jam at head of island, address safety concerns
10	Construct pilot channel to straighten river
11	Move gravel to opposite bank
12	"Repair project blowout (damage)"
13	Add rock through temp groin
14	Armor right bank of side channel outlet

Streambank stabilization measures 1 through 4 are located along the inside of the upstream meander bend at RM 13, its side channels, and the upstream portion of the Groeneveld property. Measures 1 and 2 would serve to modify the southern extent of a side channel that connects at approximately a 45 degree angle to the main channel. Measure 3 is to anchor logs that float in. Measure 4 was directed towards the planting of native medicinal plants and may not have a significant influence on streambank stability if not planted on the streambanks. Measures 1 through 4 attempt to limit bank erosion by maintaining hydraulic conveyance and sediment transport across the inside meander bend of RM 13.

Measures 5 and 6 propose limiting lateral channel migration by improving the level of protection along the riverbank, increasing hydraulic roughness on the floodplain, and providing additional riparian planting. Both measures would occur on the right bank of the Skykomish River main channel on the second meander bend along the downstream portion of the Groeneveld property. These measures pertain to rebuilding or maintaining the flood fencing in conjunction with riparian planting. During a site visit on July 18th, 2016, staff noted that the property owner mentioned that erosion of their riprap revetment was also a concern.

The meander bend at RM 11 includes measures 7 through 14 along a side channel and the adjacent properties owned by Bahnmiller, Hofstra, Labish and Johansen. Measure 7 proposes to repair the flood fence at the upstream end of the side channel. Measure 8 includes the installation of a groin and removing large woody debris (LWD) within the side channel along the Bahnmiller property. LWD removal within the natural log jam at the head of the island and left bank of the side channel was proposed as measure 9. Measure 10 suggests cutting a pilot channel through the narrow downstream portion of the island. Measure 11 would move gravel from the left side of the side channel to the opposite bank. Repair of the previous LWD structures is proposed as measure 12 along the Labish property. Measures 12 and 13 are similar in that both relate to adding riprap revetments and/or groins to the right bank of the side channel outlet along the properties of Labish and Johannsen. Measures 7 through 14 attempt to limit lateral channel migration by removing LWD, installing flood fencing, and building riprap structures.

Conceptual Alternative 2

Alternative 2 is a reach-scale design, incorporating measures outlined in Alternative 1, with the goal of withstanding lateral channel migration in the long term. Alternative 2 would provide bank protection at a local scale, where it is needed most, and address the reach-scale geomorphic processes needed for bank protection to be effective in the long term. The design could incorporate large wood material to provide the required environmental mitigation for a hardened bank stabilization project. The proposed measures are described in the following paragraphs and presented in Appendix F. Any large wood installations in the channel should take into account public safety issues during design, construction, and monitoring.

A comprehensive bank stabilization solution should have a long term design life. The County's previous projects were designed to improve local fish habitat and to reduce erosion of the agricultural fields within the Reach. Long term projects are recommended in order to provide a higher level of stream bank protection than the previous projects.

Longer term design solutions must have elements that provide bank protection in the local vicinity and also work with the reach-scale geomorphic processes. Sediment storage and lateral channel migration within the Reach causes the channels to shift their orientation to the bank and also the angle at which they meet. In order for a project to meet long term design criteria, streambank stabilization measures must be able to accommodate channel shifts and the resulting changes to the point and angle of attack on the streambank.

Individual revetment structures have limited applicability in reaches where the channel shifts occur in the short term. The revetments can be flanked unless they are constructed to cover all the potential upstream erosion locations. As the angle of attack on the stream bank increases, from parallel to perpendicular, the depth of the scour at the toe of the revetment increases. This requires significantly more material to be placed below the channel bed to account for the increased scour potential and regular maintenance on the structure when material is displaced. The design life of revetment type structures can be extended when used in conjunction with mid-channel flow defecting structures in reaches prone to lateral channel migration.

A variety of large wood structures with different primary functions could be utilized in reaches prone to lateral channel migration. Large wood structures can be designed and strategically placed to redirect flow, armor a streambank, and reduce flow velocity. Large wood revetments can be used to provide direct streambank protection (figure 3). Engineered logs jams (ELJs) can be placed in the channel to redirect and split flow (figure 4). Flood fencing can be used on top of floodplains to reduce flow velocities and accumulate LWD and sediment before it gets to farm lands (figure 5). Engineered logs jams can be built as permeable structures in channels to slow water velocities and reduce erosion potential. A combination of structures with multiple functions would have a higher degree of success than revetment structures alone in reaches prone to lateral channel migration. A summary of Alternative 2 measures is provided in Table 2. A map of the specific structures and locations is presented in Appendix F and discussed in greater detail in the next section.

Table 2. Summary of the Alternative 2 Bank Stabilization Measures

Alternative 2 Bank Stabilization Measures	Bank Stability Function	Location
Flood Fencing	Reduce avulsion risk	Floodplains
Engineered Log Jam (Flow Deflector)	Bifurcate flows	Main and Side channels
Engineered Log Jam (Permeable)	Reduce flow velocity	Side channels
Proposed Side Channel	Provide flow conveyance	Inside bends of river
Large Wood Revetment	Provide bank protection	Channel banks

Figure 3 – Example of a large wood revetment in the South Fork Nooksack River, WA (USBR and ERDC 2016)

Figure 4 – Example of Engineering Log Jams in the Elwha River, WA (USBR and ERDC 2016)

Figure 5 – Example of Flood Fencing Installation along the Skykomish River, WA (Aldrich and DeVries)

Recommendations

The recommended set of improvements is proposed as Alternative 2 and includes measures from the landowner's Alternative 1. The proposed strategy in Alternative 2 provides bank protection at a local scale, where it is needed most, and addresses the reach-scale geomorphic processes needed for bank protection to be effective in the long term. Bank protection could be provided in locations such as the Bahnmiller property, Labish property, and lower portion of the Groenveld property. Engineered log jams could be designed to manage flow upstream of the bank protection to increase its design life. A planting plan including an herbaceous cover crop, willow live stakes, cottonwood posts, and container stock trees should be developed to compliment Alternative 2. A key difference between Alternative 1 and 2 is the extent and orientation of the proposed side channel excavation within the meander bend at RM 13.

Within the meander bend at RM 13, longer term bank stabilization measures must be conducive to the transport of water and sediment across this area in a southwest direction. Alternative 1 measures to "lower the berm at the choke point" or "punch through weir and overflow area" should only be considered as short term measures to help drain water from the side channel along the Groenveld field. Sediment removal "at the choke point" in the channel and/or its left overbank would likely be replenished with sediment during the next major flood event. A side channel with a northeast to southwest alignment across the inside meander bend would provide greater flow conveyance and sediment transport capacity. The constructed side channel for the meander bend at RM 13 would relocate a majority of the existing channel away from the adjacent agricultural field and provide for a riparian buffer. Such a channel is recommended in addition to large wood structures in Alternative 2. The suite of bank protection measures for the meander bend at RM 13 is shown in Appendix G.

Several large wood structures could be constructed within the meander bend at RM 13. Alternative 1 proposed "anchoring logs that float in." Alternative 2 recommends taking a pro-active approach and constructing large wood debris jams that could reduce the flow of water and bedload sediment through the existing side channel. Converting the side channel to a backwater channel would retain its present values of flood water storage and aquatic habitat. A wood revetment could be placed at the downstream end of the side channel to protect the river right streambank. Flood fencing and riparian planting could be installed at the upstream and downstream ends of the side channel to reduce the avulsion risk across the agricultural field.

Along the meander bend at RM 12, bank stabilization measures could be used to reduce the pressure on the deteriorating riprap revetment along the outside bend (river right). The flow velocity in the main channel could be reduced by opening the inlet to the chute channel on the inside bend and placing two ELJs in the vicinity of the inlet to maintain the flow split. Placing a large wood revetment along the outside bend would serve to slow down the flow and rebuilding the revetment in locations where the existing riprap revetment has been compromised would increase the effectiveness of the revetment. Alternative 1 measures to "redo and/or maintain" the flood fencing in this area would be complimentary and are recommended. The suite of bank protection measures for the meander bend at RM 12 is provided as Appendix H.

Within the side channel on the meander bend at RM 11, bank stabilization measures could be used to reduce the amount of bed load sediment entering the side channel and address lateral channel migration locally. At the upstream end of the side channel, a few ELJs could be placed to direct more water and sediment discharge down the main channel as opposed to the side channel. This measure would be essential to addressing the sediment deposition within the side channel that is driving the lateral channel migration. Removal of riprap along the main channel river left at RM 11.3 would complement this measure.

Within the same side channel, the two primary bank erosion areas along the Bahnmiller and Labish/Johannsen properties could be addressed with a diversity of structures. ELJs are recommended to direct flow away from the areas of bank erosion as part of a long term fix. Similarly, the existing bank structures could be upgraded to a longer term design life by incorporating large wood revetments that are placed deeper than the scour depth and long enough to prevent the flow from flanking the revetment. Flood fencing and riparian vegetation efforts could be used on the floodplain to reduce flood flow velocities and avulsion hazards around the locations of bank erosion. The suite of bank protection measures for the meander bend at RM 11 is provided as Appendix I.

Conclusions

The most severe instances of local bank erosion within the Reach are being driven by processes occurring at the watershed scale. The dominant reach-scale processes of lateral channel migration and sediment deposition are a result of the more sediment entering the Reach than being transported out of the Reach. Longer term approaches to bank stabilization require accounting for these reach-scale geomorphic processes. Bank stabilization measures that only protect the existing eroding banks in their present local locations should be considered as short term solutions. Engineered logjams could be utilized within the Reach to accommodate lateral channel migration and the possibility of changing points and angle of impact along the stream banks by the river.

The present rates of sedimentation within the Reach are dictated by the spatial relationship of the Reach within the watershed. Reducing the rates of lateral channel migration or avulsion at specific locations within the Reach will likely displace the effects of the processes to locations in other channels or to downstream reaches. Conversely, the removal of riprap from upstream locations could allow those portions of the channel to migrate and store sediment with a net effect of reducing lateral channel migration, bank erosion, and sedimentation in its present locations.

Any approaches proposed should address the reach scale processes during design to reduce future rates of erosion while also managing the avulsion and erosion risk to other properties within the Reach. If riprap revetment solutions are used without additional types of structures to help address the larger reach-scale processes, the design life may be limited to the short term and the design could increase erosion downstream.

Large wood structures (ELJs, flood fencing and large wood revetments) can be designed to achieve the same results as riprap revetments. The application of large wood structures instead of riprap would decrease the amount of mitigation and environmental permitting required for bank stabilization projects.
Both large wood and riprap alternatives would reduce flood hazards and increase agricultural viability. A large wood alternative would also help restore salmon populations, which would be much more likely to receive funding at the State and Federal levels, a key aspect of implementation.

The design of large wood and/or rock structures can be sought from one of the many water resources engineering consulting firms in Snohomish and surrounding counties. Designs would likely follow the principles in Washington Department of Fish and Wildlife's Integrated Streambank Protection Guidelines (ISPG) and include a hydraulic model such as the US Army Corps of Engineers (USACE) HEC-RAS. Design guidelines are available from the Bureau of Reclamation Large Wood Design Guidelines, USACE manual 1110-2-1601, and/or the National Cooperative Highway Research Program (NCHRP) Report 568. Links to these design references are provided as follows.

Design References

Washington Department of Fish and Wildlife
Integrated Streambank Protection Guidelines (ISPG)
http://wdfw.wa.gov/publications/00046/

U.S. Army Corps of Engineers
HEC-RAS version 5.0.2 hydraulic modeling software
http://www.hec.usace.army.mil/software/hec-ras/

National Cooperative Highway Research Program
Report 568 - Riprap Design Criteria, Recommended Specifications and Quality Control
http://onlinepubs.trb.org/onlinepubs/nchrp/nchrp_rpt_568.pdf

U.S. Army Corps of Engineers
Engineer Manual 1110-2-1601 – Hydraulic Design of Flood Control Channels
http://www.publications.usace.army.mil/Portals/76/Publications/EngineerManuals/EM_1110-2-1601.pdf

Bureau of Reclamation
Large Wood Design Guidelines - National Manual
http://www.usbr.gov/research/projects/detail.cfm?id=2754

References

Bob Aldrich, Snohomish Co and Paul DeVries, R2 Resource Consultants. Flood Fencing: Reconnecting Floodplains and Riparian Areas. Available: http://www.deltarevision.com/Issues/fish/dpm/flood-fencing.pdf

Beechie T.J., Sear D.A., Olden J.O., Pess G.R., Buffington J.M., Moir H., Roni P., Pollock M.M, 2010, Process-based Principles for Restoring Ecosystems, BioScience 60: 209-222, American Institute of Biological Sciences.
Available: http://bioscience.oxfordjournals.org/content/60/3/209.short

British Columbia Ministry of the Environment, Land and Parks.
Available: https://www.for.gov.bc.ca/hts/risc/pubs/teecolo/terclass/geo.htm

Bureau of Reclamation and U.S. Army Engineer Research and Development Center (USBR and ERDC). 2016. National Large Wood Manual: Assessment, Planning, Design, and Maintenance of Large Wood in Fluvial Ecosystems: Restoring Process, Function, and Structure. 628 pages + Appendix.
Available: www.usbr.gov/pn/ and http://cw-environment.usace.army.mil/restoration.cfm
(click on “River Restoration,” then “Techniques”).

Olson, P.O., Legg, N.T, Abbe, T.B., Reinhart, M.A., and Radloff, J.K., 2014, A Methodology for Delineating Planning-Level Channel Migration Zones: Ecology Publication 14-06-025.
Available: https://fortress.wa.gov/ecy/publications/SummaryPages/1406025.html

Washington Department of Natural Resources, Geologic Provinces of Washington, 2017.
Available: http://www.dnr.wa.gov/programs-and-services/geology/explore-popular-geology/geologic-provinces-washington

Appendix A - Alternative 1, Suggestions by landowners