Nisqually Watershed Response to the 2018 Streamflow Restoration Act (RCW 90.94)

Addendum Appendices

Prepared for the Nisqually Indian Tribe
and Nisqually Watershed Planning Unit

January 16, 2019

With Assistance from:
Ecology Grant No. WRSRPPG-2018-NisqIT-00014

List of Appendices

Appendix A

Nisqually Planning Unit 2018 Working Agreement

NISQUALLY WRIA 11

PLANNING UNIT WORKING AGREEMENT TO ADDRESS ESSB 6091

GROUND RULES AND STRUCTURE FOR 2018 WATERSHED PLANNING

BACKGROUND:

Acting under authority of the 1998 Watershed Management Act (RCW 90.82), with the Nisqually Indian Tribe as the Lead Agency, the Nisqually Planning Unit adopted in October 2003 the "Nisqually Watershed Management Plan." Acting at a joint meeting held April 13, 2004, Lewis, Pierce and Thurston counties unanimously approved that plan. Continuing its meetings, the Nisqually Planning Unit in February 2007 adopted the "Phase IV Nisqually Implementation Plan," further identifying actions to be taken to implement the 2003 Plan.

In 2018 the Washington State Legislature, acting in ESSB 6091, mandated that the Nisqually Planning Unit acting under authority of RCW 90.82, must update the Nisqually Watershed Management Plan to address explicitly future permit-exempt domestic groundwater withdrawals, potential impacts of these withdrawals on minimum stream flows and other senior water rights, and develop mitigation strategies as deemed appropriate by the Planning Unit. The mandated deadline for this activity is February 1, 2019.

The new law establishes standards for exhibiting proof of an adequate water supply when applying for a building permit or subdivision for a home relying on a new permit-exempt well, including requirements about a fee and water use restriction. ESSB 6091 (codified as RCW 90.94) directs the Department of Ecology to work with Initiating Governments and Planning Units to identify potential impacts of exempt well use, identify evidence-based conservation measures and identify projects to improve watershed health and offset potential impacts to instream flows associated with permit-exempt domestic water use. Alternatively, building permit applicants may show other evidence of an adequate water supply that complies with RCW 90.03 and 90.44.

PURPOSE: The purpose of this agreement is to:

- identify governmental entities that wish to work together to implement the legislative mandate for the Nisqually Watershed Planning Unit as issued by the Washington State Legislature in ESSB 6091 and develop and submit to the Washington Department of Ecology a plan amendment that addresses the mandate,
- define the scope of the plan amendment and the expected outcomes of this process; and,
- set ground rules for participating in this process.

1.0 Parties of this Agreement

The parties of this agreement are the "Implementing Governments" (The Nisqually Tribe and Thurston, Pierce and Lewis Counties) and "other Governmental and Non-governmental participants," all of whom were identified as Watershed Planning Unit participants in the 2003

Nisqually Watershed Management Planning process. These Implementing Governments and other governmental and non-governmental participants are listed in Attachment A with the understanding that one or more of these entities may choose not to participate in this planning activity.

2.0 Scope and Expected Outcomes – The purpose of convening this Planning Unit is to address the legislative mandate of ESSB 6091 (codified as RCW 90.94). The scope of the resulting watershed plan amendment is to estimate the consumptive water use associated with domestic permit exempt well use in the Nisqually watershed and to determine appropriate mitigation for that use. It is expected that the product of this effort will be an amendment to the existing 2003 Nisqually Watershed Plan and will likely include the identification of projects and policies to ensure implementation. An adaptive management mechanism will be included to ensure that projects and policies identified by the Planning Unit to implement ESSB 6091 are being implemented and are achieving the intended outcomes. The Planning Unit will also consider projects and programmatic actions to enhance stream flows that are impacting/impeding salmon survival during critical life histories. The intent of the Planning Unit is to approve an addendum to the 2003 Watershed Plan that addresses the requirements of ESSB 6091 and to transfer said addendum to the Department of Ecology by February 1, 2019.

3.0 Agreement – The parties to this Agreement hereby agree to:

3.1 Review, discuss and seek a recommendation by consensus of the Planning Unit to adopting governments an amendment to the Nisqually Watershed Management Plan that estimates impacts from new domestic permit-exempt groundwater withdrawals for the period from 2018 to 2040 and identifies mitigation strategies to address impacts of these withdrawals.

3.2 The parties agree that the amendment may not require or obligate an Implementing Government or other participating entity to take any specific implementing action, or refrain from taking any specific action, unless that Implementing Government or entity so agrees.

4.0 Lead Agency – The Nisqually Indian Tribe will be the lead agency for the purpose of convening the Planning Unit, applying for and administering watershed planning grants, convening meetings of the Planning Unit, storing data created by this project, and providing and/or contracting for services necessary for facilitation, preparing plan amendment(s) and supporting reports.

5.0 Planning Unit –

The Planning Unit is the committee formed by the Implementing Governments under authority of the 1998 Watershed Planning Act (RCW 90.82) and as approved by the counties in their joint meeting of April 2004. In addition to other responsibilities, the Planning Unit shall address the legislative mandate established in 2018 by ESSB 6091. The approving authority of each party to this agreement shall appoint a representative to the Planning Unit, authorizing said representative to participate on its behalf in the Planning Unit. The Planning Unit shall be the policy recommendation committee for amending the Nisqually Watershed Management Plan as mandated in ESSB 6091 and established by this agreement.

The Planning Unit shall fulfill this function in the following manner: (a) by preparing and approving plan amendment(s); (b) by making a good faith effort to forward a record of Planning Unit deliberations and plan amendment(s) to the Department of Ecology by February 1, 2019. In addition, the Planning Unit may, but is not required to, support or endorse actions that implement said amendment(s).

Representation on the Planning Unit shall consist of representatives of the Implementing Governments as identified in Section 1.0 and Attachment A, and other governmental and non-governmental participants (also listed in Attachment A). The Nisqually River Council Citizens Advisory Committee is assumed to be the avenue for citizen participation on the Planning Unit. The parties recognize that the Nisqually River Council has a special role in natural resource planning in WRIA 11 and shall encourage the Council's participation in the Planning Unit deliberations. Interested parties may join the Planning Unit through October 2018 if they have interest in the subject Addendum and implementation of said Addendum.

6.0 Ground Rules -

6.1 The Planning Unit will strive to make decisions by consensus of all members of the Planning Unit. Each participating entity, as listed in Attachment A, will have one vote. For the purposes of this process, consensus shall mean general concurrence, with no one member of the Planning Unit refusing to support the decision. If the Planning Unit is unable to reach a consensus on an issue, an affirmative decision shall be made by the consensus of all authorized representatives of the Implementing Governments on the Planning Unit and 2/3 majority vote of all other governmental and non-governmental participants present. Any inability to reach full consensus shall be documented in the meeting record with the positions of the refusing parties clearly stated. If all Implementing Governmental participants are unable to reach consensus and the amendment is not adopted by the Planning Unit, the WA Department of Ecology must then adopt rules for WRIA 11 that meet the requirements of ESSB 6091, per Section 202(7)(b) of the legislation.

6.2 Prior to reaching a consensus decision on an issue, a representative of the lead agency shall clearly state the decision facing the Planning Unit. Representatives from the Nisqually Tribe and the three participating counties must be present to take a vote. For extenuating circumstances, if a representative from the Nisqually Tribe, Pierce, Thurston or Lewis County must be absent for a vote, the representative for that entity may vote in abstentia by providing their vote to the facilitator in advance of the meeting. Consensus decision will be clearly reported in the minutes distributed to Planning Unit members.

6.3 In making all decisions, the Planning Unit shall consider the best available science, as defined in the 2007 Phase IV Nisqually Implementation Plan.

6.4 Meeting notes shall be taken at all meetings. Such minutes need not be verbatim restatements of meetings, they need only reflect the decisions made and topics discussed. Draft notes shall be reviewed and approved by the Planning Unit at a subsequent meeting.

6.5 Technical and other advisory work groups may be established by the Planning Unit to develop projects, provide analyses and reports, and make recommendations to the full Planning Unit on specific issues.

6.6 Nothing contained herein or in any amendment developed under the Agreement shall prejudice the legal claims of any party hereto, nor shall participation in this planning process abrogate any party's authority or the reserved or other rights of the Nisqually Indian Tribe, except where the obligation has been accepted in writing.

6.7 Members of the Planning Unit agree to focus discussions on the assignment of fulfilling the requirements of the watershed established in ESSB 6091.

6.8 Planning Unit meetings are open to the public and an opportunity for public comment will be provided on meeting agendas.

6.8 Members recognize the Committee represents a broad range of interests. All parties agree to recognize the legitimacy of the interests and concerns of others, and expect that their interests will be respected as well.

Members commit to:

- Listening carefully to each other;
- Recognizing each person's concerns and feelings about the topic;
- Asking questions for clarification;
- Making statements that attempt to educate or explain;
- Making no personal attacks directed at individuals and/or agencies; and
- Keeping colleagues and constituents informed about the work of the Planning Unit in a timely manner

7.0 Funding - This agreement does not obligate the Implementing Governments to pay the costs for any watershed plan amendments developed by the Planning Unit unless the Implementing Government or governments to the obligation so agree.

8.0 Duration – This agreement will be in effect for five (5) years from the Agreement's effective date, unless extended by the agreement of the parties.

9.0 Authorization to Sign: The parties hereto each represent and warrant that all necessary signature and consents to enter this agreement and to assume and perform the obligations hereunder have been duly and properly obtained.

ATTACHMENT A

Planning Unit Members

Implementing Governments

Nisqually Indian Tribe – David Troutt, Natural Resources Director
Supporting Staff
George Walter, Environmental Program Manager

Lewis County – Gary Stamper, Commissioner
Supporting Staff
Fred Evander, Senior Long Range Planner
Lee Napier, Community Development Director

Pierce County – Dennis Hanberg, Planning and Public Works Director
Supporting Staff
Dan Cardwell, Long Range Planning Supervisor
Jessica Gwilt, Long Range Planner
Tom Kantz, Project Manager
Rance Smith, Development Engineering Supervisor
Barbara Ann Smolko, Senior Planner

Thurston County – Joshua Cummings, Community Planning and Economic Development Director
Supporting Staff
Kevin Hansen, Hydrogeologist
Allison Osterberg, Senior Planner
Cynthia Wilson, Community Planning Manager

Other Governmental and Non-governmental Participants

City of Lacey – Julie Rector, Water Quality Analyst

City of Olympia – Andy Haub, Water Resources Director
Supporting Staff
Jesse Barham, Habitat Coordinator
Joe Roush, Storm and Surface Water Planning Supervisor

City of Yelm – Michael Grayum, City Administrator
Supporting Staff
Grant Beck, Community Development Director

Town of Eatonville – Abby Gribi, Town Administrator

Thurston Public Utility District – Russell Olsen, Commissioner

Supporting Staff

John Weidenfeller, General Manager

Nisqually River Council Citizens Advisory Committee – Lois Ward, Vice Chair

Washington State Department of Ecology – Mike Gallagher, Southwest Region Water Resources Section Manager

Washington State Department of Fish & Wildlife – Matthew Curtis, Habitat Biologist and Kiza Gates, Water Team Lead

Washington State Department of Agriculture – Gary Bahr, Natural Resource Assessment Section Manager

The Planning Unit Agreement has been executed this 24th day of October, 2018, on one or more originals, by the parties below.

NISQUALLY INDIAN TRIBE

By: David Troutt, Natural Resources Director

The Planning Unit Agreement has been executed this 17th day of October, 2018, on one or more originals, by the parties below.

LEWIS COUNTY

By: Gary Stamper, Commissioner

The Planning Unit Agreement has been executed this 16th day of October, 2018, on one or more originals, by the parties below.

PIERCE COUNTY

By: Dennis Hanberg, Planning and Public Works Director

The Planning Unit Agreement has been executed this 3rd day of October, 2018, on one or more originals, by the parties below.

THURSTON COUNTY

By: Joshua Cummings, Community Planning and Economic Development Director

The Planning Unit Agreement has been executed this 17th day of October, 2018, on one or more originals, by the parties below.

CITY OF LACEY

Julie Rector

By: Julie Rector, Water Quality Analyst

The Planning Unit Agreement has been executed this 2 day of October, 2018, on one or more originals, by the parties below.

CITY OF OLYMPIA

Andy Haub

By: Andy Haub, Water Resources Director

The Planning Unit Agreement has been executed this ____ day of ___________, 2018, on one or more originals, by the parties below.

CITY OF YELM

____
By: Michael Grayum, City Administrator

The Planning Unit Agreement has been executed this 22 day of October, 2018, on one or more originals, by the parties below.

TOWN OF EATONVILLE

By: Abby Gribi, Town Administrator

The Planning Unit Agreement has been executed this 12th day of October, 2018, on one or more originals, by the parties below.

THURSTON PUBLIC UTILITY DISTRICT

John Weidenfeller

By: John Weidenfeller, General Manager

The Planning Unit Agreement has been executed this 17 day of October, 2018, on one or more originals, by the parties below.

NISQUALLY RIVER COUNCIL CITIZENS ADVISORY COMMITTEE

Lois Ward

By: Lois Ward, Vice Chair

The Planning Unit Agreement has been executed this 17th day of October, 2018, on one or more originals, by the parties below.

WASHINGTON STATE DEPARTMENT OF ECOLOGY

Michael J Gallagher

By: Mike Gallagher, Southwest Region Water Resources Section Manager

The Planning Unit Agreement has been executed this 3 day of October, 2018, on one or more originals, by the parties below.

WASHINGTON STATE DEPARTMENT OF FISH & WILDLIFE

By: Matthew Curtis, Habitat Biologist

The Planning Unit Agreement has been executed this 26 day of October, 2018, on one or more originals, by the parties below.

WASHINGTON STATE DEPARTMENT OF AGRICULTURE

Gary Bahr

By: Gary Bahr, Natural Resource Assessment Section Manager

Appendix B

WAC 173-511, Nisqually Instream Flow Rule

Chapter 173-511 WAC

INSTREAM RESOURCES PROTECTION PROGRAM—NISQUALLY RIVER BASIN, WATER RESOURCE INVENTORY AREA (WRIA) 11

WAC 173-511-010 General provision. These rules apply to waters within the Nisqually River basin, WRIA 11, as defined in WAC 173-500-040. This chapter is promulgated pursuant to chapter 90.54 RCW (Water Resources Act of 1971), chapter 90.22 RCW (minimum water flows and levels), and in accordance with chapter 173-500 WAC (water resources management program).

[Statutory Authority: Chapters 90.22 and 90.54 RCW. 81-04-028 (Order DE 80-42), § 173-511-010, filed 2/2/81.]

WAC 173-511-020 Purpose. The purpose of this chapter is to retain perennial rivers, streams, and lakes in the Nisqually River basin with instream flows and levels necessary to provide protection for wildlife, fish, scenic, aesthetic, environmental values, recreation, navigation, and to preserve water quality.

[Statutory Authority: Chapters 90.22 and 90.54 RCW. 81-04-028 (Order DE 80-42), § 173-511-020, filed 2/2/81.]

WAC 173-511-030 Establishment of instream flows. (1) Stream management units and associated control stations are established as follows:

STREAM MANAGEMENT UNIT INFORMATION

Control Station No. Stream Management Unit Name	Control Station Location, River Mile and Section, Township and Range	Affected Stream Reach
New gage Nisqually River	4.3 9, 18N, 1E	From influence of mean annual high tide at low base flow levels to the outlet of the Centralia City Light Power Plant.
12-0895-00 Nisqually River	21.8 28, 17N, 2E	From outlet of the Centralia City Light Power Plant at river mile 12.6 to Centralia City Light Power canal diversion at river mile 26.2, including all tributaries.
12-0884-00 Nisqually River	32.6 21, 16N, 3E	From the Centralia City Light Power canal diversion at river mile 26.2 to gage 12-0865-00 near the La Grande Power Plant, including all tributaries except the Mashel River.
12-0825-00 Nisqually River	57.8 29, 15N, 6E	From gage 12-0865-00 near the La Grande Power Plant to the headwaters including all tributaries.
12-0870.00 Mashel River	3.25 11, 16N, 4E	From mouth upstream to the headwaters including all tributaries.

(2) Instream flows established for the stream management unit described in WAC 173-511-030(1) are as follows:

INSTREAM FLOWS IN THE NISQUALLY RIVER BASIN
(in Cubic Feet per Second)

Month	Day	Lower Reach of the Nisqually River USGS Gage 12-* RM 4.3 RM 4.3	Bypass Reach of the Nisqually River USGS Gage 12-0895-00 RM 21.8	Mid Reach of the Nisqually River USGS Gage 12-0884-00 RM 32.6-
January	1	900	600	900
	15	900	600	900
February	1	900	600	900
	15	900	600	900
March	1	900	600	900
	15	900	600	900
April	1	900	600	900
	15	900	600	900
May	1	900	600	900
	15	900	600	900
June	1	900	500(closed)	800(closed)
	15	850	450(closed)	800(closed)
July	1	800	400(closed)	800(closed)
	15	800	400(closed)	800(closed)
August	1	800	370(closed)	800(closed)
	15	800	370(closed)	650(closed)
September	1	600	370(closed)	600(closed)
	15	600	370(closed)	600(closed)
October	1	700	550(closed)	700(closed)
	15	700	550(closed)	700(closed)
November	1	700	600	700
	15	700	600	700
December	1	800	600	800
	15	900	600	900

*New gage to be established.

Month	Day	Upper Reach of the Nisqually River USGS Gage 12-0825-00 RM 57.8	Mashel River USGS Gage 12-0870-00 RM 3.25
January	1	450	100
	15	450	100
February	1	450	100
	15	450	100
March	1	450	100
	15	450	100
April	1	450	100
	15	450	100
May	1	450	100
	15	450	80
June	1	600	80(closed)
	15	650	70(closed)
July	1	550	50(closed)
	15	500	40(closed)
August	1	450	30(closed)
	15	400	30(closed)
September	1	350	20(closed)
	15	300	20(closed)
October	1	300	20(closed)
	15	300	20(closed)
November	1	350	40
	15	400	70
December	1	450	100
	15	450	100

(3) Instream flow hydrographs, as represented in the document entitled "Nisqually River basin instream resource protection program," shall be used for identification of instream flows on those days not specifically identified in WAC 173-511-030(2).

[Statutory Authority: Chapters 90.22 and 90.54 RCW. 81-04-028 (Order DE 80-42), § 173-511-030, filed 2/2/81.]

WAC 173-511-040 Surface water source limitations to further consumptive appropriations. (1) The department has determined that (a) certain streams exhibit low summer flows or have a potential for going dry thereby inhibiting anadromous fish passage during critical life stages, and (b) historic flow regimes and current uses of certain other streams indicate that no water is available for additional appropriation. Based upon these determinations the following streams and lakes are closed to further appropriation for the periods indicated:

NEW SURFACE WATER CLOSURES

Stream or Lake Section, Township, and Range of Mouth or Outlet	Tributary to	Period of Closure
Mashel River NE1/4SW1/4 Sec. 29, T16N, R4E and all tributaries	Nisqually River	June 1 - Oct. 31
Red Salmon Creek (Mounts Creek) NE1/4NW1/4 Sec. 33, T19N, R1E and all tributaries	Nisqually River	April 1 - Oct. 31
Clear Creek NE1/4SE1/4 Sec. 21, T18N, R1E and all tributaries	Nisqually River	April 1 - Oct. 31
Tanwax Creek NW1/4NE1/4 Sec.20, T16N, R3E and all tributaries	Nisqually River	April 1 - Oct. 31
McAllister Creek (except Medicine Creek) NW1/4N1/4 Sec. 6, T18N, R1E and all tributaries	Puget Sound	all year
Lake Saint Clair SE1/4NW1/4 Sec. 6, T17N, R1E		all year
Toboton Creek (above Hopson Road) SW1/4SW1/4 Sec. 19, T16N, R3E and all tributaries	Nisqually River	April 1 - Nov. 30
Lackamas Creek SE1/4SE1/4 Sec. 13, T16N, R2E and all tributaries	Nisqually River	April 1 - Nov. 30
Murray Creek NW1/4NW1/4 Sec. 16, T17N, R2E	Nisqually River	April 1 - Nov. 30
Bypass Reach, Nisqually River NE1/4SE1/4 Sec. 11, T17N, R1E	Puget Sound	June 1 - Oct. 31
Mid Reach, Nisqually River SE1/4NW1/4 Sec. 1, T16N, R2E	Puget Sound	June 1 - Oct. 31

(2) The following stream and lake low flows and closures are adopted confirming surface water source limitations previously established administratively under the authority of chapter 90.03 RCW and RCW 75.20.050.

EXISTING SURFACE WATER SOURCE LIMITATIONS
CURRENT ADMINISTRATIVE STATUS OF STREAMS AND LAKES
NISQUALLY BASIN, WRIA 11

Stream	Tributary to	Action	Dates
Eaton Creek SE1/4NW1/4 Sec. 6, T17N, R1E	Lake St. Clair	Closure	12/1/53
Harts Lake and outlet streams SW1/4SE1/4 Sec. 1, T16N, R2E	Nisqually River	Low Flow (0.5 cfs bypass)	10/7/44
Horn Creek SW1/4NE1/4 Sec. 1, T16N, R2E	Nisqually River	Closure	7/22/74
Muck Creek and all tributaries SW1/4SW1/4 Sec. 36, T18N, R1E	Nisqually River	Closure	5/26/48
Ohop Creek and all tributaries SW1/4NE1/4 Sec. 25, T16N, R3E	Nisqually River	Closure	2/15/52
Ohop Lake NE1/4SE1/4 Sec. 10, T16N, R1E	Ohop Creek	Lake Level (523 ft)	3/25/66
Thompson Creek and all tributaries SE1/4NE1/4 Sec. 11, T17N, R1E	Nisqually River	Low Flow (1.0 cfs bypass)	11/19/51

EXISTING SURFACE WATER SOURCE LIMITATIONS
CURRENT ADMINISTRATIVE STATUS OF STREAMS AND LAKES
NISQUALLY BASIN, WRIA 11

Stream	Tributary to	Action	Dates
Unnamed Stream and all tributaries SW1/4NW1/4 Sec. 11, T15N, R4E	Alder Lake (Nisqually River)	Closure	4/28/64
Unnamed Stream and all tributaries SW1/4SE1/4 Sec. 17, T17N, R2E	Centralia Canal (Nisqually River)	Low Flow (0.75 cfs bypass)	11/19/51
Unnamed Stream and all tributaries SE1/4SE1/4 Sec. 27, T17N, R2E	Nisqually River	Low Flow (0.50 cfs bypass)	12/6/50
Yelm Creek and all tributaries SW1/4SW1/4 Sec. 12, T.17N, R1E	Nisqually River	Closure	8/7/51

[Statutory Authority: Chapters 90.22 and 90.54 RCW. 81-04-028 (Order DE 80-42), § 173-511-040, filed 2/2/81.]

WAC 173-511-050 Groundwater. Future groundwater withdrawal proposals will not be affected by this chapter unless it is verified that such withdrawal would clearly have an adverse impact upon the surface water system contrary to the intent and objectives of this chapter.

[Statutory Authority: Chapters 90.22 and 90.54 RCW. 81-04-028 (Order DE 80-42), § 173-511-050, filed 2/2/81.]

WAC 173-511-060 Lakes. In future permitting actions relating to withdrawal of lake waters, lakes and ponds shall be retained substantially in their natural condition. Withdrawals of water which would conflict therewith shall be authorized only in situations where it is clear that overriding considerations of the public interest will be served.

[Statutory Authority: Chapters 90.22 and 90.54 RCW. 81-04-028 (Order DE 80-42), § 173-511-060, filed 2/2/81.]

WAC 173-511-070 Exemptions. (1) Nothing in this chapter shall affect existing water rights, riparian, appropriative, or otherwise existing on the effective date of this chapter, nor shall it affect existing rights relating to the operation of any navigation, hydroelectric or water storage reservoir or related facilities.

(2) If, upon detailed analysis, appropriate and environmentally sound proposed storage facilities are found to be compatible with this chapter, such facilities may be approved.

(3) Domestic use for a single residence shall be exempt from the provisions of this chapter; provided that, if the cumulative effects of numerous single domestic diversions and/or withdrawals would seriously affect the quantity of water available for instream uses, then only domestic inhouse use shall be exempt if no alternative source is available.

(4) Stock-watering use, except that related to feedlots, shall be exempt from the provisions established in this chapter.

(5) Future rights for nonconsumptive uses may be granted.

[Statutory Authority: Chapters 90.22 and 90.54 RCW. 81-04-028 (Order DE 80-42), § 173-511-070, filed 2/2/81.]

WAC 173-511-080 Future rights. No rights to divert or store public surface waters of the Nisqually River basin, WRIA 11, shall hereafter be granted, except as provided in WAC 173-511-070, which shall conflict with the purpose of this chapter as stated in WAC 173-511-020.

[Statutory Authority: Chapters 90.22 and 90.54 RCW. 81-04-028 (Order DE 80-42), § 173-511-080, filed 2/2/81.]

WAC 173-511-090 Enforcement. In enforcement of this chapter, the department of ecology may impose such sanctions as appropriate under authorities vested in it, including but not limited to the issuance of regulatory orders under RCW 43.27A.190 and civil penalties under RCW 90.03.600.

[Statutory Authority: Chapters 43.21B, 43.27A, 90.22 and 90.54 RCW. 88-13-037 (Order 88-11), § 173-511-090, filed 6/9/88. Statutory Authority: Chapters 90.22 and 90.54 RCW. 81-04-028 (Order DE 80-42), § 173-511-090, filed 2/2/81.]

WAC 173-511-095 Appeals. All final written decisions of the department of ecology pertaining to permits, regulatory orders, and related decisions made pursuant to this chapter shall be subject to review by the pollution control hearings board in accordance with chapter 43.21B RCW.

[Statutory Authority: Chapters 43.21B, 43.27A, 90.22 and 90.54 RCW. 88-13-037 (Order 88-11), § 173-511-095, filed 6/9/88.]

WAC 173-511-100 Regulation review. The department of ecology shall initiate a review of the rules established in this chapter whenever new information, changing conditions, or statutory modifications make it necessary to consider revisions.

[Statutory Authority: Chapters 43.21B, 43.27A, 90.22 and 90.54 RCW. 88-13-037 (Order 88-11), § 173-511-100, filed 6/9/88. Statutory Authority: Chapters 90.22 and 90.54 RCW. 81-04-028 (Order DE 80-42), § 173-511-100, filed 2/2/81.]

Appendix C

Thurston County Forecasting Methods Memo

THURSTON COUNTY
WASHINGTON
SINCE 1852

COUNTY COMMISSIONERS

John Hutchings
District One
Gary Edwards
District Two
Bud Blake
District Three

COMMUNITY PLANNING &
ECONOMIC DEVELOPMENT DEPARTMENT

Creating Solutions for Our Future

Joshua Cummings, Director

MEMORANDUM

TO: WRIA 11 Planning Unit

FROM: Allison Osterberg
Thurston County Senior Planner

DATE: November 9, 2018

SUBJECT: Thurston County Forecast of Future Domestic Permit-exempt Connections in WRIA 11

This memo outlines the methodology used by Thurston County staff to calculate and evaluate the impact of new domestic permit-exempt uses projected within the portion of the Nisqually Watershed, known as Water Resource Inventory Area 11, within Thurston County jurisdiction for the period from 2018-2040. This analysis is being conducted in support of watershed planning efforts initiated by the Streamflow Restoration Act of 2018 (RCW 90.94).

Background

Under the Streamflow Restoration Act (ESSB 6091, adopted January 19, 2018), "potential impacts on a closed water body and potential impairment to an instream flow are authorized for the new domestic groundwater withdrawals exempt from permitting under RCW 90.44.050 through compliance with the requirements" established in RCW 90.94.020 and .030.

For WRIA 11, these requirements include an update to the existing, adopted watershed plan with actions "the planning units determine to be necessary to offset potential impacts to instream flows associated with permit-exempt domestic water use."

As part of the watershed planning process, the Department of Ecology must determine that the list of actions recommended by the plan, "after accounting for new projected uses of water over the subsequent twenty years, will result in a net ecological benefit to instream resources within the water resource inventory area." (RCW 90.94.020(3)(c)). In its *Interim Guidance for Determining Net Ecological Benefit* (June 2018), Ecology notes that plans must:

> "Characterize and quantify potential impacts to instream resources from the proposed 20-year new domestic permit-exempt water use at a scale that allows meaningful determinations of whether proposed offsets will be in-time and/or in the same sub-basin." (Element 1, page 4)

The guidance includes the following point for achieving this:

- Provide a quantitative evaluation of consumptive water use associated with all projected new domestic permit-exempt uses that will start over the next 20 years
- Estimates should be calculated for suitably sized sub-basins. Where possible, impacts should be quantified for individual rivers or stream reaches, but may be generalized.

Thurston County Methodology

Thurston County used the following methodology to calculate the number of new connections to permit-exempt wells for domestic water use over the period 2018-2040:

1. Define appropriate sub-basins.
2. Estimate total number of new households (dwelling units)
3. Estimate number of new households likely to rely on permit-exempt water connection
    a. Urban areas – calculate proportion of new development on permit-exempt wells, based on past development patterns
    b. Rural areas – subtract number of available connections to existing larger Group A and B water systems from the estimated number of new households (dwelling units)

1. Define appropriate sub-basins

Sub-basin boundaries should be universally agreed upon within the watershed planning unit. Where possible, sub-basin boundaries should be set to match other standard boundaries, for example, dividing along the mainstem Nisqually River, separating Pierce and Thurston counties. Sub-basin boundaries were agreed to by the WRIA 11 Watershed Planning Unit on October 17, 2018, using boundaries provided by the Nisqually Tribe's GIS Department.

2. Estimate total number of new households

Thurston County calculated the change in population and dwelling units between 2018 and 2040 using estimates developed by Thurston Regional Planning Council (TRPC). TRPC, a public agency governed by a 22-member council, develops population and employment forecasts for the Thurston Region to meet the monitoring and evaluation provisions of the Growth Management Act through a Buildable Lands Program. TRPC develops countywide forecasts consistent with those prepared by the Washington State Office of Financial Management (OFM); their population and households forecast is based on demographic trends, labor force participation, migration patterns, zoning regulations, and buildable land supply.

As shown in Table 1, population and dwelling unit forecasts were estimated by sub-basin (Thurston County portion of watershed only), and by jurisdiction: city, urban growth area (UGA), Indian Reservation, rural county. Dwelling unit estimates were also broken into type of household: single family, multifamily, or manufactured homes. Estimates were rounded.

Table 1: Population & Dwelling Unit Change, by Sub-basin 2018-2040, Thurston County portion of Nisqually Watershed, WRIA 11

Subbasin	Jurisdiction	Population change, 2018-2040	Dwelling Units Change, 2018-2040 Total	Single-Family	Multi-family	Man. Homes
McAllister						
	Lacey (City)	150	100	10	90	0

	Lacey UGA	5,350	2,280	1,940	340	0
	Reservation	520	125	123	0	2
	Rural	690	315	410	20	-115
Thompson/Yelm						
	Yelm (City)	16,130	6,620	4,391	2,231	-2
	Yelm UGA	4,220	1,720	1,480	242	-2
	Rural	1,740	650	1,110	40	-500
Lackamas/Toboton/Powell						
	Rural	970	470	500	10	-40
Upper Basin (Thurston County)						
	Rural	0	0	0	0	0
Total		**29,770**	**12,280**	9,964	2,973	-657

Source: TRPC Annual Population Estimates Work Program; TRPC Population and Employment Forecast (2015 Update); Analysis conducted July 2018.

Assumptions and Considerations
TRPC's population forecast model includes the following assumptions:

- Zoning densities achieved in the future are assumed to be similar to those for projects that are currently in the development pipeline.
- Critical areas and associated buffers are deducted from calculations of available land supply and density of projected development. In urban areas, deductions are also made based on requirements for open space, stormwater, and road rights-of-way.
- Incorporated cities will be able to provide water and other capital facilities services to most of the areas designated as urban growth areas, unless constrained by topography, existing land use patterns, or environmental barriers. As discussed in more detail below, this assumption may lead to a higher estimate of projected growth in the Yelm UGA than may be serviced by the municipal water utility currently.
- Multifamily developments include duplexes and triplexes, as well as higher density developments.
- Manufactured homes show a decline over the planning period, especially in the Thompson/Yelm sub-basin. The negative numbers reflect a projected change in housing demand over time that is built into the estimates as a percentage of manufactured homes being converted into single-family homes. This pattern is most noticeable in the rural portion of the Thompson/Yelm sub-basin because several Mobile Home Parks are in this area. Manufactured homes that convert to single-family homes were presumed to not require a new water connection in future steps of the analysis.
- Additional information on the methods and assumptions of TRPC's data program can be found in the following reports, available at https://www.trpc.org/480/Population-Housing-Employment-Data:
    - *Population and Employment Land Supply Assumptions for Thurston County*, November 2012
    - Assumptions for Type of Housing by Zoning District
    - Zoning Assumptions by Jurisdiction
    - Calibration Reports

3. Estimate number of new households likely to rely on permit-exempt water connection

Thurston County used different methodologies for estimating the number of new domestic permit-exempt connections in urban areas and rural areas to better address different development patterns and regulatory requirements between urban and rural areas.

a. Urban areas

Within incorporated city boundaries, Thurston County assumed that all future growth will be served by a municipal water utility. This same assumption could be made for Urban Growth Areas (UGAs), which are identified for future annexation by the cities within the planning period and are often served by municipal utilities even before they are annexed. However, development that relies on permit-exempt wells is permitted in the UGAs, provided that the applicant can demonstrate that a public utility is not available. The extent of this available infrastructure varies considerably among the different UGAs in Thurston County.

Within UGAs, Thurston County looked at the number of estimated new single-family units for each sub-basin, and calculated a percentage that likely would rely on a permit-exempt well. This rate was calculated by looking at patterns among past development as analyzed using the county's permitting system.

Thurston County permit records have not historically recorded the locations of wells, however, development that relies on a permit-exempt well typically also uses an on-site septic system for waste disposal. Permit-exempt well locations were presumed to exist on parcels where a septic system was known to be located, if outside a Group A/B water system boundary. Parcels with a septic system within Group A/B water systems were presumed to have a permit-exempt well if they were more than 300 feet from a known water system supply main. Permit-exempt well locations were assumed to be near a dwelling unit, and were adjusted with a review of aerial photos. Details, including well depth and discharge rate, were added based on information from the surrounding area and permit information, such as number of bedrooms.

Thurston County developed an estimate of groundwater pumping in acre-feet per year (AFY) for both permitted Group A Systems and permit-exempt wells for each UGA (Lacey and Yelm). This estimate was converted into a number of equivalent connections, using the average rate of 0.25 AFY annual groundwater pumping. The proportion of equivalent connections to a permit-exempt well was compared to the proportion of total connections with each UGA to generate an estimated percent of past development that relies on a permit-exempt well.

Table 2: Equivalent Water Service Connections by Well Type, Known Wells Outside City Limits, Thurston County

	Groundwater Pumping in Acre-Feet Per Year	**Equivalent Connections (EC) @ 0.25 AFY Per Connection**

UGA[1]	Domestic Pumping Total (AFY)	Public Supply Group B System (AFY)	Well - Domestic General	Pumping by Permit Exempt Wells (AFY) [2]	Pumping by Group A Systems (AFY)	EC on Permit Exempt Wells [3]	EC on DOH Group A Wells [3]	Total EC [3]	Percent of EC on a Permit Exempt Well	Percent of EC on a Group A Well
Lacey UGA	4,990	36	32	67	4,187	269	16,749	17,018	2%	98%
Yelm UGA	522	17	96	113	49	451	195	646	70%	30%

Source: Thurston County Water Resources, Technical Services Data Program - Calculated September 2018

Notes:
(1) UGAs consider the full UGA boundary, as of 9/1/2018, including areas outside watershed. Subbasins aggregated by WRIA 11 Planning Unit agreement.
(2) Includes DOH Group B, Two-Party and Single Domestic Wells
(3) Equivalent connections at 0.25 acre-feet per year total annual groundwater pumping

Based on this analysis, a very low proportion of development in the Lacey UGA historically has relied on permit-exempt wells (2%). A much higher proportion of development in the Yelm UGA (70%) relies on permit-exempt wells. Table 3 applies these proportions to future projected development for each UGA within the WRIA 11 watershed.

Table 3: Permit-exempt Connections, Urban Growth Areas, Thurston County portion of Nisqually Watershed, WRIA 11

Subbasin	UGA	Single-Family Units, 2018-2040	% Permit Exempt	UGA PE Connections
McAllister	Lacey UGA	1,940	2%	39
Thompson/Yelm	Yelm UGA	1,480	70%	1,036
TOTAL		**3,420**		**1,075**

Assumptions and Considerations

- All units within the incorporated boundaries of a city will be served by a public water system.
- Multifamily units in a UGA will be served by a public water system.
- The proportion of development using a permit-exempt well was calculated for the full area of each UGA, rather than only for the portion within the Nisqually watershed or within each Subbasin. This was done both to account for the small number of developments in some areas, which might not be representative, and to enable the same percentage to be used in other watershed planning processes.
- For additional background on the water use and pumping rates used to generate the equivalent water service connections in Table 2, refer to:

- Thurston County Water Resources, Technical Memorandum #1: *Water Use and Wastewater Generation in Rural/Suburban Areas of Thurston County, Washington* (November 2018; updated August 2018)
- Thurston County Water Resources, Technical Memorandum #8: *Methods Used to Calculate the Pumping Rates, Locations, and Open Intervals of Active Groundwater Wells in Thurston County, Washington* (July 2018)

- Rural areas

Outside UGAs, new households are likely to rely on a permit-exempt well for a domestic water source, unless the new development is within the boundary of a non-municipal water service that has available connections. Thurston County identified 81 water systems (Group A and larger Group B) within the WRIA 11 watershed and reviewed the Washington State Department of Health's Sentry database to calculate the number of available connections for each system. More than a third of the systems (n=29) did not have a specified number of approved connections; because of this, for these systems, no number of available connections could be calculated. Another third of the systems (n=25) have available, approved connections. For water systems with boundaries that were partially outside the watershed, the number of available connections was adjusted according to the proportion of area within the watershed. Table 4 indicates the number of available connections, where data are available, by sub-basin.

To calculate the number of permit-exempt domestic connections in rural areas, the number of adjusted available connections (Table 4) was subtracted from the projected dwelling units in each sub-basin (Table 1). The resulting number of permit-exempt connections forecast in rural areas is shown in Table 5.

Table 4: Permitted Group A and B Water Systems and Available Water Connections, Thurston County portion of Nisqually Watershed, WRIA 11

Subbasin	Group Type	# of Water Systems	# of Water Systems with Available Connections	# of Available Connects	# of Water systems with less than 100% area in watershed	# of Available Connects (adjusted for area)
McAllister						
	Group A	8	4	258	3	191
	Group B	21	4	8	4	8
	SubTotal	**29**	**8**	**266**	**7**	**199**
Thompson/Yelm						
	Group A	11	8	142	2	109
	Group B	37	8	22	6	15
	SubTotal	**48**	**16**	**164**	**8**	**123**
Lackamas/ Toboton/ Powell						

	Group A	2	1	38	0	38
	Group B	2	2	5	1	2
	SubTotal	**4**	**3**	**43**	**1**	**40**
All Basins		**81**	**27**	**473**	**16**	**363**

Source: Washington State Department of Health, Sentry Internet Database, accessed 9/10/2018: https://fortress.wa.gov/doh/eh/portal/odw/si/Intro.aspx

Table 5: Permit-exempt Connections, Rural Areas, Thurston County portion of Nisqually Watershed, WRIA 11

Subbasin	Total New Rural Dwelling Units	Available Water System Connections (Adjusted)	New Rural PE Connections
McAllister	315	199	116
Thompson/Yelm	650	124	526
Lackamas/Toboton/Powell	470	40	430
Upper Nisqually	0	0	0
TOTAL	**1,435**	**363**	**1,072**

Assumptions and Considerations

- No new Group A or larger Group B systems will be permitted over the 20-year planning period.
- No expansions of existing systems will be permitted over the 20-year planning period, and no additional connections will be available. This is likely an underestimate of the number of available connections, given the high proportion of systems that did not have information on approved connections. In addition, some water systems may have water rights to an amount above that required for their current number of approved connections, and thus may be able to expand without needing to apply for additional water rights.
- New development will connect to existing public water systems when connections are available. This assumption is only likely if new development is located within water system boundaries, and if all available connections are made available to new domestic uses.

Results – Permit Exempt Well Connections

In summary, Thurston County estimates a baseline demand for slightly more than 2,000 new permit-exempt connections in the Nisqually watershed through 2040 (Table 6). Averaged over the 22-year planning period, this equates to approximately 100 new permit-exempt connections per year.

Table 6: Total Estimated Permit-exempt Connections, Thurston County portion of Nisqually Watershed, WRIA 11, 2018-2040

Subbasin	UGA PE Connections	Rural PE Connections	Total PE Connections

McAllister	39	116	155
Thompson/Yelm	1,036	526	1,562
Lackamas/Toboton/Powell	-	430	430
Upper Nisqually (Thurston County)	-	0	0
TOTAL	**1,075**	**1,072**	**2,147**

Appendix D

Thurston PUD Group A and B System Data

Thurston PUD Group A and B System Data, 2015-2017

System #	System Name	Group	County	Active Connections	City, Zip	Avg Winter Use per connection -March 2017	Avg Summer Use per connection - August 2017	2015 Avg Annual Use per connection (gpd)	2016 Avg Annual Use per connection (gpd)	2017 Avg Annual Use per connection (gpd)
229	Nisqually Vista	B	TC	12	Olympia 98516	154	677	264	251	284
241	Trinity Muck 1	B	PC	8	Eatonville 98328	120	273	166	122	171
242	Trinity Muck 2	B	PC	8	Eatonville 98328	133	810	168	177	281
245	304th & 92	B	PC	11	Graham 98338	109	286	131	120	135
246	Mt. Ridge	B	PC	9	Graham 98338	94	215	158	138	140
250	Bald Hills	B	TC	6	Yelm 98597	174	351	213	175	196
251	Smith S Prairie	A	TC	14	Yelm 98597	360	620	182	216	210
255	77th	B	PC	6	Roy 98580	89	115	172	171	128
256	Christensen Muck 1	B	PC	9	Eatonville 98328	140	390	223	157	170
257	Christensen Muck 2	B	PC	9	Eatonville 98328	139	225	176	117	168
258	Christensen Muck 3	B	PC	9	Eatonville 98328	105	270	141	133	175
259	Hansford Muck 1	B	PC	6	Eatonville 98328	113	282	198	193	198
260	Hansford Muck 2	B	PC	6	Eatonville 98328	215	329	262	257	266
261	Trinity Muck 3	B	PC	8	Eatonville 98328	124	179	116	121	135
262	Mud Lake	B	PC	7	Eatonville 98328	187	404	269	230	235
263	Wilderness Glen	A	PC	24	Roy 98580	160	245	175	178	170
264	Travis Jack	A	PC	61	Roy 98580	126	259	161	150	165
265	Tish Hinkle	B	PC	7	Roy 98580	101	203	145	121	141
266	Y-Not	B	PC	8	Roy 98580	81	266	106	96	118
267	McKenna Estates	B	PC	8	Roy 98580	131	289	170	201	193
268	Horn Creek 1	B	PC	4	Roy 98580	258	887	380	179	185
269	Horn Creek 2	B	PC	8	Roy 98580	82	194	158	200	200
270	Brighton Creek	B	PC	8	Roy 98580	115	446	176	163	202
271	Easter Day	B	PC	8	DuPont 98327	113	542	336	277	225
272	366th	B	PC	4	Roy 98580	70	307	243	215	121
273	Boundary SK	B	PC	8	Graham 98338	137	286	185	189	163
307	Pleasant Valley	A	PC	17	Graham 98338	174	296	187	183	186
308	Evergreen Vista	A	PC	18	Graham 98338	112	527	192	149	160
309	N. Roy	B	PC	9	Roy 98580	134	233	180	172	170
310	336th 1	B	PC	8	Roy 98580	132	289	124	150	215
311	336th 2	B	PC	9	Roy 98580	121	172	168	172	156
312	304th 1	B	PC	9	Graham 98338	160	325	175	192	199
313	304th 2	B	PC	9	Graham 98338	126	239	180	181	165
314	Lake Whitman	B	PC	8	Graham 98338	66	255	156	86	120
315	Homestead 1	B	PC	6	Roy 98580	165	260	236	163	160
316	Homestead 2	B	PC	6	Roy 98580	92	160	192	143	131
318	Mathias	B	PC	4	Graham 98338	115	366	165	166	193
319	DWS Little	B	PC	6	Eatonville 98338	128	86	100	121	90
364	Nisqually Highlands	A	TC	55	Olympia 98516	132	673	257	262	252
366	Cedar Park	B	PC	6	Eatonville 98328	102	321	136	163	172
367	Durkin	B	PC	4	Roy 98580	94	342	126	117	108
386	Enslow #1	B	TC	5	Yelm 98597	140	484	220	198	228
387	Enslow #2	B	TC	4	Yelm 98597	93	395	174	173	183
388	Enslow #3	B	TC	5	Yelm 98597	59	499	185	236	225

389	Armstrong	B	PC	3	Eatonville 98328	191	367	200	159	195
System was purchased in 2015 - System went to PUD rates on 1/1/2016										
610	Webster Hill	A	PC	20	Graham, 98338	135	545	370	207	190
Systems PUD Purchased in 2017 - Don't have good data for 2015 or 2016 at this time										
618	Maxvale	A	TC	17	YELM, 98597	*	176			
662	Boots & Saddles	A	PC	36	Eatonville 98328	101	480			318
668	Roy 325th	A	PC	67	Roy 98580	291	665			370
674	Orchard	B	PC	6	Roy 98580	114	189			116
690	Meadows	A	TC	889	Olympia 98513	95	374			152
706	Brandywine 4	B	TC	2	Rochester 98579	93	124			261
707	C&M	B	TC	8	Yelm 98597	84	246			149
708	Campbell	B	TC	5	Yelm 98597	109	308			186
709	Champion Estates A	B	TC	6	Yelm 98597	97	338			150
710	Champion Estates B	B	TC	5	Yelm 98597	88	258			164
758	Wind Tree Division 1	B	TC	13	Rainier 98576	57	333			146
759	Prairie View Estates	A	PC	47	Roy 98580	117	556			245
Average Daily Usage for WRIA 11-Nisqually						129	343	191	173	185

Appendix E

Streamflow Mitigation using Floodplain Restoration (Ohop Template)

Appendix A

Streamflow Mitigation Using Floodplain Restoration Techniques

A1 Background

Several Salmon Enhancement projects in WRIA 11 have successfully improved instream habitat and riparian corridors using a variety of methods. More such projects are planned in WRIA 11, and the same methods may be applicable in other sub-basins in WRIA 11. In addition to numerous quantifiable benefits for salmonids and riparian corridor habitat, several of these methods may also directly provide additional streamflow.

The Ohop Valley Creek west of Eatonville has been the site of three major phases of stream corridor restoration using techniques that are directly applicable in other parts of WRIA 11. We view these projects as a template for future additional projects in the Ohop sub-basin and in additional WRIA 11 sub-basins during the timeframe of the 20-year Plan addendum.

In the discussion below, the estimated streamflow benefits accrued by the three Ohop project phases are assessed. Following that, we evaluate the potential quantitative benefits for other similar projects in WRIA 11.

A2 Evaluation of Streamflow Benefits from Ohop Valley Creek Restoration Phases I/II/III

Figure 1 presents specific elements of the Ohop stream corridor restoration efforts. The following specific methods were used at the Ohop Valley Creek restoration site. We consider these to be potentially applicable for other streamflow mitigation projects in WRIA 11:

1. Ditch removal with related off-channel storage
2. Beaver re-introduction
3. Floodplain reconnection and channel re-meandering
4. Log-jams
5. Revegetation

The Ohop project phases are particularly well-suited to evaluation for their possible streamflow benefits. A network of 29 wells (piezometers) was installed in 2008 and prior to the start of Phase I corridor restoration activity (A2-A11, B2-B11, and C1-C9). The groundwater monitoring network was subsequently expanded to 37 wells in 2010, prior to the start of Phase III project activity (D1-D2, D4-D9).

These 37 wells were installed in four transects as shown on Figure A1. Note that transects A2-A11 and B2-B11 were installed upstream of the Phase I/II/III work areas, effectively describing background conditions.

For the following 10 years, monthly depths to water were measured from the top of each well casing at these locations, with some data collection gaps. Also, antecedent water levels were collected before significant work began, assisting with assessment of the effects of each phase of the project. This monitoring program continues through the present.

Water levels were collected throughout this network before, during and after construction of Phase I, II and III. The following completion dates for project Phases indicate when hydraulically significant event occurred:

- **Project Phases I/II.** Constructed from 2009 to 2011, with completion in 2011. Scope of activity: Approximately 3,938 feet of new sinuous channel was constructed, with constructed log-jams. Approximately 2,482 feet of the older nearly-linear incised creek channel was disconnected in 2011 - but was allowed to remain as a waterbody for off-channel storage, receiving winter high-flow water from Ohop Valley Creek. Revegetation and invasive plant removal occurred in some parts of the project area. Because the project was constructed during the summer, the water year 2012, starting October 2011, was the first full water year to experience changes from this work. After project completion, significant beaver activity has been reported from the Phase I/II work area. Data from well transects A2-A11, B2-B11, C1-C9 and D1-D9 could potentially be used for interpretation of the effects of Phase I/II work.

- **Project Phase III.** Completion: 2014. Scope of activity: More than 6,000 additional feet of new sinuous channel was constructed, with constructed log-jams. Over 6,000 feet of the older nearly-linear incised creek channel was disconnected - but was allowed to remain as a waterbody for off-channel storage, receiving winter high-flow water from Ohop Valley Creek. Revegetation and invasive plant removal occurred in some parts of the project area. Because the project was constructed during the summer, the water year 2015, starting October 2014, was the first full water year to experience changes from this work. Data from well transects D1-D9 may be used for interpretation of the effects of Phase I/II work; however, their position is significantly upgradient of the Phase III work area.

These projects produced a large number of benefits for salmonids – with appropriate metrics beyond streamflow alone.

Assessment of the (much narrower) question of quantifiable streamflow increase involved reviewing the water level changes associated with these construction phases. Water level trends at each well across the dates of these construction phases were interpreted using graphical methods.

Graphical water levels were reviewed for all 37 wells where water levels were collected over the 10-year period of measurements. The following analysis was performed by Kevin Hansen, LHg., County Hydrogeologist for Thurston County, and reviewed by David Nazy, LHg., hydrogeologist for EA Engineering and Science. The summary results of this interpretation are presented in Table A1.

The results of the interpretation of changes in water levels are summarized below by restoration technique. To re-emphasize, the following assessment only applies to the specific question of groundwater level trends that can be reasonable associated with the work. Significant changes in groundwater occurred at each well that are normal seasonal fluctuations or climatological effects that were not interpreted to be associated with Project Phases I, II, or III.

1. **Ditch removal with related off-channel storage**. Wells C1, D2 and D4 are near the old channel (ditch) and each experienced a large and sustained rise in water levels after construction of Phase I/II (from 2 to 6 feet). These rises can largely be associated with blocking the ditch flow and allowing it to fill with water. This provided both sustained additional shallow aquifer

storage, and off-channel open water storage. Both the shallow aquifer storage and the off-channel open water storage presumably drain into Ohop Valley Creek during the following dry months. Subsequent to Phase I/II construction, seasonal groundwater level changes of approximately one foot were measured at well C1. Well D4 may have also been affected by beaver activity (see below).

2. **Beaver re-introduction.** Some of the rise in groundwater levels at well D4 may have been caused by beaver activity. After Phase I/II work was complete, intensive beaver activity began at the downstream confluence of the old channel (ditch) and the new sinuous channel, ponding significant new water along the old channel (ditch). Part of the 2.5 foot rise in groundwater levels at D4 occurred later than at wells C1 and D2, and so perhaps 1 foot of that groundwater rise can be reasonably associated with beaver activity.
3. **Floodplain reconnection and channel re-meandering.** Wells C5, C6 and D6 experienced pronounced declines in groundwater level after Phase I/II construction (-2 feet and -1 foot, respectively). Wells D5 and D7 experienced some winter groundwater level declines (approximately -1 foot). These wells are close to the new sinuous channel built during Phase I/II. Their declines can reasonably be associated with drainage of groundwater out of shallow floodplain soils following excavation of the new sinuous channel. Well C4, near the new channel, experienced a rise in water levels of about 0.8 feet; however, this well is on the east side of the new channel, and is likely affected by the sharply higher groundwater levels near the old channel described above.
4. **Log-jams.** Phases I, II and III included the creation of engineered log jams (ELJs). Insufficient data were available to assess the effects of ELJs on groundwater levels from this project area.
5. **Revegetation.** Phases I, II and III included the planting of new vegetation, and the removal invasive vegetation. Insufficient data were available to assess the effects of revegetation on groundwater levels; however, young, growing vegetation is potentially a significant user of water. For this reason, actual streamflows may be somewhat reduced below those expected. This limitation is largely offset by the high habitat-improvement value of revegetation.

Quantification of the streamflow benefits from these project phases is presented in Table A2. Significant assumptions were required to allow meaningful quantification. In the presence of uncertainties, sensitivity analysis is commonly used to develop a range of possible outcomes. Table A2 presents end members of the likely ranges for the two methods with demonstrated benefits, items 1 and 2 (*Ditch removal with related off-channel storage; Beaver re-introduction*). This approach produces a wide but possible band of streamflow benefits for these methods.

The values selected for application in Section AIII, below, are the mid-range (average) of the volume and streamflow bracketed by both two separate analytical methods and the min-max parameter sets, for determination of potential streamflow mitigation in Table A2.

A3 Application of similar techniques for mitigation in other parts of WRIA 11

All of the methods selected for salmonid enhancement at the Ohop Valley Creek projects successfully improve habitat. Based on the data from the Ohop Valley Creek projects, two of these methods can <u>also</u> serve as a viable means for enhancing streamflow:

- Ditch removal
- Beaver introduction

Suitable candidate stream reaches for application of similar projects were selected based on several criteria:

1. Similar hydrology: known or probable ditching of the stream to straighten/move the streambed. This is typically associated with a 'compressed' meander width and an incised stream bed;
2. Similar vegetation;
3. Similar geology;
4. Similar precipitation;
5. Seasonally dry;
6. Upland stream reaches, where new recharge would wet a longer stream reach;
7. Mapped presence of wetlands, hydric soils or seasonal ponded water;
8. Located on large land parcels, with either one owner or a small number of owners.

Using these criteria, 18.25 miles of candidate stream reaches were identified in Thurston County and 61.5 miles of candidate stream reaches in Pierce County. Some candidate stream reaches are already-planned projects (Ohop Phase IV); others are newly-identified potential projects. Specific locations for these reaches are not presented at this time, pending funding availability and further project-specific evaluations.

Thurston County Stream Restoration Candidates

In Thurston County, the Ohop Valley Creek template is useful for an assessment of the 18.25 miles of currently-identified candidate stream reaches. This is based on numerous similarities of hydrology, geology, precipitation, vegetation and potential instream habitat. We expect that over the 20-year Plan timeframe, this pool of candidate projects could result in multiple constructed projects. At this time, the most likely of these projects appear to be located in parts of 1) Thompson-Yelm sub-basin, and 2) Lackamas-Toboton-Powell sub-basin

Table A3 Summarizes the candidate reaches for stream restoration. Using the mapped lengths of the 18.25 miles of stream reaches in Thurston County in conjunction with the per-mile streamflow improvement calculated for the Ohop reference site, reach-specific mitigation volumes and incremental additional streamflows were calculated (see Table A3).

In practical terms, it is likely that only a portion of the candidate projects in Thurston County will actually be constructed. We assume herein that between 10% and 30% of these candidates will result in constructed projects benefitting streamflow – limited primarily by funding availability.

The sum of streamflow benefits [in Thurston County] from the combined effects of all candidate projects for this method (Ditch removal + beaver Re-Introduction) is presented in Table A3 with a factored value of either 10% or 30% of this total – a range we consider practical.

Pierce County Stream Restoration Candidates

In Pierce County, the Ohop Valley Creek template was used for a similar screening assessment of the 61.5 miles of currently-identified candidate stream reaches. This is also based on numerous similarities of hydrology, geology, precipitation, vegetation and potential instream habitat to the Ohop reference site. We expect that over the 20-year Plan timeframe, this pool of candidate projects could result in multiple constructed projects.

Table A3 Summarizes the candidate reaches for stream restoration. Using the mapped lengths of the 61.5 miles of stream reaches in Pierce County, in conjunction with the per-mile streamflow improvement calculated for the Ohop reference site, reach-specific mitigation volumes and incremental additional streamflows were calculated (see Table A3).

In practical terms, it is likely that only a portion of the candidate projects in Thurston County will actually be constructed. We assume herein that between 10% and 30% of these candidates will result in constructed projects benefitting streamflow – limited primarily by funding availability.

The sum of streamflow benefits [in Pierce County] from the combined effects of all candidate projects for this method (Ditch removal, beaver re-introduction, etc.) is presented in Table A3 with a factored value of either 10% or 30% of the total length of candidate reaches – a range we consider practical for planning purposes.

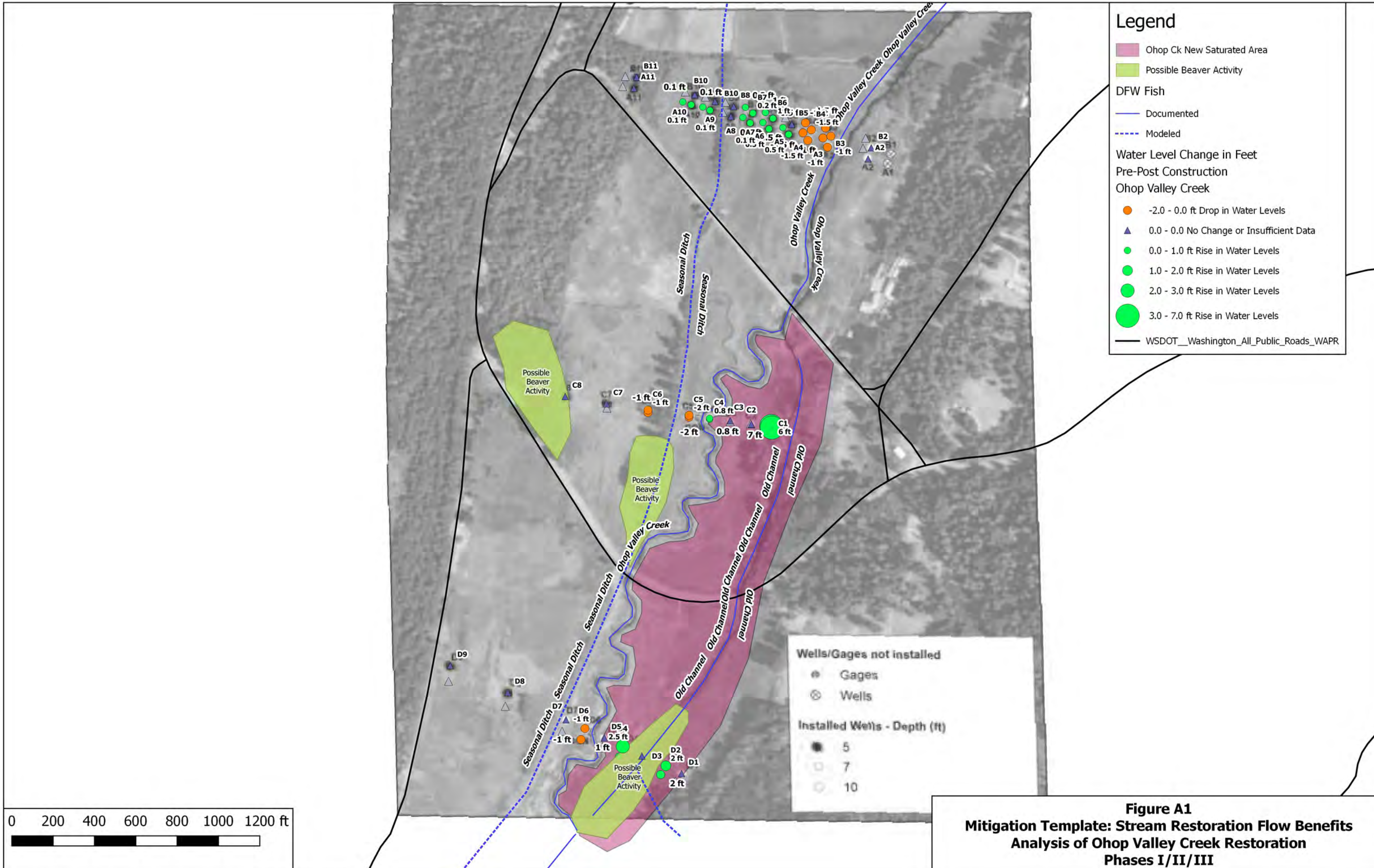


Figure A1
Mitigation Template: Stream Restoration Flow Benefits
Analysis of Ohop Valley Creek Restoration
Phases I/II/III

Table A1
Analysis of Groundwater Levels Pre/Post Construction
Ohop Valley Creek Phases I/II/III

Well ID	Monitoring Start Date	Magnitude of Change in Depth to Groundwater (feet) Between Pre- and Post-Construction	Interpreted Direction of Water Level Change	Well Depth Below Ground (ft)	Notes	X_FIPS4602	Y_FIPS4602
A2	24-Jun-08	0.0	NC - No Change	10	Weak data	1179913.089	565784.488
A3	19-Jun-08	-1.0	Fall	10	~1 ft fall in winter, ~1 ft fall in summer - well near old channel	1179718.151	565846.0476
A4	19-Jun-08	-1.5	Fall	10	~0.5 ft fall in winter, ~1.5 ft fall in summer - well near old channel	1179623.759	565880.9313
A5	19-Jun-08	0.5	Rise	5	Weak trend, summer data	1179531.42	565911.7111
A6	19-Jun-08	0.5	Rise	5	Weak trend, summer data	1179437.029	565940.4389
A7	19-Jun-08	0.1	Rise	5	Weak trend, summer data	1179346.741	565971.2187
A8	19-Jun-08	0.0	NC - No Change	5	OK data	1179254.402	566004.0505
A9	24-Jun-08	0.1	Rise	5	Weak trend, summer data	1179153.855	566036.8823
A10	24-Jun-08	0.1	Rise	5	Weak trend, summer data	1179063.567	566065.6101
A11	24-Jun-08	0.0	NC - No Change	5	Weak data	1178788.601	566151.7935
B2	24-Jun-08	0.0	NC - No Change	10	OK data	1179929.505	565837.8396
B3	19-Jun-08	-1.0	Fall	10	~1 ft fall in winter, ~1 ft fall in summer - well near old channel	1179735.593	565898.3732
B4	19-Jun-08	-1.5	Fall	10	~0.5 ft fall in winter, ~1.8 ft fall in summer - well near old channel	1179642.227	565931.205
B5	19-Jun-08	0.0	NC - No Change	5	OK data	1179547.836	565959.9328
B6	19-Jun-08	1.0	Rise	5	Summer rise; winter seepage face (no change)	1179457.548	565990.7126
B7	19-Jun-08	0.2	Rise	5	Summer rise; winter seepage face (no change)	1179361.105	566018.4144
B8	24-Jun-08	0.0	NC - offsetting changes	5	Summer rise; winter fall	1179268.766	566052.2722
B10	24-Jun-08	0.0	NC - No Change	5	OK data	1179179.504	566078.948
B10	24-Jun-08	0.0	NC - No Change	5	OK data	1179082.035	566112.8058
B11	24-Jun-08	0.0	NC - No Change	5	Weak data	1178802.965	566204.1191
C1	16-Jul-08	6.0	Significant Rise	10	Significant rise except 2015 drought year	1179417.282	564500.1313
C2	16-Jul-08	0.0	Inconclusive	10	Weak data	1179318.348	564518.4126
C3	16-Jul-08	0.0	Inconclusive	10	Weak data	1179217.263	564537.7693
C4	16-Jul-08	0.8	Rise	7	Summer rise; winter probable no change	1179117.253	564551.7492
C5	16-Jul-08	-2.0	Fall	10	3 ft fall in winter, 1 ft fall in summer - well near new channel	1179018.319	564568.9551
C6	16-Jul-08	-1.0	Fall	10	No change in winter, roughly 1 ft fall in summer - well near old ditch on DFW salmon mapping	1178820.451	564599.0656
C7	16-Jul-08	0.0	NC - No Change	5	OK data	1178619.356	564633.4775
C8	16-Jul-08	0.0	NC - No Change	5	OK data	1178421.488	564673.2663
D1	11-Jun-10	0.0	NC - No Change	10	OK data -Seasonal Change is very small	1178941.809	562842.1423
D2	11-Jun-10	2.0	Significant Rise	10	Significant rise except 2015 drought year	1178866.765	562881.2957
D3	28-Apr-11	0.0	ND		Gage - destroyed/lost - Sparse data	1178751.752	562931.053
D4	11-Jun-10	2.5	Rise	10	Rise after 2015 Phase III construction - many data gaps	1178660.394	562979.9947
D5	11-Jun-10	0.0	NC - No Change	10	OK data -Seasonal Change is very small	1178572.299	563022.4108
D6	11-Jun-10	-1.0	Fall	10	Probable fall - well near new channel	1178479.31	563070.5368
D7	11-Jun-10	0.0	Inconclusive	10	Weak data: Winter fall, Summer rise - close to creek	1178388.768	563114.5843
D8	11-Jun-10	0.0	Inconclusive	5	Weak data: too many gaps to use	1178109.801	563252.4367
D9	11-Jun-10	0.0	Inconclusive	5	Weak data: too many gaps to use	1177834.912	563388.6576

Table A2
Streamflow Benefits Analysis
Ohop Valley Creek Restoration Projects Phase I, II and III

Method	**Ditch Removal with Off-Channel Storage**		**Beaver Re-Introduction**			
	Minimal	**Maximal**	**Minimal**	**Maximal**	**Units**	**Notes**
Area of New Saturation (A)	27.44	27.44	3.36	3.36	acres	Estimates from GIS polygons
Avg. Increase in Saturated Thickness (dS)	1	2	1	2	feet	
Porosity (n)	0.15	0.3	0.15	0.3	fraction	
Percent of groundwater reaching discharge (Factor)	0.3	0.7	0.3	0.7	fraction	
Length of ditch removed	2,482	2,482	NA	NA	feet	
New Groundwater Reaching Creek (V)						
V = A x dS x n x Factor	1.2	11.5	0.1512	1.4112	acre-feet per year (afy)	Assumes 50% evapotranspiration of surface water; assume beaver pond averages 1 foot deep
Open-Water Storage	2.6	4.3	1.68	1.68	acre-feet per year (afy)	Assumes 50% evapotranspiration of surface water; assume beaver pond averages 1 foot deep
Total Volume	3.8	15.8	1.8	3.1	acre-feet per year (afy)	
Mean Values	**9.8**		**2.5**		acre-feet per year (afy)	
Timing Analysis for the New Groundwater Seepage to Streamflow						
Method #1 - all groundwater reaches creek at average groundwater velocity						
Average Groundwater Travel Distance (d)	400	480	150	250	feet	
Hydraulic Conductivity (K)	90	110	90	110	ft/day	
Hydraulic gradient (i)	0.005	0.003	0.005	0.003	ft/ft	
Porosity (n)	0.15	0.3	0.15	0.3	fraction	
Groundwater velocity (v)						
v = (K x i)/n	3.000	1.100	3.000	1.100	ft/day	
Migration time (T)						
Time = d/v	133	436	50	227	days	Time to fully drain new groundwater to provide additional streamflow using Method #1 assumptions
Discharge Rate						
Q = V/Time	0.051	0.016	0.137	0.030	acre-feet/day	
	0.026	0.008	0.069	0.015	cfs (cubic feet per second)	
Method #2 - all groundwater reaches creek as limited by hydraulic cnductivity						
Hydraulic Conductivity (K)	90	110	90	110	ft/day	
Hydraulic gradient (i)	0.005	0.003	0.005	0.003	ft/ft	
Seepage Face/Channel length	3938	3,938	700	900	feet	
Height of seepage face	1	1	1	1	feet	
Seepage Area (A)	3,938	3,938	700	900	sq. feet.	
Darcy Equation						
Q = K x i x A	1,772	1,300	315	297	cubic feet per day	
Discharge Time (T)						
Time = V/Q	93	530	253	453	days	Time to fully drain new groundwater to provide additional streamflow using Method #2 assumptions
Discharge Rate						
Q = V/Time	0.0132	0.0218	0.0006	0.0031	acre-feet/day	
	0.0067	0.0110	0.0003	0.0016	cfs (cubic feet per second)	
Unit Quantities						
Additional Streamflow per Mile	1.9E-02	5.9E-03	2.8E-03	7.8E-04	cfs per channel-mile - Method #1	per mile of stream channel; for beaver, assumes 30% of length is beaver pond
Additional Streamflow per Mile	5.0E-03	8.2E-03	1.2E-05	8.0E-05	cfs per channel-mile - Method #2	per mile of stream channel; for beaver, assumes 30% of length is beaver pond
Additional Recharge per Mile	2.63	24.52	NA	NA	acre-feet per year (afy)	per mile of ditch removed
Average Additional Streamflow per Mile	0.0096		0.0009		cfs per channel-mile	Average (mean) of min-max of both methods
Average Additional Recharge per Mile	13.57		NA		acre-feet per year (afy)	per mile of ditch removed

Table A3
Summary of Possible Stream Restoration Projects
Thurston and Pierce Counties

			Possible Ditch Removal Length		Possible Beaver Re-Introduction Only		Calculated Streamflow Benefit Using Ohop Template Results: Ditch Removal			Calculated Streamflow Benefit Using Ohop Template Results: Beaver Re-Introduction Only		
Subwatershed	Stream	Interim Tracking ID	feet	miles	feet	miles	afy [2]	Mitigated P.E. Connections [1]	cfs [3]	afy	P.E. Connections	cfs
Lackamas Toboton Powell	Lackamas Creek	Project 11	2,508	0.48			6.4		0.0046			
Lackamas Toboton Powell	Lackamas Creek	Project 12	2,185	0.41			5.6		0.0040			
Lackamas Toboton Powell	Lackamas Creek	Project 13	3,283	0.62			8.4		0.0060			
Lackamas Toboton Powell	Toboton Creek	Project 14			3,367	0.64				NA		0.0006
Lackamas Toboton Powell	Toboton Creek	Project 15	1,283	0.24	3,923	0.74	3.3		0.0023	NA		0.0007
Lackamas Toboton Powell	Toboton Creek	Project 16	3,059	0.58			7.9		0.0056			
Ohop	Ohop Valley Creek	Ohop Phase IV [4]	9,504	1.80			24.4		0.0173			
Prairie Tribs	Tanwax Creek and tribs	Tanwax 1	68,640	13.00			176.4		0.1248			
Prairie Tribs (incl. JBLM)	Muck Creek and tribs	Muck 1	205,920	39.00			529.3		0.3745			
Prairie Tribs (incl. JBLM)	Lacamas Creek and tribs (Pierce County)	Lacamas 1	40,656	7.70			104.5		0.0739			
Thompson Yelm	Yelm Creek East Branch	Project 1	4,080	0.77			10.5		0.0074			
Thompson Yelm	Yelm Creek East Branch trib	Project 1	7,523	1.42			19.3		0.0137			
Thompson Yelm	Yelm Creek East Branch trib	Project 3	9,414	1.78			24.2		0.0171			
Thompson Yelm	Yelm Creek East Branch trib	Project 9	3,502	0.66			9.0		0.0064			
Thompson Yelm	Yelm Creek South Branch	Project 17	9,657	1.83			24.8		0.0176			
Thompson Yelm	Yelm Creek South Branch trib	Project 17	4,708	0.89			12.1		0.0086			
Thompson Yelm	Yelm Creek South Branch	Project 18	11,856	2.25			30.5		0.0216			
Thompson Yelm	Yelm Creek South Branch trib	Project 18	6,107	1.16			15.7		0.0111			
Thompson Yelm	Yelm Creek	Project 19	8,754	1.66			22.5		0.0159			
Thompson Yelm	Yelm Creek East Branch	Project 19	6,790	1.29			17.5		0.0124			
Thompson Yelm	Yelm Creek South Branch	Project 19	7,570	1.43			19.5		0.0138			
Thompson Yelm	Thompson Creek	Project 20	73	0.01			0.2		0.0001			
Thompson Yelm	Thompson Creek trib	Project 20	4,012	0.76			10.3		0.0073			

Raw Possible Mitigation	Total by Method	1082.4	10,164	0.7659			0.0013
	Ohop (new projects)	24.4	229	0.0173			
	Prairie Tribs (incl. JBLM)	810.2	7,608	0.5733			
	Lackamas Toboton Powell	31.7	297	0.0224			0.0013
	Thompson Yelm	216.0	2,029	0.1529			0.0000

Mitigation Factored by 10% Project Funding	Factored Total by Method	108.2	1,016	0.0766			0.0001
	Factored Ohop (new projects)	2.4	23	0.0017			
	Factored Prairie Tribs (incl. JBLM)	81.0	761	0.0573			
	Factored Lackamas Toboton Powell	3.2	30	0.0022			0.0001
	Factored Thompson Yelm	21.6	203	0.0153			0.0000

Mitigation Factored by 30% Project Funding	Factored Total by Method	324.7	3,049	0.2298			0.0004
	Factored Ohop (new projects)	7.3	69	0.0052			
	Factored Prairie Tribs (incl. JBLM)	243.1	2,282	0.1720			
	Factored Lackamas Toboton Powell	9.5	89	0.0067			0.0004
	Factored Thompson Yelm	64.8	609	0.0459			0.0000

Notes:
1) Physical water connection consumptive use of 95 gpd or 0.1064938 afy
2) afy per mile of ditch removed
3) cfs per mile of stream channel, assumed equal to length of ditch removed
4) Project design already underway - construction expected

Appendix F

Nisqually Salmon Recovery Initiatives

F-1 Nisqually Priority Net Ecological Benefit Habitat Initiatives

Nisqually Priority Net Ecological Benefit

Habitat Initiatives

Initiative:
Mashel Watershed Recovery/Community Forest

Geographic Scope:
Mashel Watershed

Flow Restoration Priority: 1

Initiative Actions:

- Change commercial forestland management to promote mature stand forest with benefits to stream.

Estimated Ecological Benefit:

- Full implementation of Nisqually Community Forest Management Plan will contribute an estimated an additional 5 cfs of instream flow. See Figure 6 of VELMA Report.
- Community forest management will increase the quantity and quality of critical salmon habitat, including ESA-listed Chinook and steelhead.

Resources/Supporting Documentation:

- Nisqually Community Forest VELMA Report
- Nisqually Community Forest Management Plan
- Nisqually River Steelhead Recovery Team. 2014. Nisqually River Steelhead Recovery Plan.
- Nisqually Chinook Recovery Team. 2001. Nisqually Chinook Recovery Plan.

Initiative:
Mashel Base Flow

Geographic Scope:
Mashel River at Town of Eatonville

Flow Restoration Priority: 2

Initiative Actions:

- Implement stormwater projects as described by the Eatonville Stormwater Comprehensive Plan.
- Develop alternate water supply for town of Eatonville.

Estimated Ecological Benefit:

- Stormwater projects will significantly increase summer baseflow by recharging groundwater through stormwater infiltration. Net streamflow benefit to be determined.
- Substituting surface water withdrawal for the Town's drinking water from Mashel River with an alternative source will result in an estimated increase of summer base flows of 0.8 cfs.

Resources/Supporting Documentation:

- Eatonville Comprehensive Stormwater Plan
- Phase I Storage Evaluation, Eatonville
- Eatonville Alternative Water Source Report, Table 7
- Nisqually River Steelhead Recovery Team. 2014. Nisqually River Steelhead Recovery Plan.
- Nisqually Chinook Recovery Team. 2001. Nisqually Chinook Recovery Plan.

Initiative:
Ohop Valley Floodplain Restoration

Geographic Scope:
Ohop Valley from Ohop Lake to confluence of Ohop Creek and Nisqually River

Flow Restoration Priority: 3

Initiative Actions:

- Continue to restore Ohop Creek floodplain, which includes recreating a sinuous creek channel, removing agricultural ditches, and increasing floodplain connectivity .

Estimated Ecological Benefit:

- Fully restore 710 acres of floodplain in the Ohop Valley will promote groundwater recharge and wetland formation contributing to increased baseflows. The initiative is approximately 50% completed.
- Ohop Creek restoration will increase the quantity and quality of critical salmon habitat, including ESA-listed Chinook and steelhead.

Resources/Supporting Documentation:

- Lower Ohop Restoration Phase 3, Final Design and As-Built Report
- Nisqually River Steelhead Recovery Team. 2014. Nisqually River Steelhead Recovery Plan.
- Nisqually Chinook Recovery Team. 2001. Nisqually Chinook Recovery Plan.

Initiative:
Mashel River Riparian Corridor Protection and Restoration

Geographic Scope:
Mashel River, RM 3.2 (Hwy 7) to RM 6.6 (Boxcar Canyon)

Flow Restoration Priority: 4

Initiative Actions:

- Establish and maintain 75 functional engineered logjams (ELJs) to form deep pools to increase storage capacity.
- Protect entire riparian corridor to provide for natural log jam formation and other benefits.

Estimated Ecological Benefit:

- The reach has lost 50% of its pool habitat. This initiative will increase pool habitat to properly functioning conditions by protecting the riparian corridor and establishing and maintaining at least 75 ELJs. Increasing pool habitat will:
  - Increase channel volume promoting groundwater infiltration.
  - Increase volume during summer baseflow, providing critical habitat for ESA-listed juvenile salmon.
  - Habitat complexity from logjams provides high water refugia for ESA-list juvenile salmon.
  - Pool tail-outs are preferred spawning areas for ESA-list adult salmon.

Resources/Supporting Documentation:

- Mashel River Restoration Design Assessment (2004), Pg. 39/Table 6
- Mashel Eatonville Restoration Project Phase III, Final Design
- Nisqually River Steelhead Recovery Team. 2014. Nisqually River Steelhead Recovery Plan.
- Nisqually Chinook Recovery Team. 2001. Nisqually Chinook Recovery Plan.

Initiative:
Muck Creek Recovery (Includes tributaries)

Geographic Scope:
Muck Creek Watershed

Flow Restoration Priority: 5

Initiative Actions:

- Protect and restore water storage function of wetlands, including the ecosystem function of beaver dam complexes.
- Maintain prairie ecosystem with prescribed burns and riparian plantings, including removal of Douglas fir forests.

Estimated Ecological Benefit:

- A decrease in the frequency of fires has allowed Douglas firs to encroach on a significant portion of the prairie ecosystem, drawing up large quantities of water otherwise available for instream flows. Further information/modeling needed to estimate impacts of Douglas fir on streamflow in prairie ecosystems.
- Riparian and wetland/beaver dam complex restoration. Research has shown that beaver dams increase groundwater recharge and summer baseflow in streams.

Resources/Supporting Documentation:

- David H. Peter and Timothy B. Harrington. 2014. Historical Colonization of South Puget Sound Prairies by Douglas-Fir at Joint Base Lewis-McChord, Washington Northwest Science, 88(3):186-205.
- Pollock, Michael & Heim, Morgan & Werner, Danielle. 2003. Hydrologic and Geomorphic Effects of Beaver Dams and Their Influence on Influence on Fishes. American Fisheries Society Symposium. 2003.
- Nisqually River Steelhead Recovery Team. 2014. Nisqually River Steelhead Recovery Plan.

Initiative:
Prairie Tributaries Recovery

Geographic Scope:
Prairie Tributary Streams, including Yelm, Murray, Tanwax, Horn, Brighton, Kreger, Harts, and McKenna Creeks

Flow Restoration Priority: 6

Initiative Actions:

- Protect and restore water storage function of wetlands, including the ecosystem function of beaver dam complexes.
- Maintain prairie ecosystem with prescribed burns and riparian plantings, including removal of Douglas fir forests.

Estimated Ecological Benefit:

- A decrease in the frequency of fires has allowed Douglas firs to encroach on a significant portion of the prairie ecosystem, drawing up large quantities of water otherwise available for instream flows. Further information/modeling needed to estimate impacts of Douglas fir on streamflow in prairie ecosystems.
- Riparian and wetland/beaver dam complex restoration. Research has shown that beaver dams increase groundwater recharge and summer baseflow in streams.

Resources/Supporting Documentation:

- David H. Peter and Timothy B. Harrington. 2014. Historical Colonization of South Puget Sound Prairies by Douglas-Fir at Joint Base Lewis-McChord, Washington Northwest Science, 88(3):186-205.
- Pollock, Michael & Heim, Morgan & Werner, Danielle. 2003. Hydrologic and Geomorphic Effects of Beaver Dams and Their Influence on Influence on Fishes. American Fisheries Society Symposium. 2003.
- Nisqually River Steelhead Recovery Team. 2014. Nisqually River Steelhead Recovery Plan

Initiative:
Ohop Watershed Recovery/Community Forest

Geographic Scope:
Upper Ohop Watershed, from Ohop Lake to the watershed divide

Flow Restoration Priority: 7

Initiative Actions:

- Change commercial forestland management to promote mature stand forest with benefits to stream

Estimated Ecological Benefit:

- Full implementation of Nisqually Community Forest Management Plan will contribute to instream flows. VELMA modeling needs to done specifically for the Ohop Watershed in order to quantity instream flow benefit.
- Community forest management will increase the quantity and quality of critical salmon habitat, including ESA-listed Chinook and steelhead.

Resources/Supporting Documentation:

- Nisqually Community Forest VELMA Report
- Nisqually Community Forest Management Plan
- Nisqually River Steelhead Recovery Team. 2014. Nisqually River Steelhead Recovery Plan.
- Nisqually Chinook Recovery Team. 2001. Nisqually Chinook Recovery Plan.

Initiative:
Bald Hills Watershed Recovery/Community Forest

Geographic Scope:
Bald Hills Tributaries, including Powell, Lackamas, Toboton and Elbow Lake Creeks

Flow Restoration Priority: 8

Initiative Actions:

- Change commercial forestland management to promote mature stand forest with benefits to stream

Estimated Ecological Benefit:

- Full implementation of Nisqually Community Forest Management Plan will contribute to instream flows. VELMA modeling needs to done specifically for the Bald Hills tributaries in order to quantity instream flow benefit.
- Community forest management will increase the quantity and quality of critical salmon habitat, including ESA-listed Chinook and steelhead.

Resources/Supporting Documentation:

- Nisqually Community Forest VELMA Report
- Nisqually Community Forest Management Plan
- Nisqually River Steelhead Recovery Team. 2014. Nisqually River Steelhead Recovery Plan.
- Nisqually Chinook Recovery Team. 2001. Nisqually Chinook Recovery Plan.

Initiative:
Barrier Removal

Geographic Scope:
Nisqually Watershed

Flow Restoration Priority: 9

Initiative Actions:

- Remove barriers to increase available salmon habitat and ecosystem connectivity

Estimated Ecological Benefit:

- Provide immediate access to available salmon habitat

Resources/Supporting Documentation:

- WDFW Barrier Assessment
- Thurston County Barriers Analysis

Appendix F

Nisqually Salmon Recovery Initiatives

F-2 Nisqually Salmon Habitat Initiatives and Water Quantity Prioritization Crosswalk

Nisqually Salmon Habitat Initiatives and Water Quantity Prioritization Crosswalk

The Nisqually Indian Tribe Salmon Recovery Team (Recovery Team) utilized the 2018 Nisqually Habitat Project Ranking Guidance (Guidance, attached) in order to develop a prioritized list of actions that will improve water quantity (Table 1). The Guidance was developed by combining the recovery priorities for Nisqually Chinook and steelhead, both of which are listed as 'threatened' under the federal Endangered Species Act and have technically robust recovery plans. The Nisqually habitat recovery initiatives address multiple physical and biological metrics (see Appendix A in Guidance), including water quantity, that are critical to Chinook and steelhead recovery. The Recovery Team constructed Table 1 by listing and then ranking those habitat initiatives from the Guidance that will have a direct, positive impact on water quantity after full implementation. For each initiative, the specific action(s) which have water quantity benefits are also included. The resulting prioritized list of habitat initiatives contains opportunities to both improve water quantity and to significantly advance the recovery of threatened salmon and steelhead populations in the Nisqually Watershed.

Table 1. Nisqually Salmon Habitat Initiatives Prioritized for Water Quantity Restoration Potential

Habitat Initiative	VSP Impact								Salmon Recovery Tier	Streamflow Implementation Actions	Flow Restoration Priority	PU Sub-Basin
	Abundance		*Spatial Diversity*		*Diversity*		*Productivity*					
	CH	Sthd	CH	Sthd	CH	Sthd	CH	Sthd				
Mashel Watershed Recovery/ Community Forest (Boxcar to Watershed Divide)	H	H	H	M	H	M	M	H	2	• Change commercial forestland management to promote mature forests that have benefits to base flow	1	Mashel (Watershed-wide)
Mashel Baseflow	M	H	M	M	H	M	H	H	2	• Eatonville Stormwater Comp. Plan • Develop alternate water supply for town of Eatonville	2	Mashel
Muck Creek Recovery (Includes tributaries)	L	M	L	H	L	H	L	M	3	• Protect and restore water storage function of wetlands, including beaver ponds • Maintain prairie ecosystem with prescribed burns including removal of Douglas fir forests	3	Prairie Tributaries
Prairie Tributaries Recovery	M	M	L	M	L	M	M	M	4	• Protect and restore water storage function of wetlands, including beaver ponds • Maintain prairie ecosystem with prescribed burns including removal of Douglas fir forests	4	Prairie Tributaries
Upper Ohop Recovery (Lake, Lynch, 25 mile)	L	L	L	L	L	L	M	M	4	• Protect forestland and wetlands/springs	5	Ohop
Bald Hills Tributaries Recovery	L	L	L	L	L	L	L	L	4	• Protect forestland and wetlands/springs	6	Lackamas/ Toboton/ Powell

Habitat Initiative	**VSP Impact**								**Salmon Recovery Tier**	**Streamflow Implementation Actions**	**Flow Restoration Priority**	**PU Sub-Basin**
	Abundance		***Spatial Diversity***		***Diversity***		***Productivity***					
	CH	Sthd	CH	Sthd	CH	Sthd	CH	Sthd				
Ohop Valley Recovery (Mouth to Lake)	L	M	M	L	M	L	L	M	3	• Continue to restore sinuous channel and floodplain connectivity, including beaver ponds, to increase water storage	7	Ohop
Mashel River Protection and Restoration (Mouth to Boxcar)	H	H	M	M	M	M	M	H	2	• Protect and restore riparian area and floodplain to shade channel and provide wood for natural log jam formation	8	Mashel
Mashel ELJ (or other in-stream technique) construction and maintenance (Mouth to Boxcar)	H	H	M	M	M	M	L	H	2	• Increase water storage capacity of channel by ELJ forming deep pools	9	Mashel
Barrier Removal	L	M	L	H	L	H	L	L	3	• Under certain conditions barriers can cause a decrease in flow	10	Any
Invasive Plant Species Control	L	L		M		M	L	L	3	• Remove aquatic invasive vegetation that limits the water storage capacity of wetlands	11	Any
Red Salmon Creek Recovery	L	L	L	L	L	L	L	L	4	• Protect existing spring-fed system including wetlands	12	Lower Nisqually
McAllister Creek Recovery	L	L	L	L	L	L	L	L	4	• Protect existing spring-fed system including wetlands	13	McAllister

Appendix F

Nisqually Salmon Recovery Initiatives

F-3 Nisqually Habitat Project Ranking Guidance

Nisqually Habitat Project Ranking Guidance

2018 SRFB/PSAR Grant Round

Introduction

As written in the Washington State RCW, it is the task of each Lead Entity (LE) to develop and submit an annual project list to propose for funding through the Salmon Recovery Funding Board (SRFB), and on even years, a second list for consideration of Puget Sound Acquisition and Restoration (PSAR) funds. Each list must be prioritized and approved by the Nisqually Salmon Habitat Work Group (HWG) and Nisqually River Council (the LE's technical and citizens committees) and submitted to the WA Recreation and Conservation Office for review and funding consideration. Each LE must have in place an approved process by which they prioritize potential projects that directly reflects their recovery plans. Project awards are dependent on the LE's annual allocation, total dollar value of proposed projects, and final review/approval from the SRFB review panel and board members.

Beginning in 2017 the Nisqually Indian Tribe's Salmon Recovery Program, which also serves as the Nisqually Lead Entity, began updating how habitat projects being considered for State funding are prioritized. For years, the Tribe has utilized Ecosystem Diagnosis and Treatment (EDT) to forecast and inform recovery planning for both Nisqually Chinook and steelhead, as well as the criteria used for ranking habitat projects. For this update, EDT outputs were rerun to ensure the most current science available was being used to inform the process (Appendix A). Abundance, spatial diversity, diversity, and productivity parameters were all considered, allowing for a reach-scale analysis for identification of maximum habitat benefit to Nisqually Chinook and steelhead. These outputs have been summarized under "VSP (Viable Salmon Populations) Impact" on the Habitat Initiative Table (Appendix B) using the following scale: VH = very high, H = high, M = medium, L = low.

This analysis led directly to the development of the table's tier system and how initiatives are organized and prioritized within that system. Organized by color, each tier has a number of major habitat initiatives identified as vital for the recovery of Nisqually Chinook and steelhead. It is important to note that initiatives are merely listed and not ranked within each tier. For each initiative there are between one and four specific implementation metrics, which will be used to track progress within the initiative. These metrics were chosen because they are measureable targets that can be easily tracked using GIS data analysis, allowing for simplicity and repeatability.

Next steps for this update include developing specific targets for each metric that will allow the Lead Entity, project sponsors, and watershed partners a means for communicating the impact of both a single project and the overall progress made towards the watershed's protection and restoration goals. However, before these targets can be set, a more comprehensive analysis must be conducted to determine what existing impairments should be considered as "permanent" and therefore will prevent achieving 100% restoration or protection for each initiative. Please note that the goals will determine the progress of each initiative, but will not be used in project scoring. The primary objective for each project is to move the initiative metric as far as possible. Analysis to be complete by the end of 2018.

Scoring

Project scoring will be based on five criteria: what tier they fall in, project impact (measured by % change), project readiness, timing/sequencing, and cost effectiveness. Each criterion has been assigned a certain number of possible *points with bins guiding the number of points awarded for different levels and a total possible score of 100. The complete scoring matrix has been provided in Appendix C.*

Since information needed for tier and impact scoring will be drawn directly from sponsor PRISM applications and associated Salmon Project Proposals, and therefore available prior to the annual ranking meeting, this portion can be completed by the Lead Entity Coordinator in advance of the meeting. This will ensure there is plenty of time for discussion of the remaining criteria and final ranking and approval of the project list(s). This means sponsors should be prepared to have PRISM application materials no later than one week prior to the scoring meeting, ensuring projects are scored fairly and accurately.

For projects with multiple implementation metrics: the % change from the implementation metric with the greatest expected % change will be used for scoring, to award the highest possible number of points for the project.

For projects with multiple components: Points will be awarded to what is regarded as the project's primary component. For example, a project that proposes an acquisition and/or restoration of a parcel, combined with stewardship activities at an adjacent site, will be awarded points based on the acquisition and/or restoration.

If after compiling the scoring for the tier and % change measures there is a numerical tie between projects, projects will be ranked in order of % change and a spread of points will be applied as a tie breaker. For example, if three "Mainstem Riparian and Floodplain Habitat Protection and/or Restoration" projects all receive 45 points based on tier and project impact, projects will be listed in order of biggest to smallest % change and awarded 1, 0, or -1 additional points, respectively. As in this example, the spread of points will be added and subtracted in a way that creates spread between projects without inflating all the scores. No more than 4 points will be added or subtracted to avoid bringing a project up or down so far that it crosses into the next bin (half points can be awarded if there are enough projects to warrant it).

Priority sequencing will also be considered when ranking projects. *When taking timing and sequencing into consideration, se*quencing within a project area should occur in the following order:

1. Protection of the proposed parcel
2. Restoring access and connectivity (eg. removing bank hardening, restoring access to off-channel habitat, removing or improving passage at fish passage barriers)
3. Restoring capacity (eg. native plant revegetation, channel development, nutrient enhancement, road decommissions/erosion control, etc.)
4. Stewardship and maintenance of the site (eg. fencing, garbage/debris removal, ongoing removal of invasives)

Habitat restoration projects that fit logically into this order by completing the next logical step will receive higher scores for timing/sequencing than those that do not follow the order or those for which order is unimportant. Habitat protection projects that are believed to be opportunities that could become unavailable if they are not completed will receive higher scores for sequencing than projects that could are expected to still be available possibilities in the future.

Scoring for *project readiness, timing/sequencing, and cost effectiveness will be completed by attendees of the annual scoring meeting. Once a technical ranking of all projects has been completed, it will be up to the HWG to decide whether other factors should be considered. The group may adjust the technical list as they see fit, as long as there is approval from all attending members. This list, or lists, will then be presented to the Nisqually River Council for final approval.*

Habitat Initiative Narratives:

In this next section, a brief summary of each initiative has been provided, along with the most current data for its associated implementation metric(s).

TIER 1

Estuary Recovery and Resilience

The historical Nisqually River estuary contained a total area of approximately 15 square kilometers (Bortleson et al. 1980). Although modified compared to historical conditions, it is easily the largest estuary in southern Puget Sound, but only a mid-size estuary compared with others in Puget Sound. The total size of the estuary is constrained by steep bluffs along both sides of the delta area and a steep drop off at the outer edge of the delta. The historical estuary included four habitat zones and an amount of channels by zone was estimated for each zone: estuarine emergent marsh (147.9 hectares), emergent/forested transitional (9.0 hectares), forested riverine/tidal (13.5 hectares), and freshwater (10.3 hectares).

Habitat of the Nisqually River estuary has changed substantially compared to historical conditions, primarily by the dikes installed in the early 1900s to convert saltmarsh into pasture. The fill associated with the Interstate-5 crossing of the estuary has also resulted in the loss of historical estuarine habitat. With the removal of 5 miles of dike surrounding the Nisqually estuary, nearly 900 acres of historical tidelands were restored to tidal influence. The efforts have and are expected to continue to increase the ecological health of the estuary and the South Puget Sound.

The Nisqually Indian Tribe and U.S. Geological Survey (USGS) are documenting the progress of the restoration and have implemented an intensive study of channel development in the restored tidelands. A preliminary assessment has noted a “transition from a diked freshwater marsh with vegetation-choked channels to more estuarine conditions as the relic plants decompose in the now tidally influenced restoration” (Woo et al. 2011). The long-term ecological benefits of the restoration for the estuary and adjacent nearshore areas will require further monitoring and scientific studies.

Research performed by Ballanti et al. in 2017 demonstrates that the long-term outlook for the Nisqually tidal marsh depends on continued sediment supply from the watershed and the wetland response to sea level rise. With expected changes in climate, along with population and industry growth, alterations to sediment delivery to the Nisqually estuary can be anticipated. The reestablishment of vegetation in the restored marsh, although slow, may suggest movement towards future emergent marsh stability. With post-restoration vertical accretion rates of 2.5 mm/year in the restoration site between 2010 and 2014, it is possible that long-term recovery of the restoration site could match conditions of the nearby natural wetland sites under current conditions. Further monitoring and research is needed. The full paper is available on Habitat Work Schedule: http://hws.paladinpanoramic.com/project/220/5341/files.

The goal of this initiative is to recover historic habitat conditions of both surge plain forest and native saltmarsh.

Source: Nisqually Steelhead Recovery Plan, Ballanti et al. 2017

Restoration Implementation Metrics:

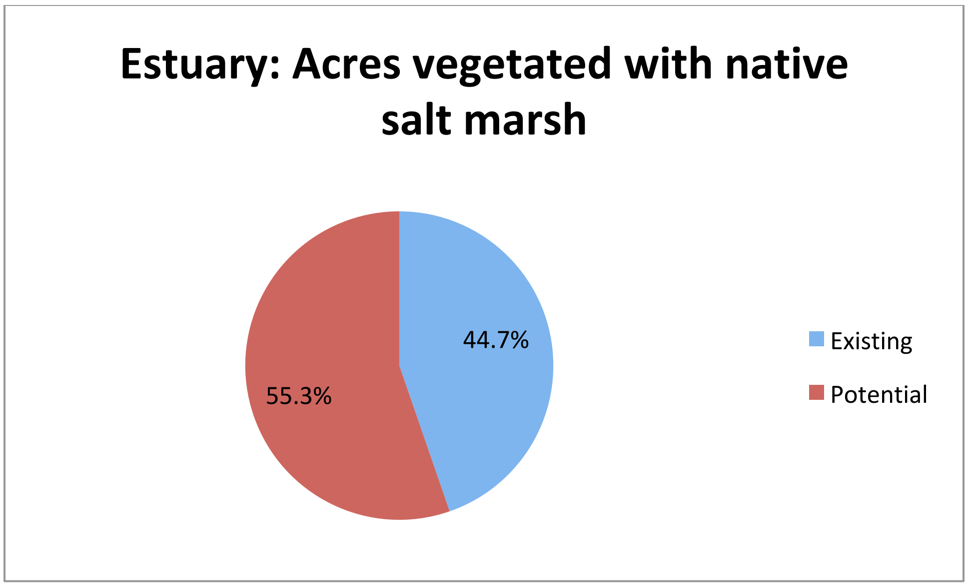


Figure 1: Represents the potential for additional saltmarsh in the restoring area in comparison with the existing saltmarsh. Potential saltmarsh includes both Mudflat (965.52 acres) and Transition Marsh (58.04 acres). Existing consists of Emergent Marsh.

Potential Saltmarsh: 1023.56 acres / 55.30%
Existing Saltmarsh: 827.33 acres / 44.70%

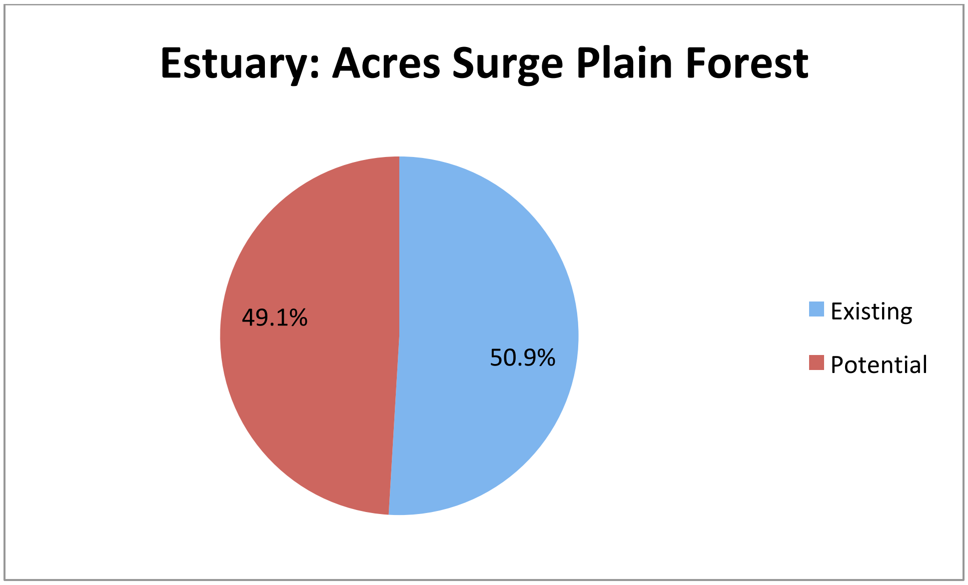


Figure 2. Represents potential and existing surge plain forest in the estuary. Area of interest includes downstream of Mounts Road, (east of the Nisqually River and downstream of I-5 on the west side. Excludes McAllister Creek. Potential includes Transition Forest (51.07 acres), Riparian Forest (392.27 acres), Developed (100.07 acres), and Agriculture/Grassland (101.98 acres) Habitat Zones.

Potential Surge Plain Forest: 645.39 acres / 49.05%
Existing Surge Plan Forest: 328.82 acres/ 50.95

Mainstem Hydrology & Sediment Process Restoration

Three hydroelectric dams are located on the mainstem of the Nisqually River (Pierce County 2012). Alder Dam and La Grande Dam comprise the Nisqually River Project and are located in the La Grande Canyon reach of the Nisqually River. La Grande Dam impounds a reservoir with a storage capacity of 2,700 acre-feet. Water from the reservoir is diverted at the dam to the powerhouse located approximately 1.7 miles downstream. The diverted water re-enters the Nisqually River downstream of the powerhouse near RM 40.8. Water is also released from the dam to the Nisqually River to maintain a continuous flow between La Grande Dam and its powerhouse (Pierce County 2012). The third dam is the Centralia City Light Yelm Hydroproject which operates a 4 foot high diversion dam at Nisqually river mile 26.2, with a 9 mile canal to a power generation facility.

The lower Nisqually River delivers on average about 100,000 metric tons per year of suspended sediment to the Puget Sound (Nelson 1974; Curran et al. 2014). Since 1945, flow to the lower river has been controlled by regulation from the Alder/La Grande Dam Complex, which effectively traps approximately 90% of the fluvial sediment generated upstream. Most of this sediment is from Mount Rainier, the principal sediment source in the Nisqually River basin (Czuba et al. 2012a). If not for the reservoir trapping sediment, some 42,000,000 m^3 of fluvial sediment that make up the river delta in Alder Lake (Czuba et al. 2012b) would otherwise serve a variety of downstream hydrologic and biologic functions with both benefits and threats as described in Czuba et al. (2011). In 2011, sediment monitoring by the USGS in the lower Nisqually River near Yelm found that 103,000 metric tons of suspended sediment, about 50% sand and 50% silt and clay, were delivered to the Puget Sound and that almost 40% of this load occurred during a single winter storm event (Curran et al. 2014).

The hydrologic record at the USGS streamflow gaging stations above and below the Alder/La Grande Dam Complex show flood storage can affect peak-flow hydrology. In the 2011 water year (October through September), regulation winter storm peaks by the Alder/La Grande Complex was minimal, but other seasonal peaks, such as from a spring freshet, were absent (Curran et al. 2014). Although reach-scale studies documenting channel morphology on the lower river are limited, studies on other large, regulated rivers in western WA (Warrick et al. 2011) indicate that, with respect to sediment, the lower Nisqually River is likely supply-limited, and during high flows, new sediment is recruited predominately from lateral bank erosion and channel migration processes.

Further studies are necessary to fully evaluate the minimum amount of sediment needed and overall initiative goals.

Source: Nisqually Steelhead Recovery Plan

Implementation Metrics

No metrics to report at this time.

Mainstem Riparian and Floodplain Protection and/or Restoration

Unlike most rivers draining into Puget Sound, the Nisqually has large protected stretches with intact floodplains, low human development, and high densities of functional off-channel habitat (Kerwin 2000; Collins and Montgomery 2002). However, due to hydropower operations, levees, and floodplain development, the Nisqually has seen a reduction in potential off-channel spawning and rearing habitat (Kerwin 2000). As of 2001, there was an estimated 350 acres of off-channel habitat in varying states of functionality associated with the mainstem Nisqually River.

The distribution of existing off-channel habitat in the Nisqually River varies substantially between reaches, the Middle Reach and the Lower Reaches (which includes the Reservation Reach) having the most off-channel habitat with 107.3 and 94.1 acres of habitat, respectively. The McKenna Reach has 51.6 acres of off-channel habitat and the Wilcox Reach has an estimated 48.1 acres, while the higher gradient and more confined Whitewater and Upper Reaches have 38.8 and 10.1 acres of off-channel habitat, respectively.

Goals for this initiative include protecting the Nisqually mainstem shoreline, as well as protection of the floodplain. Because of existing hydromodifcations deemed immovable, the potential goal for the restoration of mainstem habitat will be less than 100%. Further analysis is needed to set goals for this initiative.

Source: Nisqually Off-Channel Habitat Report, 2004

Implementation Metrics:

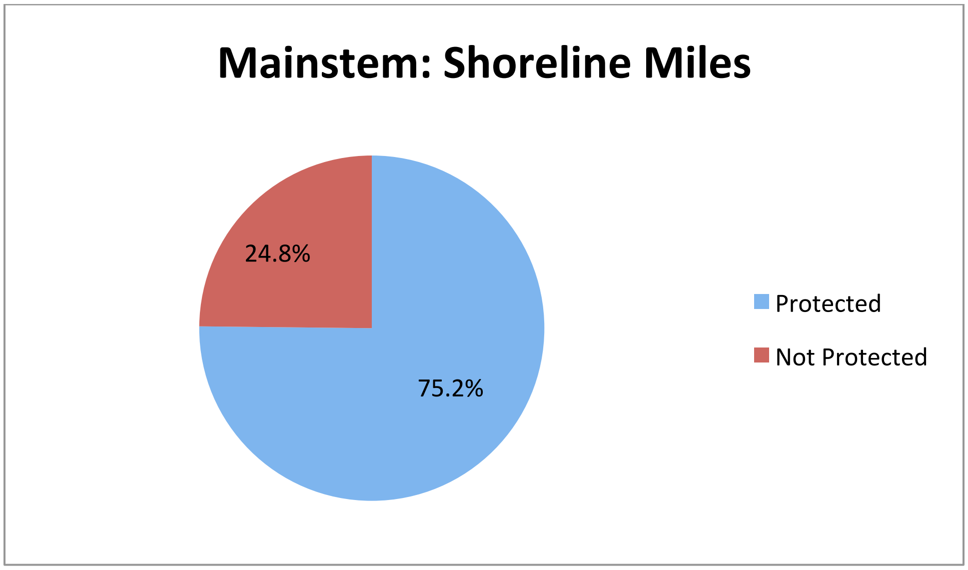


Figure 3. Represents protection status of the Nisqually River mainstem.

Total Mainstem Shoreline: 82.52 miles, 435706.94 feet
Mainstem Shoreline Mile Protected: 62.03 miles / 75.17%
Mainstem Shoreline Miles Not Protected: 20.19 miles / 24.83%

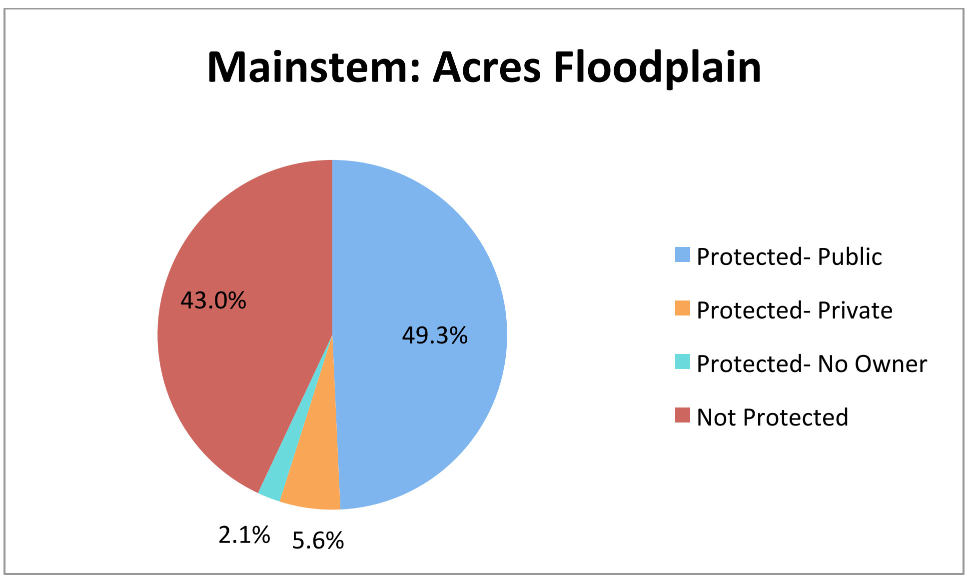


Figure 4. Represents protection status and ownership types of floodplain habitat along the Nisqually mainstem.

Total Floodplain Acreage: 12734.67 acres
Total Floodplain Protected: 4258.89 acres / 57%
Total Floodplain Not Protected: 5475.78 acres / 43%

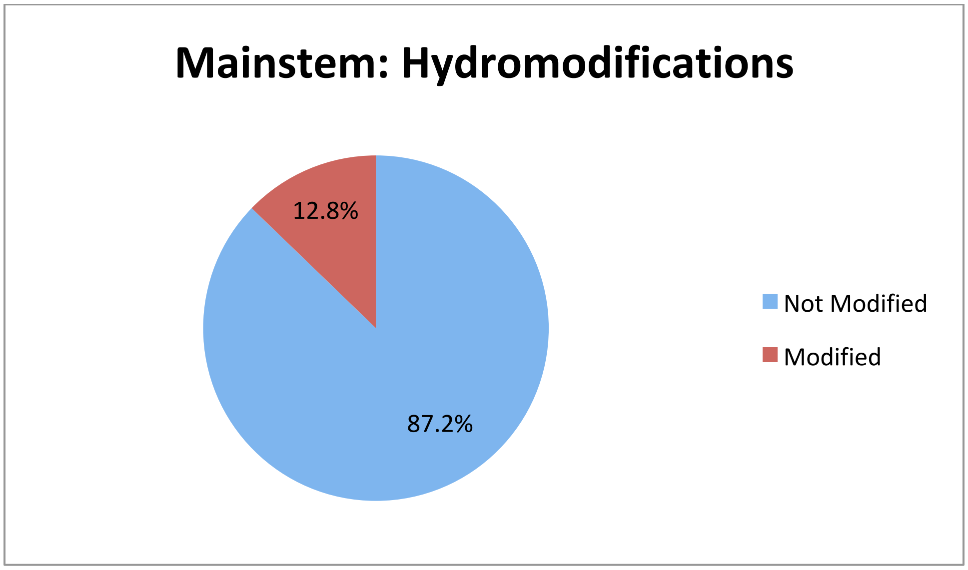


Figure 5. Represents the total length of hydromodified shorelines along the Nisqually River.

Total Length of Hydromodified Shorelines: 21.83 miles, 115261.17 feet
Shoreline Length Hydromodified: 10.54 miles, 55657.02 feet / 12.82%
Shoreline Length Unmodified: 380049.92 feet / 87.18%

TIER 2

Mashel Watershed Recovery/Community Forest Development (Boxcar to Watershed Divide)

The upper Mashel River remains in intensive commercial forestry while still in a state of recovery from massive clear-cut logging operations in the early and mid-1900s. It has been damaged by extensive sediment loads filling pools and spawning gravel, reduced water retention, elevated stream temperatures, and poor large-woody-debris recruitment. Recently, with increased domestic and export demand for timber, the Busy Wild sub-basin has been undergoing another round of intensive logging, threatening the recovery of critical watershed processes.

The Mashel Watershed Recovery Initiative endeavors to bring commercial forestlands of the Nisqually Watershed back to locally-based ownership as a functioning community forest. Currently owned by timber investment management organizations, otherwise known as TIMO's, this effort seeks to bring these lands under local community management allowing us to prioritize salmon recovery first and foremost in the forest management planning effort.

The mission of the Nisqually Community Forest is to permanently protect habitat for threatened Nisqually steelhead trout and Chinook salmon through acquisition of sensitive properties under immediate threat of clear-cut logging. Acquisition of this forestland will ensure that the watershed continues to recover from past forestry practices, while protecting a portion of the watershed critical for sediment-supply processes from intensive logging that could result in devastating erosion. Ownership of these forestlands will also safeguard against future logging activities and provide opportunities for active forestland restoration, including road abandonment and riparian enhancement.

Additional information regarding the Nisqually Community Forest can be found on the Nisqually Land Trust's website: http://nisquallylandtrust.org/our-lands-and-projects/nisqually-community-forest/.

Implementation Metrics:

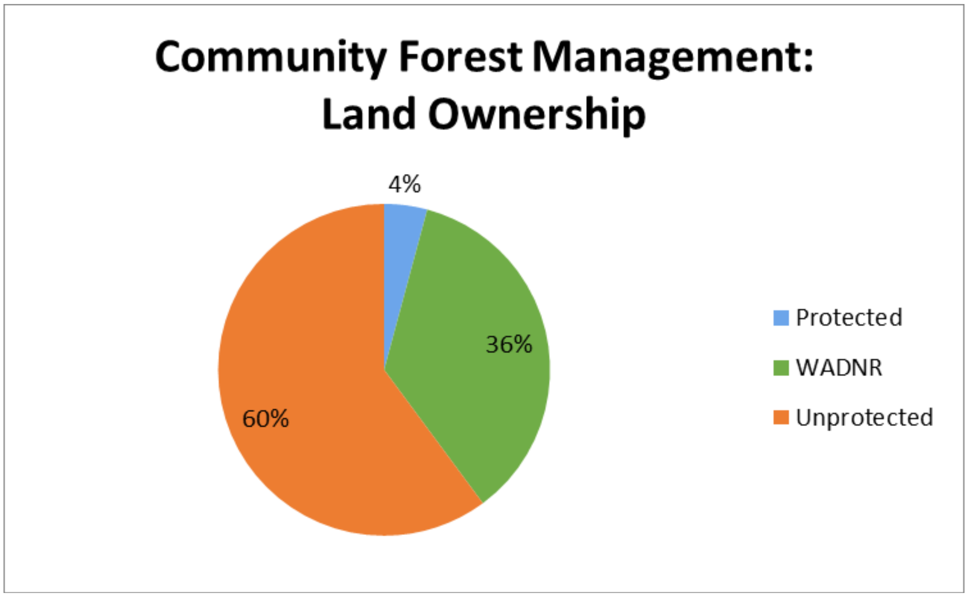


Figure 6. Represents ownership of forestlands in the upper Mashel Watershed and their protection status.

Total acres of forestland: 42298.21 acres
Forestlands Protected: 1771.44 acres / 4.19%
Forestlands - WA Department of Natural Resources Ownership: 15088.79 acres / 35.67%
Forestlands Unprotected: 25437.98 / 60.14%

Mashel River Base Flows

The Town of Eatonville, located between the Mashel River and Lynch Creek in south Pierce County, received a grant to update its draft Stormwater Management Program (2003 Program). The Comprehensive Stormwater Plan was developed on the premise that addressing stormwater in Eatonville is a critical part of salmon habitat restoration in the Mashel River, Ohop Creek and Lynch Creek. The Town is uniquely located in a critical area for salmon habitat and watershed health, and the Mashel River and Ohop Creek are the two highest priority salmon bearing tributaries to the Nisqually River. The bulk of Eatonville's stormwater is directed away from the Mashel River and sent untreated into Ohop Creek, via Lynch Creek. Lynch Creek has been listed by the Washington State Department of Ecology (WSDOE) for fecal coliform exceedance. The Mashel River has low flows in the summer and early fall causing the river to be too warm for young fish and too low for adult fish to migrate upstream. The Mashel River has been listed by WSDOE for temperature exceedance. Lynch Creek has been monitored by Pierce County and flagged for high total nitrates, phosphorus, fecal coliform, and turbidity and low dissolved oxygen.

The goal of this initiative is to complete the six priority capital improvement projects identified as critical for water quality and solving issues associated with drainage. Please refer to the full plan for more details: http://hws.paladinpanoramic.com/project/220/14472/files.

In addition to completing the Comprehensive Stormwater Plan, this initiative aims to develop an alternate water supply for the Town of Eatonville. With the Town's 400,000 gallon per day drinking water coming from the Mashel River and four other ground wells, this can put a strain on the base flows of the river. This is especially true in summer months when flows are especially low.

Sources: Town of Eatonville Comprehensive Stormwater Plan (2013), Phase I Storage Evaluation, Town of Eatonville

Implementation metrics:

No metrics to report at this time.

Mashel Engineered Logjam (or other in-stream technique) Construction and Maintenance (Mouth to Boxcar Canyon)

Known for its timber production, the upper Mashel Basin has been subject to logging and other timber-related activities for many years. Not only have legacy effects of past logging practices limited the age of existing stands, but they have greatly decreased the input of large wood into the Mashel Basin. The hardening of banks and introduction of logging roads have led to unstable slopes, increased erosion, and introduced more fine and large sediments into the system. For ESA-listed Chinook salmon and steelhead, this means their habitat is less diverse, in-stream flows are much flashier, and they have fewer places to rest and feed.

To reduce these effects, watershed partners have taken to installing a number of engineered logjams on the Mashel River. These large structures, paired with riparian plantings of native trees and shrubs, have not only added more wood to the system, but have improved channel stability and complexity and decreased the amount fine sediment moving through the system. Engineered logjams also create pools, add cover for shade, and sort gravel needed for spawning salmon. Since 2006, 43 ELJs have been installed in the Mashel River, with nine more being installed as part of the Mashel Eatonville Restoration Phase III, a project managed by South Puget Sound Salmon Enhancement Group.

Though the ELJs have added habitat complexity to basin, it has been noticed that these structures are not accruing natural wood as hoped. Until protection of upstream habitat can be guaranteed and forests are given the opportunity to mature, there will be a constant need to introduce wood into the system. To address this, the Salmon Recovery Program endeavors to have a minimum of 75 functioning logjams within the Lower Mashel Reach at any given time.

Implementation Metrics:

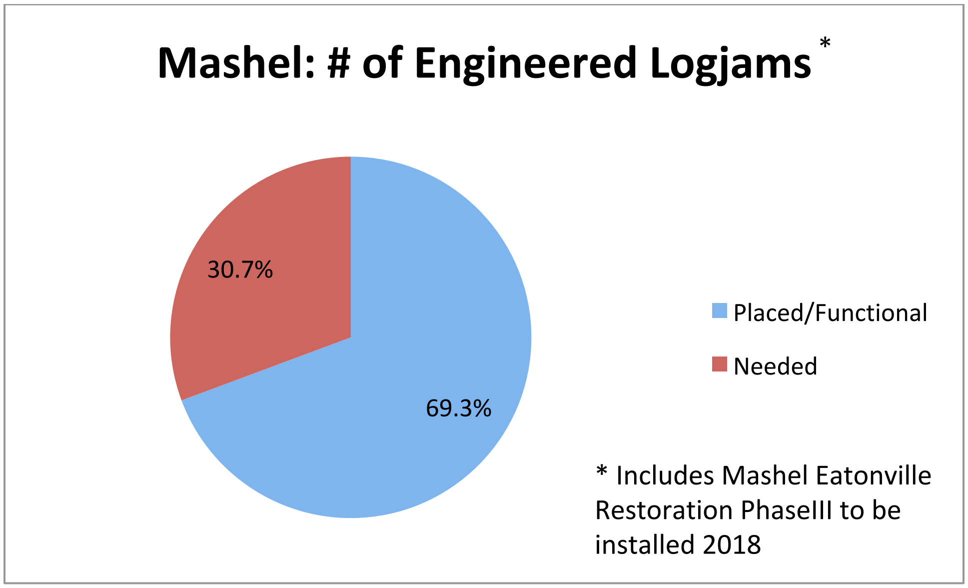


Figure 7. Represents the total number of functioning ELJs in the Mashel Basin from the river's mouth to Boxcar Canyon.

Total Number of Functioning ELJ's: 52
Target Number of Functioning ELJ's: 75
Number of ELJ's Needed: 23

Mashel River Protection and Restoration (Mouth to Boxcar Canyon)

The lower Mashel River is 6.2 square miles, extending from Box Car Canyon to its confluence with the Nisqually River. The northwestern portion has some development in and around the town of Eatonville. Eatonville draws its drinking water from the Mashel River, and secondary-treated wastewater is discharged to the river downstream from the town (Pierce County 2012). The lower Mashel River was identified as a priority area in the Nisqually Chinook Recovery Plan for improving habitat complexity. Several in-stream engineered log jam projects have been completed in the section of the river adjacent to the City of Eatonville.

An assessment completed by the Pierce Conservation District in 2004 described the loss of habitat diversity as the single largest limiting factor within the project reach. Hydro-modifications within the reach, defined as human-made structures within or adjacent to the stream channel that constrict flow or restrict flow access to the stream's floodplain, are one of the principal sub-factors that result in a disconnected floodplain and loss of riparian function. In addition, large woody debris within the reach is virtually nonexistent, particularly compared to the historic condition where a complex mixture of single large pieces and accumulations had a dominant influence on channel diversity. Currently, the natural function of LWD is limited due to diminished quantities, sizes, decay classes and the capacity of the riparian streambank vegetation to retain pieces where channel gradient and flow allow such influences. Please refer to the Mashel ELJ Initiative for more information and implementation metrics.

Source: Nisqually Steelhead Recovery Plan, Mashel River Restoration Design Technical Memorandum, 2004

Implementation Metrics:

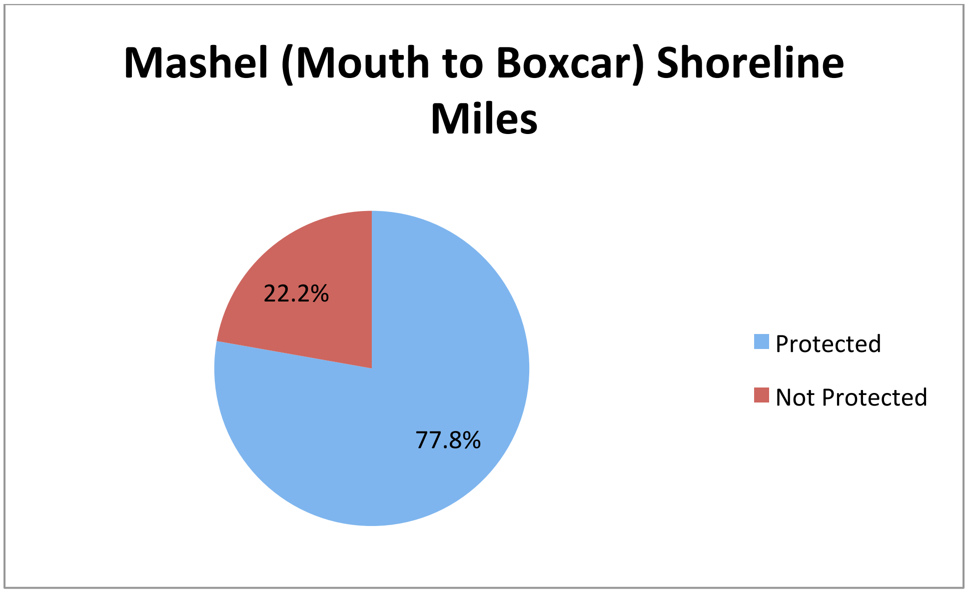


Figure 8. Represents the protection status of the Mashel River shoreline from the river's mouth to Boxcar Canyon.

Total Mashel Shoreline: 13.57 miles, 71671 feet
Mashel Shoreline Mile Protected: 10.56 miles / 77.78%
Mashel Shoreline Miles Not Protected: 3.02 miles / 22.22%

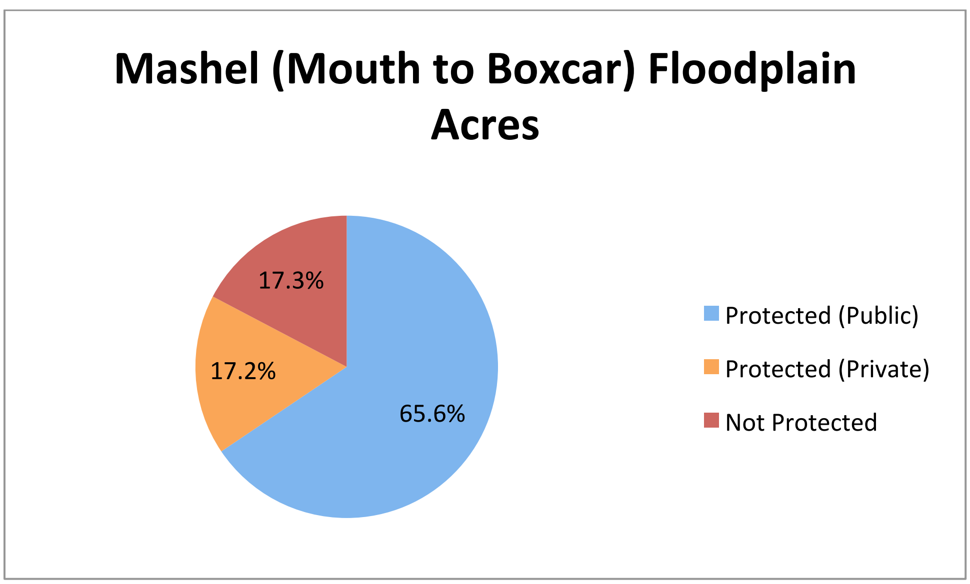


Figure 9. Represents the protection status and ownership type of floodplain habitat along the Mashel River.

Total Floodplain Acreage: 265.83 acres
Total Floodplain Protected - Private: 45.60 acres / 17.2%
Total Floodplain Protected – Public: 174.25 acres / 65.6%
Total Floodplain Not Protected: 45.98 acres / 17.3%

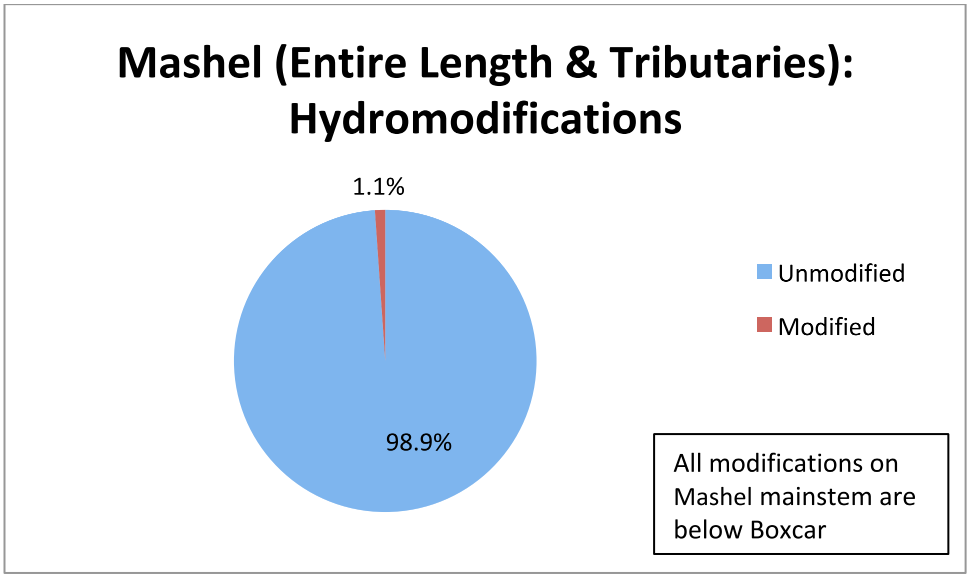


Figure 10. Represents the total length of hydromodified shoreline along the Mashel River and its tributaries.

Total unmodified length of the Mashel River and Tributaries: 350404.21 feet / 98.9%
Total hydromodified Length of the Mashel River and Tributaries: 3874.49 feet / 1.1%

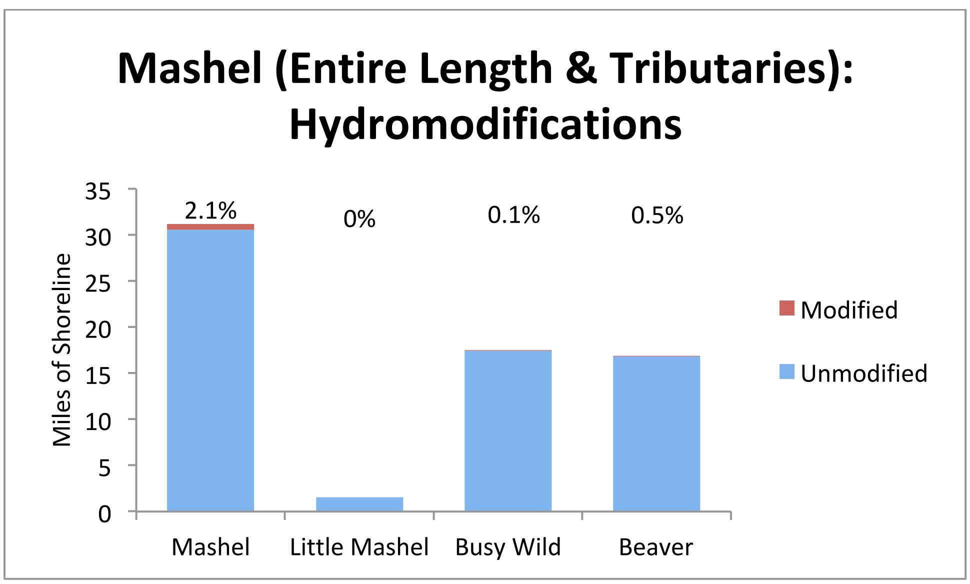


Figure 11. Represents the total length of impaired/Hydromodified shoreline for the Mashel River and its tributaries.

Total unmodified length of the Mashel River is 161297.37 feet, 30.55 miles / 97.94%
Total hydromodified length of the Mashel River is 3396.84 feet, .64 miles / 2.06%

TIER 3

Barrier Removal

The ability of salmon and trout to swim upstream to their traditional spawning grounds is vital to their recovery across Washington. Barriers to fish passage, in the form of road culverts, dams, dikes, and other obstructions, reduces the distribution and habitat available to fish, including salmon and steelhead. Culverts and bridges that are found to be undersized, outdated, and deteriorating limit upstream access for both spawning and rearing. These blockages directly result in decreased production, and in some cases, can eliminate fish populations altogether.

Tracking for this initiative will be done with the use of the Washington Department of Fish and Wildlife's Fish Passage Program web map application (http://apps.wdfw.wa.gov/fishpassage/). Because their dataset compiles information from a number of resources, it provides a near complete inventory of barriers state-wide. These resources include: Statewide Integrated Fish Distribution, National Hydrography Dataset, Washington Department of Natural Resources Transportation, and the Washington Department of Fish and Wildlife Fish Passage and Diversion Screening Inventory. This data is available for viewing and export on the program's website at any time.

According to the database, there are 203 known human-made barriers, including total and partial barriers, in the Nisqually Watershed. The goal of this initiative is to remove, improve, and/or repair 100% of these blockages.

Source: https://wdfw.wa.gov/conservation/habitat/fish_passage/barrier_estimate_information.html

Implementation Metrics:

None to report at this time.

South Sound Nearshore Recovery

The geographic areas covered by the Nisqually Chinook and Steelhead Recovery Plans include the river's terminus at the Nisqually Delta along with an additional square mile of nearshore habitat. Recovery of the surrounding nearshore and marine areas fall under the South Sound Recovery Strategy, developed by the Alliance for a Healthy South Sound in 2015-16. In addition to the Nisqually nearshore, the South Sound strategy includes four other Water Resources Inventory Areas that all drain into the South Puget Sound: Chambers-Clover (12), Deschutes (13), Kennedy-Goldsborough (14) and Kitsap (15).

The South Sound Recovery Strategy is available on the AHSS website at: http://www.healthysouthsound.org/south-sound-strategy/.

Ohop Valley Recovery
(Mouth to Ohop Lake)

In the 1930's Ohop Creek was channelized with an approximately 3.5 mile long ditch dug to drain the wetlands and various hillside seeps, diverting the flow into the main channel. The channel was excavated to improve drainage of farm fields, while old growth forests and vegetation was cleared and grasses were planted (Liddle 1998). Due to channelization, ditching, and agricultural practices, the channel lacked diversity of habitat types and experienced high summertime stream temperatures, suffered impacts of agricultural runoff, and was physically disconnected from the floodplain and adjacent wetland habitats.

The restoration of Ohop Creek began in 2009 with the re-meandering of 1 mile of stream (Phase I/II), rectifying a portion of the channelized Ohop Creek. The next phase of construction, Lower Ohop Creek Restoration Phase III, continued this effort, resulting in an additional 1.4 miles of restored stream suitable for salmon.

Juvenile Chinook utilize lower Ohop Creek for rearing and refuge from Nisqually River flood flows, taking advantage of available side channels and adjacent wetlands. Juvenile coho and steelhead would use this habitat year-round, while pink and chum salmon typically move downstream soon after emergence to rear in estuarine areas. Based on the EDT analysis, the life stages that are most affected by impacts to Ohop Creek are egg incubation, rearing, and pre-spawning holding. The impacts include changes in channel stability, flow, habitat diversity, sediment loading and key habitat quantity.

The goal of this initiative is to treat 100% percent of the remaining ditched channel, reconnecting the floodplain and restoring native vegetation throughout the valley.

Sources: Nisqually Chinook Recovery Plan, Ohop Valley Restoration Biological Assessment, Endangered Species – Section 7 Review.

Implementation Metrics:

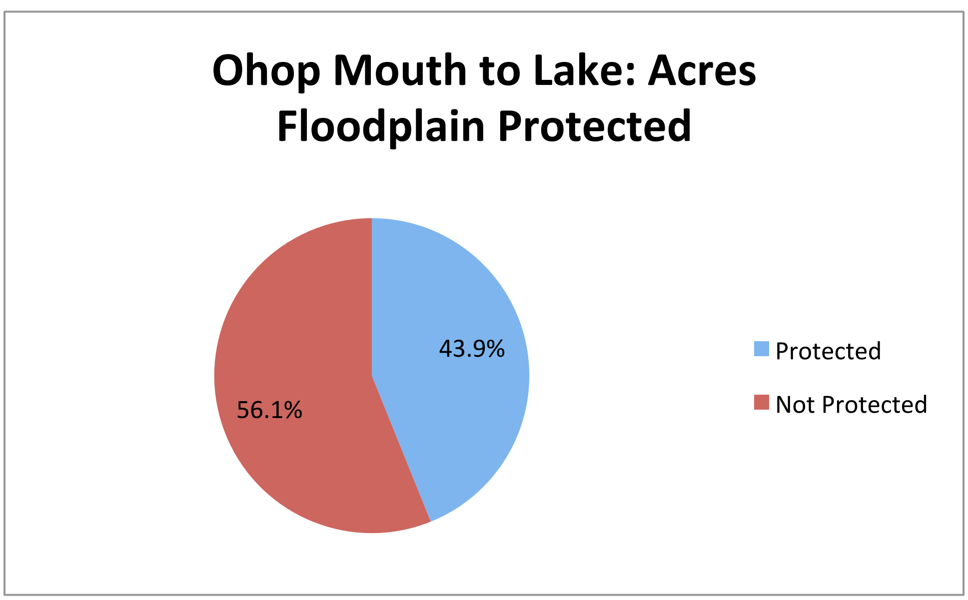


Figure 12. Represents protection status of floodplain habitat along Lower Ohop Creek.

Total Floodplain Acreage: 710.87 acres
Total Floodplain Protected: 312 acres / 43.89%
Total Floodplain Not Protected: 398.87 acres / 56.11%

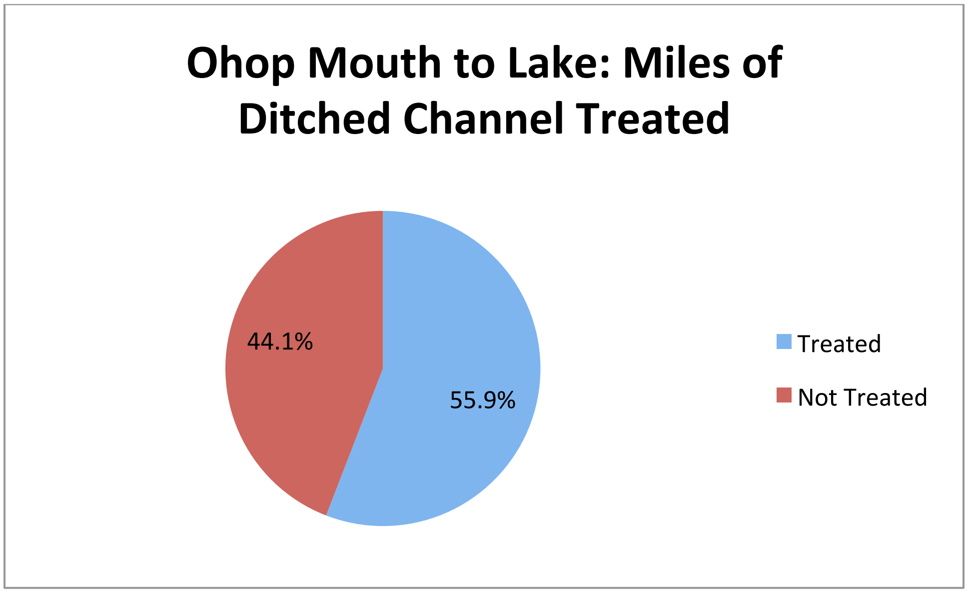


Figure 13. Represents the treatment status of ditched channel along Lower Ohop Creek.

Total Ditched Channel Length: 3.44 miles, 18144.18 feet
Ditched Channel Treated: 1.92 miles / 55.87%
Ditched Channel Not Treated: 1.52 miles / 44.13%

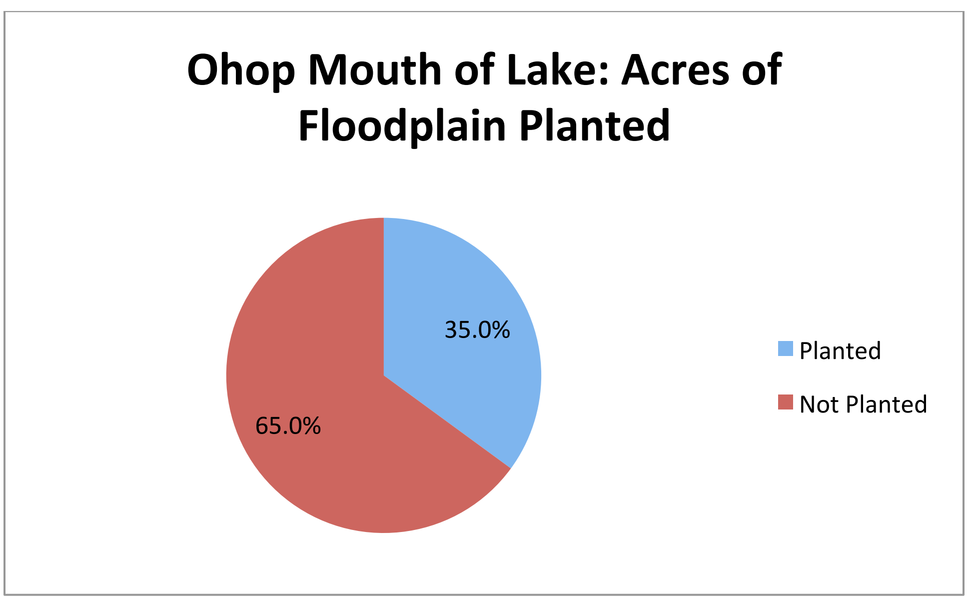


Figure 14. Represents the total impaired and planted floodplain acreage along Lower Ohop Creek.

Total Impaired Floodplain Acres: 604.51 acres
Total Floodplain Acres Planted: 211.88 acres / 35.05%
Total Floodplain Acres Not Planted: 392.63 acres / 64.95%

Muck Creek Recovery
(Includes Lacamas, Preacher, Halverson, and Johnson Creeks, and Exeter and Nixon Springs)

Muck Creek and its tributaries together comprise over 43 miles of potential steelhead stream habitat. Muck Creek originates from a series of springs and seeps in the eastern portion of the basin, the largest of which is Patterson Springs. Muck Creek is characterized by intermittent flow. Groundwater discharge to the creek is generally greatest in the lower sections. Loss of stream flow due to seepage is common in midsections of Muck Creek. The stream gradient is generally flat downstream of the forks, excepting a few moderate reaches as it cuts through a canyon in its lower reaches. The creek flows through several marshes in the flat prairie areas. The lower 14 miles of Muck Creek (with the exception of a 1.1-mile stretch in the vicinity of the City of Roy) flows through Joint Base Lewis-McChord (JBLM). Within JBLM boundaries, the creek travels through training areas and along the edge of the artillery impact area. Many creek segments on base have natural functioning riparian habitats, but others need riparian enhancement or restoration (Pierce County 2005).

The long-term outlook for Muck Creek suggests a worsening of low flow issues if land use patterns continue to move toward a more developed urban landscape. At present there is some information suggesting low flow conditions have worsened in the last 10 to 20 years. The lack of long-term monitoring in this basin is a hindrance to better understanding land use and climate impacts on flow, however JBLM is in support of salmon recovery in Muck Creek. Historical channel alternations, invasive reed canary grass, and low flow are significant challenges to improving habitat in Muck Creek upstream of the Canyon reaches.

Goals associated with Muck Creek and its tributaries include protection of shoreline and wetlands. A comprehensive restoration plan for Muck Creek is necessary, including a full hydrology assessment to investigate low flow issues that affect fish passage to the upper watershed, as well as an assessment of the wetlands and the successes of past restoration attempts. A restoration plan would also include a strategy for removing or reducing impacts of invasive reed canary grass, restoration of Muck Creek wetlands (eg. Chambers Lake), stream hydrology, and in-stream habitat complexity.

Source: Nisqually Steelhead Recovery Plan

Implementation Metrics:

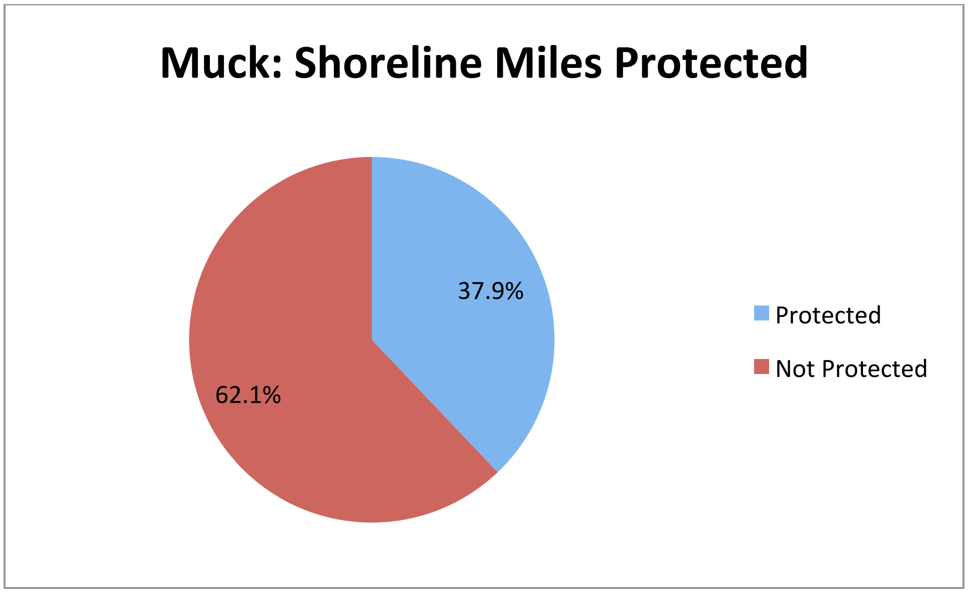


Figure 15. Represents the protection status of Muck Creek and its tributaries.

Total Muck Shoreline: 97.64 miles, 515550.98 feet
Muck Shoreline Miles Protected: 37.01 miles / 37.90%
Muck Shoreline Miles Not Protected: 60.63 miles / 62.10%

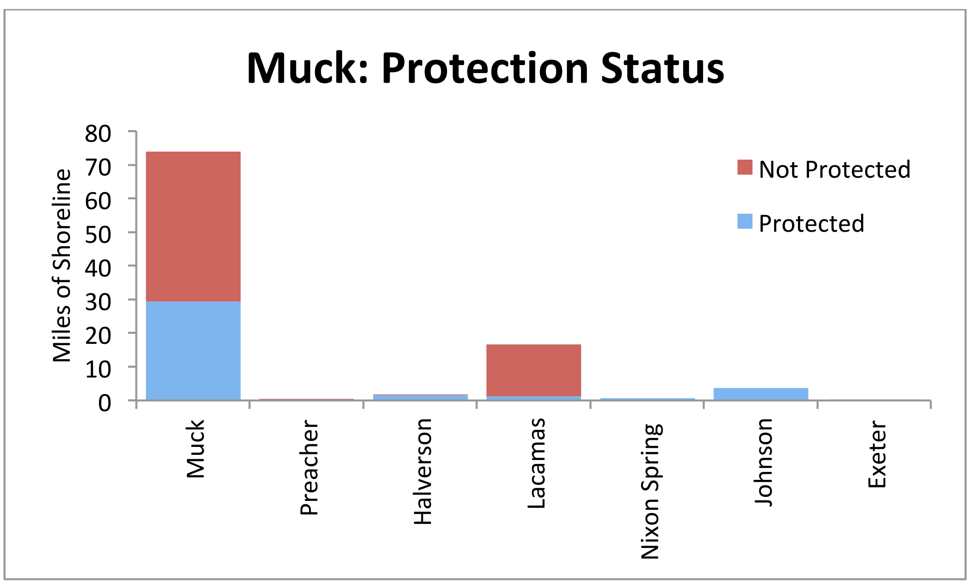


Figure 16. Represents the protection status of Muck Creek and each tributaries. Protection status for tributaries includes:

Preacher Creek:
Total Shoreline: .54 miles, 2869.83 feet
Shoreline Miles Protected: .24 miles / 44.51%
Shoreline Miles Not Protected: .30 miles / 55.49%

Halverson Creek:
Total Shoreline: 1.78 miles, 9382.72 feet
Shoreline Miles Protected: 1.54 miles / 86.40%
Shoreline Miles Not Protected: .24 miles / 13.60%

Lacamas Creek:
Total Shoreline: 16.65 miles, 87915.17 feet
Shoreline Miles Protected: 1.20 miles / 7.24%
Shoreline Miles Not Protected: 15.45 miles / 92.76%

Nixon Spring:
Total Shoreline: .63 miles, 3305.43 feet
Shoreline Miles Protected: .63 miles / 100%
Shoreline Miles Not Protected: 0 miles / 0%

Johnson Creek:
Total Shoreline: 3.75 miles, 19811.72 feet
Shoreline Miles Protected: 3.75 miles / 100%
Shoreline Miles Not Protected: 0 miles / 0%

Exeter Spring:
Total Shoreline: .31 miles, 1649.07 feet
Shoreline Miles Protected: .31 miles / 100%
Shoreline Miles Not Protected: 0 miles / 0%

Invasive Plant Species Control

Riparian weeds degrade salmon habitat by displacing native species, disrupting native succession patterns, reducing shade by outcompeting taller species, increasing sedimentation and clogging small streams and side channels. Currently, all SRFB/PSAR restoration projects, and many acquisitions, include treatment of invasives on protected parcels, as well re-vegetation efforts. However, other than those projects either owned and/or managed by watershed partners, there has been little success tracking species along river corridors in areas of private ownership. Additionally, there has been little effort to compile the data collected by individual agencies in the Nisqually Watershed.

For the past several months, the Nisqually Indian Tribe has been working with local partners to develop an early action riparian weed control plan that will capitalize on existing weed control efforts already happening in the watershed, while identifying data gaps. Since newly established weed populations can increase at rates of up to 60% per year, an early action approach to weeds is both cost effective and has the highest likelihood of success.

In addition to developing control and monitoring plans for prevalent watershed species, there is an effort to complete an updated riparian vegetation assessment that will allow for changes in riparian vegetation to be tracked over time, taking advantage of new sources of data. Expanding the assessment to include the entire channel migration zone of the mainstem will include areas that may be activated during climate change induced flooding. Data will be collected via GIS amongst partners that have entered into a memorandum of understanding for the Nisqually River Cooperative Weed Management Area.

With this endeavor still in its infancy, goals and implementation metrics have yet to be established. This information will be introduced to this guidance upon completion.

Implementation Metrics:

None to report at this time.

TIER 4

Bald Hills Tributaries Recovery
(Includes Lackamas, Toboton, Elbow, and Powell Creeks)

Lackamas, Toboton, and Powell Creeks drain small basins and are short drainages (3 to 4.5 miles long) with similar characteristics. The cumulative basin area for the three stream systems is 27.8 square miles. Basin elevations range from 340 to 2,035 feet. The creeks drain broad flat prairies of the Bald Hills area, which was once heavily forested. The channels are low gradient, spring-fed, and have low or intermittent summer flows. The watersheds are associated with wetlands and/or lakes and contain numerous beaver dams or cascades that may limit fish access (Walter 1986; Kerwin 1999). A map identifying each this sub-basin can be found in Appendix D.

Since less is known about Lackamas, Toboton, and Powell Creeks than many other streams in the Basin, the restoration potential for these tributaries is unclear. Their more rural location suggests a higher likelihood for restoration. Increased development in these drainages would put these streams at risk.

Goals associated with the Bald Hills tributaries include protection of shoreline. A strategy should be developed for pursuing riparian conservation easements in this area. Assessments are needed to further explore restoration needs and forest health in the Bald Hills. Once this has been completed, a goal for protecting forested uplands can be established.

Source: Nisqually Steelhead Recovery Plan

Implementation Metrics:

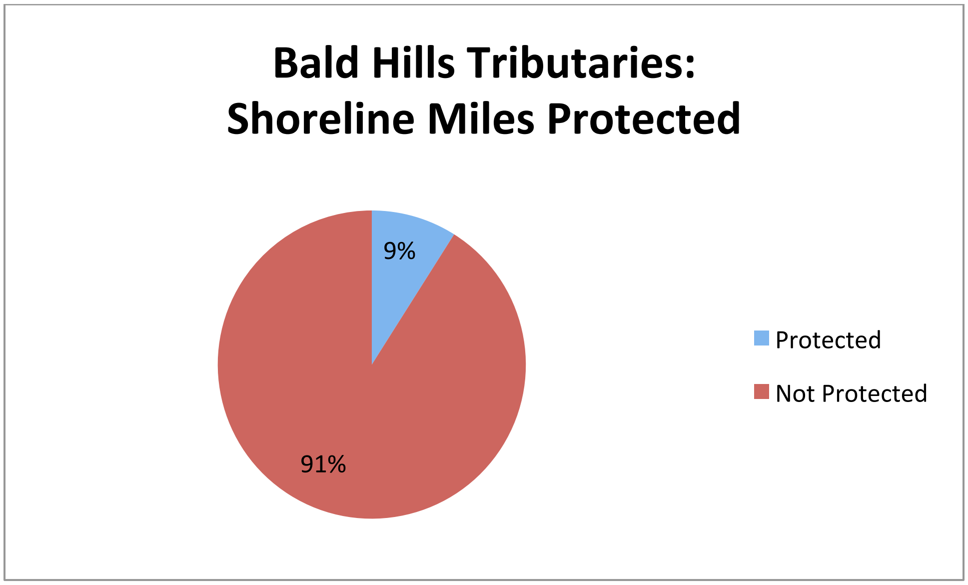


Figure 17. Represents the protection status of all the Bald Hills tributaries.

Total Bald Hills Shoreline: 28.77 miles, 151880.87 feet
Bald Hills Shoreline Miles Protected: 2.58 miles / 8.97%
Bald Hills Shoreline Miles Not Protected: 26.18 miles / 91.03%

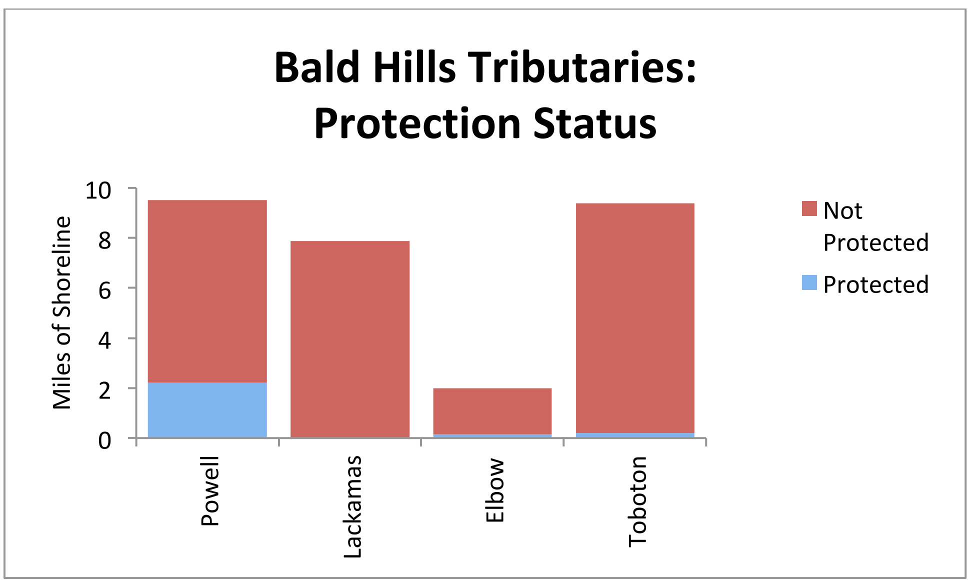


Figure 18. Represents the protection status of each of the Bald Hills tributaries. Protection status for tributaries includes:

Powell Creek:
Total Shoreline: 9.51 miles, 50190.10 feet
Shoreline Miles Protected: 2.23 miles / 23.49%
Shoreline Miles Not Protected: 7.27 miles / 76.51%

Lackamas Creek:
Total Shoreline: 7.88 miles, 41629.57 feet

Shoreline Miles Protected: 0 miles / 0%
Shoreline Miles Not Protected: 7.88 miles / 100%

Elbow Creek:
Total Shoreline: 1.99 miles, 10518.86 feet
Shoreline Miles Protected: .14 miles / 7.00%
Shoreline Miles Not Protected:1.85 miles / 93.00%

Toboton Creek:
Total Shoreline: 9.38 miles, 49542.35 feet
Shoreline Miles Protected: .21 miles / 2.23%
Shoreline Miles Not Protected: 9.17 miles / 97.77%

Prairie Tributaries Recovery
(Includes Yelm, Murray, Tanwax, Horn, Brighton, Kreger, Harts, and McKenna Creeks)

The "prairie" type tributaries are low gradient and believed to have had a large percentage of beaver ponds and complex off-channel pools historically. The substrate size was mostly small cobble/gravel, which is similar to current conditions. These streams are strongly influenced by ground water dynamics. They are located within the Southern Puget Prairies ecoregion, which is characterized by well-drained soils. Stream flow is slow to respond to fall rains as groundwater levels recharge. Flows do not increase until November or December. This sub-basin comprises multiple streams and a variety of land use types. A map identifying each sub-basin can be found in Appendix D.

The Prairie Tributaries generally originate from rural and more urban areas of the watershed. Analysis suggests these streams individually are not large producers of steelhead. However, these streams can help support a more diverse steelhead population than is there at present. The prairie tributaries tend to be good areas for chum, as well as coho. Chinook use in these reaches tend to be less, however they may be found in the lower mile of these streams near the mainstem. Portions of many of these streams have been ditched and riparian vegetation removed over many years. These streams are at risk of additional loss of flow from change in land cover and groundwater extraction.

Goals associated with the Prairie Tributaries includes protection of shoreline. A strategy should be developed for pursuing riparian conservation easements in this area. Assessments are needed to further explore restoration needs and develop goals for the prairie tributaries.

Sources: Nisqually Chinook Recovery Plan, Nisqually Steelhead Recovery Plan

Implementation Metrics:

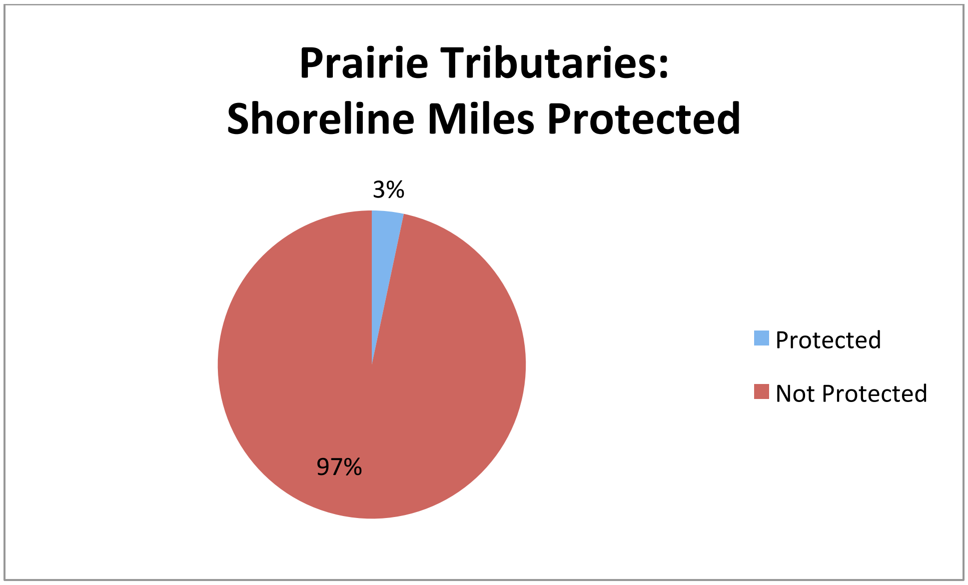


Figure 19. Represents the protection status of all the Prairie tributaries.

Total Prairie Shoreline: 91.77 miles, 481378.88 feet
Prairie Shoreline Miles Protected: 3.04 miles / 3.33%
Prairie Shoreline Miles Not Protected: 88.13 miles / 96.67%

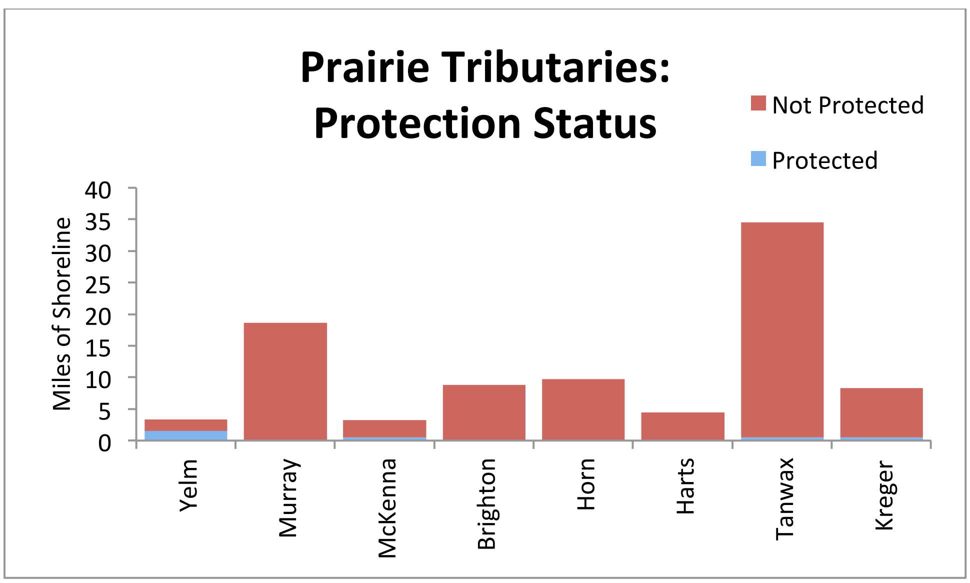


Figure 20. Represents the protection status of each of the Prairie tributaries. Protection status for tributaries includes:

Yelm Creek:
Total Shoreline: 3.39 miles, 17901.76 feet
Shoreline Miles Protected: 1.55 miles / 45.62%
Shoreline Miles Not Protected: 1.84 miles / 54.38%

Murray Creek:
Total Shoreline: 18.64 miles, 98401.12 feet
Shoreline Miles Protected: .06 miles / .32%
Shoreline Miles Not Protected: 18.58 miles / 99.68%

McKenna Creek:
Total Shoreline: 3.22 miles, 17026.48 feet
Shoreline Miles Protected: .50 miles / 15.42%
Shoreline Miles Not Protected: 2.73miles / 84.58%

Brighton Creek:
Total Shoreline: 8.84 miles, 46668.52 feet
Shoreline Miles Protected: 0 miles / 0%
Shoreline Miles Not Protected: 8.84 miles / 100%

Horn Creek:
Total Shoreline: 9.77 miles, 51559.63 feet
Shoreline Miles Protected: 0 miles / 0%
Shoreline Miles Not Protected: 9.77 miles / 100%

Harts Creek:
Total Shoreline: 4.47 miles, 23626.62 feet
Shoreline Miles Protected: 0 miles / 0%
Shoreline Miles Not Protected: 4.47 miles / 100%

Tanwax Creek:
Total Shoreline: 34.55miles, 182430.74 feet
Shoreline Miles Protected: .47 miles / 1.35%
Shoreline Miles Not Protected: 34.08 miles / 98.65%

Kreger Creek:
Total Shoreline: 8.29 miles, 43764.02 feet
Shoreline Miles Protected: .46 miles / 5.60%
Shoreline Miles Not Protected: 7.82 miles / 94.40%

Upper Ohop Recovery
(Includes Ohop Lake, Lynch Creek, and 25-Mile Creek)

Ohop Creek has fairly stable flows that are hydrologically moderated by Ohop Lake and by the extensive wetlands in the 25-Mile and Lynch Creek sub-basins (Pierce County 2012). The channel above Ohop Lake (RM 9 and RM10) is likely influenced by the backwater effect of the lake as the bed is also dominated by sandy substrate with long glides and few pools or riffles. It is moderately incised but still has some connection to its floodplain (Pierce County 2012). There is dense residential and recreational development surrounding Ohop Lake. Mountainous areas above anadromous fish use in its two major tributaries, Lynch and 25-Mile Creeks, are mostly used for timber production.

Historically, the Ohop Creek watershed included an additional area north of the current watershed boundary. However, in 1889, the upper portion of Ohop Creek was diverted north into the Puyallup Basin, which reportedly reduced the flow in Ohop Creek by about 30% (Watershed Professionals Network 2002). Consequently, at its confluence with 25-Mile Creek (approximately 4 miles north of Eatonville), Ohop Creek is the smaller of the two streams. This has resulted in less stream power to transport sediment and carve meander bends.

Anadromous spawning habitat in the Ohop Creek system is mainly limited to the 1.5 miles of creek downstream of the lake (some quantity of larger sized sediment is delivered from Lynch Creek), 1 mile of Lynch Creek, and the lower 0.5 mile of 25-Mile Creek. Ohop Lake traps all bedload sediment and most of the suspended load from the upper half of the watershed, resulting in a low sediment load downstream.

Goals associated with Upper Ohop Creek and its tributaries include shoreline protection. Assessments are needed to further explore restoration needs and forest health in the Upper Ohop Valley, as well as a study to look at the water quality of Ohop Lake. Once these have been completed, goals can be established for additional implementation metrics.

Source: Nisqually Chinook Recovery Plan, Nisqually Steelhead Recovery Plan

Implementation Metrics:

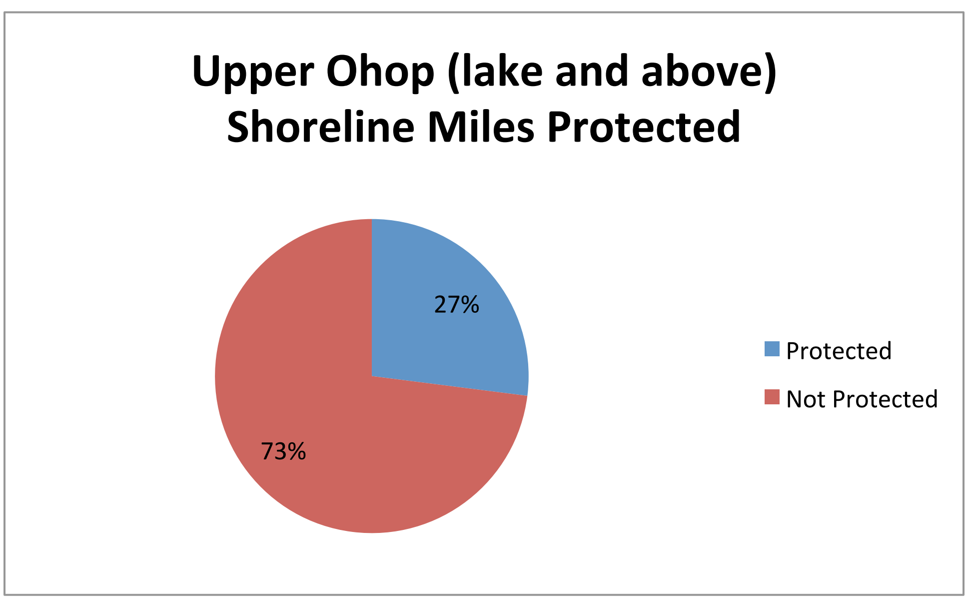


Figure 21. Represents the shoreline protection status of the Upper Ohop Basin, including Ohop Lake and Ohop Creek to the 25-mile Creek confluence and 25-mile Creek to the upstream end of the EDT reach.

Total Shoreline: 11.70 miles, 61776.60 feet
Shoreline Miles Protected: 3.16 miles / 26.97%
Shoreline Miles Not Protected: 8.54 miles / 73.03%

McAllister Creek Recovery

McAllister Creek flows directly into south Puget Sound at the Nisqually River estuary. The sub-basin is approximately 11 square miles and elevation is low. McAllister Springs, one of three large springs which feeds the creek, is only 6.7 feet above sea level. Its tributaries originate from hillside springs as high as 180 feet in elevation and traverse through moderately timbered slopes immediately above the valley floor (Kerwin 1999). Upon entering the valley, it flows through agricultural land and enters the western edge of the Nisqually River estuary.

Until recently, the largest spring in the headwaters of McAllister Creek had been used by the City of Olympia to provide municipal drinking water to Olympia and neighboring communities. The City of Olympia closed the facility, developing a wellfield upstream of the springs to provide municipal water. The closure of the McAllister Springs facility is expected to improve flow in McAllister Creek (City of Olympia 2013).

The McAllister Creek stream channel is heavily armored and altered in the vicinity of I-5 (RM 2.6) and localized armoring occurs where county and state roads cross the creek. Dikes exist in several local areas to afford property protection. These serve to limit lateral channel migration and off-channel rearing opportunities. Given its origins in low-elevation springs and a low-gradient channel, the entire length of the mainstem (approximately 6 miles) and valley tributaries is subject to tidal influence (Kerwin 1999).

Recovery goals for this reach include habitat protection.

Source: Steelhead Recovery Plan

Implementation Metrics:

None to report at this time.

Red Salmon Creek Recovery

Red Salmon Creek is a short independent stream that drains directly into the eastern portion of the Nisqually estuary. The lower part of the creek is intertidal and connects to Red Salmon Slough. This small basin is mostly residential with some agriculture. Most areas in the lower part of the basin are in protective ownership. Outside the tidal influence the creek is very shallow and broad near the mouth and deeper and narrow near the headwaters. Pool habitat is limited but spawning habitat is plentiful. Springs feed the creek and its main tributary, Washburn Creek.

A large wetland between the Interstate 5 south and northbound lanes also drains to the creek at a confluence within the intertidal saltmarsh area. It is also spring fed, and receives constant and year-round flow. Several tide gates keep the tide from entering the wetland. The culverts under the southbound lanes of Interstate 5 and the serials of tide gates are partial fish blockages that effectively keep juvenile salmon from migrating into those functional wetlands.

Major reasons for loss of productivity indicated by EDT analysis, include: decline in habitat diversity and in channel stability, along with loss of pool and beaver pond habitat.

Though habitat in Red Salmon Creek is fairly intact, there have been some minor changes to the natural channel confinement and declines in riparian function and woody debris that have led to a loss of habitat diversity, which is detrimental to all the life stages of salmon that use the creek. Juveniles that rear in the creek are also negatively affected by decreased channel stability and a small decline in the amount of pool and beaver pond habitat available in the creek.

Recovery goals for this reach include habitat protection.

Source: Nisqually Steelhead Recovery Plan, Nisqually River Basin Plan 2012

Implementation Metrics:

None to report at this time.

Appendix A:

Ecosystem Diagnosis and Treatment (EDT) Model Data and Outputs

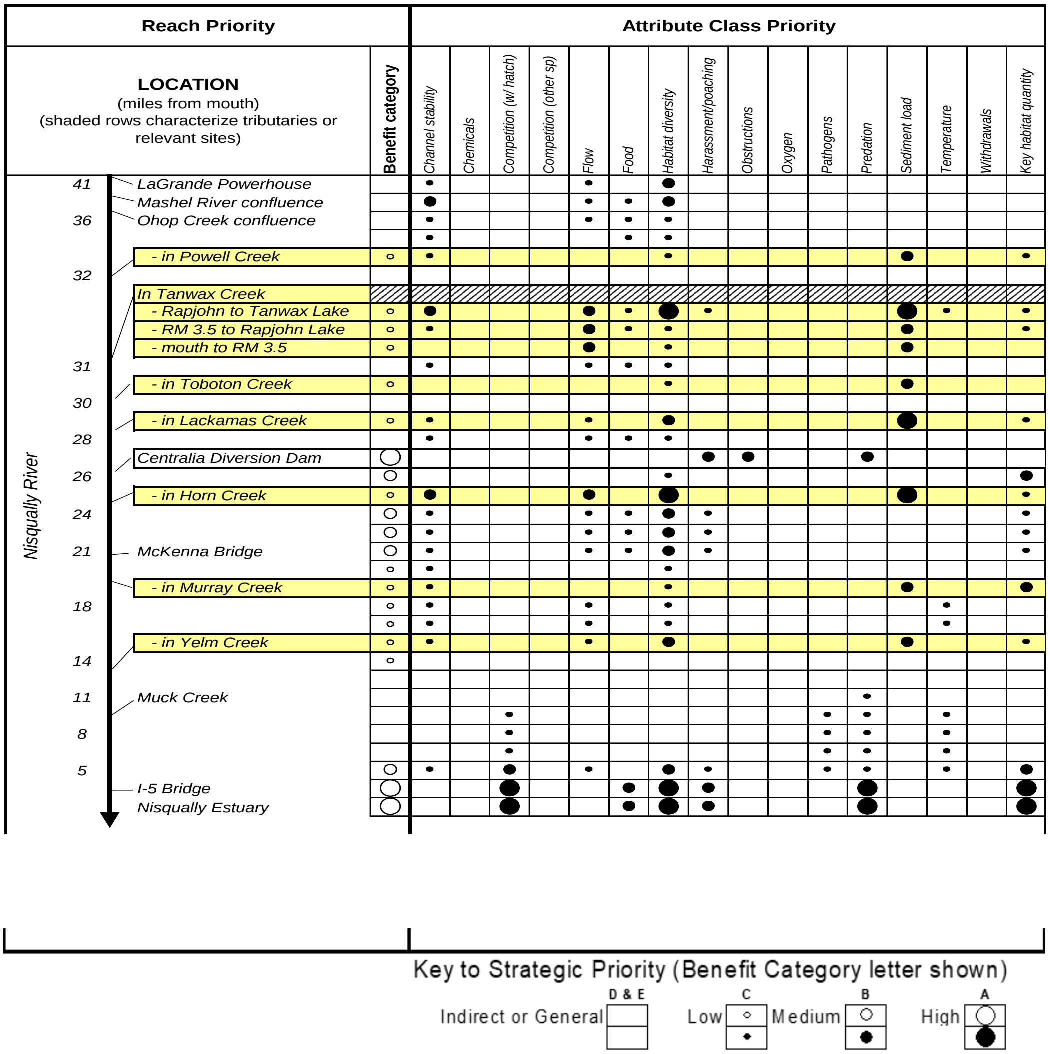
The following 16 categories are used to model the impacts of habitat on salmonids:

Factor	Definition
Channel stability	The effect of stream channel stability (within reach) on the relative survival or performance of the focus species; the extent of channel stability is with respect to its streambed, banks, and its channel shape and location.
Chemicals	The effect of toxic substances or toxic conditions on the relative survival or performance of the focus species. Substances include chemicals and heavy metals. Toxic conditions include low pH.
Competition (with hatchery fish)	The effect of competition with hatchery produced animals on the relative survival or performance of the focus species; competition might be for food or space within the stream reach.
Competition (with other species)	The effect of competition with other species on the relative survival or performance of the focus species; competition might be for food or space.
Flow	The effect of the amount of stream flow, or the pattern and extent of flow fluctuations, within the stream reach on the relative survival or performance of the focus species. Effects of flow reductions or dewatering due to water withdrawals are to be included as part of this correlate.
Food	The effect of the amount, diversity, and availability of food that can support the focus species on its relative survival or performance.
Habitat diversity	The effect of the extent of habitat complexity within a stream reach on the relative survival or performance of the focus species.
Harassment	The effect of harassment, poaching, or non-directed harvest (i.e., as can occur through hook and release) on the relative survival or performance of the focus species.
Key habitat	The relative quantity of the primary habitat type(s) utilized by the focus species during a life stage; quantity is expressed as percent of wetted surface area of the stream channel.
Obstructions	The effect of physical structures impeding movement of the focus species on its relative survival or performance within a stream reach; structures include dams and waterfalls.
Oxygen	The effect of the concentration of dissolved oxygen within the stream reach on the relative survival or performance of the focus species.
Pathogens	The effect of pathogens within the stream reach on the relative survival or performance of the focus species. The life stage when infection occurs is when this effect is accounted for.
Predation	The effect of the relative abundance of predator species on the relative survival or performance of the focus species, apart from the influence of the amount of cover habitat used by the focus species.

Factor	Definition
Salinity	The effect of the concentration of salts within the reach on the relative survival or performance of the focus species.
Sediment load	The effect of the amount of the amount of fine sediment present in, or passing through, the stream reach on the relative survival or performance of the focus species.
Temperature	The effect of water temperature with the stream reach on the relative survival or performance of the focus species.
Withdrawals (or entrainment)	The effect of entrainment (or injury by screens) at water withdrawal structures within the stream reach on the relative survival or performance of the focus species. This effect does not include dewatering due to water withdrawals, which is covered by the flow correlate.

The figures below show the relative importance of the habitat categories for Chinook and steelhead at locations throughout the watershed—the larger the dot, the greater the problem.

Nisqually Chinook
Restoration Strategic Priority Summary



Steelhead:

Life stage	Relevant months	Productivity change (%)	Life Stage Rank	Channel stability	Chemicals	Competition (w/ hatch)	Competition (other sp)	Flow	Food	Habitat diversity	Harassment/poaching	Obstructions	Oxygen	Pathogens	Predation	Sediment load	Temperature	Withdrawals	Key habitat quantity
				Change in attribute impact on survival															
Spawning	Mar-Jun	-1.0%	14							●	•						•		
Egg incubation	Mar-Jul	-10.7%	7	●												⬤	⬤		
Fry colonization	May-Jul	-11.6%	6	•				●	•	●			•		•		●		
0-age active rearing	May-Oct	-24.1%	1			•		●	•	●				•			•		
0,1-age inactive	Oct-Mar	-15.9%	3	•				●	•	●						●			
1-age migrant	Mar-Jun	-1.1%	12							•		•							
1-age active rearing	Mar-Oct	-11.9%	5					•	•	●							•		
2+-age active rearing	Mar-Oct	-3.0%	10					•		•									
2+-age migrant	Mar-Jun	-1.1%	13							•		•							
2+-age transient rearing	Jan-Dec	-0.3%	15						•										
Prespawning migrant	Nov-Apr	-1.6%	11									●							
Prespawning holding	Dec-May	-3.6%	9							●									

KEY

	Loss	Gain
None		
Small	•	∘
Moderate	●	○
High	⬤	◯
Extreme	⬤	◯

EDT Tornado Charts:

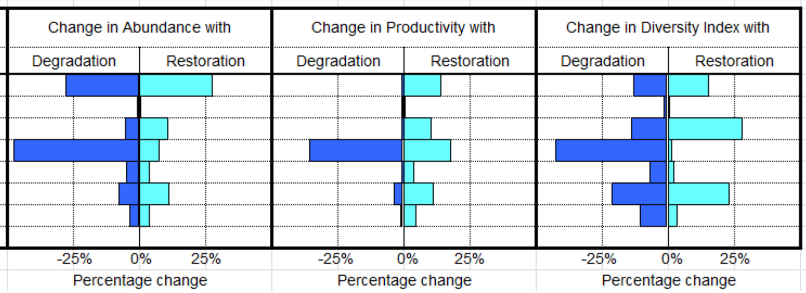
The tornado charts below show the modeled percentage of change in abundance, productivity and life history diversity by geographic area. Restoration is showing the potential if the reach was restored to historical conditions. Degradation is showing the loss if not preserved, i.e. the benefit of protection. To tier habitat initiatives utilizing the most up to date science available, data was extracted from EDT in May 2018.

From a 2018 model run:

Nisqually River Winter Steelhead

Relative Importance Of Geographic Areas For Protection and Restoration Measures

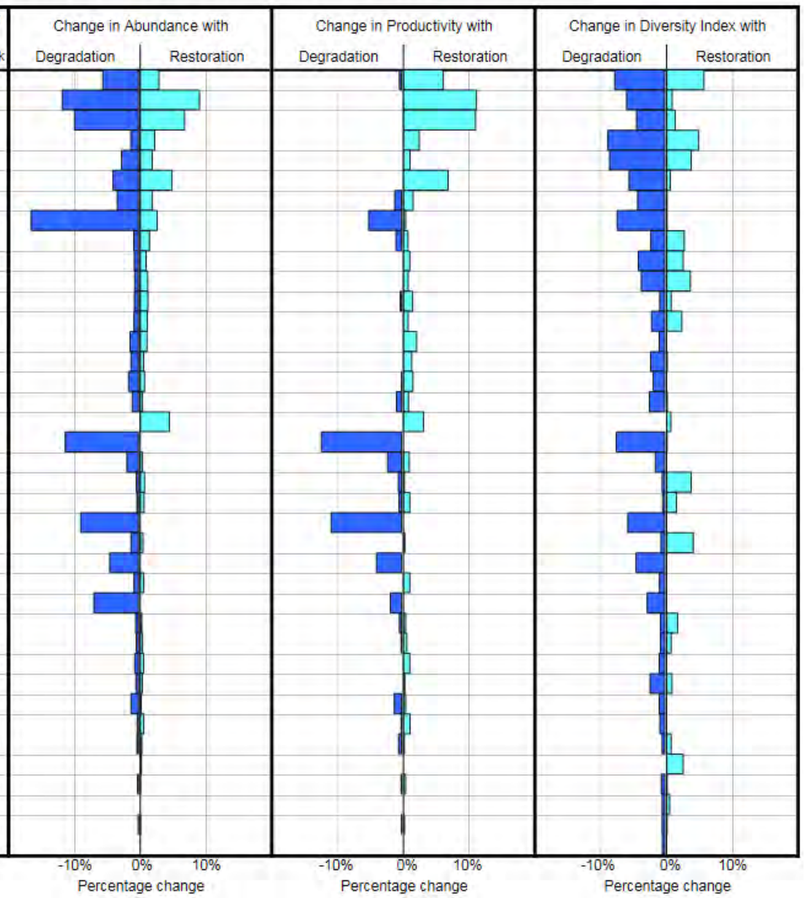
Geographic Area	Protection benefit		Restoration benefit	
	Category	rank	Category	rank
Mashel River Subwatershed	B	4	A	1
McAllister Creek	D	7	E	7
Muck Creek Subwatershed	B	3	A	3
Nisqually River Mainstem	A	1	B	4
Ohop Creek Subwatershed	C	6	D	6
Prairie Tributaries	B	2	A	2
Toboton/Powell/Lackamas Creeks	C	5	C	5



From the 2014 Nisqually Steelhead Recovery Plan (older but more detailed than the above):

Nisqually (Chinook, Coho, Steelhead) Winter Steelhead
Relative Importance Of Geographic Areas For Protection and Restoration Measures

Geographic Area	Protection benefit Category	Protection benefit rank	Restoration benefit Category	Restoration benefit rank
Muck Cr	B	6	A	1
Middle Mashel	B	9	A	2
Lower Mashel	B	11	A	2
SF Muck Cr	B	12	A	2
Tanwax Cr	B	10	B	6
Busy Wild Cr	B	14	B	6
Nisqually R McKenna	B	8	C	15
Nisqually R Whitewater	A	3	C	25
Toboton Cr	C	17	C	12
Lacamas Cr	C	20	B	10
Murray Cr	C	22	B	10
Nisqually R Upper Estuary	C	24	B	9
Horn Cr	C	23	C	13
Lynch Cr	C	21	C	18
Ohop Cr	C	19	C	20
Twentyfive Mile Cr	C	18	C	22
Powell Cr	B	15	D	32
Centralia Diversion Dam	E	40	B	8
Nisqually R Lower Reach	A	2	E	46
Yelm Cr	B	12	D	36
Brighton Cr	D	30	C	19
Kalama Cr	D	34	C	16
Nisqually R Middle Reach	A	4	E	47
Beaver Cr	D	28	C	24
Nisqually R Wilcox	B	5	E	47
Little Mashel	D	26	D	28
Nisqually R Upper Reach	B	7	E	47
Kreger Cr	D	26	D	31
McKenna Cr	D	31	D	26
Upper Mashel	D	28	D	29
Lackamas Cr	C	25	D	35
Red Salmon Cr	C	16	E	44
Thompson Cr	D	33	D	27
Clear Cr	D	32	D	39
Harts Cr	E	39	D	36
McAllister Cr	D	35	E	43
Johnson Cr	E	37	E	42
Trib 0094 Ohop	E	36	E	45
Preacher Cr	E	38	E	47

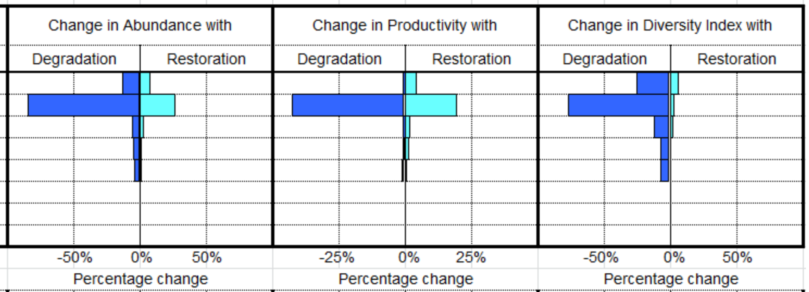


From a Chinook 2018 model run (this includes model updates done for steelhead recovery plan, etc.):

Nisqually River Chinook

Relative Importance Of Geographic Areas For Protection and Restoration Measures

Geographic Area	Protection benefit		Restoration benefit	
	Category	rank	Category	rank
Mashel Subwatershed	B	2	B	2
Nisqually River Mainstem	A	1	A	1
Ohop Creek Subwatershed	B	3	C	3
Prairie Tributaries	B	4	C	4
Toboton/Powell/Lackamas	C	5	D	5



See the 2001 Chinook Recovery Plan for older information that includes priorities within the above geographical groupings.

Appendix B:

Habitat Initiative Table and Implementation Metrics:

<table>
<tr><th rowspan="3">Habitat Initiative</th><th colspan="8">VSP Impact</th><th colspan="4" rowspan="3">Implementation Metrics</th></tr>
<tr><th colspan="2">Abundance</th><th colspan="2">Spatial Diversity</th><th colspan="2">Diversity</th><th colspan="2">Productivity</th></tr>
<tr><td>CH</td><td>Sthd</td><td>CH</td><td>Sthd</td><td>CH</td><td>Sthd</td><td>CH</td><td>Sthd</td></tr>
<tr><td>Estuary Recovery and Resilience</td><td>VH</td><td>H</td><td>H</td><td>M</td><td>VH</td><td>H</td><td>VH</td><td>H</td><td>Acres tidally inundated (transitional habitat/surge plain forest)

Goal: 645 acres</td><td>Acres vegetated w/native salt marsh

Goal: 1851 acres</td><td></td><td></td></tr>
<tr><td>Mainstem Hydro & Sediment Process Restoration</td><td>VH</td><td>VH</td><td>M</td><td>M</td><td>H</td><td>H</td><td>H</td><td>H</td><td>Sediment Budget (%natural)</td><td>Wood Budget (%natural)</td><td>Bankful (1.5yrs) flows (%natural)</td><td>Study needed to further develop goals</td></tr>
<tr><td>Mainstem Riparian and Floodplain Protection and/or Restoration</td><td>H</td><td>H</td><td>H</td><td>H</td><td>H</td><td>H</td><td>H</td><td>H</td><td>Shoreline Miles Protected</td><td>Acres Floodplain Protected (%total)</td><td>Shoreline Miles and Floodplain Acreage Restored</td><td>Infrastructure analysis needed to set goals</td></tr>
<tr><td>Mashel Watershed Recovery/Community Forest (Boxcar to Wshd Divide)</td><td>H</td><td>H</td><td>H</td><td>M</td><td>H</td><td>M</td><td>M</td><td>H</td><td>Community Forest Management

Goal: 42298 acres</td><td></td><td></td><td></td></tr>
<tr><td>Mashel Base Flows</td><td>M</td><td>H</td><td>M</td><td>M</td><td>H</td><td>M</td><td>H</td><td>H</td><td>Eatonville Stormwater Comp Plan

Goal: Plan implemented at 100%</td><td>Develop alternate water supply for Town of Eatonville</td><td></td><td></td></tr>
<tr><td>Mashel ELJ (or other in-stream technique) construction and maintenance (Mouth to Boxcar)</td><td>H</td><td>H</td><td>M</td><td>M</td><td>M</td><td>M</td><td>L</td><td>H</td><td># of ELJs

Goal: 75 functional jams at all time</td><td>ELJ Assessment Needed (periodically)</td><td></td><td></td></tr>
<tr><td>Mashel River Protection and Restoration (Mouth to Boxcar)</td><td>H</td><td>H</td><td>M</td><td>M</td><td>M</td><td>M</td><td>M</td><td>H</td><td>Shoreline Miles Protected</td><td>Acres Floodplain Protected</td><td>Shoreline Miles and Floodplain Acreage Restored</td><td>Infrastructure analysis needed to set goals</td></tr>
</table>

- DRAFT -

Habitat Initiative	VSP Impact								Implementation Metrics			
	Abundance		***Spatial Diversity***		***Diversity***		***Productivity***					
	CH	Sthd	CH	Sthd	CH	Sthd	CH	Sthd				
Barrier Removal	L	M	L	H	L	H	L	L	# Barriers Removed	***Barrier assessment update needed***		
South Sound Nearshore Recovery	M	H	H	L	H	L	M	H	See South Sound Strategy			
Ohop Valley Recovery (Mouth to Lake)	L	M	M	L	M	L	L	M	Acres Floodplain Protected	Acres Floodplain planted	Miles of Ditched Channel Treated	
Muck Creek Recovery (Includes tributaries)	L	M	L	H	L	H	L	M	Shoreline Miles Protected	Wetlands Protected (acreage)	***Functional Wetland Habitat Assessment Needed***	***Hydrology Study Needed***
Invasive Plant Species Control	L	L		M		M	L	L	Acres of infestation Treated	***Invasives Inventory/ Assessment Needed***		
Bald Hills Tributaries Recovery	L	L	L	L	L	L	L	L	Shoreline miles protected	Forested Uplands Protected	***Restoration / Forest Health Assessments Needed***	***Riparian Easement Strategy Development Needed***
Prairie Tributaries Recovery	M	M	L	M	L	M	M	M	Shoreline miles protected	Prairie Uplands Protected	***Restoration/ Prairie Health Assessments Needed***	***Riparian Easement Strategy Development Needed***
Upper Ohop Recovery (Lake, Lynch, 25 mile)	L	L	L	L	L	L	M	M	Stream Shoreline miles protected	Forested uplands protected	***Restoration/ Forest Health Assessments Needed***	***Ohop Lake Water Quality Assessment Needed***
McAllister Creek Recovery	L	L	L	L	L	L	L	L	Acres of Watershed Protected			
Red Salmon Creek Recovery	L	L	L	L	L	L	L	L	Acres of Watershed Protected			

Appendix C:

- DRAFT -

Nisqually Habitat Project Scoring Matrix

Initiative Tier	
Tier 1	30
Tier 2	25
Tier 3	20
Tier 4	15
No Tier	5

Restoration/Acquisition Projects (Highest Scoring Metric)		**Assessments**		**Design Only**	
50-100% Percent Change	30	1. Captures current habitat condition for entire initiative area. 2. Identifies restoration and protection goals for entire initiative area. 3. Develop application ready projects for initiative area.	20	Results in construction/permit ready project using maximum benefit alternative.	20
10-49% Percent Change	25	1. Captures current habitat condition for entire initiative area. 2. Identifies restoration and protection goals for entire initiative area.	15	Results in construction/permit ready project using compromised alternative.	15
1-9% Percent Change	20	Accomplishes one of three assessment goals.	10	Results in designs suitable for alternatives analysis.	10
0-.9% Percent Change	15	Does not assess entire initiative area.	5	Results in conceptual design/feasibility study only.	5

Project Readiness	
Component(s) of project in-progress under separate funding; additional funding needed to complete	20
Project ready to proceed as soon as funding secured	15
Project readiness contingent on ongoing negotiations or permitting	10
Potential project, if funding secured	5

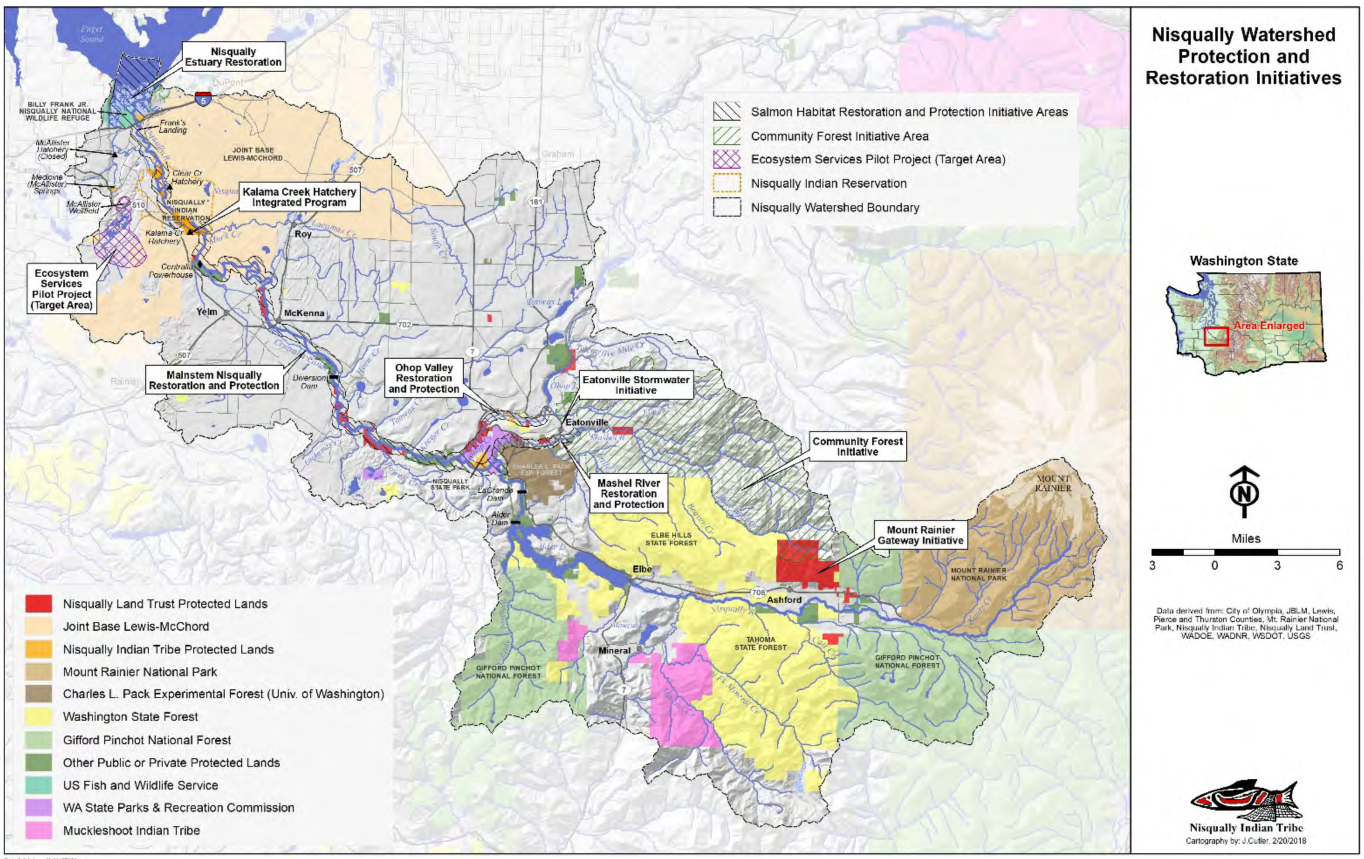
Timing/Sequencing

acquisition/assessment		***restoration/design***	
Significant chance that project opportunity will be lost if no action in this grant round	10	Next logical step in phased restoration project	10
Some chance that project opportunity will be lost if no action in this grant round	6	Logical step in restoration program	6
Project opportunity likely to exist in future	3	Project sequencing not critical	3

Cost Effectiveness	
>50% match documented in cost estimate spreadsheet	10
>25% match documented in cost estimate spreadsheet	6
15% match	3

Appendix D:

Nisqually Watershed Reference Maps



Map 1. Nisqually Watershed Protection and Restoration Initiatives Map (Nisqually Indian Tribe GIS Department, 2018)

Map 2. Nisqually Watershed Sub-basin Map (Nisqually Steelhead Recovery Plan, 2014)

Appendix E

References

Ballanti, L., K. B. Byrd, I. Woo, and C. Ellings. 2017. Remote sensing for wetland mapping and historical change detection at the Nisqually River Delta. *Sustainability* 9, 1919: 23p.

Bortleson, M.J., M.J. Chrzastowski, and A.K. Helgerson. 1980. Historical Changes of Shoreline and Wetland at Nisqually River and Nisqually Reach, Washington. U.S. Geological Survey Hydrologic Investigations Atlas HA-617 (Sheet 9). Prepared in cooperation with U.S. Department of Justice and the Bureau of Indian Affairs.

City of Olympia. 2013. McAllister Wellfield website. Available: <http://olympiawa.gov/city-utilities/drinking-water/McAllister>. Accessed: December 2013.

Collins, B.D., D.R. Montgomery, and A.J. Sheikh. 2003. Reconstructing the historical riverine landscape of the Puget Lowland. Pages 79-128. In: D.R. Montgomery, S.M. Bolton, D.B. Booth, and L. Wall (eds.). Restoration of Puget Sound Rivers. University of Washington Press, Seattle, WA.

Curran, C.A., E.E. Grossman, and C.S. Magirl. 2014 in review. Suspended Sediment Delivery to Puget Sound in the Lower Nisqually River, Washington, 2011: U.S. Geological Survey Open-File Report.

Czuba, J.A., C.S. Magirl, C.R. Czuba, E.E. Grossman, C.A. Curran, A.S. Gendaszek, and R.S. Dinicola. 2011. Sediment load from major rivers into Puget Sound and its adjacent waters: U.S. Geological Survey Fact Sheet, 2011–3083. 4 pp. Available: <http://pubs.usgs.gov/of/2011/3083/>. Accessed: March 2014.

Czuba, J.A., T.D. Olsen, C.R. Czuba, C.S. Magirl, and C.C. Gish. 2012a. Changes in Sediment Volume in Alder lake, Nisqually River Basin, Washington, 1945-2011: U.S. Geological Survey Open-File Report 2012-1068, 30 p. Available:<http://pubs.usgs.gov/of/2012/1068/>. Accessed: March 2014.

Czuba, J.A., C.S. Magirl, C.R. Czuba, C.A. Curran, K.H. Johnson, T.D. Olsen, H.K. Kimball, and C.C. Gish. 2012b, Geomorphic analysis of the river response to sedimentation downstream of Mount Rainier, Washington: U.S. Geological Survey Open-File Report 2012-1242. 134 pp. Available: <http://pubs.usgs.gov/of/2012/1242/>. Accessed: March 2014.

Ellings, C. 2004. Nisqually River Off-Channel Habitat Assessment (IAC #01-1391N) Final Report. Prepared for Nisqually Indian Tribe, Olympia WA.

Golder Associates Inc. March 2010. Phase 1 Storage Evaluation, Town of Eatonville. Prepared for the Town of Eatonville.

Kerwin, John. 1999. Salmon and Steelhead Habitat Limiting Factors WRIA 11. Washington State Conservation Commission. Final Report. January 21, 1999.

Kerwin, J. 2000. Salmon and Steelhead Habitat Limiting Factors Report. Water Resource Inventory Area 11. Washington State Conservation Commission, Olympia, WA. Report. 158 pp., Appendices.

Liddle Janet A. 1998. Ohop Valley, Celebration of the Natural and Cultural Resources of Ohop Valley. Eatonville, WA.

Nelson, L.M. 1974. Sediment transport by streams in the Deschutes and Nisqually River basins, Washington. November 1971-June 1973: U.S. Geological Survey Open-File Report 74-1078, 33 p

Nisqually Chinook Recovery Team. 2001. Nisqually Chinook Recovery Plan. Prepared by Mobrand Biometrics, Inc., Vashon, WA. August.

Nisqually Steelhead Recovery Team. 2014. Nisqually Steelhead Recovery Plan. July. Seattle WA. Prepared for Nisqually Indian Tribe, Olympia WA.

Pierce County. 2005. Muck Creek Basin Plan. Prepared for Pierce County Public Works and Utilities, Water Programs Division. Tacoma, WA.

Pierce County. 2012. Nisqually River Basin Plan. Prepared for Pierce County Public Works and Utilities, Water Programs Division. Tacoma, WA.

South Puget Sound Salmon Enhancement Group. 2006. Ohop Valley Restoration, Pierce County, WA, Biological Assessment: Endangered Species – Section 7 Review. Prepared for the Nisqually Indian Tribe, Olympia, WA.

Warrick, J.A., Draut, A.E., McHenry, M.L., Miller, I.M., Magirl, C.S., Beirne, M.M., Stevens, A.W., and J.B. Logan. 2011. Geomorphology of the Elwha River and its Delta, chap. 3 of Duda, J.J., Warrick, J.A., and Magirl, C.S., eds., Coastal habitats of the Elwha River, Washington—Biological and physical patterns and processes prior to dam removal: U.S. Geological Survey Scientific Investigations Report 2011-5120-2, p. 48-73. Available: <http://pubs.usgs.gov/sir/2011/5120/ pdf/sir20115120_ch3.pdf>. Accessed: March 2014.

Walter, G.F. 1986. Nisqually River Drainage Basin. In-stream Habitat Assessment and Policy Recommendations. Technical Report No. 15. Nisqually Indian Tribe. Olympia, WA.

Watershed Professionals Network, LLC. 2002. Nisqually River Level I watershed assessment (WRIA 11). Prepared for the Nisqually Watershed Planning Group.

Watershed Professionals Network, LLC. 2004. Mashel River Restoration Design Technical Memorandum. Prepared for Pierce Conservation District.

Woo, I., K. Turner, A. Smith, P. Markos, and J. Y. Takekawa. 2011. Assessing habitat development in response to large scale restoration at the Nisqually River Delta. Unpublished data summary report to the National Fish and Wildlife Foundation, Puget Sound Marine Conservation Fund #2006-0180-017. USGS Western Ecological Research Center, San Francisco Bay Estuary Field Station, Vallejo, CA. 21 pp.

Appendix G

Nisqually Community Forest

G-1 Managed Forestry Nisqually Community Forest Template*

*Note: internal appendices referenced in this document are not included in full, but are listed in Addendum References

Appendix

Streamflow Mitigation Using Community Forestry Techniques

1 Background

A significant body of field evidence, research and important new modeling indicates that large streamflow benefits can accrue from increasing forest stand age through Managed Forestry:

- Perry and Jones (2016) used paired forest stands comparable to those in the Nisqually River watershed to show that after a forest stand age of 40 years, re-growing forests contribute significantly to streamflow.
- Abdelnour et al (2011 and 2013) confirm that the findings of Perry and Jones (2016) can be reproduced using numerical modeling with the VELMA model code.
- McKane et al (2018) has modeled the Mashel River sub-basin using the VELMA model. Preliminary results indicate that streamflows increase substantially when forest stand ages increase.
- Managed Forest practices are already being implemented in the Nisqually Community Forest, include over 1,900 acres already purchased and under protection. This ongoing program (limited only by funding) indicates the viability of the long-term managed forest concept.
- Significant additional forest stand assessment has led to a candidate parcel list that can expand the managed forest program (Figure B1).

The Nisqually Community Forest candidate parcels were identified by the Nisqually Indian Tribe for potential implementation in Pierce, Lewis and Thurston Counties. Figure B1 shows the locations of these candidate parcels. Important work by the Nisqually Indian Tribe identified the average ages of forest stands on these parcels (also provided in Figure B1). Significant analysis with the LandTrendr application (Kennedy, et al 2018) helped detect forest clear-cutting across multiple years of LandSAT imagery.

In the discussion below, we assessed the estimated streamflow benefits that could potentially accrued by Managed Forestry.

2 Evaluation of Streamflow Benefits from Managed Forestry in the Mashel Sub-Basin

The work of Perry and Jones (2016) is critical to the understanding of the streamflow benefits of Managed Forests. Exhibit B2 provides this peer-reviewed research effort. Figure 6b is extracted below for reference from their paper, *Summer streamflow deficits from regenerating Douglas-fir forest in the Pacific Northwest, USA*:

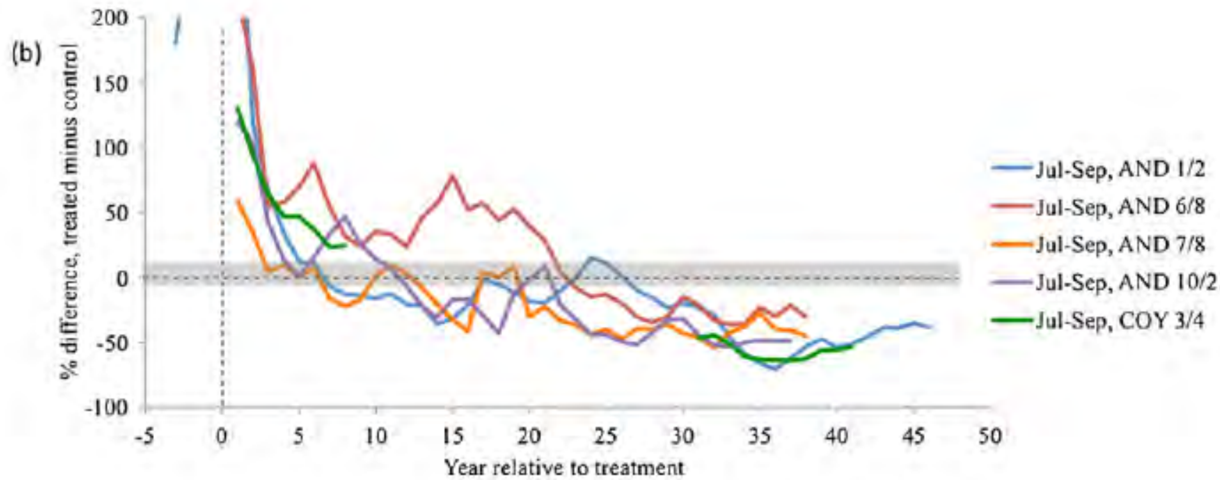


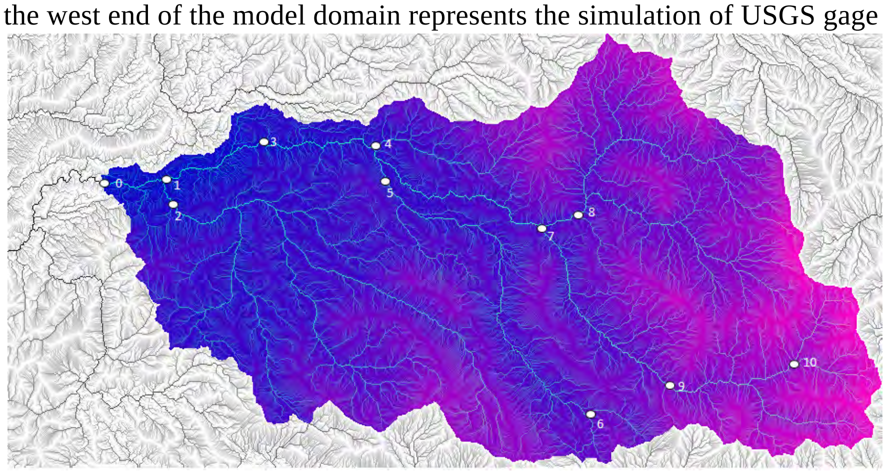
Figure 6b, (excerpted from Perry and Jones (2016).

In this figure, streamflows are compared between pairs of test basins: one cut and the other uncut. Their streamflows are expressed as the percent difference between the reference (uncut) streamflow and the clear-cut basin streamflow – over a test period of 35 to 45 years.

- Initially, streamflows rise rapidly in the cut basin, relative to the uncut partner basin.
- Streamflows then decline rapidly as vegetation re-growth uses more water relative to the uncut partner basin.
- In forests older than 35-40 years, streamflows then stabilize at 50% to 70% lower than in the uncut partner basin.

Forests with a stand age of more than 35-40 years then steadily produce more streamflow as they age, approaching un-cut (old growth) streamflows by a stand age of 100 years (Abdelnour et al, 2011 and 2013).

Computer modeling using VELMA was able to reproduce this sequence – both the hydrology and forest cover changes – for the Mashel River sub-shed (McKane et al, 2018) – at 10 reach locations. Reach 0 at the west end of the model domain represents the simulation of USGS gage 12087000:



VELMA model domain for the Mashel Sub-basin showing the stream network, simulated gages at key reaches and boundary view (McKane et al, 2018).

The VELMA modeling made a good approximation of the actual discharge in the Mashel River. Three other scenarios were simulated in the modeling: 1 year after clear-cut, 40 years after clear-cut and 240 years after clear-cut. The streamflow from the 240-year old forest stand is reported to be nearly indistinguishable at the streamflow from a 100-year-old forest stand (McKane, 2018; Abdelnour 2011; Abdelnour 2013). Lowest modeled streamflows were found at 40 years after clear-cut, while from 40 to 100 years, streamflows returned, approaching un-cut old-growth streamflows in the 100-year-old stand age modeling.

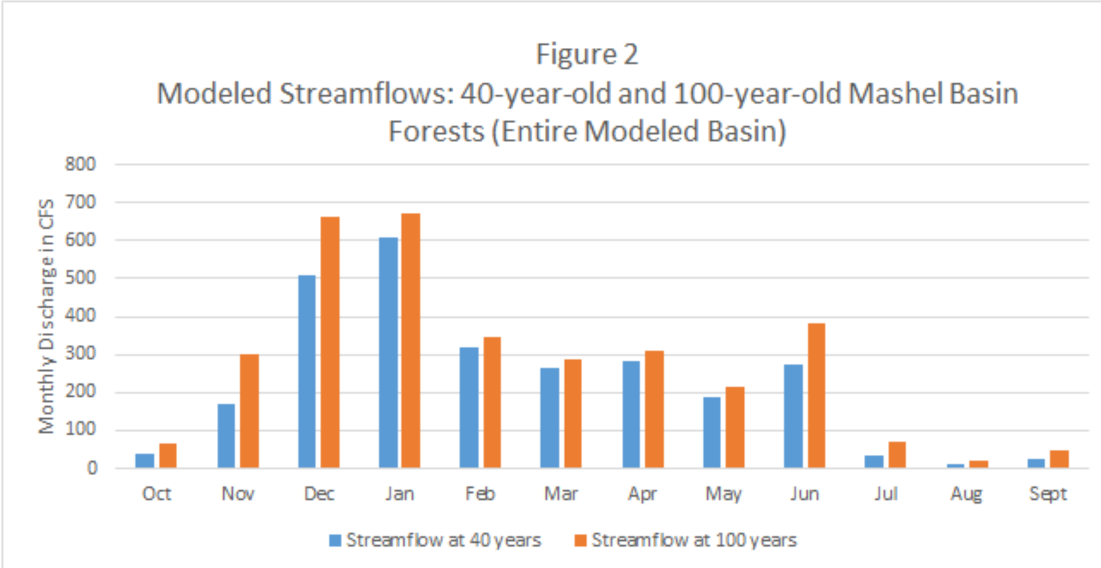
Potential Applications to Additional Managed Forest Lands in the Nisqually

The Nisqually Indian Tribe has already purchased three large parcels (three entire Sections) in the Nisqually Community Forest (NCF) project, totaling approximately 1,920 acres. The expansion of this project is envisioned, with the addition of Managed Forest lands in Thurston County in the Bald Hills area where some forest stands may exceed 40 years of age.

As described above, based on the Perry and Jones (2016) and VELMA model results (McKane et al, 2018), increasing the forest stand age can have significant beneficial effects. Additionally, the VELMA results suggest that these effects can be *quantified on a unit-area basis* given several assumptions that we will strive to maintain for candidate project sites:

1. Streamflow benefits from increasing the forest stand age occur after a forest begins to mature. Best available data suggest that a forest stand age of 40 years is necessary for the beginning of this return of streamflow.
2. McKane, et al (2018) made VELMA model runs to simulate the end-members of the forest re-growth process. They modeled the entire Mashel sub-basin as:
    a. 40-year-old forest
    b. 100-year-old forest
3. Streamflows from these two end-member VELMA simulations represent
    a. Achievable streamflow gains under managed forest practices where stand age will increase at a rate similar to natural growth rate
    b. Good correlation to the Perry and Jones (2016) test basins (Douglas Fir)
    c. The rate of streamflow increases linearly over a known time span of 60 years
    d. A known basin area (209 square kilometers)
4. Starting forest ages are at or above 40 years.
5. Chapter 90.94 RCW Streamflow Restoration Act requirements limit the time span of projects to benefits accrued within 20 years (note that this is much less than the 60-years needed to return to near-old-growth hydrology). This is only a fraction of the total streamflow benefit that may accrue over the longer time span for the Nisqually Community Forest (perpetual protection).
6. The land are under managed forestry is subject to many factors. The preliminary land acquisition program envisioned at this time is provided in Table B2 – but may change as opportunities arise.

Table B1 provides the result of comparing the 40-year-old and 100-year-old VELMA model results for the entire model domain. Figure 2 compares streamflows at 40- and 100-year forest stand ages:



Using these assumptions, differences between monthly flows in the 40-year-old and 100-year-old VELMA simulations can be used to determine a unit acre of per-year streamflow increase that can be reasonably achieved for new Managed Forestry lands added to the Nisqually Community Forest.

Table B1 provides the calculated unit benefits to streamflow, as both acre-feet per year per acre (acre-feet/year/acre), and as cfs per year per acre (cfs/yr/acre). Importantly, streamflow benefits increase over time, an *additive cumulative benefit* not seen with other potential types of mitigation methodologies.

Table B2 provides the application of the streamflow benefit rates to the conservative schedule of Managed Forestry lands acquired over the 20-year span required by the Streamflow Restoration Act. Note that both the Mashel sub-basin and the Lackamas/Toboton/Powell sub-basin are envisioned.

Note that land acquisition is conservative, based only on past funding.

Table B3 provides the application of these same streamflow benefit rates to significant additional acreage. This scenario envisions a large-scale approach to managed forestry, with land protected at nearly twice the rate of recent past land acquisitions, limited by the number of currently-evaluated parcels, over the 20-year span required by the Streamflow Restoration Act. In this scenario, the area of managed forestry is expanded to include the Upper Nisqually River sub-basin in Lewis and Pierce Counties. In the Mashel River sub-basin, thisscenario adds significantly to the additional managed forestry lands in Pierce County.

Table B4 provides the preliminary list of candidate land parcels used in this analysis. These parcels are provided from analysis of scientific data, modeling results, remote sensing data and public land records for screening purposes only. Neither owner knowledge nor consent is implied.

References

Abdelnour, A., Stieglitz, M., Pan, F., & McKane, R. (2011). Catchment hydrological responses to forest harvest amount and spatial pattern. Water Resources Research, 47(9).

Abdelnour, A., McKane, R., Stieglitz, M., Pan, F., & Cheng, Y. (2013). Effects of harvest on carbon and nitrogen dynamics in a Pacific Northwest forest catchment. *Water Resources Research*, *49*(3), 1292-1313.

Kennedy, R. E., et al. (2018). An empirical, integrated forest biomass monitoring system. *Environmental Research Letters*, 13(2), 025004.

Kennedy, R. E., Yang, Z., Braaten, J., Thompson, C., Antonova, N., Jordan, C., and Nelson, P. 2015. Attribution of disturbance change agent from Landsat time-series in support of habitat monitoring in the Puget Sound region, USA. Remote Sensing of Environment 166:271-285.

McKane, R., Barnhart, B, Brookes, A. Halama, J., Pettus, P., Djang, K., Hall, J., Kane, J., Swedeen, P., Blair, G. Webster, M., Hodgson, S., Ellings, C., Benson, L., Stonington, D. 2018. Nisqually Community Forest VELMA modeling to evaluate effects of forest management scenarios on streamflow and salmon habitat. U.S. Environmental Protection Agency. Pers. Comm. draft May 31st 2018.

Moore, G. W., Bond, B. J., Jones, J. A., Phillips, N., & Meinzer, F. C. (2004). Structural and compositional controls on transpiration in 40-and 450-year-old riparian forests in western Oregon, USA. *Tree physiology*, *24*(5), 481-491.

Perry, T. D., & Jones, J. A. (2017). Summer streamflow deficits from regenerating Douglas-fir forest in the Pacific Northwest, USA. *Ecohydrology*, *10*(2).

Appendix G

Nisqually Community Forest

G-2 Nisqually Community Forest VELMA modeling to evaluate effects of forest management scenarios on streamflow and salmon habitat (Hall et al., 2018)

Nisqually Community Forest VELMA modeling to evaluate effects of forest management scenarios on streamflow and salmon habitat

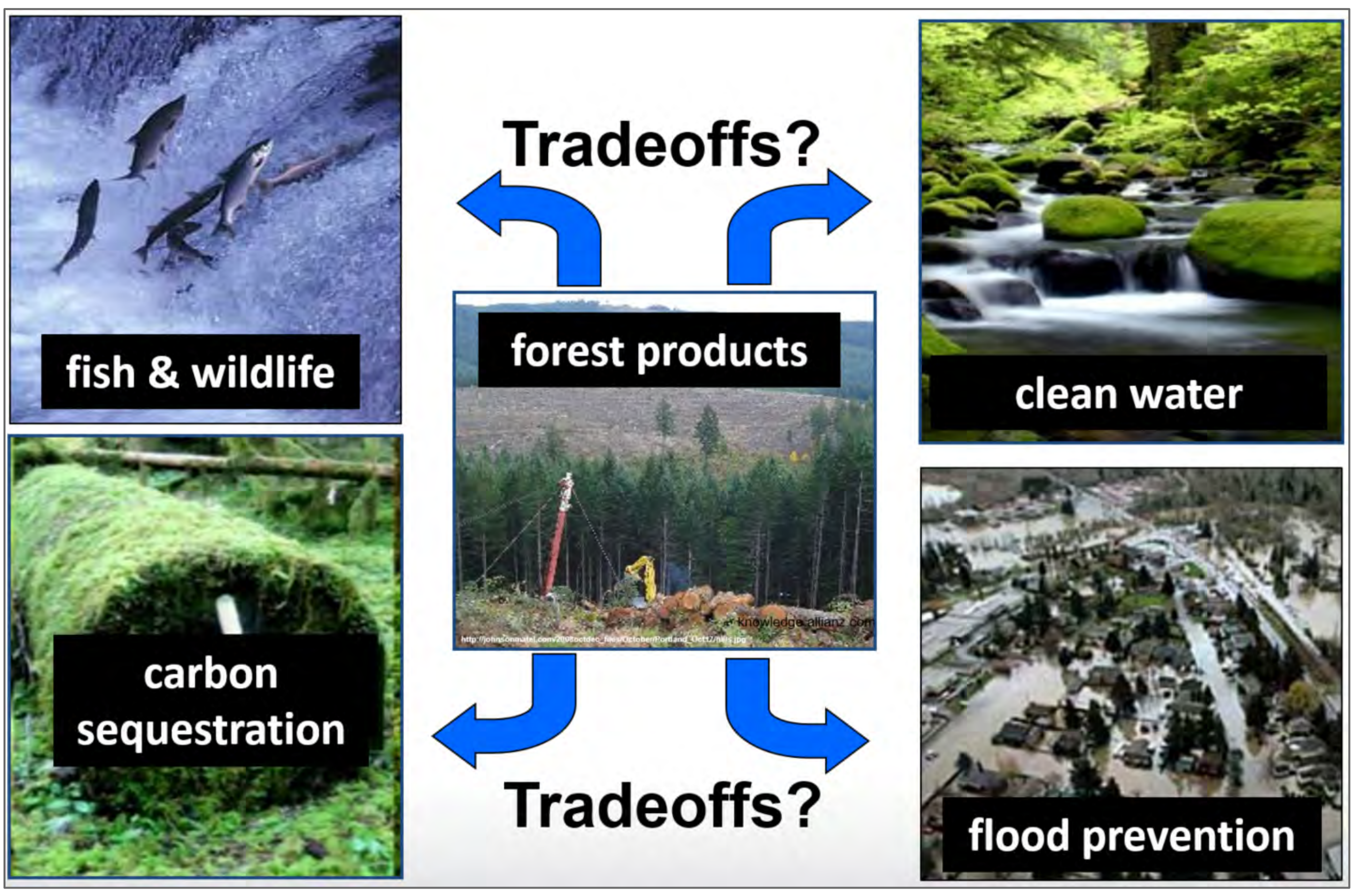
Justin Hall[1], Joe Kane[2], Paula Swedeen[3], Greg Blair[4], Max Webster[5], Sayr Hodgson[6], Chris Ellings[6], Laurie Benson[7], Dan Stonington[7]

Nisqually Community Forest partners: [1]Nisqually River Foundation; [2]Nisqually Land Trust; [3]Conservation Northwest, [4]ICF International, [5]Washington Environmental Council, [6]Nisqually Tribe, [7]Washington Department of Natural Resources

Robert McKane[8], Bradley Barnhart[8], Allen Brookes[8], Jonathan Halama[8], Paul Pettus[8], Kevin Djang[9]

[8]U.S. Environmental Protection Agency Western Ecology Division, [9]Inoventures LLC (CSRA subcontractor)

May 31, 2018



1.0 BACKGROUND AND SCOPE

The Nisqually Community Forest is an effort to purchase the commercial forests of the upper Nisqually and it's main tributaries. This will allow the forest management to be done for the greatest benefit of the community include jobs, recreation, and fish and wildlife habitat as priorities while still providing timber products. This effort was born from a concern that a new round of timber harvest using clearcuts would be detrimental to the threatened Chinook and Steelhead that depend on the tributaries for spawning, hatching, and rearing.

Salmon are important to the economic, social, cultural, and aesthetic values of the people in the Nisqually River watershed. Chinook (*Oncorhynchus tshawytscha*) and coho salmon (*O. kisutch*) and winter steelhead (*O. mykiss*) were at one time abundant in the Nisqually River. These species were a significant component of the Nisqually ecosystem and provided important fisheries for tribal and sport fishers. Declines in Chinook salmon abundance led to the listing of Puget Sound Chinook under the U.S. Endangered Species Act (ESA) in 1999. In May 2007, the Puget Sound Steelhead Distinct Population Segment (DPS) was listed as a threatened species under the ESA (Blair 2018).

Climate change and intensification of forest harvesting raise new challenges to protecting and restoring watershed functions and restoring salmonids. Scientific evidence demonstrates that the climate is changing globally at a rate faster than has been experienced in modern history. Remote sensing evidence shows that extensive harvesting of remaining mature forests (<80 years-old) across western Washington and Oregon since 1985 has established a much younger and intensively managed forest landscape (Kennedy et al. 2018).

Tribes, communities, watershed councils, and other stakeholders have mobilized to develop salmon recovery plans across Washington (http://www.rco.wa.gov/salmon_recovery/efforts.shtml). Watershed and community-based salmon recovery plans have established priorities and work schedules for restoring stream, riparian, floodplain and other habitats (http://www.rco.wa.gov/documents/salmon/lead_entities/LeadEntityDirectory.pdf). Many of these plans have been in place for a decade or more and are being updated regularly as new information and tools become available. Significant progress has been made in implementing these plans, and there have been many restoration success stories across Washington (Washington State Salmon Recovery Funding Board 2015).

However, many challenges and uncertainties remain. The questions below reflect active areas of investigation to further refine habitat restoration efforts.

1) Can forest management practices be designed that sustainably achieve diverse objectives: thriving salmon populations, forest products supporting local forest sector jobs, clean drinking water, carbon sequestration, recreational and cultural opportunities, and tourism?
2) What combination of the following restoration practices will best support salmon recovery: low flow enhancement, peak flow reduction, riparian buffers, in-stream large woody debris, cold-water refuges, and sediment control?
3) How much and where should habitat restoration efforts be located to be most effective, biologically and economically?
4) How long will it take for specific restoration actions to have desired impacts?
5) How will climate extremes and long-term trends impact future effectiveness of restoration actions?

A major challenge to addressing such questions is the timescale required for many restoration actions to take effect. The effect of riparian plantings on stream temperature is just one example. Another challenge is that every watershed reflects a unique combination of biophysical conditions that interact in ways that are difficult to predict. As a result, restoration actions that work well in one location may not be as effective in another. Fortunately, ongoing advances in modeling technologies are making it increasingly feasible to simulate how different locations will respond to restoration and climate scenarios of interest (e.g., Battin et al. 2007; Mantua et al. 2010).

This document describes a collaborative effort of Nisqually Community Forest (NCF) partners and the U.S. Environmental Protection Agency to use a well-established ecohydrological model and associated tools to help inform salmon recovery planning for the Mashel River watershed in the western foothills of Mt. Rainier in Washington State. This effort builds upon the large body of existing salmon recovery research and data in the Pacific Northwest (e.g., Beechie et al. 2008). Our goal is to help address watershed restoration planning questions such as (1) – (5), above.

2.0 Approach

2.1 Study Site

The Mashel River watershed is vitally important to restoring Chinook, winter steelhead and coho salmon in the 517 mi^2 Nisqually River Basin. The 84 mi^2 watershed is the second-largest tributary to the Nisqually River and the largest tributary by flow accessible to salmon. The mountainous topography ranges in elevation from 460 to 4845 feet. From its headwaters in the foothills of Mount Rainier the Mashel River flows west passing south of Eatonville, providing drinking water for the town of 3000 people. The river then flows southwest to its confluence with the Nisqually River at river mile 39.6. An extensive snow zone in the upper watershed provides snowmelt to streams during early summer months. Salmonids utilizing the Mashel River mainstem and tributaries are particularly vulnerable to changes in seasonal precipitation and snowpack, and unstable slopes and geomorphology (Bohle et al.1996). Mature coniferous forests that once dominated the watershed have been mostly replaced by young intensively managed forests on private and public lands. The Mashel's forest lands are considered to be among the most productive forests globally. Thus, the resource-rich Mashel River watershed provides fish and wildlife, drinking water, forest products, cultural and recreational opportunities, carbon sequestration, and many other services for a wide array of local, regional and global stakeholders.

Figure 1. Mashel River watershed location.

2.2 Nisqually Community Forest

The Nisqually Community Forest is a wholly owned subsidiary of the Nisqually Land Trust. It was formed as a collaboration between the Nisqually River Council. The Nisqually Land Trust, The Nisqually River Foundation, Northwest Natural Resource Group, the Nisqually Indian Tribe, and the Washington Environmental Council. The mission of the Nisqually Community Forest is to acquire and manage working forests in the Nisqually watershed to provide sustainable economic, environmental, and social benefits to local communities. The Nisqually Community Forest currently owns 1,920 acres on the south fork of the upper busywild, a tributary of the Mashel River. 2/3 of the sub-basin are in commercial ownership by timber investment management organizations. The Nisqually Community Forest is seeking financing to purchase some or all of the commercial forestlands of the watershed.

2.3 Model Description

Our primary goal is to apply a set of well-validated modeling tools for the Mashel River watershed to address the set of questions listed in section 1.0, above. We are especially interested in identifying forest management practices to achieve a robust Nisqually Community Forest (NCF) supporting local conservation, and cultural and economic goals, including salmon recovery, local forest sector jobs, educational and recreational opportunities, and tourism. We anticipate that modeling results of this initial study will establish a technical foundation for NCF staff to conduct routine modeling applications to help inform local forest management decisions.

An important premise of our NCF collaboration is that well-managed working forests can simultaneously promote salmon recovery, forest sector jobs and other community goals. In this report we will briefly describe several tools that our group is linking together to help land managers identify whole-watershed management practices that best balance multiple objectives. These tools include:

- VELMA ecohydrology model
- Penumbra stream temperature model
- EDT fish habitat model

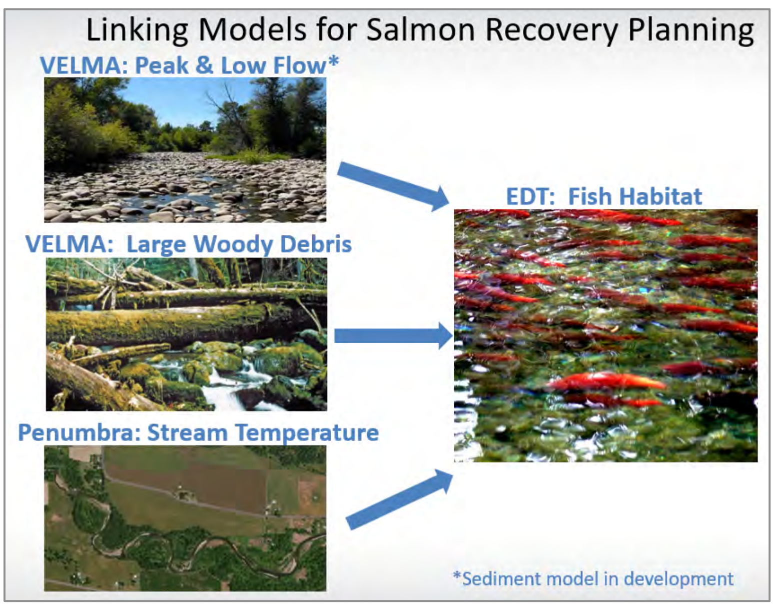


Figure 2. Watershed-scale models will feed spatial and temporal information on streamflow and large woody debris (VELMA) and stream shading and temperature (Penumbra) to a fish population model (EDT) to assess effects of riparian restoration and floodplain reconnection on salmonid reproduction, growth, and survival.

2.3.1 Description of the VELMA Ecohydrology Model

Watershed simulations will be conducted using the Visualizing Ecosystem Land Management Assessments (VELMA) ecohydrological model, a process-based ecohydrological model that dynamically simulates the interaction of hydrological and biogeochemical processes across multiple scales: plots → hillslopes → watershed (Abdelnour et al. 2011, 2013; McKane et al. 2014a). Details of the model including publications, downloadable executable model, and a user manual describing calibration and application methods can be found on EPA's

VELMA website: https://www.epa.gov/water-research/visualizing-ecosystem-land-management-assessments-velma-model-20.

Briefly, VELMA is a spatially-distributed model, with each pixel within a watershed representing a 4-layer soil column and vegetation with specified characteristics (Figure 3). Pixels are typically 30m, but smaller or larger grids can be specified depending upon questions to be addressed. VELMA simulates the effects of climate, land use, fire and other disturbances on streamflow, evapotranspiration (ET), vertical and lateral flow, plant and soil carbon and nitrogen dynamics, and transport of dissolved nutrients and contaminants to streams and estuaries. The model uses a daily time step but simulations can extend for centuries if necessary. Publicly available data are used to apply the model. See Appendix A for details on data requirements and sources.

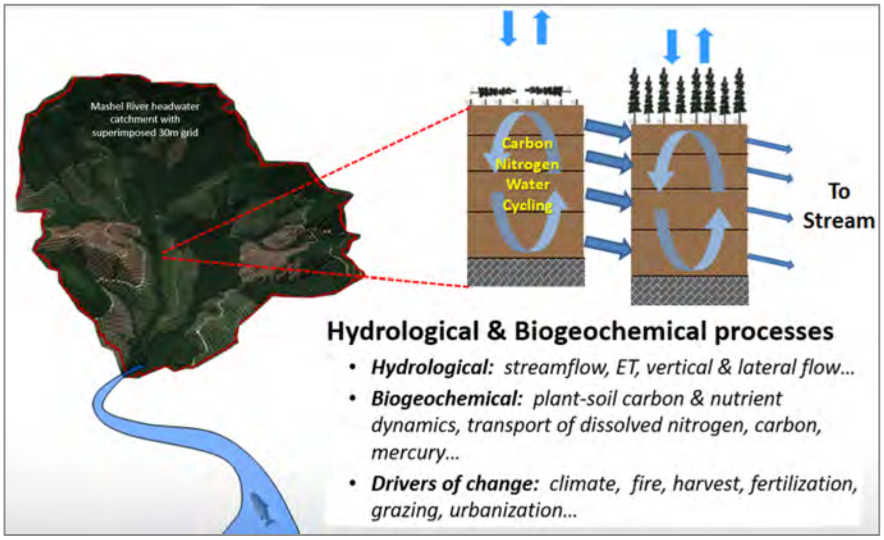


Figure 3. Conceptual diagram of the VELMA ecohydrological model.

2.3.2 Description of the Penumbra Stream Shading and Temperature Model

Penumbra is a landscape shade and irradiance simulation model that simulates how solar energy spatially and temporally interacts within dynamic ecosystems such as riparian zones, forests, and other terrain that cast topological shadows. Direct and indirect solar energy accumulates across landscapes and is the main energy driver for increasing aquatic and landscape temperatures at both local and holistic scales. Landscape disturbances such as land use change, clearcutting, and fire can cause significant variations in the resulting irradiance reaching particular locations. Penumbra can simulate solar angles and irradiance at definable temporal grains as low as one minute while simulating landscape shadowing up to an entire year. Landscapes can be represented at sub-meter resolutions with appropriate spatial data inputs, such as field data or elevation and surface object heights derived from light detection and ranging (LiDAR) data.

To dynamically simulate the effects of vegetation growth and canopy dynamics on stream shade and temperature at daily to inter-annual time scales, Penumbra has been integrated into the VELMA program code. The linkage of VELMA-Penumbra aims to provide sufficient shade or irradiance assessments at spatial resolutions and temporal scales suitable for assisting watershed stakeholders with riparian restoration planning. For example, where should riparian buffers be located, and how tall, wide or dense do they need to be to achieve desired stream temperature reductions?

2.3.3 Description of the Ecosystem Diagnosis and Treatment (EDT) Salmon Habitat Model

EDT is a hierarchically organized, spatially-explicit model that analyzes aquatic habitat along multiple salmonid life history trajectories to help managers and scientists investigate the biological and environmental constraints on species performance within a watershed.

Briefly, EDT is a life-cycle habitat model that characterizes the aquatic environment temporally (monthly) and spatially (stream reaches) “through the eyes of salmon.” Salmonid habitat is evaluated along numerous pathways, termed life history trajectories, which are defined by a particular species’ life history. Trajectories can be thought of as variable habitat pathways through time and space that a species might use to complete its life cycle. Fish could spawn early, or later; they could spawn higher or lower in the system; move quickly through some areas and pause in others. Each of these behaviors represents a different life history trajectory in EDT and a different sampling of the environmental conditions of the stream. The quality and quantity of habitat along each trajectory is assessed as the productivity and capacity of salmonids potentially using that pathway. The integration of performance across the trajectories estimates the productivity and capacity of a fish population in the environment and their variation due to heterogeneity of the habitat and fish behavior. These population-level metrics are then used to compare the alternative scenarios (e.g. land use scenarios, restoration actions, protection scenarios etc.). The population-level estimate of productivity and capacity can be disaggregated to study habitat constraints at sub-basin, stream reach, life-stage, and attribute levels.

We applied EDT to the Mashel River watershed using VELMA streamflow results for historic (1990 onward) timber harvests throughout the watershed, as determined using Landsat/LandTrendr change detection satellite imagery.

Appendix C (Blair 2018) provides a detailed description of methods and results for the effects of reconstructed summer low flows on salmon habitat.

2.4 Summary of Mashel Watershed Modeling Results to Date

Subsections 2.4.1 – 2.4.6 provide a high-level briefing of VELMA-Penumbra-EDT modeling results to date for the Mashel River watershed. Those subsections address one or more of the five key questions pertaining to NCF goals listed above in section 1. Section 2.5 provides an overall summary of model results with regard to these questions.

2.4.1 Effects of Forest Stand Age on Summer Low Flows

Recent empirical studies in western Oregon have established that young, rapidly growing forests can transpire over 3 times more water than mature forests. These studies were conducted at relatively small scales, ranging from individual trees and stands of trees (Moore et al. 2006), to small headwater catchments (Perry and Jones 2016). Thus, it is technically difficult to extrapolate those results to watersheds having a complex stand age structure, as is generally the case throughout much of the Pacific Northwest. Figure 4 shows that the Mashel watershed has a spatially complex forest biomass and age structure.

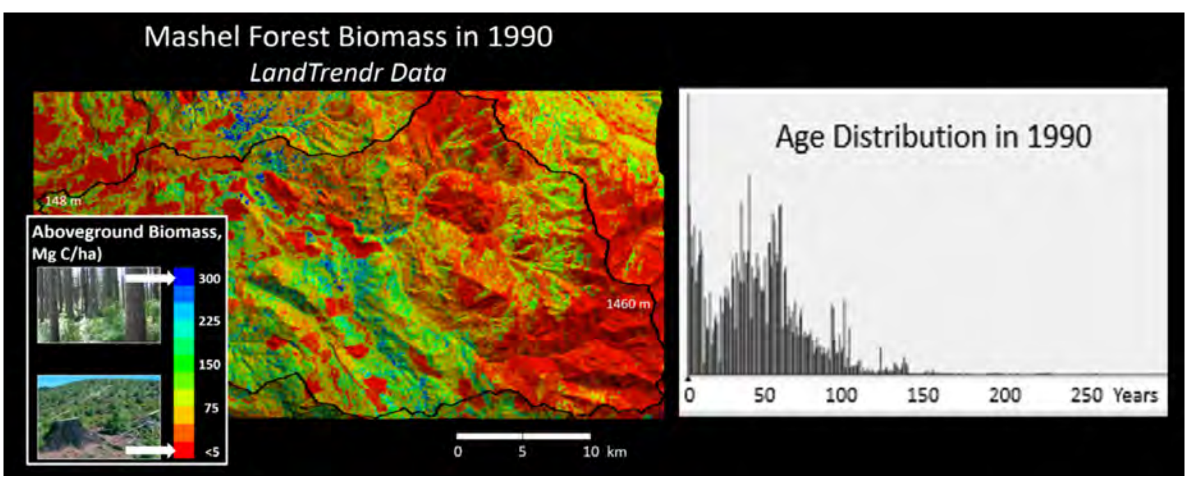


Figure 4. Mashel River watershed forest biomass and age structure in 1990 as detected by Landsat-LandTrendr remote sensing technology (Kennedy et al. 2018). Forest cover and other environmental conditions in 1990 were used as the starting point for historical model simulations described in this report.

Low summer flows are thought to be an important limiting factor for salmonid spawning and rearing in the Mashel River watershed, possibly contributing to the listing of Chinook and winter steelhead as endangered and threatened species, respectively. However, this hypothesis has been difficult to test through analysis of observed streamflow data.

We used VELMA to synthesize available data in order to evaluate whether or not forest stand age might be a factor in reducing summer low flows in the Mashel watershed. To do so, we modified VELMA in 2015 to include observed effects of tree and stand age on transpiration rates for a study conducted at the HJ Andrews Experimental Forest in the western Oregon Cascades (Moore et al. 2004).

As described in **Appendix B**, prior to incorporating the observed effect of stand age on transpiration (Moore et al. 2004) into VELMA, the model was unable to accurately simulate observed summer low flows <u>both</u> before and after clearcutting of an intensively monitored old-growth forest catchment (HJ Andrews experimental Watershed 10). After incorporating this effect, VELMA accurately simulated <u>both</u> pre- and post-harvest summer low flows at that site.

Importantly, VELMA's transpiration-based simulation of the effects of stand age on summer low flows was verified by a subsequent study (Perry and Jones 2016) that compared low summer flows for paired young and old forest catchments at the HJ Andrews site. Thus, the calibration and validation of VELMA's method for simulating summer low flows is based on completely different experimental methods and scales of observation: tree-level transpiration measurements for calibration, and catchment-level streamflow measurements for validation.

Having successfully calibrated VELMA for the HJ Andrews site, we applied it with no additional calibration to the Mashel River watershed about 200 miles north. That is, no model parameter values were changed, only model drivers for climate, terrain, soils and vegetation biomass and stand age (both locations are dominated by west Cascade coniferous forests).

Figure 5 shows that VELMA closely predicted observed streamflow data at the USGS stream gauge at the Mashel River outlet. Both peak and low flows are in generally good agreement with observed data, especially considering that VELMA was not recalibrated to fit observed Mashel streamflow data.

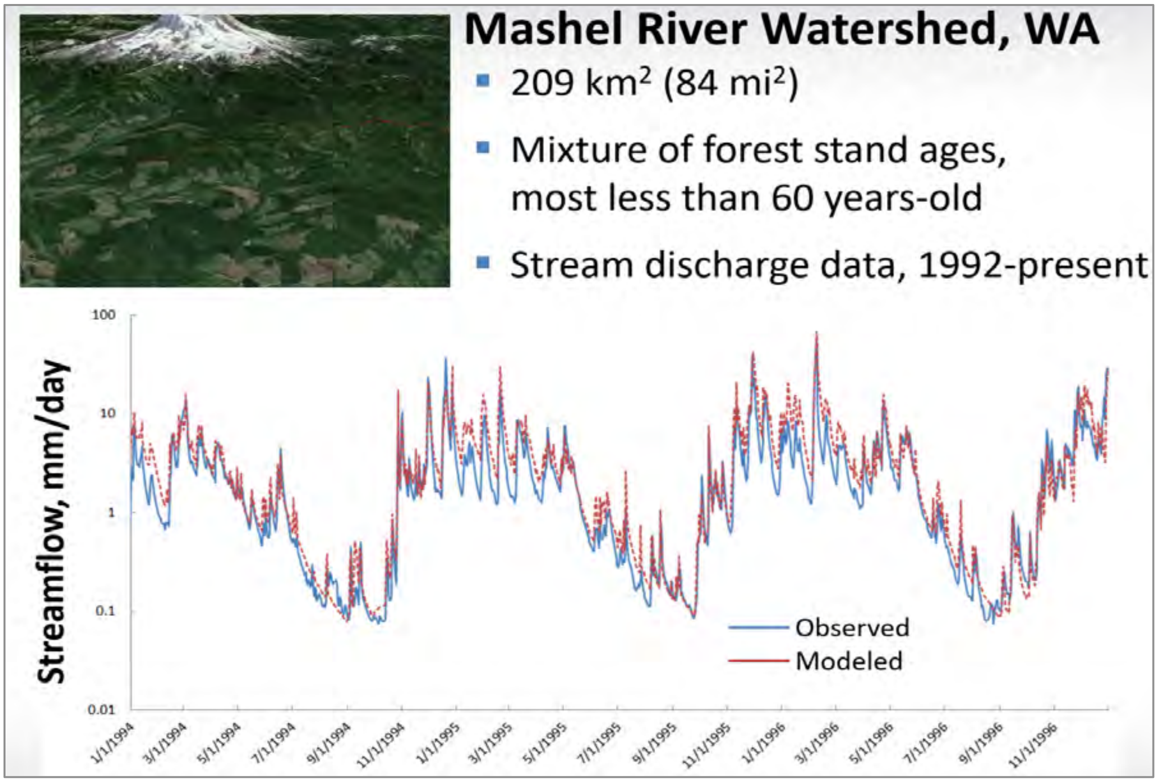


Figure 5. Modeled vs. observed streamflow (log of daily flow) at the USGS stream gauge at the outlet of the Mashel River watershed near its confluence with the Nisqually River. Use of a log scale is a standard practice for magnifying differences in modeled versus observed low flows.

Having established that VELMA accurately represents peak and low flows for actual forest stand age spatial patterns in the Mashel River watershed, we ran two additional watershed-scale VELMA simulations to explore changes in streamflow for two hypothetical landscapes, one with a homogeneous 100-year-old forest, and the other with a 40-year-old landscape (Table 1).

Table 1. VELMA simulations for different Mashel River watershed landscapes. All landscapes were simulated from 2006-2014 using best available climate data and initial LandTrendr forest biomass and age data for 2006.

Simulated landscape treatment applied to the entire 84 mi^2 Mashel River watershed	**Data used to initialize VELMA**
Actual forest mosaic of stand ages, ranging from 0 to 250 years old	Actual forest stand age and biomass spatial patterns initialized based on LandTrendr remote sensing data (Kennedy et al. 2018)
40-year-old forest	Hypothetical homogeneous forest 40 years old across entire watershed. Initial biomass for this simulation initialized based on observed successional data for coniferous forests in Western Washington (Janisch and Harmon 2002)
100-year-old forest	Hypothetical homogeneous forest 100 years old across entire watershed. Initial biomass for this simulation based on observed successional data for coniferous forests in Western Washington (Janisch and Harmon 2002)

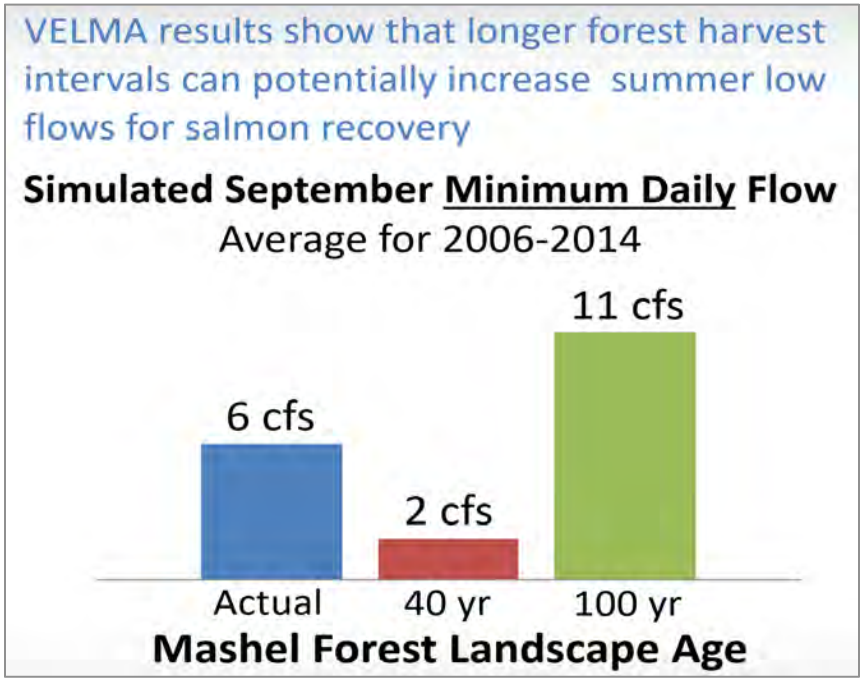


Figure 6. Mashel River watershed simulated effects of stand age on minimum daily streamflow during September, averaged for the years 2006-2014. "Actual", "40 yr" and "100 yr" simulated landscape treatments are defined in Table 1.

A comparison of simulated low flow differences for the landscape treatments described in Table 1 is shown in Figure 6. The 40-year-old virtual landscape produced simulated September minimum low flows that were about 3x lower than the Actual forest landscape. In contrast, the 100-year-old virtual landscape produced flows that were almost 2x higher than the Actual landscape, and over 5x higher than the 40-year-old landscape.

For reference, a flow of 6 cfs (Figure 6, Actual landscape) looks like the photograph in Figure 7.

Figure 7. Mashel River streamflow at 6 cfs on August 15, 2015 as recorded by the USGS stream gauge located just below this photo and close to the Mashel's confluence with Nisqually River (photo by B. McKane).

Finally, we also used VELMA to simulate clearcutting of a catchment draining into Busy Wild Creek, an upper reach of the Mashel River containing high quality salmon habitat. Simulated summer low flow results are shown in Figure 8, superimposed as the heavy red line over observed low flow results for paired young and old watersheds in Oregon (Perry and Jones 2016). The simulated Busy Wild Creek results are clearly consistent with the observed post-harvest temporal development of low flow deficits (relative to mature forests).

Thus, two lines of independent evidence, observational and modeled, indicate summer low flow deficits will persist for many decades unless alternative management actions are implemented. Preliminary VELMA simulations exploring one potential management alternative is described in Section 2.4.4.

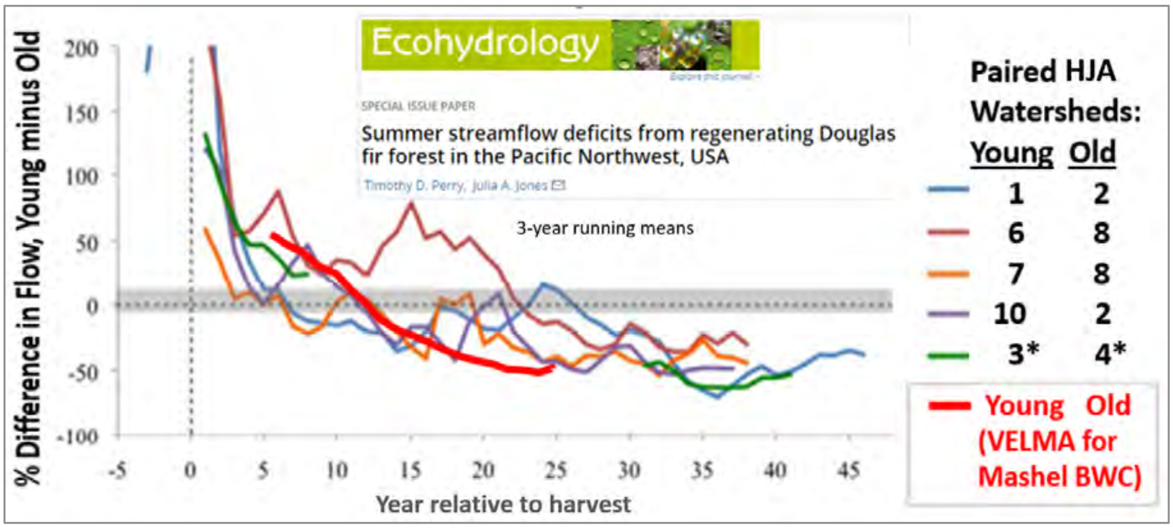


Figure 8. Figure 9b from Perry and Jones (2016) showing low flow results for five paired young and old watersheds at the HJA Andrews (HJA) and Coyote Creek (*) experimental watersheds in Oregon. The heavy red line superimposed on this figure shows VELMA simulated results for a catchment draining into the Busy Wild Creek in the upper Mashel River watershed. Daily low flow results for all watersheds were smoothed using 3-year running averages per calendar day. Note that observed unsmoothed daily low flows can be considerably larger, as shown in Figure 8 and Appendix B.

2.4.2 Effects of Summer Low Flows on Salmon Habit Potential

Mashel salmonids are particularly vulnerable to changes in seasonal precipitation and temperature because of the watershed's hydrologic flashiness, low summer flows and potential for sediment transport. The VELMA results described above demonstrate a clear link between the establishment of young forest landscapes and pronounced summer low flows in the Mashel.

To explore the effects of We applied the EDT fish habitat model to VELMA's simulated historical (1991 – 2000) low flow results for fish-bearing stream reaches within the Mashel watershed. These spatially-explicit VELMA outputs were applied as input to the Ecosystem Diagnosis and Treatment (EDT) fish habitat model to evaluate salmonid habitat potential and population responses.

Appendix C (Blair 2018) provides a detailed description of the modeling methods and results used for this project.

Figure 9 is a watershed-scale summarization of EDT modeled effects of summer low flows on adult salmonid abundance for coho, fall Chinook and winter steelhead. Winter steelhead showed the largest decrease in abundance, a consequence of it life cycle dependency on summer flows. This dependency is less pronounced for coho and fall Chinook which were correspondingly less impacted. Note that the EDT results shown in Figure 9 do not yet include forest harvest effects on stream temperature, large woody debris, or sediments.

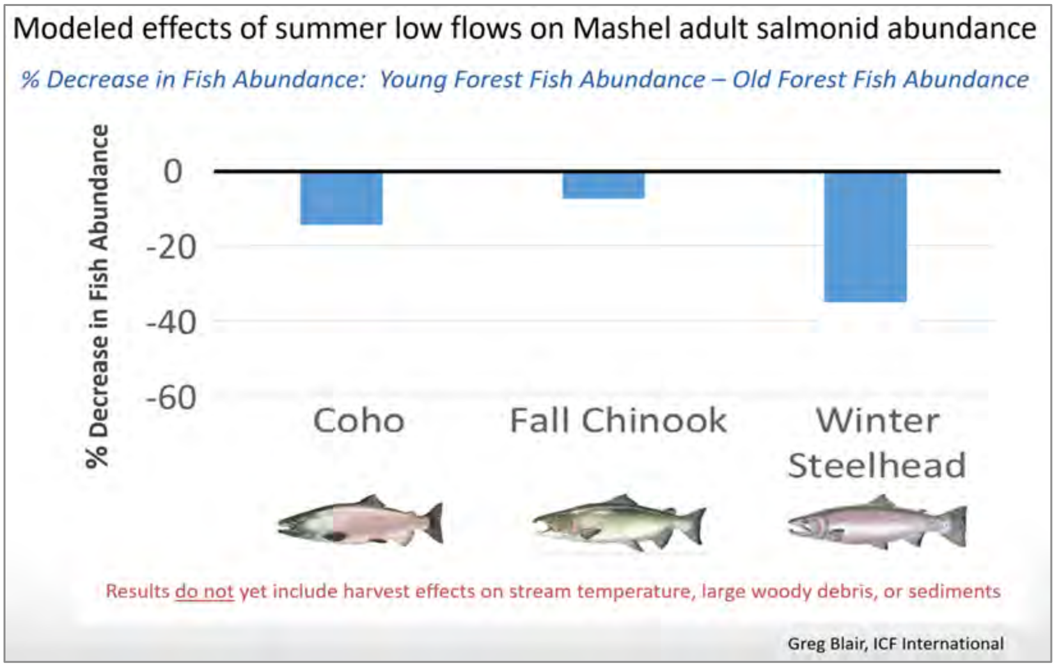


Figure 9. EDT salmon habitat model results for three species of native Mashel River salmonids. Simulated percentage decreases in adult fish abundance summarize responses to VELMA simulated summer low flows for 1991-2000. VELMA forcing data included historical temperature and precipitation data (http://www.prism.oregonstate.edu/) and LandTrendr remote sensing harvest data (http://geotrendr.ceoas.oregonstate.edu/landtrendr/).

Appendix C describes how historical timber harvests are still affecting salmonid habitat potential. Ongoing EDT applications are focused on how a community forest-based management plan could be more protective and supportive of salmon recovery. Future climate projections pose additional challenges for salmonid recovery planning. EDT is being used to investigate how impacts of future climate on flow can be alleviated by alternative forest management and instream habitat restoration. The Nisqually Indian Tribe is using these results to incorporate climate change adaptation planning into ongoing salmonid recovery planning.

2.4.3 Effects of Stand Age on Near-Stream Large Woody Debris

Large woody debris (LWD) provides critical salmon habitat in Northwest streams (https://blog.nature.org/science/2016/06/30/fish-forest-large-wood-benefits-salmon-recovery-log-jams-habitat-restoration/) . Log jams are especially important for scouring pools and capturing gravel that provide spawning and rearing habitat for salmonids. The Mashel River is typical of many Northwest streams in which present-day LWD levels are far below natural levels characteristic of once common old-growth forest watersheds (. Options for restoring LWD are limited.

A short-term but labor-intensive option is to install engineered log jams (ELJs). For example, the Nisqually Tribe has installed a number of engineered log jams (ELJs) along the LWD-poor lower reaches of the Mashel River. Maintenance of ELJs is difficult in flashy rivers like the Mashel.

The long-term option in managed forests is to establish and maintain robust riparian forest buffers that after many decades of growth can begin to produce LWD of sufficient diameter to improve in-stream habitat conditions.

We are using VELMA to explore both the short and long-term options for restoring in-stream LWD. Figure 10 shows VELMA results for LWD recruitment within 30-meter riparian buffers (each side of stream) for major streams within the Mashel watershed. Simulated 30-m pixels shown in red, yellow and light green are indicated as having no or low levels of LWD recruitment. These areas correspond to private commercial forests with short (~40 years) harvest intervals. Pixels shown in shades of blue have relatively high levels of LWD recruitment. These areas correspond to publicly owned lands in the Elbe Hills State Forest. Note that VELMA does not simulate direction of tree fall or transport of LWD within streams. VELMA's LWD recruitment results will be incorporate into the EDT fish habitat model for an upcoming round of Mashel EDT-VELMA simulations. This will be an important step for adding additional realism to the EDT simulated results for the effects of summer low flows on salmon habitat and survival.

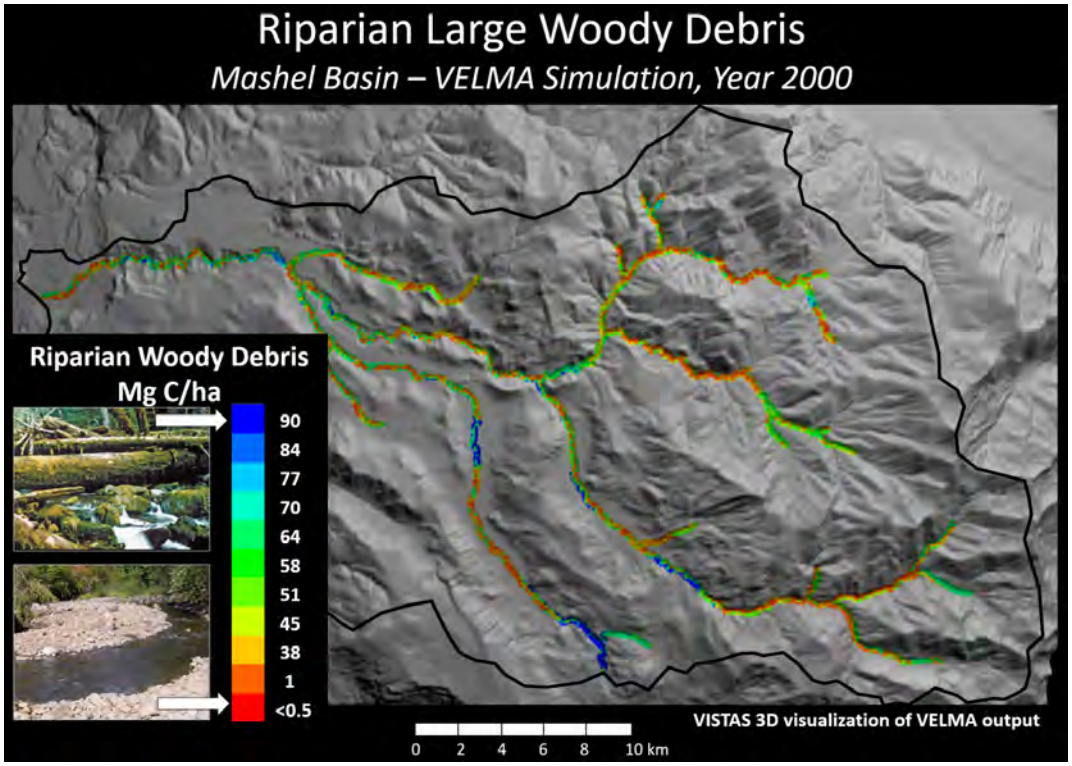


Figure 10. VELMA simulated results showing large woody debris (LWD) accumulated within 30-meter riparian buffers (each side of stream) for major streams within the Mashel watershed. VELMA simulates total stocks of LWD on the ground (Mg C/ha, shown here) and its rates of recruitment and decomposition (Mg C ha-1 year-1). It does not simulate LWD direction of fall and in-stream transport.

2.4.4 Effects of Forest Thinning vs. Clearcutting on Peak and Low Flows

VELMA is being used to test a central NCF idea – that long forest harvest intervals (80 years or longer) coupled with periodic thinning can improve summer low flow conditions for salmon spawning and rearing in the Mashel River watershed. **Figure 11** summarizes potential benefits of this approach.

Initial VELMA simulations to test this idea were recently conducted for the 100 mi^2 Tolt River watershed in the Cascade Range east of Seattle. Simulations were conducted as part of EPA's collaboration with the Snoqualmie Tribe and other stakeholders (https://cfpub.epa.gov/si/si_public_record_report.cfm?direntryid=337423). The simulated Tolt watershed results described here are informing preparations to simulate various thinning options for the Mashel watershed.

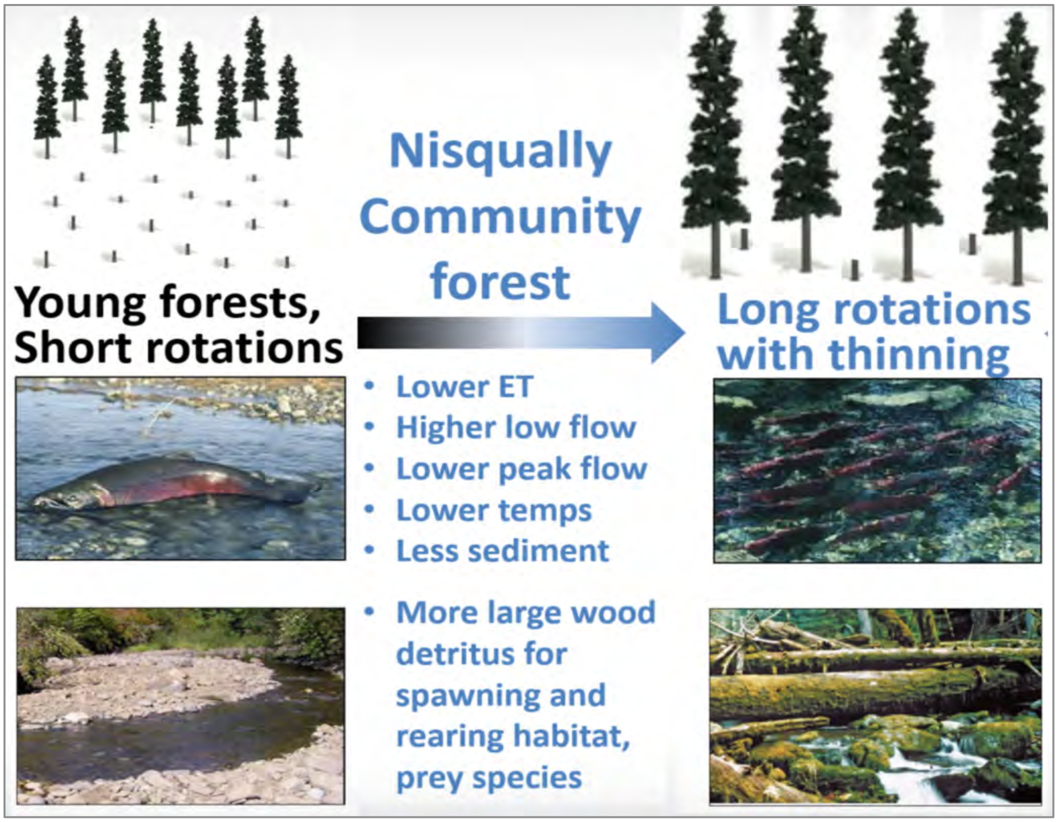


Figure 11. VELMA is being used to examine potential benefits of long harvest intervals coupled with pre-harvest thinning for improving stream habitat conditions for Mashel River salmonids.

For the Tolt River watershed we used VELMA to simulate two different harvesting scenarios: (1) actual historical clearcut harvests for 1990 – 2010 based on LandTrendr satellite change detection technology (Kennedy et al. 2018); and (2) actual historical harvests but with thinning of harvested stands by 60% instead of clearcutting. **Figure 11** illustrates these alternative harvest scenarios and the simulated consequences on the stand age structure of the Tolt watershed in 2010. As expected, the 2010 landscape for the actual clearcut-only scenario is clearly younger and has substantially less forest biomass (not shown) than the corresponding thinning-only scenario. Note that most harvesting in the Tolt occurred on private commercial forest lands. Less intensively harvested U.S. Forest Service lands occupying the westernmost upper watershed are shown in Figure 12 as a mixture of harvested (red) and unharvested old-growth (blue) pixels.

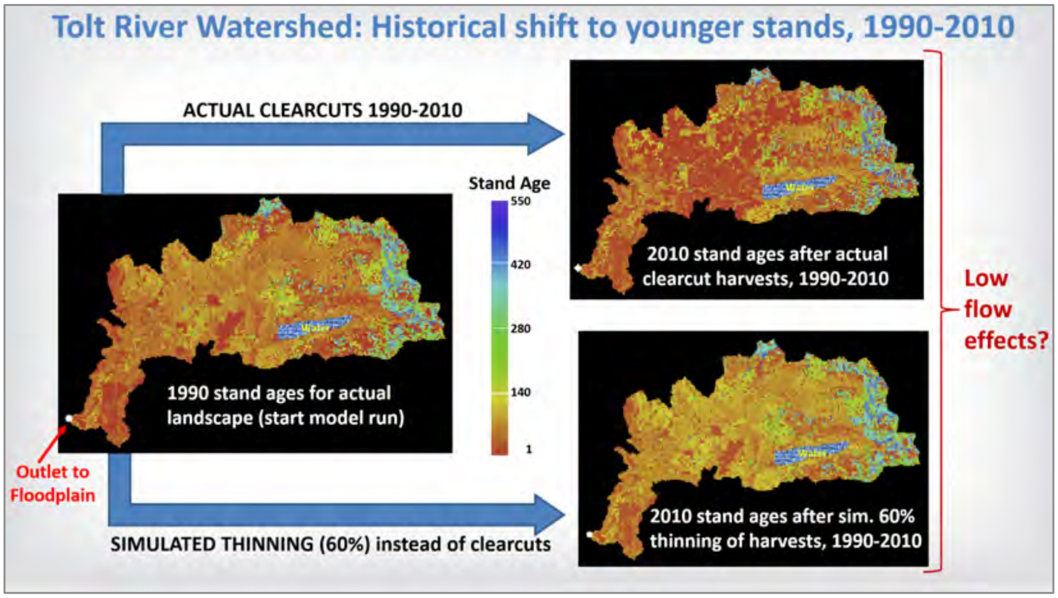


Figure 12. Tolt River watershed alternative VELMA harvesting scenarios for actual historical clearcut harvests (upper right); and for the same actual historical harvests but with thinning of harvested stands by 60% instead of clearcutting (lower right). Model simulations ran for the years 1990 – 2010. Snotel climate stations in and near the Tolt watershed provided daily precipitation and temperature data for these simulations.

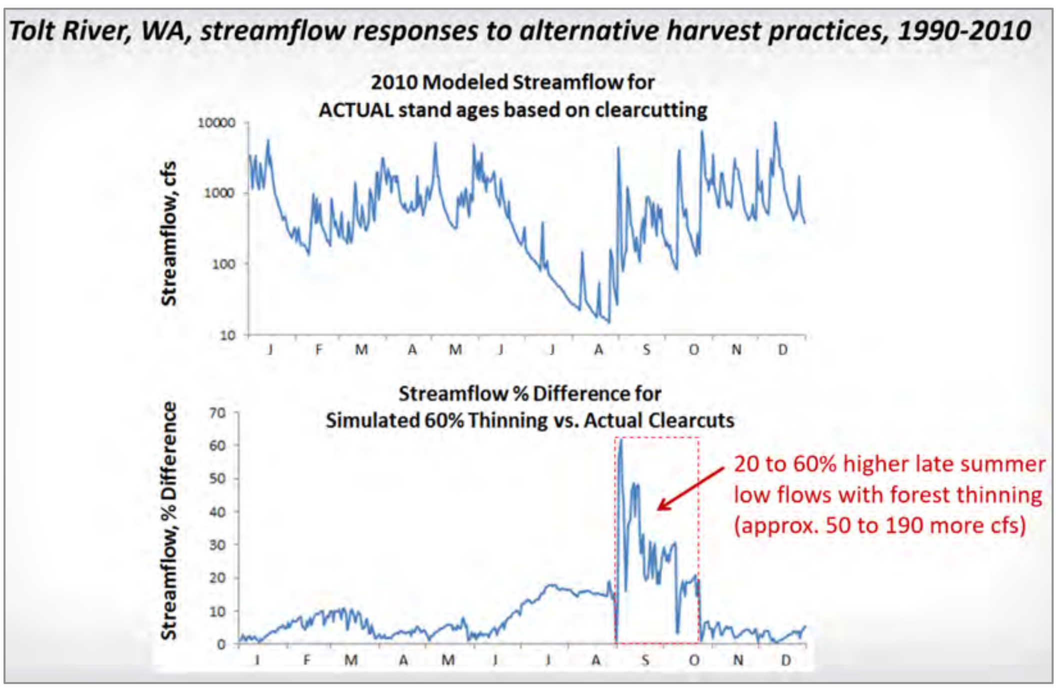


Figure 13 VELMA simulation of 2010 streamflow for the Tolt River just above the confluence with the Snoqualmie River. Upper graph: simulated streamflow for actual historical clearcut harvests. Lower graph: the percent increase in streamflow for the same historical harvests but with 60% thinning of harvested stands instead of clearcutting (Figure 12). For the two months between late August and late October, the thinning scenario generally increased streamflow by between 20 and 60 percent. For this river system, those percentage increases in flow correspond to an increase of 50 to 190 cubic feet per second, a significant amount in terms of floodplain reconnection and salmon habitat restoration goals near the Tolt-Snoqualmie confluence.

<u>2.4.5 Effects of Climate Change on Snow Pack</u>

Accumulation of winter snowpack and the timing of spring and summer snowmelt is important to maintaining adequate streamflow for salmon and drinking water for the Town of Eatonville near the outlet of the Mashel River. To simulate effects of climate change on snowpack dynamics, we calibrated VELMA's snow model against snowpack monitoring data for two nearby NRCS Snotel sites: Mowich at 3160 ft and Burnt Mountain at 4170 ft These elevations fall within the Mashel's general snow zone.

This approach allowed VELMA to predict streamflow dynamics throughout the year with reasonable accuracy, including during times of rapid snowmelt such as the early February 1996 rain-on-snow event (shown as the largest peak flow event in Figure 5 in Section 2.4.1, above). That event caused extreme flooding throughout western Washington and Oregon. In our Mashel watershed simulations, rapid snowmelt contributed about 1/3 of total peak streamflow during that several-day rain-on-snow event.

We ran a simple model test of snowpack sensitivity to modern climate conditions, selecting 2012 as a reasonable approximation of average April 1 snowpack from among the simulated years of 2006 – 2014.

We then reran the 2012 simulation after adding 3.5 ^{o}C to the 2012 daily temperature record. The simulated 3.5 ^{o}C increase in temperature by 2112 was intended as a rough approximation of century-scale projections by some climate models.

Figure 14 shows simulated snowpack results for April 1 of 2012 (left panel) and for our hypothetical +3.5 ^{o}C condition for 2112 (right panel). The simulated near absence of snowpack for April 1, 2112 was similar to the situation in 2015 when frequent record high temperatures led to the near-record low snowpack levels across the Pacific Northwest.

Further climate change simulations for the Mashel watershed will rely on the University of Washington Climate Impacts Group's database of dynamically downscaled climate projections for the Pacific Northwest (https://cig.uw.edu/resources/data/cig-datasets/).

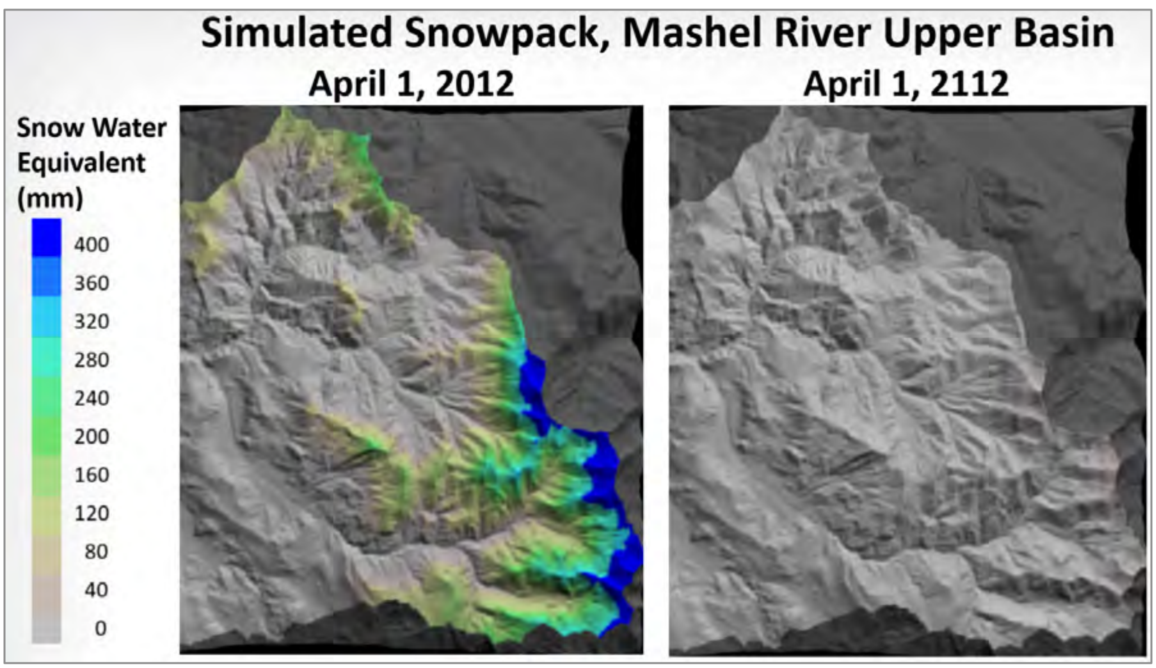


Figure 14 Simulated snowpack results for April 1 of 2012 (left panel) and for a hypothetical 3.5 ^{o}C increase in temperature by 2112 (right panel).

2.4.5 Riparian Shading and Stream Temperature

The Penumbra model, developed at Oregon State University and the US EPA laboratory in Corvallis, OR (Halama 2017), is being applied to the entire Mashel River watershed to characterize incident solar irradiance and shading by topography and objects such as forest vegetation. The height of forest vegetation across the watershed was determined at a 30-meter scale using LandTrendr remote sensing data (Kennedy et al. 2018). Figure 15 shows modeled incident irradiance at the soil surface after accounting for shading by topography and vegetation. See Halama (2017) for additional details and time series of images for the Mashel watershed.

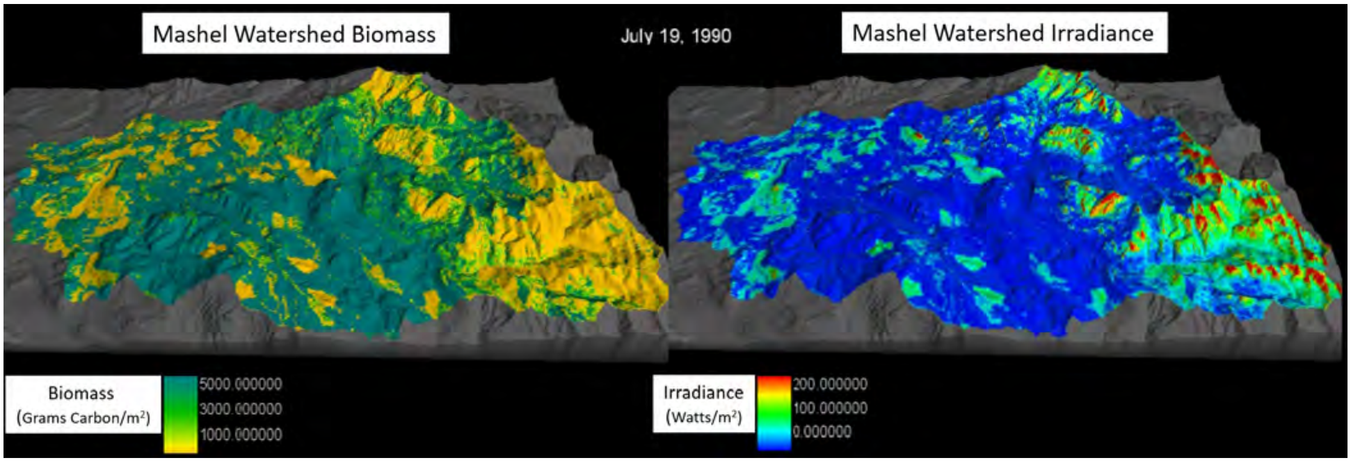


Figure 15. Penumbra model simulation of solar irradiance reaching ground and stream surfaces across the 84 mi^2 Mashel River watershed, after accounting for topographic and object (forest) shading.

The integration of Penumbra with VELMA is enabling dynamic simulation of the effects of vegetation growth and harvest events on shade-attenuated irradiance reaching ground and water surfaces. Importantly, Penumbra also includes a soil temperature model accounts for irradiance reaching the soil surface. Together, these features enable dynamic simulation of the effects of vegetation growth and harvest events on soil and groundwater temperature, and how such indirect sources of heat contribute to direct warming of streams from incident irradiance.

The capability of Penumbra-VELMA for predicting stream temperature under different environmental conditions is undergoing beta testing for well-monitored forest stream networks at the HJ Andrews Experimental Forest and the Tectah River watershed in California (J. Halama, personal communication). Preparations for a post-testing round of Mashel watershed Penumbra-VELMA simulations are being made to explore (1) historical effects of forest management, and (2) potential future effects of climate and forest management that include various riparian buffer designs and upland thinning densities.

2.5 Summary and Next Steps

The how do the preceding model results inform NCF's primary questions?

1) Can watershed management practices be designed that sustainably achieve multiple NCF objectives?
    - Salmon recovery:
        - Mashel watershed VELMA simulations illustrate how a critical salmon habitat factor, summer low flows, can be remediated through stand age management that favors longer harvest intervals and periodic thinning (see sections 2.4.1 and 2.4.4).
        - EDT fish habitat model simulations indicate that historical low flows reconstructed by VELMA contributed to reduced abundances of Mashel salmonid species: winter steelhead, fall Chinook and coho (see section 2.4.2). The EDT simulations did not include effects of historical harvests on stream temperature, large woody debris or sediments. Our models are capable of addressing stream temperature (Penumbra-VELMA, section 2.4.5) and LWD (section 2.4.3). Work to add effects of harvest, roads and fire on

sediment loss and transport to VELMA is pending. Thus, it is scientifically feasible to address salmonid responses to these multiple habitat factors in future simulations.

- Forest products supporting local forest sector jobs
  - Two things are needed to address this goal: modeled quantities of harvested timber (MBF), and the translation of those biophysical values into economic and employment values that include harvesters, sawmill and other forest sector workers. VELMA is already designed to quantify timber production for user-specified forest management practices. For example, our Mashel simulations for reconstructed historical harvests (section 2.4.1) have provided raw data for such an analysis, but our focus thus far has been on streamflow. Future Mashel watershed simulations will specifically address timber yields. Collaboration with forest economists and market experts will be needed for the employment translation.
- Carbon sequestration
  - VELMA's biogeochemical submodel simulates the effects of climate, land management and fire on ecosystem carbon stocks. For every simulation, results are reported for (1) net carbon gains or losses for vegetation, detritus including slash, and soil organic matter, and (2) the ecosystem carbon cycling processes responsible for those changes. These model capabilities can help forest managers anticipate how different forest management practices – such as clearcutting, thinning, slash piling and burning, prescribed burning, etc. – are going to affect the carbon balance of NCF forests at stand and watershed scales over decades and centuries. Forest carbon budget assessments will be an important component of Mashel VELMA simulations going forward.
- Clean drinking water
  - Mashel River water quality is essential to the health and well-being of residents Eatonville and downriver communities below the confluence of the Mashel and Nisqually rivers. VELMA can simulate how riparian buffers, wetlands, bioswales and other rural and urban green infrastructure can protect sources of drinking water from nonpoint and point sources of pollutants, for example, from intensively managed forest and agricultural lands, wastewater treatment plants, and septic systems. Sediments are not modeled at present but plans are pending to build sediment transport and deposition into VELMA.
- Recreational, cultural and tourism opportunities
  - The use of VELMA to help address salmon recovery and improvements in water quality and other environmental and aesthetic amenities also feeds into NCF plans to expand recreational and cultural opportunities on Community Forest lands. VELMA incorporates powerful visualization tools such as Visualizing Terrestrial and Aquatic Systems (VISTAS; http://blogs.evergreen.edu/vistas/) to enable model users to better understand and communicate about large and complex environmental problems that span spatial and temporal scales. Figure 15 in section 2.4.5 is just one example of 3D, multi-year animations being used to communicate simulate alternative future landscapes for different decision options.

2) What combination of the following restoration practices will best support salmon recovery: low flow enhancement, peak flow reduction, riparian buffers, in-stream large woody debris, cold-water refuges, and sediment control?
   - We are past the midpoint of being able to address this important question. VELMA and Penumbra are already addressing spatial and temporal effects of management on peak and low flows (section 2.4.1), riparian shading (section 2.4.5), and riparian large woody debris (section

2.4.3). EDT is already simulating how modeled summer low flows impact salmon habitat quality and population responses (section 2.4.2). Collectively, these models are being used to assess advantages and disadvantages of alternative management choices, for example, clearcutting, thinning, long harvest intervals, riparian buffer options and various combinations of all of these.

Next steps include application of Penumbra-VELMA to evaluate effectiveness of riparian buffer options for lowering stream temperature in fish bearing streams; development and application of a VELMA sediment submodel; and, finally, combining all of these elements to identify best practices for optimizing tradeoffs among the objective listed under Question #1. Figure 16 is a hypothetical example of what such tradeoffs might look like for different forest management scenarios.

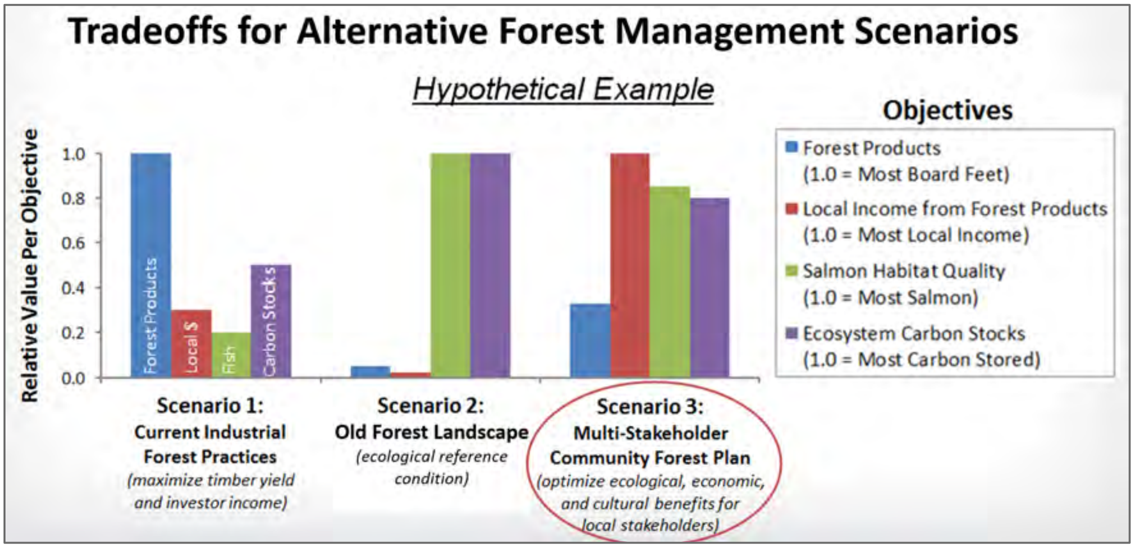


Figure 16. A conceptual example of multi-objective tradeoffs for different forest management approaches.

3) How much and where should habitat restoration efforts be located to be most effective, biologically and economically?

   - Restoration managers are constantly faced with deciding how much and where to allocate scarce resources. Our modeling tools lend themselves to informing those decisions because they are spatially and temporally explicit and can be applied to landscapes using optimization tools that can be programmed to exhaustively search through all possible candidate solutions (http://moeaframework.org/). For example, an important salmon habitat restoration problem is to identify where best to establish or enhance existing cold-water refuges, for example, shaded side-channels, deep pools or groundwater-influenced reaches where fish can survive during periodic temperature extremes and under projected future warming. Penumbra-VELMA simulations and optimizations will be set up to identify cold water refuge candidate locations based on objectives for riparian shading, stream temperature, and groundwater inflow.

4) How long will it take for specific restoration actions to have desired impacts?

   - Addressing this question is especially important for recovery of endangered or threatened species such as Chinook salmon and steelhead. In such cases, implementation of fast-responding solutions, such as thinning practices (section 2.4.4), is critically important. Even so, relatively quick fixes will be most effective when combined with slow-responding solutions such as shifts to longer harvest intervals.

Table 2. Provisional list of times required for selected restoration actions to have their desired impacts. Time estimates are based on preliminary results for our Mashel, Tolt and HJ Andrews

modeling applications, as well as on published literature. This table will be refined as modeling work progresses.

Restoration objective	Action	Approximate time to desired impact
- Increase low summer flows	- Thin existing young stands - Long rotations, >80 yr	- Months, good for at least 10 years - At least several decades depending on existing stand ages
- Decrease peak flows	- Long rotations	- Decade or less (once most existing clearcuts reach >10 years)
- Increase large woody debris	- Robust riparian buffers - Engineered log jams	- 50 years for small diameter LWD or >80 years for large diameter LWD - Immediate for shading, months to years for pool formation and streambed gravel
- Decrease summer stream temperatures	- Robust riparian buffers - Thin to increase flow - Long rotations to increase flow	- multiple decades depending on stream width and veg height - Months, good for at least 10 years - At least several decades depending on existing stand ages

5) How will climate extremes and long-term trends impact future effectiveness of restoration actions?

- Development of practical whole-watershed restoration strategies for mitigating and/or adapting to projected trends in Northwest climate will be a major emphasis of NCF modeling going forward. This will build upon work to date that has identified strategies for mitigating peak and low flows, enhancing cold water refuges, and improving in-stream habitat conditions. Effects of climate change on snowpack dynamics (e.g., section 2.4.5, Figure 14) and consequences for stream flow and temperature need to be estimated. What are the best mitigating strategies and how long will it take before these have an impact (e.g., Table 2)?

<u>Next Steps</u>

The results described in this report represent a first step for establishing a practical modeling framework that NCF partners can use to help inform watershed management decisions pertaining to the questions and solutions described above.

EPA and NCF are building on this foundation to achieve an additional set of high priority goals:

1) Complete tech transfer and training for new versions of VELMA-Penumbra, and data acquisition and analysis tools (LandTrendr, downscaled climate projections, VISTAS 3D visualization tool)
2) Conduct a new round of Mashel VELMA-Penumbra forest management modeling simulations to:
    a) Prioritize NCF land acquisitions in the Mashel watershed, focusing on catchments that contribute the greatest and/or coolest summer flows to fish-bearing stream reaches. The coupled VELMA-Penumbra models will be used to determine existing and potential future flow quality and quantity, based on changing riparian vegetation and climatic conditions.
    b) Identify forest and in-stream management strategies to help mitigate and adapt to effects of climate extremes and long-term climate trends. This will include such strategies as enhancement of cold water refuges, thinning and long harvest intervals for increasing summer low flows, snowpack management, etc.
    c) Optimize riparian buffer management in terms of width, location and density. Emphasis will be placed on methods for establishing effective cold-water refuges under a warming climate.

d) Identify a range of forest management options that quantify tradeoffs for salmon, local forest sector jobs, clean drinking water, carbon sequestration, and cultural and recreational opportunities.

3) Communicate lessons learned from NCF modeling activities to other communities, tribes and regional partners sharing similar goals.

With regard to item (3), we anticipate that lessons learned from NCF model applications will immediately transfer to other communities and tribes with whom we are directly engaged in regional Puget Sound salmon recovery planning. For example, our NCF modeling experience to date has been incorporated into VELMA modeling collaborations with the Snoqualmie Tribe and other partners involved in salmon recovery planning in the Tolt River watershed, another intensively managed forest watershed that also provides about 30% of Seattle's drinking water. We are also actively communicating our NCF modeling results to the Northwest Community Forest Coalition (http://nwcommunityforests.org/about-the-coalition/), and to local, tribal, state, federal and NGO members of the Puget Sound Partnership.

With these partners, we have submitted a 2019-2022 Puget Sound Partnership Near Term Action proposal to apply a state-of-the-art, coupled terrestrial-marine ecosystem modeling framework to help local planners visualize how effects of their decisions will propagate downstream with far reaching benefits and tradeoffs for terrestrial and marine ecosystem services. This partnership aims to establish Puget Sound science-governance partnerships that bring together ecosystem scientists and restoration planners representing local communities and tribes. Our ultimate goal is to more tightly integrate ecosystem service concepts and modeling into estuarine and coastal watershed planning and management.

Appendix D contains two abstracts that briefly describe (1) the Puget Sound coupled terrestrial-marine ecosystem modeling framework, and (2) the partnership of ecosystem modelers and local restoration planners and manager engaged in applying that framework to Puget Sound watersheds.

3.0 References

Abdelnour, A., Stieglitz, M., Pan, F., & McKane, R. (2011). Catchment hydrological responses to forest harvest amount and spatial pattern. Water Resources Research, 47(9).

Abdelnour, A., B McKane, R., Stieglitz, M., Pan, F., & Cheng, Y. (2013). Effects of harvest on carbon and nitrogen dynamics in a Pacific Northwest forest catchment. Water Resources Research, 49(3), 1292-1313.

Battin, J., Wiley, M. W., Ruckelshaus, M. H., Palmer, R. N., Korb, E., Bartz, K. K., & Imaki, H. (2007). Projected impacts of climate change on salmon habitat restoration. Proceedings of the National Academy of Sciences, 104(16), 6720-6725.

Beechie, T., Pess, G., Roni, P., & Giannico, G. (2008). Setting river restoration priorities: a review of approaches and a general protocol for identifying and prioritizing actions. North American Journal of Fisheries Management, 28(3), 891-905.

Blair, G. (2018). Evaluating effects of forest management scenarios on streamflow and fish using the VELMA ecohydrologic model and EDT salmon habitat model. Internal technical memo submitted to the U.S. Environmental Protection Agency, Western Ecology Division, Corvallis, Oregon, USA, February 2015, revised May 2018.

Judge, M. (2011). Implementation status assessment. Final report. A qualitative assessment of implementation of the Puget Sound Chinook salmon recovery plan. A report for the National Marine Fisheries Service. Everett, WA: Lighthouse Natural Resources Consulting. Lighthouse Natural Resource Consulting, Everett, WA.

Kennedy, R. E., Ohmann, J., Gregory, M., Roberts, H., Yang, Z., Bell, D. M., ... & Neeti, N. (2018). An empirical, integrated forest biomass monitoring system. Environmental Research Letters, 13(2), 025004.

Mantua, N., Tohver, I., & Hamlet, A. (2010). Climate change impacts on streamflow extremes and summertime stream temperature and their possible consequences for freshwater salmon habitat in Washington State. Climatic Change, 102(1-2), 187-223.

McKane R., A. Abdelnour, A. Brookes, C. Burdick, K. Djang, T. Jordan, B. Kwiatkowski, F. Pan, W. Peterjohn, M. Stieglitz, D. Weller (2012). Identifying green infrastructure BMPs for reducing nitrogen export to a Chesapeake Bay agricultural stream: Model synthesis and extension of experimental data. Proceedings of the Ecological Society of America, August 2012, Portland, OR.

McKane, R.B., A. Brookes, K. Djang, M. Stieglitz, A. Abdelnour, F. Pan (2014a). Enhanced version of VELMA ecohydrological modeling and decision support framework to address engineered and natural applications of GI for reducing nonpoint inputs of nutrients, contaminants, and sediments. U.S. Environmental Protection Agency, Report No. ORD-010080.

McKane, R.B., A. Brookes, K. Djang, M. Papenfus, J. Ebersole, D. Phillips, J. Halama, P. Pettus, C. Burdick, and M. Russell (2014b). Sustainable and Healthy Communities Pacific Northwest Demonstration Study. U.S. Environmental Protection Agency, Report No. ORD-007386.

McKane, R., L. Benson, A. Brookes, K. Djang, J. Halama, P. Pettus, J. Ebersole, M. Papenfus, B. Barnhart and B. Rashleigh (2015). Can longer forest harvest intervals increase summer streamflow for salmon recovery? Proceedings of the 5th Salmon Recovery Conference, May 27-29, 2015, Vancouver, Washington.

McKane, R.B. (2018). How Visualizing Ecosystem Land Management Assessments (VELMA) modeling quantifies co-benefits and tradeoffs in Community Forest management. 2018 Northwest Community Forest Forum, May 10, 2018, Astoria, OR.

Washington State Salmon Recovery Funding Board (2015). Proceedings of the 5th Salmon Recovery Conference, May 27-29, 2015, Vancouver, Washington.

APPENDICES

A) Visualizing Ecosystems for Land Management Assessment (VELMA) Model Requirements Information Sheet

B) Details Concerning the Analysis of PNW Summer Stream Flows Using VELMA

C) Blair, G. (2018). Evaluating effects of forest management scenarios on streamflow and fish using the VELMA ecohydrology model and EDT salmon habitat model. Internal technical memo submitted to the U.S. Environmental Protection Agency, Western Ecology Division, Corvallis, Oregon, USA, February 2015, revised May 2018.

D) Scaling up: Puget Sound science-governance partnerships for applying a coupled terrestrial-marine modeling framework to inform local to basin-scale ecosystem restoration planning.

APPENDIX A. Visualizing Ecosystems for Land Management Assessment (VELMA) – Model Requirements Information Sheet

Tool type	Tool for ecohydrological modeling and decision support
Purpose and Objectives	The Visualizing Ecosystems for Land Management Assessment (VELMA) ecohydrological model version 2.0 was built by the US Environmental Protection Agency and the Georgia Institute of Technology. VELMA is designed to assist users in predicting the effectiveness of alternative green infrastructure (GI) scenarios for protecting water quality, and also estimates potential ecosystem service co-benefits and tradeoffs. (Factsheet p.1, available here: https://www.epa.gov/sites/production/files/2016-06/documents/velma_fact_sheet_8_4_15.pdf)
Brief description	VELMA helps communities, land managers, policy makers and other decision makers assess the effectiveness of GI options for improving water quality of streams, rivers and estuaries. VELMA predicts how natural and engineered green infrastructure options control the fate and transport of water, nutrients and toxics across multiple spatial and temporal scales – from plots to basins, from days to centuries. VELMA also quantifies how different GI strategies affect ecosystem service co-benefits and tradeoffs – that is, the ecosystem's capacity to simultaneously provide clean water, flood control, food and fiber, climate (greenhouse gas) regulation, fish and wildlife habitat, etc. VELMA is a spatially distributed, ecohydrological model that links a land surface hydrology model with a terrestrial biogeochemistry model for simulating the integrated responses of vegetation, soil, and water resources to interacting stressors. For example, VELMA can simulate how changes in climate and land use interact to affect soil water storage, surface and subsurface runoff, vertical drainage, evapotranspiration, vegetation and soil carbon and nitrogen dynamics, and transport of nitrate, ammonium, and dissolved organic carbon and nitrogen to water bodies. VELMA differs from other existing ecohydrology models in its simplicity, flexibility, and theoretical foundation. The model has a user-friendly Graphics User Interface (GUI) for easy input of model parameter values. In addition, advanced visualization of simulation results can enhance understanding of results and underlying concepts. User manual, software and technical documentation, and references can be downloaded here: https://www.epa.gov/water-research/visualizing-ecosystem-land-management-assessments-velma-model-20
Sponsorship organization and developers	US Environmental Protection Agency, Safe and Sustainable Waters Research Program
Target users	The tool could be used by companies directly or in partnership with consultants or EPA scientists to evaluate green infrastructure scenarios for water quality and other ecosystem-service outcomes.
Target sector	Communities, land managers, policy makers, and other decision makers seeking to evaluate the effectiveness of green infrastructure options to enhance water quality and secure additional ecosystem-service co-benefits and tradeoffs.
Latest update	VELMA Version 2.0
VELMA 2.0 Release year	2014
Availability	Freely available and open source code
Data input required	• Climate data o Daily climate station data (e.g., SNOTEL or other station data, preferably within the modeled watersheds) ▪ Daily average temperature ▪ Daily total precipitation

	▪ Spatial climate grids for monthly average temperature and precipitation are obtainable from https://daymet.ornl.gov/ (1.0 km grid) and http://www.prism.oregonstate.edu/ (0.8 km grid) o Hydrology o Daily stream flow (important): catchment-scale daily streamflow data for one or more representative, gauged catchments that are within, or hydrologically similar to your study area. USGS national streamflow data: https://help.waterdata.usgs.gov/tutorials/surface-water-data/how-do-i-access-historical-streamflow-data ▪ Stream chemistry / water quality: concentration (mg/liter) of dissolved nutrients in stream water (ammonium, nitrate, and organic nitrogen and carbon). These data can be for periodic grab samples or automated flow-weighted sampling systems. Various sources, e.g., state/federal/university. Unavailable for many watersheds. • GIS data layers o Elevation data, usually based on 30-meter DEM (download from USGS Seamless website at http://free-gis-data.blogspot.com/2009/01/usgs-global-seamless-map-server.html) o Vegetation characteristics ▪ Land cover types -- conifer, hardwood, shrub, etc. There are a number data sources, for example, the National Land Cover Database (NLCD) at http://www.mrlc.gov/nlcd2006.php ▪ Total biomass and net primary production -- estimates can be based on a combination of plot measurements and remote sensing. There are typically many sources, published and online, including the USFS Forest Inventory and Analysis National Program at http://www.fia.fs.fed.us/tools-data/default.asp. For 30-m scale data describing historical (1985-present) changes in forest biomass and stand age for Washington and Oregon, see Oregon State University's LandTrendr website: http://landtrendr.forestry.oregonstate.edu/ ▪ Nutrient concentrations -- percent N in leaves stems, and roots can generally be obtained from the literature. o Land use ▪ Land ownership ▪ Forest management units: where and when will forest parcels be harvested, and how much will be harvested (clearcut vs. thinning). GIS for this can sometimes be obtained from land owner/manager, or remote sensing data, or combination of these. ▪ Forest stand age and rotation length. Sources are usually the same as above. o Soil properties: STATSGO soil survey data from NRCS is often the best bet for forested areas (http://soildatamart.nrcs.usda.gov/USDGSM.aspx): ▪ Soil physical properties: soil depth to bedrock; texture; rock fraction ▪ Soil chemical properties: total soil carbon and nitrogen by depth (preferably for the top 1 meter)
Information derived/ provided	The following papers describe the hydrological (2011) and biogeochemical (2013) outputs of the model: • Abdelnour, A., Stieglitz, M., Pan, F., & McKane, R. (2011). Catchment hydrological responses to forest harvest amount and spatial pattern. Water Resources Research, 47(9).

	• Abdelnour, A., B McKane, R., Stieglitz, M., Pan, F., & Cheng, Y. (2013). Effects of harvest on carbon and nitrogen dynamics in a Pacific Northwest forest catchment. Water Resources Research, 49(3), 1292-1313.
Software required	Runs on Microsoft Windows. Requires installation of Java and the VELMA software program.
Expertise required	Basic GIS skills including preparation of watershed maps (ascii format) for elevation, soil properties, land cover, land use, climate grids, etc. Working knowledge of hydrological and biogeochemical principles, including familiarity with methods for estimating (from published studies) water and nutrient budgets for different land cover and soil types. An understanding of environmental modeling methods (calibration, validation, etc.) is highly recommended. Programming skills are not required.
Labor/time investment	This depends on the application scale, calibration requirements, and questions asked. • Preparation of GIS layers (terrain, land cover, land use, soil data, etc.) for relatively small catchments (<1 mi^2) may require 1 person-week. Double to triple that for large basins, e.g., up to 1000 mi^2. This assumes that required data are publicly available (see above) and the VELMA user has the required expertise (see above). • Model calibration for previously uncalibrated ecosystems: This may require 1-2-person months, if an existing set of calibrated parameters does not exist for the ecosystem being modeled. This will also depend upon the expertise of the person doing the calibration. Note that an automated calibration routine is now available for VELMA and is being used for various applications nationally. Highly recommended for new and experienced VELMA users. • Model calibration for previously calibrated ecosystems: If VELMA has previously been calibrated for an ecosystem type (e.g., PNW coniferous forests, Eastern hardwood forests, corn croplands, Central Plains rangelands, etc.), these can be transferred to new locations within an ecoregion, without significant loss of accuracy for hydrological and ecological response variables – e.g., streamflow and C and N dynamics in plants and soils (McKane et al. in preparation). This assumes that users have assembled accurate data inputs (see above). • Scenario development can be very simple (e.g., effects of climate or harvest on streamflow) and can be set up in a day or two. More complex scenarios (e.g., interactive effects of changes in land use and climate on water quality) might require several days or more to set up for large, complex watersheds. Set up time also depends on the skill/experience of the scenario developer.
Fees/ costs	Free of charge
Website	https://www.epa.gov/water-research/visualizing-ecosystem-land-management-assessments-velma-model-20 Downloads for VELMA software, user manual, publications and helpful links. Additional details can be obtained through the contact below.
Contact	Bob McKane, Ph.D. VELMA Team Lead USEPA-ORD-NHEERL-WED Corvallis, OR 541-754-4631 mckane.bob@epa.gov

APPENDIX B. Details Concerning the Analysis of Pacific Northwest Summer Stream Flows Using VELMA

This document is a summary of our application of the VELMA ecohydrological model to analyze the effects of forest management on summer stream flows (SSFs). VELMA is designed to simulate effects of land use and climate on stream flow, snow accumulation and melt, soil and vegetation dynamics, cycling, transport and fate of nutrients and contaminants, and other ecohydrological processes (Abdelnour et al. 2011, 2013). Although VELMA is being used to inform management plans for mitigating potential effects of climatic variability and trends that may exacerbate summer low flows, those effects and mitigating strategies are not discussed here.

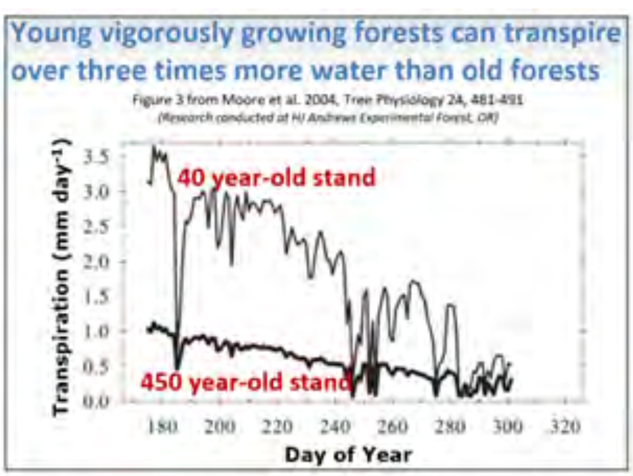
Note: Although this summary repeats some of the content presented in the body of this VELMA Nisqually Community Forest report, additional details and context are provided that illuminate how VELMA was designed, calibrated and validated to address stand age effects on summer streamflow. This material attempts to answer questions that have been posed to the EPA VELMA team in regard to the model's capabilities for addressing this important topic.

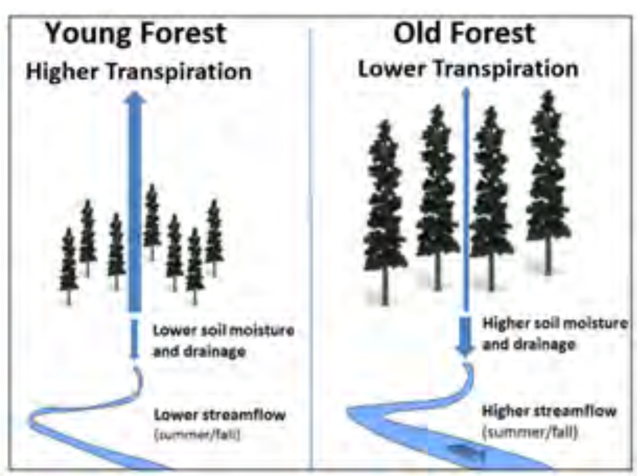
Background

Our EPA VELMA team has been collaborating with the Nisqually Community Forest (NCF) group to use VELMA for identifying salmon-friendly management practices for their working forest lands in the Nisqually River Basin's Mashel River watershed. See the attached abstract for details. Briefly, the Mashel River was once a prime salmon producing tributary, but habitat degradation and other factors have led to the extinction of the Mashel Chinook salmon run and steep declines in steelhead and coho salmon populations. A major NCF concern is that summer low flows may be limiting fish access and quality of spawning and rearing habitats.

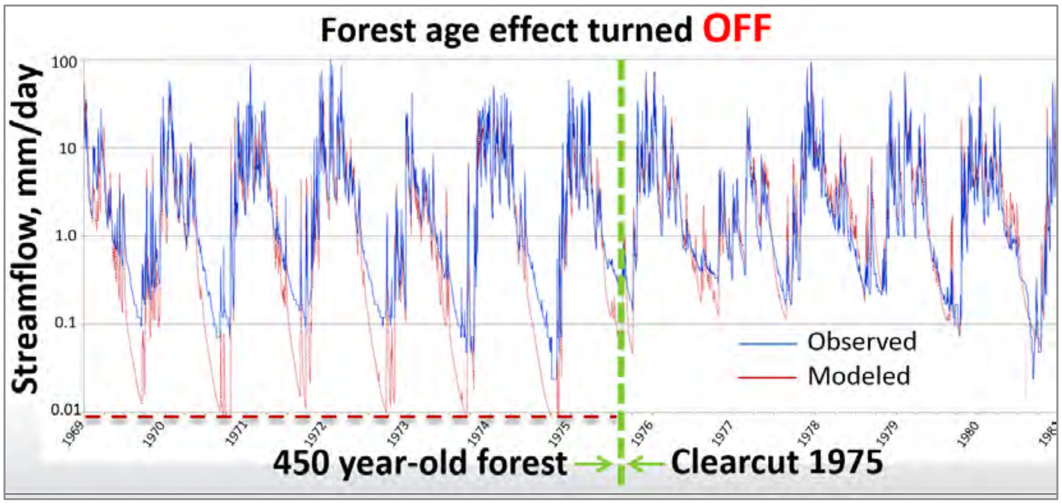
Methods and results

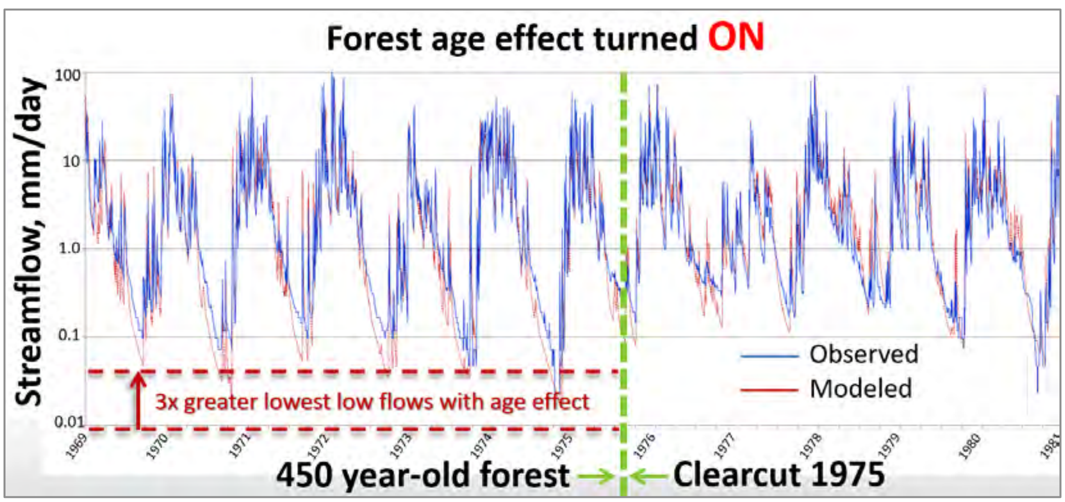
To address summer low flow issues, we modified VELMA's canopy transpiration submodel to account for the results of a study (Moore et al. 2004) describing changes in tree and stand-level sap flow for adjacent young and old conifer stands at the U.S. Forest Service H.J. Andrews Experimental Forest, a National Science Foundation Long Term Ecological Research site in the western Oregon Cascades. Sap flow measurements are a well-established method for estimating canopy transpiration rates. Moore et al. (2004) found that a 40-year-old conifer stand transpired over three times more water than an adjacent 450-year-old stand. The left figure, below, describes transpiration rates for the young and old forest stands (from Moore et al. 2004, attached). The figure to the right is a conceptual diagram (B. McKane) showing the connection between transpiration and streamflow.





As shown in the following two figures, we found that VELMA more accurately predicted summer stream flows at our model calibration site (H.J. Andrews Watershed 10) after incorporating the age effect on transpiration observed by Moore et al. Without this age-related modification, it was not possible to calibrate VELMA to accurately simulate both pre- and post-harvest summer stream flows. That is, it was possible to accurately simulate one or the other, but not both simultaneously, as we are now able to do after including the age effect.

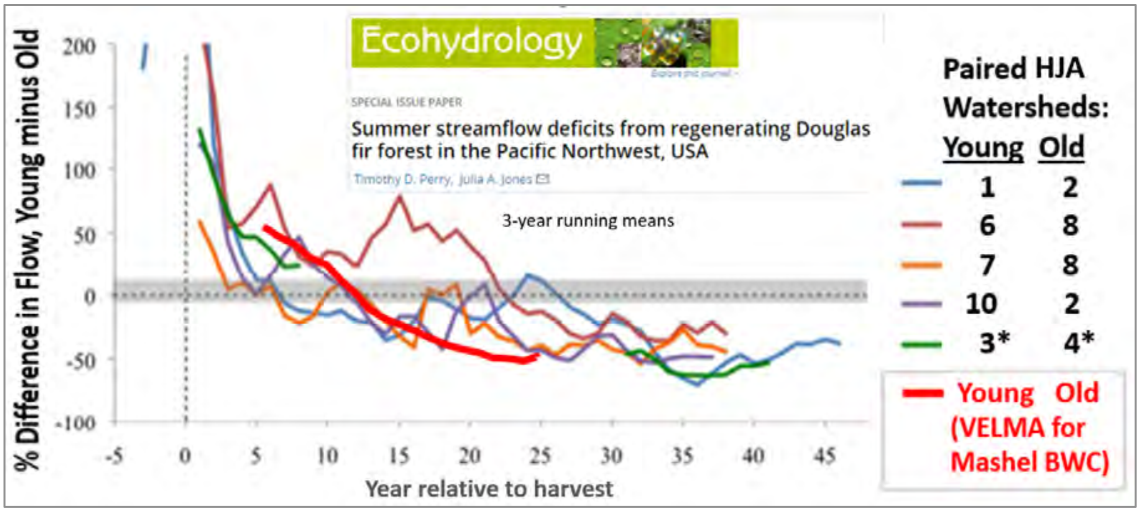




These VELMA results were first presented at the 2015 Salmon Recovery Conference (McKane et al. 2015), and again with additional information, at the 2016 at the South Sound Science Symposium (McKane et al. 2016). For details, see South Sound Science Symposium slides 14-25 posted at https://www.slideshare.net/emmettoconnell/bob-mckane-nisqually-community-forest-velma-modeling.

Corroborating evidence

Shortly after our 2016 South Sound presentation, a paper by Perry and Jones (2016) appeared in the journal Ecohydrology. Their paper examined effects of stand age on observed stream flow data, rather than transpiration (sap flow) data, for paired young and old forest watersheds at HJ Andrews and the Coyote Creek watershed in the Oregon Coast Range. Figure 6b, below, from Perry and Jones summarizes those results.



In this figure, the gray horizontal dashed line equals the percentage difference in young forest stream flow minus old forest stream flow (all H.J. Andrews stream flow measurements are continuously recorded using well-maintained stream gauges). The horizontal axis is years since the young forests were clearcut. Positive values on the vertical axis indicate times when flow from a young forest watershed **exceeds** flow from its paired old forest watershed neighbor. Negative values indicate when the young forest produces **less** flow than the old forest.

Note that summer stream flows immediately after clearcutting far exceed old forest flows by 50 to >200 percent (calculated using 3-year running averages of daily flow data). Excess flows decrease after regrowth begins to reestablish a forest canopy. Young forest stream flow deficits generally begin to appear within 10 years of clearcutting, as vigorous regrowth and transpiration kick in. Observed stream flow deficits of -50 to -60% were common by 25 to 35 years after harvest.

Our VELMA model results for the HJ Andrews site are consistent with (1) observed excess summer flows in the first few years following clearcutting, and (2) the subsequent observed transition to summer flow deficits in vigorously growing young forests.

Importantly, modeled changes in summer flow dynamics hold up very well when we apply VELMA to the Mashel watershed's Busy Wild Creek (BWC) subwatershed. VELMA's simulated BWC result is shown as the bright red line, superimposed on the Perry & Jones (2016) figure, above.

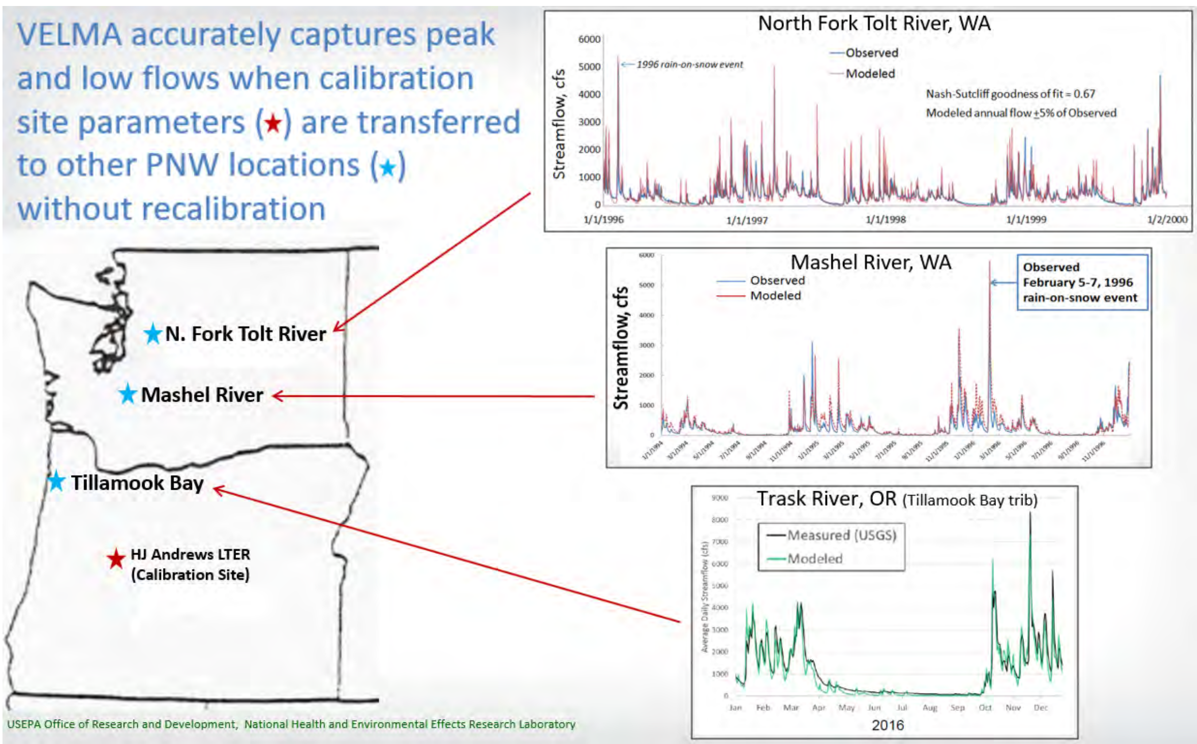
Perry and Jones noted one caveat regarding the apparent early "hydrological recovery" for the blue and dark red lines in the figure above, when those young stands were 23 and 13 years-old, respectively. They state that "*both trends are attributable to an extreme freezing event that killed regenerating vegetation*", an event described by Hicks et al. (1991). Vegetation in those watersheds later recovered and experienced summer flow deficits consistent with deficits for the range of observed young forest watersheds.

Model calibration and validation

Our VELMA summer stream flow results are based solely on calibration to the Moore et al. (2004) sap flow (transpiration) results for young vs. old stands at the H.J. Andrews and Coyote Creek sites. That is, no recalibration of the model was performed to fit VELMA results to Perry and Jones (2016) stream flow results. Thus, the good fit of modeled to observed summer low flow predictions is a validation test, not a calibrated result. The term "validation" is used here in the generally understood meaning, not the strict meaning for which no complex model can be truly validated (Refsgaard and Henriksen 2004).

To calibrate VELMA for the HJ Andrews site (including transpiration data of Moore et al. 2004), we used a genetic algorithm that exhaustively searches for best fit parameter values and their combinations (many tens of thousands of possibilities), thereby removing human bias from the calibration process. This automated process was unable to confirm the null hypothesis that observed differences in young vs. old forest summer flows are unaffected by stand age.

The resulting H.J. Andrews, Oregon, calibration has proven to be regionally robust, meaning that we have been able to apply the same set of parameter values to other locations in Oregon and Washington with very little loss in accuracy for predicting daily to inter-annual variations in stream flow, including SSFs. The figure below shows the locations and observed vs. modeled flow results for these sites.



Taken together, these multi-site results represent a severe test of VELMA's ability to simulate local to regional-scale controls on stream flow. Local-scale controls include plot and hillslope-scale hydrologic processes, for example, infiltration, storage, runoff and transpiration. Regional-scale controls include biophysical constraints imposed by longitudinal, latitudinal and elevational differences in climate, soils, vegetation, and disturbance regimes. Despite inherent uncertainties in the underlying environmental data, results thus far indicate that the available forcing data are sufficiently accurate, and that VELMA's ecohydrological processes and system-level feedbacks are sufficiently robust, to characterize local and regional controls on stream flow.

Expression of flow differences in terms of percentages versus cubic feet per second

The Perry and Jones analysis reports <u>percent differences</u> in stream flow for young vs. old forest watersheds. This makes it easier to see (1) age-related trends by eliminating absolute differences in flow volume (largely a function of watershed size), and (2) variability in flow due to climatic differences across sites. Sites in their study included eight watersheds in the Oregon Cascade Range (H.J. Andrews), and two watersheds in the Oregon Coast Range (Coyote Creek).

So, one might ask, how large are the percentage differences in young vs. old forest summer flows, when those percentages are expressed in absolute terms, that is, in cubic feet per second (cfs)? The following bar chart shows VELMA summer flow results expressed in cfs for the 84 mi^2 Mashel watershed for three landscape conditions: the Mashel watershed's actual forest landscape (based on LandTrendr stand age data); a virtual 40-year-old forest covering the entire Mashel watershed; and a virtual 100-year-old forest covering the entire Mashel watershed. Note that VELMA's flow predictions account for the effects of spatially-explicit climate data (temperature and climate), the model drivers for which were identical across all three simulations. Thus, modeled differences in late summer flows (September minimum cfs) in this figure are due only to the effects of forest age.

As a point of reference, here is what 6 cfs of stream flow looks like near the USGS stream gauge just above the Mashel's outlet into the Nisqually River (B. McKane photo).

Conclusions

1) The findings of Perry and Jones (2016) provide the strongest empirical evidence to date for a significant stand age effect on summer stream flows in PNW forest watersheds. Their paper reports two key findings describing relative differences in summer flows for paired young and old forest watersheds. References to percent differences in flow = 100 * (young forest flow – old forest flow) / (old forest flow). Quoting Perry and Jones (2016):

   a. *"…forest harvest produced large streamflow increases from June through December in the first 10 years after harvest. Maximum percent increases (in unsmoothed data) were 683% at AND 1 (in 1966, fourth year of 1962-1966 clearcutting treatment); 328% at AND 6 (in 1975,* *one year after treatment); 90% at AND 7 (in 1974, year of treatment); 203% at AND 10 (in 1976, one year after treatment); and 149% at COY 3 (in 1971, year of treatment).* [Note: "AND" and "COY" refer to watersheds at the H.J. Andrews Experimental Forest, and Coyote Creek, respectively.]

b. *"Analysis of 60-year records of daily streamflow from eight paired-basin experiments…revealed that the conversion of old-growth forest to Douglas-fir plantations had a major effect on summer streamflow. Average daily streamflow in summer (July through September) in basins with 34- to 43-year-old plantations of Douglas-fir was 50% lower than streamflow from reference basins with 150- to 500-year-old forests dominated by Douglas-fir, western hemlock, and other conifers. Study plantations are comparable in terms of age class, treatments, and growth rates to managed forests in the region."*

2) VELMA previously and independently produced summer stream flow results that are very close to those reported by Perry and Jones' (2016) for observed long-term flow data for the H.J. Andrews and Coyote Creek sites in Oregon (points 1a and 1b, above). VELMA flow results are based on calibration to an earlier H.J. Andrews study by Moore et al. (2004), who reported sap flow-based transpiration estimates showing that a 40-year-old forest transpired over 3 times more water in summer than an adjacent 450-year-old forest. Prior to incorporating the Moore et al. findings in VELMA, we found that VELMA could not accurately predict both pre-harvest and post-harvest summer stream flows in H.J. Andrews Watershed 10, a 450-year-old Douglas-fir dominated watershed that was clearcut in 1975. After incorporating the Moore et al. findings, VELMA accurately predicted both the spike in summer flows during the 10 years after clearcutting, and the subsequent transition to summer flow deficits about 50% below old forest summer flows.

3) We also applied the same H.J. Andrews VELMA parameter set to the 84-square mile Mashel River watershed, located >200 miles northward in Puget Sound's Nisqually River basin. Modeled flows for the Mashel watershed provided a good fit to observed summer low flows, as well as observed peak winter storm flows. This exercise demonstrated VELMA's ability to extrapolate observed age-related effects on summer low flows (Perry and Jones 2016) across a >200-mile latitudinal gradient, while also providing additional insight into the mechanism behind those observational findings. Namely, that higher rates of transpiration in young stands (Moore et al. 2004) leave less available soil water for runoff to streams. Ongoing model applications at additional watersheds in Oregon (Trask River) and Washington (Tolt River) support our model-based insights about the effects on forest stand age on summer stream flow.

4) Why is this important? The VELMA model enables the empirical studies of Moore et al. (2004) and Perry and Jones (2016) to be integrated and extrapolated to larger landscapes, thereby providing a spatially-explicit quantitative framework that forest managers and other decision makers can use to explore future effects on summer flows for different management options they may be considering.

5) An important remaining question is, how old do stands need to be for summer flows to recover and approach old forest summer flows? The stream gauge data for the Perry and Jones study extends less than 50 years post-harvest. Our working hypothesis is that stand-level transpiration rates will become increasingly limited as trees approach their maximum height. There is an extensive literature on this, e.g., Ryan et al. (2000), references therein and citing references. Douglas fir and other dominant conifers in western OR and WA reach maximum heights of about 50-70 meters within 80 to 100 years, depending on site quality (e.g., Means and Sabin 1989). If stream flow data for 50 to 100-year-old forest watersheds are indeed lacking, sap flow measurements may be best for age-related comparisons of stream flow at that time scale. We are reaching out to PNW researchers about this.

6) To model the effects of stand age on stream flow, it's critical to establish an accurate spatial representation of forest stand age across a modeled watershed, for example, for a 30-m grid. That is now possible with Dr. Robert Kennedy's (Oregon State University) Landsat-based change detection tool, LandTrendr (http://landtrendr.forestry.oregonstate.edu/). For additional details see slides 11-12 in the South Sound Symposium talk (McKane et al. 2016).

7) It's unlikely that a major shift to long harvest intervals will soon occur, though some private forest industry companies have begun doing so, such as Starker Forests in the Oregon Coast Range. However, new VELMA modeling work for the Tolt watershed in the Cascade Range east of Seattle indicates that thinning practices can also boost summer low, especially when done in combination with longer harvest intervals. New simulations for the Mashel watershed will also investigate thinning effects on summer flow.

8) Statistical methods have been used to try to detect forest stand age effects on summer low flows (e.g., Lin and Wei 2008). However, intensively managed river basins typically have a complex logging history and, consequently, a mix of stand age classes. Consequently, it will be extremely difficult to statistically detect an age-related summer low flow signal whenever a basin's stream gauge is located near its outlet, a common situation with placement of USGS gauges. As noted above, forest stands less than 10 years-old can produce over several hundred percent more summer flow compared to old forest reference stands. Depending on the age class distribution within a basin, these excess flows can potentially counterbalance summer flow deficits (up to 50-60% lower than old forests) for stands 10 – 45 years-old. In such cases, one might conclude there is no age effect on flow. Of course, this conclusion would overlook important impacts on upstream contributing subwatersheds – for example, low flow impacts on salmon survival due to accessibility and lower quality of spawning and rearing habitats (Hicks et al. 1991).

References

Abdelnour, A., Stieglitz, M., Pan, F., & McKane, R. (2011). Catchment hydrological responses to forest harvest amount and spatial pattern. *Water Resources Research*, *47*(9).

Abdelnour, A., B McKane, R., Stieglitz, M., Pan, F., & Cheng, Y. (2013). Effects of harvest on carbon and nitrogen dynamics in a Pacific Northwest forest catchment. *Water Resources Research*, *49*(3), 1292-1313.

Hicks, B. J., Beschta, R. L., & Harr, R. D. (1991). Long-term changes in streamflow following logging in western Oregon and associated fisheries implications. Journal of the American Water Resources Association, 27, 217–226.

Lin, Y., & Wei, X. (2008). The impact of large-scale forest harvesting on hydrology in the Willow watershed of Central British Columbia. *Journal of Hydrology*, *359*(1-2), 141-149.

McKane, R., B. Barnhart, J. Halama, P. Pettus, A. Brookes, Joe Ebersole, K. Djang, G. Blair, J. Hall, J. Kane, P. Swedeen, and L. Benson. Nisqually Community Forest VELMA modeling. 2016 South Sound Science Symposium, Olympia, Washington, September 20, 2016.

McKane, R., L. Benson, A. Brookes, K. Djang, J. Halama, P. Pettus, Joe Ebersole, M. Papenfus, AND B. Barnhart. Can longer forest harvest intervals increase summer streamflow for salmon recovery? Salmon Recovery Conference, Vancouver, WA, May 27 - 29, 2015.

Means, J. E., & Sabin, T. E. (1989). Height growth and site index curves for Douglas-fir in the Siuslaw National Forest, Oregon. *Western Journal of Applied Forestry*, *4*(4), 136-142.

Moore, G. W., Bond, B. J., Jones, J. A., Phillips, N., & Meinzer, F. C. (2004). Structural and compositional controls on transpiration in 40-and 450-year-old riparian forests in western Oregon, USA. *Tree physiology*, *24*(5), 481-491.

Perry, T. D., & Jones, J. A. (2017). Summer streamflow deficits from regenerating Douglas-fir forest in the Pacific Northwest, USA. *Ecohydrology*, *10*(2).

Refsgaard, J. C., & Henriksen, H. J. (2004). Modelling guidelines––terminology and guiding principles. *Advances in Water Resources*, *27*(1), 71-82.

Ryan, M. G., Bond, B. J., Law, B. E., Hubbard, R. M., Woodruff, D., Cienciala, E., & Kucera, J. (2000). Transpiration and whole-tree conductance in ponderosa pine trees of different heights. *Oecologia*, *124*(4), 553-560.

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End Appendix B

APPENDIX C. Evaluating effects of forest management scenarios on streamflow and fish using the VELMA ecohydrology model and EDT salmon habitat model

Memorandum

To: Bob McKane and Joe Ebersole, EPA

From: Greg Blair, ICF

Date: Revision May 29, 2018

Re: Evaluating effects of forest management scenarios on streamflow and fish using the VELMA ecohydrologic model and EDT salmon habitat model

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BACKGROUND AND SCOPE

Salmon are important to the economic, social, cultural, and aesthetic values of the people in the Nisqually River watershed. Chinook (*Oncorhynchus tshawytscha*) and coho salmon (*O. kisutch*) and winter steelhead (*O. mykiss*) were at one time abundant in the Nisqually River. These species were a significant component of the Nisqually ecosystem and provided important fisheries for tribal and sport fishers. Declines in Chinook salmon abundance led to the listing of Puget Sound Chinook under the U.S. Endangered Species Act (ESA) in 1999. In May 2007, the Puget Sound Steelhead Distinct Population Segment (DPS) was listed as a threatened species under the ESA.

The Mashel River subwatershed is important to restoring both species in the Nisqually watershed. The Mashel River is the second-largest tributary to the Nisqually River by area. The entire drainage covers over 84 square miles and is the largest tributary by flow accessible to salmon. The topography of the basin is more varied than other basins in the watershed; basin elevations range from 460 to 4845 feet. From its headwaters near the foothills of Mount Rainier, the Mashel River flows west toward the town of Eatonville. The river passes south of Eatonville and then flows southwest to the confluence with the Nisqually River at RM 39.6. The upper Mashel River covers approximately 34 square miles and is all mountainous, forested terrain. A majority of the terrain is new growth forest nearing harvest age. The forest was intensely harvested by commercial foresters and the upper watershed was last cut in the late 1980s. The watershed and salmonids utilizing its mainstem and tributaries are particularly vulnerable to changes in seasonal precipitation and temperature because of its high relief topography, moderate to high elevation (elevations range from 460 ft to 4,845 ft), and well documented unstable slopes and geomorphology (Bohle et al.1996).

Climate change raises new challenges to protecting and restoring watershed functions and restoring salmonids. Scientific evidence demonstrates that the climate is changing globally at a rate faster than has been experienced in modern history. Understanding locally-relevant projections for climate change in the watershed will make it possible for the Nisqually community (tribe, state, and local watershed organizations) to develop and implement plans that will increase the resiliency of their natural resources, economy, cultural practices, and infrastructure.

Chinook recovery planning and watershed restoration planning in the Nisqually River and other Puget Sound watersheds used the Ecosystem Diagnosis and Treatment (EDT) model to identify habitat factors limiting population recovery and predict recovery potential for restoration strategies and actions (Blair et al. 2009; Thompson et al. 2009). Analysis of existing conditions relied largely on field data and individuals with experience in the watersheds. Analysis of future conditions was largely based on professional judgements of restoration benefits and did not include a detailed analysis of land use or effects of climate change. The Puget Sound region needs scientific models to help predict future conditions for alternative land management scenarios and with future climate.

The purpose of this work assignment is to provide support services to the U.S. Environmental Protection Agency (hereinafter EPA) in developing approaches for converting output from EPA's VELMA eco-hydrological model to input parameters to the EDT salmon habitat model, to develop methods to transfer information between these models, and apply the methods for a set of forest cover scenarios for the Mashel River basin.

Four forest cover scenarios were constructed in VELMA: 1) a basin-wide mature forest condition (hereafter 240-year landscape), 2) a basin-wide clearcut scenario, and 3) the actual forest cover as observed in the early 1990s. VELMA model simulations were for a 20 year period with climate information from 1990 to 2010. The scenarios do not include timber harvest during the 20 year simulation.

This analysis is limited to effects of the forest landscape condition on stream hydrology (see Moore et al. 2004; Perry 2007). Other, maybe just as significant, effects of the forest landscape on stream condition of significance to salmonid survival are water temperature, sediment delivery and transport, riparian condition, and recruitment of wood to the stream channel. Additional modules to VELMA planned by EPA to address these aspects of forest cover on stream condition would be an important next step.

EDT MODEL AND SETUP

EDT is a hierarchically organized, spatially explicit model that analyzes aquatic habitat along multiple salmonid life history trajectories to help managers and scientists investigate the biological and environmental constraints on species performance within a watershed.

Briefly, EDT is a life-cycle habitat model that characterizes the aquatic environment temporally (monthly) and spatially (stream reaches) "through the eyes of salmon." Habitat is evaluated along numerous pathways, termed life history trajectories that are defined by the salmonid life history. Trajectories can be thought of as pathways through time and space that salmonids might use to complete their life history that vary in regard to habitat quality and quantity. Fish could spawn early, or later; they could spawn higher or lower in the system; move quickly through some areas and pause in others. Each of these behaviors represents a different life history trajectory in EDT and a different sampling of the environmental conditions of the stream. The quality and quantity of habitat along each trajectory is assessed as the productivity and capacity of salmonids potentially using that pathway. The integration of performance across the trajectories estimates the productivity and capacity of a fish population in the environment and their variation due to heterogeneity of the habitat and fish behavior. These population-level metrics are then used to compare the alternative scenarios (e.g. land use scenarios, restoration actions, protection scenarios etc.). The population-level estimate of productivity and capacity can be disaggregated to study habitat constraints at sub-basin, stream reach, life-stage, and attribute levels.

EDT quantifies the suitability of an environment in terms of the productivity and capacity parameters of the Beverton-Holt production function (Beverton and Holt 1957) (Figure 1). This results in an estimate of habitat potential in terms that can be related to measures of desired fish population performance such as those in the Viable Salmonid Population concept (McElhany et al. 2000).

The Beverton-Holt function is used to characterize habitat potential because of its tractable mathematical qualities and its fundamental relationship to fisheries population dynamics (Hilborn and Walters 1992). The function has two parameters: density-independent survival (or productivity) and the asymptotic carrying capacity (Figure 1). These parameters can be related to the quality and quantity of habitat, respectively (Hayes et al. 1996).

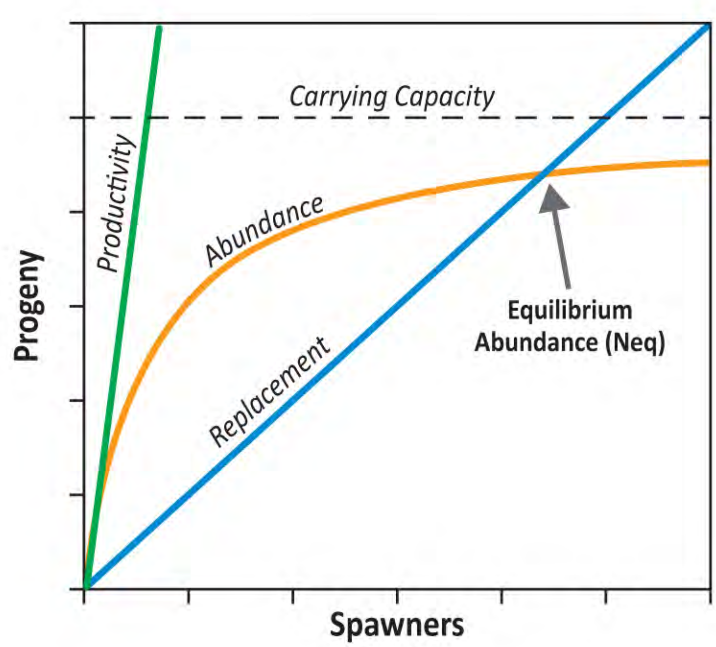


Figure 1. Features of the Beverton-Holt stock-recruitment relationship.

Information used to derive species performance in EDT is organized through a hierarchical information structure with three levels. Together, these levels can be thought of as an information pyramid in which each level builds on information from the next lower level (Figure 2). Moving up through the levels provides an increasingly organism-centered view of the ecosystem.

Levels 1 and 2 together characterize the environment as it can be described by different types of data. Model outputs from VELMA are Level 1 information. VELMA provides the characterization of the environment needed to analyze performance of the species. The predictions from VELMA for flow are translated into Level 2 ratings and estimates of channel wetted area using predefined procedures. Level 1 and Level 2 information is not specific to a species, but instead forms a species-independent description of the aquatic environment. The Level 3 category of information, on the other hand, is a characterization of that same environment from a different perspective: "through the eyes of the salmon"(Mobrand et al. 1997). This category describes biological performance in relation to the state of the environment described by the Level 2 information.

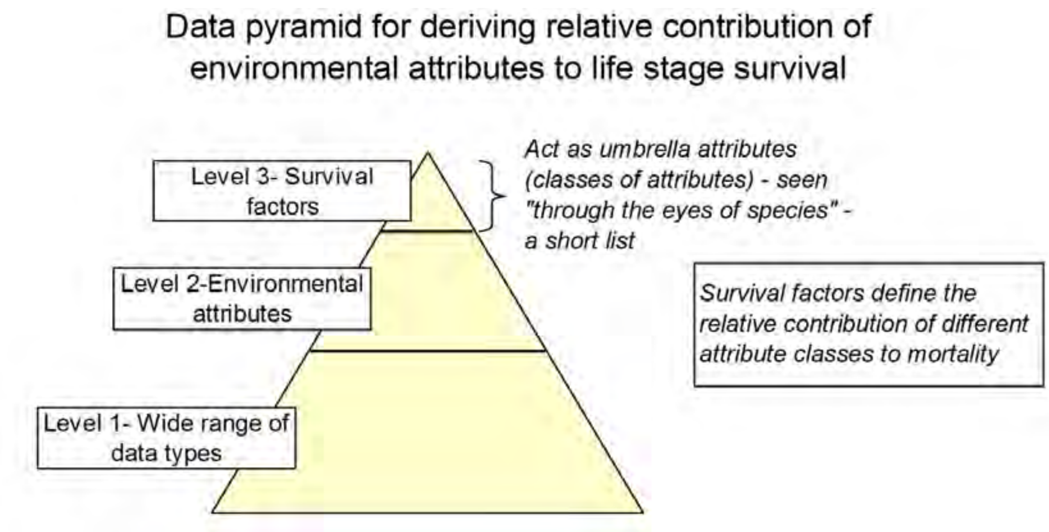


Figure 2. The EDT Information Structure as a "data pyramid." Information begins as raw data, observations, and predictive models like VELMA (Level 1), is organized into a species-neutral description of the environment (Level 2), and is then characterized as performance of a particular species (Level 3).

The flow of information from Level 1 to Level 3 and subsequently through the EDT model is seen in Figure 3. It results in estimates of the population performance parameters described previously. The entire procedure provides a pathway for linking potential forest management actions to outcomes that are relevant to the values or objectives of stakeholders in the Nisqually watershed. It provides a system of logic (rationale) to explain how actions are transferred into desired outcomes for salmonids.

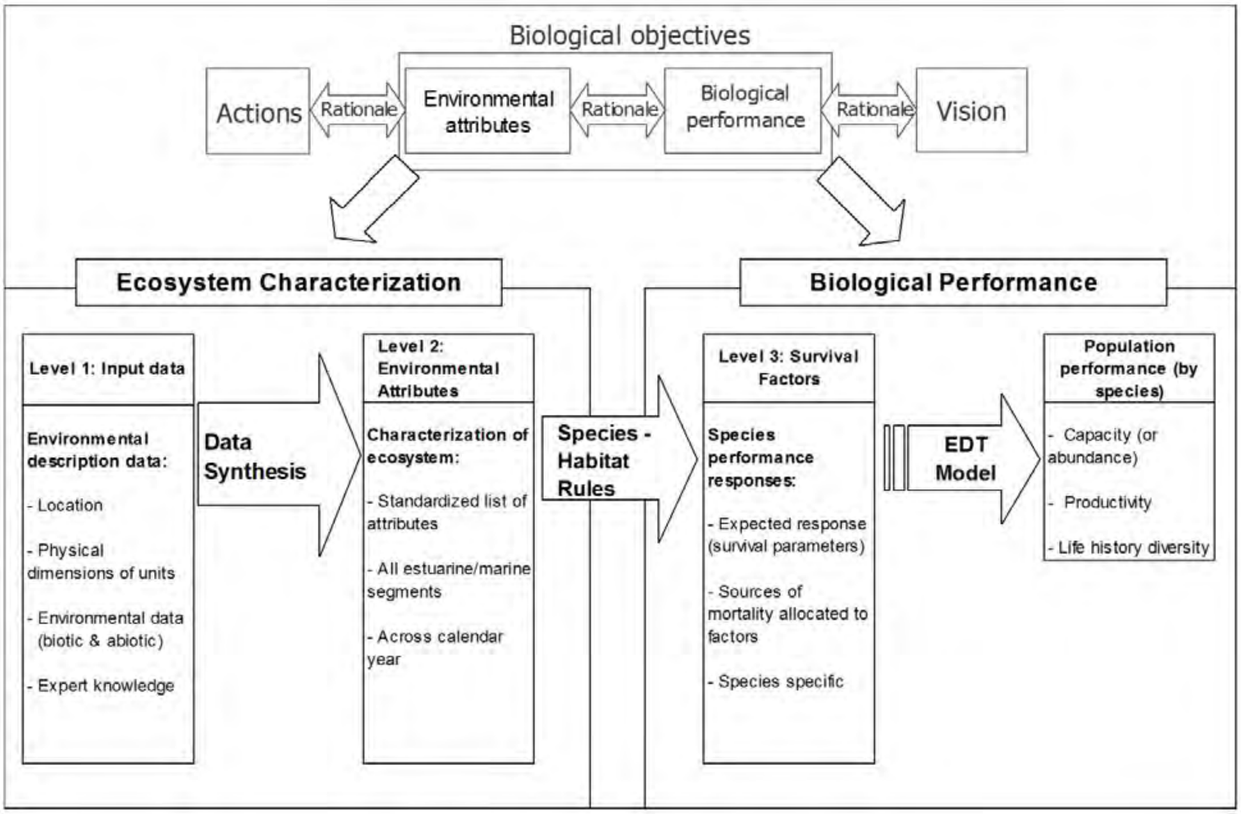


Figure 3. EDT Information Structure. Species-Habitat rules relate characteristics of the environment to potential performance of the focal species

This analysis is based on the existing EDT model developed for the Nisqually Indian Tribe for salmon and steelhead recovery planning and evaluation. A detailed description of the EDT model developed for the Nisqually watershed is described in the Nisqually steelhead recovery plan (NSRT 2014). The anadromous portion of the Mashel stream network was divided into 11 reaches based on differences in channel characteristics largely determined by channel confinement and gradient (Figure 4).

This EDT model analysis examined difference in salmon habitat potential due to changes in predicted stream flow between the 240-year landscape and the actual forest cover in 1990 projected forward 20 years.

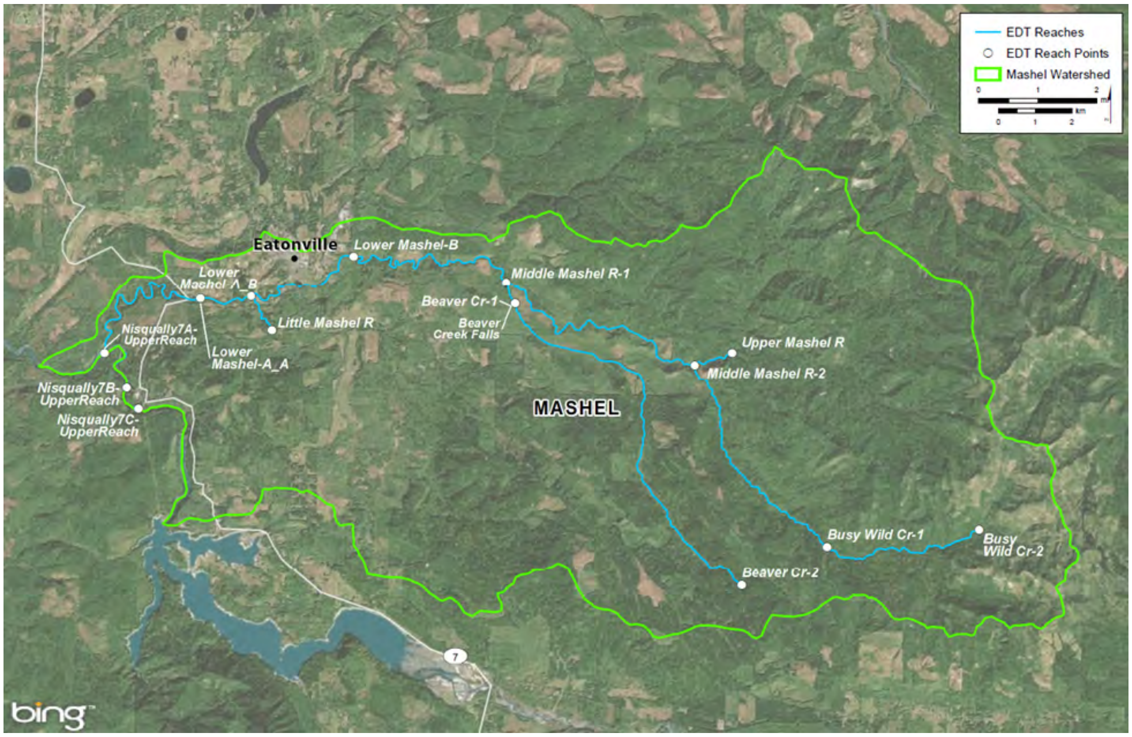


Figure 4. Mashel subwatershed and EDT reaches. The reach labels identify the upper end of each reach. Stream network only shows the anadromous portion of the subwatershed.

Predicted effects of forest cover were predominately a reduction in flow for the actual forest landscape as seen by differences in mean annual flow (MAF) by year (Figure 5). Reductions in MAF were greatest near the end of the VELMA simulation period (years 2000 to 2010); after 20 years of forest regeneration.

Effects of clearcutting large portions of the Busy Wild drainage in the 1980s leading up to the start of the VELMA simulation are seen in an increase in MAF during the first half of the simulation (Figure 5). The pattern shifts after 10 years and MAF are less than the 240-year landscape with forest regeneration. In contrast, the Beaver Creek drainage was not harvested to the same extent as other areas and does not show an increase in MAF as other reaches in the Mashel. Higher MAF observed in the lower Mashel reaches are from input from the Mashel headwaters.

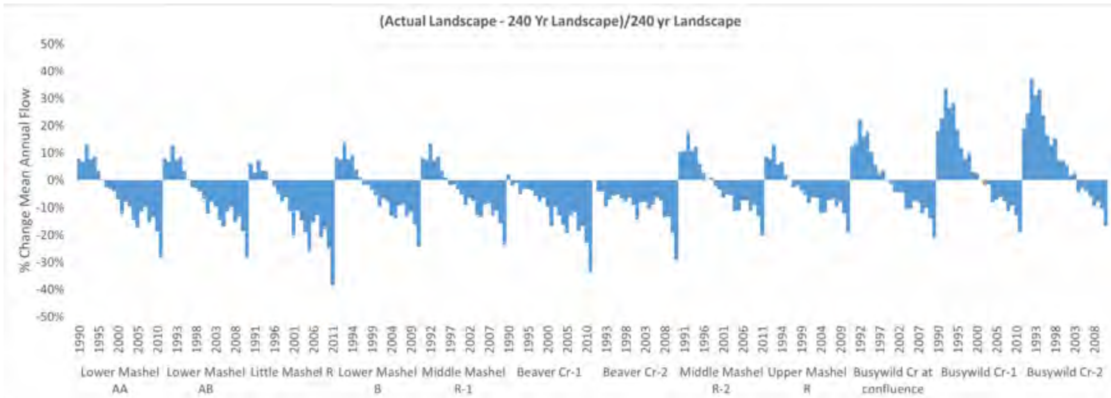


Figure 5. Difference in mean annual flow predicted by VELMA by Mashel EDT reach and year.

Annual peak flows (daily average) with the actual forest scenario increased slightly compared to the 240-year landscape scenario (Figure 6 top panel). There was a bigger increase in number of days daily flow was predicted to be 2X the November to April daily average (Figure 6 bottom panel) suggesting timber harvest may not be having a large effect on the highest flows of the year, but is causing a slight upward shift in the magnitude of smaller peaks during the winter months. In other words, the pattern is due to a differential increase in the magnitude of smaller, frequent high flow events relative to larger floods in the upper watershed. This pattern is most pronounced in the Busy Wild drainage in the years immediately following the extensive clear cuts in the drainage.

These predictions align well with conclusions for hydrologic changes reported in the Mashel watershed analysis (Bohle et al. 1996). They projected increases in peak flows of less than 10% from clear cuts from past timber harvest and from 14% to 20% for fully clear cut conditions. They concluded timber harvest "could have led to significant short term increases in peak flows in the past". They also noted the forest road network may be contributing to higher peak flows in the watershed. The effect of forest roads on flow were not modeled in VELMA for these simulations. LiDAR data exists for the watershed that could allow mapping of forest roads and a future analysis of effects of roads.

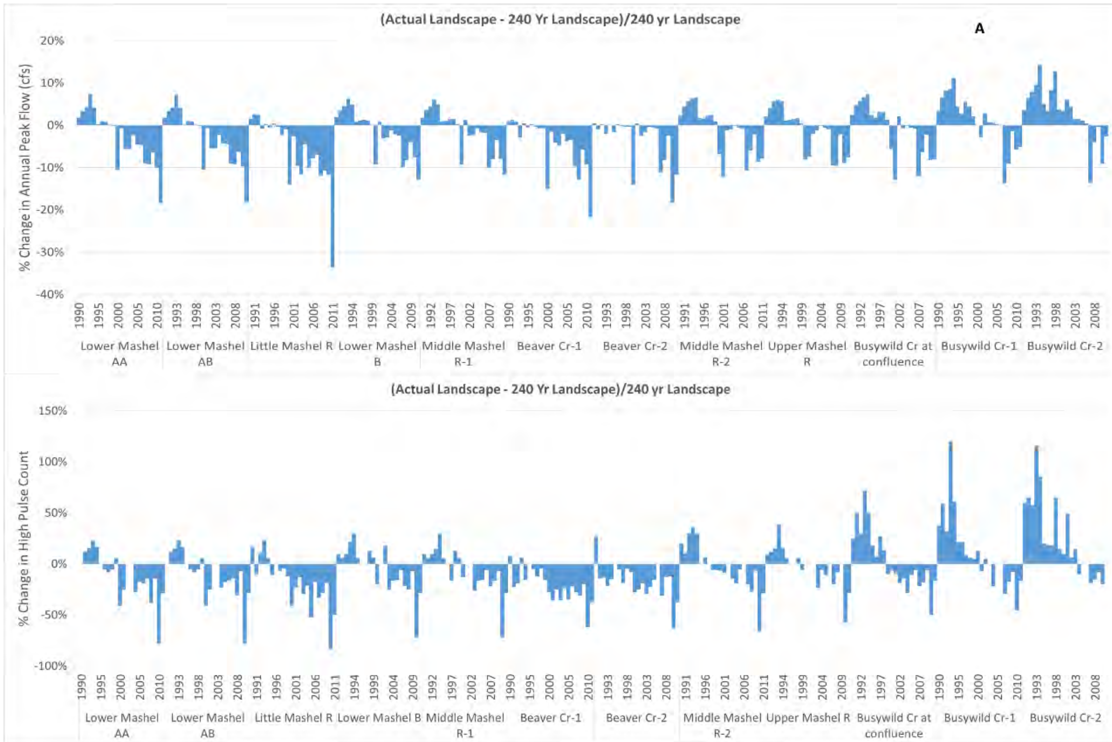


Figure 6. Predicted change in peak flows. Annual peak flow based on predicted daily average flow (top panel – A). Change in high pulse flows are number of days peak flow was 2X daily average from November to April (bottom panel – B). Note differences in scale.

The 30 day minimum stream flow was affected most by landscape condition (Figure 6). In some years the predicted effect of forest cover reduced summer base flow by 60% compared to the 240-year landscape.

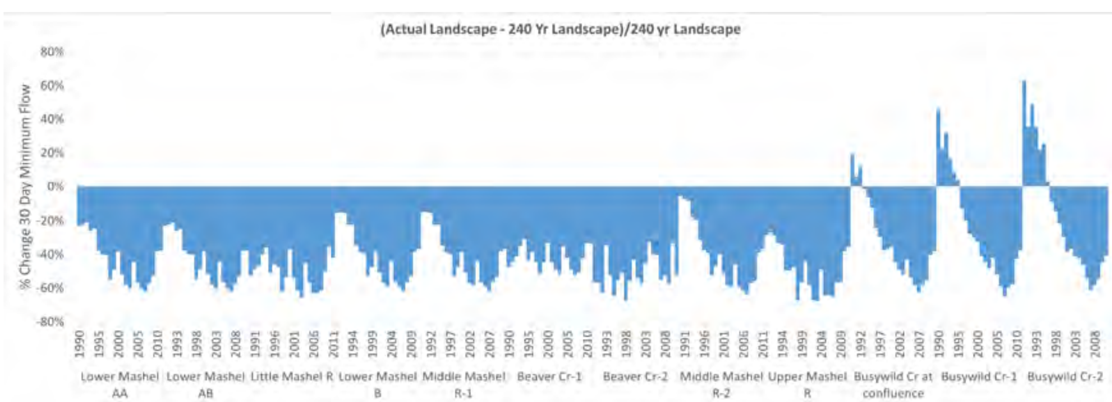


Figure 6. Difference in 30-day minimum stream flow predicted by VELMA by Mashel EDT reach and year.

The effect of forest landscape was greatest the last 10 years of the simulation as forest regeneration occurred in areas of the upper watershed that were harvested the 1980s. During the latter period of the simulation average reductions in summer base flow were approximately 50% (Table 1).

Table 1. 30 Day minimum flow predicted by VELMA the last 10 years of the simulation (2000 to 2010)

EDT Reach	% change 30-Day Min Flow	30 Day Minimum Flow (cfs)	
		240-year Landscape	Actual Forest
Lower Mashel AA	-53%	15.8	7.6
Lower Mashel AB	-53%	15.7	7.6
Lower Mashel B	-52%	12.5	6.1
Middle Mashel R-1	-52%	12.3	6.0
Middle Mashel R-2	-54%	9.5	4.5
Upper Mashel R	-57%	5.0	2.2
Little Mashel R	-54%	3.0	1.4
Beaver Cr-1	-44%	1.6	0.9
Beaver Cr-2	-47%	0.3	0.2
Busy Wild Cr at mouth	-50%	4.6	2.3
Busy Wild Cr-1	-49%	3.2	1.6
Busy Wild Cr-2	-46%	1.3	0.7

Translation of Alterations Stream Flow to Salmonid Survival in EDT

Stream flow affects salmonid survival by reducing density independent survival (productivity parameter of the Beverton-Holt function) of several life stages. Higher stream flow may impact survival of salmonids through displacement of fry and older juveniles from preferred habitats. Lower stream flow during the summer may impact survival by increasing predation risk or reducing foraging opportunities of juveniles. Lower stream flows may also impact up stream migration of adults.

Stream flow also affects salmonid survival by reducing habitat quantity (capacity parameter of the Beverton-Holt function) during summer low flow. Lower summer flows may result in the loss of habitat units or reduce the area of habitat available to salmonids increasing competition for space.

The following describes the translation of previously described changes in stream flow to EDT Level 2 attributes. This is in two parts: 1) effects on Level 2 attributes linked to productivity, and 2) effects on quantity of stream habitat – capacity.

The analysis is based on average conditions during the last 10 years of the VELMA simulation. Stream flows were changing rapidly during the first 10 years with forest regeneration such that averages during that period were less interesting. Management scenarios that include ongoing harvest rotations would better support an analysis of the entire simulation period.

1) Analysis of Effects of Stream Flow on Productivity

Effects of stream flow on productivity are captured with the survival factor Flow:

The effect of the amount of stream flow, or the pattern and extent of flow fluctuations, within the stream reach on the relative survival or performance of the focus species.

Primary environmental attributes (Level 2) describing stream flow in EDT are:

Alteration of Inter-annual Low Flow: The extent of relative change in average daily flow during the normal low flow period compared to an undisturbed watershed of comparable size, geology, and flow regime.

Intra-Annual Flow Pattern (Flashiness): The average extent of intra-annual flow variation during the primary runoff season – in other words, the attribute is a measure of a stream's "flashiness" during storm runoff. Flashiness is correlated with percent total impervious area and road density, but is attenuated as drainage area increases.

Alteration of Inter-annual High Flow: The extent of relative change in average peak annual discharge compared to an undisturbed watershed of comparable size, geology, orientation, topography, and geography (or as would have existed in the pristine state).

A more complete description of each attribute and rating rules are included in Appendix C.1.

The effect of altered stream flow on survival is modified by secondary environmental attributes such as channel confinement, wood, bank hardening, riparian condition, and substrate size (Figure 7). For example, life stage survival relationships in EDT assume effects of altered high flow are more severe in reaches lacking refuge from flow and structure to disrupt flow paths in the reach – e.g., reaches with less wood or extensive hardened banks. Survival relationships assume effects of altered low flow are more severe in reaches lacking complex habitat structure – e.g., reaches with fewer pools, less wood, or degraded riparian condition. In contrast, survival relationships in EDT assume alteration of low flow is less severe in reaches that are more confined.

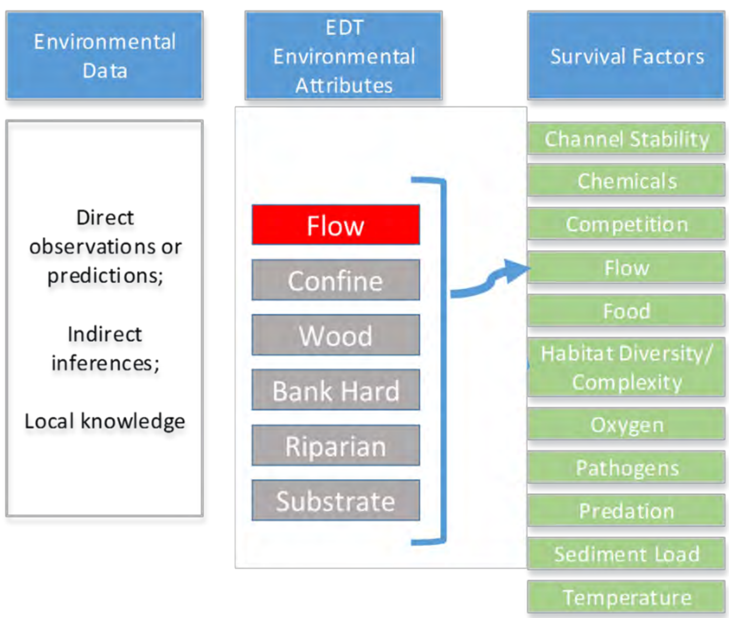


Figure 7. Conceptual view of species-life stage survival relationships in EDT. Example is generic across species and life stages.

Translation rules for converting VELMA flow predictions to EDT Level 2 flow ratings are shown in Figure 8. The percentage change in each flow metric by reach for years 2000 to 2010 were averaged to complete the Level 2 rating value for each attribute.

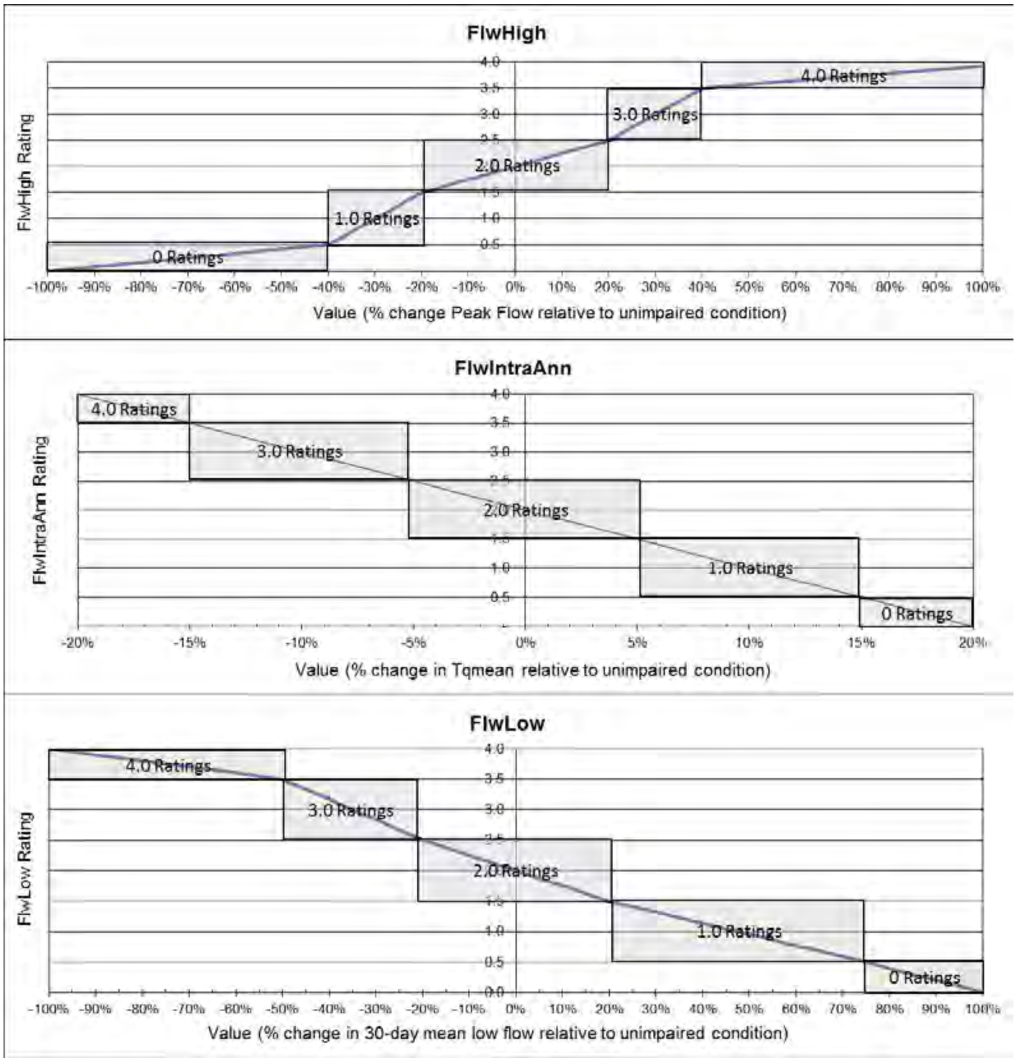


Figure 8. Translation relationships to convert predicted change 30-day minimum flow to EDT Low Flow ratings.

Resulting Level 2 ratings for low flow by reach are shown in Table 2. A 2.0 rating is the normative flow condition in EDT. EDT ratings of 0 and 4 are extreme conditions with a 0 describing an extreme case of reduction in peak flows or an increase in low flow that could be attributed to a hydro-regulated watershed. A 4 rating describes an extreme increase in peak flow or a decrease in low flow that could be attributed to hydrologically impaired watershed.

Table 2.Flow low Level 2 ratings for the Actual Forest scenario by reach. Ratings for the 240-year Landscape scenario are 2.0 by definition.

EDT Reach	Average % change 30-Day Min Flow (2000 to 2010)	EDT Low Flow Rating (Actual Landscape)
Lower Mashel AA	-53%	3.5
Lower Mashel AB	-53%	3.5
Lower Mashel B	-52%	3.5
Middle Mashel R-1	-52%	3.5
Middle Mashel R-2	-54%	3.5
Upper Mashel R	-57%	3.6
Little Mashel R	-54%	3.5
Beaver Cr-1	-44%	3.3
Beaver Cr-2	-47%	3.4
Busy Wild Cr-1	-49%	3.5
Busy Wild Cr-2	-46%	3.4

Resulting Level 2 ratings for high flow by reach are shown in Table 3. Early in the simulation predicted peak flows were slightly higher. The latter half of the simulation there was a predicted reduction in peak flows with forest regeneration. High flow ratings in EDT are based on the 2000 to 2010 period.

Table 3.Flow high Level 2 ratings for the Actual Forest scenario by reach based on the 2000 to 2010 simulation period. Ratings for the 240-year Landscape scenario are 2.0 by definition.

EDT Reach	Average % change Annual Peak Flow (1990 to 1999)	Average % change Annual Peak Flow (2000 to 2010)	EDT High Flow Rating (Actual Landscape)
Lower Mashel AA	2%	-6%	1.8
Lower Mashel AB	2%	-6%	1.8
Lower Mashel B	3%	-5%	1.9
Middle Mashel R-1	3%	-4%	1.9
Middle Mashel R-2	3%	-5%	1.9
Upper Mashel R	3%	-5%	1.9
Little Mashel R	0%	-9%	1.8
Beaver Cr-1	0%	-7%	1.8
Beaver Cr-2	0%	-5%	1.9
Busy Wild Cr-1	6%	-3%	1.9
Busy Wild Cr-2	7%	-1%	2.0

Resulting Level 2 ratings for intra-annual variability in high flow by reach are shown in Table 4. Ratings are based on the change in TQMean. TQMean is proposed as a metric of hydrologic alteration in urban settings (Konrad and Booth 2002). It may not be as useful an indicator of hydrologic alteration in forested landscapes.

With regards to change in High Pulse count, the pattern is a differential increase in the magnitude of smaller, frequent high flow events (positive percentage change) early in the simulation (Table 4). The last 10 years of the simulation show a pattern of slightly lower magnitude high flow events (negative percentage change).

Table 4.Flow intra-annual variability (flashiness) Level 2 ratings for the Actual Forest scenario by reach. Ratings are based on change in TQMean for 2000 to 2010. Ratings for the 240-year Landscape scenario are 2.0 by definition.

EDT Reach	Average % change TQMean (1990 to 1999)	Average % change TQMean (2000 to 2010)	Average % change High Pulse Count (1990 to 1999)	Average % change High Pulse Count (2000 to 2010)	EDT Intra High Flow Rating (Actual Forest)
Lower Mashel AA	3%	0%	5%	-20%	2.0
Lower Mashel AB	3%	0%	5%	-18%	2.0
Lower Mashel B	4%	1%	10%	-12%	1.9
Middle Mashel R-1	4%	1%	8%	-12%	1.9
Middle Mashel R-2	4%	2%	12%	-11%	1.8
Upper Mashel R	5%	3%	10%	-7%	1.8
Little Mashel R	3%	-2%	1%	-28%	2.3
Beaver Cr-1	2%	-2%	-8%	-28%	2.2
Beaver Cr-2	1%	0%	-7%	-20%	2.0
Busy Wild Cr-1	6%	2%	37%	-7%	1.8
Busy Wild Cr-2	5%	3%	52%	3%	1.8

2) Analysis of Effects of Stream Flow on Capacity

The following is a "proof of concept" analysis of effects of flow on habitat wetted area in the Mashel subwatershed. The challenge was to determine effects of altered hydrology on channel wetted area by EDT reach in the Mashel subwatershed to estimate habitat quantity by reach and month.

Channel wetted area used in previous analyses of current conditions and recovery planning were based on field measurements collected in a watershed analysis completed in the 1990s (Bohle et al.1996). The impacts forest cover on stream flow predicted by VELMA suggests the 1990s analysis is insufficient to evaluate changes in area under alternative forest management scenarios.

Our proof of concept approach was to show how wetted width could be predicted through a series of representative channel transects in the watershed. LiDAR information was available for most of the anadromous portion of the watershed. The very upper section of Busy Wild Creek was not covered in the 2004 LiDAR data. We calculated channel profile at 33 transects using 2004 LiDAR information for the watershed (Figure 9). Channel profiles for each transect are shown in Appendix C.2.

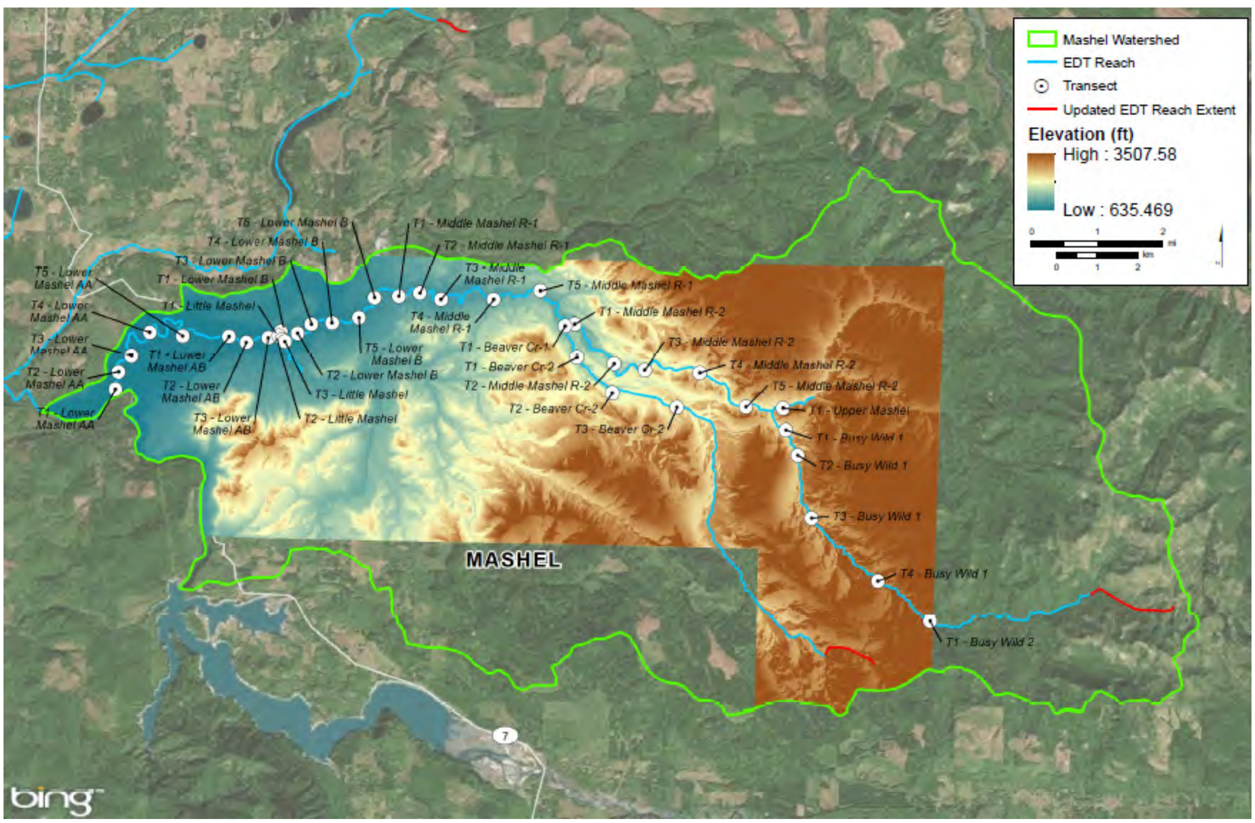


Figure 9. Location of LiDAR based transects used to estimate wetted width across the range of VELMA predicted monthly flows.

Manning's Equation was used to determine width of the water in the channel segments at various flowrates. The typical representation of Manning's Equation when using English units of measure is:

$$Q = A\,\frac{1.49}{n}\,R^{2/3}\sqrt{S}$$

Where: Q = Flowrate

A = Area of Flow

n = dimensionless Manning's coefficient

R = Hydraulic Radius (area of flow divided by wetted perimeter of channel)

S = Slope of the Energy Grade Line of the Channel

For this analysis, the equation is rearranged to solve for width instead of flow. The width of the actively flowing channel is expressed in both the A and R variables of the equation, and due to the irregular shape of the channel segments, a direct solution is not available.

The Corps of Engineers numerical hydraulic model HEC-RAS for one-dimensional steady state flow was used to solve the equation for multiple flows at each channel segment. HEC-RAS solves the Manning's equation for irregularly shaped channels at the downstream boundary of the model when the "Normal Depth" boundary condition option is selected. Upstream of the boundary condition HEC-RAS solves a different set of equations to determine flow characteristics in the channel; however, for this analysis only the boundary condition solution was used. A single channel cross section was input into HEC-RAS and defined as a downstream boundary condition with "Normal Depth" as the selected solution scheme.

Geometry of each cross section analyzed was obtained from a LiDAR generated topography. The channel cross section geometry was input into the HEC-RAS model and set as a downstream boundary condition. The Manning's n coefficient was estimated by comparing aerial photography of the channel at the cross section to standard text book guidance for Manning's n values. The energy grade line slope was assumed to be equivalent to the down valley slope in the vicinity of the cross section, and was obtained from the LiDAR generated topography.

The range of flowrates for the river or creek segment being analyzed was obtained from the VELMA hydrologic modeling. The range identified the upper and lower limits of flowrates of interest. The range was then evenly distributed to include 10 separate flowrates for analysis. These were input into the HEC-RAS model and the model was run. The HEC-RAS model solved Manning's equation for each of the ten flowrates and generated top width of flow at the cross section. An example is shown in Figure 10.

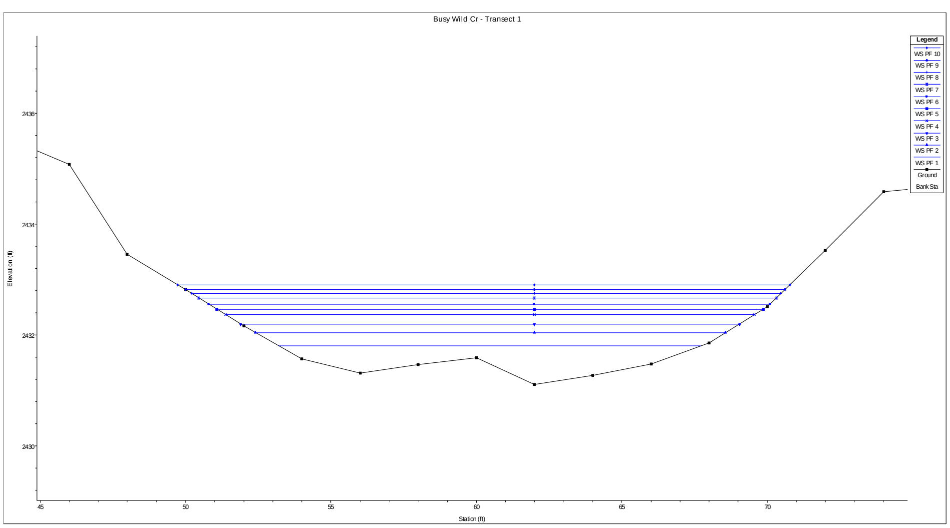


Figure 10. Example cross section with wetted width across a range of flow values.

Wetted width was predicted by interpolation of monthly average stream flow across the 10 flow rate/width relations described previously. An example is shown in Table 5.

Table 5. Example conversion flow to wetted width – Reach: Mashel R AA. Width is the average of 5 transects in the reach.

	240-year Landscape			Actual Forest	
Month	**Flow (cfs)**	**Wetted Width (m)**		**Flow (cfs**	**Wetted Width (m)**
Jan	659	37.7		609	37.3
Feb	429	33.8		414	33.6
Mar	382	33.2		375	33.1
Apr	326	32.4		321	32.3
May	207	30.0		203	29.9
Jun	182	29.5		132	28.3
Jul	54	21.6		28	17.5
Aug	23	16.7		12	15.3
Sep	33	18.2		16	15.5
Oct	64	23.2		42	19.7
Nov	375	33.1		270	31.3
Dec	464	34.1		386	33.3

The percentage change in wetted widths did not always following the pattern seen for minimum flow (Table 2). Based on the channel transect predictions it appears the reduction in summer base flow would tend to have a higher impact on juvenile capacity in the smaller streams in the Mashel subwatershed. (Table 6). This may because the smaller streams lack the deeper pools that may be present in the mainstem Mashel River. Bohle et al. (1996) report few large channel forming pieces of wood. Subsequent site visits in recent years has supported this observation.

Table 6. Predicted percentage change in wetted channel width by reach and month between the 240-year Landscape and Actual Forest scenarios (negative values = reduced width under Actual Forest scenario).

Reach	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Lower Mashel AA	-1%	0%	0%	0%	0%	-4%	-19%	-8%	-15%	-15%	-6%	-2%
Lower Mashel AB	-1%	-1%	0%	0%	-1%	-11%	-17%	-7%	-13%	-13%	-4%	-5%
Lower Mashel B	-1%	0%	0%	0%	0%	-3%	-14%	-5%	-10%	-11%	-3%	-1%
Middle Mashel R-1	0%	0%	0%	0%	0%	-4%	-12%	-16%	-9%	-9%	-3%	-1%
Middle Mashel R-2	0%	0%	0%	0%	1%	-4%	-10%	-3%	-7%	-8%	-4%	-1%
Upper Mashel R	0%	0%	0%	0%	0%	-2%	-2%	-1%	-2%	-2%	-2%	-1%
Little Mashel R	-3%	-2%	-1%	-2%	-2%	-10%	-18%	-7%	-11%	-14%	-13%	-8%
Beaver Cr-1	-1%	-1%	-1%	-1%	-6%	-26%	-43%	-17%	-37%	-30%	-6%	-5%
Beaver Cr-2	-1%	-1%	-1%	-1%	-1%	-10%	-47%	-44%	-49%	-38%	-17%	-3%
Busy Wild Cr-1	0%	0%	0%	1%	0%	-3%	-13%	-34%	-22%	-9%	-6%	-1%
Busy Wild Cr-2	0%	1%	1%	1%	1%	-2%	-28%	-19%	-26%	-10%	-1%	0%

EDT Model Results for Winter Steelhead

Recall, EDT quantifies the suitability of an environment in terms of the productivity and capac parameters of the Beverton-Holt production function (see Figure 1). Productivity defines popu performance at low abundance, when competition for resources is negligible. It is the theoreti maximum number of recruits that would be produced per spawner (on average) in the absenc any competition. Capacity regulates potential abundance, since the environment has a finite ar of habitat and food that can be utilized by the population. As a population grows, competition f resources among individuals increases, ultimately placing a limit on how large the population grow.

EDT is a life-cycle habitat model that characterizes the aquatic environment temporally (mont and spatially (stream reaches) "through the eyes of salmon." Habitat is evaluated along numer pathways (trajectories) that are defined by the salmonid life history. Life history pathways developed in EDT following life history assumptions specific to each species (Figure 11).

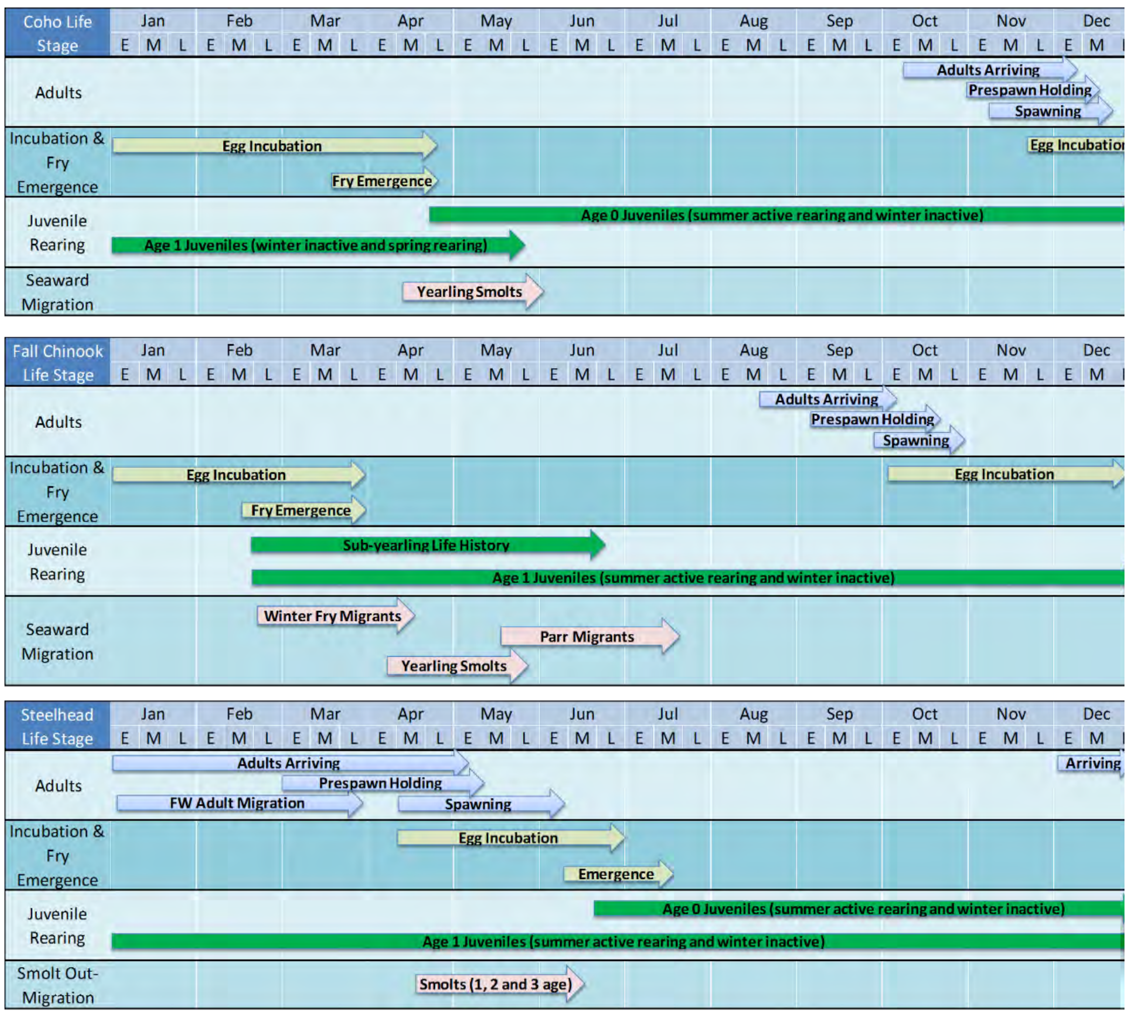


Figure 11. Mashel River Coho (top), Fall Chinook (middle), and Winter Steelhead (bottom) life history.

Equilibrium abundance (abundance) is reported from the spawner-recruit function to facilitate comparison of results between scenarios. Over several years of relatively stable environmental conditions (accounting for year to year variation) the population will tend toward an equilibrium point, which is where the replacement line and the Beverton-Holt function intersect (see Figure 1). At the equilibrium point, the population is replacing itself in each generation – the population growth rate is 1.0 (recruits per spawner = 1). The equilibrium abundance would be what we would tend to observe on the average over some period of years, if habitat conditions remain relatively constant.

EDT results for coho, Fall Chinook, and Winter Steelhead spawning in the Mashel subwatershed are shown in Table 7. Note that productivity and abundance estimates assume a marine survival that was not calibrated to recent year observations. Therefore these results should be evaluated relative to the habitat scenarios and not recent year averages for the Mashel.

Winter steelhead are predicted to be most sensitive of the three species to effects of reduced summer flows under the actual forest scenario. Adult abundance back to spawning was predicted to be 35% less from effects of reduced summer flows under the actual landscape scenario. Winter steelhead are sensitive to low flow conditions at fry emergence, during their first summer, and during their second summer before migrating to sea as two year old smolts. Nisqually River winter steelhead migrate to sea as 1 year olds (36%), 2 year olds (62%) and three year olds (2%) (Washington Department of Fish and Wildlife, smolt migration monitoring).

Coho are intermediate with abundance predicted to be 14% less from effects of reduced summer flow. Fall Chinook are least impacted with abundance predicted to be 7% less from effects of reduced summer flow (Table 7).

Table 7. EDT model results for Coho, Fall Chinook and Winter Steelhead spawning in the Mashel subwatershed.

Species	Scenario	Productivity	Capacity	Abundance
Coho	Actual Forest	2.1	335	172
	240-year Landscape	2.2	373	201
Fall Chinook	Actual Forest	2.9	886	584
	240-year Landscape	3.0	935	625
Winter Steelhead	Actual Forest	3.5	628	448
	240-year Landscape	5.8	831	688

To assess the relative effect of the actual forest landscape condition flow on each stream segment we use a technique called a *splice analysis*. For the splice analysis, we created a sequence of scenarios by successively replacing each 240-year landscape condition stream reach with the actual forest condition counterpart. Using this technique, we obtain an estimate of the relative impact to Mashel River subpopulation performance of the actual forest landscape flow by stream reach.

Generally, model results show decreasing impacts higher in the basin. This is largely the result of reduced production potential moving up the drainage as a function of stream size and corresponding spawning distribution. Predicted impacts are also affected by the potential of the reach to support salmon and steelhead. The model results will show a greater impact of flow effects in high quality reaches that are core habitat for the species.

For Winter Steelhead the Middle Mashel reaches ranked highest for impact, followed by the Lower Mashel AA reach (Figure 12). Scaling the change in abundance to reach length tended to flatten differences among reaches. However, the Middle Mashel reaches still tend to show a greater impact of reduced stream flow relative to other reaches.

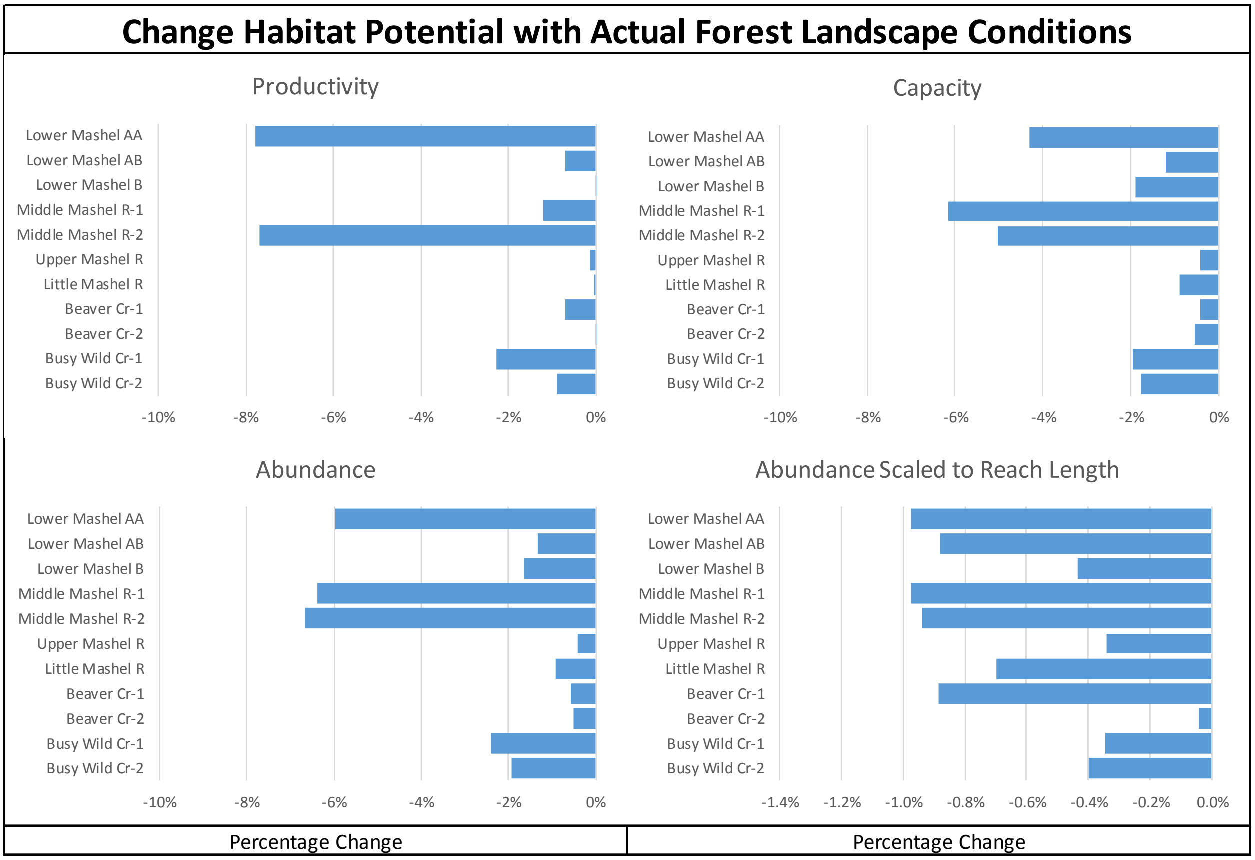


Figure 12. Relative impact of Actual Forest landscape flow on habitat potential for Mashel Winter Steelhead.

The pattern was different for coho (Figure 13). For coho loss of habitat capacity with change in wetted channel width was driving impacts in most reaches. However, lower Busy Wild Creek and the lower most reach of the Mashel are predicted to be most impacted, affecting both productivity and capacity of coho originating from the Mashel River. These results reflect the relative potential of each reach for coho with 240-year landscape flows. The Lower Busy Wild reach and lower Mashel River reach are some of the higher quality reaches and are more important for Coho relative to other reaches. Thus degradation of these reaches is predicted to have a greater impact on the Mashel subpopulation relative to other reaches.

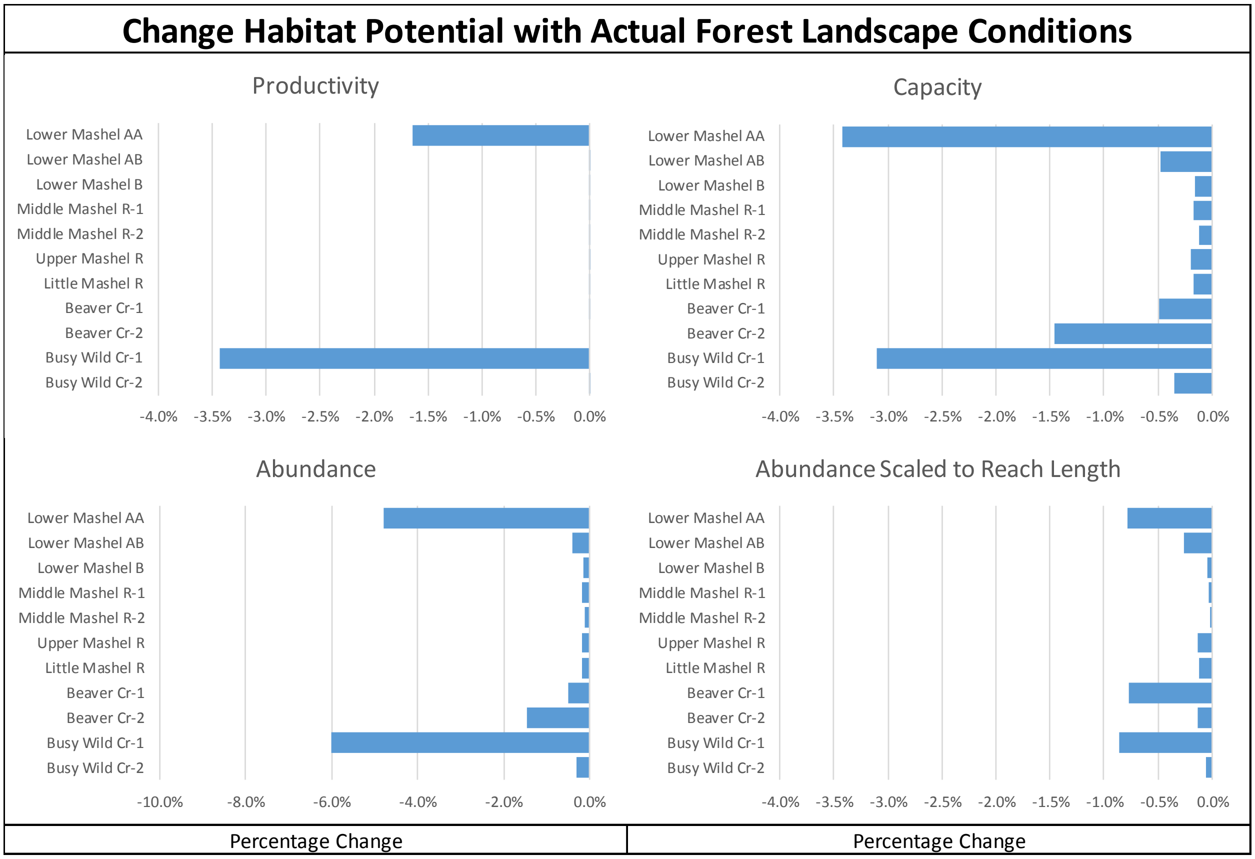


Figure 13. Relative impact of Actual Forest landscape flow on habitat potential for Mashel Coho.

Fall Chinook use of the Mashel subwatershed is more limited. The upper reaches of Beaver Creek and Busy Wild Creek likely too small and high in the system to be used by Chinook. Chinook distribution is skewed more towards the larger downstream reaches in the subwatershed. Results tend to reflect this pattern of Chinook use. Impacts of reduced summer flow are more pronounced in the two lower most reaches of the Mashel River.

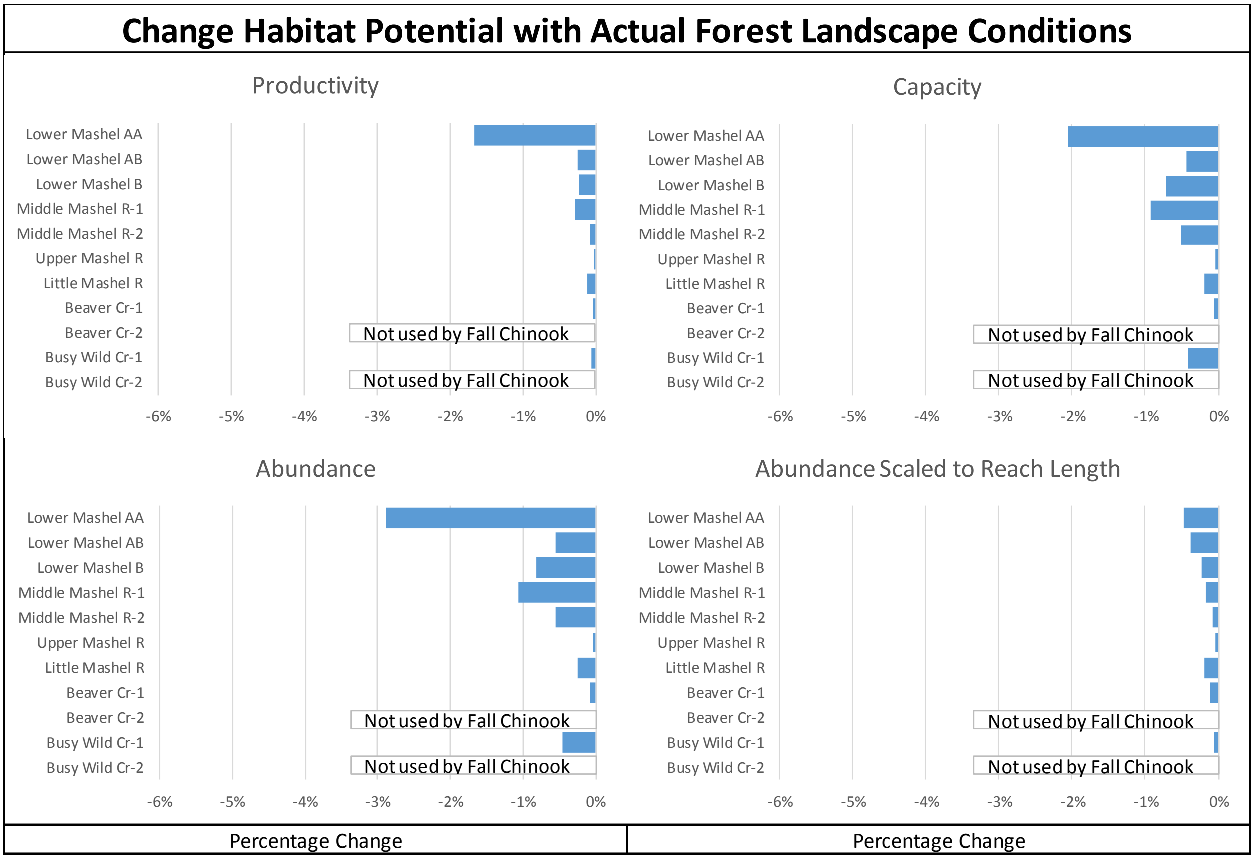


Figure 14. Relative impact of Actual Forest landscape flow on habitat potential for Mashel Fall Chinook.

Figures 15 – 17 show percentage difference in segment productivity and capacity along representative life history trajectories for each species. The predicted loss of summer low flow relative to the 240-year landscape scenario is affecting both productivity and capacity of the trajectory. Productivity is the density independent impact of lower flow, whereas the impact on capacity is largely a loss in wetted area. Productivity is impacting capacity through the Beverton-Holt survival function where maximum density per unit area (capacity) is reduced from reductions in productivity of the reach. Note the differences in scale among species and between productivity and capacity.

Winter Steelhead are most sensitive to effects of reductions in summer flow (Figure 15). This is because of their longer duration in freshwater (two summers) and timing of fry emergence in early summer at the start of the low flow period compared to Coho and Chinook. Reduced summer flow is impacting productivity and capacity for steelhead. Winter Steelhead adults are entering after the low flow period and spawning and incubation is mostly just before the loss of summer flow.

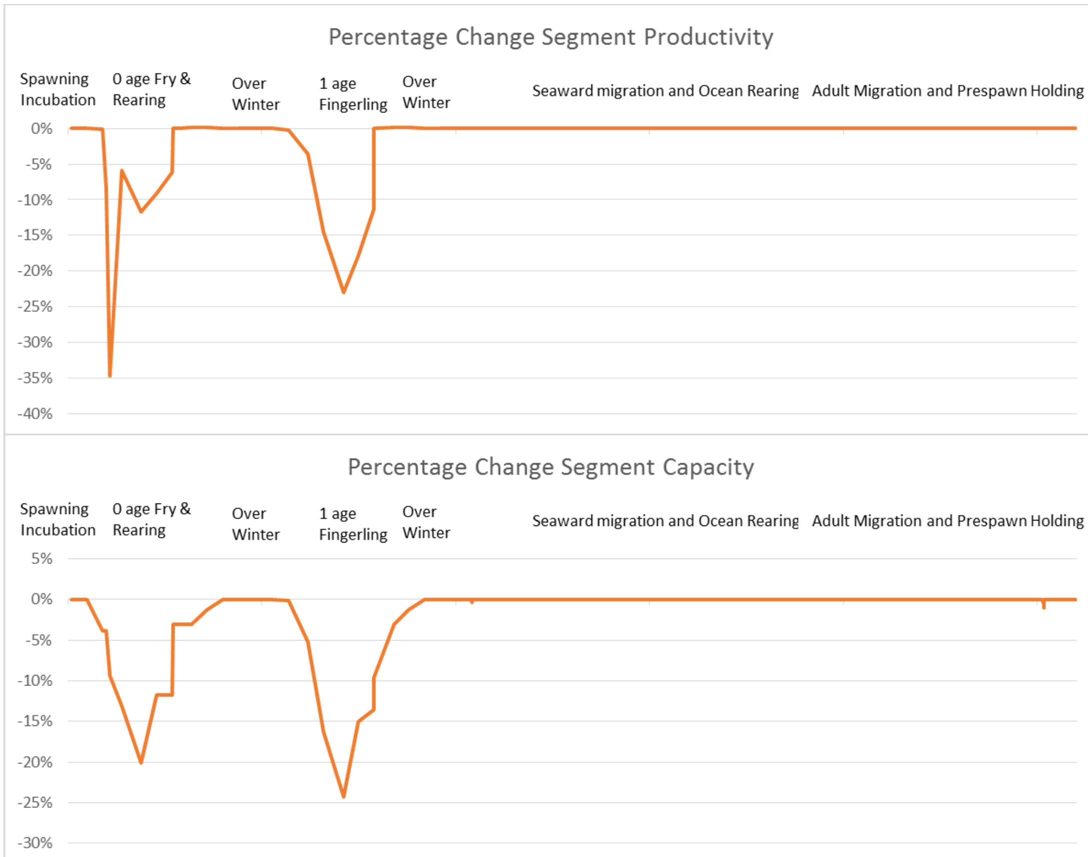


Figure 15. Representative Winter Steelhead trajectory profile (originating from Middle Mashel R-1 reach) showing effects of loss of summer stream flow on segment productivity and capacity. Percentage change is change in segment productivity and capacity with predicted Actual Forest flow relative to the predicted 240-year Landscape flow ([Actual – 240-year]/240-year).

Coho are sensitive to effects of reductions in summer flow during summer juvenile rearing (Figure 16). Coho are residing in pools during the summer which is hypothesized to reduce the impact of reduced flows on productivity. However, reduced summer flow is impacting capacity through loss of habitat quantity. Adult Coho return to the Mashel for spawning from October to November. This particular trajectory is entering in October and there is a brief reduction in capacity due to effects of reduced flow during October. However, even though the impact on segment capacity may be relatively large the effect on population performance is low because, relative to the number of Coho surviving to spawn, the loss in capacity is minor.

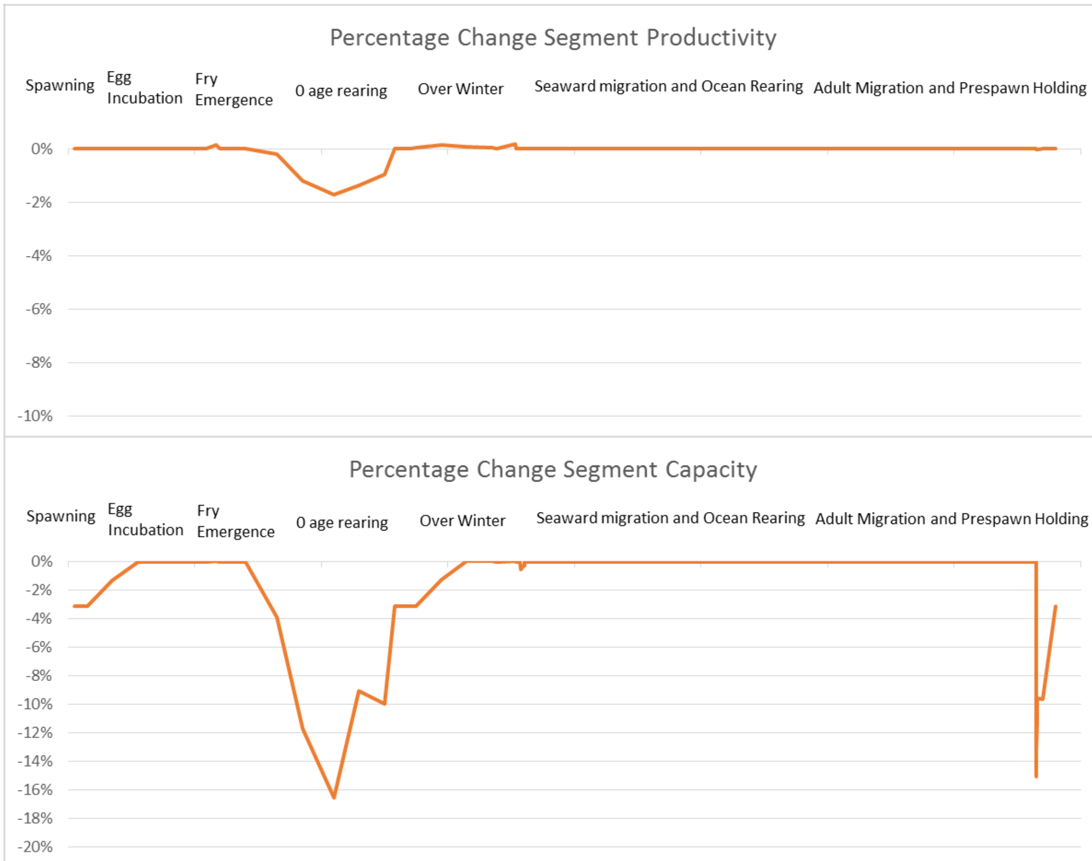


Figure 16. Representative Coho trajectory profile (originating from Middle Mashel R-1 reach) showing effects of loss of summer stream flow on segment productivity and capacity. Percentage change is change in segment productivity and capacity with predicted Actual Forest flow relative to the predicted 240-year Landscape flow ([Actual – 240-year]/240-year).

Finally, Fall Chinook are least sensitive to effects of reductions in summer flow during the summer juvenile rearing period (Figure 17). Fall Chinook juveniles are leaving the Mashel subwatershed from February to mid-June as subyearling fish. Adult Fall Chinook are entering the Mashel River in during the last couple of weeks of September and into October. Peak spawning in the Mashel is in October (NIT unpublished spawning ground survey data). The effects of reduced flow on adult migration and holding in the Mashel is seen in a reduction in productivity and capacity. The very slight improvement in productivity during fry emergence is based on reduction in high flow in April.

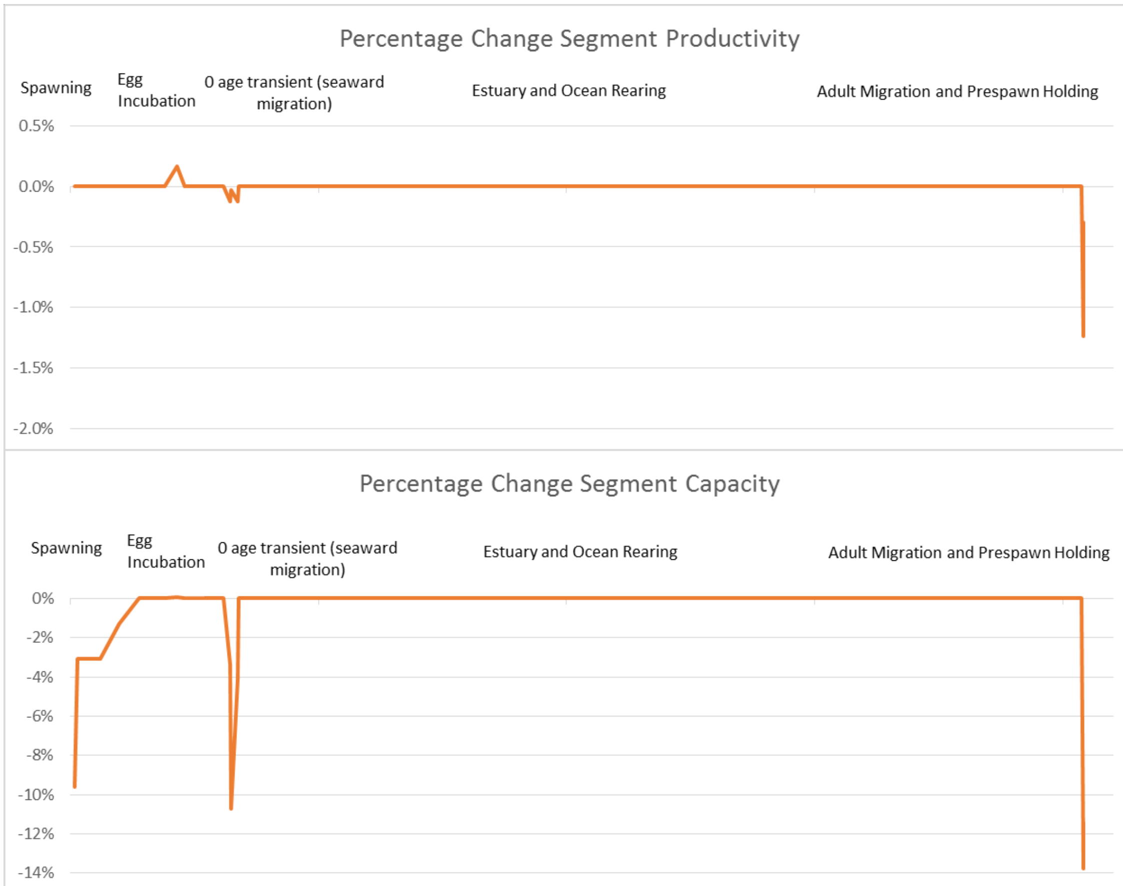


Figure 17. Representative Fall Chinook trajectory profile (originating from Middle Mashel R-1 reach) showing effects of loss of summer stream flow on segment productivity and capacity. Percentage change is change in segment productivity and capacity with predicted Actual Forest flow relative to the predicted 240-year Landscape flow ([Actual – 240-year]/240-year).

EDT INSTALLATION INSTRUCTIONS

The following describes how to access the new version of EDT and setup of the application modules on a user's computer.

Requirements

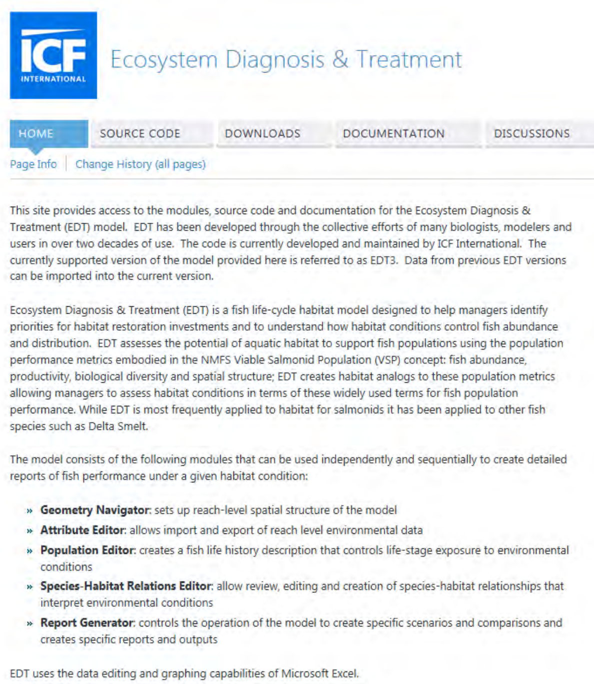
This section describes the basic computer skills necessary to work with EDT, as well as the software and hardware needed to run the programs.

What you should know

This manual assumes a familiarity with basic operating system functionality, such as copying, saving, and deleting files and installing applications; familiarity with various utilities, such as unzipping files; and familiarity with Web-based activities, such as navigation and filling in forms.

What software and hardware you need

The EDT Codeplex Website (http://edt.codeplex.com/) has everything needed to install and start using EDT. It has the links to the required software and links to EDT applications.



Step 1 Review System Requirements to run EDT:

- Windows 7 operating system or higher
- NET Framework 4
- SQL Server Compact Edition 3.5

Prerequisites

All prerequisites for the EDT application suite should be installed automatically as part of the installation process outlined above. If there is a problem installing the prerequisites, you may need to install them manually.

- .NET Framework 4
  - Note: the .NET Framework is often installed already; the application installer will warn you if it is not.
- SQL Server Compact Edition 3.5
  - When you run the installer, you will be prompted for a directory location.
  - Navigate to the directory location you chose.
  - There should bet two files at this location:
    - SSCERuntime_x86-ENU.msi
    - SSCERuntime_x64-ENU.msi
  - If you are running a 32-bit version of Windows, install only SSCERuntime_x86-ENU.msi.
  - If you are running a 64-bit version of Windows, install both files.
    - To check if you are running a 64 or 32 version of windows, right-click on My Computer and select "Properties". There should be a line that says "System type: [32/64]-bit operating system"

Step 2 Install Applications

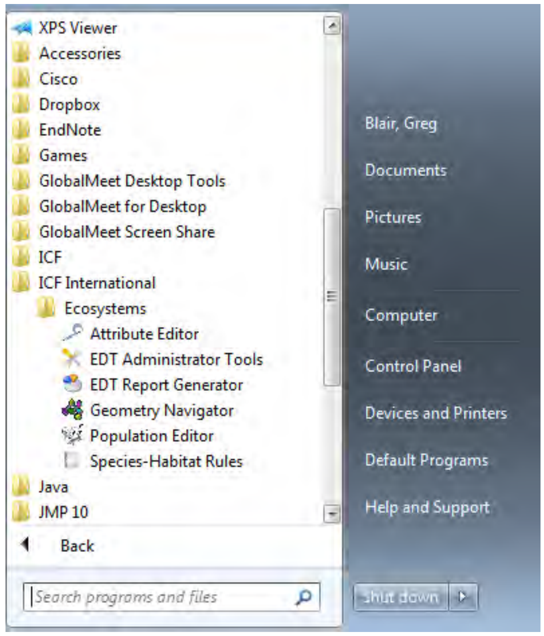
Install Applications in the Suite

To install each application, click on the hyperlink. You should be prompted to download a "setup.exe" file; if you see a warning about downloading the file, choose to continue/keep the download. Once the setup.exe file has download it, browse to the download location and double-click to run it. The setup.exe will install all prerequisites needed to run the EDT application suite. You will be prompted to accept an End User License Agreement for each prerequisite, and will need to have administrator permissions to install them. Once the prerequisites have been installed, the EDT application you downloaded will be installed, too.

- Project Administration Console
- Geometry Navigator
- Attribute Editor
- Population Editor
- Species-Habitat Rules Editor
- Report Generator
- Excel Plugin

If you have any questions or difficulties, email karl.dickman@icfi.com for help.

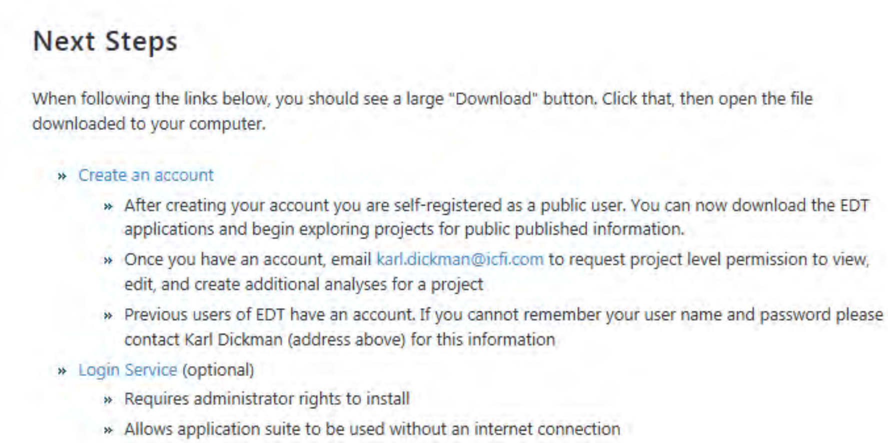
A successful install of each of the applications will create an ICF International folder with the EDT programs in your start menu under All Programs:



Step 3 Setup User Account

- User accounts are managed for projects and permissions (read and write datasets).
- Once you have registered and created a public user account, notify your ICF Project Manager or your Project Administrator, who will work with the ICF EDT Administrator to assign you the appropriate permissions. In the interim, you may navigate through EDT projects, viewing published datasets, and running reports on published datasets and populations. Once you receive your permissions, you will be able to look at any dataset beyond the official, "published," dataset for a project and create new datasets for the project.

Create Account:



Types of user accounts in EDT:

Role	Description
Administrator	ICF employee. Can do everything in support of EDT model and users.
Project Director	ICF employee. Can create new projects and deactivate projects.
Project Manager	ICF employee. Can create, read, edit, and delete draft datasets; assign roles; publish drafts.
Owner	The project sponsor. Can create, read, edit, and delete draft datasets; publish draft datasets. Can assign subordinate roles, such as project reviewer or participant.
Participant	Assigned to one or more projects. Can read/download and edit/upload existing data sets and create new draft data sets.
Reviewer	Assigned to one or more projects. Can read/download draft and published datasets.
Public	No project assignments, initial permission when register on EDT site. Can read/download published reports.

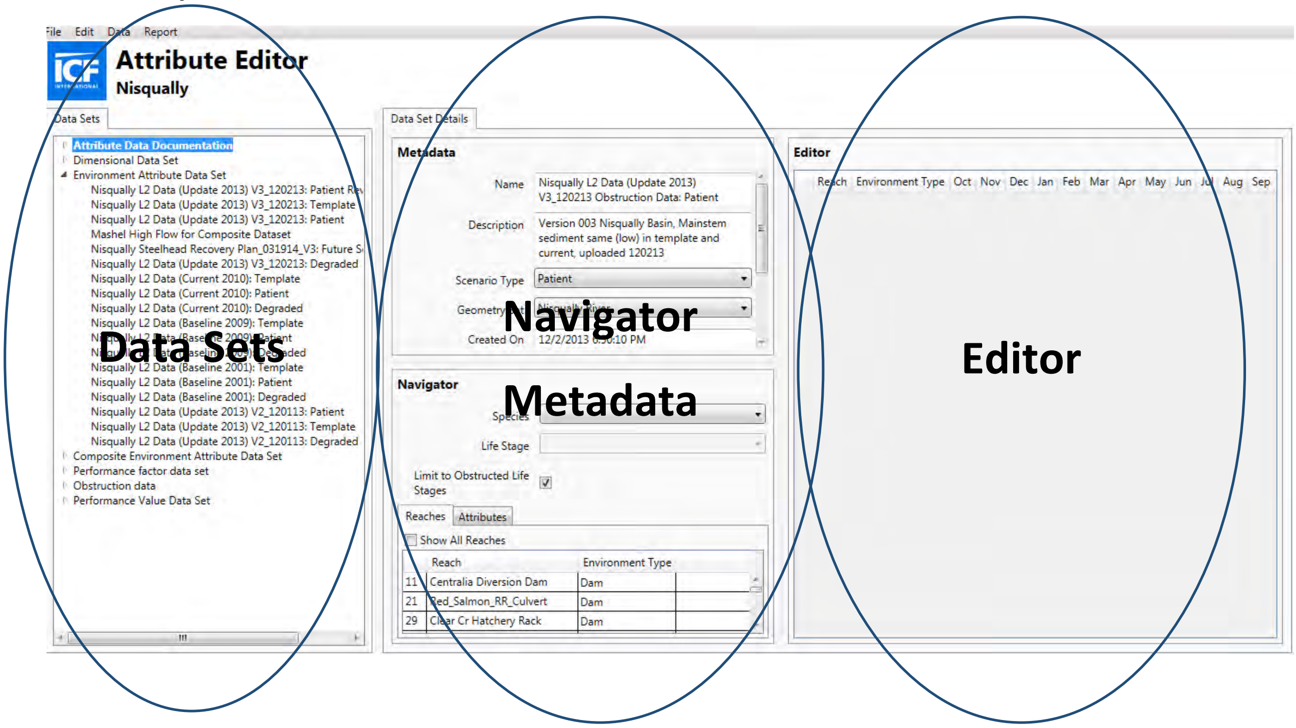
OVERVIEW OF MODULES AND FUNCTIONS

The new version of the model is constructed in modules much like Microsoft Office©. Modularization has allowed us to expand the capabilities of the model at each step during the setup, application, and review and allows users to load only those pieces of the model they need. Several of the modules can operate as stand-alone tools independent of a typical EDT modeling exercise.

Each module is designed to carry out one of the steps in the EDT modeling process:

Purpose	EDT Module
Gather Habitat Data	Attribute Editor
Define Scenarios of Interest	Attribute Editor
Generate Reports	EDT Report Generator
Describe Species Behavior	Population Editor
Review and edit reach linkages and route chaining	Geometry Navigator
Review/Modify Biological Constraints	Species-Habitat Rules
Identify project attributes,	EDT Administration Tools

Module Layout



REFERENCES

Beverton, R. J. H., and S. J. Holt. 1957. On the dynamics of exploited fish populations. U.K. Ministry of Agriculture, Fisheries Investigation Service 2(19):553.

Blair, G.R., L.C. Lestelle, and L.E. Mobrand. 2009. The Ecosystem Diagnosis and Treatment Model: A tool for assessing salmonid performance potential based on habitat conditions. Pages 289–309 in E. E. Knudsen, J. H. Michael, and C. S. Steward, editors. Pacific salmon environment and life history models: advancing science for sustainable fisheries in the future. American Fisheries Society, Symposium 71, Bethesda, Maryland.

Bohle, T., C.E. Cupp, R. Denman, R. Jackson, J. Kirtland, J. Metzler, E. Salminen, and K. Sargent. 1996. Mashel Watershed Analysis Resource Assessment Report. Washington Department of Natural Resources, South Puget Sound Region, Enumclaw, Washington.

Konrad, C.P., and D.B. Booth. 2002. Hydrologic trends associated with urban development for selected streams in the Puget Sound Basin, Western Washington. Tacoma, Wash: U.S. Dept. of the Interior, U.S. Geological Survey. Available online at https://pubs.usgs.gov/wri/wri024040/pdf/WRIR02-4040.pdf

McElhany, P., M. H. Ruckelshaus, M. J. Ford, T. C. Wainwright, and E. P. Bjorkstedt. 2000. Viable salmonid populations and the recovery of evolutionary significant units: U.S. Department of Commerce. Seattle, WA. NOAA Tech. Memo NMFS-NWFSC-42.

Mobrand, L.E., J.A. Lichatowich, L.C. Lestelle, and T.S. Vogel. 1997. An approach to describing ecosystem performance "through the eyes of salmon". Canadian Journal of Fisheries and Aquatic Sciences 54:2964–2973.

Moore, G. W., B. J. Bond, J. A. Jones, N. Phillips, and F. C. Meinzer. 2004. Structural and compositional controls on transpiration in 40- and 450-year-old riparian forests in western Oregon, USA. Tree Physiology, 24, 5, 481-91.

NSRT (Nisqually Steelhead Recovery Team). 2014. Draft Nisqually Winter Steelhead Recovery Plan. Report (available here: http://nisquallyriver.org/blog/2015/02/23/nisqually-steelhead-recovery-plan/)

Perry, T. D. 2007. Do vigorous young forests reduce streamflow?: Results from up to 54 years of streamflow records in eight paired-watershed experiments in the H.J. Andrews and South Umpqua Experimental Forests. M.S. Oregon State University 2008

Thompson, B. E., L. C. Lestelle, G. R. Blair, L. E. Mobrand, and J. B. Scott. 2009. EDT application in salmon recovery planning: diagnosing habitat limitations and modeling restoration action effectiveness. Pages 311–335 in E. E. Knudsen, J. H. Michael, and C. S. Steward, editors. Pacific salmon environment and life history models: advancing science for sustainable fisheries in the future. American Fisheries Society, Symposium 71, Bethesda, Maryland.

Appendix C.1 – EDT Environmental Attributes (Level 2) Describing Flow Alterations

Environmental attributes are referred to as Level 2 attributes. Level 2 information creates a generalized depiction of the aquatic environment, essentially as a set of conclusions derived from the Level 1 information. Level 2 Environmental Attributes are the main input to EDT through the Attribute Editor. The EDT Environmental Attributes (Level 2) for flow characteristics are defined below.

Level 2 attributes for flow are characterized using ratings on a scale of 0 to 4, spanning a spectrum of conditions. Generally, there is a consistent direction to the attribute ratings, where 0 or low values will tend to correspond with pristine environmental conditions and higher values tend toward more degraded conditions. In the case of flow a 2 rating corresponds to the unaltered, pristine condition, whereas a value of 0 is the altered condition with reduced peak flow or higher low flow and a 4 is a severe reduction in performance related to the altered condition of higher peak flow or lower low flow.

Alteration of Inter-annual High Flow

The extent of relative change in average peak annual discharge compared to an undisturbed watershed of comparable size, geology, orientation, topography, and geography (or as would have existed in the pristine state). Changes in the timing and quantity of flow, due to land uses and flow regulation, can affect responses of stream dwelling organisms like salmonids, leading to changes in overall performance of their populations (Poff et al. 1997; Bunn and Arthington 2002). This attribute does not address the effect of flow on channel width or other EDT attributes. The effect of high flow on maximum channel width is incorporated in the maximum width attribute.

Note that the ratings for this attribute do not follow the typical 0 (normative)-4 (highly altered) rating scheme of EDT attributes. Instead, a rating of 2 is the normative condition and 0 and 4 represent extreme deviations from normative.

Categorical rating definitions for Alteration of High Flow in EDT

0 Rating	1 Rating	2 Rating	3 Rating	4 Rating
Peak annual flows expected to be strongly reduced relative to an undisturbed watershed of similar size, geology, orientation, topography, and geography (i.e. the pristine state for the watershed);	Peak annual flows expected to be moderately reduced relative to an undisturbed watershed of similar size, geology, orientation, topography, and geography	Peak annual flows expected to be comparable to an undisturbed watershed of similar size, geology, orientation, topography, and geography	Peak annual flows expected to be moderately increased relative to an undisturbed watershed of similar size, geology, orientation, topography, and geography	Peak annual flows expected to be strongly increased relative to an undisturbed watershed of similar size, geology, orientation, topography, and geography

Alteration of Inter-annual Low Flow

The extent of relative change in average daily flow during the normal low flow period compared to an undisturbed watershed of comparable size, geology, and flow regime. Changes in the timing and quantity of flow due to land uses and flow regulation can affect responses of stream dwelling organisms like salmonids, leading to changes in overall performance of their populations (Poff et al. 1997; Bunn and Arthington 2002). This attribute does not address the effect of flow on channel width or other EDT attributes. The effect of low flow on minimum channel width is incorporated in the minimum width attribute.

Note that the ratings for this attribute do not follow the typical 0 (normative)-4 (highly altered) rating scheme of EDT attributes. Instead, a rating of 2 is the normative condition and 0 and 4 represent extreme deviations from normative.

Categorical rating definitions for Alteration of Low Flow in EDT

0 Rating	1 Rating	2 Rating	3 Rating	4 Rating
Average daily low flows expected to be strongly increased compared to an undisturbed watershed of similar size, geology, and flow regime	Average daily low flows expected to be moderately increased compared to an undisturbed watershed of similar size, geology, and flow regime	Average daily low flows expected to be comparable to an undisturbed watershed of similar size, geology, and flow regime	Average daily low flows expected to be moderately reduced compared to an undisturbed watershed of similar size, geology, and flow regime	Average daily low flows expected to be severely reduced compared to an undisturbed watershed of similar size, geology, and flow regime

Intra-Annual Flow Pattern (Flashiness)

The average extent of intra-annual flow variation during the primary runoff season – in other words, the attribute is a measure of a stream's "flashiness" during storm runoff. Flashiness is correlated with percent total impervious area and road density, but is attenuated as drainage area increases. Flashiness often leads to habitat alteration and loss of species in urbanized systems especially (Booth et al. 2001).

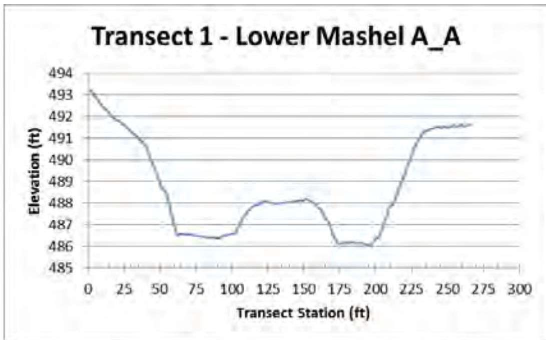
Note that the ratings for this attribute do not follow the typical 0 (normative)-4 (highly altered) rating scheme of EDT attributes. Instead, a rating of 2 is the normative condition and 0 and 4 represent extreme deviations from normative. Ratings greater than 2 characterize systems with high levels of impervious surfaces (urbanized).

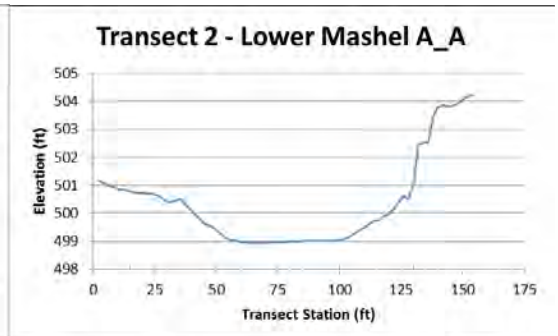
Categorical rating definitions for Intra-Annual Flow Pattern in EDT

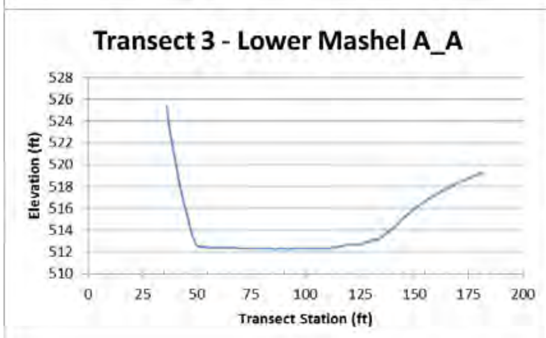
0 Rating	1 Rating	2 Rating	3 Rating	4 Rating
Storm runoff response (rates of change in flow) expected to be slowed greatly	Storm runoff response (rates of change in flow) expected to be moderately	Storm runoff response (rates of change in flow) comparable to an undisturbed	Storm runoff response (rates of change in flow) expected to be moderately	Storm runoff response (rates of change in flow) expected to be strongly

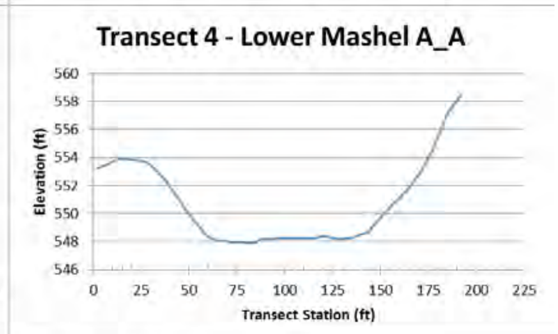
relative to an undisturbed watershed of similar size, geology, orientation, topography, and geography	slowed relative to an undisturbed watershed of similar size, geology, orientation, topography, and geography	watershed of similar size, geology, orientation, topography, and geography	increased relative to an undisturbed watershed of similar size, geology, orientation, topography, and geography	increased relative to an undisturbed watershed of similar size, geology, orientation, topography, and geography

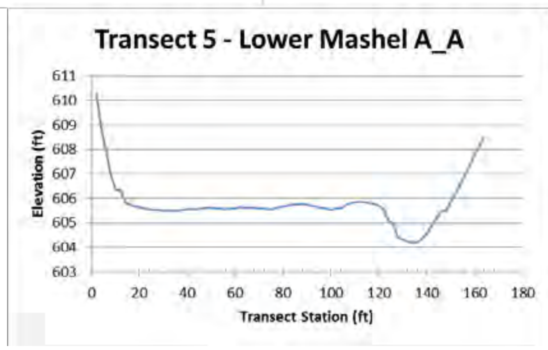
Appendix C.2 – Mashel Channel Profiles

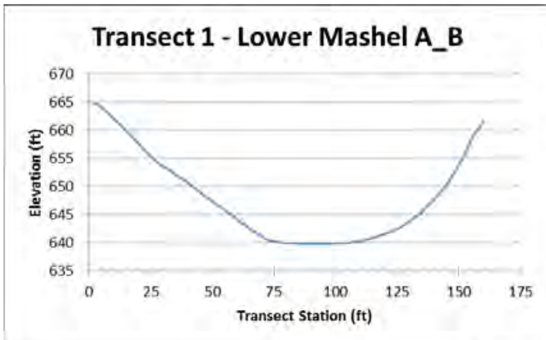


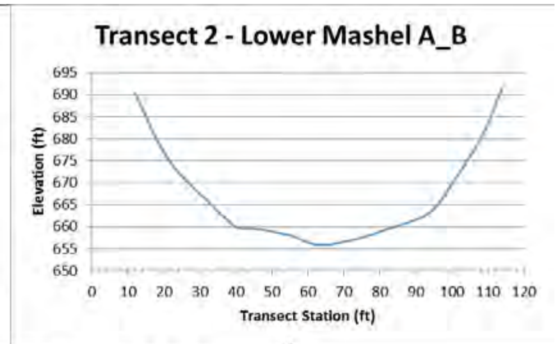


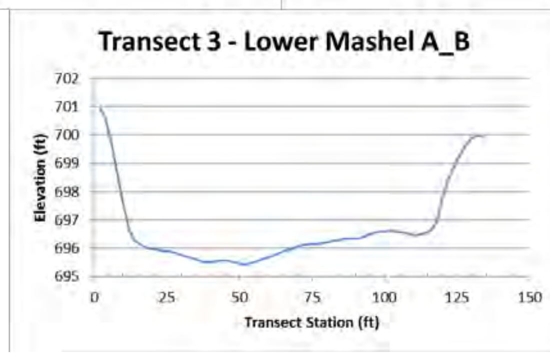


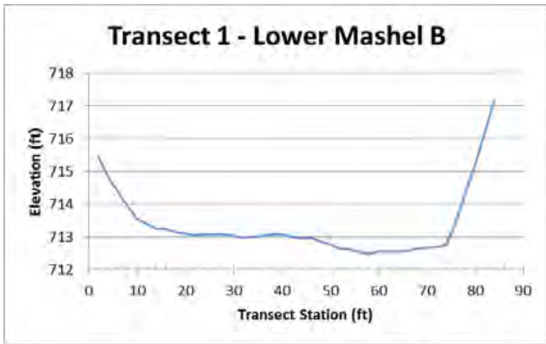


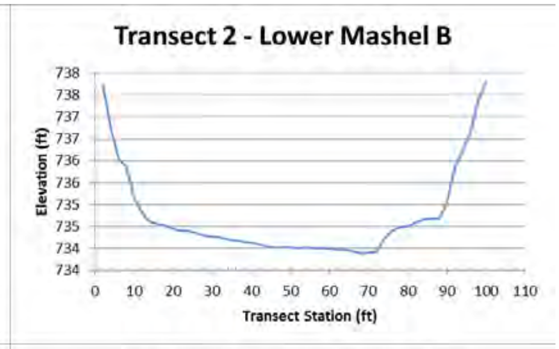


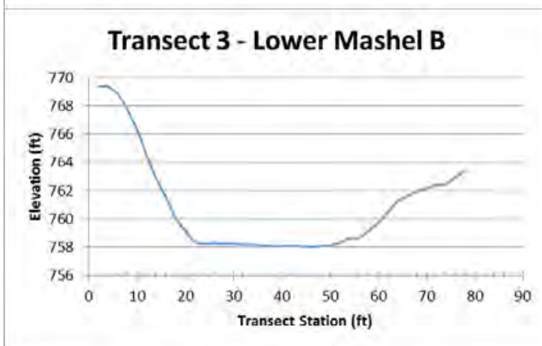

Transect 1 - Lower Mashel A_B
Elevation (ft)
670
665
660
655
650
645
640
635
0
25
50
75
100
125
150
175
Transect Station (ft)

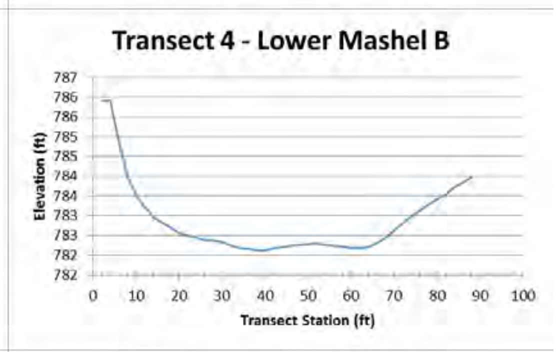

Transect 2 - Lower Mashel A_B
Elevation (ft)
695
690
685
680
675
670
665
660
655
650
0
10
20
30
40
50
60
70
80
90
100
110
120
Transect Station (ft)

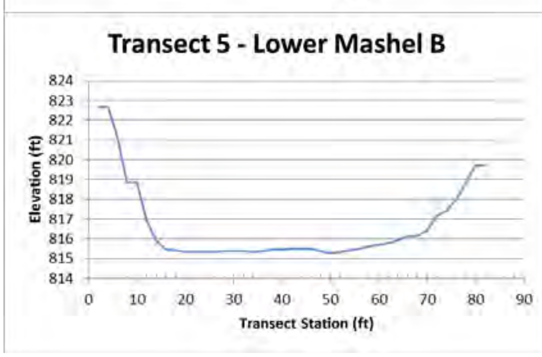

Transect 3 - Lower Mashel A_B
Elevation (ft)
702
701
700
699
698
697
696
695
0
25
50
75
100
125
150
Transect Station (ft)

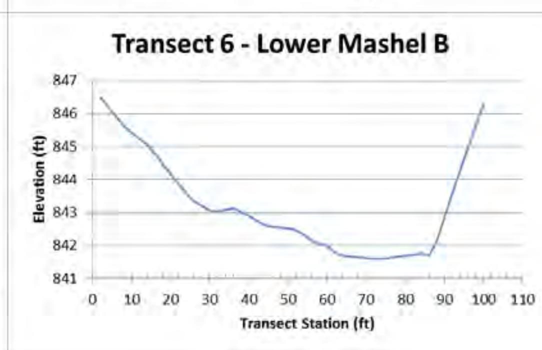

Transect 1 - Lower Mashel B
718
717
716
715
714
713
712
Elevation (ft)
0 10 20 30 40 50 60 70 80 90
Transect Station (ft)

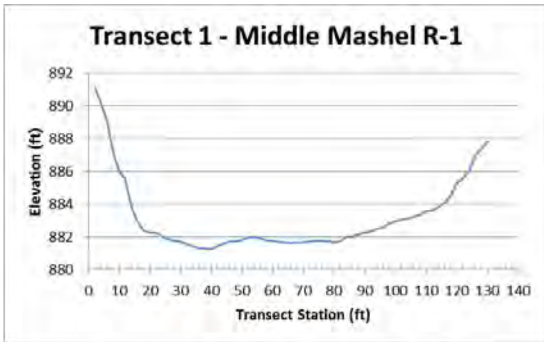

Transect 2 - Lower Mashel B
738
738
737
737
736
736
735
735
734
734
Elevation (ft)
0 10 20 30 40 50 60 70 80 90 100 110
Transect Station (ft)

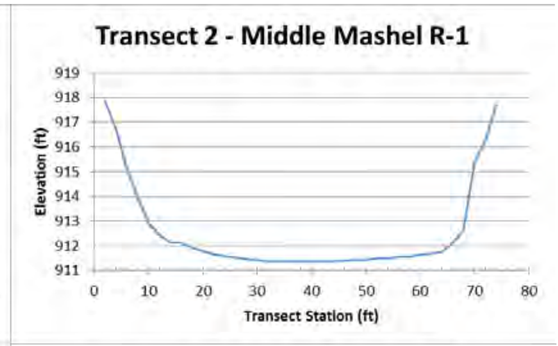

Transect 3 - Lower Mashel B
770
768
766
764
762
760
758
756
Elevation (ft)
0 10 20 30 40 50 60 70 80 90
Transect Station (ft)

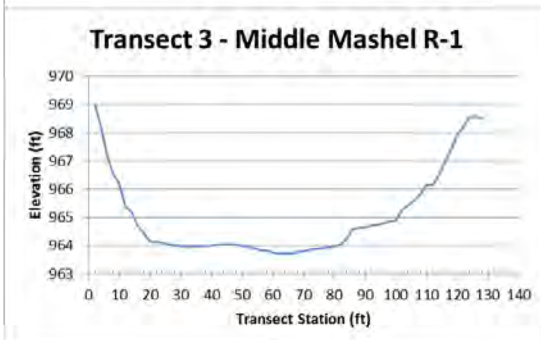

Transect 4 - Lower Mashel B
787
786
786
785
785
784
784
783
783
782
782
Elevation (ft)
0 10 20 30 40 50 60 70 80 90 100
Transect Station (ft)

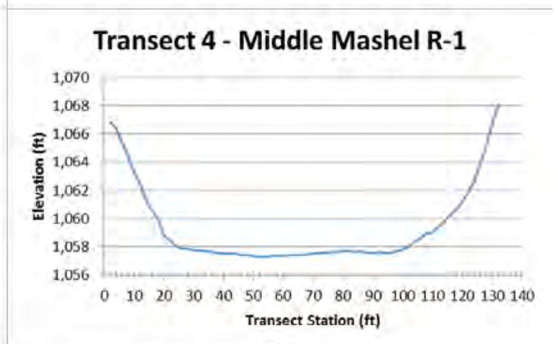

Transect 5 - Lower Mashel B
824
823
822
821
820
819
818
817
816
815
814
Elevation (ft)
0 10 20 30 40 50 60 70 80 90
Transect Station (ft)

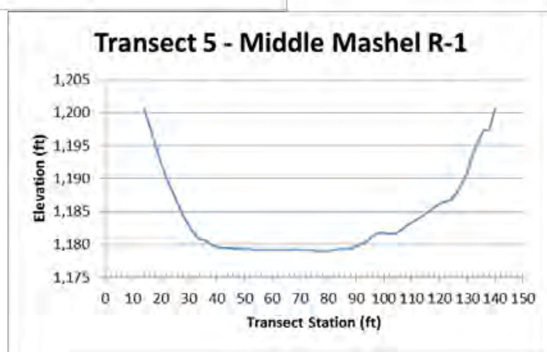

Transect 6 - Lower Mashel B
847
846
845
844
843
842
841
Elevation (ft)
0 10 20 30 40 50 60 70 80 90 100 110
Transect Station (ft)

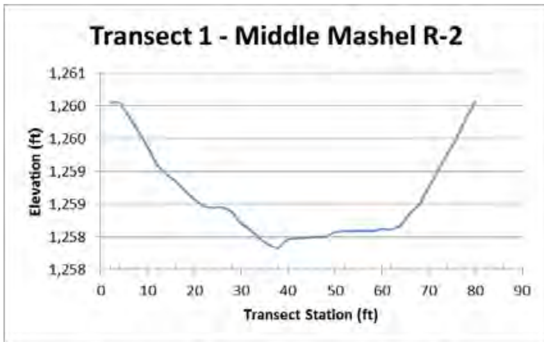

Transect 1 - Middle Mashel R-1
Elevation (ft)
Transect Station (ft)

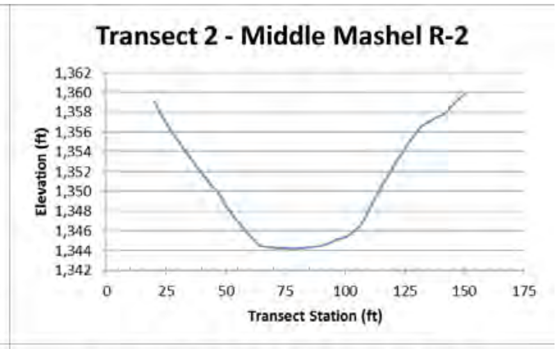

Transect 2 - Middle Mashel R-1
Elevation (ft)
Transect Station (ft)

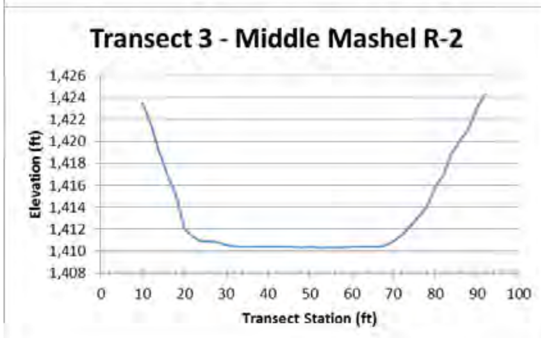

Transect 3 - Middle Mashel R-1
Elevation (ft)
Transect Station (ft)

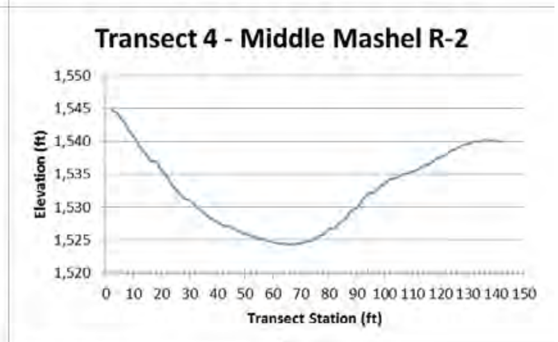

Transect 4 - Middle Mashel R-1
Elevation (ft)
Transect Station (ft)

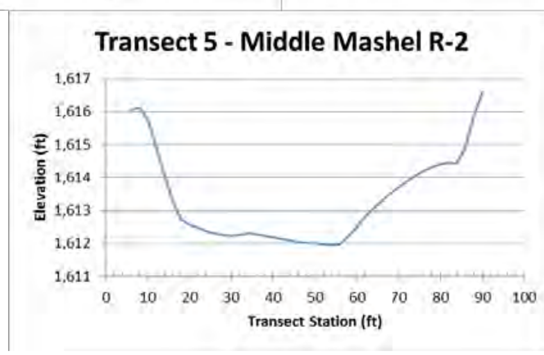

Transect 5 - Middle Mashel R-1
Elevation (ft)
Transect Station (ft)

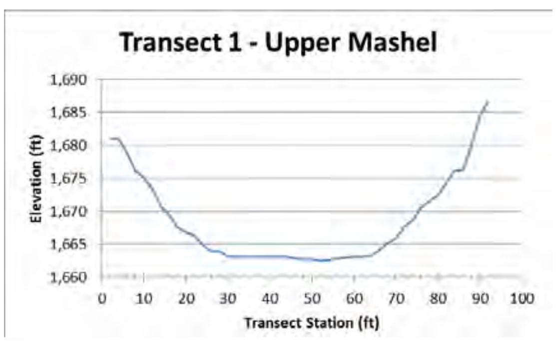

Transect 1 - Middle Mashel R-2
Elevation (ft)
Transect Station (ft)


Transect 2 - Middle Mashel R-2
Elevation (ft)
Transect Station (ft)

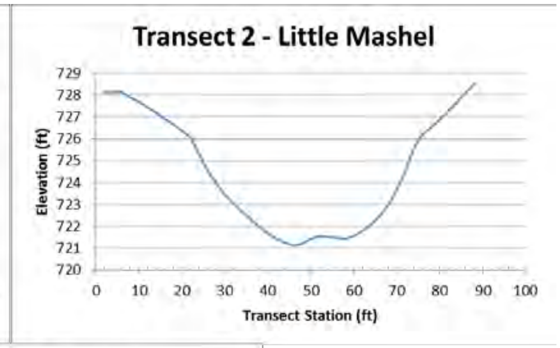

Transect 3 - Middle Mashel R-2
Elevation (ft)
Transect Station (ft)


Transect 4 - Middle Mashel R-2
Elevation (ft)
Transect Station (ft)

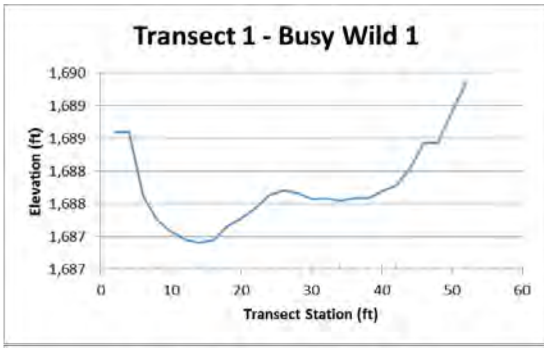

Transect 5 - Middle Mashel R-2
Elevation (ft)
Transect Station (ft)

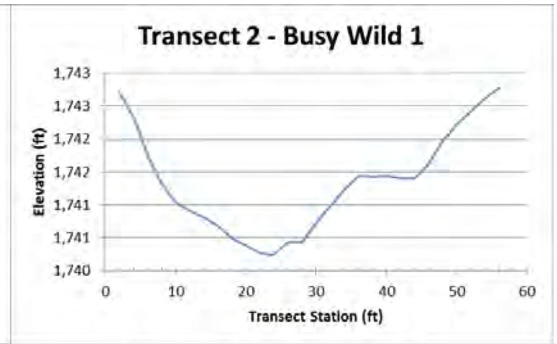

Transect 1 - Upper Mashel
Elevation (ft)
Transect Station (ft)

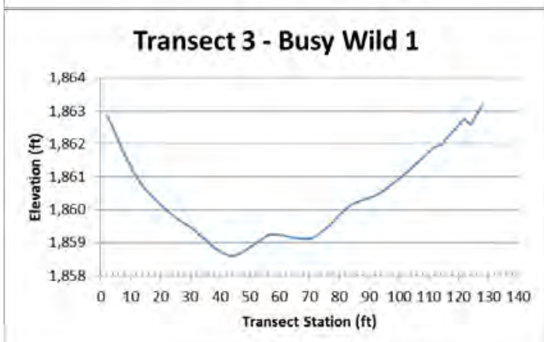

Transect 1 - Little Mashel
Elevation (ft)
713
713
712
712
711
711
710
710
709
0 10 20 30 40 50 60 70 80
Transect Station (ft)

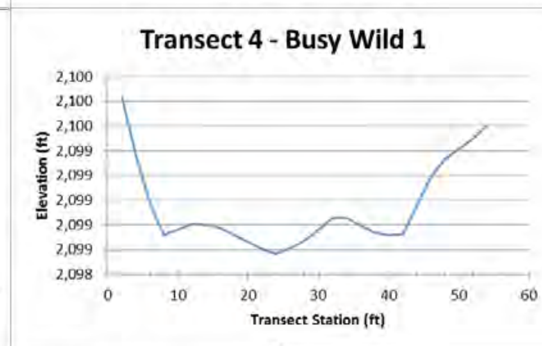

Transect 2 - Little Mashel
Elevation (ft)
729
728
727
726
725
724
723
722
721
720
0 10 20 30 40 50 60 70 80 90 100
Transect Station (ft)

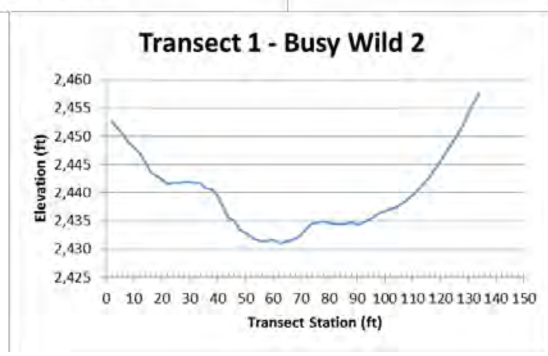

Transect 3 - Little Mashel
Elevation (ft)
734
734
734
734
734
734
733
0 10 20 30 40
Transect Station (ft)











End Appendix C.2

APPENDIX D.

Scaling up: Puget Sound science-governance partnerships for applying a coupled terrestrial-marine modeling framework to inform local to basin-scale ecosystem restoration planning.

Part 1 of 2: Abstract for the *2018 Salish Sea Ecosystem Conference, Seattle, WA*

Abstract for the Salish Sea Ecosystem Conference, April 4-6, 2018

AN INTEGRATED ENVIRONMENTAL AND HUMAN SYSTEMS MODELING FRAMEWORK FOR PUGET SOUND RESTORATION PLANNING

Robert McKane[1], Jonathan Halama[1], Paul Pettus[1], Bradley Barnhart[1], Allen Brookes[1], Kevin Djang[2], Tarang Khangoankar[3], Isaac Kaplan[4], Chris Harvey[4], Phillip Levin[5], Emily Howe[5], Michael Schmidt[6], Raphael Girardin[6]

[1]U.S. Environmental Protection Agency, Corvallis, OR; [2]CSRA, Corvallis; [3]Pacific Northwest National Laboratory, Seattle, WA; [4]National Oceanic and Atmospheric Administration, Seattle; [5]The Nature Conservancy, Seattle; [6]Long Live the Kings, Seattle

Local, state, federal, tribal and private stakeholders have committed significant resources to restoring Puget Sound's terrestrial-marine ecosystem. Though jurisdictional issues have promoted a fragmented approach to restoration planning, there is growing recognition that a more coordinated systems-based restoration approach is needed to achieve recovery goals. This presentation describes our collaborative effort to develop and apply an integrated environmental and human systems modeling framework for the Puget Sound Basin, inclusive of all marine and land areas (1,020 and 12,680 sq. mi.). Our goal is to establish a whole-basin systems modeling framework that dynamically simulates biophysical interactions and transfers (water, nutrients, contaminants, biota) across terrestrial-marine boundaries. The core environmental models include a terrestrial ecohydrological model (VELMA), an ocean circulation and biogeochemistry model (Salish Sea Model), and an ocean food web model (Atlantis). This environmental subsystem will be linked with an agent-based modeling subsystem (e.g., Envision) that allows human decision-makers to be represented in whole-basin simulations. The integrated environmental and human systems framework aims to facilitate discourse among different stakeholders and decision makers (agents) and enable them play out the ecological, social and economic consequences of alternative ecosystem restoration choices. All these models are currently being applied in Puget Sound, but they have not yet been integrated. The linked models will better capture the propagation of human impacts throughout the terrestrial-marine ecosystem, and thereby provide a more effective decision support tool for addressing restoration of high priority environmental endpoints, such as the Vital Signs identified by the Puget Sound Partnership (http://www.psp.wa.gov/vitalsigns/). Our overview will include examples of existing stand-alone model applications, and conceptual plans for linking models across terrestrial-marine boundaries. The Puget Sound multi-model framework described here can potentially be expanded to address the entire Salish Sea transboundary ecosystem (https://www.eopugetsound.org/maps/salish-sea-basin-and-water-boundaries).

(continued)

Part 2 of 2: Abstract for the *2018 A Community of Ecosystem Services (ACES) Conference, Washington DC* (http://www.conference.ifas.ufl.edu/aces/index.html)

A SCIENCE-GOVERNANCE PARTNERSHIP FOR INTEGRATING ECOSYSTEM SERVICES INTO PUGET SOUND RESTORATION PLANNING

Robert McKane[1], Brad Barnhart[1], Paul Pettus[1], Jonathan Halama[1], Allen Brookes[1], Kevin Djang[2], Tarang Khangoankar[3], Isaac Kaplan[4], Chris Harvey[4], Hem Nalini Morzaria Luna[4], Michael Schmidt[5], Emily Howe[6], Phillip Levin[6], Tessa Francis[7], Joel Baker[7], Stephen Stanley[8], Colin Hume[8]

[1]U.S. Environmental Protection Agency, Corvallis, OR, USA
[2] Inoventures LLC, Corvallis, OR, USA
[3]Pacific Northwest National Laboratory, Seattle, WA, USA
[4]NOAA Northwest Fisheries Science Center, Seattle, WA, USA
[5]Long Live the Kings, Seattle, WA, USA
[6]The Nature Conservancy, Seattle, USA
[7]University of Washington Puget Sound Institute, Tacoma, WA, USA
[8]Washington Department of Ecology, Lacey, WA, USA

Numerous studies have established that impacts from mounting population and climatic pressures are decreasing the capacity of coastal watersheds and estuaries to provide services essential to human health and well-being – clean drinking water, flood protection, habitat for fish and wildlife, and many other economic, social and health benefits (e.g., Barbier et al. 2011). The Puget Sound National Estuary in the State of Washington, USA, is one example of this global problem and search for solutions. Puget Sound communities, tribes, state and federal governments have committed substantial resources to restoring terrestrial and marine ecosystem services. However, jurisdictional barriers have often promoted a fragmented approach to restoration planning, and decision makers often do not have access to scientific information and tools for anticipating environmental, economic and social tradeoffs associated with different decision choices.

Here we describe an example of a Puget Sound science-governance partnership aimed at bringing together ecosystem scientists and restoration planners representing local communities and tribes. The goal of this partnership is to more tightly integrate ecosystem service concepts and modeling into estuarine and coastal watershed planning and management. Currently, local planners and managers face the difficult challenge of extrapolating impacts of their restoration actions over time and space and across jurisdictional boundaries. Similarly, ecosystem scientists find it difficult to accurately model large coastal watersheds such as Puget Sound (>31,000 km^2) without the detailed on-the-ground knowledge that local planners and managers possess. Therefore, our partnership seeks to integrate the expertise of both groups.

Together, we are using a state-of-the-art, coupled terrestrial-marine ecosystem modeling framework to help local planners visualize how effects of their decisions will propagate downstream with far reaching benefits and tradeoffs for terrestrial and marine ecosystem services. We will briefly describe this framework and examples of its ecosystem service applications within the Puget Sound ecosystem.

Appendix H

Eatonville Capital Improvement Projects and Aquifer Storage & Recovery Mitigation Memo

2200 6th Avenue, Suite 707
Seattle, WA 98121
Telephone: 206-443-7646
www.eaest.com

Streamflow Mitigation resulting from the Town of Eatonville's Projects

Background

Several Salmon Enhancement projects in WRIA 11 have successfully improved instream habitat and riparian corridors using a variety of methods. More such projects are planned in WRIA 11, and the same methods may be applicable in other sub-basins in WRIA 11. In addition to numerous quantifiable benefits for salmonids and riparian corridor habitat, several of these methods may also directly provide additional streamflow.

The Town of Eatonville has identified six priority Capital Improvement Projects (CIP) projects that are intended to help mitigate identified stormwater management issues. These CIP projects can also provide mitigation for permit-exempt water withdrawals by improving instream habitat during the dryer part of the year (May – September) which corresponds to lower flows in the Mashel River and Ohop Creek. Projects include infiltrating stormwater that would otherwise contribute to runoff during, and soon after precipitation events. Because infiltrated water can contribute to baseflow several months after infiltration, the CIP projects described below are likely to increase baseflow discharge to streams during the dry season.

Although the projects reduce flows during the wet part of the year when flow is not a limiting factor, they also increase flows later during the dry time of the year when flows are limiting. Because there is not year-round mitigation, the projects are considered lower priority water offset projects, per Ecology's Interim Guidance for Determining Net Ecological Benefit, Publication 18-11-009. However, trading a small portion of streamflow during the wet season for a much larger portion of streamflow in the dry season provides substantial net ecological benefits to instream resources.

The CIP projects analysis focuses on quantifying infiltration of stormwater between October and April when approximately 80% of the 43.63 inches of annual precipitation occurs in Eatonville (Intellicast) and estimating the increase in discharge to baseflow resulting from that recharge between May and September, assuming no infiltration during that time.

Monthly precipitation, mean monthly discharge at USGS gage 12087000 and instream flows from Chapter 173-511 WAC are shown in Figure 1. Although infiltration of stormwater can occur during any precipitation event that generates runoff, focusing on the period between October and April for recharge and discharge between May and September captures most of the precipitation and identifies the benefits during the naturally lower flow time of the year. Because approximately 20 % of annual precipitation occurs between April and October, some infiltration of stormwater is likely to occur during this time. Because these events would contribute to increased baseflow, this analysis is relatively conservative.

The Town of Eatonville has also evaluated the potential for aquifer storage and recovery (ASR). The project is intended to increase flow during the low-flow period in the Mashel River, while protecting the ability of the Town to have a secure water supply to meet existing and projected water demands. The project would include diversion of water using the Town's existing sources between November and May

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www.eaest.com

when instream flows are met, storage in an aquifer, and then recovery of the stored groundwater in the summer months to decrease reliance on the Town's surface water sources. Additional information regarding ASR is provided later in this memo.

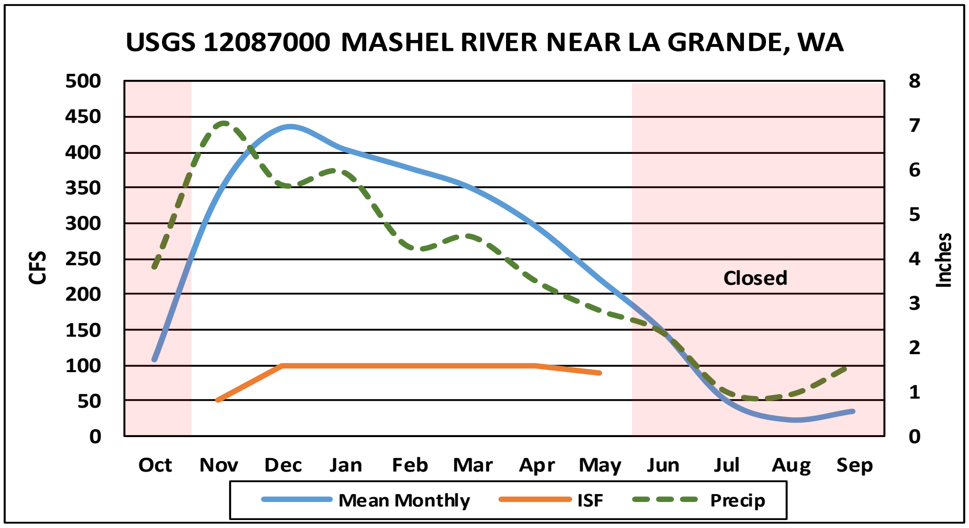

Figure 1 – Monthly Precipitation, Mean Monthly Flows, and Instream Flows

Evaluation of Streamflow Benefits from Eatonville Stormwater CIP Projects

Figure 2 presents the locations of the six priority CIP projects, which are briefly described below.

- CIP # 1 - Bioretention Trench East of Madison Avenue South (B on Figure 2)
  This project will provide water quality treatment of half of the stormwater from Madison Avenue South and infiltration in a 400 foot bioretention swale along Madison Avenue.

- CIP # 2 - Infiltration Pond at Sewage Lagoon (I on Figure 2)
  This project will provide water quality pretreatment and infiltration through a 200 foot bioretention swale before discharging into an infiltration pond constructed by modifying the existing sewage lagoon.

- CIP # 3 - Green Street and Bioretention Trench on Center Street #1 (E on Figure 2)
  This project will provide water quality treatment and infiltration of half of the stormwater from Center Street between Antonie Avenue North and Cedar Avenue North through a 400 foot bioretention swale along the roadside.

- CIP # 4 - Green Street and Bioretention Trench on Center Street #2 (J on Figure 2)
  This project will provide water quality treatment and infiltration along 800 feet of bioretention swale.

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- CIP # 5 - Drywell at Rainier Avenue South (H on Figure 2)
  This project consists of construction of a 72-inch diameter, 6-foot deep drywell for stormwater infiltration.

- CIP # 6 - Green Street and Bioretention Trench at Pennsylvania Avenue North (M on Figure 2)
  This project provides water quality treatment and infiltration of half of the stormwater from Pennsylvania Avenue North through a 400 foot roadside bioretention swale.

Subbasin attributes, such as basin area, runoff curve numbers, and the estimated reduction in runoff resulting from CIP implementation were obtained from the 2013 Eatonville Stormwater Management Plan. This information was used to calculate runoff and the rate and volume of water that could be available for infiltration between October and April, after implementation of the CIPs. This information is summarized for each priority CIP in Table 1.

The groundwater basin (Lynch Creek/Ohop Creek or Mashel River the CIP is in is based on a 2013 Technical Memorandum assessing the potential infiltration suitability within the Town of Eatonville, prepared by Golder Associates (Appendix C, 2013 Eatonville Stormwater Management Plan). Golder's memorandum concludes that shallow groundwater flows toward both Lynch/Ohop Creeks and the Mashel River, with a groundwater divide in Central Eatonville. Golder also characterized infiltration potential of surface soils, with the Barneston gravelly coarse loamy sand, the Everett Gravelly sandy loan, the Indianola Loamy sand, and the Ragnar sandy loam having the highest potential for infiltration. All six of the priority CIPs are in areas with the highest potential for infiltration.

Priority CIP	Letter	Subbasins	Acres	GW Basin	Distance to Stream (Feet)	Impervious Area	Volume Precip/year (AF)	Composite CN[1]	Ave Runoff Oct-Apr (CFS)	Ave Flow Reduction with LID[2]	Flow Reduction with LID (CFS)
1	B	22,23	32.54	Mashel	1750	81%	118.31	94	0.211	60%	0.127
2	I	19,20,24	22.85	Mashel	710	75%	83.08	95.75	0.151	5%	0.008
3	E	5	25.21	Ohop	3900	65%	91.66	93	0.162	25%	0.040
4	J	2,5,6,7,8,9,10	76.31	Ohop	4500	63%	277.45	93	0.490	16%	0.080
5	H	13, 1217	21.01	GW Divide	2750	78%	76.39	94.5	0.137	23%	0.031
6	M	6,7	15.45	GW Divide	4500	65%	56.17	93	0.099	22%	0.022

[1] Appendix B2, 2013 Eatonville Stormwater Management Plan
[2] Apprendix E, 2013 Eatonville Stormwater Management Plan

Table 1 – Basin Attributes Used to Estimate Stormwater Runoff and Water Available for Infiltration

The flow reduction value in the last column was used as the infiltration rate for each CIP. This value was calculated using the area of each subbasin, average precipitation between October and April, runoff curve numbers, and the estimated reduction on stormwater runoff after implementation of the CIPs. It represents an average value over the seven-month period rather than a value associated with a precipitation event.

The infiltration rate was used to calculate increased discharge to the nearest steam using the USGS program STRMDEPL08. STRMDEPL08 uses analytical solutions to estimate streamflow depletion by a pumping well. Because artificial recharge will have an equal and opposite effect on a stream as pumping, the program can also be used to estimate the amount of increased discharge resulting from infiltration.

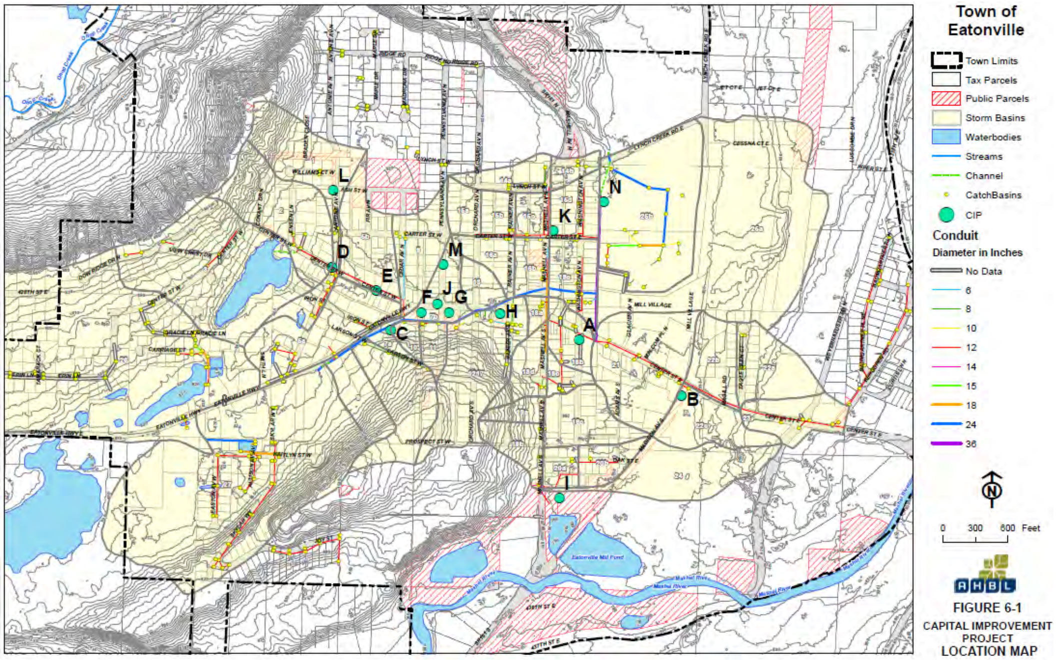

Figure 2 – Capital Improvement Project Location Map (2013 Eatonville Stormwater Management Plan)

STRMDEPL08 includes an analytical solution (Hunt, 1999) for impacts on a stream that is partially penetrating an aquifer. The Eatonville groundwater storage evaluation report (Golder, 2010) includes descriptions, characteristics, maps and cross sections of the hydrogeologic units near the Town of Eatonville. This report indicates surficial glacial material extending to both Ohop Creek and the Mashel River. Transmissivity and Storage Coefficient values for the Alluvial Aquifer from the Golder report were used for this analysis.

Golder estimated transmissivity values between 10,000 and 40,000 ft^2/day and storage coefficient values between 0.1 and 10. A transmissivity value of 25,000 ft^2/day and a storage coefficient value of 1 were used for the analysis. Other input parameters include distance to the stream, streambed conductance, and number of days to run the analysis. An average value of .0021 ft/sec was selected for streambed conductance. The distance to the stream was measured on maps in the Stormwater Management Plan and the program was run for 20 years.

The program can be run on a daily time step. The calculated infiltration rate for each CIP was used each day between October and April with no infiltration occurring between May and September. Impacts to the stream are also calculated daily over a 20-year period. Results for each CIP are shown in Figures 3-14 and summarized in Tables 2-7. Average CFS represents the average contribution to baseflow resulting from infiltration between May and September. Acre-Feet represents the volume of baseflow discharged each year. Percent Recharge Rate represents a ratio between the increase in baseflow discharge vs. the infiltration rate at each CIP.

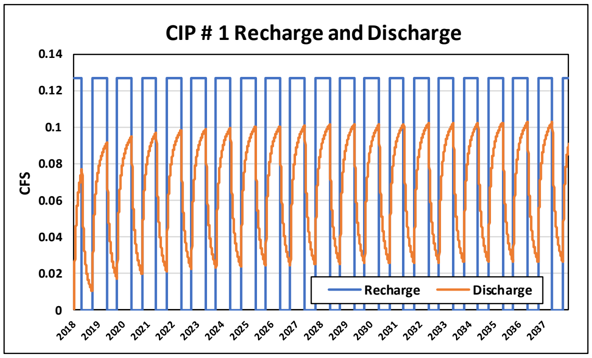

Figure 3 – Daily Recharge and Discharge at CIP #1

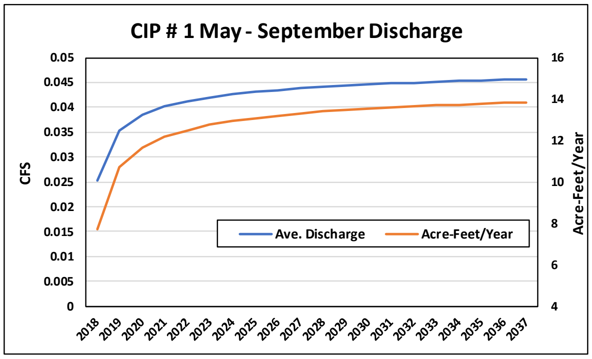

Figure 4 – May - September Discharge at CIP #1

CIP #1 Madison Avenue Bioretention			
Year	**Average CFS**	**Acre Feet**	**% Recharge Rate**
2018	0.025	7.699	20%
2019	0.035	10.691	28%
2020	0.038	11.655	30%
2021	0.040	12.164	32%
2022	0.041	12.500	32%
2023	0.042	12.742	33%
2024	0.043	12.938	34%
2025	0.043	13.079	34%
2026	0.043	13.197	34%
2027	0.044	13.299	35%
2028	0.044	13.396	35%
2029	0.044	13.462	35%
2030	0.045	13.527	35%
2031	0.045	13.585	35%
2032	0.045	13.649	35%
2033	0.045	13.689	36%
2034	0.045	13.731	36%
2035	0.045	13.769	36%
2036	0.046	13.816	36%
2037	0.046	13.843	36%

Table 2 – Summary of Streamflow Benefits from CIP #1

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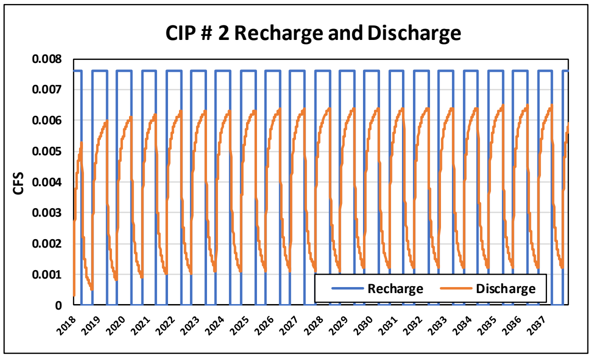

Figure 5 – Daily Recharge and Discharge at CIP #2

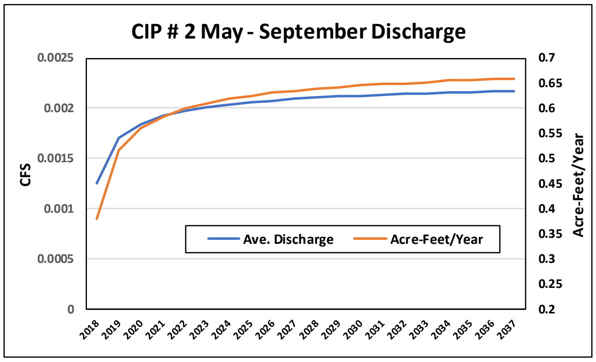

Figure 6 – May - September Discharge at CIP #2

CIP #2 Infiltration Pond			
Year	**Average CFS**	**Acre Feet**	**% Recharge Rate**
2018	0.001	0.379	16%
2019	0.002	0.517	22%
2020	0.002	0.560	24%
2021	0.002	0.583	25%
2022	0.002	0.599	26%
2023	0.002	0.610	26%
2024	0.002	0.618	27%
2025	0.002	0.625	27%
2026	0.002	0.630	27%
2027	0.002	0.635	28%
2028	0.002	0.639	28%
2029	0.002	0.642	28%
2030	0.002	0.645	28%
2031	0.002	0.648	28%
2032	0.002	0.650	28%
2033	0.002	0.652	28%
2034	0.002	0.655	28%
2035	0.002	0.656	28%
2036	0.002	0.658	29%
2037	0.002	0.659	29%

Table 3 – Summary of Streamflow Benefits from CIP #2

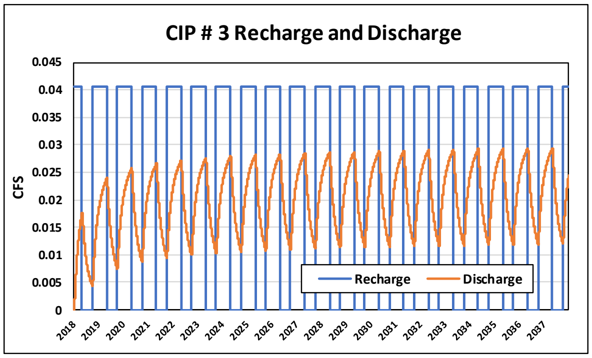

Figure 7 – Daily Recharge and Discharge at CIP #3

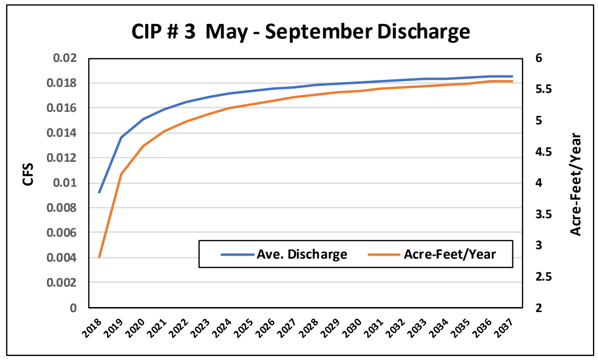

Figure 8 – May - September Discharge at CIP #3

CIP #3 Green & Center St. #1 Bioretenion			
Year	**Average CFS**	**Acre Feet**	**% Recharge Rate**
2018	0.009	2.801	23%
2019	0.014	4.139	34%
2020	0.015	4.589	37%
2021	0.016	4.831	39%
2022	0.016	4.988	41%
2023	0.017	5.104	42%
2024	0.017	5.197	42%
2025	0.017	5.263	43%
2026	0.018	5.321	43%
2027	0.018	5.369	44%
2028	0.018	5.415	44%
2029	0.018	5.448	44%
2030	0.018	5.479	45%
2031	0.018	5.507	45%
2032	0.018	5.537	45%
2033	0.018	5.557	45%
2034	0.018	5.576	45%
2035	0.018	5.595	46%
2036	0.019	5.618	46%
2037	0.019	5.629	46%

Table 4 – Summary of Streamflow Benefits from CIP #3

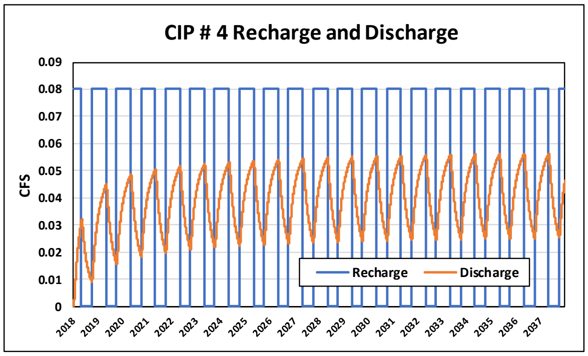

Figure 9 – Daily Recharge and Discharge at CIP #4

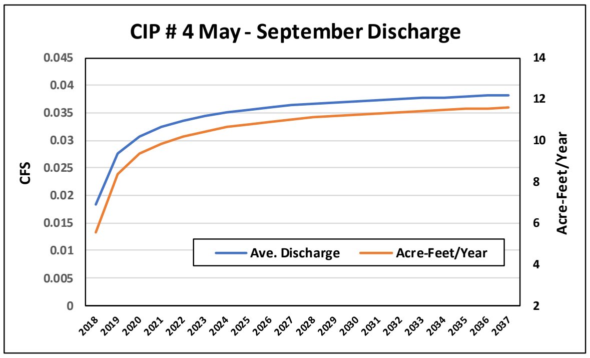

Figure 10 – May - September Discharge at CIP #4

CIP #4 Green & Center St. #2 Bioretenion			
Year	**Average CFS**	**Acre Feet**	**% Recharge Rate**
2018	0.018	5.547	23%
2019	0.028	8.367	34%
2020	0.031	9.331	38%
2021	0.032	9.849	40%
2022	0.034	10.194	42%
2023	0.034	10.441	43%
2024	0.035	10.642	44%
2025	0.036	10.786	44%
2026	0.036	10.909	45%
2027	0.036	11.016	45%
2028	0.037	11.114	46%
2029	0.037	11.184	46%
2030	0.037	11.252	46%
2031	0.037	11.312	46%
2032	0.037	11.376	47%
2033	0.038	11.420	47%
2034	0.038	11.462	47%
2035	0.038	11.502	47%
2036	0.038	11.550	47%
2037	0.038	11.578	48%

Table 5 – Summary of Streamflow Benefits from CIP #4

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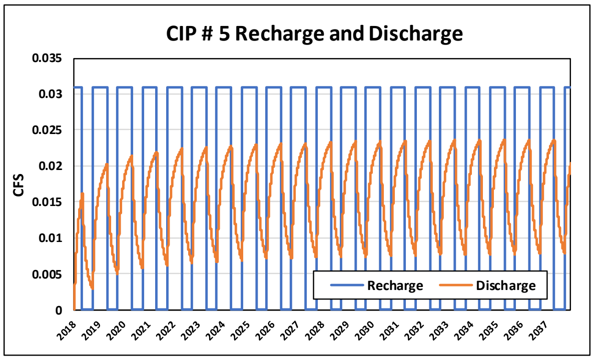

Figure 11 – Daily Recharge and Discharge at CIP #5

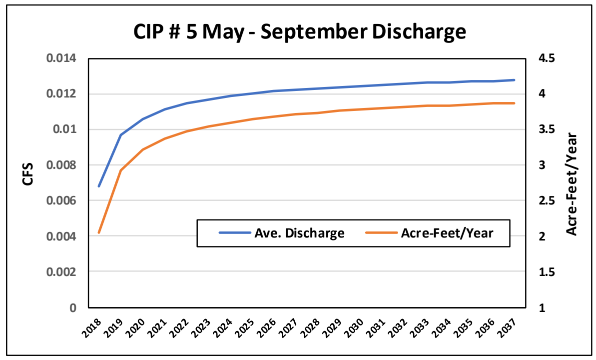

Figure 12 – May - September Discharge at CIP #5

CIP #5 Drywell at Rainier Avenue South			
Year	**Average CFS**	**Acre Feet**	**% Recharge Rate**
2018	0.007	2.055	22%
2019	0.010	2.929	31%
2020	0.011	3.215	34%
2021	0.011	3.368	36%
2022	0.011	3.468	37%
2023	0.012	3.540	38%
2024	0.012	3.598	38%
2025	0.012	3.641	39%
2026	0.012	3.677	39%
2027	0.012	3.707	40%
2028	0.012	3.736	40%
2029	0.012	3.757	40%
2030	0.012	3.775	40%
2031	0.013	3.794	40%
2032	0.013	3.812	41%
2033	0.013	3.825	41%
2034	0.013	3.836	41%
2035	0.013	3.849	41%
2036	0.013	3.861	41%
2037	0.013	3.870	41%

Table 6 – Summary of Streamflow Benefits from CIP #5

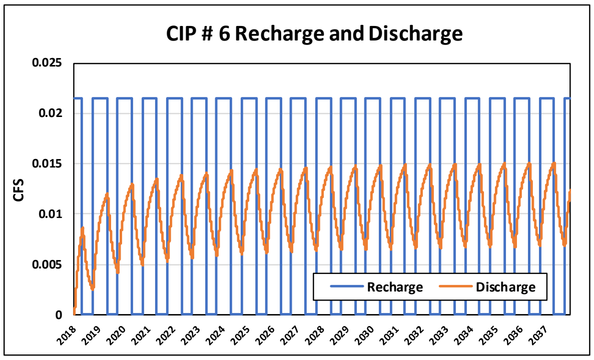

Figure 13 – Daily Recharge and Discharge at CIP #6

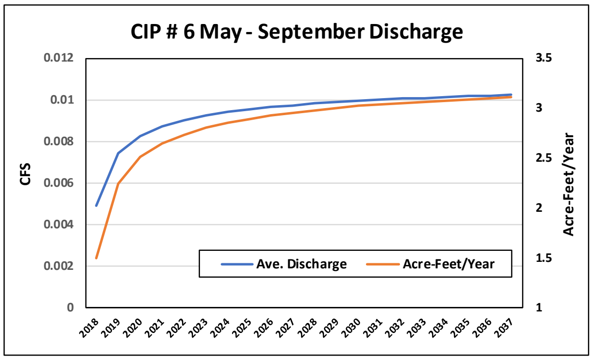

Figure 14 – May - September Discharge at CIP #6

CIP #6 Green St & Pensylvania Ave Bioretenion			
Year	**Average CFS**	**Acre Feet**	**% Recharge Rate**
2018	0.005	1.487	23%
2019	0.007	2.242	34%
2020	0.008	2.502	38%
2021	0.009	2.641	40%
2022	0.009	2.732	42%
2023	0.009	2.798	43%
2024	0.009	2.852	44%
2025	0.010	2.891	44%
2026	0.010	2.925	45%
2027	0.010	2.953	45%
2028	0.010	2.979	46%
2029	0.010	2.998	46%
2030	0.010	3.018	46%
2031	0.010	3.033	46%
2032	0.010	3.050	47%
2033	0.010	3.061	47%
2034	0.010	3.073	47%
2035	0.010	3.083	47%
2036	0.010	3.095	47%
2037	0.010	3.104	48%

Table 7 – Summary of Streamflow Benefits from CIP #6

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As shown in the recharge-discharge graphs, modeled discharge to the stream begins to increase each year almost immediately after recharge begins and continues to increase until the recharge period ends when it begins to drop off. Discharge continues to decline through the non-recharge months until the next recharge cycle begins. The amount of discharge increases over time, reaching close to a constant annual cycle near the end of the 20-year modeled period.

As shown in Tables 3-7, discharge rates and volumes in the low-flow season increase each year. Also noted in the table is the percentage of the recharge rate that discharges during between May and September. These values could be used to estimate benefits when actual infiltration rates are known as the relative results are not dependent on the recharge rate. It should also be noted that the lowest modeled percentage of recharge is at CP #2, reaching a maximum of 29% after 20 years. CP #2 is the closest site to a stream. Therefore, discharge occurs more immediately than at more distant locations. In addition, the relative annual fluctuation in discharge is greater at CP #2 and CP #1 because they are closer to the stream and discharge is more immediate closer to the stream. As such, sites further from the streams around the center of Eatonville may be more beneficial to the streams during the low flow months.

Although shallow groundwater flow directions in the center of the Town of Eatonville are not well-defined, infiltration sites in the center and southern part of town are likely to mostly benefit the Mashel River. Sites in the northern half of town are more likely to benefit Lynch and Ohop Creeks. Therefore, implementation of the six priority CIPs could benefit both the Ohop and Mashel subbasins as well as downstream in the Nisqually River. Additional benefits include improvements in water quality discharging to streams. The total benefit of all six priority CIP projects combined in presented in Table 8.

	CIP # 1		CIP # 2		CIP # 3		CIP # 4		CIP # 5		CIP # 6		Total	
Year	Average CFS	Acre Feet	Average CFS	Acre Feet	Average CFS	Acre Feet	Average CFS	Acre Feet	Average CFS	Acre Feet	Average CFS	Acre Feet	Average CFS	Acre Feet
2018	0.025	7.699	0.001	0.379	0.009	2.801	0.018	5.547	0.007	2.055	0.005	1.487	0.066	19.969
2019	0.035	10.691	0.002	0.517	0.014	4.139	0.028	8.367	0.010	2.929	0.007	2.242	0.095	28.885
2020	0.038	11.655	0.002	0.560	0.015	4.589	0.031	9.331	0.011	3.215	0.008	2.502	0.105	31.852
2021	0.040	12.164	0.002	0.583	0.016	4.831	0.032	9.849	0.011	3.368	0.009	2.641	0.110	33.435
2022	0.041	12.500	0.002	0.599	0.016	4.988	0.034	10.194	0.011	3.468	0.009	2.732	0.114	34.480
2023	0.042	12.742	0.002	0.610	0.017	5.104	0.034	10.441	0.012	3.540	0.009	2.798	0.116	35.235
2024	0.043	12.938	0.002	0.618	0.017	5.197	0.035	10.642	0.012	3.598	0.009	2.852	0.118	35.845
2025	0.043	13.079	0.002	0.625	0.017	5.263	0.036	10.786	0.012	3.641	0.010	2.891	0.120	36.285
2026	0.043	13.197	0.002	0.630	0.018	5.321	0.036	10.909	0.012	3.677	0.010	2.925	0.121	36.660
2027	0.044	13.299	0.002	0.635	0.018	5.369	0.036	11.016	0.012	3.707	0.010	2.953	0.122	36.978
2028	0.044	13.396	0.002	0.639	0.018	5.415	0.037	11.114	0.012	3.736	0.010	2.979	0.123	37.280
2029	0.044	13.462	0.002	0.642	0.018	5.448	0.037	11.184	0.012	3.757	0.010	2.998	0.124	37.492
2030	0.045	13.527	0.002	0.645	0.018	5.479	0.037	11.252	0.012	3.775	0.010	3.018	0.124	37.695
2031	0.045	13.585	0.002	0.648	0.018	5.507	0.037	11.312	0.013	3.794	0.010	3.033	0.125	37.878
2032	0.045	13.649	0.002	0.650	0.018	5.537	0.037	11.376	0.013	3.812	0.010	3.050	0.125	38.074
2033	0.045	13.689	0.002	0.652	0.018	5.557	0.038	11.420	0.013	3.825	0.010	3.061	0.126	38.205
2034	0.045	13.731	0.002	0.655	0.018	5.576	0.038	11.462	0.013	3.836	0.010	3.073	0.126	38.332
2035	0.045	13.769	0.002	0.656	0.018	5.595	0.038	11.502	0.013	3.849	0.010	3.083	0.127	38.453
2036	0.046	13.816	0.002	0.658	0.019	5.618	0.038	11.550	0.013	3.861	0.010	3.095	0.127	38.599
2037	0.046	13.843	0.002	0.659	0.019	5.629	0.038	11.578	0.013	3.870	0.010	3.104	0.127	38.683

Table 8 – Summary of Streamflow Benefits from all CIP Projects

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Uncertainties and Limitations

The above analysis was performed using data in previous reports and average values of aquifer parameters, precipitation, and estimates of runoff. The analytical tool used to calculate timing and benefits to baseflow is a generalization and does not account for natural variation in soils and aquifer materials, groundwater pumping, individual storm events, or annual climatic variability that could result in a wide range in the volume of infiltration and the timing of benefits to streams. The constant infiltration rates used are based on monthly precipitation averages and an estimate of runoff reductions resulting from implementation of CIP projects. Changes in permeability of infiltration sites over time and water lost to evapotranspiration was not considered.

The distance from the infiltrations sites to the streams is based on a straight line to the closest segment of stream and does not consider changes in groundwater flow directions or down-gradient discharge. Groundwater level data near the Mashel River suggests the river is more frequently a losing reach, suggesting that baseflow discharge may be more likely to occur at a downstream location.

Aquifer Storage and Recovery (ASR)

The Town of Eatonville completed a preliminary evaluation of ASR in 2010 (Golder, 2010). This assessment included evaluation of all potential aquifers near Eatonville for their potential use for groundwater storage. The volcanic aquifer, composed of basalt was determined to exhibit the best potential for groundwater storage, due in part to its limited hydraulic connection with the Mashel River as well as its proximity to Eatonville's water system infrastructure. The volcanic aquifer may also be capable of storing enough water to meet the Town's increasing water system demands.

Because the Mashel River is closed by Chapter 173-511 WAC from June through October, capturing and storing water between November and May to supplement use in the summer months may be the best option for obtaining new water rights for the Town of Eatonville. Golder estimated that the volcanic aquifer may be capable of storing between 20 and 80 acre-feet of water. Capture and storage of 20 to 80 acre-feet would reduce winter flows in the Mashel River between 0.07 and 0.25 cfs. Withdrawal of stored groundwater in the summer months, in lieu exercising Eatonville's surface water rights, is estimated to increase summer flows in the Mashel River between 0.11 and 0.45 cfs.

Uncertainties regarding the volcanic aquifer's hydraulic properties, ability to store water, and water quality issues may make ASR infeasible. However, ASR is a potential WRIA 11, summer mitigation option that can increase water supplies for the Town of Eatonville while benefitting instream resources.

Summary

The Town of Eatonville has investigated several actions and opportunities to address stormwater management issues and provide a secure water source to meet future demands these potential actions could also provide mitigation for consumptive use in the Mashel River and Ohop Creek subbasins, as well as downstream reaches.

The rate and volume of mitigation water potentially available from Eatonville's projects after 20 years of implementation is summarized in Table 9.

Action	CFS	Acre-Feet/Year
CIP #1	0.046	13.843
CIP #2	0.002	0.659
CIP #3	0.019	5.629
CIP #4	0.038	11.578
CIP #5	0.013	3.870
CIP #6	0.010	3.104
ASR	0.11 - 0.45	20 - 80
Total	**0.238 - 0.578**	**58.683 - 118.683**

Table 9 – Summary of Eatonville's Potential Mitigation Quantities

Appendix I

Eatonville Water Conservation Memo

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Water Conservation in the Town of Eatonville

Background

Thurston County directed EA to review Eatonville's 2012 Alternative Water Source Investigation Report by RH2 regarding potential water conservation in Eatonville in order to quantify potential mitigation benefits to the Mashel River. The following is a summary of the findings in the Alternative Water Source Investigation Report.

RH2 estimates that 16% of the water in the water system is lost to leaks and unauthorized (unmetered) uses. In order to comply with the Water Use Efficency Rule, the target for efficiency is 10% loss. Thus, RH2 assumed that Eatonville would take actions to reduce losses in the distribution system by 6%. RH2 made assumptions about RH2 made assumptions about unauthorized use and water lost to evapotransporation and calculated that by reducing losses (by finding and fixing leaks) by 6%, approximately 10,500 gpd, or 3.8 MG per year could remain in the Mashel River, rather than be diverted by Eatonville and lost in the system. This is equal to an annual average of 0.016 cfs, or 11.66 acre-feet per year.

At the Water Treatment Plan, RH2 estimates that there is 19% loss between the diversion and where water enters the distribution system. This loss is assumed to occur in clear well leaks, piping leaks, treatment process leaks, and miscalibrated meters. Because the treatment plant is very close to the Mashel River it is assumed that much of the leakage at the plant infiltrates and returns to the river. However, there is a bypass reach between the diversion and where the water is expected to return to the river. RH2 assumed that Eatonville could reduce leakage in the treatment plant system by 80%. Thus, the diversion could be reduced by approximately 18.8 MG per year, which is 51,471 gpd, or 0.079 cfs, which is equal to 57.695 acre-feet per year.

Thus, total conservation efforts by Eatonville could save 0.095 cfs or 69.3567 acre-feet per year.

Appendix J

Thurston PUD Deepening Wells Memo

Commissioners
Linda Oosterman – District 1
Russell E. Olsen – District 2
Chris Stearns – District 3

Thurston PUD

Providing safe, reliable, affordable, and sustainable service.

December 12, 2018

RE: WRIA 11 – Drilling Wells in Deeper Aquifers

Lisa Dally Wilson P.E.
Dally Environmental
inquiry@dallyenvironmental.com

Hi Lisa,

It was good speaking to you in the afternoon of December 6th. I wanted to provide more information in response to your inquiry concerning drilling wells into deeper aquifers. We identified three potential wells in the prairie area of WIRA 11, as George Walter requested. Information and system data on these wells is listed below in a table.

There can be significant advantages to drilling wells in deeper aquifers if it frees up water in aquifers that affect surface water stream flows. For a Group A water system with a significant water right, the advantages in shifting wells to draw on deeper aquifer could reduce the impact on streams. However, drilling wells into deep aquifers can be very costly. Quite often there are not many wells drilled into the deeper aquifers and so often, there is not good data on which to gage the success of drilling wells in deeper aquifers. Without good data, it is our policy to always use a hydrogeologist to evaluate the success of drilling a well into a deeper aquifer. The three wells we would consider drilling into deeper acquirers, based on Mr. Walter's recommendation to identify wells in the prairie area of WIRA 11 in Thurston and Pierce counties, are the Webster Hill, Maxvale and Smith Prairie water systems.

In seeking to support Mr. Walter's request, we asked for a cost estimate to analyze the aquifers to receive an evaluation on success in drilling these wells. We requested this cost estimate from a respected hydrogeological firm, Pacific Ground Water Group. This analysis would cost between $7,000 and $9,000 and would provide an estimate to see if there was a good chance that the water could be available in sufficient quality and quantity in deeper aquifers. Funding would need to be available to conduct a hydrogeological analysis before even considering drilling a well. Unless, or until, an analysis was done on the deeper aquifer, and provided data demonstrating there was a good possibility of drilling a successful well, it is not something I would be willing to recommend our District take on.

Often, water in the deeper aquifers may be fossilized and if available is unusable without significant costly treatment. If it appeared that there was the opportunity to secure a good water source in a deeper aquifers, we might be willing to consider submitting a request for funding to drill wells on one or more of these water systems. In an ideal situation, if a deeper well for a water system was drilled and provided water in sufficient quantity and quality, the use of water in a water system could be transferred to the well in the deeper aquifer. Water in the shallower aquifer could then be used to reduce or mitigate the impact on surface steam flows and become a backup or emergency well. I am not a hydrogeologist, but the comments above represent the advantages, disadvantages, threats and opportunities to the District when seeking to use water in deeper versus shallow aquifers. It has potential but has significant challenges. I hope this helps. Don't hesitate to let me know if you need anything else.

Sincerely,

John Weidenfeller

John Weidenfeller
General Manager
Thurston PUD

Water System Information

Water System:	**Webster Hill**	**Maxvale**	**Smith South Prairie**
DOH WFI #:	598755	74864	57851E
County:	Pierce County	Thurston	Thurston
Type of System:	Group A	Group A	Group A
Well Depth:	166 feet	137	84 feet
Well Gallons Per Minute:	100	PER DOH SENTRY 67gpm, NO WELL LOG ECOLOGY SITE	30
Active Connections:	20	11	14
Authorized Connections:	20	48	16
Well Tag:	AEF407	AGN726	AEJ337
Qa and Qi: **Qa – acre feet, af** **Qi – gallons per minute, gpm**	Qa 20.16, Qi 100	Qa 28, 236 Irrigation, 1 Stock Watering /550 gpm	QA 8 QI 45
Water Rights Certificate:	G2-00989C	CG2-00792	G2-27519P
Water Rights Used:	5.85AF USED 2017, 2018 THROUGH OCT.BILLING 4.93AF USED	2018 THROUGH OCT BILLING 3.75 AF OF DOMESTIC SUPPLY – NEW GROWING SYSTEM	7.85AF USED 2017, 2018 THROUGH OCT.BILLING 6.37AF USED

CC: George Walter, Nisqually Tribe
PUD Commissioner Russell E. Olsen

Appendix K

Washington Water Trust Memo

K-1 Summary

MEMO

To: Lisa Dally Wilson

FR: Jason Hatch, Washington Water Trust

RE: Summary. Nisqually Water Rights Survey: Prairie Tributaries-2018
For Nisqually Indian Tribe

DT: December 21, 2018

Lisa:

Please find a below a high level overview of *Nisqually Water Rights Survey: Prairie Tributaries-2018*
If you need additional information, please let me know.

Summary

Nisqually Water Rights Survey: Prairie Tributaries

The scope of work for this project, reads:

Conduct a rapid water rights assessment to identify water rights within the prairie subbasin streams (Prairie Tributaries) in Pierce County which have an identified beneficial use, "wet" water. These prairie streams include: Muck-Murray, Upper Tanwax Creek, Lower Tanwax Creek and Kreger Creek. (Project Area) *WWT would build upon the analysis of water rights identified in 2010 from 2009 aerial photographs (Muck, Tanwax), and conduct an aerial GIS "flyover" on 2017 aerial photographs to identify upwards of 10 targeted water rights in the subject basin. Water right POU (Place of Use) and parcel data will identify approximate acreage and ownership of identified water rights. This exercise will focus on acreage of above 10 acres of aerially observed water rights with rough estimates of use and will result in a technical memo of target water rights. These water rights will require more precise investigation (estimated acreage, water rights research) prior to any outreach to water right holders.*

WWT used a rapid assessment to identify and provisionally rank potential water rights according to their likelihood of beneficial use and seasonaility, matching the needs of Nisqually watershed planning. We reviewed 362 non-duplicate water right documents with a source originating within the project area, identified areas from 2013, 2015, and 2017 NAIP (USDA) photos with at least 10 acres of cultivation and potential irrigation, and subsequently ranked them according to estimated acres and annual quantities of potential beneficial use. The Prairie Tributaries portion of the Nisqually watershed has not been adjudicated and the rights are represented by a mixture of claims, certificates, and permits from sources both ground and surface.

Twenty-two water rights have been identified in this rapid assessment, comprised of an estimated 1,508 beneficially used acres with an approximate 2,282 acre feet of water. These water rights have been prioritized 1-4, with 1 being the most confident of having been beneficially used in the period evaluated, and 4 being the least confident of a robust beneficial use record. Tier 1 is comprised of six water rights with an estimated 705 beneficially used acres with 673 AFY. Tier 2 has four water rights with an estimated 304 beneficially used acres with 632 AFY. Tier 3 has nine water right with an estimated 409 beneficially used acres with 802 AFY. While Tier 4 has three water rights with an estimated 90 acres with 176 AFY.

All potential projects require further substantial investigation prior to project development and ultimately landowner/water right holder willingness to participate in a project. These projects may range from full season permanent acquisition to changed irrigation practices which may prove more efficient, require less withdrawal and focus agricultural operations on the most productive land. Some changed irrigation practices may be accompanied by an actual source switch from a small tributary to a mainstem river or surface to groundwater, which would not only provides mitigation but also restoration benefit.

Appendix K

Washington Water Trust Memo

K-2 Washington Water Trust Full Report

NISQUALLY RAPID WATER RIGHTS ASSESSMENT: PRAIRIE TRIBUTARIES FOR NISQUALLY INDIAN TRIBE-2018

WASHINGTON WATER TRUST 1530 WESTLAKE Ave N Suite 400, Seattle, WA 98109

Overview

In 2018, the Nisqually Indian Tribe contracted with Washington Water Trust (WWT) to conduct a rapid assessment of water rights-water rights survey as part of their response to RCW 90.94.020, the Streamflow Restoration Act. The Nisqually Basin has until February 1, 2019 to adopt a watershed plan which:

At a minimum… must include those actions that the planning units determine to be necessary to offset potential impacts to instream flows associated with permit-exempt domestic water use. The highest priority recommendations must include replacing the quantity of consumptive water use during the same time as the impact and in the same basin or tributary. Lower priority projects include projects not in the same basin or tributary and projects that replace consumptive water supply impacts only during critical flow periods. The watershed plan may include projects that protect or improve instream resources without replacing the consumptive quantity of water where such projects are in addition to those actions that the planning unit determines to be necessary to offset potential consumptive impacts to instream flows associated with permit-exempt domestic water use. RCW 90.94.020(4)(b)

Scope of Work

WWT was requested to: *Conduct a rapid water rights assessment to identify water rights within the prairie subbasin streams (Prairie Tributaries) in Pierce County which have an identified beneficial use, "wet" water. These prairie streams include: Muck-Murray, Upper Tanwax Creek, Lower Tanwax Creek and Kreger Creek.* Identified water rights in the rapid assessment of this Project Area (Prairie Tributaries) and associated parcels could result in projects to initiate a flow restoration program of the type required under RCW 90.94.020. Water rights have been identified through this rapid assessment of paper water right records, a review of the potential beneficial use based on aerial photography, as well as the prospective suitability for inclusion in a flow restoration strategy.

Rapid Assessment Caveats

Since this is a *Rapid Water Rights Assessment* with budget and time constraints, the identified water rights are subject to multiple caveats. The most prominent caveat is that they would require further research prior to subsequent project development. The information provided in this assessment, while a reasonable start to finding potential water rights to serve project needs, does not hold a sufficient level of corroboration to meet the statutory requirement set forth in RCW 90.94, particularly in terms of determinative quantification of beneficial use and consumptive use of the attached water rights. Prior to developing flow restoration projects, additional analytical review of scientific assessments of streams, stream flow needs and associated fish populations, is necessary. Furthermore, none of the water rights in the Nisqually Basin are adjudicated, and many water right claims have never even been quantified for beneficial use. Adjudication of a basin provides a greater level of certainty of the quantities associated with water right certificates, permits and claims, since the certified or claimed use has faced some level of authorized quantification by either state agency or superior court. Adjudication also increases the likelihood that water acquired for instream flow or mitigation purposes is protected from potential diversion from downstream users.

While WWT utilizes the same evaluation criteria as employed by Ecology, authority for determining (or adjudicating) the extent and validity of water rights is the purview of Superior Courts, Ecology, or other entities with jurisdiction under Washington State law. The material provided in this assessment is not intended to be construed as legal advice.

BACKGROUND

Nisqually Rapid Water Rights Assessment: Prairie Tributaries

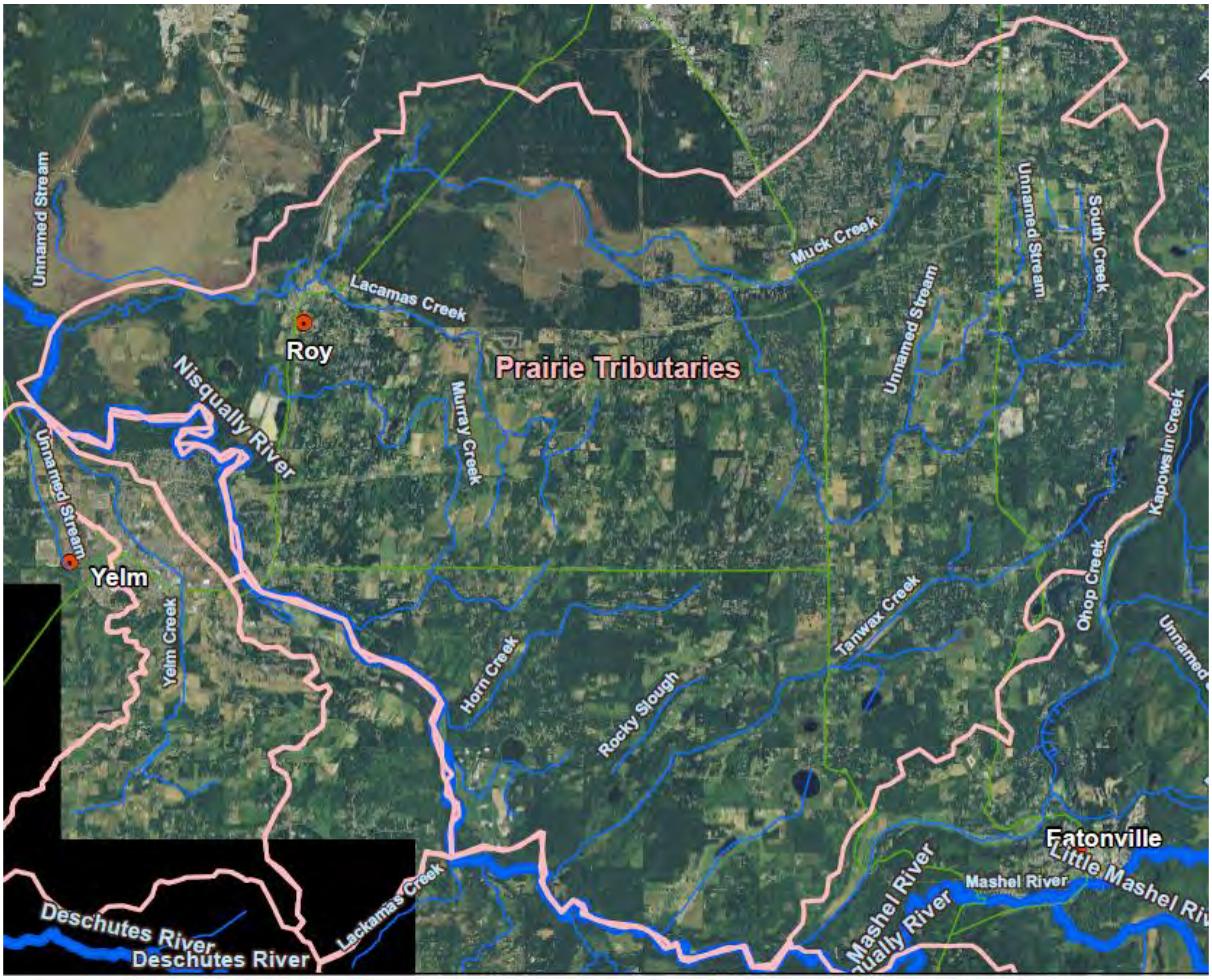
The scope of work for this project reads:

Conduct a rapid water rights assessment to identify water rights within the prairie subbasin streams (Prairie Tributaries) in Pierce County which have an identified beneficial use, "wet" water. These prairie streams include: Muck-Murray, Upper Tanwax Creek, Lower Tanwax Creek and Kreger Creek. (Project Area)

This scope would be: *a rapid assessment of water rights within the identified watersheds. WWT would build upon the analysis of water rights identified in 2010 from 2009 aerial photographs (Muck, Tanwax), and conduct an aerial GIS "flyover" on 2017 aerial photographs to identify upwards of 10 targeted water rights in the subject basin. Water right POU (Place of Use) and parcel data will identify approximate acreage and ownership of identified water rights. This exercise will focus on acreage of above 10 acres of aerially observed water rights with rough estimates of use and will result in a technical memo of target water rights. These water rights will require more precise investigation (estimated acreage, water rights research) prior to any outreach to water right holders.*

The Streamflow Restoration Act requires that Nisqually watershed planning partners update their watershed plan to identify actions which will mitigate for 20 years of forecast rural exempt well development. In response, WWT was commissioned to provide a rapid assessment to identify water rights in the Project Area, which given more thorough extent and validity analysis, could serve to offset expected well mitigation needs.

Study Area: Prairie Tributaries



Approach

WWT reviewed surface and ground water certificates, permits, and claims in the Project Area utilizing data from the Department of Ecology Water Rights Application Tracking System (WRATS), Pierce County parcel records and US Department of Agriculture aerial photography. A list of reviewed water rights is attached as an electronic file in *Appendix A: Nisqually Prairie Tributaries Water Rights.*

WWT delivered the *FEASIBILITY ANALYSIS FOR A NISQUALLY WATER BANK Final Draft: June 2010* to the Nisqually Indian Tribe, evaluating the conceptual feasibility of a water bank. In addition, WWT identified 34 water rights of interest with 5 acres or more of paper water right authorized acres, estimating irrigation from 2009 aerial photographs. While some water rights on the 2010 list also are on the prospective list for this assessment, it should be noted that when considering a potential water rights change either for flow or mitigation purposes, the most recent five to ten year period of beneficial use (this rapid assessment) is of most relevance to review and approval of changes.

WWT used a rapid assessment to identify and provisionally rank potential water rights according to their likelihood of beneficial use and seasonaility. We reviewed all areas where at least 10 acres of cultivation suggested potential irrigation, and subsequently selected water rights or potentially irrigated areas for additional project development, including providing a brief analysis of project development notes. There were more than one hundred fields showing ten or more irrigated acres, many of which were only referenced by unmapped claims in the WRTS file.

This assessment moves beyond the "paper water rights" listed on certificates and includes a review of how water rights appear to have been beneficially used after a review of GIS data, aerial photography and county assessor records. Because many of the original water rights have experienced non-use and may be relinquished, this assessment focused on water rights showing evidence of potential irrigation as assessed from 2013, 2015, and 2017 NAIP photos and ranked them according to estimated acres and annual quantities of potential beneficial use. These estimates need additional ground-truthing to determine if actual irrigation use aligns with what is suggested by aerial photography. A number of water rights have overlapping legal places of use (POU), which may mean that some water rights are supplemental to others and may or may not coincide with actual irrigation on the ground. County parcel data reveals the underlying ownership for places of use where beneficially used water rights are identified.

The data provided in this report is subject to the limitation as to whether or not Ecology has mapped water rights or confirmed the accuracy of such mapping through the ARCGIS-based Geographic Water Rights Information System (GWIS). This information can be incomplete, or have mapping errors impacting the legal description of the water rights place of use. Also, Ecology does not monitor and update quantities of water rights based on real time beneficial use (extent determinations) unless a change is requested. Washington water law is governed by the doctrine of prior appropriation which requires consistent beneficial use of the water. Any water right that has undergone a period of non-use or reduced use for five years or more without a sufficient cause for non-use (RCW 90.14.140) will be relinquished or partially relinquished, yielding an actual transferrable quantity not reflected in the paper water right. Any project seeking a change to water rights must demonstrate the extent of beneficial use of water rights and must prove that other water rights will not be impaired by the change. In the event, this project would move to subsequent phases for more in-depth documentation of beneficially used water rights and subsequently projects, WWT could work closely with participating landowners and basin partners to secure the appropriate level of documentation necessary for any water rights applications developed for water projects supporting the Nisqually Watershed Management Plan.

DATA and METHODS

The following types of data were reviewed in this analysis.

- Geographical Water Rights Information System Data (GWIS) Place of Use Polygons-Ecology
- Water Rights Application Tracking System (WRATS)–Ecology
- USGS Topographic Data
- National Agriculture Imagery Program (NAIP) Aerial Orthophotography (2013, 2015 and 2017)
- Pierce County Parcel and Ownership Information

- The USDA Geospatial Data Gateway version of the Watershed Boundary Dataset (WBD) layers via the United State Geological Survey

Note: All GIS analysis completed with ESRI ArcMap 10.2.1 Software

To assess all the water rights and claims within the Project Area, WWT:

1) Identified the water rights within the study area with at least 10 acres of irrigation;

2) Reviewed the attributes of those water rights;

3) Estimated the amount of irrigation associated with each water right with aerial photos (2013, 2015 and 2017);

4) Ranked water rights and claims which may be viable as trust water/mitigation projects, yet require more substantive extent and validity review, prior to targeted outreach; and

5) Provided additional project discussion for the selected water rights or potential water use areas for context to water right legal status and/or project development potential.

Identifying water rights

To identify the water rights within the study area, all water right points of diversion, as mapped by Ecology, were selected within the defined boundary of the Project Area using ESRI ArcMap 10.2.1 software's "select by location" tool and joined by the water right document number to find the associated place of use.

Water right attributes

Limited information was available for the water rights and claims in the Project Area through Ecology's GWIS database. To find more information about these water rights and claims, Ecology's Water Rights Tracking Database-Water Resources Explorer-was used to view scanned certificates, records of examination and claims for target water rights (accessed November 2018). These documents provided additional information including source, purpose and asserted quantities.

Land use and ownership data

Land use and ownership data is often helpful when determining the type and extent of water use. To obtain land use information, the Pierce county parcel layers were used to find parcels with water rights appurtenant to them. County Assessor Tax data was downloaded and joined to the parcel layer by the parcel number (accessed December 2018). Where necessary, parcel numbers were entered into the county assessor's property search website where additional information on land use, permits and land parcel ownership history was obtained (accessed December 2018).

RESULTS AND PROJECT DEVELOPMENT POTENTIAL

Water Rights List and Results

WWT developed a tiered list from 362 non-duplicative water right records and hundreds of additional claims listed in the Ecology Water Rights Tracking System (WRTS) for the Project Area, analyzing 2013, 2015, and 2017 NAIP (USDA) photos with at least 10 acres of cultivation and potential irrigation. We then estimated acres and estimated annual consumptive quantities of potential beneficial use and performed a coarse records search to verify the legal status of the underlying water rights. This data, along with the location of the water use areas in the water shed, allowed us to organize water rights into tiers, which we did according to criteria of potential extent of beneficial use of the water right, transferrability considerations, and potential to contribute to stream flow restoration and biological benefit.

Twenty-two water rights have been identified in this rapid assessment, comprised of an estimated maximum of 1,588 beneficially used acres with an approximate 2,439 acre feet (AFY) of water. These water rights have been prioritized into for tiers. Tier 1 is comprised of six water rights with an estimated 785 beneficially used acres with up to 849 AFY of consumptive use water, 595 AFY of which is groundwater. Tier 2 has four water rights with an estimated 304 beneficially used acres with 632 AFY, with 312 AFY from groundwater sources. Tier 3 has nine water right with an estimated 409 beneficially used acres with 802 AFY, 267 AFY from groundwater. While Tier 4 has three water rights with an estimated 90 acres with 176 AFY, 137 AFY from groundwater.

It should be noted that there are several hundred unprocessed and unmapped claims in the area which could not be reviewed within the current scope, as they require substantial investigation. Since the Prairie Tributaries portion of the Nisqually watershed has not been adjudicated, the rights are represented by a mixture of claims, certificates, and permits. Ecology can approve changes within this watershed, as long as beneficial use is substantiated and the proposed change does not cause harm ("impairment") to other water right holder. And yet, in this unadjudicated basin, water right holder may not exercise water rights against one another (curtailment), because only a Superior Court in the context of a water rights adjudication has that authority in Washington State.

Many areas analyzed via aerial photos suggested cultivation and potential diversion of water. However, providing further certainty of the quantities of water available for project development in the watershed will require significant additional analysis and scrutiny. Typically, this includes comprehensive records searches and ultimately site visit with owners of areas of potential irrigation to determine actual use. Such a due diligence review include using extensive legal and technical expertise, potential hydrologic modeling in the case of ground water rights to fully assess and quantify the extent and validity of each water right of interest. A future more detailed assessment of the subject water rights will provide a greater understanding as to the potential of water rights to mitigate future uses.

For the purposes of this rapid assessment, WWT prioritized water rights according to beneficial use history and likelihood of transferability downstream. This assessment is based on WWT's 21-year history as Washington State's most prominent player in trust water rights transfers, during which we have completed hundreds of voluntary instream flow agreements with water rights owners throughout the state and shepherded those changes through the Washington State Trust Water Rights Program application process.

The water rights analyzed by WWT are attached in *Appendix A: Nisqually Prairie Tributaries Water Rights*. A summary of tiers below helps explain why water rights were included in those tiers and what flow restoration tools could be built on transactions involving those water rights. As mentioned above, listing these water rights does not imply or replace certainty of beneficial use that would come from a determination of extent and validity by Ecology, but it does provide information about where to start looking to build a long term flow restoration strategy in the target area.

Tier 1 Water Rights

- High certainty of beneficial use - Water rights grouped into tier 1 possess unique potential for project development due to high level of certainty of beneficial use coupled with other attributes adding promise to potential project development. For example, two of the water rights are large established, working farms and all other tier 1 water rights have very clear evidence of irrigation infrastructure.
- Easily incentivized water transfers - Large farms with strong evidence of beneficial use can free up larger quantities of water with a single transaction that has a lot of up front certainty as far as transferrable water. Proven incentives can be used, such as late-season or dry year fallowing agreements, efficiency upgrades, or purchasing portions of the water rights that are not as economically viable. For example, a farm may upgrade to a center pivot irrigation system and forego purchasing an end gun to water the corners. Center pivot systems typically increase crop yields with less application of water overall, so farms can "sell" their corner water into trust for other uses, stream flow restoration, or for mitigation of other uses. In addition, one of the farms in tier 1 is owned by an entity with whom trust water organizations have worked successfully in the past. Another large farm in tier 1 has recently gone through a Report of Examination (ROE) by Ecology to quantify their beneficial use, adding a great deal of certainty to quantities of beneficially used water.
- Increased possibilities of biological benefit – One tier 1 farm is also at the confluence of Tanwax Creek and the Nisqually River, and has storage ponds on the property. This opens up an opportunity for the farms to augment flows in the bottom of the system, if flows are needed that system. This project could be done by replacing out of stream diversions in lower Tanwax Creek with either stored water on the property or via a source switch project to change the Tanwax Creek point of diversion to the Nisqually River. Likewise, Silver Lake, which drains directly into the Nisqually River, feeds water rights that could use storage to offset late season withdrawals if fish use that system. In addition, there are no other apparent water rights with active irrigation in the Silver Lake drainage area. This increases the reliability of instream flow acquired from this water right because even though the water rights lack the power of an adjudication. Instead, an agreement with the water right owner to not divert water will secure flows all the way to the Nisqually River, since no other water users appear to have standing to claim impairment.

Tier 2 Water Rights

- Moderate certainty of beneficial use – These are either smaller areas of high certainty irrigation or larger areas of less certain irrigation where not as much water may be available for transfer. In some cases, Ecology may have agreed to a donation, indicated historic water use, but not quantified it via an extent and validity review in a ROE.
- Potential for instream flow transfers – While there is less certainty around the validity and extent of these water rights, there are nevertheless opportunities to pursue projects that could lead to increased flow restoration in target reaches. For example, the Prairie Tributary region possesses a multitude of small lakes and ponds with apparent water use occurring

downstream, but not all of the water rights associated with these uses have been mapped by Ecology. There may be claims or Ecology has lacked the resources to process permits or other applications into quantified certificates.

- Moderate chance of biological benefit – Tier 2 water rights may include larger water rights where flow protections mechanisms are more complicated, such as water rights high up on the South Fork system where many downstream diverters could use up water made available from projects upstream. In another case, the Tier 2 included a water right near the bottom of Murray Creek with good potential for source substitution, but less certainty of how and to what extent current water rights are used.

Tier 3 and Tier 4 Water Rights

These water rights are viable candidates for flow restoration projects, because they are marked by apparent underlying water use on at least 10-20 acres. While not having the apparent utility as tier 1 and tier 2 in terms of certainty of beneficial use, transferability, or biological benefit, many of them may raise to tier 1 or tier 2 status with additional information not available in a rapid assessment. Likewise, many of them may turn out to fall from consideration altogether if additional analysis reveals that water has not been used to a large extent. In addition, some lower tier water rights have already been applied to new development, giving them a great deal of certainty but a much lower probability that they will be available for instream flow use at a competitive incentive cost.

Towards a Future Flow Restoration Strategy

This rapid assessment is best understood as a very preliminary first step toward a future stream flow restoration strategy in Prairie tributaries of the Nisqually Watershed. Any flow restoration strategy in a basin requires significant time analyzing water rights and understanding how their transfer to instream flow will impact critical stream reaches where flow is limiting a critical life history stages for species of concern. This helps identify projects where public funds spent to acquire water are more likely to restore streams in a meaningful way, whether that is for the purpose of improving fish and wildlife habitat, or enhancing stream flows as mitigation for future uses. Nothing in this rapid assessment is intended to replace a developed strategy for water acquisition in the Nisqually basin. This rapid assessment has been developed to support future phases of streamflow restoration efforts and watershed planning in the basin.

Appendix L

Yelm Water Right

OTHER STRATEGIES – GROUNDWATER RECHARGE USING RECLAIMED WATER

BACKGROUND

The City of Yelm currently provides drinking water within its service area, which includes Yelm's Urban Growth Area, from the shallow (TQa) aquifer. Wastewater is treated to a Class A reclaimed water standards. This reclaimed water is then:

- Sold for irrigating parks and playfields - 71 AF in 2016
- Recharged into the TQa aquifer slightly up gradient from the point of withdrawal at Cochrane Park - 62 AF in 2016
- Discharged to the Centralia Power Canal (primary point of discharge) or the Nisqually River (secondary point) – 273 AF in 2016

Future growth in the City will be served by a new well drilled deep in the lower (TQu) aquifer. The City of Yelm is currently pursuing additional water rights necessary to utilize this well and expects to have an application submitted as part of the Streamflow Restoration Act (Chapter 90.94 RCW) early in 2019.

The mitigation plan being prepared in support of this application anticipates that impacts to the Nisqually River are fully avoided through an agreement with Tacoma Power, the owner of the Alder Dam, to increase flows in the Nisqually River to compensate for Yelm's impacts.

The plan further fully avoids impacts to Yelm Creek by increasing reclaimed water infiltration at Cochrane Park.

If approved, the City of Yelm will be pumping water from the deeper TQu aquifer, treating it to Class A reclaimed water standards, and discharging it through groundwater recharge into the TQa aquifer, irrigation, or directly to the Centralia Power Canal and Nisqually River.

MITIGATION STRATEGY

Water pumped from the deeper TQu aquifer pursuant to a new water rights certificate would be treated to Class A reclaimed water standards and infiltrated to the TQu aquifer.

Reclaimed water infiltrated to avoid impacts to Yelm Creek as identified in Yelm's water rights mitigation plan would not be eligible to offset impacts of exempt wells, as it will be required to offset impacts from pumping the water in the first place.

In order to infiltrate reclaimed water in a manner that benefits instream flows of Yelm and Thompson Creek:

- Yelm's water rights application must be approved.
- The Yelm Sewer Facilities Plan must be updated by the City and approved by the Washington Department of Ecology to include the location of new Rapid Infiltration Basins.

- Yelm's operating permit would have to be modified to allow the direct discharge of reclaimed water to the groundwater.
- Rapid Infiltration Basins in locations most beneficial to instream flows would need to be constructed. In some locations, this may also include the extension of the reclaimed water distribution system.

The City of Yelm would work with the watershed partners to establish a structure for obtaining the funding necessary to plan for and construct the infiltration system and to create a formula for implementing this big measure program.

Other Strategies – Conversion from individual or group wells to Yelm's Water System

Background

The City of Yelm currently provides drinking water within its service area, which includes Yelm's Urban Growth Area. With a limited number of new connections available without additional water rights, it is Yelm's policy to reserve its existing water connections to serve vacant properties within the current city limits. There are a number of pre-existing exempt wells within the City limits and a larger number within the Urban Growth Area.

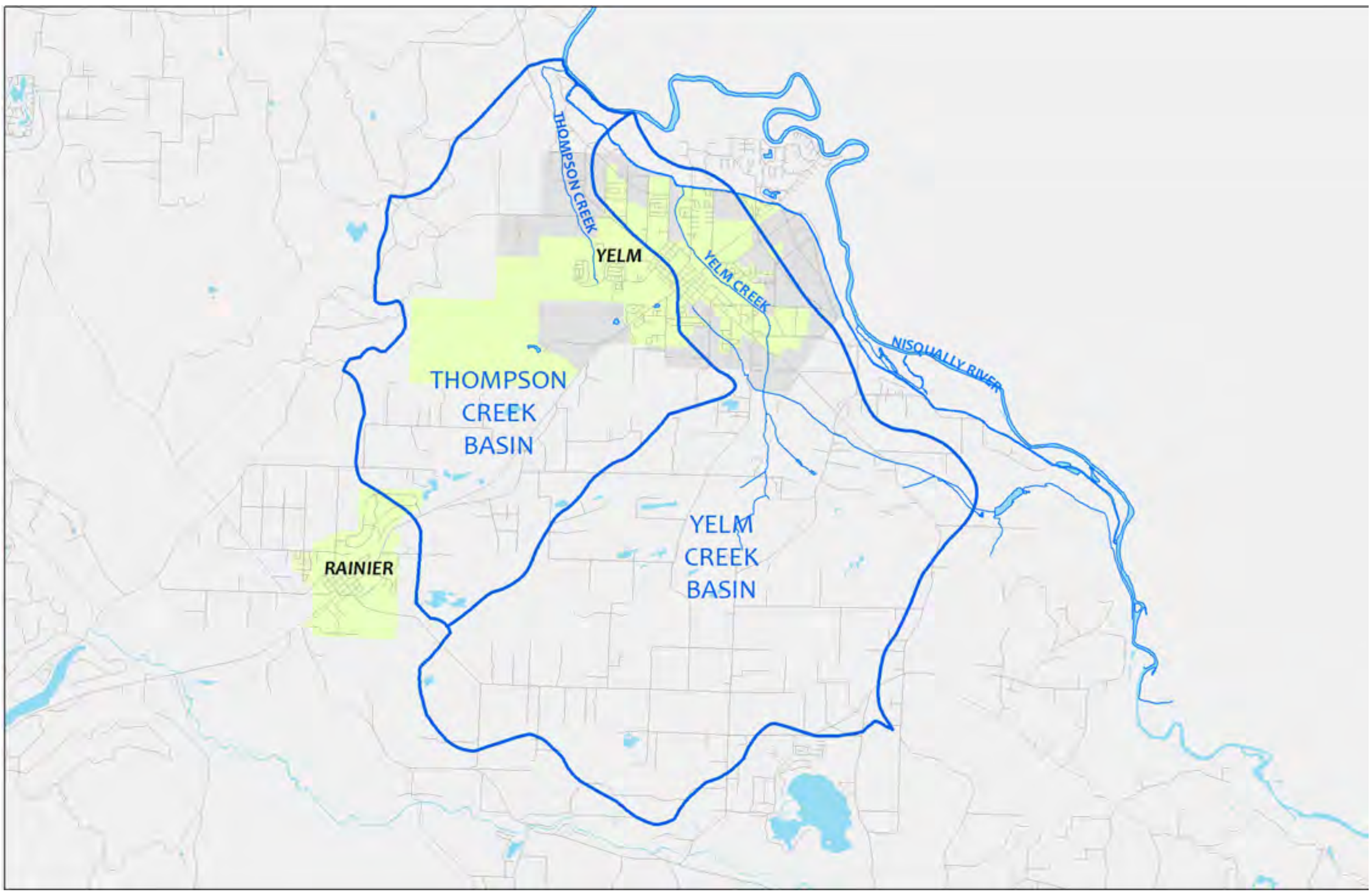
Future growth in the City will be served by a new well drilled deep in the lower (TQu) aquifer. The City of Yelm is currently pursuing additional water rights necessary to utilize this well and expects to have an application submitted as part of the Streamflow Restoration Act (Chapter 90.94 RCW) early in 2019.

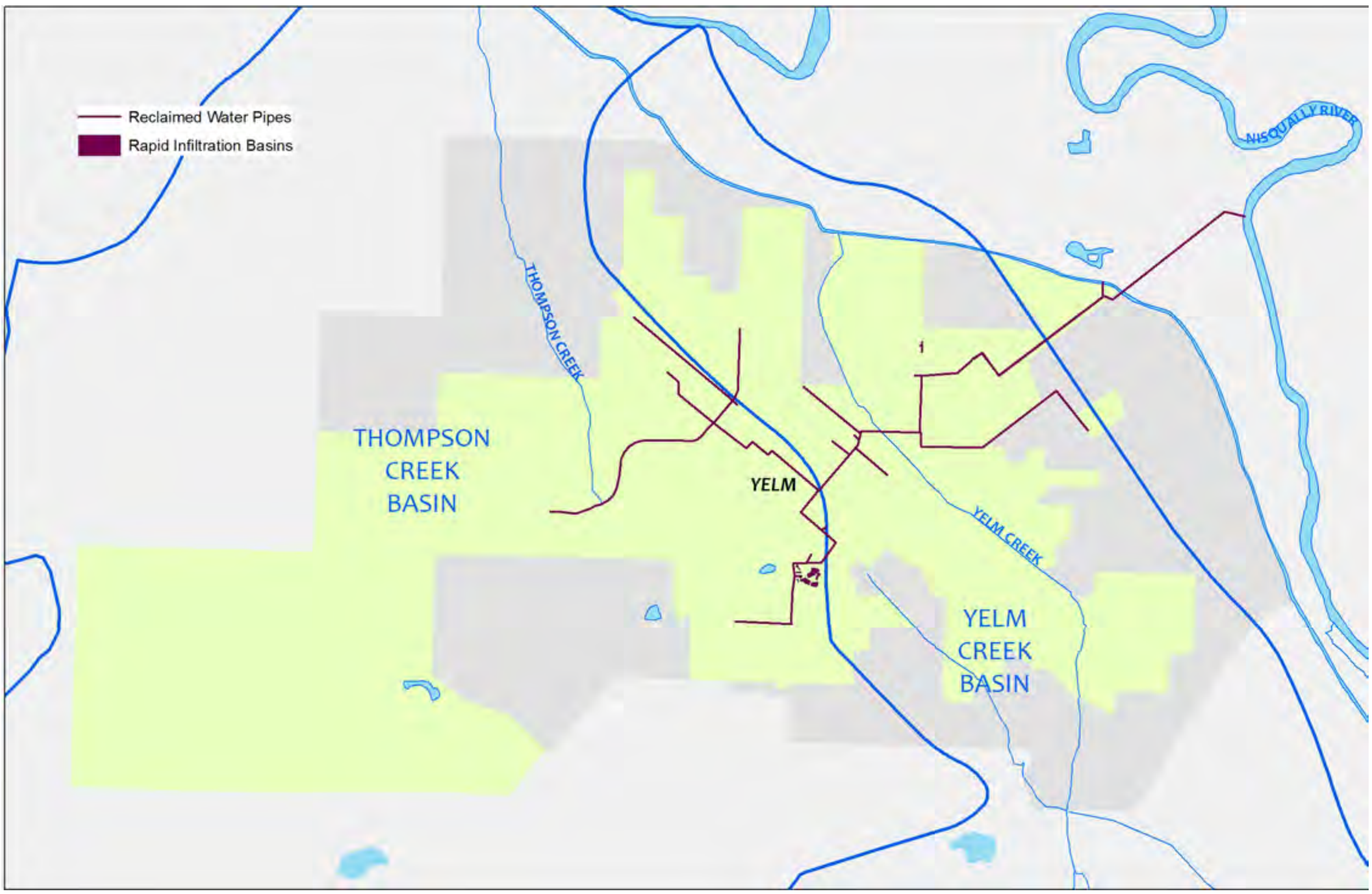
The City of Yelm is currently pursuing additional water rights necessary to utilize this well and expects to have an application submitted as part of the Streamflow Restoration Act (Chapter 90.94 RCW) early in 2019.

When these new water rights are approved, Yelm will be in the position to serve properties with existing wells located within both its retail service area (the current city limits) and future water service area (the UGA) to city water.

Mitigation Strategy

As wells are removed from service as properties within the Yelm service area connect to city water, the City would receive credit for the water rights associated with the exempt well. This credit could be held in trust by the City or appropriate agency and used for full mitigation of a new exempt well in the Thompson/Yelm Creek basins.


THOMPSON CREEK
YELM
YELM CREEK
NISQUALLY RIVER
THOMPSON CREEK BASIN
YELM CREEK BASIN
RAINIER



Reclaimed Water Pipes
Rapid Infiltration Basins
NISQUALLY RIVER
THOMPSON CREEK
THOMPSON CREEK BASIN
YELM
YELM CREEK
YELM CREEK BASIN

CITY OF YELM
WASHINGTON

Conceptual Mitigation Plan Status Update

RCW 90.94.090 (12)

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November 15, 2018

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INTRODUCTION

The City of Yelm is eligible pursuant to the Streamflow Restoration Act (ESSB 6091) for submission of a pilot project aimed at addressing development of public water supplies in areas where instream flows have been established.

It is the intent of the pilot projects to inform the legislative task force that is reviewing new appropriations and their relationship to instream flows and developing a mitigation sequencing process and scoring system to address such appropriations. Section 90.94.090 RCW requires that the Washington State Department of Ecology furnish the task force with information on conceptual mitigation plans for each pilot project application no later than November 15, 2018. This report is intended to provide Ecology with information satisfying this requirement.

Background

Yelm has been one of the fastest growing Cities in Washington State for the past 20 years, and embraces the requirements for good planning under the Growth Management Act for the sustainable provision of urban services within urban centers.

Towards that end, Yelm began planning for infrastructure improvements needed to accommodate the expected growth and in 1994 applied for additional water rights to the Department of Ecology.

Yelm worked with watershed partners through the watershed planning process to develop a new source of supply designed to minimize impacts (stream depletions) to the nearby Nisqually River and distribute the impacts to other watershed features where partners could assist with mitigation. This was accomplished through the installation of well SW1A, a deep well targeting the confined TQu aquifer.

A groundwater flow model was developed to conservatively predict (over-estimate) the stream depletions that would result from pumping the requested 942 acre-feet per year (AFY) from the TQu aquifer, a volume based on a detailed demand forecast.

The City's 2011 water right application relied on a partnership with the Cities of Lacey and Olympia to develop a shared mitigation package that was developed in coordination with the Washington Department of Ecology, Washington Fish and Wildlife Service, and the Nisqually and Squaxin Island Indian Tribes. The mitigation plan involved both in-kind and out-of-kind elements that were judged in total to represent a net ecological benefit to the watershed (USFWS, 2011). The City of Yelm's application was appealed, challenging Ecology's use of Overriding Consideration of Public Interest (OCPI) with respect to allowing two very small and brief stream depletions (impacts) when no water is available (closure periods). That appeal was upheld by the State Supreme Court in Foster v. Yelm in 2015.

Since that time, Yelm has been evaluating the best approach to secure groundwater rights to allow the City to grow into the future. Yelm has maintained the original objectives, which support the watershed planning effort:

- Develop a new deep source of supply;
- Responsible and sustainable use of the resource;
- Minimize and mitigate impacts to the watershed;
- Re-use and recycle municipal water to benefit the streamflow and ecological health of the Nisqually Watershed.

The Yelm mitigation plan is in-progress, and largely complete. However, several key mitigation alternatives are still being evaluated, so an overview will be presented in this memorandum.

IMPACTS

The approach to modeling, model construction, baseline development, and pumping scenario has been presented previously, and any model file updates will be presented in the final mitigation plan. Original model documentation will be submitted with the 2019 mitigation plan to support the new water right application.

The surface water features of interest were defined in the 2011 Mitigation Plan, Table 3-1:

Table 3-1
Regulatory Status of Key Water Bodies in WRIAs 11 and 13

Water Body	Regulatory Status (Chapters 173-511 and 173-513 WAC)
WRIA 11 (Nisqually River Watershed)	
Lower Nisqually River[1] (RM[2] 4.3 to RM 12.6) Control Station: "New gage" at RM 4.3	Open year round. New appropriations subject to instream flows of 600-900 cfs varying seasonally.
Bypass Reach of Nisqually River (between RM 12.6 – RM 26.2) Control Station: 12-0895-00 at RM 21.8	Closed to new appropriations June 1 – October 31 (370-500 cfs varying seasonally). New appropriations subject to instream flows of 600 cfs in remaining months.
Middle Nisqually River (from RM 26.2 – approximately RM 39.9) Control Station: 12-0884-00 at RM 32.6	Closed to new appropriations June 1 – October 31 (600-800 cfs varying seasonally). New appropriations subject to instream flows of 700-900 cfs in remaining months.
Upper Nisqually River (from approximately RM 39.9 to headwaters including all tributaries) Control Station: 12-0825-00 at RM 57.8	New appropriations subject to instream flows of 300-650 cfs varying seasonally.
McAllister Creek	Closed to new appropriations (year round).
Lake Saint Clair	Closed to new appropriations (year round).
Yelm Creek	Closed to new appropriations (year round).
WRIA 13 (Deschutes River Watershed)	
Deschutes River (from confluence with Capitol Lake upstream to RM 41)	Closed to new appropriations April 15 – November 1. New appropriations subject to instream flows in remaining months (150-400 cfs, varying seasonally).
Woodland Creek and all tributaries	Closed to new appropriations (year round).
Long Lake	Closed to new appropriations (year round).
Patterson Lake (a.k.a. Pattison Lake)	Closed to new appropriations (year round).
Hicks Lake	Closed to new appropriations (year round).

Yelm's impacts to McAllister Creek and Lake Saint Clair have fully mitigated in-kind though the City of Olympia's actions to switch from the McAllister Springs source to the McAllister Wellfield groundwater source.

The impacts to surface water features in the Nisqually and Deschutes watershed basins that require mitigation beyond those fully mitigated in-kind through actions taken by watershed partners are as follows:

NISQUALLY RIVER

Yelm's cumulative (all reaches as measured at RM 4.3) depletion in the Nisqually River is conservatively predicted to be 0.32 cfs for the maximum month (August). Extrapolating this maximum average monthly depletion results in the year-round volume of 235 AFY.

Yelm Creek

Yelm's predicted depletion in Yelm Creek is predicted to be between 0.04 and 0.06 cfs for the maximum month (April). Extrapolating this maximum average monthly depletion results in the year-round volume of between 29.0 and 43.4 AFY.

Tri-Lakes and Woodland Creek

Yelm's cumulative impact to the Tri-Lakes and Woodland Creek surface water features, as would be expected to be measured at the lower end of Woodland Creek, is predicted to be 0.02 CFS year-round, the equivalent of 14.5 AFY.

Deschutes River

Yelm has fully mitigated the irrigation season impact to the Deschutes River though its participation in retiring the Smith Ranch water right as described in the 2011 mitigation plan. What remains are the "shoulder season" impacts, where the closure period of April 15 through November 1 begins before the irrigation season and ends after the irrigation season ends. The period of remaining impacts is thus two weeks in April and the month of October.

Using the maximum month depletions rate of 0.24 cfs in March, these impacts are:

- 6.66 AF for 14 days in April
- 14.8 AF for 31 days in October

Most of Yelm's impacts occur in the upper river, above Silver Spring.

PLANNED MITIGATION APPROACH SUMMARY

Yelm's current approach to mitigation targets the impacts originally predicted using the conservative model and pumping forecast of 942 AFY. The City of Yelm's planned mitigation approach is to address only Yelm's impacts that were not addressed by the joint (three-city) mitigation plan with in-kind actions (replacement water in time and in-place) where possible.

By feature, the planned approach is as follows:

NISQUALLY RIVER

Yelm is pursuing two actions to fully mitigate in-kind impacts to the Nisqually River.

The first is the artificial recharge of reclaimed water, from the TQu aquifer, in areas that will enhance base flow, direct discharge of reclaimed water to key hydrologic features, and the acquisition and retirement of water rights.

Flows in the Nisqually River are primarily controlled by operation of Alder/La Grande dams by Tacoma Power and the river diversion through the Centralia City Light Project. The second potential action would be an agreement with Tacoma Power to provide an additional 0.32 cfs to the Nisqually River year-round for in-kind mitigation and expect that effort to be successful.

YELM CREEK

Yelm recharges the shallow aquifer system with reclaimed water at Yelm's Cochrane Memorial Park recharge facility. Yelm will expand year-round recharge at that and new locations to fully mitigate in-kind the impact to Yelm Creek. This potentially has additional benefits to other local surface water features.

TRI-LAKES/WOODLAND CREEK

Yelm is pursuing the acquisition of year-round water rights to retire to fully mitigate in-kind the impacts to Tri-Lakes/Woodland Creek. Some mitigation actions taken in other areas for the benefit of Yelm Creek or the Deschutes River may also benefit these water bodies.

DESCHUTES RIVER

Yelm is proposing to fully mitigate in-kind for the Deschutes River closure period through acquisition and retirement of water rights.

Only if the acquisition of water rights is not reasonably attainable will Yelm pursue out-of-kind actions mitigation measures.

Work on the mitigation program is on going and has included a variety of specific actions, including:

- Updating the Yelm groundwater model features to better reflect the Deschutes River Basin;
- Researching consumptive water rights that may be available within the Deschutes River Basin;
- Analyzing aquifer recharge, aquifer storage and recovery, and exempt well replacement.

Yelm has already evaluated several in-kind mitigation alternatives at the Deschutes River and found most to be not reasonably attainable. These evaluations have focused on the upper reach (Smith Ranch) because:

- Yelm's impacts are concentrated in the upper river;
- Yelm has access to property at Smith Ranch;
- Mitigation in the upper river can address the impacts to the middle and lower reaches as well.

To this point, the only reasonably attainable in-kind action that Yelm has identified is acquisition and retirement of existing water rights to offset the shoulder season depletions.

Some candidate water rights in appropriate locations have been identified, and Yelm is continuing to identify acquisition opportunities.

Should the acquisition and retirement of water rights be found not reasonably attainable, Yelm will update the out of kind mitigation plan to ensure that net ecological benefit is achieved.

SUMMARY

The development of Yelm's mitigation plan to support its pilot application for water rights under the Streamflow Restoration Act, Title 90.94 RCW, is well underway.

The City has focused on identifying and pursuing several in-kind actions that will full mitigate its impacts at most features influenced by Yelm's planned future pumping. Mitigation alternatives in the upper Deschutes River are limited, though Yelm continues to pursue water rights to acquire and retire in order to address the two small and brief shoulder season impacts.

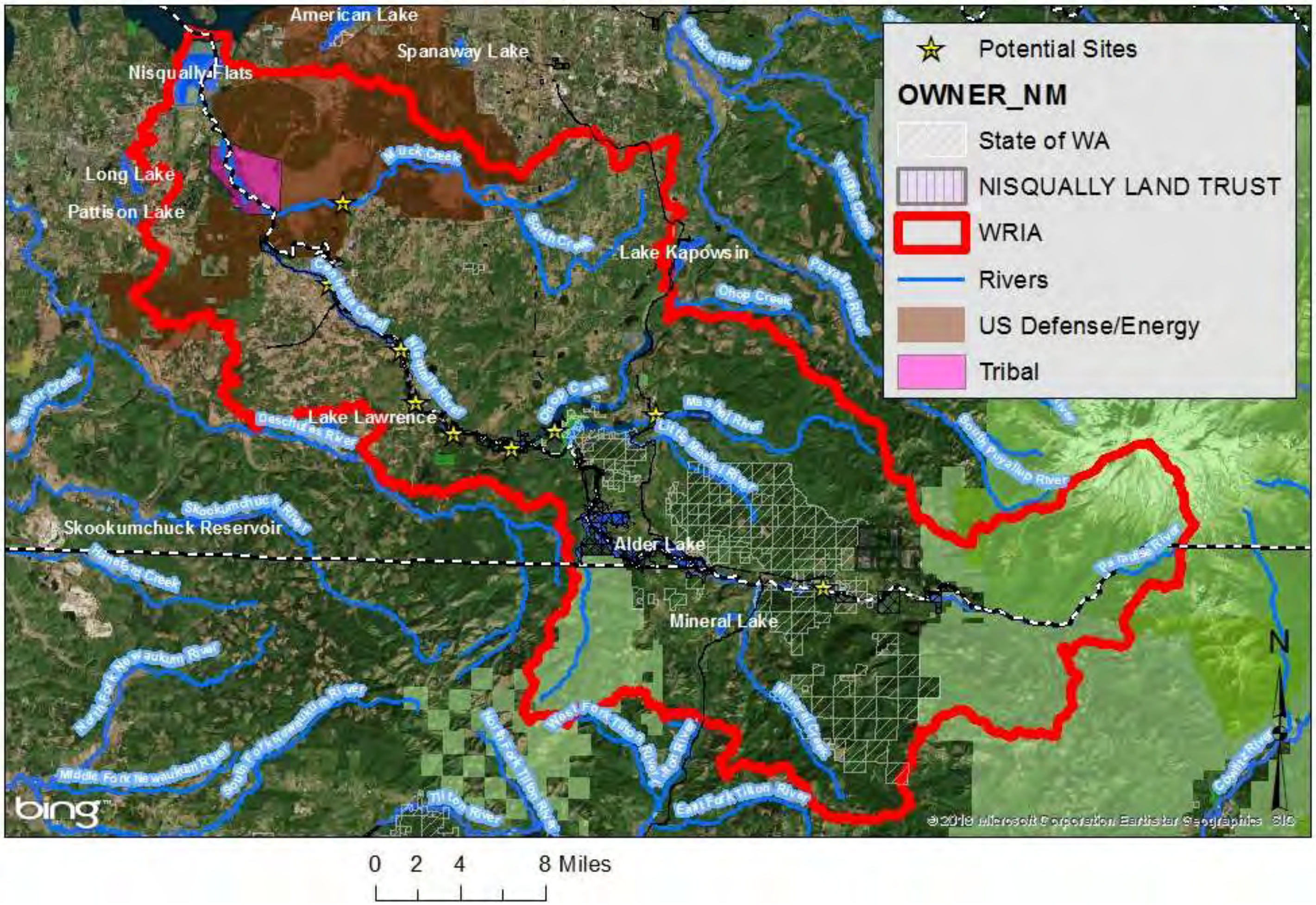
In the meantime, Yelm has already fully mitigated the planned irrigation-season impacts in the Deschutes River, and is participating in several out-of-kind mitigation actions at Smith Ranch that have already been determined to represent significant ecological benefit and progress toward watershed restoration.

In the final mitigation plan, Yelm will describe how those actions factor into the final Deschutes River mitigation package.

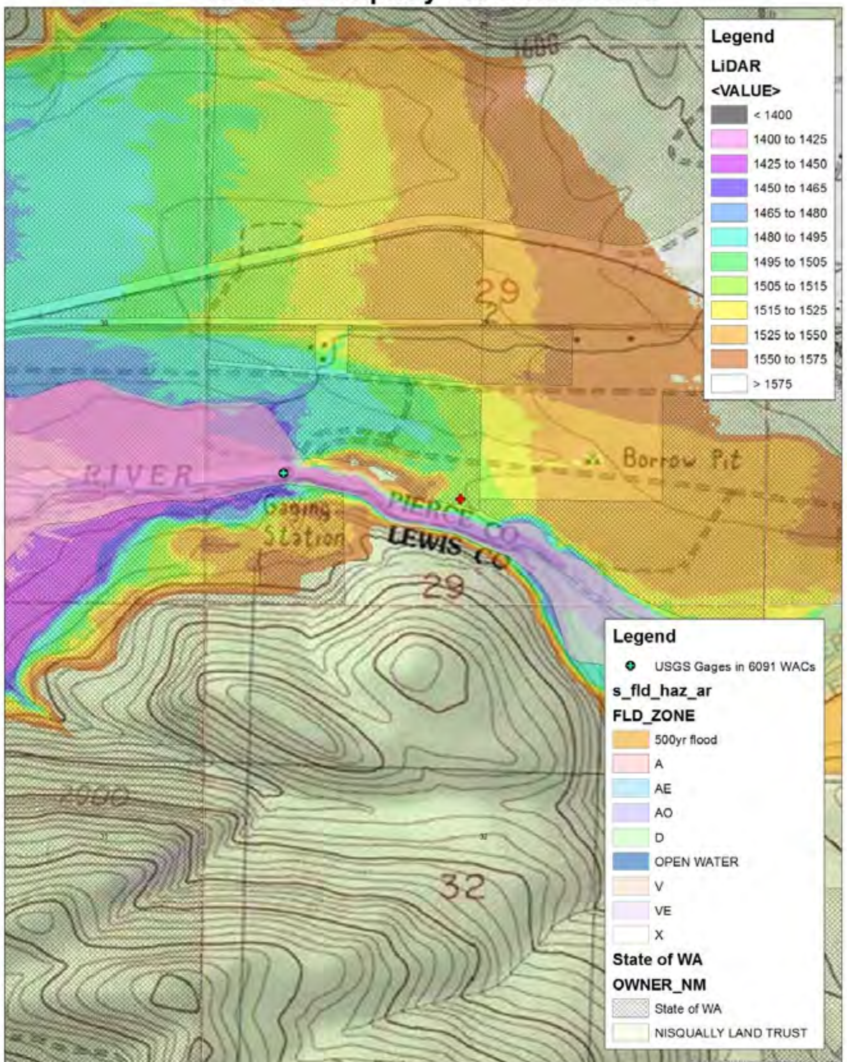
Appendix M

Potential Managed Aquifer Recharge Mitigation Facilities in WRIA 11

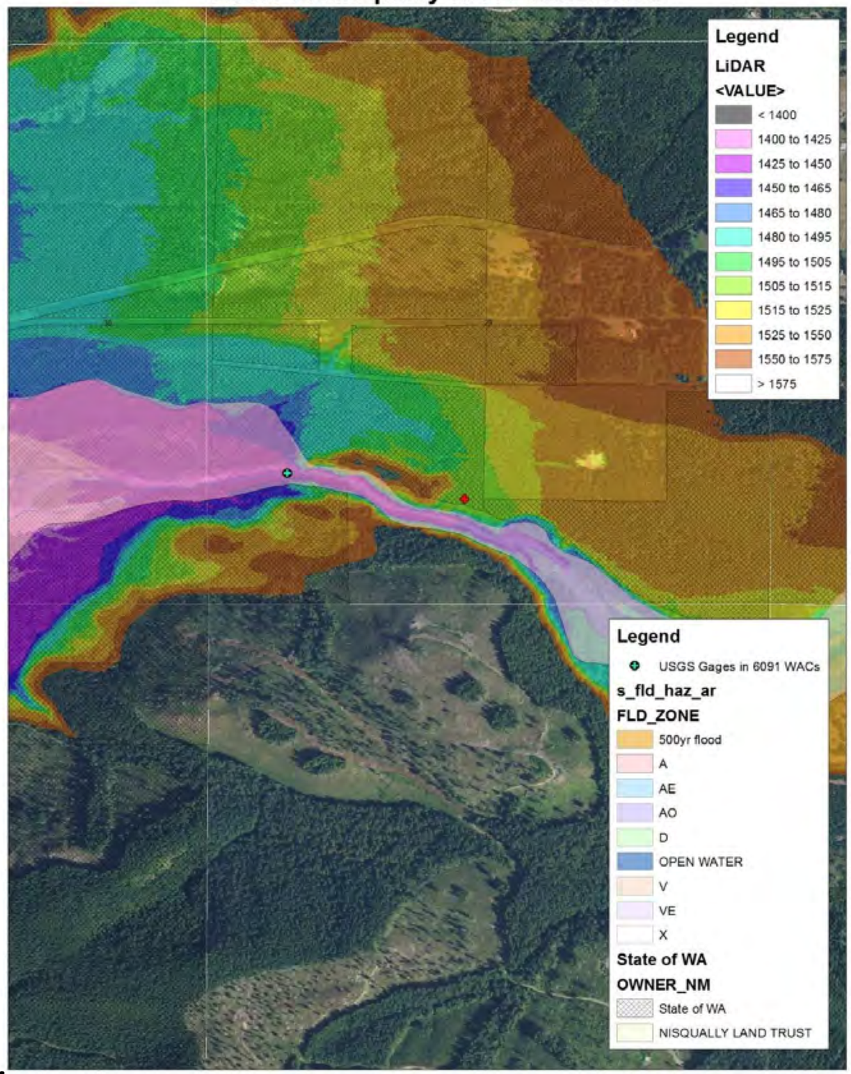
Potential Locations for Mitigation Facilities
WRIA 11 Nisqually River Watershed



Potential Locations for Mitigation Facilities
WRIA 11 Nisqually River Watershed

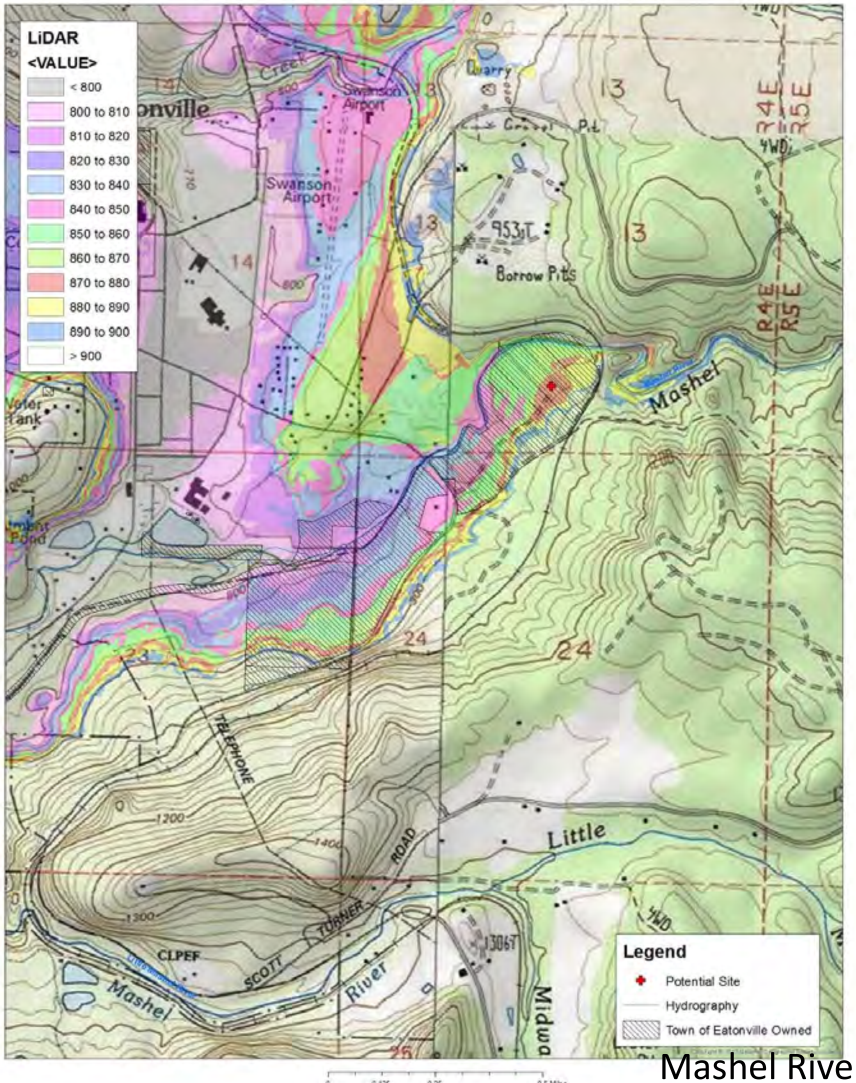


Potential Locations for Mitigation Facilities
WRIA 11 Nisqually River Watershed

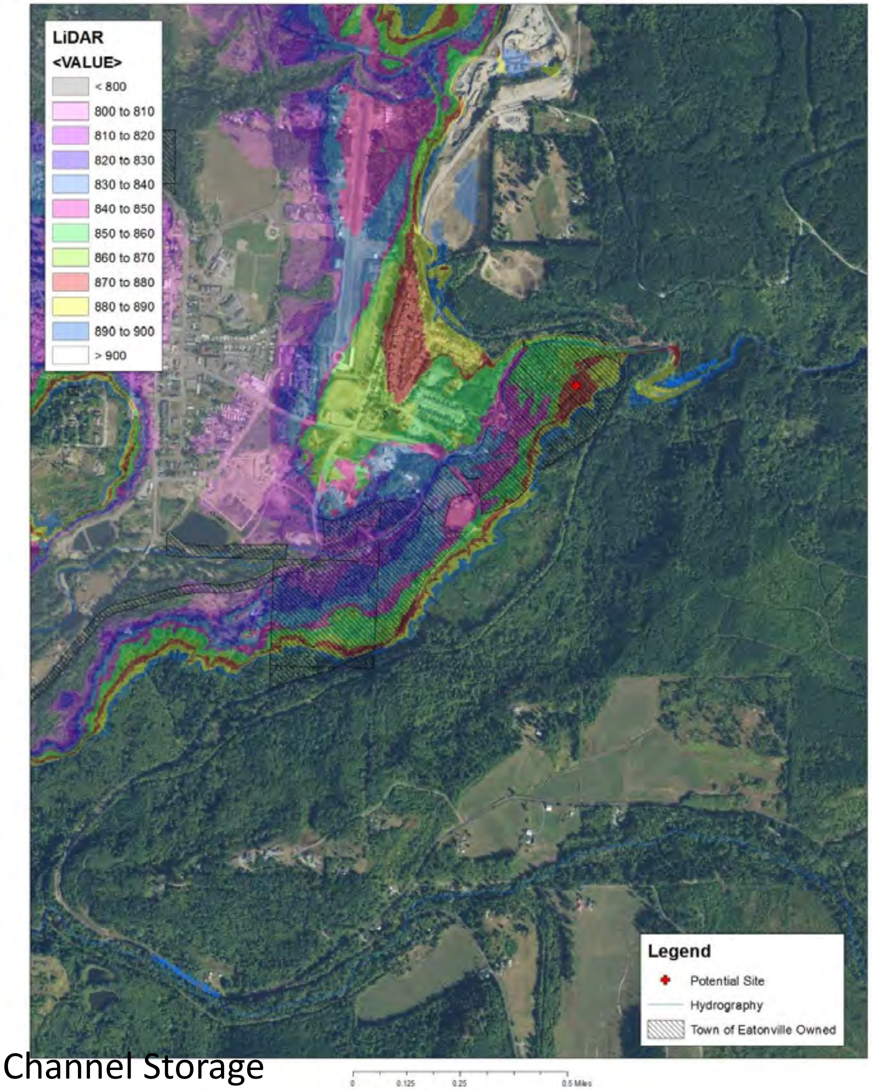


Nisqually abv Alder

Potential locations for Mitigation Facilities
WRIA 11 Nisqually River Watershed

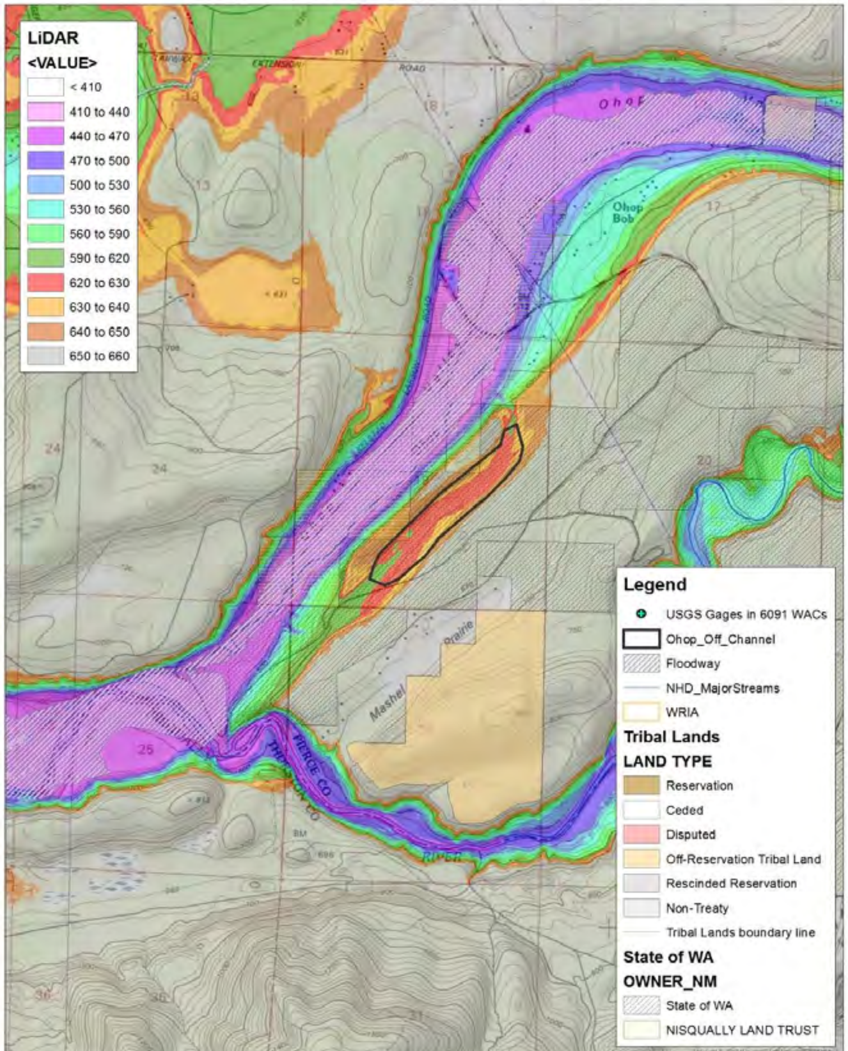


Potential locations for Mitigation Facilities
WRIA 11 Nisqually River Watershed

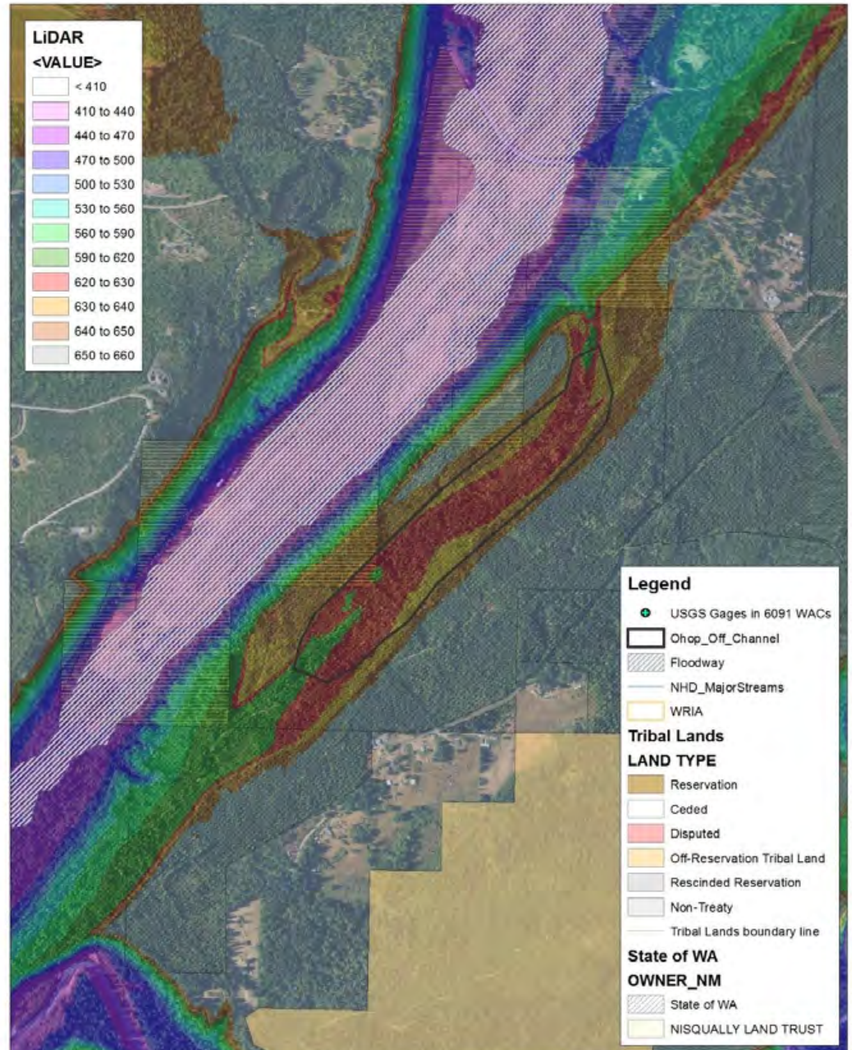


Mashel River Off Channel Storage

Potential locations for Mitigation Facilities
WRIA 11 Nisqually River Watershed

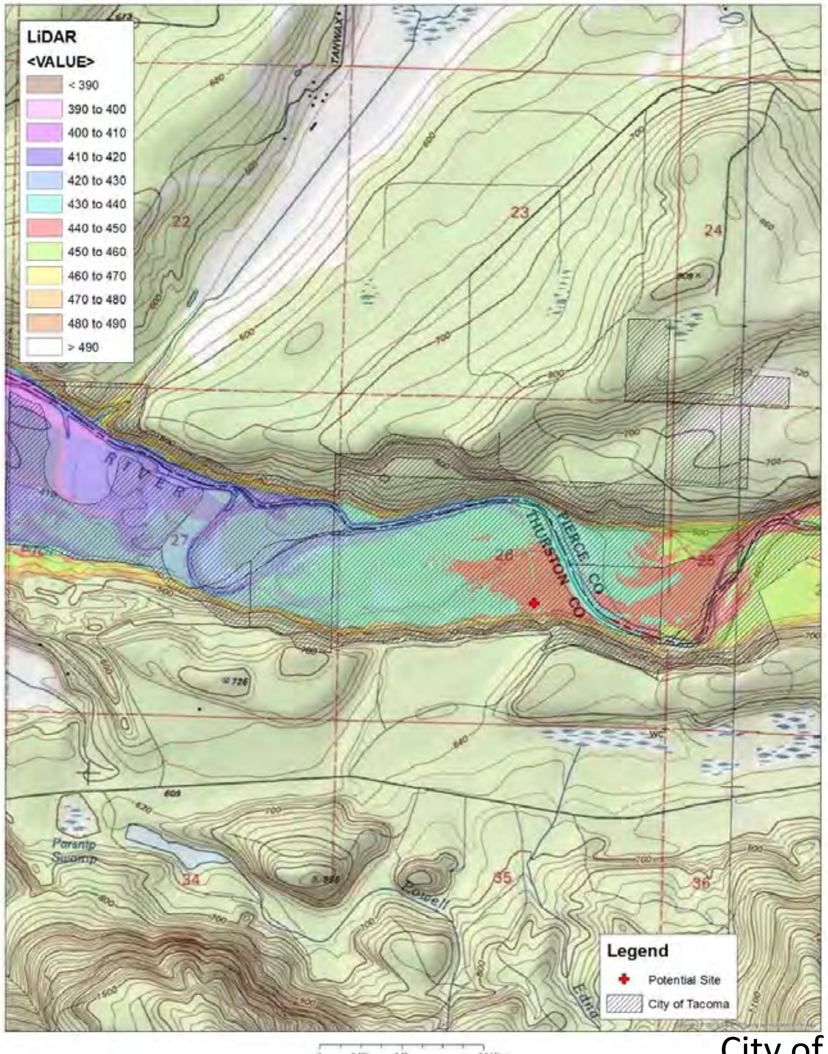


Potential locations for Mitigation Facilities
WRIA 11 Nisqually River Watershed

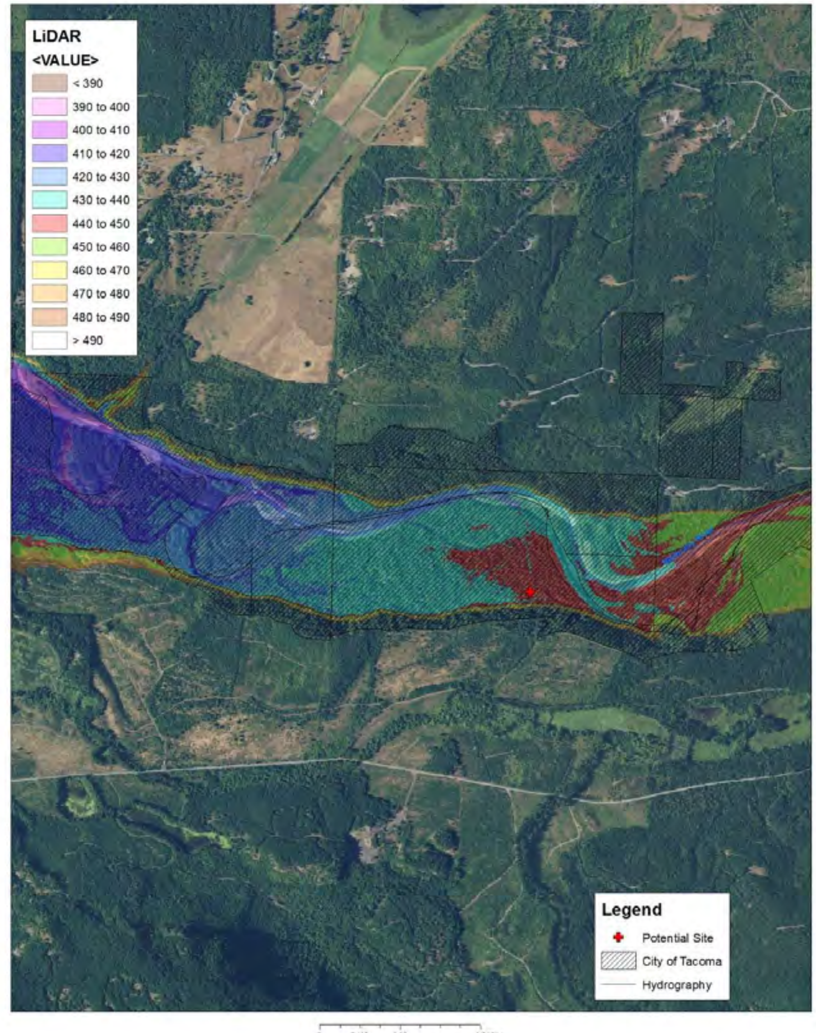


Ohop Off Channel Storage

Potential locations for Mitigation Facilities
WRIA 11 Nisqually River Watershed

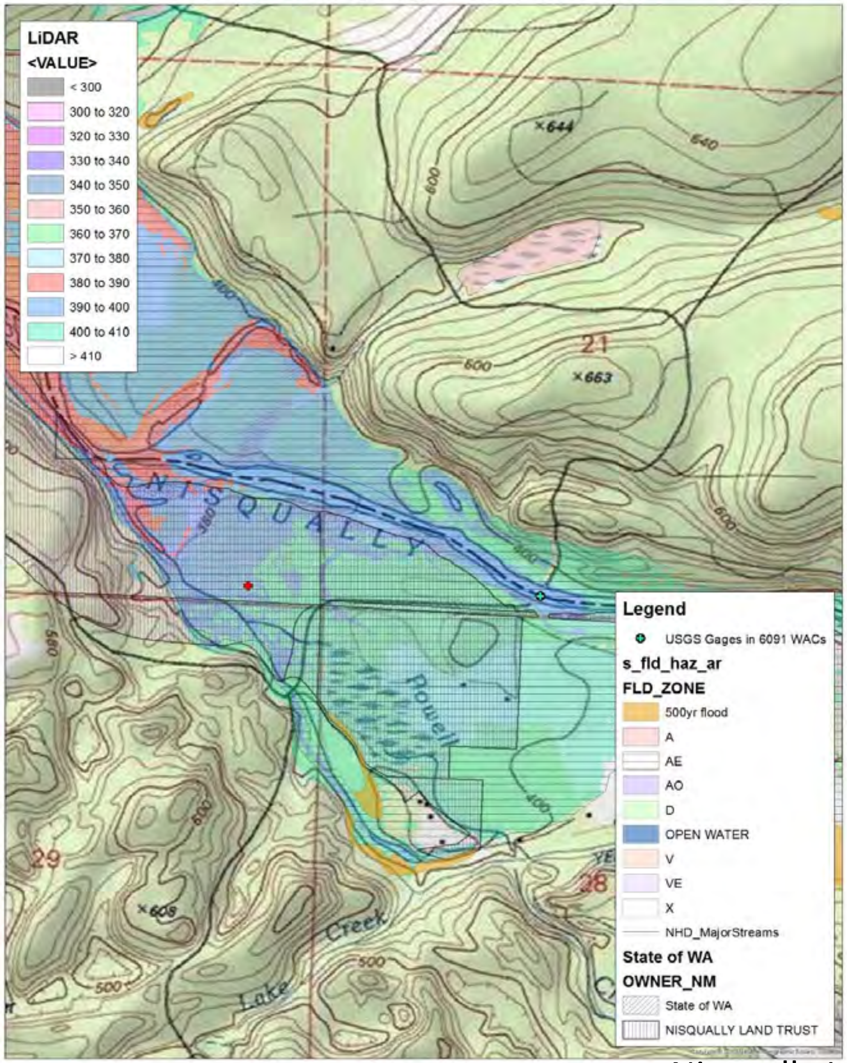


Potential locations for Mitigation Facilities
WRIA 11 Nisqually River Watershed

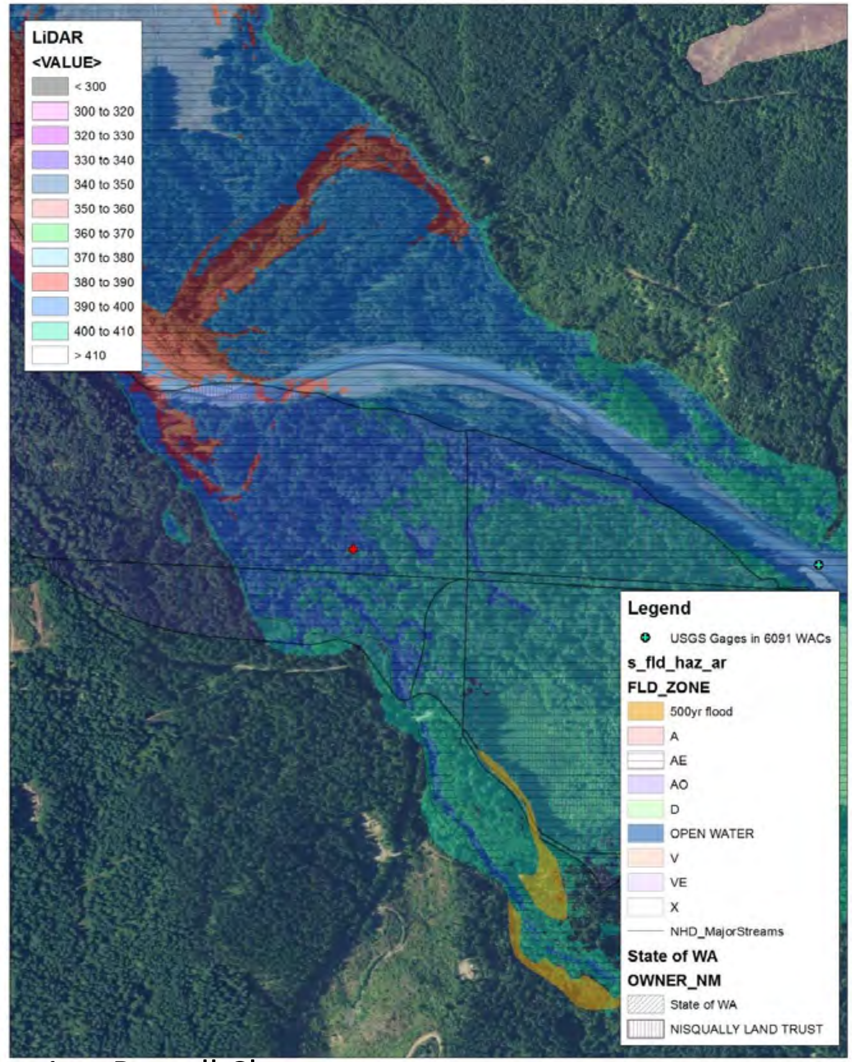


City of Tacoma Owned

Potential locations for Mitigation Facilities
WRIA 11 Nisqually River Watershed

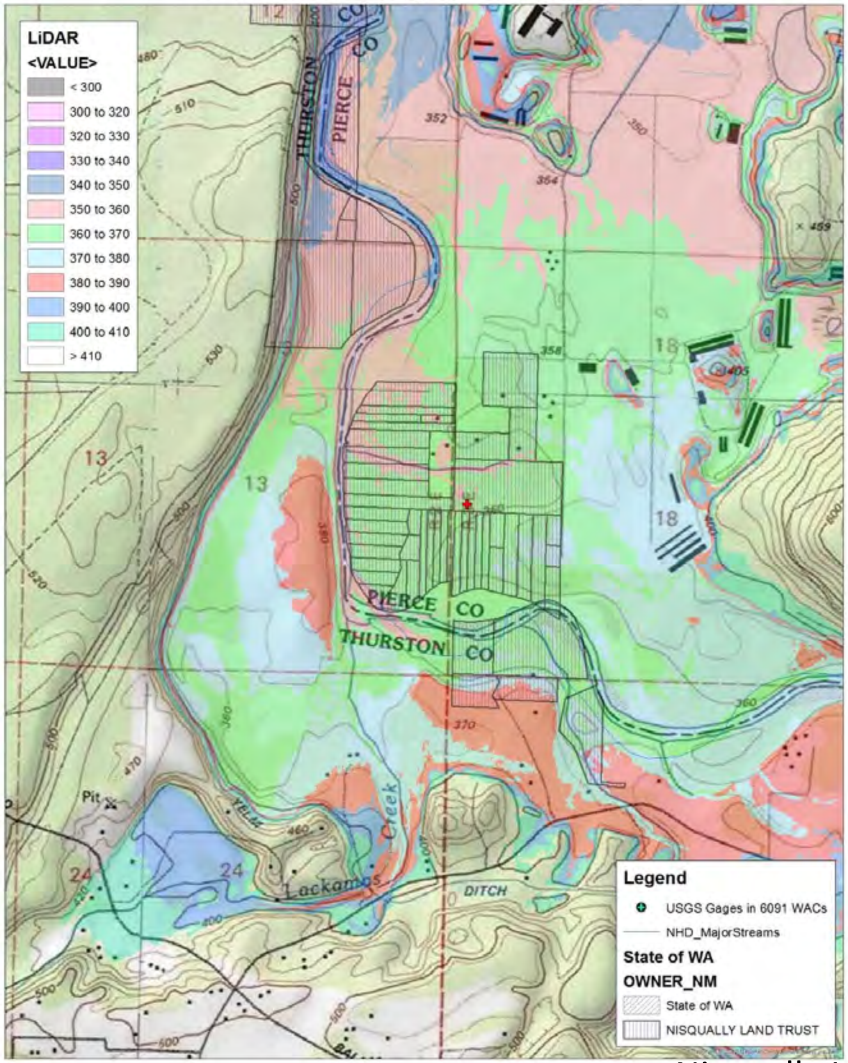


Potential locations for Mitigation Facilities
WRIA 11 Nisqually River Watershed

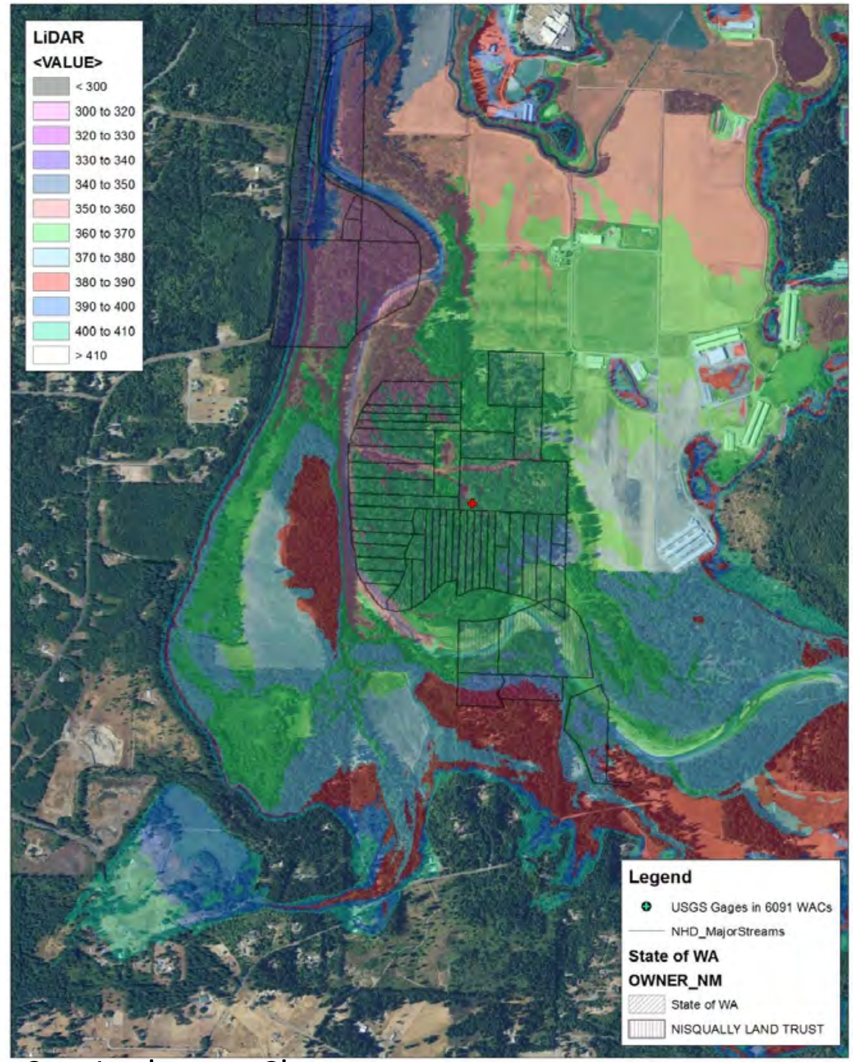


Nisqually Land Trust 1 at Powell Ck

Potential locations for Mitigation Facilities
WRIA 11 Nisqually River Watershed

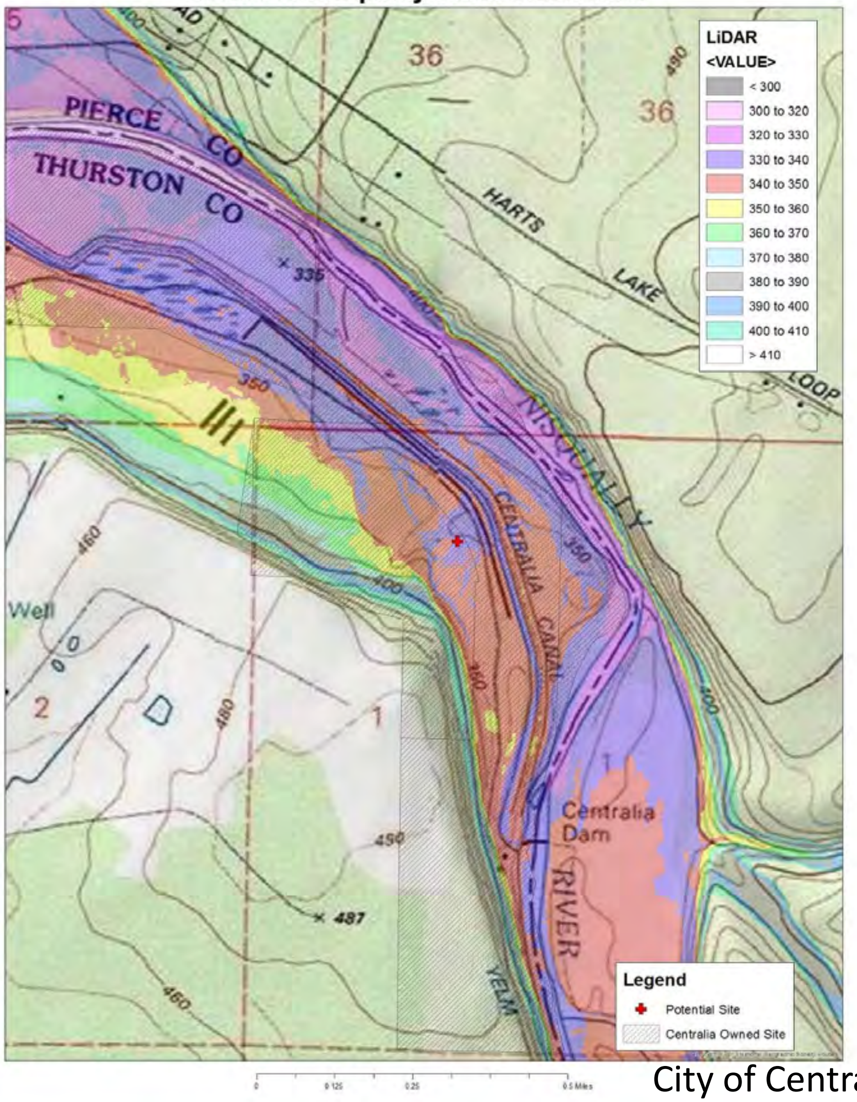


Potential locations for Mitigation Facilities
WRIA 11 Nisqually River Watershed

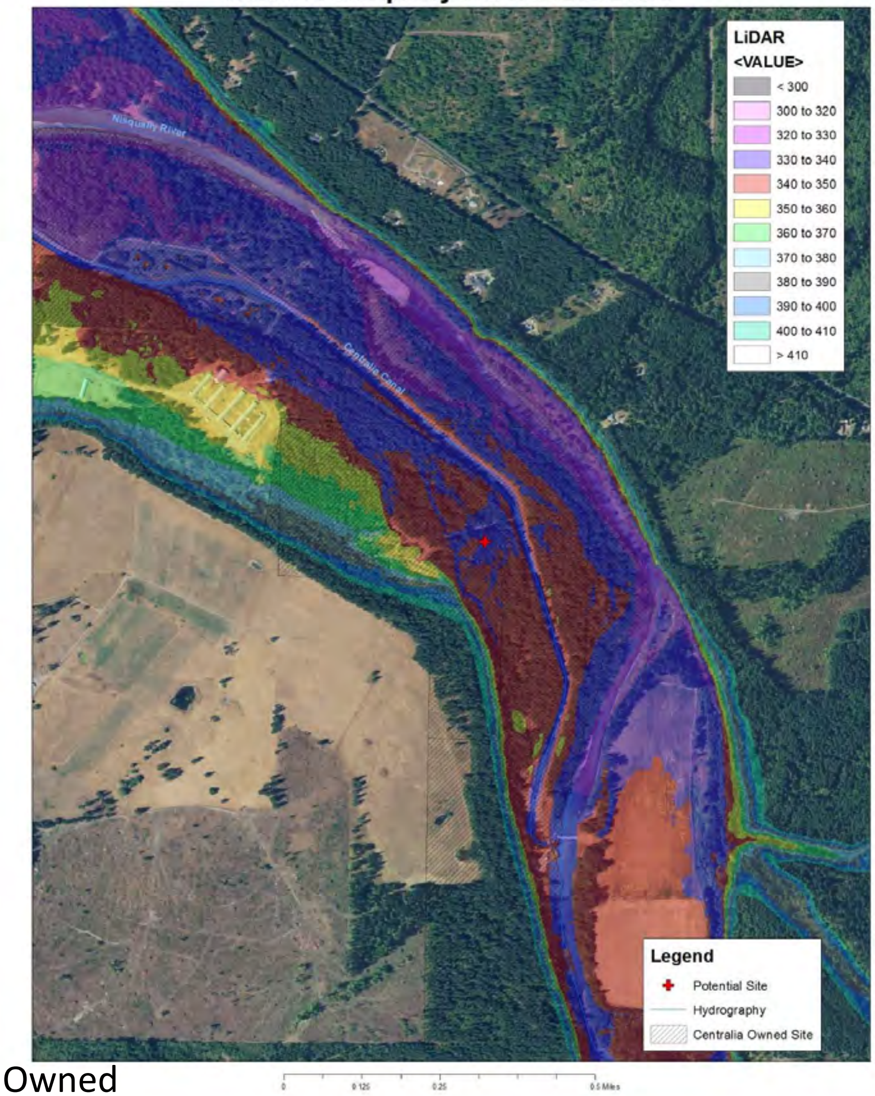


Nisqually Land Trust 2 at Lackamas Ck

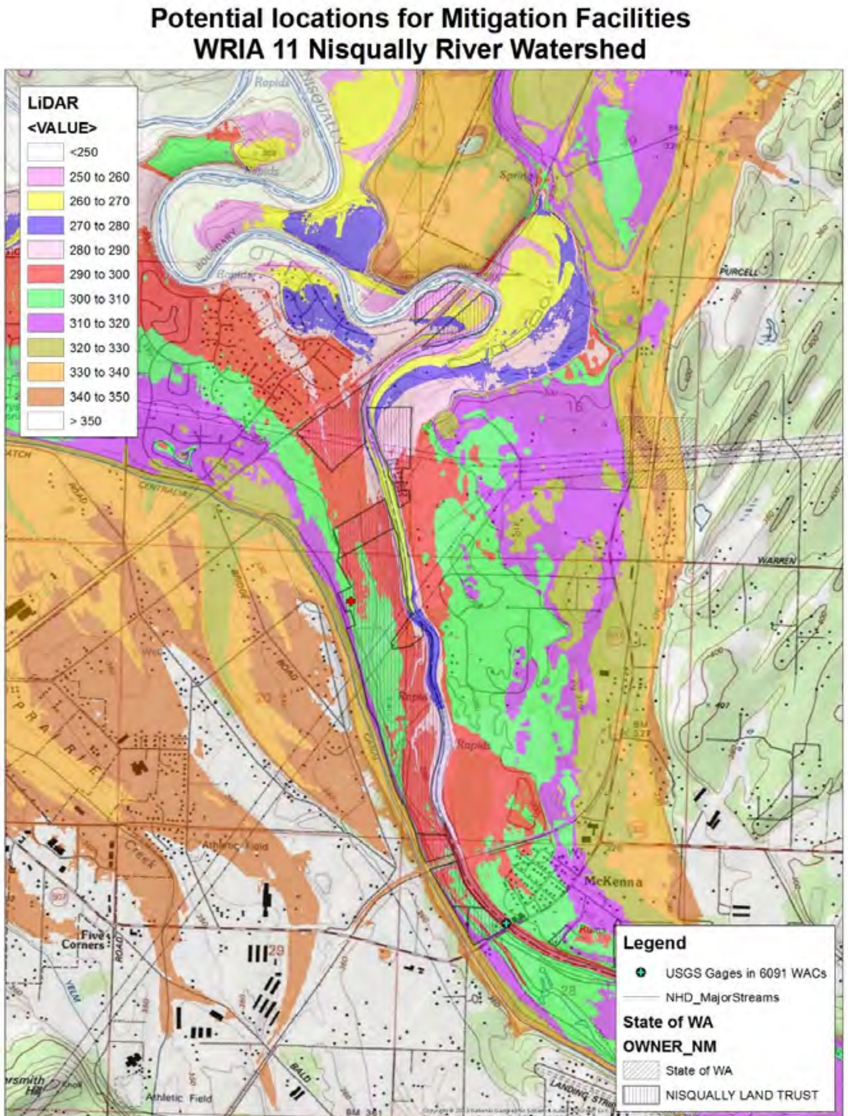
Potential locations for Mitigation Facilities
WRIA 11 Nisqually River Watershed

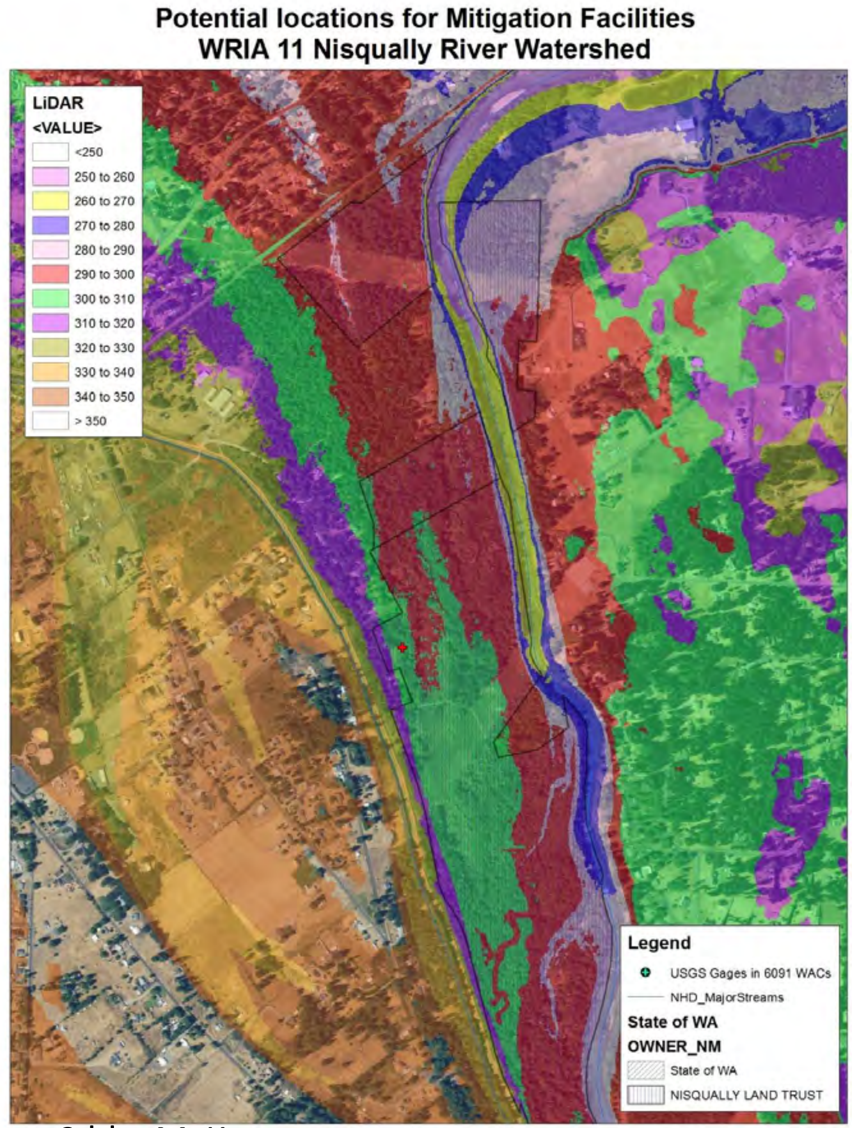


Potential locations for Mitigation Facilities
WRIA 11 Nisqually River Watershed



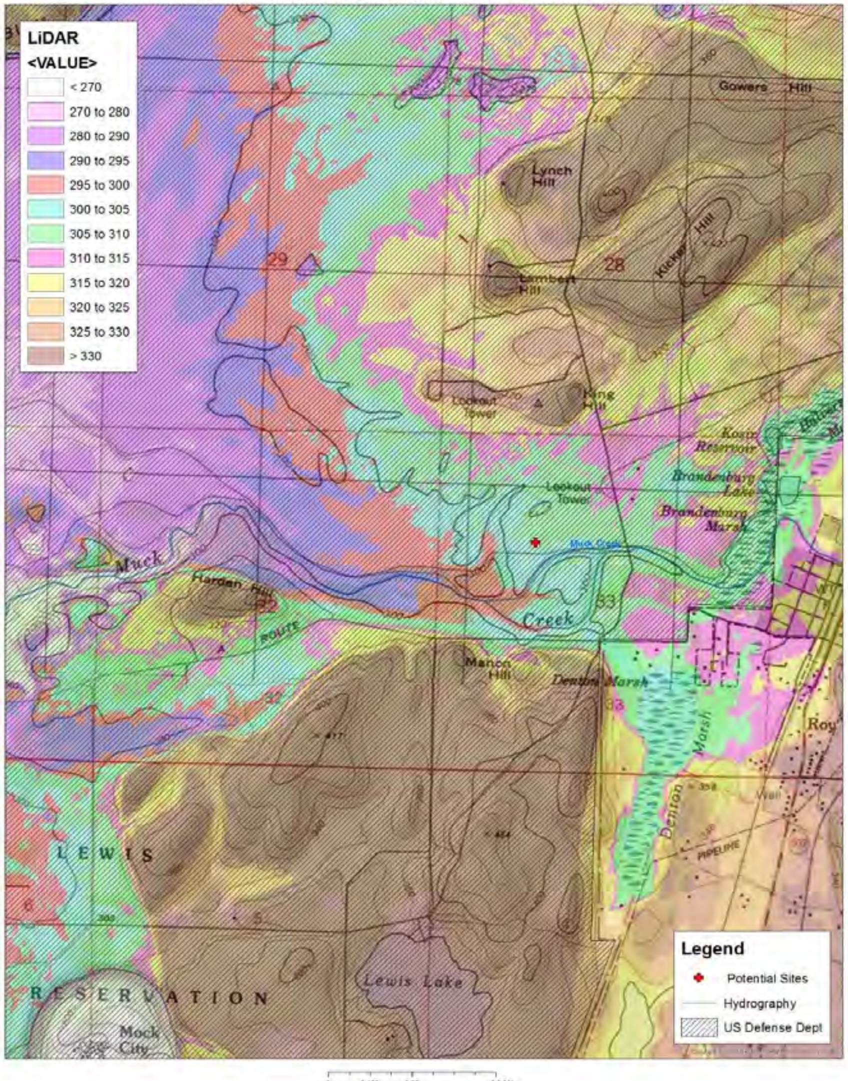
City of Centralia Owned



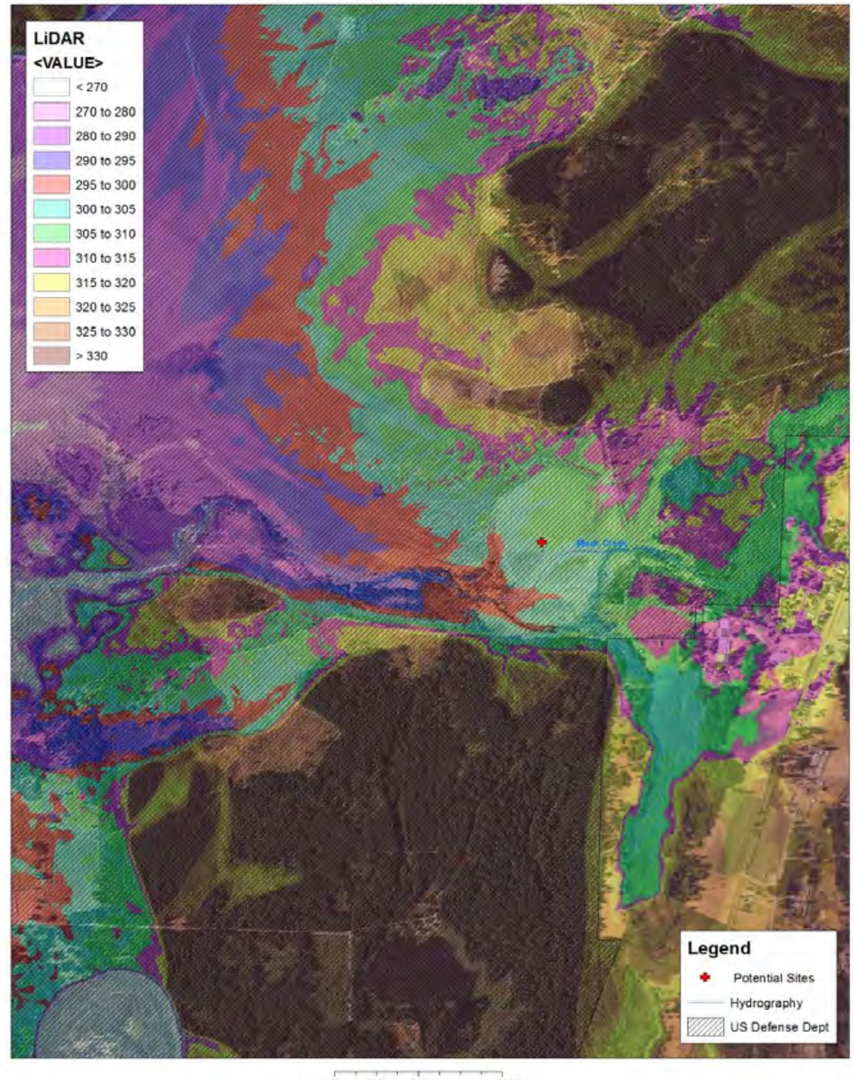


Nisqually Land Trust 3 blw McKenna

Potential locations for Mitigation Facilities
WRIA 11 Nisqually River Watershed



Potential locations for Mitigation Facilities
WRIA 11 Nisqually River Watershed



Appendix N

Pierce County Groundwater Habitat Projects Memo

Pierce County
Planning & Public Works

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January 4, 2019

Project Related Potential for Increasing Stream Flows and Retaining Water

Pierce County has identified three project types that can be applied to various situations with respect to increasing stream flows and water retention but are highly site specific: beaver dam analogs (BDA); large woody debris (LWD) jams; and the creation of groundwater channels. BDAs and LWD jams can be used to achieve similar ends, to accumulate sediment and raise incised channels back up to full floodplain utilization height and to raise groundwater levels. Since LWD jams and BDAs can be used to accomplish the similar outcomes depending on the complexities and project specifics, they are discussed together. Groundwater channels have been used in Pierce County and other areas to create habitat while accessing groundwater and contributing to instream flows in a more direct method.

Prairie ecosystems and their streams may benefit the most from BDAs in locations that are lacking naturally occurring beavers and their dams. The intended benefits are well documented by Weber et al (2017), Beechie et al (2010), Pollock et al (2015), and others. Quantifiable project contributions will be measured through installation of groundwater monitoring wells before installation of any structure to establish baseline groundwater levels and monitored and recorded at a frequency determined to be suitable by the designing engineer. Location specific implementation can include Pierce County proper as well as JBLM with the inclusion of willing landowners and funding. Pierce County has experience and success with groundwater monitoring in several areas (Neadham, Puyallup River and Clear Creek, Puyallup River) for project specific deliverables so the concept can be translated to Nisqually based needs. Additional historic information is needed in areas such as Muck Creek to determine if there were year-round base flows to consider this restoration or in the event of lacking said base flows, enhancement. These monitoring wells can guide additional work in prairie ecosystems such as comparing Douglas fir riparian population and water uptake rates with groundwater levels. These species would not be a typical component of prairie riparian ecosystems and have much higher water uptake than those species that would be typically found. Monitoring findings could present strategies for removal of these Douglas firs with riparian restoration and the use of the existing trees into LWD jams throughout the Muck Cr system where appropriate.

Groundwater channels have been used by Pierce County in the Neadham Rd area of the Puyallup River. Groundwater monitoring wells were installed before installation to determine excavation depths needed for the headwater pool. Structures of this nature need a clearly defined reason for implementation before installing. The Neadham example used by Pierce County was for the purpose of creating fish habitat. This particular groundwater source was more closely tied to hyporheic flow from the Puyallup River rather than purely from groundwater. Examples from WDFW-created groundwater channels in the Hoh River include headwater/feeder pools created in adjacent upland areas and against the valley walls. These sources provided the same fish habitat while accessing groundwater that is less influenced by hyporheic flows from the Hoh River. Additional monitoring is required to ensure the groundwater source isn’t providing water with low dissolved oxygen levels which would be detrimental to fish.

Pollock, M.M., G. Lewallen, K. Woodruff, C.E. Jordan and J.M. Castro (Editors) 2015. The Beaver Restoration Guidebook: Working with Beaver to Restore Streams, Wetlands, and Floodplains. Version 1.02. United States Fish and Wildlife Service, Portland, Oregon. 189 pp.

Weber, N., Bouwes, N., Pollock, M. M., Volk, C., Wheaton, J. M., Wathen, G., Wirtz, J., & Jordan, C. E. (2017). Alteration of stream temperature by natural and artificial beaver dams. PloS one, 12(5), e0176313.

Beechie, Timothy J.; Sear, David A.; Olden, Julian D.; Pess, George R.; Buffington, John M.; Moir, Hamish; Roni, Philip; Pollock, Michael M. 2010. Process-based principles for restoring river ecosystems. BioScience. 60(3): 209-222.