Stillaguamish Temperature TMDL Adaptive Assessment and Implementation
Snohomish County Public Works, Surface Water Management
G1000349

1/1/2010 – 5/1/2015

Final Total Project Cost: $296,481

Final Ecology Grant Contribution: $222,361

Project Description

The purpose of the Stillaguamish TMDL Project is to improve water quality conditions for temperature and salmon habitat in the Stillaguamish basin by identifying sources of cold groundwater in the streams and rivers which would most benefit from protection.

Several methodologies were followed, which led to task completion. These are documented in separate reports (appended here), as follows:

- Watershed Characterization
- Base Flow Analysis
- Temperature Regime Studies
  - FLIR (Forward Looking Infrared Imagery) Temperature Imagery Analysis
  - River Thermal Profiling
  - *2008-2012 Continuous Temperature Monitoring*
- Groundwater Seepage Study
- Assessment Synthesis and Project Identification Report
- Riparian Implementation

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Beginning thermal profile of NF Stillaguamish River in front of Whitehorse Mountain, river mile 34. August 16, 2011

Snohomish County Public Works Surface Water Management

DEPARTMENT OF ECOLOGY State of Washington

Project Accomplishments

Watershed Characterization

Watershed Characterization maps locations of water flow importance and relative degradation among 107 Assessment Units following department of Ecology's detailed methods (Stanley et al. 2011).

Results were used to describe how stream temperature may be influenced by the relative importance of water flow processes - *Delivery, Storage, (Recharge & Discharge – Groundwater*) – and *Degradation*.

58 Assessment Units (AUs) draining tributaries were used to test whether water temperature (standardized 7-day average daily maximum C) in 2008-2012 was related to water flow process results.

Cooler water temperature among AUs was significantly correlated with relative water *Recharge* importance and the *Groundwater* component of the water flow importance model.

Water temperature was not correlated with AU drainage area (2-10 mi^2), percent riparian buffer forest cover, any other water flow importance process, overall importance or overall degradation.

For 38 floodplain and tributary AUs with cold-water inflow mapped from infrared imagery, we found significantly higher count and thermal effect (temp x size) for AUs with greater *Groundwater* flow importance. For tributaries only, the thermal effect (but not count) was significant.

These results suggest that the combined influence of *Recharge* and *Discharge* as components of the *Groundwater* process have relatively more weight influencing water temperature.

To our knowledge, this is the first evaluation of water flow responses based on hypothesis testing of the processes that Watershed Characterization in Puget Sound represents, and therefore validates it (at least partially) as a coarse screening tool for planning-level decision-support.

Baseflow (1911-2013)

Forty gages in the Stillaguamish watershed (1911-2013) are described for the period of record, drainage area, climate phase and computed average 7-day and 30-day averaged daily flow. A USGS Baseflow Index model (PART) was implemented for 34 gages for each year of useable data.

Variable low flow pattern between cool- and warm-climate phases was persistent for decades. A sharp decline in flow in 1985 defined a break in flow response for this report, but lagged the 1976-1977 North Pacific Ocean phase change as published elsewhere.

The annual low flow in the NF Stillaguamish River was 55% higher in 1947-1984, compared to 1985-present, but flow has been significantly increasing in the NF Stillaguamish River since 1985. The nearby Skykomish and Sauk Rivers confirm the same low flow patterns between 1928-2013. Jim Creek, Pilchuck Creek, SF Stillaguamish River, and Squire Creek show similar patterns of flow response between climate phases, but have varying severity of responses (and limited datasets).

Squire Creek, the snow-dominated, headwater mountain stream appears to be more flow sensitive to climate phase changes compared to Pilchuck Creek and Jim Creek. Higher elevation, headwater streams with relatively protected land conservation status may actually be more vulnerable to temperature increases based on flow sensitivity to climate change than some developed lowland locations. But, this warrants additional investigation.

Temperature Regime Analysis

129 cold-water inputs were identified in the Stillaguamish River, NF and SF Stillaguamish rivers, and in Pilchuck Creek from Thermal Infrared (TIR) imagery. 96 of these were considered cold-water "refuges."

Cold-water refuges were classified by source (tributaries, floodplain, side channels, seep/springs, hyporheic) and estimated size of influence on the receiving river (*temperature difference x size*).

Half of all cold-water inputs were located in the NF Stillaguamish River where spacing (per mile) was most frequent due to cold-water discharge from side channels, floodplain locations and seeps/springs, in addition to tributaries. Cold-water inputs into the SF Stillaguamish River were dominated by tributary sources.

Restoration of cold-water refuges in the North Fork will be supported by river and floodplain restoration, whereas restoration of cold-water refuges in the South Fork will be more based on AU restoration and habitat enhancement at tributary confluence locations.

Field-based thermal profiling using a continuously recording thermistor found numerous locations of tributary and groundwater inflow that mitigated downstream heating in Jim Creek and Pilchuck Creek.

Patches of colder water were often in (or downstream from) deeper pools in locations with groundwater inflow (seepage), suggesting restoration of pool scour in flow gaining reaches should provide temperature benefits as well as habitat improvement in Pilchuck and Jim creeks.

Between 2008-2012, 242 datasets of continuously recorded temperature were collected in summer in mainstems, side channels, and tributaries where temperature standards are 12, 16, or 17.5 Celsius.

The 7-day average daily maximum temperature, on average, was warmest in 2009 and 2010 and coolest in 2008 and 2011.Tributaries and side channels were coldest, exceeding temperature standards by 30% among all years. Mainstem locations were warmest, exceeding temperature standards by 70% among all years.

- 17.5 C standard - tributaries were coolest and exceeded the standard only 2% of the time (1.4 days/year). Side channels were notably warm compared to elsewhere, but still may be temperature refuges in discrete locations.
- 16 C standard, side channels were coolest, then tributaries, compared to mainstem sites, and the difference between side channel temperature and mainstem locations was greatest relative to other comparisons. Side channels exceeded the temperature standard 9% of the time.
- 12 C standard, water temperature was coldest in side channels, then tributaries and mainstems, but exceeded standards 74% of the time. Protecting tributaries and restoring side channels is recommended.

Climate changes may have a relatively greater impact on flow and temperature in headwaters (12 C), as increasing AU sensitivity to heating corresponded with increasing exceedance (%), making protection more challenging.

Restoration of side channels and riparian vegetation along mainstem locations for sites with a 12 C and 16 C standard will offer temperature benefits in the floodplain where resilience to effects from climate change are likely to be greatest relative to tributaries, except in Puget Lowland tributaries.

Seepage Study

A seepage study to determine reach-scale flow gain or flow loss was implemented on September 1, 2011 in lower Pilchuck Creek and in Jim Creek on September 4, 2012 near the time of annual low flow.

In Pilchuck Creek, groundwater seepage contributed 60% of the flow accumulation in the lower 7 miles. The majority of groundwater inflow, 77%, occurred from RM 0-3.1.

In this reach, upstream from I-5, flow contribution from tributaries, floodplain areas, or other groundwater discharge locations predominantly arose from the east, coincident with permeable upland glacial deposits or alluvium in the floodplain, as also highlighted by the Watershed Characterization.

In locations with flow gaining reaches, such as lower Pilchuck Creek, large wood jams that scour deep pools will improve groundwater seepage flow to this key habitat type.

In Jim Creek, the contribution of groundwater as seepage flow was estimated for 3 cross-section pairs. Whereas the first cross-section pair far upstream was estimated to have groundwater inflow, the other 2 locations appeared to be losing reaches, where net surface flow decreased downstream due to loss of surface flow downstream of Vos Creek.

Vos Creek contributed 16.5% of the total Jim Creek flow during the seepage study. And, Vos Creek was very cold, originating from the Arlington Heights outwash aquifer. As above, promoting AU area restoration of water flow processes (*Recharge, Surface Storage*) could support seasonal storage and summer base flow.

Project Identification and Implementation

This project identifies 90 potential projects, of which, 40 are side channel and wood placement project types. Restoring isolated side channel habitats and river processes that support side channel formation along with tributary protection and restoration in floodplain locations is recommended.

Strategically, restoration of cold-water refuges in the North Fork Stillaguamish River will be supported by side channel connections and river process restoration, whereas restoration of cold-water refuges in the South Fork will be based more on Assessment Unit restoration and habitat enhancement at tributary confluence locations.

Due to past low flow variability and expected future climate change, restoration of side channels and riparian vegetation within floodplain locations for sites with a 12 C standard will offer temperature benefits where sensitivity to effects of climate change are likely to be less.

In locations with flow gaining reaches, such as lower Pilchuck Creek, large wood jams that scour deep pools should improve groundwater seepage flow to this key habitat type (as well as providing structural habitat improvement).

In a flow-losing reach, protecting and restoring tributary shading and flow (such as at Vos Creek in Jim Creek), as well as habitat quantity and quality at the cold tributary confluence is important. Large wood restoration can improve habitat suitability (pools and cover) at locations where temperature characteristics are most likely to be favorable during summer.

AU area protection and restoration of water flow processes that target *Recharge, Discharge and Groundwater* model parameters from Watershed Characterization will promote seasonal water flow that improves temperature and/or creates more favorable (temperature/size) habitat patches.

This project identifies 50 potential riparian planting locations that are spatially discrete and functionally linked to the water flow processes and temperature results, and do reflect shading deficits identified in Department of Ecology's Temperature TMDL Plan. Many locations with shading deficits also need planting, in tributaries and not along larger rivers. Tributary locations can be shaded faster with smaller trees and narrower buffers, are not typically subject to erosion from channel migration.

Smaller tributaries contribute colder water to mainstem locations creating thermal refuges, and our results suggest many locations are relatively insensitive to warmer air temperature and watershed position relative to mainstem river locations.

Finally, the projects suggested here are not exhaustive of all possible strategies, ideas, data, and public or private stakeholder interests that could address this habitat and water quality problem. Recommendations are additive to those proposed in the TMDL implementation plan. Also, project concepts require additional feasibility, review and consideration of costs, benefits, and risks.

Water Quality Improvements

Two locations were planted as part of this project, in the lower South Fork Stillaguamish River and in Trib 80 (Pilchuck Creek). A total of 8.8 acres riparian buffer was planted in 2013 and 2014, along 2700 lineal feet of channel.

Finally, we estimated pollutant load reduction values for these BMPs using the EPA's STEPL 4.1 model for implementation of 3.5 acres and 5.3 acres of the "streambank stabilization and fencing" model BMP on Trib80 in Pilchuck Creek and South Fork Stillaguamish River, respectively.

The Next Steps for Continued Success

Results from this grant, including recommended projects will be communicated to watershed stakeholder groups that implement water quality improvement projects. Detailed, area-specific descriptions and presentation of supporting data from component studies that support project identification will continue to be developed for outreach and communication.

Detailed feasibility analysis, including landowner outreach needs to be conducted for construction implementation, particularly for more complicated projects involving side channel restoration and wood placement. For some projects, conceptual designs will be needed in order to seek grant funding for final design and implementation.

Projects that improve shading, as recommended in the TMDL Implementation Plan, should continue to be to implemented, particularly on smaller streams draining to the North Fork, South Fork, and mainstem Stillaguamish Rivers.

Annual temperature monitoring should continue at multiple locations in mainstem rivers and tributaries to evaluate long-term trends and determine how or whether locations are relatively sensitive to effects of climate variability or are resilient to these changes.