Skagit Basin Water Mitigation Feasibility Assessment

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1 Overview

The objective of the research described herein, and funded under Engrossed Senate Bill No. 6589, is to assess mitigation alternatives for permit exempt wells in the Skagit river basin that are subject to the Skagit River Basin Instream Resources Protection Program Rule (WAC 173-503).

There is a need to explore mitigation alternatives for a set of specific properties that are currently without a legal water right, and there is an interest from a number of entities to enable development more generally into the future. The specific properties of interest are those that constructed houses after WAC 173-503 went into effect on April 14, 2001 in response to a 2006 rule amendment issued by Ecology which was overturned by The Washington State Supreme Court ruled against on October 3, 2013 in a case brought by the Swinomish Tribe (Swinomish Indian Tribal Community v. Washington State Department of Ecology).

The implication of this ruling is that all of these properties no longer have a secure, uninterruptible, water right and thus need to mitigate. To date, only one mitigation alternative for a small development has been deemed amenable to all interested parties. This has negative consequences for current owners of the relevant properties and restricts potential future development in rural areas throughout the basin. The instream flow rule also has implications for bareland parcels where the owners want to build a home but have not yet. This study does not consider these properties in cost estimates, which could be thought of as additional demand for housing. This is to maintain focus on those who have been most adversely affected by the rule changes and legal decisions, which are individuals that have built structures that have little to no market value without a legal water right. However, cost estimates reported in this study can be used to consider mitigation for new construction. In particular, a discussion is provided on how the relative costs of mitigation alternatives vary with and without new development.

The enabling legislation states the objective as follows, "to examine the feasibility of using effectively sized water storage to recharge the Skagit River Basin when needed to meet minimum instream flows and provide non-interruptible water resources to users of permit exempt wells within the Skagit river basin." To the greatest extent possible this report builds on previous studies in order to avoid duplication. The goal is to identify the least cost mitigation option in a spatially explicit manner for all of the affected properties. A scenario that was not considered in this study based on the scope of the legislation is large scale storage in the form of a reservoir. The timeline for reservoirs is measured in decades rather than years. Also, a single large reservoir is likely to not be a good option in the Skagit watershed because of multiple critical low flow problems on subtributaries dispersed through the region.

While this report discusses a range of options most of the modeling effort is in piping and trucking for flow augmentation. This is a complement to existing studies which have considered piping and trucking for direct use to replace an existing well. The logic underlying this decision is that there is reason to believe that it is less costly to mitigate instream flow at a single point near a river than at each parcel separately. This does raise the issue of whether mitigation is in-place. Uncertainty over this shapes the analysis as is discussed in the report.

The study area is shown in Figure 1. The red areas are the affected properties. The boundaries of the HUC-12 watersheds within the Skagit River Basin are shown along with (blue) the major tributaries of the Skagit River.

Key Findings:

- For most properties piping or trucking for flow augmentation is the cheapest alternative with slightly more for trucking.

- Applying the lowest cost option after comparing all scenario results, most properties have an estimated mitigation cost of between $6,000 and $9,000.
- There are three basins where winter flow augmentation may be cheaper than piping or trucking. These three basins contain about 40 properties.
- Large differences in piping results based on augmentation point location in some subbasins motivates a more detailed analysis of where mitigation needs to occur in those cases.
- Incorporating future development beyond the 455 properties considered in this study will make piping more competitive relative to trucking.

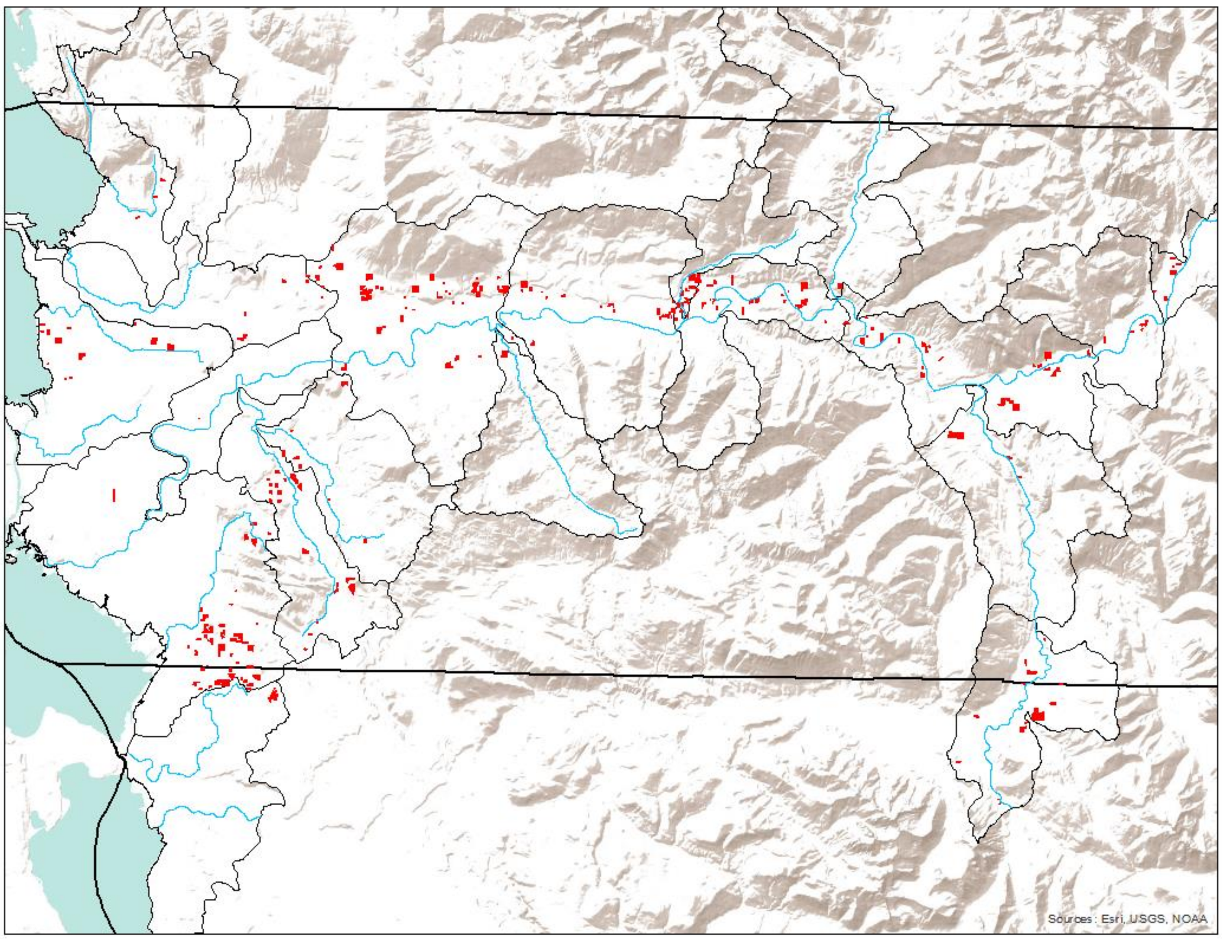

Figure 1. Skagit Basin with build properties in red, HUC-12 watershed boundaries in black, and Skagit Mainstem and tributaries in blue.

The stakeholder outreach process has resulted in a number of important comments and questions that will be addressed in the version of this report to be completed after the public review process. There was not adequate time to update the analysis addressing many of these questions in this version of the report. Incorporating these changes will likely lead to an upward adjustment in costs for piping and trucking scenarios. An exception is incorporating future development which will drive costs down for the piping scenario. Items that will be included in the final report that are not addressed herein include:

- Piping costs when restricting pipe paths to follow roadways. This will include a land cost when piping needs to extend from a roadway to an augmentation point (following assumptions in the reclaimed water study in Nookachamps Creek).
- Identification of critical biological points on subtributaries. This will inform whether augmentation points need to be located on subtributaries rather than at the headwaters of the subbasin.
- Consideration of capacity and inchoate rights public water systems as potential limitations on the provision of flow augmentation throughout the watershed.
- Greater focus on mitigation costs assuming the augmentation point is at the headwaters of each subbasin rather than the low, middle, high cost points used in this version of the report.
- Additional operating and management costs for piping.
- A detailed summary of a potential implementation of the piping for flow augmentation scenario for one subbasin.
- An expanded description on the effects of future development on costs for piping versus trucking (see Section 8.1).

2 Previous Studies

A range of scenarios that could potentially provide the Skagit properties with a legal uninterruptible water right have been considered and discussed in previous reports.

Under SB 5965 Ecology has authored, still in draft form, a review of Skagit water supply options (Dept of Ecology, draft). It does not include any new cost estimates. The report focuses on extension of public water systems for direct use, rainwater collection/trucking, building in areas not in hydraulic continuity with the Skagit River, and private mitigation plans. Trucking costs per household "range from $25,000 for an indoor only system to $260,000 for a system capable of irrigating up to 10,000 square feet". These costs are in present value terms, so they represent the one-time cost to the household. In addition to cost, DOH regulations and the willingness of banks to lend to properties with cistern-based water systems are identified as obstacles.

Under contract with Ecology, RH2, a consultancy, considered the feasibility of extending existing public water systems directly to properties as a replacement for wells (RH2 Engineering, 2014). In addition to providing cost estimates this report addresses an important legal issue that is relevant to this study in regards to municipal inchoate rights as a mitigation source. As stated on page 4, inchoate water rights found to be in good standing can be "transferred" to be integrated into a regional water system. A color coding system is used to categorize the standing of municipal inchoate rights. Tatoosh Water Company has been given a blue rating by DOH which means that it is not adequate for adding new service connections. Expansion would require a new Comprehensive Water System Plan. Also discussed in the report is the issue of leakage, which is substantial at close to 50%. Tatoosh's water right allows for a maximum withdrawal of 1,135 acre-feet of water. The maximum over a 12-year period starting in 2000 was 112.1 acre-feet.

A project that received serious consideration used wetlands restoration for water storage. The reports summarizing this project also provide discussion of legal issues relevant to this study (Associated Earth Sciences, Inc., 2014). Specifically, whether Upper Skagit Indian Tribe (USIT) needs a permit to divert or store water for mitigation. The key question identified in this study is whether the water code related to stormwater management is relevant.

The potential to rely on reclaimed water for instream flow mitigation has also been considered in collaboration with Skagit County Sewer District No. 2 in the Nookachamps Creek Basin. The idea behind the approach is that flows in the Nookachamps Creek can be augmented by reclaimed municipal water in a way that mitigates for wells in the basin. An important legal point discussed in the report summarizing this option is that the instream flow rule does allow water to be moved from its origin basin to another basin where mitigation is provided. Estimates of total costs for the project range between $10 and $14.2 million.

3 Household Water Use Assumptions

There remains uncertainty over how much water households that rely on wells actually. In part this is because there is variation across households. The best case data source is actual metering data. A study was performed by Golder Associates, Inc. (Einberger, C. et. al., 2014) in Skagit County where well water use was metered for 18 houses. Water use per day ranged from 56 to 456 gallons. The average across all properties was 175 gallons per day. An attempt was made to separate out indoor use by looking at the average for the year after removing peaks in the summer months. The study found that there was no apparent water use for 7 of the 18 properties. Their estimate for the range of indoor use was 41 to 289 gallons per day with an average of 131 gallons per day. Outdoor use averaged over the entire year ranged between 6 and 112 gallons per day with an average of 56 gallons per day.

Building from the Golder Associates study and assumptions in a study by Ecosystem Economics (2015) and others it was assumed that the consumptive use per household for indoor use only is 15 gallons per day, or 0.0168 ac-ft/year. In scenarios that include outdoor use it was assumed that 0.08 ac-ft is consumptively used per year (Ecosystem Economics, 2015). Therefore, in the indoor+outdoor scenarios it was assumed that 0.1 af/year is used.[1]

One way in which the study attempts to be conservative in mitigation requirements is to assume that the full consumptive use for each property needs to be mitigated for. This is despite the fact that low flow issues only occur in certain times of the year. However, the complexity of ground and surface water continuity makes the possibility of satisfactorily only mitigating partial use based on timing problematic.

[1] 1 US liquid gallon/day = 0.00112014 acre-feet/year.

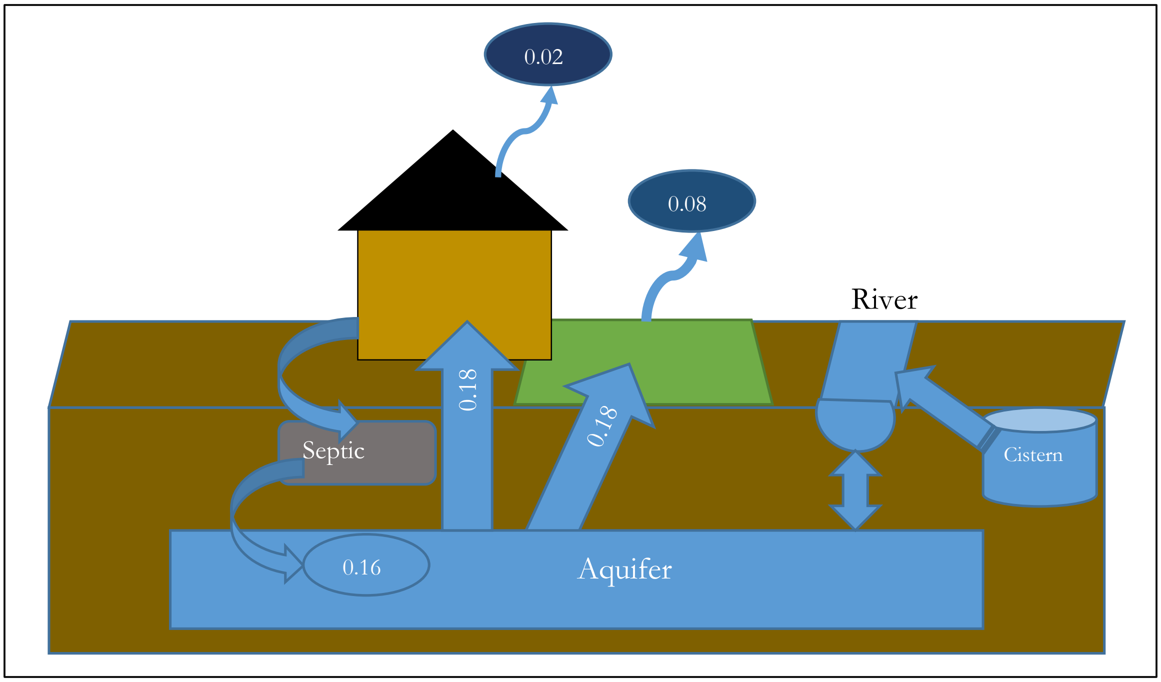

Figure 2. Assumptions on water diversions and consumptive use in acre-feet per year.

3.1 Data Sources

Data for the in-stream augmentation analyses were obtained from either publicly available databases (e.g. County websites) or directly from the WA State Department of Ecology. The data listed in **Error! Reference source not found.** give the source location for the base datasets used to estimate the distance between existing municipal systems/sources and augmentation points on a HUC-12 mainstem:

Table 1. GIS data sources for municipal pipeline extension modeling.

Data Description	Online Location
DEM elevation	National Hydrography Dataset http://www.horizon-systems.com/nhdplus/NHDPlusV1_17.php
Flowlines	National Hydrography Dataset http://www.horizon-systems.com/nhdplus/NHDPlusV1_17.php
Flow accumulation	National Hydrography Dataset http://www.horizon-systems.com/nhdplus/NHDPlusV1_17.php
HUC-12 boundary	WA State Department of Ecology ftp://www.ecy.wa.gov/gis_a/inlandWaters/waterdiversions.zip
Skagit PUD mains	WA State Department of Ecology *Personal communications*
Tatoosh Water Co. mains	WA State Department of Ecology *Personal communications*

Parcels without water right	WA State Department of Ecology *Personal communications*
Roads	Skagit County Geographic Information Services http://www.skagitcounty.net/Departments/GIS/Digital/streets.htm

4 Piping for Flow Augmentation

The extension of pipelines from existing PUD systems provides the backbone of the analysis. Given that there are an infinite number of points where pipelines could be extended it was necessary to develop a rationale for only looking at a limited number of points. The key decisions made were:

a. In piping for flow augmentation the analysis primarily considers a single pipeline extending to a river for each subbasin.
b. Use HUC-12 subbasins as the unit of analysis. Properties are scattered throughout the entire basin so it is valuable to find a way to break apart the larger region into smaller units.
c. Only augmentation on the mainstem of the tributary. It is possible that critical minimum flow issues are on subtributaries.
d. Three augmentation points on the tributary mainstems are identified that provide a range of cost estimates.

4.1 Cost Assumptions

Piping cost assumptions can be separated into fixed and recurrent, or variable, costs. Fixed costs include the pipeline, which is a function of the pipeline length and diameter. Recurrent costs include the utility charge to pumping water.

The following formulas were used to estimate the piping costs. Piping costs decrease the smaller gauge pipe used so the minimum pipe diameter is calculated with the following formula (WSU, 2016):

$V = 0.408x(Q/D^2)$
V = water flow velocity inside the pipe (ft/second)
Q = flow rate of water inside pipe (gpm)
D = pipe inside diameter

Fixed Cost Assumptions

- Pipeline length represents the pathway between existing utility infrastructure and a stream augmentation point with the smallest slope. The cost of the pipeline and installation was estimated to be $200,000/inch-mile.

- Pipeline diameters available are either 0.25”, 0.5”, 0.75” or 1” (inner diameter). The diameter selected for a basin depends on the volume of water required.

Recurrent Cost Assumptions:

- Utility pumping charges were assumed to occur when water needs to move uphill to reach the augmentation point. In these cases, it was assumed that the cost to lift one acre-foot of water 1 foot in elevation is $0.102 (UC Cooperative Extension, 2016).

- Utility water charges were assumed to be similar to those used in the 2015 Ecosystem Economics report and were as follows:
    - Monthly Fixed Charge: $21
    - Monthly Consumptive Block Charge:
        - Indoor only: $18
        - Outdoor and Indoor: $30
    - Total Utility Charges:
        - Indoor only: $473/year
        - Outdoor and Indoor: $661/year

- A discount rate of 5% is used to convert recurrent costs to a present value (20 year period).

4.2 Pathway Delineation Assumptions

The following assumptions were made for all three approaches included in this study:

- Parcels are only mitigated within the HUC-12 basin in which they lie.

- The HUC-12 scale is sufficiently small such that augmentation can occur at any point within the sub-basin and fulfill mitigation needs for all the parcels in that basin.

- Mitigation activities are focused on the mainstem, and need not occur at the closest surface water body to a parcel.

- The volume of water delivered at a given augmentation point on a mainstem will be equivalent to the sum of all the mitigation needs required for parcels within the HUC-12.

4.3 Mainstem Delineation

In following with the assumption that mitigating along the mainstem is sufficient to meet in-stream flow augmentation needs, mainstem features in each HUC12 were identified using flow accumulation estimates and flowline features reported in the National Hydrography Dataset (for source data, see Table 1). The NHD flowlines overlapping the greatest flow accumulation pathway was assumed to be the mainstem in each basin (Fig 1). Each mainstem flowpath was assigned a Flow_ID value for reference purposes.

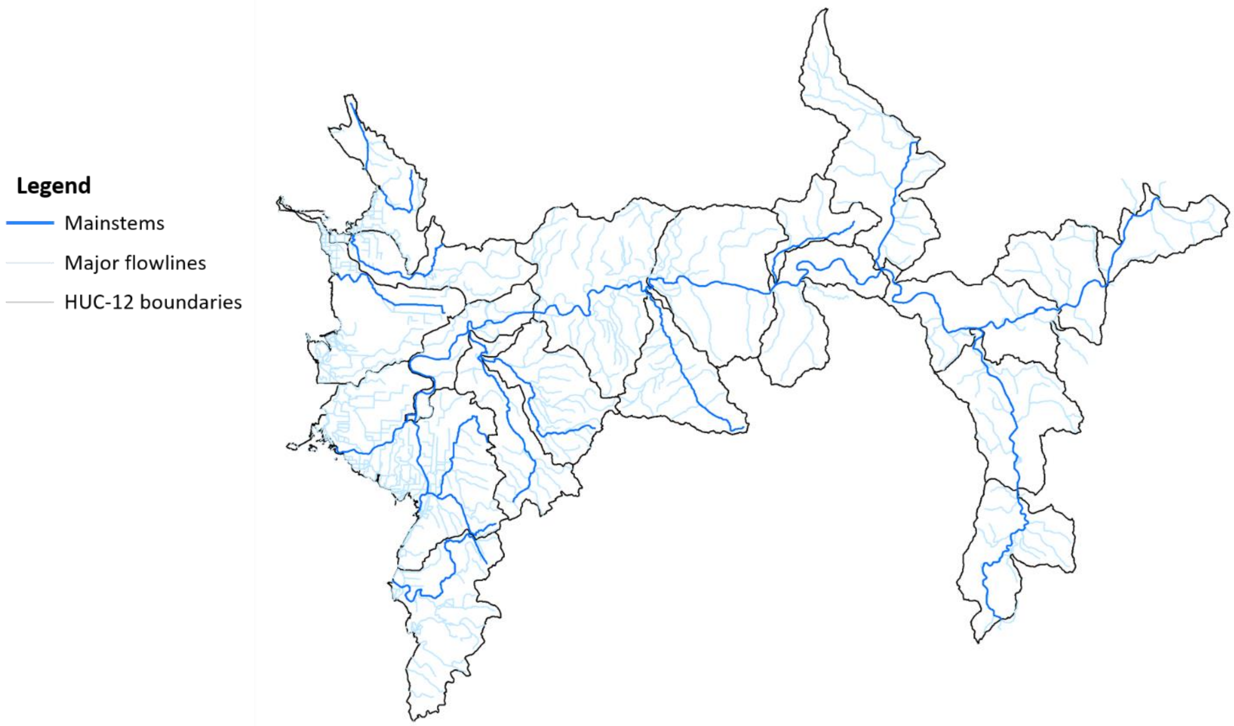

Fig 1. Mainstem and major flowline features within each HUC-12 sub-basin.

4.4 Piped Distance Model

A model was created in ArcGIS 10.2.2 to estimate the length of pipe required to deliver water from an existing municipal system to an augmentation point on a HUC12 mainstem (Fig 1). The model used in all three of the approaches below is designed to find the pipe pathway with the smallest slope between a given municipal system and a specific point on a stream.

In this model, elevation data were used to estimate slope within the study area. Slope data were reclassified by quantiles to fit a scale of 1-10 to reflect preferential pathway options. The least accumulative cost distance (based on these weighted slope values) between the two points of interest was calculated to create a cost surface. These data were then used to calculate the least-cost path between the given municipal and stream augmentation points. This is the pipe distance used to calculate augmentation costs. A more technical description of the process is provided in the Appendix (Section 10).

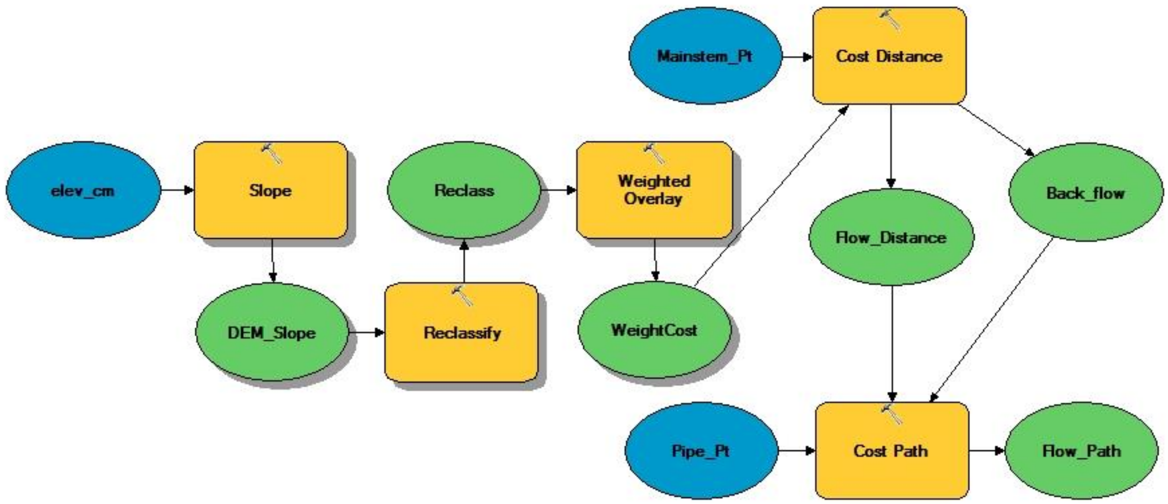

Fig 1. Piped distance model. This model shows the data (blue), tools (yellow), and outputs (green) used to calculate the pathway between a given municipal pipe point and stream augmentation point that has the smallest slope.

4.5 Least Cost Approach

<u>Overview of approach:</u> The least cost approach represents the most pragmatic solution (from a financial perspective) for piped in-stream augmentation and the serves as a lower bounds on the cost assessments included in this study.

In this approach, augmentation occurs where the HUC-12 mainstem is closest to an existing municipal piped infrastructure. This represents the shortest possible distance between the mainstem and a municipal system and makes no attempt to augment near a particular property where withdrawals are being made.

4.6 Highest Elevation Approach

<u>Overview of approach:</u> This approach represents a high-end estimate of piped mitigation costs. Here, augmentation occurs on a mainstem at the point closest to the property with the highest elevation in the HUC-12 basin (one property per basin).

4.7 Most Upstream Approach

<u>Overview of approach:</u> This approach represents an alternate high-end estimate of piped mitigation costs. Here, augmentation occurs on a mainstem at the point closest to the most upstream property in the HUC-12 basin (one property per basin).

4.8 Results

A complete summary of results per household by subbasin is reported in Table 2. The same values are shown in map form in Figure 3 through Figure 8. Not surprisingly, piping cost estimates are much more variable than trucking (reported in the next section). This is due to the fixed costs associated with laying pipeline over long distances. This effect not only plays out across subbasins, but can be seen in how much costs vary depending on the augmentation point within a subbasin.

A more conservative approach to mitigation from a biological standpoint would be to focus on the high elevation or upstream estimates. For some subbasins these two are the same points. Focusing on these points the lowest costs found are just over $6,000, which is similar to the lowest costs for trucking as well. An important characteristic of piping costs is that there are more affected properties in subbasins that have more extensive public water system pipelines. This means that costs tend to be lower per household in subbasins with more affected properties. This is shown in Figure 9. For example, subbasins 70204 and 70104 have mitigation costs close to $6,000 and nearly 150 properties between them.

A place where more detailed modeling could lower piping costs are those where the difference between the lower bound and the high/upper cost estimates are large. A large difference points to highly variable costs across the subbasin, which means that there is potentially a lot to be gained from carefully factoring in biological information on where critical low flow points are. Subbasins that fit this description include 50905, 51104, and 70107. In contrast, subbasins like 51101 have nearly the same lower and upper cost estimates, which would motivate being conservative and simply mitigating at the most upstream point in the subbasin.

An additional consideration when comparing indoor only versus indoor+outdoor use cost estimates is that adding outdoor use significantly lowers the cost per unit of water to the household. This comes out in the difference between the cost estimates for indoor versus indoor+outdoor use. It is likely that most households value indoor use water significantly more than outdoor use. However, the value for outdoor use only needs to be greater than the variable costs of pumping the water in order for them to be better off with a higher mitigation cost that allows for indoor+outdoor use. This is an important difference between piping and trucking that should be considered when evaluating which alternative to pursue. In many subbasins trucking is the cheaper option when considering indoor use only. However, piping is cheaper in many subbasins when outdoor use is included. From a strict financial return perspective, if homebuyers value outdoor use more than the mitigation cost then it may be worth pursuing the piping option.

There is little data on how much individuals value outdoor water use. Some evidence is provided by studies that look at how much water use varies with price in municipalities that use block rate pricing. However, extrapolating results from cities to rural houses may be problematic. One possibility for deriving an estimate of outdoor use values was provided by the instream flow rule in the Dungeness on the Olympic Peninsula that went into effect in 2013. Two zones were defined where mitigation permitted indoor and outdoor use in one area while in the other zone only indoor use is permitted. A statistical analysis of land transactions affected by this rule, summarized in detail in the appendix in Section 11, arrived at an estimate for outdoor use of around $20,000. However, an important caveat is that the statistical confidence in this estimate is very low, so ideally further study should be done.

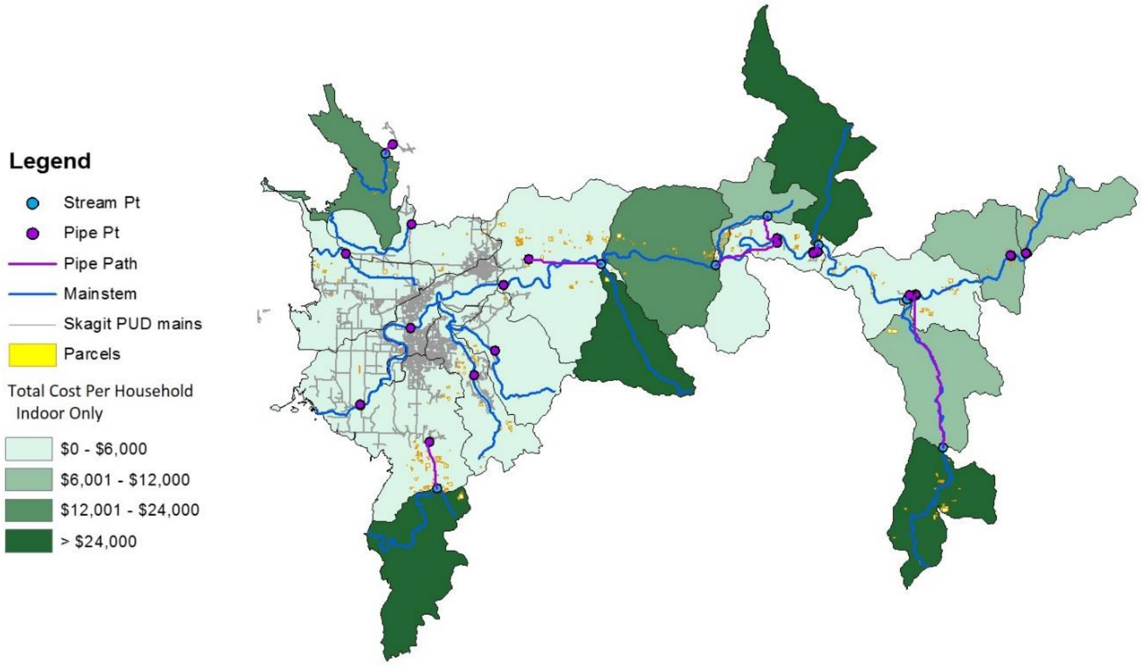

Figure 3. Least Cost Approach- Indoor use only.

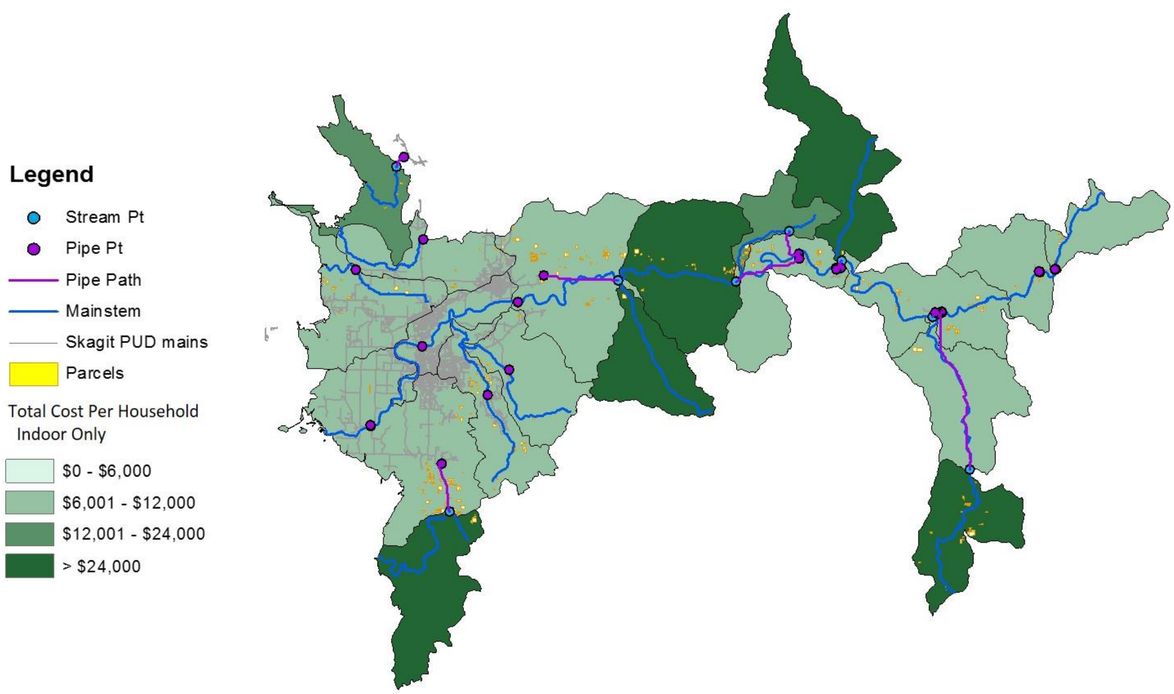

Figure 4. Least Cost Approach- Indoor +outdoor use.

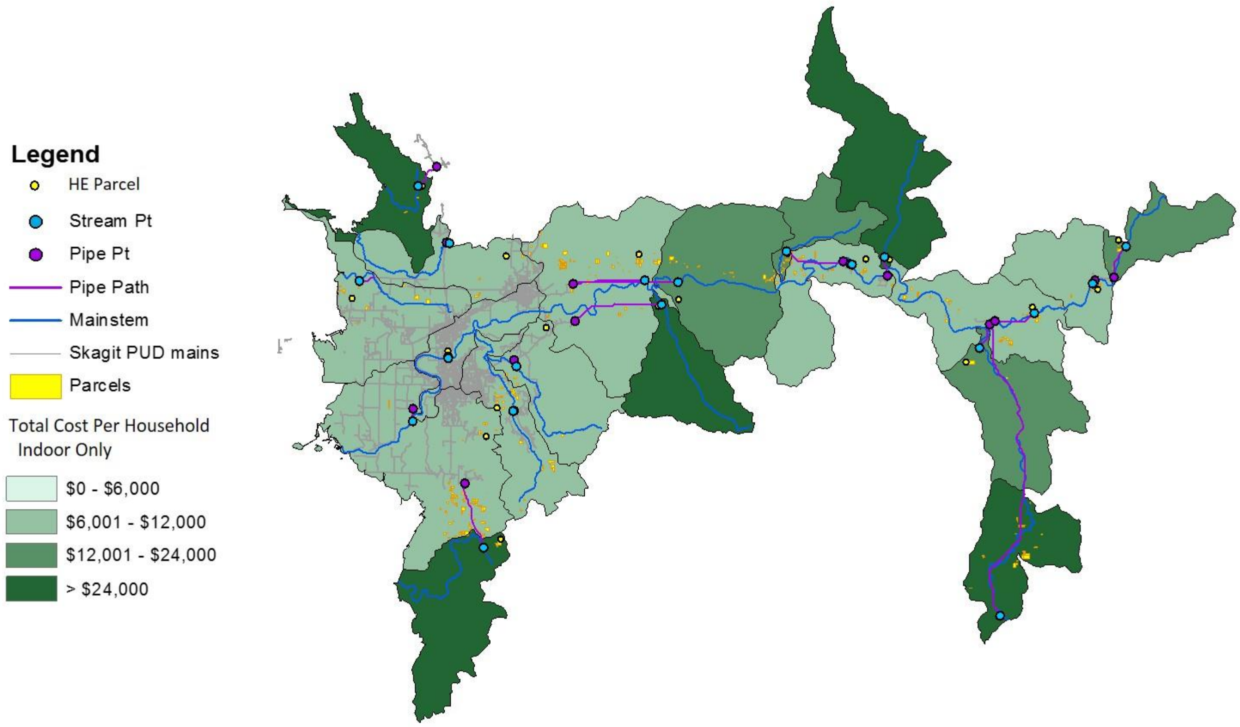

Figure 5. High Elevation Approach- Indoor use only.

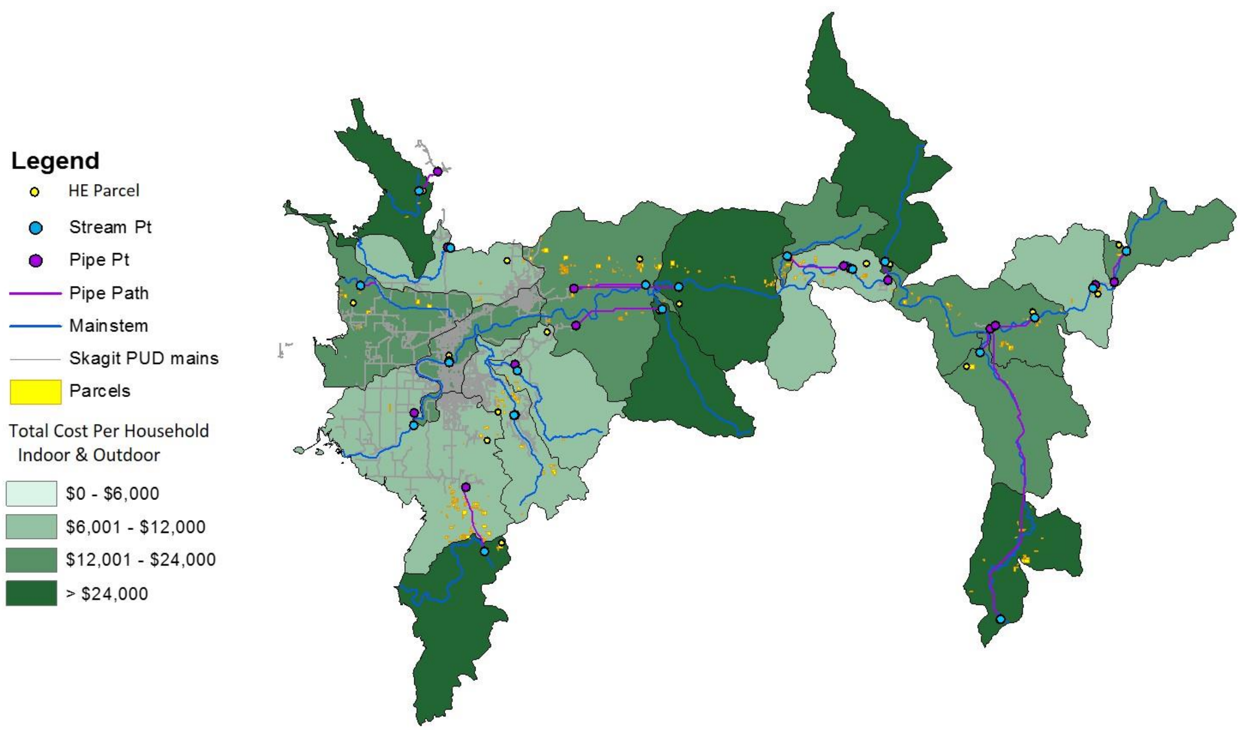

Figure 6. High Elevation Approach- Indoor + outdoor use.

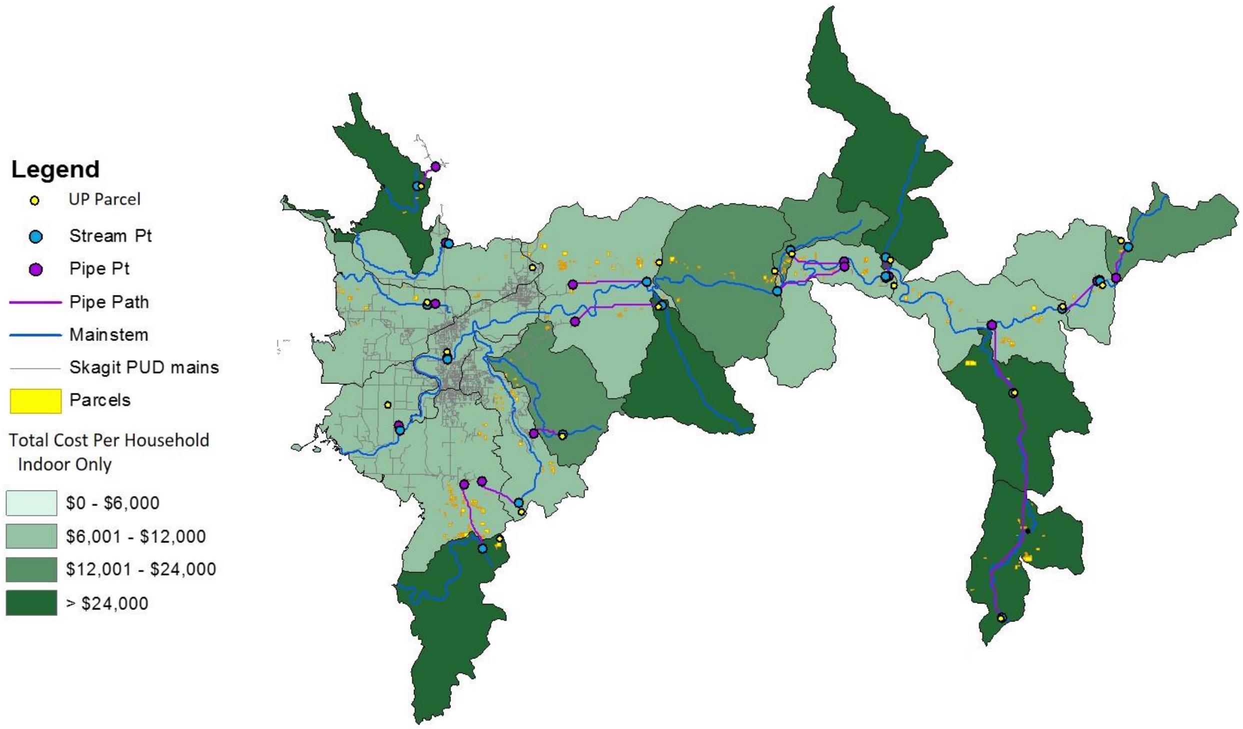

Figure 7. Most Upstream Approach- Indoor use only.

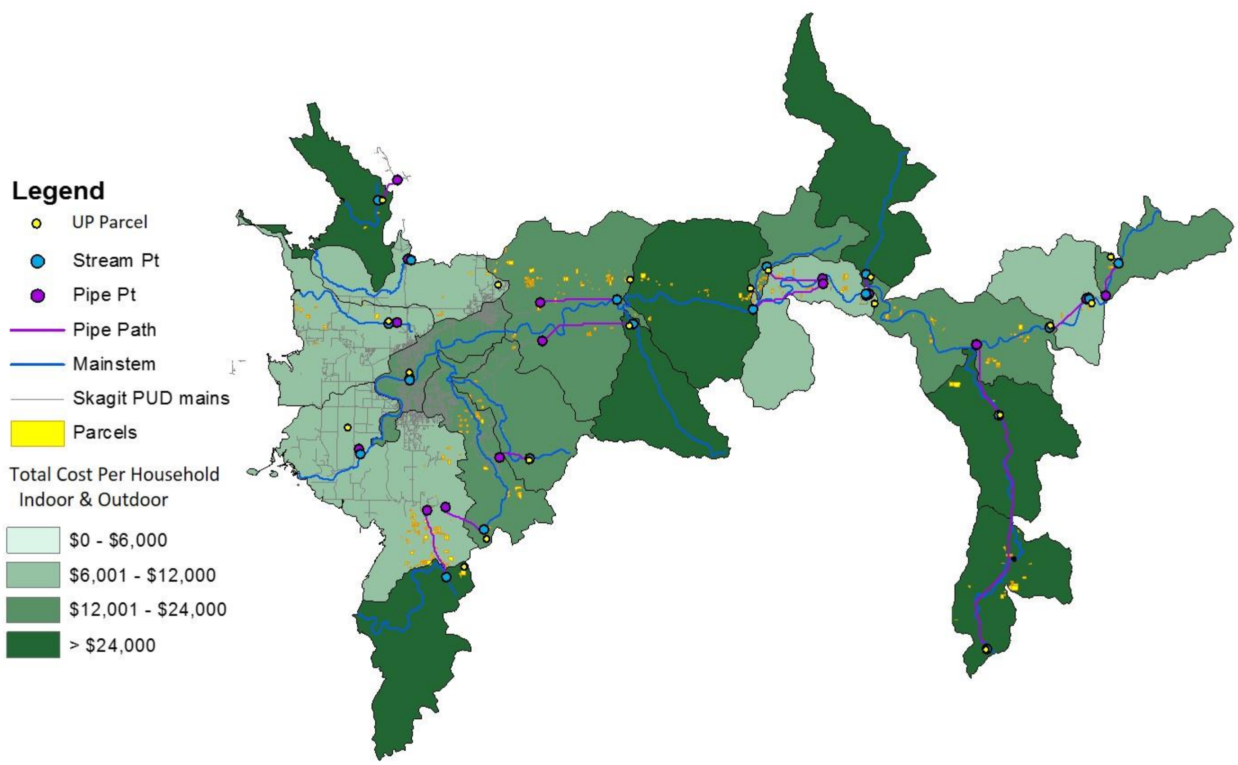

Figure 8. Most Upstream Approach- Indoor + outdoor use.

Table 2. Summary of piping cost estimate results.

				Total Cost Per Household					
				Lower Bound		High Elevation		Upstream	
Flow_ID	HUC_Mainstem	HUC-12 Basin	Number of Propertie	Indoor Only	Indoor/Outdoor	Indoor Only	Indoor/Outdoor	Indoor Only	Indoor/Outdoor
0	171100020204	Lower Samish River	7	$ 5,895	$ 8,238	$ 7,400	$ 9,744	$ 7,400	$ 9,743
2	171100020301	Oyster Creek-Frontal Samish Bay	4	$ 17,562	$ 19,917	$ 29,695	$ 32,043	$ 29,694	$ 32,036
3	171100020302	Joe Leary Slough-Frontal Padilla Bay	17	$ 5,895	$ 8,238	$ 8,793	$ 14,034	$ 7,475	$ 11,399
5	171100050905	Copper Creek-Skagit River	9	$ 6,207	$ 8,550	$ 18,311	$ 20,656	$ 18,311	$ 20,654
6	171100051007	Lake Shannon-Baker River	1	$ 34,908	$ 37,251	$ 72,839	$ 75,182	$ 72,840	$ 75,186
7	171100051101	Rocky Creek-Skagit River	7	$ 6,273	$ 8,616	$ 7,748	$ 10,091	$ 6,274	$ 8,617
8	171100051104	Aldon Creek-Skagit River	39	$ 5,963	$ 8,374	$ 9,353	$ 15,155	$ 9,746	$ 15,943
9	171100060404	Prairie Creek-Sauk River	23	$ 30,750	$ 57,958	$ 50,442	$ 97,359	$ 50,401	$ 97,250
10	171100060405	Sauk River	6	$ 8,957	$ 11,300	$ 20,183	$ 22,526	$ 45,630	$ 47,973
11	171100070103	Grandy Creek	28	$ 10,107	$ 16,713	$ 12,944	$ 22,349	$ 12,815	$ 22,079
12	171100070104	Mill Creek-Skagit River	52	$ 5,969	$ 8,461	$ 6,026	$ 8,633	$ 6,001	$ 8,559
13	171100070105	Loretta Creek-Skagit River	28	$ 14,462	$ 25,373	$ 17,730	$ 31,910	$ 14,447	$ 25,349
14	171100070106	Day Creek	3	$ 90,283	$ 92,626	$ 103,558	$ 105,901	$ 103,569	$ 105,954
15	171100070107	Hansen Creek	79	$ 5,895	$ 8,238	$ 11,709	$ 16,959	$ 11,832	$ 17,143
16	171100070201	East Fork Nookachamps Creek	17	$ 5,895	$ 8,238	$ 7,211	$ 10,870	$ 12,063	$ 20,575
17	171100070202	Nookachamps Creek	33	$ 5,895	$ 8,238	$ 6,009	$ 8,466	$ 10,416	$ 17,308
18	171100070203	Skagit River	1	$ 5,895	$ 8,238	$ 10,582	$ 12,925	$ 10,582	$ 12,926
19	171100070204	Skagit Delta-Frontal Skagit Bay	94	$ 5,941	$ 8,306	$ 6,741	$ 9,507	$ 6,255	$ 8,778
21	171100080304	Stillaguamish River-Frontal Port Susan	7	$ 30,848	$ 33,201	$ 38,409	$ 40,767	$ 38,050	$ 40,392

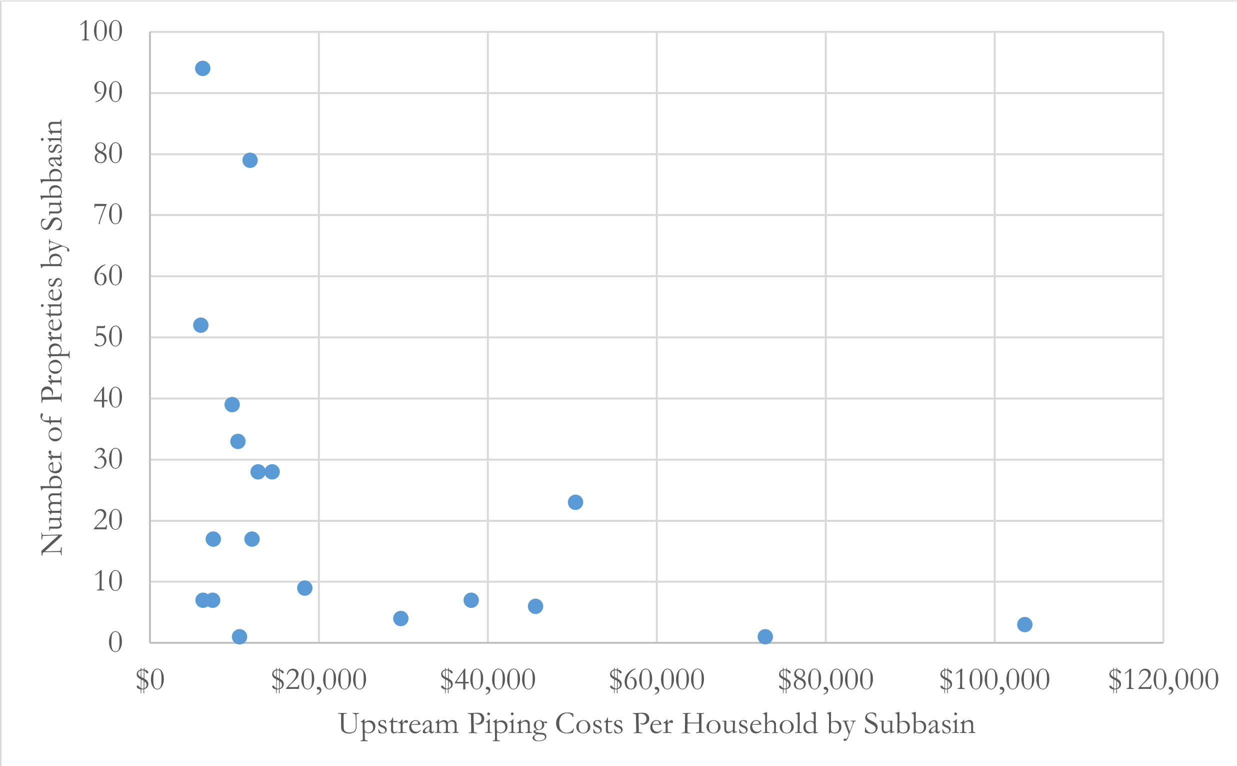

Figure 9. Relationship between the number of properties and piping mitigation costs by subbasin.

5 Trucking for Flow Augmentation

The focus of this study in terms of trucking is for flow augmentation. This complements previous studies where trucking potable water for direct use has been considered. The difference in the cost estimates for these two approaches is due to the quantity of water being moved. Trucking water for flow augmentation requires moving about 1/10th as much water as for direct use in the case of indoor use only. This does mean that the transportation modeling done for this analysis for flow augmentation can be directly used for trucking water for direct use if needed.

In the piping for flow augmentation scenario it was necessary to identify specific flow augmentation points. Similarly, for trucking there are many points where trucks could go to augment flows. In order to minimize uncertainty over the timing and quantity of the relationship between the release of water and flow augmentation we assumed that trucks would transport water to cisterns located near rivers. Throughout the region roads follow rivers fairly closely so there are a large number of augmentation potential points. Therefore, we developed an approach similar to the piping scenarios to arrive at a medium and high cost estimate for each subbasin based on the locations of properties within the subbasin. To find these values a trucking cost estimate is calculated for every property. For the high estimate the value associated with the property that has the highest cost in each subbasin is applied to all properties in the subbasin. The average cost estimate is the average of all of the cost for all properties in the subbasin. The low and high estimates apply the cost for the properties that have the lowest and highest trucking cost estimates.

Two approaches were used for calculating the cost of delivering water: Truck Operating Cost Approach and the Commercial Truck Rate Approach. In Table 3 the first set of values under the general column heading "$/gallon" are estimates of what it costs to move 1 gallon of water to each subbasin. The annual cost is found by multiplying a value from one of these columns by gallons per day and then by 365 days (e.g. 0.057gpd*15g*365days). In order to arrive at a total cost per household for mitigation the series of annual costs are added together at a discounted rate.

Discounting is done to reflect the time value of money. Consider a situation where each household makes an annual payment similar to what the assessment fee paid by farms in an irrigation district. The annual fees that do not have to be paid until some point in the future need to be discounted because there is value in not having to make the payment now. The formula for this calculation is shown below which includes the discount rate (i), time horizon in years (n), and annual cost (C).

$$PV = C\left(\frac{1-(1+i)^{-n}}{i}\right)$$

It is our assumption that mitigation needs to reflect costs made in perpetuity. However, a lifespan of 50 years was used in this analysis in order to make the trucking costs more comparable to the piping scenarios. In the piping scenario it makes sense to assume that the pipe infrastructure will need to be replaced at some point in the future, which we assume is 50 years. An often misunderstood point about discounting is that extending the time horizon further compared to an already long horizon like 50 years will change results significantly. In actuality, going from 50 to 100 years does not change results a great deal. For example, the present value of a stream of $100 payments made for 50 years is $2,148 compared to $2,450 for 100 years.

While results are reported for indoor only and indoor + outdoor for piping they are not for trucking. As mentioned already, the $/gallon reported in this section can be used to calculate costs for any amount of water. Our assumption was that if a property owner were mitigating via trucking they would commit to only use indoor water. The logic behind this is summarized in Section **Error! Reference source not found.**.

5.1 Truck Operating Cost Approach

The truck operating cost approach uses the Truck Cost Model, developed by Mark Berwick (2003) at the Upper Great Plains Institute at North Dakota State University and included the inputs below for vehicle operating and fixed costs. The payload of 33,377 lbs. assumes a 4,000-gallon truck capacity, tandem axle, straight truck which is common in the region[2]. Larger capacity tractor trailer trucks would have difficulty navigating tight turn spaces at home sites.

[2] Based upon phone conversations with several trucking firms in the area.

Inputs

Variable Costs	
Weight	
Pay Load	33,377
Tractor Weight (Pounds)	17,500
Trailer Weight (Pounds)	1,000
Fuel Cost	
Fuel Price/Gallon	$2.750
Loaded Truck Miles/Gallon	5.50
Empty Truck Miles/Gallon	6.50
Percent Time Loaded	50%
Percent Time Empty	50%
Round Trip Travel Distance (Miles)	80.00
Labor Cost	
Round Trip Driving Time (Hours)	2.50
Unloading Time (Hours)	0.50
Loading Time (Hours)	0.50
Dwell Time (Hours)	0.50
Driver Labor Cost/Hour	20.00
Tire Cost	
Tractor Tire Cost/Tire	$400
Trailer Tire Cost/Tire	$300
Tractor Tire Miles/Tire	250,000
Trailer Tire Miles/Tire	50,000
Maintenance and Repair Cost	
Base Repair Cost/Mile	$0.0900

Fixed Costs	
Equipment Cost	
Purchase Price of Tractor	$95,000
Purchase Price of Trailer	$15,000
Useful Life of Tractor (Years)	5
Useful Life of Trailer (Years)	5
Interest Rate	8%
License Fee	
Annual License Fee	$1,718
Number of Tractors and Trailers in Fleet	4
Annual Miles	80,000
Management and Overhead Cost	
Overhead Cost Rate	4%
Insurance Cost	
Insurance Premium	$9,000

Run Model

Outputs

Total Trucking Cost	**$165.75**
Total Trucking Cost/Hour	$41.44
Total Trucking Cost/Mile	**$2.0719**
Total Trucking Cost/Ton	$9.9320
Total Trucking Cost/Loaded Ton-Mile	**$0.2483**

Figure 10. Inputs into Truck Operating Cost Model.

5.2 Commercial Truck Rate Approach

Given that the shipment of potable water by truck is a specialize movement, requiring specialized truck equipment, the market for contracting commercial firms to provide this service in the Skagit Valley region is quite thin. Transportation firms providing these services were contacted in order to obtain reasonable rates. The rates were all comparable and between $115 and $120 per hour for delivery, utilizing a 4,000-gallon water truck. This approach merely took this quoted rate, included ½ hour of loading and unloading time and the round-trip travel time from Mt. Vernon to each household.

5.3 Results

A concise summary of the trucking for flow augmentation results are shown in Table 3. The high cost estimates by subbasin are shown in Figure 11. For this scenario most of the 455 properties have mitigation costs between $6,000 and $12,000. Costs are less than $6,000 only immediately near Mt. Vernon, which was assumed to be the departure point. The difference between the high and average cost estimates are different to a meaningful degree in many subbasins. While they are less than $500 for some subbasins the average cost estimates is more than $1,000 less than the high cost in some areas.

Table 3. Summary of results for trucking for flow augmentation scenario.

		$/gallon				Annual Cost Per Household				50 Year Present Value			
		Commercial		Truck Operating		Commercial		Truck Operating		Commercial		Truck Operating	
HUC12	HUC 12 Name	High	Medium	High	Medium	High	Medium	High	Medium	High	Medium	High	Medium
171100020204	Lower Samish River	0.0570	0.0499	0.0292	0.0224	312.08	273.28	159.87	122.64	6,704	5,871	3,434	2,635
171100020301	Oyster Creek-Frontal Samish Bay	0.0617	0.0588	0.0400	0.0345	337.81	321.66	219.00	188.89	7,257	6,910	4,705	4,058
171100020302	Joe Leary Slough-Frontal Padilla Bay	0.0537	0.0494	0.0271	0.0231	294.01	270.43	148.37	126.47	6,316	5,809	3,187	2,717
171100050905	Copper Creek-Skagit River	0.1048	0.1028	0.1170	0.1144	573.78	562.89	640.58	626.40	12,326	12,092	13,761	13,456
171100051007	Lake Shannon-Baker River	0.0819	0.0819	0.0759	0.0759	448.40	448.40	415.55	415.55	9,633	9,633	8,927	8,927
171100051101	Rocky Creek-Skagit River	0.1114	0.1052	0.1135	0.1100	609.92	575.81	621.41	602.02	13,102	12,370	13,349	12,933
171100051104	Aldon Creek-Skagit River	0.0993	0.0898	0.1024	0.0906	543.67	491.88	560.64	496.18	11,679	10,567	12,044	10,659
171100060404	Prairie Creek-Sauk River	0.1288	0.1171	0.1260	0.1153	705.18	641.34	689.85	631.21	15,149	13,777	14,819	13,560
171100060405	Sauk River	0.1055	0.0994	0.1034	0.1002	577.61	543.94	566.12	548.50	12,408	11,685	12,161	11,783
171100070103	Grandy Creek	0.0746	0.0711	0.0625	0.0606	408.44	389.14	342.19	331.55	8,774	8,359	7,351	7,122
171100070104	Mill Creek-Skagit River	0.1001	0.0819	0.0788	0.0656	548.05	448.60	431.43	359.32	11,773	9,637	9,268	7,719
171100070105	Loretta Creek-Skagit River	0.0729	0.0677	0.0596	0.0523	399.13	370.72	326.31	286.11	8,574	7,964	7,010	6,146
171100070106	Day Creek	0.0701	0.0698	0.0378	0.0376	383.80	382.34	206.96	205.86	8,245	8,213	4,446	4,422
171100070107	Hansen Creek	0.0703	0.0568	0.0445	0.0329	384.89	310.95	243.64	180.26	8,268	6,680	5,234	3,872
171100070201	East Fork Nookachamps Creek	0.0533	0.0476	0.0252	0.0191	291.82	260.84	137.97	104.67	6,269	5,603	2,964	2,249
171100070202	Nookachamps Creek	0.0549	0.0442	0.0286	0.0165	300.58	242.18	156.59	90.57	6,457	5,203	3,364	1,946
171100070203	Skagit River	0.0367	0.0367	0.0072	0.0072	200.93	200.93	39.42	39.42	4,316	4,316	847	847
171100070204	Skagit Delta-Frontal Skagit Bay	0.0545	0.0485	0.0324	0.0206	298.39	265.65	177.39	112.92	6,410	5,707	3,811	2,426
171100080304	Stillaguamish River-Frontal Port Susan	0.0563	0.0561	0.0288	0.0286	308.24	306.99	157.68	156.82	6,622	6,595	3,387	3,369

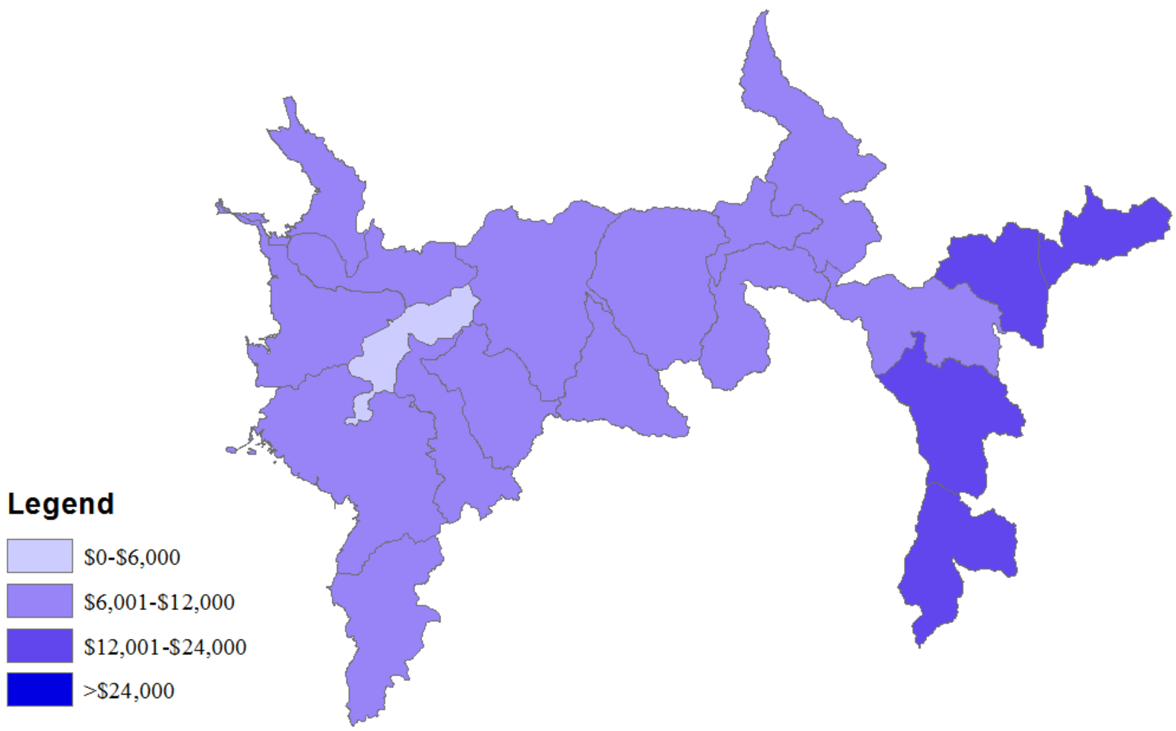

Figure 11. Total cost per household in present value terms for trucking for mitigation assuming a 50 year time horizon, highest estimate per subbasin, and 15 gallons per day.

6 Winter Flow Capture

Winter flow capture has already been considered in the Carpenter-Fisher, as discussed earlier in this document. The consideration that shapes the winter flow capture scenario in this report is a landowner in Child's basin that is interested in building a pond for storage to be used for mitigation for nearby properties. There was a consideration of doing a basin scale analysis that would involve a search for locations ideal for capturing winter flows. This alternative was decided against because it was determined that the results were very unlikely to focus in on alternatives that had a good chance of succeeding. The key limitation is not potential sites that would be amenable to pond construction, but rather landowners willing to build a pond. Therefore, our approach has been to use the Child's basin case study to consider whether this alternative may be the lowest cost option for some locations.

The EPA provides guidance on detention ponds in Report EPA 832-F-99-048. It goes without saying that costs depend on a number of factors related to the soil type, terrain, and climate. The EPA estimates typical costs to range between $23.46 to $48.30 per cubic meter[3]. Child's basin contains fewer than 10 properties. For ease of calculation we simply assume that it is necessary to mitigate for 10 properties. Assuming indoor use only this corresponds to 1 acre-foot of storage. There are 1,233 cubic meters in an acre-foot, so the lowest cost estimate is $28,926, or $2,892 per house. Using the upper cost estimate from EPA gives $5,955 per household. Due to evaporative loss and other inefficiencies it is not advisable to assume the smallest possible pond size. A more conservative estimate is to assume pond capacity that is double the mitigation requirement. Taking the average of the two EPA values gives $8,848 per household.

In comparison to the other scenarios a cost of $8,848 per household is higher than most of the trucking and piping flow augmentation results. However, it is in the realm of being cheaper for some of the subbasins that are more expensive for both of these options. Therefore, it could make sense for the more remote properties.

7 Rainwater Collection

Rainwater catchment has been considered in detail by Ecology and other entities (Dept. of Ecology, draft; Ecosystem Economics, 2015). Therefore, we do not revisit any of those cost calculations. Our focus here is to compare those costs to the piping, trucking, and winter flow capture estimates. As summarized in the report "Skagit Basin Water Supply Options" (Ecology, draft), capital costs for rainwater collection are estimated to be $25,000 per house. This puts as a cheaper option to trucking for direct use alone, but more expensive than all of the other options in most cases.

8 Integrated Results

In this section we integrate the results from all of the alternatives considered to identify the least cost option by subbasin and summarize the number of properties by cost range. We also discuss how various other factors affect the relative costs of each option.

Table 4 compares cost estimates by subbasin for piping and trucking where the upper cost estimates within each scenario is applied. Trucking is the cheaper option for 263 properties compared to 192 for piping. The right-most column simply reports the minimum of the two to provide an easy overall summary. This last column is also useful for comparisons to the winter flow storage and rainwater collection. Results do show that winter flow capture may be cheaper for three of the subbasins that contain, between them, just under 40 properties. To summarize, mitigation costs are estimated to be between $6,000 and $10,000 for most of the 455 affected properties. A summary of the number of properties by mitigation cost range is reported in Figure 12.

[3] The report was written in 1999 so it is necessary to inflate these values to current dollars. $1 in 1999 is worth approximately $1.38 in 2016 dollars (Bureau of Labor Statistics).

Table 4. Summary of results comparing trucking and piping for flow augmentation using upper cost estimates for each.

HUC Number	Basin Name	# of Properties	Piping	Trucking	Lower Cost Choice
171100020204	Lower Samish River	7	$7,400	$6,704	$6,704
171100020301	Oyster Creek-Frontal Samish Bay	4	$29,694	$7,257	$7,257
171100020302	Joe Leary Slough-Frontal Padilla Bay	17	$7,475	$6,316	$6,316
171100050905	Copper Creek-Skagit River	9	$18,311	$12,326	$12,326
171100051007	Lake Shannon-Baker River	1	$72,840	$9,633	$9,633
171100051101	Rocky Creek-Skagit River	7	$6,274	$13,102	$6,274
171100051104	Aldon Creek-Skagit River	39	$9,746	$11,679	$9,746
171100060404	Prairie Creek-Sauk River	23	$50,401	$15,149	$15,149
171100060405	Sauk River	6	$45,630	$12,408	$12,408
171100070103	Grandy Creek	28	$12,815	$8,774	$8,774
171100070104	Mill Creek-Skagit River	52	$6,001	$11,773	$6,001
171100070105	Loretta Creek-Skagit River	28	$14,447	$8,574	$8,574
171100070106	Day Creek	3	$103,569	$8,245	$8,245
171100070107	Hansen Creek	79	$11,832	$8,268	$8,268
171100070201	East Fork Nookachamps Creek	17	$12,063	$6,269	$6,269
171100070202	Nookachamps Creek	33	$10,416	$6,457	$6,457
171100070203	Skagit River	1	$10,582	$4,316	$4,316
171100070204	Skagit Delta-Frontal Skagit Bay	94	$6,255	$6,410	$6,255
171100080304	Stillaguamish River-Frontal Port Susan	7	$38,050	$6,622	$6,622
Totals	Properties	455			
	Piping Cheaper	192			
	Trucking Cheaper	263			

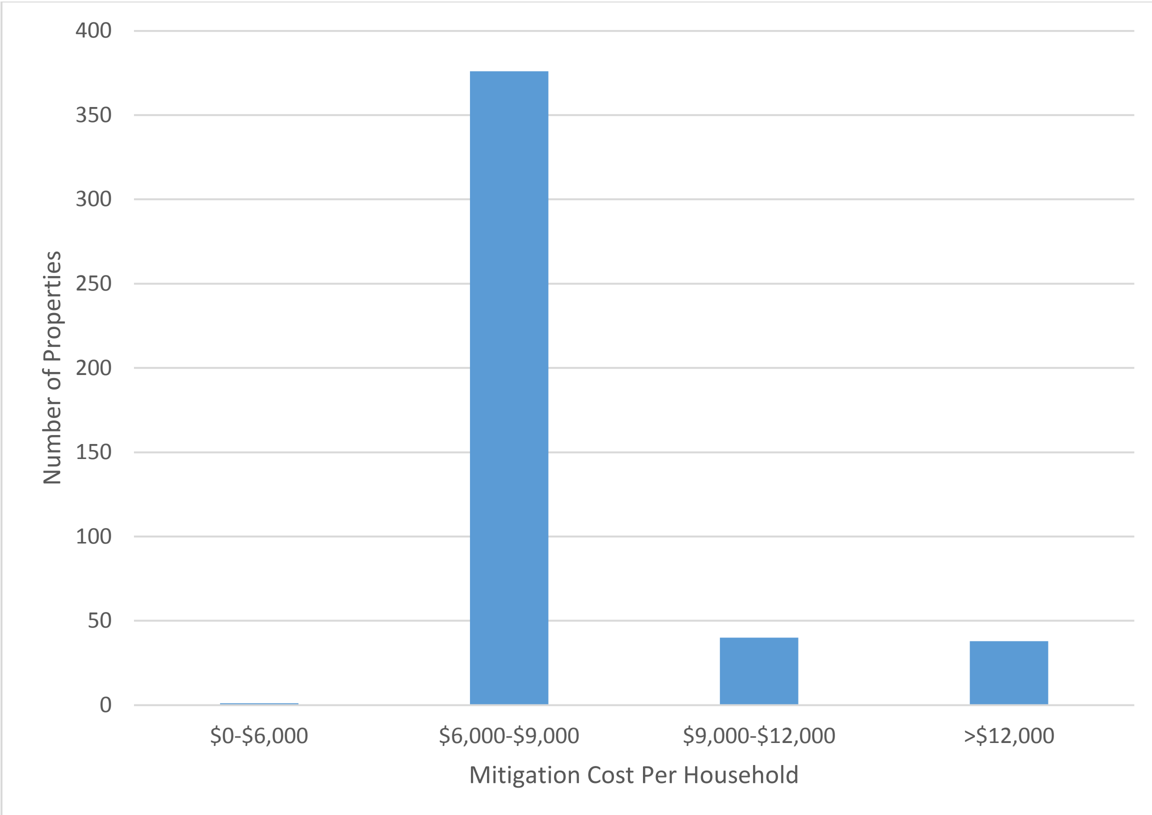

Figure 12. Number of properties by mitigation cost range.

8.1 The Effect of Future Development on Cost Estimates

In order to limit the scope of this study the analysis to this point of the report has focused solely on the properties that built houses after 2001. However, it is clear that there is demand for additional development and, importantly, the absolute and relative costs of the mitigation options change as a function of development. The reason for this is the difference in the relative share of total costs that are fixed versus variable costs. Nearly all of the costs associated with trucking are variable with the exception of the infrastructure at the augmentation point (cistern and water screening). In contrast, most of the costs for piping for flow augmentation are fixed costs. This means that piping will become cheaper per household the more development that occurs. Considering future development is motivated by the two points: (1) trucking was found to be the cheapest option for a majority of existing houses, (2) piping was only a little more expensive than trucking for many houses. Therefore, it is important to consider how many more houses would be required under future development to make piping the cheaper option.

8.2 Truck Now/Pipe Later Option

Building from the previous section there is a mitigation option that is worth considering in more detail which can be referred to as Truck Now/Pipe Later. There are three reasons to consider this option.

1. Future development is uncertain.

2. Piping is more expensive for most houses if both were to be implemented right now.
3. There is no trucking specific infrastructure required that is also not required for piping.

The logic to considering this hybrid approach is simple. The investments required at the point of augmentation for trucking can be used in the piping scenario. The fact that no trucking specific infrastructure investment is required means that there is risk of making a sizeable investment that becomes obsolete if piping is pursued.

9 References[4]

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Ecosystem Economics. Pilz, D., Aylward, B. and E. Borgen. Strategy Paper for the Skagit Water Exchange: Avoidance Options and Mitigation Alternatives- a report for Washington Water Trust. 2015. [DRAFT].

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[4] For data source references, see Table 1.

10 Appendix 1. GIS Routines for Finding Piping Paths

10.1 Least Cost Approach

Analysis methods:

1. Find shortest distance between municipal pipe infrastructure polylines and mainstem polylines in each basin (Generate Near Table tool- ensure "Location" option is checked).

2. Use the table created to make new shapefiles of the mainstem augmentation points (Display XY Data – From X and From Y) and infrastructure pipe points (Display XY Data tool- Near X and Near Y) There should be one each per basin.

3. Break each new shapefile into individual point shapefiles. This can be done manually using the Select tool, or can be automated in ArcGIS Modelbuilder using the Iterate Feature Selection and Select tools.

4. Create a batch process that runs the least cost path model (Section 1.2.4) to find the augmentation pathway with the smallest elevation change for each stream-pipe pair in a basin.

5. Convert least cost path raster files created in Step 4 to polylines (Raster to Polyline tool).

6. Add a new column to each polyline file and assign the corresponding mainstem Flow_ID (for identification purposes).

7. Append all polyline files, create a new field named "Dist_m", and calculate line length (in meters) for each pipe pathway (Calculate Geometry tool).

8. Final pathways shows routes from existing mains to augmentation points. *Note: because the polyline conversion is from the center of a raster cell, the actual lines may not directly intersect with the pipe and mainstem points used.*

10.2 Highest Elevation Approach

Analysis methods:

1. Link elevation point data to each parcel (Extract Values to Points tool- ensure Append Input Raster Attributes is checked).

2. Identify and select the property in each HUC-12 basin with the maximum elevation (Attribute Table > Summarize by HUC-12 and Maximum elevation).

3. From the table created, select the corresponding properties from the parcel shapefile and export to a new shapefile containing only those selected properties at maximum elevation (Select tool). There should be 1 per basin.

4. Find shortest distance between properties with the greatest elevation and mainstem polylines for each basin (Generate Near Table tool- ensure "Location" option is checked).

5. From the table created, make a new shapefile of the nearest stream points (Display XY Data tool- Near X and Near Y). There should be one each per basin.

6. Find shortest distance between the nearest stream points (Step 5) and the existing utility infrastructure polylines for each basin (Generate Near Table tool- ensure "Location" option is checked).

7. From the table created, make a new shapefile of the nearest pipe points (Display XY Data tool- Near X and Near Y).

8. Break the new shapefiles created in Steps 5 and 7 into individual point shapefiles. This can be done manually using the Select tool, or can be automated in ArcGIS Modelbuilder using the Iterate Feature Selection and Select tools.

9. Create a batch process that runs the least cost path model (Section 1.2.4) to find the augmentation pathway with the smallest elevation change for each stream-pipe pair in a basin.

10. Convert least cost path raster files created in Step 9 to polylines (Raster to Polyline tool).

11. Add a new column to each polyline file and assign the corresponding mainstem Flow_ID (for identification purposes).

12. Append all polyline files, create a new field named "Dist_m", and calculate line length (in meters) for each pipe pathway (Calculate Geometry tool).

13. Final pathways show routes from existing mains to augmentation points. *Note: because the polyline conversion is from the center of a raster cell, the actual lines may not directly intersect with the pipe and mainstem points used.*

10.3 Most Upstream Approach

Overview of approach: This approach represents an alternate high-end estimate of piped mitigation costs. Here, augmentation occurs on a mainstem at the point closest to the most upstream property in the HUC-12 basin (one property per basin).

Analysis methods:

1. Create points on the mainstem flowline (Feature Vertices to Point tool).

2. Select the lower most point on each mainstem flowline (basin discharge point) and create a new point shapefile (Select tool).

3. Find furthest parcel property from discharge point (Generate Near Table tool- ensure "Location" option is checked, "Find Nearest Feature" is unchecked). This is the "most upstream" parcel for each basin.

4. Using the table created, select the matching properties from the parcel shapefile and export to a new shapefile containing only those selected properties (Select tool). There should be 1 per basin. *Note: before exporting selected properties, visually verify results (e.g. properties are in the same HUC-12 basin as the discharge point, properties visually match expectations of "most upstream")*

5. Find shortest distance between the most upstream properties and mainstem polylines for each basin (Generate Near Table tool- ensure "Location" option is checked).

6. From the table created, make a new shapefile of the nearest stream points (Display XY Data tool- Near X and Near Y). There should be one each per basin.

7. Find shortest distance between the nearest stream points (Step 6) and the existing utility infrastructure polylines for each basin (Generate Near Table tool- ensure "Location" option is checked).

8. From the table created, make a new shapefile of the nearest pipe points (Display XY Data tool- Near X and Near Y).

9. Break the new shapefiles created in Steps 6 and 8 into individual point shapefiles. This can be done manually using the Select tool, or can be automated in ArcGIS Modelbuilder using the Iterate Feature Selection and Select tools.

10. Create a batch process that runs the least cost path model (Section 1.2.4) to find the augmentation pathway with the smallest elevation change for each stream-pipe pair in a basin.

11. Convert least cost path raster files created in Step 10 to polylines (Raster to Polyline tool).

12. Add a new column to each polyline file and assign the corresponding mainstem Flow_ID (for identification purposes).

13. Append all polyline files, create a new field named "Dist_m", and calculate line length (in meters) for each pipe pathway (Calculate Geometry tool).

14. Final pathways show routes from existing mains to augmentation points. *Note: because the polyline conversion is from the center of a raster cell, the actual lines may not directly intersect with the pipe and mainstem points used.*

11 Appendix 2: Empirical Estimate of Outdoor Water Use Values

Collaboration between Michael Brady and Jonathan Yoder of WSU and Tryg Hoff and Dave Christensen of the Department of Ecology.

The Dungeness instream flow rule that went into effect in 2013 has added a hurdle to anyone seeking to build a home in the basin that is outside of a public water service (PWC) area. Figure 1 shows all of Clallam County where the blue line is the boundary of the Dungeness watershed. Any prospective homeowner needs to mitigate the impact of their future water use by acquiring a water right. There is a public water bank from which new residential development can purchase mitigation rights.

The implementation of the rule provides an opportunity to empirically test whether outdoor water use is valued by home buyers, and estimate this value. There are two different zones in terms of how water can be used after mitigating. In the "yellow zone", shown as yellow in Figure 2, only indoor water use is permitted. In the green zone mitigation water can be used for indoor and outdoor use. The pink parcels are serviced by PWC, and no mitigation is required.

This brief report provides estimates of the economic value of outdoor water use as a proportion of property values. Available data on property sales transactions for both zones that occurred before and after the rule supports a difference-in-difference regression analysis (DD) to discern the effect of an outdoor watering restriction on property values. This involves estimating a multivariable regression with the (natural logarithm of) sale price of the individual property as the dependent variable and independent variables including the size of the property, a binary variable equal to 1 if the property is in the green zone (0 if in yellow), another binary variable equal to 1 if the sale occurred in 2013 or later (0 if before), and then what is referred to as an interaction term. This is the key variable of interest as it captures whether permitting outdoor use after mitigation increases property values. It is called an interaction term because it combines by multiplication the zone binary variable and the sale time period binary variable. It is equal to 1 if the sale is in the green

Data were provided by the Clallam County Assessor's Office, including sales occurring from 2010 through 2015, a parcel boundary layer, and PWC service areas. Department of Ecology provided two Dungeness rule area GIS layers that make it possible to designate the green and yellow zone.

There are many multi-parcel sales in the sales data. For these sales each individual parcel is listed as a row but is given the total sale price. Therefore, the data set was aggregated by excise number, which is unique for a sale. The result is that the acre total of individual parcels in the multi-parcel sale is summed. After the multi-parcel aggregation, the number of observations in each category (zone and time period) are reported in Table 1.

Number of sales of vacant parcels (use code 9100) outside of PWC area before and after rule (2013) in the yellow and green zone.

Zone	Pre-rule	Post-rule	Total
Yellow	14	50	64
Green	58	125	183
Total	72	175	247

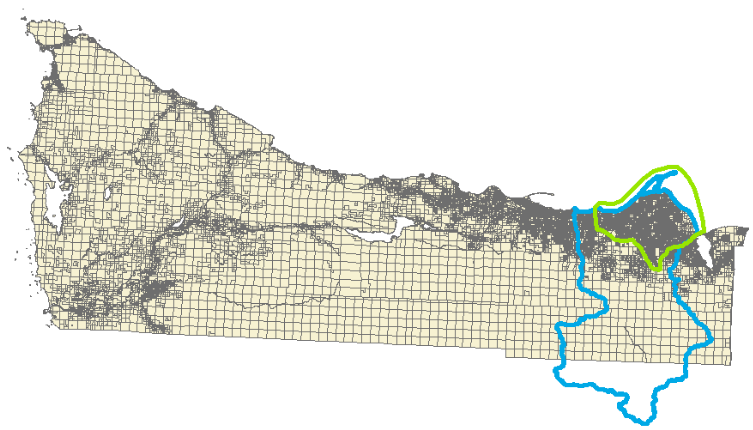

Figure 1. Clallam County and Dungeness Watershed.

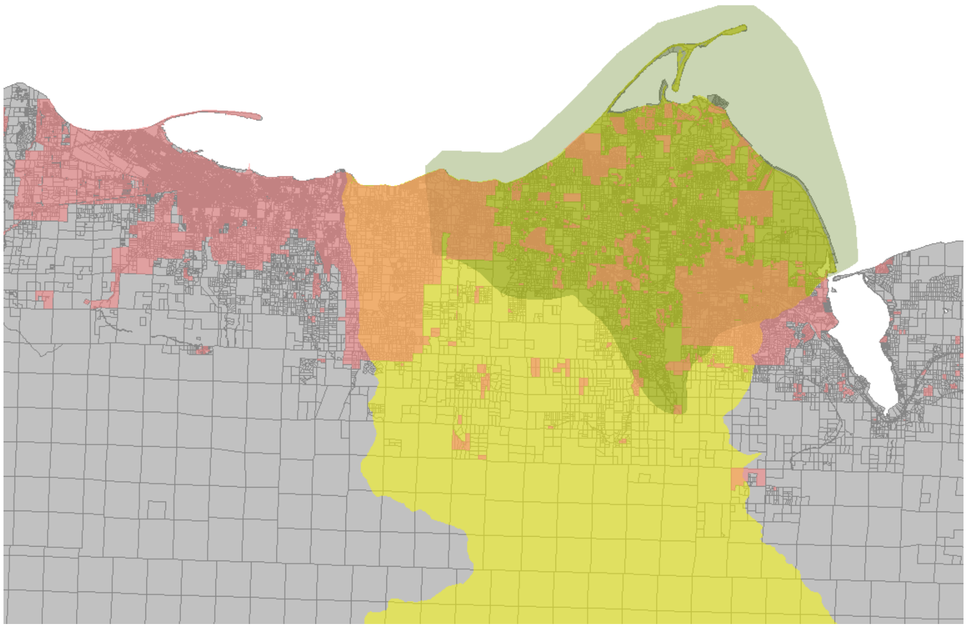

Figure 2. Close-up of Dungeness and indoor use only (yellow), indoor and outdoor use (green), and PWC serviced areas (pink/orange).

It is instructive to look at differences in mean prices in the 2x2 DD set-up to appreciate the importance of conditioning on covariates like lot size (Table 1). Prices were very similar in the two zones before and then again after the instream flow rule went into effect. This would seem to show no effect of the outdoor restriction on prices. However, Table 2 shows the mean lot size in the same set-up. Average lot size dropped in both cases but more in absolute and percentage terms in the green zone. These are significant changes so it is clearly important to control for lot size.

Mean sale price by zone and time period relative to the rule.

Zone	Pre-rule	Post-rule
Yellow	116,378.6	101,774
Green	115,669	100,263

Mean lot size by zone and time period relative to the rule.

Zone	Pre-rule	Post-rule
Yellow	4	3.22
Green	2.7	1.6

Coefficient estimates and standard errors for the DD regression are provided in Table 3. Price is increasing at a decreasing rate as shown by the sign and significance of acres and acres squared. The acres squared explanatory variable is a necessary approach when the effect of lot size on price varies as lot size varies. In other words, the increase in price associated with an increase in lot size of 1 acre, for example, is different going from 1 to 2 acres as opposed to going from 5 to 6 acres.

The DD coefficient of interest (Green x Post) has a magnitude of 0.24. The standard error of the coefficient results in a p-value of 0.34. The economic interpretation of the point estimate of the coefficient is that a property would lose just over 20% of its value if it was "moved" from the green to yellow zone, or equivalently (all else equal), if a restriction were imposed on outdoor water use.

Difference-in-difference regression results.

	Estimate	se
(Intercept)	10.994	0.206
Green zone	0.045	0.218
Post	-0.275	0.222
Green*Post	0.209	0.249
Acres	0.164	0.030
Acres sq.	-0.004	0.001
n	236	

The estimated percent change in the price of a property from hypothetically moving it from the yellow to green zone ($\hat{p}$), which is meant to capture only the change of allowing outdoor water use, is calculated based on the coefficient estimate ($\hat{c}$) associated with the covariate "Green*Post" and its variance ($\hat{V}(\hat{c})$) (Kennedy, 1981).

$$\hat{p} = 100\left(\exp\left[\hat{c} - \frac{1}{2}\hat{V}(\hat{c})\right] - 1\right)$$

The variance of $\hat{p}$ is given by (van Garderen and Shah, 2002)

$$\hat{V}(\hat{p}) = 100^2 \exp[2\hat{c}]\left(\exp\left[-\hat{V}(\hat{c})\right] - \exp\left[-2\hat{V}(\hat{c})\right]\right)$$

Plugging the relevant values into these two formulas gives an estimated percentage effect of being able to use water for outdoor uses of $\hat{p} = 20.18\%,$ which has an estimated variance of $\hat{V}(\hat{p}) = 860.12$ and a standard error of $\sqrt{\hat{V}(\hat{p})} = 29.33$.

A final interpretation of the results is made difficult by the combination of the coefficient point estimate compared to the confidence interval. The point estimate alone suggests that there is a significant economic value associated with outdoor water use. The average vacant property sale price in the data sample is about $100,000. A 20% effect suggests that the value of outdoor water use is about $20,000 for the average-valued property. However, the 95% confidence interval around the point estimate is very large and includes zero and extends into negative values.