Review of Skagit County Water Quality Monitoring Program

Interlocal Cooperative Agreement between
Skagit County
and
Washington State University

Tom Cichosz
Michael E. Barber

State of Washington Water Research Center
PO Box 643002
Pullman, Washington 99164-3002

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TABLE OF CONTENTS

Executive Summary iii

1.0 Introduction 1

2.0 Scope of Work 2

2.1 Task 1 – Assessment of Monitoring Program 2

2.2 Task 2 - Natural Background Conditions 5

2.3 Task 3 - Affects on Salmonid Population 8

2.4 Task 4 - Temporal Changes in Water Quality 16

2.5 Task 5 – Water Quality Benchmarks 23

2.6 Task 6 – Responses to Public Comments 28

2.7 Task 7 – Possible Next Steps 33

2.8 Task 8 – Cost Estimate 37

3.0 References 41

Executive Summary

At the request of Skagit County, we conducted an external review of their current water quality monitoring program. The scope of work included eight tasks related to the assessment of the Program's goals and procedures, describing available methods for determining whether streams are unable to meet water quality standards due to natural conditions, examining the potential impacts of water quality on salmon, responding to public comments concerning the Program, recommending next steps, and providing cost estimates for these steps.

Overall, we found the monitoring program to be very effective as a trend monitoring program to assess water quality conditions within the County. This conclusion is based on the review of data, peer-reviewed literature, project reports, a field reconnaissance trip, and personal communication with Skagit County staff. Our two main recommendations with regard to the use of the seasonal Kendal test to identify trends was that the existing procedure should be modified to account for variability in stream discharges and that the data should be analyzed using each month as a "season." We also recommended a procedure for determining when there is sufficient data for trend identification which County personnel can easily incorporate into future reports.

Given the variability of site conditions, land uses, development pressures, and drainage basin characteristics, we believe that while the current program may identify problem areas, additional information will be necessary spatially and temporally in order to definitively identify the cause and effect relationships needed for enforcement action (so called "triggers for corrective action"). Task 7 recommended and ranked eleven possible areas for future avenues of work that could help strengthen the existing program. Ultimately, more sites that are closer together (e.g., upstream and downstream of a particular land use) may be required in order to categorically defend any assumed cause-effect outcome.

The costs of these recommendations ranged from low to very high and thus may not be fully implementable by the County. The recommendations and ranking attempted to balance out cost versus necessity based on our professional experience and scientific procedures found in the published literature. Incorporating flow into the statistical analysis was the area we felt most strongly about as this will help eliminate variability caused by

storm events and climate change impacts. However, this may require an additional 1/4 time person at the County and budget for installation of stream gauges.

1.0 Introduction

In response to development pressures, the Washington State Legislature enacted Chapter 36.70A RCW, known as the Growth Management Act (GMA), in 1990. The Act included 13 goals that required state and local governments manage future development by identifying and protecting critical areas, designating urban growth areas, creating plans, and implementing plans. The GMA has been amended several times to further clarify and define requirements and to establish a framework for improved coordination among local governments. For example, in 1991 the Act was modified to create the Growth Management Hearings Boards and in 1995 a goal addressing shoreline management was added. In Skagit County, the Western Washington Growth Management Hearings Board is the entity responsible for determining whether local governments are in compliance with the GMA and resolve disputes concerning comprehensive plans and development regulations adopted under the GMA.

To help meet its obligations under the Critical Areas section of the GMA, Skagit County Public Works Surface Water Management established a county-wide water quality monitoring program in July 2001 under the Skagit County Baseline Monitoring Project. In October 2003, the project was modified and extended through County Resolution R20030210 (later replaced by Resolution R20040211). The current program, referred to as the Skagit County Monitoring Program, is designed to determine water quality conditions and trends in agricultural-area streams in Skagit County by sampling at 40 locations throughout the region. The Critical Areas protection of ongoing agricultural areas (SCC 14.24.120) protects existing natural resources in agricultural areas. Data collected by the Monitoring Program will be used to assess the effectiveness of County Ordinance O20030020 (Critical Areas Regulation for Ongoing Agriculture) which examines whether or not water quality is changing over time.

The purpose of this report is to examine the comprehensive monitoring plan being implemented by the County to determine if it is consistent with their overall objective of protecting critical fish habitat within agricultural areas. The following report addresses the eight tasks identified in Skagit County Contract #C20070661.

2.0 Scope of Work

This chapter addresses each of the tasks specified in the contract. Each section describes the primary objective of the task and then describes the process that was used to evaluate the task. Recommendations are made under Task 7 with the associated costs described in Task 8.

Task 1 – Assessment of Monitoring Program

Objective 1: Determine whether the current Skagit County Water Quality Monitoring Program adequately describes the condition of the sample sites with respect to Washington State Water Quality Standards as codified in WAC 173-201a. Provide general comments on the monitoring program.

WAC 173-201a describes water quality standards for surface waters of the state of Washington consistent with public health and public enjoyment of the waters and the propagation and protection of fish, shellfish, and wildlife. Copies of the data Excel spreadsheets and the 2004, 2005, and 2006 annual reports were obtained from the Skagit County Public Works web site. The Quality Assurance Project Plan (QAPP) developed by Haley (2003) was also downloaded and examined.

The reports do a good job in summarizing the results from the water quality sampling plan. According to the reports, the sampling locations were chosen based on watercourse location within the agricultural zones, and were located to meet one or more of the following objectives: 1) Downstream from agricultural influences to represent possible effects of agricultural land use activities on water quality; 2) Upstream from agricultural activities to represent background conditions, 3) Locations chosen to gather water quality information in support of TMDL development or implementation, and 4) Receiving waters for watercourses draining agricultural lands. With 40 locations spread throughout the watershed, it would appear that the plan more than adequately addresses the general goals established.

Whether or not these are the best sites could not be determined from the information provided. Alternative sites that were not selected and more information on selection criteria would need to be examined and subjective assessments quantified. Nevertheless, the sites appeared to cover the range of activities.

On January 24, 2008, a tour of the field sites was conducted by WSU and Skagit County personnel. The goal of this trip was to evaluate the selection with respect to surrounding land use and look for any obvious signs of concerns. Based on this visit, I am comfortable in the assessment that the sites indeed do cover the wide range of land uses and stream types within the County.

Two types of trends are typically considered in hypothesis testing: one is a step (shift) change; the other is a monotonic trend (Hirsh et al., 1991; Xu et al., 2003). In the absence of a catastrophic event or a new facility going online, water quality data are generally not analyzed for step changes. Instead, monotonic trends (linear or non-linear changes in a consistent direction) are determined. The County is currently using the seasonal Kendall test for statistical analysis of the water quality parameters to identify positive and negative changes in pollutant loading. The seasonal Kendall test, a generalization of the Mann-Kendall test, is widely used to detect monotonic trends in water quality data (Gilbert, 1987; Helsel and Hirsch 1992). A number of water quality trend studies have been performed using this methodology (Hirsh et al., 1982; Alden et al., 2000; Raike et al., 2003). Kennedy (2003) states that although many trend assessment methods are available, the nonparametric seasonal Kendall test often performs better than parametric methods (e.g., t tests, linear model test, cumulative deviation test) for data sets that are commonly non-normal, vary seasonally, and contain outliers and censored values (See task 4). While the procedures for each test may differ significantly, the overarching difference between parametric and nonparametric (also known as distribution free or distribution independent) tests is that an assumption regarding the underlying statistical distribution of the data is required for parametric tests whereas no such assumption is required for nonparametric tests.

Based on information presented in annual reports of this monitoring program, it is very unclear how the data is being processed prior to and/or during any trend analyses being conducted. No description of the statistical software programs or analytical techniques used to run the analyses is provided. It is unclear if a pre-packaged software program specifically designed for these particular analyses (e.g. ESTREND; Schertz et al. 1991 or WQHYDRO) has been utilized. If pre-packaged software is being utilized, this should be, at a minimum, clearly defined so that readers/reviewers of this program can gather necessary information from relevant user manuals; Alternatively, methods used for data processing and analysis should be highlighted in the annual report(s), with adequate reference to user manuals so that readers/reviewers can get additional information if desired. If pre-packaged software is not being utilized, clear descriptions of the software and data processing techniques used are necessary to allow for thorough understanding of the validity of any analyses performed; to date, this information is lacking from any reports related to this monitoring program. Information necessary for a thorough understanding of analyses will include, but may not be limited to, specific algorithms used for analyses, a clear definition of how and why 'seasons' are defined for the Seasonal Kendall Test, how data is censored or adjusted to account for the presence of "Below Detection Limit" or "Non-Detected" water quality constituents, and what is done to account for missing data due to lost samples or missed sampling dates[1].

Whether or not bi-monthly sampling needs to be continued remains a question that should be addressed by the County. It would seem that the potential for serial correlation may preclude the use of data that is collected too frequently (Darken et al., 2002). Serial correlation is defined as autocorrelation in the absence of seasonality or trend. Serial correlation in water quality time series invalidates tests of significance, such as seasonal Kendall analysis, because these tests assume data independence. Not that too much data is necessarily bad. However, a 1991 USGS document regarding their ESTREND program for detecting trends in water quality suggests that using water quality data with values collected more frequent than monthly will likely be serially (or auto) correlated (Schertz et al. 1991). Therefore the sampling plan should be re-assessed in light of the goals and procedures used to gauge the metrics of these goals[2].

[1] Additional details on the methodology were provided in a subsequent e-mail communication with Rick Haley on March 17, 2008. The following information was provided in that exchange. Data were analyzed using WQStat Plus (Intelligent Decision Tech, vendor was Waterloo Hydrogeologic); four seasons were defined, starting with 1/1-3/31, 4/1-6/30, 7/1-9/30, and 10/1-12/31 chosen to correspond with water year and local seasons; and data below detection limit substituted with ½ of detection limit.

[2] During the review of this report we were informed by Rick Haley that the County took this approach this year to test all the data and then test the mean of each 4-wk period (2 data points for each mean). They found that there were very few differences between the 2-wk and 4-wk trends.

A list of the beneficial uses of water for the lower Skagit River and its tributaries is provided in Table 602 of WAC 173-201A. These uses include water supply, recreation, and char spawning and rearing. In addition, we also examined the 2002/2004 303(d) list for both category 2 and category 5 pollutants of concern. Our overall assessment of the monitoring plan is that it more than adequately addresses the range of existing water quality conditions in the watershed with respect to nutrients, fecal coliform, dissolved oxygen, pH, turbidity, and temperature. In other words, the Skagit County data is suitable for determining the condition of a site compared to state WQ standards. The only category 5 contaminant not regularly sampled appears to be PCBs in fish tissue which is probably beyond the scope of the surface water quality monitoring program.

Task 2 – Natural Background Conditions

Objective 2: Describe available methods for determining whether streams are unable to meet water quality standards due to natural conditions per WAC 173-201a-260.

According to the Idaho Department of Environmental Quality "natural background conditions exist when there is no measurable difference between the quality of water now and the quality of water that would exist if there were no human-caused changes in the watershed". Similarly, the US EPA defines natural background as background concentration due only to non-anthropogenic sources, i.e., non-manmade sources. In Washington Administrative Code 173-201a-260, the legislature defined "natural and irreversible human conditions" and said that when a water body does not meet its assigned criteria due to natural climatic or landscape attributes, the natural conditions constitute the water quality criteria. This is not always easy to quantify especially since human-caused impacts don't always affect all aspects of water quality equally so it is possible for water to be considered natural for one parameter but not another. State water quality standards generally include provisions that allow for water quality to exceed numeric criteria due to natural background conditions of the water body.

The processes for establishing site-specific criteria and conducting a use attainability analysis (UAA) have similar steps for data collection and analysis. Under 40 CFR 131.10(g) states may remove a designated use which is not an existing use, as defined in § 131.3, or establish sub-categories of a use if the State can demonstrate that attaining the designated use is not feasible because:

1. Naturally occurring pollutant concentrations prevent the attainment of the use; or
2. Natural, ephemeral, intermittent or low flow conditions or water levels prevent the attainment of the use, unless these conditions may be compensated for by the discharge of sufficient volume of effluent discharges without violating State water conservation requirements to enable uses to be met; or
3. Human caused conditions or sources of pollution prevent the attainment of the use and cannot be remedied or would cause more environmental damage to correct than to leave in place; or
4. Dams, diversions or other types of hydrologic modifications preclude the attainment of the use, and it is not feasible to restore the water body to its original condition or to operate such modification in a way that would result in the attainment of the use; or
5. Physical conditions related to the natural features of the water body, such as the lack of a proper substrate, cover, flow, depth, pools, riffles, and the like, unrelated to water quality, preclude attainment of aquatic life protection uses; or
6. Controls more stringent than those required by sections 301(b) and 306 of the Act would result in substantial and widespread economic and social impact.

The Washington State Department of Ecology (Ecology) developed a draft guidance document for UAAs in 2005. The DRAFT Use Attainability Analysis Guidance for Washington State DRAFT – Version 1.2, July 2005 states that Ecology has not successfully completed enough (any) UAAs to develop strict policy guidelines at this point. Nevertheless, as with any criterion adjustment, criteria based on natural conditions must be scientifically defensible. The key pieces of information that will generally be used to identify natural conditions include:

- Current water quality,
- The contribution of natural sources of pollution and natural physical conditions, and
- The contribution of human-induced conditions.

The contribution from human sources must be distinguished in order to accurately determine the natural condition. The guidance document also states that UAAs for waterbodies used by ESA species will need an extra degree of planning and coordination with Ecology, EPA, the tribes, and the resource agencies to determine information needs.

There are no clearly defined steps that can be universally applied to every water quality parameter. Reference conditions, water quality sites clearly upstream of known human disturbances, would likely be the best source of information. This is likely to be somewhat problematic in some watersheds due to extensive forest management practices upstream. For instance, hydrograph modification from upland watersheds could be responsible for stream temperature deterioration due to changes in base flow. Ecology and the US EPA acknowledge that it may be necessary to use neighboring or similar watersheds to establish reference condition. However, agreeing to what constitutes an appropriate surrogate watershed would likely be subject to major discussion and negotiation.

The use of numerical models can be used to evaluate conditions with and without human impacts. For example, a temperature model could be used in conjunction with an analysis of existing riparian vegetation to see if allowing full vegetation cover would improve stream temperature. Given the public's skepticism of models, this approach may also prove to be controversial if the results don't match public sentiment.

Finally, there may be some questions, debate, and confusion as to what exactly defines natural condition. For example, as discussed in more detail in under Task 6, the Cattlemen's letter suggests that the County's water quality monitoring program is an experiment where the null hypothesis is that all streams are essentially the same. In observing the variety of waterways during our inspection of the monitoring locations it became clear that all Skagit County waterways are not the same nor should they be expected to respond the same way to external inputs. Subsequent discussion with Skagit County staff confirmed that this was not the hypothesis of their program. If it were assumed that all streams in the watershed were created equal, then any stream with concentrations greater than the most pristine stream in the basin could be deemed impacted by human activity which is not necessarily true. Nevertheless, public misconceptions about water quality often complicate the determination of natural condition.

Task 3 – Effects on Salmonid Population

Objective 3: Based on Skagit County's water quality data, examine the water quality conditions in Skagit County and identify which conditions negatively affect salmonid populations.

This section provides a general subjective overview of the perceived and/or probable impacts of water quality conditions observed under the Skagit County Monitoring Program on salmonid fishes. The ability to definitively assess the impacts of water quality conditions on the salmonid fishes found in Skagit County waterways is limited under this contract by a lack of readily available, detailed information regarding species-specific distributions and particularly, species and life-stage specific uses of each waterway being monitored (e.g. spawning/incubation, rearing only, migration only, or some combination of these). Currently, almost all of the waters in Skagit County listed for salmonid presence are used for rearing and many are considered spawning habitat as well. This may or may not reflect reality especially in the case of agricultural ditches. The water quality needs of salmonids vary across species, and dramatically across life stages within a species. As an example, DO requirements in a reach used for a short period solely as a migration corridor will vary substantially from those in more prolonged life-stages (e.g juvenile rearing); coincidentally, the potential impacts of water quality limitations on salmonid species will vary dependent on the species and life-stage present as well as the duration of their exposure to any adverse water quality conditions.

Baseline information on salmonid presence/absence at Skagit County monitoring sites provided for this review (via Salmonscape online) is not life-stage specific. More detailed information on life-stage specific use of many stream segments within Skagit County is readily available online (see Streamnet.org); compilation and validation of that information with local fisheries experts was beyond the scope of this contract. Any future efforts to relate water quality and salmonid habitat conditions in Skagit County waterways should consider doing so in a species and life-stage specific context.

Temperature

Temperature is one of the most important factors affecting fish physiology (BioAnalysts, Inc. 1998) and salmonid distributions are known to be strongly linked to temperature (Power 1990). Based on Skagit County Monitoring Program data gathered to date, temperatures at most monitoring locations have the potential to negatively impact salmonid use or habitat conditions.

The effects of temperature on freshwater fishes including salmonids have been reviewed in detail by numerous authors (See Elliot 1981; Jobling 1981; and Alabaster and Lloyd 1982). In warm summer periods salmonids are often exposed to temperatures that exceed their optimum temperature regime which may negatively impact a variety of physiologic processes. In some more extreme or prolonged cases the elevated temperature regimes may be lethal (Grande and Andersen (1991). Important physiological functions affected by temperature include growth, food consumption, metabolism, reproduction, activity and survival (BioAnalysts, Inc. 1998).

Fish appear to select temperatures that maximize the amount of energy available for activity and growth (Fry 1971; Jobling 1994). Because different physiological processes (e.g. ingestion and metabolism) may have different optimal temperatures, temperatures selected by fish often represent a compromise or preferred temperature. Preferred and optimal temperatures are often species and life stage specific and may vary between stocks within the same species. An overview of preferred temperatures for salmonid species commonly found within Skagit County waterways illustrates that preferred temperatures rarely exceed 16°C for any species or life stage (Table 1).

Washington state water quality standards vary by water body and are based on designated beneficial uses, taking into account various potential uses by salmonids. Based on information presented in the Skagit County Monitoring Program annual report (Skagit

County Public Works 2007), state water temperature standards range from 16 to 17.5°C at established monitoring sites. In all cases state water quality standards tend to exceed preferred temperature ranges for most salmonid species during most life stages (refer to Table 1).

Table 1. Overview of preferred temperatures of salmonid fishes based on species and life history stage.

WQ Parameter	**Migration**	**Spawning**	**Incubation**	**Juvenile Rearing**	**Sources**
Preferred Temperature (°C)					
Fall Chinook	10.6-19.4	5.6-13.9	5.0-14.4	12-14	Bjornn and Reiser 1991; Bell 1986
Spring Chinook	3.3-13.3	5.6	5.0-14.4	12-14	Bjornn and Reiser 1991; Bell 1986
Summer Chinook	13.9-20.0	5.6	5.0-14.4	12-14	Bjornn and Reiser 1991; Bell 1986
Chum	8.3-15.6	7.2-12.8	4.4-13.3	12-14	Bjornn and Reiser 1991; Bell 1986
Coho	7.2-15.6	4.4-9.4	4.4-13.3	12-14	Bjornn and Reiser 1991; Bell 1986
Pink	7.2-15.6	7.2-12.8	4.4-13.3		Bjornn and Reiser 1991; Bell 1986
Sockeye	7.2-15.6	10.6-12.2	4.4-13.3	12-14	Bjornn and Reiser 1991; Bell 1986
Steelhead	10.6-19.4	3.9-9.4		10-13	Bjornn and Reiser 1991; Bell 1986
Rainbow Trout		2.2-20.0			Bell 1986
Cutthroat Trout		6.1-17.2			Bell 1986

Review of Skagit County Monitoring data (Skagit County Public Works 2007) illustrates that only five sampling locations (Sites 11, 21, 29, 30 and 48) appear to have met state water quality standards at all times since sampling began. Based on established state standards, all of these sites are considered salmonid habitat. These sites likely meet or only slightly/ occasionally exceed preferred temperature conditions for salmonids using these waterways.

Six Skagit County monitoring locations (Sites 4, 14, 18, 22, 24 and 47) have temperature conditions over the period of record which sporadically, but not uncommonly, exceed state water quality standards. Temperatures at these locations would therefore also exceed the lower preferred temperatures for various life history stages of any salmonids present at these locations. It is likely that negative physiologic impacts to some salmonid life history stages occur at these locations although the extent and duration of those impacts cannot be definitively stated based on the available data.

The remaining twenty-nine monitoring locations in Skagit County appear to have regular exceedences of state temperature standards. Since state standards are generally higher than preferred temperatures, temperatures at these locations are likely to regularly exceed preferred temperature ranges for any salmonids inhabiting these areas. Temperatures at these locations likely result in regular and potentially prolonged negative physiologic impacts to salmonids during at least some life history stages. The extent and duration of those impacts cannot be definitively stated based on the available data.

Dissolved Oxygen

Based on Skagit County Monitoring Program data gathered to date, dissolved oxygen (DO) levels have the potential to negatively impact salmonid use or habitat conditions at some monitoring sites. Insufficient DO levels can negatively impact swimming performance, feeding behavior, food conversion efficiency, and growth rates of salmonids.

Juvenile salmonids can survive over a wide range of DO concentrations although levels near saturation (>80%) are typically considered optimal. Juvenile salmonids can survive when DO concentrations are <5 mg/l, but growth, food conversion efficiency and swimming abilities are negatively impacted. Minimum recommended DO for spawning fish is at least 80% of saturation and not even temporarily less than 5.0 mg/l and the same levels are assumed to also adequately meet the needs of migrating salmonids (Bjornn and Reiser 1991). The DO levels necessary for successfully incubating salmonid eggs and larvae are typically much lower than for many other life stages, but are dependent on intra-gravel gas levels which are not being measured as part of the Skagit County Monitoring Program.

Most of the data regarding oxygen requirements of salmonids are based on laboratory studies (Bjornn and Reiser 1991). Although such data provides useful guidelines, caution should be used when extrapolating the data to fish in natural streams (Brett and Blackburn 1981) since water quality, fish acclimation and other factors will differ between the lab and field.

Using the aforementioned generalized criteria of 80% saturation and 5 mg/l as a guideline, twelve monitoring sites in the Skagit County Monitoring Program have DO values which may negatively impact salmonids (Table 2). Two of these sites are known to be used by salmonids, four are believed not to be use by salmonids, and salmonid use of the remaining six sites is unclear. If salmonids are using these habitat areas, there are most probably at least some negative impacts to their success based on limited DO at some times of the year. If recent surveys have not been conducted to evaluate use of these areas by salmonids, it is recommended that such surveys be conducted so that any potential impacts of low DO levels at these sites can be better evaluated.

Table 2. List of sites for which existing data suggests salmonids may incur negative impacts due to reduced DO levels.

Site #	General Description	Salmonids Present	General Timeline of DO Concern*
3	Thomas Creek at Highway 99	Unknown	May/June – Early October
15	Nookachamps Creek at Knapp Rd.	Unknown	July – August/Early Sept.
33	Alice Bay Pump Station	No	Sporadic, Infrequent
34	No Name Slough at Bayview-Edison Rd	Yes	June-September
35	Joe Leary Slough at D'Arcy Rd	No	Sporadic, Frequent
37	Edison Pump Station	No	Sporadic, Frequent
38	North Edison Pump Station	Unknown	Sporadic, Frequent
40	Big Indian Slough at Hwy 20 Scales	Unknown	April - August
41	Maddox Ck/Big Ditch at Milltown Rd	Yes	August - December
42	Carpenter Ck/Hill Ditch at Cedardale Rd	Unknown	July - September
43	Wiley Slough at Wylie Rd	Unknown	Sporadic, Frequent
44	Sullivan Slough at La Conner-Whitney Rd	No	Sporadic, Frequent

* Timeline is generalized based review of existing data; DO concerns will likely vary in timing and duration from year to year.

Some authors suggest that the optimal DO levels for some salmonids or life stages in natural streams are higher than the aforementioned guidelines (e.g. Davis et al. 1963, Davis 1975, Dahlberg et al. 1968). In accordance with this concept, Washington state water quality standards for DO vary based on the types of fish present and the type of fish use, but generally range from 8.0 - 9.5 mg/l for waterways within the Skagit County monitoring program.

If the more stringent state water quality standards are used as a benchmark to evaluate potential negative impacts of DO conditions on salmonids, an additional 10 sites show the potential to regularly have conditions which may negatively impact the salmonids using them. Of these, three sites are known to be utilized by salmonids (Sites 11, 14 and 28), five sites are listed by Ecology as core salmonid spawning and rearing streams (Sites 12, 13, 17, 21 and 24) and information was unavailable regarding salmonid use of the remaining two (Sites 31 and 36). Similar to the aforementioned sites, if recent surveys have not been conducted to evaluate use of each of these areas by salmonids, it is recommended that such surveys be conducted so that any potential impacts of low DO levels at these sites can be better evaluated.

Negative impacts to salmonids at any of these 10 additional sites are likely to occur if salmonids are found to be using the areas. However, any impacts are likely species and life stage specific. Without detailed information regarding species and life stage specific use of each area, it is not feasible to provide more detail as to the extent of any potential negative impacts at this time.

Nutrients

Nutrient values observed to date during the Skagit County Monitoring Program are not thought to have any direct deleterious impacts to salmonids. In general, salmonids are largely indifferent to nutrient levels, and with the exception of ammonia, elevated nutrient levels are not directly toxic to them. The primary issues caused by nutrients are indirect and related to eutrophication type impacts such as increases in the degree or frequency of algal blooms and increased severity of nightly oxygen reductions (Bell 1991). While most waterways experience some diurnal oxygen fluctuations, agricultural waterways and slow moving water in lakes are well known to exhibit this type of behavior. In King County Washington, salmonid deaths have been reported in traps left out over night in agricultural watercourses (WSU and UW 2007). Similar conditions could exist in Skagit County.

Most fish including salmonids are indifferent to nitrate levels; nitrite levels may be toxic to salmonids in some instances (Bell 1991). Crawford and Allen (1977) found that for Chinook salmon fingerlings in freshwater, the 48-hour median lethal nitrite concentration was 19 mg/l and in natural seawater, 1,070 mg/l nitrite caused only 10% mortality in 48 hours.

Information on nitrite levels toxic specifically to other salmonid species were not readily located. However it is likely that the values would not diverge substantially from those cited here for Chinook salmon. Nitrite levels observed in Skagit County waterways to date do not appear to exceed 1 mg/l, suggesting that even if tolerance values for other salmonid species differ dramatically from those reported for Chinook salmon, no deleterious effects are likely.

Turbidity and Total Suspended Solids (TSS)

Reported turbidity and TSS values observed to date during the Skagit County Monitoring Program are not likely to have any direct deleterious impacts to salmonids. Observed values to date are typically well within the acceptable ranges for long term exposure by salmonids; in instances where levels are elevated, they do not appear to remain elevated for extended periods and are typically within ranges considered tolerable for short term exposure by salmonids.

In general, turbidity and TSS are not likely to directly inhibit activities or cause mortality of salmonids in natural waters within the Pacific Northwest unless extreme circumstances arise. Most commonly impacts of increased turbidity or TSS are realized indirectly when fine sediments settle out of the water column and inhibit spawning or incubation success of salmonids or through alteration of productivity rates and food production. Based on the available data, no conclusions can be drawn regarding potential indirect effects of observed turbidity and TSS levels on salmonids or their habitats throughout Skagit County.

Most streams commonly experience periods of elevated turbidity and suspended sediment during storms and periods of snowmelt. Newly emergent fry are more susceptible than older salmonids to elevated turbidity levels (Bjornn and Reiser 1991). Newly emergent coho and steelhead showed reduced growth and increased emigration when exposed to turbidities ranging from 25-50 NTUs relative to those exposed to clear water (Sigler et al. 1984). Feeding and territorial responses of juvenile coho salmon have been shown to be interrupted during short-term continuous exposures (2.5 - 5 days) to waters with turbidity levels approaching 60 NTUs (Berg and Northcote 1985), and juvenile coho salmon were found to avoid waters with turbidity in excess of 70 NTUs (Bisson and Bilby 1982).

Salmonids may avoid waters with high silt loads or cease movement and migration when such conditions are unavoidable (Bjornn and Reiser 1991). However, turbidity levels which have been found to inhibit migration of salmonids have exceeded 4,000 mg/l (roughly 200-4000 NTU depending on the materials being transported) and relatively large quantities of suspended materials (500-1,000 mg/l or roughly 100-1,000 NTUs) can be transported for short durations without detriment to most fish species (Bell 1986).

Other Variables

pH values observed to date during the Skagit County Monitoring Program are not thought to have any direct impacts to salmonids. According to Bell (1991) there is no optimum pH value for fish. Impacts of altered pH on fish are typically indirect and may occur through limitation in food production (best if pH values are 6.7-8.3), and altered tolerance to low DO concentrations. Both the permissible pH range and the degree of indirect impacts due to altered pH values depend on many other factors including temperature, DO, the content and makeup of various cations and anions, and prior acclimatization of the fish in question.

Conductivity values observed to date during the Skagit County Monitoring Program are not likely to have any direct deleterious impacts to salmonids. Literature review found no relevant information regarding negative impacts to salmonids directly due to changes in conductivity. Any impacts to salmonids related to changes in conductivity are likely to be indirect, and caused by the particular constituents which alter conductivity values or due to related changes in habitat conditions (e.g. food production) tied to altered conductivity.

Salinity values observed to date during the Skagit County Monitoring Program are not likely to have any direct deleterious impacts to salmonids since they are euryhaline species.

Observed salinities in Skagit County only rarely exceed 1.0 part-per-thousand (ppt) in freshwater habitats. In brackish or tidally influenced waters, the ability of fish to migrate to areas more suitable as water quality changes should allow them to find optimum conditions for effective osmoregulation throughout the smoltification process.

In general this parameter is not well understood, and tolerance values are likely variable among species and stocks. However, the following excerpt from Healy (1991) concerning Chinook salmon is likely to be generally applicable to other salmonid species found throughout freshwater habitats in Skagit County:

> "Although many Chinook fry appear unable to survive immediate transfer to 30 ppt salinity, they are clearly able to survive transfer to 20 ppt or less, and osmoregulatory capability develops quickly in fry exposed to intermediate salinities (Weisbart 1968, Wagner et al. 1969, Clarke and Shelbourn 1985). I have transferred Chinook fry directly from downstream migrant traps on the Nanaimo River into sea water of 32 ppt in the laboratory with no apparent short-term ill effects or retardation of growth compared with controls maintained in freshwater and brackish of 15 ppt (Healey, unpublished data). Some Chinook fry therefore appear to be able to tolerate immediate transfer to high salinity."

Wagner (1969) found that fall Chinook tolerated higher salinities with increasing size and suggested that slower growing spring Chinook showed delayed tolerance to salinity due to slower growth rates. In this study, fall Chinook were able to tolerate 15-20 ppt salinity immediately after hatching, and 30 ppt at a size of 65mm.

Task 4 – Temporal Changes in Water Quality

Objective 4: Determine whether the trends analysis conducted by Skagit County adequately describes temporal changes in water quality and identify any trends that appear to be associated with active agricultural areas.

It is generally accepted that analysis of water-quality data to determine long-term trends is complicated by three basic problems: (1) the variety and complexity of environmental causes of trends; (2) changes over time in the protocols and methods used to collect and analyze water samples; and (3) changes in frequency or timing of sampling. Confidence in trend detection is influenced by the duration of monitoring and generally improves with time. The USGS conducted an initial analysis of change detection capabilities as part of their Long Term Resource Management Project (Lubinski et al, 2001). Using an $\alpha = 0.20$ and a 20% change in annual mean values, the USGS researchers examined level of sampling effort. For water quality parameters, monthly sampling was generally deemed sufficient although results for macroinvertebrate and fish were mixed.

In a water quality study in Big Cypress National Preserve, USGS scientists used the seasonal Kendall test to analyze trends. The uncensored seasonal Kendall test only permits comparisons of data from the same seasons over the period of record, which reduces the effect of seasonal water quality changes and improves one's ability to determine long-term trends. They concluded that the uncensored seasonal Kendall test requires a minimum of 5 years of data be available, that censored (less than) data be no more than about 5 percent of the data set, and that there is only one censoring level. They also reported that this test allows the water quality data to be flow or stage adjusted. The uncensored seasonal Kendall test is considered robust; that is, it is not sensitive to outliers in the data (Schertz et al., 1991).

Reckhow et al. (1993) recommended that nonparametric analysis be used to analyze water quality data because the parametric assumptions (e.g., normally distributed data, linearity, and independence) are often difficult to justify. Among these tests, they suggest that Kendall's Tau or the seasonal Kendall's Tau test are often good choices for distribution-free tests. This sentiment has been expressed by many other scientists and engineers studying trend analysis (Gilbert, 1987; Lettenmaier et al., 1991; Burton and Pitt, 2002). Based on this information, it would appear that the statistical evaluation procedure being used is appropriate for identifying water quality trends.

This is not to say that there are no problems with the seasonal Kendall test. Among the shortcomings of the test are its restriction to monotonic (unidirectional) trends and the limited insight it provides in comparison to other methods that might be preferred by an experienced statistician. The seasonal Kendall trend test only indicates whether or not a trend exists and the significance level of the trend. A related procedure, the seasonal Kendall slope estimator (Hirsch et al., 1982), can be used to calculate the magnitude of the trend as is done in the current Skagit County water quality monitoring program. It is computed as the median of the slopes of the ordered pairs of values used to compute the seasonal Kendall statistic, and is used in this report as an estimate of the annual average change (Larson, 2001). Nevertheless, in spite of these shortcomings, the seasonal Kendall test has become the industry standard at identifying water quality trends.

One of the difficulties facing the Skagit County analysis is that trend identification is not sufficient to identify cause(s). Numerous factors can potentially impact water quality variations such as inherent hydrologic variability, global warming, crop rotation, failing infrastructure (septic systems), urbanization, forest management, and extreme events such as forest fires and landslides. For example, the precipitation records from nearby Bellingham, Washington extend back to 1896 as illustrated in Figure 1. As shown, there has been a steady increase in average annual precipitation. Moreover, the increasing trend is even more significant beginning around 1950. Figure 2 illustrates a subset of the total annual precipitation beginning in 1946. The slope of the trend line is larger indicating a larger trend although a considerable amount of variability exists as indicated by the low R^2 value.

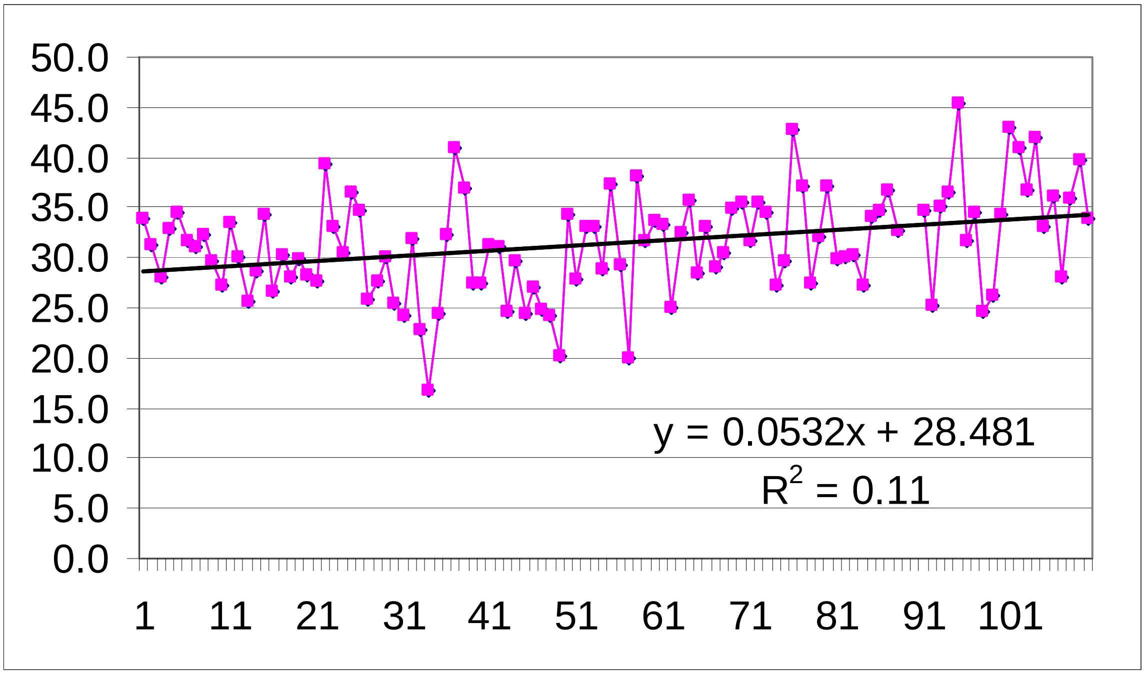

Figure 1. Annual precipitation total for Bellingham, Washington since 1896. (http://cdiac.esd.ornl.gov/)

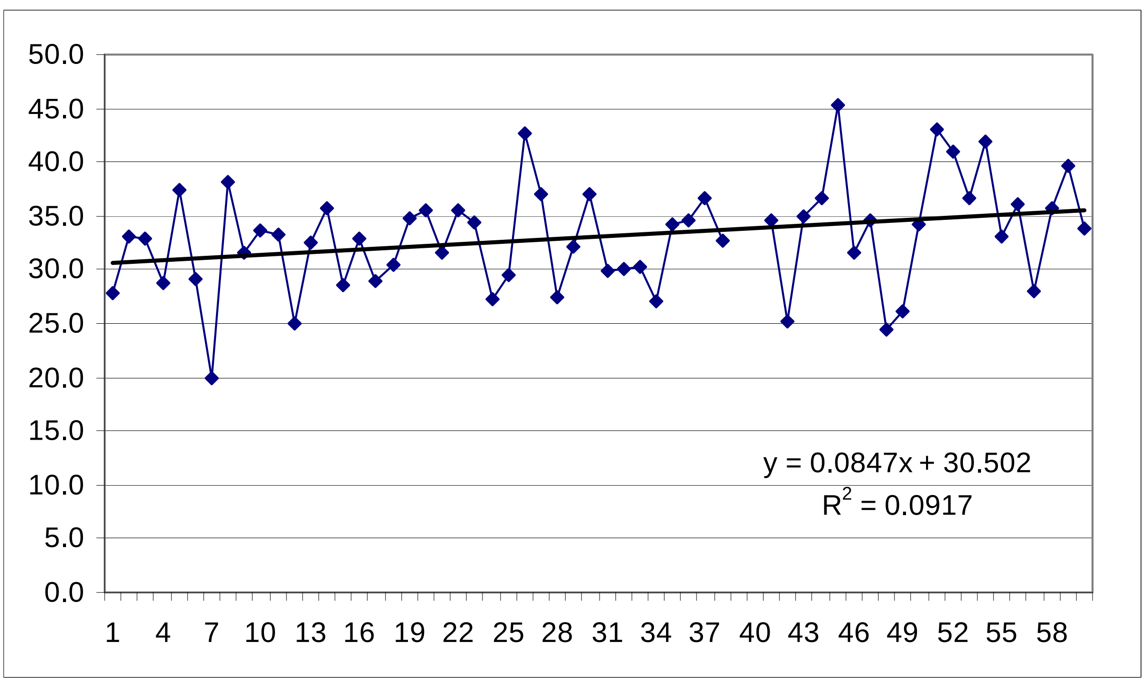

Figure 2. Subset of annual precipitation total for Bellingham, Washington since 1946.

Figure 3 looks at recent departures from normal or average conditions between 2001 and 2005. The five year actual precipitation is shown plotted against the reoccurring average year condition. The difference between actual and average can be potentially significant with respect to the anticipated amount of runoff and the resulting water quality.

The effect of stream flow or discharge volume on concentrations is often considered an important factor in water quality trend analyses. If a pollutant originates from non-point sources, then increased flow would tend to increase the concentration of that pollutant (Cavanaugh and Mitsch, 1989). The Commonwealth of Virginia conducted a comparison of flow-adjusted versus non-flow-adjusted analyses on twenty years worth of water quality data (Commonwealth of Virginia, 2006). Since no trends were initially found using the non-flow-adjusted data in their study, conversion to flow-adjusted resulted in only marginal statistical differences. However, they were quick to point out that if trends had been identified in the non-flow-adjusted data, then larger differences would be expected. Smith et al. (1982) found that flow-adjustment of phosphorus concentrations at 303 NASQAN stations changed results from 38 increasing, 62 decreasing to 40 increasing, 45 decreasing trends.

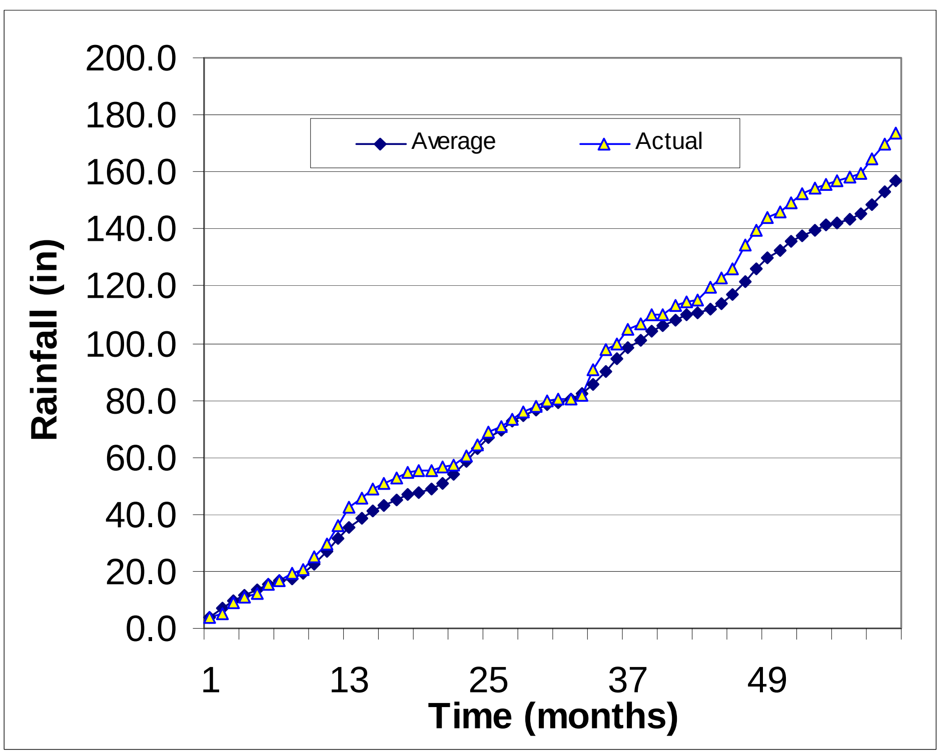

Figure 3. Deviations from average precipitation between 2001-2005.

The impacts of climate change on stream temperature are not adequately factored into the current monitoring design. While trends in water temperature can be identified, the process for determining whether or not the trends are hastened by changes in agricultural, urban land use, forest practices, or hydrologic shifts is not defined. This is not an easy task as uncertainties in all aspects would require significant data collection of precipitation (and snow pack), land use, and stream flows as well as a computer model to evaluate spatial distribution. Land use changes could be tracked over time by obtaining historic LandSat or other remote sensing images and creating GIS layers.

Arguably, the non-agricultural sites (e.g. sites 14, 31, 25, 30) may be helpful in spotting large trends over decades assuming that if there were regional climate change effects, the response of the non-agricultural sites would be the same as the response of the agricultural sites. This is a fairly large assumption given the inherent variability in watershed characteristics that were observed. For example, climate change that causes lower summer flows may also be responsible for increased summer temperatures but the impact on a small stream may be substantially more pronounced than on a larger stream or the Skagit River. Furthermore, the assumption would presume that percent changes would be uniform across the spectrum of parameters meaning that all waterways would have the same sensitivity to flow and temperature changes. Again, we believe that more work would be needed to clearly indicate that this was the case.

In addition to evaluating the impact of climate variability, the distinction between agricultural impacts and other sources of pollution must be determined. It is our understanding that agricultural impacts are distinctly different from rural impacts caused by septic systems. Consequently, monitoring efforts should consider trying to account for sources of pollution linked to failed septic system drainage fields versus those that are not associated with human sources. Optical brighteners (OBs) (fluorescent whitening agents in the detergent industry) are fluorescent white dyes that are added to almost all laundry soaps and detergents. OBs are typically removed from underground waters by adsorption onto soils and organic materials. They are also removed from surface waters by adsorption and by photo decay. Since adsorption is a critically important process in the performance of septic field systems, the recovery of OBs in nearby waters (either surface or ground water) indicates ineffective natural cleansing of waste waters (Aley, 1991). OBs are fluorescent white dyes that absorb wavelengths in the ultraviolet (UV) or near-UV range (360 to 365 nm) and fluoresce in the blue region (400 to 440 nm) of the visible spectrum. As such, they can be detected by use of a relatively inexpensive long wave fluorescent ultraviolet light or a "black" light. A common approach among volunteer monitoring groups has therefore been to place cotton pads in the stream for several days (seven is a common number) and then collect and analyze with a hand-held UV light.

While inexpensive and easy to conduct without much formal training, this presence-absence approach suffers from a number of drawbacks. Hagedorn et al. (2005) identify lack of accuracy, inability to distinguish between OBs and other fluorescent compounds, lack of sensitivity at low concentrations, and the inability to determine concentration as major disadvantages. They recommend using more accurate fluorometric methods involving the use of an instrument (e.g., a Turner Designs fluorometer) where some level of quantification of both the excitation source and the emission detector can be obtained.

Changes in water quality are sometimes related to a reference site. During the January field trip particular interest was focused on identifying a "typical" reference location or sampling pairs (sites on the same stream upstream and downstream of human activities). Unfortunately, no one location could be identified as a reference given the diverse nature of streams and rivers in the County. Furthermore, the variety of land uses on those streams with two or more sampling locations means that changes seen at the downstream location (for better or worse) cannot easily be mapped to one particular location. In short, while the monitoring plan undertaken by Skagit County is an excellent approach for assessing water quality in the region, it will likely be inadequate in terms of "…**identify any trends that appear to be associated with active agricultural areas."** Any trend identified by the current plan will likely require a more targeted and intensive monitoring effort to quantify the actual source of the non-point loading.

It should also be noted that the County's plan for assessing degradation of water quality focuses primarily on chemical analysis of water quality. Other indicators such as habitat surveys, macroinvertebrate studies, and fish sampling are not considered in this program and it is unclear whether or not integration at the County level exists.

Task 5 – Water Quality Benchmarks

Objective 5: Determine what water quality benchmarks Skagit County should use to compare with future water quality data to determine if harm is occurring.

Water quality benchmarks often consist of maximum contaminant levels and health advisories for drinking water, criteria for the protection of aquatic life, and/or criteria for the protection of fish-eating wildlife. MacDonald, et al. (1999) published a compendium of environmental quality benchmarks used for ecosystem planning in British Columbia. Their review of numerous agencies concluded that chemical benchmarks were often used and that these benchmarks were often tied to local or national water quality standards. A number of places use water quality indexes as a means to improve comprehension of general water quality issues, communicates water quality status, and illustrates the need for and effectiveness of protective practices. Cude (2001) reported the Oregon Water Quality Index is a single number that expresses water quality by integrating measurements of eight water quality variables (temperature, dissolved oxygen, biochemical oxygen demand, pH, ammonia and nitrate nitrogen, total phosphorus, total solids, and fecal coliform). Similarly, the Washington State Department of Ecology has a WQI based on temperature, dissolved oxygen, pH, total nitrogen, total phosphorus, total suspended sediment, turbidity, and fecal coliform bacteria. Hallock (2002) states that monthly WQI scores are suitable for statistical trend analysis. While it is somewhat tempting to recommend that this type of index be used as the benchmark, it is likely too contentious to develop a new index that looks at the parameters likely to impact fish habitat.

The NRCS (2005) proposed a Conservation Security Program "Benchmark Water Quality Nutrient and Pest Management" that was essentially a checklist of activities and assurances related to agricultural practices. While this document might be useful as an educational tool for farmers, it would be difficult to develop a defensible trigger for action based on compliance.

The Washington State Department of Ecology (Hallock and Ehinger, 2003) and a US Geological Survey report (Schertz et al., 1991) both recommend a minimum of 5 years of monthly data for trend analysis. Skagit County now has that amount of data at many of its locations. However this rule of thumb should be dependent upon the variability in the water quality parameter. The Department of Water for the Australian government conducted a state-wide assessment of water quality in 2004 in which they identified a procedure for determining the number of samples necessary for trend validation (http://apostle.environment.wa.gov.au/idelve/srwqa/). A trend in the data series was considered to be detected only when two criteria were met. The first criterion was that the Kendall test for trend on the data series must be statistically significant. The second criterion was that the effective number of independent samples collected (n^*) had to approximately equal or exceed the 'estimated' number of independent samples ($n^\#$) required to detect a trend. These were calculated as:

$$n^* = \left[\frac{1}{n} + \frac{2}{n^2} \sum_{j=1}^{n-1} (n-j)\, \rho(jt) \right]^{-1}$$

where n is the number of samples, j is the lag number (a counter), t is the sampling interval [days] and ρ is the coefficient of correlation (autocorrelation coefficient).

The same study reported that the estimated number of independent samples ($n^\#$) needed to detect a linear trend (in a variable distributed normally about the trend line) was estimated using the function (Lettermaier, 1976; Ward et al., 1990):

$$n^\# = \frac{12\,\sigma^2}{\Delta^2} \left[t_{\alpha/2,(n-2)} + t_{\beta,(n-2)} \right]^2$$

where σ is the standard deviation, Δ is the magnitude of the trend, t is the critical values of the t-distribution using α = 0.05 and β = 0.10.

If the water quality at a site is currently meeting state water quality standards, then the benchmark for determining harm should be that standard. In other words, no action is needed until a violation of state standards has occurred.

If the current conditions are in violation of state water quality standards, trend analysis using the seasonal Kendall's test may indicate 1) improving, 2) deteriorating, or 3) neutral water quality conditions. Under the County's "no harm" standard, no harm is occurring if (a) water quality meets state water quality standards, AND (b) fish habitat is not deteriorating due to agriculture [see SCC 14.24.120(3)(a)]. If the trend indicates improving or neutral conditions, then under the current interpretation of the GMA, no "additional harm" is being done by agricultural interests [part (b) of no harm criterion]. Skagit County may wish to look for opportunities to expedite or improve water quality conditions but mandating action will likely be difficult. While the Supreme Court's ruling interpreting GMA sets the minimum that the County must do to protect water quality, not the maximum, it is often difficult to economically justify and enforce efforts beyond the minimum. Obviously, if the trend indicated deteriorating conditions, then the cause should be identified and steps taken to improve the situation.

As previously stated, the current monitoring plan is unlikely to clearly identify a particular land use responsible for variation in water quality. Water quality in waterways can also be affected by changes in discharge that may create or hide trends in a fixed-interval data series. One suggestion is that the County incorporates flow adjustment into their statistical analysis procedures. This may be difficult for some tidally influenced sites but overall this should improve the County's ability to sort out hydrologic variability (e.g., climate change or natural variability) as a cause for any particular trend.

To illustrate this point further, average monthly August and September flow data from the USGS gauge on Wiseman Creek in Skagit County from 1974-1982 are plotted in Figure 4. Although the mean discharges for August and September are 2.9 ft^3/s and 4.3 ft^3/s, respectively, considerable variation exists between years. Furthermore, even within a particular month, there can be considerable variation (see Figure 5). Data collected on

September 7 versus data collected on September 22 could reflect very different watershed characteristics and obscure interpretation efforts. This could be of significant concern particularly with a short data set.

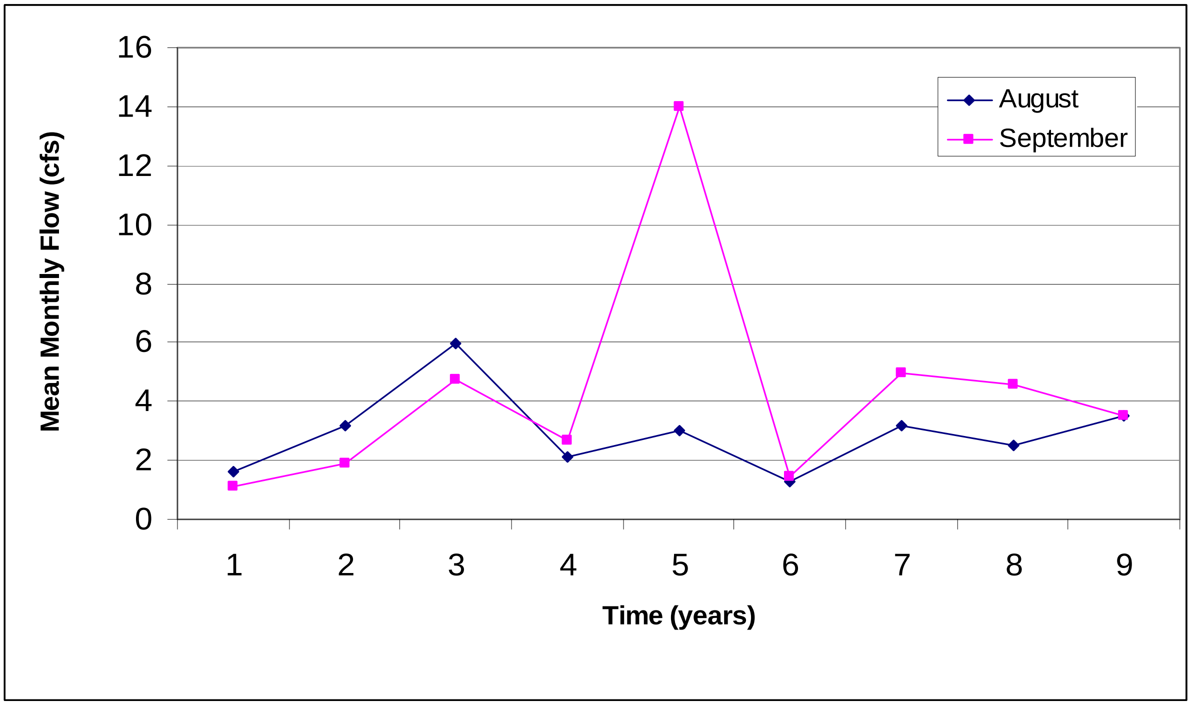

Figure 4. USGS gauge 12197700 on Wiseman Creek near Lyman, WA.

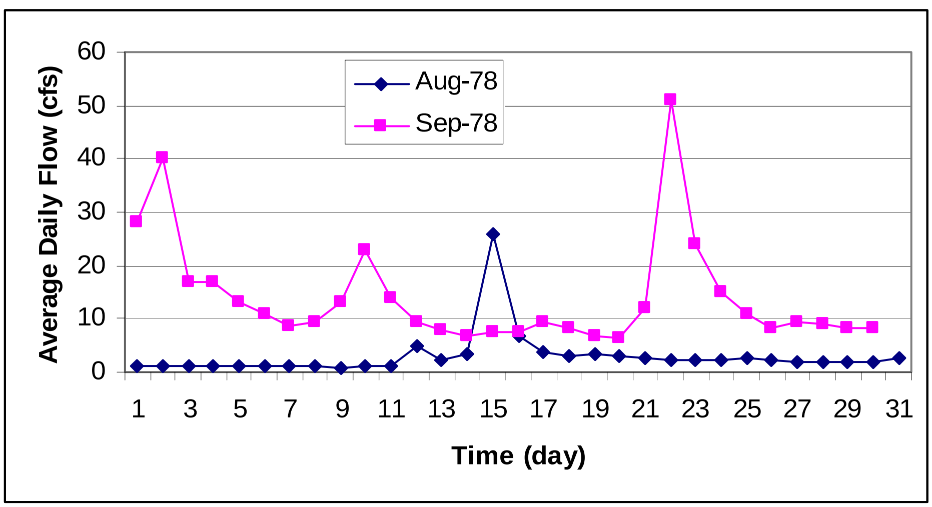

Figure 5. Daily flow variations at Wiseman Creek gauge in 1978.

We are not suggesting that all streams in Skagit County experience these sorts of daily or monthly fluctuations in average flows; only that it is possible and, without sufficient flow data, water quality trends could be masked or accentuated. Furthermore, data collected without benefit of flow data can still be used to identify trends. It is just more likely that more challenges will be made with regard to the interpretation based on perceived or real "natural" variations. In looking at Figure 4, for example, it is not hard to imagine that September stream temperatures in years 1-5 would show a positive trend while years 5-9 would show a negative trend due to variability in stream flow.

As pointed out by Skagit County staff, it is logistically challenging to collect flow data at every site because staff gauges and rating curves are not reliable over time due to frequent channel changes. Our experiences in similar watersheds have found this to require monthly gauging and somewhat subjective interpretation of pressure transducer results (staff gauges are totally inadequate as no information exists between visits). Even when selecting nearby culverts, bridge openings and other favorable gauge locations, problems caused by shifting channel shape due to sedimentation (or erosion) and ice formation are likely to exist and cannot be helped. We adopted a procedure that essentially caused us to look at the change with respect to transducer responses between gauging events. Barring a peak event, changes in rating curves were assumed to be linear. However, if we saw a large storm event, then we would use a point shift in the rating curve coinciding with the peak water depth. We also looked at downstream gages to see if our modifications seemed reasonable. This is obviously not a perfect solution. Furthermore, other problems exist. Vandalism of $500-700 pressure transducers can be a problem so replacement costs need to be factored into the O&M budget.

Finally, a p-value of 0.10 is considered to be the cut-off point for whether the trend is statistically significant (Smith et al., 1987). Recall that p- is short for probability: the probability of getting something as or more extreme than your result by chance alone (i.e., when there is no effect in the population). However, a more common value appears to be 0.05 which reduces the level of uncertainty. We recommend using 0.05 as the confidence level.

In summary, the approach would be this:

1. Is site meeting state water quality standards?
   1A. If yes, then there is no need for action.
   1B. If no, perform flow-adjust seasonal Kendall's test.

2. Is there a deteriorating trend in the flow-adjust seasonal Kendall's test?
   2A. If no, then there is no need for action.
   2B. If yes, this is trigger for further action.

Understandably, you could have deteriorating conditions and still be meeting state water quality standards under (1A). However, it seems unlikely that there would be support for eliminating all impacts. In addition, you could be failing to meet state water quality standards but not exasperating the problem under (2A).

In this approach, source identification activities constitute a separate function from the trend monitoring program. The trigger referred to in (2B) would identify the fact that a problem exists but it would not necessarily be sufficient in determining a definitive cause-effect relationship which would be required to initiate a remedial action plan. The next step once a negative trend was determined would likely require intensive sampling over short reaches of the stream until the source(s) could be identified.

Task 6 – Responses to Public Comment

Objective 6: Respond generally to comments from the public that Skagit County receives in its three-year review of the program.

Comments to Skagit County's three-year review consisted primarily of a letter dated December 21, 2007 on behalf of the Cattleman's Association and a letter dated November 16, 2007 on behalf of the Swinomish Tribe. The Cattleman's letter (signed by Randy Good and Jean Shea) discusses a number of nuances associated with the GMA. Their major points, however, seem to focus on the lack of a defined "trigger for corrective action," statistical confidence ("exact confidence level"), the monitoring program's lack of ability to detect the cause of deterioration, and that trends take years to determine.

These comments seem justifiable on some level although there will likely be some disagreement on the details of the solution and the action(s) required. In terms of a trigger, the procedure outlined in Task 5 we feel should address this issue as well as those concerns that trends take several years to be reliable and the statistical confidence question.

We have already stated that we do not feel the current monitoring program will allow Skagit County to identify direct cause-effect relationships so in that area we agree. The discussion needs to focus on two areas. First, the monitoring plan could potentially be modified to more specifically target changes in water quality due to agricultural practices by adding sites (or moving sites) upstream and downstream of specific agricultural areas. Economically and politically this may not be feasible but it would help in the assessment. Second, the plan could establish the procedure for conducting a detailed investigation upstream of any site where negative water quality trends exist that could be done on a relatively short time frame rather than a protracted multi-year sampling event. If it takes 5-10 years to establish a trend and another 5-10 years to determine cause and mitigation, then this would not appear to be an ideal solution.

In the last paragraph of page 4 the letter says "The monitoring data in fact is a scientific Experiment where the hypothesis of the monitoring program states that all stream temperatures are the same, all streams have the same pH, and all streams have the same populations of fecal coliform." As previously stated, we do not believe this should be (or is) the null hypothesis of the County's Water Quality Monitoring Program. Any preconceived assumption regarding the similarities or differences between streams and rivers should be avoided as it may skew the interpretation of the data. Furthermore, even if two streams respond similarly or identically to a measured external input (e.g., regional climate change), direct comparisons between the two streams should be avoided until all other complex factors are thoroughly understood. As a hypothetical example, a 2^{o}F change in air temperature measured at a single location could produce the same statistically significant warming water trend in two streams in terms of % change or absolute change. Perhaps it is because both streams are responding to the same input but perhaps it is because of other complex changes not adequately incorporated in the analysis. One stream could be higher in the watershed and not be fully exposed to the entire temperature change but it could be coupled with less groundwater exchange or forest harvesting that leads to the same end condition at the sampling location. And of course the opposite is true, a 2^{o}F change in air temperature could produce two vary different responses with one stream demonstrating a significantly larger change without it necessarily being tied to an additional anthropogenic factor. In short, we believe that comparisons should be made on the same stream at upstream and downstream locations rather than by comparing other streams.

In the summary and recommendations section, the Cattleman's letter identifies twelve suggestions (really only eleven since item 1 and item 8 are the same). Several items related to whether or not specific sites should be included. Generally, we believe that Skagit County and the local stakeholders are in much better position to debate these specifics.

As stated in Task 3, we agree with item nine stating that fecal coliform are not generally a concern for salmonids. However, fecal coliform data are good indicators of other potential problems and is worth being collected even if it is not analyzed in connection with the CAO. Moreover, salmonids are not the only drivers for the Ag-CAO, and fecal coliform contamination is a major issue in Skagit County, for human health and downstream shellfish resources. Sources include agricultural activities so fecal coliform is a legitimate parameter for this program.

Storm sampling, involving the installation of flow activated ISCO discrete samplers, would be a good way to conduct stormwater sampling proposed in item ten. However, these samplers are relatively expensive (although composite samplers are less) and it is not readily apparent what the best way to present the data would be (e.g., event mean concentration, peak concentration). It also would need to be flow averaged somehow as hydrologic variability could significantly impact loading. This is perhaps one step beyond the trend analysis currently being conducted but should lead to a better cause-effect relationship. For instance, since non-point pollution is highly correlated to runoff, a sample collected in one year during a storm event will likely be significantly larger than a sample taken in a previous year when no rainfall occurred. This does not necessarily mean that water quality is deteriorating. Flow adjusting water quality samples (see recommendations) may also get around this situation.

The letter also recommends discontinuation of monitoring on the sloughs as these are not likely salmonid waterways. During our field trip, however, we observed one of the sloughs discharging into a stream via a pumping system. It would probably be prudent to examine the relative impact of slough discharges into receiving waters before discontinuing sampling. While dilution may be sufficient to mitigate current conditions, it is far easier to spot future changes in the slough rather than trying to detect changes after it is mixed with a larger water source.

We strongly disagree with item eleven. There is more than sufficient, unbiased, literature indicating that shade is a benefit to stream temperature. Bormann (2000) lists 45 environmental and physical factors influencing stream water temperature. Among these factors are weather conditions such as air temperature, relative humidity, and wind speed, stream site physical characteristics such as stream width, depth and roughness, and the presence of shading vegetation and topography (Brown 1969, Beschta and Weatherred 1984, Bartholow 1991, Brown and Barnwell1987, Edinger et al. 1968 and Johnson, 2004). It has been argued that solar radiation is the dominant factor influencing stream temperatures and that the shade of riparian vegetation can significantly reduce stream warming (Brown 1969, Beschta 1997, Theurer et al. 1984, and Chen et al. 1997). This is not to say there is no debate over relative importance of shade. Larson and Larson (1996) believe air temperature is primarily responsible for driving stream temperatures and that solar radiation and riparian shade are not as significant. However, the fundamental theory related to stream temperatures clearly indicates the energy balance is dependent on solar radiation. Moreover, our past modeling experience has shown us that improved shading does help in at least mitigating the rate of increase.

The Swinomish Tribe's letter (signed by Larry Wasserman) focused on two main topics. Their first point was that water quality at most sites was not meeting state water quality standards for at least some parameters and that water quality is worse at sample sites adjacent to lands most impacted by agricultural uses as compared to upstream sites. This is likely to be an ongoing point of contention. It is difficult to argue with the data which clearly show that some streams do not meet water quality standards; however, it is also clear that GMA does not require the County to mandate restoration of all streams and waterways. Moreover, while it may appear that water quality is worse at sample sites adjacent to agricultural lands, it is difficult to definitively state this because: 1) the goal of Skagit County's water quality sampling program was not to identify the worst water quality and land use combinations in the area, 2) comparisons between two different streams are extremely difficult (as previously discussed), and 3) many of the areas upstream of the sampling locations are mixed use (even rural and agriculture are distinct) so cause/effect relationships are impossible to quantify. Nevertheless, opportunities for grant funding to support voluntary measures should be pursued by the County and local watershed groups.

Second, they believe that the monitoring and adaptive management program still does not address cause and effect, and is not designed adequately to assess the contribution of pollutants from individual farms. As previously stated, we agree with this general assessment. There should be more paired waterways sites (again referring to upstream/downstream comparisons on a particular stream) coordinated with detailed land use documentation.

Task 7 – Possible Next Steps

Objective 7: Identify next steps Skagit County should take to determine the sources(s) of water quality problems based on the collected water quality data.

The following is a list of possible recommendations that could be adopted by Skagit County if resources allow. It is likely not feasible to implement all of the recommendations. Moreover, while we listed recommendations in terms of high, medium, and low priority, establishing a final prioritization list of recommendations should be done in consultation with local stakeholders.

Recommendations:

High Priority

1. All of the water quality parameters being monitored as part of this program are highly influenced by flows, either through increased inputs (e.g. TSS) or dilution (e.g. salinity), or some combination of these factors (e.g. nutrient levels) during increase flows. Assessment of water quality trends is therefore also potentially influenced by changes in annual flow regimes over time, and the inclusion of that variability (or failure to account for that variability) in water quality analyses may have a substantive impact on analyses and results, at the very least by confounding the interpretation of any findings. Consequently, all of the statistical analyses should be adjusted for flow. The methodology for flow adjustment can be found in Smith et al. (1982) and Smith et al. (1987). The authors recommend trying regression models to find the best fit (highest r^2) relationship of various functional forms of discharge ($f(Q)$) at each location and then use that relationship to conduct a residual analysis. Common models are:
    - Linear ---- $f(Q) = Q$
    - Log ---- $f(Q) = \ln(Q)$
    - Inverse ---- $f(Q) = 1/Q$

2. Seasonality in the Kendall test should be defined on a monthly basis. This would be consistent with the original Hirsch et al. (1982) study where separate monthly scores

were summed to obtain the test statistic. It appears from the number of samples that Skagit County is currently using a longer definition of “season.”

3. Identify and monitor more pairs of upstream and downstream watershed sampling locations on individual streams. As previously stated, we do not feel that the current plan adequately identifies trends caused solely by agricultural sources. To accomplish this, shorter reaches targeting specific land uses will need to be sampled. While some folks may not like this approach as it will single out specific land owners and practices, it would seem unlikely that the current plan would produce sufficient justification for enforcement actions. To get the most benefit from this type of program, the County should also consider going forward with the comprehensive land use mapping discussed later.

4. The County should critically evaluate the selection and used of each site now that several years of monitoring have been conducted. Will the data likely help meet the objectives of this (or other) County program? Keeping sites in the network simply because of legacy is not a good use of resources. Sites that may be useful for other County goals should be identified as such along with a description of their benefit so that future evaluation of site utility can see if the data is worthwhile.

Medium Priority

5. Initiate study using optical brighteners to begin determining areas where septic system failures may be contributing to high fecal coliform and nutrient problems. This test may not be conclusive especially when positive concentrations are obtained because it doesn’t negate the possibility for more than one source of pollution. In other words, if OBs are present, it doesn’t necessarily mean that the only source of pollution is human. However, the absence of OBs is a powerful indicator of agricultural and other non-point source pollution.

6. To allow for better interpretation of the impacts of observed water quality conditions or trends on fish, the County should clearly define fish use in streams being

monitored as part of this program, including not only species distributions, but also life stage specific uses (e.g. spawning/incubation, rearing only, migration only, or some combination of these). This would result in quarterly sampling of fish to verify presence or absence at various life cycles. This should also involve determining current fish condition (length, weight) as future questions will likely arise regarding how harm is defined. Except for ammonia, most nutrients don't directly harm salmonids and since diurnal evaluation of DO swings are not routinely measured, the impacts of eutrophication will be somewhat difficult to ascertain (see next item).

7. With regard to nutrient data, as previously stated, impacts to fisheries are generally indirect and due to changes in system productivity and potentially related changes in water quality (e.g. increased diel variations in DO levels due to increased aquatic vegetative growth or algal blooms). Inclusion into this monitoring program of a measure or index of stream or water body productivity may be beneficial to allow evaluation of any observed trends in nutrient levels on local salmonid species. The utility of C-14 tracer investigations for primary productivity has been well established. Other sampling strategies that might be conducted include zooplankton tows and algal speciation.

8. Develop comprehensive land use GIS layers for the county so that changes over time can be tracked and linked to water quality changes. This would involve remote sensing images and field verification. The land use categories should be defined as narrowly as possible. The term "agriculture" is insufficient in that it doesn't identify cattle, alfalfa, row crops, waste disposal and other applications that impact water quality. Understandably, these uses change frequently due to crop rotation, changes in cattle operations, etc. However, it may be difficult to ascertain cause/effect trends if this is one of the variables not accounted for in the analysis. On top of this layer, a habitat assessment layer should be completed documenting stream bank, sediment, riparian corridor and other pertinent information. This should also document the location of agricultural BMPs already implemented along the waterways.

9. While distinctly different from the TMDL issues facing the County, opportunities for collaboration should be closely examined.

Low Priority

10. Initiate a use attainability study which involves all the stakeholders in the County as well as representatives from Ecology. This will likely be necessary in building a defensible argument for or against future remediation requirements by identifying natural versus anthropogenic impacts. There are likely some monitoring stations that have never and will never reach state water quality standards. However, it is not sufficient to simply assert that nothing needs to be done to improve water quality in these reaches. A scientific assessment is needed. While this may be somewhat outside the scope of the current program which is intended to ensure *status quo*, when taken into consideration the TMDL issues also facing the County, a coordinated effort may well be warranted. Some stakeholders may want to separate TMDL and GMA issues since the focus of the TMDL is on meeting state water quality standards but this approach has the potential to miss grant and other opportunities to benefit both goals of maintaining and improving water quality.

11. Since this monitoring program is being driven by the Growth Management Act (thereby implying an expected long term change in land use and development within the study area), a corresponding alteration of flow characteristics can be expected in any developed areas. The ability to address and account for these changes in any trend analyses is considered imperative to the ability to accurately define any trends in water quality conditions in waterways throughout the County. Therefore, monitoring of developing areas seems prudent. Furthermore, steps could be taken to develop a land use/water quantity-quality model that would enable the County to incorporate changes initiated by urbanization and sort them out from agricultural impacts. More flow and water quality data could be collected on the fringes of urbanizing areas to help populate the model.

Task 8 – Cost Estimate

Objective 8: Estimate costs for pursuing the recommendations developed for Task 7.

To the maximum extent possible, we are estimating costs in terms of effort (person-hours or person-days) rather than dollars. The actual cost will depend on the level and experience of people conducting the activities, whether or not the work is done in-house or contracted out, and the level of detail agreed to by stakeholders and regulatory agencies.

<u>Recommendation 1:</u>

More effort should be made to incorporate flow measurements into the analyses. This will take additional effort but should not be overly expensive. Some sites already have Ecology or USGS flow measurement at or near their locations. Other sites do not have pressure transducers (~$500-700 each) or adequate rating curves. Installation is typically under $1000 per location including materials and labor (excluding the pressure transducer). Monthly stream gaging would be needed to establish the rating curves as the shape changes dramatically in many small streams. The time requirement to gauge streams would likely require two additional days per month in the field. Work with the pressure transducer data and rating curve would require two or three days per month in the office (as previously mentioned, manipulating the rating curve and transducer measurements can be time consuming). And another one to two days per year would be spent on the analyses and interpretation of flow results. The most troublesome could be the coastal streams because of tidal influences however we are not convinced that these sites are going to be useful in identifying trends due to agriculture.

<u>Recommendation 2:</u>

Analyzing the data on a monthly basis should not require much time after the initial time spent reformatting spread sheet summaries. Likely this would be on the order of one to two days for the first year set-up time and less than an additional day in subsequent analysis years. It may take slightly more effort to write-up the annual reports if monthly comparisons are needed for each parameter.

Recommendation 3:

Incorporating more paired sites could be done relatively inexpensively at the cost of decreased spatial resolution across the County. Conversely, additional sites could be added in which additional effort and sample analysis costs would need to be factored into the program. At some point, the data collection effort becomes too great for one person and an assistant would need to be hired. Since Skagit County personnel are already familiar with cost of sampling, they are probably in a better position to estimate cost and staffing need. It should be pointed out, however, that there may be opportunities to partner with other County, State, and Tribal programs to reduce the need for additional staff.

Recommendation 4:

The internal review of the sampling locations needs to be done with respect to a number of other programs in the County and with local stakeholder groups. In our tour, there were a few sites that did not seem to be capable of answering the goals of this program. For example, the sites on the lower mainstem of the Skagit River seem to reflect so many varied uses that tying trends to agricultural practices will be impossible. Even the site higher up on the Skagit has limited utility as a reference site because it is influenced by dam releases and melting of glaciers. While there may be other reasons for continuing this site, its use as a reference location would likely prove to be problematic. The site downstream of Big Lake is also likely impacted by residential communities and recreational water sports. There may be utility to other County programs so we are reluctant to state categorically that these sites should be abandoned but there would appear to be opportunities to track agricultural practices better at other sites. This task could be done with very little extra funding. It should also be done in association with local TMDL efforts (Recommendation 9).

Recommendation 5:

The primary cost of optical brighteners is in the equipment (~$10,000 for a fluorometer) and the training time for someone to learn the procedure. There would also be additional sample collection and analysis time but this would likely add less than 15 minutes to the total time spent at each site.

Recommendation 6:

To define fish usage, a three to four year effort of electrofishing, redd surveying, and habitat assessment should be completed. It would be likely that 3 to 4 sites could be sampled in a day. Although sampling could be done quarterly, there would be sufficient work for a half-time person when data analysis, permitting, and preparation are factored in to the job description. Moreover, during sampling, another person would likely be needed. In addition, backpack shockers, block nets, and other supplies would add another $10-15,000.

Recommendation 7:

To help assess nutrient impacts, diel dissolved oxygen sampling could be conducted by deploying Hydrolabs or similar oxygen probes to field sites. Generally, 3-4 days of data would be sufficient but periodic visits during the time span to verify calibration are essential. Probes can probably be rented more economically than buying. If say all of the sample locations were surveyed (not likely since security issues would be significant at several sites), five at a time, it would require nearly a month of time for each set of measurements. Four monthly summer (June, July, August, and September) sampling of primary productivity at five or six representative sites using C-14 would cost approximately $25,000 per year. This would include size fractioning of algae into 3 sizes and several nutrient spike samples to determine system response to nutrient addition. Monthly zooplankton and algae samples could be collected with relatively inexpensive sampling equipment at little additional cost. However, sample identification and analysis of results would cost about $500 per sample for both algae and zooplankton. In addition, if there is a strong correlation between TSS and turbidity, continuous turbidity meters could be deployed to account for storm event and identify bank instability and erosion during peak runoff events.

Recommendation 8:

The County already has GIS people so the real cost to adding additional vegetation, stream habitat conditions, and land use information would be in obtaining the data. Field surveys documenting riparian vegetation would be done with GPS and minor equipment purchases for estimating tree height and canopy cover. Substrate surveys identifying areas of sediment deposition, spawning gravels, and stream bank condition could similarly be performed. High resolution satellite images could be used to develop base maps but field verification of use would need to be conducted.

Recommendation 9:
This would not require very much additional effort (see recommendation cost 4). At some level, this is probably already being discussed. This recommendation only seeks to reinforce the concept.

Recommendation 10:
It is difficult to estimate the cost of completing a use attainability analysis since some sites may be easier or harder to negotiate. Although a UAA is a structured scientific assessment of the factors affecting the attainment of a use which may include physical, biological, and economic factors, the actual study will require input from a variety of agencies and user groups. As such, a considerable amount of time could be spent coordinating and negotiating. It could easily add up to a person-year's worth of effort for the County plus $200,000 in scientific assessments.

Recommendation 11:
The cost of monitoring urbanizing areas depends on whether or not these are new sites or relocation of existing sites. Several sites now being monitored are not specifically agricultural sites and these locations may be adequate but time during the field reconnaissance visit did not permit an adequate assessment of whether these sites would be the best for the current growth plans.

Model development, calibration, and adoptions could easily cost $250,000. It would likely require a consultant, university researcher, a new modeler position within the County. There would have to be public meetings to promote and explain the model for it to be widely accepted.

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