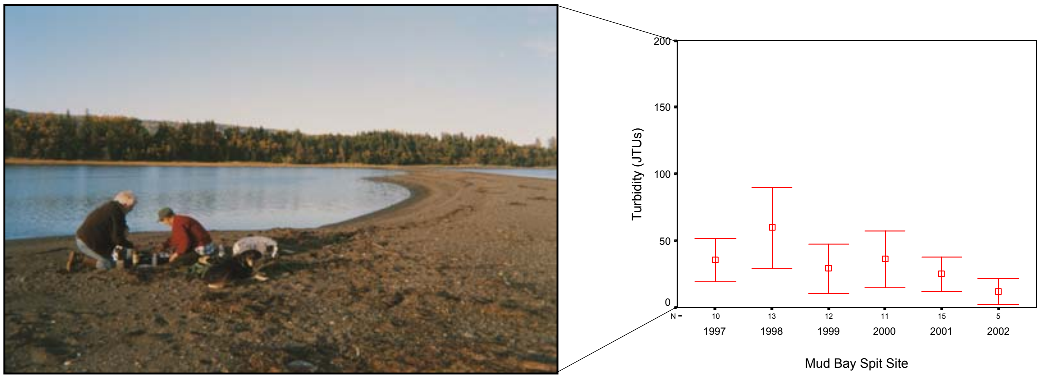
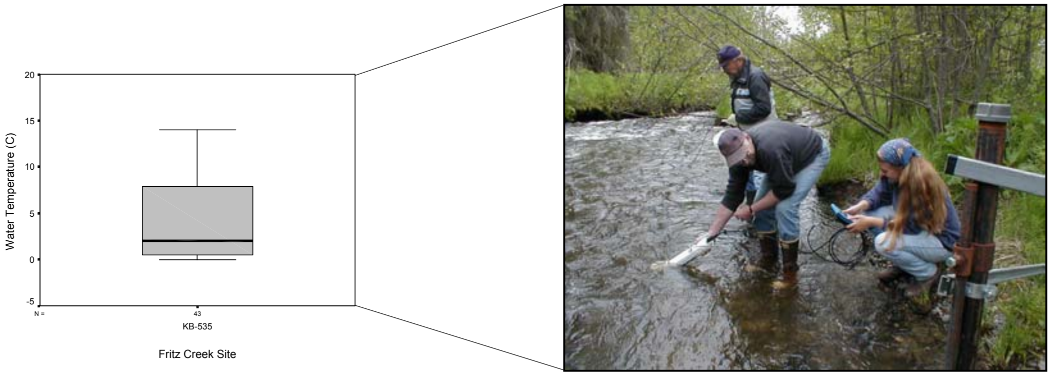
Exxon Valdez Oil Spill
Restoration Project 02667 Final Report

Effectiveness of Citizens' Environmental Monitoring Program





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April 2003

Exxon Valdez **Oil Spill**
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Restoration Project 02667
Final Report

Study History: Project 02667 examines data previously collected through the Citizens' Environmental Monitoring Program in the Kachemak Bay and Anchor River watersheds. This one-year project was originally funded from October 1, 2001 to September 30, 2002. Due to contract issues with the Alaska Department of Environmental Conservation, the project was granted a deadline extension to December 31, 2002.

Abstract: Cook Inlet Keeper analyzed five years of past data from the Citizens' Environmental Monitoring Program, the first consistent and coordinated community-based water quality monitoring program in Alaska. The objective of the analysis was to determine if sampling frequency, methods, parameters, and site selection are effective at meeting the monitoring objectives of detecting significant changes in water quality over time. Based on the analysis, the following recommendations are made: 1) prioritize collecting five year baseline data sets (n=80), 2) state explicitly what significant change can be detected: 2°C, 0.25 pH units, and 5% saturation of dissolved oxygen, 3) deploy continuous temperature loggers during summer months, 4) consider new turbidity method with a higher maximum range, 5) consider new orthophosphate and nitrate-nitrogen methods with lower detection limits, 6) continue colorimetric pH method as a quality control check on Hanna Meter, 7) coordinate with USGS to establish stage or discharge stations on smaller streams, 8) add a method to measure flow, 9) provide citizens with summary statistics of their site annually, 10) secure long-term funding for volunteer coordinators. These recommendations will increase the effectiveness of community-based monitoring programs.

Key Words: Anchor River, baseline data, citizens, Cook Inlet, environment, estuarine, freshwater, Kachemak Bay, monitoring, significant change, volunteers, water quality

Project Data: Cook Inlet Keeper compiles and presents all collected water quality monitoring findings from the Kachemak Bay and Anchor River Citizens' Environmental Monitoring Program sites in a variety of ways. In addition to publishing formal annual reports with narrative, charts, graphs, GIS maps and photos, Keeper also publishes monitoring information in its bi-annual newsletter and on its web page (www.inletkeeper.org). In July 2000, Cook Inlet Keeper and other Cook Inlet partners worked together to create a unified database in Microsoft Access for volunteer-collected data from the Cook Inlet watershed. In July 2002, with cooperation from the Alaska Department of Environmental Conservation and with funding from the *Exxon Valdez* Trustee Council (Restoration Project 02668), Gold Systems, Inc. was contracted to develop a new Microsoft Access database that will be capable of exporting Citizens' data to STORET. (STORET is a repository for water quality, biological, and physical data and is used by state environmental agencies, EPA, other federal agencies, and universities.)

Citation:
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EFFECTIVENESS OF CITIZENS' ENVIRONMENTAL MONITORING PROGRAM

EXECUTIVE SUMMARY

As state and federal budgets for water quality monitoring continue to decline, volunteer data will become more important in state monitoring programs. To best serve citizens and their efforts to conserve their local resources, it is imperative to understand the strengths and limitations of volunteer-collected data. This report examines data collected through the Citizens' Environmental Monitoring Program in the Kachemak Bay and Anchor River watersheds with the aim of identifying the program's strengths and providing recommendations to improve the quality and quantity of volunteer-collected data in Alaska.

After five years of data collection, Cook Inlet Keeper and its partners have gained an understanding of monitoring techniques that work with volunteers, parameters that are most indicative of watershed/estuarine health, and how many volunteers can be maintained over time. To build on the success of developing a scientifically-credible volunteer monitoring program, the monitoring design, developed in 1996, was analyzed to see if it can meet the goal of detecting significant change in water quality over time. Sampling frequency, method precision, geographic representation, manpower and funding must all be considered in assessing the effectiveness of the Citizens' Environmental Monitoring Program.

OBJECTIVES

This analysis of CEMP data has the following objectives:

1. Evaluate whether CEMP sampling frequency, sampling methods, water quality parameters, and site selection are effective at detecting significant change in water quality over time.
2. Generate recommendations for improved CEMP protocols to better represent water quality in the Cook Inlet watershed, which will lead to more effective and scientifically-defensible community monitoring efforts.

METHODS

Five years of data stored in the CEMP database were analyzed using SPSS software to determine variability within sites, between sites, and over time. Preliminary analysis entailed generating descriptive statistics (mean, standard deviation, and range) and graphical presentations of the data from all sites, except those with 5 or fewer site visits. Box plots were examined and outliers were identified and interpreted.

Longitudinal patterns were explored in watersheds that had at least 5 sites. Due to the increased frequency of sampling in the summer, annual means had a seasonal bias. One-way analysis of variance (ANOVA) was used to test the hypothesis that there was no change in water quality parameters at sites within a watershed. Linear regression was used to estimate the coefficients of the linear equation that best describes the relationship between river mile and temperature and river mile and conductivity. ANOVA was used to determine changes over temporal scales (i.e. annual, seasonal) at sites with greater than 25 observations.

In an effort to understand spatial trends in the estuarine data, sites were grouped based on their location and how that related to general circulation patterns within Kachemak Bay. Groupings include north vs. south side of the bay sites, inside vs. outside the Homer Spit sites, and Beluga Slough/Lake vs. bay sites. ANOVA tests were used to detect significant differences between sites and site groupings.

Spearman's rank coefficients were examined to determine which water quality characteristics were related.

The statistical power of the sampling design to detect change was determined using SamplePower 2.0 software. A t-test was performed to test the mean difference in two independent groups that share a common within-group standard deviation. The mean standard deviation of the freshwater sites (or estuarine sites) for each parameter tested was used as the baseline standard deviation to be compared with a future data set using the same sampling methods, and thus a similar standard deviation. The effect size for a t-test is the mean difference between groups divided by the common within-group deviation. Conventional values for alpha (0.05), power (80%) and 95% confidence intervals (CI) were used.

RESULTS

The Kachemak Bay and Anchor River CEMP database contained data from 90 sites and included 1,322 site visits between 9/28/96 and 6/30/02. With the deletion of sites with 5 or fewer visits, the dataset contained 46 sites and 1,214 site visits. These sites represent 27 freshwater and 19 estuarine locations.

Freshwater Sites

Longitudinal patterns were examined in Diamond Creek and Woodard Creek watersheds. Diamond Creek watershed contains a state recreation area with hiking and ski trails; Homer Baling Facility is the largest industrial presence within the watershed. Woodard Creek is an urban stream with extensive channelization, road crossings, buildings and parking lots in the riparian zone. Generally, there was a trend of decreasing water temperature heading upstream. The differences in the means were not significant in Diamond Creek, but were significant in Woodard Creek. Regression analysis was used to determine the coefficients (i.e. slope and constant) and the strength (R, R^2) of the linear relationship between river mile and water temperature. This relationship was stronger in Woodard Creek (R=0.294) than on Diamond Creek (R=0.057).

Woodard and Diamond Creeks showed a pattern of decreasing conductivity values heading upstream. There was a significant difference in means between sites in both Diamond Creek and Woodard Creek. Woodard had a significantly higher level of conductivity than Diamond Creek. The slope of the relationship was much larger in Woodard Creek (-66.579) than in Diamond Creek (-13.792).

No change in mean annual water temperature was found at any of the 11 sites that had at least 25 observations. Annual patterns in turbidity and conductivity showed the greatest variability. Four percent of the turbidity values observed at all sites exceeded the method's range (200 JTUs). Two methods were used to measure pH: Hanna Meter (sensitivity = 0.1 units) and colorimeter (sensitivity = 0.25 units). The Hanna Meter method exhibited greater variability. Eighty-four percent of orthophosphate values were below the detection limit of 0.2 ppm and eighty-two percent of the nitrate-nitrogen values were below the detection limit of 1 ppm at freshwater sites.

Spearman's rank coefficients were used to determine which water quality characteristics were related. Water temperature had strong relationships with other parameters, except conductivity.

A baseline dataset of 16 samples (one year of sampling) would be useful to detect a 4.7° C change in mean annual temperature when compared to a second year of data. A comparison of two, three-year data sets (n=48) could detect a change of 2.7° C. It would require two datasets with 334 samples each (21 years) to detect a 1.0° C change. Summer temperatures with a smaller standard deviation would require fewer samples to detect these changes.

A comparison of two, one-year data sets could detect a 10.5% change in saturation of dissolved oxygen. Two, five-year data sets (n=80) could detect a 4.6% change. Two, five-year data sets would also be useful for measuring a 0.22 unit change in pH with the Hanna Meter. The colorimetric method with its sensitivity of 0.25 units would only be able to detect a 0.25 unit change (n=28). No significant level of change was identified for conductivity and turbidity because their standard deviations varied too widely, which made them inappropriate for a t-test.

Estuarine Sites

Longitudinal patterns in temperature were evident with an increase of temperature heading into the bay on the south side. There were significant differences in means of the south side sites and inside Homer spit sites. The longitudinal pattern was not apparent in the sites outside the bay because of differences in seasonal distribution of sampling dates. Temperatures on the north side were warmest in Beluga Slough and tended to be warmer inside the Homer Spit than outside. There was a significant difference in mean temperatures between the four site groupings.

Salinity patterns showed that south side sites have a stronger marine signal than north side sites; however, this may be confounded by site placement near river mouths on the north side. There were significant differences in mean salinity values for south side sites, inside Homer Spit sites, and Beluga Slough/Lake sites. Mean salinity values were significantly different between the four site groupings. Turbidity was highest at sites with lower salinity, which again reflects the contribution of river water at these sites.

No change in annual water temperatures was found at the 5 sites that had at least 25 observations. Annual patterns in turbidity showed the greatest variability. Sixty-six percent of conductivity readings exceeded the method's upper detection limit of 1999 uS/cm. Ninety-two percent of orthophosphate values were below the detection limit of 0.2 ppm and ninety-five percent of the nitrate-nitrogen values were below the detection limit of 1 ppm at estuarine sites.

Based on Spearman's rank coefficients, water temperature had strong relationships with all other parameters. Power analysis results were similar to those found for the freshwater sites.

CONCLUSIONS AND RECOMMENDATIONS

The CEMP Partnership of the Cook Inlet Watershed has achieved the goals set for state-wide and national monitoring programs. Cook Inlet Keeper, with Cook Inlet partners and the Alaska Department of Environmental Conservation, has developed a Quality Assurance Project Plan and standardized field methods to increase the comparability of results among partners. Keeper provides water chemistry training for volunteers and other Cook Inlet partners on lab, field, and quality assurance methods. In July 2000, Cook Inlet Keeper and partners worked together to create a unified database in Microsoft Access for volunteer-collected data from the Cook Inlet watershed. A new Microsoft Access database is presently being beta tested that will be capable of exporting Citizens' data to STORET.

The Citizens' Environmental Monitoring Program has collected baseline water quality data since 1996 providing the most comprehensive water quality datasets on Kachemak Bay watersheds. The program is well suited to be expanded into other regions within Alaska. The data are robust enough to provide information on temporal and spatial patterns that will be valuable for comparison in the future. The program has also educated hundreds of people about their natural resources and the impacts we have on our environment and what that means to water quality.

Based on the analysis of the Kachemak Bay and Anchor River CEMP data, the following recommendations are made:

1. The annual sampling frequency of 16 sites per year is reasonable considering manpower and funding limitations. Prioritize getting five-year, baseline data sets (n=80) on fewer sites than smaller data sets on more sites.
2. State explicitly what significant change the CEMP is designed to detect. With a five-year baseline dataset, CEMP methods can detect a change of 2^{o}C, 0.25 pH units, and 5% saturation of dissolved oxygen when compared to another five-year data set.
3. Temperature is related to most other water quality parameters. Deploy temperature loggers in downstream sites during the summer months on as many streams as possible.
4. Change turbidity method to one that has a higher maximum range. Consider the Nephelometric method (2130) from *Standard Methods for the Examination of Water and Wastewater, 19th Edition 1995*.
5. Upgrade orthophosphate and nitrate-nitrogen methods to ones with lower detection limits. Consider the Ascorbic Acid method (8048) for orthophosphate from *Hach Water Analysis Handbook* and the Cadmium Reduction method (8192) from *Hach Water Analysis Handbook* or CHEMetrics Nitrate Test Kit (Cat. No. K-6902) for nitrate-nitrogen.
6. Continue colorimetric pH method as a quality control check on the Hanna Meter.
7. Coordinate with USGS to establish a stage gauging station or discharge station on smaller Kachemak Bay watershed streams, like Diamond Creek.
8. Measure flow along with water quality data to improve interpretability of turbidity and conductivity data. Consider the Discharge Current Meter method with AA and pygmy velocity meters or the Global Flow Probe Velocity Meter at downstream sites.
9. Provide volunteer monitors with summary statistics of their site annually. Encourage volunteers to perform and document a replicate analysis if they encounter outliers.
10. Secure long-term funding for volunteer coordinators to recruit and train volunteers, manage data and supplies, and provide quality assurance.

EFFECTIVENESS OF CITIZENS' ENVIRONMENTAL MONITORING PROGRAM

INTRODUCTION

Background

Throughout the United States, citizens have been collecting valuable information on the health of their local environment for over 30 years. At least 750 organizations, involving more than half a million people, are actively involved in watershed monitoring across the nation. As state and federal budgets for water quality monitoring continue to decline, more and more citizens are stepping forward to help gauge the health of our public resources. These programs serve two purposes: 1) to provide an opportunity for the community, youth, landowners, and planners to learn about local water resource characteristics and problems, thereby fostering a sense of stewardship for those resources, and 2) to provide data for Federal, State, Tribal, and local water quality agencies and private organizations for use in watershed planning, assessment, reporting, and water quality management.

The National Directory of Volunteer Monitoring Programs indicates there are several key users of the data collected by volunteer groups including the groups themselves, state, local and federal governments, universities, and other community organizations. Eighty-five percent of the monitoring groups use the data for their own purposes, 56% report that state governments utilize the information, and 55% indicate that local governments are using the information. Data use by a government agency is often a function of the quality assurance/quality control (QA/QC) measures instituted by the volunteer monitoring program. Forty-five percent of the groups indicate that they have a quality assurance plan, with 27% indicating that it is state approved, and 18% report that their plan is EPA approved (U.S. EPA, 1998).

Volunteer-collected data are used to determine baseline conditions, to screen for potential water quality problems, as a component in Clean Water Act reporting, and as a means to monitor restoration efforts. In Oregon, watershed councils are using volunteer-collected data as baseline measurements to detect changes in water quality that may result from land use changes. The Oregon Department of Environmental Quality (DEQ) uses volunteer-collected continuous temperature data to determine where sampling should be focused for Total Maximum Daily Load (TMDL) assessments (Williams, 2000). The use of volunteer data for screening purposes can be an extremely important component to overall state monitoring programs because it allows for cost effective preliminary assessment of water quality.

Several states have focused monitoring efforts around restoration projects. Working with the Oregon DEQ, several volunteer groups monitor riparian habitat to predict site potential for restoration to increase shade, therefore reducing water temperature (Williams, 2000). Pennsylvania currently uses volunteer data to monitor mine remediation sites, and has acknowledged the data could be used for monitoring riparian and wetland restoration as well as other best management practices implemented to reduce non-point source pollution (Wilson, 2000). In Maryland, volunteer data have been used in computer modeling systems to select restoration sites for submerged aquatic vegetation within the Chesapeake Bay (ASIWPCA, 2002).

Although volunteer programs have become an integral part of federal and state efforts to protect natural resources, questions still arise about the credibility and appropriateness of citizen-collected data. At the national level there have been several discussions on agency use of volunteer data and how it should be incorporated into federal and state monitoring efforts in the future. The Intergovernmental Task Force on Monitoring Water Quality (ITFM) and the EPA 305(b) Consistency Workgroup Meeting highlight specific improvements that should be incorporated into state and national monitoring programs. The following recommendations were made (USGS, 1996):

- Develop nationally consistent quality assurance plans and standardized field methods to increase the comparability of results from different programs.
- Promote national training for volunteers on lab, field, and quality assurance methods.
- Increase user confidence in volunteer collected data by properly documenting when it is incorporated into statewide water quality databases. Understanding the limitations and strengths of volunteer-collected data will increase user confidence.
- Provide for volunteer participation in every level of government water monitoring teams.

As states look to decrease non-point source pollution, volunteer data will become more important in state monitoring programs. To best serve citizens and their efforts to conserve their local resources, it is imperative that we understand the strengths and limitations of volunteer-collected data. This report examines data collected through the Citizens' Environmental Monitoring Program in the Kachemak Bay and Anchor River watersheds with the aim of identifying the program's strengths and providing recommendations to improve the quality and quantity of volunteer-collected data in Alaska.

Citizens' Environmental Monitoring Program

In 1996, Cook Inlet Keeper and the Homer Soil and Water Conservation District established the Citizens' Environmental Monitoring Program (CEMP) to actively involve citizens in collecting reliable water quality data in the Cook Inlet Basin. Educating people about their natural resources, discussing the impacts we have on our environment and what that means to water quality, and the benefit of having more eyes watching out for watershed and estuarine health are reasons enough to engage volunteers in monitoring their streams and bays. However, with dwindling resources for water quality monitoring at both state and federal levels, the need for volunteer-collected data is increasing in Alaska, especially when the monitoring program is well designed and institutes quality assurance/quality control measures.

With EPA funding passed through the Alaska Department of Environmental Conservation and guidance from a Technical Advisory Committee, Keeper developed a Kachemak Bay Pilot Project as a working template that could be adopted by other groups interested in conducting citizen-based monitoring programs. The objectives of CEMP are to: 1) inventory baseline water quality in the Cook Inlet Basin, 2) detect and track water quality trends and report significant changes, and 3) raise public awareness of the importance of water quality through hands on involvement. Water quality parameters, data quality objectives, and site selection criteria were developed with a Technical Advisory Committee (TAC) made up of professionals representing various federal, state, and local agencies and diverse scientific backgrounds.

With assistance from the TAC, Keeper selected water quality parameters and testing methods that have proven successful in citizen-based programs throughout the United States. Primary parameters (water temperature, turbidity, dissolved oxygen, pH, and salinity) are measured using standard EPA-approved procedures and/or methods which are in use by established citizen volunteer monitoring programs (e.g. Friends of Casco Bay's Citizens Water Quality Monitoring Program, Texas Watch's Volunteer Environmental Monitoring Program). Methods for additional parameters (conductivity, nitrate-nitrogen, orthophosphate, apparent color, fecal and total coliform bacteria) are taken from the "Volunteer Estuary/Lake/River/Stream Monitoring: A Method's Manual" published by U.S. EPA.

To ensure adequate quality assurance oversight and consistency of CEMP data, Cook Inlet Keeper produced a Quality Assurance Project Plan (QAPP) in 1998, which describes both how the program is managed (quality assurance) and how its technical activities are carried out (quality control). In September 2002, an updated QAPP was submitted to the Alaska Department of Environmental Conservation (ADEC) and is currently under review. Quality assurance and quality control measures outlined in the QAPP include: training requirements, re-certification procedures, blind performance evaluation standards, duplicate sample analysis, and split sample analysis with a state-certified laboratory (Cook Inlet Keeper, 1998). CEMP data are compiled annually and submitted to the ADEC and distributed to concerned citizens, decision makers, resource managers and others, as well as made available on Keeper's web page.

Since Cook Inlet Keeper established Alaska's first consistent and coordinated volunteer water quality monitoring program in 1996, other groups have requested Keeper's assistance in establishing volunteer monitoring in their communities. Through these collaborations, the CEMP Partnership of the Cook Inlet Watershed has evolved and includes the Anchorage Waterways Council, Cook Inlet Keeper, Environment and Natural Resources Institute - University of Alaska Anchorage, Kenai Watershed Forum, Matanuska-Susitna Borough, and Homer, Wasilla and Upper Susitna Soil and Water Conservation Districts. The Partnership has been working to integrate the interests and concerns of the Native communities throughout Cook Inlet and, in addition, is working with the Native American Fish and Wildlife Society to share examples of methods, protocols, and Quality Assurance information. The partnership has trained more than 450 volunteers throughout the Cook Inlet Watershed to monitor more than 198 sites.

After five years of data collection, Cook Inlet Keeper and its partners have gained an understanding of monitoring techniques that work with volunteers, parameters that are most indicative of watershed/estuarine health, and how many volunteers can be maintained over time. To build on the success of developing a scientifically-credible volunteer monitoring program, the monitoring design, developed in 1996, has been analyzed to see if it can meet the goal of detecting significant change in water quality over time. When the program began, the level of significant change that was detectable was unclear. The results of this analysis will help to define "significant change" explicitly.

Creating a monitoring program to measure natural variability in aquatic and marine ecosystems is an ambitious goal as these are highly dynamic systems. River levels, ice cover, tidal influence change dramatically throughout the year. Sampling frequency, method precision, and geographic representation must all be considered when trying to quantify this variability. More practical issues of manpower and funding must also be considered to create a sustainable monitoring program. These factors will all be discussed in this assessment of the effectiveness of the Citizens' Environmental Monitoring Program.

OBJECTIVES

This analysis of CEMP data has the following objectives:

1. Evaluate whether CEMP sampling frequency, sampling methods, water quality parameters, and site selection are effective at detecting significant change in water quality over time.
2. Generate recommendations for improved CEMP protocols to better represent water quality in the Cook Inlet watershed, which will lead to more effective and scientifically defensible community monitoring efforts.

METHODS

CEMP Methods

Cook Inlet Keeper's CEMP database consists of data collected from freshwater and estuarine sites in the Kachemak Bay and Anchor River watersheds (see Figure 1, site locations). The program prioritizes coastal watersheds as they are systems that are threatened with the greatest change due to human development. By measuring water quality along the gradient from freshwater to estuarine waters we gain an understanding of the magnitude of change in watersheds that affects the marine system. As marine resources are so critical to local economies, understanding the linkages between freshwater and marine systems should be prioritized.

Volunteer sampling locations are selected to represent the various hydrologic, geographic, biologic, land use, and other conditions within the watersheds. An effort has been made to select sites that represent a balance between more impacted and less impacted areas. In the challenging climate of Southcentral Alaska, it was also necessary to select sites that are safely and reasonably accessible. Finally, to maintain volunteer involvement, it has been important to select monitoring sites in which volunteer team members have a personal interest.

For estuarine waters, an effort has been made to locate sites where there is at least 3 meters of water at low tide. This preferred minimum water depth requirement allows a Secchi disk reading at almost any tidal stage. Unfortunately, requiring a strict minimum depth is not always feasible in the dynamic waters of Cook Inlet. Because of the limited number of accessible spots, and because consistency is also related to convenience, a number of near-shore stations have been, and will continue to be sampled by wading-in from shore. The disadvantages are that Secchi disk readings cannot be taken (turbidity tubes are used in shallower water); and that these typically shallower inter-tidal areas can be more dynamic than sub-littoral areas and thus harder to characterize until large amounts of data can be collected over time. Also surface grab samples may collect water that is influenced by freshwater runoff when the bay is strongly stratified. The advantage is that at nearshore stations, both shallow inter-tidal and sub-littoral areas can be close to important habitat zones and food sources for freshwater and marine organism.

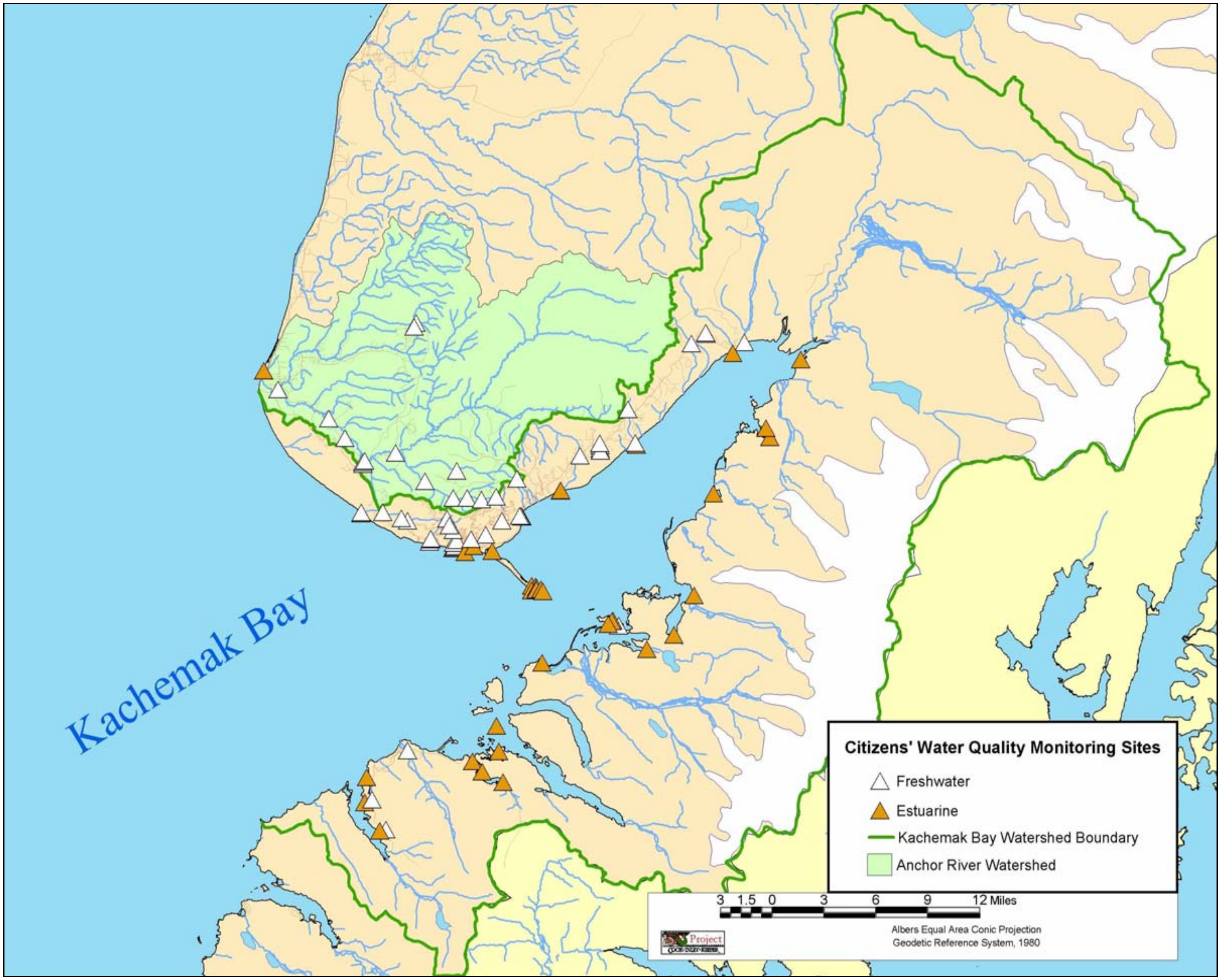


Figure 1. CEMP monitoring sites in Kachemak Bay and Anchor River watersheds.

Volunteers study procedures during a Phase I training.

Volunteer monitor training involves four phases. Phase I is an introduction to the watershed concept and monitoring procedures. Phase II is designed to teach the volunteers to use the monitoring kits and equipment. This phase involves both laboratory and field training. Phase III is an on-site training. Volunteers may begin monitoring on their own after successful completion of Phases I-III. Each volunteer must also attend an annual re-certification (Phase IV).

Surface water samples are taken at all monitoring stations monthly between September and April and twice monthly from May through August for a total of 16 sampling events per site per year. The sampling period is designated as the last Sunday of each month (as well as the second Sunday of each month from May through August), plus or minus two days (i.e. Friday through Tuesday). The recommended time for sampling is 2:00 P.M., and the time allowance range is from 1:00 P.M. to 5:00 P.M., however, some estuarine sites require more flexibility in sampling time because of restricted access due to low tides.

Sampling equipment and methods, as well as data quality objectives for sensitivity, precision and accuracy, are outlined in Table 1. Additional details about analytical methods can be found in Appendix I. Water samples are collected using a 2.5-gallon plastic bucket with an attached cord if necessary. Volunteers are instructed to rinse the bucket (and all testing containers) three times with water from their site before taking the sample to be tested. Water quality testing is performed on the sample in the bucket. Some sites are well suited to performing in situ testing of some parameters. Volunteers are encouraged to test in situ if it is safe to do so at their site.

All data are reviewed by Keeper's Research Coordinator to ensure they meet program data quality objectives. The data quality objectives and quality assurance procedures for this program have been designed to identify and correct problems in data collection and reporting. If the results of quality assurance reviews indicate that the integrity of data are questionable and data quality objectives are not being met, the data are flagged as unacceptable for inclusion in the CEMP database.

Table 1. Data Quality Objectives.

Parameter	Method/Range	Units	Sensitivity (a)	Precision	Accuracy	Calibration Method
Temperature	Thermometer -5.0 to +50.0°C	Degrees Celsius (°C)	0.5°C	±1.0°C (b)	±0.5°C (b)	NIST Certified Thermometer
Turbidity	Turbidity 0 to 200 JTU	Jackson Turbidity Units (JTU)	5 JTU	±3 units (c)	±3 units at 0 - 200 JTU (c)	Checked against LaMotte meter
Dissolved Oxygen	Micro Winkler Titration 0 to 20 mg/l	Milligrams per liter (mg/l)	0.1 mg/l	±0.9 mg/l (b)	±0.3 mg/l (b)	Checked against LaMotte DO Meter
Salinity	Hydrometer 0 to 42 ppt (1.0000 to 1.0700 SG)	Parts per thousand (ppt)	0.1 ppt (0.0005 specific gravity)	±1.0 ppt (b)	±0.82 ppt (b)	Standard Solutions Methods
Conductivity	Hanna Combo Meter HI98129 (c) 0 to 3999 microS/cm HI98130 (c) 0.00 to 20.00 milliS/cm	(converted to 25 C) Micro-Siemens/cm (µS/cm) MilliSiemens/cm (mS/cm)	1 uS/cm 0.01 mS/cm	+/- 2% f.s. +/- 2% f.s.	+/- 2% f.s. +/- 2% f.s.	Standard Solutions Method
	Hanna Water Test Meter (HI98204) 0 to 1999 microS/cm	Micro-Siemens/cm (µS/cm) (converted to 25 C)	1.0 x 10^{-6} S	±0.5 units (c)	2% full scale (c)	Standard Solutions Method
pH	pH Octet Comparator (Wide-Range) 3.0 to 10.0 units	Standard pH units	0.25 units	±0.6 units (b)	±0.4 units (b)	Checked against Hach pH Meter
	Hanna Water Test Meter (HI98204)0.0 to 14.0	Standard pH units	0.1 units	±0.2 units (c)	± 0.2 units (c)	Standard Solutions Method
Orthophosphate	Ascorbic acid reduction (Colorimetric) 0 to 4 ppm (0 to 4.0mg/L)	ppm (mg/L)	0.2 ppm	±0.5 ppm (c)	±0.5 ppm (c)	Standard Solutions Methods
Nitrate-Nitrogen	Zinc reduction (Colorimetric) 0 to 15 ppm (15.0mg/L)	ppm (mg/L)	1.0 ppm	±0.5 ppm (c)	±0.5 ppm (c)	Standard Solutions Methods
Apparent Color	Compare to color chart 147 standard colors	Color index number	1 to 2 Color Numbers	NA	NA	Checked against Hach Spectrophotometer
Coliforms (Total & *E. coli*)	Chromogenic agents in medium, detects *E. coli* & total coliform 0 to 60 CFU	Number of colony forming units (CFU) per 100 ml	1 CFU	NA	NA	Send water sample split to EPA/ADEC Certified Lab

Footnotes for Table 1
NA = not available
(a) Determined by the increments measurable with the stated method reflecting estimation where allowed.
(b) Data taken from the Quality Assurance Project Plan for Friends of Casco Bay, 1995, p. 21; based on data taken from EPA Volunteer Water Monitoring: A Guide for State Managers, 1990, EPA 440/4-90-010, p. 39; and the Quality Assurance Project Plan for the Chesapeake Bay Citizen Monitoring Program, Section 5, p. 2.
(c) Data taken from the manufacturer's instruction manuals.

Statistical Methods

Five years of data stored in the CEMP database were analyzed using SPSS software to determine variability within sites, between sites, and over time. Preliminary analysis entailed generating descriptive statistics (mean, standard deviation, and range) and graphical presentations of the data from all sites, except those with 5 or fewer site visits. Box plots were examined and outliers (data points with values greater than 1.5 box lengths from the upper or lower edge of box) were identified and interpreted. When outliers could be traced to data entry errors or procedural errors, they were deleted from the dataset.

Longitudinal patterns were explored with standard error plots in watersheds that had at least 5 sites. The standard error (SE) of the mean is a measure of the uncertainty about the mean. Plots show means with bars that represent two standard errors. The number of samples (N) taken at each site or year is provided on the x-axis. Due to the increased frequency of sampling in the summer, annual means had a seasonal bias. One-way analysis of variance (ANOVA) was used to test the hypothesis that there was no change in water quality parameters at sites within a watershed. Linear regression was used to estimate the coefficients of the linear equation that best describes the relationship between river mile and temperature and river mile and conductivity. ANOVA was used to determine changes over temporal scales (i.e. annual, seasonal) at sites with greater than 25 observations.

In an effort to understand spatial trends in the estuarine data, sites were grouped by location within Kachemak Bay. Groupings include north vs. south side of the bay sites, inside vs. outside the Homer Spit sites, and Beluga Slough/Lake vs. bay sites. ANOVA tests were used to detect significant differences between sites and site groupings.

Spearman's rank coefficients were examined to determine which water quality characteristics were related.

The statistical power of the sampling design to detect change was determined using SamplePower 2.0 software. A t-test was performed to test the mean difference in two independent groups that share a common within-group standard deviation. The mean standard deviation of freshwater sites (or estuarine sites) for each parameter tested was used as the baseline standard deviation to be compared with a future data set using the same sampling methods, and thus a similar standard deviation. The effect size for a t-test is the mean difference between groups divided by the common within-group deviation. Conventional values for alpha (0.05), power (80%) and 95% confidence intervals (CI) were used.

Reporting Methods

Recommendations to improve the CEMP protocols have been proposed in this report. These improvements have been presented to the CEMP Technical Advisory Committee and to the CEMP Partnership of the Cook Inlet Watershed. Keeper also convened an annual water quality conference in February 2003 as part of the Alaska Forum on the Environment in Anchorage, Alaska. This conference was for current and potential monitoring partners and agencies to communicate findings from the analysis and to facilitate CEMP planning and development.

RESULTS

The Kachemak Bay and Anchor River CEMP database contained data from 90 sites and included 1,322 site visits between 9/28/96 and 6/30/02. With deletion of sites with 5 or fewer visits, the dataset contained 46 sites and 1,214 site visits. These sites represent 27 freshwater and 19 estuarine locations.

Descriptive statistics (overall mean, standard deviation, and range) were generated for these 46 sites for each parameter: temperature, turbidity, dissolved oxygen, dissolved oxygen saturation, salinity (estuarine sites only), conductivity (freshwater sites only), pH, orthophosphate, and nitrate-nitrogen. See Appendix II for boxplots displaying median and standard deviations and Appendix III for descriptive statistics in tabular form. Data are organized by watershed for freshwater sites and by location within Kachemak Bay for estuarine sites. In all plots, sites are ordered from downstream to upstream in the watersheds and from down current to up current in the Bay. See Appendix IV for a glossary of statistical terms.

Freshwater Sites

The 27 freshwater sites represent 10 watersheds (Figure 2): Anchor River (AR-1010, AR-1035, AR-1034, KB-470, KB-490, KB-400), Diamond Creek (KB-1110, KB-1130, KB-1140, KB-1150, KB-1160), Woodard Creek (KB-110, KB-120, KB-150, KB-180, KB-190), Rice Creek (KB-556, KB-555, KB-550, KB-551), Miller's Landing Creek (KB-911, KB-912), Bidarka Creek (KB-210), Falls Creek (KB-577), Fritz Creek (KB-535), McNeil Canyon Creek (KB-545), and Fish Creek on the south side of Kachemak Bay (KB-710).

Longitudinal Patterns

Longitudinal patterns were examined in Diamond Creek and Woodard Creek watersheds. Diamond Creek watershed contains a state recreation area with hiking and ski trails; Homer Baling Facility is the largest industrial presence within the watershed (Figure 3). Woodard Creek is an urban stream with extensive channelization, road crossings, buildings and parking lots in the riparian zone (Figure 4). Generally, there was a trend of decreasing water temperature heading upstream (Figure 5). The differences in the means were not significant in Diamond Creek, but were significant in Woodard Creek ($F_{4,110}$=3.15, p=0.017). Sites were also plotted based on their location in the watershed by river mile (Figure 6). Regression analysis was used to determine the coefficients (i.e. slope and constant) and the strength (R, R^2) of the linear relationship between river mile and water temperature (Table 2). This relationship was stronger in Woodard Creek (R=0.294) than on Diamond Creek (R=0.057). 95% confidence intervals (CI) provide a measure of uncertainty for the slope and constant values.

Certain sites (KB-1150, KB-120, KB-150) fall above the regression lines shown in Figure 5. These sites had the greatest number of observations in the summer (48-53%)(Figure 7). Although the CEMP sampling frequency is designed to increase the number of summer observations (2 site visits/month, May – August), these sites had a greater percentage of summer observations than other sites. The longitudinal pattern is still evident in summer means (Figure 8), although it is strongly influenced by the number of samples (N) taken at a site.

Figure 2. CEMP freshwater sites included in analysis from the Kachemak Bay and Anchor River watersheds.

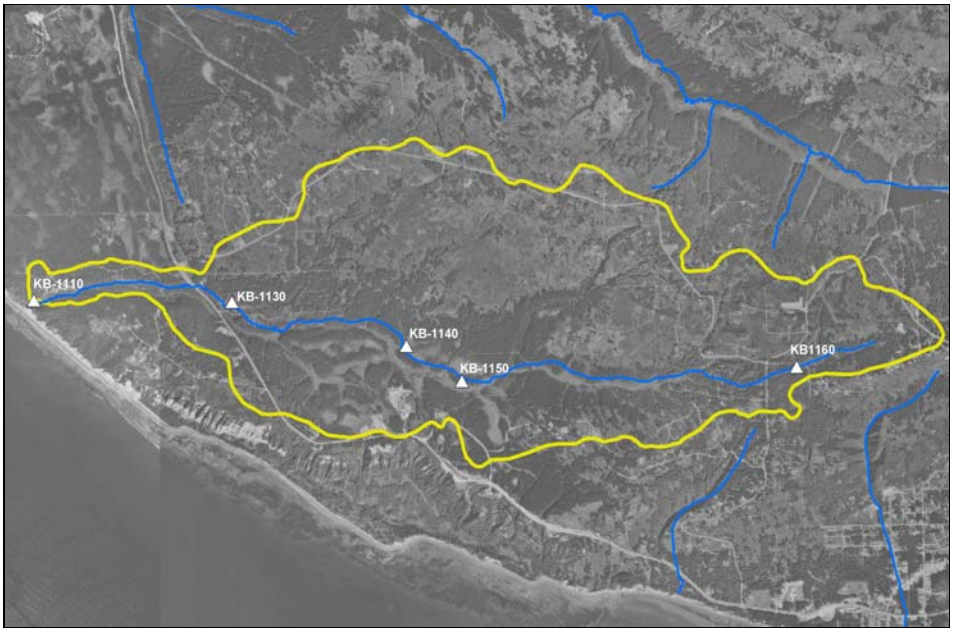


Figure 3. CEMP sites on Diamond Creek watershed.

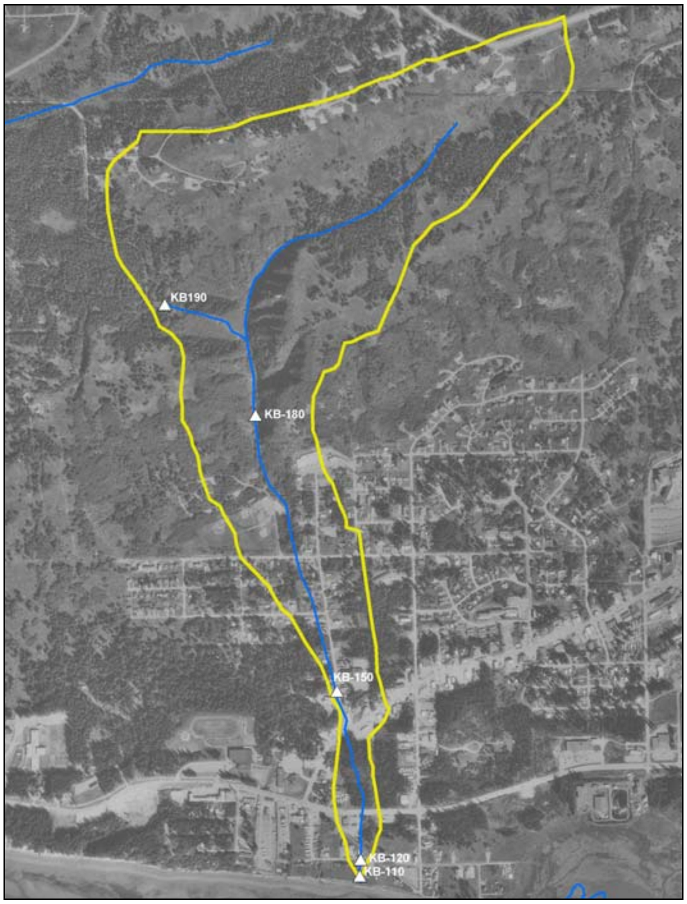


Figure 4. CEMP sites on Woodard Creek watershed.

Table 2. Results from Linear Regression Analysis based on river mile.

Watershed	Parameter	Slope	95% CI for slope	Constant	95% CI for constant	R	R^2
Diamond Creek	Temperature	-0.149	-.532 .234	7.082	5.984 8.181	0.057	0.003
Woodard Creek	Temperature	-2.744	-4.438 -1.051	8.395	7.035 9.756	0.294	0.086
Diamond Creek	Conductivity (25°C)	-13.792	-20.322 -7.262	127.581	108.586 146.576	0.306	0.094
Woodard Creek	Conductivity (25°C)	-66.579	-108.824 -24.333	197.778	164.970 230.586	0.297	0.088

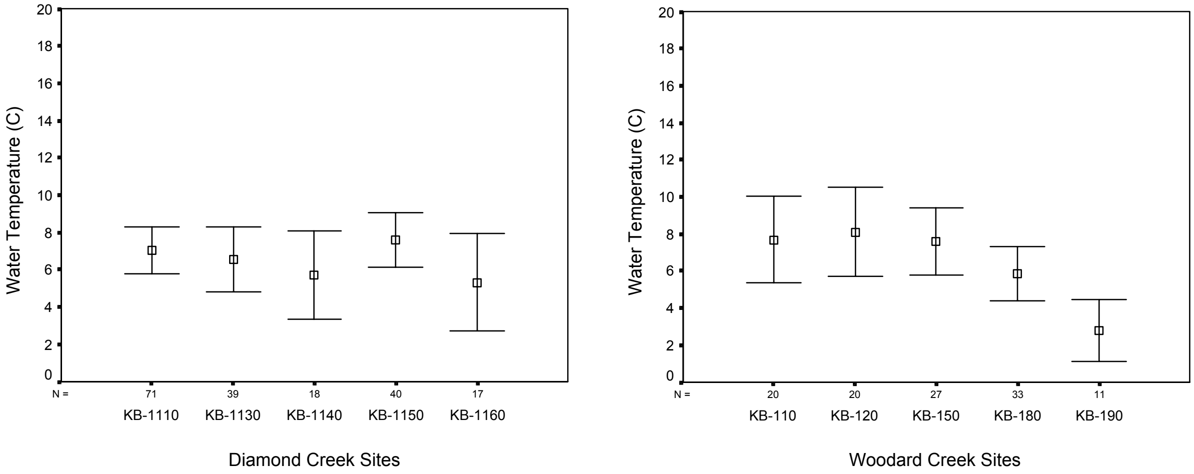


Figure 5. Water temperatures by site in Diamond and Woodard Creek watersheds.

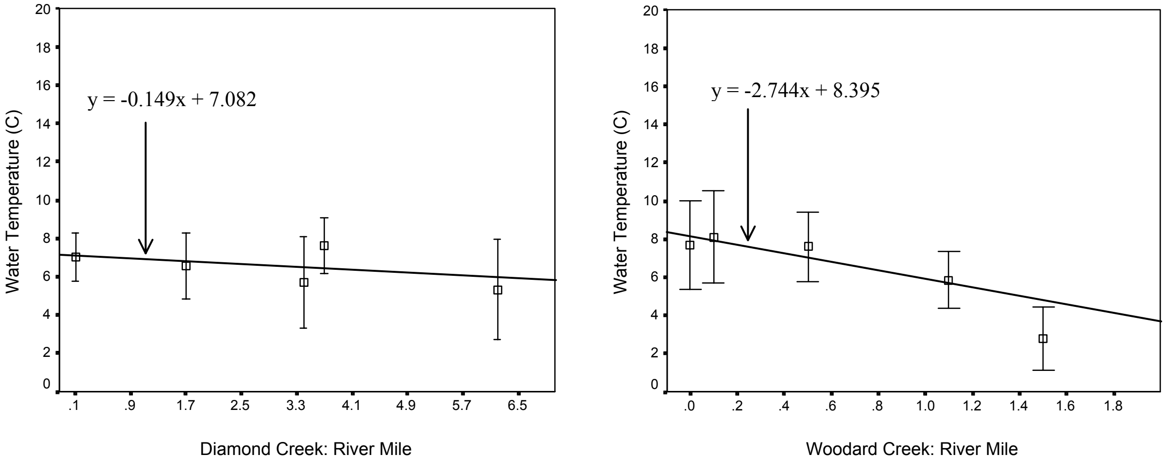


Figure 6. Water temperatures by river mile for Diamond and Woodard Creek sites.

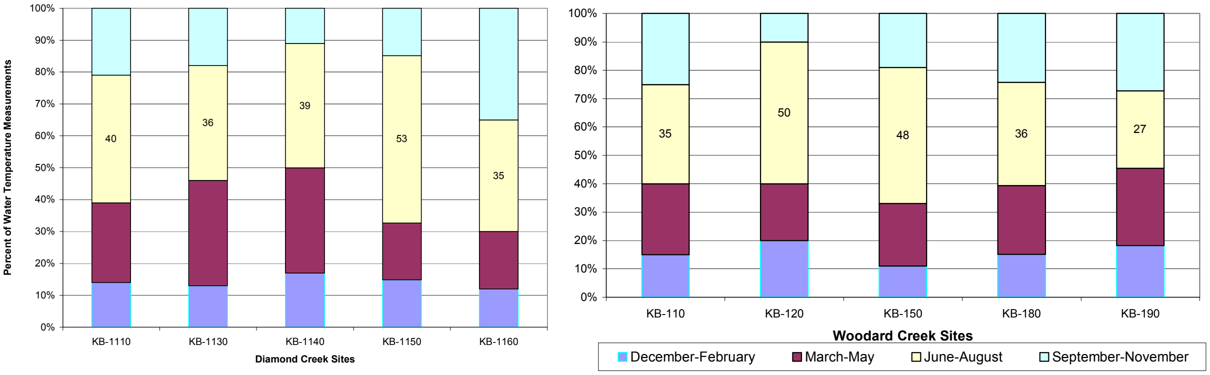


Figure 7. Seasonal distribution of observations at Diamond and Woodard Creek sites.

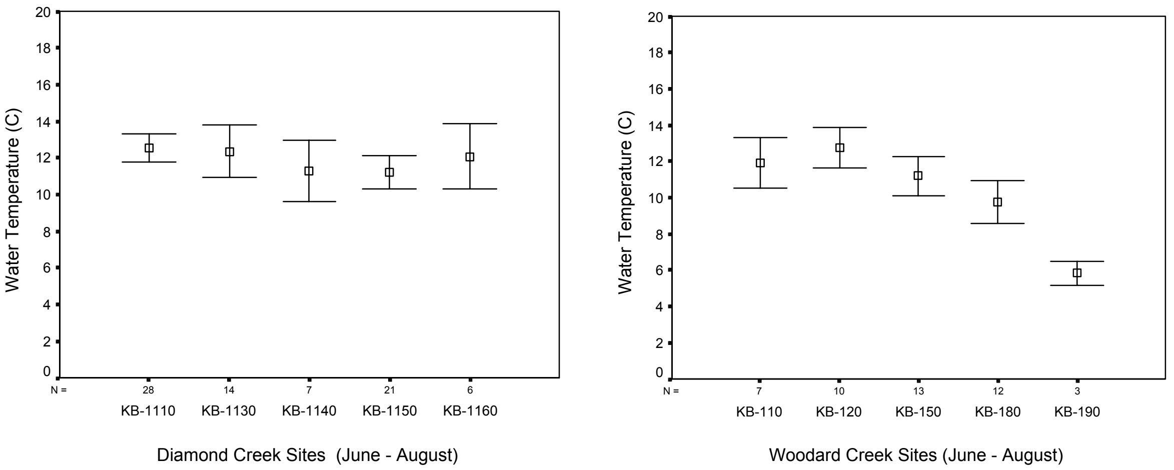


Figure 8. Summer water temperatures by site on Diamond and Woodard Creeks.

Another possible source of variation in water temperature values is collection time. However, mean collection times at Woodard Creek sites did not seem to vary significantly enough to account for the longitudinal pattern described above (Table 3).

Table 3. Mean collection times at Woodard Creek sites.

Woodard Creek Sites	Mean observation time
KB-110	3:28 pm
KB-120	1:27 pm
KB-150	1:54 pm
KB-180	1:10 pm
KB-190	2:29 pm

Woodard and Diamond Creeks showed a pattern of decreasing conductivity values heading upstream (Figure 9). There was a significant difference in means between sites in both Diamond Creek ($F_{4, 169}$=5.30, p=0.00005) and Woodard Creek ($F_{4, 102}$=3.29, p=0.014). Sites were also plotted based on their location in the watershed by river mile (Figure 10). Woodard had a significantly higher level of conductivity than Diamond Creek ($F_{1,272}$=24.12, p=0.000002).

The regression analysis showed that the relationship between river mile and conductivity was equally strong in both watersheds (Table 2). The slope of the relationship is much larger in Woodard Creek (-66.579) than in Diamond Creek (-13.792).

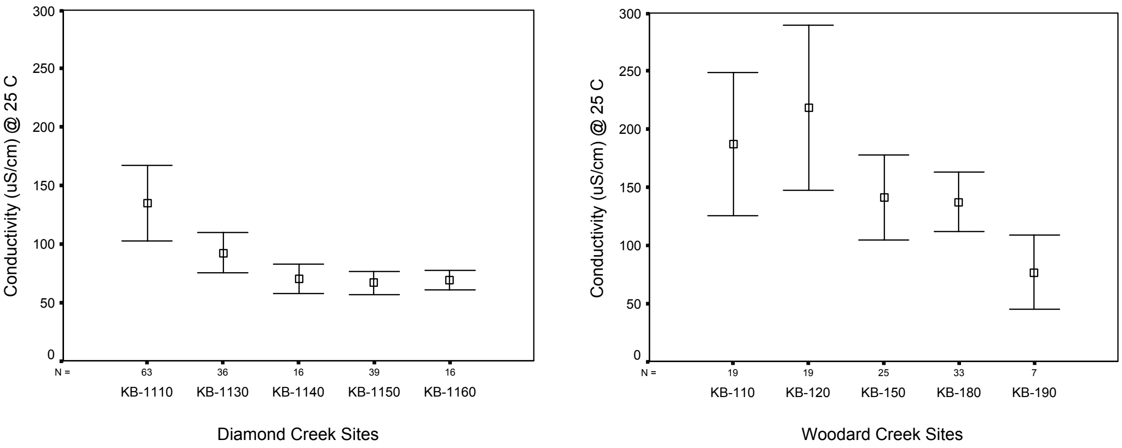


Figure 9. Conductivity values by site in Diamond and Woodard Creek watersheds.

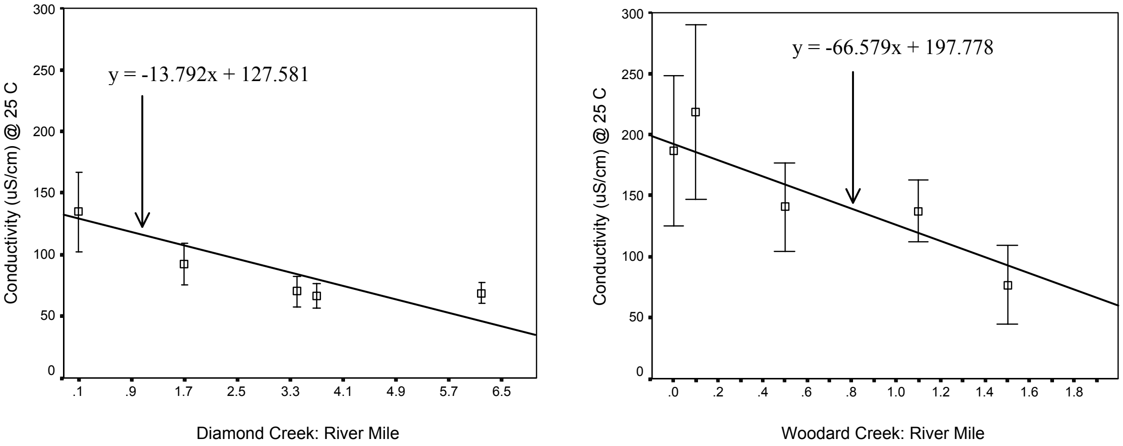


Figure 10. Conductivity values by river mile for Diamond and Woodard Creek sites.

Temporal Patterns

No change in mean annual water temperature was found at any of the 11 sites that had at least 25 observations (Figure 11). Annual patterns in turbidity and conductivity showed the greatest variability (Figure 12 and 13). Four percent of the turbidity values observed at all sites exceeded the method's range (200 JTUs). Two methods were used to measure pH: the Hanna Meter (sensitivity = 0.1 units) and a colorimeter method (sensitivity = 0.25 units). The Hanna Meter method exhibited greater variability (Figure 14). Eighty-four percent of orthophosphate values were below the detection limit of 0.2 ppm and eighty-two percent of the nitrate-nitrogen values were below the detection limit of 1 ppm at freshwater sites.

Seasonal temperature patterns across years were assessed at Diamond Creek site: KB-1110. No significant change in mean seasonal temperatures was found across the five years. However, summer data suggests a downward trend with decreasing temperatures over years (Figure 15). Homer Airport's meteorological records support the finding that 1997 was warmer than later years (Table 4).

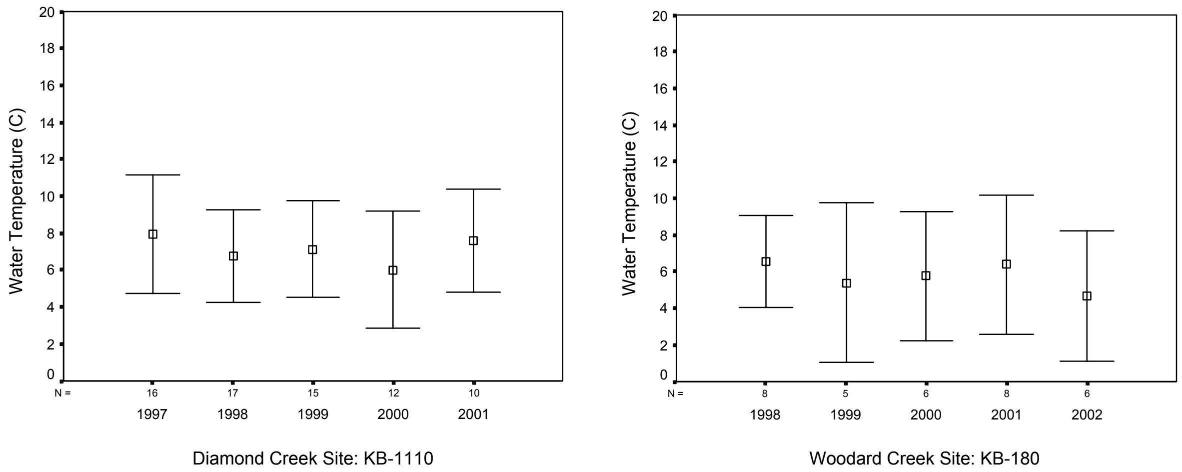


Figure 11. Annual water temperatures at sites in Diamond and Woodard Creek watersheds.

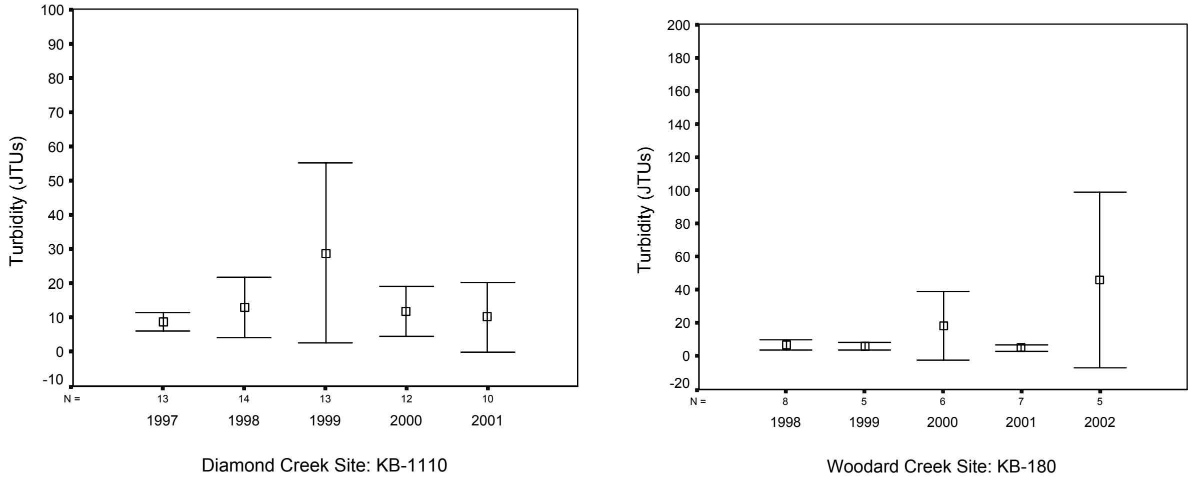


Figure 12. Turbidity values over years at Diamond and Woodard Creek sites.

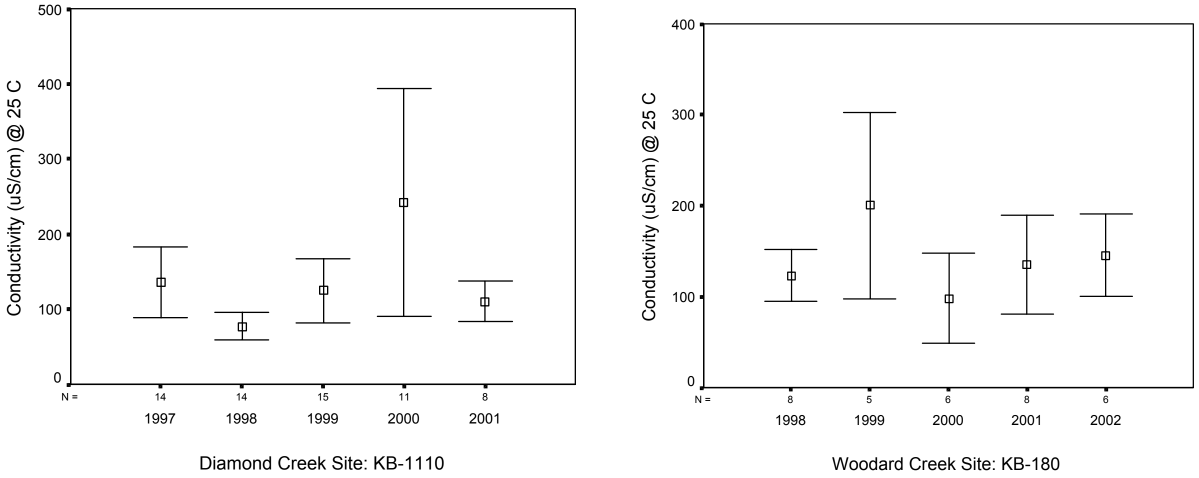


Figure 13. Conductivity values over years at Diamond and Woodard Creek sites.

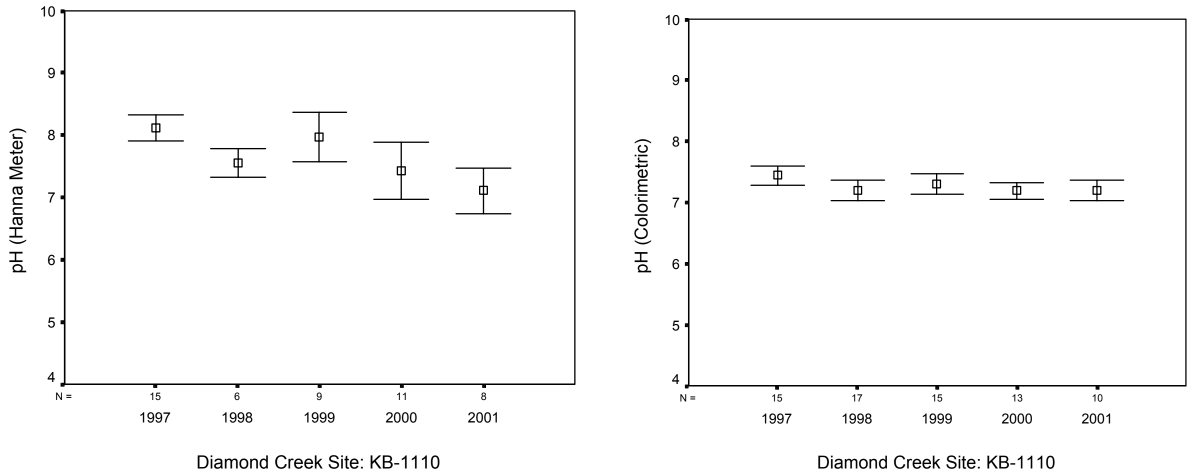


Figure 14. pH values over years for two methods at a Diamond Creek site.

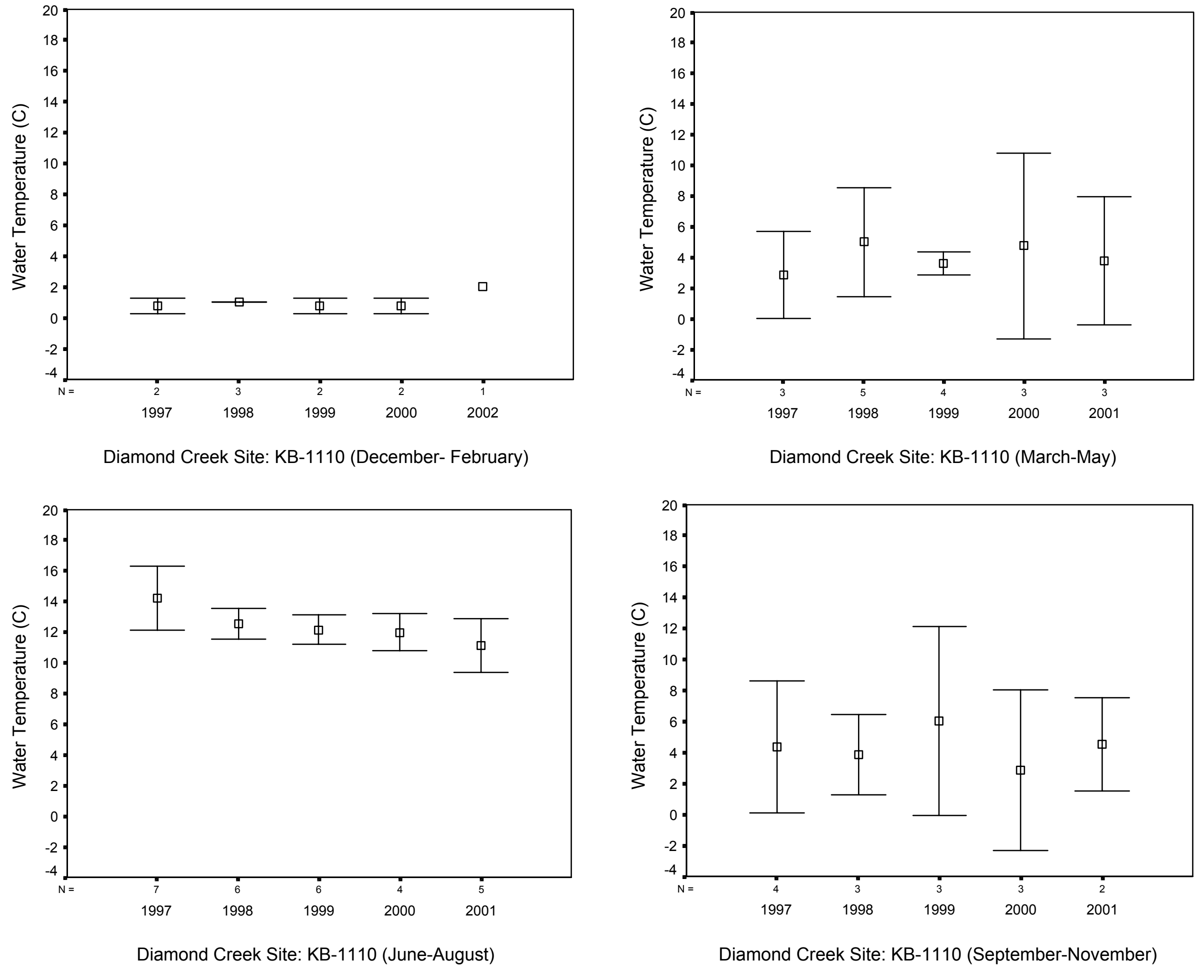


Figure 15. Seasonal water temperatures over years at a Diamond Creek site.

Table 4. Homer Airport's mean summer air temperature from 1997-2001.

Year	Homer Summer (June, July, August) Mean Air Temperature (F)
1997	55.29
1998	52.11
1999	52.75
2000	52.07
2001	53.92

Correlations

Spearman's rank coefficients were used to determine which water quality characteristics were related (Table 5). (Parameters related at the p=.01 level are more significantly related than those at the p=.05 level). Water temperature had the strongest relationship with other parameters, particularly dissolved oxygen and pH (colorimetric method). As temperature increased, dissolved oxygen (mg/L) decreased as warmer water can hold less oxygen. The relationship between temperature and percent saturation is the opposite. As water temperatures drop, percent saturation drops which may reflect low flow (less turbulence) and ice cover in winter. Correlation coefficients for other sites showed similar relationships, although some sites showed a significant negative relationship between conductivity and turbidity. When conductivity was low because of a higher ratio of surface water to ground water, turbidity was high.

Table 5. Spearman's rank correlations (rho) for KB-1110.

Parameters	Water Temperature	Turbidity	Dissolved Oxygen	% Saturation	Conductivity @ 25C	pH (Hanna Meter)	pH (Color-imetric)
Water Temperature	1.000						
Turbidity	**-.343	1.000					
Dissolved Oxygen	**-.875	* .276	1.000				
% Saturation	** .411	-.157	.009	1.000			
Conductivity @ 25C	-.090	.050	.030	.021	1.000		
pH (Hanna Meter)	.162	-.056	-.066	.258	* .330	1.000	
pH (Colorimetric)	** .578	** -.366	**-.476	** .458	.004	** .392	1.000

* Correlation is significant at the p=.05 level.

** Correlation is significant at the p= .01 level.

Power Analysis

A baseline dataset of 16 samples (one year of sampling) would be useful to detect a 4.7°C change in mean annual temperature when compared to a second year of data (Table 6). A comparison of two, three-year data sets (n=48) could detect a change of 2.7°C. It would require two datasets with 334 samples each (21 years) to detect a 1.0°C change. Summer temperatures with a smaller standard deviation would require fewer samples to detect these changes.

A comparison of two, one-year data sets could detect a 10.5% change in saturation of dissolved oxygen. Two, five-year data sets (n=80) could detect a 4.6% change. Two, five-year data sets would also be useful for measuring a 0.22 unit change in pH with the Hanna Meter. The colorimetric method with its sensitivity of 0.25 units would only be able to detect a 0.25 unit change (n=28). No significant level of change was identified for conductivity and turbidity because their standard deviations varied too widely, which made them inappropriate for a t-test.

Table 6. Results from t-test power analysis on freshwater sites.

Parameter	Standard Deviation	Sample size (n)	Difference in mean	Lower CI	Upper CI	% Power
Annual Temperature	4.60	16	4.7 °C	1.42	7.98	80
		32	3.3 °C	1.01	5.59	81
		48	2.7 °C	0.84	4.56	81
		64	2.3 °C	0.70	3.90	80
		80	2.1 °C	0.67	3.53	82
		334	1.0 °C	0.30	1.70	80
Summer Temperature (June-August)	2.00	6	3.6 °C	1.12	6.10	80
		12	2.4 °C	0.71	4.05	80
		18	1.9 °C	0.58	3.26	80
		24	1.7 °C	0.50	2.80	80
		30	1.5 °C	0.46	2.52	80
		64	1.0 °C	0.30	1.70	80
Dissolved Oxygen (% saturation)	10.30	16	10.5 %	3.15	17.85	80
		32	7.3 %	2.18	12.42	80
		48	6.0 %	1.84	10.16	81
		64	5.2 %	1.61	8.79	81
		80	4.6 %	1.39	7.81	80
		268	2.5 %	0.75	4.25	80
pH (Hanna Meter)	0.49	16	0.50 units	0.15	0.85	80
		32	0.35 units	0.11	0.59	80
		48	0.29 units	0.09	0.49	82
		64	0.25 units	0.08	0.42	82
		80	0.22 units	0.07	0.37	81
		169	0.15 units	0.05	0.25	80
pH (Colorimetric)	0.28	16	0.29 units	0.09	0.49	81
		21	0.25 units	0.08	0.42	81

Estuarine Sites

The 19 estuarine sites include 8 sites on the south side of Kachemak Bay, 5 sites inside the Homer Spit, 4 sites outside the Homer Spit, and 2 sites along Beluga Slough on the north side of Kachemak Bay (Figure 16). The south side sites range from Peterson Bay to Seldovia and, except for the Neptune Bay site (KB-887), are not near a river mouth. The sites inside the Homer Spit include one at Miller's Landing (KB-900), one in Mud Bay (KB-1200), two in the Homer Harbor (KB-509, KB-506), and one at the end of the Spit (KB-500). The outer, north bay sites are at the mouths of Woodard (KB-100), Benny (KB-10), and Diamond Creeks (KB-1100) and the Anchor River (AR-1000). The Beluga Slough sites are at the outflow of the slough (KB-310) and of the lake (KB-350).

<u>Longitudinal Patterns</u>

The estuarine sites were grouped based on their location and how that related to general circulation patterns within Kachemak Bay. Marine waters are known to flow into Kachemak Bay along the south coast setting up a longitudinal pattern of up current (outer bay) to down current (inner bay) flow. South side sites have been arranged along this current gradient from down to up current sites (Peterson Bay to Seldovia). The circulation pattern moves from the inner bay to the outer bay on the north side. The Homer Spit is a significant feature that affects this circulation pattern. Generally, the north side tends to be more influenced by riverine inputs than the south side of Kachemak Bay. However, the 20-30 foot tidal cycle that occurs twice a day is also a source of great variability in water chemistry patterns.

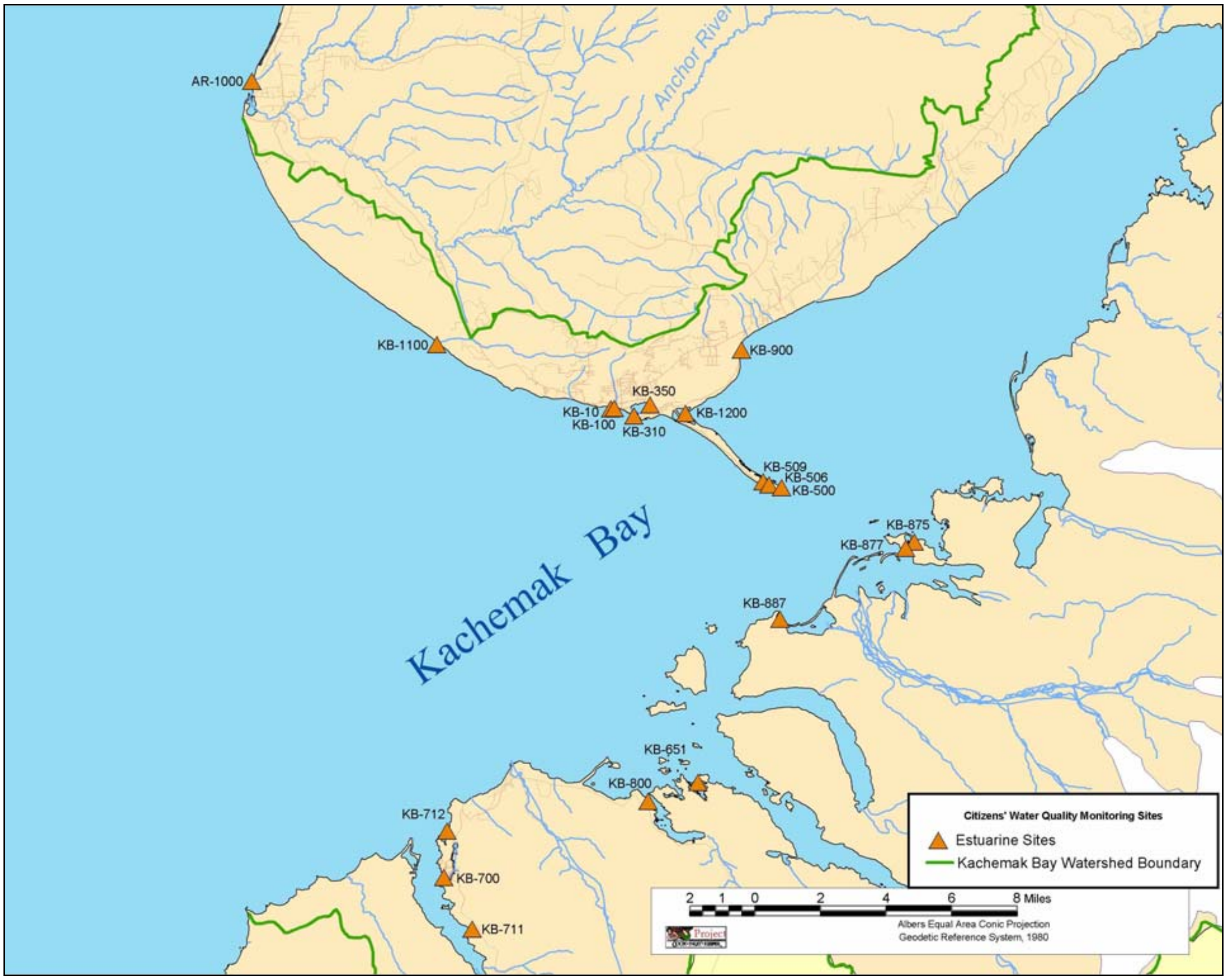


Figure 16. CEMP estuarine sites included in the analysis from the Kachemak Bay and Anchor River watersheds.

Longitudinal patterns in temperature were evident with an increase of temperature heading into the bay on the south side (Figure 17). There were significant differences in the means of the south side sites ($F_{7, 150}$=5.45, p=0.00001) and inside Homer Spit sites ($F_{4, 141}$=2.54, p=0.043). The longitudinal pattern was not apparent in the sites outside the bay because of differences in seasonal distribution of sampling dates. For instance, Benny Creek (KB-10) had only been sampled in summer months. Temperatures on the north side were warmest in Beluga Slough and tended to be warmer inside the Homer Spit than outside. There was a significant difference in mean water temperatures between the four site groupings ($F_{3, 489}$=6.28, p=0.0003).

Salinity patterns showed that south side sites have a stronger marine signal than north side sites; however, this may be confounded by site placement near river mouths on the north side (Figure 18). There were significant differences in mean salinity values for south side sites ($F_{7, 144}$=11.1, p<0.000005), inside Homer Spit sites ($F_{4,134}$=3.23, p=0.015), and Beluga Slough/Lake sites ($F_{1,95}$=93.56, p<0.000005). Mean salinity values were significantly different between the four site groupings ($F_{3, 464}$=103.64, p<0.000005).

Turbidity was highest at sites with lower salinity, which again reflects the contribution of river water at these sites (Figure 19). The greatest variability in turbidity was seen at KB-900 (Miller's Landing) which is the inner most site in the bay.

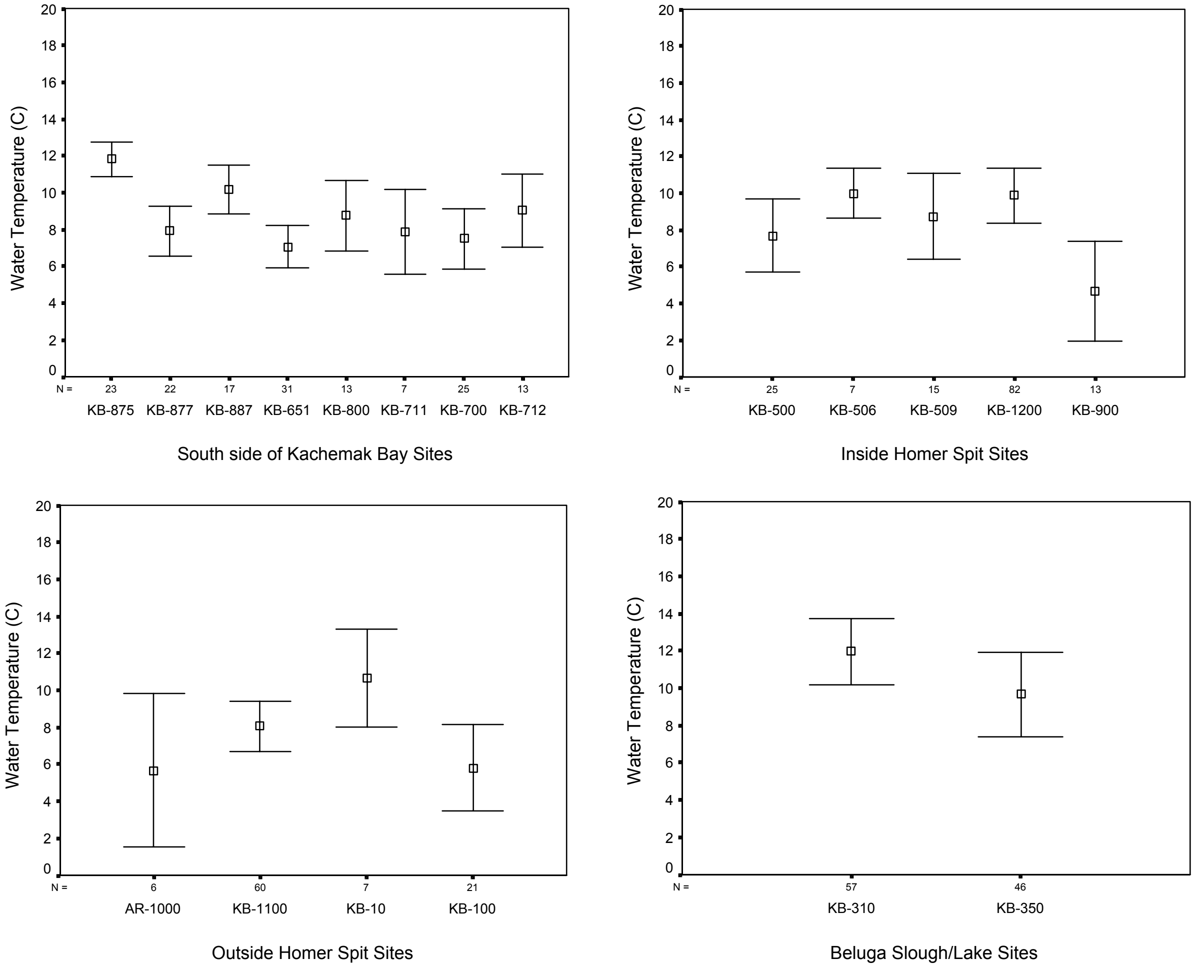
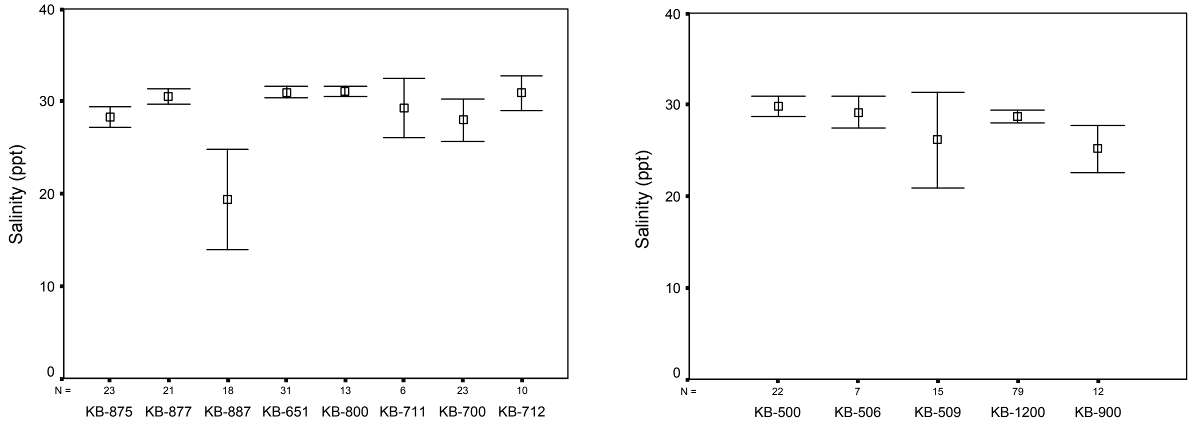
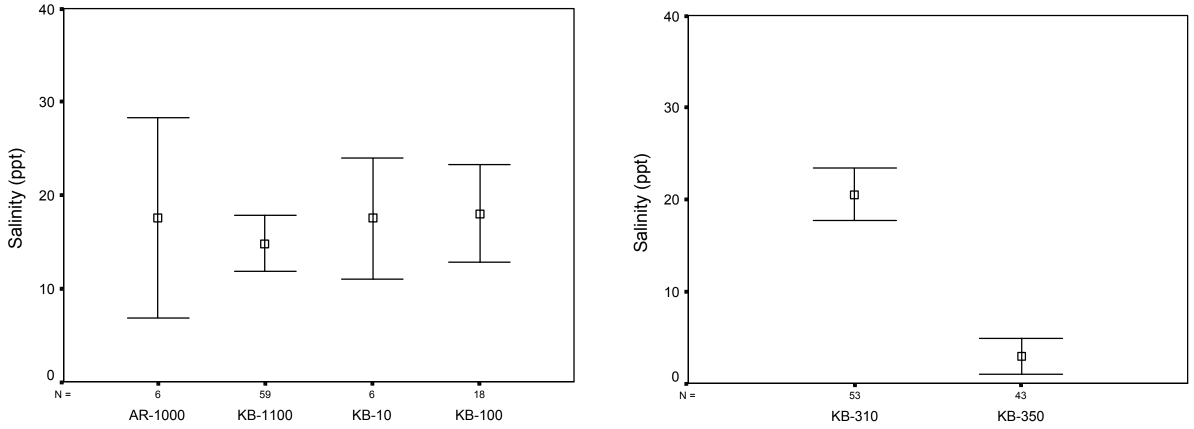


Figure 17. Water temperatures for estuarine site groupings.



South side of Kachemak Bay Sites

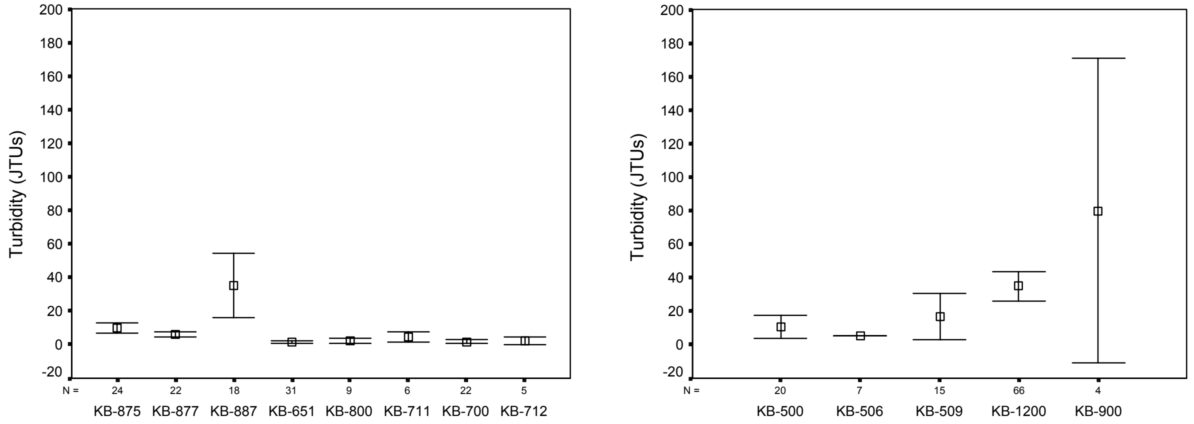
Inside Homer Spit Sites



Outside Homer Spit Sites

Beluga Slough/Lake Sites

Figure 18. Salinity values for estuarine site groupings.



South Side of Kachemak Bay Sites

Inside Homer Spit Sites

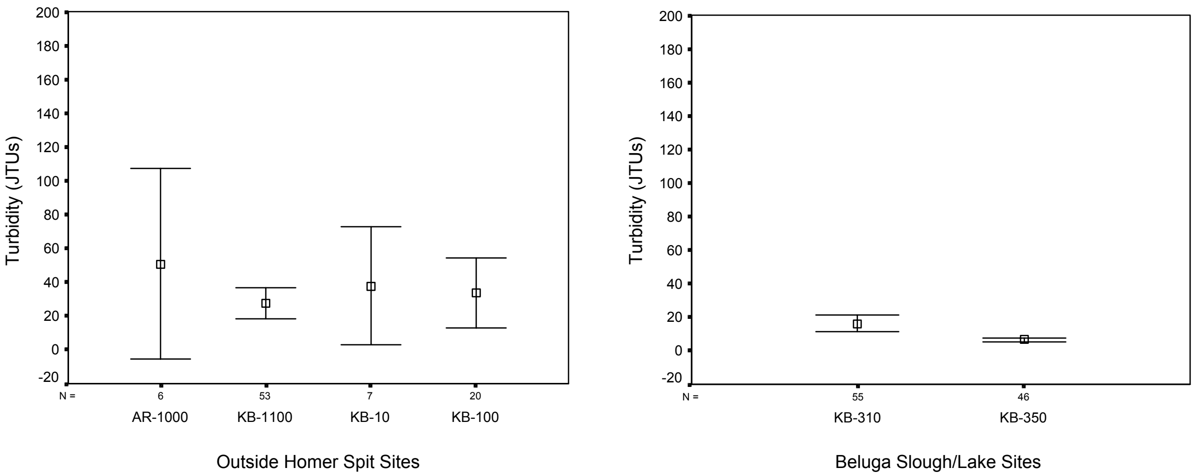


Figure 19. Turbidity values for estuarine site groupings.

Temporal Patterns

No change in annual water temperatures was found at the 5 sites that had at least 25 observations. There was a significant difference in dissolved oxygen (% saturation) at two sites (Figure 20): KB-1200 ($F_{5,81}$=3.77, p=0.004), KB-310 ($F_{3,50}$= 3.74, p=0.017). Annual patterns in turbidity showed the greatest variability. Sixty-six percent of conductivity readings exceeded the method's upper detection limit of 1999 uS/cm. Ninety-two percent of orthophosphate values were below the detection limit of 0.2 ppm and ninety-five percent of the nitrate-nitrogen values were below the detection limit of 1 ppm at estuarine sites.

Seasonal temperature patterns across years were assessed at Mud Bay Spit Site: KB-1200, which had 82 temperature observations that were fairly well distributed across seasons (Figure 21). No significant change in mean seasonal temperatures was found across the five years. Salinity patterns suggest a decrease in salinity during the Summer and Fall when ice melt and precipitation add increased amounts of freshwater into the bay (Figure 22).

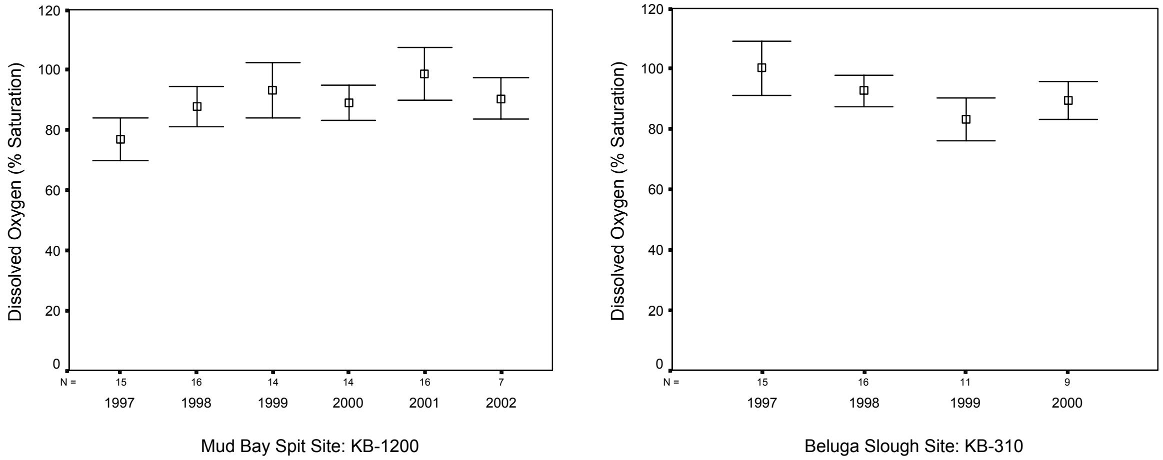
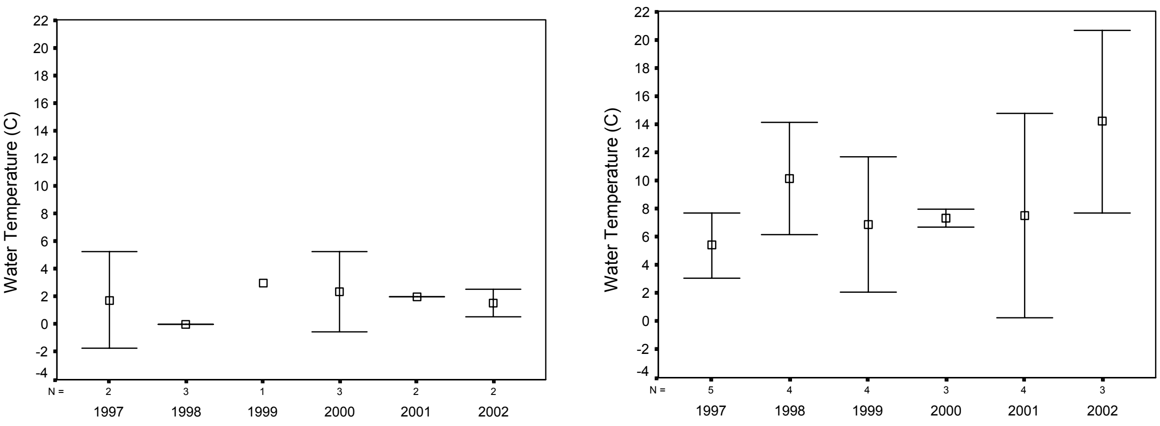
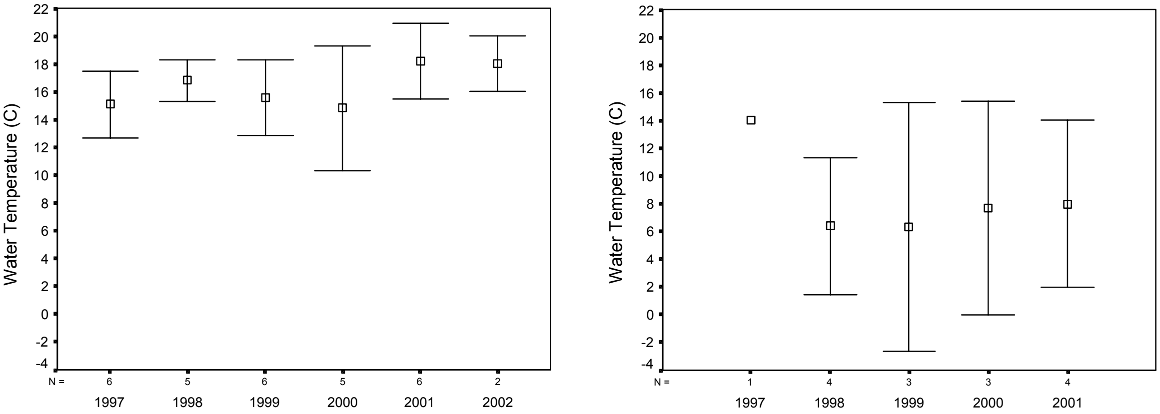


Figure 20. Dissolved oxygen as percent saturation over years for two estuarine sites.



Mud Bay Spit Site: KB-1200 (December- February)

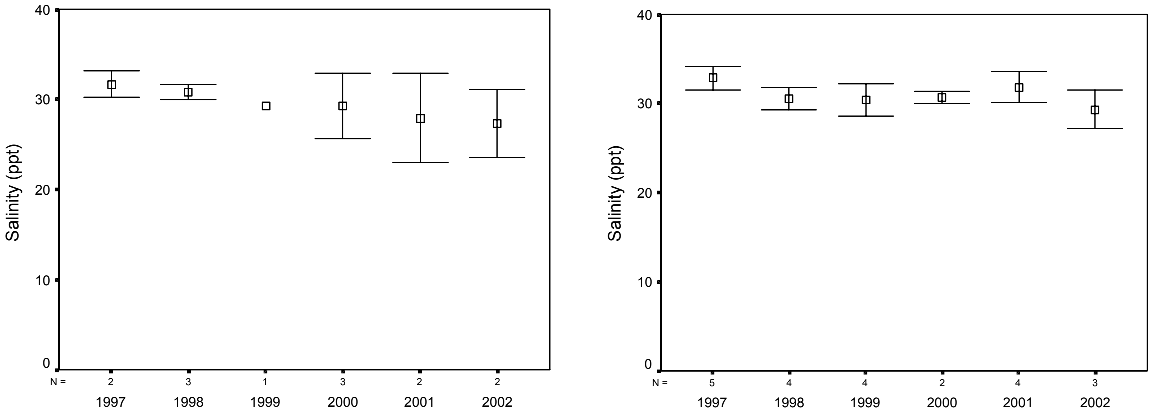
Mud Bay Spit Site: KB-1200 (March - May)



Mud Bay Spit Site:KB-1200 (June-August)

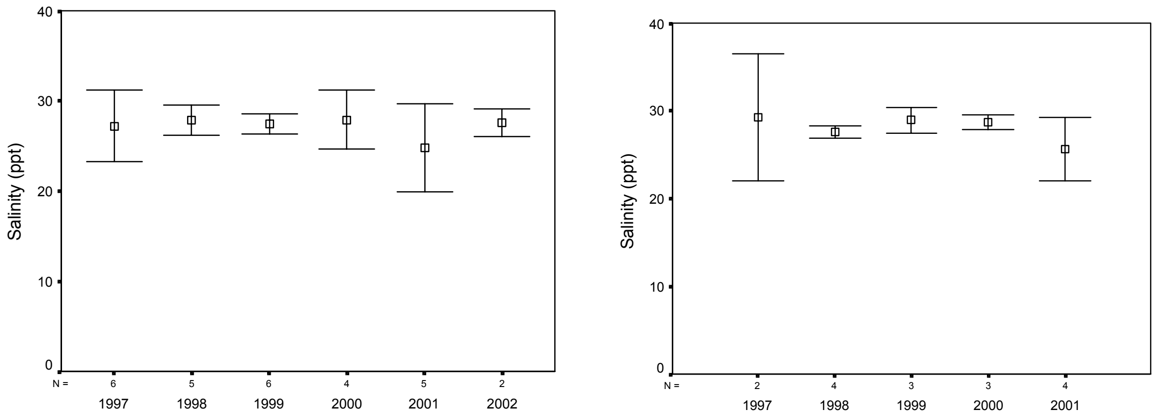
Mud Bay Spit Site: KB-1200 (September- November)

Figure 21. Seasonal water temperatures over years at a Mud Bay site inside the Homer Spit.



Mud Bay Spit Site: KB-1200 (December - February)

Mud Bay Spit Site: KB-1200 (March - May)



Mud Bay Spit Site: KB-1200 (June-August)

Mud Bay Spit Site: KB-1200 (September - November)

Figure 22. Seasonal salinity values over years at a Mud Bay site inside the Homer Spit.

Correlations

Based on Spearman's rank coefficients, water temperature had strong relationships with all other parameters (Table 7). Percent saturation of dissolved oxygen was positively related to pH.

Table 7. Spearman's rank correlations (rho) for KB-1200:

Parameters	Water Temp.	Turbidity	Dissolved Oxygen	% Sat.	pH (Hanna Meter)	pH (Color-imetric)	Salinity
Water Temperature	1.000						
Turbidity	**-.353	1.000					
Dissolved Oxygen	**-.467	-.173	1.000				
% Saturation	** .603	**-.566	* .278	1.000			
pH (Hanna Meter)	** .725	**-.334	-.119	** .689	1.000		
pH (Colorimetric)	** .679	-.232	-.194	** .632	** .875	1.000	
Salinity	**-.373	.118	.136	*-.232	.025	.071	1.000

* Correlation is significant at the p =.05 level.

** Correlation is significant at the p = .01 level.

Power Analysis

A baseline dataset of 16 samples would be useful to detect a 4.5 ^{o} C change in mean annual temperature when compared to a second year of data (Table 8). A comparison of two, three-year data sets (n=48) could detect a change of 2.5^{o} C. It would require two datasets with 292 samples each (18 years) to detect a 1.0^{o} C change. It would require fewer samples to detect these changes in summer temperatures, but approximately the same number of years.

A comparison of two, one-year data sets could detect a 11.3% change in saturation of dissolved oxygen. Two, five-year data sets (n=80) could detect a 4.9 % change. Two, five-year data sets would also be useful for measuring a 0.21 unit change in pH with the Hanna Meter. The colorimetric method with its sensitivity of 0.25 units would only be able to detect a 0.25 unit change (n=44). No significant level of change was identified for salinity and turbidity because their standard deviations varied too widely, which made them inappropriate for t-test analysis.

Table 8. Results from t-test power analysis on estuarine sites.

Parameter	Standard Deviation	Sample size (n)	Difference in mean	Lower CI	Upper CI	% Power
Annual Temperature	4.32	16	4.5 °C	1.37	7.53	80
		32	3.1 °C	0.93	5.21	80
		48	2.5 °C	0.76	4.24	80
		64	2.2 °C	0.65	3.65	80
		80	1.9 °C	0.58	3.26	80
		292	1.0 °C	0.30	1.70	80
Summer Temperature (June-August)	3.3	6	5.9 °C	1.80	10.00	80
		12	3.9 °C	1.18	6.68	80
		18	3.2 °C	0.94	5.36	80
		24	2.7 °C	0.82	4.62	80
		30	2.4 °C	0.71	4.11	80
		172	1.0 °C	0.30	1.70	80
Dissolved Oxygen (% saturation)	11.09	16	11.3 %	3.38	19.22	80
		32	7.9 %	2.39	13.41	80
		48	6.4 %	1.92	10.88	80
		64	5.5 %	1.63	9.37	80
		80	4.9 %	1.45	8.37	80
		310	2.5 %	0.75	4.25	80
pH (Hanna Meter)	0.46	16	0.47 units	0.14	0.80	80
		32	0.33 units	0.10	0.56	81
		48	0.27 units	0.08	0.46	81
		64	0.23 units	0.07	0.39	80
		80	0.21 units	0.07	0.35	82
		149	0.15 units	0.05	0.25	80
pH (Colorimetric)	0.41	16	0.42 units	0.13	0.71	80
		32	0.29 units	0.09	0.49	80
		44	0.25 units	0.08	0.42	81

DISCUSSION

Frequency

The present sampling design for the Citizens' Environmental Monitoring Program aims for 16 sampling events per site per year. Based on this frequency, longitudinal patterns in temperature and conductivity were detectable at freshwater sites. Longitudinal patterns in temperature, salinity and turbidity were seen at estuarine sites. However, annual means were affected by distribution of observations throughout the year. Comparisons of seasonal means may be more useful, although seasonal sample size was typically very small (n=3-6) in a year. The sampling frequency in the summer is already doubled by having volunteers sample twice a month.

The regression analysis showed that changes in temperature and conductivity by river mile (i.e. slope) were greater in Woodard Creek than in Diamond Creek. This may be related to the amount of urbanization in Woodard Creek, which increases heading downstream. Over time a slope change beyond the bounds set by the 95% confidence intervals may suggest that downstream sites are changing faster than upstream sites. A change in the constant value only may point to an environmental shift that is affecting the entire watershed. The river mile regression models explained a small proportion of the variability in the temperature/conductivity values. Incorporating other parameters, like elevation, drainage size, and extent of wetlands, may improve these models.

A recent USGS report suggests that streams within the Cook Inlet Basin may experience a water temperature change of 3.0 ^{o}C in the coming years (Kyle and Brabets, 2001). This magnitude of change is considered significant for the incidence of disease in fish populations. Based on the power analysis results, CEMP will be able to detect a change of 3.0 ^{o}C by comparing two, three-year datasets. Detecting a smaller change would be more useful in the hopes of mitigating the effects of this change rather than to just document the results. To detect a 1.0 ^{o}C change would require a sampling size of 334. Investing in continuous temperature loggers that the volunteers download and calibrate bimonthly would be useful in this endeavor.

One of the goals of this analysis was to define "significant change" for the CEMP. Results from the power analysis suggest that a five-year baseline data set (n=80) would be valuable to detect a change of 2.0^{o}C, 0.25 pH units (Hanna Meter method), and 5% saturation of dissolved oxygen when compared to another five-year data set.

Methods

Certain methods resulted in many "out-of-range" readings. For example, turbidity exceeded the method range 4% of the time. Conductivity exceeded the maximum range 66% of the time at estuarine sites. Inexpensive conductivity meters with a maximum range appropriate for estuarine sites (50,000 uS/cm) are not presently available. With the inclusion of salinity data at estuarine sites, conductivity measurements may not be necessary.

Orthophosphate and nitrate-nitrogen methods resulted in many (>80%) zero values. The methods are not appropriate tools for trend analysis as the detection levels are too high, but can be useful as screening tools to flag a site for follow up. More precise data would be valuable as nutrient criteria for aquatic life are still under development in Alaska.

In comparing the two methods employed to measure pH, the variability in Hanna Meter readings was greater than the colorimetric method because of differences in their sensitivity levels. Having two methods provides a quality control check that is useful. However, for trend analysis, the Hanna Meter data are more sensitive. The colorimetric method could be considered a backup method if the meter is not functioning properly.

Parameters

Correlation coefficients showed temperature had the strongest correlation with all other parameters, except conductivity. This temperature relationship is a known fact, so it is encouraging that these volunteer-collected data show this pattern. Temperature measurements should be a priority at all site visits. Incorporating continuous temperature loggers will increase understanding of temperature variations on monthly, daily and hourly scales.

Turbidity and conductivity showed great variability in means and standard deviations across sites and years. Analysis of variance assumes homogeneity of variance so tests on the significance of differences in turbidity and conductivity means were not valid. These parameters are strongly related to discharge levels, and thus change dramatically across annual, seasonal, and monthly scales. Discharge information would be a valuable addition to the monitoring program.

Compiling data by site for each parameter provides a useful tool for volunteers. With an understanding of the expected range of data for their site based on previously collected data, volunteers may be able to verify the accuracy of outliers. Outliers may be insignificant occurrences or very important data points. Volunteer should be encouraged to perform and document a replicate analysis if they encounter an outlier. Summary statistics presented in Appendix III: maximum, minimum, mean and standard deviation, should be compiled annually for each site and provided to volunteer monitors. Outliers can be defined as values that are two standard deviations away from the mean.

Site selection

With the present sampling locations on Diamond and Woodard Creeks, longitudinal patterns were seen where sites were significantly different from each other. For these watersheds, three to five sites that represent upper, middle, and lower reaches of the stream seem to be appropriate for understanding longitudinal patterns and providing an understanding of the slope of the river mile regression line. Other watersheds may have different longitudinal patterns depending on watershed size, amount of impervious cover, and discharge patterns, and therefore require a greater or lesser number of monitoring sites. For small watersheds (< 2-square mile drainage) that come down from the Homer bench, where discerning longitudinal patterns may not be a priority, one site at a downstream location should be adequate. In larger watersheds, like the Anchor River (225-square mile drainage), sites should be placed at downstream locations of major tributaries as manpower allows. Placing sites upstream and downstream of a specific land-use of concern may be appropriate to detect particular pollutants.

For estuarine sites in Kachemak Bay, the challenge of measuring natural variability is profoundly increased by the 20-30 ft tidal cycle that occurs twice a day. The four site groupings (south side, inside Homer Spit, outside Homer Spit, and Beluga Slough) showed significant differences between sites and groupings. This suggests that the present CEMP coverage of Kachemak Bay is not adequate. With the efforts of the Kachemak Bay Research Reserve to characterize the bay using data loggers at two locations in the bay, it may be most useful for CEMP sites to serve two purposes: 1) to provide a reciprocal quality control check with the KBRR sensors, and 2) to focus on locations with the greatest risk to change due to human use. For instance, prioritize sampling at the Homer Harbor, Beluga Slough, Seldovia Harbor, and sites related to important fisheries, like China Poot Bay and the Anchor River mouth.

Manpower

The willingness of volunteers to dedicate time and effort to monitoring their rivers and bays is a great testament to the value Alaskans hold for their natural surroundings. Cook Inlet Keeper has trained more than 100 volunteers in the Kachemak Bay watershed since 1996. Seventeen of these have been monitoring a site for more than 3 years. Eight of these amazing citizens have contributed five years of service. The December 2002 training in Homer introduced 11 new volunteers to the CEMP.

The Kachemak Bay/Anchor River CEMP database contains information on 90 sites; however, 44 sites of those sites had 5 or fewer sites visits. This is due to the challenge of retaining volunteers and having consistent access to sites. Sites are often located in areas that are of significance to volunteers, so sites may be discontinued when a volunteer leaves the program. With a goal of attaining five year datasets, when a monitor discontinues sampling at a location with more than two years of data, a new volunteer should be set up at that site as soon as possible.

With current funding levels and Keeper staff positions, the Kachemak Bay/Anchor River CEMP is able to maintain 35 active volunteers a year. This has only been possible with a paid volunteer coordinator who recruits, trains, manages and inspires volunteers to keep the program viable. Without this coordination, the sustainability of a long-term monitoring program is tenuous. Whatever the ideal number of sites for this area, having volunteers to sample them and a coordinator to manage them are limiting factors.

Funding

Volunteer monitoring programs are the most cost-effective approach to gaining baseline information on streams and bay. However, volunteer monitoring programs are not without their costs. Field and lab equipment, calibration solutions, and computers must all be maintained at a yearly cost. A paid volunteer coordinator is essential for volunteer and data management. Without a consistent, reliable source of funding for a volunteer monitoring program, the program's design is of little consequence. Having long term state or foundation support to sustain a monitoring program is imperative.

CONCLUSIONS AND RECOMMENDATIONS

The CEMP Partnership of the Cook Inlet Watershed has achieved the goals set for state-wide and national monitoring programs. Cook Inlet Keeper, with Cook Inlet partners and the Alaska Department of Environmental Conservation, has developed a Quality Assurance Project Plan and standardized field methods to increase the comparability of results among partners. Keeper provides training for volunteers and other Cook Inlet partners on lab, field, and quality assurance methods. In July 2000, Cook Inlet Keeper and partners worked together to create a unified database in Microsoft Access for volunteer-collected data from the Cook Inlet watershed. A new Microsoft Access database is presently being beta tested that will be capable of exporting Citizens' data to STORET. (STORET is a repository for water quality, biological, and physical data and is used by state and federal agencies, universities, and private citizens.)

The Citizens' Environmental Program has collected baseline water quality data since 1996 providing the most comprehensive water quality datasets on Kachemak Bay watersheds. The program is well suited to be expanded into other regions within Alaska. The data are robust enough to provide information on temporal and spatial patterns that will be valuable for comparison in the future. The program has also educated hundreds of people about their natural resources and the impacts we have on our environment and what that means to water quality.

This report aims to increase user confidence in volunteer collected data by identifying the program's strengths mentioned above and by providing recommendations to improve the quality and quantity of volunteer-collected data in Alaska. Based on the analysis of the Kachemak Bay and Anchor River CEMP data, the following recommendations are made:

1. The annual sampling frequency of 16 sites per year is reasonable considering manpower and funding limitations. Prioritize getting five-year, baseline data sets (n=80) on fewer sites than smaller data sets on more sites.
2. State explicitly what significant change the CEMP is designed to detect. With a five-year baseline dataset, CEMP methods can detect a change of 2°C, 0.25 pH units, and 5% saturation of dissolved oxygen when compared to another five-year data set.
3. Temperature is related to most other water quality parameters so having extensive temperature data is a good investment. Deploy continuous temperature loggers in downstream sites during the summer months on as many streams as possible. Volunteers should download these data during their bimonthly site visits.
4. Change turbidity method to one that has a higher maximum range. Consider the Nephelometric method (2130) from *Standard Methods for the Examination of Water and Wastewater, 19th Edition 1995*. This method will require that volunteers bring their samples to a common place within 24 hours of sampling to share the use of a turbidity meter.
5. Upgrade orthophosphate and nitrate-nitrogen methods to ones with lower detection limits. Consider the Ascorbic Acid method (8048) for orthophosphate from *Hach Water Analysis Handbook* adapted from *Standard Methods for the Examination of Water and Wastewater, 19th Edition. 1995,* and the Cadmium Reduction method (8192) from *Hach Water Analysis Handbook* or CHEMetrics Nitrate Test Kit (Cat. No. K-6902) for nitrate-nitrogen. Ascorbic Acid and Cadmium Reduction methods will require that volunteers bring their samples to a common place within 24 hours of sampling to share the use of a spectrophotometer.

6. Continue colorimetric pH method as a quality control check on the Hanna Meter.
7. Coordinate with USGS to establish a stage gauging station or discharge station on smaller Kachemak Bay watershed streams, like Diamond Creek.
8. Measure flow along with water quality data to improve interpretability of turbidity and conductivity data and to make these data more useful for developing Total Maximum Daily Loads (TMDLs). Consider the Discharge Current Meter method with AA and pygmy velocity meters or the Global Flow Probe Velocity Meter, Global Water Instrumentation Inc. (Cat. No. FP101 & FP102) at downstream sites.
9. Provide volunteer monitors with summary statistics of data from their site if previous data have been collected. Encourage volunteers to perform and document a replicate analysis if they encounter outliers to verify their measurement.
10. Secure long-term funding for volunteer coordinators to recruit and train volunteers, manage data and supplies, and provide quality assurance.

ACKNOWLEDGEMENTS

First and foremost, Cook Inlet Keeper must express its deepest appreciation to the more than 450 dedicated citizens who have taken the time to attend volunteer training sessions and who have braved often adverse weather conditions to collect and analyze water quality samples from Cook Inlet streams and bays. In addition, Keeper thanks its volunteer-based Technical Advisory Committee and Citizens Advisory Panel for their time and effort in developing and guiding the Project. Special thanks goes to Technical Advisory Committee members Steve Frenzel and Bob Ourso of the U.S. Geological Survey.

Keeper thanks the U.S. Environmental Protection Agency, the Alaska Department of Environmental Conservation and the U.S. Geological Survey for their continued guidance and cooperation in developing and refining this program.

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APPENDIX I

CEMP Analytical Methods

Water Temperature

Armored alcohol-filled thermometer factory calibrated against thermometer standards traceable to N.I.S.T. (The National Institute of Standards and Technology); Model 545; range -5.0°C to +45.0°C in 0.5°C increments -- LaMotte Chemical Products; Cat. No. 1066.

Turbidity

Water turbidity is tested by one or both of the following methods:
1) Water with a depth of greater than 3 meters is tested using a 20 cm diameter Secchi disk with black and white quadrants attached to a 30 meter calibrated stretch-resistant line marked at 0.5 meter intervals -- LaMotte Chemical Products; Cat No. 0171-CL.
2) Shallow water is tested using turbidity columns (Jackson Turbidity Tube); range 0 JTU to 200+ JTUs in 5 JTU increments; accuracy ± 3 Jackson Turbidity Units (JTUs) -- LaMotte Chemical Products Cat No. 7519 and Standard Turbidity Reagents; Cat No. 7520.

Dissolved Oxygen

Volunteers use precision dissolved oxygen two phase (fixation and titration) test kits; azide modification of Winkler titration method; range 0 to 20 mg/l in 0.1 mg/l increments; reagents sufficient for 25 tests at 0 to 20 mg/l range -- LaMotte Chemical Products; Cat. No. 5856/XDO.

Salinity (estuarine sites only)

Specific gravity/salinity is tested using a LaMotte hydrometer with 500-ml hydrometer jar; range l.0000 to 1.0700 specific gravity in 0.0005 increments (0 to 42ppt salinity) – LaMotte Chemical Products; Cat. Nos. 3-0011 (hydrometer) and 3-0024 (jar). LaMotte 1.000/1.070.

Conductivity

Hanna "4-in-1" Water Test Meter; range from 0 to 1999 micro-seimens/cm in 1 micro-seimens/cm increments; Hanna Combo 98129; range 0 to 3999 uS/cm in 1 uS/cm increments.

pH

pH is tested and verified in both of the following ways:
1) Octet color comparator test kits; wide range 3.0 to 10.0 pH units in 1.0 unit increments and narrow range 7.2 to 8.6 pH units in 0.2 unit increments; accuracy ±0.2 pH units -- LaMotte Chemical Products; Cat. Nos. 2117/P-3100 (3.0 to 10.0 units) and 2110/P-CR (7.2 to 8.6 units).
2) Hanna "4-in-1" Water Test Meter; Hanna Combo 98129 and 98130 meters; wide range 0.0 to 14.0 pH.-- Hanna Instruments EN 50081-1.

Orthophosphate

Monitors use ascorbic acid reduction and an Octet Comparator to screen for orthophosphate from 0 to 2.0ppm – LaMotte Chemical Products; Cat. No. 3121.

Nitrate-Nitrogen

Volunteers use a two tablet reagent Octa-Color Slide system to screen for nitrate-nitrogen from 0 to 15ppm (0 to 66ppm as nitrate) – LaMotte Chemical Products; Cat. No.3354.

Color

Water color is monitored by describing the apparent color of sample water and comparing the color to numbered color chips in the Borger Color System booklet – LaMotte Chemical Products; Cat. No. 1580.

Fecal and Total Coliform Bacteria

Analysis employs the Coliscan screening technique developed by Micrology Laboratories.[1]

Methods References Table:

Parameter	Method	Reference	Modification
Temperature	Thermometer	(a)	Alcohol-filled thermometer
Turbidity	Secchi Disk Depth	(h)	
	Jackson Turbidity	(c)	
Dissolved Oxygen	Azide Modified Winkler Titration	(e)	Micro method; 60 ml bottle
Salinity	Gravimetric	(g)	
Conductivity	Electrometric	(b)	
pH	Colorimetric	(c)	
	Electrometric (Hanna)	(b)	
Orthophosphate	Colorimetric	(j)	
Nitrate-Nitrogen	Colorimetric	(c)	
Apparent Color	Borger Color System	(c)	
Fecal Coliforms (Total & E. coli)	"Coliscan"	(k)	

(a) U.S. EPA. 1979 (revised 1983). Methods for Chemical Analysis of Water and Wastes. EPA-600/4-79-020. Method 170.1. Environmental Monitoring and Support Laboratory, Cincinnati, OH. ***In*** The Friends of Casco Bay. 1995 Quality Assurance Project Plan. Pg. 15. Friends of Casco Bay, South Portland, ME.

(b) Hanna Instruments. 1996. The Water Analysis Handbook. Hanna Instruments, Woonsocket, RI. ***And*** manufacturer's instructions.

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(g) U.S. EPA. 1993. Volunteer Estuary Monitoring: A Methods Manual. EPA-842-B-93-004. USEPA, Washington, D.C. ***And,*** Campbell, G. & Wildberger, S. 1992. The Monitor's Handbook. LaMotte, Chestertown, MD.

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(j) U.S. EPA. 1997. Volunteer Stream Monitoring: A Methods Manual. EPA-841-B-97-004. USEPA, Washington, D.C. ***And,*** Campbell, G. & Wildberger, S. 1992. The Monitor's Handbook. LaMotte, Chestertown, MD. ***And*** manufacturer's instructions.

(k) Micrology Laboratories, LLC. 1996. Coliscan® for Coliform and Fecal Coliform Testing. Micrology Laboratories, Goshen, IN.

(l) Environment and Natural Resources Institurte. E. B. Major. *University of Alaska Anchorage* 707 A Street, Suite 101, Anchorage, AK 99501

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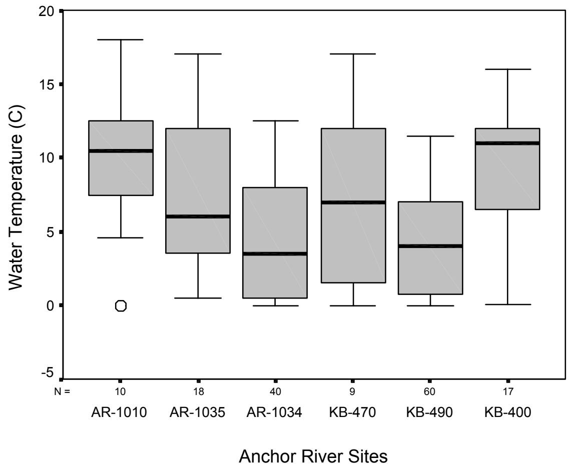
[1] Micrology Laboratories LLC. 1996. Coliscan ™**Easygel**™- *Procedures & Detection of Waterborne Coliforms and Fecal Coliforms*, 6p. RCS, Goshen, Indiana.

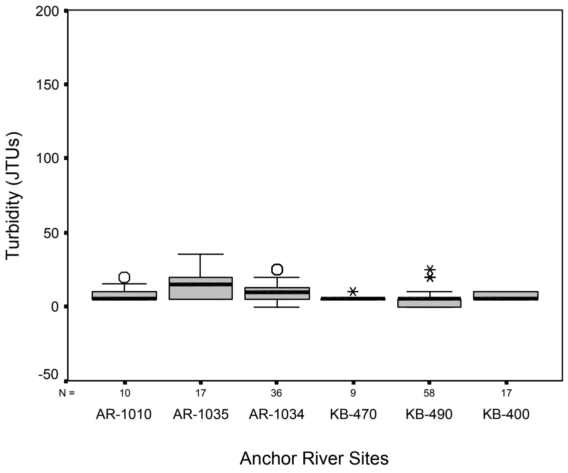
APPENDIX II

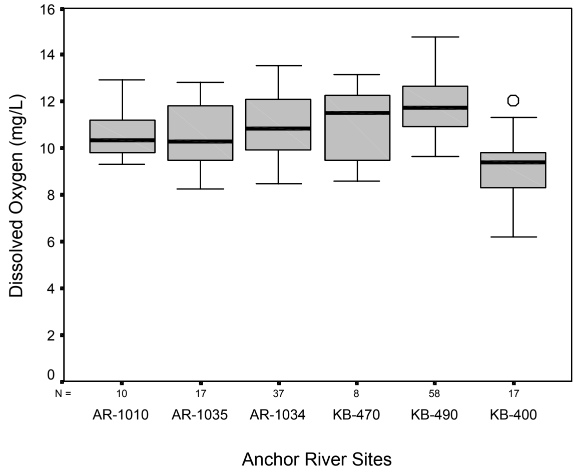
Boxplots have been generated for all sites with more than 5 site visits. Plots are based on the median, quartiles, and extreme values. The box represents the range which contains 50% of values. The whiskers are lines that extend from the box to the highest and lowest values, excluding outliers. Outlier (circles) are cases with values between 1.5 and 3 box lengths from the upper or lower edge of the box. Extremes (stars) are cases with values more than 3 box lengths from the upper or lower edge of the box. A line across the box indicates the median.

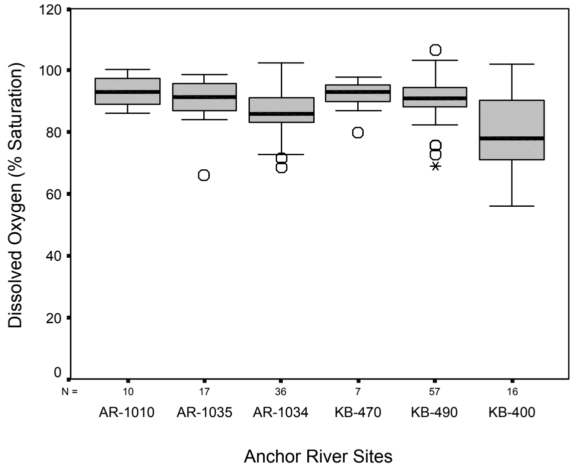
Data are organized by watershed for the freshwater sites and by location within Kachemak Bay for the estuarine sites. Sites are ordered from downstream to upstream in the watersheds and from down current to up current in the Bay.

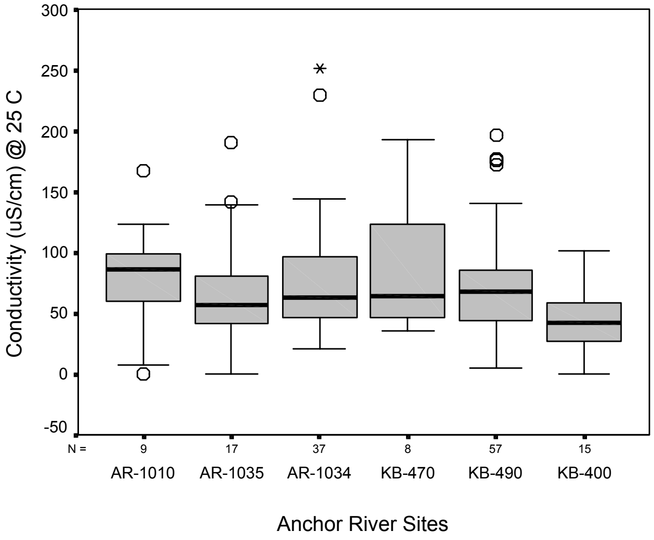
Anchor River Watershed

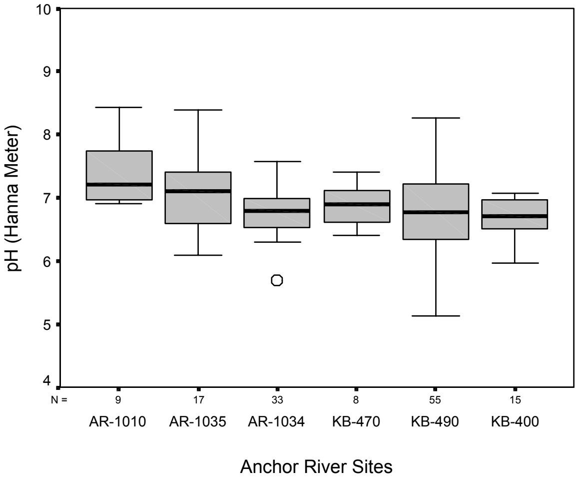


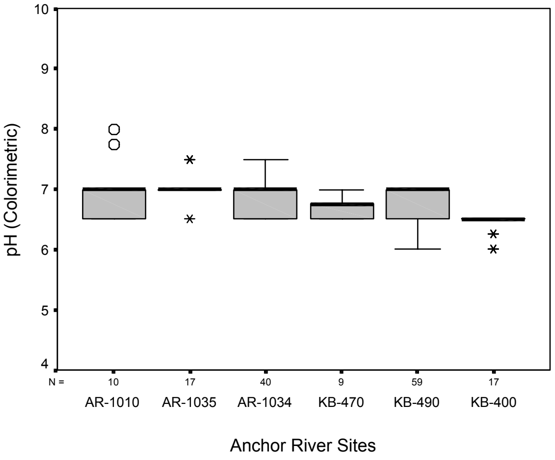







Conductivity (uS/cm) @ 25 C
300
250
200
150
100
50
0
-50
N = 9 17 37 8 57 15
AR-1010
AR-1035
AR-1034
KB-470
KB-490
KB-400
Anchor River Sites


pH (Hanna Meter)
10
9
8
7
6
5
4
N = 9 17 33 8 55 15
AR-1010
AR-1035
AR-1034
KB-470
KB-490
KB-400
Anchor River Sites


pH (Colorimetric)
10
9
8
7
6
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4
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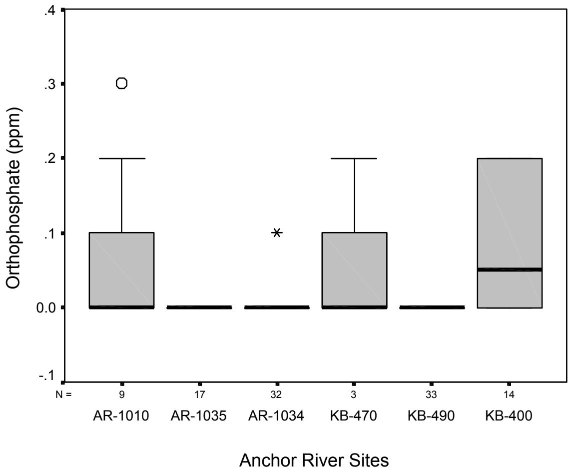
Anchor River Sites


Orthophosphate (ppm)
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.2
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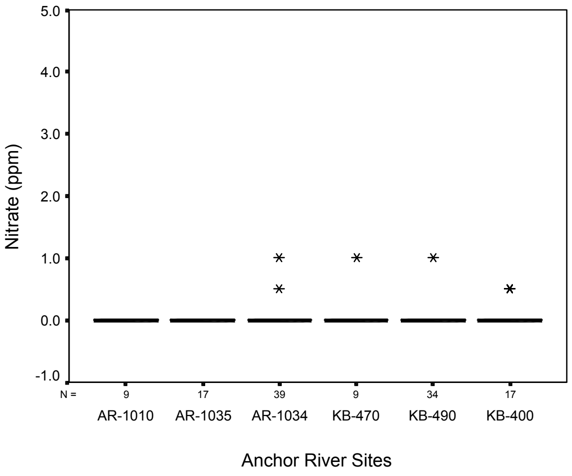
KB-400
Anchor River Sites


Nitrate (ppm)
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2.0
1.0
0.0
-1.0
N = 9 17 39 9 34 17
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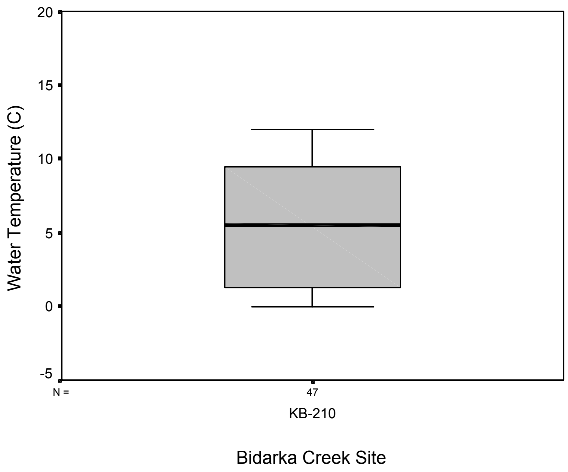
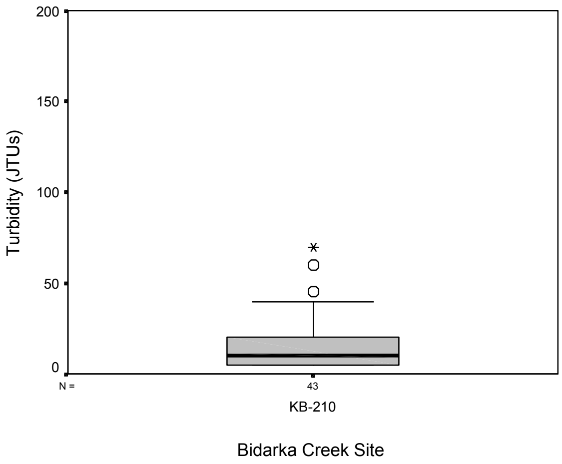
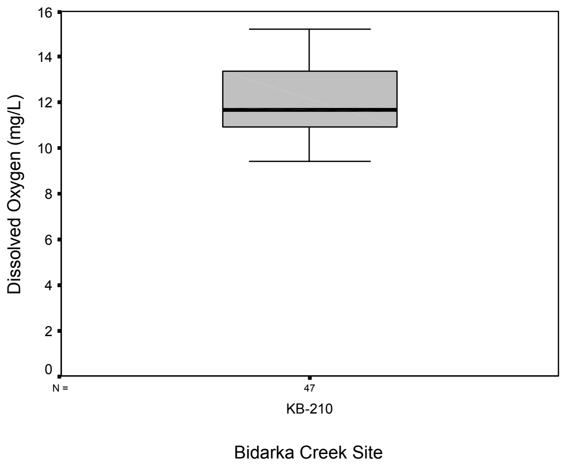
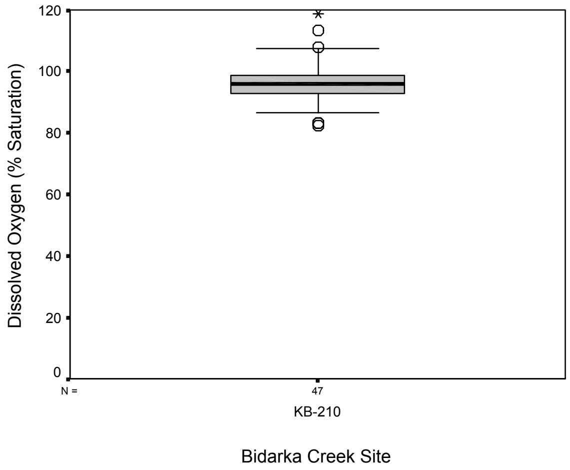
AR-1034
KB-470
KB-490
KB-400
Anchor River Sites

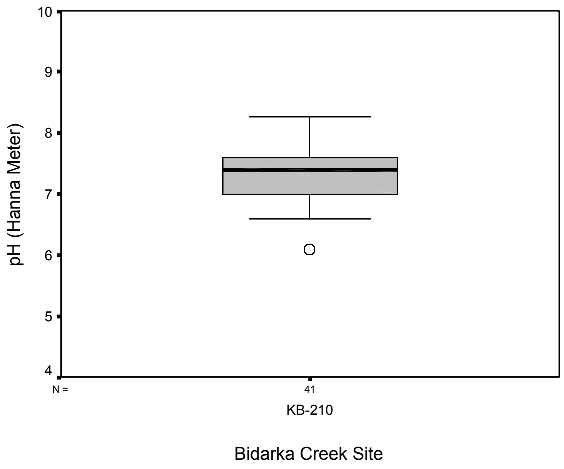
Bidarka Creek Watershed

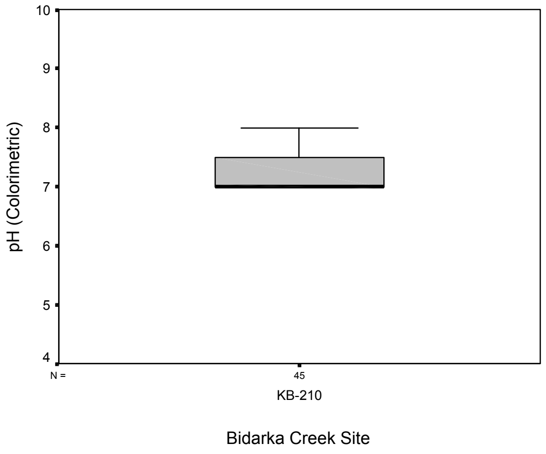


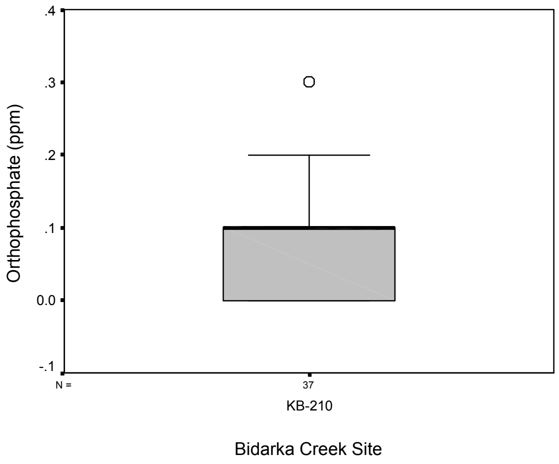


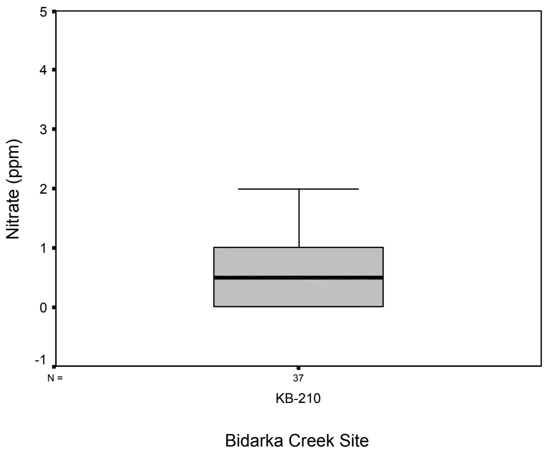




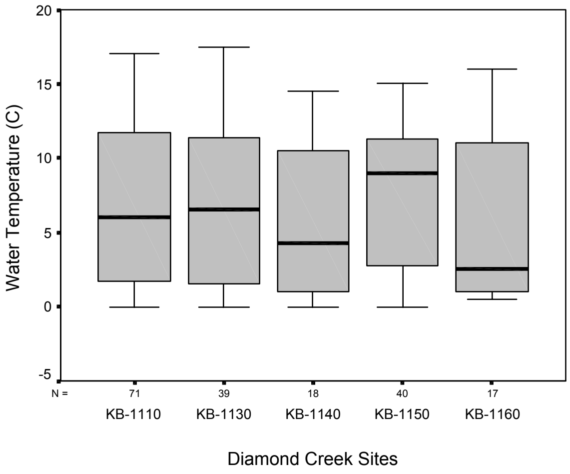

10
9
8
7
6
5
4
pH (Hanna Meter)
N =
41
KB-210
Bidarka Creek Site

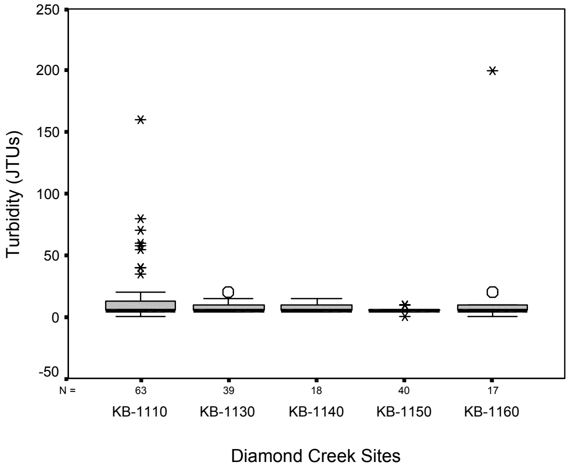

10
9
8
7
6
5
4
pH (Colorimetric)
N =
45
KB-210
Bidarka Creek Site

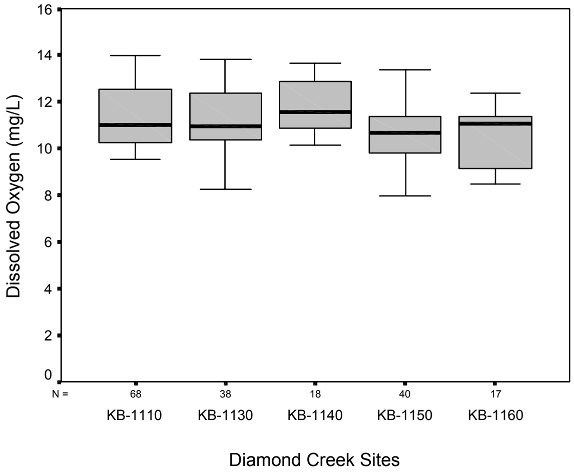

.4
.3
.2
.1
0.0
-.1
Orthophosphate (ppm)
N =
37
KB-210
Bidarka Creek Site

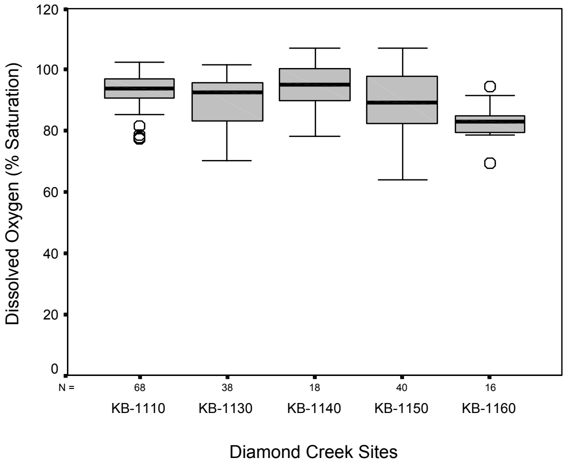

5
4
3
2
1
0
-1
Nitrate (ppm)
N =
37
KB-210
Bidarka Creek Site

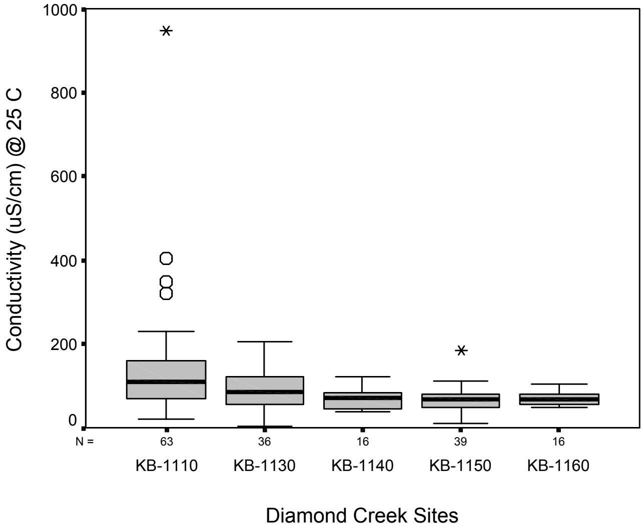
Diamond Creek Watershed

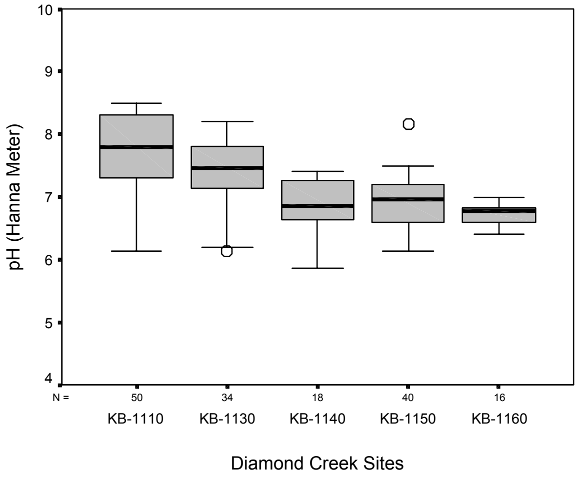


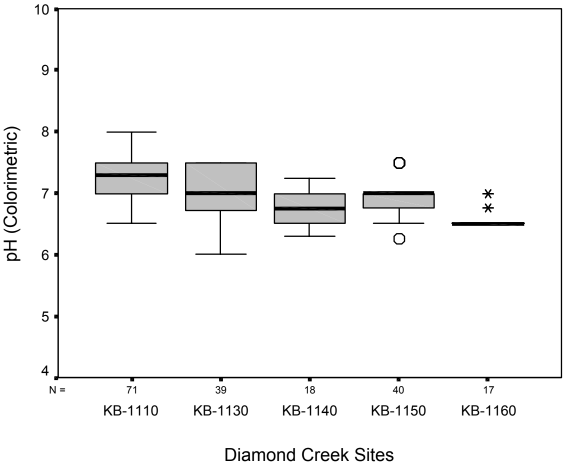


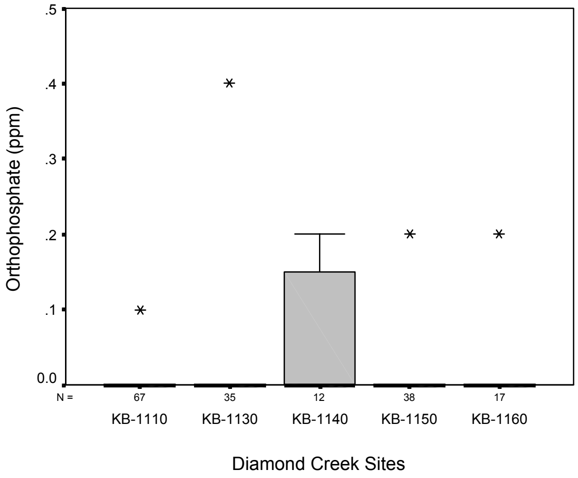


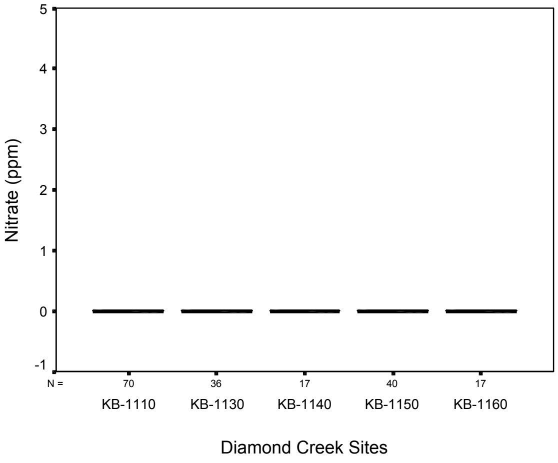




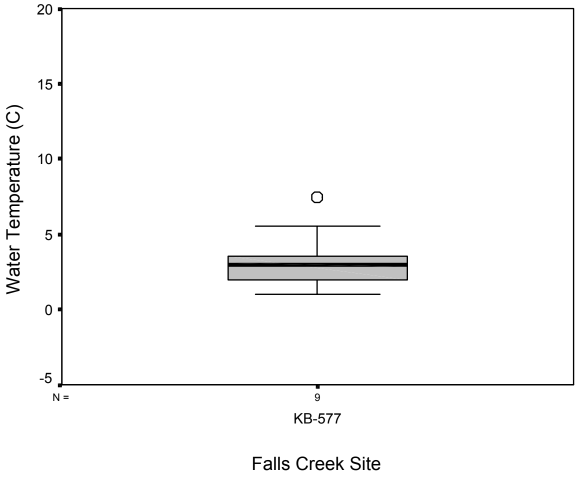

pH (Hanna Meter)
10
9
8
7
6
5
4
N =
50
34
18
40
16
KB-1110
KB-1130
KB-1140
KB-1150
KB-1160
Diamond Creek Sites

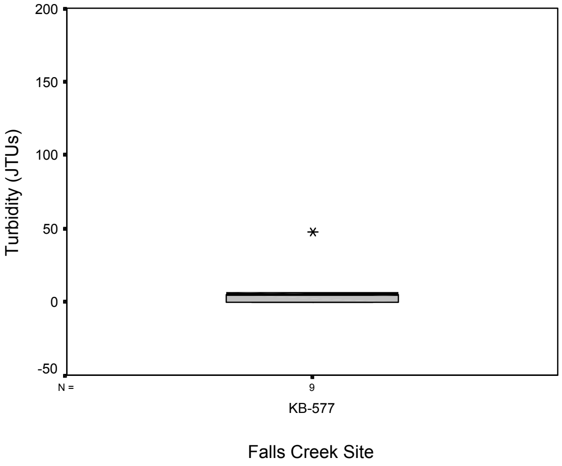

pH (Colorimetric)
10
9
8
7
6
5
4
N =
71
39
18
40
17
KB-1110
KB-1130
KB-1140
KB-1150
KB-1160
Diamond Creek Sites

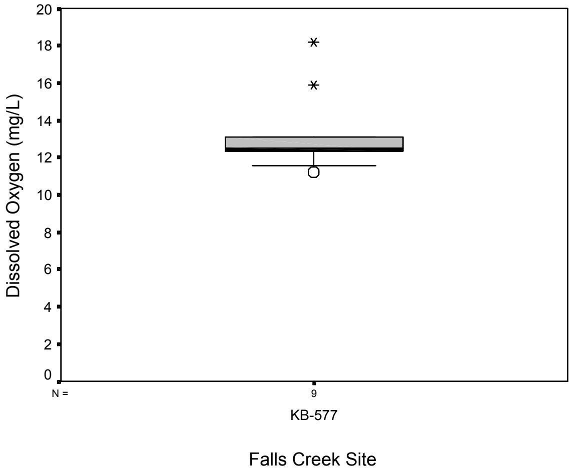

Orthophosphate (ppm)
.5
.4
.3
.2
.1
0.0
N =
67
35
12
38
17
KB-1110
KB-1130
KB-1140
KB-1150
KB-1160
Diamond Creek Sites

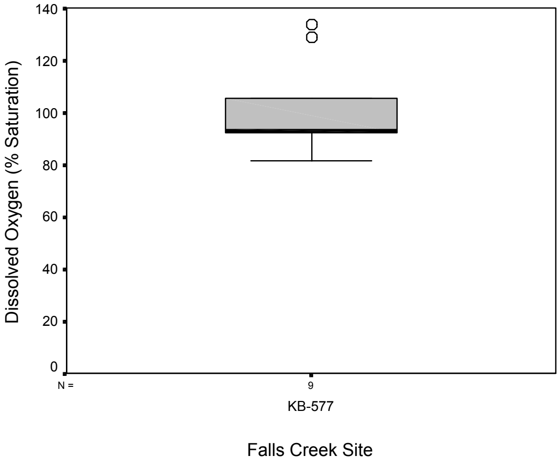

Nitrate (ppm)
5
4
3
2
1
0
-1
N =
70
36
17
40
17
KB-1110
KB-1130
KB-1140
KB-1150
KB-1160
Diamond Creek Sites

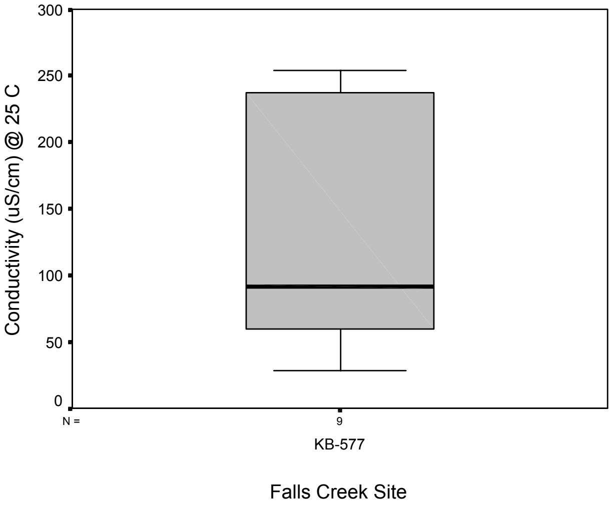
Falls Creek Watershed

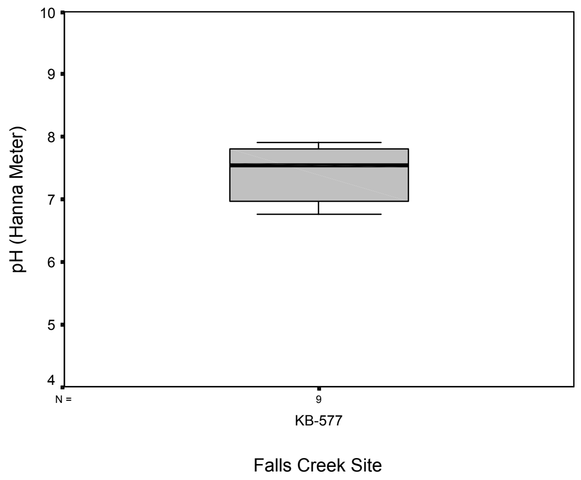


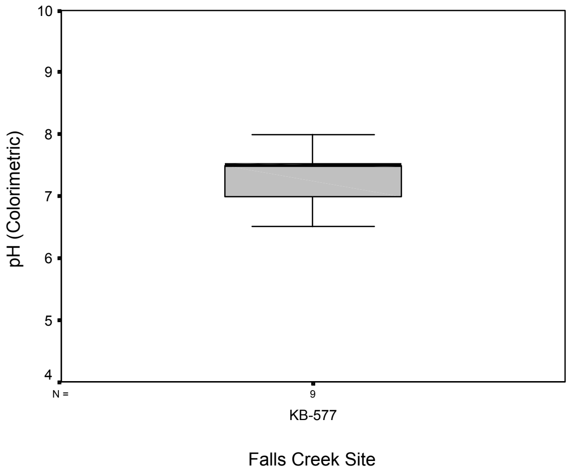


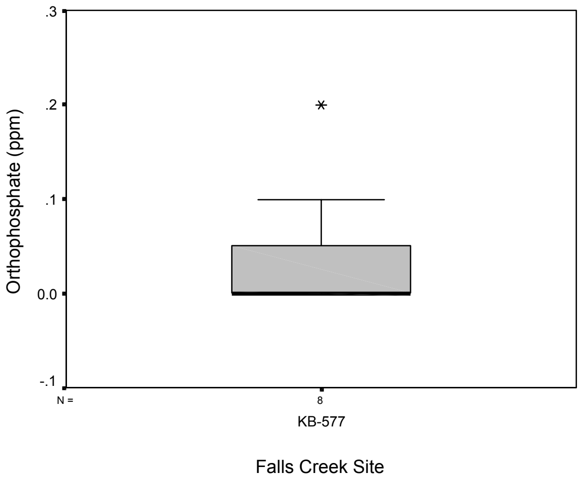


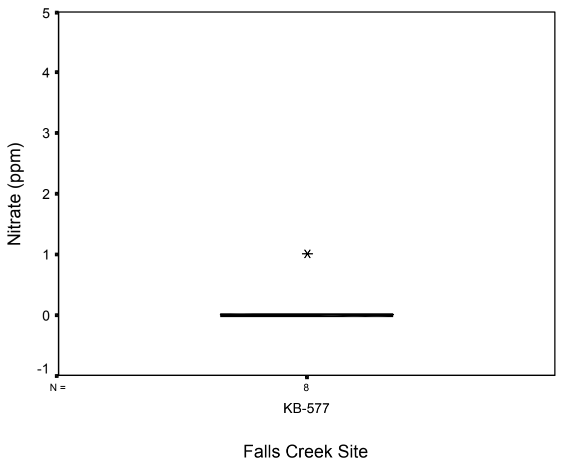




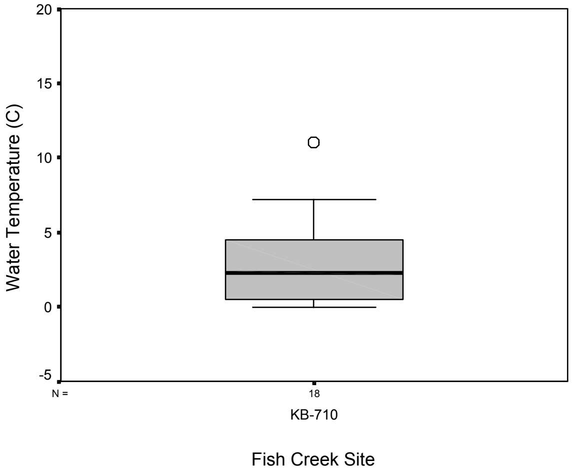

pH (Hanna Meter)
10
9
8
7
6
5
4
N =
9
KB-577
Falls Creek Site

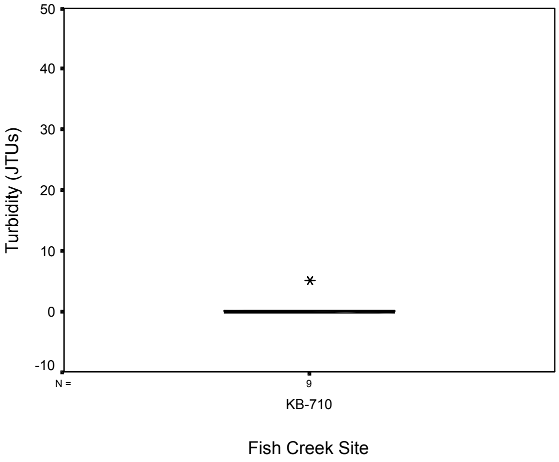

pH (Colorimetric)
10
9
8
7
6
5
4
N =
9
KB-577
Falls Creek Site

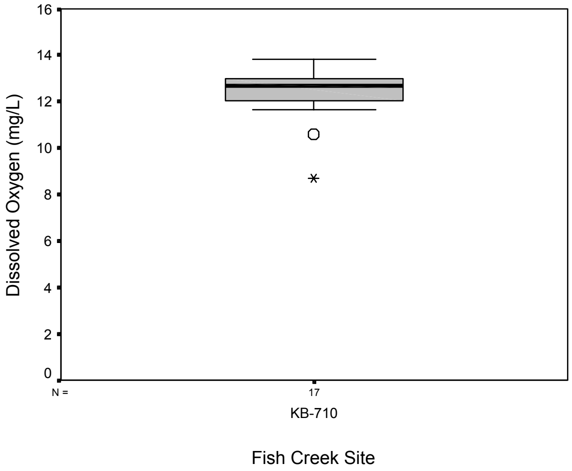

Orthophosphate (ppm)
.3
.2
.1
0.0
-.1
N =
8
KB-577
Falls Creek Site

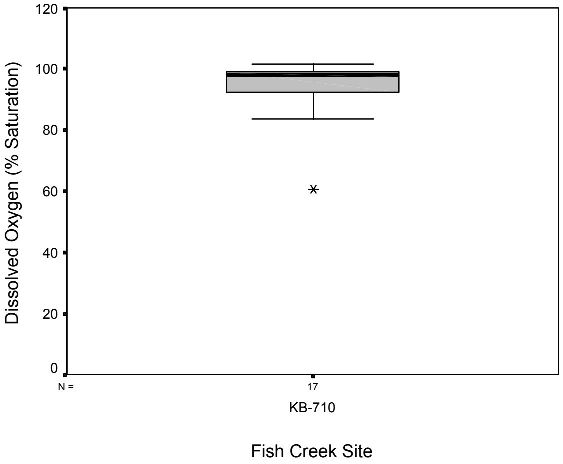

Nitrate (ppm)
5
4
3
2
1
0
-1
N =
8
KB-577
Falls Creek Site

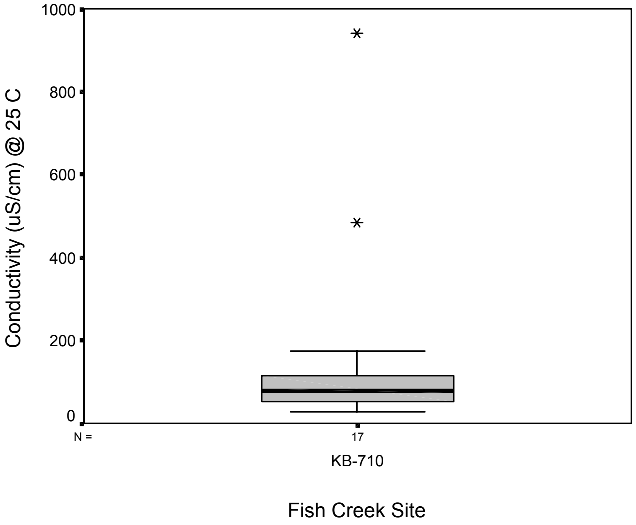
Fish Creek Watershed

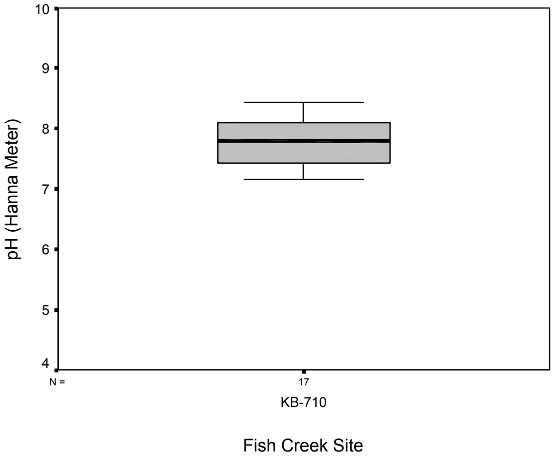


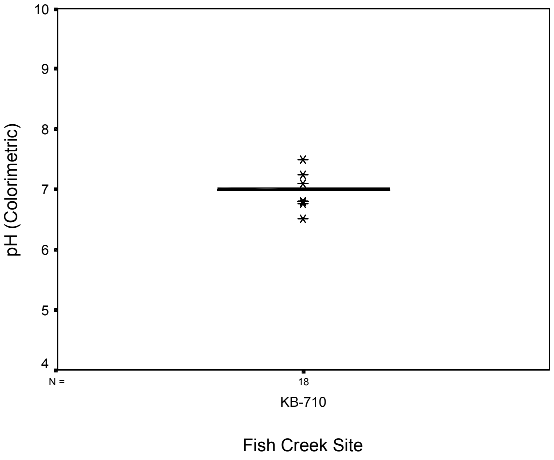


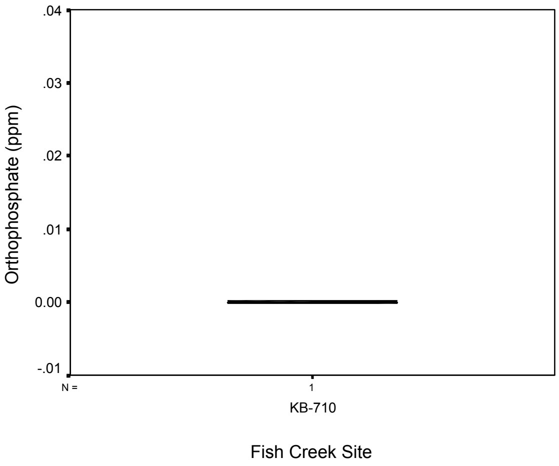


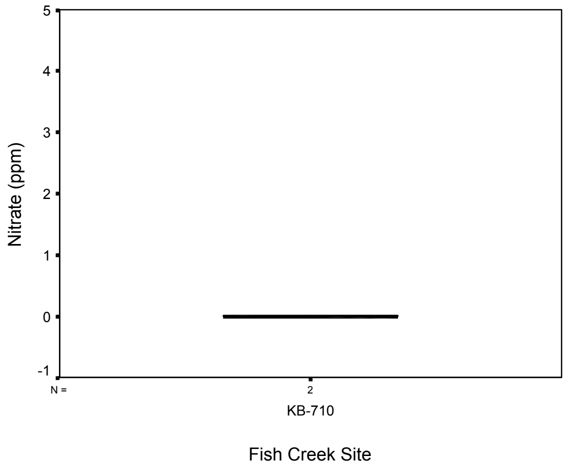




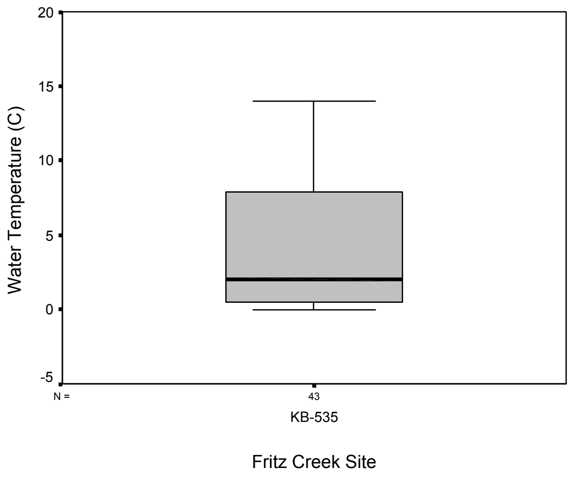

10
9
8
7
6
5
4
pH (Hanna Meter)
N =
17
KB-710
Fish Creek Site

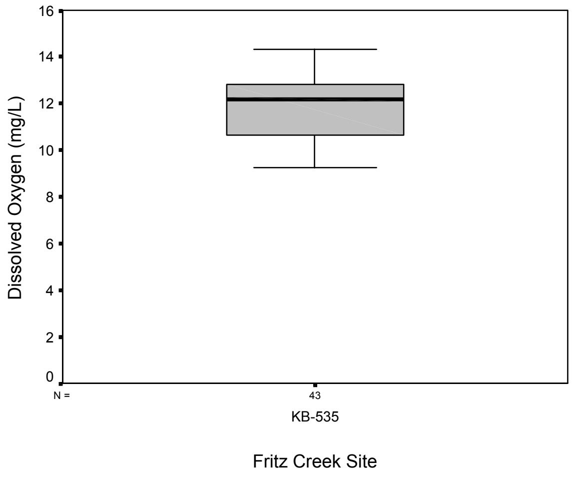

10
9
8
7
6
5
4
pH (Colorimetric)
N =
18
KB-710
Fish Creek Site

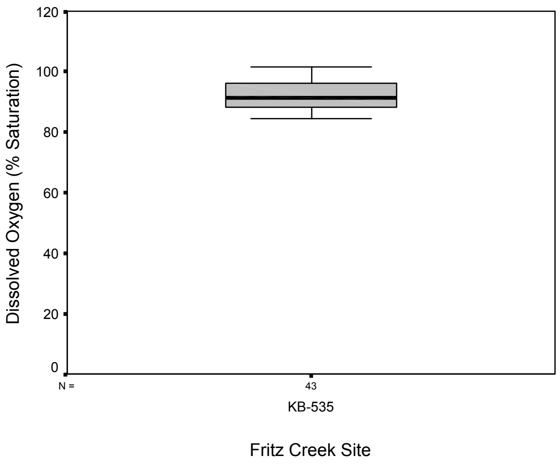

.04
.03
.02
.01
0.00
-.01
Orthophosphate (ppm)
N =
1
KB-710
Fish Creek Site

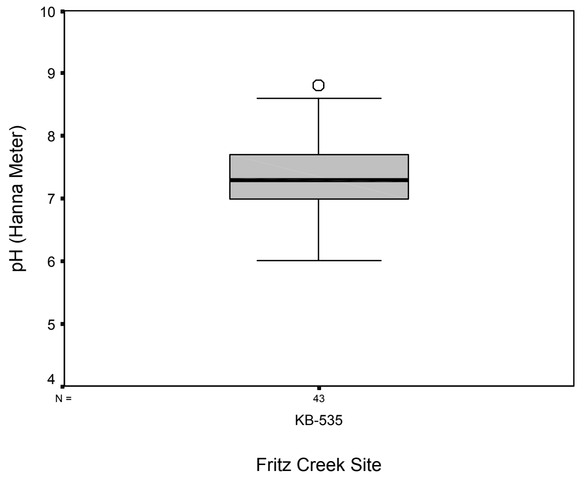

5
4
3
2
1
0
-1
Nitrate (ppm)
N =
2
KB-710
Fish Creek Site

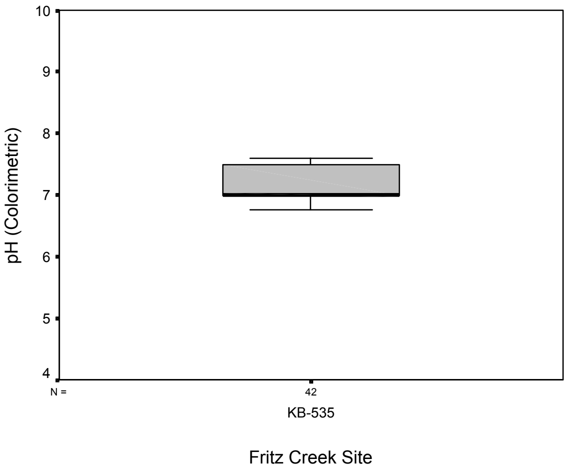
Fritz Creek Watershed

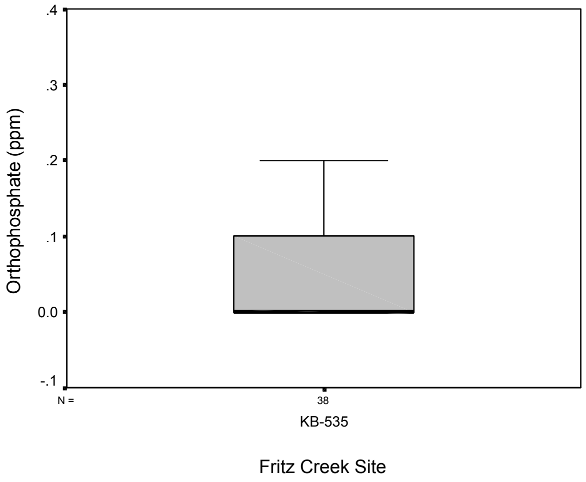


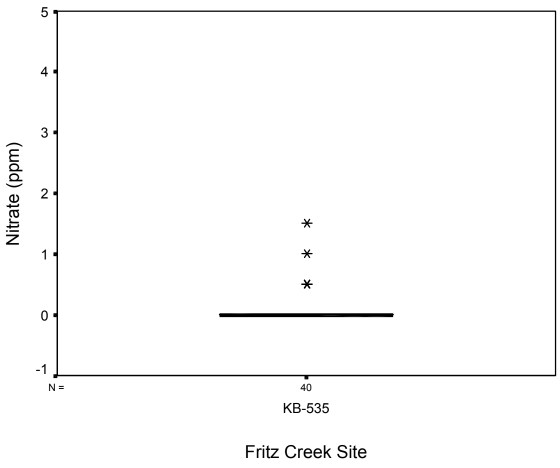




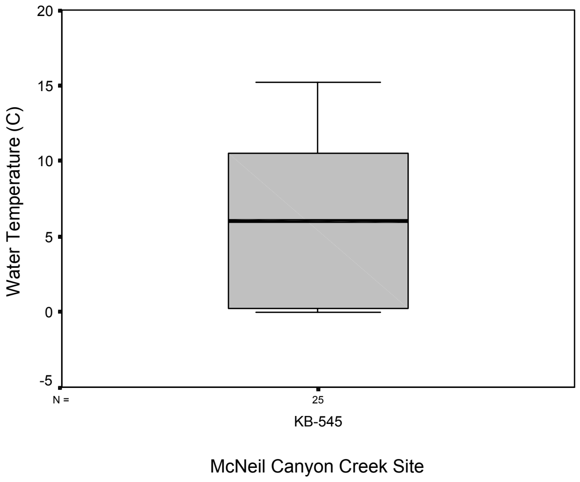

10
9
8
7
6
5
4
pH (Hanna Meter)
N =
43
KB-535
Fritz Creek Site

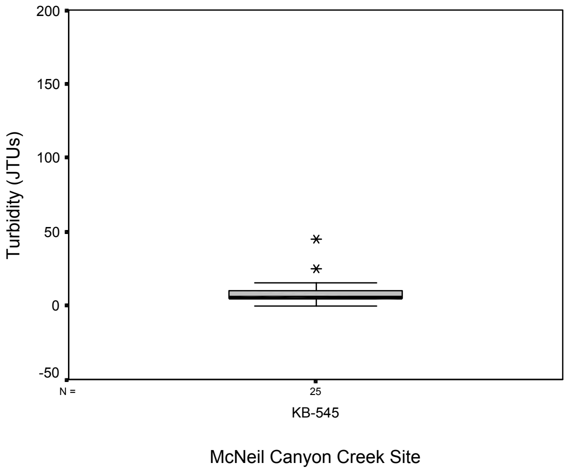

10
9
8
7
6
5
4
pH (Colorimetric)
N =
42
KB-535
Fritz Creek Site

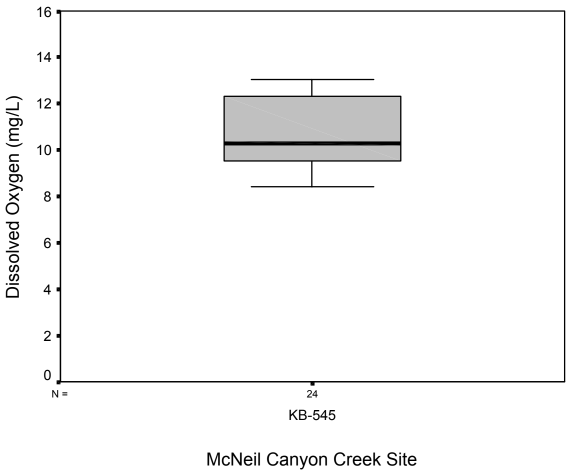

.4
.3
.2
.1
0.0
-.1
Orthophosphate (ppm)
N =
38
KB-535
Fritz Creek Site

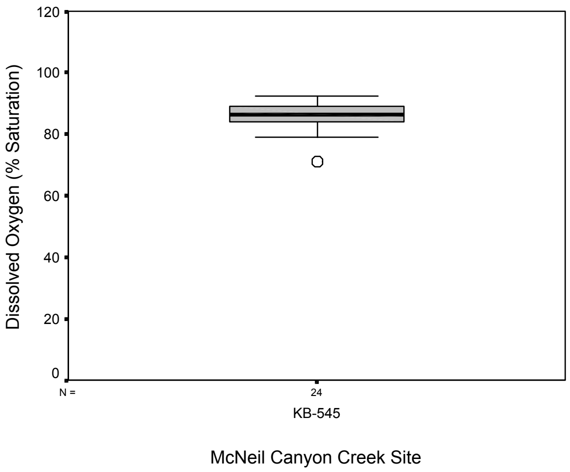

5
4
3
2
1
0
-1
Nitrate (ppm)
N =
40
KB-535
Fritz Creek Site

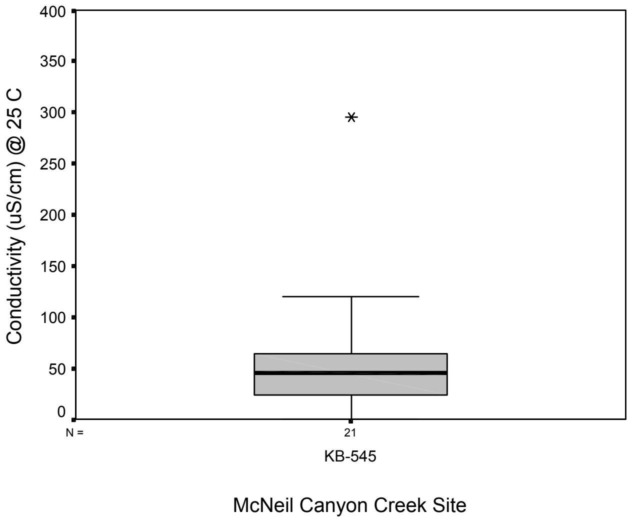
McNeil Canyon Creek Watershed

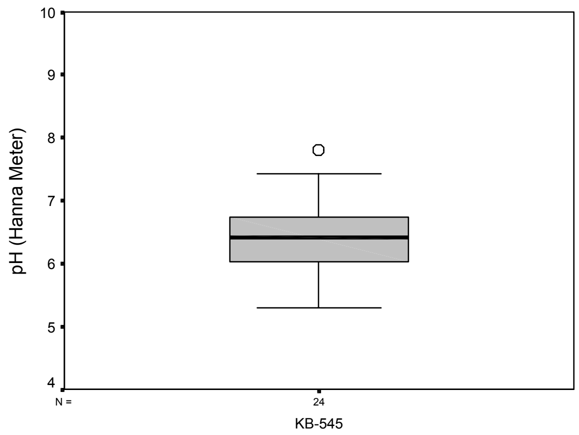




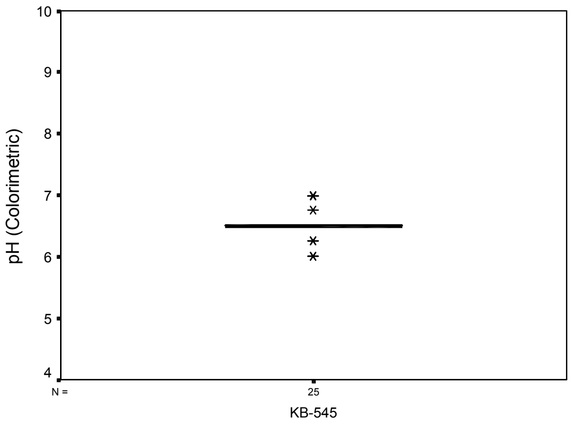




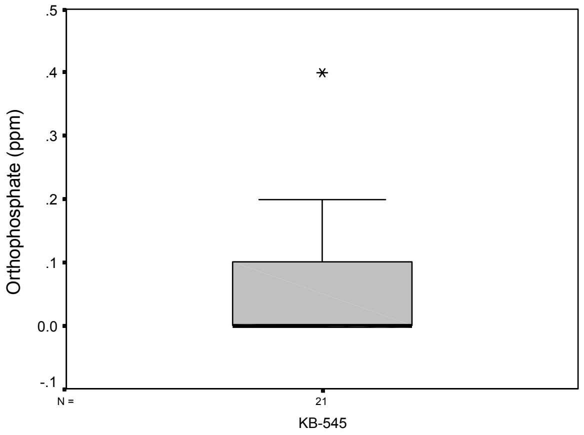




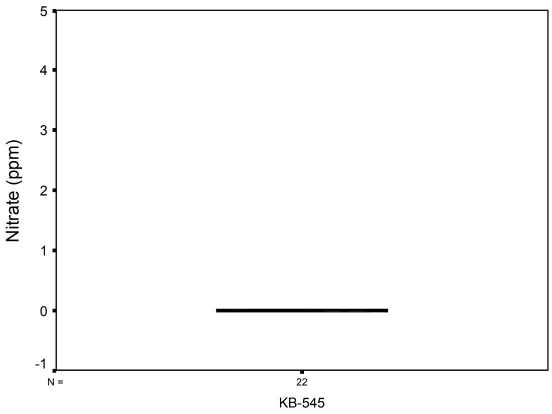
McNeil Canyon Creek Site



McNeil Canyon Creek Site

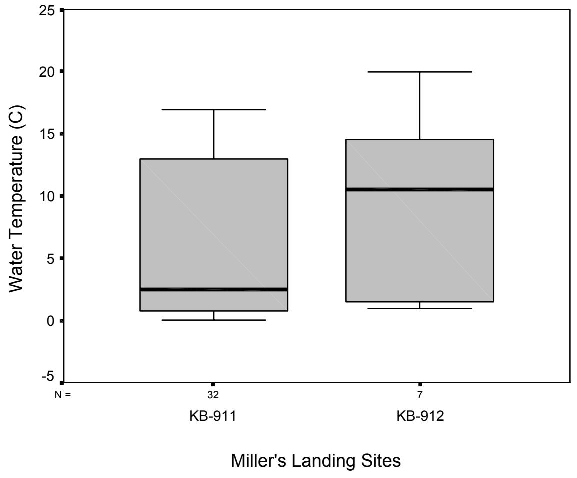


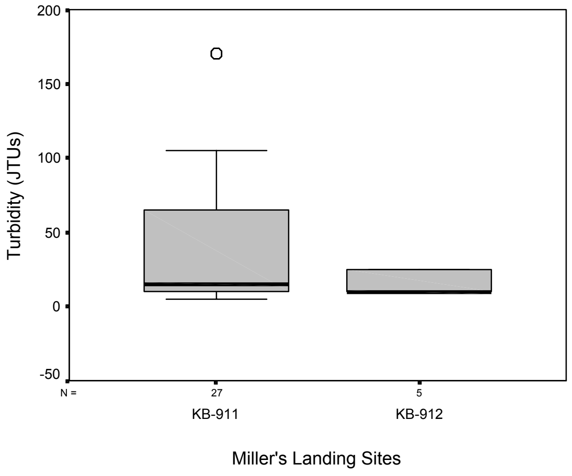
McNeil Canyon Creek Site

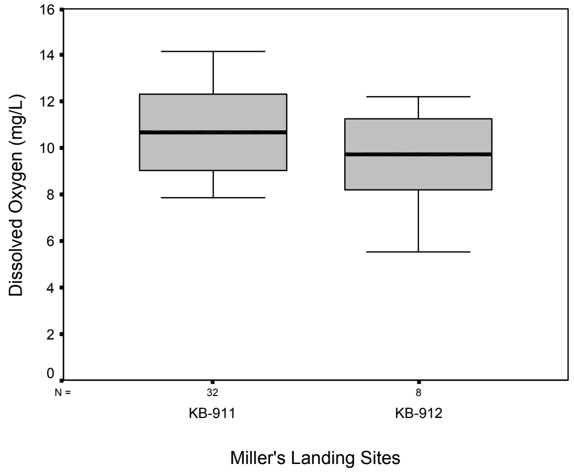


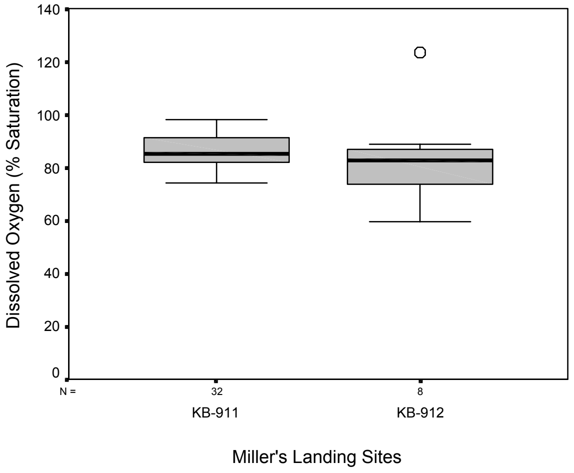
McNeil Canyon Creek Site

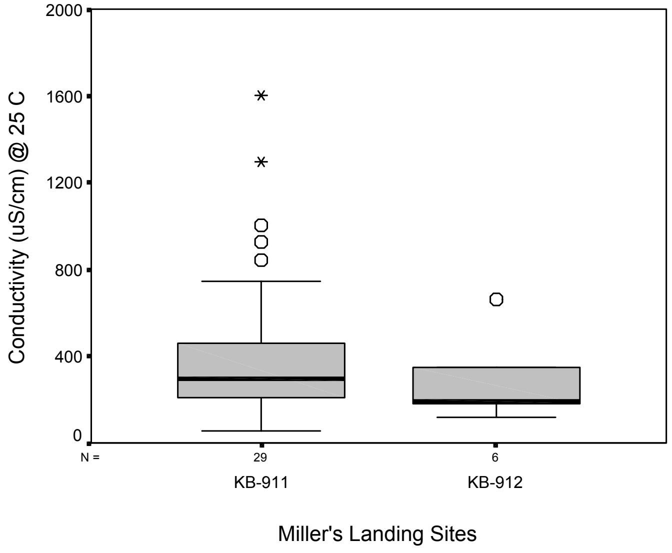
Miller's Landing Watershed

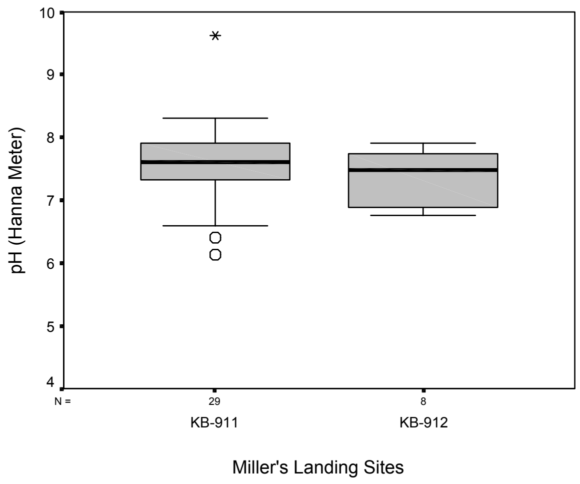




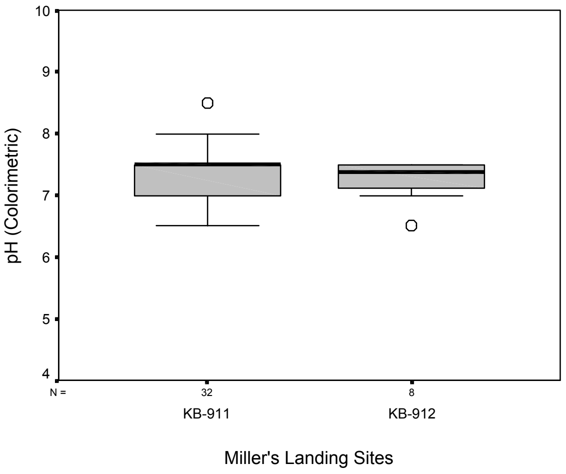




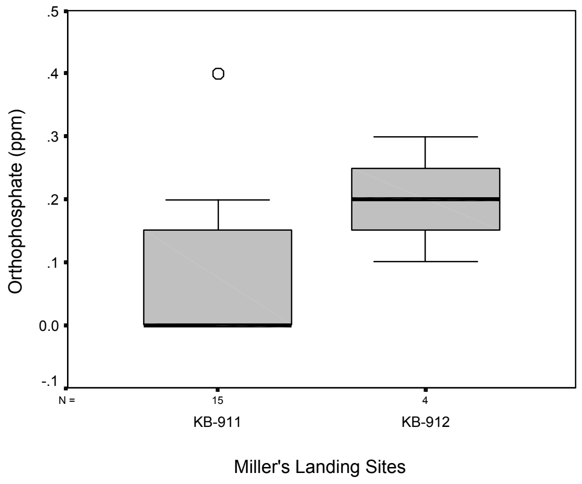




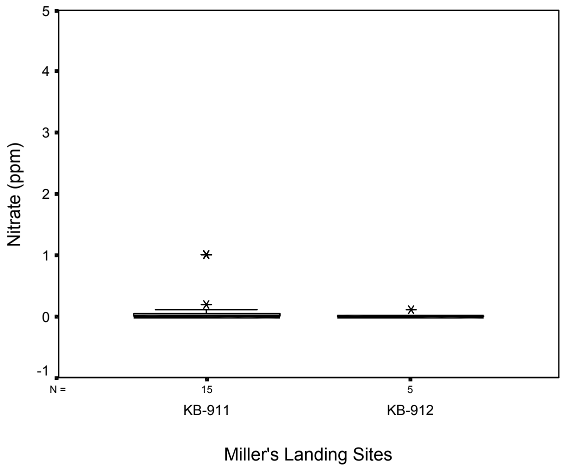
pH (Hanna Meter)
10
9
8
7
6
5
4
N =
29
8
KB-911
KB-912
Miller's Landing Sites



pH (Colorimetric)
10
9
8
7
6
5
4
N =
32
8
KB-911
KB-912
Miller's Landing Sites

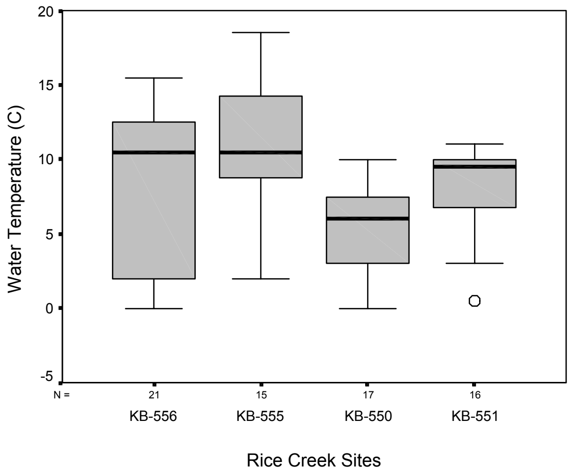


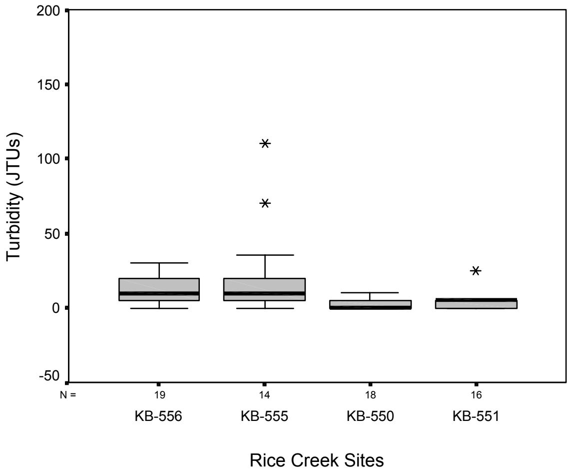
Orthophosphate (ppm)
.5
.4
.3
.2
.1
0.0
-.1
N =
15
4
KB-911
KB-912
Miller's Landing Sites

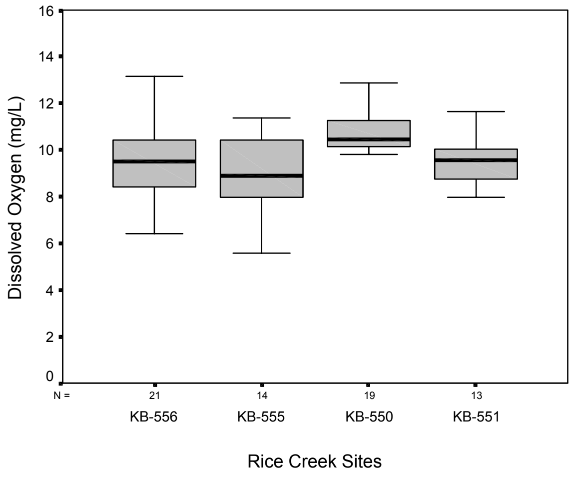


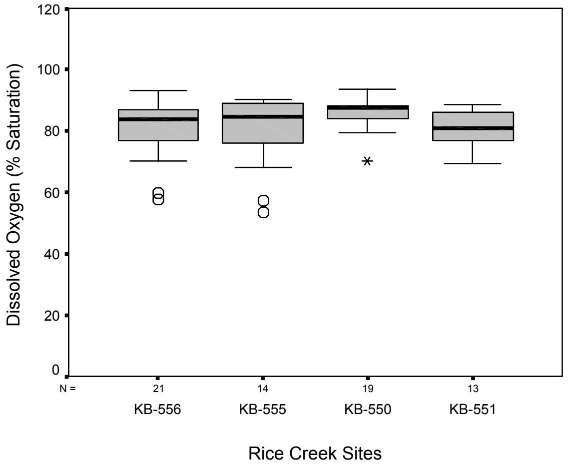
Nitrate (ppm)
5
4
3
2
1
0
-1
N =
15
5
KB-911
KB-912
Miller's Landing Sites

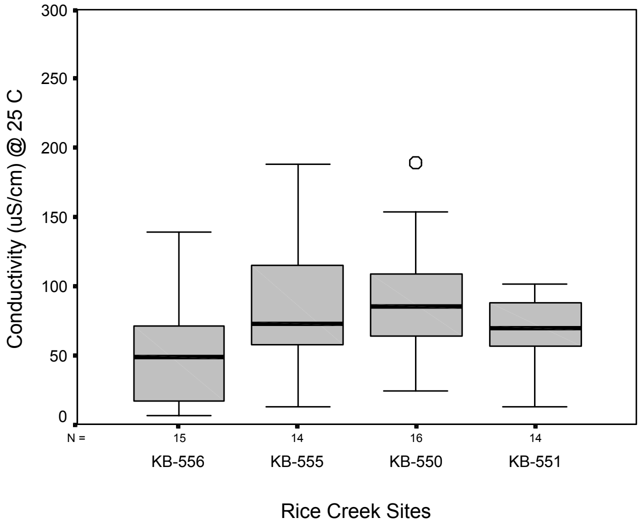
Rice Creek Watershed

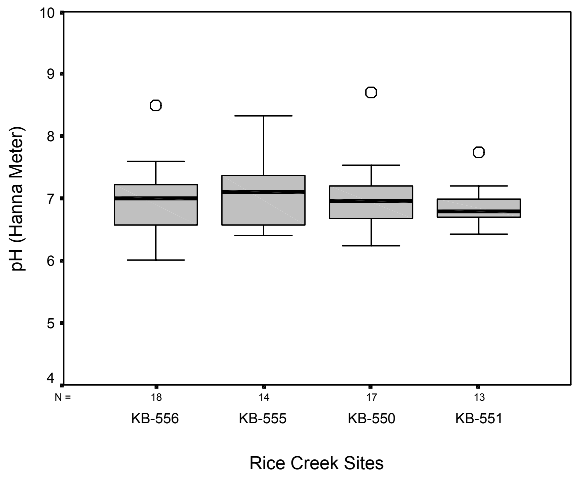


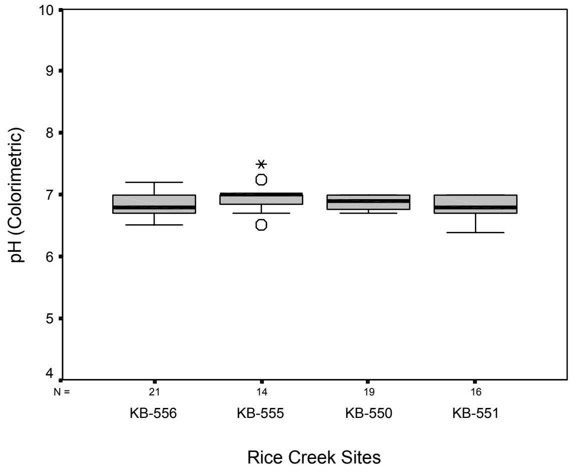


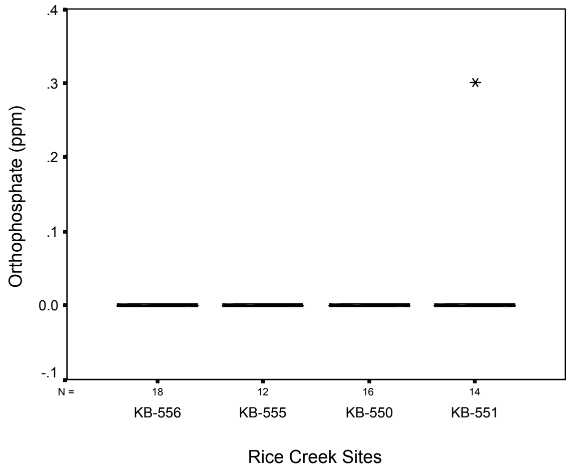


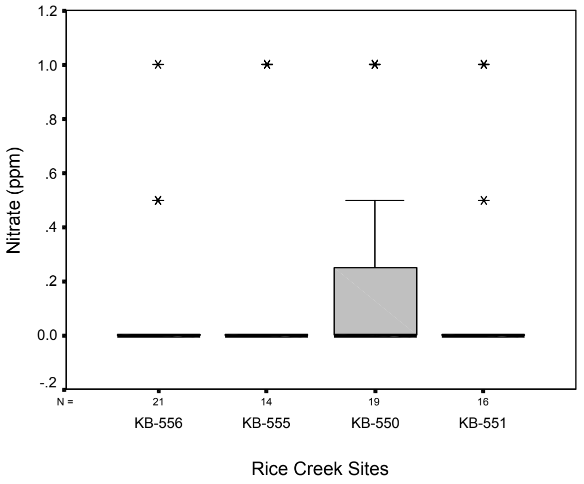




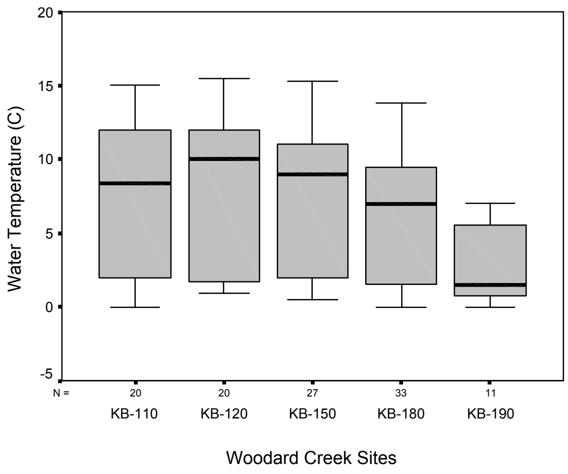

pH (Hanna Meter)
10
9
8
7
6
5
4
N =
18
14
17
13
KB-556
KB-555
KB-550
KB-551
Rice Creek Sites

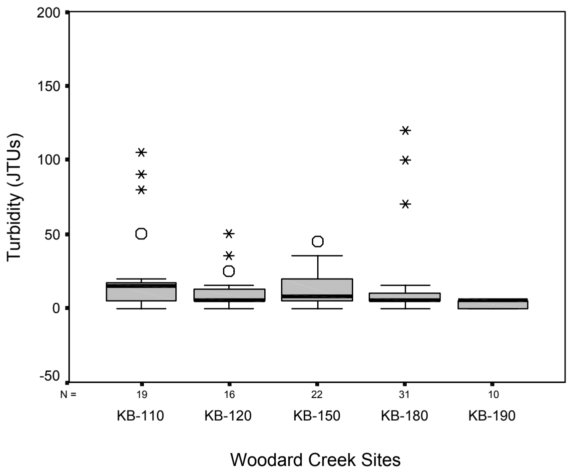

pH (Colorimetric)
10
9
8
7
6
5
4
N =
21
14
19
16
KB-556
KB-555
KB-550
KB-551
Rice Creek Sites

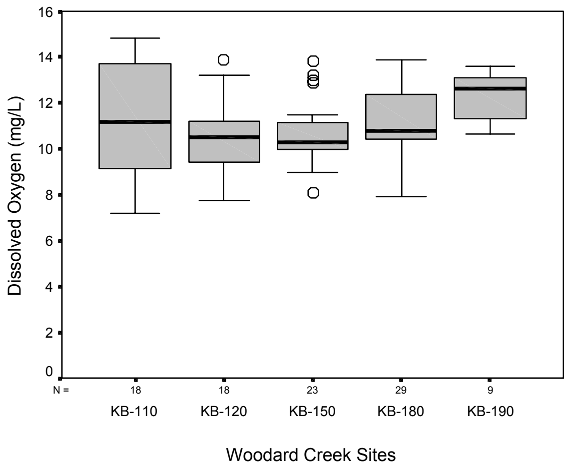

Orthophosphate (ppm)
.4
.3
.2
.1
0.0
-.1
N =
18
12
16
14
KB-556
KB-555
KB-550
KB-551
Rice Creek Sites

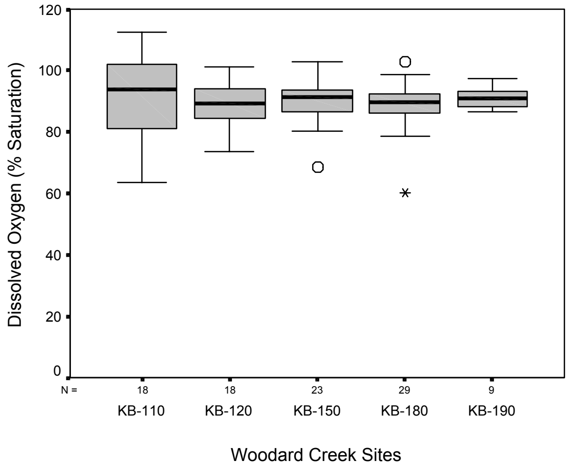

Nitrate (ppm)
1.2
1.0
.8
.6
.4
.2
0.0
-.2
N =
21
14
19
16
KB-556
KB-555
KB-550
KB-551
Rice Creek Sites

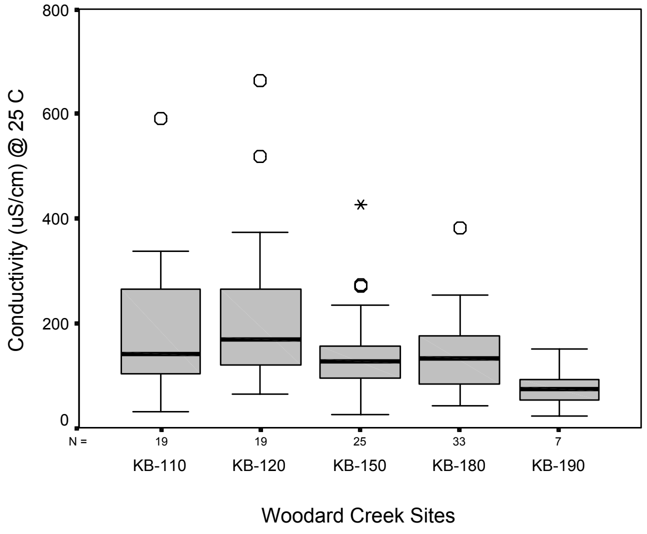
Woodard Creek Watershed

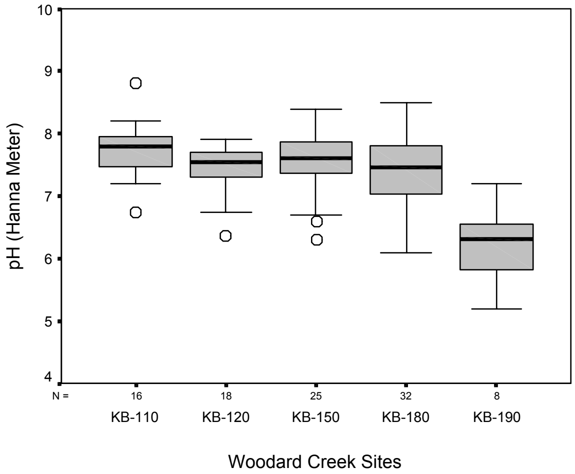


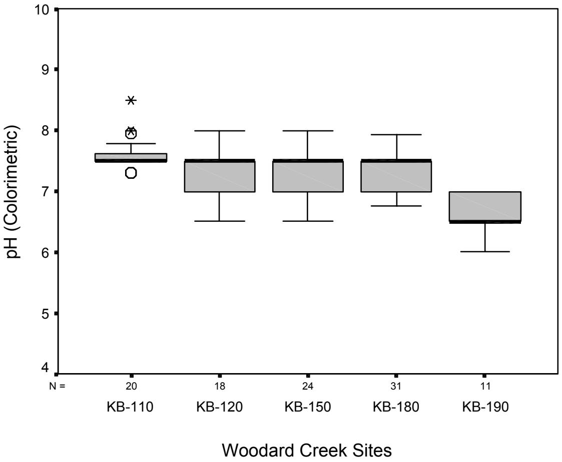


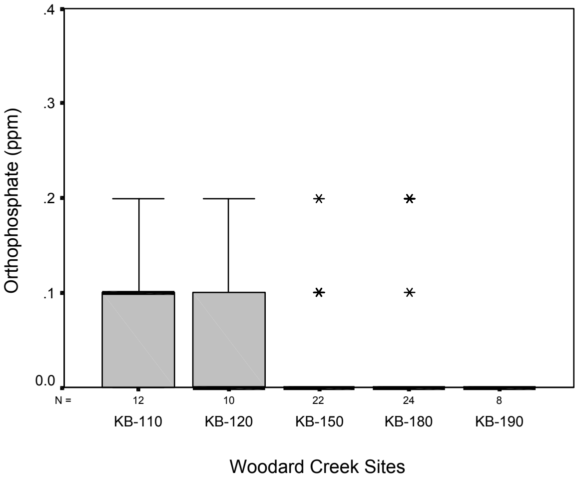


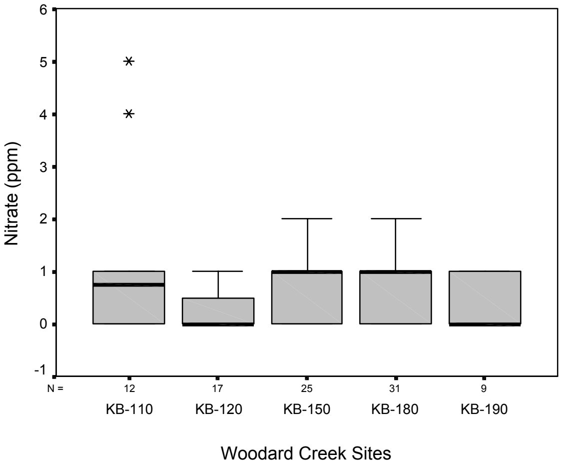




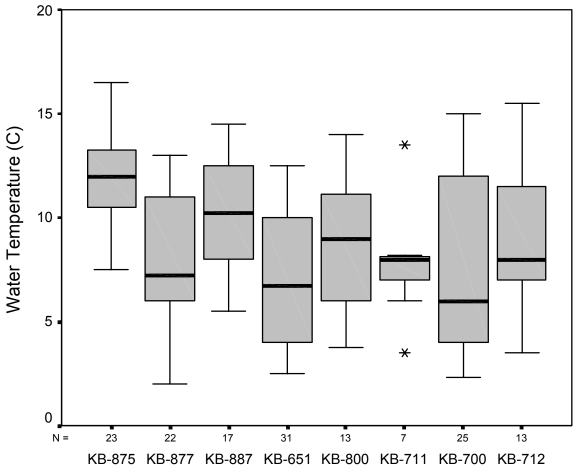

pH (Hanna Meter)
10
9
8
7
6
5
4
N =
16
18
25
32
8
KB-110
KB-120
KB-150
KB-180
KB-190
Woodard Creek Sites

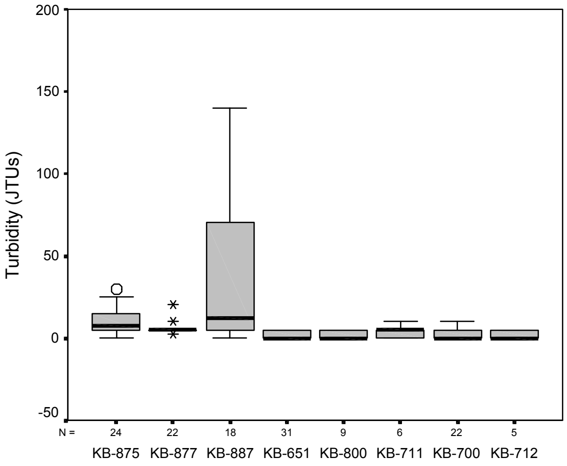

pH (Colorimetric)
10
9
8
7
6
5
4
N =
20
18
24
31
11
KB-110
KB-120
KB-150
KB-180
KB-190
Woodard Creek Sites

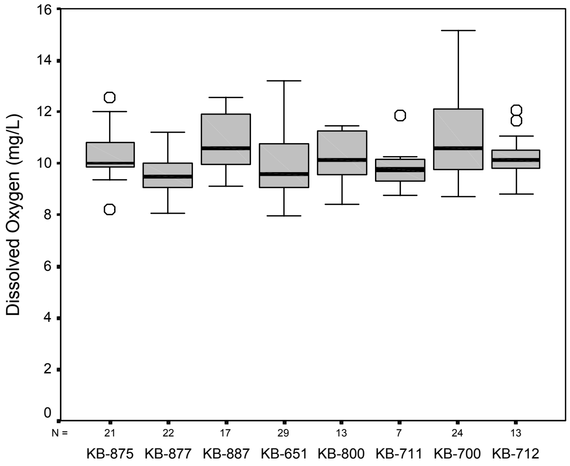

Orthophosphate (ppm)
.4
.3
.2
.1
0.0
N =
12
10
22
24
8
KB-110
KB-120
KB-150
KB-180
KB-190
Woodard Creek Sites

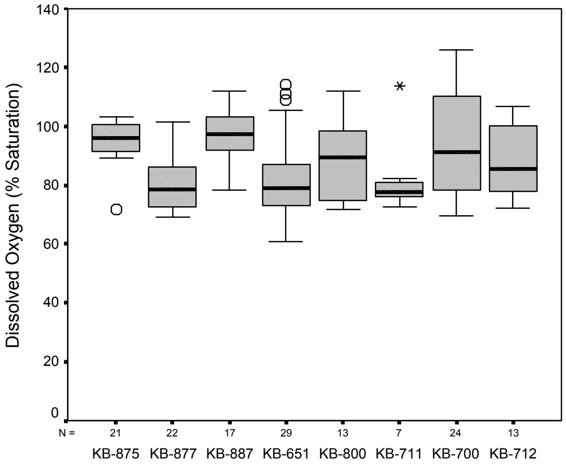

Nitrate (ppm)
6
5
4
3
2
1
0
-1
N =
12
17
25
31
9
KB-110
KB-120
KB-150
KB-180
KB-190
Woodard Creek Sites

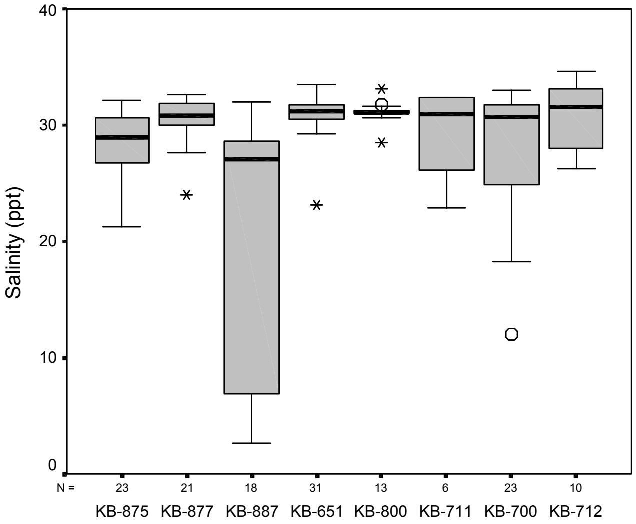
Southside of Kachemak Bay – Estuarine Sites

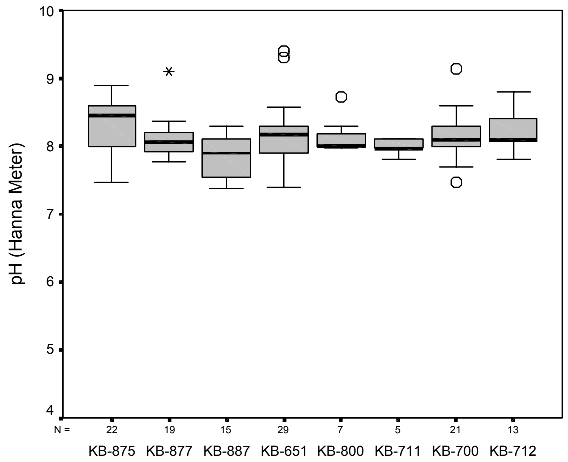


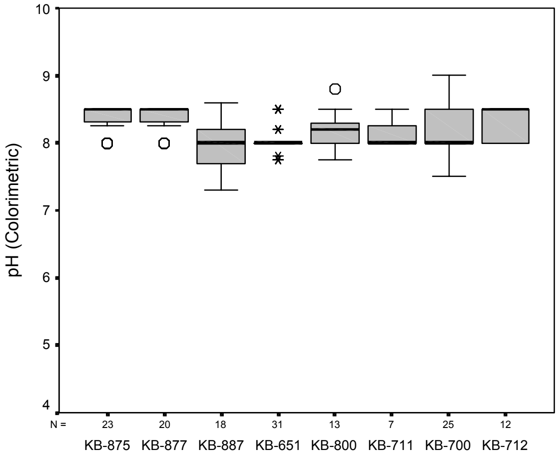


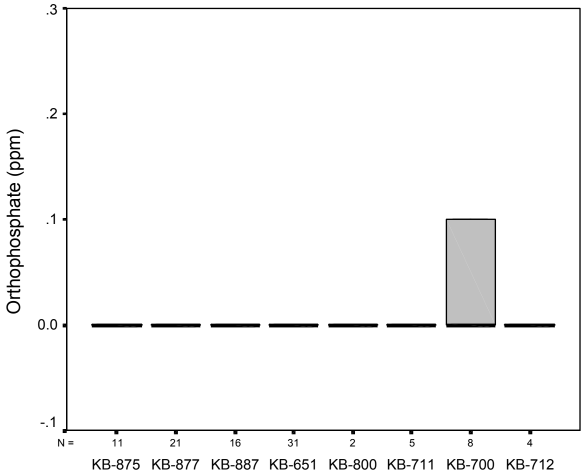


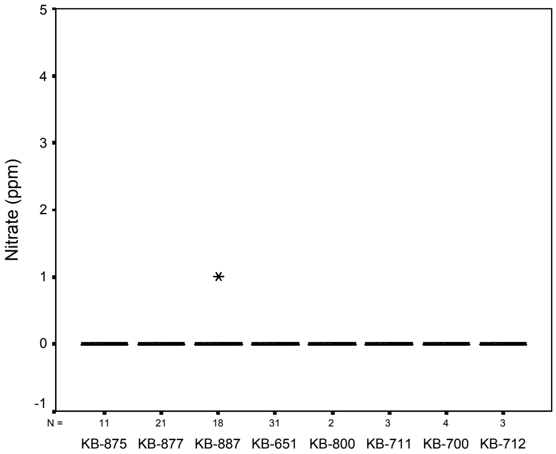




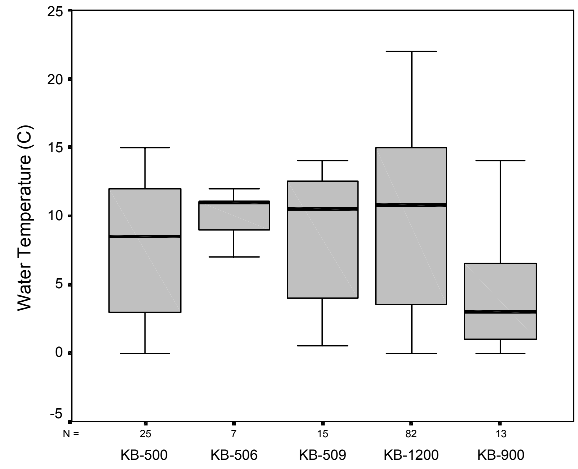

pH (Hanna Meter)
10
9
8
7
6
5
4
N =
22
19
15
29
7
5
21
13
KB-875
KB-877
KB-887
KB-651
KB-800
KB-711
KB-700
KB-712

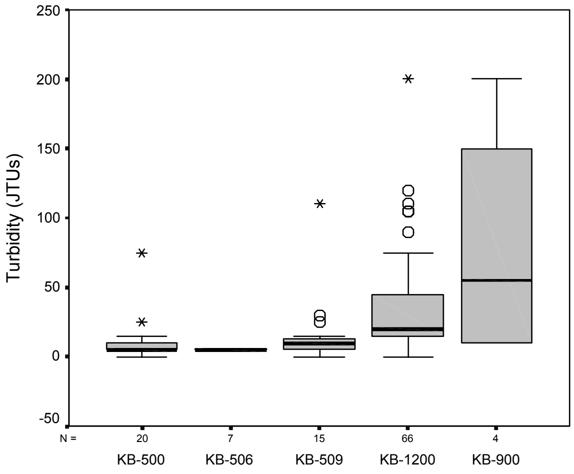

pH (Colorimetric)
10
9
8
7
6
5
4
N =
23
20
18
31
13
7
25
12
KB-875
KB-877
KB-887
KB-651
KB-800
KB-711
KB-700
KB-712

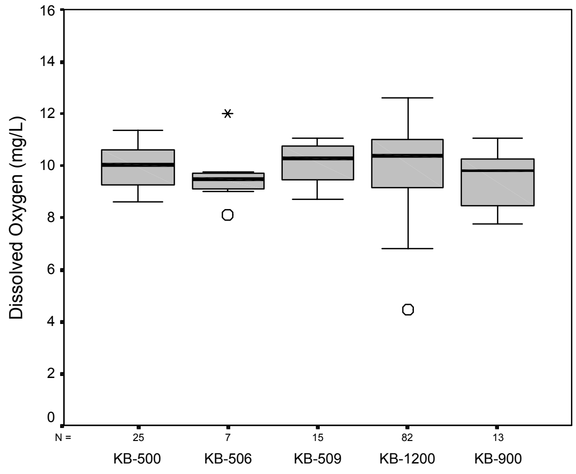

Orthophosphate (ppm)
.3
.2
.1
0.0
-.1
N =
11
21
16
31
2
5
8
4
KB-875
KB-877
KB-887
KB-651
KB-800
KB-711
KB-700
KB-712

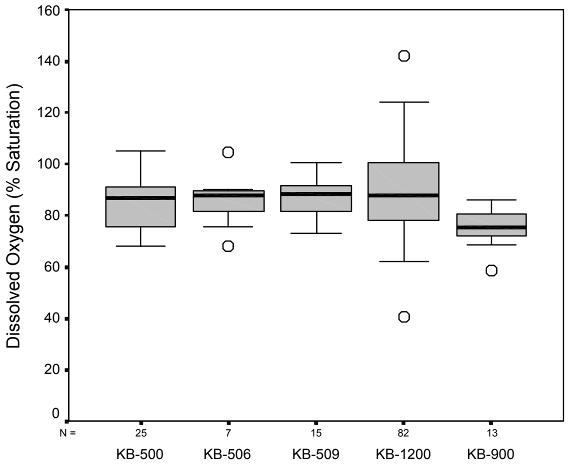

Nitrate (ppm)
5
4
3
2
1
0
-1
N =
11
21
18
31
2
3
4
3
KB-875
KB-877
KB-887
KB-651
KB-800
KB-711
KB-700
KB-712

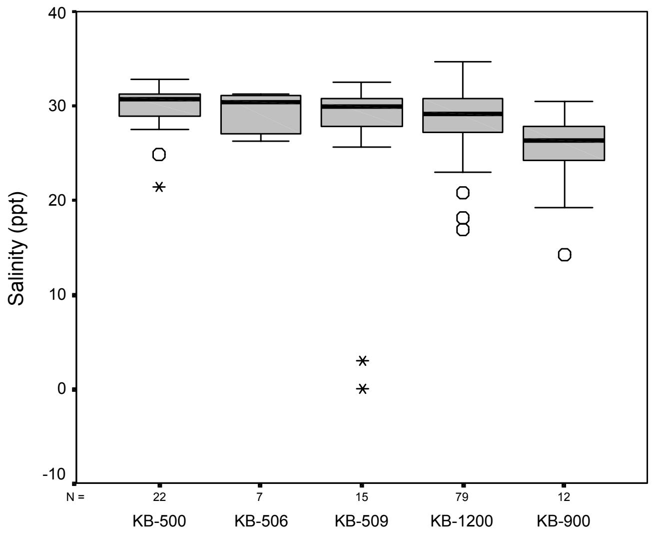
Northside of Kachemak Bay (inside Homer Spit) – Estuarine Sites

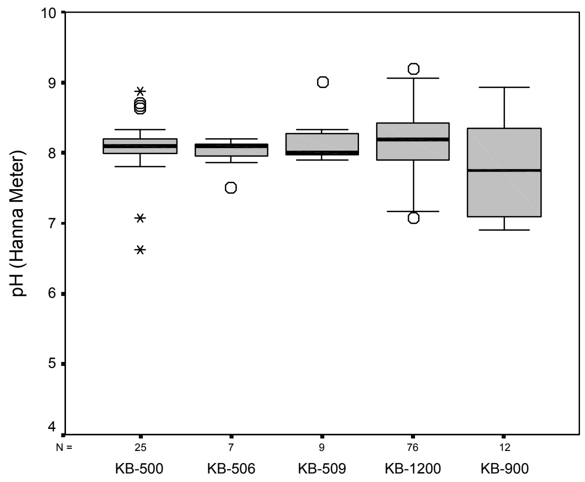


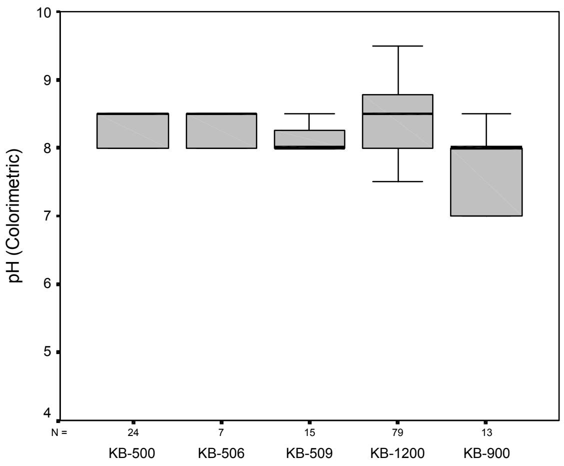


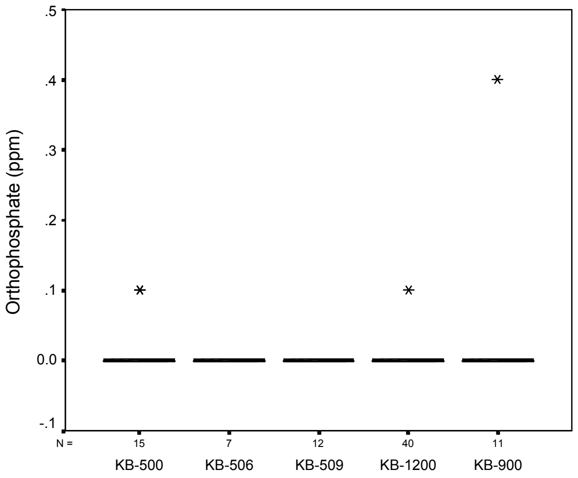


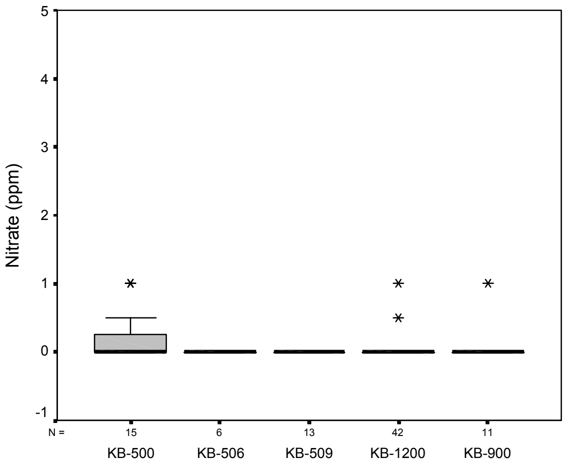




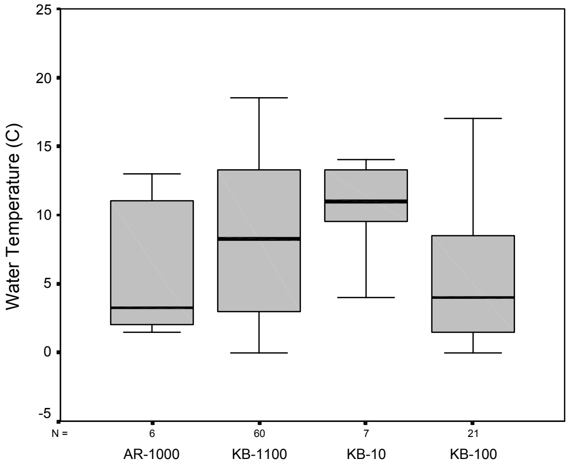

pH (Hanna Meter)
10
9
8
7
6
5
4
N =
25
7
9
76
12
KB-500
KB-506
KB-509
KB-1200
KB-900

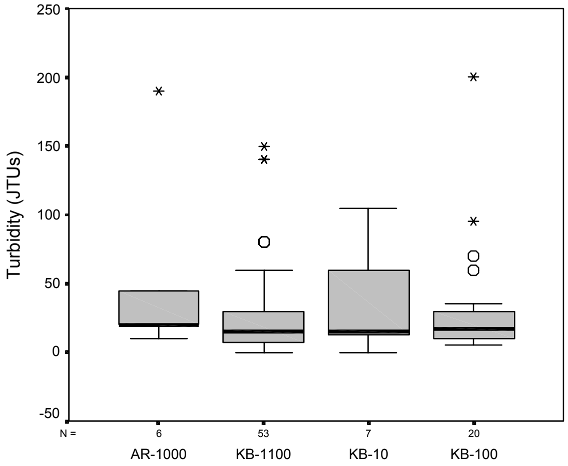

pH (Colorimetric)
10
9
8
7
6
5
4
N =
24
7
15
79
13
KB-500
KB-506
KB-509
KB-1200
KB-900

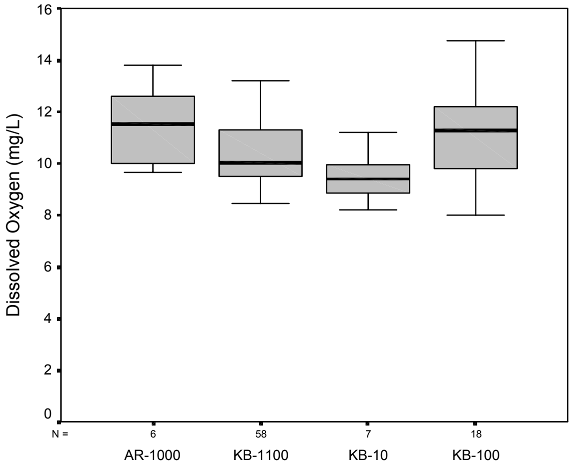

Orthophosphate (ppm)
.5
.4
.3
.2
.1
0.0
-.1
N =
15
7
12
40
11
KB-500
KB-506
KB-509
KB-1200
KB-900

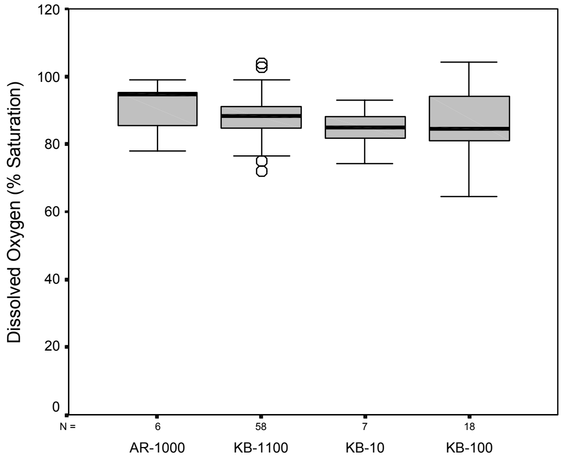

Nitrate (ppm)
5
4
3
2
1
0
-1
N =
15
6
13
42
11
KB-500
KB-506
KB-509
KB-1200
KB-900

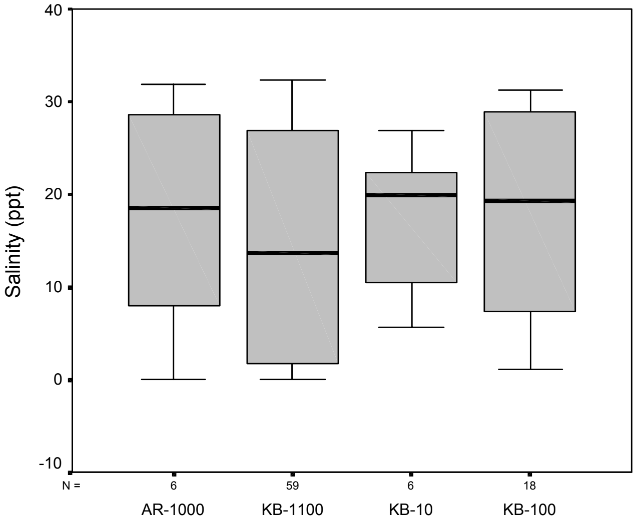
Northside of Kachemak Bay (outside Homer Spit) – Estuarine Sites

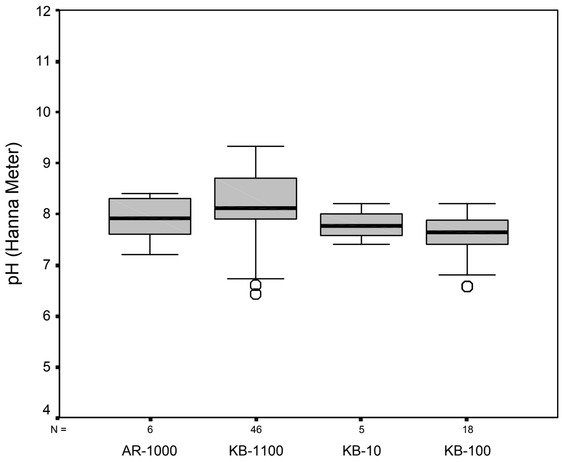


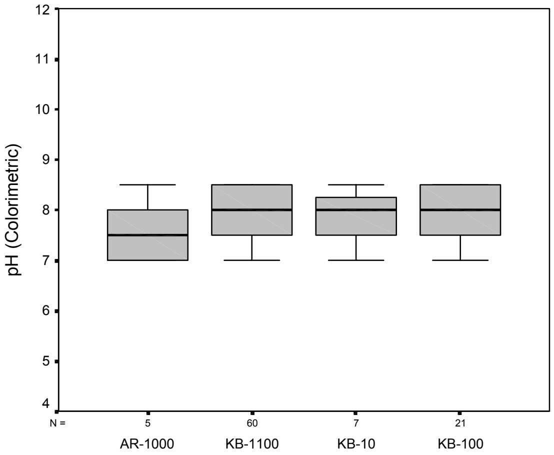


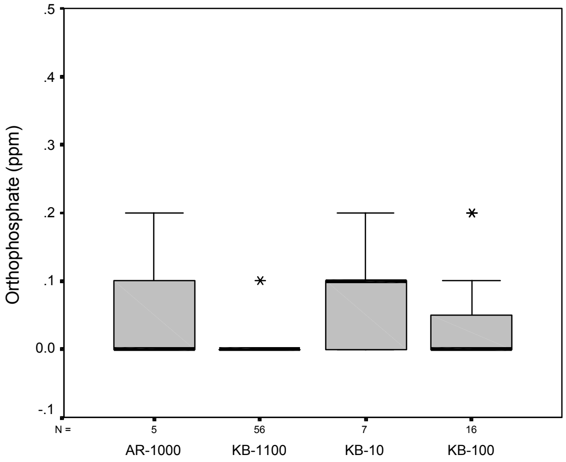


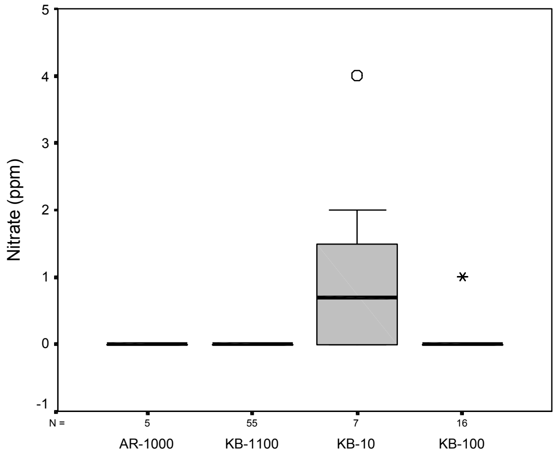




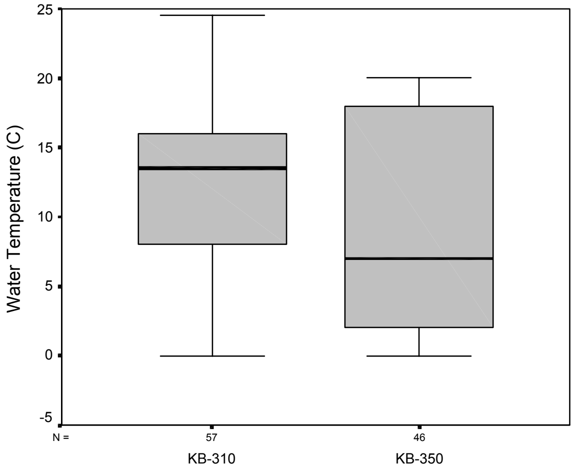

pH (Hanna Meter)
12
11
10
9
8
7
6
5
4
N =
6
46
5
18
AR-1000
KB-1100
KB-10
KB-100

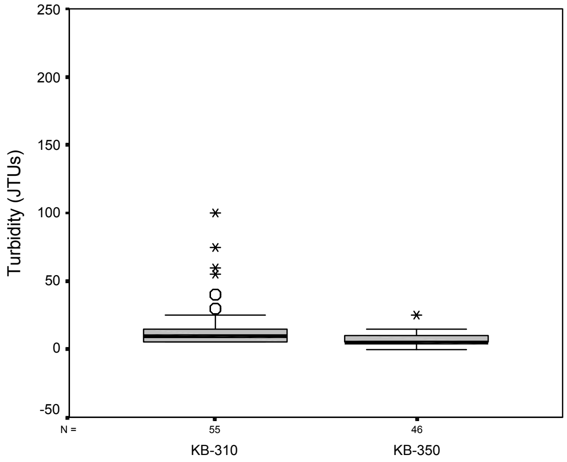

pH (Colorimetric)
12
11
10
9
8
7
6
5
4
N =
5
60
7
21
AR-1000
KB-1100
KB-10
KB-100

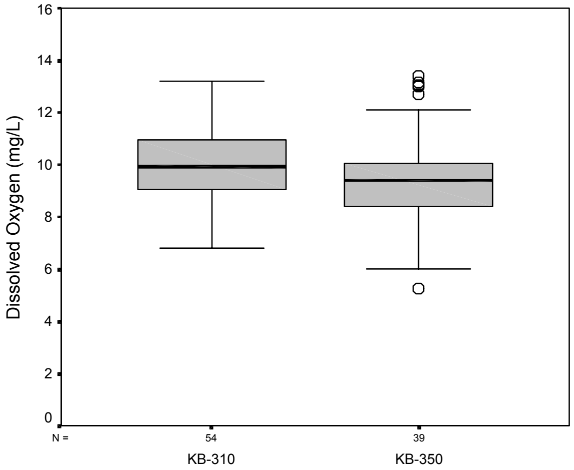

Orthophosphate (ppm)
.5
.4
.3
.2
.1
0.0
-.1
N =
5
56
7
16
AR-1000
KB-1100
KB-10
KB-100

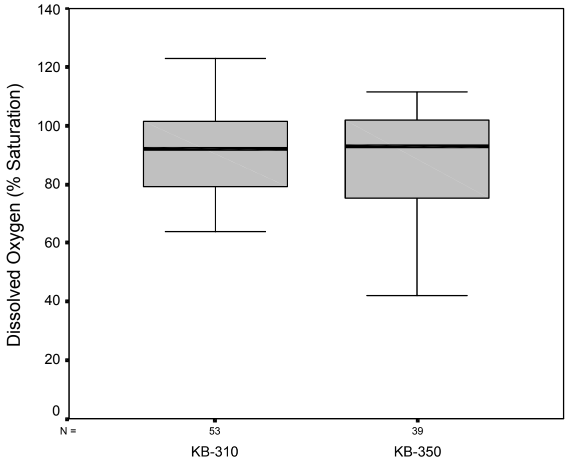

Nitrate (ppm)
5
4
3
2
1
0
-1
N =
5
55
7
16
AR-1000
KB-1100
KB-10
KB-100

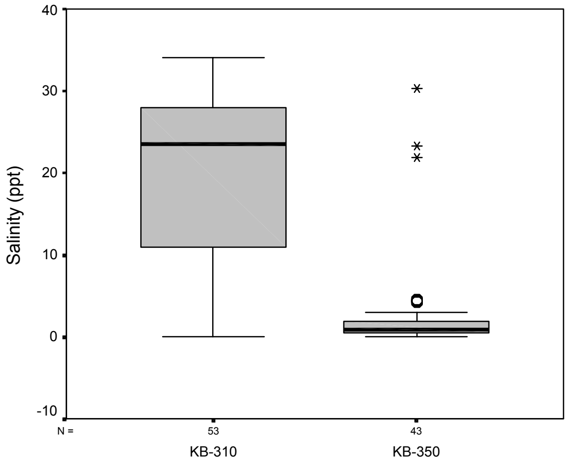
Beluga Slough/Lake

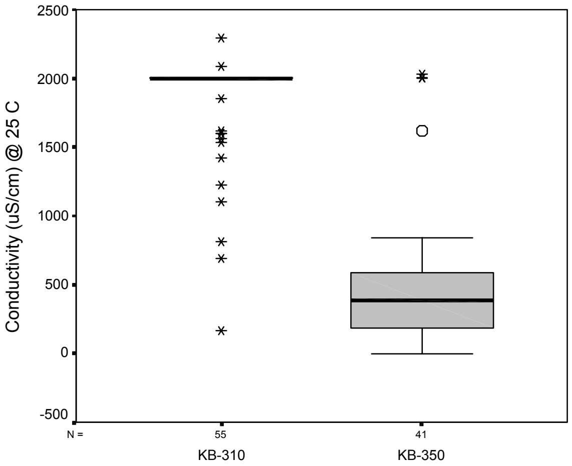


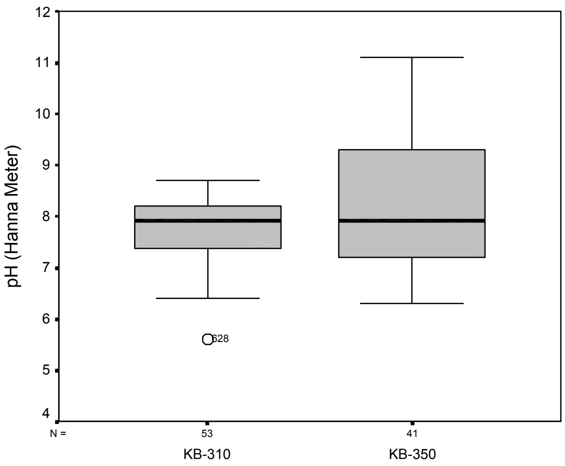




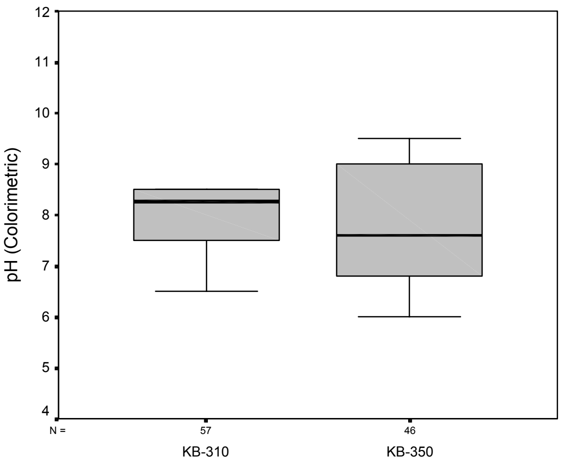




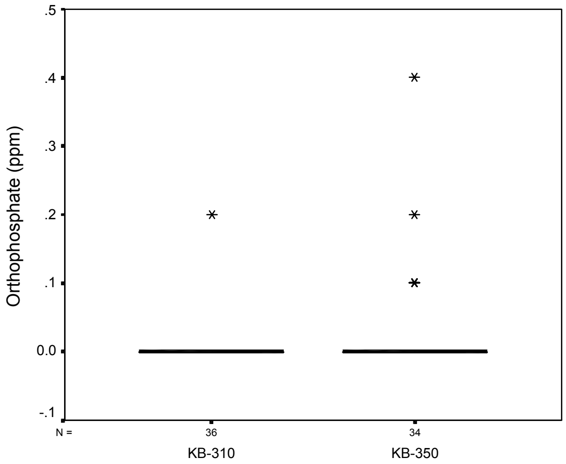




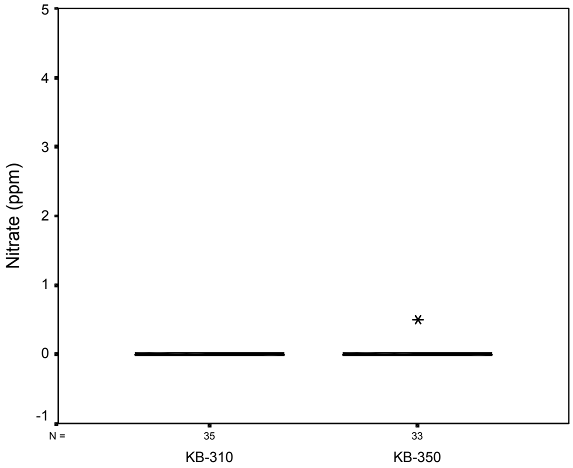
12
11
10
9
8
7
6
5
4
pH (Hanna Meter)
628
N =
53
41
KB-310
KB-350



12
11
10
9
8
7
6
5
4
pH (Colorimetric)
N =
57
46
KB-310
KB-350



.5
.4
.3
.2
.1
0.0
-.1
Orthophosphate (ppm)
N =
36
34
KB-310
KB-350



5
4
3
2
1
0
-1
Nitrate (ppm)
N =
35
33
KB-310
KB-350

APPENDIX III

Anchor River Watershed

	Water Temp (C)	Turbidity (JTUs)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (% Sat.)	Conductivity (uS/cm) @25 C	pH (Hanna Meter)	pH (Colori-metric)	Ortho-phosphate (ppm)	Nitrate-Nitrogen (ppm)
AR-1010									
N	10	10	10	10	9	9	10	9	9
Minimum	.00	5.00	9.33	86.25	.00	6.90	6.50	.00	.00
Maximum	18.00	20.00	12.95	100.27	167.23	8.43	8.00	.30	.00
Mean	9.9000	8.5000	10.6817	93.32	79.7081	7.3748	7.0250	.0667	.0000
Std. Deviation	5.11012	5.29675	1.15802	4.933	52.35709	.50934	.50621	.11180	.00000
AR-1035									
N	18	17	17	17	17	17	17	17	17
Minimum	.50	5.00	8.27	66.23	.36	6.10	6.50	.00	.00
Maximum	17.00	35.00	12.80	98.77	190.83	8.40	7.50	.00	.00
Mean	7.5000	14.1176	10.6304	90.21	70.2459	7.1020	7.0294	.0000	.0000
Std. Deviation	4.96458	8.88033	1.45502	7.683	48.52085	.64984	.21437	.00000	.00000
AR-1034									
N	40	36	37	36	37	33	40	32	39
Minimum	.00	.00	8.50	68.51	20.93	5.70	6.50	.00	.00
Maximum	12.50	25.00	13.55	102.37	251.15	7.57	7.50	.10	1.00
Mean	4.3313	10.2083	11.1260	85.7277	78.1477	6.7807	6.8231	.0031	.0385
Std. Deviation	3.85697	6.22136	1.30230	7.20268	48.51252	.39517	.26815	.01768	.17713
KB-470									
N	9	9	8	7	8	8	9	3	9
Minimum	.00	5.00	8.60	79.87	35.92	6.40	6.50	.00	.00
Maximum	17.00	10.00	13.13	97.77	192.41	7.40	7.00	.20	1.00
Mean	7.3333	5.5556	11.0333	91.6534	87.0251	6.8833	6.6667	.0667	.1111
Std. Deviation	6.47592	1.66667	1.69593	6.18231	58.34897	.34133	.17678	.11547	.33333
KB-490									
N	60	58	58	57	57	55	59	33	34
Minimum	.00	.00	9.65	69.05	5.35	5.13	6.00	.00	.00
Maximum	11.50	25.00	14.80	106.51	196.46	8.27	7.00	.00	1.00
Mean	4.2625	4.1379	11.7236	90.63	70.5708	6.7618	6.7763	.0000	.0294
Std. Deviation	3.45049	5.14167	1.12043	6.780	42.76076	.67139	.27906	.00000	.17150
KB-400									
N	17	17	17	16	15	15	17	14	17
Minimum	.03	5.00	6.20	56.10	.00	5.97	6.00	.00	.00
Maximum	16.00	10.00	12.07	101.84	101.01	7.07	6.50	.20	.50
Mean	9.5900	6.6176	9.1765	79.35	46.6509	6.6800	6.4118	.0786	.1176
Std. Deviation	4.65392	2.32869	1.61111	13.663	27.70447	.31942	.17547	.08926	.21862

Bidarka Creek Watershed

	Water Temp (C)	Turbidity (JTUs)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (% Sat.)	Conductivity (uS/cm) @25 C	pH (Hanna Meter)	pH (Colori-metric)	Ortho-phosphate (ppm)	Nitrate-Nitrogen (ppm)
KB-210									
N	47	43	47	47	44	41	45	37	37
Minimum	.00	5.00	9.40	82.40	50.52	6.10	7.00	.00	.00
Maximum	12.00	70.00	15.20	118.67	723.44	8.27	8.00	.30	2.00
Mean	5.4872	16.7442	12.0642	96.01	213.49	7.3431	7.2578	.0595	.5946
Std. Deviation	3.95340	15.46439	1.44282	7.011	116.95	.45413	.28958	.06855	.55073

Diamond Creek Watershed

	Water Temp (C)	Turbidity (JTUs)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (% Sat.)	Conductivity (uS/cm) @25 C	pH (Hanna Meter)	pH (Colori-metric)	Ortho-phosphate (ppm)	Nitrate-Nitrogen (ppm)
KB-1110									
N	71	63	68	68	64	50	71	67	70
Minimum	.00	.00	9.53	77.34	22.16	6.13	6.50	.00	.00
Maximum	17.00	160.00	14.00	102.48	947.19	8.50	8.00	.10	.00
Mean	7.0317	15.4365	11.3453	93.25	134.8406	7.6800	7.2634	.0015	.0000
Std. Deviation	5.29031	25.33063	1.30980	5.382	128.99475	.65618	.31418	.01222	.00000
KB-1130									
N	39	39	38	38	36	34	39	35	36
Minimum	.00	5.00	8.27	70.42	3.05	6.13	6.00	.00	.00
Maximum	17.50	20.00	13.80	101.66	205.31	8.20	7.50	.40	.00
Mean	6.5513	7.0513	11.1259	90.11	92.4289	7.3666	6.9923	.0114	.0000
Std. Deviation	5.37483	3.75534	1.37463	7.802	51.09979	.55695	.40025	.06761	.00000
KB-1140									
N	18	18	18	18	16	18	18	12	17
Minimum	.00	5.00	10.13	78.34	37.45	5.87	6.30	.00	.00
Maximum	14.50	15.00	13.63	106.96	122.77	7.40	7.25	.20	.00
Mean	5.6972	6.9444	11.7389	94.02	70.4497	6.8667	6.7667	.0583	.0000
Std. Deviation	5.02472	3.03842	1.09277	8.265	24.90726	.40568	.27225	.09003	.00000
KB-1150									
N	40	40	40	40	39	40	40	38	40
Minimum	.00	.00	7.97	63.97	9.07	6.13	6.25	.00	.00
Maximum	15.00	10.00	13.37	106.88	183.55	8.17	7.50	.20	.00
Mean	7.6125	5.2500	10.6592	89.09	66.6555	6.9142	6.9062	.0053	.0000
Std. Deviation	4.68493	1.58114	1.17710	94.47	31.41628	.42926	.26966	.03244	.00000
KB-1160									
N	17	17	17	16	16	16	17	17	17
Minimum	.50	.00	8.47	69.42	49.94	6.40	6.50	.00	.00
Maximum	16.00	200.00	12.40	94.61	102.90	7.00	7.00	.20	.00
Mean	5.3235	17.9412	10.5324	82.81	68.7542	6.7313	6.5882	.0118	.0000
Std. Deviation	5.40527	47.10556	1.37891	5.804	16.58048	.15938	.17547	.04851	.00000

Falls Creek Watershed

	Water Temp (C)	Turbidity (JTUs)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (% Sat.)	Conductivity (uS/cm) @ 25 C	pH (Hanna Meter)	pH (Colori-metric)	Ortho-phosphate (ppm)	Nitrate-Nitrogen (ppm)
KB-577									
N	9	9	9	9	9	9	9	8	8
Minimum	1.00	.00	11.23	81.51	28.54	6.77	6.50	.00	.00
Maximum	7.50	47.50	18.20	133.52	253.95	7.90	8.00	.20	1.00
Mean	3.1667	8.0556	13.3296	100.87	139.6463	7.4074	7.2500	.0375	.1250
Std. Deviation	2.13600	14.98842	2.25243	18.331	96.03553	.46121	.46771	.07440	.35355

Fish Creek Watershed

	Water Temp (C)	Turbidity (JTUs)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (% Sat.)	Conductivity (uS/cm) @ 25 C	pH (Hanna Meter)	pH (Colori-metric)	Ortho-phosphate (ppm)	Nitrate-Nitrogen (ppm)
KB-710									
N	18	9	17	17	17	17	18	1	2
Minimum	.00	.00	8.70	60.82	26.56	7.17	6.50	.00	.00
Maximum	11.00	5.00	13.80	101.56	940.16	8.43	7.50	.00	.00
Mean	3.0556	1.1111	12.4176	93.90	153.4377	7.7922	6.9833	.0000	.0000
Std. Deviation	2.97662	2.20479	1.22932	9.693	228.55975	.43534	.20436	.	.00000

Fritz Creek Watershed

	Water Temp (C)	Turbidity (JTUs)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (% Sat.)	Conductivity (uS/cm) @ 25 C	pH (Hanna Meter)	pH (Colori-metric)	Ortho-phosphate (ppm)	Nitrate-Nitrogen (ppm)
KB-535									
N	43	41	43	43	37	43	42	38	40
Minimum	.00	.00	9.27	84.36	14.95	6.00	6.75	.00	.00
Maximum	14.00	65.00	14.30	101.44	154.12	8.80	7.60	.20	1.50
Mean	4.6035	10.8537	11.8570	92.23	72.6369	7.2992	7.1631	.0408	.1000
Std. Deviation	4.46900	15.52830	1.27638	5.132	33.98636	.60037	.23192	.06961	.30382

McNeil Canyon Creek Watershed

	Water Temp (C)	Turbidity (JTUs)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (% Sat.)	Conductivity (uS/cm) @ 25 C	pH (Hanna Meter)	pH (Colori-metric)	Ortho-phosphate (ppm)	Nitrate-Nitrogen (ppm)
KB-545									
N	25	25	24	24	21	24	25	21	22
Minimum	.00	.00	8.43	70.92	.00	5.30	6.00	.00	.00
Maximum	15.25	45.00	13.03	92.57	295.37	7.80	7.00	.40	.00
Mean	5.7520	8.0000	10.7160	85.59	57.7743	6.3931	6.5500	.0571	.0000
Std. Deviation	5.24270	9.46485	1.39951	4.826	63.53377	.59320	.27951	.10757	.00000

Miller’s Landing Watershed

	Water Temp (C)	Turbidity (JTUs)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (% Sat.)	Conductivity (uS/cm) @ 25 C	pH (Hanna Meter)	pH (Colorimetric)	Orthophosphate (ppm)	Nitrate-Nitrogen (ppm)
KB-911									
N	32	27	32	32	29	29	32	15	15
Minimum	.00	5.00	7.85	74.11	52.62	6.13	6.50	.00	.00
Maximum	17.00	170.00	14.17	97.88	1602.04	9.63	8.50	.40	1.00
Mean	6.2375	42.4074	10.7021	86.18	435.1541	7.5954	7.3969	.0733	.1533
Std. Deviation	6.34074	48.42461	1.85768	6.367	374.35780	.64314	.41009	.12228	.34819
KB-912									
N	7	5	8	8	7	8	8	4	5
Minimum	1.00	10.00	5.53	59.44	115.93	6.77	6.50	.10	.00
Maximum	20.00	25.00	12.23	123.36	664.46	7.90	7.50	.30	.10
Mean	9.0714	16.0000	9.5083	83.65	282.3252	7.3604	7.2500	.2000	.0200
Std. Deviation	7.80186	8.21584	2.25188	18.513	202.74430	.45495	.35355	.08165	.04472

Rice Creek Watershed

	Water Temp (C)	Turbidity (JTUs)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (% Sat.)	Conductivity (uS/cm) @ 25 C	pH (Hanna Meter)	pH (Colorimetric)	Orthophosphate (ppm)	Nitrate-Nitrogen (ppm)
KB-556									
N	21	19	21	21	15	18	21	18	21
Minimum	.00	.00	6.43	57.68	6.65	6.00	6.50	.00	.00
Maximum	15.50	30.00	13.17	93.20	139.23	8.50	7.20	.00	1.00
Mean	8.2048	12.1053	9.6317	81.22	49.4779	6.9687	6.7905	.0000	.0952
Std. Deviation	5.41253	10.45038	1.81654	9.684	37.63088	.55235	.21013	.00000	.25588
KB-555									
N	15	14	14	14	14	14	14	12	14
Minimum	2.00	.00	5.57	53.44	12.48	6.40	6.50	.00	.00
Maximum	18.50	110.00	11.40	90.22	187.89	8.33	7.50	.00	1.00
Mean	10.8967	22.6786	8.9417	80.06	86.7736	7.0788	6.9571	.0000	.1429
Std. Deviation	4.37274	30.76687	1.81104	12.203	50.82463	.52109	.23358	.00000	.36314
KB-550									
N	17	18	19	19	18	17	19	16	19
Minimum	.00	.00	9.80	70.24	23.54	6.23	6.70	.00	.00
Maximum	10.00	10.00	12.90	93.48	189.15	8.70	7.00	.00	1.00
Mean	5.4235	2.5000	10.8579	85.93	91.1303	6.9867	6.8737	.0000	.2105
Std. Deviation	2.94099	3.53553	1.04939	5.127	43.07362	.56721	.12402	.00000	.38427
KB-551									
N	16	16	13	13	14	13	16	14	16
Minimum	.50	.00	7.97	69.52	12.78	6.43	6.38	.00	.00
Maximum	11.00	25.00	11.63	88.63	100.91	7.73	7.00	.30	1.00
Mean	8.1125	4.6875	9.6410	80.49	66.8909	6.8790	6.7891	.0214	.1563
Std. Deviation	2.96915	5.90727	1.24916	6.379	27.50820	.34834	.19853	.08018	.35208

Woodard Creek Watershed

	Water Temp (C)	Turbidity (JTUs)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (% Sat.)	Conductivity (uS/cm) @ 25 C	pH (Hanna Meter)	pH (Colori- metric)	Ortho- phosphate (ppm)	Nitrate- Nitrogen (ppm)
KB-110									
N	20	19	18	18	19	16	20	12	12
Minimum	.00	.00	7.20	63.60	29.84	6.73	7.30	.00	.00
Maximum	15.00	105.00	14.85	112.50	592.03	8.80	8.50	.20	5.00
Mean	7.6865	24.4737	11.1463	91.22	187.0328	7.7469	7.6043	.0833	1.1583
Std. Deviation	5.18326	32.05441	2.42710	12.698	134.25569	.45441	.27743	.07177	1.63232
KB-120									
N	20	16	18	18	19	18	18	10	17
Minimum	.90	.00	7.77	73.71	65.40	6.37	6.50	.00	.00
Maximum	15.50	50.00	13.90	101.28	664.70	7.90	8.00	.20	1.00
Mean	8.1125	11.8750	10.6426	89.44	218.4727	7.4217	7.3575	.0500	.2765
Std. Deviation	5.40098	13.64734	1.63519	7.372	155.52022	.42515	.36852	.08498	.43233
KB-150									
N	27	22	23	23	25	25	24	22	25
Minimum	.50	.00	8.07	68.69	25.44	6.30	6.50	.00	.00
Maximum	15.30	45.00	13.80	102.70	425.88	8.40	8.00	.20	2.00
Mean	7.5865	13.6364	10.6464	89.86	140.8635	7.5551	7.3458	.0273	.8400
Std. Deviation	4.70511	12.55292	1.41121	7.149	91.12954	.49657	.37847	.05505	.74610
KB-180									
N	33	31	29	29	33	32	31	24	31
Minimum	.00	.00	7.90	60.24	40.72	6.10	6.75	.00	.00
Maximum	13.83	120.00	13.87	102.99	381.62	8.50	7.94	.20	2.00
Mean	5.8515	14.8387	11.1805	89.32	137.3666	7.3669	7.2965	.0292	.6452
Std. Deviation	4.29263	28.21004	1.41826	7.633	73.07105	.57806	.27968	.06903	.69754
KB-190									
N	11	10	9	9	7	8	11	8	9
Minimum	.00	.00	10.67	86.52	23.19	5.20	6.00	.00	.00
Maximum	7.00	5.00	13.60	97.45	149.28	7.20	7.00	.00	1.00
Mean	2.7727	3.0000	12.2778	90.94	76.7476	6.2167	6.6364	.0000	.3333
Std. Deviation	2.75103	2.58199	1.07471	3.607	42.62862	.63346	.32333	.00000	.50000

Southside of Kachemak Bay

	Water Temp (C)	Turbidity (JTUs)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (% Sat.)	Salinity (ppt)	pH (Hanna Meter)	pH (Colori-metric)	Ortho-phosphate (ppm)	Nitrate-Nitrogen (ppm)
KB-875									
N	23	24	21	21	23	22	23	11	11
Minimum	7.50	.00	8.20	71.57	21.28	7.47	8.00	.00	.00
Maximum	16.50	30.00	12.53	103.15	32.14	8.90	8.50	.00	.00
Mean	11.8217	10.2083	10.2817	95.24	28.3397	8.3258	8.3859	.0000	.0000
Std. Deviation	2.21851	7.44241	.93906	7.124	2.69083	.39760	.19552	.00000	.00000
KB-877									
N	22	22	22	22	21	19	20	21	21
Minimum	2.00	2.50	8.03	68.94	24.02	7.77	8.00	.00	.00
Maximum	13.00	20.00	11.20	101.35	32.63	9.10	8.50	.00	.00
Mean	7.9318	5.7955	9.4742	79.71	30.5003	8.1158	8.3938	.0000	.0000
Std. Deviation	3.16715	3.39698	.72389	8.339	2.01643	.29046	.18706	.00000	.00000
KB-887									
N	17	18	17	17	18	15	18	16	18
Minimum	5.50	.00	9.10	78.47	2.61	7.37	7.30	.00	.00
Maximum	14.50	140.00	12.57	112.01	31.98	8.30	8.60	.00	1.00
Mean	10.1912	35.2778	10.8863	97.95	19.4036	7.8460	7.9458	.0000	.1111
Std. Deviation	2.73794	40.67346	1.16625	8.386	11.44911	.31892	.32520	.00000	.32338
KB-651									
N	31	31	29	29	31	29	31	31	31
Minimum	2.50	.00	7.95	60.62	23.14	7.40	7.75	.00	.00
Maximum	12.50	5.00	13.20	113.97	33.56	9.40	8.50	.00	.00
Mean	7.0484	1.7742	9.9195	82.58	31.0087	8.1713	8.0629	.0000	.0000
Std. Deviation	3.21213	2.25403	1.29681	13.741	1.78109	.43110	.21870	.00000	.00000
KB-800									
N	13	9	13	13	13	7	13	2	2
Minimum	3.75	.00	8.40	71.55	28.53	7.97	7.75	.00	.00
Maximum	14.00	5.00	11.47	111.98	33.06	8.73	8.80	.00	.00
Mean	8.7500	1.9444	10.2756	88.65	31.1010	8.1524	8.1962	.0000	.0000
Std. Deviation	3.46254	2.42956	1.01531	12.801	.98471	.28012	.28245	.00000	.00000
KB-711									
N	7	6	7	7	6	5	7	5	3
Minimum	3.50	.00	8.73	72.44	22.92	7.80	8.00	.00	.00
Maximum	13.50	10.00	11.83	113.60	32.39	8.10	8.50	.00	.00
Mean	7.8857	4.1667	9.8833	82.54	29.2777	7.9867	8.1429	.0000	.0000
Std. Deviation	3.01243	3.76386	1.00531	14.055	3.94906	.12383	.24398	.00000	.00000
KB-700									
N	25	22	24	24	23	21	25	8	4
Minimum	2.30	.00	8.70	69.70	12.00	7.47	7.50	.00	.00
Maximum	15.00	10.00	15.15	125.94	32.99	9.13	9.00	.10	.00
Mean	7.5120	1.8182	10.9424	94.43	27.9651	8.1540	8.1800	.0375	.0000
Std. Deviation	4.09159	2.90544	1.70690	16.634	5.45160	.35831	.31885	.05175	.00000

Southside of Kachemak Bay (Continued)

	Water Temp (C)	Turbidity (JTUs)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (% Sat.)	Salinity (ppt)	pH (Hanna Meter)	pH (Colori- metric)	Ortho- phosphate (ppm)	Nitrate- Nitrogen (ppm)
KB-712									
N	13	5	13	13	10	13	12	4	3
Minimum	3.50	.00	8.80	72.26	26.19	7.80	8.00	.00	.00
Maximum	15.50	5.00	12.07	106.84	34.65	8.80	8.50	.00	.00
Mean	9.0385	2.0000	10.2615	88.25	30.8740	8.2179	8.2917	.0000	.0000
Std. Deviation	3.60244	2.73861	.91632	11.986	3.06148	.29459	.25746	.00000	.00000

Northside of Kachemak Bay (inside Homer Spit)

	Water Temp (C)	Turbidity (JTUs)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (% Sat.)	Salinity (ppt)	pH (Hanna Meter)	pH (Colori- metric)	Ortho- phosphate (ppm)	Nitrate- Nitrogen (ppm)
KB-500									
N	25	20	25	25	22	25	24	15	15
Minimum	.00	.00	8.60	67.78	21.39	6.63	8.00	.00	.00
Maximum	15.00	75.00	11.35	104.88	32.85	8.87	8.50	.10	1.00
Mean	7.6800	10.7500	9.9980	85.19	29.8714	8.0920	8.2823	.0133	.2000
Std. Deviation	4.96840	16.08162	.81053	10.199	2.64598	.46381	.24787	.03519	.36839
KB-506									
N	7	7	7	7	7	7	7	7	6
Minimum	7.00	5.00	8.10	68.16	26.32	7.50	8.00	.00	.00
Maximum	12.00	5.00	12.00	104.73	31.27	8.20	8.50	.00	.00
Mean	10.0000	5.0000	9.5964	86.10	29.1932	7.9905	8.2857	.0000	.0000
Std. Deviation	1.75594	.00000	1.19521	11.608	2.26329	.24015	.26726	.00000	.00000
KB-509									
N	15	15	15	15	15	9	15	12	13
Minimum	.50	.00	8.70	73.19	.00	7.90	8.00	.00	.00
Maximum	14.00	110.00	11.03	100.73	32.55	9.00	8.50	.00	.00
Mean	8.7333	16.6667	10.0711	87.57	26.1395	8.1530	8.1333	.0000	.0000
Std. Deviation	4.50344	27.03613	.76931	7.994	10.19515	.35252	.22887	.00000	.00000
KB-1200									
N	82	66	82	82	79	76	79	40	42
Minimum	.00	.00	4.43	40.60	16.86	7.07	7.50	.00	.00
Maximum	22.00	200.00	12.60	142.01	34.65	9.20	9.50	.10	1.00
Mean	9.8829	35.0000	10.0258	89.31	28.7379	8.2060	8.4775	.0025	.0357
Std. Deviation	6.73551	36.53239	1.34157	15.667	3.18608	.46950	.50578	.01581	.17083
KB-900									
N	13	4	13	13	12	12	13	11	11
Minimum	.00	10.00	7.73	58.46	14.20	6.90	7.00	.00	.00
Maximum	14.00	200.00	11.07	85.82	30.43	8.93	8.50	.40	1.00
Mean	4.6538	80.0000	9.5859	74.93	25.1637	7.7917	7.7308	.0364	.0909
Std. Deviation	4.92182	90.55385	1.09422	6.863	4.47448	.71012	.56330	.12060	.30151

Northside of Kachemak Bay (outside Homer Spit)

	Water Temp (C)	Turbidity (JTUs)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (% Sat.)	Salinity (ppt)	pH (Hanna Meter)	pH (Colori-metric)	Ortho-phosphate (ppm)	Nitrate-Nitrogen (ppm)
AR-1000									
N	6	6	6	6	6	6	5	5	5
Minimum	1.50	10.00	9.67	77.89	.00	7.20	7.00	.00	.00
Maximum	13.00	190.00	13.80	98.90	31.93	8.40	8.50	.20	.00
Mean	5.6667	50.8333	11.5222	91.12	17.6097	7.8889	7.6000	.0600	.0000
Std. Deviation	5.05635	69.16767	1.63648	7.879	13.13829	.47966	.65192	.08944	.00000
KB-1100									
N	60	53	58	58	59	46	60	56	55
Minimum	.00	.00	8.43	72.08	.00	6.43	7.00	.00	.00
Maximum	18.50	150.00	13.20	103.79	32.30	9.33	8.50	.10	.00
Mean	8.0758	27.3113	10.3707	87.64	14.8300	8.1855	8.0217	.0018	.0000
Std. Deviation	5.27327	33.90403	1.15450	6.022	11.62715	.69184	.51358	.01336	.00000
KB-10									
N	7	7	7	7	6	5	7	7	7
Minimum	4.00	.00	8.20	74.20	5.63	7.40	7.00	.00	.00
Maximum	14.00	105.00	11.20	92.98	26.90	8.20	8.50	.20	4.00
Mean	10.6429	37.8571	9.4881	84.55	17.5005	7.7867	7.8571	.0714	1.1000
Std. Deviation	3.49660	46.17513	1.01929	6.331	7.92706	.32197	.55635	.07559	1.47309
KB-100									
N	21	20	18	18	18	18	21	16	16
Minimum	.00	5.00	8.00	64.34	1.07	6.57	7.00	.00	.00
Maximum	17.00	200.00	14.73	104.29	31.26	8.20	8.50	.20	1.00
Mean	5.8024	33.7500	11.0194	86.89	18.0010	7.5407	7.8929	.0375	.1250
Std. Deviation	5.35884	45.67837	1.72218	10.489	11.12558	.50727	.53951	.07188	.34157

Beluga Slough/Lake

	Water Temp (C)	Turbidity (JTUs)	Dissolved Oxygen (mg/L)	Dissolved Oxygen (% Sat.)	Salinity (ppt)	Conductivity (uS/cm) @ 25 C	pH (Hanna Meter)	pH (Colori-metric)	Ortho-phosphate (ppm)	Nitrate-Nitrogen (ppm)
KB-310										
N	57	55	54	53	53	55	53	57	36	35
Minimum	.00	5.00	6.80	63.85	.00	164.37	5.60	6.50	.00	.00
Maximum	24.50	100.00	13.20	123.11	34.09	3695.69	8.70	8.50	.20	.00
Mean	11.9579	16.0909	9.8818	91.76	20.5139	1961.1373	7.7830	7.9535	.0056	.0000
Std. Deviation	6.68054	18.60135	1.27261	14.158	10.4902	571.59788	.59788	.59526	.03333	.00000
KB-350										
N	46	46	39	39	43	41	41	46	34	33
Minimum	.00	.00	5.23	41.95	.00	.00	6.30	6.00	.00	.00
Maximum	20.00	25.00	13.40	111.67	30.38	2035.18	11.10	9.50	.40	.50
Mean	9.6630	6.7391	9.4894	86.54	2.8804	538.1036	8.2220	7.7978	.0353	.0303
Std. Deviation	7.75389	4.11196	1.93765	20.415	6.3507	569.54855	1.37920	1.10403	.08121	.12115

APPENDIX IV

Glossary of Statistical Terms

Analysis of variance, or ANOVA, is a method of testing the null hypothesis that several group means are equal in the population, by comparing the sample variance estimated from the group means to that estimated within the groups.

Results from an ANOVA are expressed as: $F_{4, 102}$=3.29, p=0.014.

F statistic is a measure of the variability left unexplained by a model that assumes means are equal from a model that assumes means are different. An F-statistic in the range from 3.0 to 4.0 is moderately suggestive that the model with unequal means is true. A larger F-statistic is strongly suggestive that the null hypothesis, that the means are equal, is untrue. F-statistics are affected by the **degrees of freedom**, which are the two numbers in subscript. The first number is the numerator degrees of freedom, which is the number of means being compared minus 1. The second number is the denominator degrees of freedom which is the total number of observations/sample (n) minus 1. The smaller the **p-value** the greater the evidence that the null hypothesis is not true. A p-value of 0.05 is used by convention as the cutoff to determine significance.

Linear regression estimates the coefficients of the linear equation, involving one or more independent variables (i.e. temperature, conductivity), that best predict the value of the dependent variable (i.e. river mile).

R, the multiple correlation coefficient, is the correlation between the observed and predicted values of the dependent variable. The values of R range from 0 to 1. Larger values of R indicate stronger relationships.

R-squared is the proportion of variation in the dependent variable explained by the regression model. It ranges in value from 0 to 1. Small values indicate that the model does not fit the data well.

95% Confidence Interval (CI) is a range of values which has a 95% chance of including the population value of the parameter estimate (i.e. slope, constant).

Mean is a measure of central tendency. The arithmetic average; the sum divided by the number of cases.

Median is the value above and below which half the cases fall, the 50th percentile.

Power analysis is used to anticipate the likelihood that the study will yield a significant effect. Power, effect size, sample size, and alpha form a closed system - once any three are established, the fourth is completely determined. The goal of a power analysis is to find an appropriate balance among these factors by taking into account the substantive goals of the study, and the resources available to the researcher.

Power is the proportion of studies that will yield a statistically significant effect. By convention, power is usually set at 80%.

Effect size (for t-tests) is the mean difference divided by the standard deviation.

Alpha is the significance level used for rejecting the null hypothesis. The probability of rejecting the null hypothesis when in fact the null hypothesis is true.

Standard deviation is a measure of dispersion around the mean. In a normal distribution, 68% of cases fall within one standard deviation of the mean and 95% of cases fall within 2 standard deviations of the mean.

Standard error is a measure of how much the value of a test statistic varies from sample to sample. It is the standard deviation of the sampling distribution for a statistic. For example, the standard error of the mean is the standard deviation of the sample means.

Spearman's rank coefficient is a rank-order correlation coefficient which measures association at the ordinal level. This is a nonparametric version of the Pearson correlation based on the ranks of the data rather than the actual values. Values of the coefficient range from -1 to +1. The sign of the coefficient indicates the direction of the relationship, and its absolute value indicates the strength, with larger absolute values indicating stronger relationships.

Range is the difference between the largest and smallest values of a numeric variable; the maximum minus the minimum.

T-Test (independent groups) compares means for two groups that share a common within group standard deviation.