Alaska Soil and Water Conservation District

and

Bristol Bay Native Association

Fecal Coliform and Water Quality Assessment of the Lower Nushagak River

State of Alaska Department of Environmental Conservation
Project ACWA 06-01

Final Report

July 2005 to June 2006

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Alaska Soil and Water Conservation District
510 L Street, Suite 280
Anchorage, Alaska 99501
Phone: (907) 271-2424 x108
Email: akswcd@alaskaswcds.org

Bristol Bay Native Association
P.O. Box 310
Dillingham, Alaska
Phone: (907) 842-5257
Email: sflensburg@bbna.com

Report prepared by:
Zender Environmental Science and Planning Services
308 G Street, Suite 312, Anchorage, Alaska 99501
Phone: (907) 277-2111
Email: lzender@zender-engr.net or lferber@zender-engr.net

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Introduction

Background

The Nushagak River is a large, productive salmon-producing system in Southwest Alaska. Originating on the southwest flanks of the Alaska Range, the Nushagak watershed drains an extensive area of tundra, wetlands, and forested lowlands and eventually empties into Bristol Bay. The Nushagak River is one of the most important areas in the region for biodiversity conservation and is a priority water body for protection in the Alaska Clean Water Actions (ACWA) program. It is a key producer of five species of Pacific salmon and several species of freshwater fish. The Nushagak also provides extensive habitat for waterfowl and shorebirds, as well as terrestrial birds and mammals. Seven predominately Alaska Native communities and approximately 250 Native allotments depend on the Nushagak River and its tributaries for subsistence harvesting, commercial fisheries, and renewable resource-based economic activities.

Concerns about declining water quality due to increasing pressures to develop state, federal, and Native lands have grown in recent years, as have threats from non-point source pollution associated with community growth. Proposed revisions to the Alaska Department of Natural Resources (ADNR) Bristol Bay Area Plan and Nushagak Mulchatna Rivers Recreation Management Plan increase the potential for access to and development of state lands in the watershed. The number of Native allotments on the market has risen dramatically in recent years, and parcels are typically purchased for large sport fishing and hunting operations. These changes in land use practices create concerns about solid and human waste and waste water disposal methods at these remote sites. Most of the state-owned and state-selected land in the watershed is managed by ADNR. The Bureau of Land Management manages federal land, as well as ANCSA Corporation selected land and some state-selected land (NMWC, 2001).

In addition to local development concerns, deposits of copper, gold, molybdenum, and silver have been identified near the headwaters of the Koktuli River, within the Nushagak-Mulchatna watershed. Known as the Pebble Project, extensive drilling, environmental, socio-economic, and cultural studies are being conducted by consultants of Northern Dynasty Minerals, Inc. to develop plans for an open pit mine (NDM, 2006). Exploration results from Pebble have also spurred renewed interest in other mineral deposits in the upper Nushagak watershed, such as the Shotgun Hills gold deposit near the King Salmon River, a key tributary of the upper watershed. Concerns about potential impacts from the mine and increased development have been expressed by many people living in the Bristol Bay region.

Objectives of this project were three-fold. First, we performed a fecal coliform assessment on the Lower Nushagak River to assess whether or not guide camps and/or villages affect bacterial counts. Second, a water quality assessment of the Lower Nushagak River was included in conjunction with the fecal coliform assessment to document present-day conditions. Finally, we assessed motor boat quantity/usage and petroleum sheen presence on Lower Nushagak.

Previous Water Quality Assessments

The U.S. Geological Survey collected stream discharge on the Nushagak River at Ekwok from 1975 to 1993 (USGS site 15302500). Water quality data was collected by the USGS at Ekwok from 1956 to 1986, and at New Stuyahok and Portage Creek from 1970 to 1971 (USGS, 2006). The Nushagak-Mulchatna Watershed Council sampled tributaries of the Nushagak for water quality and benthic macroinvertebrates approximately twice per year from 1999 to 2003 (data sheets on file at BBNA). A recent study (1999-2000) through the University of Alaska Fairbanks investigated mercury concentrations in surface water and muscle and liver tissues of salmon at several locations in Alaska including the Nushagak River at Portage Creek (Duffy and Zhang, 2001). Also in 1999, The University of Alaska Anchorage (ANHP and ENRI) and the Bristol Bay Native Association identified environmental indicators for the Nushagak/Mulchatna River watershed (Boggs et al., 1999). The bulk of the surface water quality indicators recommended were included in the current study. In addition, two current projects being conducted through the Bristol Bay Native Association include an instream flow reservation project on the Koktuli River, and a Traditional Use Area Conservation Planning Project, which will provide local knowledge on ecological observations and habitat values.

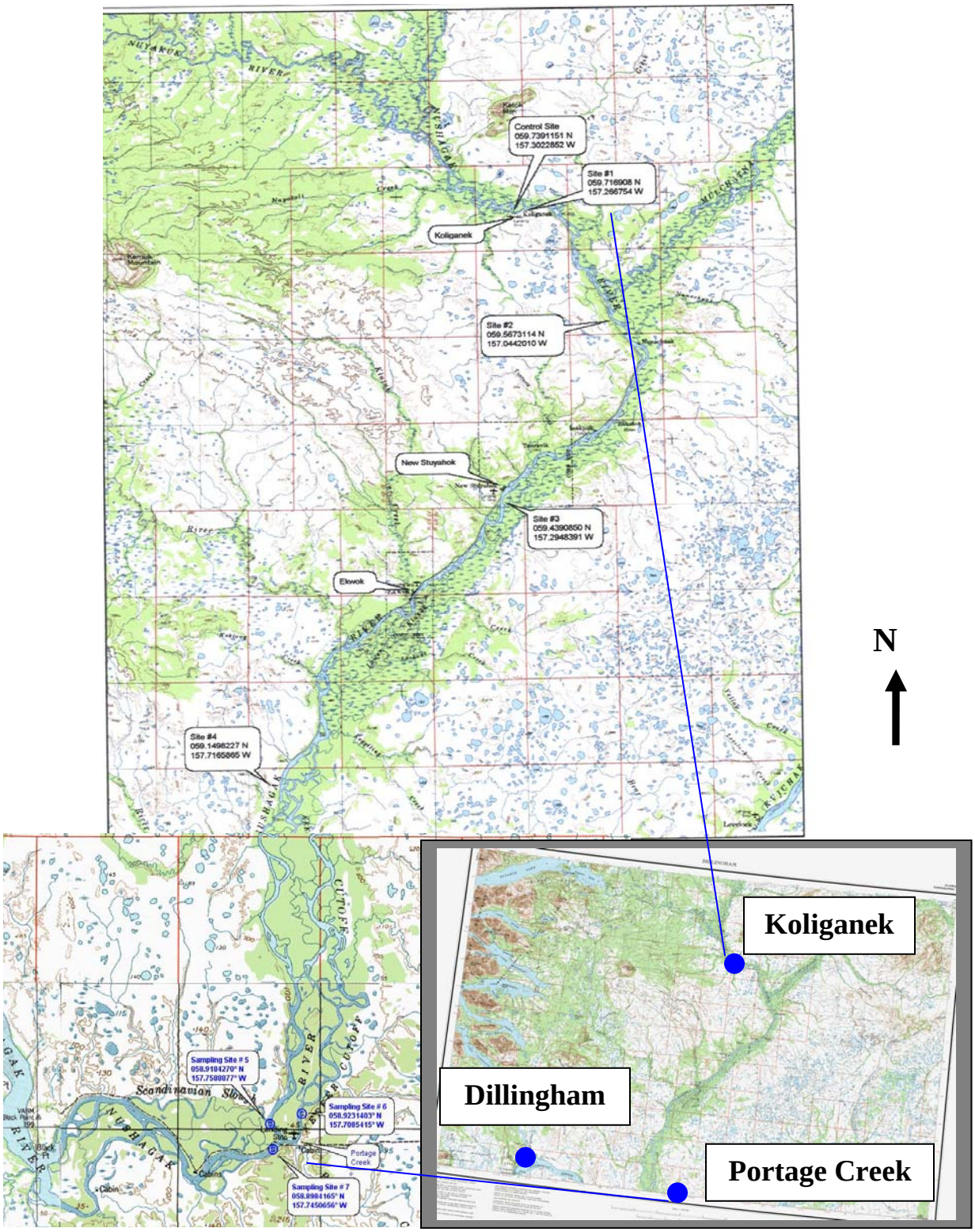
Study Area

The climate of the Nushagak River is predominantly maritime, with average summer temperatures ranging from 37 to 66 ºF and winter temperatures from 4 to 30 ºF. Annual precipitation is approximately 20-35 inches. The river is generally ice-free from May/June until mid-November. Elevation of the sampling sites ranged from 200 feet near Koliganek to 30 feet at Portage Creek. The people living in the four Alaska Native villages within the study area are principally southern Yup'ik Eskimo who live a predominantly subsistence lifestyle (ACIS, 2006).

The lower Nushagak River sub-watershed (3,059,000 acres) was identified as the highest priority basin in the Nushagak Mulchatna watershed by the Nushagak Mulchatna Watershed Council (NMWC, 2001). The Council named the lower Nushagak the highest priority because of several reasons including 1) locals use this sub-watershed the most heavily compared to other sub-watersheds, 2) Alaska Native Claims Settlement Act (ANCSA) corporation lands and the majority of Native allotments in the watershed are located along this river corridor, 3) all five communities (Koliganek, New Stuyahok, Ekwok, Portage Creek, and Dillingham) are located in the lower Nushagak sub-watershed, 4) community development and inadequate infrastructures have lead to increased pollution, and 5) the lower Nushagak receives the greatest amount of commercial recreation use, both in the number of permitted camp operations and client user days (NMWC, 2001).

This study sampled eight sites from Koliganek to Portage creek, which covered approximately 80 river miles of the lower Nushagak River.

Figure 1: Maps of Study Area



Methods

Study design

The study design of this project was driven by the relatively short hold time for fecal coliform samples to reach the laboratory and be prepared for analysis (30 hours). All other laboratory-analyzed parameters had hold times of at least 48 hours. Lab samples were shipped to the Anchorage laboratory on the first flight the morning following the sampling day. A second method to determine fecal coliform bacteria concentrations was employed with samples being incubated and enumerated in Dillingham. All data were entered into the Alaska SWCD DASLER-X database and uploaded into STORET.

Sample site selection

Bristol Bay Native Association Environmental Program staff worked with Choggiung Limited staff and the Nushagak Mulchatna Watershed Council to identify appropriate sample sites on Native lands on the lower Nushagak River for this study. Alaska SWCD staff worked with ADNR personnel and resources to identify potential sampling locations on State-owned lands.

With this information, eight sample sites were identified. Three sites were selected in the vicinity of Portage Creek, which hosts relatively high concentrations of guide camps for both fishing and hunting. One site was chosen as a control site above the village of Koliganek, and two sites located downstream of villages (Koliganek and New Stuyahok) were selected for comparison with the sites downstream of guide camps. Two additional sites were chosen, the mouth of the Mulchatna River, and Keeper's Cutoff, where the main stem of the Nushagak breaks into two distinct channels until re-joining in Portage Creek. A ninth site was established in June 2006, and stream discharge was estimated at this site near the old USGS gage. GPS coordinates of sample sites were entered into the BBNA ArcGIS database for future use. A summary of the sample site locations is:

Table 1: Lower Nushagak River Sample Site Descriptions and GPS Coordinates

Sample Site	Location Description	Latitude (º)	Longitude (º)
Control	Above Koliganek	59.73209	-157.29866
Site 1	Below Koliganek	59.73053	-157.27261
Site 2	Below mouth of Mulchatna River	59.62221	-157.10503
Site 3	Below New Stuyahok	59.44092	-157.31445
Site 4	Above Keeper's Cutoff (not sampled—see Recommendations for Future Monitoring)		
Site 5	Above Portage Creek, West channel	58.91524	-157.75339
Site 6	Above Portage Creek, East channel	58.91774	-157.72197
Site 7	Below Portage Creek, confluence of W. & E channels	58.90524	-157.74316
Site 8	Above Ekwok, at old USGS gage	59.34866	-157.47411

At each of the eight sites, four sub-sites were identified (labeled subsites A-D). The main site was located at the place of highest stream flow, generally at its mid-point. Water two feet from the "affected" bank, meaning the side of the river that was most likely to be affected by a guide camp or village, was labeled subsite A. Subsite D was located two feet from the "unaffected" bank, and subsites B and C were half-way from the main site to the un/affected banks.

Monitoring frequency

Two sampling events occurred during this project, each lasting 12-14 hours. Sampling events occurred on August 30, 2005 and June 13, 2006.

Parameter selection

Water quality parameters were selected to effectively assess fecal coliform concentrations for comparison to ADEC water quality standards per the ACWA identified actions. In addition, parameters common to most baseline water quality studies were also included in the study to document current conditions and screen for any exceedances. Selected parameters for surface water included:

Field

- Total coliform (Coliscan Easygel)
- *E. Coli* bacteria (Coliscan Easygel)
- Air Temperature (thermometer)
- Water Temperature (YSI 556)
- Dissolved oxygen (YSI 556)
- pH (YSI 556)
- Specific conductance (YSI 556)
- Oxidation-reduction potential (ORP, YSI 556)
- Turbidity (turbidimeter)
- Stream Discharge (estimate with Global Flow meter, June 2006 only)
- Petroleum sheen or other effects, visual observation

Laboratory

- Fecal coliform (SM 9222D)
- Total Nitrate-nitrogen (EPA 300.0)
- Total phosphorus (August 2005 only, EPA 365.2)
- Alkalinity (SM 2320 B)
- Hardness (calculation)
- Dissolved metals (EPA 200.8)
- Dissolved mercury (EPA 245.1)

Measurement and Analysis techniques

Field measurements and laboratory analyses followed ADEC- and/or EPA-approved methods whenever possible for credibility and continuity. The list of selected parameter above briefly identifies the methods used; additional details can be found in the Alaska SWCD quality assurance plan for this project. SGS Environmental Services, an ADEC-approved lab, was selected to perform the lab analysis for this project. The Coliscan Easygel method for *E. Coli* and Total Coliform analysis is used by several volunteer monitoring programs, including Cook Inlet Keeper and the Anchorage Waterways Council. Field and lab sample results are in Appendix A.

Data Management

Field data sheets printed on Rite in the Rain paper were used to record field measurements and observations. Data sheets were checked to ensure complete-ness before departing each sample site. Data from field sheets were entered into a Microsoft Excel spreadsheet upon return to Anchorage, where precision and accuracy checks were made. Any data that did not meet data quality objectives were flagged in the Excel spreadsheet. Laboratory data were reviewed upon receipt and also entered into the Excel spreadsheet. Data were next checked by the project QA officer and then qualified data were entered into the Alaska SWCD DASLER-X database. The database has been sent to the ADEC STORET Coordinator to upload into STORET.

Quality Assurance

The quality assurance plan for this project was approved by ADEC prior to any data collection. The project QA officer and Technical Advisory Committee made recommendations to the study design of this project to ensure its quality and success. An ADEC-laboratory was contracted for this project. All field measurements made with the YSI 556 multi-probe instrument (dissolved oxygen, water temperature, pH, specific conductance, and ORP) were made in duplicate with 10% distilled water blanks. Ten percent blanks and duplicates were made for turbidity measurements. Coliscan Easygel bacteria samples were associated with 10% distilled water blanks, and replicate samples were made in the June 2006 sampling. One site was duplicated for all laboratory analyses. Duplicate measurements are included in Appendix A with the water quality data. Quality assurance distilled water blank results and instrument calibration logs are included in Appendix B.

The Alaska SWCD quality assurance plan for this study outlines data management and quality assurance protocols for this study in further detail.

Water Quality Data

Results

Results from this study on the lower Nushagak River will be presented relative to our three study objectives: 1) perform a fecal coliform assessment, 2) assess present-day water quality conditions, and 3) assess motor boat effects on the river. Select data are presented here, and all data are available in Appendix A. Data presented in Appendix A were entered into the DASLER-X database accompanying this report unless it is struck. Historic data (May to through September samples only) collected by USGS at Ekwok will be used for comparison to this study's sample parameters (USGS, 2006) whenever comparable analytical methods were used.

Fecal Coliform

Fecal coliform concentrations generally met ADEC drinking water quality standards (geometric mean of < 20 CFU/100 mL in a 30 day period). All samples collected met ADEC water supply (aquaculture, irrigation, etc.) standards (geometric mean of < 200 CFU/100 mL in a 30 day period). Samples that did not meet the drinking water standards are highlighted below (Table 2). Note that all fecal coliform lab samples were collected at subsite A at each site (nearest the "affected" bank).

Table 2: Laboratory Fecal Coliform Results

Site	Fecal Coliform forming units per 100 mL				RPD (%)	StdDev
	Aug-05		Jun-06			
Control a	1		18			
1a	4		31			
2a	6		22			
3a	145		12	14	15.39	1.41
5a	3	0	4		200	2.12
6a	4		14			
7a	6		11			

Coliscan Easygel coliform tests revealed similar results in the August 2005 sampling. *E. Coli* counts showed seven samples (from all subsites and the main sites) to be greater than 20 CFU/100 mL (see Appendix A). All but one of these samples grew only one bacteria from the 3 mL of sample water collected (sample concentrations 33 CFU/100 mL), so the exceedances could possibly be attributed to extrapolating results from the small sample volume. The one clear exceedance was at Site 3a, with an *E. Coli* concentration of 167 CFU/100 mL. This correlated nicely with the laboratory analysis at the same site (145 CFU/100 mL). Other samples showed similar trends between Coliscan Easygel *E. Coli* and laboratory fecal coliform counts (Figure 2). Figure 3 shows proportions of *E. Coli* and other Coliform bacteria that comprise the total coliform counts from August 2005. Note that all sites on the x-axis were samples, and the y-axis is a logarithmic scale. Sites with missing bars indicate concentrations of 0 CFU/100 mL.

Coliscan Easygel tests were also used in the June 2006 sampling. However, due to reasons described in the Discussion section below, the sample data were not considered valid. The results can be reviewed in Appendix A. Historic USGS fecal coliform data collected between May 1979 to August 1986 showed a range of 1 to 40 CFU/100 mL. These values correspond to data collected in this study with the exception of the August 2005 Site 3a sample.

Figure 2: Fecal Coliform (laboratory) and Coliscan Easygel *E. Coli* at subsites A, August 2005

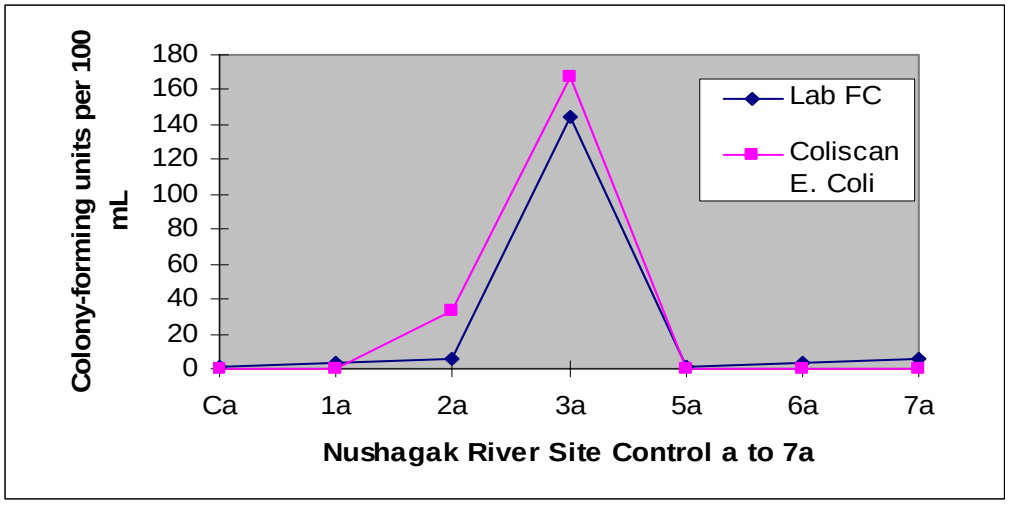
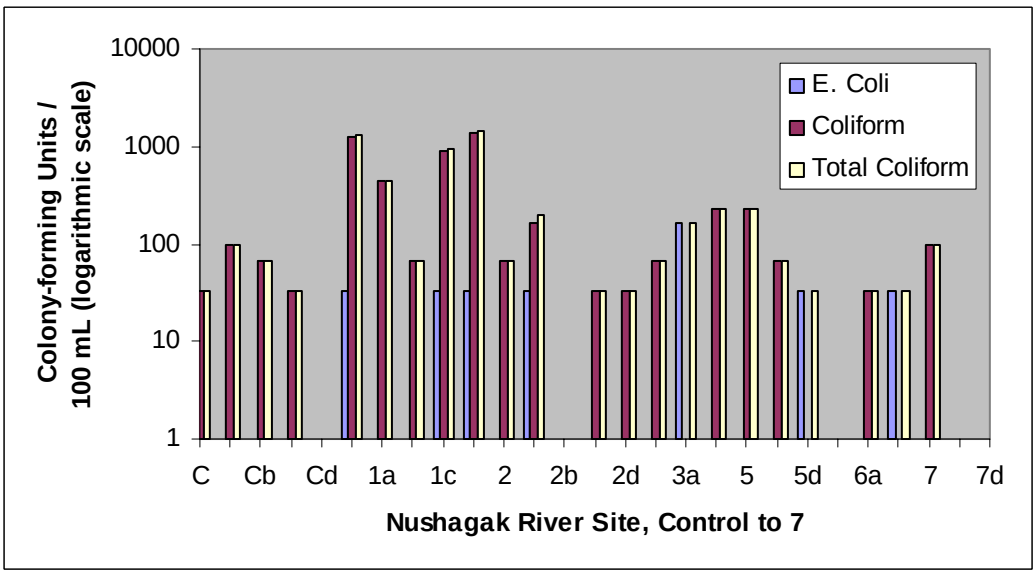


Figure 3: Proportions of E. Coli, Coliform, and Total Coliform bacteria at all sites, August 2005



Water Quality Assessment

Additional water quality parameters measured from the lower Nushagak River met almost all ADEC water quality standards for drinking water, drinking water maximum contaminants levels, and chronic aquatic life criteria. See Appendix C for further details on the relevance of each water quality parameter.

Field

Water Temperature: Temperature ranged from 11.6 to 12.3 ºC in August 2005, and from 6.0 to 9.1 ºC in June 2006. The average air temperatures during the sampling events were 13.3 and 11.7, respectively for August 2005 and June 2006. All results therefore meet the ADEC water quality standard for drinking water (15ºC), as well as the more strict water supply aquaculture standard of 13ºC for spawning areas and egg and fry incubation. Historic USGS water temperature data ranged from 1.5 to 16.5 ºC (May through September, 1956 to 1986), data from this study fall within this temperature range.

Dissolved oxygen: Dissolved oxygen ranged from 9.9 mg/L (91.2 % saturation) to 12.3 mg/L (115.2 % saturation) in August 2005, and from 11.2 mg/L (90.4 % saturation) to 12.9 mg/L (109.9 % saturation) in June 2006. ADEC water quality standards for growth of fish, shellfish, other aquatic life, and wildlife state that waters that are home to anadromous or resident fish should be between 7 -17 mg/L and should never exceed 110% of saturation. Therefore, the only exceedance for dissolved oxygen is the high percent saturation value in August 2005 (115.2 %) at Site 7. Historic USGS dissolved oxygen data ranged from 9.8 to 13.0 mg/L and 88 to 104% saturation (May through September, 1979 to 1986). Dissolved oxygen concentrations (mg/L) from this study fall within the range of the USGS historical data, though several percent saturation values from both August 2005 (Sites 5, 6, and 7) and June 2006 (Site 3 and 5) exceeded 104%. The discussion section contains further thoughts on the elevated dissolved oxygen measurements.

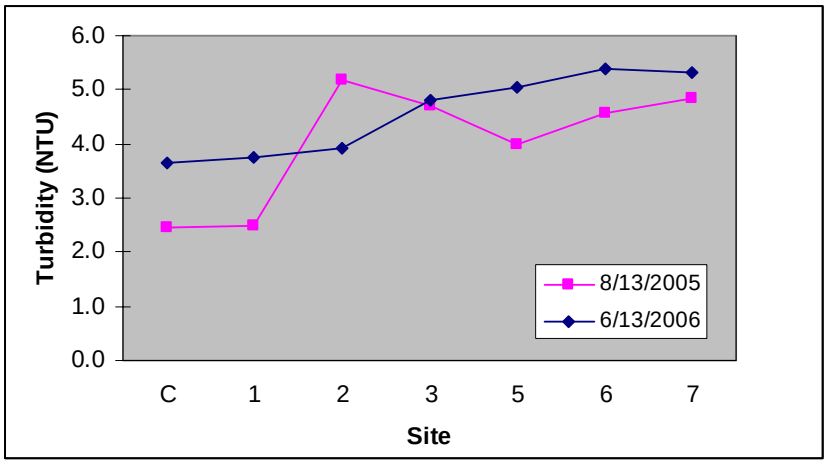
pH: The pH ranged from 6.9 to 7.4 in August 2005, and from 5.7 to 6.6 in June 2006. ADEC drinking water quality standards' acceptable range is pH 6.0 to 8.5, is 5.0 to 9.0 for water supply (agriculture and industrial), and is 6.5 to 8.5 for both water supply aquaculture and contact recreation. Eight sampling sites (including subsites) were below pH 6.0 in June 2006. Historic USGS pH data ranged from 6.1 to 7.6 (May through September, 1956 to 1986). Thus, data from the current study are within this range, except for the eight measurements made in June 2006 that were less than pH 6.0. The discussion section contains further thoughts on the relatively low pH readings.

Specific Conductance: Specific conductance results for August 2005 were quite stable, varying from 63 to 64 µS/cm. In June 2006, values ranged from 34 to 43 µS/cm. There are no ADEC water quality standards for specific conductance. Historic USGS data for specific conductance ranged from 24 to 65 µS/cm (May through September, 1956 to 1986), so data from the current study fall within this range.

Oxidation-Reduction Potential (ORP): Measurements for ORP were lower in August 2005, ranging from 167 to 209 mV, compared to 292 to 626 in June 2006. There are no ADEC water quality standards for ORP. There are no historic USGS data for oxidation-reduction potential.

Turbidity: Turbidity values were generally low, ranging from 2.3 to 10.5 NTU (average 3.9 NTU) in August 2005, and in June 2006 from 3.9 to 8.1 NTU (average 6.0 NTU). Figure 4 shows the general trend of increasing turbidity from upriver (control site) to downriver (Site 7). ADEC standards for turbidity stipulate that drinking water is to be no more than 5 NTU above natural conditions when natural turbidity is < 50 NTU. Historic USGS data for turbidity ranged from 0 to 8.1 NTU (average 2.9; May through September 1979 to 1986). It appears that turbidity values from the current study are somewhat higher than the USGS measured at Ekwok. The discussion section contains further thoughts on the slightly higher turbidity measurements.

Figure 4: Turbidity of the Lower Nushagak River



Stream Discharge: Stream discharge was estimated at the old USGS gage site at Ekwok, where stream discharge measurements were made several times per year from 1978 to 1993. The average of the 16 measurements made during this time that were closest to June 13 was 40,919 CFS (range 23,600 to 74,000 CFS). Our estimate (using a Global flow meter) was 33,361 CFS falls within this range. There are no ADEC standards for stream discharge.

Stream stage data, measured daily by a National Oceanic and Atmospheric Administration (NOAA) volunteer at Ekwok, was obtained from NOAA staff (NOAA, 2006). Figures 5a and 5b show relative stage data for 2005 and 2006 (flood stage is 16 feet). No discharge measurements accompany the stage data, but it is useful to have a record of storm events or dry periods preceding the sampling events.

Figure 5a: NOAA Nushagak River Stage Data at Ekwok (2005)

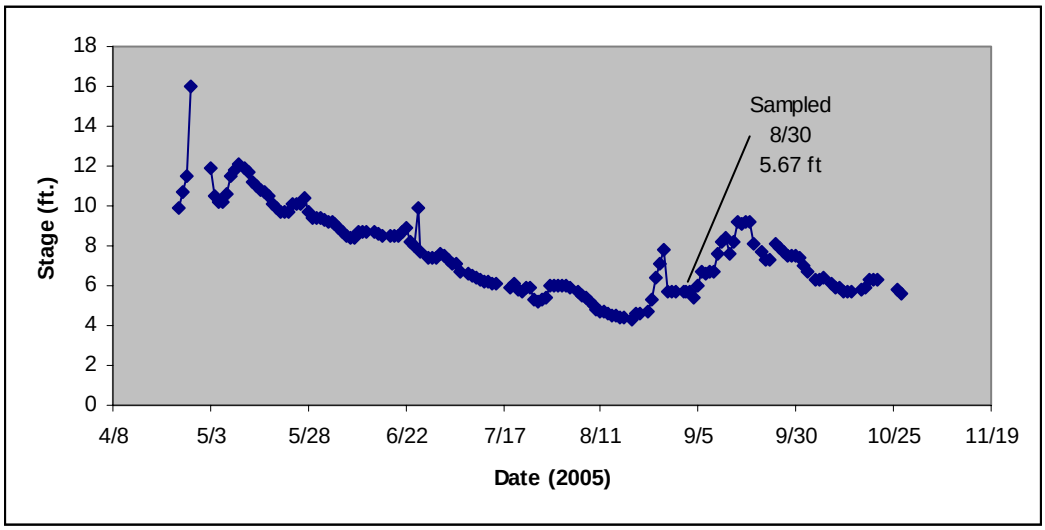
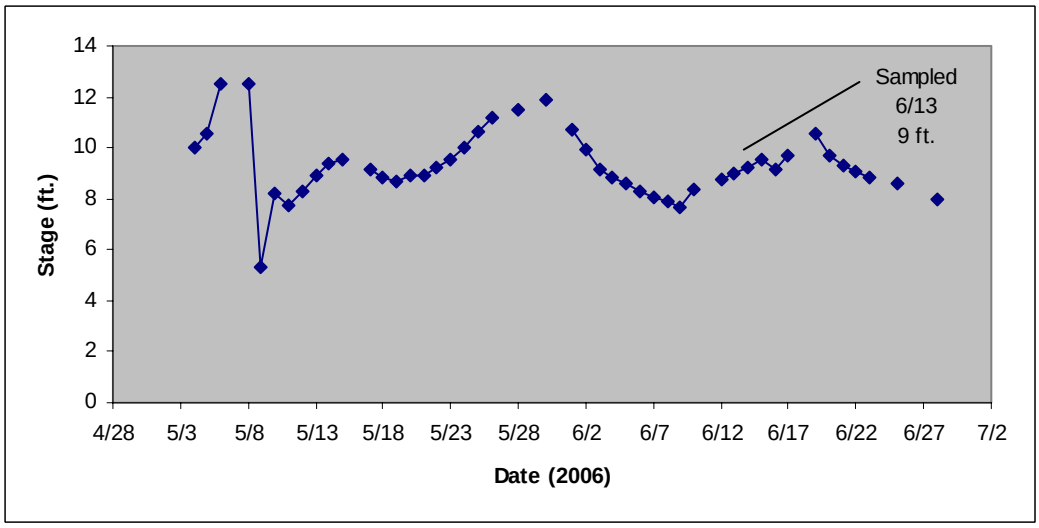


Figure 5b: NOAA Nushagak River Stage Data at Ekwok (2006)



Laboratory

Total Nitrate-nitrogen: Total nitrate-nitrogen values were lower in August 2005 than in June 2006, ranging from < 0.100 to 0.201 mg/L and 0.128 to 0.197 mg/L, respectively. These values are well below the ADEC drinking water MCL of 10 mg/L. In August 2005, the laboratory also reported total nitrite-nitrogen values, all of which were below the detection limit of 0.100 mg/L. Historic USGS unfiltered Total Nitrogen as Nitrate ranged from 0.9 to 4 mg/L (May through September 1979 to 1981). Total nitrate-nitrogen data collected in the current study were clearly lower than the USGS data in Ekwok. It is possible that the USGS collection site at Ekwok was simply higher in nitrate-nitrogen, perhaps from groundwater inputs, or that the analytical techniques are not comparable.

Total phosphorus: Total phosphorus samples were collected in August 2005 only for several reasons: price increases for all laboratory samples, the ICP/MS metals scan also includes dissolved phosphorus, and because all August samples were below the relatively high detection limit of 0.10 mg/L. This detection limit corresponds with EPA's maximum suggested total phosphorus level. Historic USGS unfiltered phosphorus samples ranged from 0.01 to 0.16 mg/L (May through September 1979 to 1986). Apparently the USGS samples were analyzed at a lower detection limit than was possible in the current study.

Total Alkalinity: Total alkalinity values ranged from 25.0 to 26.5 mg/L in August 2005, and from 22.0 to 24.0 mg/L in June 2006. These data meet the chronic aquatic life criteria of a *minimum* of 20 mg/L (20,000 µg/L) for total alkalinity. Historic USGS unfiltered alkalinity as calcium carbonate ranged from 18 to 20 mg/L (June through August 1979 to 1986). The current study found higher total alkalinity values than the USGS data at Ekwok, assuming that methods are comparable.

Total Hardness: Total hardness ranged from 24.4 to 27.5 mg/L in August 2005, and from 20.0 to 22.4 mg/L in June 2006. Hardness values were calculated by the laboratory. There are no ADEC standards for total hardness. Historic USGS data at Ekwok found hardness as mg/L calcium carbonate to range from 15 to 31 mg/L (May through September, 1956 to 1986). Therefore, total hardness data from the current study fall within this range.

Dissolved metals including mercury: Results of the 27 dissolved metals and other elements are listed in Appendix A with corresponding maximum drinking water contaminant levels (MCL) and aquatic life criteria when available. Over half of the analytes were undetectable at the practical quantitation limit (PQL) used by the laboratory. None of the 27 analytes exceeded ADEC drinking water MCLs nor aquatic life criteria. However, four dissolved iron samples exceeded the national secondary drinking water standards, which are unenforceable. The secondary standard for iron is 300 µg/L, and the four values that exceeded this standard ranged from 318 µg/L to 397 µg/L (Sites 2, 5, 6, and 7, August 2005). Historic USGS data at Ekwok for filtered iron ranged from 74 to 230 µg/L (May through September, 1979 to 1986), which is below the PQL of the method used in the current study. Thus, the current study found higher concentrations of dissolved iron in August 2005 than the USGS found in Ekwok. The discussion section elaborates on the effects of dissolved iron concentrations.

Motorboat Effects

At sample sites and during transit between sites, the sampling team was observant of any motor boat effects that might be present, such as visible sheens, empty oil containers, and eroded river banks. Data sheets, a digital camera with video capability, and a GPS unit were available to document any motorboat effects observed. The sampling team observed no motorboat effects during either sampling event. Some eroded river banks were observed (photos are included in the photo log accompanying this report), but determining the cause of the erosion (natural, trampled banks, motorboat, or other causes) was not possible from these observations.

Discussion

Fecal Coliform

Fecal coliform concentrations on the lower Nushagak River generally met ADEC drinking water quality standards. Of the three exceptions determined by laboratory analysis, two samples were collected below villages (August 2005 Site 3a, June 2006 Site 1a), and one at the mouth of the Mulchatna River (June 2006 Site 2a). Site 3a is below the village of New Stuyahok where a concentration of 145 CFU/100 mL was found in August 2005. As shown in Table 2, duplicate samples taken at this site in June 2006 revealed concentrations that meet ADEC standards (12 and 14 CFU/100 mL). Because sources of fecal coliform bacteria are numerous (humans, moose, beaver, bear, birds, etc.), it is difficult to tell the source of the higher fecal coliform bacteria concentrations.

It is advisable to continue monitoring the lower Nushagak River to determine if any locations consistently exceed water quality standards. If "hot spots" are identified, more sophisticated analyses could be performed to determine the source(s). These fecal coliform results do not show a clear trend of either guide camps or villages affecting the water quality of the lower Nushagak River.

It is recommended that Coliscan Easygel and/or Coliscan MF (membrane filter) continue to be used in future sampling events. As noted above, Coliscan Easygel results were similar to lab results in August 2005. In June 2006, apparently the sample volume was too low (2.5 mL) for the concentrations of bacteria present. In addition, the chemical film present in the Petri dishes was cracked in most dishes, and the film was peeling away from the sides of the dishes in many of the dishes (Micrology Laboratories, the producers of Coliscan products, have corrected this problem). Micrology laboratories suggest that in the future the Coliscan MF be used for lower concentrations of bacteria. Of course, it is impossible to tell before a sample is collected how high the concentration is, and therefore whether Coliscan Easygel or MF is the more appropriate test. This subject deserves additional discussion with Micrology Laboratories prior to future monitoring endeavors.

Dissolved Oxygen, pH, Turbidity, and Dissolved Iron

A few of the water quality parameters deserve further discussion. The dissolved oxygen values found in this study were generally higher than the historic USGS data at Ekwok, and in one instance exceeded the 110% saturation ADEC water quality standard. The USGS generally sampled during the mid-afternoon and evening, approximately the same time as the current study sampled sites 3 to 7, so the higher values cannot be explained by diurnal photosynthesis rates. The higher dissolved oxygen concentrations could be related to greater biomass in the river, which would evolve more oxygen through photosynthesis. This, however, is speculation, as the current study did not collect chlorophyll *a* or any other biomass indicators. As shown in the calibration log and quality assurance sample record (Appendix C), the YSI 556 was calibrated at each sampling site, and we have confidence in the dissolved oxygen data.

The YSI instrument was calibrated for pH three times during the June 2006 sampling. Each calibration showed the initial pH readings to be no more than 0.14 pH units from the standards (pH 4.0 and 7.0, see Appendix C). Therefore, it is assumed that the instrument was operating correctly. It is noted that when the distilled water for blank samples was vigorously agitated, the YSI instrument read a very low pH of 3.5, but when the water was still, it read pH 5.6. Because the YSI probe was placed in the water in June exactly as it had been placed in August 2005, the amount of agitation the probe received in the water should not be different from August. Because of the accurate initial pH readings in calibration and the same techniques performed in sample collection, the pH data were deemed valid for the current study.

Average turbidity measurements in the current study were slightly higher in June 2006 (6.0 NTU) than August 2005 (3.9 NTU), which could be explained by the higher water levels causing increased sediment load in the river. The higher turbidity values could also possibly be attributed to phytoplankton or other microorganisms in the water column, though we did not measure these parameters. A sizable storm event occurred approximately one week before the August 2005 sampling, likely increasing the turbidity concentrations during the August sampling. Both August and June turbidity values are somewhat higher than the USGS average of 2.9 NTU, though it is uncertain if the USGS measurements were made under similar conditions to the current study. Regardless, turbidity concentrations measured during the current study are considered low and indicative of excellent water quality.

As for the dissolved iron concentrations, according to information from an EPA website, noticeable effects from excess iron are “rusty color, sediment, metallic taste, and/or reddish/orange staining” (USEPA, 2006). Thus, the iron concentrations found in August 2005 do not pose a health risk.

In summary, the overall water quality was found to be excellent during the two sampling events conducted on the lower Nushagak River. Continued water quality monitoring should be performed to further characterize present-day conditions and protect this precious resource.

Recommendations for future monitoring

As in any study, a great deal of knowledge is gained in performing field work and reviewing data. The following is a list of suggestions for future monitoring efforts on the lower Nushagak River:

1) Because the sampling events were planned for one day, the sampling days were long, and both times one sample site had to be dropped due to time constraints of meeting an aircraft in Portage Creek before dusk. Each site takes approximately 1.5 hours to complete, and boating 80 river miles in a day takes time as well. Therefore, it is recommended to break each sampling event into two days. This will allow for Site 4 to be sampled and to have time to travel up the Mulchatna River to determine its contributions to the Nushagak River.

2) Continue local monitor involvement. The local monitors and boat operators that assisted with the sampling had a great deal of knowledge of the Nushagak River, local fauna, and many other things that made the sampling events possible. As well, the monitors are gaining a great deal of experience and will likely be able to perform such sampling with limited technical assistance from outside the region.

3) The discharge measurement at Ekwok was an estimate. It is recommended that techniques other than the Global flow meter be investigated for future sampling events.

4) Add *E. Coli* laboratory analysis to the list of parameters. Fecal coliform sampling should continue as well, as the ADEC water quality standards are for fecal coliform. A number of sources believe that *E. Coli* is a better estimator of fecal coliform than the current fecal coliform test. See a paper by Michael P. Doyle and Marilyn C. Erickson titled "Closing the door on the fecal coliform assay" in Microbe, vol 1, 2006.

5) Investigate using Coliscan MF for future sampling events. Coliscan products are generally easy to use and inexpensive, so it is recommended that Coliscan Easygel and/or Coliscan MF be used. More sites and subsites can be sampled because of the lower costs than the $50 laboratory samples. In the same vein, upon arrival to the Nushagak River (generally the day before the sampling event), it would be wise to take a few Coliscan samples to gain an idea of the bacterial concentrations.

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Appendix A--Water Quality Data

Coliscan Easygel Results from August 05 Sampling

Sample ID	(blue/purple) # *E. Coli* colonies	# *E. Coli* colonies per 100 mL	(pink/red) # Coliform colonies	# Coliform colonies per 100 mL	(teal) # Non-coliform	Total Coliform per 100 mL
Control-main	0	0	1	33	0	33
Ca	0	0	3	100	0	100
Cb	0	0	2	67	0	67
Cc	0	0	1	33	0	33
Cd	0	0	0	0	0	0
1-main	1	33	38	1267	0	1300
1a	0	0	13	433	0	433
1b	0	0	2	67	0	67
1c	1	33	27	900	0	933
1d	1	33	42	1400	0	1433
2-main	0	0	2	67	0	67
2a	1	33	5	167	0	200
2b	0	0	0	0	0	0
2c	0	0	1	33	0	33
2d	0	0	1	33	0	33
3-main	0	0	2	67	0	67
3a	5	167	0	0	0	167
3d	0	0	7	233	0	233
5-main	0	0	7	233	0	233
5a	0	0	2	67	0	67
5d	1	33	0	0	0	33
6-main	0	0	0	0	0	0
6a	0	0	1	33	0	33
6d	1	33	0	0	0	33
7-main	0	0	3	100	0	100
7a	0	0	0	0	0	0
7d	0	0	0	0	0	0

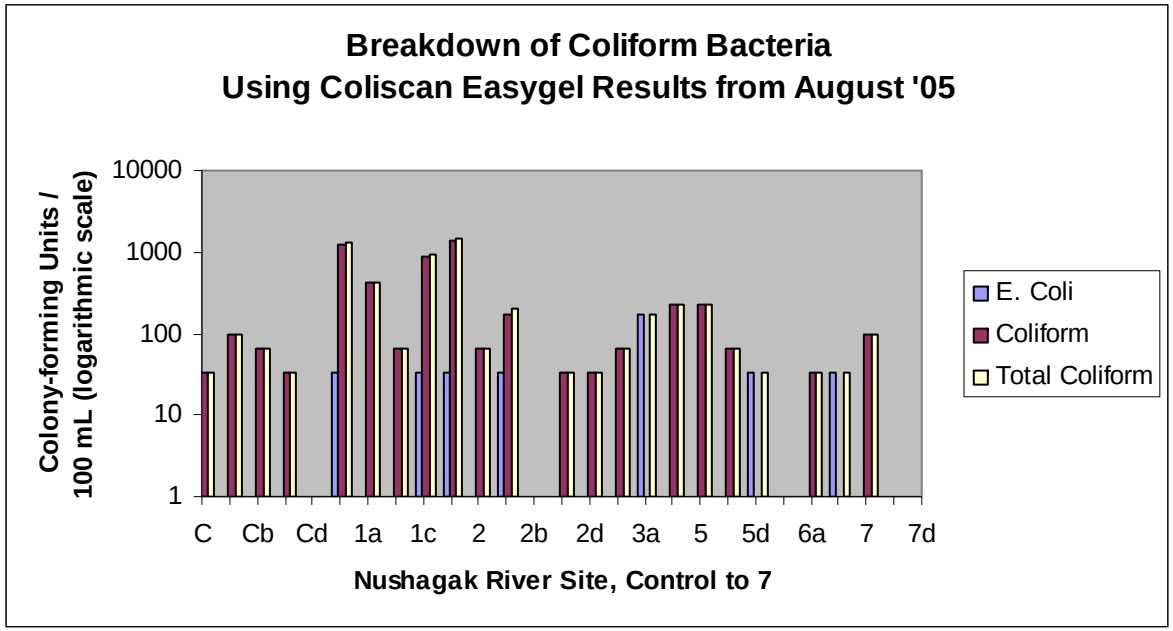
Note: Highlighted cells indicate ADEC drinking water quality exceedances (>20 CFU/mL)

Coliscan Easygel Results from August 05 Sampling

	Sample	Date: 8/30/05	Date: 8/31/05	Date: 9/1/05	
Sample ID	volume (mL)	Time collected	Time plated	Enumerated	Comments
Control-main	3	10:22	8:35	11:09	
Ca	3	10:45	8:35	11:09	
Cb	3	10:40	8:35	11:10	
Cc	3	10:00	8:35	11:10	
Cd	3	9:53	8:35	11:11	
1-main	3	11:15	8:38	11:14	Pink = 2 lg, 36 small
1a	3	11:38	8:38	11:16	
1b	3	11:33	8:38	11:22	
1c	3	11:43	8:38	11:23	Pink = 1 lg, 26 small
1d	3	11:46	8:38	11:24	Pink = 5 lg, 37 small
2-main	3	13:35	8:38	11:26	Pink = 1 lg, 1 small
2a	3	13:16	8:40	11:28	Pink = 1 lg, 4 small
2b	3	13:22	8:40	11:29	
2c	3	13:58	8:40	11:30	
2d	3	14:02	8:40	11:30	
3-main	3	15:08	8:40	11:31	
3a	3	15:30	8:40	11:32	
3d	3	15:41	8:42	11:33	
5-main	3	18:44	8:42	11:35	Pink = 7 small
5a	3	18:10	8:42	11:36	Pink = 1 lg, 1 small
5d	3	18:23	8:42	11:36	
6-main	3	19:15	8:45	11:38	
6a	3	19:30	8:45	11:39	
6d	3	19:41	8:45	11:40	
7-main	3	19:57	8:45	11:41	Pink = 3 small
7a	3	20:06	8:45	11:42	
7d	3	20:16	8:45	11:42	

Notes from Coliscan Easygel August 2005 Sampling Incubation:

1) 8/31: All samples in incubator by 8:45
2) 8/31: 12:30 temp checked--35 C. Rotated bottom two bags of petri dishes to top
3) 8/31: 15:00 temp checked--34 C. Rotated bottom two bags up to top.
4) 8/31: 17:30 temp checked--34 C. Rotated bottom two bags to top.
5) 8/31: 19:30 temp checked--35 C. Rotated bottom two bags to top.
6) 8/31: 21:00 temp checked--34 C. Rotated bags
7) 9/1: 8:00 temp checked--30 C. Rotated bags. (cold night in garage).



Note:
All sites labeled on x-axis were sampled. Sites with missing or no bars indicate 0 CFU/100 mL

Coliscan Easygel Results from June 2006

Sample ID	# *E. Coli* colonies	# E. Coli colonies per 100 mL				# Coliform colonies	# Coliform colonies per 100 mL				# Non-coliform colonies	# Non-coliform colonies per 10		
			Average	Standard Deviation	RPD/CV			Average	Standard Deviation	RPD/CV			Average	Standard Deviation
C-main	0	0	0	0	0	0	0	0	0	0	0	0	0	0
C-main	0	0				0	0				0	0		
C-main	0	0	**0**	0	0	0	0	**0**	0	0	0	0	**0**	0
Ca	0	0				0	0				0	0		
Ca	0	0				0	0				0	0		
Ca	0	0	**0**	0	0	0	0	**0**	0	0	0	0	**0**	0
1-main	0	0				5	200				0	0		
1-main	0	0				4	160				0	0		
1-main	0	0	**0**	0	0	0	0	**120**	105.8	88.2	0	0	**0**	0
1a	0	0				0	0				0	0		
1a	0	0				0	0				0	0		
1a	0	0	**0**	0	0	2	80	**27**	46.2	173.2	0	0	**0**	0
2-main	0	0				0	0				0	0		
2-main	0	0				0	0				1	40		
2-main	0	0	**0**	0	0	0	0	**0**	0	0	0	0	**13**	23.1
2a	0	0				0	0				0	0		
2a	0	0	**0**	0	0	5	200	**100**	141.4	200	0	0	**0**	0
3-main	0	0				0	0				1	40		
3-main	0	0				0	0				0	0		
3-main	0	0	**0**	0	0	0	0	**0**	0	0	0	0	**13**	23.1
3a	0	0				0	0				0	0		
3a	0	0				0	0				0	0		
3a	0	0	**0**	0	0	0	0	**0**	0	0	0	0	**0**	0
5-main	0	0				0	0				0	0		
5-main	0	0	**0**	0	0	0	0	**0**	0	0	0	0	**0**	0
5a	0	0				0	0				0	0		
5a	0	0				0	0				0	0		
5a	0	0	**0**	0	0	0	0	**0**	0	0	0	0	**0**	0
5b	0	0				0	0				0	0		
5b	0	0	**0**	0	0	0	0	**0**	0	0	0	0	**0**	0
5c	0	0				0	0				0	0		
5c	0	0	**0**	0	0	0	0	**0**	0	0	0	0	**0**	0
5d	0	0				0	0				0	0		
5d	0	0	**0**	0	0	0	0	**0**	0	0	1	40	**20**	28.3
6-main	0	0				0	0				0	0		
6-main	0	0	**0**	0	0	0	0	**0**	0	0	0	0	**0**	0
6a	0	0				0	0				0	0		
6a	0	0	**0**	0	0	0	0	**0**	0	0	0	0	**0**	0
7-main	0	0				0	0				0	0		
7-main	0	0	**0**	0	0	0	0	**0**	0	0	0	0	**0**	0
7a	0	0				0	0				0	0		
7a	0	0	**0**	0	0	0	0	**0**	0	0	0	0	**0**	0
7d	0	0				0	0				0	0		
7d	0	0	**0**	0	0	0	0	**0**	0	0	0	0	**0**	0

Coliscan Easygel Results from June 2006

	Replicate	Sample	Date: 6/13/06	Date: 6/14/06	Date: 6/15/06	
Sample ID	Number	volume (mL)	Time collected	Time plated	Enumerated	Comments
C-main	1	2.5	9:57	7:15	15:59	firm, hardly cracked
C-main	2	2.5	9:58	7:15	16:00	little liquid
C-main	3	2.5	9:59	7:15	16:02	firm
Ca	1	2.5	11:40	7:15	16:03	firm
Ca	2	2.5	11:41	7:15	15:26	firm
Ca	3	2.5	11:42	7:15	16:04	firm, no cracks
1-main	1	2.5	10:56	7:20	15:40	2 lg, 3 small, firm not cracked
1-main	2	2.5	10:57	7:20	15:41	2 lg, 2 small, firm not cracked
1-main	3	2.5	10:58	7:20	15:42	firm not cracked
1a	1	2.5	11:31	7:20	15:44	little liquid
1a	2	2.5	11:32	7:20	15:45	little liquid
1a	3	2.5	11:33	7:20	15:27	firm
2-main	1	2.5	13:21	7:24	15:16	media firm
2-main	2	2.5	13:22	7:24	15:16	media has some liquid
2-main	3	2.5	13:23	7:24	15:17	media firm
2a	1	2.5	13:38	7:24	15:17	some liquid
2a	2	2.5	13:39	7:24	15:18	5 small (small as bubbles), firm
3-main	1	2.5	14:25	7:31	15:33	little liquid
3-main	2	2.5	14:26	7:31	15:34	little liquid
3-main	3	2.5	14:27	7:31	15:35	little liquid
3a	1	2.5	14:58	7:31	15:35	little liquid
3a	2	2.5	14:59	7:31	15:36	little liquid
3a	3	2.5	15:00	7:31	15:38	little liquid
5-main	1	2.5	18:03	7:35	15:28	little liquid
5-main	2	2.5	18:04	7:35	15:29	firm
5a	1	2.5	17:17	7:35	16:07	liquid
5a	2	2.5	17:18	7:35	15:30	little liquid
5a	3	2.5	17:19	7:35	15:31	firm
5b	1	2.5	17:50	7:35	16:10	little liquid
5b	2	2.5	17:51	7:35	16:11	little liquid
5c	1	2.5	18:16	7:35	16:09	little liquid
5c	2	2.5	18:17	7:35	16:11	liquid
5d	1	2.5	18:25	7:35	16:04	little liquid
5d	2	2.5	18:26	7:35	16:05	little liquid
6-main	1	2.5	19:54	7:48	15:49	firm, not cracked
6-main	2	2.5	19:55	7:48	15:50	firm
6a	1	2.5	20:18	7:48	15:50	firm
6a	2	2.5	20:19	7:48	15:51	little liquid
7-main	1	2.5	18:47	7:55	15:56	firm
7-main	2	2.5	18:48	7:55	15:58	little liquid
7a	1	2.5	19:24	7:55	15:53	firm
7a	2	2.5	19:25	7:55	15:55	weird plate edges, firm
7d	1	2.5	19:11	7:55	15:55	firm
7d	2	2.5	19:12	7:55	15:56	firm

Notes from June 2006 Coliscan Sample Incubation:

6/14/2006

1) All samples in incubator at 8:40am--34 deg C
2) 12:06 rotated samples, 33 C
3) 14:00 rotated samples, 33 C, raised temperature
4) 15:30 rotated samples, 34 C
5) 17:15 rotated samples 32 C
6) 19:00 rotated samples, new thermometer, 90 deg F
7) 21:30 rotated samples, 95F

6/15/2006

8) 7:30 rotated samples 90F
9) 9:00 removed samples from incubator & inspected. Found very few bacteria. Will incubate for a couple of additional hours to see if anything else grows.
10) 11:32 rotated 90F
11) 13:00 90F
12) 15:00 removed from incubator and enumerated.

Note on June 2006 Coliscan Easygel Comment section: Comments such as "firm" and "little liquid" refer to the media, which may or may not have completely gelled. Petri dish media had cracks in it unless noted.

Air Temperature Results, ºC		
Site	**August-05**	**June-06**
Control	-	11
1	12	9.5
2	13	10.3
3	12.5	14.0
5	14	10.3
6	14.5	15.1
7	14	-
Average	**13.3**	**11.7**

Site	Barometric Pressure and WaterTemperature Results (measured with YSI 556 Multi-probe)																			
	Aug-05					Jun-06					Aug-05					Jun-06				
	Barometric Pressure (in. Hg)					Barometric Pressure (in. Hg)					Water Temperature (deg. C)					Water Temperature (deg. C)				
	Rep. 1	Rep. 2	Average	RPD (%)	StdDev	Rep. 1	Rep. 2	Average	RPD (%)	StdDev	Rep. 1	Rep. 2	Average	RPD (%)	StdDev	Rep. 1	Rep. 2	Average	RPD (%)	StdDev
Control-main	29.72	29.72	29.72	0.00	0.00	29.83	29.83	29.83	0.00	0.00	11.6	11.6	11.6	0.09	0.01	6.2	6.2	6.2	0.16	0.01
Ca						29.83	29.83	29.83	0.00	0.00						6.0	6.0	6.0	0.00	0.00
Cb						29.84	29.84	29.84	0.00	0.00						6.0	6.0	6.0	0.17	0.01
Cc						29.83	29.83	29.83	0.00	0.00						6.3	6.3	6.3	0.00	0.00
Cd						29.83	29.83	29.83	0.00	0.00						6.4	6.4	6.4	0.16	0.01
1-main	-	-	-	-	-	29.85	29.85	29.85	0.00	0.00	11.7	11.7	11.7	0.00	0.00	6.1	6.1	6.1	0.00	0.00
1a						29.84	29.84	29.84	0.00	0.00						6.1	6.1	6.1	0.00	0.00
1b						29.84	29.84	29.84	0.00	0.00						6.1	6.1	6.1	0.00	0.00
1c						29.84	29.84	29.84	0.00	0.00						6.2	6.2	6.2	0.16	0.01
1d						29.83	29.83	29.83	0.00	0.00						6.3	6.3	6.3	0.00	0.00
2-main	29.82	29.82	29.82	0.00	0.00	29.86	29.86	29.86	0.00	0.00	11.2	-	-	-	-	6.5	6.5	6.5	0.46	0.02
2a						29.85	29.85	29.85	0.00	0.00						6.5	6.5	6.5	0.00	0.00
2b						29.86	29.86	29.86	0.00	0.00						6.4	6.4	6.4	0.00	0.00
2c						29.84	29.84	29.84	0.00	0.00						7.2	7.2	7.2	0.14	0.01
2d						29.85	29.86	29.86	0.03	0.01						9.1	9.1	9.1	0.00	0.00
3-main	29.86	29.86	29.86	0.00	0.00	29.89	29.89	29.89	0.00	0.00	11.7	11.7	11.7	0.09	0.01	7.1	7.0	7.1	0.57	0.03
3a						29.87	29.88	29.88	0.03	0.01						7.4	7.4	7.4	0.13	0.01
3b						29.88	29.88	29.88	0.00	0.00						7.2	7.2	7.2	0.00	0.00
3c						29.88	29.88	29.88	0.00	0.00						7.5	7.5	7.5	0.13	0.01
3d						29.90	29.91	29.91	0.03	0.01						8.1	8.0	8.0	0.12	0.01
5-main	29.98	29.98	29.98	0.00	0.00	29.86	29.95	29.91	0.30	0.06	12.3	12.3	12.3	0.00	0.00	8.3	8.3	8.3	0.00	0.00
5a						29.94	29.94	29.94	0.00	0.00						8.4	8.4	8.4	0.12	0.01
5b						29.94	29.95	29.95	0.03	0.01						8.3	8.3	8.3	0.00	0.00
5c						29.94	29.94	29.94	0.00	0.00						8.4	8.3	8.3	0.12	0.01
5d						29.96	29.96	29.96	0.00	0.00						8.6	8.6	8.6	0.12	0.01
6-main	29.98	29.99	29.99	0.03	0.01	29.92	29.92	29.92	0.00	0.00	12.1	12.1	12.1	0.00	0.00	8.5	8.5	8.5	0.12	0.01
6a						29.92	29.92	29.92	0.00	0.00						8.7	8.7	8.7	0.12	0.01
6b						29.93	29.93	29.93	0.00	0.00						8.6	8.5	8.6	0.47	0.03
6c						29.92	29.93	29.93	0.03	0.01						~~8.9~~	8.5	8.5	-	-
6d						Not sampled due to gravel bar presence											Not sampled due to gravel bar presence				
7-main	29.99	29.99	29.99	0.00	0.00	29.95	29.95	29.95	0.00	0.00	12.3	12.3	12.3	0.16	0.01	8.4	8.4	8.4	0.12	0.01
7a						29.94	29.94	29.94	0.00	0.00						8.6	8.6	8.6	0.23	0.01
7b						29.94	29.94	29.94	0.00	0.00						8.4	8.4	8.4	0.12	0.01
7c						29.95	29.94	29.95	0.03	0.01						8.4	8.4	8.4	0.00	0.00
7d						29.95	29.95	29.95	0.00	0.00						8.5	8.5	8.5	0.00	0.00

Notes for YSI Measurements:

1) The symbol "-" indicates that measurements that were not made and their associated RPD/CV and standard deviation are not applicable.
2) The TAC recommended sampling all subsites with the YSI multi-probe for the June 2006 sampling.
3) Subsite 6d was not sampled in June 2006 due to gravel bar presence.
4) Several measurements were not taken at Site 2 in August 2005 because of intense rain showers.
5) Results that are struck (ex: ~~value~~) did not meet data quality objectives and were not included in the average results nor entered into the DASLER-X database.

Site	Dissolved Oxygen Results (measured with YSI 556 Multi-probe)																			
	Aug-05					Jun-06					Aug-05					Jun-06				
	Dissolved Oxygen (mg/L)					Dissolved Oxygen (mg/L)					Dissolved Oxygen (% Sat.)					Dissolved Oxygen (% Sat.)				
	Rep. 1	Rep. 2	Average	RPD (%)	StdDev	Rep. 1	Rep. 2	Average	RPD (%)	StdDev	Rep. 1	Rep. 2	Average	RPD (%)	StdDev	Rep. 1	Rep. 2	Average	RPD (%)	StdDev
Control-main	9.9	9.9	9.9	0.10	0.01	11.3	11.3	11.3	0.18	0.01	91.2	91.1	91.2	0.11	0.07	90.9	90.8	90.9	0.11	0.07
Ca						11.3	11.3	11.3	0.27	0.02						90.4	90.3	90.4	0.11	0.07
Cb						11.3	11.3	11.3	0.00	0.00						90.3	90.4	90.4	0.11	0.07
Cc						11.3	11.2	11.3	0.18	0.01						90.8	90.9	90.9	0.11	0.07
Cd						11.2	11.2	11.2	0.09	0.01						90.5	90.4	90.5	0.11	0.07
1-main	10.3	10.1	10.2	2.36	0.17	11.4	11.4	11.4	0.18	0.01	94.6	92.5	93.6	2.24	1.48	91.5	91.5	91.5	0.00	0.00
1a						11.4	11.4	11.4	0.09	0.01						91.5	91.4	91.5	0.11	0.07
1b						11.3	11.4	11.3	0.18	0.01						91.2	91.3	91.3	0.11	0.07
1c						11.3	11.3	11.3	0.00	0.00						91.1	91.2	91.2	0.11	0.07
1d						11.2	11.2	11.2	0.00	0.00						90.9	90.8	90.9	0.11	0.07
2-main	10.8	-	10.8	-	-	12.2	12.2	12.2	0.00	0.00	98.0	-	98.0	-	-	99.4	99.4	99.4	0.00	0.00
2a						12.3	12.3	12.3	0.00	0.00						99.6	99.7	99.7	0.10	0.07
2b						12.3	12.3	12.3	0.08	0.01						99.6	99.5	99.6	0.10	0.07
2c						12.0	11.9	11.9	0.17	0.01						99.2	98.7	99.0	0.51	0.35
2d						11.2	11.2	11.2	0.00	0.00						97.3	97.3	97.3	0.00	0.00
3-main	10.7	10.7	10.7	0.37	0.03	12.6	12.6	12.6	0.24	0.02	-	-	-	-	-	104.3	104.0	104.2	0.29	0.21
3a						12.8	12.8	12.8	0.08	0.01						106.8	106.7	106.8	0.09	0.07
3b						12.8	12.7	12.7	0.31	0.03						105.5	105.2	105.4	0.28	0.21
3c						12.4	12.4	12.4	0.16	0.01						103.3	103.3	103.3	0.00	0.00
3d						12.3	12.3	12.3	0.16	0.01						103.7	103.9	103.8	0.19	0.14
5-main	11.3	-	11.3	-	-	12.7	12.7	12.7	0.00	0.00	105.2	-	105.2	-	-	108.0	107.9	108.0	0.09	0.07
5a						12.9	12.9	12.9	0.16	0.01						109.9	109.9	109.9	0.00	0.00
5b						12.8	12.8	12.8	0.16	0.01						108.4	108.6	108.5	0.18	0.14
5c						12.7	12.7	12.7	0.16	0.01						108.2	108.2	108.2	0.00	0.00
5d						12.7	12.7	12.7	0.16	0.01						108.8	108.5	108.7	0.28	0.21
6-main	11.6	-	11.6	-	-	11.9	11.9	11.9	0.08	0.01	107.7	-	107.7	-	-	101.5	101.6	101.6	0.10	0.07
6a						11.9	11.9	11.9	0.00	0.00						102.5	102.5	102.5	0.00	0.00
6b						11.9	11.9	11.9	0.17	0.01						102.0	101.9	102.0	0.10	0.07
6c						11.8	11.8	11.8	0.17	0.01						101.1	101.0	101.1	0.10	0.07
6d						Not sampled due to gravel bar presence										Not sampled due to gravel bar presence				
7-main	12.3	-	12.3	-	-	12.2	12.2	12.2	0.41	0.04	115.2	-	115.2	-	-	103.8	103.5	103.7	0.29	0.21
7a						12.1	12.1	12.1	0.25	0.02						103.5	103.6	103.6	0.10	0.07
7b						12.2	12.2	12.2	0.25	0.02						104.0	103.8	103.9	0.19	0.14
7c						12.1	12.1	12.1	0.17	0.01						103.1	102.9	103.0	0.19	0.14
7d						12.0	11.9	12.0	0.17	0.01						102.1	102.0	102.1	0.10	0.07

Specific Conductance and pH Results (measured with YSI 556 Multi-probe)																					
Site	Aug-05					Jun-06					Aug-05					Jun-06					
	Specific Conductance (uS/cm)					Specific Conductance (uS/cm)					pH					pH					
	Rep. 1	Rep. 2	Average	RPD (%)	StdDev	Rep. 1	Rep. 2	Average	RPD (%)	StdDev	Rep. 1	Rep. 2	Average	RPD (%)	StdDev	Rep. 1	Rep. 2	Rep. 3	Average	RPD (%)	StdDev
Control-main	63	63	63	0.00	0.00	33	34	34	2.99	0.71	6.9	6.9	6.9	0.15	0.01	5.9	5.9		5.9	0.17	0.01
Ca						34	34	34	0.00	0.00						6.3	6.3		6.3	0.16	0.01
Cb						34	34	34	0.00	0.00						6.4	6.4		6.4	0.16	0.01
Cc						33	34	34	2.99	0.71						5.9	5.9		5.9	0.00	0.00
Cd						33	33	33	0.00	0.00						~~5.3~~	5.8	5.8	5.8	0.17	0.01
1-main	63	62	63	1.60	0.71	34	34	34	0.00	0.00	6.9	7.0	6.9	1.15	0.06	5.8	5.8		5.8	0.00	0.00
1a						34	34	34	0.00	0.00						6.3	6.3		6.3	0.16	0.01
1b						34	34	34	0.00	0.00						5.9	5.9		5.9	1.02	0.04
1c						33	33	33	0.00	0.00						5.9	5.9		5.9	0.34	0.01
1d						34	33	34	2.99	0.71						6.2	6.2		6.2	0.16	0.01
2-main	63	-	-	-	-	34	34	34	0.00	0.00	6.9	-	-	-	-	6.0	6.0		6.0	0.50	0.02
2a						35	34	35	2.90	0.71						6.3	6.2		6.2	1.12	0.05
2b						34	34	34	0.00	0.00						6.0	6.0		6.0	0.17	0.01
2c						36	36	36	0.00	0.00						6.0	6.0		6.0	0.67	0.03
2d						43	43	43	0.00	0.00						5.7	5.8	5.8	5.8	0.95	0.06
3-main	65	63	64	3.13	1.41	35	35	35	0.00	0.00	7.2	7.3	7.2	0.41	0.02	6.4	6.4		6.4	0.16	0.01
3a						36	36	36	0.00	0.00						6.5	6.5		6.5	0.46	0.02
3b						35	35	35	0.00	0.00						6.4	6.4		6.4	0.31	0.01
3c						37	37	37	0.00	0.00						6.4	6.4		6.4	0.00	0.00
3d						38	38	38	0.00	0.00						6.6	6.6		6.6	0.15	0.01
5-main	64	64	64	0.00	0.00	36	36	36	0.00	0.00	7.3	7.3	7.3	0.55	0.03	6.1	6.1		6.1	0.49	0.02
5a						35	35	35	0.00	0.00						5.9	6.0		5.9	0.84	0.04
5b						35	35	35	0.00	0.00						6.0	6.1		6.1	1.15	0.05
5c						36	36	36	0.00	0.00						6.3	6.3		6.3	0.16	0.01
5d						37	37	37	0.00	0.00						6.5	6.5		6.5	0.31	0.01
6-main	64	64	64	0.00	0.00	37	37	37	0.00	0.00	7.3	7.3	7.3	0.27	0.01	6.5	6.5		6.5	0.15	0.01
6a						38	37	38	2.67	0.71						6.6	6.5		6.6	1.07	0.05
6b						37	37	37	0.00	0.00						6.5	6.5		6.5	0.46	0.02
6c						37	37	37	0.00	0.00						6.5	6.5		6.5	0.15	0.01
6d						Not sampled due to gravel bar presence										Not sampled due to gravel bar presence					
7-main	63	64	64	1.57	0.71	36	36	36	0.00	0.00	7.5	7.4	7.4	0.13	0.01	6.5	6.5		6.5	0.46	0.02
7a						36	36	36	0.00	0.00						6.8	6.8		6.8	0.74	0.04
7b						36	36	36	0.00	0.00						6.5	6.5		6.5	1.23	0.06
7c						37	37	37	0.00	0.00						6.4	6.4		6.4	0.16	0.01
7d						38	37	38	2.67	0.71						6.5	6.5		6.5	0.31	0.01

Oxidation Reduction Potential Results (measured with YSI 556 Multi-probe)											
Site	Aug-05					Jun-06					
	Oxidation-reduction potential (mV)					Oxidation-reduction potential (mV)					
	Rep. 1	Rep. 2	Average	RPD (%)	StdDev	Rep. 1	Rep. 2	Rep. 3	Average	RPD/CV (%)	StdDev
Control-main	210	209	209	0.53	0.78	591	587		589	0.76	3.18
Ca						608	601		605	1.14	4.88
Cb						589	586		587	0.43	1.77
Cc						581	577		579	0.74	3.04
Cd						437	489	495	474	6.71	31.76
1-main	173	174	173	0.58	0.71	620	616		618	0.68	2.97
1a						618	611		615	1.15	5.02
1b						627	626		626	0.11	0.49
1c						629	623		626	0.91	4.03
1d						600	595		598	0.79	3.32
2-main	188	-	-	-	-	494	492		493	0.34	1.20
2a						460	464		462	0.80	2.62
2b						484	485		484	0.19	0.64
2c						503	507		505	0.73	2.62
2d						510	510		510	0.12	0.42
3-main	166	168	167	1.02	1.20	379	379		379	0.05	0.14
3a						400	400		400	0.07	0.21
3b						397	397		397	0.05	0.14
3c						403	403		403	0.07	0.21
3d						393	393		393	0.08	0.21
5-main	185	184	185	0.87	1.13	341	341		341	0.03	0.07
5a						291	293		292	0.41	0.85
5b						318	318		318	0.06	0.14
5c						355	355		355	0.06	0.14
5d						360	359		359	0.28	0.71
6-main	181	182	182	0.72	0.92	396	396		396	0.03	0.07
6a						401	403		402	0.30	0.85
6b						402	403		402	0.12	0.35
6c						402	401		401	0.10	0.28
6d						Not sampled due to gravel bar presence					
7-main	185	184	184	0.22	0.28	386	386		386	0.13	0.35
7a						361	359		360	0.67	1.70
7b						382	385		383	0.65	1.77
7c						390	389		389	0.36	0.99
7d						382	381		381	0.45	1.20

Turbidity Measurements							
Aug-05							
Site	**Rep. 1**	**Rep. 2**	**Rep. 3**	**Rep. 4**	**Average**	**RPD/CV (%)**	**StdDev**
Control	2.6	2.6			2.6	0.00	0.00
Ca	2.4	2.4			2.4	0.00	0.00
Cb	2.4	2.5			2.5	4.08	0.07
Cc	2.6	2.4	2.5		2.5	4.00	0.10
Cd	2.3	2.2			2.3	4.44	0.07
1	2.5	2.3	2.6		2.5	6.19	0.15
1a	2.3	2.3			2.3	0.00	0.00
1b	2.4	2.4			2.4	0.00	0.00
1c	2.6	2.3			2.5	12.24	0.21
1d	2.8	2.8			2.8	0.00	0.00
2	3.3	3.5			3.4	5.88	0.14
2a	7.2	7.1			7.2	1.40	0.07
2b	10.0	11.0			10.5	9.52	0.71
2c	2.4	2.5			2.5	4.08	0.07
2d	2.7	2.2	2.2		2.4	12.20	0.29
3	4.0	6.0	4.4	5.5	5.0	18.74	0.93
3a	3.7	3.7			3.7	0.00	0.00
3d	5.5	5.3			5.4	3.70	0.14
5	4.1	4.2			4.2	2.41	0.07
5a	3.9	4.8	3.9		4.2	12.37	0.52
5d	3.6	3.7			3.7	2.74	0.07
6	4.3	6.2	4.3		4.9	22.24	1.10
6a	3.8	4.1	4.3	3.8	4.0	5.46	0.22
6d	5.7	4.2	4.6	4.6	4.8	13.49	0.64
7	4.3	4.1			4.2	2.86	0.08
7a	4.7	5.6	4.3	5.2	5.0	12.00	0.60
7d	5.3	5.7	5.1	5.3	5.3	5.16	0.28

Notes:

1) All August 05 measurements were taken in duplicate with one reading per measurement.

2) USGS protocols were used for the June 06 sampling, with each sample having four readings (22.2% duplicates).

3) Subsites b and c were not sampled at sites 5-7 in August 05 due to time constraints/poor weather.

4) Subsite 6d was not sampled in June 06 due to the presence of a gravel bar.

5) A LaMotte 2020 Turbidimeter was used in August 05, and a Hach 2100 Turbidimeter in June 06.

6) Results that are struck-through (~~value~~) did not meet data quality objectives and were not included in the average results nor entered into the DASLER-X database.

Turbidity Measurements										
Jun-06										
Site	**Rep. 1**	**Rep. 2**	**Rep. 3**	**Rep. 4**	**Rep. 5**	**Rep. 6**	**Rep. 7**	**Average**	**CV (%)**	**StdDev**
Control-main	5.4	5.0	5.4	4.9				5.2	4.72	0.24
Ca	~~7.5~~	4.2	4.7	4.3				4.4	6.46	0.29
Cb	5.3	4.5	4.2	4.4				4.6	9.97	0.46
Cc	4.9	5.0	4.9	5.2				5.0	2.73	0.14
Cd	4.9	4.8	5.0	5.0				4.9	2.46	0.12
Cd	5.7	4.8	5.1	5.1				5.2	7.86	0.41
1-main	5.3	6.5	5.0	4.4				5.3	16.14	0.86
1-main	5.1	5.2	5.0	5.0				5.1	2.29	0.12
1a	4.2	4.1	4.2	3.9				4.1	4.09	0.17
1b	4.6	4.3	4.7	4.1				4.4	6.15	0.27
1c	5.6	5.2	6.0	5.3				5.5	6.55	0.36
1d	5.4	5.4	5.2	5.0				5.2	3.09	0.16
1d	5.7	5.6	5.1	5.2				5.4	5.27	0.28
2-main	6.1	5.6	5.6	5.4				5.7	5.47	0.31
2a	6.3	7.1	6.4	6.3				6.5	5.85	0.38
2b	5.9	6.4	6.0	5.9				6.0	3.83	0.23
2c	3.7	3.9	3.6	4.2				3.9	6.65	0.26
2d	4.8	3.8	4.0	3.8				4.1	12.18	0.50
3-main	6.6	7.3	6.1	6.3				6.6	7.92	0.52
3a	5.8	6.4	6.1	5.8				6.0	4.68	0.28
3b	6.6	6.5	6.0	6.1				6.3	4.49	0.28
3c	7.7	8.2	7.5	7.6				7.8	4.03	0.31
3d	5.3	5.5	5.3	5.3				5.3	2.49	0.13
5-main	6.8	6.3	7.0	5.8				6.5	8.40	0.54
5-main	7.4	6.8	6.3	5.8				6.6	10.29	0.68
5a	7.0	6.7	7.1	7.0				7.0	2.17	0.15
5b	6.1	6.6	5.7	5.8				6.1	6.74	0.41
5c	6.9	6.4	5.9	5.9				6.3	8.08	0.51
5d	8.4	8.5	7.2	8.4				8.1	7.87	0.64
6-main	8.3	7.8	7.8	7.3				7.8	5.49	0.43
6-main	7.0	6.7	6.4	6.5				6.6	3.77	0.25
6a	7.0	6.6	6.6	6.6				6.7	2.73	0.18
6b	6.7	7.2	6.6	7.1				6.9	4.13	0.29
6c	8.9	~~9.3~~	6.9	7.5				7.7	13.64	1.06
6c	~~10.2~~	7.4	7.1	7.5	(sample was re-run…high variability)			7.3	2.77	0.20
6d	Not sampled due to gravel bar presence									
7-main	6.7	6.6	6.0	5.8				6.3	6.72	0.42
7a	6.5	7.3	6.6	7.0				6.8	5.76	0.39
7b	6.4	6.5	6.7	6.9				6.6	3.82	0.25
7c	7.7	7.0	7.8	7.3				7.4	5.39	0.40
7d	7.6	7.6	~~7.1~~	~~9.6~~	8.6	8.6	7.9	8.1	6.26	0.51

Total Nitrate-N and Nitrite-N Data--August 2005										
Site	**Total Nitrate-N (mg/L)**	**Total Nitrate-N (mg/L)**	**Total Nitrate-N (mg/L)**	**Total Nitrate-N (mg/L)**	**Total Nitrate-N (mg/L)**	**Total Nitrite-N (mg/L)**	**Total Nitrite-N (mg/L)**	**Total Nitrite-N (mg/L)**	**Total Nitrite-N (mg/L)**	**Total Nitrite-N (mg/L)**
	Rep. 1	Rep. 2	Average	RPD (%)	StdDev	Rep. 1	Rep. 2	Average	RPD (%)	StdDev
Control-main	<0.100					<0.100				
1	<0.100					<0.100				
2	0.201					<0.100				
3	<0.100					<0.100				
5	<0.100	<0.100	<0.100	0	0	<0.100	<0.100	<0.100	0	0
6	<0.100					<0.100				
7	<0.100					<0.100				
PQL (mg/L)	0.100					0.100				
Drinking water MCL (mg/L)	10					1				

Total Phosphorus Data--August 2005					
Site	**Total Phosphorus (mg/L)**	**Total Phosphorus (mg/L)**	**Total Phosphorus (mg/L)**	**Total Phosphorus (mg/L)**	**Total Phosphorus (mg/L)**
	Rep. 1	Rep. 2	Average	RPD (%)	StdDev
Control-main	<0.100				
1	<0.100				
2	<0.100				
3	<0.100				
5	<0.100	<0.100	<0.100	0	0
6	<0.100				
7	<0.100				
PQL (mg/L)	0.100				

Total Alkalinity and Total Hardness Data--August 2005										
Site	**Total Alkalinity (mg/L)**	**Total Alkalinity (mg/L)**	**Total Alkalinity (mg/L)**	**Total Alkalinity (mg/L)**	**Total Alkalinity (mg/L)**	**Total Hardness (mg/L)**	**Total Hardness (mg/L)**	**Total Hardness (mg/L)**	**Total Hardness (mg/L)**	**Total Hardness (mg/L)**
	Rep. 1	Rep. 2	Average	RPD (%)	StdDev	Rep. 1	Rep. 2	Average	RPD (%)	StdDev
Control-main	25.0					26.1				
1	25.0					24.6				
2	25.5					27.5				
3	26.0					24.4				
5	26.0	26.5	26.3	1.87	0.92	25.7	27.0	26.4	1.16	0.35
6	26.0					26.3				
7	26.5					25.5				
PQL (mg/L)	10.0					20.0				
Aquatic Life Criteria (mg/L) [1]	20									

Note:

1) Aquatic Life Criteria for alkalinity is *minimum* 20,000 ug/L (20 mg/L). Therefore, data meet chronic aquatic life criteria for total alkalinity.

Total Nitrate-nitrogen and Alkalinity Data--June 2006										
Site	**Total Nitrate-N (mg/L)**	**Total Nitrate-N (mg/L)**	**Total Nitrate-N (mg/L)**	**Total Nitrate-N (mg/L)**	**Total Nitrate-N (mg/L)**	**Total Alkalinity (mg/L)**	**Total Alkalinity (mg/L)**	**Total Alkalinity (mg/L)**	**Total Alkalinity (mg/L)**	**Total Alkalinity (mg/L)**
	Rep. 1	Rep. 2	Average	RPD (%)	StdDev	Rep. 1	Rep. 2	Average	RPD (%)	StdDev
Control	0.161					<40				
1	0.168					22				
2	0.197					22				
3	0.147	0.156	0.152	5.94	0.01	22	22	22	0	0
5	0.145					24				
6	0.130					22				
7	0.128					24				
PQL (mg/L)	0.100					40/20				
Drinking water MCL (mg/L)	10									
Aquatic Life Criteria (mg/L)						20				

Note:

1) Aquatic Life Criteria for alkalinity is *minimum* 20,000 ug/L (20 mg/L). Therefore, data meet chronic aquatic life criteria for total alkalinity.

Total Hardness Data--June 2006					
Site	**Total Hardness (mg/L)**	**Total Hardness (mg/L)**	**Total Hardness (mg/L)**	**Total Hardness (mg/L)**	**Total Hardness (mg/L)**
	Rep. 1	Rep. 2	Average	RPD (%)	StdDev
Control	20.9				
1	21.5				
2	20.7				
3	21.4	21	21.2	1.89	0.28
5	20.0				
6	22.4				
7	21.9				
PQL (mg/L)	5.0				

Results of Metals Analysis by ICP/MS																
Site (all units ug/L)	**C**		**1**		**2**		**3**		**5**		**6**		**7**		**Drinking Water MCL [2]**	**Aquatic Life Criteria [3]**
Sample Date	Aug-06	Jun-06	Aug-06	Jun-06	Aug-06	Jun-06	Aug-06	6/13/2006 [1]	8/5/2006 [1]	Jun-06	Aug-06	Jun-06	Aug-06	Jun-06		
Mercury	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	2	0.77
Aluminum	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20		87[T]
Antimony	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	6	
Arsenic	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	50	150
Barium	7.6	5.27	6.6	4.85	4.9	5.2	5.6	4.96	5.0	4.2	5.3	4.23	5.2	3.97	2000	
Beryllium	<0.400	<0.400	<0.4	<0.4	<0.400	<0.400	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	<0.4	4	
Cadmium	<0.500	<0.500	<0.5	<0.5	<0.500	<0.500	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	<0.5	5	0.094
Calcium	6880	5820	6350	5740	6840	5690	6320	5750	6500	5490	6540	5500	6430	5470		
Chromium	3.77	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	100	
Cobalt	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4		
Copper	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	1000	
Iron	<250	<250	<250	<250	318	<250	266	<250	374	<250	397	<250	389	<250	300	1000
Lead	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2	<0.2		0.5
Magnesium	2030	1550	1830	1440	1670	1470	1750	1480	1835	1430	1820	1440	1840	1450		
Manganese	4.0	5.2	4.1	5.0	12.1	5.4	5.9	5.4	6.6	7.8	6.8	8.2	6.4	8.5	500	
Molybdenum	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10		
Nickel	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	100	16.2
Phosphorus	<200	<200	<200	<200	<200	<200	<200	<200	<200	<200	<200	<200	<200	<200		
Potassium	<500	<500	<500	<500	<500	<500	<500	<500	<500	<500	<500	<500	<500	<500		
Selenium	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	50	4.6
Silver	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	100	0.32 [A]
Thallium	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1	2	
Zinc	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	5000	36.3
Silicon	2580	2500	2140	2300	2760	2390	2240	2500	2380	2860	2340	2650	2360	2710		
Sodium	1790	1270	1640	1170	2110	1230	1960	1320	2170	1510	2190	1430	2200	1480		
Tin	<1	<1	<1	1.04	<1	<1	<1	<1	<1	<1	<1	<1	<1	<1		
Titanium	7.1	<5	7.0	5.9	8.3	5.3	7.7	5.1	7.3	5.4	7.9	<5	7.5	<5		
Vanadium		<20		<20		<20		<20		<20		<20		<20		

Notes:

1) Site 3 June 2006 and Site 5 August 2005 data are averages of two samples. See following table for replicate, RPD, and standard deviation values.

2) MCL=Maximum Contaminant Level. MCLs with blue shading indicate National Secondary Drinking Water Standards, which are not enforceable.
MCL units are mg/L, so were converted to ug/L for this table.

3) Aquatic life criteria are for chronic, total water unless noted by "T" (total) or "A" (acute). Criteria are calculated using average August 2005 hardness values from all sites (25.8 mg/L).

4) Gray shading indicates that analyte practical quantitation limit (PQL) is lower than the aquatic life criteria.

5) Yellow shading indicates that the value exceeds the MCL.

Results of Metals Analysis by ICP/MS--Replicate, RPD, and Standard Deviation Values										
Site (all units ug/L)	August 2005, Site 5					June 2006, Site 3				
	Rep. 1	Rep. 2	Average	RPD (%)	StdDev	Rep. 1	Rep. 2	Average	RPD (%)	StdDev
Mercury	<0.200	<0.200	<0.2	0.00	0.00	<0.2	<0.2	<0.2	0.00	0.00
Aluminum	<20.0	<20.0	<20	0.00	0.00	<20	<20	<20	0.00	0.00
Antimony	<1.00	<1.00	<1	0.00	0.00	<1	<1	<1	0.00	0.00
Arsenic	<5.00	<5.00	<5	0.00	0.00	<5	<5	<5	0.00	0.00
Barium	5.02	5.04	5.0	0.40	0.01	4.94	4.97	4.96	0.61	0.02
Beryllium	<0.400	<0.400	<0.4	0.00	0.00	<0.4	<0.4	<0.4	0.00	0.00
Cadmium	<0.500	<0.500	<0.5	0.00	0.00	<0.5	<0.5	<0.5	0.00	0.00
Calcium	6570	6430	6500	2.15	98.99	5610	5890	5750	4.87	197.99
Chromium	<1.00	<1.00	<1	0.00	0.00	<1	<1	<1	0.00	0.00
Cobalt	<4.00	<4.00	<4	0.00	0.00	<4	<4	<4	0.00	0.00
Copper	<1.00	<1.00	<1.00	0.00	0.00	<1	<1	<1	0.00	0.00
Iron	380	367	374	3.48	9.19	<250	<250	<250	0.00	0.00
Lead	<0.200	<0.200	<0.2	0.00	0.00	<0.2	<0.2	<0.2	0.00	0.00
Magnesium	1850	1820	1835	1.63	21.21	1460	1500	1480	2.70	28.28
Manganese	6.76	6.48	6.6	4.23	0.20	5.04	5.65	5.35	11.41	0.43
Molybdenum	<10.0	<10.0	<10	0.00	0.00	<10	<10	<10	0.00	0.00
Nickel	<2.00	<2.00	<2	0.00	0.00	<2	<2	<2	0.00	0.00
Phosphorus	<200	<200	<200	0.00	0.00	<200	<200	<200	0.00	0.00
Potassium	<500	<500	<500	0.00	0.00	<500	<500	<500	0.00	0.00
Selenium	<5.00	<5.00	<5	0.00	0.00	<5	<5	<5	0.00	0.00
Silver	<1.00	<1.00	<1	0.00	0.00	<1	<1	<1	0.00	0.00
Thallium	<1.00	<1.00	<1	0.00	0.00	<1	<1	<1	0.00	0.00
Zinc	<5.00	<5.00	<5	0.00	0.00	<5	<5	<5	0.00	0.00
Silicon	2450	2310	2380	5.88	98.99	2480	2520	2500	1.60	28.28
Sodium	2190	2150	2170	1.84	28.28	1310	1330	1320	1.52	14.14
Tin	<1.00	<1.00	<1	0.00	0.00	<1	<1	<1	0.00	0.00
Titanium	7.50	7.13	7.3	5.06	0.26	5.04	5.16	5.1	2.35	0.08
Vanadium	<20.0	<20.0	<20	0.00	0.00	<20	<20	<20	0.00	0.00

Stream Discharge Measurement Taken at Old USGS Gage site in Ekwok

June 12, 2006, Start time 18:30
Daniel Chythlook, Luki Akelkok, Sr., & Lisa Ferber
Lat: N59.34866, Long: W157.47411
Estimated stream width: 1000 ft.
Comments: We set out to make 20 measurements across the width of the river approximately every ~50 ft.
However, we over-estimated distances between measurement locations and so made 16 measurements.
The Global Flow Meter telescoped to 9 ft., so depths greater than this are estimates and highlighted in red.

Section Number	(Feet) Section Width	(Feet) Total Depth	(Feet) 0.2 depth	(ft./sec) 0.2 velocity	(Feet) 0.8 depth	(ft./sec) 0.8 velocity	(ft.^3/sec) Discharge	Comments
1	62.5	7.5	1.5	3.5	6	2.7	1453	West shore
2	62.5	20	4	4.4	9	1.7	3813	Measurement taken at 9 ft, though 0.8 depth was ~15
3	62.5	20	4	5	9	1.8	4250	Measurement taken at 9 ft, though 0.8 depth was ~15
4	62.5	20	4	3.3	9	3.2	4063	Measurement taken at 9 ft, though 0.8 depth was ~15
5	62.5	20	4	5	9	4	5625	Measurement taken at 9 ft, though 0.8 depth was ~15
6	62.5	9	1.8	5.82	7.2	3.5	2621	
7	62.5	6	1.2	5.15	4.8	-	1931	Drifted off station
8	62.5	3.2	0.64	4.6	2.56	3.2	780	
9	62.5	2.7	0.54	4.6	2.16	3.2	658	
10	62.5	4.1	0.82	4.8	3.28	2.9	987	
11	62.5	5.5	1.1	4.3	4.4	1.9	1066	
12	62.5	5.8	1.16	4	4.64	3.3	1323	
13	62.5	5	1	3.8	4	2.6	1000	
14	62.5	8	1.6	3.5	6.4	2.7	1550	
15	62.5	7.9	1.58	4.3	6.32	3.3	1876	
16	62.5	3	0.6	2.2	2.4	1.7	366	East shore

Estimated Discharge	33,361 CFS

Wildlife Observed at Sample Sites During June 2006 Sampling

All wildlife identified by Daniel Chythlook by call or sight

Site	Wildlife Observed
Control	Flycatcher, white-crowned sparrow
1	Bald eagle, merganser, fly catcher
2	Swallows, wood thrush, flycatcher, king fisher, 2 bald eagles, arctic tern
3	No wildlife recorded
5	Varied thrush, white-crowned sparrow
6	Varied thrush
7	Common loon

Appendix B--Calibration logs and Quality Assurance Blanks

Instrument Calibration Log--August 2005 Sampling

YSI 556 Multimeter TTT Environmental ID WQM-16 (556 MPS)

Date	Time	Location	Temperature (deg C) NIST/YSI	Barometer (mm Hg)	Conductivity (vs. 1.413 mS/cm standard)	Dissolved oxygen (vs. 100% saturation)	pH Standards 4 & 7	ORP, Zobell Solution (temp-dependent)	Comments
8/26/2005	16:00	Anchorage	25.58 / 25.51	29.85	1.413	100	4.00 / 7.00	224	Picked up today from TTT
8/29/2005	18:40	Koliganek	16.11	29.54	1.413	100	4.00 / 7.03	235	Looks good!
8/30/2005	9:08	Control d	12.39	29.70	1.413	100	4.00 / 7.05	240	Calibrated at subsite d
8/30/2005	12:50	Site 2	16.16	29.79	1.395	100	4.08 / 7.04	228.9	Checked all except DO, which I calibrated
8/30/2005	13:51	Site 2	-	-	-	100	-	-	
8/30/2005	15:20	Site 3	-	-	-	100	-	-	
8/30/2005	18:08	Site 5	14.85	29.97	1.413	100	4.00 / 7.04	236	
8/30/2005	19:00	Site 5	-	-	-	100	-	-	Kept reading super saturated

Turbidity Meter (LaMotte 2020)

Date	Time	Location	Standard (1 or 10 NTU)	Initial Reading (NTU)	Reading after Calibration (NTU)	Comments	
8/26/2005	15:42	Anchorage	10	12	10		
8/26/2005	15:45	Anchorage	1	0.30	1		
8/29/2005	16:30	Koliganek	1	0.85	1		
8/30/2005	9:07	Control	1	0.95	1		
8/30/2005	12:51	Site 2b	1	1	-	Not calibrated	
8/30/2005	13:26	Site 2b	10	11	10		
8/30/2005	15:06	Site 3	10	10	-	Not calibrated--no need	
8/30/2005	18:06	Site 5	1	0.95	1		

CHEMetrics Dissolved Oxygen

Site	DO (ppm)
Control	8
1	8
2	8
3	8
5	8
6	8
7	8

Distilled Water Blanks from August 2005 Sampling

YSI 556 and Turbidity

Site	DO mg/L	DO % Sat.	Water Temp (C)	ORP (mV)	pH	Specific Conductance (uS/cm)	Turbidity (NTU)
Control	9.18	83.1	11.69	320.1	5.58	1	1
1	-	-	-	-	-	-	-
2	-	-	-	-	-	-	0.95
3	-	91.7	12.62	304.6	5.96	1	0.50
5	-	-	-	-	-	-	0.70
6	-	-	-	-	-	-	0.75
7	-	-	-	-	-	-	-

Coliscan Easygel

Sample ID	# *E. Coli* colonies	# *E. Coli* colonies/ 100 mL	# Coliform colonies	# Coliform colonies per 100 mL	# Non-coliform colonies	# Total Coliform colonies	Sample volume (mL)	Date: 8/30/05 Time collected	Date: 8/31/05 Time plated	Date: 9/1/05 Time enumerated
C blank	2	67	1	33	0	100	3	9:50	8:35	11:12
3 blank	0	0	0	0	0	0	3	15:40	8:42	11:34
5 blank	0	0	0	0	0	0	3	18:24	8:42	11:37
7 blank	0	0	0	0	0	0	3	20:10	8:45	11:43

Yellow highlight indicates flagged data

Distilled Water Blanks from June 2006 Sampling

Blanks

Site	DO mg/L	DO % Sat.	Barometric Pressure (mm Hg)	Water Temp (C)	ORP (mV)	pH	Specific Conductance (uS/cm)	Turbidity (NTU) Measure 1	Turbidity (NTU) Measure 2	Turbidity (NTU) Measure 3	Turbidity (NTU) Measure 4	Turbidity Average (NTU)
Control-d	9.98	86	29.84	8.88	482.5	3.52	3	0.12	0.08	0.08	0.08	0.09
1												
2d	8.75	80.3	29.85	11.13	498.4	5.39	1					
3-main								0.06	0.05	0.05	0.05	0.05
5												
6												
7												

Comments:

1) We realized after taking the blank pH reading at site control-d that agitating the distilled water cup while taking the reading caused the pH to be noticably low.
2) At control-d, the pH was checked with 7.0 solution after the first measurement, which read 7.05. We then proceeded to the second replicate.

Coliscan Easygel

Sample ID	# *E. Coli* colonies	# Colifor	# Non-coliform	# Total Coliform	Sample volume (mL)	Date: 6/13/06 Time collected	Date: 6/14/06 Time plated	Date: 6/15/06 Enumerated	Comments
C-main-blank	0	0	0	0	2.5	10:02	7:15	16:03	firm
1a-blank	0	0	0	0	2.5	11:27	7:20	15:43	firm
2a-blank	0	0	0	0	2.5	13:40	7:24	15:19	firm
6-main blank	0	0	0	0	2.5	19:56	7:48	15:48	firm
5b-blank	0	0	0	0	2.5	17:52	7:35	16:08	liquid

Appendix C--Information on Water Quality Parameters

Sources:

EPA Volunteer Stream Monitoring Manual
(http://www.epa.gov/volunteer/stream/index.html)

USGS Water Quality Information News website
(http://water.usgs.gov/owq/Explanation.html)

Russell Mainstream Supply Ltd., Technical Area (United Kingdom)
(http://www.rmprocesscontrol.co.uk/Technical.htm#ORP)

Lenntech—Metals in Aquatic Freshwater
(http://www.lenntech.com/aquatic/metals.htm)

Information below was taken from the EPA Volunteer Stream Monitoring Manual
(http://www.epa.gov/volunteer/stream/index.html)

DISSOLVED OXYGEN

What is dissolved oxygen and why is it important?

The stream system both produces and consumes oxygen. It gains oxygen from the atmosphere and from plants as a result of photosynthesis. Running water, because of its churning, dissolves more oxygen than still water, such as that in a reservoir behind a dam. Respiration by aquatic animals, decomposition, and various chemical reactions consume oxygen.

Wastewater from sewage treatment plants often contains organic materials that are decomposed by microorganisms, which use oxygen in the process. (The amount of oxygen consumed by these organisms in breaking down the waste is known as the biochemical oxygen demand or BOD. A discussion of BOD and how to monitor it is included at the end of this section.) Other sources of oxygen-consuming waste include stormwater runoff from farmland or urban streets, feedlots, and failing septic systems.

Oxygen is measured in its dissolved form as dissolved oxygen (DO). If more oxygen is consumed than is produced, dissolved oxygen levels decline and some sensitive animals may move away, weaken, or die.

DO levels fluctuate seasonally and over a 24-hour period. They vary with water temperature and altitude. Cold water holds more oxygen than warm water (Table 5.3) and water holds less oxygen at higher altitudes. Thermal discharges, such as water used to cool machinery in a manufacturing plant or a power plant, raise the temperature of water and lower its oxygen content. Aquatic animals are most vulnerable to lowered DO levels in the early morning on hot summer days when stream flows are low, water temperatures are high, and aquatic plants have not been producing oxygen since sunset.

NITRATES

What are nitrates and why are they important?

Nitrates are a form of nitrogen, which is found in several different forms in terrestrial and aquatic ecosystems. These forms of nitrogen include ammonia (NH3), nitrates (NO3), and nitrites (NO2). Nitrates are essential plant nutrients, but in excess amounts they can cause significant water quality problems. Together with phosphorus, nitrates in excess amounts can accelerate eutrophication, causing dramatic increases in aquatic plant growth and changes in the types of plants and animals that live in the stream. This, in turn, affects dissolved oxygen, temperature, and other indicators. Excess nitrates can cause hypoxia (low levels of dissolved oxygen) and can become toxic to warm-blooded animals at higher concentrations (10 mg/L) or higher) under certain conditions. The natural level of ammonia or nitrate in surface water is typically low (less than 1 mg/L); in the effluent of wastewater treatment plants, it can range up to 30 mg/L.
Sources of nitrates include wastewater treatment plants, runoff from fertilized lawns and cropland, failing on-site septic systems, runoff from animal manure storage areas, and industrial discharges that contain corrosion inhibitors.

TEMPERATURE

Why is temperature important?

The rates of biological and chemical processes depend on temperature. Aquatic organisms from microbes to fish are dependent on certain temperature ranges for their optimal health. Optimal temperatures for fish depend on the species: some survive best in colder water, whereas others prefer warmer water. Benthic macroinvertebrates are also sensitive to temperature and will move in the stream to find their optimal temperature. If temperatures are outside this optimal range for a prolonged period of time, organisms are stressed and can die. Temperature is measured in de-grees Fahrenheit (F) or degrees Celsius (C).

For fish, there are two kinds of limiting temperatures the maximum temperature for short exposures and a weekly average temperature that varies according to the time of year and the life cycle stage of the fish species. Reproductive stages (spawning and embryo development) are the most sensitive stages.

Table 5.5 provides temperature criteria for some species.

Temperature affects the oxygen content of the water (oxygen levels become lower as temperature increases); the rate of photosynthesis by aquatic plants; the metabolic rates of aquatic organisms; and the sensitivity of organisms to toxic wastes, parasites, and diseases.

Causes of temperature change include weather, removal of shading streambank vegetation, impoundments (a body of water confined by a barrier, such as a dam), dis-charge of cooling water, urban storm water, and groundwater inflows to the stream.

Table 5.5

Maximum average temperatures for growth and short-term maximum temperatures for selected fish (°C and ° F)

Species	Max. weekly average temp. for growth (juveniles)	Max. temp. for survival of short exposure (juveniles)	Max. weekly average temp. for spawning [a]	Max. temp. for embryo spawning [b]
Atlantic salmon	20 °C (68 °F)	23 °C (73 °F)	5 °C (41 °F)	11 °C (52 °F)
Bluegill	32 °C (90 °F)	35 °C (95 °F)	25 °C (77 °F)	34 °C (93 °F)
Brook trout	19 °C (66 °F)	24 °C (75 °F)	9 °C (48 °F)	13 °C (55 °F)
Common carp	---	---	21 °C (70 °F)	33 °C (91 °F)
Channel catfish	32 °C (90 °F)	35 °C (95 °F)	27 °C (81 °F)	29 °C (84 °F)
Largemouth bass	32 °C (90 °F)	34 °C (93 °F)	21 °C (70 °F)	27 °C (81 °F)
Rainbow trout	19 °C (66 °F)	24 °C (75 °F)	9 °C (48 °F)	13 °C (55 °F)
Smallmouth bass	29 °C (84 °F)	---	17 °C (63 °F)	23 °C (73 °F)
Sockeye salmon	18 °C (64 °F)	22 °C (72 °F)	10 °C (50 °F)	13 °C (55 °F)

a - Optimum or mean of the range of spawning temperatures reported for the species
b - Upper temperature for successful incubation and hatching reported for the species
c - Upper temperature for spawning

(Brungs and Jones 1977)

pH

What Is pH and why is it important?

pH is a term used to indicate the alkalinity or acidity of a substance as ranked on a scale from 1.0 to 14.0. Acidity increases as the pH gets lower. Fig. 5.9 present the pH of some common liquids.

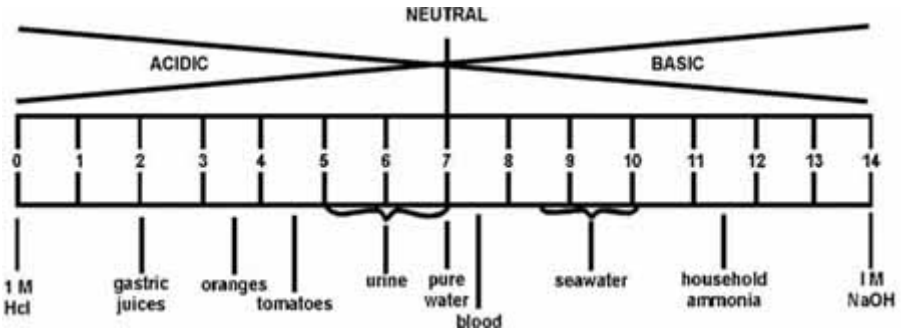


Figure 5.9

pH of selected liquids

pH affects many chemical and biological processes in the water. For example, different organisms flourish within different ranges of pH. The largest variety of aquatic animals prefer a range of 6.5-8.0. pH outside this range reduces the diversity in the stream because it stresses the physiological systems of most organisms and can reduce reproduction. Low pH can also allow toxic elements and compounds to become mobile and "available" for uptake by aquatic plants and animals. This can produce conditions that are toxic to aquatic life, particularly to sensitive species like rainbow trout. Changes in acidity can be caused by atmospheric deposition (acid rain), surrounding rock, and certain wastewater discharges.

The pH scale measures the logarithmic concentration of hydrogen (H+) and hydroxide (OH-) ions, which make up water (H+ + OH- = H2O). When both types of ions are in equal concentration, the pH is 7.0 or neutral. Below 7.0, the water is acidic (there are more hydrogen ions than hydroxide ions). When the pH is above 7.0, the water is alkaline, or basic (there are more hydroxide ions than hydrogen ions). Since the scale is logarithmic, a drop in the pH by 1.0 unit is equivalent to a 10-fold increase in acidity. So, a water sample with a pH of 5.0 is 10 times as acidic as one with a pH of 6.0, and pH 4.0 is 100 times as acidic as pH 6.0.

TURBIDITY

What is turbidity and why is it important?

Turbidity is a measure of water clarity how much the material suspended in water decreases the passage of light through the water. Suspended materials include soil particles (clay, silt, and sand), algae, plankton, microbes, and other substances. These materials are typically in the size range of 0.004 mm (clay) to 1.0 mm (sand). Turbidity can affect the color of the water.

Higher turbidity increases water temperatures because suspended particles absorb more heat. This, in turn, reduces the concentration of dissolved oxygen (DO) because warm water holds less DO than cold. Higher turbidity also reduces the amount of light penetrating the water, which reduces photosynthesis and the production of DO. Suspended materials can clog fish gills, reducing resistance to disease in fish, lowering growth rates, and affecting egg and larval development. As the particles settle, they can blanket the stream bottom, especially in slower waters, and smother fish eggs and benthic macroinvertebrates. Sources of turbidity include:

- Soil erosion
- Waste discharge
- Urban runoff
- Eroding stream banks
- Large numbers of bottom feeders (such as carp), which stir up bottom sediments
- Excessive algal growth.

PHOSPHORUS

Why is phosphorus important?

Both phosphorus and nitrogen are essential nutrients for the plants and animals that make up the aquatic food web. Since phosphorus is the nutrient in short supply in most fresh waters, even a modest increase in phosphorus can, under the right conditions, set off a whole chain of undesirable events in a stream including accelerated plant growth, algae blooms, low dissolved oxygen, and the death of certain fish, invertebrates, and other aquatic animals.

There are many sources of phosphorus, both natural and human. These include soil and rocks, wastewater treatment plants, runoff from fertilized lawns and cropland, failing septic systems, runoff from animal manure storage areas, disturbed land areas, drained wetlands, water treatment, and commercial cleaning preparations.

Forms of phosphorus

Phosphorus has a complicated story. Pure, "elemental" phosphorus (P) is rare. In nature, phosphorus usually exists as part of a phosphate molecule (PO_4). Phosphorus in aquatic systems occurs as organic phosphate and inorganic phosphate. Organic phosphate consists of a phosphate molecule associated with a carbon-based molecule, as in plant or animal tissue. Phosphate that is not associated with organic material is inorganic. Inorganic phosphorus is the form required by plants. Animals can use either organic or inorganic phosphate.

Both organic and inorganic phosphorus can either be dissolved in the water or suspended (attached to particles in the water column).

The phosphorus cycle

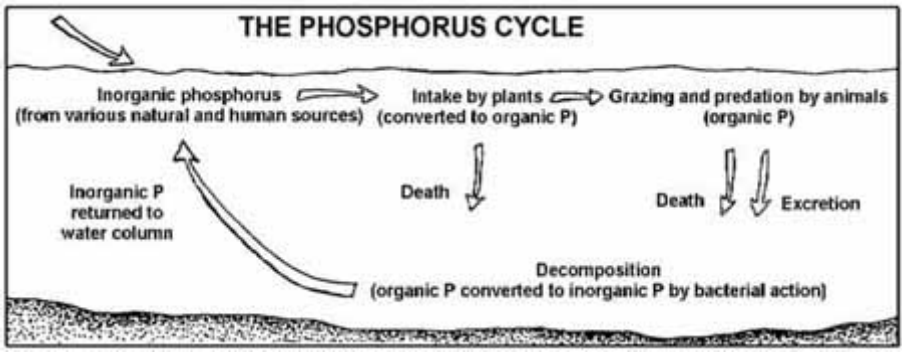


Figure 5.12

The phosphorus cycle
Phosphorus changes form as it cycles through the aquatic environment.

Phosphorus cycles through the environment, changing form as it does so (Fig. 5.12). Aquatic plants take in dissolved inorganic phosphorus and convert it to organic phosphorus as it becomes part of their tissues. Animals get the organic phosphorus they need by eating either aquatic plants, other animals, or decomposing plant and animal material.

As plants and animals excrete wastes or die, the organic phosphorus they contain sinks to the bottom, where bacterial decomposition converts it back to inorganic phosphorus, both dissolved and attached to particles. This inorganic phosphorus gets back into the water column when the bottom is stirred up by animals, human activity, chemical interactions, or water currents. Then it is taken up by plants and the cycle begins again.

In a stream system, the phosphorus cycle tends to move phosphorus downstream as the current carries decomposing plant and animal tissue and dissolved phosphorus. It becomes stationary only when it is taken up by plants or is bound to particles that settle to the bottom of pools.

In the field of water quality chemistry, phosphorus is described using several terms. Some of these terms are chemistry based (referring to chemically based compounds), and others are methods-based (they describe what is measured by a particular method).

The term "orthophosphate" is a chemistry-based term that refers to the phosphate molecule all by itself. "Reactive phosphorus" is a corresponding method-based term that describes what you are actually measuring when you perform the test for orthophosphate. Because the lab procedure isn't quite perfect, you get mostly orthophosphate but you also get a small fraction of some other forms.

More complex inorganic phosphate compounds are referred to as "condensed phosphates" or "polyphosphates." The method-based term for these forms is "acid hydrolyzable."

CONDUCTIVITY

What is conductivity and why is it important?

Conductivity is a measure of the ability of water to pass an electrical current. Conductivity in water is affected by the presence of inorganic dissolved solids such as chloride, nitrate, sulfate, and phosphate anions (ions that carry a

negative charge) or sodium, magnesium, calcium, iron, and aluminum cations (ions that carry a positive charge). Organic compounds like oil, phenol, alcohol, and sugar do not conduct electrical current very well and therefore have a low conductivity when in water. Conductivity is also affected by temperature: the warmer the water, the higher the conductivity. For this reason, conductivity is reported as conductivity at 25 degrees Celsius (25 C).
Conductivity in streams and rivers is affected primarily by the geology of the area through which the water flows. Streams that run through areas with granite bedrock tend to have lower conductivity because granite is composed of more inert materials that do not ionize (dissolve into ionic components) when washed into the water. On the other hand, streams that run through areas with clay soils tend to have higher conductivity because of the presence of materials that ionize when washed into the water. Ground water inflows can have the same effects depending on the bedrock they flow through.
Discharges to streams can change the conductivity depending on their make-up. A failing sewage system would raise the conductivity because of the presence of chloride, phosphate, and nitrate; an oil spill would lower the conductivity.
The basic unit of measurement of conductivity is the mho or siemens. Conductivity is measured in micromhos per centimeter (µmhos/cm) or microsiemens per centimeter (µs/cm). Distilled water has a conductivity in the range of 0.5 to 3 µmhos/cm. The conductivity of rivers in the United States generally ranges from 50 to 1500 µmhos/cm. Studies of inland fresh waters indicate that streams supporting good mixed fisheries have a range between 150 and 500 µhos/cm. Conductivity outside this range could indicate that the water is not suitable for certain species of fish or macroinvertebrates. Industrial waters can range as high as 10,000 µmhos/cm.

TOTAL ALKALINITY

What is total alkalinity and why is it important*?*

Alkalinity is a measure of the capacity of water to neutralize acids (see pH description). Alkaline compounds in the water such as bicarbonates (baking soda is one type), carbonates, and hydroxides remove H+ ions and lower the acidity of the water (which means increased pH). They usually do this by combining with the H+ ions to make new compounds. Without this acid-neutralizing capacity, any acid added to a stream would cause an immediate change in the pH. Measuring alkalinity is important in determining a stream's ability to neutralize acidic pollution from rainfall or wastewater. It's one of the best measures of the sensitivity of the stream to acid inputs.
Alkalinity in streams is influenced by rocks and soils, salts, certain plant activities, and certain industrial wastewater discharges.
Total alkalinity is measured by measuring the amount of acid (e.g., sulfuric acid) needed to bring the sample to a pH of 4.2. At this pH all the alkaline compounds in the sample are "used up." The result is reported as milligrams per liter of calcium carbonate (mg/L $CaCO_3$).

FECAL BACTERIA

What are fecal bacteria and why are they important?

Members of two bacteria groups, coliforms and fecal streptococci, are used as indicators of possible sewage contamination because they are commonly found in human and animal feces. Although they are generally not harmful themselves, they indicate the possible presence of pathogenic (disease-causing) bacteria, viruses, and protozoans that also live in human and animal digestive systems. Therefore, their presence in streams suggests that pathogenic microorganisms might also be present and that swimming and eating shellfish might be a health risk. Since it is difficult, time-consuming, and expensive to test directly for the presence of a large variety of pathogens, water is usually tested for coliforms and fecal streptococci instead. Sources of fecal contamination to surface waters include wastewater treatment plants, on-site septic systems, domestic and wild animal manure, and storm runoff.
In addition to the possible health risk associated with the presence of elevated levels of fecal bacteria, they can also cause cloudy water, unpleasant odors, and an increased oxygen demand. (Refer to the section on dissolved oxygen.)

Indicator bacteria types and what they can tell you

The most commonly tested fecal bacteria indicators are total coliforms, fecal coliforms, *Escherichia coli*, fecal streptococci, and enterococci. All but *E. coli* are composed of a number of species of bacteria that share common characteristics such as shape, habitat, or behavior; *E. coli* is a single species in the fecal coliform group.
Total coliforms are a group of bacteria that are widespread in nature. All members of the total coliform group can occur in human feces, but some can also be present in animal manure, soil, and submerged wood and in other places outside the human body. Thus, the usefulness of total coliforms as an indicator of fecal contamination depends on

the extent to which the bacteria species found are fecal and human in origin. For recreational waters, total coliforms are no longer recommended as an indicator. For drinking water, total coliforms are still the standard test because their presence indicates contamination of a water supply by an outside source.
Fecal coliforms, a subset of total coliform bacteria, are more fecal-specific in origin. However, even this group contains a genus, *Klebsiella*, with species that are not necessarily fecal in origin. *Klebsiella* are commonly associated with textile and pulp and paper mill wastes. Therefore, if these sources discharge to your stream, you might wish to consider monitoring more fecal and human-specific bacteria. For recreational waters, this group was the primary bacteria indicator until relatively recently, when EPA began recommending *E. coli* and enterococci as better indicators of health risk from water contact. Fecal coliforms are still being used in many states as the indicator bacteria.
E. coli is a species of fecal coliform bacteria that is specific to fecal material from humans and other warm-blooded animals. EPA recommends E. coli as the best indicator of health risk from water contact in recreational waters; some states have changed their water quality standards and are monitoring accordingly.
Fecal streptococci generally occur in the digestive systems of humans and other warm-blooded animals. In the past, fecal streptococci were monitored together with fecal coliforms and a ratio of fecal coliforms to streptococci was calculated. This ratio was used to determine whether the contamination was of human or nonhuman origin. However, this is no longer recommended as a reliable test.
Enterococci are a subgroup within the fecal streptococcus group. Enterococci are distinguished by their ability to survive in salt water, and in this respect they more closely mimic many pathogens than do the other indicators. Enterococci are typically more human-specific than the larger fecal streptococcus group. EPA recommends enterococci as the best indicator of health risk in salt water used for recreation and as a useful indicator in fresh water as well.

Which Bacteria Should You Monitor?

Which bacteria you test for depends on what you want to know. Do you want to know whether swimming in your stream poses a health risk? Do you want to know whether your stream is meeting state water quality standards? Studies conducted by EPA to determine the correlation between different bacterial indicators and the occurrence of digestive system illness at swimming beaches suggest that the best indicators of health risk from recreational water contact in fresh water are *E. coli* and enterococci. For salt water, enterococci are the best. Interestingly, fecal coliforms as a group were determined to be a poor indicator of the risk of digestive system illness. However, many states continue to use fecal coliforms as their primary health risk indicator.
If your state is still using total or fecal coliforms as the indicator bacteria and you want to know whether the water meets state water quality standards, you should monitor fecal coliforms. However, if you want to know the health risk from recreational water contact, the results of EPA studies suggest that you should consider switching to the *E. coli* or enterococci method for testing fresh water. In any case, it is best to consult with the water quality division of your state's environmental agency, especially if you expect them to use your data.

STREAM FLOW

What is stream flow and why is it important?

Stream flow, or discharge, is the volume of water that moves over a designated point over a fixed period of time. It is often expressed as cubic feet per second (ft^3/sec).
The flow of a stream is directly related to the amount of water moving off the watershed into the stream channel. It is affected by weather, increasing during rainstorms and decreasing during dry periods. It also changes during different seasons of the year, decreasing during the summer months when evaporation rates are high and shoreline vegetation is actively growing and removing water from the ground. August and September are usually the months of lowest flow for most streams and rivers in most of the country.
Water withdrawals for irrigation purposes can seriously deplete water flow, as can industrial water withdrawals. Dams used for electric power generation, particularly facilities designed to produce power during periods of peak need, often block the flow of a stream and later release it in a surge.
Flow is a function of water volume and velocity. It is important because of its impact on water quality and on the living organisms and habitats in the stream. Large, swiftly flowing rivers can receive pollution discharges and be little affected, whereas small streams have less capacity to dilute and degrade wastes.

Stream velocity, which increases as the volume of the water in the stream increases, determines the kinds of organisms that can live in the stream (some need fast-flowing areas; others need quiet pools). It also affects the amount of silt and sediment carried by the stream. Sediment introduced to quiet, slow-flowing streams will settle quickly to the stream bottom. Fast moving streams will keep sediment suspended longer in the water column. Lastly, fast-moving streams generally have higher levels of dissolved oxygen than slow streams because they are better aerated.

This section describes one method for estimating flow in a specific area or reach of a stream. It is adapted from techniques used by several volunteer monitoring programs and uses a float (an object such as an orange, ping-pong ball, pine cone, etc.) to measure stream velocity. Calculating flow involves solving an equation that examines the relationship among several variables including stream cross-sectional area, stream length, and water velocity. One way to measure flow is to solve the following equation:

$$\text{Flow} = ALC / T$$

Where:

A = Average cross-sectional area of the stream (stream width multiplied by average water depth).

L = Length of the stream reach measured (usually 20 ft.)

C = A coefficient or correction factor (0.8 for rocky-bottom streams or 0.9 for muddy-bottom streams). This allows you to correct for the fact that water at the surface travels faster than near the stream bottom due to resistance from gravel, cobble, etc. Multiplying the surface velocity by a correction coefficient decreases the value and gives a better measure of the stream's overall velocity.

T = Time, in seconds, for the float to travel the length of L

Information below was taken from Russell Mainstream Supply Ltd., Technical Area (United Kingdom) (http://www.rmprocesscontrol.co.uk/Technical.htm#ORP)

OXIDATION-REDUCTION POTENTIAL (ORP)

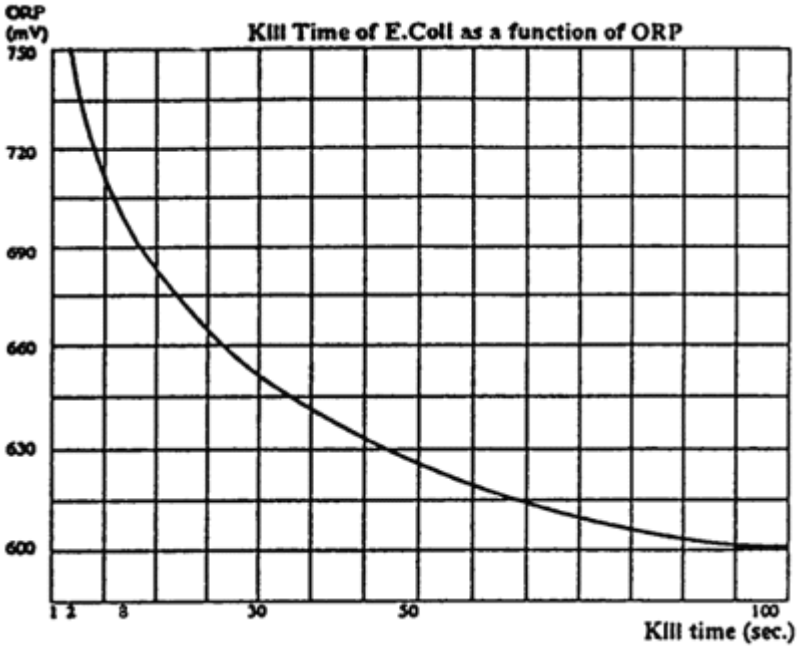
Oxidation-Reduction Potential (ORP) or Redox potential measurements are used to monitor chemical reactions, to quantify ion activity, or to determine the oxidizing or reducing properties of a solution. ORP is a measurement of the electrical potential of a redox reaction and serves as a yardstick to judge how much oxidation or reduction takes place under existing conditions.

ORP electrodes measure the voltage across a circuit formed by the measuring metal half cell and the reference half cell. When the ORP electrode is placed in the presence of oxidizing or reducing agents, electrons are constantly transferred back and forth on its measuring surface, generating a tiny voltage. The ORP measurement can be made using the millivolt mode of a pH meter.

ORP measurement may be utilized very successfully in many commercial and industrial applications. These include:

- Cyanide Oxidation
- Aquarium Monitoring
- Chromate Reduction
- Drinking Water
- Swimming Pool Water
- Pulp Bleaching
- Cooling Tower
- Ozone Monitoring
- Water Pollution Monitoring

ORP technology has been gaining recognition worldwide and is found to be a reliable indicator of bacteriological water quality for sanitation - determine free chlorine parameter. In swimming pool application, the ideal ORP value is approximately 700 mV where the Kill Time of E.Coli bacteria is the fastest to ensure good water quality. However ORP value also depends on the pH of pool water, which is typically between 7.2 and 7.6 pH.



The pH of pool water has to be maintained at optimum level by dosing appropriate chemicals. If the pH of swimming pool is acceptable and ORP value is below 700 mV, then hypochlorite or other oxidizing chemicals need to be added.

Information below was taken from the USGS Water Quality Information—News website (http://water.usgs.gov/owq/Explanation.html)

HARDNESS

Many industrial and domestic water users are concerned about the hardness of their water. Hard water requires more soap and synthetic detergents for home laundry and washing, and contributes to scaling in boilers and industrial equipment. Hardness is caused by compounds of calcium and magnesium, and by a variety of other metals. General guidelines for classification of waters are: 0 to 60 mg/L (milligrams per liter) as calcium carbonate is classified as soft; 61 to 120 mg/L as moderately hard; 121 to 180 mg/L as hard; and more than 180 mg/L as very hard.

Mean values of hardness at 344 stations during the 1975 water year are represented by the chart. The highest 7 values, those over 1,120 mg/L, are lumped in the last bar of the chart in order to maintain the scale. About half of the mean hardness values for the stations are in the soft to moderately hard categories, and about half can be classified as hard to very hard.

Patterns of hardness in the United States are shown on the map of accounting units at the bottom of the figure. Softest waters were in parts of the New England, South Atlantic-Gulf, Pacific Northwest, and Hawaii regions. Moderately hard waters were common in many of the rivers of the Tennessee, Great Lakes, Pacific Northwest, and Alaska regions. Hard and very hard waters were found in some of the streams in most of the regions throughout the country. Hardest waters (greater than 1,000 mg/L) were measured in streams in Texas, New Mexico, Kansas, Arizona, and southern California.

(From Briggs, J.C., and Ficke, J.F., 1977, Quality of Rivers of the United States, 1975 Water Year--Based on the National Stream Quality Accounting Network (NASQAN): U.S. Geological Survey Open-File Report 78-200, 436 p.)

Note to Readers: Water hardness is based on major-ion chemistry concentrations. Major-ion chemistry in ground water is relatively stable and generally does not change over time. Although the map illustrates data from 1975, these data have been found to be accurate and useful in current assessments.

There are, however, several caveats about the nature, use, and interpretations of these data: (1) the data illustrated represent water hardness on a national and regional scale and must be so interpreted; (2) the 1975 data are not designed to be used to make local decisions or decisions on the scale of individual homeowner property; and (3) information that is directly relevant to water hardness and other chemical properties at a home or immediate locale should be provided by the local health agency, local water utility, or by the vendor of a local water-softening system.

METALS

Information below was taken from Lenntech—metals in aquatic freshwater (http://www.lenntech.com/aquatic/metals.htm)

How metals get into freshwater

Metals are introduced in aquatic systems as a result of the weathering of soils and rocks, from volcanic eruptions, and from a variety of human activities involving the mining, processing, or use of metals and/or substances that contain metal pollutants. The most common heavy metal pollutants are arsenic, cadmium, chromium, copper, nickel, lead and mercury. There are different types of sources of pollutants: point sources (localized pollution), where pollutants come from single, identifiable sources. The second type of pollutant sources are nonpoint sources, where pollutants come from dispersed (and often difficult to identify) sources. There are only a few examples of localized metal pollution, like the natural weathering of ore bodies and the little metal particles coming from coal-burning power plants via smokestacks in air, water and soils around the factory.
The most common metal pollution in freshwater comes from mining companies. They usually use an acid mine drainage system to release heavy metals from ores, because metals are very soluble in an acid solution. After the drainage process, they disperse the acid solution in the groundwater, containing high levels of metals. See also acids & alkalis.

The term 'heavy metal' is somewhat imprecise, but includes most metals with an atomic number greater than 20, and excludes alkali metals, alkaline earths, lanthanides and actinides.

What happens when an excess of metals enters freshwater ecosystems?

When the pH in water falls, metal solubility increases and the metal particles become more mobile. That is why metals are more toxic in soft waters. Metals can become 'locked up' in bottom sediments, where they remain for many years. Streams coming from draining mining areas are often very acidic and contain high concentrations of dissolved metals with little aquatic life. Both localized and dispersed metal pollution cause environmental damage because metals are non-biodegradable. Unlike some organic pesticides, metals cannot be broken down into less harmful components in the environment.
Campbell and Stokes (1985) described two contrasting responses of an organism to a metal toxicity with declining pH:
- If there is little change in speciation and the metal binding is weak at the biological surface, a decrease in pH will decrease owning to competition for binding sites from hydrogen ions.
- Where there is a marked effect on speciation and strong binding of the metal at the biological surface, the dominant effect of a decrease in pH will be to increase the metal availability.

Generally the ionic form of a metal is more toxic, because it can form toxic compounds with other ions. Electron transfer reactions that are connected with oxygen can lead to the production of toxic oxyradicals, a toxicity mechanism now known to be of considerable importance in both animals and plants. Some oxyradicals, such as superoxide anion (O_2^-) and the hydroxyl radical (OH^-), can cause serious cellular damage.

Some inorganic pollutants are assimilated by organisms to a greater extent than others. This is reflected in the Bioconcentration Factor (BCF), which can be expressed as follows:
BCF = concentration of the chemical in the organism / concentration of the chemical in the ambient environment.

The ambient environment for aquatic organisms is usually the water or sediments. With inorganic chemicals, the extent of long-term bioaccumulation depends on the rate of excretion. Toxic chemicals can be stored into tissues of species, especially fat tissues. Bioaccumulation of cadmium in animals is high compared to most of the other metals, as it is assimilated rapidly and excreted slowly. Also the sensitivity of individuals of a particular species to a pollutant may be influenced by factors such as sex, age, or size. In general the concentrations of metals in invertebrates is inversely related to their body mass. In fish, the embryonic and larval stages are usually the most sensitive to pollutants.
Benthic organisms are likely to be the most directly affected by metal concentrations in the sediments, because the benthos is the ultimate repository of the particulate materials that are washed into aquatic systems.

Metal tolerance

Some metals, such as manganese, iron, copper, and zinc are essential micronutrients. They are essential to life in the right concentrations, but in excess, these chemicals can be poisonous. At the same time, chronic low exposures to heavy metals can have serious health effects in the long run.
Tolerance to metals has also been recorded in invertebrates and in fish. After exposure for 24 hours to a copper concentration of 0.55

mg/l, rainbow trout showed a 55 per cent inhibition of sodium uptake and a 4 per cent reduction in affinity for sodium, which resulted in an overall decrease in total sodium concentration of sulphydryl-rich protein (Lauren and McDonald 1987a,b). The protein was considered to be a metallothionein. These low molecular weight proteins contain many sulphur-rich amino acids which bind and detoxify some metals. The pretreatment of an organism with low doses of a metal may stimulate metallothionein synthesis and provide tolerance during a subsequent exposure (Pascoe and Beattie, 1979).

Many rivers are polluted with heavy metals from old mine workings and some species of algae become very tolerant to polluted conditions. A survey of 47 sites with different concentration of zinc found the filamentous green alga 'Hormidium rivulare' to be abundant everywhere, tolerating zinc concentrations as high as 30.2 mg Zn/l.

Toxicity of metals

For the protection of human health, the maximum permissible concentrations for metals in natural waters that are recommended by the Environmental Protection Agency (EPA), are listed below:

Maximum Permissible Concentrations (MPC) of Various Metals in Natural Waters For the Protection of Human Health

Metal	*Chemical Symbol*	*mg m^{-3}*
Mercury	Hg	0.144
Lead	Pb	5
Cadmium	Cd	10
Selenium	Se	10
Thallium	Tl	13
Nickel	Ni	13.4
Silver	Ag	50
Manganese	Mn	50
Chromium	Cr	50
Iron	Fe	300
Barium	Ba	1000

Source: EPA (1987); Federal Register *56* (110): 26460-26564 (1991).

This table gives an idea of the relative toxicity of various metals. Mercury, lead and cadmium are not required even in small amounts by any organism.

Because metals are rather insoluble in neutral or basic pH, pHs of 7 or above give a highly misleading picture of the degree of metal pollution. So in some cases it may underestimate significantly the total of metal concentrations in natural waters.