McAllister Creek Water Quality Survey for Fecal Coliform Bacteria, Total Suspended Solids, Turbidity, and Nutrients

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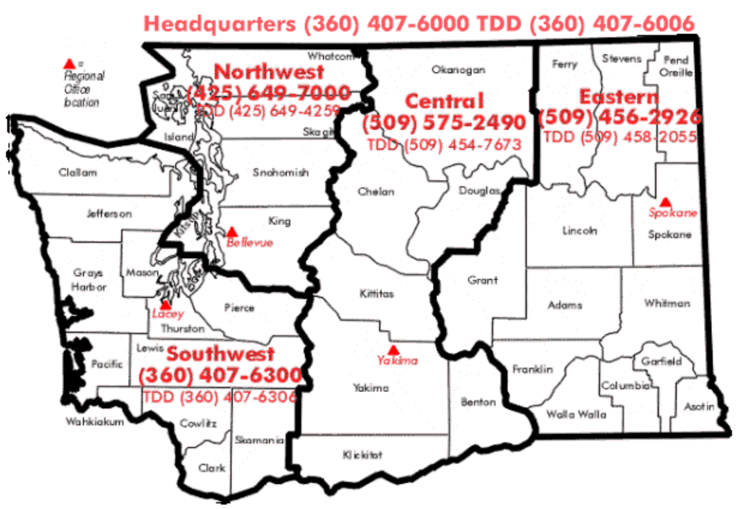

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Acknowledgements

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Abstract

Water samples collected in the McAllister Creek basin, March through June 2001, had high concentrations of fecal coliform bacteria. Many sites exceeded the Class A water quality standard. High concentrations of nitrite+nitrate-nitrogen, ammonia-nitrogen, and total phosphorus were also identified. The primary sources of fecal coliform bacteria, nutrients, and sediment are agricultural tidegates discharging into the creek. Contributions were also seen from stormwater discharges and tributaries. Mainstem conditions worsened when 24 hour precipitation exceeded 0.5 inches.

Introduction

McAllister Creek is a Class A waterbody located in Thurston County, Washington. The creek is in the Nisqually Basin and lies to the west of the Nisqually River. It flows northward for approximately 5.5 miles from its origin at McAllister Springs to discharge at Nisqually Reach (Nisqually Chinook Recovery Team, 2001 and Williams et.al., 1975). The creek drains an area of approximately 42 square miles (Roberts and Pelletier, 2001).

Landuse is varied along the course of McAllister Creek. The creek starts as a large spring which has been tapped and developed by the City of Olympia to provide drinking water to nearby urban areas. It then travels from a shallow pond over a weir and runs through undeveloped wetland habitat, agricultural fields, cattle operations, and a small commercial area near Martin Way and I-5. The creek has bank-side residences, an RV park, a state operated fish hatchery, a private trout farm, and receives stormwater from a variety of sources. There are at least 15 tidegates draining the agricultural lowlands located upstream of the I-5 bridge and two tidegates below the I-5 bridge that drain the Nisqually Wildlife Refuge into the estuarine area.

McAllister Creek is a low gradient stream and is subject to tidal influence throughout its entire length (Nisqually Chinook Recovery Team, 2001). It is thought that multiple channel alterations from road construction projects, as well as flow reductions due to the water withdrawals at the head of the stream, have lowered the gradient further. The result of this is to reduce its effective flushing during ebb tide, releasing water in tidal pulses to Nisqually Reach (Whiley and Walter, 1996).

This water quality investigation in the McAllister Creek watershed was initiated by the Department of Ecology in response to the shellfish downgrade in the Nisqually Reach by the State Department of Health. It was designed to investigate potential sources for bacteria in McAllister Creek and to assist in focusing the pending Total Maximum Daily Load Study by Ecology's Environmental Assessment Program. Past studies conducted by the Nisqually Tribe (Whiley and Walter, 1996 and 1998) and Ecology (Roberts and Pelletier, 2001) suggest that McAllister Creek is the primary contributor of fecal coliform bacteria to Nisqually Reach. McAllister Creek is listed on Ecology's section 303(d) list of impaired waterbodies for fecal coliform bacteria (the creek is also on the 303 (d) list for dissolved oxygen, but was not addressed in this study).

This survey was also of interest to the Washington State Department of Transportation (WSDOT). WSDOT was scheduled to replace 6 of their malfunctioning tidegates. They were also planning to install a stormwater treatment facility to improve the quality of stormwater draining I-5. With their interest in obtaining background information for both bacteria and sediment in the lower reach water column, WSDOT chose to contribute laboratory costs in support of this study.

Therefore the objectives for this study were to:

1. Investigate potential sources of fecal coliform bacteria in McAllister Creek.
2. Document fecal coliform bacteria, total suspended solids, and turbidity concentrations in the lower reach of McAllister Creek prior to replacement of WSDOTs tidegates and installation of a stormwater treatment facility.

Sampling Methods

Sampling was conducted approximately every two weeks from March 28, 2001, through June 25, 2001. Locations for sampling sites were chosen after reviewing the Nisqually Tribes' reports (Whiley and Walter, 1996 and 1998) and discussing the creek with Anthony Whiley (personal communication). Sites were also selected to address WSDOT concerns. Sampling was limited to sites that were accessible by boat. No samples were taken that required access to private property. Site locations are presented in Figure 1 and described in Table 1.

Mainstem grab samples were collected mid-channel or approximately 1 ft below the surface. Samples were collected by hand or with an extension pole to better access a sampling location. Conductivity, salinity, and temperature measurements were taken directly from the creek when possible; otherwise samples were collected in a 1000 mL plastic bottle and read immediately.

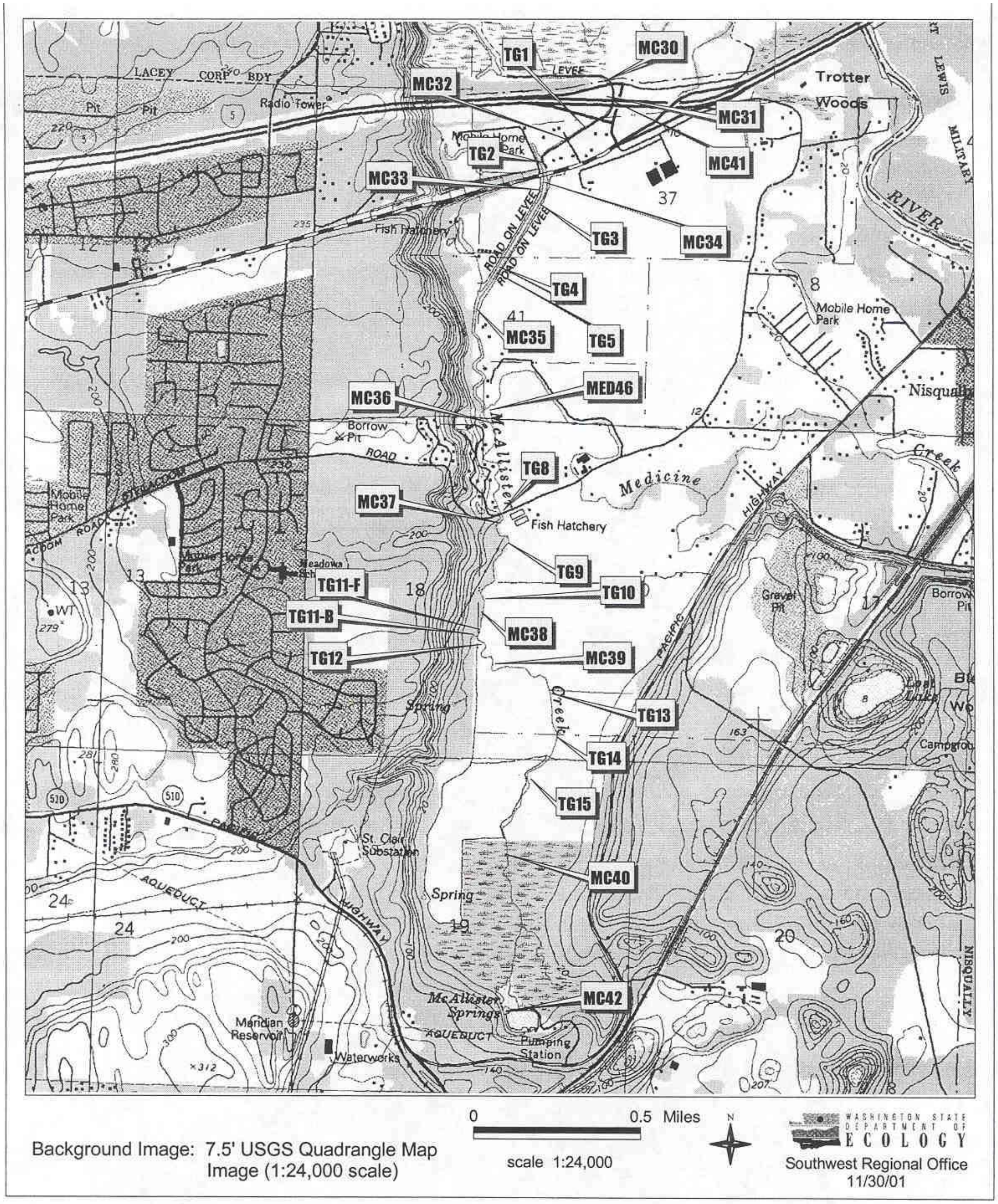


Figure 1. McAllister Creek monitoring stations, March - June 2001

Table 1. Site Names and Location Descriptions.

Site Name	Site Description
	Mainstem Sites
MC42	McAllister Creek at Spring outfall weir
MC40	McAllister Creek below springs
MC39	McAllister Creek just above confluence with Little McAllister
MC38	McAllister Creek below confluence with Little McAllister
MC37	McAllister Creek above Fish Hatchery Outflow and below Tidegate #9
MC36	McAllister Creek just upstream of Medicine Creek and below houses
MED46	Medicine Creek Mouth
MC35	McAllister Creek above series of Tidegates
MS Up of T5	Mainstem above T5 - acting as background when walked in to sites
MC34	McAllister Creek above Martin Way
MC32	McAllister Creek above I-5 At RV bridge
MC41	McAllister Creek below TG1 and above MC31
MC30	McAllister Creek Downstream of I-5
	Tidegate and Stormwater
TG15	Tidegate 15
TG14	Tidegate 14
TG13	Tidegate 13
TG12	Tidegate 12
TG11-Front	Tidegate 11 - front gate at confluence of ditch and Little McAllister
TG11-Back	Tidegate 11 - back gate at confluence of ditch and Little McAllister
TG10	Tidegate 10
TG9	Tidegate 9
TG8	Tidegate 8
TG5	Tidegate 5
TG4	Tidegate 4
MC33	County **Stormwater** outfall from swale/tidegate above Martin Way
MC31	**Stormwater** outfall from culvert under I-5

Sample sites were accessed from a 2-person flat-bottomed boat propelled by electric motor, except on two occasions. On May 23, 2001, and June 11, 2001, only lower sites, accessible by the dike trail, were sampled. On both events an upstream site (MS Up of TG5) was established by sampling just upstream of tidegate 5 (TG5) using an extension pole. Additionally, on June 11, a background sample was collected at the McAllister Springs weir (MC42). This background site was accessed by driving to the McAllister Springs facility managed by the City of Olympia.

Many of the tidegates were malfunctioning due to corrosion and age. These factors influenced the way that water was collected from each tidegate. Samples were collected from free-fall water leaving a tidegate, from water as it emerged from a gap between the tidegate and lid, or through the corroded top of a tidegate.

Samples were collected during an ebb tide when water was draining freely out of the watershed. Timing was established to account for the approximate 2-hour lag between the National Oceanic and Atmospheric Administration tide station at Dupont Wharf, Nisqually Reach, and the lower end of the watershed (MC30) (Whiley, 2001, personal communication). Salinity and conductivity were also used to check for marine influence.

Data Quality

Data, with associated qualifying codes (qualifiers), can be found in Appendix A, Table A1; qualifiers provide details about the sample. The summary of field and laboratory methods, accuracy, and abbreviations used can be found in Table A2.

Field samples were collected following Ecology's guidelines for water quality field sampling and measurement protocols (Ecology, 1993). All laboratory samples were analyzed according to quality assurance and quality control procedures followed by Ecology's Manchester Environmental Laboratory (Ecology, 2000).

Sample size varied for each site within this survey (from 0 to 7) based on accessibility and timing within tidal flux. Small and variable sample sizes should be considered when reviewing the data and its compliance with water quality standards.

Data at or below the laboratory reporting limits were assumed to be the reporting limit and were included in data analyses. All other qualified data were reviewed and the qualified value used in data analyses.

The samples for total suspended solids collected on March 28, 2001, were over-dried at the laboratory; they were given a J qualifier since they may be biased low. These data were used in data analyses.

Samples for fecal coliform (FCMF: to be analyzed by the lab using the membrane filter method) and Enteroccoci (ENTMF: to be analyzed by the lab using the membrane filter method) were collected in the same bottle. However, fecal coliform samples using the MPN method (FCMPN: to be analyzed by the lab using the Most Probable Number method) were collected in a separate bottle. The FCMPN data were originally collected with the possibility they could be used to compare with Department of Health data in the marine environment.

Sample bottles for pH were filled to the top leaving no headspace and sent to the lab for analysis. In general, these values should be used cautiously since pH is unstable. In particular two samples need to be considered carefully. The pH sample for TG4 on April 30, 2001, arrived at the lab with a crack in the lid; it is unclear whether air had entered the bottle. A pH sample was not taken for MC31on April 30, 2001, therefore, the lab analyzed pH from volume taken from the turbidity sample bottle.

No discharge measurements were taken during this study. It's important to note that McAllister Creek mainstem has a large dilution capacity with the potential to mask contributions from sources entering the system with low volume and high concentration.

Site MC34 may not have been completely mixed across the stream channel; there were agricultural and stormwater discharges entering McAllister Creek just upstream of this site. This should be considered when reviewing the data for this site.

Laboratory Data

Holding Times

Standard methods (APHA, et al, 1998) set a 6-hour window for microbial samples. However, due to logistical challenges in collecting and transporting samples, the Manchester Environmental Laboratory has tested and approved a standard holding time of 24-hours. All microbial samples were analyzed within this 24-hour holding time except for two samples (MC25 and MED46) on March 28, 2001, which were analyzed within 30 hours. The concentrations are qualified with a 'JH' establishing the values as estimates; the data were used in analyses. All general chemistry samples met holding times.

Precision

Sampling precision and field variability were estimated by collecting duplicate field samples at 20% of the sampling sites. Duplicate field samples were collected sequentially at the same site and as close to the same time as possible. The sampling precision was then determined and expressed as the % coefficient of variation (CV). The CV is calculated by dividing the standard deviation by the mean of the duplicate pairs; the percent CV is then calculated by multiplying by 100. Data from the field duplicate samples were used only to estimate variability; they were not used in general data analyses.

Bacteria concentrations in the environment are known to be variable, therefore, precision for bacteria field duplicates are generally acceptable up to 50% CV. Additionally, when concentrations are close to the method detection limit (less than 50 cfu/100mL) a CV greater than 50% is acceptable. The arithmetic average CV for bacterial results are presented in Table A3.

Listed below are specific issues of quality assurance that were taken into consideration for bacteria samples. Routine samples (RS) were used in data analyses.

- Concentrations for ENTMF on April 30, 2001, at MC30 were 14,000 cfu/100 mL (RS) and 5000 cfu/100 mL resulting in a CV of 67%. Poor precision could be due to natural variability compounded by the run-off event in the watershed. These values should be used with caution due to the low precision.
- On May 9, 2001, at MC40, values of 13 cfu/100mL (RS) and 2 cfu/100mL resulted in a CV of 104% for FCMF. The high % CV was most likely due to values being close to the detection limit.
- Tidegate 5 (TG5) had a CV of 62% (2300 cfu/100mL (RS) and 900 cfu/100mL) on May 9, 2001. The poor precision could be a result of natural variability of bacteria in the environment. Since both values, if used in calculating the mean FCMF for the site, would result in a violation of the water quality standard (GM 970 cfu/100 mL (see Table C2) to GM 849 cfu/100 mL), the data were retained and the routine value was used in data analyses. These values should be used with caution due to the low precision.
- The CV for ENTFC at MED46 on May 9, 2001, was 54%. The high % CV was most likely due to values close to the detection limit (31 cfu/100 mL (RS) and 69 cfu/100 mL).
- The CV of 70% for FCMF at TG4 on June 11, 2001, was a result of differences in laboratory dilution – 17000 cfu/100mL (RS) versus 50000 cfu/100 mL.

For all other parameters, precision for field duplicate pairs should be within 20% CV. When duplicate values are close to zero or the reporting limit, the CV will be artificially high. The precision for all general chemistry were within CV 20%. Table A4 presents the average CV for the other laboratory parameters.

Field Data

Field replicate samples for temperature, salinity, and conductivity were all within acceptable range; they were used primarily as ancillary information and results will not be fully discussed in this report.

Salinity was used as a tracer for tidal influence. The field salinity ranged from 0-2 ppt for regular samples; the lab equipment could not determine salinity below 2 ppt, so most data were qualified as below detection. No comparison for precision was made between lab and field salinity.

Conductivity was measured in the field and in the lab. An average CV of 4% was calculated for values below 1000 umhos/cm, generally ranging from 0-15%. The data pair for MC32 (lab:358 umhos/cm; field: 170 umhos/cm) had a CV of 50%. The data are reported, but values should be used with caution.

Other Data

Additional samples were taken that are not representative of the study design. These data are provided in Table A1; the quality is described below.

The samples taken at the hatchery outlet (HATOUT29) were collected from an area where hatchery water may have intermingled with the mainstem water; therefore the data are not representative. Due to corrosion on the bottom of Tidegate 1 (TG1) the data most likely are not representative. Tidegate 2 (TG2) was never exposed above the water level, however, turbid water was bubbling out at the water's surface; samples were collected but were diluted by mainstem flow. Since this was an initial investigation I have included these data, however, data for TG1, TG2, and HATOUT29 need to be used with caution and will not be discussed in this report.

Three additional sites were sampled one time only during the study period on March 28, 2001: a culvert located back behind TG11-Front and TG11-Back; a discharge from a black pipe (coming from the left bank, looking downstream, at the second house down from Steilacoom Road); and a large spring discharging from a culvert (BIGS24) entering on the left bank just downstream from MC35.

Additional bacteria samples were also collected from TG4 and TG5. These samples were taken with an interest to investigate variability.

Precipitation

Precipitation data were obtained from a meteorological station located at The Evergreen State College, Olympia, Washington (The Evergreen State College, 2001). The 24 and 48 hour precipitation information can be found in Table A5. The data represent total rainfall between the hours of midnight to midnight.

Results

Data results can be found in Appendix A, Table A1. Due to the tidal nature of McAllister Creek, sites were not always accessible, exposed, or discharging. The resulting variability in sample size needs to be considered when reviewing the data relative to standards. Sample dates without associated data indicates that no sample was collected.

McAllister Creek is a Class A waterbody. Select water quality criteria can be found in Appendix B, Table B1.

Bacteria

Fecal coliform bacteria are not directly harmful to humans, but act as indicators for other associated pathogens and animal wastes entering a waterbody. Human waste from failing septic systems, and animal wastes from cattle, chickens, pets, and a wide range of wildlife are some of the sources of fecal coliform bacteria. High fecal coliform concentrations can result in waters and shellfish that are unsuitable for consumption and recreational use.

The freshwater Class A water quality criterion for fecal coliform has two parts and both must apply to meet the standard (see Table B1, WAC 173-201A). The criterion reads: fecal coliform organism levels shall both not exceed a geometric mean value of 100 colonies/100mL, and not have more than 10 percent of all samples obtained for calculating the geometric mean value exceeding 200 colonies/100mL.

This study identified thirteen sampling locations that did not meet the water quality criterion for fecal coliform bacteria (see Appendix C). These sites include Medicine Creek (MED46), four sites on McAllister Creek (MC up of TG5, MC34, MC32 and MC30), six agricultural tidegates (TG13, TG11-Front, TG10, TG9, TG5, and TG4) and both stormdrains (MC33 and MC31). Figure C1 graphically shows the sites in relation to the first part of the fecal coliform standard. As can be seen from Table C1, the sample size was less than 10 and therefore it only took one sample over 200 colonies/100 mL to result in an exceedance of the second part of the criterion.

Bacteria concentrations increased in the McAllister Creek mainstem in response to precipitation, especially on the days with greater than 0.5 inches of rain (April 30, 2001, and June 11, 2001). For example, on April 30, 2001, after approximately 0.71 inches of rain fell over a 24 hour period, the background sample collected below the springs (MC40) had a concentration of 16 cfu/100mL, but reached 1000 cfu/100mL at the mouth of the creek (MC30). On days when no precipitation had fallen, concentrations less than 50 cfu/100 mL were found at the mouth.

Bacteria concentrations from samples taken at certain tidegates also responded to precipitation. This was particularly evident during the rain event on April 30, 2001, where 0.71 inches of rain fell in 24 hours (1.08 inches in 48 hours). TG4 had a fecal coliform concentration of 110,000 cfu/100 mL. As seen in Table C2, however, bacteria data collected from tidegates were variable. Some tidegates had high concentrations even when no recent precipitation was recorded, for example TG5 on May 9, 2001.

Medicine Creek was sampled at the mouth. Samples collected here routinely had higher bacteria concentrations than samples from McAllister Creek just upstream of the confluence.

Little McAllister Creek and a ditch converged before draining out through both TG11-Back and TG11-Front. There was one fecal coliform concentration at TG11-Front (230 cfu/100mL on June 25, 2001) that indicated a potential source and resulted in a water quality violation.

The stormwater collected at MC33 and MC31 did not meet water quality standards. Though the sample size was small for MC33 (N=2), bacteria concentrations were quite high during both events, 3,400 cfu/100mL and 1,400 cfu/100mL. The stormwater collected at MC31 had variable concentrations of bacteria (see Table C2), but elevated concentrations were seen particularly in June (240 cfu/100mL and 810 cfu/100mL).

Bacteria were also analyzed using the MPN method, primarily at the downstream site. The geometric mean for the study period was 69 cfu/100mL; this does not exceed the water quality standard. Data were collected for possible use by the State Department of Health. The difference seen in MF and MPN data could be due to differences in the two methods, collection of samples in separate bottles, and in the difference in the number of samples taken (no MPN sample was collected on March 28, 2001).

Enteroccoci samples were collected as background information in the event that Ecology changes its State water quality standard for bacteria from fecal coliform to Enteroccoci. The data are presented in Table A1, but are not discussed in this report.

Total Suspended Solids and Turbidity

Total Suspended Solids

Total suspended solids is a relative measure of the quantity of suspended material carried in the water. It is the portion of solid organic and inorganic material that is retained after the sample is filtered. There is no water quality standard for total suspended solids in Washington State at this time.

Total suspended solids concentrations on the mainstem ranged from 1-3 mg/L in the upper reach to 2-4 mg/L at the mouth. Medicine Creek, the agricultural tidegates and stormdrains add sediment into McAllister Creek (Figure D1). TG5 had the highest total suspended solids during the study period with 407 mg/L occurring during the rain event on April 30, 2001.

Turbidity

Turbidity is a measure of water clarity. It is the result of light being scattered and absorbed rather than transmitted through the water; the higher the intensity of scattered light, the higher the turbidity. It is an indicator of suspended particles such as clay, silt, organic matter, and small biological organisms.

The two uppermost sites, MC42 and MC40, were established to represent background turbidity levels for the McAllister Creek mainstem. Background values are needed to determine exceedances of the water quality standard of not more than 5 nephelometric turbidity units (NTU) over background levels (Table B1). This criterion was not violated on the mainstem (Figure D1, Table A1).

Medicine Creek tended to have a higher turbidity than McAllister Creek at the point of confluence. Data from Medicine Creek cannot be compared to the water quality standard because no background site was established upstream.

The tidegates also had turbidity levels higher than the mainstem. This is seen particularly at TG9, TG4, and TG5. TG5 had the highest turbidity seen during the study; on April 30, 2001, TG5 had a turbidity of 190 NTU. Background sites were not established for the tidegates and therefore the water quality standard cannot be applied.

Nutrients

The investigation for nutrients in McAllister Creek was added after finding high conductivity at TG4 on April 11, 2001. The conductivity of TG4 exceeded the scale of the field meter at greater than 1000 umhos/cm; high nutrient concentrations were suspected since the salinity was zero. Nutrient sampling was conducted on the subsequent sampling events that occurred by boat, April 30, 2001, and June 25, 2001. There are no State water quality standards for nutrients, though there are general guidelines describing concentrations normally seen from non-polluted streams.

Nitrogen

Nitrogen is a very common element in the air and terrestrial environment. Plants and bacteria carry out a biological process called nitrogen fixation, which can transform atmospheric nitrogen (N2) to ammonia (NH3), which transforms to nitrite (NO2) and then to nitrate (NO3). Usually nitrite is unstable in the environment in the presence of oxygen and transforms to nitrate; the combination of nitrite+nitrate-nitrogen (nitrite+nitrate) was analyzed in this study. High levels of these constituents are indicative of organic matter entering the system and of oxygen consumption associated with the breakdown of organic material. Most surface waters contain nitrite+nitrate in concentrations less that 1 mg/L. Ammonia is present before organic matter has had a chance to breakdown. In non-polluted waters it is usually found at levels below 0.1 mg/L and often less than 0.01 mg/L. High ammonia concentrations can be toxic to aquatic life. Ammonia, nitrate, and nitrite can promote the growth of aquatic algae and plants.

Concentrations of nitrite+nitrate in the McAllister Creek mainstem hovered around 1.0 mg/L (Figure E1), the upper range of what is usually expected in non-polluted environments. Ammonia-nitrogen (ammonia) concentrations were elevated in the lower reach during the rain event on April 30, 2001, (0.71 inches the day of sampling). High ammonia concentrations may be indicative of fresh organic waste running into the system.

Medicine Creek was only sampled for nutrients on April 30, 2001. The total nitrogen and nitrite+nitrate concentrations were slightly less than the mainstem, but ammonia concentrations appeared to be elevated relative to total nitrogen present as well as in comparison to mainstem sites (see Figure E1).

A general range for ammonia in natural systems is 0.05 – 0.1 mg/L. During the runoff event on April 30, 2001, many of the tidegates (particularly TG13, TG5, and TG4) were discharging high ammonia concentrations indicative of fresh manure sources (see Figure E1). Of specific note is TG4 with an ammonia concentration of 21.1 mg/L comprising most of the total nitrogen (27.2 mg/L) present in the discharge. This concentration of ammonia was well above the chronic non-fish bearing criteria for total ammonia toxicity of 2.15 mg/L and came close to the acute criterion of 21.44 mg/L (EPA, 1986). Ammonia toxicity is dependent on temperature, pH and the concentration of ammonia. As mentioned in the Data Quality section of this report, the pH sample for this site arrived at the lab with a cracked lid, which may have compromised the accuracy of this pH measurement. However, the chronic toxicity criterion was exceeded even when the full range of potential pH values were run in the equation (6.5 S.U. – 9.0 S.U.). Additionally, when compared to the other data collected on both April 30, 2001, and June 11, 2001, it is clear that this discharge was exceptionally high.

Total Phosphorus

Phosphorus is not a common element in the hydrosphere and can be the limiting factor for aquatic plant growth. It is often found in surface waters as a result of detergents, fertilizers, and human and animal wastes. Phosphorus concentrations greater than 0.1 mg/L may stimulate plant growth.

Background total phosphorus concentrations of 0.18 mg/L in McAllister Creek (see Figure E2) were elevated relative to what is generally found in surface waters. Concentrations increased slightly and variably as you move downstream. There was a notable increase in total phosphorus concentrations between the background site MC40 and downstream at MC39, particularly during the rain event on April 30, 2001, where concentrations increased to 0.237 mg/L.

Total phosphorus concentrations in Medicine Creek were similar to those found in the mainstem McAllister Creek.

Most of the agricultural tidegates had total phosphorus concentrations above 0.1 mg/L; tidegates TG15, TG14, and TG13 had concentrations greater than 0.5 mg/L (Figure E2). In particular, TG5 and TG4 had the highest total phosphorus concentrations at 2.25 mg/L and 1.47 mg/L respectively, during the rain event on April 30, 2001.

Other Data

Other data, as described in the Data Quality section of this report, were collected as part of this study and can be found at the bottom of Table A1. Three types of data are documented here: samples that were not representative of the site, sites sampled only one time, and samples collected in addition to the routine sample.

Representative samples were not taken from TG1, TG2, and HATOUT29 (they merged with mainstem waters) and will not be discussed. The data collected from the culvert behind the TG11 area had a fecal coliform concentration of 71 cfu/100mL. It's unclear what this culvert is draining. A black pipe extruding from the bank of the second residence downstream of the Steilacoom Road Bridge had a fecal coliform concentration of 2 cfu/100 mL. The large culvert on the left bank, just downstream of MC35, is from a large spring source; the fecal coliform concentration there was 1 cfu/100mL.

For investigative purposes, extra samples were taken from TG5 on April 30, 2001, and June 11, 2001, and from TG4 on June 11, 2001, in addition to the regular sample. For example, the discharge from TG5 on April 30, 2001, had a concentration of 22,000 cfu/100 mL at 2:10 PM and approximately 8900 cfu/100 mL at 7:00 PM (the time the regular sample was taken). Water with high bacteria concentrations may have been discharging from the tidegates for a few hours (see Table A1).

Conclusions

High concentrations of bacteria, nutrients, and sediment are entering the mainstem from tributaries as well as the point source discharges from the agricultural tidegates and stormwater.

The current water quality data verify that McAllister Creek is contributing high concentrations of fecal coliform bacteria into the estuarine area below the I-5 Bridge, especially during rain events greater than 0.5 inches in 24 hrs. This is similar to what has been described by Whiley and Walter (1996 and 1998) and Roberts and Pelletier (2001).

Based on watershed activities, a likely source for the bacteria and nutrients is chicken manure being applied to fields as fertilizer. Cattle are also present in the basin (currently not fully fenced off from the creek), but it is not clear what contribution they may have to bacteria conditions in the creek.

Bacteria, nutrients, and sediment from other sources such as septic systems, wildlife, natural processes, and the fish hatcheries were not directly addressed in this study. They may be contributing to water quality problems in McAllister Creek.

The highest fecal coliform, nutrient, and sediment concentrations came from the agricultural tidegates. Six (TG13, TG11-Front, TG10, TG9, TG5, and TG4) out of the eleven tidegates that were sampled exceeded water quality criteria for bacteria. The high concentrations seen at the tidegates could result from a combination of chicken manure application, tillage depth, high water table, as well as tile drains and ditches delivering to the Creek. The tidegates are in varying states of disrepair; however, it is not clear that this is the cause of the problem. It appears that there are sources of sediment and organic waste that would enter the system at low tide with properly functioning tidegates. However, malfunctioning tidegates may allow for excess water to back up into the ditches which would provide additional transport of pollutants to the creek.

Medicine Creek does not meet water quality criteria for fecal coliform and contributes high sediment concentrations to mainstem McAllister Creek. Though it did not appear to be as great a source for bacteria, nutrients, or sediment compared to the tidegates and stormwater, Medicine Creek does contribute to the water quality problems in McAllister Creek.

The area draining through tidegates TG11-Back and TG11-Front does not seem to be a large contributor of fecal coliform bacteria. There was one high concentration (230 cfu/100mL) found on June 25, 2001, at TG11-Front that resulted in a water quality violation. Since the water from the ditch and Little McAllister Creek co-mingle before exiting the two tidegates, the source remains unclear.

Both stormwater discharges sampled for this study violated the water quality standard for fecal coliform bacteria. MC33, draining stormwater from Martin Way, had notably high bacteria concentrations.

The sample size for many of the sampling sites was small, ranging from 0 – 7. Continued sampling is needed for more complete understanding of sources and variability within the basin for fecal coliform, nutrients, total suspended solids, and turbidity.

The Washington State Department of Transportation did not replace its tidegates on McAllister Creek or construct the stormwater treatment facility under I-5 during 2001 as originally planned. However, the data from this study can provide information to guide monitoring of water quality for future construction work.

Recommendations

- A sampling regime to obtain an increased sampling size for all sites is recommended. The critical time for bacteria and sediment appears to be during rain events. It would be valuable to examine low flow conditions.

- Attempts should be made to sample the creek during a tidal phase where a low high tide preceeds a low low tide. This tidal sequence appeared to provide the best conditions to access and sample tidegates. Additionally, permission to access private property should be requested to allow for sampling on the field side of the dike where necessary.

- Immediate action should be initiated to reduce the levels of bacteria, sediment, and nutrients discharging from the tidegates. Landowners should be contacted and solutions initiated with the assistance of the Thurston Conservation District. (This has been initiated).

- More information is necessary to understand what areas are being drained by the tidegates entering McAllister Creek. For example, it is unclear what area drains through tidegate 1 (TG1). This should be investigated, and if possible, sampling initiated.

- TG2 and TG3 were not accessible during the tidal phases experienced during this study. Permission to access private property should be obtained for future monitoring studies so that sampling can be accomplished directly from the ditch feeding the tidegate located on the other side of the dike.

- The majority of the tidegates in the system seem to be malfunctioning. This was particularly evident with TG1, TG4, and TG5 where the metal pipes were corroded and appeared to allow tidewaters to pass freely. If the land is to stay in agricultural production and cattle operations, evaluation of each tidegate should occur. Those malfunctioning should be fixed or replaced to allow for effective monitoring of the best management practices implemented on the land.

- The influence of tile drains, a general high water table, and the malfunctioning tidegates all have a confounding effect on explaining the original source of waters draining into McAllister Creek. It would be beneficial to fully investigate these issues to understand how the water is moving through the system and where potential sources may be.

- Sampling Medicine Creek more intensely would be beneficial to further understand the sources entering McAllister Creek. This would include sampling upstream sites in addition to sampling the mouth. Additionally, there are two tidegates just upstream of the mouth of Medicine Creek, the condition and operation of these tidegates should be evaluated.

- Little McAllister did not seem to be a notable source of bacteria to the McAllister Creek system from this investigation. I would recommend obtaining access to sample Little McAllister on the far side of the dike in order to separate it from the ditch that flows into it from the east.

- Immediate action should be initiated to identify, and reduce, the source of high bacteria levels entering McAllister Creek through the stormwater tidegate just upstream of Martin Way (MC33).

- Effective best management practices should be implemented for the I-5 stormwater discharging directly into McAllister Creek.

- Hatcheries are not usually a primary source for fecal coliform bacteria, but often add to the nutrient load of a waterbody. Sampling hatchery discharge into McAllister Creek would provide important information.

- The residences, RV Park, and commercial facilities in the basin are on septic systems. The effectiveness of these systems should be confirmed.

- Site MC34 was a sampling location also used by the Nisqually Tribe. It is unclear whether complete mixing would occur at this point in the channel since there are sources entering McAllister Creek from both banks, just upstream. Mixing should be evaluated if water quality is monitored at this site in subsequent studies.

- This water quality investigation was restricted to the area of McAllister Creek from the upper springs to just below the 1-5 Bridge (above the Nisqually National Wildlife Refuge boundary). Future studies investigating bacteria sources should consider sampling additional sites in the upper basin as well as sampling water quality in the lower estuarine area of the creek.

References

APHA et al, (American Public Health Association, American Water Works Association, and Water Environmental Federation) 1998. Standard Methods for the Examination of Waste and Wastewater, 20th Edition. Washington D.C.

Ecology, 1993. Field Sampling Measurement Protocols for the Watershed Assessments Section. Washington State Department of Ecology. Olympia, Washington

Ecology, 2000. Manchester Environmental Laboratory Lab Users Manual, 5th Edition. Washington State Department of Ecology. Manchester, Washington.

Nisqually Chinook Recovery Team, 2001. Nisqually Indian Tribe. Nisqually Natural Resources, Water Quality Program. Olympia, WA.

Roberts, Mindy and G. Pelletier. February 2001. Estimating loads of nutrients, bacteria, DO and TSS from 71 watershed tributary to South Puget Sound. Puget Sound Research 2001, Bellevue, Washington.

The Evergreen State College, 2001. Online weather information. Internet address: http://kokanee.evergreen.edu/weather/simple_search.asp, Olympia, Washington

U.S. Environmental Protection Agency, 1983. Methods for Chemical Analysis of Water and Wastes. EPA 600/4-79-020. Environmental Monitoring Supply Laboratory, Cincinnati, OH.

……..1986. Quality Criteria for Water 1986. EPA report 440/5-86-001, Washington, DC

Washington Administrative Code (WAC) Chapter 173-201A. Water quality standards for the surface waters of the State of Washington. 1997.

Whiley, Anthony, 2001. Personal communication. Anthony Whiley, Fisheries Biologist, Washington State Department of Fisheries. Olympia, WA.

Whiley, Anthony J. and George F. Walter, 1996. Investigation of Fecal Coliform Sources within the Drainage to the Nisqually Reach. Nisqually Indian Tribe. Nisqually Natural Resources, Water Quality Program. Technical Report Number 2. Olympia, WA.

……..1998. Analysis of Fecal Coliform Concentrations in the Nisqually River Drainage. Nisqually Indian Tribe. Nisqually Natural Resources, Water Quality Program. Technical Report Number 5. Olympia, WA.

Williams, R. Walter, Richard M. Laramie, James J. Ames, et.al, 1975. A Catalog of Washington Streams and Salmon Utilization, Volume 1, Puget Sound Region. Washington Department of Fisheries, Olympia WA.

Appendix A

Table A1. McAllister Creek data collected March 28, 2001 through June 25, 2001.

Site	Date	Time	Lab#	Field Temp	Lab Cond	Field Cond	Lab Salinity	Q	Field Salinity	Q	pH	Q	Entero-cocci (MF)	Q	Fecal Coliform (MF)	Q	Fecal Coliform (MPN)	Q	NH3	Q	NO2NO3	Q	Total Persulfate Nitrogen	Q	TP	Q	TSS	Q	TURB	Q
				°C	umhos/cm	umhos/cm	ppt		ppt		S.U.		cfu/100mL		cfu/100mL		cfu/100mL		mg/L		mg/L		mg/L		mg/L		mg/L		NTU	
McAllister Creek at Spring outfall weir																														
MC42	3/28/01	16:50	01139242	10.1	144	150			0				1	U	1												1	UJ	0.5	U
MC42	4/11/01																													
MC42	4/30/01																													
MC42	5/9/01	12:40	01199242	11.5		160			0				2		3															
MC42	5/23/01																													
MC42	6/11/01	14:15	01249242	11.8		150			0						2		9.3													
MC42	6/25/01																													
McAllister Creek below springs																														
MC40	3/28/01	11:50	01139240	12	152	150	2	U	0				4		10												3	J	1.2	
MC40	4/11/01	13:30	01159240	11	150	150	2	U	0				3		7												3		0.8	
MC40	4/30/01	16:40	01189240	12	148	150	2	U	0		7		14		16				0.027		0.757		0.85		0.184		1		0.9	
MC40	5/9/01	13:05	01199240	12	151	160	2	U	0				6		13		4.5										2		0.8	
MC40	5/23/01																													
MC40	6/11/01																													
MC40	6/25/01	13:30	01269240	11.9		150			0		7		17		32		95		0.018		0.715		0.858		0.181		1	U	0.5	
McAllister Creek just above confluence with Little McAllister																														
MC39	3/28/01	13:00	01139239	10.3	159	170	2	U	0				4		10												2	J	1.2	
MC39	4/11/01	14:15	01159239	11		151			0				6		5															
MC39	4/30/01	17:30	01189239	12	165	170	2	U	0		7.3		30		95				0.072		0.683		0.814		0.237		2		0.9	
MC39	5/9/01	14:10	01199239	12.5		165			0				16		10															
MC39	5/23/01																													
MC39	6/11/01																													
MC39	6/25/01	15:10	01269239	13		165			0		7.2		8		32				0.048		0.668		0.798		0.213		1	U	0.5	U
McAllister Creek below confluence with Little McAllister																														
MC38	3/28/01	13:45	01139238	10	163	170	2	U					13		11												4	J	1.4	
MC38	4/11/01	14:40	01159238	11	158	152	2	U	0				8		4												3		1.4	
MC38	4/30/01																													
MC38	5/9/01	14:30	01199238	12.95		170			0				13		6															
MC38	5/23/01																													
MC38	6/11/01																													
MC38	6/25/01	15:40	01269238	13.3		166			0		7.2		12		53				0.039		0.745		0.872		0.201		1		0.7	
McAllister Creek above Fish Hatchery Outflow and below Tidegate #9																														
MC37	3/28/01	14:00	01139237	10	164	170	2	U	0				19		31												3	J	1.6	
MC37	4/11/01	15:10	01159237	11.5		152			0				22		21												3		1.6	
MC37	4/30/01	18:15	01189237	13	164	170	2		0		7.4		66		180	J			0.058		0.828		0.965		0.215		2		1.3	
MC37	5/9/01	14:55	01199237	13		170			1				11		8															
MC37	5/23/01																													
MC37	6/11/01																													
MC37	6/25/01	16:25	01269237	3.4		170			0		7.3		28		33				0.028		0.831		0.934		0.19		1		0.9	
McAllister Creek just upstream of Medicine Creek and below houses																														
MC36	3/28/01	14:25	01139236	10.2	167	170	2	U	0				32		53												4	J	2.1	
MC36	4/11/01																													
MC36	4/30/01																													
MC36	5/9/01	15:15	01199236	13		170			2				14		3															
MC36	5/23/01																													
MC36	6/11/01																													
MC36	6/25/01	16:40	01269236	14		170			0		7.4		23		25				0.026		0.753		0.821		0.193		2		1	
Medicine Creek Mouth																														
MED46	3/28/01	10:00	01139246		174		2	U	0				410	JH	210	JH											4	J	2.7	
MED46	4/11/01	11:17	01159246	9.75	172	140	2	U	0				110		190		46										2		2.3	
MED46	4/30/01	14:45	01189246	10.25	213	220	2	U	0		7.2		3600	J	360				0.084		0.388		0.701		0.195		6		12	
MED46	5/9/01	15:20	01199246	18.5		221			2				31		110		33										6		11	
MED46	5/23/01																													
MED46	6/11/01																													
MED46	6/25/01																													

Table A1. McAllister Creek data collected March 28, 2001 through June 25, 2001.

Site	Date	Time	Lab#	Field Temp	Lab Cond	Field Cond	Lab Salinity	Q	Field Salinity	Q	pH	Q	Entero-cocci (MF)	Q	Fecal Coliform (MF)	Q	Fecal Coliform (MPN)	Q	NH3	Q	NO2NO3	Q	Total Persulfate Nitrogen	Q	TP	Q	TSS	Q	TURB	Q
				°C	umhos/cm	umhos/cm	ppt		ppt		S.U.		cfu/100mL		cfu/100mL		cfu/100mL		mg/L		mg/L		mg/L		mg/L		mg/L		NTU	
McAllister Creek above series of Tidegates																														
MC35	3/28/01	14:40	01139235	10.1	170	165	2	U	0				26		68												3	J	2.5	
MC35	4/11/01	15:30	01159235	11	166	170	2	U	0				34		47												2		2.2	
MC35	4/30/01	18:45	01189235	11.5	166	175	2	U	0		7.4		220	J	200				0.063		0.904		1.04		0.201		2		1.7	
MC35	5/9/01	15:40	01199235	13.3	165	170	2	U	1				14		14												3		1.5	
MC35	5/23/01																													
MC35	6/11/01																													
MC35	6/25/01	17:10	01269235	13.8		175			1		7.4		12		32				0.023		0.785		0.909		0.195		2		1.3	
Mainstem just above TG5 - acting as background when walked in to sites																														
MS Up of T5	3/28/01																													
MS Up of T5	4/11/01																													
MS Up of T5	4/30/01																													
MS Up of T5	5/9/01																													
MS Up of T5	5/23/01	13:40	01219242	NFS	194		2	U					36		65												3		2	
MS Up of T5	6/11/01	15:45	01249266	NFS											390															
MS Up of T5	6/25/01																													
McAllister Creek above Martin Way																														
MC34	3/28/01	15:10	01139234	10.2	186	190	2	U	0				290	J	160												3	J	2.4	
MC34	4/11/01	16:05	01159234	11.75	239	250	2	U	0				46		40												3		2.3	
MC34	4/30/01	19:20	01189234	11.75	278	280	2	U	0		7.3		5000	G	750	J			0.095		0.972		1.16		0.205		2		2.3	
MC34	5/9/01	16:10	01199234	13.5	191	190	2	U	1				7		9												3		2	
MC34	5/23/01	14:45	01219234		490		2	U					7		26												4		2.8	
MC34	6/11/01	16:33	01249234												1200	J														
MC34	6/25/01	17:45	01269234	14.3		270			0		7.5		10		20				0.036		0.825		0.876		0.199		2		1.5	
McAllister Creek above I-5 At RV bridge																														
MC32	3/28/01	15:45	01139232	10.1	269	300	2	U					330	J	210												3	J	2.9	
MC32	4/11/01	16:15	01159232	11.75	312	320	2	U	0				29		51												2		2.4	
MC32	4/30/01	19:30	01189232	11.5	358	170	2	U	0		7.5		5000	G	1200	J	1100		0.098		0.939		1.13		0.205		2		2.3	
MC32	5/9/01	16:18	01199232	13.5	235	240	2	U	1				2		7		7.8										4		2.5	
MC32	5/23/01	15:00	01219232		605		2	U					7	U	66		33										4		2.5	
MC32	6/11/01																													
MC32	6/25/01	17:55	01269232	14.5		400			0		7.5		6		40				0.038		0.816		0.91		0.192		2		1.7	
McAllister Creek below TG1 and above MC31																														
MC41	3/28/01																													
MC41	4/11/01																													
MC41	4/30/01																													
MC41	5/9/01	16:30	01199241	13.7	256	260	2	U	2				11		6												4		2.7	
MC41	5/23/01	15:25	01219241		610		2	U					13		45		130										3		2.5	
MC41	6/11/01																													
MC41	6/25/01	18:05	01269241	14.6		440					7.5		15		36				0.035		0.812		0.94		0.201		3		1.9	
McAllister Creek downstream of I-5																														
MC30	3/28/01	16:00	01139230	10.05	269	270	2	U	0				300	J	200	J											3	J	2.3	
MC30	4/11/01	16:20	01159230	11.5	339	340	2	U	1				51		46		49										3		2.2	
MC30	4/30/01	20:00	01189230	11	367	360	2	U	0		7.3		14000	J	1000	J	540		0.098		0.938		1.15		0.205		3		2.2	
MC30	5/9/01	16:45	01199230	13.95	243	250	2	U	1				3		10		2										4		2.8	
MC30	5/23/01	15:35	01219230		594		2	U					21		46		79										4		2.6	
MC30	6/11/01	17:15	01249230	12.8		550			0						820	J	540													
MC30	6/25/01	18:24	01269230	14.8		430			0		7.5		23		40		49		0.034		0.809		0.922		0.198		2		1.7	
Tidegate 15																														
TG15	3/28/01																													
TG15	4/11/01	13:50	01159215										57		21															
TG15	4/30/01	17:00	01189215	14.5	194	200	2	U	0		7.4		500		170	J			0.041		0.014		0.204		0.489		5		2.8	
TG15	5/9/01	13:30	01199215	12.75		170			0				21		15															
TG15	5/23/01																													
TG15	6/11/01																													
TG15	6/25/01																													
Tidegate 14																														
TG14	3/28/01																													
TG14	4/11/01																													
TG14	4/30/01	17:15	01189214	14.5	235	240	2	U	0		7.1		61		84				0.028		0.016		0.28		0.464		3		3	
TG14	5/9/01																													
TG14	5/23/01																													
TG14	6/11/01																													
TG14	6/25/01																													

Table A1. McAllister Creek data collected March 28, 2001 through June 25, 2001.

Site	Date	Time	Lab#	Field Temp	Lab Cond	Field Cond	Lab Salinity	Q	Field Salinity	Q	pH	Q	Entero-cocci (MF)	Q	Fecal Coliform (MF)	Q	Fecal Coliform (MPN)	Q	NH3	Q	NO2NO3	Q	Total Persulfate Nitrogen	Q	TP	Q	TSS	Q	TURB	Q
				°C	umhos/cm	umhos/cm	ppt		ppt		S.U.		cfu/100mL		cfu/100mL		cfu/100mL		mg/L		mg/L		mg/L		mg/L		mg/L		NTU	
Tidegate 13																														
TG13	3/28/01	12:50	01139213	12.5		260			0				12		6												1	UJ	0.8	
TG13	4/11/01	14:10	01159213										22		10															
TG13	4/30/01	16:00	01189213	14.5	300	300	2	U	0		7.7		130		740	J			0.588		0.053		0.774		0.639		6		3	
TG13	5/9/01	13:55	01199213	15.75		320			0				97		48															
TG13	5/23/01																													
TG13	6/11/01																													
TG13	6/25/01																													
Tidegate 12																														
TG12	3/28/01	13:20	01139212										340		150															
TG12	4/11/01	14:30	01159212										69		96															
TG12	4/30/01	17:40	01189212	12.5	160	170	2	U	0		6.9		110		160				0.043		0.05		0.503		0.202		4		2.9	
TG12	5/9/01	14:20	01199212	14.25		170			0				19		1															
TG12	5/23/01																													
TG12	6/11/01																													
TG12	6/25/01																													
Tidegate 11 - front gate at confluence of ditch and Little McAllister																														
TG11-F	3/28/01	13:21	01139211	9.5		15							20		15												8	J	4.2	
TG11-F	4/11/01	14:37	01159211										26		16															
TG11-F	4/30/01																													
TG11-F	5/9/01	14:26	01199225										4		28															
TG11-F	5/23/01																													
TG11-F	6/11/01																													
TG11-F	6/25/01	15:25	01269211	13.1		163			1		7.1		85		230				0.024		1.63		1.69		0.06		2		1.3	
Tidegate 11 - back gate at confluence of ditch and Little McAllister																														
TG11-B	3/28/01																													
TG11-B	4/11/01	14:35	01159225										37		14															
TG11-B	4/30/01	17:50	01189225	10.75	144	150	2	U	0		7.2		61		69				0.027		1.6		1.87		0.071		22		6.6	
TG11-B	5/9/01	14:26	01199211	13.75		165			0				4		47															
TG11-B	5/23/01																													
TG11-B	6/11/01																													
TG11-B	6/25/01																													
Tidegate 10																														
TG10	3/28/01																													
TG10	4/11/01	14:50	01159210										140		77														10	
TG10	4/30/01	18:00	01189210	13.75	271	290	2	U	0		7		2800	J	4000	J			0.04		0.087		0.579		0.41		19		10	
TG10	5/9/01	14:40	01199210	16		190			1				3	U	45															
TG10	5/23/01																													
TG10	6/11/01																													
TG10	6/25/01	15:55	01269210	15.6		410			0		6.9		42		99				0.021		0.164		0.303		0.143		2		3.3	
Tidegate 9																														
TG9	3/28/01	13:53	01139209	10		220			0				440		1300												13	J	15	
TG9	4/11/01	15:00	01159209	11.75	204	210							330		800												11		16	
TG9	4/30/01	18:10	01189209	14	233	240	2	U	0		7.2		3400		6300	J			0.041		0.097		0.351		0.219		5		12	
TG9	5/9/01	14:50	01199209	16.5		240			1				120		31															
TG9	5/23/01																													
TG9	6/11/01																													
TG9	6/25/01	16:10	01269209	17.1		320			0		7		180		26				0.03		0.041		0.189		0.126		2		6.1	
Tidegate 8																														
TG8	3/28/01																													
TG8	4/11/01																													
TG8	4/30/01	15:20	01189208	10.2	131	140	2	U	0				770		150				0.031		0.028		0.384		0.857		11		30	
TG8	5/9/01																													
TG8	5/23/01																													
TG8	6/11/01																													
TG8	6/25/01																													

Table A1. McAllister Creek data collected March 28, 2001 through June 25, 2001.

Site	Date	Time	Lab#	Field Temp	Lab Cond	Field Cond	Lab Salinity	Q	Field Salinity	Q	pH	Q	Entero-cocci (MF)	Q	Fecal Coliform (MF)	Q	Fecal Coliform (MPN)	Q	NH3	Q	NO2NO3	Q	Total Persulfate Nitrogen	Q	TP	Q	TSS	Q	TURB	Q
				°C	umhos/cm	umhos/cm	ppt		ppt		S.U.		cfu/100mL		cfu/100mL		cfu/100mL		mg/L		mg/L		mg/L		mg/L		mg/L		NTU	
Tidegate 5																														
TG5	3/28/01	14:58	01139205	10		280							1500	J	1200												18	J	22	
TG5	4/11/01	15:45	01159205	14.5	248	260							270		57												19		22	
TG5	4/30/01	19:00	01188015	12	249	270	2	U	0				490		8900	J			0.267		0.035		0.604		2.25		407		190	
TG5	5/9/01	15:50	01199205	21	310	320	2	U	1				190		2300	J											30		39	
TG5	5/23/01	13:35	01219205		585		2	U					200		370												24		29	
TG5	6/11/01	15:37	01249205						0						17000	G														
TG5	6/25/01	17:20	01269205	20.8		>1000			0		7.1		320		92				0.366		0.102		0.622		0.269		17		24	
Tidegate 4																														
TG4	3/28/01																													
TG4	4/11/01	15:50	01159204	15	1350	>1000			0				1700	J	550												14		14	
TG4	4/30/01	19:10	01189204	11.75	1500	>1000	2	U	0		6.9	J	170000	J	110000	J			21.1		0.03		27.2		1.47		50		50	
TG4	5/9/01	16:00	01199204	20	2490	>1000	2	U	1				75		200												24		32	
TG4	5/23/01	14:00	01219204		4770		2						69		290												54		75	
TG4	6/11/01	15:58	01249204												17000	G														
TG4	6/25/01																													
Stormwater **from swale/ tidegate goes into McAllister above Martin Way**																														
MC33	3/28/01																													
MC33	4/11/01																													
MC33	4/30/01	14:00	01189233	10.4	36.9		2	U	0		6.6		2100	J	3400	J			0.014		0.071		0.318		0.07		4		6.1	
MC33	5/9/01																													
MC33	5/23/01																													
MC33	6/11/01	14:45	01249233												1400															
MC33	6/25/01																													
Stormwater **from culvert under I-5**																														
MC31	3/28/01																													
MC31	4/11/01	16:16	01159231	9	110	120							14		1												1	U	0.6	
MC31	4/30/01	20:15	01189231	10	123	149	2	U	0		7.3		790	J	100	J											6		14	
MC31	5/9/01	16:40	01199231		188		2	U					1		1														1.6	
MC31	5/23/01																													
MC31	6/11/01	16:50	01249231												240	J														
MC31	6/25/01	18:15	01269231										570	J	810	J			0.01	U	2.07		2.33		0.031					
Tidegate 1																														
TG1-Bot	5/9/01	16:25	01199201	21		>1000			5				7		96															
TG1-Top	5/9/01	16:26	01199200	18		>1000			4				7		52															
Tidegate 2																														
T2	3/28/01	15:18	01139201										390		210	J											13	J	6	
T2	4/11/01	16:11	01159202										57		37															
Tidegate 4																														
TG4	6/11/01	13:37	01249257												50,000	G														
Tidegate 5																														
TG5	4/30/01	14:10	01189205	10.35	297	310	2	U	0		7		2000	J	22,000	J			0.23		0.038		0.571		0.49		54		60	
TG5	6/11/01	13:37	01249255												50,000	G														
Hatchery Outlet																														
HATOUT29	4/30/01	15:30	01189229	12	169	170	2	U	0		7.7		130		410				0.122		0.821		1.06		0.227		3		1.5	
HATOUT29	5/9/01	14:50	01199229	13		170			2				4		4															
Big Springs just downstream of MC35																														
BIGS24	3/28/01	14:44	01139224										2		1															
Black pipe 2 houses down form Steilacoom Road																														
Black pipe	3/28/01	10:25	01139225										23	JH	2	JH														
Culvert near TG11	3/28/01	13:21	01139226										120		71															

Q = qualifying code
U = value at or below the reporting limit
J = estimate, true values can be equal to or greater than reported results
JH = values are estimates, the holding time was greater than 24 hrs but less than 30 hrs
G = results may be well above the reported values; sample was not diluted enough and growth was almost confluent on the plate.

Table A2 . Summary of field and laboratory measurements and methods.

Field measurements	Abbreviation	Method	Accuracy
Temperature	Temp	Red alcohol thermometer	+/- 0.2 ^{o}C
Conductivity	Cond	Beckman field meter	+/- 5 %
Salinity	Salinity	Vista hand held refractometer	1 ppt
Laboratory Parameters	**Abbreviation**	**Method ***	**Lower Reporting Limit**
Fecal coliform	FCMF	SM16-909C - membrane filter	1 cfu/100 mL **
Fecal coliform	FCMPN	SM16-908C - most probable number - A-1 medium	1.8 cfu/100 mL
Enterococci	ENTMF	EPA 1600 - membrane filter	1cfu/100 mL
Turbidity	Turb	SM2130	0.5 NTU
Total Suspended Solids	TSS	EPA160.2	1 mg/L
Total Persulfate nitrogen	TPN	SM4500NB	0.01 mg/L
Ammonia - nitrogen	NH3	EPA350.1	0.01 mg/L
Nitrite - nitrate nitrogen	NO2NO3	SM4500PI	0.01 mg/L
Total phosphorus	TP	SM4500PI	0.01 mg/L
Salinity	Salinity	SM2520	2 ppt
Conductivity	Cond	EPA 120.1	1 umhos/cm at 25 ^{o}C
pH	pH	EPA 150.1	0.1 Standard Unit (S.U.)

* SM =APHA et al, (American Public Health Association, American Water Works Association, and Water Environmental Federation) 1998. Standard Methods for the Examination of Waste and Wastewater, 20th Edition. Washington D.C.

EPA = U.S. Environmental Protection Agency, 1983. Methods for Chemical Analysis of Water and Wastes. EPA 600/4-79-020. Environmental Monitoring Supply Laboratory, Cincinnati, OH.

* * cfu = colony forming unit

Table A3. Field precision for bacteria sampling.

	Number of samples	Average % CV for values <50 cfu/100mL	Average % CV for values >50 cfu/100mL	Average % CV for all values
Fecal coliform (MF)	24	26	17	21
Fecal coliform (MPN)	7	9	28	20
Enterococcus (MF)	19	17	27	22

Table A4. Field precision for nutrient, sediment, and general chemistry samples.

	Number of Samples	Average % CV for values
Salinity	most samples below detection	
Conductivity	13	0.2
Total Suspended Solids (TSS)	19	4.5
Turbidity	16	6.1
Ammonia-nitrogen (NH3)	6	2.2
Nitrite+Nitrate-nitrogen (NO2NO3)	6	3.4
Total Persulfate nitrogen (TPN)	6	2.1
Total Phosphorus (TP)	6	1.5

Table A5. Precipitation data obtained from The Evergreen State College, Olympia, WA.

Date*	24 hour total Precipitation (inches)**
3/27/01	0.68
3/28/01	0.02
4/10/01	0.34
4/11/01	0
4/29/01	0.37
4/30/01	0.71
5/8/01	0
5/9/01	0
5/22/01	0
5/23/01	0
6/10/01	0.4
6/11/01	0.67
6/24/01	0.19
6/25/01	0

* Sampling date is in bold

**Precipitation represents rain between midnight to midnight.

Appendix B

Table B1: Class A (excellent) fresh water quality standards and characteristic uses for McAllister Creek; additionally Class AA fresh and marine water quality standards and characteristic uses for selected parameters are described (WAC173-201A)

	Class A (Fresh water)	**Class AA (Fresh water)**	**Class AA (Marine water)**
General Characteristic:	Shall meet or exceed the requirements for all or substantially all uses.	Shall markedly and uniformly exceed the requirements for all or substantially all uses.	Shall markedly and uniformly exceed the requirements for all or substantially all uses.
Characteristic Uses:	Shall include, but not be limited to, the following: domestic industrial, and agricultural water supply; stock watering; salmonid and other fish migration, rearing, spawning, and harvesting; clam, oyster, and mussel rearing, spawning, and harvesting; crustaceans and other shellfish rearing spawning, and harvesting; wildlife habitat; primary contact recreation, sport fishing, boating, and aesthetic enjoyment; and commerce and navigation.	Shall include, but not be limited to, the following: domestic industrial, and agricultural water supply; stock watering; salmonid and other fish migration, rearing, spawning, and harvesting; clam, oyster, and mussel rearing, spawning, and harvesting; crustaceans and other shellfish rearing spawning, and harvesting; wildlife habitat; primary contact recreation, sport fishing, boating, and aesthetic enjoyment; and commerce and navigation.	Shall include, but not be limited to, the following: domestic industrial, and agricultural water supply; stock watering; salmonid and other fish migration, rearing, spawning, and harvesting; clam, oyster, and mussel rearing, spawning, and harvesting; crustaceans and other shellfish rearing spawning, and harvesting; wildlife habitat; primary contact recreation, sport fishing, boating, and aesthetic enjoyment; and commerce and navigation.
Water Quality Criteria:			
Fecal Coliform:	Shall both not exceed a geometric mean value of 100 colonies/100 mL, and not have more than 10% of all samples obtained for calculating the geometric mean value exceeding 200 colonies/100mL.	Shall both not exceed a geometric mean value of 50 colonies/100 mL, and not have more than 10% of all samples obtained for calculating the geometric mean value exceeding 100 colonies/100mL.	Shall both not exceed a geometric mean value of 14 colonies/100 mL, and not have more than 10% of all samples obtained for calculating the geometric mean value exceeding 43 colonies/100mL.
Dissolved Oxygen:	Shall exceed 8.0 mg/L	Shall exceed 9.5 mg/L	Shall exceed 7.0 mg/L. When natural conditions occur causing the dissolved oxygen to be depressed near or below 7.0 mg/L, natural dissolved oxygen levels may be degraded by up to 0.2 mg/L by human-caused activities.
Temperature:	Shall not exceed 18.0ºC due to human activities. When conditions exceed 18.0º C, no temperature increase will be allowed which will raise the receiving water temperature by greater than 0.3ºC. Increases from non-point sources shall not exceed 2.8ºC.	Shall not exceed 16.0º C due to human activities. When conditions exceed 16.0º C, no temperature increase will be allowed which will raise the receiving water temperature by greater than 0.3ºC. Increases from non-point sources shall not exceed 2.8ºC.	Shall not exceed 13.0º C due to human activities. When conditions exceed 16.0º C, no temperature increase will be allowed which will raise the receiving water temperature by greater than 0.3ºC. Increases from non-point sources shall not exceed 2.8ºC.

Table B1: Class A (excellent) fresh water quality standards and characteristic uses for McAllister Creek; additionally Class AA fresh and marine water quality standards and characteristic uses for selected parameters are described (WAC173-201A)

Water Quality Criteria:	Class A (Fresh water)	Class AA (Fresh water)	Class AA (Marine water)
pH:	Shall be within the range of 6.5 to 8.5 with a man-caused variation with a range of less than 0.5 units.	Shall be within the range of 6.5 to 8.5 with a man-caused variation with a range of less than 0.2 units.	Shall be within the range of 7.0 to 8.5 with a man-caused variation with a range of less than 0.2 units.
Turbidity	Shall not exceed 5 NTU over background turbidity when the background turbidity is 50 NTU or less, or have more than a 10% increase in turbidity when the back ground is more than 50 NTU.	Shall not exceed 5 NTU over background turbidity when the background turbidity is 50 NTU or less, or have more than a 10% increase in turbidity when the back ground is more than 50 NTU.	Shall not exceed 5 NTU over background turbidity when the background turbidity is 50 NTU or less, or have more than a 10% increase in turbidity when the back ground is more than 50 NTU.

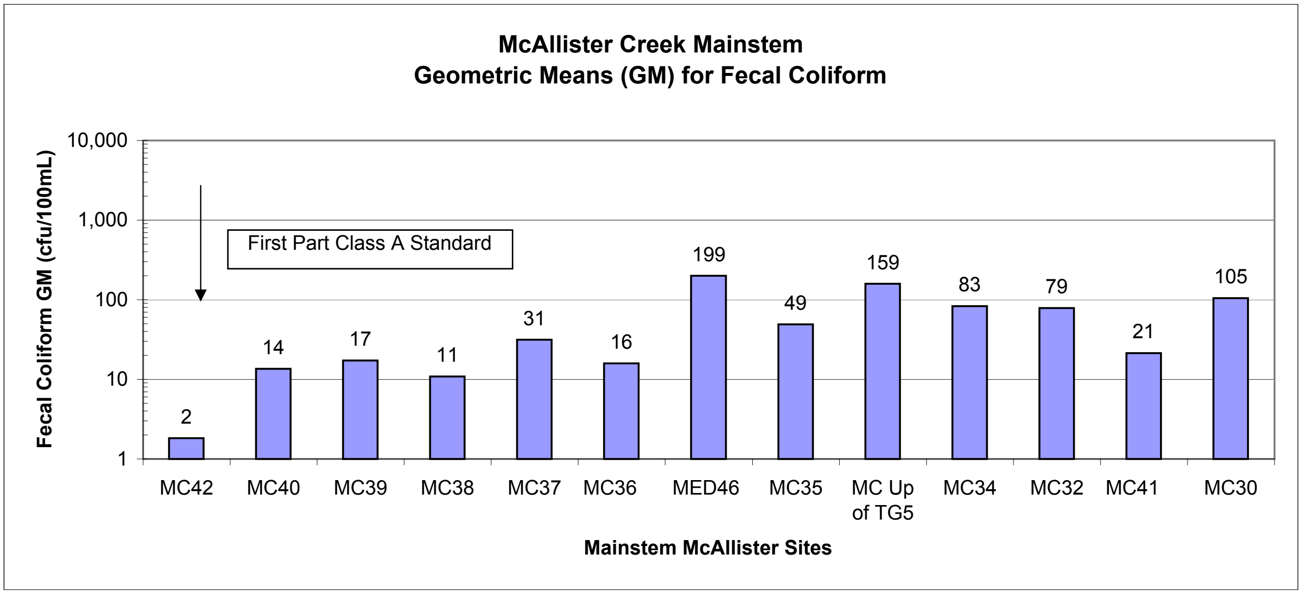
Appendix C

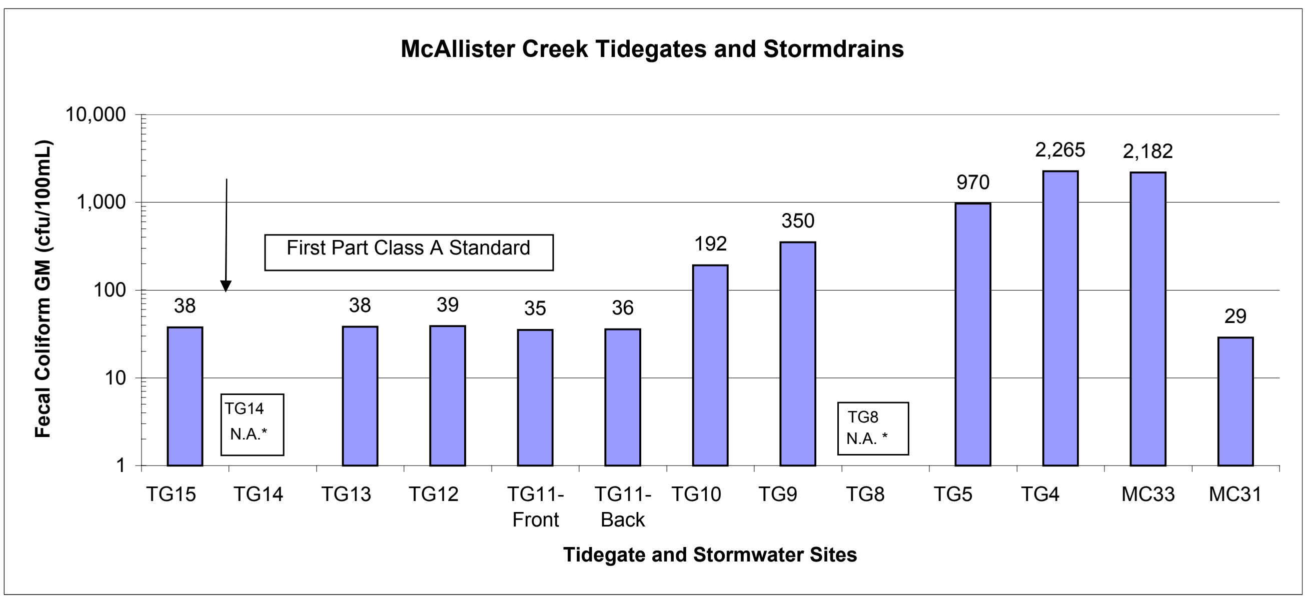
Table C1. Comparison of McAllister Creek fecal coliform levels with the Class A Freshwater Criterion. Highlighted sites did not meet the criterion.

Site			Freshwater Class A Standard for Fecal Coliform	
McAllister Creek (Upstream to downstream)	N	Geometric Mean	GM below #100/100 mL?	10% or less of all samples for calculating GM exceed #200/100 mL?
MC42	3	2	YES	YES, 0 of 3 samples exceeded 200
MC40	5	14	YES	YES, 0 of 5 samples exceeded 200
MC39	5	17	YES	YES, 0 of 5 samples exceeded 200
MC38	4	11	YES	YES, 0 of 4 samples exceeded 200
MC37	5	31	YES	YES, 0 of 5 samples exceeded 200
MC36	3	16	YES	YES, 0 of 3 samples exceeded 200
MED46	**4**	**199**	**NO**	**NO, 2 of 4 samples exceeded 200**
MC35	5	49	YES	YES, 0 of 5 samples exceeded 200
MS Up of T5	**2**	**159**	**NO**	**NO, 1 of 2 samples exceeded 200**
MC34	**7**	**83**	**YES**	**NO, 2 of 7 samples exceeded 200**
MC32	**6**	**79**	**YES**	**NO, 2 of 6 samples exceeded 200**
MC41	3	21	YES	YES, 0 of 3 samples exceeded 200
MC30	**7**	**105**	**NO**	**NO, 2 of 7 samples exceeded 200**
Tidegates/ Stormdrains (Upstream to downstream)	N	Geometric Mean	GM below #100/100 mL?	10% or less of all samples for calculating GM exceed #200/100 mL?
TG15	3	38	YES	YES, 0 of 3 samples exceeded 200
TG14	1	NA	YES	YES, 0 of 1 samples exceeded 200
TG13	**4**	**38**	**YES**	**NO, 1 of 4 samples exceeded 200**
TG12	4	39	YES	YES, 0 of 4 samples exceeded 200
TG11-Front	**4**	**35**	**YES**	**NO, 1 of 4 samples exceeded 200**
TG11-Back	3	36	YES	YES, 0 of 3 samples exceeded 200
TG10	**4**	**192**	**NO**	**NO, 1 of 4 samples exceeded 200**
TG9	**5**	**350**	**NO**	**NO, 3 of 5 samples exceeded 200**
TG8	1	NA	YES	YES, 0 of 1 sample exceeded 200
TG5	**7**	**970**	**NO**	**NO, 5 of 7 samples exceeded 200**
TG4	**5**	**2,265**	**NO**	**NO, 4 of 5 samples exceeded 200**
MC33	**2**	**2,182**	**NO**	**NO, 2 of 2 samples exceeded 200**
MC31	**5**	**29**	**YES**	**NO, 2 of 5 samples exceeded 200**

Table C2. A summary of the fecal coliform data for sampling sites in McAllister Creek.

		Fecal Coliform bacteria concentration (cfu/100 mL)								
Site Name	Site Description	3/28/01	4/11/01	4/30/01	5/9/01	5/23/01	6/11/01	6/25/01	# of samples	Geometric Mean
	Mainstem Sites (upstream to downstream)									
MC42	McAllister Creek at Spring outfall	1			3		2		3	2
MC40	McAllister Creek below springs	10	7	16	13			32	5	14
MC39	McAllister Creek just above confluence with Little McAllister	10	5	95	10			32	5	17
MC38	McAllister Creek below confluence with Little McAllister	11	4		6			53	4	11
MC37	McAllister Creek above Fish Hatchery Outflow and below Tidegate #9	31	21	180	8			33	5	31
MC36	McAllister Creek just upstream of Medicine Creek and below houses	53			3			25	3	16
MED46	Medicine Creek Mouth	210	190	360	110				4	199
MC35	McAllister Creek above series of Tidegates	68	47	200	14			32	5	49
MC Up of TG5	Mainstem just above TG5 - acting as background when walked in to sites					65	390		2	159
MC34	McAllister Creek above Martin Way	160	40	750	9	26	1,200	20	7	83
MC32	McAllister Creek above I-5 At RV bridge	210	51	1,200	7	66		40	6	79
MC41	McAllister Creek below TG1 and above MC31				6	45		36	3	21
MC30	McAllister Creek downstream of I-5	200	46	1,000	10	46	820	40	7	105
	Tidegate and Stormdrains (upstream to downstream)									
TG15	Tidegate 15		21	170	15				3	38
TG14	Tidegate 14			84					1	NA
TG13	Tidegate 13	6	10	740	48				4	38
TG12	Tidegate 12	150	96	160	1				4	39
TG11-Front	Tidegate 11 - front gate at confluence of ditch and Little McAllister	15	16		28			230	4	35
TG11-Back	Tidegate 11 - back gate at confluence of ditch and Little McAllister		14	69	47				3	36
TG10	Tidegate 10		77	4,000	45			99	4	192
TG9	Tidegate 9	1,300	800	6,300	31			26	5	350
TG8	Tidegate 8			150					1	NA
TG5	Tidegate 5	1,200	57	8,900	2,300	370	17,000	92	7	970
TG4	Tidegate 4		550	110,000	200	290	17,000		5	2,265
MC33	Stormwater from swale/ tidegate goes into McAllister above Martin Way			3,400			1,400		2	2,182
MC31	Stormwater from culvert under I-5		1	100	1		240	810	5	29

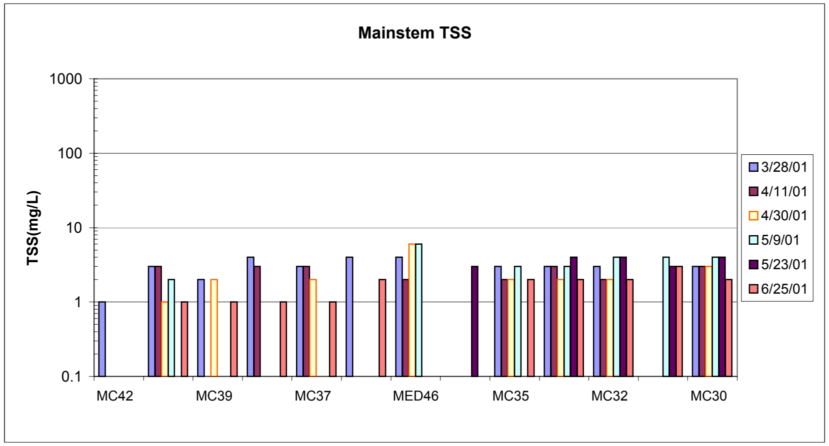


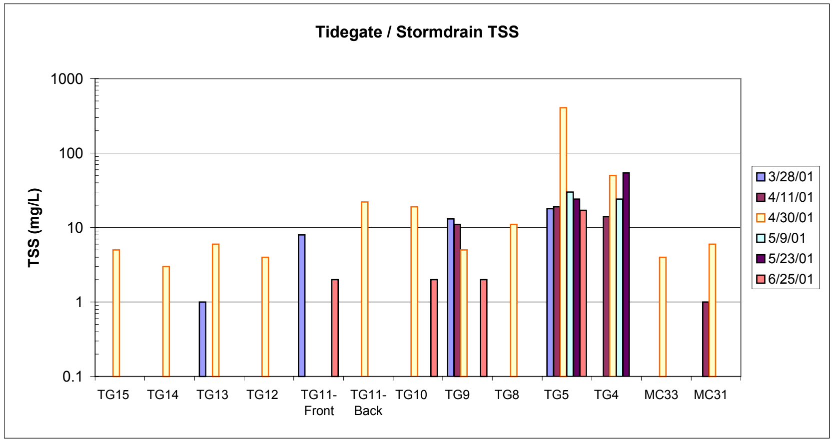


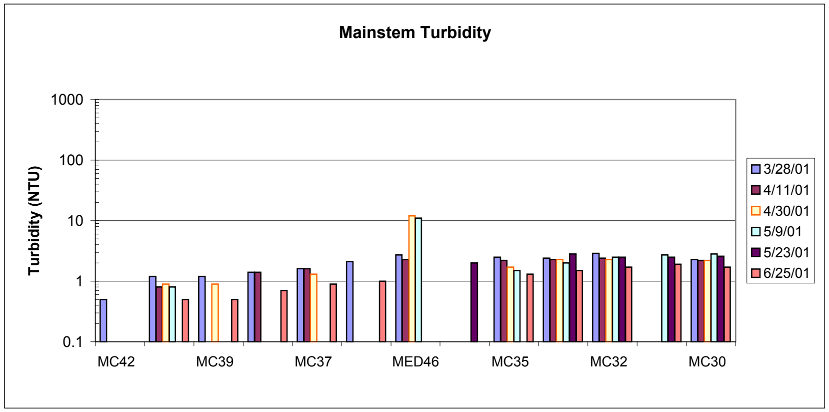
* N.A. = not applicable, sample size was 1

Figure C1. Fecal coliform geometric mean values for McAllister Creek study sites. Note that the scale is logarithmic.

Appendix D







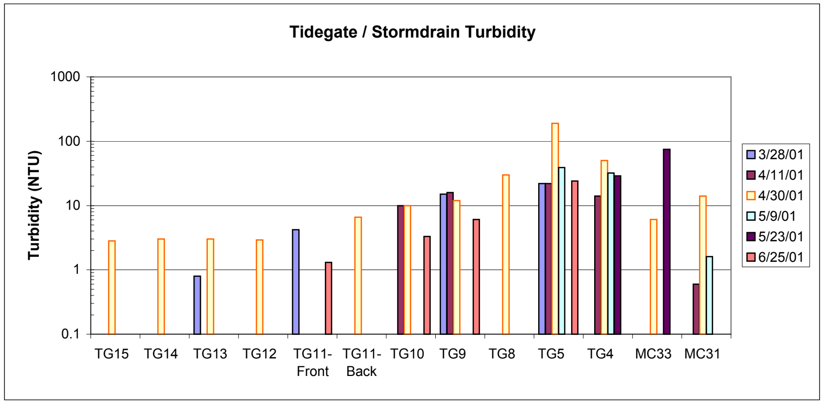


Figure D1. Total suspended solids and turbidity data for sampling sites in McAllister Creek. Note that the scale is logarithmic.

Appendix E

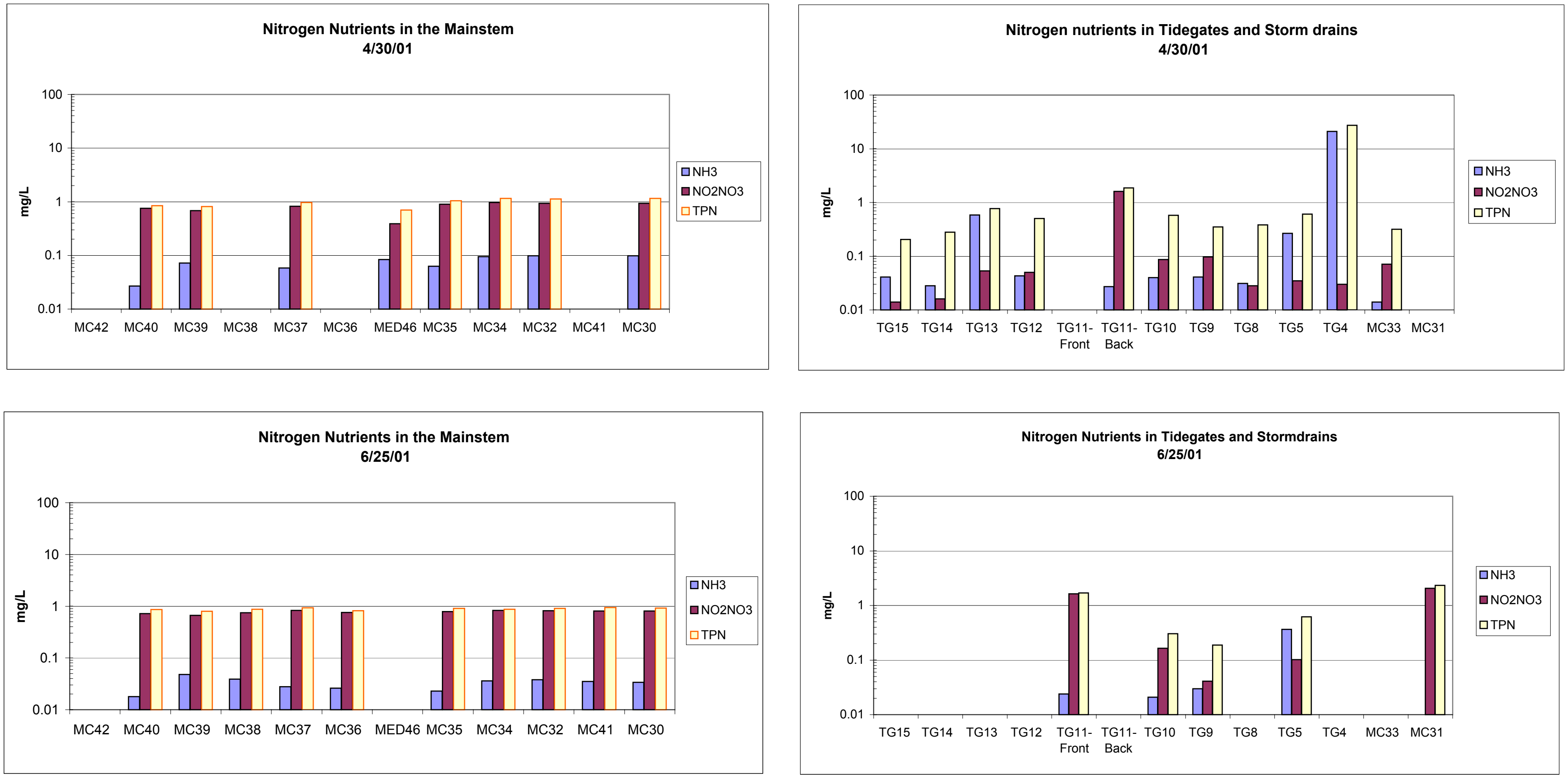
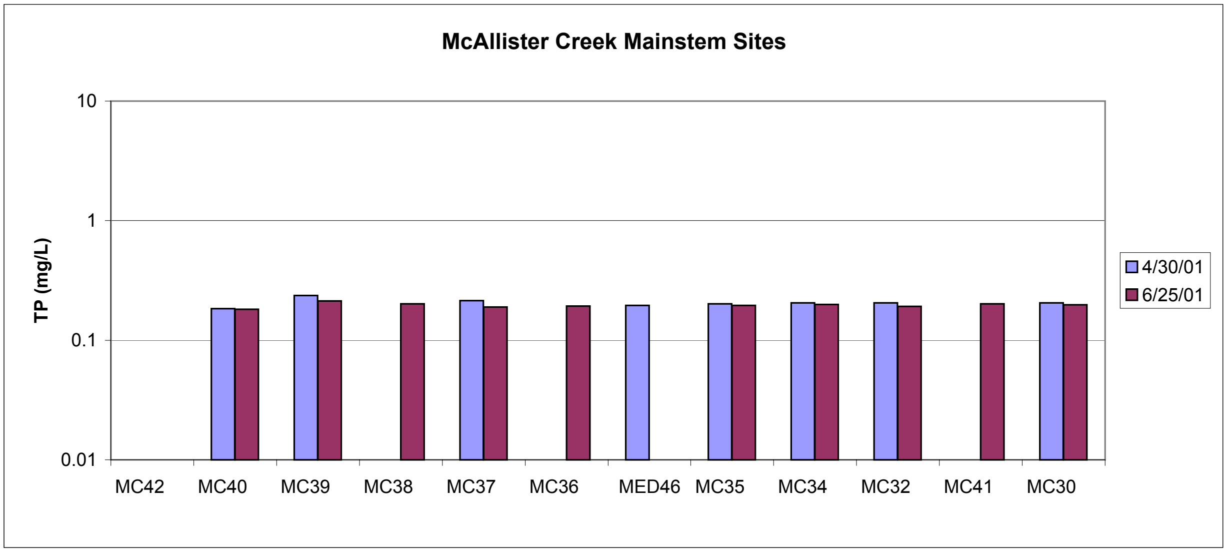


Figure E1. Relative concentrations of total nitrogen (TPN), total ammonia-nitrogen (NH3), and nitrite+nitrate nitrogen (NO2NO3) in McAllister Creek. Note that the scale is logarithmic.



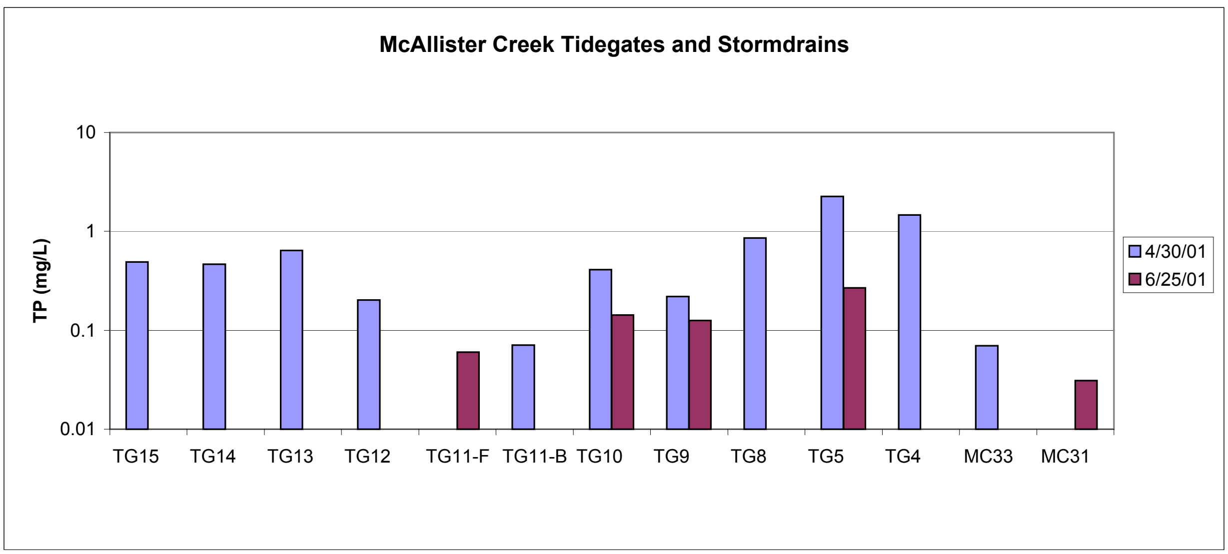


Figure E2. Total phosphorus concentrations at sites in McAllister Creek. Note that the scale is logarithmic.