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Appendix A

McAllister Creek Groundwater Survey

Geology and Hydrogeology (Nisqually Reach and tributaries)

The Nisqually watershed study area is composed of glacially derived sediments overlying tertiary sedimentary rock. The area is located close to the southernmost extent of recent glacial advances. The geologic description for the study site is based on Drost et al. (1998) and Pacific Groundwater Group (1998 and 2000). Figure A-1 shows the surficial hydrogeology.

The unconsolidated material in the study area can be divided into six units. The most recent material is alluvial and deltaic sand deposited in the bottom of the Nisqually Valley. Below the alluvial and deltaic material lies the uppermost glacial unit in the area, the Vashon recessional outwash (Qvr), which is made up of sand and gravel. The Qvr covers much of the study area and, where saturated, forms unconfined or perched aquifers. The surficial aquifers also provide baseflow to local streams.

A thick layer of Vashon till underlies the recessional outwash in most areas. This "hardpan" layer consists of poorly sorted sand, gravel, and boulders that are held in a mixture of silt and clay. The till forms a confining layer preventing upward flow from the underlying Vashon advance outwash (Qva) aquifer except in the McAllister Springs corridor.

The Qva aquifer underlying the till consists of gravel in a matrix of sand and is a major water source for the area. Figure A-2 shows the general flow direction in the Qva aquifer in 1988. A silt and clay layer, the Kitsap Formation, underlies the Vashon outwash and forms a second confining layer.

Below the Kitsap Formation is a second aquifer composed of undifferentiated Pre-Vashon deposits including the Salmon Springs Drift (?) and materials older and younger than Salmon Springs Drift (?). The aquifer is also referred to as the sea level (Qc) aquifer system (Pacific Groundwater Group, 2000). The Qc aquifer is composed of coarse sand and gravel and is confined in most places except in the McAllister Springs area. The Qc merges with the Qva and Qvr units in the McAllister Springs area to form a single, connected aquifer system referred to as the McAllister Gravel Aquifer (MG) (Pacific Groundwater Group, 1998 and 2000). Figure A-3 shows the general flow direction in 1988.

The MG is a large, very permeable unit that occupies an abandoned channel of the Nisqually River in the McAllister Springs area, formed by erosion before glaciation (Pacific Groundwater Group, 1998 and 2000). The unit consists of cobbly sand and gravel with silt varying locally. The MG cuts into the encircling uplands and receives discharge from the upland Qvr and Qva aquifers.

The MG merges with the Qc from the west, south, and east to form a sea level aquifer system that provides much of the flow in McAllister Creek via McAllister and Abbott springs as well as many small springs along the edge of the Nisqually Valley. In addition, the sea level aquifer system flows upward to floodplain sediments on the McAllister Creek valley floor.

During the summer months, groundwater from the sea level aquifer is probably the only major source of recharge to the floodplain sediments. This recharge eventually drains into McAllister Creek via ditches and Medicine Creek, a tributary to McAllister Creek. Even in winter, when runoff from precipitation is much higher than in the summer, groundwater is still a major source of flow to the creek (Pacific Groundwater Group, 2000).

Objectives

The objectives for groundwater analysis were to (1) assemble existing data related to groundwater flow and quality in the area and (2) sample wells representative of groundwater entering McAllister Creek via springs, including McAllister Springs, or subsurface flow. This information was needed to help interpret the influence of groundwater on TMDL analyses for McAllister Creek. Constituents investigated included temperature, conductivity, dissolved oxygen, nitrate-+nitrite-N, total persulfate N, ammonia-N, total phosphorus, and orthophosphate.

Methods

Well and Spring Selection

The criteria for selecting wells for groundwater sampling were the following:

- The well or spring is located near the creek of interest and is hydraulically connected to the creek.
- A driller's report (well log) is available for the well.
- The well is capable of producing samples representative of groundwater.
- The well does not have a water treatment device (such as a water softener or iron treatment system) or a large storage tank that cannot be bypassed during well purging and sampling.
- The current well or spring owner grants access to the well.

Drilling logs for the three wells sampled are presented in Table A-1. Locations of the wells and springs sampled are shown in Figure A-4. Latitude and longitude references are listed in Table A-2.

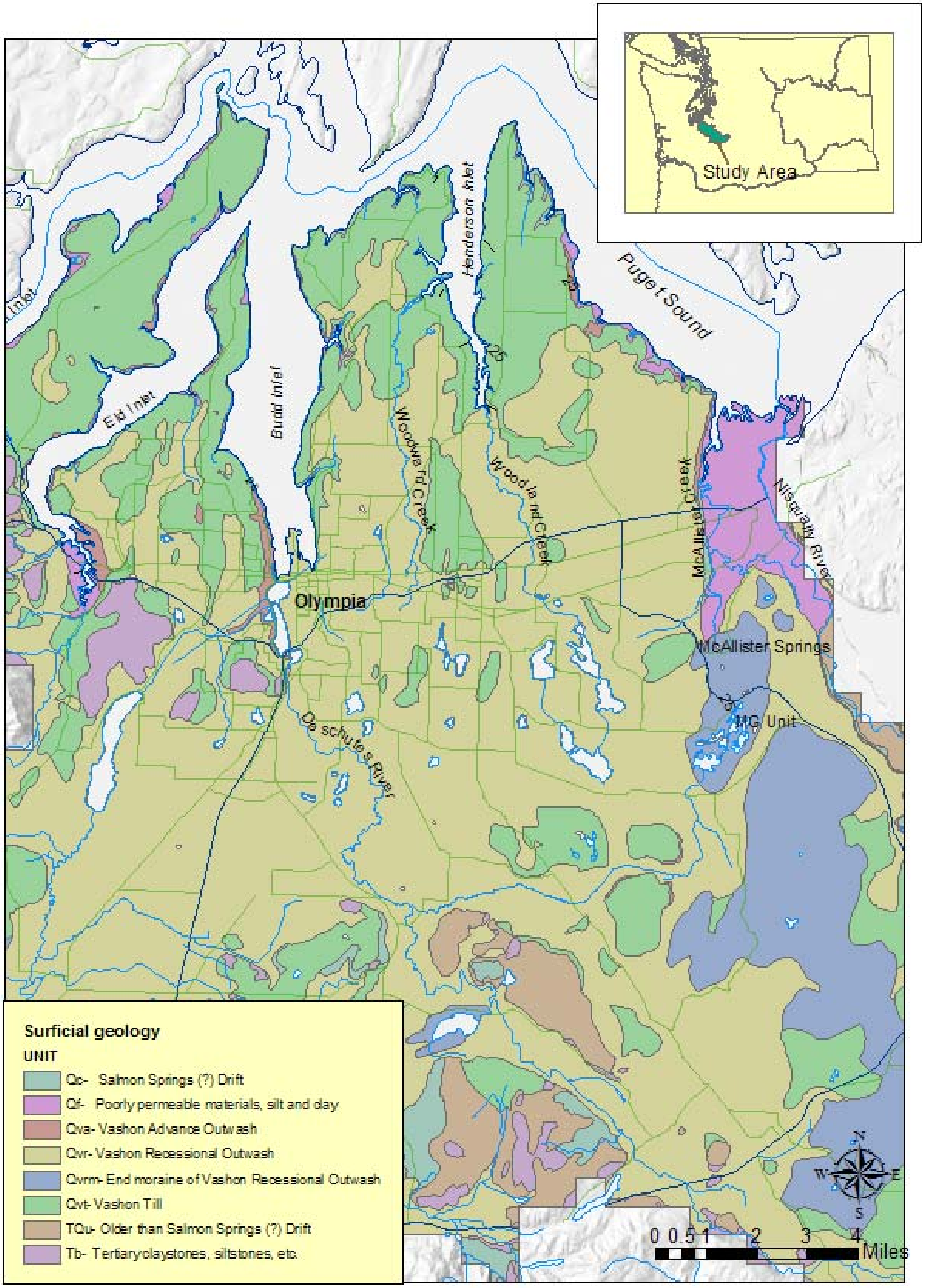

Figure A-1. Surficial geology of the Henderson-Nisqually study area (from Drost et al., 1998).

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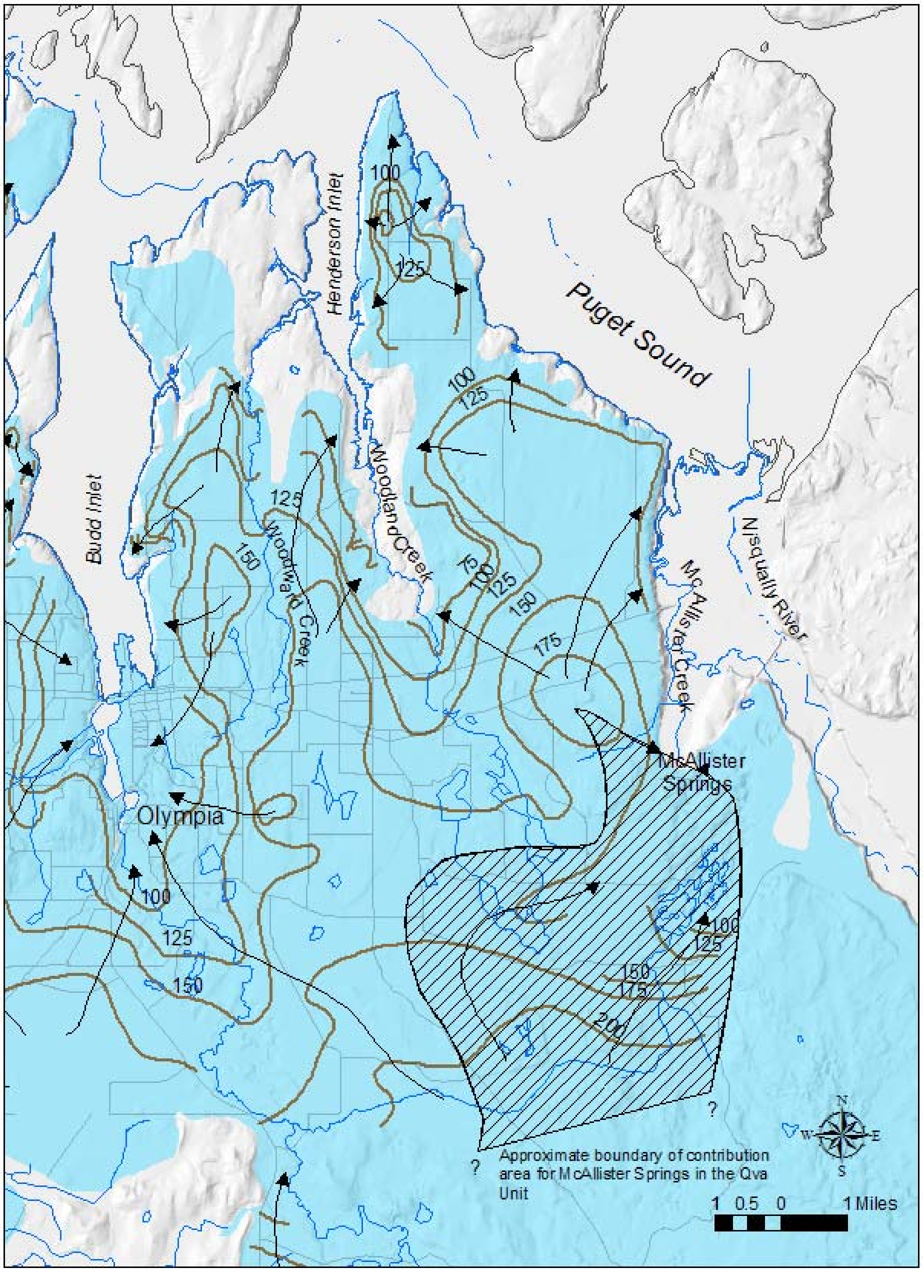

Figure A-2. Water level contours and flow directions in the Qva aquifer in 1988 (from Drost et al., 1998).

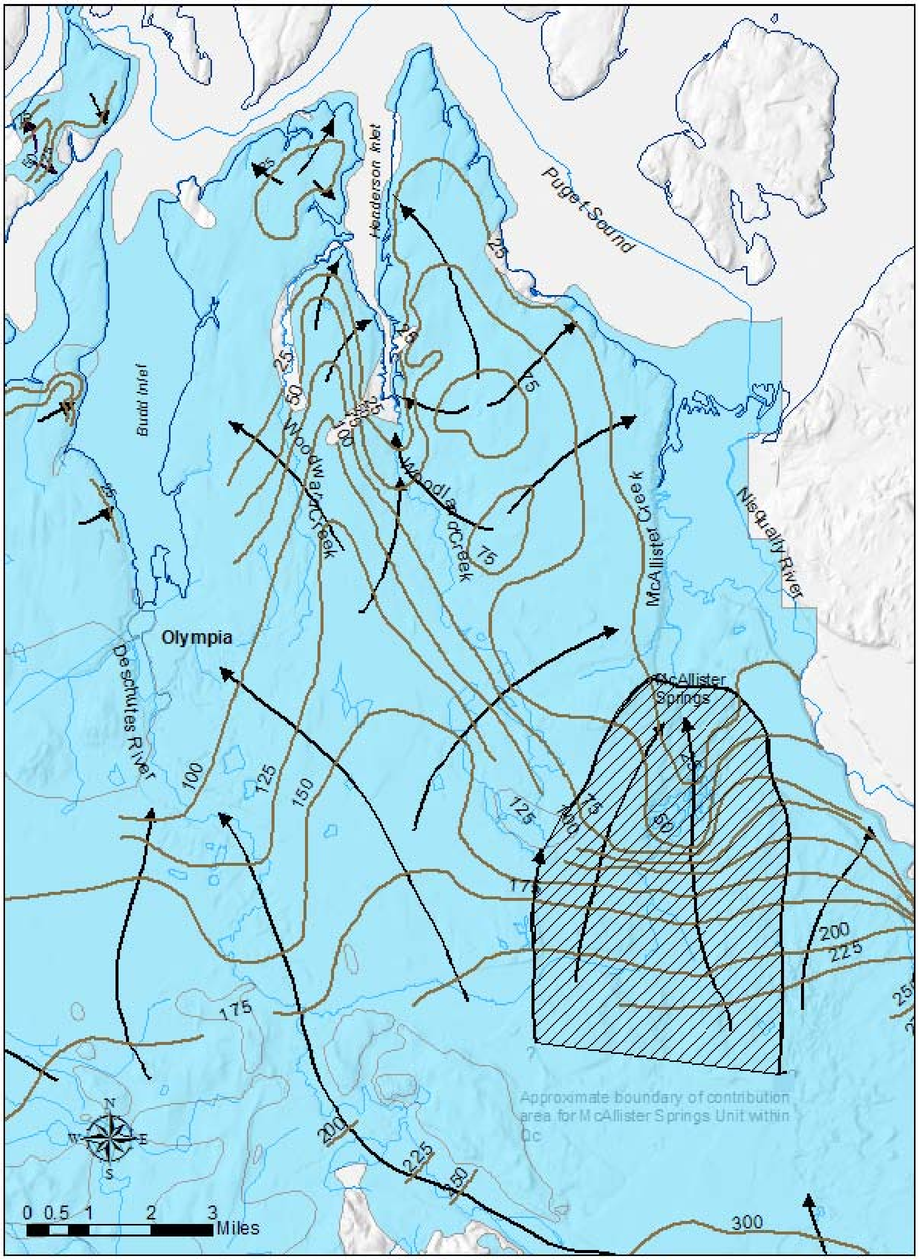

Figure A-3. Water level contours and flow directions in the Qc aquifer in 1988 (from Drost et al., 1998).

Table A-1. Drillers' lithologic logs for wells monitored in the McAllister Springs area.

Well tag number	Township, range, section, ¼-¼ section	Driller's description of materials encountered during well construction	Thickness (feet)	Depth of bottom (feet)	Well driller	Year drilled	Static water level (feet)
AGJ-750	18N/1E-18 NW-NE	Topsoil	1	1	Patterson/ Russell	1988	213
		Gravelly sand	9	10			
		Cemented gravel	10	20			
		Gravelly sand, large rocks	40	60			
		Cemented gravel	20	80			
		Crushed rock, sand	40	120			
		Cemented gravel	40	160			
		Gravelly sand with clay, brown	40	200			
		Cemented gravel, blue	20	220			
		Cemented gravel, brown	40	260			
		Gravelly sand (water)	15	275			
		Gravel	5	280			
AGJ-751	18N/1E-18 NW-NE	Sand, clay, silt	40	40	Pattison	1963	flowing artesian
		Gravel, clay, sand	8	48			
		Gravel, sandy	20	68			
		Coarse sand	2	70			
		Gravel, sand, clay	12	82			
McAllister Springs well	18N/1E-19 SW-SE	Topsoil and clay	1	1	Richardson	1989	60
		Clay	8	9			
		Clay and gravel	6	15			
		Gravel, clay, boulders	1	16			
		Clay and gravel, seepage	15	31			
		Gravel and sand	11	42			
		Clay and gravel	22	64			
		Gravel and sand	31	95			
		Clay and gravel	3	98			
		Sand and gravel, water	4	102			
		Sand, clay, gravel	24	126			
		Sand and gravel, water	11	137			

Table A-2. Latitude and longitude references for McAllister area sampling sites.

Site ID	GPS Latitude (deg, min, sec)	GPS Longitude (deg, min, sec)
AGJ-750	47 03 10 N	122 43 51 W
AGJ-751	47 03 10 N	122 43 32 W
McAllister Springs Well	47 01 38 N	122 43 28 W
McAllister Springs	47 01 41 N	122 43 19 W

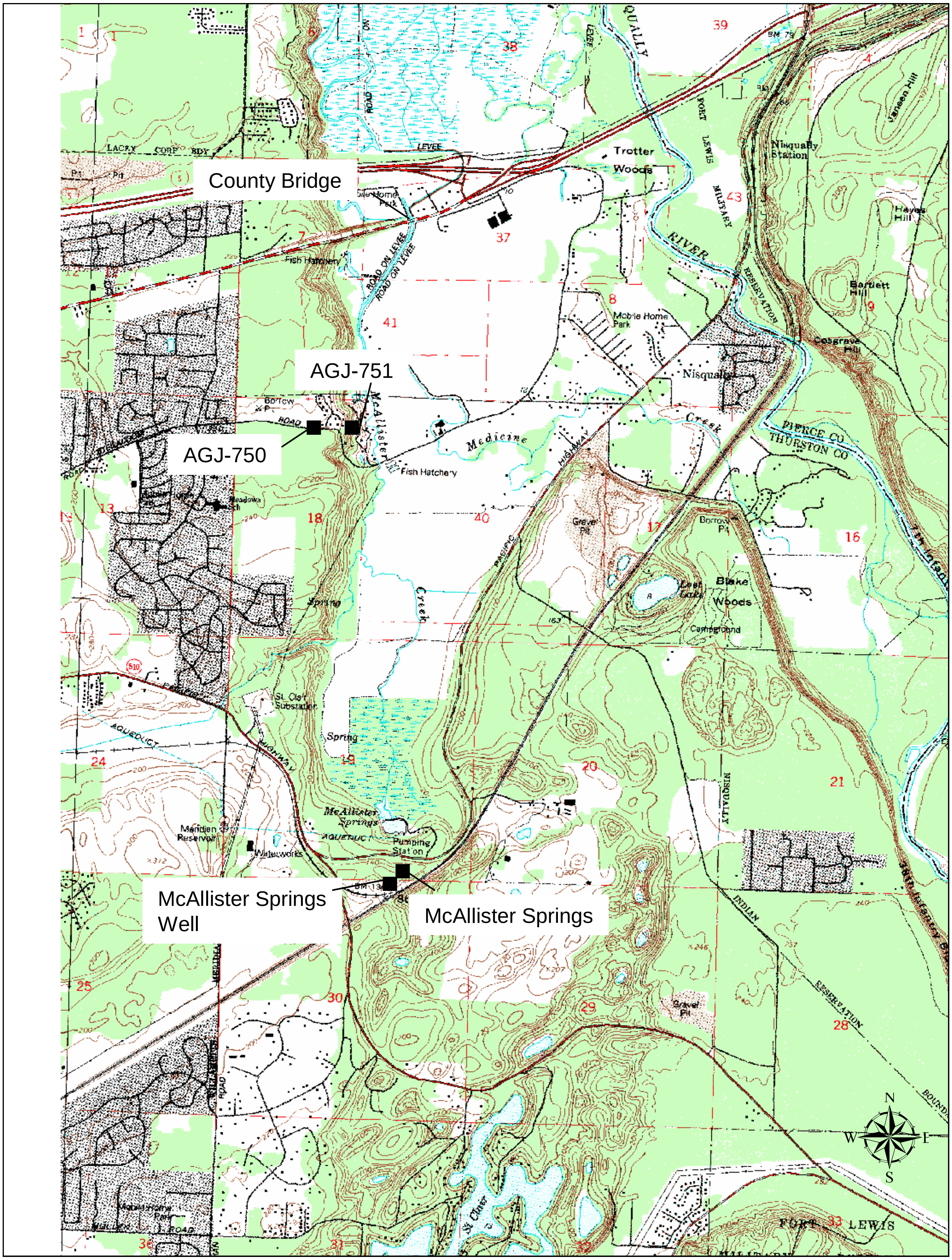

Figure A-4. Sites sampled near McAllister Creek.

Groundwater Sampling

Wells and springs selected for monitoring were field located on USGS 1:24,000 quad maps. A global positioning system (GPS) was used at each site to determine latitude and longitude for analysis and plotting via Arcview GIS software.

Samples were analyzed for specific conductivity, ammonia-N (NH3), nitrate+nitrite-N (NO2/3), total persulfate nitrogen (TPN), total phosphorus (TP) and orthophosphate (ortho-P), chloride (Cl), and total dissolved solids (TDS). Table A-3 lists the analytical methods used.

Wells

One well (AGJ-750) was sampled twice, in October 2002 and in March 2003. The other two wells (AGJ-751 and the McAllister Springs well) were sampled in October 2002. Attempts to measure groundwater levels were unsuccessful.

Wells were purged prior to sampling. A garden hose was attached to the discharge closest to the well head. The existing submersible pump in place in each well was used for purging standing water in the well and storage tank. Purge water from the garden hose was connected to an enclosed flow cell where temperature, pH, conductivity, and dissolved oxygen were measured and recorded every three minutes. Flow cell measurements were considered stable when consecutive measurements were within 5%. Samples were collected after indicator parameters stabilized.

The flow cell was disconnected from the discharge hose for sample collection. Samples were collected directly from the hose into bottles supplied by Manchester Environmental Laboratory (MEL). Sample bottles were placed on ice, maintained at 4ºC, and delivered to MEL for analysis.

Table A-3. Field and laboratory analysis methods used.

Analyte	Standard Methods Test Method [1]
Field	
Temperature	WTW Field Meter
pH	WTW Field Meter
Specific Conductivity	WTW Field Meter
Dissolved Oxygen	WTW Field Meter/4500-O[C]
Laboratory	
Ammonia-Nitrogen	4500-NH3 H
Nitrate+Nitrite-N	4500-NO3 I
Total Persulfate Nitrogen	4500-NO3 B Modified
Orthophosphate	4500-P G
Total Phosphorus	4500-P I
Chloride	EPA 300
Total Dissolved Solids	2540 C

[1] APHA, 1998. Standard Methods for the Examination of Water and Wastewater (20th Edition).

Springs

McAllister Springs was sampled in October 2002 and in March 2003. Field measurements for temperature, pH, conductivity, and dissolved oxygen were taken using a WTW Multimeter. Field probes were lowered into the springs as close to the discharge areas as possible, and measurements were recorded until stable. At McAllister Springs, a peristaltic pump with a silastic tube was used to sample water from the spring at three feet below the surface near the discharge area beneath the City of Olympia waterworks building.

Wells and springs

Dissolved oxygen samples were collected on three occasions for analysis using the Winkler Titration Method (APHA, 1998). Results of the Winkler Method were compared with results obtained with the WTW Multimeter on two occasions (see *Quality Assurance* Section).

Quality Assurance

Laboratory Duplicates

Blind duplicate samples were submitted to the laboratory for one well sampled in October 2002 and for samples from McAllister Springs in March 2003. Differences between the duplicate samples represent the combined variability from sampling and analysis. Results are shown in Table A-4.

Table A-4. Relative percent differences for duplicate samples from McAllister Springs, March 3, 2003.

	Conductivity Lab (uS/cm)	NH3 (mg/L)		NO2/3 (mg/L)	TPN (mg/L)	TP (mg/L)	Ortho-P (mg/L)	Cl (mg/L)	TDS (mg/L)
Sample 1	149	0.010	U	1.21	1.22	0.130	0.101	3.84	106
Sample 2	149	0.010	U	1.20	1.22	0.131	0.102	3.79	112
RPD %	0.0	0.0		0.8	0.0	0.8	1.0	1.3	5.5

U: Below the detection limit shown.

Relative percent differences (RPDs) were low for all constituents, indicating that variability due to sampling and analysis was well within acceptable limits for this study (Sargeant et al., 2003). For constituents of particular interest, the difference between both nitrate+nitrite-N and total phosphorus duplicates was 0.8%. No difference was found in conductivity values for the two sets of samples.

Dissolved Oxygen Methods Comparison

The Winkler Titration Method (APHA, 1998) for dissolved oxygen measurement was used for comparison with the WTW Multimeter on October 29, 2002 at Beatty Spring and on March 3, 2003 at McAllister Springs. In the range of interest, 4-7 mg/L, the RPD for dissolved oxygen was about 7%. The differences were not consistent on the two dates. The October 2002 multimeter result was higher than the Winkler result, and the March 2003 multimeter result was lower than the Winkler. However the differences are within the defined accuracy limit for dissolved oxygen in this study, 15% (Sargeant et al., 2003). The Winkler Method was considered more reliable and, when both measurements were available, the Winkler result was used for data analysis.

De-ionized water from MEL was used as a blank to observe any contamination from reusing the silastic tubing in the peristaltic pump at more than one site during a sampling day. Each of the laboratory parameters were below detection limits, indicating that no measurable contamination occurred due to tubing reuse.

Miscellaneous QA Issues

Orthophosphate, the dissolved fraction of total phosphorus, was 5-10% higher than total phosphorus in October 2002 samples. This is within the MEL 20% acceptance range for RPD for these analyses which were conducted on two different instruments (Momohara, 2005). These differences did not affect the data analysis or conclusions. Orthophosphate results were compared with USGS orthophosphate data in this report (Drost et al., 1998), because total phosphorus was not measured in the USGS study.

Results

Results for the McAllister Creek basin wells and springs obtained during this study are presented in Appendix F. Mean concentrations of selected constituents are shown in Table A-5. The three wells sampled during the study were completed in the Qc sea level aquifer.

Table A-5. Mean values for selected constituents at McAllister Springs and three wells near McAllister Creek.

Location	Temp °C	Lab Cond uS/cm	DO mg/L	DO % saturation	NO2/3 mg/L	TPN mg/L	Ortho-P mg/L	TP mg/L
McAllister Springs	10.9	149	4.5	41	1.18	1.22	0.105	0.120
AGJ-750	10.8	158	5.71	51	1.96	2.53	0.065	0.072
AGJ-751	10.0	158	7.3	64	2.02	2.10	0.061	0.057
McAllister Springs Well	10.7	147	8.8	65	2.12	2.23	0.085	0.081

Dissolved Oxygen

The mean McAllister Springs dissolved oxygen was 4.5 mg/L (n=2) which was lower than that found in the wells. The dissolved oxygen concentration in area wells was 8.7, 7.3, and 6.6 mg/L in October 2002.

Nitrate+nitrite-Nitrogen

The mean nitrate+nitrite-N concentration at McAllister Springs was 1.18 mg/L. The mean nitrate+nitrite-N concentration in the three McAllister Creek area wells was 2.03 mg/L.

Phosphorus

The mean total phosphorus concentration at McAllister Springs was 0.120 mg/L, and the mean orthophosphate value was 0.105 mg/L. The total phosphorus and orthophosphate concentrations were somewhat lower in the wells than in McAllister Springs. Both means were 0.070 mg/L.

Temperature

The temperature at McAllister Springs was 10.9°C during both sampling events. The temperature in the wells varied between 10.0° and 10.9°C with a median of 10.7°C.

Conductivity

The mean specific conductivity value at McAllister Springs was 149 uS/cm. Conductivity in the three wells sampled ranged from 147 to 158 uS/cm.

Discussion

Groundwater Flow in the McAllister Creek Basin

Groundwater flow from two aquifer systems, the uplands system and the sea level system, makes up most of the input to McAllister Creek (Pacific Groundwater Group, 2000). The uplands aquifer system is composed of Qva and Qvr sediments which discharge to Little McAllister Creek and numerous small springs on the western bluffs above the creek. The sea level aquifer system is composed of Qc and McAllister Gravel sediments. Unlike the surrounding areas, confining layers are absent in McAllister Gravels. The McAllister Gravels also collect flow from the upland areas south, southeast, and southwest of McAllister Creek (Pacific Groundwater Group, 1998). The sea level aquifer system discharges to the headwaters of McAllister Creek, to McAllister and Abbott springs, as well as to many small springs that discharge at the edge of the valley and to Medicine Creek.

The sea level aquifer also upwells to the valley floor, eventually reaching the creek through ditches and tributaries. Water from the two wells west of the creek are probably representative of flow into the valley bottom sediments that eventually seeps upward and is collected in McAllister Creek.

McAllister Creek Groundwater Flow Analysis, August 2000 (PGG, 2000)

An intensive analysis of McAllister Creek flow was conducted in August 2000 to document aquifer sources and groundwater flow rates (Pacific Groundwater Group, 2000). Precipitation was about 20% higher than the long-term average during the 2000 water year up until the flow study. Therefore, resulting estimates shown below may also be about 20% higher than the long-term average.

Results of the study indicated that summer low flow is almost exclusively derived from groundwater as observed in this inventory of sources:

- McAllister Springs: 15.5 cfs (29% of flow at the county bridge) – headwaters of the creek
- Abbott Springs: 5-10 cfs (9-19% of county bridge flow) – also headwaters (Drost et al., 1999; model flow estimate)
- Little McAllister Creek: 4.1 cfs (7.7% of county bridge flow)
- Stoker Springs: 5.8 cfs (11% of county bridge flow)
- Three smaller springs: 3 cfs (5.7% of county bridge flow)
- Medicine Creek: 0.5 cfs (Whiley and Walter, 1996)
- Deep groundwater: 15-20 cfs (28-38% of county bridge flow)

Even the relatively small discharge from Little McAllister Creek is derived mainly from groundwater. The sea level aquifer makes up most of the flow to McAllister and Abbott springs as well as many unnamed springs that emerge at the valley floor and flow upward to the floodplain sediments in the valley. The total estimated flow into McAllister Creek between the headwaters and the county bridge from the sea level aquifer in August 2000 was 56 cfs.

Small seasonal variation in groundwater inflow to McAllister Creek (+/- 10-20%) is expected (Pacific Groundwater Group, 2000). Higher precipitation and resulting runoff to the creek occur during the winter months but probably exert little influence on water quality in the creek. Most of the runoff collects in groundwater-fed wetlands, ditches, and tributaries before gradually discharging to the creek.

Comparison of Ecology 2002-2003 Results with USGS Data (1998) Summary for Wells and Springs near McAllister Springs

Drost et al. (1998) summarized water quality for wells in the McAllister Springs area during the fall and early summer of 1988 and 1989. Mean values for 19 wells and two springs in the area are shown in Table A-6.

The distribution of wells and springs among the aquifers was: 17 wells in the sea level (Qc) aquifer, one well in the Vashon advance outwash (Qva), two wells in the recessional outwash (Qvr), and McAllister and Abbott springs. Water from the three aquifers converges in the McAllister Gravels in the area around McAllister Springs (Figure A-1).

Table A-7 shows the overall mean and median concentrations for the constituents of interest in wells and springs in the McAllister Springs area sampled in 1988-89 by Drost et al. (1998). Results from the current study are compared with the 1988-89 data below.

Table A-6. Mean values for McAllister Springs area wells and springs sampled in 1988-89 (Drost et al., 1998).

Well ID	Date	Geo hydrologic unit	Depth of Well ft	Temp C°	Cond (lab) uS/cm	DO mg/L	NO2/3 mg/L	Dissolved phosphorus mg/L
17N/01E-05E01	11/14/1988	Qc	218	11.0	151	7.5	0.37	0.19
	6/7/1989	Qc	218					
17N/01E-05N01	11/15/1988	Qc	305	11.0	138	0.1	0.005	0.13
	6/7/1989	Qc	305					
17N/01E-08L03	11/15/1988	Qc	171	10.8	131	6.3	0.57	0.04
	6/2/1989	Qc	171					
17N/01W-01B04	11/18/1988	Qc	191	11.0	157	6.8	4.7	0.03
	5/19/1989	Qc	191					
17N/01W-01F01	11/14/1988	Qc	160	10.5	146	4.7	2.0	0.05
	5/16/1989	Qc	160					
18N/01E-17Q01	11/16/1988	Qc	260	10.5	134	3.5	0.20	0.13
	6/9/1989	Qc	260					
18N/01E-19J01	11/14/1988	Qc	68	11.5	272	2.9	7.9	0.20
18N/01E-19J01S	11/16/1988	Qvr	--	11.3	186	1.4	0.13	0.35
(Abbott Springs)	6/19/1989	Qvr	--					
18N/01E-19Q01S	11/16/1988	Qvr	--	10.3	147	4.9	1.6	0.10
(McAllister Springs)	6/19/1989	Qvr	--					
18N/01E-20M01	11/15/1988	Qc	130	11.0	168	2.2	0.86	0.14
18N/01E-21N02	11/17/1988	Qc	200	10.8	154	7.3	1.9	0.04
	6/14/1989	Qc	200					
18N/01E-28M01	11/18/1988	Qc	194	10.0	132	9.2	0.85	0.05
	6/30/1989	Qc	194					
18N/01E-30C01	11/19/1988	Qvr	26	11.8	106	8.7	1.8	0.01
	6/24/1989	Qvr	26					
18N/01E-30N02	11/14/1988	Qc	190	10.5	154	7.4	3.1	0.05
	5/8/1989	Qc	190					
18N/01E-31A01	11/16/1988	Qc	92	10.3	134	3.6	0.54	0.08
	5/19/1989	Qc	92					
18N/01E-31F01	11/16/1988	Qc	214	10.5	128	5.1	1.4	0.07
	5/10/1989	Qc	214					
18N/01E-31H03	11/18/1988	Qc	193	10.5	152	0.1	0.005	0.16
	6/21/1989	Qc	193					
18N/01E-31N01	11/17/1988	Qva	139	11.0	121	0.1	0.005	0.16
	6/15/1989	Qva	139					
18N/01E-32C02	11/16/1988	Qc	128	11.5	121	0.7	0.34	0.03
	6/14/1989	Qc	128					
18N/01E-32H02	11/18/1988	Qc	216	10.5	129	6.5	0.84	0.06
	6/21/1989	Qc	216					
18N/01E-36M02	11/14/1988	Qc	160	10.5	163	9.3	4.4	0.02
	5/10/1989	Qc	160					
Mean				10.8	149	4.7	1.59	0.097
Median				10.8	146	4.9	0.85	0.065

Qvr = Vashon recessional outwash aquifer
Qva = Vashon advance aquifer
Qc = Sea level aquifer

Table A-7. Mean, median, and range for selected constituents in 19 wells and two springs in the McAllister Springs area (sampled in 1988-89; Drost et al., 1998).

Constituent	Mean	Median	Minimum	Maximum
Temperature (C°)	10.8	10.8	10.0	11.8
Dissolved oxygen (mg/L)	4.7	4.9	0.1	9.3
Nitrate+nitrite-N (mg/L)	1.59	0.85	<0.010	7.9
Dissolved phosphorus (mg/L)	0.10	0.07	0.10	0.35
Conductivity (uS/cm)	149	146	106	272

Dissolved oxygen

The mean dissolved oxygen (DO) value for McAllister Springs was similar in the two studies: 4.9 mg/L (44% of saturation) in 1988-89 and 4.5 mg/L (41% of saturation) in 2002-03. The median DO for the wells and springs sampled in the 1988-89 study was 4.9 mg/L with a range of 0.10 to 9.3 mg/L. Dissolved oxygen concentrations in local wells did not seem to be related to depth or geohydrologic unit in the McAllister Springs area. This may be explained by the convergence of water from various aquifers and depths at the McAllister Gravels Aquifer and the valley floodplain. Groundwater from the three surrounding aquifers (Qva, Qvr, and Qc) emerges at the McAllister Gravels and the downstream valley floor. This convergence may cause water with different DO concentrations and other water quality characteristics to be found at similar depths. Dissolved oxygen values from wells may also be positively biased in some wells due to the introduction of air by pumps in the well system or leaks that could not be detected.

A summary of water quality for the larger group of wells in north Thurston County sampled as part of the USGS (Drost et al., 1998) study indicated that geohydrologic unit corresponded more with DO than locations near McAllister Springs, as shown in Table A-8. The median DO for the Qvr wells in the larger study was 6.7 mg/L (n=19); for Qva, 5.7 mg/L (n=120); and for Qc, 3.3 mg/L (n=122).

Table A-8. Median concentrations of selected constituents in 261 wells in north Thurston County by geohydrologic unit (Drost et al., 1998). Samples were collected in 1988-89.

Constituent	Qvr	Qva	Qc
Dissolved oxygen (mg/L)	6.7	5.7	3.3
Conductivity (uS/cm)	129	124	144
Nitrate-nitrite-N (mg/L)	1.7	0.78	0.34
Dissolved phosphorus (mg/L)	0.02	0.02	0.05

Qvr =Vashon recessional outwash aquifer
Qva =Vashon advance aquifer
Qc =Sea level aquifer

The DO values from the wells sampled in the current study were somewhat higher than the median from the USGS sample for the Qc unit. The median of three samples was 7.3 mg/L. The lower DO at the springs and possibly in the seepage into the creek downstream of McAllister Springs may be due to the small sample size in this study compared to 19 wells sampled in the USGS study. The difficulty in making accurate DO measurements in private wells could have caused a positive bias.

Temperature

The temperature values obtained at McAllister Springs in this study, 10.9°C on both occasions, were slightly higher than the mean USGS value of 10.3°C for 1988-89. Slightly different sampling locations or equipment calibration are the most likely explanation for the difference.

The median temperature value for both the wells in this study and for the McAllister Springs area wells and springs in the USGS study was 10.8°C.

Nitrate+nitrite-Nitrogen

The mean nitrate+nitrite-N concentration at McAllister Springs in the current 2002-03 TMDL study, 1.18 mg/L, is somewhat lower than the two USGS values in 1988-89 (1.6 mg/L). The difference may be due to slightly different sample locations or depths, sampling or analytical methods, or a real difference. Discharge from McAllister Springs is collected in an artificial lagoon which is about 20 feet deep near the City of Olympia waterworks building. Many locations and depths are possible for sampling. Seasonal differences in nitrate+nitrite-N values were not observed in either the current or former study.

The mean nitrate+nitrite-N concentration found at Abbott Springs by Drost et al. (1998), 0.13 mg/L, was lower than that in McAllister Springs. Coinciding lower dissolved oxygen values of 1.3 to 1.5 mg/L indicate the potential for denitrification along the groundwater flow path. Nitrate+nitrite-N results were below detection in three other wells in the McAllister Springs area with dissolved oxygen concentrations of 0.1 mg/L in 1988-89. Elevated iron concentrations were also observed at the low nitrate wells, which combined with low dissolved oxygen, indicate denitrifying conditions.

The median nitrate+nitrite-N concentration in the 21 wells and springs sampled by USGS near McAllister Springs in 1988-89, 0.85 mg/L, was about half of the values found in the three wells sampled during this 2002-03 study. Two of the wells, Sandra Lee St and Sockeye Lane, are in residential areas where on-site sewage systems and residential fertilizer use could be sources of increased nitrate. However, the Sandra Lee St well is 280 feet deep with a number of fine-grained layers, which would minimize local impacts. The Sockeye Lane well is a flowing artesian well, which precludes significant impacts from local sources. In addition, the McAllister Springs well, located in a forested area not close to any obvious nitrate source, had the same concentration as the two residential area wells.

The USGS nitrate+nitrite-N median for 21 locations near McAllister Springs was close to the median for the Qva unit in the larger north-county group of 0.78 mg/L. This concentration is mid-way between medians found in the Qvr, 1.7 mg/L, and the Qc, 0.34 mg/L, by USGS (Drost et al., 1998), consistent with the interpretation that water quality in and around the McAllister Gravels represents a mixture of waters from different aquifer zones.

Phosphorus

The mean 2002-03 total phosphorus concentration at McAllister Springs was 0.120 mg/L. The orthophosphate mean was slightly lower at 0.105 mg/L. Orthophosphate (referred to as dissolved phosphorus) was sampled in 1988-89 but total phosphorus was not sampled. The mean for McAllister Springs, 0.100 mg/L, was virtually the same as observed in this study.

Orthophosphate in the wells sampled in this study was about the same as that found in the 19 wells sampled near McAllister Creek in 1988-89: 0.070 mg/L in the current study compared to 0.084 mg/L in the earlier study.

The orthophosphate median for the 1988-89 McAllister Springs area wells and springs, 0.07 mg/L, was somewhat higher than the medians for all three geohydrologic units of interest in the larger north-county group which ranged from 0.02 to 0.05 mg/L.

Conductivity

The mean conductivity for McAllister Springs area wells and springs, 146 uS/cm, is closer to the median conductivity found in the Qc unit (144 uS/cm) in the larger Drost et al. (1998) group than to those for the Qvr and Qva units which were 129 and 124 uS/cm respectively. This may indicate that a large portion of the flow to the McAllister Springs area is from the deeper sea level aquifer.

Fecal coliform and fecal streptococci bacteria

Abbott Springs, at the headwaters of McAllister Creek, was the only location in the USGS (Drost et al., 1998) group of 21 wells and springs where fecal coliform and fecal streptococci were found. Fecal coliform counts were 450 and >60 colonies/100 ml in November 1988 and June 1989 respectively, while fecal streptococci counts were 3,100 and >100 colonies/100 ml on the same dates. Bacteria were not sampled for in the current study.

Conclusions

Most of the summer flow in McAllister Creek is derived from groundwater, as determined by a flow study by Pacific Groundwater Group (2000). The following are the main contributors to creek flow in order of their flow contribution:

- McAllister Springs
- Groundwater seepage into the valley bottom
- Abbott Springs
- Stoker Springs
- Little McAllister Creek
- Three smaller springs
- Medicine Creek

Groundwater inflow between McAllister Springs and the county bridge was approximately 56.5 cfs in 2000. Seasonal variation is predicted to be 10-20%.

The mean dissolved oxygen value in McAllister Springs, 4.5 mg/L, was similar to the value that Drost et al. (1998) obtained in 1988-89. The median dissolved oxygen value in 19 wells near McAllister Springs in 1988-89 was likewise 4.9 mg/L, indicating that local groundwater converging in the creek basin has a similar average dissolved oxygen.

The higher median dissolved oxygen in the three wells near McAllister Creek sampled in this 2002-03 study, 7.3 mg/L, may be due to the small number of samples or to introduction of air in well pumps or leaks in the system.

The temperature measured at McAllister Springs in this study was 10.9°C; however, equipment calibration was inadequate. The USGS found a mean of 10.3°C in 1988-89. The mean temperature in the wells was 10.8°C which coincides with the median for the USGS study.

The mean nitrate+nitrite-N concentration in McAllister Springs was 1.18 mg/L, slightly lower than the median found by the USGS in its 1988-89 study (Drost et al., 1999). Nitrate+nitrite-N entering the creek from Abbott Springs is probably negligible based on samples from the USGS in 1988-89.

Nitrate+nitrite-N in three wells averaged 2 mg/L, about two times the concentration found by the USGS in wells and springs near McAllister Springs in 1988-89. The small sample size in this study may account for the difference. Residential nitrate sources near two of the three wells could also be a contributing factor; however, the well distant from potential sources had the same nitrate concentration.

Recommendations

Evaluate existing temperature data collected by the City of Olympia for incoming spring temperature to determine if temperature is changing and, if so, investigate possible causes.

Investigate possible widespread changes in groundwater nitrate concentrations in wells and springs in the McAllister Creek basin.

Implement more detailed comparisons between the WTW Multimeter dissolved oxygen results and the Winkler Method dissolved oxygen results.

Appendix B

Nisqually River Field and Laboratory Results

Table B-1. Nisqually River Field and Laboratory Results at Rm 3.4, Old Pacific Highway bridge.

Date	Time	Cond (umhos/cm)	Fecal Coliform (col/100 mL)		*E-coli* (col/100 mL)		Flow (cfs)	
5/28/2002	15:15		20	15	28	28	911	E
7/31/2002	9:10	70	17J	18J	17J	14J	512	E
9/4/2002	9:45	66	9	15	8	12	374	E
9/18/2002	9:30	70	41J	48J	28J	45J	885	E
10/30/2002	8:23		8J	4J	2J	4J	571	E*
11/12/2002	8:48		7	J	7	J	566	E*
12/2/2002	12:18	50	22		31		519	E*
1/29/2003	10:35	62	4		3		3030	E*
2/18/2003	14:23		5		5		1580	E*
5/6/2003	14:45		2		2		808	E*
5/22/2003	16:00		4		3		633	E*
6/18/2003	14:30		17		15		493	E*
7/23/2003	10:50		32		31		521	E*
8/25/2003	12:40		6				374	E*
9/23/2003	12:40		16		13		381	E*

E: USGS estimate of flow for Nisqually RM 21.8, * indicates USGS provisional data.
J: For bacteria, indicates estimated count; samples analyzed over 24 hours after collection

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Appendix C

Ohop Creek Field and Laboratory Results

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Table C-1. Ohop Creek Field and Laboratory Results.

Date	Time	Temp (°C)	Fecal Coliform (col/100 mL)		*E-coli* (col/100 mL)		Flow (cfs)	
Twenty-five Mile Creek, Ohop Creek tributary at RM 10.2T								
3/25/2002	13:40		1		2			
4/24/2002	14:35		4		3			
5/28/2002	12:55		73		60			
Ohop Creek upstream from Ohop Lake off of Orville Road at RM 9.9								
3/25/2002	13:30		2		1			
5/28/2002	12:35		130		96			
6/24/2002	15:25		200		200			
7/31/2002	11:40		160		160			
9/4/2002	13:10		40		40			
9/18/2002	14:50		14		14			
10/30/2002	11:40		4		6			
11/18/2002	10:50		41		67			
12/18/2002	11:32		11		14			
1/29/2003	11:12		13		14			
2/26/2003	12:45		1		1			
3/26/2003	11:40		1U		2			
4/29/2003	11:38		3		8			
5/21/2003	11:40		7		20			
6/9/2003	11:45		140		130			
Lynch Creek, Ohop Creek tributary at RM 6.2T								
3/25/2002	14:00		5	4	5	5	46.4	e
4/24/2002	14:55		3	1	2	2	13.3	e
5/28/2002	13:10		140		110		10.6	e
6/24/2002	15:45		37		36		8.6	
7/31/2002	11:55		41		41		9.6	
9/4/2002	13:55		160		160		5.6	
9/18/2002	15:15		40		25		4.7	
10/30/2002	12:45		14		17		5.9	
11/18/2002	11:24		31		23		9.1	
12/18/2002	12:25		9		12		37.2	
1/29/2003	11:28		200		200		22.2	
2/26/2003	Time not recorded		88		66		7.8	
3/26/2003	12:10		24		24		33.9	e
4/29/2003	12:36		270J		270J		38.0	
5/21/2003	12:19		6		3		6.6	
6/9/2003	12:22		57		39		8.7	

e: Flow discharge is estimated from a flow discharge curve.
J: For bacteria, indicates estimated count; samples analyzed over 24 hours after collection.
U: Analyte was not detected at or above the reported result.

Table C-1 (cont.).

Date	Time	Temp (°C)	Fecal Coliform (col/100 mL)		*E-coli* (col/100 mL)		Flow (cfs)	
Ohop Creek downstream from Ohop Lake off of Orville Road at RM 6.0								
3/25/2002	13:05		4		3		144.0	E
4/24/2002	14:20		3		1		58.0	E
5/28/2002	12:25		92		100		42.0	E
6/24/2002	15:15		67		63		13.0	E
7/31/2002	11:25		47		44		5.6	E
9/4/2002	12:53		270		260		13.0	E
9/18/2002	14:30		43		33		6.5	E
10/30/2002	11:30		18		15		9.3	E
11/18/2002	10:40		7		6		26.4	E
12/18/2002	11:22		5		8		107.8	E
1/29/2003	11:00		150		190		116.6	E
2/26/2003	12:28		48		51		60.6	E
3/26/2003	11:22		35		27		122.2	E
4/29/2003	11:24		610J		600J		89.9	E
5/21/2003	11:22		6		9		40.3	E
6/9/2003	11:30		140		100		11.0	E
Ditch west of Ohop Creek at Ohop Valley Road at RM3.3DIT								
3/25/2002	12:44		6		14			
4/24/2002	14:03		20		27			
5/28/2002	11:56		35		29			
Ohop Creek at Ohop Valley Road at RM 3.3								
3/25/2002	12:40		5		9			
4/24/2002	14:00		4		9			
5/28/2002	11:55		130		130			
6/24/2002	14:55		82		78			
7/31/2002	11:10		92		92			
9/4/2002	12:30		170		160			
9/18/2002	14:20		100		88			
10/30/2002	11:15		43		52			
11/18/2002	10:30		5		8			
12/18/2002	11:10		11		31			
1/29/2003	10:49		8		11			
2/26/2003	12:16		290J		280J			
3/26/2003	11:11		1400J		1300J			
4/29/2003	11:12		13		13			
5/21/2003	11:12		31		22			
6/9/2003	11:15		49		43			

E: Flow estimate based on USGS flow discharge estimate at Ohop Lake outlet and Lynch Creek flows.
J: For bacteria, indicates estimated count; samples analyzed over 24 hours after collection.

Table C-1 (cont.).

Date	Time	Temp (°C)	Fecal Coliform (col/100 mL)		*E-coli* (col/100 mL)		Flow (cfs)
Ditch at Peterson Road at RM2.2D							
5/28/2002	12:10		220		160		
6/24/2002	14:45		64		63		
7/31/2002	11:00		100		100		
9/4/2002	12:20		610		580		
9/18/2002	14:10		34		31		
10/30/2002	11:08		1		5		
11/18/2002	10:15		1		5		
12/18/2002	11:00		185		220		
1/29/2003	10:40		9		6		
2/26/2003	12:08		13		8		
4/29/2003	11:03		11		4		
5/21/2003	11:00		440		350		
6/9/2003	11:05		140		32		
Ohop Creek at State Highway 7 at RM 2.0							
3/25/2002	12:05		3	8	8	3	
4/24/2002	13:45		7		9		
5/28/2002	11:40		300		290		
6/24/2002	14:35		78		71		
7/31/2002	10:50		85		80		
9/4/2002	12:10		330		300		
9/18/2002	14:00		140		92		
10/30/2002	11:00		47		33		
11/18/2002	10:05		9		18		
12/18/2002	10:54		10		29		
1/29/2003	10:32		18		9		
2/26/2003	12:03		4		5		
3/26/2003	11:02		11		15		
4/29/2003	10:53		180J		190J		
5/21/2003	10:52		45		25		
6/9/2003	10:55		72		43		

J: For bacteria, indicates estimated count; samples analyzed over 24 hours after collection.

Table C-1 (cont.).

Date	Time	Temp (°C)	Fecal Coliform (col/100 mL)		*E-coli* (col/100 mL)		Flow (cfs)	
Ohop Creek at mouth at RM 0.1								
3/25/2002	no access to site - data not collected						100.7	e
4/24/2002	13:10	14.7	14	10	6	20	44.0	e
5/28/2002	11:10	15.0	500J	570	380	380	33.5	e
6/24/2002	12:55	18.4	64	61	56	56	21.1	
7/31/2002	no access to site - data not collected						9.5	e
9/4/2002	11:15		500	450	500	440	14.4	
9/18/2002	13:20	13.3	59	80	55	68	7.3	
10/30/2002	10:23	6.5	17	14	20	27	8.0	
11/18/2002	9:01	7.9	21J	27J	27J	29J	40.2	
12/18/2002	10:12		26	27	33	24	62.6	
1/29/2003	9:44		9J	12	14J	19	82.6	e
2/26/2003	11:15		7	5	5	7	22.1	
3/26/2003	10:23		9	20	16	30	86.4	e
4/29/2003	10:15		55	33	45	39	97.8	
5/21/2003	10:10		56	35	41	46	16.1	
6/9/2003	10:20		43	63	55	48	15.1	

e: Flow discharge is estimated from a flow discharge curve.
J: For bacteria, indicates estimated count; samples analyzed over 24 hours after collection.

Appendix D

Red Salmon Creek Field and Laboratory Results

Table D-1. Red Salmon Creek Field and Laboratory Results.

Date	Time	Temp (°C)	Conductivity (umhos/cm)	Salinity (ppt)	Fecal Coliform (col/100 mL)		*E-coli* (col/100 mL)		Flow (cfs)
Red Salmon Creek upstream of railroad tracks at RM 1.44									
5/6/2003	15:30				10		7		3.47e
5/19/2003	14:35				8		6		3.68e
6/18/2003	15:05				34		22		3.29e
7/23/2003	10:20				94		80		2.64e
8/25/2003	12:15				55				3.32e
9/23/2003	12:10				36		31		2.60
Wash Creek tributary to Red Salmon at RM 1.42T									
5/6/2003	15:00				130		130		1.82
5/19/2003	4:48				67		64		1.73
6/18/2003	14:55				270		230		1.77
7/23/2003	10:05				230	260	200	240	1.70
8/25/2003	12:00				54	74			1.80
9/23/2003	11:55				130	130	106	72	1.71
Red Salmon Creek at Mounts Road SW at RM 1.40									
6/24/2002	13:25	12.1	315	0	68	60	73	55	6.79
7/31/2002	8:15	10.6	174	0	100J	120J	100J	120e	6.29
9/4/2002	10:16	10.8	220	0	46	40	43	31	5.56
9/18/2002	10:35	14.3	850	0	44		36		5.85
10/30/2002	7:47	nd	nd	0	28J		40J		5.44
11/12/2002	8:30	nd	nd	0	110J		120J		5.48
12/2/2002	11:40	9.9	336	0	57	48	49	39	4.47
1/29/2003	9:39	nd	979	0	67J	84J	67J	68J	6.69
2/18/2003	13:18	nd	nd	0	24	24	40	25	5.75
5/6/2003	15:45	nd	nd	nd	49	61	49	63	5.29
5/19/2003	14:20	nd	nd	nd	22	28	18	23	5.41
6/18/2003	15:20	11.6	398	nd	130	110	96	88	5.06
7/23/2003	8:55	11.4	3218	0.2	130J		120J		4.34
8/25/2003	11:00	11.6	230.6	0.1	43				5.12
9/23/2003	10:30	11.2	180	0.1	55J		41J		4.31

e: Flow estimated from flow discharge measurements at Salmon Creek RM 1.40 and Wash Creek (RM 1.42T).
J: For bacteria, indicates estimated count; samples analyzed over 24 hours after collection.
nd: not sampled for.

Table D-1 (cont.)

Date	Time	Temp (°C)	Conductivity (umhos/cm)	Salinity (ppt)	Fecal Coliform (col/100 mL)		*E-coli* (col/100 mL)		Flow (cfs)
Unnamed Tributary to Red Salmon Creek at RM 1.30T									
6/24/2002	14:30	19.2	1000	1	6		5		2.35
7/31/2002	7:54	13.5	1351	nd	160J		5J		1.87
9/4/2002	11:05	13.7	830	0	26		26		2.37
9/18/2002	11:11	14.3	850	0	10	8	9	7	2.02
10/30/2002	7:25	nd	nd	0	79J	78e	77J	69J	2.12
11/12/2002	7:58	nd	nd	0	270J	270e	230J	300J	nd
12/2/2002	11:02	7.0	921	0	2		8		2.19
1/29/2003	10:15	nd	7160	nd	23		21		nd
2/18/2003	13:40	nd	nd	0	11		16		3.94
5/6/2003	15:00	nd	nd	nd	29		29		1.82
5/19/2003	14:20	nd	nd	nd	8		7		1.73
6/18/2003	15:45	16.8	1982	nd	20		14		2.69
7/23/2003	9:00	16.7	175	0.9	86J		86J		3.00
8/25/2003	11:25	15.5	2236	1.4	40		nd		2.28
9/23/2003	10:23	13.5	1314	0.7	19		19		1.74

J: For bacteria, indicates estimated count; samples analyzed over 24 hours after collection.
nd: not sampled for.

Appendix E

McAllister Creek Field and Laboratory Results

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Table E-1: McAllister Creek Field and Laboratory Results - Laboratory Data McAllister Creek Mainstem

Station Name	Date	Fecal Coliform #/100 mL		*E-coli* #/100 mL		Ammonia-Nitrogen mg/L		Nitrite/Nitrate mg/L		Total Persulfate Nitrogen mg/L		Total Phosphorus mg/L		Ortho-Phosphate mg/L		BOD mg/L
McAllister Creek at McAllister Springs																
MC6.3	6/25/2002	2		2												
McAllister Creek downstream of wetlands																
MC5.8	6/25/2002	35		31												
MC5.8	7/30/2002					0.028		0.876		0.957		0.157		0.141		
MC5.8	11/13/2002	21		14												
MC5.8	12/16/2002	93J	69J	81J	57J											
MC5.8	1/21/2003	140	92	130	84											
MC5.8	2/18/2003	45	45	45	43											
MC5.8	3/5/2003	20	19	10	9											
MC5.8	3/19/2003	27	20	27	18											
MC5.8	4/16/2003	17	15	15	12	0.016	0.012	0.799	0.796	0.919	0.875	0.169	0.169	0.130	0.130	
MC5.8	5/13/2003	9	10	9	9	0.022	0.019	0.858	0.888	0.920	0.922	0.178	0.180	0.130	0.128	
MC5.8	7/15/2003	63	84	51	72	0.022	0.018	0.767	0.766	0.857	0.869	0.178	0.183	0.154	0.154	
MC5.8	8/27/2003	60	79	52	70	0.028		0.876		0.966		0.120		0.128		
McAllister Creek upstream of Little McAllister Creek tributary																
MC5.4	6/25/2002	17		16												
MC5.4	7/30/2002					0.049		0.744		0.86		0.181		0.168		
MC5.4	11/13/2002	35	80	25	77											
MC5.4	12/16/2002	130		120												
MC5.4	1/21/2002	54	56	38	52											
MC5.4	2/18/2003	70		62												
MC5.4	3/5/2003	24		23												
MC5.4	3/19/2003	28		27												
MC5.4	4/16/2003	18		16		0.040		0.845		0.981		0.194		0.148		
MC5.4	5/13/2003	29		26		0.050		0.747		0.885		0.217		0.161		
MC5.4	7/15/2003	102		74		0.053		0.655		0.798		0.206		0.177		
MC5.4	8/27/2003	61		55		0.043		0.766		0.937		0.146		0.143		
McAllister Creek just upstream of Steilacoom Road																
MC4.7	6/25/2002	13		11												
MC4.7	7/30/2002					0.036	0.035	0.941	0.907	1.05	1.02	0.172	0.169	0.146	0.150	
MC4.7	11/13/2002	31		23												
MC4.7	12/16/2002	100		68												
MC4.7	1/21/2003	69	72	66	65											
MC4.7	2/18/2003	68	43	67	43											
MC4.7	3/5/2003	31	24	29	14											
MC4.7	3/19/2003	14	35	11	15											
MC4.7	4/16/2003	26	22	21	16	0.036		1.02		1.02		0.186		0.044		
MC4.7	5/13/2003	31	27	25	21	0.042		0.959		0.994		0.201		0.147		
MC4.7	7/15/2003	100	95	88	77	0.042		0.815		0.949		0.191		0.162		
MC4.7	8/27/2003	88		84		0.038		0.913		1.07		0.140		0.135		

J: For bacteria indicates estimated count, samples analyzed over 24 hours after collection

Table E-1: McAllister Creek Field and Laboratory Results - Laboratory Data McAllister Creek Mainstem

Station Name	Date	Fecal Coliform #/100 mL		*E-coli* #/100 mL		Ammonia-Nitrogen mg/L		Nitrite/Nitrate mg/L		Total Persulfate Nitrogen mg/L		Total Phosphorus mg/L		Ortho-Phosphate mg/L		BOD mg/L
McAllister Creek just downstream of residential area and just upstream of Medicine Creek.																
MC4.5	6/25/2002	9		8												
MC4.5	7/30/2002					0.029		0.913		1.01		0.163		0.149		
MC4.5	11/13/2002	63		60												
MC4.5	12/16/2002	140	96	120	64											
MC4.5	1/21/2003	60		51												
MC4.5	2/18/2003	52	39	47	33											
MC4.5	3/5/2003	21J	8J	17	5											
MC4.5	3/19/2003	29	32J	27	27J											
MC4.5	4/16/2003	27	21	23	18	0.039		1.05		1.25		0.188		0.038		
MC4.5	5/13/2003	27	43	26	39	0.039		0.991		1.10		0.200				
MC4.5	7/15/2003	110	100	87	92	0.037		0.818		0.969		0.195		0.163		
MC4.5	8/27/2003	190	120	170	88	0.031	0.032	0.909	0.933	1.05	1.04	0.180	0.165	0.135	0.135	
McAllister Creek at RM 4.35 just downstream of impassable log jam																
MC4.35	6/26/2002	40		31												
MC4.35	2/18/2003	41	37	39	31											
MC4.35	3/5/2003	17	17	15	15											
MC4.35	3/19/2003	35	35	31	31											
MC4.35	4/16/2003	25		20		0.038		1.070		1.210		0.184		0.133		
MC4.35	5/13/2003	45	56	44	39	0.045	0.046	1.110	1.110	1.210	1.190	0.199	0.200	0.141	0.140	
MC4.35	7/15/2003	80	79	69	63	0.034	0.034	0.838	0.843	0.979	0.985	0.190	0.198	0.160	0.160	
MC4.35	8/27/2003	210	275	180	255	0.026		0.947		1.060		0.144		0.129		
McAllister Creek at RM 4.3 just upstream of blue bridge																
MC4.3	6/26/2002	40		31												
MC4.3	11/13/2002	43		40												
MC4.3	12/16/2002	106		90												
MC4.3	1/21/2003	90		84												
MC4.3	2/18/2003	32		32												
MC4.3	3/5/2003	14		13												
MC4.3	3/19/2003	44		32												
MC4.3	4/16/2003	21	29	17	25	0.033		1.09		1.25		0.183		0.129		
MC4.3	5/13/2003	45		42		0.045		1.12		1.23		0.197		0.139		
MC4.3	7/15/2003	84		67		0.036		0.861		1.00		0.197		0.161		
MC4.3	8/27/2003	160		130		0.028		0.965		1.09		0.141		0.129		

J: For bacteria indicates estimated count, samples analyzed over 24 hours after collection.

Table E-1: McAllister Creek Field and Laboratory Results - Laboratory Data McAllister Creek Mainstem

Station Name	Date	Fecal Coliform #/100 mL		*E-coli* #/100 mL		Ammonia-Nitrogen mg/L		Nitrite/Nitrate mg/L		Total Persulfate Nitrogen mg/L		Total Phosphorus mg/L		Ortho-Phosphate mg/L		BOD mg/L
McAllister Creek at RM 3.7 just upstream of the Martin Way bridge																
MC3.7	6/26/2002	32		28												
MC3.7	7/30/2002					0.046	0.046	1.03	0.971	1.16	1.12	0.170	0.190	0.142	0.144	
MC3.7	11/13/2002	31		28												
MC3.7	12/16/2002	150	92	120	84											
MC3.7	1/21/2003	31	67	26	62											
MC3.7	2/18/2003	43	37	42	33											
MC3.7	3/5/2003	17	22	9	19											
MC3.7	3/19/2003	28	28	17	27											
MC3.7	4/16/2003	20	22	19	17	0.053	0.049	1.15	1.15	1.32	1.35	0.186	0.184	0.128	0.128	
MC3.7	5/13/2003	33	41	28	35	0.057	0.056	1.21	1.21	1.34	1.17	0.204	0.203	0.136	0.134	
MC3.7	7/15/2003	49		39		0.057		0.959		1.13		0.210		0.174		
MC3.7	8/27/2003	80		72		0.047		1.00		1.16		0.164		0.147		
McAllister Creek at RM 3.1 just downstream of Interstate-5 bridge																
MC3.1	6/26/2002	65		60												
MC3.1	11/13/2002	29J		26J												
MC3.1	12/16/2002	89		72												
MC3.1	1/21/2003	67		56												
MC3.1	2/18/2003	32		32												
MC3.1	3/5/2003	17		12												
MC3.1	3/19/2003	27		20												
MC3.1	4/16/2003	24		16		0.056		1.12		1.32		0.190		0.127		
MC3.1	5/13/2003	56		48		0.057		1.21		1.33		0.194		0.129		
MC3.1	7/15/2003	120	110	110	94	0.047	0.050	0.984	0.989	1.17	1.18	0.193	0.196	0.160	0.160	
MC3.1	8/27/2003	190	260	43	250	0.045		1.01		1.16		0.145		0.138		
McAllister Creek at RM 2.8 just downstream of straight channel in the Nisqually Refuge next to Treaty Tree																
MC2.8	6/26/2002	56		53												
MC2.8	2/18/2003	36		33												
MC2.8	3/5/2003	1		NAF												
MC2.8	3/19/2003	1U		NAF												
McAllister Creek at RM 2.2 just upstream of tide gate B on Nisqually Wildlife Refuge																
MC2.2	6/26/2002	170		170												
MC2.2	11/13/2002	27J	17J	24J	17J											
MC2.2	12/16/2002	33	33	29	27											
MC2.2	1/21/2003	37	18	29	6											
MC2.2	2/18/2003	29		27												
MC2.2	3/5/2003	27		20												
MC2.2	3/19/2003	26		24												

J: For bacteria indicates estimated count, samples analyzed over 24 hours after collection.

NAF: Not analyzed for.

U: Analyte was not detected at or above the reported result.

Table E-1: McAllister Creek Field and Laboratory Results - Laboratory Data McAllister Creek Mainstem

Station Name	Date	Fecal Coliform #/100 mL		*E-coli* #/100 mL		Ammonia-Nitrogen mg/L		Nitrite/Nitrate mg/L		Total Persulfate Nitrogen mg/L		Total Phosphorus mg/L		Ortho-Phosphate mg/L		BOD mg/L
McAllister Creek at RM 1.5 just downstream of tide gate A on Nisqually Wildlife Refuge																
MC1.5	11/13/2002	12J	6J	10J	6J											
MC1.5	12/16/2002	6		6												
MC1.5	12/16/2002	50														
MC1.5	1/21/2003	23		7												
MC1.5	1/21/2003	25														
MC1.5	2/18/2003	29		25												
MC1.5	3/5/2003	31		9												
MC1.5	3/19/2003	38		36												
MC1.5	8/27/2003	110		100		0.093		0.982		1.19		0.222		0.127		
McAllister Creek at RM 0.1 near the mouth, Department of Health shellfish station number 234																
MC0.1	11/13/2002	7J		6J												
MC0.1	12/16/2002	17J		15J												
MC0.1	1/21/2003	13		6												
MC0.1	2/18/2003	6	10	2	6											
MC0.1	3/5/2003	23	26	8	9											
MC0.1	3/19/2003	15	16J	12	15J											
MC0.1	4/16/2003	47	64	39	48	0.079		0.997		1.18		0.209		0.095		
MC0.1	5/13/2003	68J	48J	64J	48J	0.065	0.068	0.742	0.739	0.946	0.87	0.216	0.197	0.089	0.090	
MC0.1	7/15/2003	120	120	120	110	0.124		0.766		1.33		0.190E		0.135		
Department of Health shellfish station number 224 off of Luhr Beach																
DOH224	6/26/2002	7		5												
DOH224	11/13/2002	4J		3J												
DOH224	12/16/2002	15J	15J	14J	13J											
DOH224	1/21/2003	6	11	5	8											
DOH224	2/18/2003	2		1												
DOH224	3/5/2003	13		2												
DOH224	3/19/2003	6		6												
DOH224	4/16/2003	29		26		0.084		0.851		1.1		0.151		0.080		
DOH224	5/13/2003	13J		10J		0.042		0.280		0.403		0.111		0.059		
DOH224	7/15/2003	89		79		0.097		0.587		1.02		0.170E		0.119		

J: For bacteria indicates estimated count, samples analyzed over 24 hours after collection.

E: Reported result is an estimate because it exceeds the calibration.

Table E-2: McAllister Creek Field and Laboratory Results - Laboratory Data McAllister Tributaries and Tide gates

Station Name	Date	Fecal Coliform #/100 mL		*E-coli* #/100 mL		Ammonia-Nitrogen mg/L		Nitrite/Nitrate mg/L		Total Persulfate Nitrogen mg/L		Total Phosphorus mg/L		Ortho-Phosphate mg/L		BOD mg/L
Tide gate 15 east bank W=sampled at tide gate outfall L=sampled by tide gate inflow																
TG-15W	6/25/2002	57		49												
TG-15L	11/13/2002	6		6												
TG-15W	11/13/2002	3UJ		NAF												
TG-15L	12/16/2002	29J	20J	26J	20J											
TG-15L	1/21/2003	2		1												
TG-15L	2/18/2003	1		1												
TG-15L	3/5/2003	77		74												
TG-15L	3/19/2003	10		10												
TG-15L	4/16/2003	2	3	1	2	0.076	0.079	0.038	0.038	0.427	0.356	0.634	0.629	0.424	0.439	
TG-15L	5/13/2003	41		19		0.020		0.460		0.657		0.312		0.283		
TG-15W	5/13/2003	96		76		0.010U		0.010U		0.175		0.473		0.346		
TG-15L	7/15/2003	33J		18J		0.076		0.012		1.27		1.18		0.452		
TG-15L	8/27/2003	51J		47		0.014		0.021		0.300		0.650E		0.496		5
TG-15L-CD	10/22/2003	640														
TG-15L-CD	12/8/2003	48														
TG-15L-CD	2/23/2004	5														
TG-15L-CD	3/22/2004	5														
Tide gate 14 east bank W=sampled at tide gate outfall L=sampled by tide gate inflow																
TG-14W	6/25/2002	34		34												
TG-14L	11/13/2002	1U		NAF												
TG-14L	12/16/2002	190J		29J												
TG-14L	1/21/2002	3U	4	NAF	3											
TG-14L	2/18/2003	1U	1U	NAF	NAF											
TG-14L	3/5/2003	7		4												
TG-14L	3/19/2003	4		3												
TG-14L	4/16/2003	3		3		0.314		0.025		0.5375		0.636		0.480		
TG-14L	5/13/2003	5		3		0.179		0.117		0.510		0.500		0.324		
TG-14L	7/15/2003	46J		23J		0.107		0.221		3.84		2.27		0.539		
TG-14L	8/27/2003	27J		16J		0.044		0.081		0.67		0.581		0.410		11
TG-14L-CD	10/22/2003	1010														
TG-14L-CD	12/8/2003	45														
TG-14L-CD	2/23/2004	5	5U													
TG-14L-CD	3/22/2004	5U														
Tide gate 13 east bank W=sampled at tide gate outfall L=sampled by tide gate inflow																
TG-13W	6/25/2002	65		65												
TG-13L	11/13/2002	46		46												
TG-13W	11/13/2002	40	J	40	J											
TG-13L	12/16/2002	21	J	20	J											
TG-13L	1/21/2002	9		3												
TG-13L	2/18/2003	6		6												
TG-13L	3/5/2003	1U	3	NAF	2											
TG-13L	3/19/2003	22		15												
TG-13L	4/16/2003	3		2		0.608		0.023		0.705		0.681		0.590		
TG-13L	5/13/2003	64	59	62	57	0.702	0.714	0.010U	0.010U	0.849	0.928	0.843	0.811	0.613	0.602	
TG-13W	5/13/2003	28		27		0.624		0.010U		0.738		0.682		0.512		
TG-13L	6/26/2003	30														
TG-13L	7/15/2003	240	240J	220	210J	0.608	0.598	0.010U	0.010U	0.905	0.880	0.699	0.697	0.522	0.516	
TG-13L	8/27/2003	240	135	230	110	0.753		0.010U		0.936		0.610		0.526		2
TG-13L-CD	10/22/2003	300														
TG-13L-CD	12/8/2003	5														
TG-13L-CD	2/23/2004	5														
TG-13L-CD	3/22/2004	5														
Tide gate 12 east bank W=sampled at tide gate outfall L=sampled by tide gate inflow																
TG-12W	6/25/2002	49		47												
TG-12L	11/13/2002	6		6												
TG-12L	12/16/2002	100J		100J												
TG-12L	2/18/2003	28		28												
TG-12L	3/5/2003	4		4												
TG-12L	3/19/2003	18		18												
TG-12L	4/16/2003	18		16		0.044		1.02		1.12		0.190		0.130		
TG-12L	5/13/2003	28		27		0.017		0.324		0.649		0.141		0.087		
TG-12L	7/15/2003	42		34		0.032		0.381		0.622		0.194		0.151		
TG-12L	8/27/2003	240		80		0.016		0.367		0.486		0.120		0.114		2U
TG-12L-CD	10/22/2003	165														
TG-12L-CD	12/8/2003	30														
TG-12L-CD	2/23/2004	60														
TG-12L-CD	3/22/2004	45														
TG-12L-CD	3/22/2004	30														
Little McAllister Creek upstream site																
LMC0.2	12/16/2002	10														
LMC0.2	1/21/2002	40														
LMC0.2	3/5/2003	50														
LMC0.2	3/19/2003	15														
LMC0.2	4/16/2003	15														
LMC0.2	5/13/2003	15														
LMC0.2	6/26/2003	90														
LMC0.2	7/15/2003	1850														
LMC0.2	8/27/2003	110														

J: For bacteria indicates estimated count, samples analyzed over 24 hours after collection.

NAF: Not analyzed for.

U: Analyte was not detected at or above the reported result.

Table E-2: McAllister Creek Field and Laboratory Results - Laboratory Data McAllister Tributaries and Tide gates

Station Name	Date	Fecal Coliform #/100 mL		*E-coli* #/100 mL		Ammonia-Nitrogen mg/L		Nitrite/Nitrate mg/L		Total Persulfate Nitrogen mg/L		Total Phosphorus mg/L		Ortho-Phosphate mg/L		BOD mg/L
Tide gate 11 and Little McAllister Creek (combined discharge from tide gate) W=sampled at tide gate outfall L=sampled by tide gate inflow																
TG-11W	6/25/2002	96		84												
TG-11W	11/13/2002	29J		28J												
TG-11L	2/18/2003	45		45												
TG-11L	3/5/2003	21		19												
TG-11L	3/19/2003	26		23												
TG-11W	4/16/2003	68		57		0.016		2.675		2.92		0.068		0.033		
TG-11W	5/13/2003	40		36		0.022		2.88		2.83		0.088		0.038		
TG-11L	7/15/2003	57		49		0.027		1.90		2.19		0.075		0.046		
TG-11L	8/27/2003	120		110		0.043		2.28		2.11		0.053		0.041		2U
Culvert at tide gate 11 drains wetland creek area on west bank																
TG-11C	11/13/2002	20J														
TG-11C	3/5/2003	1		1												
TG-11C	3/19/2003	7J	11J	5J	11J											
TG-11C	4/16/2003	170		170		0.016		4.21		4.37		0.091		0.040		
TG-11C	5/13/2003	17		9		0.017		4.28		4.75		0.097		0.051		
TG-11C	7/15/2003	190		170		0.012		5.29		5.78		0.154		0.049		
TG-11C	8/27/2003	51		46		0.011		5.85		6.73		0.044		0.032		
Tide gate 10 east bank W=sampled at tide gate outfall L=sampled by tide gate inflow																
TG-10W	6/25/2002	18		18												
TG-10L	11/13/2002	3J		3J												
TG-10W	11/13/2002	6		3												
TG-10L	12/16/2002	150J		120J												
TG-10L	1/21/2003	31		23												
TG-10L	2/18/2003	72		69												
TG-10L	3/5/2003	1U		NAF												
TG-10L	3/19/2003	10		6												
TG-10L	4/16/2003	28		26		0.034		0.546		1.08		0.219		0.093		
TG-10W	4/16/2003	24		22		0.034		0.604		1.06		0.199		0.096		
TG-10W	5/13/2003	2		2		0.055		0.062		0.363		0.233		0.100		
TG-10L	5/13/2003	19		18		0.032		0.650		0.868		0.200		0.117		
TG-10L	7/15/2003	5		5		0.016		0.501		0.730		0.182		0.140		
TG-10W	7/15/2003	6		5		0.020		0.410		0.575		0.169		0.135		
TG-10L	8/27/2003	21		20		0.020		0.321		0.475		0.152		0.118		4U
TG-10L-CD	10/22/2003	590														
TG-10L-CD	12/8/2003	35														
TG-10L-CD	2/23/2004	50														
TG-10L-CD	3/22/2004	5	15													
Tide gate 9 east bank W=sampled at tide gate outfall L=sampled by tide gate inflow																
TG-9W	6/25/2002	20		20												
TG-9L	11/13/2002	29J		29J												
TG-9L	12/16/2002	400	440J	280	320J											
TG-9L	1/21/2003	63		57												
TG-9W	1/21/2003	40		37												
TG-9L	2/18/2003	109		102												
TG-9W	2/18/2003	120		110												
TG-9L	3/5/2003	17		14												
TG-9W	3/5/2003	5		4												
TG-9L	3/19/2003	42		41												
TG-9W	3/19/2003	24		19												
TG-9L	4/16/2003	49		49		0.024		0.035		1.12		0.433		0.108		
TG-9W	4/16/2003	32		27		0.018		0.037		1.01		0.370		0.078		
TG-9W	5/13/2003	1700J		1700J		0.012		0.010U		0.473		0.235		0.038		
TG-9L	5/13/2003	7		7		0.029		0.180		0.673		0.296		0.074		
TG-9L	7/15/2003	45		45		0.021		0.010U		0.308		0.210		0.094		
TG-9W	7/15/2003	36		32		0.028		0.010U		0.308		0.201		0.061		
TG-9L	8/27/2003	270		260		0.060		0.010U		0.313		0.188		0.028		4U
TG-9W	8/27/2003	270		270		0.062		0.010U		0.397		0.198		0.031		
TG-9L	10/22/2003	1640														
TG-9L	12/8/2003	25														
TG-9L	2/23/2004	60														
TG-9L	2/23/2004	65														
TG-9L	3/22/2004	305														
Tide gate 8 east bank W=sampled at tide gate outfall L=sampled by tide gate inflow																
TG-8L	12/16/2002	760		680												
TG-8L	1/21/2003	9		9												
TG-8L	2/18/2003	12		12												
TG-8L	3/5/2003	5		5												
TG-8L	3/19/2003	64		64												
TG-8W	4/16/2003	180		170		0.030		0.205		0.674		0.288		0.133		
TG-8W	5/13/2003	2800J		2800J		0.059		0.681		1.01		1.46		0.086		

J: For bacteria indicates estimated count, samples analyzed over 24 hours after collection.

NAF: Not analyzed for.

U: Analyte was not detected at or above the reported result.

Table E-2: McAllister Creek Field and Laboratory Results - Laboratory Data McAllister Tributaries and Tide gates

Station Name	Date	Fecal Coliform #/100 mL		*E-coli* #/100 mL	Ammonia-Nitrogen mg/L	Nitrite/Nitrate mg/L	Total Persulfate Nitrogen mg/L	Total Phosphorus mg/L	Ortho-Phosphate mg/L	BOD mg/L
Upstream larger pipe on west bank (area with 2 pipes together) mid-residential area.										
MC4.6TULB	12/16/2002	74		61						
MC4.6TULB	1/21/2003	440		360						
MC4.6TULB	2/18/2003	4		4						
MC4.6TULB	3/5/2003	38		36						
MC4.6TULB	3/19/2003	60		60						
MC4.6TULB	4/16/2003	18		18	0.142	1.00	1.27	0.126	0.021	
MC4.6TULB	5/13/2003	7		5						
MC4.6TULB	7/15/2003	25		24	0.210	0.637	0.994	0.154	0.018	
MC4.6TULB	8/27/2003	5		5	0.025	2.19	2.19	0.020	0.005	
Downstream smaller pipe on west bank (area with 2 pipes together) mid-residential area.										
MC4.6TDLB	12/16/2002	6		6						
Black pipe west bank under blackberries, mid-residential area. (sampled when flow present)										
MC4.5TLB	12/16/2002	1		1						
MC4.5TLB	1/21/2003	6		6						
MC4.5TLB	2/18/2003	1U		NAF						
MC4.5TLB	3/19/2003	7		6						
McAllister Tributary west bank from upstream pond in residential area										
MC4.5T	6/25/2002	24		16						
Upstream west bank tributary at RM 4.4, opposite Medicine Creek										
MC4.4TLBU	3/5/2003	1		1						
MC4.4TLBU	3/19/2003	16		15						
MC4.4TLBU	4/16/2003	1		1	0.038	1.37	1.52	0.120	0.044	
MC4.4TLBU	5/13/2003	5		4	0.038	1.42	1.54	0.130	0.038	
MC4.4TLBU	7/15/2003	280J		280J	0.040	1.74	1.96	0.088	0.036	
MC4.4TLBU	8/27/2003	3U		NAF	0.057	1.47	1.55	0.723	0.026	
Downstream west bank tributary at RM 4.4, opposite Medicine Creek										
MC4.4TLBD	3/19/2003	41		36						
MC4.4TLBD	4/16/2003	4		1	0.010	2.85	3.00	0.063	0.024	
MC4.4TLBD	5/13/2003	21		11	0.016	2.85	2.72	0.065	0.028	
MC4.4TLBD	7/15/2003	10		10	0.011	2.27	2.50	0.071	0.037	
MC4.4TLBD	8/27/2003	7		6	0.010U	1.82	1.91	0.688	0.051	
Medicine Creek at RM 0.3 upstream from tide gates 6 and 7										
MED0.3	12/16/2002	3	10	3						
MED0.3	1/21/2003	3	5U	2						
MED0.3	2/18/2003	2		1U						
MED0.3	3/5/2003	1		1						
MED0.3	3/19/2003	10		8						
MED0.3	4/16/2003	16		13	0.057	0.130	0.225	0.133	0.015	
MED0.3	5/13/2003	25		24	0.011	0.024	0.22	0.162	0.016	
MED0.3	7/15/2003	10		8	0.012	0.010U	0.331	0.101	0.016	
MED0.3	8/27/2003	6		6	0.054	0.010U	0.311	NAF	0.018	
Medicine Creek at RM 0.0 (mouth) below tide gates										
MED0.0	6/25/2002	47		41						
MED0.0	2/18/2003	15		13						
MED0.0	3/5/2003	53		51						
MED0.0	3/19/2003	36		32						
MED0.0	4/16/2003	31		27	0.020	0.861	1.19	0.143	0.024	
MED0.0	5/13/2003	75		72	0.051	0.660	0.963	0.189	0.035	
MED0.0	7/15/2003	110		110	0.043	0.614	0.945	0.123	0.057	
MED0.0	8/27/2003	410		400	0.060	0.630	0.938	0.132	0.054	
West bank Tributary at RM 4.34 from pond										
MC4.34P	6/26/2002	250		200						
MC4.34P	2/18/2003	1U		NAF						
MC4.34P	3/5/2003	1U		NAF						
MC4.34P	3/19/2003	2		2						
MC4.34P	4/16/2003	3		3	0.010U	2.46	2.21	0.140	0.130	
MC4.34P	5/13/2003	6		3	0.014	2.60	2.56	0.117	0.072	
MC4.34P	7/15/2003	56		47	0.014	2.53	2.75	0.100	0.078	
MC4.34P	8/27/2003	21		19	0.011	2.59	2.34	0.066	0.067	
West bank tributary at RM 4.3, flowing of sheet metal just upstream of from blue bridge.										
MC4.3T	6/26/2002	130		130						
MC4.3T	2/18/2003	260		260						
MC4.3T	3/19/2003	25		22						
MC4.3T	5/13/2003	8		7	0.286	2.99	3.57	0.147	0.090	
MC4.3T	7/15/2003	79J		79J	0.362	2.53	3.11	0.207	NAF	
MC4.3T	8/27/2003	33		31	0.262	2.84	2.97	0.155	0.124	

J: For bacteria indicates estimated count, samples analyzed over 24 hours after collection.

NAF: Not analyzed for.

U: Analyte was not detected at or above the reported result.

Table E-2: McAllister Creek Field and Laboratory Results - Laboratory Data McAllister Tributaries and Tide gates

Station Name	Date	Fecal Coliform #/100 mL		*E-coli* #/100 mL		Ammonia-Nitrogen mg/L		Nitrite/Nitrate mg/L		Total Persulfate Nitrogen mg/L		Total Phosphorus mg/L		Ortho-Phosphate mg/L		BOD mg/L
Tide gate 5 east bank W=sampled at tide gate outfall L=sampled by tide gate inflow																
TG-5W	6/26/2002	160		140												
TG-5L	11/13/2002	200J		200J												
TG-5L	12/16/2002	310J		290J												
TG-5L	1/21/2003	210		190												
TG-5L	2/18/2003	12		11												
TG-5L	3/5/2003	6		5												
TG-5L	3/19/2003	6		4												
TG-5L	4/16/2003	16		15		0.432		0.272		1.22		0.3		0.015		
TG-5L	5/13/2003	27J		27		0.662		0.010U		1.01		0.296		0.056		
TG-5L	6/26/2003	70														
TG-5L	7/15/2003	760J		600		0.129		0.603		1.22		0.182		0.051		
TG-5L	8/27/2003	1300		1300		0.091		0.396		0.703		0.326		0.072		
TG-5L	10/22/2003	50														
TG-5L	12/8/2003	5														
TG-5L	2/23/2004	5U														
TG-5L	3/22/2004	5U														
Tide gate 4 east bank W=sampled at tide gate outfall L=sampled by tide gate inflow																
TG-4W	6/26/2002	270		230												
TG-4L	11/13/2002	20J	31J	9J	31J											
TG-4L	12/16/2002	710J		690J												
TG-4L	1/21/2003	8		8												
TG-4L	2/18/2003	48		36												
TG-4L	3/5/2003	2		1												
TG-4L	3/19/2003	1U		NAF												
TG-4L	4/16/2003	14		14		0.214		0.188		0.825		0.256		0.023		
TG-4L	5/13/2003	25		25		0.314		0.071		0.881		0.366		0.015		
TG-4L	6/26/2003	160														
TG-4L	7/15/2003	480		370		0.084		0.565		1.06		0.163		0.057		
TG-4L	8/27/2003	1000		970		0.184		0.168		0.712		0.248		0.014		4U
TG-4L	10/22/2003	405														
TG-4L	12/8/2003	20														
TG-4L	2/23/2004	15														
TG-4L	3/22/2004	5														
TG-4L	4/19/2004	5U														
TG-4L	5/19/2004	40														
Tide gate 3 east bank W=sampled at tide gate outfall L=sampled by tide gate inflow																
TG-3L	12/16/2002	310J		290J												
TG-3L	1/21/2003	20		20												
TG-3L	2/18/2003	10		8												
TG-3L	3/5/2003	9		8												
TG-3L	3/19/2003	9		7												
TG-3L	4/16/2003	7		5		0.030		0.466		1.08		0.210		0.086		
TG-3L	5/13/2003	14		13		0.019		0.225		0.541		0.270		0.174		
TG-3L	6/26/2003	135														
TG-3L	7/15/2003	130		77		0.055		0.257		0.657		0.216J		0.195		
TG-3W	7/15/2003	34		18		0.062		0.166		0.493		0.203J		NAF		
TG-3L	8/27/2003	48		47		0.020		0.168		0.356		0.201		0.144		2U
TG-3L	10/22/2003	135														
TG-3L	12/8/2003	5U														
TG-3L	2/23/2004	5														
TG-3L	3/22/2004	15														
TG-3L	4/19/2004	10														
TG-3L	5/19/2004	20														
TG-3L	6/17/2004	30														
Stormwater discharge upstream of Martin Way west bank																
SW2L	12/16/2003	60														
SW2W	1/21/2003	280		260												
SW2L	1/21/2003	30														
SW2L	3/5/2003	235														
SW2L	3/19/2003	120														
Tide gate 2 west bank, under Martin Way, sampled by tide gate inflow																
TG-2L	11/13/2002	120J		72J												
TG-2L	12/16/2002	66		63												
TG-2L	1/21/2003	5		4												
TG-2L	2/18/2003	5		5												
TG-2L	3/5/2003	5		3												
TG-2L	3/19/2003	13		12												
TG-2L	4/16/2003	12		11		0.047		0.842		0.766		0.193		0.094		
TG-2L	5/13/2003	13		11		0.017		0.345		0.451		0.166		0.067		
TG-2L	7/15/2003	10	11	9	8	0.027	0.026	0.258	0.265	0.469	0.459	0.143	0.138	0.071	0.072	
TG-2L	8/27/2003	16		15		0.036		0.331		0.418		0.151		0.071		2

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Table E-2: McAllister Creek Field and Laboratory Results - Laboratory Data McAllister Tributaries and Tide gates

Station Name	Date	Fecal Coliform #/100 mL		*E-coli* #/100 mL		Ammonia-Nitrogen mg/L		Nitrite/Nitrate mg/L		Total Persulfate Nitrogen mg/L		Total Phosphorus mg/L		Ortho-Phosphate mg/L		BOD mg/L
Tide gate 1 west bank at commercial development along I-5 sampled tide gate inflow																
TG-1W	6/26/2002	130		96												
TG-1L	11/13/2002	3600J		3400J												
TG-1L	12/16/2002	250		230												
TG-1L	1/21/2003	92		92												
TG-1L	2/18/2003	11		8												
TG-1L	3/5/2003	4		4												
TG-1L	3/19/2003	18		18												
TG-1L	4/16/2003	68		17		0.835		0.148		2.29		0.994		0.052		
TG-1L	5/13/2003	3000J		3000J		0.198		0.039		1.87		0.368		0.047		
TG-1L	2/23/2004	10														
Stormwater discharge under I-5 west bank																
SW1W	11/13/2002	100J		64J												
SW1W	12/16/2002	88														
SW1L	12/16/2002	60														
SW1W	1/21/2003	34	31	29	29											
SW1L	1/21/2003	38														
SW1L-TC	2/18/2003	10														
SW1L-TC	3/5/2003	5U														
SW1W	3/19/2003	37J		31J												
SW1L-TC	3/19/2003	1360														
SW1L	4/16/2003	5U														
SW1W	8/27/2003	20		18		0.022		0.156		0.349		0.209		0.147		
Tide gate B east bank South tide gate Nisqually Wildlife Refuge, sampled tide gate inflow																
TG-BW	6/26/2002	450		420												
TG-BL	12/16/2002	29J	34J	26J	31J											
TG-BL	1/21/2003	8	6	5	6											
TG-BL	2/18/2003	4		1												
TG-BL	3/5/2003	2		1												
TG-BW	3/5/2003	3		1												
TG-BL	3/19/2003	2		1												
TG-BW	3/19/2003	1U		NAF												
TG-BL	4/16/2003	11	9	10	8	0.016	0.019	0.010U	0.010U	1.14	1.155	0.22	0.209	0.024	0.027	
TG-BL	5/13/2003	18	14	14	11	0.010U	0.018	0.010U	0.347	1.47	0.431	0.183	0.165	0.015	0.068	
TG-BL	8/27/2003	31	26	11	20	0.015J	0.019E	naf		0.834	0.761	1.62	1.55	0.928	0.923	8
Tide gate A east bank North tide gate Nisqually Wildlife Refuge, sampled tide gate inflow																
TG-AW	6/26/2002	560		560												
TG-AL	11/13/2002															
TG-AL	12/16/2002	6		6												
TG-AL	1/21/2003	10	11	9	9											
TG-AL	2/18/2003	4	3	1	1											
TG-AL	3/5/2003	5	8	3	4											
TG-AL	3/19/2003	5	3	4	3											
TG-AL	4/16/2003	6		6		0.018		0.010U		1.21		0.332		0.035		
TG-AL	5/13/2003	29		15		0.010U		0.010U		1.52		0.358		0.023		
TG-AL	6/26/2003	48														
TG-AL	7/15/2003	84		80		0.138		0.010U		3.51		1.22		0.104		
TG-AL	8/27/2003	14		9		0.010U		naf		0.389		0.66		0.190		6

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U: Analyte was not detected at or above the reported result.

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Table E-3: McAllister Creek Field and Laboratory Results - Field Results McAllister Creek Mainstem

Station Name	Date	Time	Depth meters	Temperature °C	Conductivity (µmhos) field	Conductivity (µmhos) lab	pH SU	Dissolved Oxygen Field mg/L	Dissolved Oxygen Winkler mg/L	Dissolved Oxygen saturation %	Flow Discharge cfs
McAllister Creek at RM 5.8 at downstream end of wetlands											
MC5.8	11/13/2002	10:16	0.0	9.8	120		6.9	6.4		55.2	
MC5.8	11/13/2002	10:22	1.0	9.8	121		6.8	5.8		50.3	
MC5.8	11/13/2002	10:23	1.8	9.8	121		6.7	5.3		45.3	
MC5.8	12/16/2002	9:50	0.0	9.1	176		7.0	*	6.2	53.8	
MC5.8	12/16/2002	9:55	1.0	9.1	173		7.0	*		*	
MC5.8	12/16/2002	10:55	1.5	9.1	173		6.9	*		*	
MC5.8	1/21/2003	14:37	0.0	8.9	141		7.1	6.7	6.9	56.1	
MC5.8	1/21/2003	14:40	1.0	8.9	140		6.9	6.4		54.3	
MC5.8	1/21/2003	14:43	1.8	8.9	141		6.9	6.7		57.1	
MC5.8	2/18/2003	13:35	0.0	9.2	106		8.2	8.1	8.4	70.1	
MC5.8	2/18/2003	13:38	1.0	9.2	107		7.8	7.6		66.1	
MC5.8	2/18/2003	13:40	2.0	9.2	107		7.7	7.4		64.6	
MC5.8	3/5/2003	13:25	0.0	9.7	131		7.2	7.3		64.2	
MC5.8	3/5/2003	13:28	1.0	9.7	131		7.2	7.1		62.3	
MC5.8	3/19/2003	12:40	0.0	9.4	93		7.1	6.7		58.5	
MC5.8	3/19/2003	12:43	1.0	9.4	93		7.0	6.6		57.3	
MC5.8	4/16/2003	13:30	0.0	10.9	*		7.2	7.6	7.7	68.9	
MC5.8	4/16/2003	13:33	1.0	10.9	*		7.1	7.7		69.7	
MC5.8	5/13/2003	13:20	0.0	12.4	121		7.3	8.1	8.3	76.2	
MC5.8	5/13/2003	13:23	1.0	12.4	121		7.2	7.9		74.4	
MC5.8	7/15/2003	13:40	0.0	13.4	142		7.0	7.8	8.0	73.7	
MC5.8	7/15/2003	13:43	1.0	13.4	142		6.9	7.7		72.6	
MC5.8	8/27/2003	16:30	0.0	13.3	*		7.0	7.9	8.0	74.7	
McAllister Creek at RM 5.4 upstream of Little McAllister Creek tributary											
MC5.4	11/13/2002	10:45	0.0	9.8	146		6.9	5.9	5.8	51.6	
MC5.4	11/13/2002	10:50	1.0	9.8	147		6.9	6.1		52.8	
MC5.4	11/13/2002	10:52	2.0	9.8	146		6.9	6.3		57.0	
MC5.4	12/16/2002	10:30	0.0	9.0	282		7.2	*		*	
MC5.4	12/16/2002	10:32	1.0	9.0	282		7.1	*		*	
MC5.4	12/16/2002	10:33	1.2	9.0	279		7.0	*		*	
MC5.4	1/21/2003	15:02	0.0	8.8	194		7.1	8.9	9.1	76.1	
MC5.4	1/21/2003	15:05	1.0	8.8	194		7.0	6.7		56.8	
MC5.4	1/21/2003	15:08	2.0	8.8	191		6.9	6.5		55.9	
MC5.4	1/21/2003	15:10	2.5	8.8	190		6.9	6.4		54.8	
MC5.4	2/18/2003	14:04	0.0	9.0	119	175	7.7	10.3		86.6	
MC5.4	2/18/2003	14:07	1.0	9.0	120		7.5	8.4		71.4	
MC5.4	3/5/2003	13:55	0.0	9.6	145		7.3	7.6	7.3	66.5	
MC5.4	3/5/2003	13:58	1.0	9.6	145		7.3	7.3		63.4	
MC5.4	3/19/2003	13:15	0.0	9.3	105		7.1	7.4	7.2	58.4	
MC5.4	3/19/2003	13:18	1.0	9.3	105		7.1	6.5		56.5	
MC5.4	4/16/2003	14:00	0.0	11.3	*		7.1	7.8		70.6	
MC5.4	4/16/2003	14:03	1.0	11.3	*		7.0	7.6		69.1	
MC5.4	5/13/2003	14:00	0.0	12.7	134		7.3	8.2		77.7	
MC5.4	5/13/2003	14:03	0.5	12.7	134		7.2	8.3		79.0	
MC5.4	7/15/2003	14:25	0.0	14.7	153		7.1	8.4		81.3	
MC5.4	7/15/2003	14:28	0.7	14.7	153		7.1	8.2		79.4	
MC5.4	8/27/2003	16:00	0.0	14.4	*		7.2	9.6		93.0	
McAllister Creek at RM 4.7 just upstream of Steilacoom Road											
MC4.7	11/13/2002	11:18	0.0	9.8	204		7.0	8.8		74.8	
MC4.7	11/13/2002	11:20	1.0	9.8	202		6.9	6.1		53.7	
MC4.7	11/13/2002	11:21	1.5	9.7	203		6.9	5.7		50.2	
MC4.7	12/16/2002	10:52	0.0	9.0	333		7.2	*		*	
MC4.7	12/16/2002	10:53	1.0	9.0	330		7.1	*		*	
MC4.7	12/16/2002	10:54	1.5	9.0	34		7.1	*		*	
MC4.7	1/21/2003	15:30	0.0	8.7	262		7.0	7.1		61.3	
MC4.7	1/21/2003	15:35	1.0	8.7	260		6.9	6.8		57.4	
MC4.7	2/18/2003	14:30	0.0	9.0	133		7.4	9.5		80.4	
MC4.7	2/18/2003	14:33	1.0	9.0	133		7.3	8.3		71.2	
MC4.7	3/5/2003	14:50	0.0	9.5	160		7.2	7.8	7.7	68.9	
MC4.7	3/5/2003	14:53	1.0	9.5	160		7.2	7.6		66.8	
MC4.7	3/19/2003	13:00	0.0	9.3	112		7.0	7.0		61.3	
MC4.7	3/19/2003	13:03		9.3	113		7.0	6.4		59.2	
MC4.7	4/16/2003	14:50	0.0	11.6	*		7.1	8.2	8.1	75.1	
MC4.7	4/16/2003	14:53	1.0	11.5	*		7.1	7.5		68.7	
MC4.7	5/13/2003	14:30	0.0	12.9	138		7.1	8.6	8.6	82.0	
MC4.7	7/15/2003	15:20	0.0	15.1	164		7.1	8.4	8.7	82.3	
MC4.7	7/15/2003	15:23	1.0	15.0	164		7.1	7.4		74.9	
MC4.7	8/27/2003	15:10	0.0	14.3	*		7.2	8.9	9.0	86.5	

Table E-3: McAllister Creek Field and Laboratory Results - Field Results McAllister Creek Mainstem

Station Name	Date	Time	Depth meters	Temperature °C	Conductivity (µmhos) field	lab	pH SU	Dissolved Oxygen Field mg/L	Winkler mg/L	saturation %	Flow Discharge cfs
McAllister Creek at RM 4.6 Shallow area about mid-residential area.											
MC4.6	5/19/2003	17:15									75.34
MC4.6	6/16/2003	16:10									61.41
MC4.6	6/27/2004	13:35									41.62
MC4.6	7/11/2003	12:00									56.15
MC4.6	7/15/2003	16:45									54.43
MC4.6	7/15/2003	17:00									53.46
MC4.6	7/25/2003	13:25									44.68
MC4.6	7/25/2003	13:40									42.63
MC4.6	12/31/2003	8:15									44.57
MC4.6	12/31/2003	8:35									53.69
MC4.6	3/19/2004	13:15									99.87
MC4.6	3/19/2004	13:35									96.62
MC4.6	3/19/2004	13:50									92.68
McAllister Creek at RM 4.5 just downstream of residential area and just upstream of Medicene Creek.											
MC4.5	11/13/2002	11:30	0.0	9.7	238		7.1	9.8		79.3	
MC4.5	11/13/2002	11:32	1.0	9.7	241		7.0	7.4		64.5	
MC4.5	12/16/2002	11:05	0.0	8.9	387		7.2	*		*	
MC4.5	12/16/2002	11:08	1.0	9.0	374		7.1	*		*	
MC4.5	12/16/2002	11:11	1.5	8.9	381		7.1	*		*	
MC4.5	1/21/2003	15:45	0.0	8.7	288		7.0	7.0		57.7	
MC4.5	1/21/2003	15:48	1.0	8.7	280		7.0	7.6		64.4	
MC4.5	2/18/2003	14:40	0.0	9.0	137	198	7.6	10.6	11.0	94.7	
MC4.5	2/18/2003	14:41	1.0	9.0	138		7.5	9.4		79.7	
MC4.5	3/5/2003	14:50	0.0	9.5	159		7.3	7.2		71.3	
MC4.5	3/5/2003	14:53	0.3	9.5	159		7.2	7.1		70.2	
MC4.5	3/19/2003	14:10	0.0	9.3	115		7.0	7.1	7.4	61.8	
MC4.5	3/19/2003	14:13	0.5	9.3	115		7.0	7.1		61.8	
MC4.5	4/16/2003	15:05	0.0	11.6	*		7.1	8.4	8.6	77.0	
MC4.5	4/16/2003	15:08	1.0	11.6	*		7.1	8.2		75.8	
MC4.5	5/13/2003	14:45	0.0	13.0	141		7.2	8.8		84.8	
MC4.5	7/15/2003	15:35	0.0	15.3	165		7.2	8.8		86.5	
MC4.5	8/27/2003	14:40	0.0	14.4	*		7.1	9.4		91.1	
McAllister Creek at RM 4.35 just downstream of impassable log jam											
MC4.35	2/18/2003	15:15	0.0	9.1	123		7.1	6.2		54.3	
MC4.35	3/5/2003	16:26	0.0	9.6	144		7.2	7.7	8.0	67.1	
MC4.35	3/19/2003	16:14	0.0	9.5	158		7.2	7.2	7.5	63.6	
MC4.35	4/16/2003	15:25	0.0	11.7	*		7.0	*		*	
MC4.35	5/13/2003	11:30	0.0	11.7	108		7.2	9.4	9.3	86.4	
MC4.35	7/15/2003	16:05	0.0	15.3	170		7.4	8.9	8.9	88.1	
MC4.35	8/27/2003	16:25	0.0	14.6	*		7.3	9.4	9.6	92.0	
McAllister Creek at RM 4.3 just upstream of blue bridge											
MC4.3	11/13/2002	10:30	0.0	9.7	233		7.2	*	5.9	51.9	
MC4.3	11/13/2002	10:32	1.0	9.7	233		7.2	*		*	
MC4.3	11/13/2002	10:33	2.0	9.7	233		7.2	*		*	
MC4.3	12/16/2002	11:37	0.0	9.0	403		7.3	6.5	7.0	56.4	
MC4.3	12/16/2002	11:39	1.0	9.0	402		7.3	6.4		54.5	
MC4.3	12/16/2002	11:46	2.0	9.0	400		7.1	6.3		53.9	
MC4.3	1/21/2003	16:00	0.0	8.7	307		7.0	6.5	6.8	53.1	
MC4.3	1/21/2003	16:03	1.0	8.7	302		7.0	6.4		54.6	
MC4.3	2/18/2003	15:10	0.0	9.1	128	207	7.1	6.2		54.1	
MC4.3	2/18/2003	15:13	1.0	9.1	128		7.1	6.1		7.1	
MC4.3	3/5/2003	16:18	0.0	9.6	149		7.3	7.9		70.4	
MC4.3	3/19/2003	16:15	0.0	9.5	162		7.2	7.3		64.7	
MC4.3	4/16/2003	15:05	0.0	11.7	*		7.0	*		*	
MC4.3	5/13/2003	11:55	0.0	12.0	112		7.0	8.7		81.0	
MC4.3	5/13/2003	11:58	1.0	12.0	112		7.0	8.4		70.6	
MC4.3	7/15/2003	15:30	0.0	15.3	175		7.3	9.3	9.6	91.8	
MC4.3	7/15/2003	15:33	1.0	15.3	176		7.3	8.9		87.6	
MC4.3	8/27/2003	16:15	0.0	14.6	*		7.3	*	9.0	88.5	
MC4.3	8/27/2003	16:18	1.0	14.6	*		7.3	*	9.0	88.5	

* Field parameter did not meet data quality control objectives.

Table E-3: McAllister Creek Field and Laboratory Results - Field Results McAllister Creek Mainstem

Station Name	Date	Time	Depth meters	Temperature °C	Conductivity (µmhos) field	Conductivity (µmhos) lab	pH SU	Dissolved Oxygen Field mg/L	Dissolved Oxygen Winkler mg/L	Dissolved Oxygen saturation %	Flow Discharge cfs
McAllister Creek at RM 3.7 just upstream of the Martin Way bridge											
MC3.7	11/13/2002	10:10	0.0	9.7	389		7.2	*		*	
MC3.7	11/13/2002	10:12	1.0	9.7	387		7.2	*		*	
MC3.7	11/13/2002	10:15	2.0	9.8	391		7.2	*		*	
MC3.7	12/16/2002	11:10	0.0	9.0	1002		7.5	6.9	6.9	60.6	
MC3.7	12/16/2002	11:12	1.0	9.0	1020		7.4	6.7		58.1	
MC3.7	12/16/2002	11:14	2.0	9.0	1039		7.3	6.6		57.3	
MC3.7	12/16/2002	11:16	2.5	9.0	1550		7.3	7.5		56.6	
MC3.7	1/21/2003	15:40	0.0	8.5	1039		7.1	7.0	7.3	59.5	
MC3.7	1/21/2003	15:43	1.0	8.5	2314		7.0	6.9		59.2	
MC3.7	2/18/2003	15:00	0.0	9.0	3372		7.1	6.2	6.5	53.8	
MC3.7	3/5/2003	16:05	0.0	9.5	207		7.4	7.7	8.0	67.8	
MC3.7	3/19/2003	16:07	0.0	9.5	246		7.3	7.4		65.2	
MC3.7	4/16/2003	14:55	0.0	11.8	*		7.0	*	8.3	76.7	
MC3.7	5/13/2003	12:15	0.0	12.3	142		7.2	8.5	8.4	80.2	
MC3.7	5/13/2003	12:19	1.0	12.3	143		7.2	8.1		76.1	
MC3.7	7/15/2003	14:40	0.0	15.9	300		7.5	8.5		85.5	
MC3.7	7/15/2003	14:43	1.0	15.9	380		7.4	8.4		83.1	
MC3.7	8/27/2003	15:35	0.0	15.1	*		7.4	8.9	8.5	84.1	
McAllister Creek at RM 3.1 just downstream of Interstate-5 bridge											
MC3.1	11/13/2002	9:45	0.0	9.8	398		7.3	*	5.8	51.1	
MC3.1	12/16/2002	11:00	0.0	9.0	2135		7.5	7.1		61.6	
MC3.1	1/21/2003	15:00	0.0	8.3	3090		7.2	7.9		67.1	
MC3.1	2/18/2003	15:40	0.0	9.0	561		7.1	6.1	6.3	53.1	
MC3.1	3/5/2003	16:50	0.0	9.5	352		7.3	8.1		71.4	
MC3.1	3/19/2003	16:00	0.0	9.5	438		7.4	7.6	7.9	67.1	
MC3.1	4/16/2003	14:45	0.0	11.8	*		7.1	*		*	
MC3.1	5/13/2003	12:30	0.0	12.6	190		7.2	8.5		80.4	
MC3.1	7/15/2003	14:30	0.0	16.2	538		7.6	10.4		97.4	
MC3.1	8/27/2003	15:25	0.0	15.3	*		7.7	8.9		88.5	
McAllister Creek in straight channel downstream of Interstate-5 bridge											
MC3.0	7/25/2003	12:00									55.36
MC3.0	7/25/2003	12:15									54.18
McAllister Creek at RM 2.8 just downstream of straight channel in the Nisqually Refuge next to Treaty Tree											
MC2.8	3/5/2003	14:45	0.0	10.6	1800		7.6	5.1		48.0	
McAllister Creek at RM 2.2 just upstream of tide gate B on Nisqually Wildlife Refuge											
MC2.2	11/13/2002	9:25	0.0	9.8	6397		7.3	*		*	
MC2.2	11/13/2002	9:27	1.0	9.9	8513		7.3	*		*	
MC2.2	11/13/2002	9:29	2.0	9.9	10632		7.3	*		*	
MC2.2	12/16/2003	10:45	0.0	9.2	13820		7.5	7.4		67.8	
MC2.2	12/16/2003	10:47	1.0	9.2	13748		7.4	7.2		65.2	
MC2.2	12/16/2003	10:49	2.0	9.2	22169		7.5	7.1		66.9	
MC2.2	1/21/2003	14:20	0.0	8.4	13464		7.3	7.4	7.7	65.7	
MC2.2	1/21/2003	14:25	1.0	8.4	13402		7.3	7.3		65.2	
MC2.2	2/18/2003	13:55	0.0	8.8	1945		7.3	7.5		64.8	
MC2.2	2/18/2003	13:58	1.0	8.8	1934		7.2	7.1		61.6	
MC2.2	3/5/2003	14:15	0.0	9.4	1547		7.4	8.6		75.3	
MC2.2	3/19/2003	14:06	0.0	9.6	1229		7.4	8.2		72.4	
McAllister Creek at RM 1.5 just downstream of tide gate A on Nisqually Wildlife Refuge											
MC1.5	11/13/2002	8:57	0.0	10.0	29686		7.6	*	6.6	58.5	
MC1.5	11/13/2002	8:59	1.0	10.9	36658		7.6	*		*	
MC1.5	11/13/2002	9:01	2.0	11.0	36848		7.6	*		*	
MC1.5	12/16/2002	10:26	0.0	9.2	22249		7.5	7.7	7.6	72.0	
MC1.5	12/16/2002	10:28	1.0	9.1	22350		7.5	7.6		71.2	
MC1.5	12/16/2002	10:30	2.0	9.8	32901		7.7	6.5		65.7	
MC1.5	12/16/2002	10:31	3.0	9.9	33351		7.7	6.4		64.5	
MC1.5	1/21/2003	14:10	0.0	8.5	26849		7.5	7.7		73.7	
MC1.5	1/21/2003	14:13	1.0	8.5	27232		7.5	7.5		71.2	
MC1.5	2/18/2003	13:45	0.0	8.8	5268		7.3	7.4		65.7	
MC1.5	2/18/2003	13:50	1.0	8.8	5333		7.2	7.2		63.4	
MC1.5	3/5/2003	14:00	0.0	9.2	2754		7.5	8.2		72.3	
MC1.5	3/19/2003	13:50	0.0	9.6	2254		7.6	8.4		74.8	
MC1.5	8/27/2003	13:30	0.0	18.8	*		7.6	8.4		91.3	

* Field parameter did not meet data quality control objectives.

Table E-3: McAllister Creek Field and Laboratory Results - Field Results McAllister Creek Mainstem

Station Name	Date	Time	Depth meters	Temperature °C	Conductivity (µmhos) field	Conductivity (µmhos) lab	pH SU	Dissolved Oxygen Field mg/L	Dissolved Oxygen Winkler mg/L	Dissolved Oxygen saturation %	Flow Discharge cfs
McAllister Creek at RM 0.1 near the mouth, Department of Health shellfish station number 234											
MC0.1	11/13/2002	8:40	0.0	10.2	36239		7.7	*		*	
MC0.1	11/13/2002	8:43	1.0	10.7	38562		7.8	*		*	
MC0.1	11/13/2002	8:46	2.0	10.8	38499		7.7	*		*	
MC0.1	12/16/2002	9:48	0.0	9.2	26312		7.7	8.4		80.6	17
MC0.1	12/16/2002	9:49	1.0	9.7	31541		7.7	7.4		73.1	
MC0.1	12/16/2002	9:50	2.0	10.0	34686		7.8	6.8		68.6	
MC0.1	12/16/2002	9:51	3.0	10.0	34678		7.8	6.8		69.0	
MC0.1	1/21/2003	14:03	0.0	8.6	32251		7.6	8.0		77.0	
MC0.1	1/21/2003	14:06	1.0	8.7	34123		7.7	7.4		72.7	
MC0.1	2/18/2003	13:30	0.0	8.8	22931		7.5	7.3		69.4	20
MC0.1	2/18/2003	13:33	1.0	8.7	25852		7.6	7.3		69.4	
MC0.1	3/5/2003	13:45	0.0	8.9	21836		7.5	8.8		84.0	9
MC0.1	3/19/2003	13:30	0.0	9.3	15682		7.4	8.4		78.5	
MC0.1	4/16/2003	13:35	0.0	12.7	*		7.5	*		*	4
MC0.1	5/13/2003	10:00	0.0	13.4	9750		7.6	8.6		86.2	7
MC0.1	7/15/2003	14:00	0.0	20.4	9724		7.6	8.0		92.4	4
Department of Health shellfish station number 224 off of Luhr Beach											
DOH224	11/13/2002	8:25	0.0	10.58	37825		7.7	*	5.5	49.4	
DOH224	12/16/2002	9:30	0.0	9.52	30890		7.6	8.0	7.3	85.1	25
DOH224	1/21/2003	13:49	0.0	8.6	34355		7.7	8.9	8.3	76.9	
DOH224	2/18/2003	13:20	0.0	8.7	25801	39400	7.6	7.3	7.0	69.3	28
DOH224	3/5/2003	13:35	0.0	8.82	29912		7.7	9.1	9.3	85.6	19
DOH224	3/19/2003	13:15	0.0	8.88	25700		7.6	8.9	8.9	85.1	
DOH224	4/16/2003	13:05	0.0	12.63	*		7.6	*	9.2	86.5	9
DOH224	5/13/2003	9:40	0.0	12.76	19837		8.0	9.7	9.5	99.4	21
DOH224	7/15/2003	13:15	0.0	21.54	21268		7.9	10.5	10.7	121.2	10

* Field parameter did not meet data quality control objectives.

Table E-4: McAllister Creek Field and Laboratory Results - Field Results McAllister Tributaries and Tidegates

Station Name	Date	Time	Temperature °C	Conductivity (µmhos) field	Conductivity (µmhos) lab	pH SU	Dissolved Oxygen Field mg/L	Dissolved Oxygen Winkler mg/L	Dissolved Oxygen saturation %	Flow Discharge cfs
Tide gate 15 east bank W=sampled at tide gate outfall L=sampled by tide gate inflow										
TG15L	11/13/2002	10:35	9.6	185		*	3.3		28.0	
TG15W	11/13/2002	10:05	9.2	186		6.9	4.4		35.7	
TG15L	12/16/2002	11:55	8.1	*		7.3	5.2		48.1	
TG15L	1/21/2003	16:02	7.6	1277		*	4.2		33.9	
TG15L	2/18/2003	14:52	10.5	160		7.6	6.3		53.5	
TG15L	3/5/2003	15:20	9.9	175		7.6	9.0		80.5	
TG15L	3/19/2003	14:17	10.7	285		7.2	4.6		40.0	
TG15L	4/16/2003	14:10	12.2	*		7.1	6.3		57.8	
TG15L	5/13/2003	12:00	13.3	564		6.6	3.1		28.0	
TG15W	5/13/2003	13:40	18.0	161		7.1	8.4		89.5	
TG15L	7/15/2003	15:16	14.9	*		6.9	*		*	
TG15L	8/27/2003	14:48	16.3	*		6.9	4.1	6.0	41.2	
TG15L	10/22/2003	13:00	ND							4.16
TG15L	12/8/2003	13:20	ND							0.28
TG15L	2/23/2004	14:00	12.2				7.4			
Tide gate 14 east bank W=sampled at tide gate outfall L=sampled by tide gate inflow										
TG14L	11/13/2002	10:30	9.3	270		*	2.2		18.2	
TG14L	12/16/2002	11:39	9.1	*		7.4	5.6		50.3	
TG14L	1/21/2003	16:07	7.6	532		*	6.2		51.3	
TG14L	2/18/2003	14:57	9.3	249		7.2	3.2		25.4	
TG14L	3/5/2003	13:30	9.6	247		7.1	5.8		53.2	
TG14L	3/19/2003	14:23	9.9	297		6.9	2.1		21.0	
TG14L	4/16/2003	14:19	14.6	*		7.2	3.6		35.8	
TG14L	5/13/2003	11:50	10.2	298		6.7	3.1		27.6	
TG14L	7/15/2003	15:28	15.8	*		6.7	*		*	
TG14L	8/27/2003	14:36	13.9	*		6.7	4.5	6.2	46.8	
TG14L	12/8/2003	13:30	ND					5.3		
TG14L	2/23/2004	14:10	13.5					2.4		
Tide gate 13 east bank W=sampled at tide gate outfall L=sampled by tide gate inflow										
TG13L	11/13/2002	10:20	12.3	254		*	2.3		21.1	
TG13W	11/13/2002	9:50	11.9	288		7.2	3.8		40.5	
TG13L	12/16/2002	11:48	11.3	*		7.5	2.7		31.6	
TG13L	1/21/2003	16:17	11.9	212		*	2.6		24.4	
TG13L	2/18/2003	15:03	11.6	196		7.4	2.7		25.9	
TG13L	3/5/2003	15:33	12.3	240		7.5	2.3		21.4	
TG13L	3/19/2003	14:30	12.1	280		7.1	2.6		24.9	
TG13L	4/16/2003	14:28	13.5	*		7.2	1.2		10.5	
TG13L	5/13/2003	11:39	14.6	351		6.7	0.4		4.0	
TG13W	5/13/2003	13:45	15.4	266		7.1	2.3	3.1	23.0	
TG13L	7/15/2003	15:39	16.0	*		7.1	*		*	
TG13L	8/27/2003	14:17	17.0	*		7.2	1.3	1.9	12.6	
TG13L	10/22/2003	12:29	ND					1.1		
TG13L	12/8/2003	13:37	ND							7.93
TG13L	2/23/2004	13:27	12.5					2.4	22.1	

ND: not sampled for

* Field parameter did not meet quality control objectives.

Table E-4: McAllister Creek Field and Laboratory Results - Field Results McAllister Tributaries and Tidegates

Station Name	Date	Time	Temperature °C	Conductivity (µmhos) field	Conductivity (µmhos) lab	pH SU	Dissolved Oxygen Field mg/L	Dissolved Oxygen Winkler mg/L	Dissolved Oxygen saturation %	Flow Discharge cfs
Tide gate 12 east bank W=sampled at tide gate outfall L=sampled by tide gate inflow										
TG12L	11/13/2002	11:05	9.4	150		*	4.3		37.3	
TG12L	12/16/2002	11:22	9.1	*		7.6	6.4		59.8	
TG12L	2/18/2003	14:37	8.5	890		7.7	7.4		63.1	
TG12L	3/5/2003	15:06	8.5	275		8.0	6.0		60.0	
TG12L	3/19/2003	14:00	9.3	990		6.8	6.7		60.1	
TG12L	4/16/2003	13:45	12.7	*		7.4	8.7		82.0	
TG12L	5/13/2003	12:23	14.1	608		6.7	0.5		4.7	
TG12L	7/15/2003	14:51	16.8	*		6.8	*		*	
TG12L	8/27/2003	15:14	15.5	*		6.8	2.2		21.9	
TG12L	10/22/2003	12:44	ND					1.0		0.54
TG12L	12/8/2003	12:45	ND							2.45
TG12L	2/23/2004	13:35	10.30					8.7	78.0	
Tide gate 11 and Little McAllister Ck (combined discharge from TG) W=sampled at tide gate outfall L=sampled by tide gate inflow										
TG11W	11/13/2002	9:30	8.9	142		7.3	8.3		70.2	
TG11L	2/18/2003	14:15	8.6	133		7.4	9.3		79.7	
TG11L	3/5/2003	14:10	8.7	144		7.4	9.4		80.9	
TG11L	3/19/2003	13:30	8.9	111		7.0	8.4		72.8	
TG11L	4/16/2003	14:15	11.8	*		7.2	10.2		93.8	
TG11L	5/13/2003	14:10	13.6	135		7.2	9.6		92.6	
TG11L	7/15/2003	14:40	14.5	157		7.0	7.8		75.6	
TG11L	8/27/2003	15:40	14.3	*		7.1	7.4		71.8	
Culvert at tide gate 11 drains wetland creek area on west bank										
TG-11C	11/13/2002	9:30	9.2	175		7.2	7.2		62.2	
TG-11C	3/5/2003	14:10	8.7	144		7.4	9.4		80.9	
TG-11C	3/19/2003	13:30	No measurements, flow too low							
TG-11C	4/16/2003	14:17	10.5	*		7.2	9.0		80.7	
TG-11C	5/13/2003	14:05	No measurements, flow too low							
TG-11C	7/15/2003	14:30	12.8	212		7.3	8.9		82.5	
TG-11C	8/27/2003	15:50	12.6	*		7.2	8.3		77.8	
Tide gate 10 east bank W=sampled at tide gate outfall L=sampled by tide gate inflow										
TG10L	11/13/2002	9:55	8.7	120		*	3.8		32.1	
TG10W	11/13/2002	10:56	8.6	*		6.8	3.0	2.1	28.0	
TG10L	12/16/2002	10:37	8.8	1848		7.2	7.0		62.7	
TG10L	1/21/2003	15:11	8.3	467		*	7.2		60.1	
TG10L	2/18/2003	15:20	8.3	501		7.3	5.1		42.0	
TG10L	3/5/2003	15:54	9.3	726		7.4	7.1		61.9	
TG10L	3/19/2003	14:43	9.8	1554		7.0	8.3		72.4	
TG10L	4/16/2003	14:42	14.0	*		7.2	6.5		63.1	
TG10L	5/13/2003	11:19	13.4	259		7.0	3.7		34.8	
TG10W	5/13/2003	14:15	14.8	565		7.0	1.9		18.9	
TG10W	7/15/2003	15:00	16.4	235		6.9	1.6		15.8	
TG10L	8/27/2003	14:00	17.3	*		7.0	2.4	3.3	24.4	
TG10L	10/22/2003	12:01	ND					1.7		1.31
TG10L	12/8/2003	11:57	ND					8.7		1.35
TG10L	2/23/2004	13:15	10.3					8.3	74.0	

ND: not sampled for

* Field parameter did not meet quality control objectives.

Table E-4: McAllister Creek Field and Laboratory Results - Field Results McAllister Tributaries and Tidegates

Station Name	Date	Time	Temperature °C	Conductivity (µmhos) field	Conductivity (µmhos) lab	pH SU	Dissolved Oxygen Field mg/L	Dissolved Oxygen Winkler mg/L	Dissolved Oxygen saturation %	Flow Discharge cfs
Tide gate 9 east bank W=sampled at tide gate outfall L=sampled by tide gate inflow										
TG9L	11/13/2002	9:42	8.6	4000		*	4.6		39.9	
TG9W	11/13/2002	11:07	9.8	127		7.2	13.1		111.1	
TG9L	12/16/2002	10:30	8.0	*		7.1	5.5		46.0	
TG9W	12/16/2002	11:50	8.2	742		7.1	*	5.8	49.2	
TG9L	1/21/2003	15:06	7.4	1367		*	5.1		44.1	
TG9W	2/18/2003	14:25	8.3	503		7.2	6.0		50.2	
TG9L	3/5/2003	16:02	8.7	352		7.2	5.7		59.8	
TG9L	3/19/2003	14:50	9.8	1554		7.0	8.3		72.4	
TG9L	4/16/2003	14:50	13.8	*		6.8	1.2		10.5	
TG9W	4/16/2003	14:40	14.1	*		7.0	11.7		114.1	
TG9L	5/13/2003	11:07	14.6	624		7.0	4.0		37.8	
TG9W	5/13/2003	14:25	17.1	320		6.9	6.7		70.6	
TG9L	7/15/2003	14:20	16.7	*		6.7	*		*	
TG9W	7/15/2003	15:15	20.0	487		6.8	3.2	2.9	35.2	
TG9L	8/27/2003	13:30	18.0	*		6.5	1.1	2.2	11.4	
TG9L	10/22/2003	11:48						0.8		0.71
TG9L	12/8/2003	12:17						5.0		2.41
TG9L	2/23/2004	12:50	9.7					8.4	74.2	
Tide gate 8 east bank W=sampled at tide gate outfall L=sampled by tide gate inflow										
TG8L	12/16/2002	12:07	8.0	177		6.9	*		*	0.13
TG8L	1/21/2003	13:20	6.9	247		7.0	5.4		44.3	0.03
TG8L	2/18/2003	15:30	7.5	172		7.3	5.7		43.6	stagnant
TG8L	3/5/2003	15:45	7.9	203		7.2	4.9		41.8	stagnant
TG8L	3/19/2003	11:35	7.8	144		7.2	5.4		45.2	stagnant
TG8L	4/16/2003	16:00	11.7	*		7.3	6.5		59.4	stagnant
TG8L	5/13/2003	15:30	14.4	148		7.3	7.0		69.3	stagnant
Upstream west bank tributary at RM 4.4, opposite Medicine Creek										
MC4.4TLBU	2/18/2003	14:52	9.8	106		7.7	16.4		107.1	
MC4.4TLBU	3/5/2003	14:55	9.2	145		7.6	11.0		95.1	
MC4.4TLBU	7/15/2003	15:55	15.9	168		7.3	8.2		81.2	
MC4.4TLBU	8/27/2003	14:30	14.6	*		7.1	8.8		85.8	
Downstream west bank tributary at RM 4.4, opposite Medicine Creek										
MC4.4TLBD	7/15/2003	15:50	16.7	163		7.7	9.2		93.6	
Medicine Creek at RM 0.3, above tide gates 6 and 7										
MED0.3	11/13/2002	12:03	8.0	257		7.0	1.5		11.6	
MED0.3	12/16/2002	13:40	7.8	184	219	7.0	1.8		15.4	0.24
MED0.3	1/21/2003	16:30	6.7	220	251	6.9	*		*	0.20
MED0.3	2/18/2003	14:20	7.5	212	220	6.9	6.2		50.8	0.84
MED0.3	3/5/2003	13:35	7.7	226	229	6.8	5.3		45.0	0.51
MED0.3	3/19/2003	15:10	8.8	211	290	*	6.8		55.0	1.19
MED0.3	4/16/2003	14:20	11.9	215	222	6.8	5.6		51.0	0.72
MED0.3	5/13/2003	11:45	12.7	232		6.8	5.6		53.0	0.51
MED0.3	7/15/2003	14:20	16.9	275		6.8	2.0		21.1	stagnant
MED0.3	8/27/2003	16:25	18.0	424		7.0	0.7		9.0	stagnant

ND: not sampled for

* Field parameter did not meet quality control objectives.

Table E-4: McAllister Creek Field and Laboratory Results - Field Results McAllister Tributaries and Tidegates

Station Name	**Date**	**Time**	**Temperature °C**	**Conductivity field (µmhos)**	**Conductivity lab (µmhos)**	**pH SU**	**Dissolved Oxygen Field mg/L**	**Dissolved Oxygen Winkler mg/L**	**Dissolved Oxygen saturation %**	**Flow Discharge cfs**
Medicine Creek at RM 0.0 (mouth) below tide gates										
MED0.0	3/5/2003	15:05	8.7	210		7.3	9.2	8.9	78.7	
MED0.0	3/19/2003	14:20	8.7	144		7.0	7.5		64.8	
MED0.0	4/16/2003	15:16	14.6	*		7.2	10.9	10.7	107.7	
MED0.0	5/13/2003	15:00	16.6	186		7.3	7.3		75.8	
MED0.0	7/15/2003	15:45	0.7	181		7.3	6.5	6.8	66.6	
MED0.0	8/27/2003	14:10	16.4	*		7.1	7.0	7.2	71.5	
West bank tributary at RM 4.3, flowing of sheet metal just upstream of from blue bridge.										
MC4.3T	2/18/2003	15:35	9.6	165		6.9	6.0		53.2	
MC4.3T	5/13/2003	12:00	13.6	264		7.6	8.0		76.9	
MC4.3T	7/15/2003	16:20	16.6	321		7.6	9.0		91.0	
MC4.3T	8/27/2003	15:55	16.2	195		7.5	8.8		89.0	
Tide gate 5 east bank W=sampled at tide gate outfall L=sampled by tide gate inflow										
TG5L	11/13/2002	9:05	7.5	333		*	8.3		62.1	
TG5L	12/16/2002	10.03	7.8	*		7.0	7.1		61.6	
TG5L	1/21/2003	14:45	7.6	10641		*	4.3		36.2	
TG5L	2/18/2003	13:19	9.5	190		7.6	8.9		77.0	
TG5L	3/5/2003	13:41	8.9	209		7.1	6.0		52.0	
TG5L	3/19/2003	12:56	9.0	364		6.5	4.1		36.0	
TG5L	4/16/2003	12:32	12.3	*		6.8	5.7		53.9	
TG5L	5/13/2003	10:29	12.6	2927		6.6	4.1		39.6	
TG5L	7/15/2003	13:48	20.5	*		6.8	*		*	
TG5L	8/27/2003	13:00	23.6	*		7.1	8.2	8.3	98.2	
TG5L	10/22/2003	11:19						2.8		0.46
TG5L	12/8/2003	11:40						4.1		0.98
TG5L	2/23/2004	12:25	9.3					3.4	29.8	0.28
Tide gate 4 east bank W=sampled at tide gate outfall L=sampled by tide gate inflow										
TG4L	11/13/2002	8:50	9.0	340		*	6.4		56.0	
TG4L	12/16/2003	9:58	8.2	*		7.0	6.0		51.7	
TG4L	1/21/2003	14:40	7.3	179		*	7.9		65.5	
TG4L	2/18/2003	13:22	8.3	6744		6.9	7.7		68.4	
TG4L	3/5/2003	13:36	8.5	555		7.2	5.4		60.6	
TG4L	3/19/2003	12:53	8.6	646		6.2	4.7		41.6	
TG4L	4/16/2003	12:22	11.4	*		6.7	11.9		111.2	
TG4L	5/13/2003	10:21	13.1	12041		6.8	11.8		117.7	
TG4L	7/15/2003	13:37	20.0	*		6.7	*		*	
TG4L	8/27/2003	12:30	24.7	*		7.2	9.9	13.1	123.0	
TG4L	10/22/2003	11:08						5.1		0.12
TG4L	12/8/2003	11:18						3.3		1.40
TG4L	2/23/2004	12:16	9.0					3.5		0.30

ND: not sampled for

* Field parameter did not meet quality control objectives.

Table E-4: McAllister Creek Field and Laboratory Results - Field Results McAllister Tributaries and Tidegates

Station Name	Date	Time	Temperature °C	Conductivity		pH SU	Dissolved Oxygen			Flow Discharge cfs
				field	lab		Field	Winkler	saturation	
				(µmhos)			mg/L		%	
Tide gate 3 east bank W=sampled at tide gate outfall L=sampled by tide gate inflow										
TG3L	12/16/2002	11:55	9.2	29857		7.0	6.1		60.4	
TG3L	1/21/2003	16:10	8.2	7040		7.1	*		*	
TG3L	2/18/2003	15:15	10.3	5900		7.3				
TG3L	3/5/2003	14:30	9.6	3160		7.5				
TG3L	3/19/2003	14:45	9.6	21000		*	11.4		108.0	
TG3L	4/16/2003	12:25	11.2	23151		6.9	8.1		83.0	
TG3L	5/13/2003	12:50	14.9	17800		7.1	7.5		78.2	
TG3L	7/15/2003	15:00	19.1	14276		6.9	4.2		47.4	
TG3L	8/27/2003	16:00	21.6	9370		7.9	17.0		198.0	
TG3L	10/22/2003	10:50					4.6			0.05
TG3L	12/8/2003	11:00					6.9			0.23
TG3L	2/23/2004	12:00	11.8				14.8			
Stormwater discharge upstream of Martin Way west bank										
SW2W	11/13/2002	9:55	12.0	206		8.0	9.4		90.1	
Tide gate 2 west bank, under Martin Way, sampled by tide gate inflow										
TG2L	11/13/2002	8:00	9.2	1824		7.2	8.0	7.0	70.6	1.09
TG2L	12/16/2002	12:15	9.1	17922		6.9	3.2		30.6	
TG2L	1/21/2003	15:50	8.4	4500		7.1	*		*	
TG2L	2/18/2003	14:50	8.5	3850		6.8	6.7		57.2	
TG2L	3/5/2003	14:10	10.1	5740		8.2	13.9		90.0	
TG2L	3/19/2003	14:30	10.0	5600		*	13.2		118.0	
TG2L	4/16/2003	12:00	11.9	13700		6.9	8.8		85.5	
TG2L	5/13/2003	12:35	14.6	1197		7.7	10.7		105.2	
TG2L	7/15/2003	15:20	17.9	377		8.1	11.1		116.8	2.30
TG2L	8/27/2003	14:25	17.6	215		8.0	9.6		100.0	
Tide gate 1 west bank at commercial development along I-5 sampled tide gate inflow										
TG1L	11/13/2002	8:20	6.1	67		7.2	6.8	7.0	55.0	<0.01
TG1L	12/16/2002	11:00	7.8	1335		6.8	7.2		66.1	
TG1L	1/21/2003	15:30	7.5	1450		6.9	*		*	
TG1L	2/18/2003	15:40	10.5	1330		6.7	11.8		105.2	
TG1L	3/5/2003	15:40	9.7	1850		7.2	13.0		116.0	
TG1L	3/19/2003	15:40	9.9	1187		*	11.8		107.0	
TG1L	4/16/2003	14:50	20.0	2031		6.8	7.7		85.1	
TG1L	5/13/2003	12:20	20.4	3377		7.1	11.1		123.0	
TG1L	2/23/2004	14:30	10.20							0.03
Stormwater discharge under I-5 west bank										
SW1W	1/21/2003	15:05	8.0	51		7.5	11.3		94.1	
Tide gate B east bank South tide gate Nisqually Wildlife Refuge, sampled tide gate inflow										
TGBL	12/16/2002	10:15	9.7	44572		7.2	4.4		47.4	
TGBL	1/21/2003	14:50	6.4	3000		6.5	*		*	
TGBL	2/18/2003	13:55	8.0	2300		6.7	9.8		83.8	
TGBL	3/5/2003	15:25	8.4	6050		6.6	*		*	
TGBL	3/19/2003	13:50	9.9	2100		*	10.9		9.0	
TGBL	4/16/2003	12:58	14.3	1904		7.1	10.4		102.2	
TGBL	5/13/2003	11:15	14.1	18600		6.7	4.5		46.0	
TGBL	7/15/2003	14:00								
TGBL	8/27/2003	14:30	21.1	32200		7.8	8.3		102.7	

ND: not sampled for

* Field parameter did not meet quality control objectives.

Table E-4: McAllister Creek Field and Laboratory Results - Field Results McAllister Tributaries and Tidegates

Station Name	Date	Time	Temperature °C	Conductivity field (µmhos)	Conductivity lab (µmhos)	pH SU	Dissolved Oxygen Field mg/L	Dissolved Oxygen Winkler mg/L	Dissolved Oxygen saturation %	Flow Discharge cfs
Tide gate A east bank North tide gate Nisqually Wildlife Refuge, sampled tide gate inflow										
TGAL	12/16/2002	10:40	10.4	43798		6.8	0.6		7.0	
TGAL	1/21/2003	14:40	6.1	3600		6.3	*		*	
TGAL	2/18/2003	13:25	8.4	7300		6.4	*		*	9.84
TGAL	3/5/2003	15:15	8.6	68000		6.9	*		*	
TGAL	3/19/2003	13:30	10.3	2737		*	9.8		87.0	
TGAL	4/16/2003	12:50	14.2	1978		7.1	9.6		94.3	
TGAL	5/13/2003	11:05	14.8	16700		6.9	6.8		71.1	
TGAL	7/15/2003	13:38	25.8	13266		7.5	14.9		191.3	
TGAL	8/27/2003	13:40	22.2	25200		7.8	12.4		153.0	

* Field parameter did not meet quality control objectives.

Table E-5. McAllister Creek Field and Laboratory Results - Groundwater Data McAllister Area

Date	Time	Site ID	Unique Well ID	Address	Lab No.	Temp °C	pH SU	Cond Field uS/cm	Cond Lab uS/cm	DO	NH3-N mg/L	NO2/3-N mg/L	TPN mg/L	TP mg/L	Ortho P	Cl	TDS
10/01/02	12:20	Lee	AGJ-750	Sandra Lee St	40-8020	10.9	7.11	156	156	6.57 (M)	0.010 U	1.93	2.06	0.0563	0.0619	4.41	128
03/04/03	10:55	Lee	AGJ-750	Sandra Lee St	10-8032	10.7	6.72	158	159	4.85 (M)	0.010 U	1.98	3.00	0.088	0.0676	4.40	112
10/02/02	11:10	MCAL-1		McAllister Spring well	40-8021	10.7	7.16	145	147	8.75 (M)	0.010 U	2.12	2.23	0.0805	0.0849	3.71	123
10/08/02	10:50	Sockeye	AGJ-751	Sockeye La	41-8023	10.0	7.11	156	158	7.30 (M)	0.010 U	2.00	2.17	0.0557	0.0614	4.49	124
10/08/02	10:55	Sockeye	AGJ-751	Sockeye La	41-8024	--	--	--	158	--	0.010 U	2.04	2.02	0.0584	0.0612	4.47	120
10/22/02	9:30	MCSPRING		McAllister-main spring	43-8020	10.9	6.32	146	148	4.02 (M)	0.010 U	1.14	na	0.109	0.108	3.66	115
03/03/03	9:55	MCSPRING		McAllister-main spring	10-8030	10.9	6.46	149	149	4.93 (M)	0.010 U	1.21	1.22	0.130	0.101	3.84	106
03/03/03	10:05	MCSPRING		McAllister-main spring	10-8031				149	4.90 (W)	0.010 U	1.20	1.22	0.131	0.102	3.79	112
04/01/03	9:30	BL-1		Field Blank (Lab DI H20)							0.010 U	0.010 U	0.025	0.010 U		0.10	

DO - dissolved oxygen
NH3-N - ammonia-N
NO2/3-N - nitrate+nitrite-nitrogen
TPN - total persulfate nitrogen
TP - total phosphorus
Ortho-P - orthophosphate
Cl -chloride
TDS - total dissolved solids

M - Multimeter
W - Winkler Method
U - Below detection limit shown

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Appendix F

McAllister Creek In-situ Continuous Temperature, pH, Dissolved Oxygen, and Conductivity Measurements

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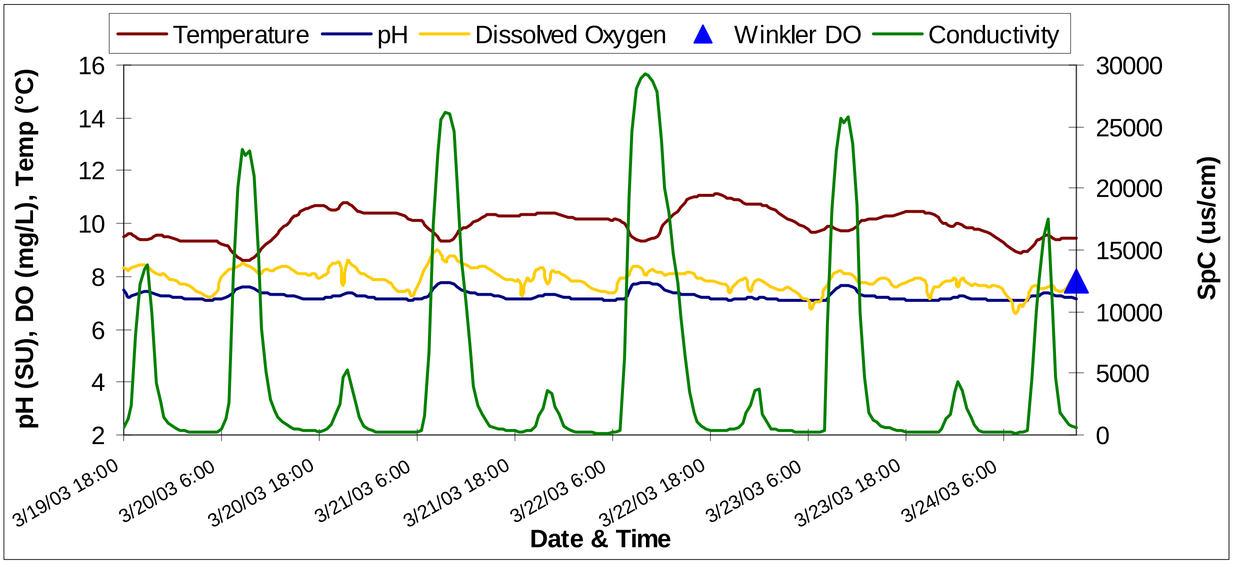
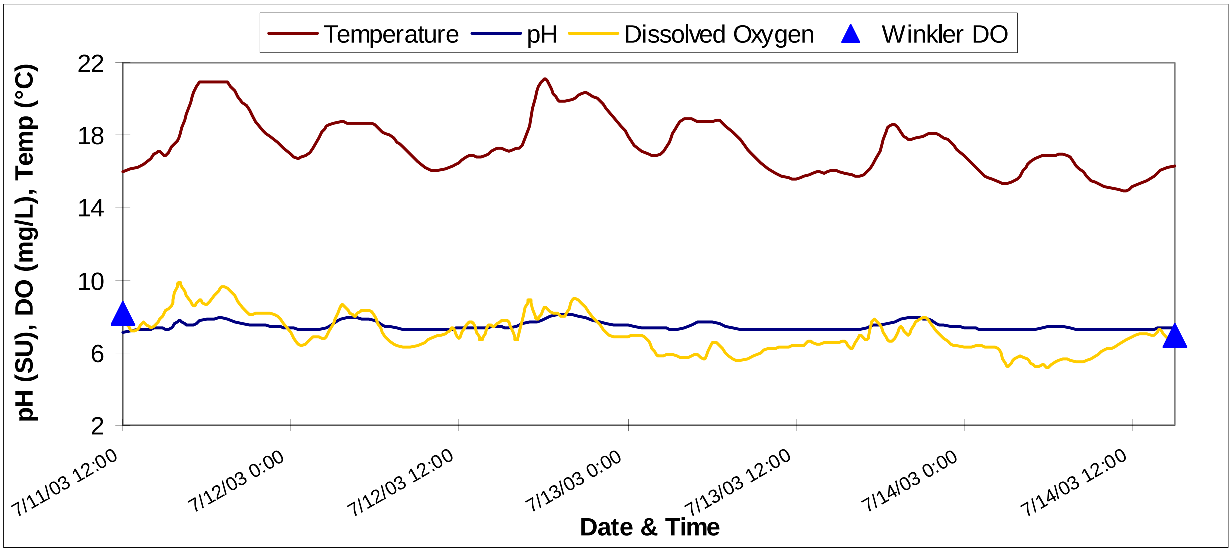
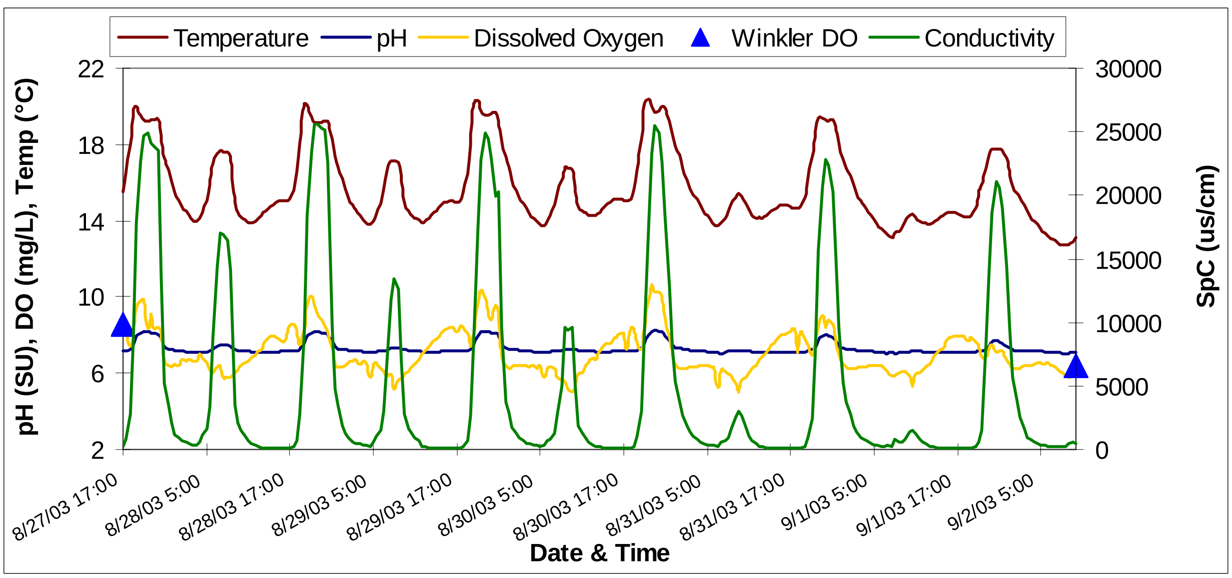
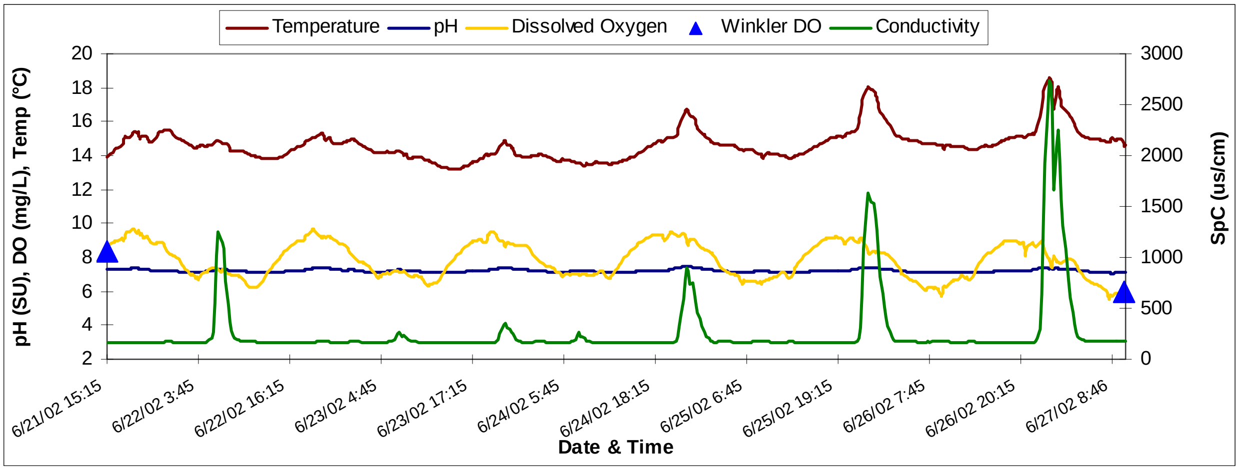
Figures F-1. McAllister Creek RM 3.7

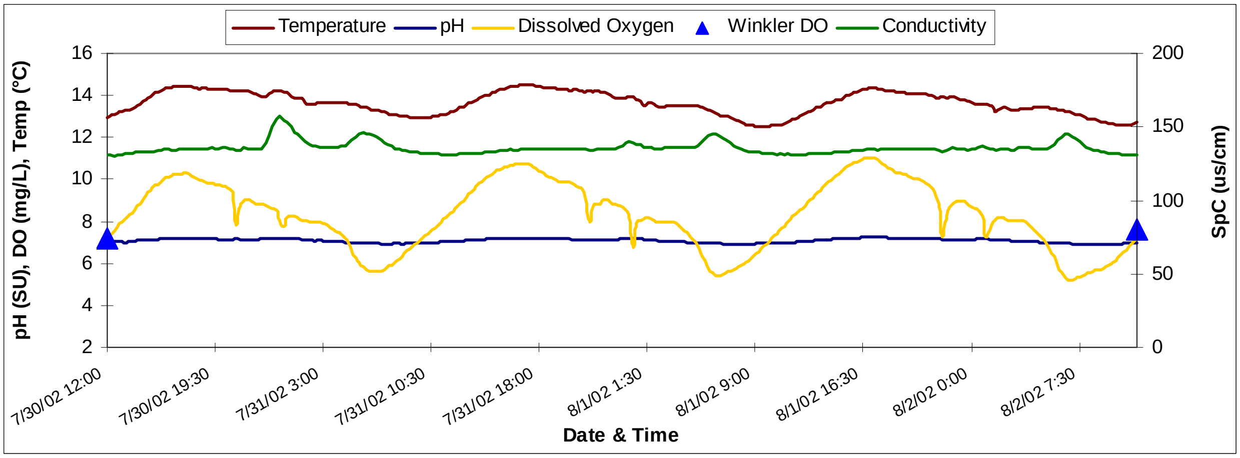


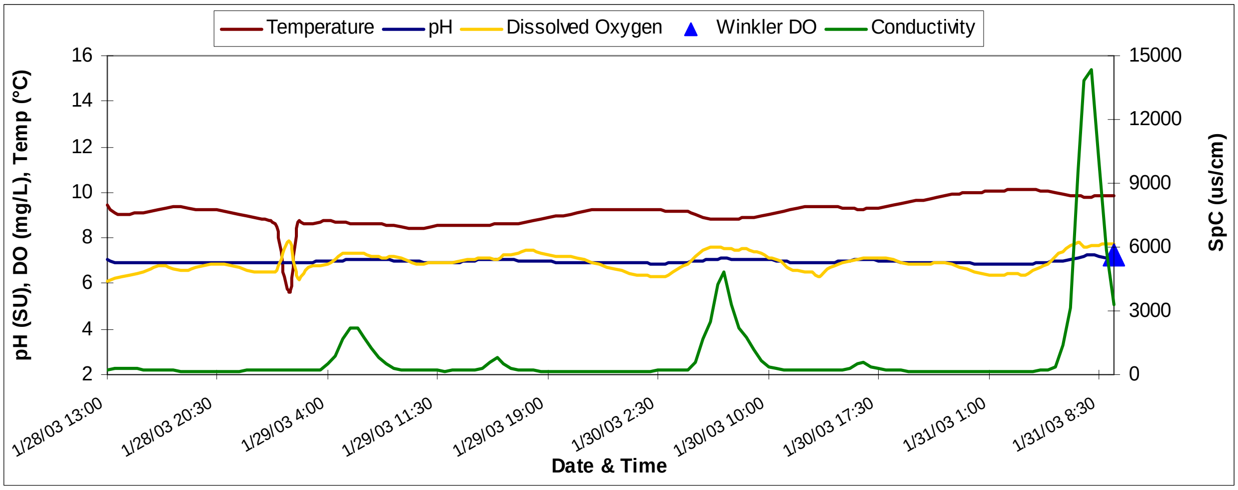




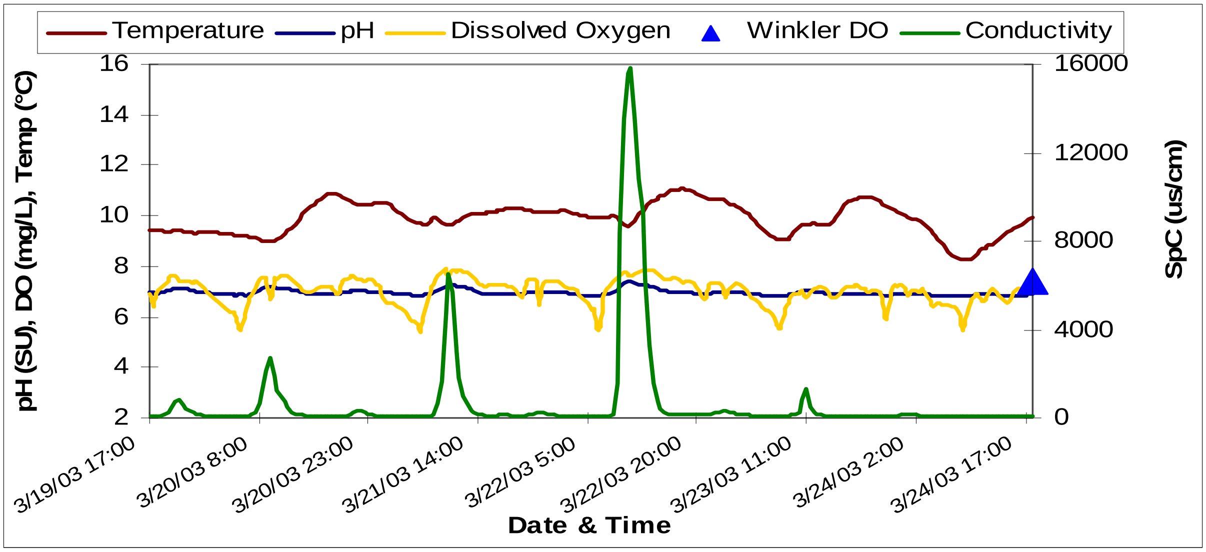
Figures F-2. McAllister Creek RM 4.7

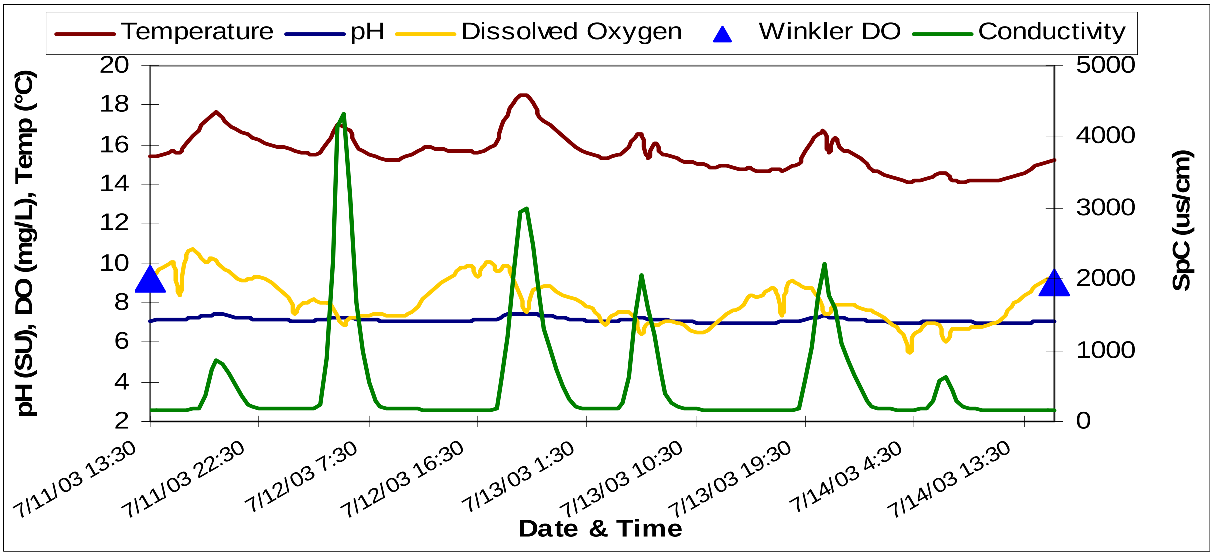


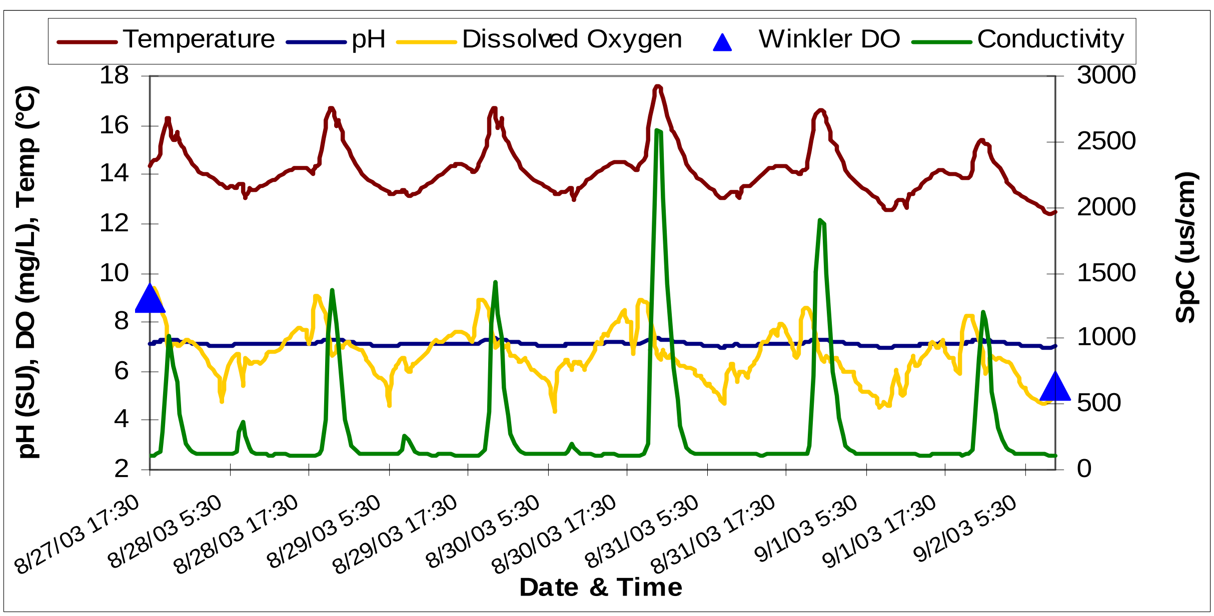




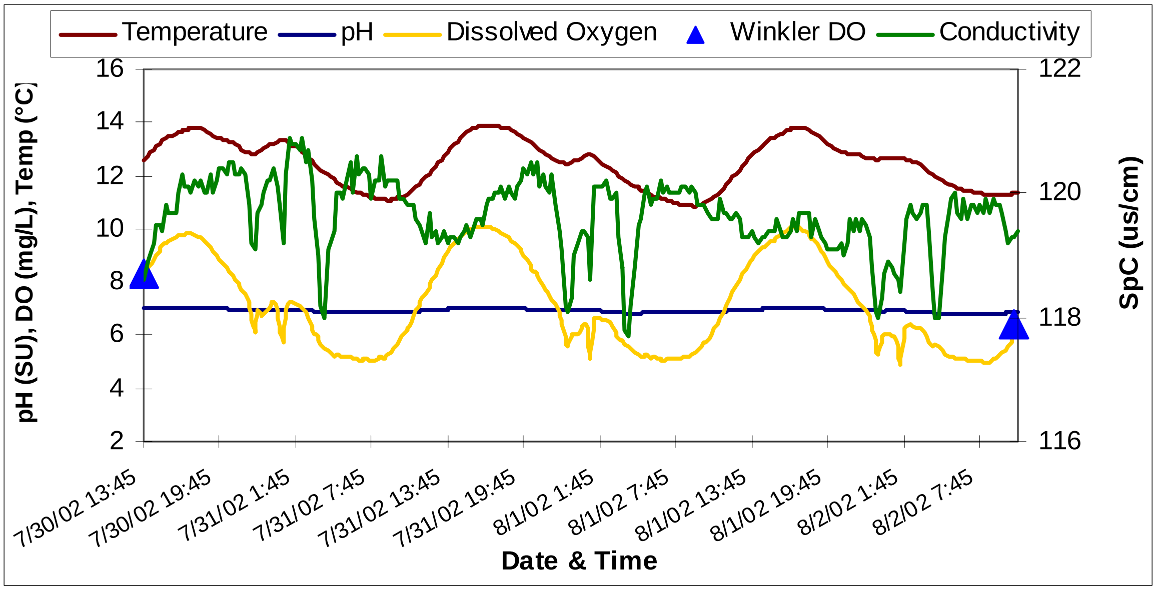
Figures F-2 (cont). McAllister Creek RM 4.7

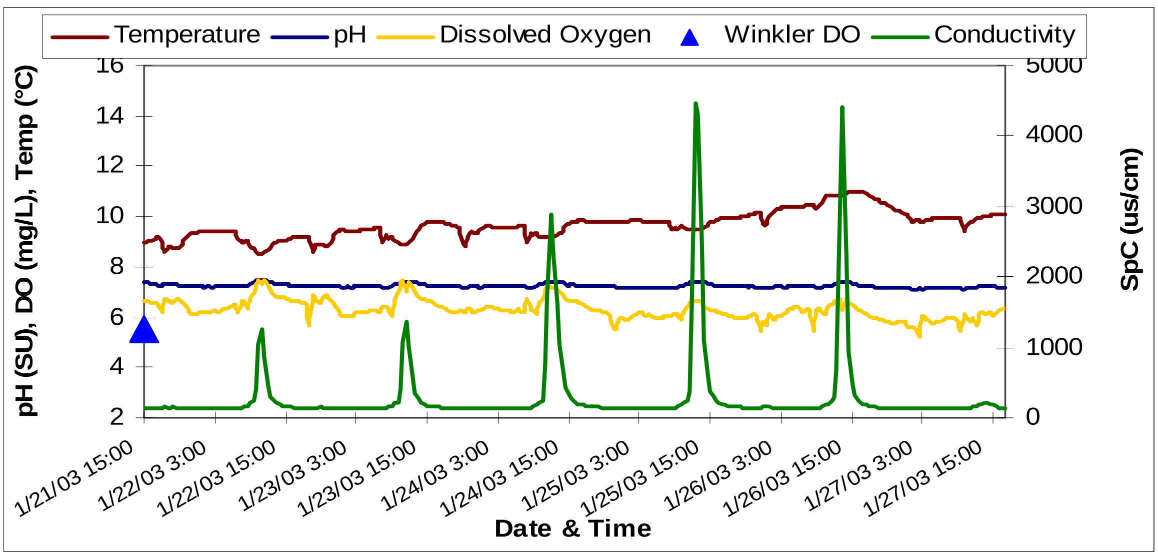


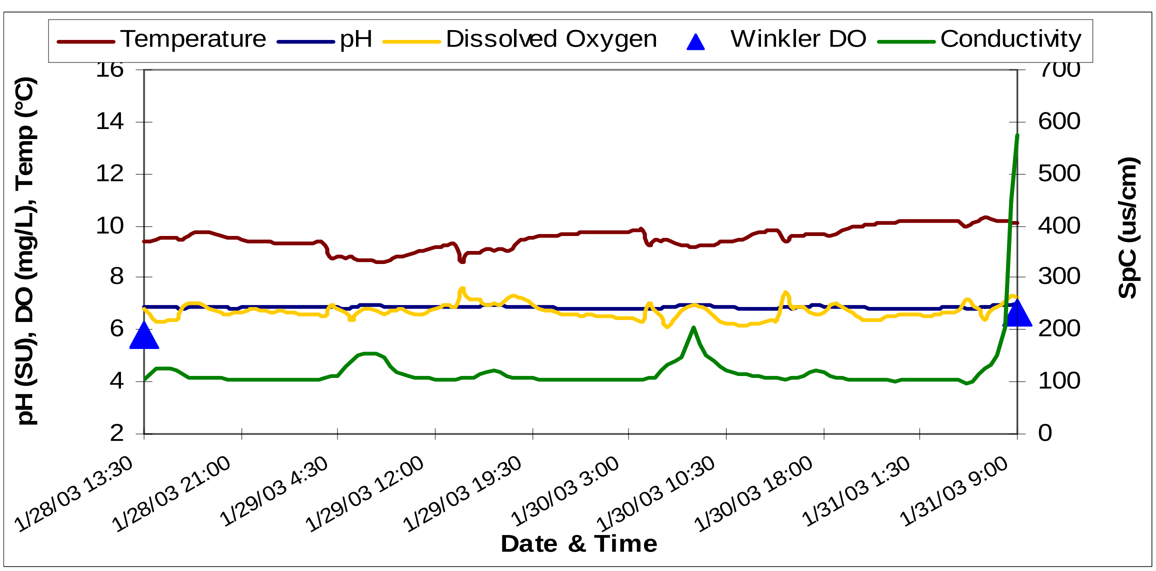




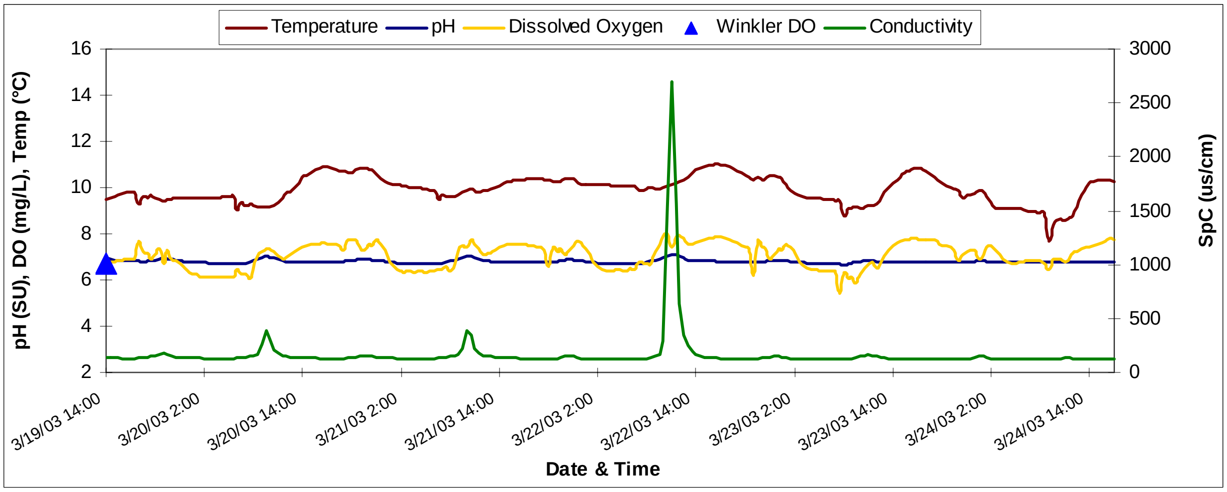
Figures F-3. McAllister Creek RM 5.8

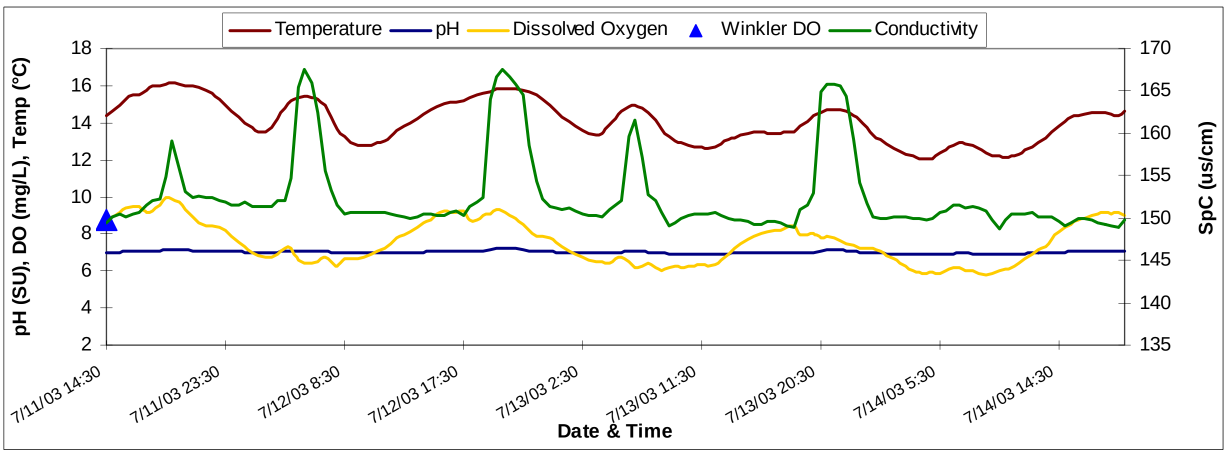






Figures F-3 (cont.). McAllister Creek RM 5.8





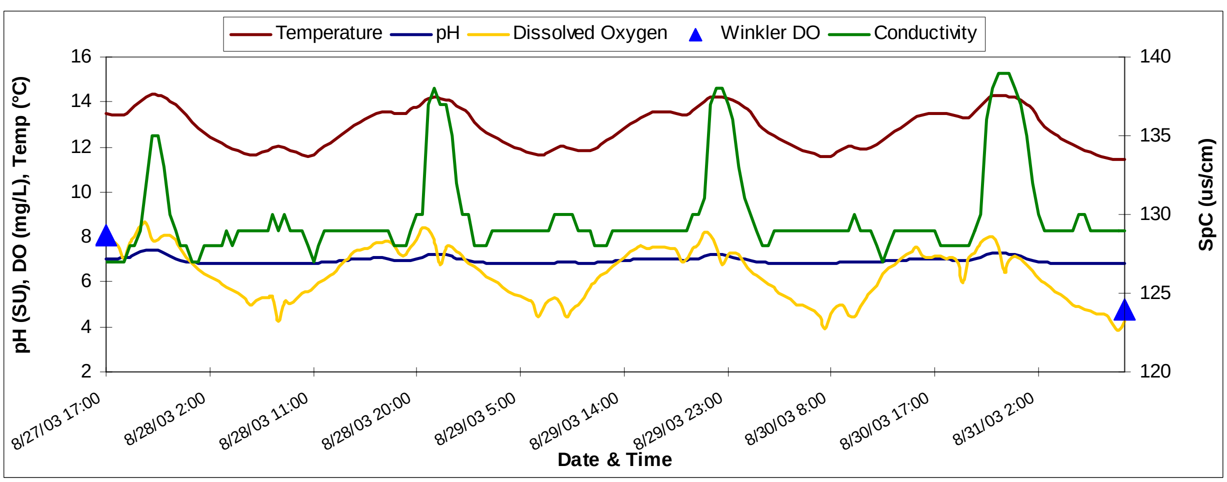
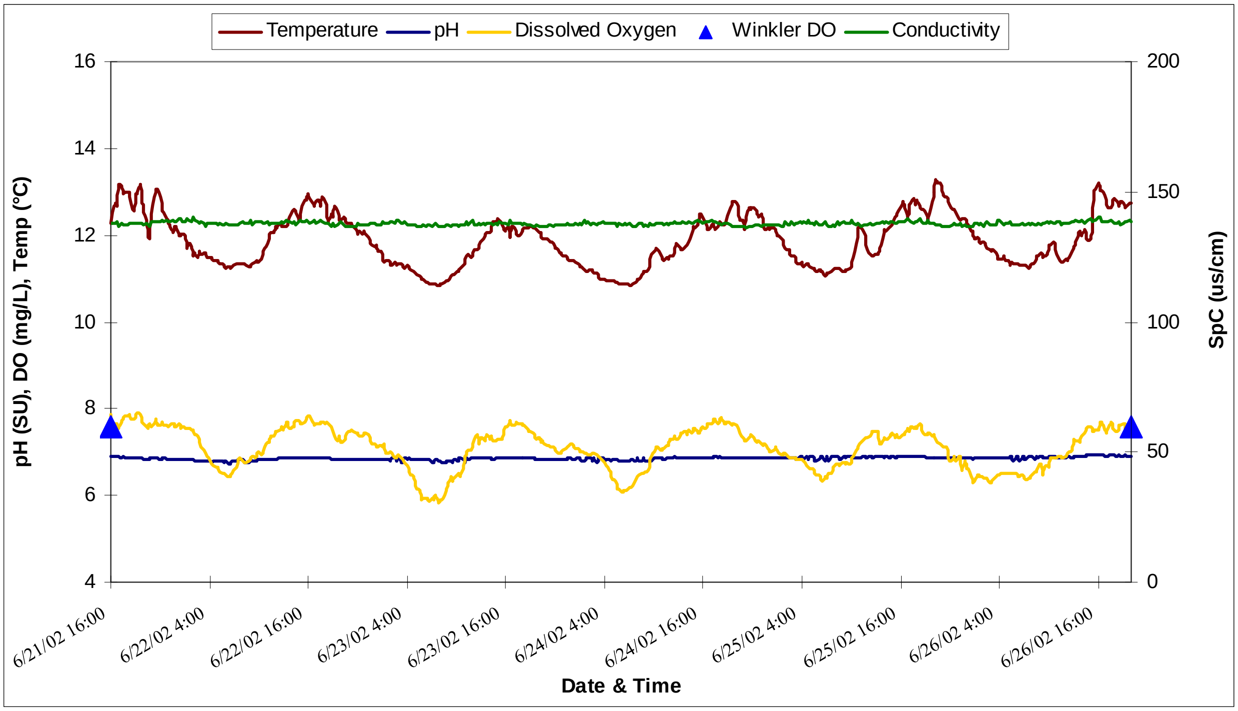


Figure F-4. McAllister Creek RM 6.0



Appendix G

Data Quality

Laboratory Data

Laboratory samples were analyzed according to quality assurance and quality control procedures followed by Ecology's Manchester Environmental Laboratory (MEL). All general chemistry samples met holding time requirements. Microbiology samples were analyzed within 30 hours, which is standard procedure for MEL. Microbiology samples were not analyzed within the six-hour window described in Standard Methods (APHA, 1998) because of the logistical challenges in collecting and transporting samples within the given timeframe. MEL was used for all laboratory analysis of membrane filter (MF) fecal coliform and *E-coli* bacteria, nutrients, conductivity, salinity, and biochemical oxygen demand.

Duplicate field samples were used to estimate total variation (field and laboratory), expressed as the coefficient of variation (CV). Duplicates are two field samples collected sequentially at the same site as close as possible in time. The percent CV is calculated by dividing the standard deviation by the mean of the duplicate pairs, and multiplying by 100. Field duplicates were collected for approximately 20% of all bacteria samples and 10% of the general chemistry samples analyzed by MEL.

Values below the detection limit were assumed to be the detection limit for analysis purposes. Laboratory and field replicates were arithmetically averaged for data analysis.

Precision for bacteria field duplicate results should not exceed 50% CV. At levels close to the method detection limit (less than 50 col/100 mL), a CV greater than 50% is acceptable. For all other parameters, precision for field duplicate measurements should not exceed 20% CV for results above the reporting limit. For results close to the reporting limit, a higher CV may be acceptable. Table G-1 presents the arithmetic average CV for field duplicate samples.

Table G-1. Coefficient of Variation for McAllister Creek Laboratory Sampling Parameters.

Parameter	Average % CV for all values and number of duplicates		Average % CV for values < 50 col/100mL and number of duplicates		Average % CV for values ≥ 50 col/100mL and number of duplicates	
Fecal coliform	20%	n=114	23%	n=82	13%	n=32
E-coli	25%	n=112	28%	n=81	16%	n=29
Ammonia-nitrogen	7.2%	n=20	n/a		n/a	
Nitrate+nitrite-N	7.8%	n=19	n/a		n/a	
Total persulfate nitrogen	6.9%	n=20	n/a		n/a	
Orthophosphate	6.0%	n=20	n/a		n/a	
Total phosphorus	2.7%	n=20	n/a		n/a	
BOD	0%	n=1	n/a		n/a	

Precision for bacteria results was very good with % CV values greater than 50 only where individual results were < 50 col/100 mL. On March 13, 2003, field duplicate nutrient results for tide gate B had a high CV ranging from 7-134%. The precision (% CV) for bacteria duplicates at that site for the same day were very good. The difference in nutrient levels is probably due to environmental variability, and results are acceptable but will be used with caution.

Other than the exceptions noted above, all data were acceptable for use without qualification. Data variability will be taken into consideration in using the data for modeling and other analysis as well as interpreting results.

Field Data

Field instruments were calibrated according to the manufacturer's instructions. Meters were pre-calibrated before deployment. Winkler dissolved oxygen measurements and laboratory conductivity samples were obtained in the field to check the meters. Post calibration checks were conducted after field sampling. Field meter parameters that did not meet quality control standards are qualified in the data appendices, and values are not reported. Table G-2 lists data quality standards for field measurements.

Table G-2. Measurement Quality Objectives for Field Determinations.

Analysis	Accuracy % deviation from true value	Precision Relative standard deviation	Bias % deviation from true value
pH[1]	0.2 s.u.	0.05 s.u.	0.10 s.u.
Water Temperature	± 0.2°C		
Dissolved Oxygen	15	5% RSD	5
Specific Conductivity	10	<10% RSD	5

Quality assurance results for in-situ continuous field monitoring with Hydrolabs are described in Table G-3.

Table G-3. Quality assurance results for continuous recording Hydrolabs installed in McAllister Creek.

Sites and Monitoring Period	Met QA objectives
McAllister Creek RM 6.0 (McAllister springs)	
June 21 - 26, 2002	Met
McAllister Creek RM 5.8	
July 30 - August 2, 2002	Met
January 21- 27, 2003	Met
January 28 - 31 2003	Met
March 19 - 24, 2003	Met
July 11 - 14, 2003	pH failed
August 27 – 31, 2003	Conductivity failed
McAllister Creek RM 4.7	
June 21 - 27, 2002	Met
July 30 - August 2, 2002	Met
January 28 - 31, 2003	Met
March 19 - 24, 2003	Met
July 11 - 14, 2003	Met
August 27 - September 2, 2003	Conductivity failed
McAllister Creek RM 3.7	
January 28 - 31, 2003	Met, Probe out of water at low tide
March 19 - 24, 2003	Met
July 11 - 14, 2003	Conductivity failed
August 27 - September 2, 2003	Conductivity failed

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Appendix H

Compliance with Water Quality Standards

Table H-1. Nisqually Reach annual compliance with fecal coliform water quality standards for marine water (DOH data for January 2001 through March 2004).

Station	Tidal condition	Number of sample events	Geometric mean (<14 col/100 mL)	Percentage of samples >43 col/100 mL (<10%)	Meets fecal coliform standard
245	all	33	3.3	8.4%	Yes
246	all	33	3.8	5.6%	Yes
247	all	32	3.2	5.7%	Yes
248	all	32	2.6	1.0%	Yes
245	flood	20	2.7	8.9%	Yes
246	flood	20	2.7	0.0%	Yes
247	flood	19	2.9	1.8%	Yes
248	flood	19	2.6	0.0%	Yes
245	ebb	13	4.3	7.7%	Yes
246	ebb	13	6.4	7.7%	Yes
247	ebb	13	3.7	7.7%	Yes
248	ebb	13	2.6	0.0%	Yes

Table H-2. Ohop Creek compliance with fecal coliform water quality standard.

Site	Number of sample events	Geometric mean (≤ 100 col/100mL)	Percentage of samples exceeding ≥ 200col/100mL (10% not to exceed)	Meets fecal coliform standard
RM 10.2 T				
Annual	3	7	0%	Yes
June-Sept	0			
Nov-Apr	3	7	0%	Yes
RM 9.9				
Annual	15	15	0%	Yes
June-Sept	5	76	0%	Yes
Nov-Apr	7	4	0%	Yes
RM 6.2T				
Annual	16	33	0%	Yes
June-Sept	5	56	0%	Yes
Nov-Apr	8	27	13%	No
RM 6.0				
Annual	16	34	13%	No
June-Sept	5	87	20%	No
Nov-Apr	8	22	13%	No
RM3.3Dit	3	16	0%	Yes
RM 3.3				
Annual	16	40	13%	No
June-Sept	5	91	0%	Yes
Nov-Apr	8	22	25%	No
RM2.2D				
Annual	13	39	23%	No
June-Sept	5	113	20%	No
Nov-Apr	6	12	0%	Yes
RM2.0				
Annual	16	36	13%	No
June-Sept	5	117	20%	No
Nov-Apr	8	12	0%	Yes
RM 0.1				
Annual	14	38	14%	No
June-Sept	4	102	25%	No
Nov-Apr	7	16	0%	Yes

Table H-3. Red Salmon Creek compliance with fecal coliform water quality standard, freshwater and marine water.

Freshwater sites	Number of sample events	Geometric mean (≤ 50col/100mL)	Percentage of samples exceeding ≥ 100col/100mL (10% not to exceed)	Meets fecal coliform standard
RM 1.44	6	28	0%	Yes
RM 1.42T (Wash Creek)	6	130	67%	No
Marine water sites	**Number of sample events**	**Geometric mean (≤ 14col/100mL)**	**Percentage of samples exceeding ≥ 43 col/100mL (10% not to exceed)**	**Meets fecal coliform standard**
RM 1.40	15	57	73%	No
RM 1.30T (unnamed trib)	15	25	27%	No

Table H-4. McAllister Creek and tributary compliance with fecal coliform water quality standard, freshwater and marine water.

Freshwater sites	Number of sample events	Geometric mean (≤ 50 col/100mL)	Percentage of samples exceeding ≥ 100 col/100mL (10% not to exceed)	Meets fecal coliform standard
McAllister Creek RM 5.8	11	35	9%	Yes
Tide gate 15	18	17	6%	Yes
Tide gate 14	18	16	17%	No
Tide gate 13	19	22	21%	No
McAllister Creek RM 5.4	11	44	18%	No
Tide gate 12	17	42	18%	No
Little McAllister Ck	9	48	22%	No
Tide gate 11	9	48	11%	No
Culvert near TG 11	7	24	29%	No
Tide gate 10	18	20	11%	No
Tide gate 9	19	54	26%	No
McAllister Creek RM 4.7	11	42	0%	Yes
Tide gate 8	7	75	43%	No
Pipe MC4.6TULB	9	26	11%	No
Pipe MC4.6TLB	4	3	0%	Yes
McAllister Creek RM 4.5	11	43	27%	No
Upstream tributary from pond MC4.4TLBU	6	6	17%	No
Downstream Tributary from pond MC4.4TLBD	5	12	0%	Yes
Medicine Ck at RM 0.3	10	6	0%	Yes
Medicine Ck at RM 0.0	8	59	25%	No
McAllister Creek RM 4.35	8	47	13%	No
Tributary from pond M3.4P	8	8	13%	No
Tributary east bank RM 4.3	6	51	33%	No
McAllister Creek at RM 4.3	11	50	18%	No
Tide gate 5	17	38	35%	No
Tide gate 4	18	36	33%	No
Tide gate 3	17	22	18%	No
Tide gate 2	11	14	9%	Yes
Tide gate 1	10	84	40%	No
Stormwater discharge under I5	8	29	13%	No
Marine water sites	**Number of sample events**	**Geometric mean (≤ 14col/100mL)**	**Percentage of samples exceeding ≥ 43 col/100mL (10% not to exceed)**	**Meets fecal coliform standard**
McAllister Creek RM 3.7	11	40	36%	No
McAllister Creek RM 3.1	11	51	55%	No
McAllister Creek RM 2.8	4	7	50%	No
McAllister Creek RM 2.2	7	36	14%	No
Tide gate B	8	8	0%	Yes
Tide gate A	10	12	20%	No
McAllister Creek RM 1.5	7	24	14%	No
DOH 234	28	20	21%	No
DOH 224	29	12	10%	Yes

Table H-5. McAllister Creek synoptic surveys compliance with freshwater or marine water dissolved oxygen criteria.

Site	Number of samples*	Dissolved oxygen minimum (mg/L)	Dissolved oxygen median (mg/L)	Meets water quality standards
Freshwater Criteria Lowest 1-day minimum 9.5 mg/L				
RM 5.8	21	5.3	7.3	No
RM 5.4	20	5.8	7.4	No
Marine Water Criteria Lowest 1-day minimum 7.0 mg/L				
RM 4.7	17	5.7	7.6	No
RM 4.5	15	7.0	8.2	Yes
RM 4.35	6	6.2	8.4	No
RM 4.3	16	5.9	7.2	No
RM 3.7	15	6.5	7.5	No
RM 3.1	9	5.8	7.9	No
RM 2.2	9	7.1	7.4	Yes
RM 1.5	12	6.4	7.5	No
RM 0.1	12	6.8	7.7	No
DOH 224	9	5.5	8.9	No

* Vertical dissolved oxygen profiles were obtained where possible during the synoptic surveys; minimum and median are based on all results.

Table H-6. McAllister Creek synoptic surveys tide gates and tributaries compliance with freshwater or marine water dissolved oxygen criteria.

Site	Number of samples	Dissolved oxygen minimum (mg/L)	Dissolved oxygen median (mg/L)
Freshwater Criteria Lowest 1-day minimum 9.5 mg/L			
Tide gate 15	12	3.1	5.6
Tide gate 14	12	2.1	3.6
Tide gate 13	13	0.4	2.4
Tide gate 12	10	0.5	6.2
Tide gate 11	8	7.4	8.9
Culvert at Tide gate11	5	7.2	8.9
Tide gate 10	15	1.6	5.1
Tide gate 9	17	0.8	5.5
Tide gate 8	6	4.9	5.6
Medicine Creek at RM 0.3	8	0.7	3.8
Medicine Creek at RM 0.0	6	6.8	7.4
Tributary at McAllister Creek RM 4.3	4	6.0	8.4
Tide gate 5	12	2.8	5.0
Tide gate 4	12	3.3	6.2
Marine Water Criteria Lowest 1-day minimum 7.0 mg/L			
Tide gate 3	9	4.2	7.5
Tide gate 2	8	3.2	9.2
Tide gate 1	6	7.0	9.4
Tide gate B	6	4.4	9.1
Tide gate A	6	0.6	9.7

Appendix I

Time-of-Travel Results

To understand circulation patterns, travel-time studies were conducted in McAllister Creek/ estuary as well as in the region to the northwest of Luhr Beach. Transport patterns help identify sources potentially contributing to water quality impairments. This appendix provides additional data to data summarized in the body of the report.

McAllister Creek and Estuary

Time-of-travel studies for McAllister Creek were conducted on a strong ebbing tide on October 7, 2002. High tide at Dupont Wharf occurred at 6:50 a.m. (13.7 ft); peak ebb velocity was 1.6 knots at 10:38 a.m. within the Nisqually Reach, and low tide occurred at 12:53 p.m. (2.5 ft). Personnel from Ecology, Department of Health, and Thurston County released surface drogues (oranges and grapefruits) within the creek, and combined surface and subsurface drogues at several locations within the system following high tide. High tide within McAllister Creek is delayed at least one hour.

Table I-1 presents the data for each release from sites shown in Figures I-1 and I-2. On a strongly ebbing tide, McAllister Creek velocities ranged from 0.5 to 1.6 ft/s, with the fastest values within the straightened reaches near Interstate-5. Estuarine velocities were also strong, ranging from 0.6 to 1.4 ft/s, during the large tidal exchange.

Table I-1. Drogue releases and tracking data for October 7, 2002 (strong ebbing tide velocity). *Italicized* values represent composite estimates for specific reaches.

Release	Start time	End time	Time (min)	Distance (ft)	Velocity (ft/s)	Velocity (m/s)
Tide Gate 15	*8:56*	*11:14*	*118*	*4,900*	*0.69*	*0.21*
Steilacoom Road	*11:00*	*11:40*	*40*	*2,000*	*0.83*	*0.25*
Blue Bridge	*8:30*	*10:50*	*140*	*6,300*	*0.75*	*0.23*
	8:30	10:18	108	3,200	0.49	0.15
	10:18	10:50	32	3,100	1.6	0.49
Tide Gate 1	*7:52*	*8:04*	*12*	*1,050*	*1.5*	*0.44*
McAllister Estuary 1	*7:40*	*11:39*	*239*	*14,800*	*1.0*	*0.31*
	7:40	8:43	63	2,500	0.66	0.20
	8:43	9:32	49	4,800	1.6	0.50
	9:32	10:15	43	2,600	1.0	0.31
	10:15	11:39	84	4,900	0.97	0.30
McAllister Estuary 2	*7:47*	*9:51*	*124*	*8,900*	*1.2*	*0.36*
	7:47	8:29	42	3,700	1.5	0.45
	8:29	9:51	82	5,200	1.1	0.32
McAllister Estuary 3	*7:57*	*10:08*	*131*	*4,700*	*0.60*	*0.18*
	7:57	9:37	100	2,300	0.38	0.12
	9:37	10:08	31	2,400	1.3	0.39
McAllister Estuary 4	*10:28*	*11:30*	*62*	*4,500*	*1.2*	*0.37*
McAllister Estuary 5	*11:17*	*11:55*	*38*	*3,200*	*1.4*	*0.43*

The March 25, 2003 releases targeted a moderate ebbing tide. Predicted high tide at Dupont Wharf was at 10:03 a.m. (11.8 ft) and low tide at 5:50 p.m. (-0.2 ft). Maximum current expected in the Nisqually Reach was 1.3 knots at 2:32 p.m. Surface drogues were released at five locations through McAllister Creek north to Luhr Beach and tracked from just after high tide to the peak ebbing velocities. Table I-2 and Figures I-3 and I-4 summarize the data.

Within the riverine section of McAllister Creek, drogues traveled at 0.6 to 0.9 ft/s (0.2 to 0.3 m/s), but the drogue velocities were significantly lower north of the Interstate-5 (I-5) bridge where the creek opens into an estuary (0.4 ft/s or 0.1 m/s). The interaction of the tides and the shoreline shape near Luhr Beach produces a northeasterly circulation pattern with fairly rapid surface velocities of 1.2 ft/s (0.4 m/s).

Table I-2. Drogue releases and tracking data for March 25, 2003 (moderate ebbing tide velocity). *Italicized* values represent composite estimates for specific reaches.

Release	Start time	End time	Time (min)	Distance (ft)	Velocity (ft/s)	Velocity (m/s)
Tide Gate 15	*11:50*	*14:00*	*130*	*6,000*	*0.77*	*0.23*
	11:50	12:20	30	800	0.44	0.14
	12:20	13:11	51	900	0.29	0.09
	13:11	13:30	19	2,500	2.19	0.67
	13:30	14:00	30	1,800	0.30	0.30
Steilacoom Road	*14:39*	*15:15*	*36*	*2,000*	*0.93*	*0.28*
Blue Bridge	*10:45*	*12:15*	*90*	*3,200*	*0.59*	*0.18*
Lower McAllister	*10:55*	*11:45*	*50*	*1,200*	*0.40*	*0.12*
Luhr Beach	*11:16*	*13:04*	*108*	*7,500*	*1.2*	*0.35*
	11:16	12:02	46	2,800	1.0	0.31
	12:02	13:04	62	4,700	1.3	0.39

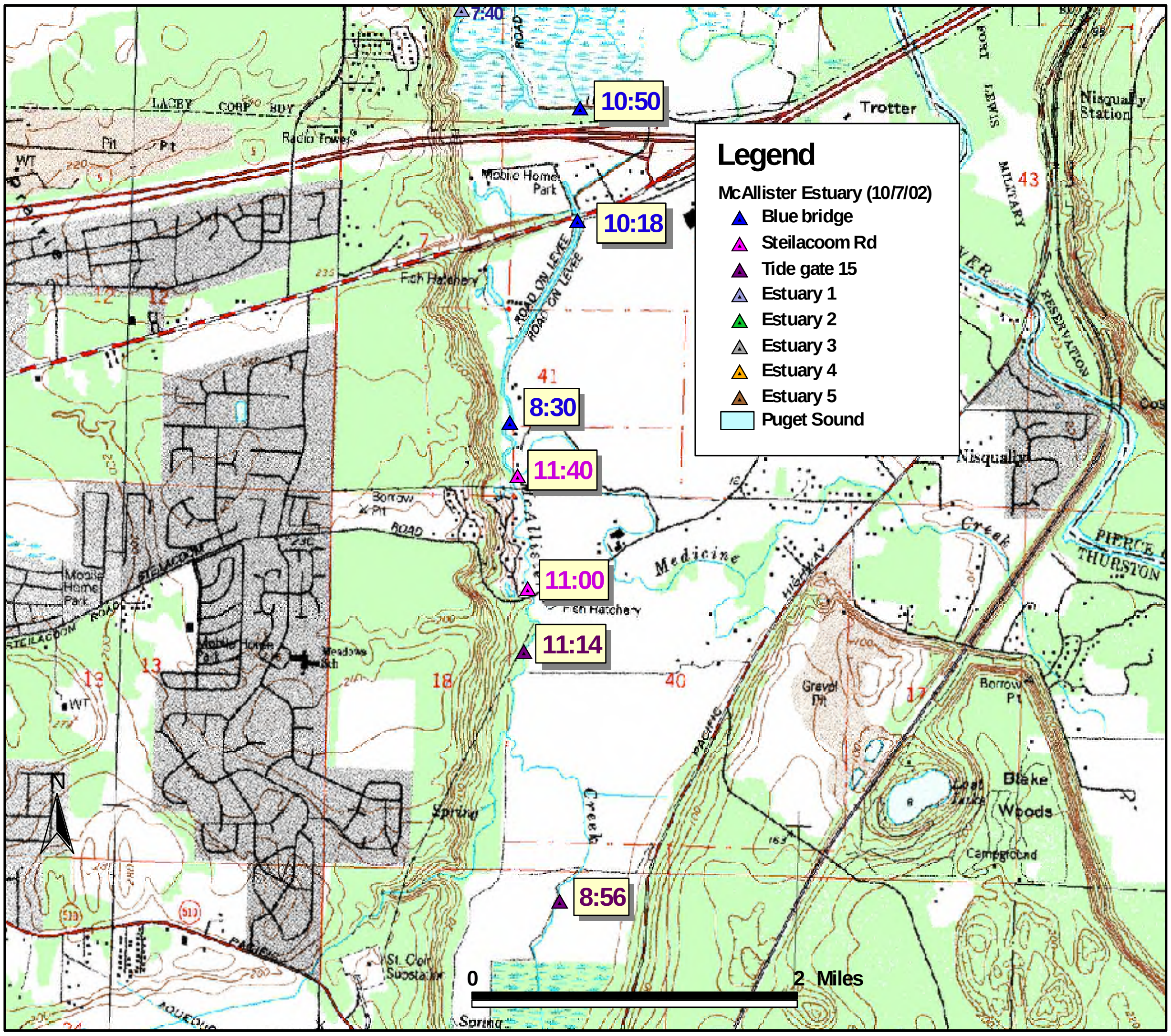

Figure I-1. Drogue locations for October 7, 2002 releases within McAllister Creek.

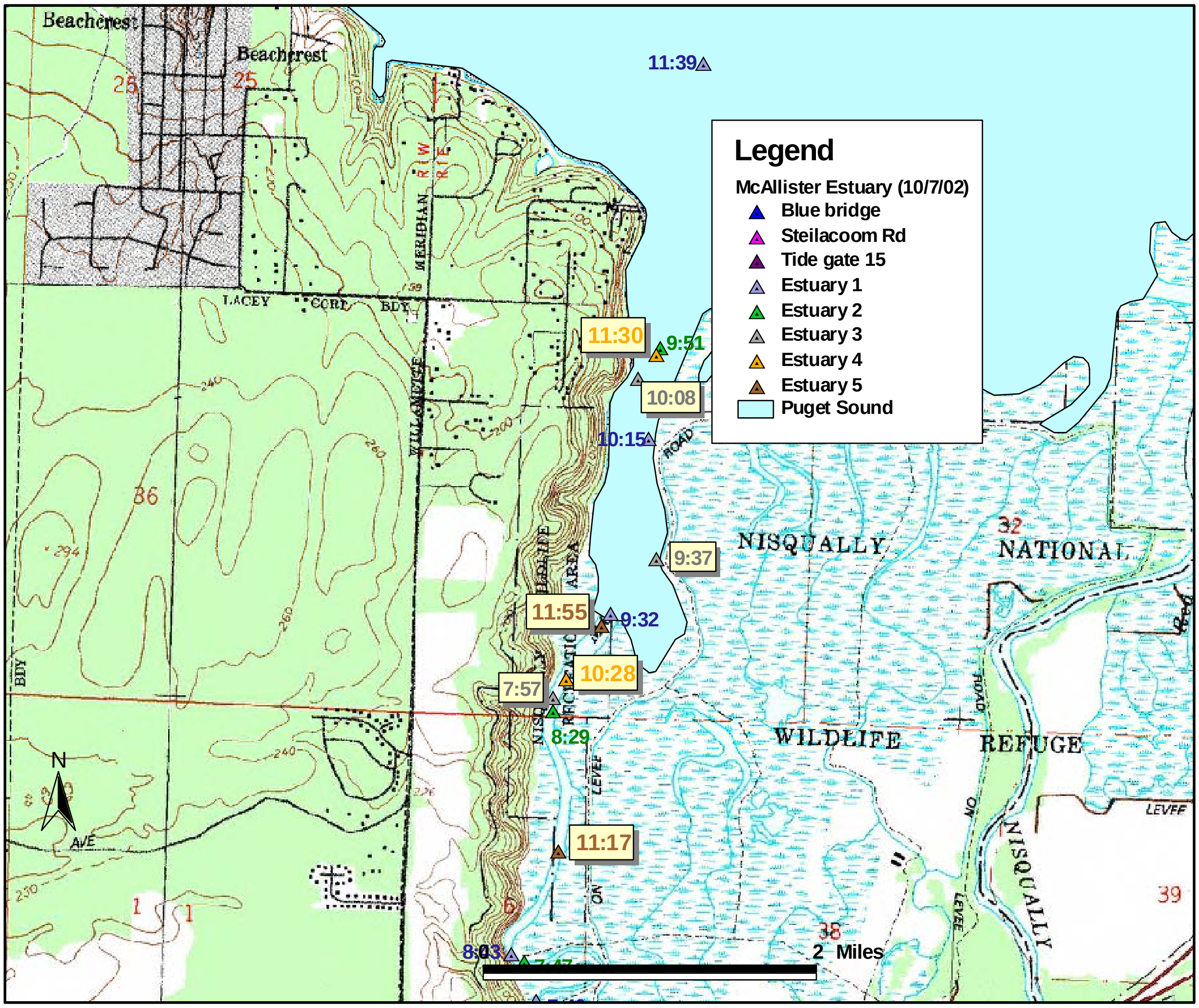

Figure I-2. Drogue locations for October 7, 2002 releases within McAllister estuary.

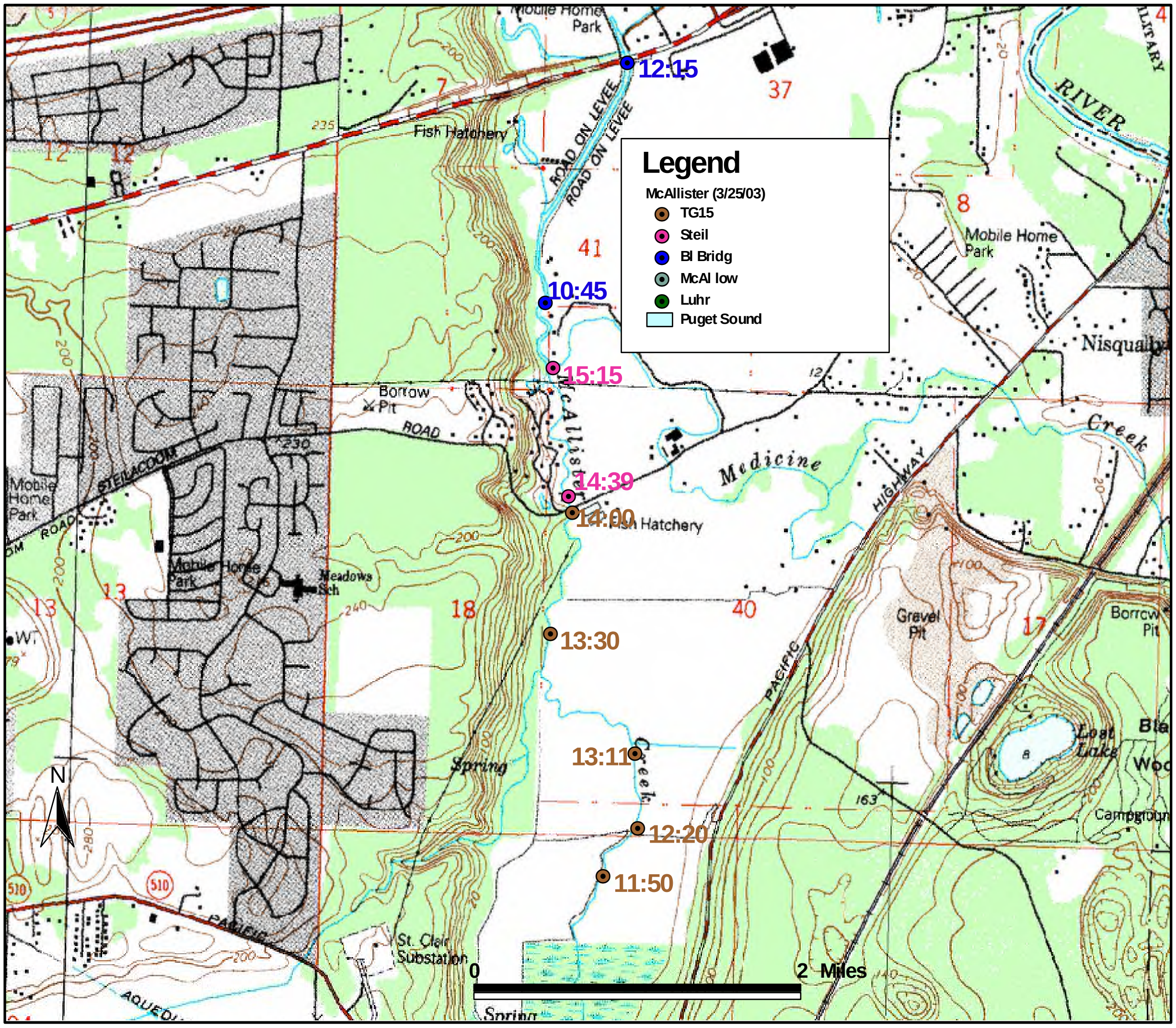

Figure I-3. Drogue locations for March 25, 2003 releases within McAllister Creek.

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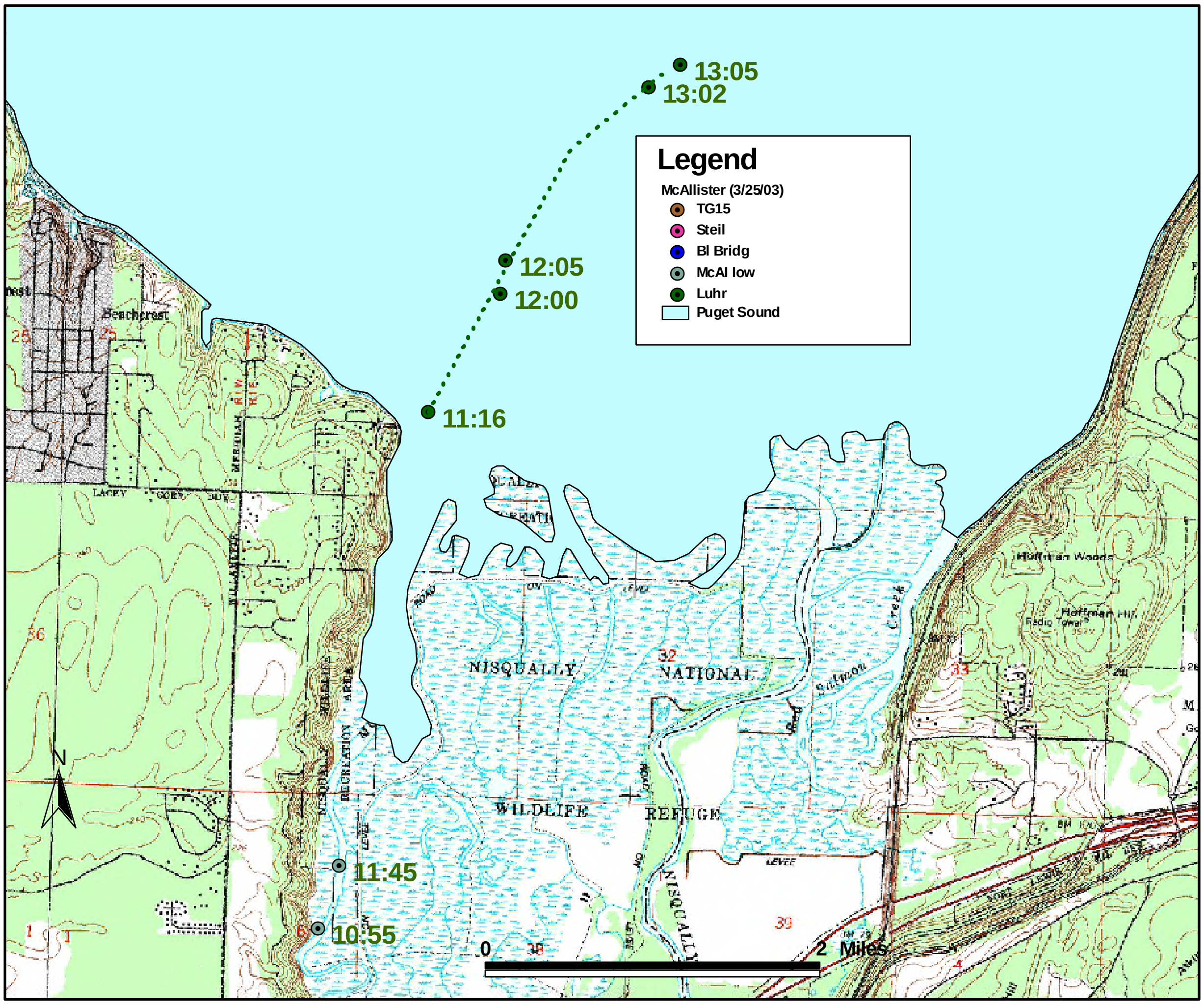

Figure I-4. Drogue locations for March 25, 2003 ebbing tide release near Luhr Beach.

Additional drogue releases occurred in July 2003 on low ebbing tidal velocities. On July 21, 2003, high tide occurred at 1:03 p.m. (9.0 ft), with an expected peak tidal current of 0.6 knots in the Nisqually Reach at 3:58 p.m. Drogues released at Martin Way averaged velocities of 1.3 ft/s (0.4 m/s) under the Interstate-5 bridge and out to the McAllister estuary, where tidal currents slowed significantly. A second drogue released on July 23, 2003 traveled 0.5 ft/s (0.15 m/s) between Little McAllister Creek and Steilacoom Road. Nisqually Reach tidal currents were expected to peak at 0.4 knots at 6:59 p.m. following a high tide at 4:05 p.m. (10.6 ft).

Table I-3 summarizes the data, and Figure I-5 presents the drogue locations. Velocities were of similar magnitude to those found in the March 2003 release through the McAllister Creek watershed.

Table I-3. Drogue releases and tracking data for July 21 and 23, 2003 (low ebbing tide velocity). *Italicized* values represent composite estimates for specific reaches.

Release	Start time	End time	Time (min)	Distance (ft)	Velocity (ft/s)	Velocity (m/s)
Little McAllister	*18:49*	*20:06*	*77*	*2,300*	*0.50*	*0.15*
Martin Way	*14:45*	*15:54*	*69*	*6,000*	*1.3*	*0.40*
	14:45	14:54	9	500	0.93	0.28
	14:54	15:54	60	5,000	1.4	0.42

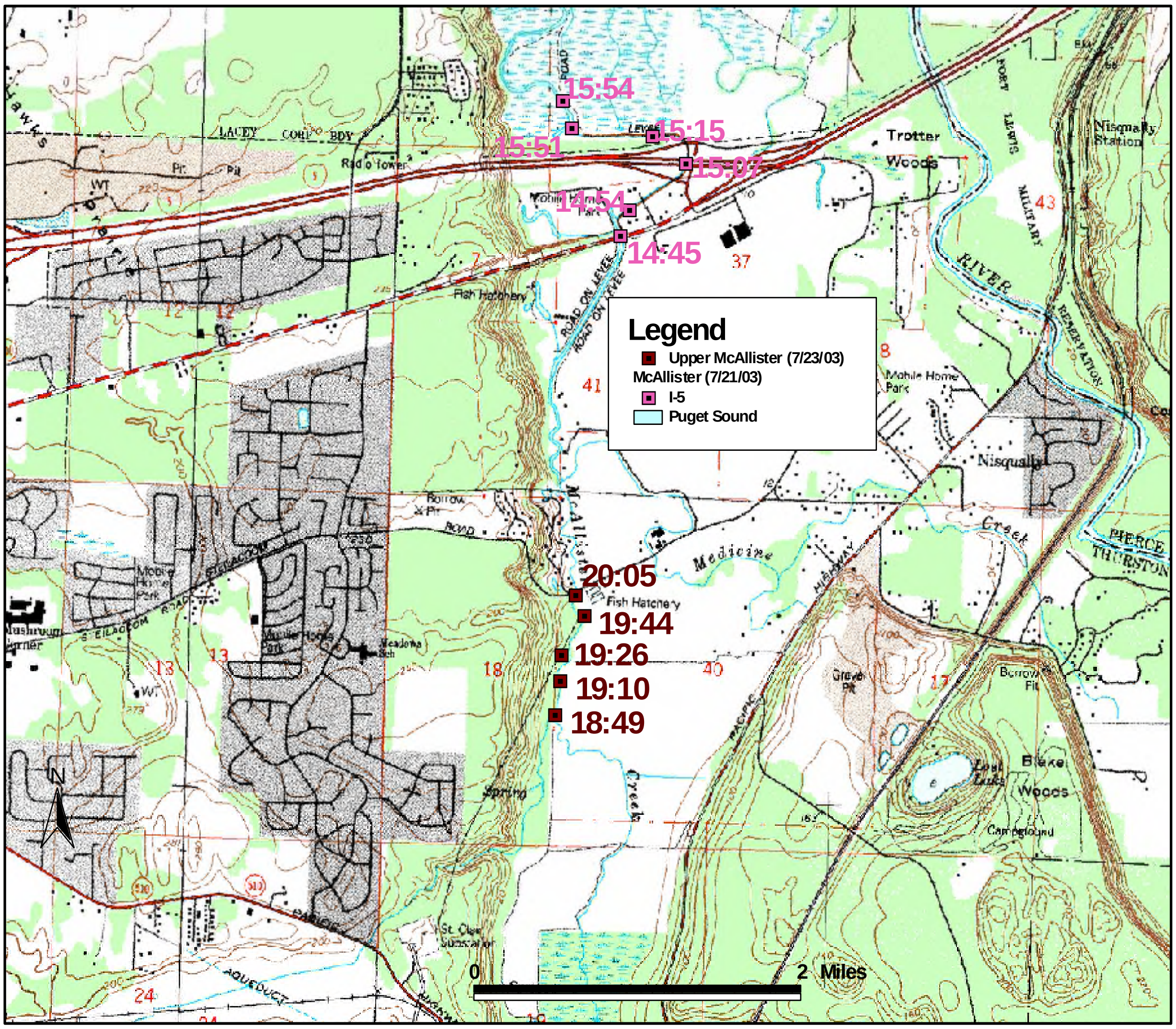

Figure I-5. Drogue locations for July 21 and 23, 2003 releases within McAllister Creek.

In summary, while drogue velocity varied within reaches of McAllister Creek, composite velocities averaged 0.7 ft/s during strong and moderate ebbing tidal velocities for the stretch between tide gate 15 and just downstream of the I-5 bridge. During a low ebbing velocity period in July 2003, the fastest reaches had velocities of 1.3 ft/s, compared with 1.5 ft/s during the larger tidal exchanges. Consequently, water parcels likely travel from the McAllister Creek springs to the I-5 bridge within five to six hours, or within a single high-to-low-tide cycle. Sources of bacteria to McAlister Creek near its headwaters can impact the southern estuary within a single tidal cycle. In the October 2002 estuary time-of-travel study for a strongly ebbing current, drogues traveled from just downstream of the I-5 bridge to Luhr Beach in three to four hours.

These two findings suggest sources to McAllister Creek within a two-hour travel time upstream of I-5 could influence water quality at Luhr Beach. Based on a typical creek velocity of 0.7 ft/s, the area of influence extends up to the Medicine Creek confluence. Areas upstream of Medicine Creek affect water quality at Luhr Beach and beyond over a 12-hour tidal cycle.

Luhr Beach to Tolmie State Park

On September 25, 2003, several drogue groups were released from the shoreline between Luhr Beach and Tolmie State Park. Table I-4 summarizes the data, and Figure I-6 presents the initial and final drogue locations.

Drogues were released approximately four hours after high tide (12.0 ft at 5:13 a.m.) and tracked through peak ebb tide velocity (1.4 knots at 9:21 a.m.) to low tide (0.6 ft at 11:47 a.m.). Luhr Beach drogues traveled the fastest (1.2 ft/s or 0.35 m/s) and the farthest (9,500 ft) from the release point, consistent with the March 25, 2003 findings associated with the ebbing-tide circulation pattern. During the ebbing tide, drogues released near the north end of Meridian Road initially traveled moderately quickly (0.15 ft/s) to the northwest but stalled near the headland southeast of Beachcrest. The DeWolf Bight release also traveled to the northwest at a velocity (0.13 ft/s) similar to that of the Meridian release. The Butterball Cove release, however, traveled to the southeast on the ebbing tide. The Tolmie release initially traveled toward the northeast but continued counterclockwise and stalled.

Table I-4. Drogue releases and tracking data for September 25, 2003 (low ebbing tide velocity). *Italicized* values represent composite estimates for specific reaches.

Release	Start time	End time	Time (min)	Distance (ft)	Velocity (ft/s)	Velocity (m/s)
Luhr Beach	*8:56*	*11:12*	*136*	*9,500*	*1.2*	*0.35*
	8:56	10:56	120	5,400	0.75	0.23
Meridian	*8:47*	*12:35*	*228*	*2,000*	*0.15*	*0.05*
	8:47	10:41	114	1,600	0.23	0.07
	10:41	12:35	114	400	0.06	0.02
DeWolf Bight	*8:39*	*10:36*	*117*	*900*	*0.13*	*0.04*
Butterball Cove	*8:34*	*10:32*	*118*	*800*	*0.11*	*0.03*
Tolmie State Park	*8:27*	*11:28*	*181*	*2,000*	*0.18*	*0.06*
	8:27	10:23	116	1,100	0.16	0.05
	10:23	11:28	65	900	0.23	0.07

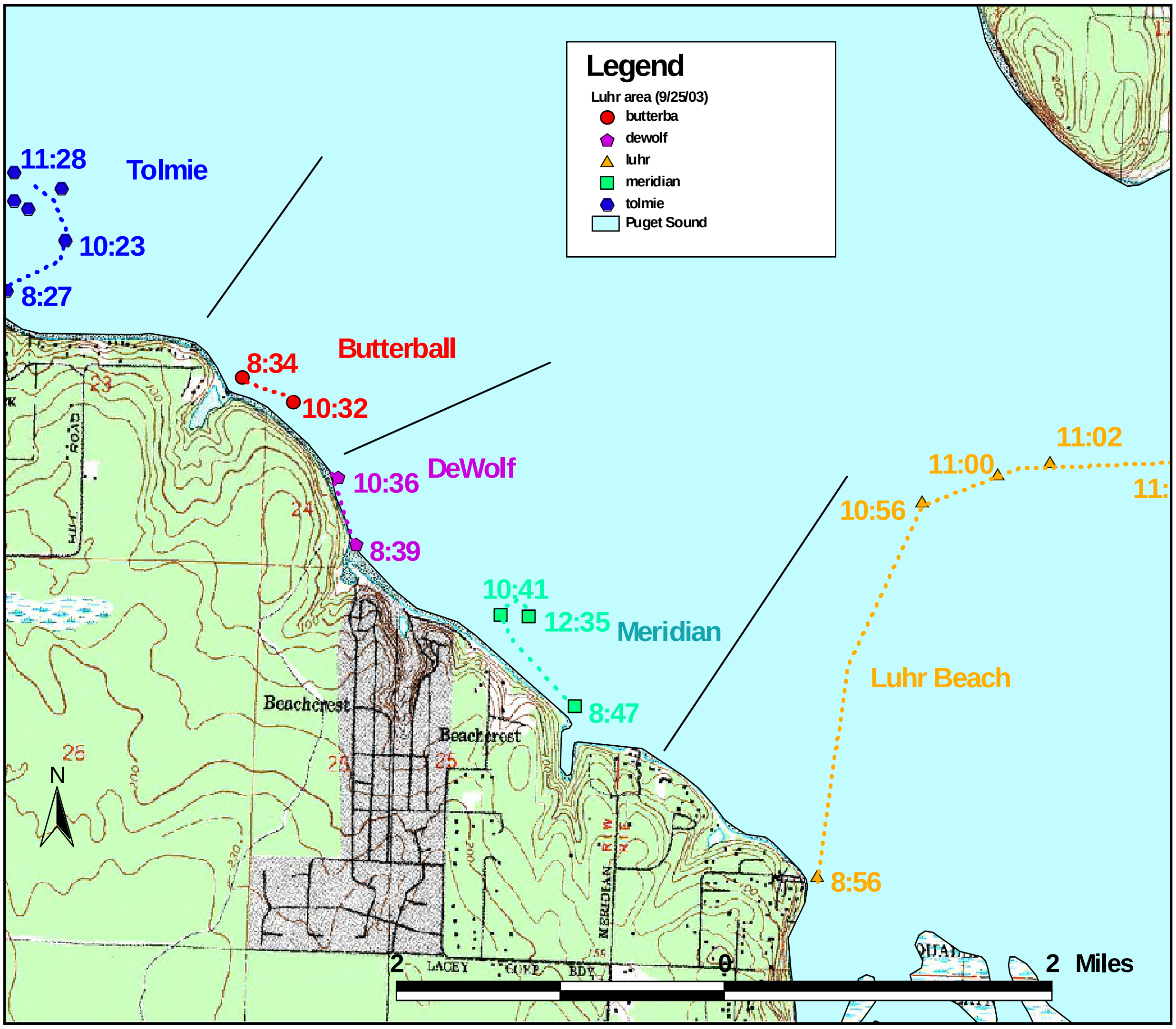

Figure I-6. Drogue locations for September 25, 2003 releases between Luhr Beach and Tolmie State Park.

During ebbing tides, conditions in McAllister estuary and near Luhr Beach appear to influence water quality to the north and east of Luhr Beach. Shoreline areas between Luhr Beach and Meridian Road appear to be the primary influence of water quality in that area. Water quality between Meridian Road and the headland northwest of Beachcrest appear to be governed by local conditions rather than by conditions northwest of Butterball Cove or near Luhr Beach. Finally, Tolmie-area shorelines appear to form an independent circulation cell, and local sources likely affect local water quality. These circulation patterns are consistent with the net shore drift cells presented in Schwartz and Hatfield (1982).

Appendix J

McAllister Creek Limiting Nutrients and Loading Analysis

Limiting Nutrients

Nutrients are required for algal development and growth. The nutrients of primary importance are phosphorus and nitrogen. The ratio of nitrogen to phosphorus is generally accepted as an indicator of which nutrient is more limiting or more likely to become limiting to algal growth (Carroll and Pelletier, 1991). The ratio of nitrogen to phosphorus (N:P) in algal biomass is approximately 7.2 to 1 on a mass basis. Hence an N:P ratio in stream water that is less than 7.2 suggests that nitrogen is the limiting nutrient (Chapra, 1997). It is generally assumed that, if the N:P ratio is less than 10:1, there is likely to be a nitrogen limitation. If the ratio is greater than 17:1, phosphorus is generally assumed to be the limiting nutrient (Carroll and Pelletier, 1991). Table J-1 describes the N:P ratio for each site based on the average total nitrogen and phosphorus levels for the samples obtained, the apparent limiting nutrient, and minimum and maximum dissolved oxygen levels.

A similar approach to looking at limiting nutrients is described by Lee and Jones-Lee (1998), where the ratios of available nitrogen (ammonia and nitrate) and available phosphorus (orthophosphate) are compared for the period of maximum algal mass. For McAllister Creek, that period is during July and August. Lee and Jones-Lee (1998) state that if the ratio of concentrations is substantially less than 7.5 to 1, nitrogen is potentially limiting. The ratios of available nitrogen and phosphorus are described in Table J-1. If the ratio of nitrogen to phosphorus was less than 7, the site was assumed to be nitrogen limited; if greater than 16, the site was assumed to be phosphorus limited.

Excessive nutrients (phosphorus and nitrogen) were seen at most sites on McAllister Creek, as well as in the tributaries and tide gates. All of the mainstem sites showed a ratio indicating a very slight nitrogen limitation. Most of the tide gates on the east bank were also nitrogen limited and have very low dissolved oxygen levels. Most of the west bank tributaries were phosphorus limited with the exception of tide gates 1 and 2.

Phosphorus is greatly affected by sediment oxygen levels. A number of investigators have theorized that phosphorus in the aerobic sediment surface layer is sorbed to precipitated iron hydroxides. Such attachment impedes transfer back into the water. When oxygen levels drop, the iron hydroxides are dissolved as they become reduced. This leads to an associated release of dissolved phosphorus into the sediment pore waters where it is free to diffuse into the overlying water (Chapra, 1997). At low tide, the tide gates drain an extensive agricultural ditch system.

Soils in the basin include mucky hydric soils, and they are frequently water saturated, depriving plant roots of oxygen during the growing season (Thurston County WWM, 1993). In addition, flow in the ditches is restricted to low tide. Higher phosphorus levels and low dissolved oxygen are likely somewhat due to natural wetland conditions and to the tide gate drainage system, especially on the east bank. Little McAllister Creek provides the majority of water discharge from tide gate 11, and it is the likely reason that tide gate 11 has higher dissolved oxygen levels and is phosphorus limited for nutrients.

Table J-1. Dissolved oxygen values and limiting nutrients for McAllister Creek sites.

Site	DO (min) mg/L	DO (max) mg/L	Total N:P ratio	Available N:P ratio	Limiting nutrient
McAllister Creek RM 5.8	5.3	7.3	5.7	6.1	Nitrogen
Tide gate 15	3.1	5.6	0.8	0.1	Nitrogen
Tide gate 14	2.1	3.6	1.4	0.5	Nitrogen
Tide gate 13	0.4	2.4	1.2	1.3	Nitrogen
McAllister Creek RM 5.4	5.8	7.4	4.7	4.7	Nitrogen
Tide gate 12	0.5	6.2	4.5	3.0	Nitrogen
Tide gate 11	7.4	8.9	35.4	49.1	Phosphorus
Culvert at tide gate11	7.2	8.9	56.0	137.3	Phosphorus
Tide gate 10	1.6	5.1	3.7	3.2	Nitrogen
Tide gate 9	0.8	5.5	2.1	1.0	Nitrogen
McAllister Creek RM 4.7	5.7	7.6	5.7	6.2	Nitrogen
Tide gate 8	4.9	5.6	1.0	No summer flow	Nitrogen
Tributary at RM 4.6			14.8	131.4	Phosphorus
McAllister Creek 4.5	7.0	8.2	5.9	6.2	-
Tributary at RM 4.4 upstream			6.2	53.2	Phosphorus
Tributary at RM 4.4 downstream			11.4	46.6	Phosphorus
Medicine Creek at RM 0.3	0.7	3.8	2.1	2.5	Nitrogen
Medicine Creek at RM 0.0	6.8	7.4	6.9	12.2	-
McAllister Creek RM 4.35	6.2	8.4	6.2	6.4	Nitrogen
Tributary from pond RM 4.34			23.3	35.5	Phosphorus
Tributary at McAllister Creek RM 4.3	6.0	8.4	19.0	24.2	Phosphorus
McAllister Creek RM 4.3	5.9	7.2	6.4	6.5	Nitrogen
Tide gate 5	2.8	5.0	3.8	9.9	-
Tide gate 4	3.3	6.2	3.4	14.1	-
Tide gate 3	4.2	7.5	2.9	1.4	Nitrogen
McAllister Creek 3.7	6.5	7.5	6.4	6.7	Nitrogen
Tide gate 2	3.2	9.2	3.2	4.6	Nitrogen
Tide gate 1	7.0	9.4	3.1	12.4	-
Stormwater discharge at I-5			1.7	1.2	Nitrogen
McAllister Creek RM 3.1	5.8	7.9	6.9	7.0	-
Tide gate B	4.4	9.1	2.3	No data	Nitrogen
Tide gate A	0.6	9.7	2.3	1.4	Nitrogen
McAllister Creek RM 1.5	6.4	7.5	5.4	No data	-
McAllister Creek RM 0.1	6.8	7.7	5.6	6.6	Nitrogen
DOH shellfish station 224	5.5	8.9	6.4	5.8	Nitrogen

Nutrient Loading

To determine if nutrients could be contributing to excessive plant growth in the creek, a mass balance was performed using nutrient concentrations and loading at McAllister RM 5.8 as the natural, or background, condition. As mentioned, McAllister Creek RM 5.8 is at the downstream end of a large wetland complex that is not diked or drained, as is the creek downstream.

As mentioned in the section on fecal coliform loading, McAllister Creek mainstem loading can only be estimated, due to difficulty in obtaining flow measurements in a tidally-influenced area. To calculate nutrient loading on McAllister Creek, flow estimates provided by the Pacific Groundwater Group (2000) were used, as with the fecal coliform loading estimates. Precipitation was about 20% higher than the long-term average during the Pacific Groundwater Group flow study. Therefore, estimates shown below may also be about 20% higher than the long-term average. The arithmetic average of all nutrient data for a site was used to estimate nutrient loading. Nutrient concentrations at McAllister RM 5.8 were assumed to represent natural nutrient input.

Tables J-2 and J-3 describe estimates of total phosphorus and nitrogen loading currently found at the McAllister mainstem sites. Both tables also include an estimate of what nutrient loading should be at each site if input concentrations of nutrients were equivalent to those seen at McAllister RM 5.8 and how much reduction in nutrients is needed to meet RM 5.8 nutrient levels.

Table J-2. Estimate of total phosphorus loading in McAllister Creek and reductions needed to meet total phosphorus levels seen at McAllister RM 5.8.

McAllister Creek site or inflow	Average total phosphorus concentration (± 1 standard deviation in parentheses)	Estimated flow (cfs)	Estimated total phosphorus in pounds per day (± 1 standard deviation in parentheses)	Total phosphorus reduction needed to meet RM 5.8 levels (based on average value)
RM 5.8	*0.161 mg/L (0.136-0.186 mg/L)*	*28.0*	*24 (21-28)*	*Background: 0% reduction*
RM 5.8-4.3 inputs*		32.2	28 (24-32)	
MC4.3 should be	0.180 mg/L (0.153-0.206 mg/L)	60.2	52 (44-60)	10% reduction
MC4.3 is		60.2	58 (50-67)	
RM 4.3-3.7 inputs*		7.1	6 (5-7)	
MC3.7 should be	0.189 mg/L (0.170-0.207 mg/L)	67.3	64 (55-74)	6% reduction
MC3.7 is		67.3	68 (62-75)	
RM 3.7-3.1 inputs*		2.1	2 (2-2)	
MC 3.1 should be	0.181 mg/L (0.157-0.205 mg/L)	69.4	70 (63-77)	0% reduction
RM 3.1 is		69.4	68 (59-77)	

* Loading is based on a concentration of 0.161 mg/L of total phosphorus.

Table J-3. Estimate of total nitrogen loading in McAllister Creek and reductions needed to meet total nitrogen levels seen at McAllister RM 5.8.

McAllister Creek site or inflow	Average total nitrogen concentration (± 1 standard deviation in parentheses)	Estimated flow (cfs)	Estimated total nitrogen in pounds per day (± 1 standard deviation in parentheses)	Total nitrogen reduction needed to meet RM 5.8 levels (based on average value)
RM 5.8	*0.921 mg/L (0.878-0.963 mg/L)*	*28.0*	*139 (133-145)*	*Background: 0% reduction*
RM 5.8-4.3 inputs*		32.2	160 (152-167)	
MC4.3 should be	1.143 mg/L (1.024-0.261 mg/L)	60.2	299 (285-313)	19% reduction
MC4.3 is		60.2	371 (332-409)	
RM 4.3-3.7 inputs*		7.1	35 (34-37)	
MC3.7 should be	1.204 mg/L (1.116-1.292 mg/L)	67.3	406 (366-446)	7% reduction
MC3.7 is		67.3	437 (405-469)	
RM 3.7-3.1 inputs*		2.1	10 (10-11)	
MC 3.1 should be	1.246 mg/L (1.155-1.337 mg/L)	69.4	447 (415-480)	4% reduction
RM 3.1 is		69.4	466 (432-500)	

* Loading is based on a concentration of 0.921 mg/L of total nitrogen.