Inventory of Created Wetlands, Duck Creek, Juneau, Alaska

Baseline Data for Assessment of Existing Created Wetlands and Future Wetland Creation Sites

Final Report for work performed between 2004 -2008

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BACKGROUND

Wetlands are a valuable component of a watershed, serving important functions including storm and flood water retention, shoreline protection and water-quality improvement as well as providing wildlife habitat[1]. Storm and flood water retention and to some extent shoreline protection result from the wetland's ability to store large volumes of water within saturated soils. The chemical conditions that dominate in the saturated soil of wetlands in turn provide for improvements in water quality. Nitrate, sulfate and phosphate levels are moderated, the oxidation of organic carbon to inorganic carbon promotes carbon storage as carbonate minerals and metal species are immobilized via precipitation as insoluble salts. The latter function of wetlands is especially important in wetlands of marine origin where sulfate levels are significant and anaerobic conditions produce significant levels of sulfide. The importance of wetlands as a vital watershed component has become increasingly apparent as development pressure on original wetland areas continues to diminish their number and acreage. Municipalities as well as state and federal agencies have employed significant resources in efforts to accommodate needs for developable land while maintaining functional wetland systems. While preservation of existing wetlands and their supporting water systems is the most obvious solution, it is not always the most economically feasible. Other approaches include wetland creation or restoration as compensation for wetland destruction in another area of a watershed.

Duck Creek flows south through the densely populated Mendenhall Valley, approximately 10 miles northwest of Alaska's capital city of Juneau (see Figure 1). The watershed area of Duck Creek lies within that of the Mendenhall valley, which in turn drains into a major estuarine wetland before entering the inland coastal waterway. The main stream of Duck Creek along with two tributaries, East Fork and El Camino, drain approximately 1080 acres (1.7 square miles)[2]. Duck creek once supported a large spawning population of chum salmon but now only remnant populations of coho salmon, cutthroat, and Dolly Varden are found. High density urban development in the Mendenhall valley in the 1960's coincided with the demise of the chum salmon population. Continued development pressure throughout the Duck Creek corridor suggests the remaining anadromous fish species risk a similar fate. Stormwater and septic discharge, poorly installed culverts, gravel mining activities, channel relocation and filling of associated wetland areas all contribute to the declines in habitat and water quality on Duck Creek. The percentage of impermeable surfaces adjacent to the stream corridor is estimated at 36% of that present prior to the development of the 1960s[3]. Between 1994 and 2001 Duck Creek was listed on the State of Alaska's 303(d) list of impaired water bodies for deficiencies including low DO, residues, metals, fecal coliform, and turbidity. Since 1998 Duck Creek has been the target of federal, state and local agency efforts at restoration and in 2002 Duck Creek was removed from the Section 303(d) list and placed into category 4a.

Figure 1: Aerial photograph of the Duck Creek watershed, circa 1995.

One of the more persistent impairments to Duck Creek has been reduction of water quality through groundwater intrusion. Throughout the urban development of the Duck Creek watershed, minor relocations of the streambed were made in order to facilitate construction. Oftentimes these relocation events allowed intrusion of the shallow, anaerobic and iron-rich groundwater common to Southeast Alaska. Oxygen-free groundwater, while maintained at circumneutral pH is capable of solvating large amounts of iron(II). Upon exposure to atmospheric oxygen, the dissolved iron(II) is oxidized to iron(III) which readily precipitates over a wider range of pH values as finely-divided $Fe(OH)_3(s)$ (often referred to as “iron floc”). The process is similar to that which occurs in acid-mine drainage:[4]

$$Fe^{2+}(aq) + \frac{1}{4}O_2(aq) + H^+(aq) \rightarrow Fe^{3+}(aq) + \frac{1}{2}H_2O(l) \qquad \textbf{(1)}$$

$$Fe^{3+}(aq) + 3H_2O(l) \rightarrow Fe(OH)_3(s) + 3H^+(aq) \qquad \textbf{(2)}$$

The insoluble iron(III)hydroxide coats any substrate with which it comes in contact blocking out dissolved oxygen and severely degrading the habitat quality of the stream.[5] The process also produces a net 2 moles of acid-equivalents (H^+) per mole of iron(II) oxidized thus driving the pH down and further impacting the ability of the stream to support aquatic life.

The University of Alaska Southeast (UAS), in partnership with the National Marine Fisheries Service (NMFS), Southeast Conference of Alaska, the State of Alaska Department of Environmental Conservation (ADEC) and the U.S. Fish & Wildlife (USFWS) have pursued restoration efforts on Duck Creek since 2001. UAS has engaged primarily in assessments of improved water quality and habitat resulting from early stream bed and bank improvements throughout the main reach of Duck Creek and in particular wetland creation along the East Fork of Duck Creek. The UAS effort seeks to provide continuity from early to current efforts at stream restoration by providing biological and physical data for use in assessments of progress.

Wetland creation in the watershed has taken place along the East Fork, in dredge ponds that were excavated in the 1950’s to provide gravel fill for road construction (Figure 2). Flow through the ponds is northeast to southwest and they are identified historically, from north to south as the Allison pond (AP), the Church of the Nazarene pond (CoN), the Nancy Street pond (NS) and the Forest Service pond (FS). In 1998 NMFS converted the CoN pond to a wetland area[3]. This created wetland is now referred to as the CoN wetland. The CoN wetland was originally constructed to serve as a stormwater runoff treatment site but has since shown increasing potential for sulfate and iron storage as well as overwintering habitat for salmonids. In September 2005 conversion of the NS pond to a wetland was began and was completed in September 2006. The NS wetland also serves as a stormwater runoff treatment site and provides habitat for overwintering coho salmon, cutthroat trout and Dolly Varden char.

Figure 2: Aerial photograph of the East Fork of Duck Creek (circa 2000) showing, from north to south (upper to lower), Allison pond (AP), Church of Nazarene (CON) created wetland, unimproved Nancy Street (NS) pond and the Forest Service (FS) pond. Sampling sites are indicated in this photograph.

The two ponds at the north and south extreme of the East Fork of Duck Creek remain as they were originally excavated. The Allison pond, located at the north end of the East Fork, is considered an excellent candidate for wetland creation and discussions for CBJ access to the property have been initiated. At the south end of the East Fork lies the

Forest Service pond which provides excellent habitat for wintering fish and plans are to preserve that pond in its current state.

PURPOSE AND OBJECTIVES

The purpose of the partnership between the USFWS and UAS is to evaluate the efficacy of past and recent efforts at habitat restoration activities along the East Fork of Duck Creek in Juneau, Alaska. Through measurements of water quality parameters along the East Fork and assessments of wetland characteristics at the two created wetland sites, collected between 2004 and 2007, this study has shed light on the potential of remediation efforts to improve water and habitat quality. The bulk of the collected data originates from the created wetlands and thus provides direct evidence but the project has also produced baseline data from the unimproved ponds along the East Fork and that data will allow comparisons that may guide future restoration efforts in Duck Creek and similar drainages.

In an addition to presenting and interpreting the data collected for this project, additional data collected from other sites on Duck Creek shall be discussed. Working with Dr. S. Nagorski (UAS) and Dr. E. Hood (UAS) under an Alaska Clean Water Act (ACWA) grant from the ADEC, the author has collected water quality data from Duck Creek sites upstream and downstream of the East Fork.

METHODS

From 2004 through March of 2008, bi-monthly water quality parameters (WQPs) were measured and water samples collected at twelve sites within each of the four East Fork locations; AP (APa, APb), CON (CoN2, CoNb, CoNc, CoN3) NS (NSa, NSb, NSc, NSd) and FS (FSa, FSb). Analogous data has been collected on a semi-regular basis at several but not all locations along the East Fork under various programs since 2001. WQPs measured include dissolved oxygen (DO), temperature (T), conductivity, pH and turbidity. Water samples were analyzed for standard anion concentrations (choride, nitrite, nitrate and sulfate), base cation concentrations (sodium, ammonium, potassium, magnesium and calcium) and dissolved iron concentrations. Data collection at the NS location was halted during 2005 and 2006 due to construction associated with the wetland conversion.

Surface water measurements and sample collection were carried out along the East Fork at the sites indicated in Figure 2. Dissolved oxygen, temperature and conductivity measurements were determined with an YSI 85 field meter and pH measurements were carried out with a Thermo Orion 250 handheld pH meter. Both instruments were calibrated against standards prior to each use. Reported conductivity values are temperature corrected by the YSI 85 meter. Samples were collected in HDPE bottles at ~6” below the surface in water of ~24” depth. Samples were returned to the laboratory where a portion was used to determine turbidity. Turbidity measurements were conducted with a Hach 2100P turbidimeter. The remaining sample was filtered through a 0.45 μm membrane filter and split. One portion was acidified (HNO_3(conc) or

HCl(conc), depending on the analyses to be performed) and the other left unpreserved. Acidified samples were stored at 5^o C and neutral samples were frozen until analysis. The neutral samples were analyzed for anion and cation concentrations by ion-exchange chromatography (Dionex DX-500, AS12A/$NaHCO_3$/Na_2CO_3, CS12A/H_2SO_4 resp.). Samples acidified with nitric acid were analyzed for total dissolved iron while samples acidified with hydrochloric acid were analyzed for iron(II) and iron(III) distributions. Iron analyses were carried out according to the ferrozine method[6].

In August of 2004, 2006 and 2007 the CON wetland characteristics (water depth, per cent cover, live stems and species) were determined. In August 2007 an analogous inventory was carried out on the newly created NS wetland. The wetland inventories were performed by dividing the wetland into transects of various length. Each transect was then sampled at evenly-spaced intervals. The CON wetland included 4 transects with sampling points every 10 m. The NS wetland included 6 transects with sampling points every 10 m. Per cent cover, number live stems and plant species were determined with a quadrant at all sampling points. Plant matter within a quadrant was cut and collected at a number of sampling points, chosen so as to provide a typical distribution of plant cover within each wetland site. Annual biomass production was determined by drying and weighing the plant matter to give an average mass of plant matter per unit area.

Total biomass generated in the CON wetland was determined by choosing representative quadrants throughout the wetland and cutting all plant matter to ground level. The plant matter was then thoroughly dried and weighed. The mass of plant matter found in each transect was considered representative of all transects with similar % plant cover. Five types of transects were identified based on the % plant cover. Using the total number of transects with similar % cover as a scaling factor, weighted average of plant matter in g/m^2 was calculated from this data (Table 8). The total biomass generated during a growing season was determined by multiplying the total m^2 of the wetland (4047 m^2) by the plant mass/m^2.

In October 2004 and October 2007 population estimates of juvenile coho salmon were made at the CON wetland. In October 2007 population estimates of juvenile Coho salmon were made at the FS pond, the NS wetland and the CON wetland. Minnow traps accessible only to juvenile coho salmon were baited with salmon eggs, set throughout each wetland and left for ~18 hours. The traps were collected and all fish within the traps counted and identified. Coho salmon and Dolly Varden were measured for length. The coho salmon were then marked (fluorescent dye or the dorsal fin clipped) and all fish released. The traps were reset, retrieved after ~18 hours and all fish counted and identified with attention to recapture of the marked coho. Population estimates of juvenile coho within each wetland was determined as described by Ricker [7].

RESULTS

Water quality measurements at various sites along Duck Creek, funded through this project as well as others provide a broad view of water quality developments since the creation of the CON and NS wetlands. Data collected from the main stem of Duck Creek at sites upstream and downstream from the created wetlands along the East Fork, allows for an assessment of changes to water quality upon passing through the created wetlands of the East Fork. The site downstream of the East Fork is referred to as DC1 and is located at a section of Duck Creek where, in addition to receiving water from the created wetlands, culvert replacement, streambed lining and bank revegetation was undertaken through an improvement project funded by the National Marine Fisheries Service[3]. The site upstream from the East Fork is referred to as DC3 and is located on an unimproved section of Duck Creek that is subject to groundwater intrusion, streambank erosion and heavy urban pollutant inputs (e.g. fuel oil discharges).

Table 1 presents average warm and cold water quality parameters for the two sites along the main tributary of Duck Creek (DC1, DC3) as well as for selected East Fork sites. Warm conditions correspond to temperatures above 10^{o}C and cold conditions to those below 10^{o}C. Data for sites FS and AP are average values from two sampling locations at each of these sites while the information provided for CON and NS originates from a single sampling location at the outlets of these water bodies.

Table 1: Water quality parameters collected between July 2004 and December 2007 at sites along Duck Creek for warm and cold conditions.

	DC1[a]	**FS(a+b)**	**NSd**	**CoN2**	**AP(a+b)**	**DC3[a]**
T (^{o}C) warm	13±2	15±2	14±3	14±2	15±2	11±0.8
T (^{o}C) cold	4±3	5±3	5±4	5±3	6±3	6±2
DO (ppm) warm	8.1±1.0	8.3±1.6	7.3±1.4	6.2±1.5	7.4±1.7	4.5±2.1
DO (ppm) cold	9.8±1.5	8.4±2.5	6.3±2.2	5.3±2.0	5.2±2.2	5.1±2.1
Conductivity (μS/m^2) warm	182±11	141±27	144±20	145±19	143±19	167±66
Conductivity (μS/m^2) cold	152±38	104±28	125±40	122±28	111±15	212±57
pH warm	7.2±0.3	7.2±0.3	6.8±0.3	6.7±0.4	6.6±0.4	6.9±0.2
pH cold	6.7±0.5	7.1±0.6	6.4±0.5	6.3±0.4	5.9±0.6	6.4±2.0
Turbidity (NTU) warm	8±5	7±4	18±18	11±9	12±9	29±11
Turbidity (NTU) cold	12±10	14±8	28±22	19±6	22±10	17±18

[a] Data collected under grants received from the National Marine Fisheries Service and the Alaska Department of Environmental Conservation, Alaska Clean Water Action.

Field data from the Duck Creek stream corridor suggest restoration and wetland enhancement efforts are influencing water quality. Average dissolved oxygen levels tend to increase moving south (downstream) along the stream channel through the various improvement projects. The lowest DO levels are found on the main stem at unimproved DC3. Conductivity and pH levels at DC3 are highly variable, particularly during low flow (i.e. cold periods) when groundwater dominates. At the sampling location furthest downstream, DC1, field measurements of water quality show consistently high DO levels and relatively stable pH and turbidity values. Conductivity values are high and flashy at this site due presumably to its proximity to two major transportation corridors. As shown later in discussions of dissolved solutes, the primary contributors to the higher conductivity values correspond to salts used for road de-icing.

Figure 3 illustrates DO data collected at the inlet and the outlet of the CON wetland over a 7 year period. While increases in DO levels are not immediately apparent from this illustration, a moderating effect for this parameter appears to develop as the wetland ages. The extreme high and extreme low values that are still observed at the inlet and at the upstream, unimproved AP pond (data not shown) are eliminated as water moves through the created wetland.

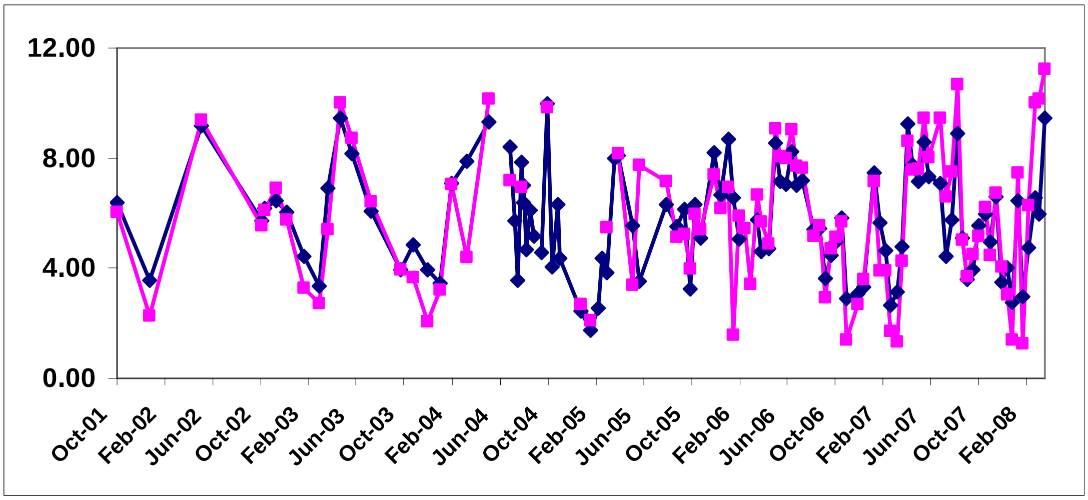

Figure 3: Dissolved oxygen levels (mg/L) at the inlet (—■) and outlet (—♦) of the CON wetland.

Among the four East Fork locations, the lowest DO levels are found at the CON location, a result consistent with the anaerobic environment that dominates this freshwater wetland. It is noted that dissolved oxygen (D.O.) levels were acceptable within the channel of CON while the periphery of the wetland exhibited D.O. levels characteristic of an anaerobic system. Within each East Fork location, increasing DO levels during the warmer months are observed and can be associated with submerged and partially submerged plant growth. Differences are further accentuated due to freezing of large areas of surface water during the colder months resulting in limited dissolution of atmospheric oxygen. Conductivity is relatively consistent during warm periods at the four locations but is higher at the two wetland sites during cold, low-flow periods. Moving downstream from the AP location, through the two created wetlands and into the FS location, pH tends from acidic towards more neutral values. The AP, CON and NS locations are identified with larger degrees of groundwater intrusion compared to FS which may be responsible for increased hydrogen ion equivalents at these locations (reaction 2). Turbidity levels are scattered across the four locations where the large standard deviations observed for NS are most likely associated with construction activities from September 2005 through September 2006.

Table 2 presents analogous data on samples collected from the outlet of the NS site but for this table the NS data has been further categorized into pre-wetland construction (July 2004 through September 2005) and post-wetland construction (September 2006 through March 2008). Table 2 reveals small but noticeable changes to the system since the renovation efforts. Water temperature and pH levels appear to have stabilized between warm and cold periods, DO levels have increased slightly and conductivity has decreased. While each of these improvements to water quality is tenuous given the standard deviations associated with the values, the trend suggests further improvement can be anticipated as the created wetland continues to develop.

Table 2: Water quality parameters for the NS location (outlet sampling site) pre and post wetland conversion.

	7/04 – 4/05	9/06 – 3/08
T (^oC) warm	16.7±1.6	13±3
T (^oC) cold	5.0±2.5	3.9±2.8
DO (ppm) warm	6.2±1.3	8.6±1.7
DO (ppm) cold	5.7±2.6	6.6±2.0
Conductivity (μS/m^2) warm	135±8	124±44
Conductivity (μS/m^2) cold	147±35	103±14
pH warm	7.0±0.2	6.7±0.2
pH cold	6.3±0.4	6.5±0.5
Turbidity (NTU) warm	5.4±3.4	13±9
Turbidity (NTU) cold	23±10	19±6

Extensive collections of all water quality data collected at each of the twelve sites within the four East Fork locations is found in Appendix 1 (Tables A1 – A12).

Groundwater Intrusion One of the more visible water quality impairments on Duck Creek is heavy deposits of iron floc resulting from groundwater intrusion. The furthest upstream sampling location, DC3, represents one of the more severely impacted locations along the main stem (Figure 4). A sampling site within the CON location and referred to as CoNb is also subject to large inputs of groundwater and heavy deposits of iron floc. High levels of dissolved iron often characterize water samples from both of these sites. Diminished dissolved oxygen (DO) levels due to reaction 1 and low pH values due to reaction 2 are associated with this impairment. The capacity of the wetland system to moderate the effects of groundwater intrusion is illustrated by comparing water quality parameters measured at the CoNb sampling site to those at the CoN2 site (Table 3). The CoN2 site is approximately 60 feet from CoNb and the intervening wetland area is heavily vegetated with horsetail and average water depths of 8 inches. The short run through the vegetated CON wetland produces measureable increases in DO and pH. The higher DO and pH values of water exiting the CON wetland are more in compliance with those values identified by the Alaska Department of Environmental Conservation as acceptable for aquatic life.[8]

Water temperature is influenced by groundwater intrusion. Inflow of constant temperature subsurface water tends to moderate variations in surface water temperatures. This effect is apparent in comparisons of warm and cold average temperatures at CoNb and DC3 compared to CoN2. Warm temperatures at the CoN2 outlet often exceed the 13^{o}C limit for egg and fry incubation and spawning and occasionally exceed the 15^{o}C limit for migration routes and rearing areas.[8] The warm period of 2004, from June through August resulted in CoN2 water temperatures exceeding the DEC criteria on several occasions.

Figure 4: Photograph (3/20/07) of upstream site DC3 showing heavy deposits of $Fe(OH)_3$.

Table 3: Average water quality data from 2004 to 2007 for Duck Creek sites subject to groundwater infiltration.

	CoNb	DC3	CON2
T (^oC) warm	13±2	11±0.8	14±2
T (^oC) cold	6±3	6±2	5±3
DO (ppm) warm	3.5±1.3	4.5±2.1	6.2±1.5
DO (ppm) cold	2.3±2.0	5.1±2.1	5.3±2.0
Conductivity ($\mu S/m^2$) warm	123±16	167±66	145±19
Conductivity ($\mu S/m^2$) cold	101±32	212±57	122±28
pH warm	6.4±0.4	6.9±0.2	6.7±0.4
pH cold	5.9±1.4	6.4±2.0	6.3±0.4
Turbidity (NTU) warm	6.2±2.5	29±11	11±9
Turbidity (NTU) cold	12±23	17±18	19±6

Dissolved iron levels measured at the three sites shed further light on the effects of groundwater intrusion. Table 4 presents dissolved iron and dissolved oxygen measurements made at the groundwater-impacted site, CoNb and the CON outlet site, CoN2. Dissolved iron is defined as the sum of ferric (Fe^{3+}) and ferrous (Fe^{2+}) concentrations. These data demonstrate the inverse relationship between Fe(aq) and oxygen availability and comparisons of the two sites show the moderating effects of the wetland. Significant increases in dissolved oxygen levels from CoNb to CoN2 are obvious.

Table 4: Dissolved iron (Fe^{2+}(aq) & Fe^{3+}(aq)) and dissolved oxygen (DO) levels measured between 2004 and 2008 at the CON location. All values are reported in mg/L.

	CoNb		**CoN2**			**CoNb**		**CoN2**	
DATE	**Fe(aq)**	**DO**	**Fe(aq)**	**DO**	**DATE**	**Fe(aq)**	**DO**	**Fe(aq)**	**DO**
7/21/04	0.34	4.67	0.42	5.71	**10/29/06**	35.82	0.80	0.40	5.84
8/6/04	0.33	3.80	0.23	7.85	**11/12/06**	14.39	0.80	0.37	2.91
8/29/04	0.27	4.10	0.23	6.11	**12/24/06**	18.17	0.80	0.30	3.31
9/8/04	1.20	2.81	0.27	5.16	**1/20/07**	3.68	4.19	0.09	7.48
9/26/04	0.74	3.73	0.30	4.57	**2/4/07**	20.94	0.80	0.57	5.65
10/23/04	35.90	0.17	0.33	4.04	**2/18/07**	5.23	1.29	0.48	4.64
11/13/04	26.09	0.46	0.20	4.35	**4/15/07**	11.38	3.48	0.27	9.24
2/28/05	3.42	3.23	0.06	4.36	**4/29/07**	3.39	1.74	0.12	7.74
3/31/05	0.18	5.68	0.07	7.99	**5/12/07**	7.84	2.21	0.20	7.14
8/12/05	0.79	1.90	0.55	6.30	**5/27/07**	5.10	3.07	0.21	8.57
9/6/05	0.35	4.10	0.10	5.51	**6/9/2007**	5.04	0.46	0.37	7.33
9/24/05	2.22	0.48	0.22	6.15	**7/8/2007**	5.71	0.80	0.38	7.09
10/9/05	1.73	2.40	0.22	3.24	**7/23/2007**	4.40	2.67	0.24	4.42
12/27/05	14.30	3.40	0.02	6.65	**8/6/2007**	5.19	0.90	0.88	5.75
1/28/06	7.56	6.38	0.49	6.57	**8/20/07**	4.93	2.65	0.53	8.90
2/11/06	8.73	4.27	0.00	5.07	**9/2/07**	6.75	0.97	0.66	5.10
4/28/06	19.97	3.58	0.37	4.72	**9/29/07**	8.88	1.10	0.23	3.94
5/14/06	4.43	1.50	0.15	8.56	**10/13/07**	3.86	1.94	0.13	5.54
5/29/06	16.16	1.91	0.24	7.14	**10/30/07**	5.50	2.16	0.18	5.98
6/10/06	1.15	3.85	0.37	7.06	**11/11/07**	6.62	1.73	0.19	4.94
6/23/06	0.25	4.50	0.45	8.24	**11/27/07**	18.16	1.37	0.13	6.60
7/8/06	2.44	4.40	0.36	7.00	**12/11/07**	3.73	8.03	1.55	3.50
9/3/06	5.54	0.86	0.30	5.45	**12/26/07**	7.39	1.42	0.10	4.02
9/17/06	28.59	0.80	0.58	3.62	**3/4/08**	4.79	1.53	2.18	6.57
10/2/06	23.47	0.80	0.29	4.46					

Turbidity values were measured throughout the duration of the project and further suggest improvements to East Fork water quality due to passage through a wetland area. Turbidity is related to the amount of suspended material in the water column and is a measure of light attenuation due to absorption and reflection by solids. Turbidity can be expected to closely parallel total suspended solids (TSS). The state of Alaska water quality standards for turbidity state that to protect fish and wildlife, turbidity may not exceed 25 nephelometric turbidity units (NTUs) above natural background conditions. Turbidity values obtained at the inlet and outlet of the CoN wetland exceed water quality standards during high flow events, but as shown in Figure 5, the water clarity is improved upon passage through the wetland. One mechanism by which the CON wetland may be improving turbidity values is by providing nuclei onto which suspended particles adsorb and subsequently precipitate. These particles are may be amorphous $Fe(OH)_3$ sequestered by the CON wetland or FeS formed under conditions of sulfate reduction (see below).

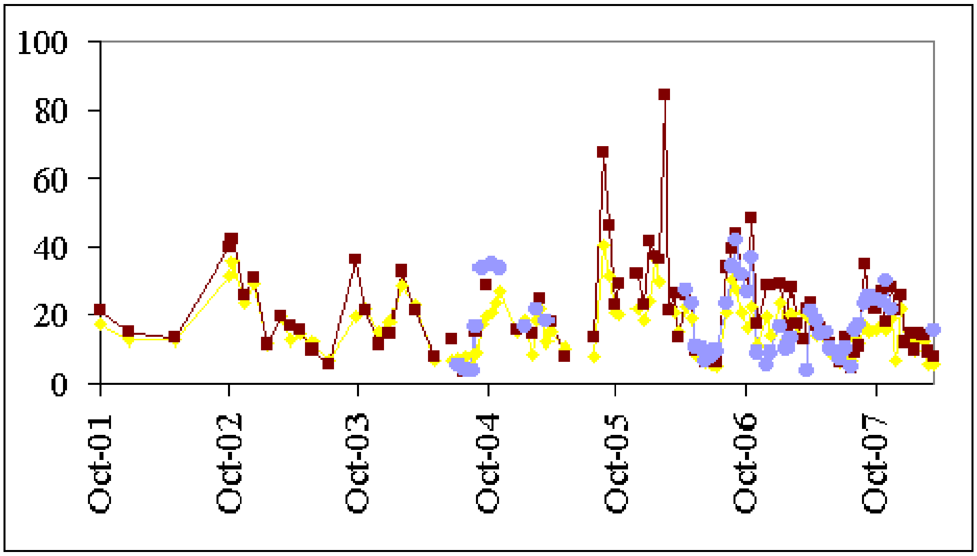

Figure 5: Turbidity values (NTU) measured at 8" to 12" depth before and after the CON created wetland; AP - average (●), CoN3 - inlet (■), CoN2 – outlet (♦).

Comparing parameters measured above and below the CON wetland provide further evidence of beneficial wetland function. A very obvious feature of the CON wetland is illustrated by comparing the sulfate (SO_4^{2-}) levels measured at CoN2 with those measured above (AP) and below (FS) the created wetland. In Figure 6 sulfate data for these sites is presented for the 18 month period between April 2007 and October 2007. Compared to sites upstream and downstream, the CON location exhibits minimal fluctuations in sulfate levels throughout the season suggesting its reduction to sulfide ($SO_4^{2-} \rightarrow S^{2-}$) occurs readily. The reduction of sulfate in a wetland system provides for precipitation of many heavy metal contaminants as metal sulfides and this precipitation reaction most likely buffer the [SO_4^{2-}].

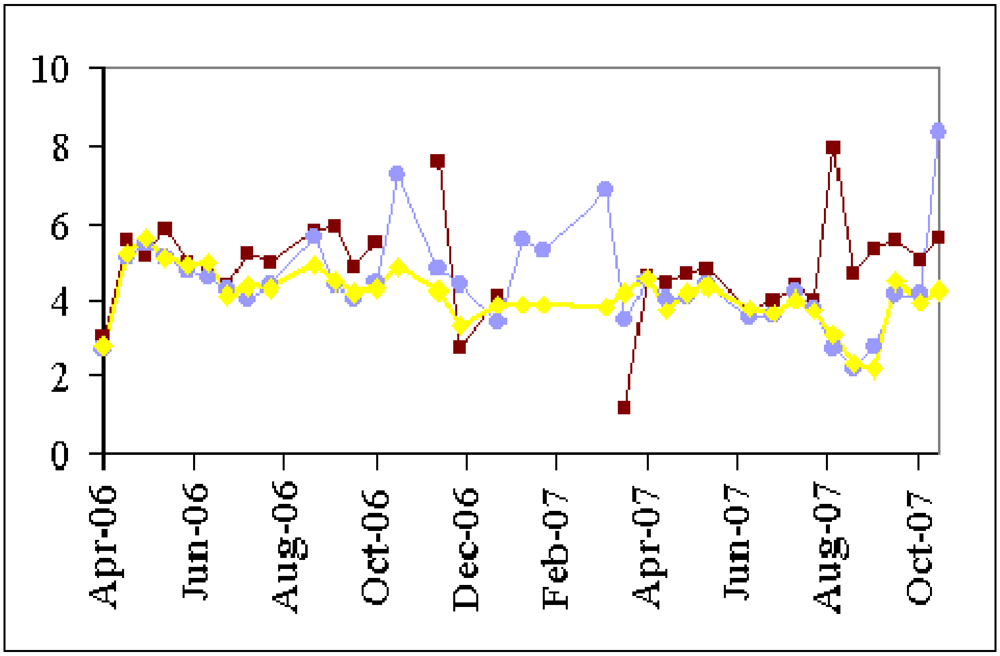

Figure 6: Sulfate levels (mg/L) before and after the CON created wetland; AP – avg (●), CoN2 – outlet (♦), FS –avg (■),

The City of Juneau uses chloride salts of calcium and as road deicing agents. Marine inputs from atmospheric aerosols also supply inputs of these ions but on a constant, less flashy basis. Comparisons of sodium ion (Na^+), calcium ion (Ca^{2+}) and chloride ion (Cl^-) levels throughout Duck Creek suggest some sequestering capacity from the created wetland. Figure 7 shows sodium ion levels along the East Fork for an eighteen month period. Significant increases are observed during cold months at the CON location compared to the downstream FS location. A less pronounced increase in sodium ion levels is observed at the upstream AP location. Clay mixed with glacial silt is common to the Mendenhall Valley and the flocculation of clay particles when exposed to high sodium concentrations is known to occur.[9] Increased exposure to bottom sediments in the slower moving created wetland may promote flocculation and subsequent precipitation thus providing for removal of sodium ions. Quantification of exchangeable sodium on wetland sediments as a function of aqueous sodium levels is needed to verify this conclusion.

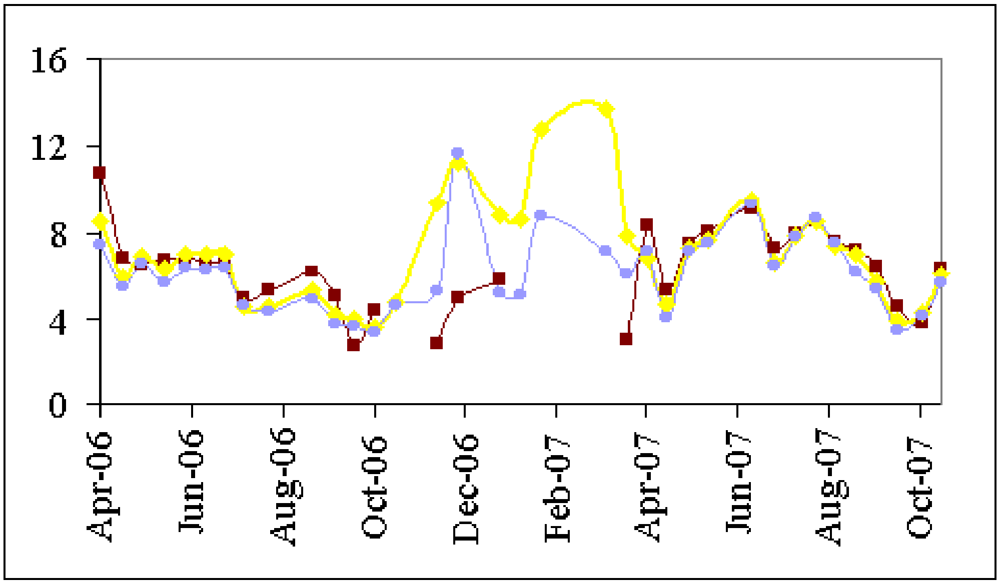

Figure 7: Sodium levels (mg/L) before and after the CON created wetland; AP – avg (●), CoN2 – outlet (♦), FS –avg (■).

Similar plots of chloride and calcium levels show much less variation on passing through the CON location. However, comparisons of these ion levels to those of the unimproved DC3 site continue to show concentration buffering at the created wetland (i.e. the concentrations are more stable at the CON location.[10]

PHYSICAL CHARACTERISTICS OF THE CON AND NS LOCATION

In order to evaluate plant growth and colonization as well as other physical aspects of the created wetland sites, each site was inventoried for plant colonization and fish utilization at times considered ideal for these determinations. Plant inventories and water depth were determined towards the end of the growing season. Fish inventories were carried out just prior to freezing winter temperatures set in.

In August of 2004, 2006 and 2007 the CON created wetland location was divided into transects located to encompass all flooded and wet areas associated with the wetland and estimates of water depth, per cent cover and number of live stems within specified sections, were made at equally spaced points along these transects. Plant species found within the sections were identified. Tables 5 - 7 summarize the collected CON data.

Table 5: Physical characteristics of the CON wetland for August 2004. Sampling along four transects at points 14.5 m apart with a 25 x 25 cm^2 quadrant.

Site	depth (cm)	% cover	live stems (/0.016 m^2)	description of quadrat	plant species[a]
1a	8	90	57	saturated mud	HT, SS
1b	4	60	104	saturated mud	HT, SS
1c	3	95	14	saturated mud	HT, SS, BJ
1d	15	35	17	standing water, iron oxide	HT, FMM

2a	5	75	50	saturated mud	HT, SS
2b	10	75	50	standing water	HT, SS
2c	7	35	37	saturated mud	HT, SS WBW, moss
2d	37	90	116	standing water, iron oxide	HT
3a	15	50	69	standing water	HT, SS, BJ, BR
3b	35	95	89	standing water	HT, SS
3c	47	30	48	standing water	HT
3d	16	80	78	standing water	HT, SS
3e	12	20	9	standing water	SS
4a	14	40	90	standing water	carex, merten's sedge
4b	21	80	76	standing water	HT, SS
4c	22	40	32	standing water	HT

[a] See Table 13 for key to plant abbreviations.

Table 6: Physical characteristics of the CON wetland for August 2006. Sampling along four transects at points 14.5 m apart with a 25 x 25 cm^2 quadrant.

site	depth (cm)	% cover	live stems (/0.016 m^2)	description of quadrat	plant species[a]
1a	21	100	50	standing water	HT, SS
1b	21	65	60	standing water, iron oxide	HT, SS, FMM
1c	15	40	15	standing water, iron oxide	HT, SS
1d	15	95	15	standing water, iron oxide	HT, SS
2a	14	40	58	standing water, iron oxide	HT, SS, RA
2b	21	75	48	standing water, iron oxide	SS, HT
2c	27	80	72	standing water, iron oxide	SS, HT
2d	20	25	26	standing water, bacterial sheen	HT, SS, WBW, CG
3a	20	75	46	standing water, iron oxide	SS, HT
3b	27	75	56	standing water, iron oxide	HT, SS
3c	31	60	33	standing water, iron oxide	HT, SS
3d	28	90	33	standing water, iron oxide	SS, HT
3e	43	20	14	standing water, iron oxide	HT, SS
4a	29	45	55	moving water	HT, SS, BR
4b	34	85	29	moving water, iron oxide	HT, SS, CG
4c	35	80	23	standing water	SS, HT

[a] See Table 13 for key to plant abbreviations.

Table 7: Physical characteristics of the CON wetland for August 2007. Sampling along four transects at points 12 m apart with a 30 x 30 cm^2 quadrant.

site	depth (cm)	% cover	live stems (/ 0.01 m^2)	description of quadrat	plant species[a]
1a	17	80	30	standing water	SS,HT
1b	5	100	69	standing water, iron oxide	SS,HT
1c	9	100	45	standing water, iron oxide, bacterial sheen	SS,HT
1d	2	100	48	saturated mud	SS,HT,FMM
2a	1	100	51	saturated mud	SS,HT,RA
2b	13	95	32	standing water, iron oxide	HT,SS
2c	13	85	27	standing water, iron oxide	HT,SS
2d	1	60	48	saturated mud, iron oxide	HT,SS,RA,VG
3a	9	90	32	standing water, iron oxide, bacterial sheen	HT,SS
3b	10	90	45	standing water, iron oxide	HT,SS,VG
3c	24	80	48	standing water, iron oxide, bacterial sheen	HT,SS
3d	19	60	48	standing water, iron oxide, bacterial sheen	HT,SS
3e	6	70	33	standing water, iron oxide	HT,SS

3f	10	40	12	standing water, iron oxide, bacterial sheen	HT,SS
3g	10	90	36	standing water, iron oxide, bacterial sheen	HT,SS
4a	19	20	27	standing water	HT,BR
4b	18	65	48	standing water	HT,SS
4c	26	30	36	standing water	HT,SS

[a] See Table 13 for key to plant abbreviations.

Horsetail, sitka spruce, bulrush and marsh marigold were the primary species utilized when the CON wetland was originally planted in 1998. Percent cover has increased significantly since the wetland was first planted; the original percent cover was estimated at <1%. Within the sample plots cover ranges from 30% to 95%. The horsetail and sitka sedge have done very well in this environment. Of particular note is the ability of the horsetail to thrive even in the presence of heavy iron oxide floc.

Plant productivity correlates with high rates of mineral uptake by vegetation. Subsequent burial when the plants die followed by peat accumulation provides a mechanism for permanent removal of metal and other contaminant. Average annual biomass determinations in the CON wetland were made in 2004, 2006 and 2007. Results are presented in Table 8 and show an increasing trend. Tables 9 – 11 provide the data from which the average results were calculated.

Table 8: Annual biomass production for the CON wetland, 2004, 2006 and 2007.

	2004	**2006**	**2007**
Avg. plant matter (g/m^2)	121.32	146.57	248.25
biomass (kg/yr)	490.0	597.2	1005

Table 9: Mass of plant matter for 2004 CON biomass determinations.

site	plant matter (g/m^2)	% cover
1a	3078	90
1b	4996	60
2b	4535	75
2c	3317	35
4a	5191	40

Table 10: Mass of plant matter for 2006 CON biomass determinations.

site	plant matter (g/m^2)	% cover
1a	1707	100
1b	3332	65
2b	4917	75
2c	4481	80
3e	1487	20
4a	3302	45

Table 11: Mass of plant matter for 2007 CON biomass determinations.

site	plant matter (g/m^2)	% cover
1c	2800	100
3a	2937	90
3d	1814	60

4a	1377	20

In August of 2007 the newly created wetland at the NS location was divided into transects located to encompass all flooded and wet areas associated with the wetland and estimates of water depth, per cent cover and number of live stems within specified sections, were made at equally spaced points along these transects. Plant species found within the sections were identified. Table 12 summarizes the collected NS data.

Table 12: Physical characteristics of the NS wetland for August 2007. Sampling along six transects at points 12 m apart with a 30 x 30 cm^2 quadrant. All quadrants sampled are described as saturated mud 5 – 10 cm deep with little if any iron oxide or bacterial sheen present.

site	depth (cm)	% cover	live stems per 0.01 m^2	plant species[a]
1a	12	7	11	SS
1b	11	2	3	SS,DLR
1c	13	20	47	SS,DLR
1d	11	75	45	SS,DLS
2a	12	5	24	SS,CLPW,DLR
2b	13	25	13	SS,VG,DG
2c	5	2	4	SS,DLS
3a	23	15	9	NLB
3b	8	25	29	SS,DLR
3c	33	70	n/d	CLPW
3d	21	50	15	FMM,BR,DG
3e	14	10	9	SS,DLS
3f	14	15	16	NM,KS,DLS,WB
3g	12	15	32	KS,DLS,DLR,BJ
3h	18	15	14	KS,MG
4a	13	0	0	
4b	25	40	66	SR,BR
4c	7	20	7	NLB,CLPW
4d	11	5	10	DG,WB
4e	12	20	28	DLS,DLR,KS
4f	28	70	66	SR,DG,DLR,NLB
4g	16	20	26	SS,DG
4h	20	50	92	MG
5a	19	2	24	DLR,KS
5b	5	5	4	SS
5c	10	15	11	SS,DLS
5d	30	5	6	KS,DG
5e	20	40	8	DLSW,WB,KS
5f	18	20	59	WB,DLS,KS,
5g	17	15	2	DLS,NLB,KS
5h	21	15	2	BR,CLPW
6a	11	1	1	KS
6b	10	15	53	KS,DLR
6c	11	10	29	DLS,DLR,KS,WB
6d	19	20	9	SS,CLPW
6e	23	70	39	FLPW,KS,DLS,WB,DG
6f	22	3	1	BR,CLPW
6g	22	40	18	SR,NLB,BJ

6h	16	10	3	DLS,DG,KS

[a] See Table 13 for key to plant abbreviations.

Table 13: Key to plant abbreviations found in Tables # -

Plant Name	**Abbr.**
Kellog's Sedge (*Carex kelloggii*)	KS
Sitka Sedge (*Carex sitchensis*)	SS
Small-Flowered Bulrush (*Scirpus microcarpus*)	BR
Creeping Spike-Rush (*Elocharis palustris*)	SR
Dagger-Leaved Rush (*Juncus ensifolius*)	DLR
Bluejoint (*Calamagrostis canadensis*)	BJ
Northern Mannagrass (*Glyceria borealis*)	NM
Common Velvet-Grass (*Holcus lanatus*)	VG
Floating-Leaved Pondweed (*Potamogeton natans*)	FLPW
Clasping-Leaved Pondweed (*Potamogeton richardsonii*)	CLPW
Narrow-Leaved Bur-Reed (*Sparganium angustifolium)*	NLB
Ditch-Grass (*Ruppia maritima*)	DG
Diverse-Leaved Water-Starwort (*Callitriche heterophylla*)	DLS
White Water-Buttercup (*Ranunculus aquatilis*)	WB
Floating Marsh-Marigold (*Caltha natans*)	FMM
Swamp Horsetail (*Equisetum fluviatile*)	HT
Red Alder (*Alnus ruba*)	RA
Chamisso's Cotton Grass (*Eriophorum chammissonis*)	CG
Western Black Willow (*Salix lasiandra*)	WBW

Total biomass estimates were made for the NS wetland in a manner entirely analogous to that described above for the CON wetland. The total area used for the NS calculation was 13,586 m^2. For 2007 total biomass turnover was estimated as 2,374 kg. The data used to determine this value is presented in Table 14.

Table 14: Mass of plant matter for 2007 NS biomass determinations.

site	**plant matter (g/m^2)**	**% cover**
1a	762	7
1d	2923.4	75
3g	1322.2	15
4b	3747.1	40
4h	6293.8	50
5f	1487.5	20
6b	759.8	15

Mark-recapture methods were utilized to derive fish population estimates at the CON location in October 2004 and at the CON, NS and FS location in October 2007. Fish population estimates were not made in 2005 due to construction at the NS location. In October 2006 fish were trapped and counted in the FS pond, the NS wetland and the CON wetland but freezing conditions did not allow for recapture. Fish were found primarily within the main channel of the CON wetland and within the deeper pools of the NS wetland. Traps were set only along the northern shoreline of the FS pond (water depth never exceeded 1 meter). All fish were in good condition and appeared healthy.

The number and type of fish collected in the first round of traps for all sites and all years is presented in Table 15.

Table 15: Total number of fish collected in minnow traps for population estimates.

site	**2004**	**2006**	**2007**
FS	data not available	10 Coho (6 traps) 8 DV 0 CT 5 SB	62 Coho (20 traps) 28 DV 0 CT 2 SB
popn. est.			**insufficient recapture**
NS	data not available	50 Coho (6 traps) 0 DV 0 CT 4 SB	105 Coho (30 traps) 4 DV 14 CT 47 SB
popn. est.			**201 – 356 coho**
CoN	108 Coho (15 traps) 4 DV 1 CT 36 SB	45 Coho (6 traps) 1 DV 2 CT 9 SB	145 Coho (20 traps) 0 DV 2 CT 55 SB
popn. est.	**383 – 809 coho**		**260 – 440 coho**

Counts from the initial capture show the numbers found in Table 15 with average coho lengths of 103±19 mm for the CON location, 107±14 mm for the NS location and 118±12 mm for the FS location.   Analysis of the 2007 data yielded coho populations of 260 – 440 juvenile coho with an average length of 95±18 mm for the CON wetland and 201 – 356 juvenile coho with an average length of 104±13 mm for the NS wetland. The recapture rate for traps set in the FS pond was insufficient to provide a valid estimate of juvenile coho population (668 – 2320), however the average length of the trapped fish was 105±21 mm .

CONCLUSION

WQP's:

Data collected since monitoring of the Church of the Nazarene created wetland began in 2001 indicates that features consistent with a natural wetland rich in sulfate have begun to develop. The colonization of the CON wetland by iron-resistant horsetail appears to facilitate precipitation and sequestration of iron oxides. The onset of increasingly anaerobic conditions in certain areas of the wetland appears to facilitate the precipitation of sulfide species including those of iron and other heavy metals. The plant matter in the wetland provides substrate that effectively traps precipitated iron compounds in the shallower portions of the wetland where the groundwater seeps predominate thus keeping the main channel relatively free of turbidity. The main channel of the wetland maintains acceptable dissolved oxygen levels and supports over-wintering coho salmon.

Vegetation:

The NS wetland has shown impressive development in the year since its creation. Improvements in water quality parameters are tentative but appear to support a positive contribution from the renovation project. The addition of fill-dirt to the NS pond during its conversion to a more shallow wetland has most likely limited its contribution to iron levels since no obvious localized sites of groundwater intrusion were noted during the summer 2007 survey. The rapid development of submerged and partially submerged plants at NS will however, serve to sequester precipitated iron hydroxide from water passing through the created wetland. This sequestration process has been effectively demonstrated at the more established CON created wetland. Improvements in water quality parameters such as dissolved oxygen and turbidity can be expected to accompany further plant colonization. Data collected at the Forest Service and Allison Ponds will provide valuable baseline data for comparative assessments of the functional values of the created wetlands along the East Fork of Duck Creek.

Fish Utilization:

Despite water quality impairments in Duck Creek , this project documented overwintering utilization by coho salmon, cutthroat trout and Dolly Varden char in the created wetlands at Church of Nazarene and Nancy Street. Additional studies of outmigrant population estimates and condition factor of these overwintering fish would give additional insight to the habitat productivity of these wetlands.

Future Work:

The data collected in this project will serve as a detailed baseline for future determinations of wetland function. Fish utilization is a straightforward indicator of habitat restoration and should be continued on a regular basis. Continued surveys of herbaceous cover will indicate the success rate of planted species (80% considered successful[11]) as well as if a specific species from among those planted at NS will dominate, as has occurred with sitka sedge and horsetail at the CON site. In addition the appearance of exotic or aggressive species could be monitored and information regarding the wetland's ability to resist these encroachments obtained. While surveys of herbaceous plant cover provide useful data regarding the aforementioned features, they fail to effectively correlate with the wetlands' hydrological function. Measurements of plant productivity (i.e. annual biomass production) and parameters such as soil organic matter, vertical structure and nutrient flux provide better assessments.[12] Monitoring of these parameters is most efficient if conducted annually for five years preferably at the end of the growing season.[11] Since one of the primary goals for construction of the NS wetland was pollutant attenuation, assessments of this function would also be useful. Immobilization of pollutants is the first step in an attenuation process with adsorptive sites on sediment and organic detrital matter serving as substrate. Adsorption of ions and other solutes to sediment particles is influenced by the redox potential of the surrounding environment thus measurements of E_h values would provide insight into pollutant retention.[13] Finally, comparisons to proximal natural wetland systems (i.e. a reference wetland) would provide further information regarding the success of the wetlands created at the NS and CON sites.[12]

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Student Presentations:

"Observed Effects of a Created Wetland on Stream Water Quality, Duck Creek, Juneau, AK" presented by Jess Parks in 2005 at the 26th international meeting of the Society of Wetland Scientists in Charleston, SC.

"Dissolved Oxygen Levels in Urban Streams" presented by Matthew Nelson in 2005 at the 60th Meeting of the Northwest Regional Section of the American Chemical Society in Fairbanks, AK.

"Wetland Creation in Southeast Alaska; Using Water Quality Parameters to Gauge Attainment of Project Goals" presented by Steffi Schreiber in 2008 at the 29th international meeting of the Society of Wetland Scientists in Washington, DC.

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Data Appendices:

Table S1: Water quality data for Forest Service pond, site a.

FSa		DO (mg/L)	T (^{o}C)	cond (μS/cm)	pH	turb (NTU)
7/21/04		9.53	18.7	132.3	7.38	2.31
7/28/04		6.83	17.4	125.5	7.37	3.15
8/6/04		6.52	17.2	128	7.45	2.52
8/11/04		8.3	18.8	133.3	7.43	2.38
8/18/04		7.17	18.9	134.9	7.42	1.83
8/29/04		5.73	17.6	130.4	7.24	2.97
9/8/04		4.82	15.1	130.1	6.78	4.94
9/26/04		4.86	10	115.3	6.6	14.4
10/23/04		6.13	5.2	114.9	6.46	17.6
11/13/04		6.07	4.7	114.9	6.82	16.2
1/28/05	frozen					
2/28/05		5.2	1	70	7.22	3.08
3/31/05		9.84	5	110	7.38	11.3
4/27/2006		5.9	7	122.5	7	39.5
5/14/2006		9.01	9	134.8	7.44	22.3
5/27/2006		8.64	17.3	166.4	7.14	10.5
6/10/2006		8.61	15	161.8	7.06	8.22
6/24/2006		9.54	13.4	146.1		6.22
7/8/2006		8.83	16.1	156.4	7.09	6.61
7/21/2006		8.98	15.7	150.7	7.09	6.54
8/19/2006		6.8	11	124.5	6.22	14.6
9/3/2006		7.23	11.3	118.1	7.05	19.3
9/17/2006		6.97	9.2	133.7	6.83	26.9
10/2/2006		5.97	9.2	108.4	6.79	17.9
10/15/06		6.98	7.8	110.3	6.85	14.3
10/29/06		8.49	4.8	101.4	7.13	26.2
11/12/06	frozen					
12/10/06		4.64	0.5	45.6	6.57	14.2
12/24/06		4.02	0.9	93.5	6.62	3.44
1/20/07		6.75	1.2	83.2	7.16	5.28
2/4/07	frozen					
2/18/07	frozen					
3/4/07	frozen					
3/20/07	frozen					
4/1/07	frozen					
4/15/07		10.77	1	42.2	5.6	4.35
4/29/07		9.6	6.2	127.5	6.45	11.1
5/12/07		9.51	8.8	130.2	6.33	10.1
5/27/07		11.76	11.3	135.1	7.25	8.43
6/9/07		9.85	13.8	150.2	6.65	7.91
7/8/07		10.3	16.1	18.72	6.98	3.12
7/23/07		8.14	14.3	144.3	7.08	6.74
8/6/07		8.94	14.6	155.8	6.77	5.99
8/20/07		9.86	16.02	160.3	7.26	4.95
9/2/07		8.63	15		6.87	6.3
9/15/07		8.6	12.1	184.6	6.53	10
9/29/07		6.57	8.7		6.47	17
10/13/07		8.2	7.4	109.6	6.99	14.2
10/30/07		8.17	6.3	99.2	6.25	18.2

11/11/07		8.31	4	110.2	5.79	15.4
11/27/07		9.57	3.9	110.3	6.56	13.4
12/11/07	frozen					
12/26/07		4.31	0.8	83.1	7.8	3.81
1/7/2008	Frozen					
1/21/2008	Frozen					
2/2/2008	Frozen					
2/16/2008	Frozen					
3/4/2008	Frozen					
3/14/2008	Frozen					
3/29/2008	Frozen					

Table S2: Water quality data for Forest Service pond, site b.

FSb		DO (mg/L)	T (^{o}C)	cond (μS/cm)	pH	turb (NTU)
7/21/04		9.44	18.8	134.9	7.37	2.27
7/28/04		7.6	17.4	125.4	7.41	3.33
8/6/04		6.19	17.4	126.4	7.36	2.34
8/11/04		8.6	19	132.1	7.63	1.92
8/18/04		6.96	19	134.5	7.54	1.59
8/29/04		5.12	16.7	127.3	7.26	2.74
9/8/04		5.3	14.3	122.4	7.14	5.03
9/26/04		5.15	9.9	112.4	7.03	14.4
10/23/04		6.7	5.3	113.5	6.81	16.5
11/13/04		7.45	4.1	109.9	7.27	16.1
1/28/05	frozen					
2/28/05	frozen					
3/31/05		9.75	4.8	107.4	7.42	9.22
4/27/2006		6.31	6.8	123	7.25	34.5
5/14/2006		10.2	9.6	134.3	7.42	22.6
5/27/2006		8.43	16.5	161.4	7.37	8.98
6/10/2006		8.33	14.9	162.3	7.63	8.26
6/24/2006		9.88	13.3	145		5.89
7/8/2006		9.1	16.3	155.9	7.28	6.19
7/21/2006		9.24	15.1	150	6.91	6.12
8/19/2006		8.6	10.9	122.1	7.23	9.41
9/3/2006		7.65	11.6	116.1	7.04	20.1
9/17/2006		8.01	9.3	132	7.07	27.4
10/2/2006		7.95	9.1	107.7	6.8	
10/15/06		7.37	7.8	107.9	6.88	13.9
10/29/06		8.52	5.2	98.6	7.17	19
11/12/06	frozen					
12/10/06		13.01	0.2	43.9	6.89	8.92
12/24/06	frozen					
1/20/07		12.8	1.2	84.3	7.49	1.32
2/4/07		12.6	0.8	87	7.54	4.88
2/18/07	frozen					
3/4/07	frozen					
3/20/07	frozen					
4/1/07	frozen					
4/15/07		13.29	0.3	23.2	6.61	6.64
4/29/07		9.31	6.1	126.8	7.5	11.4
5/12/07		9.62	8.7	129.8	6.9	10.1
5/27/07		11.74	11.6	137.7	7.43	7.74

6/9/07		9.5	13.8	152	7.49	6.86
7/8/07		10.29	16.1	181.6	7.32	3.53
7/23/07		9.27	14.4	144.2	7.36	6.7
8/6/07		9.21	14.6	155.3	7.39	5.52
8/20/07		9.78	16.01	158	7.6	4.64
9/2/07		8.42	14.6		7.09	5.58
9/15/07		8.3	12	210	7.37	12.7
9/29/07		7.3	9	173.9	7.3	16.1
10/13/07		8.1	7.3	110.9	7.77	13.7
10/30/07		9.27	6.4	103.1	7.89	12.8
11/11/07		10	3.5	105.5	7.81	14.2
11/27/07		10.36	3.8	107.8	8.42	12.6
12/11/07		14.5	0.5	80.2	8.7	1.5
12/26/07	frozen					
1/7/2008	frozen					
1/21/2008	frozen					
2/2/2008	frozen					
2/16/2008	frozen					
3/4/2008	frozen					
3/14/2008	frozen					
3/29/2008	frozen					

Table S3: Water quality data for Nancy Street pond/created wetland, site d.

NSd		DO(mg/L)	T(^{o}C)	cond(uS/cm)	pH	turb(NTU)
7/7/04		7.80	17.00	139.80	7.12	4.81
7/21/04		6.69	17.80	142.60	6.71	3.99
7/28/04		5.38	15.50	123.60	6.98	5.74
8/6/04		6.20	16.80	130.50	7.16	2.72
8/11/04		8.03	18.30	138.20	7.23	2.55
8/18/04		6.53	18.40	142.50	6.99	3.13
8/29/04		5.05	16.10	137.50	6.69	7.53
9/8/04		4.32	13.60	125.50	6.80	12.80
9/26/04		8.86	9.79	155.00	6.60	23.80
9/26/04		4.73	9.90	106.30	6.59	23.70
10/10/04		9.18	9.28	166.00	6.63	22.30
10/23/04		2.96	4.90	99.20	6.43	30.80
10/24/04		4.64	4.38	166.00	6.50	21.30
11/7/04		6.63	3.97	161.00	6.55	22.70
11/13/04		4.39	3.90	94.00	6.29	15.00
11/21/04		8.00	4.91	176.00	5.11	26.90
12/5/04		6.46	4.12	172.00	5.55	23.30
12/22/04		10.70	3.40	172.00	5.82	47.40
1/4/05		3.54	3.35	174.00	6.40	21.30
1/28/05		1.42	1.70	101.70	6.64	6.90
2/17/05		3.54	2.14	188.00	6.21	8.20
2/28/05		3.71	2.50	95.70	6.46	12.50
3/11/05		4.81	3.99	155.00	6.46	36.50
3/31/05		7.06	5.50	103.40	6.32	15.90
3/27/05		2.84	5.14	180.00	6.22	32.80
4/10/05		8.47	7.64	177.00	6.90	15.00
4/24/05		8.94	10.49	172.00	7.14	12.10
5/17/05		7.07	11.66	175.00	6.64	5.79

6/3/05		7.23	15.70	140.00	7.24	
7/18/05		8.31	15.10	170.00	6.83	
8/2/05			14.63	169.00	6.72	10.40
8/10/05		8.30	19.80	155.00	7.15	4.56
8/20/05			14.26	175.00	6.44	60.40
9/6/05		8.20	12.20	122.80	6.82	22.00
9/10/05			11.48	176.00	6.44	66.20
9/24/05		5.83	10.40	110.90	7.01	55.80
10/9/05		2.88	8.80	106.00	6.39	87.50
10/22/05		5.93	7.30	98.00	6.79	91.90
10/22/05	sn	8.80	6.87	79.00	6.34	37.20
11/4/05		5.88	5.07	167.00	6.37	54.30
11/6/05		6.57	3.80	91.50		
11/18/05	sn	10.83	4.94	65.00	6.61	147.50
11/26/05		7.51	4.00		4.65	24.60
12/3/05		5.31	3.05	186.00	6.49	26.50
12/10/05		7.90	2.90	145.00	5.78	27.60
12/17/05		6.90	4.43	165.00	6.47	31.10
12/26/06		7.57	3.70	91.90	6.70	36.60
1/14/06		7.08	2.40	101.60	6.59	30.30
1/14/06	sn	7.28	2.56	142.00	6.30	33.60
1/27/06	sn	4.01	2.01	205.00	6.28	39.40
1/28/06		8.35	1.00	94.20	4.82	36.70
2/11/06		4.75	5.00	103.10	6.78	42.90
2/11/06	sn	3.02	2.26	226.00	6.14	35.00
2/25/06		2.94	4.00	112.30	6.27	9.42
2/25/06	sn	4.75	2.37	220.00	6.23	14.20
3/11/06		3.08	4.70	109.50	7.13	25.80
3/15/06	sn	6.82	1.88	235.00	6.81	
3/28/06		5.27	4.60	117.90	6.85	18.80
4/8/06		2.77	8.90	146.70	6.92	32.90
4/27/06		4.84	7.50	113.20	7.18	96.30
5/14/06		8.70	10.10	126.10	7.10	26.90
5/27/06		7.92	16.30	162.90	6.56	14.40
6/10/06		6.97	14.50	148.20	6.52	14.20
6/24/06		8.54	12.40	141.30		13.40
7/8/06		7.45	15.70	154.00	6.59	5.62
7/21/06		8.87	15.70	154.80	6.91	8.81
8/19/06		6.43	11.40	117.40	6.61	24.60
9/3/06		5.70	11.40	109.80	6.77	36.80
9/17/06		6.82	9.00	118.60	6.63	36.10
10/2/06		5.03	9.00	98.90	6.59	28.80
10/15/06		5.40	7.90	101.60	6.80	25.70
10/29/06		7.09	3.90	83.70	6.78	30.50
11/12/06		3.73	2.50	96.80	6.30	20.30
12/10/06		3.33	1.70	101.70	6.44	23.90
12/24/06		5.32	2.00	107.70	5.74	19.90
1/20/07		9.07	2.00	101.80	6.94	26.20
2/4/07		5.52	1.80	107.40	6.03	17.50
2/18/07		5.21	2.10	116.20	6.70	22.90
3/4/07		4.68	0.80	107.40	7.16	18.90
3/20/07		5.25	0.80	122.50	7.35	12.00
4/1/07		6.15	2.20	124.80	7.12	14.90

4/15/07		9.74	4.10	101.40	6.06	18.60
4/29/07		9.44	6.30	117.50	6.01	15.10
5/12/07		8.60	9.30	118.10	6.42	13.30
5/27/07		10.37	11.70	130.40	6.59	13.00
6/9/07		8.75	14.50	143.50	6.74	10.70
7/8/07		9.48	16.00	19.48	6.84	6.98
7/23/07		7.03	14.30	133.70	6.83	9.59
8/6/07		8.06	14.60	149.00	6.59	7.78
8/20/07		9.35	16.00	158.40	6.76	11.40
9/2/07		7.95	14.00		6.75	9.99
9/15/07		8.10	11.90	164.30	6.15	14.60
9/29/07		6.18	8.70		6.47	17.00
10/13/07		7.30	7.40	101.50	6.28	17.10
10/30/07		7.50	6.10	95.00	5.70	19.80
11/11/07		7.60	3.20	94.20	5.46	21.80
11/27/07		8.95	3.40	97.70	6.11	19.60
12/11/07		4.59	1.70	88.50	5.04	12.60
12/26/07		4.63	2.20	108.10	5.91	21.20
1/7/2008		3.85	1.6	117.0	6.65	14.80
1/21/2008		7.16	1.6	99.6	6.92	16.20
2/2/2008		4.04	0.8	54.5	6.53	12.50
2/16/2008		5.82	1.5	101.8	6.70	14.20
3/4/2008		8.30	3.1	88.9	7.15	16.20
3/14/2007		9.02	3.7	95.3	7.03	13.60
3/29/2008		11.58	5.6	104.0	6.94	8.80

Table S4: Water quality data for Nancy Street pond/created wetland, site c.

NSc		DO(ppm)	T(oC)	cond(uS/cm)	pH	turb(NTU)
9/24/05		4.44	10.20	110.20	6.45	63.70
10/9/05		2.61	9.10	108.50	6.55	74.40
10/22/05		6.08	7.10	97.50	6.83	85.90
1/14/06	frozen					
1/28/06	frozen					
2/11/06	frozen					
2/25/06	frozen					
3/11/06	frozen					
9/17/06		6.30	9.20	120.00	6.54	37.10
10/2/06		4.80	9.00	99.30	6.57	29.10
10/15/2006		4.91	7.80	100.70	6.53	25.60
10/29/2006		6.63	3.80	84.60	6.73	31.00
11/12/2006	frozen					
12/10/2006	frozen					
12/24/2006	frozen					
1/20/2007	frozen					
2/4/2007	frozen					
2/18/2007	frozen					
3/4/2007	frozen					
3/20/2007	frozen					
4/1/2007	frozen					
4/15/2007	frozen					
4/29/2007		9.56	6.60	118.10	6.31	15.60
5/12/2007		8.10	9.60	119.80	6.37	15.30
5/27/2007		11.17	11.80	130.40	6.50	13.70

6/9/2007		8.85	15.30	148.70	6.80	10.90
7/8/2007		9.42	16.10	19.38	6.81	8.98
7/23/2007		7.40	15.10	137.70	6.96	8.36
8/6/2007		8.47	15.30	150.30	6.55	8.88
8/20/2007		10.15	16.50	160.50	6.94	11.70
9/2/2007		8.40	15.20		6.69	10.30
9/15/2007		9.40	12.30	175.60	6.07	12.40
9/29/2007		5.57	8.70		5.54	20.60
10/13/2007		7.32	7.80	101.50	6.58	17.90
10/30/2007		8.83	6.00	92.00	5.61	18.50
11/11/2007		7.45	3.00	93.70	5.73	22.90
11/27/2007		8.65	2.2	95.3	6.10	12.70
12/11/2007	frozen					
12/26/2007	frozen					
1/7/2008	frozen					
1/21/2008	frozen					
2/2/2008	frozen					
2/16/2008	frozen					
3/4/2008	frozen					
3/14/2008	frozen					
3/29/2008		11.12	5.8	108.4	6.31	9.5

Table S5: Water quality data for Nancy Street pond/created wetland, site b.

NSb		DO(mg/L)	T(oC)	cond(uS/cm)	pH	turb(NTU)
7/21/04		8.41	17.60	142.80	7.00	3.47
7/28/04		5.11	16.40	131.70	7.05	3.21
8/6/04		6.90	16.70	133.00	7.16	3.36
8/11/04		8.40	15.40	139.90	7.48	3.05
8/18/04		7.36	18.00	146.10	7.04	3.18
8/29/04		6.32	16.40	135.70	7.00	4.68
9/8/04		5.38	15.10	132.20	7.12	9.29
9/26/04		4.76	9.70	102.70	6.92	21.90
10/23/04		2.96	5.80	101.80	5.69	25.60
11/13/04		3.41	4.70	94.80	5.98	24.50
1/23/05	frozen					
2/28/05		7.52	0.80	25.70	5.53	13.00
3/31/05		7.61	5.30	104.90	5.90	17.70
8/10/05		7.85	20.10	160.50	7.06	6.15
9/6/05		6.80	11.80	121.00	6.46	25.70
9/24/05		6.14	10.50	113.50	6.17	58.10
10/9/05		4.51	9.10	118.00	6.18	27.20
10/22/05		7.10	7.00	104.70	5.56	46.80
1/14/06	frozen					
1/28/06	frozen					
2/11/06	frozen					
2/25/06	frozen					
3/11/06	frozen					
9/17/06		5.96	9.10	122.20	6.52	35.70
10/2/06		5.07	9.20	103.70	6.34	23.20
10/15/2006		4.60	7.90	105.90	6.19	20.30
10/29/2006		6.04	4.10	8.87	6.43	17.10
11/12/2006		2.28	2.10	10.10	6.37	22.80
12/10/2006		2.43	2.40	104.50	6.49	25.60

12/24/2006		3.50	2.60	114.90	5.66	20.70
1/20/2007		6.90	2.70	106.30	6.43	27.20
2/4/2007		3.68	2.20	110.10	6.08	19.50
2/18/2007		3.75	2.40	123.50	5.39	19.60
3/4/2007	frozen					
3/20/2007	frozen					
4/1/2007		5.08	1.30	123.70	6.24	20.10
4/15/2007		9.17	3.90	106.20	6.08	20.20
4/29/2007		7.45	6.20	120.00	5.13	16.70
5/12/2007		7.52	8.80	122.30	5.94	13.70
5/27/2007		8.30	10.80	125.60	5.98	14.70
6/9/2007		6.56	12.80	139.20	6.53	11.20
7/8/2007		6.73	15.00	19.53	6.45	10.30
7/23/2007		5.39	13.80	133.70	6.72	11.10
8/6/2007		6.72	13.90	148.90	6.37	10.10
8/20/2007		8.68	15.50	162.80	6.60	17.20
9/2/2007		6.22	14.70		6.45	15.70
9/15/07		4.40	11.60	182.70	5.85	29.60
9/29/2007		5.43	8.90		5.61	15.90
10/13/2007		5.64	7.90	106.10	5.97	15.60
10/30/2007		7.20	6.40	97.10	5.23	16.20
11/11/2007		6.34	3.50	99.10	5.09	17.70
11/27/2007		6.66	3.00	98.30	5.30	20.30
12/11/2007	frozen					
12/26/2007	frozen					
1/7/2008	frozen					
1/21/2008	frozen					
2/2/2008	frozen					
2/16/2008	frozen					
3/4/2008		8.01	3.3	97.5	4.72	16.5
3/14/2008	frozen					
3/29/2008		10.20	5.2	108.3	5.82	7.6

Table S6: Water quality data for Nancy Street pond/created wetland, site a.

NSa		DO(mg/L)	$T(^oC)$	cond(uS/cm)	pH	turb(NTU)
08/10/05		7.68	19.50	160.50		6.15
10/09/05		4.33	9.10	118.70	6.56	21.10
10/22/05		6.40	7.30	106.10	6.34	21.70
11/06/05		6.36	4.20	97.40		
11/26/05		7.89	5.70		5.54	17.40
12/10/05		7.97	3.60	143.50	6.17	24.10
12/26/06		7.00	4.00	96.70	5.90	22.80
01/14/06		5.28	1.70	102.80	6.37	31.60
01/28/06		frozen				
02/11/06		3.84	3.50	102.20	6.60	35.80
02/25/06		frozen				
03/11/06		frozen				
03/28/06		6.55	3.70	117.40	5.99	29.00
04/08/06		7.82	7.30	126.30	7.01	13.70
04/27/06		6.20	6.10	193.50	6.06	22.30
05/14/06		8.13	8.90	122.10	6.01	18.40
05/27/06		5.35	16.20	166.40	6.52	10.50

06/10/06		6.95	15.30	151.00	6.60	9.42
06/24/06		8.12	12.00	142.00		6.88
07/08/06		6.45	14.10	152.30	6.44	9.74
07/21/06		6.98	14.00	150.80	6.91	5.44
08/19/06		5.55	10.90	118.20	6.84	21.50
09/03/06		5.50	11.20	114.40	6.79	30.90
09/17/06		3.65	9.10	122.10	6.51	29.30
10/02/06		4.43	9.20	102.10	6.56	24.20
10/15/06		4.62	8.00	103.40	6.36	18.40
10/29/06		5.53	4.60	89.80	6.38	22.40
11/12/06		2.66	2.80	103.10	6.42	22.50
12/10/06		2.92	2.60	107.00	6.37	21.80
12/24/06		3.23	2.70	114.00	5.44	19.70
01/20/07		7.43	2.70	105.20	6.74	25.70
02/04/07		5.39	2.40	112.30	6.45	12.10
02/18/07		4.62	2.50	125.10	5.41	19.30
03/04/07		2.46	1.10	112.30		17.60
03/20/07		2.61	1.10	134.30	6.02	26.60
04/01/07		4.68	1.80	131.40	5.22	23.60
04/15/07		10.70	4.00	178.40	5.83	17.50
04/29/07		7.35	6.10	120.10	5.85	14.70
05/12/07		6.94	8.30	118.50	6.31	14.80
05/27/07		8.31	10.00	123.40	6.31	12.80
06/09/07		7.37	12.80	140.20	6.67	9.43
07/08/07		5.63	14.70	19.37	6.45	10.00
07/23/07		5.40	13.20	134.60	6.80	9.85
08/06/07		6.03	13.20	150.20	5.96	7.49
08/20/07		8.23	13.60	152.30	6.50	11.70
09/02/07		5.13	12.20		6.31	12.90
09/15/07		3.60	11.20	179.50	5.97	25.20
09/29/07		4.33	8.80		5.78	15.00
10/13/07		5.38	7.80	104.10	6.35	16.70
10/30/07		6.25	6.40	95.10	5.43	17.20
11/11/07		5.22	4.10	102.20	5.10	18.10
11/27/07		6.52	3.90	100.30	5.61	21.60
12/11/07		4.24	2.70	99.60	4.96	8.00
12/26/07		4.03	2.70	116.80	4.90	20.20
01/07/08		2.60	2.00	119.40	6.65	13.20
01/21/08		6.25	1.20	102.50	5.33	14.20
02/02/08		3.20	1.40	105.00	4.53	7.40
02/16/08		4.84	2.10	106.20	6.56	14.60
03/04/08		7.25	3.50	100.00	4.75	16.40
03/14/08		7.45	2.40	98.30	4.87	10.70
03/29/08		9.65	4.80	109.40	5.68	8.70

Table S7: Water quality data for Church of Nazarene created wetland, site 2.

CoN2		DO(mg/L)	T(^{o}C)	cond(uS/cm)	pH	turb(NTU)
10/13/01		6.40	7.80	200.00	6.53	17.10
1/3/02		3.55	3.30	125.10	5.89	12.50
5/14/02		9.18	7.80	166.80	n/a	12.30
10/15/02		5.71	8.20		6.50	31.70
10/23/02		6.19	9.50	100.60	6.45	35.30

11/21/02		6.45	4.80	90.80	6.17	23.40
12/18/02		6.05	4.20	100.10	6.59	28.90
1/31/03		4.42	3.50	105.00	6.36	11.51
3/10/03		3.35	3.80	105.00	6.26	19.20
4/3/03		6.91	5.60	112.40	6.32	12.70
5/3/03		9.45	9.60	124.50	6.69	14.40
6/3/03		8.17	14.30	111.40	6.95	12.00
7/21/03		6.07	14.60	125.80	7.21	6.65
10/4/03		3.93	10.20	122.80	6.44	19.70
11/5/03		4.85	4.60	113.00	6.94	21.90
12/12/03		3.93	3.60	114.50	6.52	14.90
1/11/04		3.46	3.20	117.20	5.90	17.90
2/10/04		7.09	3.00	81.30	5.90	28.50
3/20/04		7.90	4.70	106.60	6.20	22.90
5/15/04		9.30	16.50	144.20	7.28	6.91
6/10/04						
7/7/04		8.42	16.30	145.20	6.97	7.11
7/21/04		5.71	16.00	148.60	6.60	7.55
7/28/04		3.55	15.20	127.20	6.95	5.85
8/6/04		7.85	17.10	145.00	6.93	4.34
8/10/04		6.39	17.35	152.80	6.91	8.18
8/11/04		7.01	17.40	147.80	6.92	4.91
8/18/04		4.69	16.80	152.00	5.83	4.43
8/29/04		6.11	15.00	143.90	6.93	4.81
9/8/04		5.16	12.60	134.90	6.68	9.09
9/9/04			9.73	180.00	6.59	8.94
9/26/04		4.57	9.90	112.10	6.90	17.30
10/10/04		9.98	9.44	176.00	6.66	19.20
10/23/04		4.04	5.30	113.00	6.65	20.40
11/7/04		6.32	4.48	180.00	6.64	23.40
11/13/04		4.35	5.10	119.00	6.53	27.00
1/4/05		2.44	3.20	193.00	6.66	14.70
1/28/05		1.76	2.40	123.60	6.64	18.50
2/17/05		2.53	2.58	204.00	6.12	8.45
2/28/05		4.36	3.30	97.90	6.18	18.10
3/12/05		3.84	4.27	162.00	6.62	21.70
3/31/05		7.99	5.90	117.20	6.62	11.80
4/10/05		8.10	5.38	189.00	6.86	15.10
5/17/05		5.56	11.60	155.00	6.36	10.10
6/3/05		3.52	13.30	132.80	7.19	
8/10/05		6.30	17.30	152.80	6.91	8.18
9/6/05		5.51	11.40	122.00	6.25	40.40
9/24/05		6.15	10.20	114.90	6.24	31.70
10/9/05		3.24	9.20	120.60	6.42	20.50
10/22/05		6.31	7.40	109.00	6.61	19.80
11/6/05		5.08	4.40	101.10		
12/10/05		8.20	3.70	85.40	6.00	21.60
12/26/05		6.65	4.20	98.40	6.45	18.30
1/14/06		8.67	2.20	105.00	6.69	23.90
1/28/06		6.57	2.00	102.80	6.27	36.40
2/11/06		5.07	2.30	118.60	6.60	29.60
3/28/06		5.77	3.30	116.50	5.77	20.80
4/8/06		4.62	6.20	123.90	6.96	14.90

4/27/06		4.72	6.10	120.70	7.18	22.30
5/14/06		8.56	9.10	122.50	6.06	19.10
5/27/06		7.14	15.80	163.40	7.00	8.32
6/10/06		7.06	14.70	149.40	6.90	8.10
6/24/06		8.24	12.10	143.00		6.14
7/8/06		7.00	14.30	154.90	6.73	5.95
7/21/06		7.20	14.10	152.00	6.90	5.40
8/19/06		5.40	10.90	121.10	6.87	20.70
9/3/06		5.45	11.30	116.00	6.83	30.30
9/17/06		3.62	9.20	123.00	6.51	27.70
10/2/06		4.46	9.30	103.40	6.60	20.80
10/15/06		4.97	8.10	102.80	6.54	15.90
10/29/06		5.84	4.90	90.30	6.79	22.20
11/12/06		2.91	2.90	102.20	6.57	10.60
12/10/06		3.06	2.70	107.60	6.45	19.50
12/24/06		3.31	3.00	115.60	5.74	13.90
1/20/07		7.48	2.90	107.80	6.78	23.30
2/4/07		5.65	2.80	113.10	6.13	12.60
2/18/07		4.64	2.60	126.90	4.95	20.20
3/4/07		2.65	1.20	111.90		13.70
3/20/07		3.13	1.00	134.10	5.45	20.70
4/1/07		4.78	2.10	133.10	5.95	20.10
4/15/07		9.24	4.10	109.60	6.34	18.40
4/29/07		7.74	6.20	120.00	6.40	14.00
5/12/07		7.14	8.50	119.10	6.60	14.20
5/27/07		8.57	10.20	124.30	6.10	12.80
6/9/07		7.33	12.90	139.90	6.65	9.42
7/8/07		7.09	14.20	199.70	6.85	6.11
7/23/07		4.42	13.80	132.40	6.75	8.36
8/6/07		5.75	13.30	147.70	6.26	6.65
8/20/07		8.90	13.80	153.20	6.57	12.30
9/2/07		5.10	12.40		6.55	11.20
9/15/07		3.60	11.20	185.60	5.75	16.40
9/29/07		3.94	8.70		5.69	14.70
10/13/07		5.54	7.80	106.00	6.28	15.30
10/30/07		5.98	6.30	93.80	6.15	17.40
11/11/07		4.94	4.00	100.80	5.89	15.70
11/27/07		6.60	3.80	98.00	5.93	18.70
12/11/07		3.50	3.00	106.60	4.99	6.60
12/26/07		4.02	2.70	117.30	5.56	22.00
1/7/2008		2.74	2.0	119.8	5.30	12.80
1/21/2008		6.47	1.2	104.6	4.42	11.90
2/2/2008		2.95	1.8	100.0	5.30	9.50
2/16/2008		4.73	2.0	106.9	5.20	14.10
3/4/2008		6.57	3.0	86.7	5.04	12.00
3/14/2008		5.95	1.8	93.5	5.34	5.50
3/29/2008		9.45	4.5	106.4	5.30	6.00

Table S8: Water quality data for Church of Nazarene created wetland, site b.

CoNb	site	DO(mg/L)	T(^{o}C)	cond(uS/cm)	pH	turb(NTU)
7/21/04		4.67	15.20	139.80	6.43	9.25
7/28/04		4.54	15.10	127.30	6.84	5.41

8/6/04		3.80	14.70	130.20	6.71	5.34
8/11/04		3.65	16.50	136.90	6.85	5.42
8/18/04		2.22	15.60	136.00	6.56	10.00
8/29/04		4.10	13.30	127.90	6.83	5.34
9/8/04		2.81	11.40	115.10	6.24	5.37
9/26/04		3.73	9.20	101.00	6.28	6.59
10/23/04		0.17	6.40	148.90	6.41	2.81
11/13/04		0.46	5.70	102.20	5.85	3.84
1/23/05	frozen					
2/28/05		3.23	2.90	50.10	6.31	4.77
3/31/05		5.68	5.80	79.20	5.65	7.40
8/10/05		1.90	13.40	141.20	6.62	6.14
9/6/05		4.10	11.00	84.60	6.38	7.82
9/24/05		0.48	8.90	150.60	6.23	3.01
10/9/05		2.40	8.70	89.30	6.08	3.27
10/22/05		2.90	7.60	81.30	14.10	5.15
11/6/05		0.56	6.40	97.40		
11/26/05		3.24	3.30		5.48	8.00
12/10/05		9.73	6.30	86.80	4.62	11.60
12/26/05		3.40	4.30	92.00	4.95	40.50
1/14/06	frozen					
1/28/06		6.38	0.50	30.20	5.83	141.00
2/11/06		4.27	3.70	85.70	6.15	0.95
2/25/06	frozen					
3/11/06	frozen					
3/28/06	frozen					
4/8/06	insuff.water					
4/27/06		3.58	4.60	96.70	6.83	3.19
5/14/06		1.50	6.00	101.00	6.00	4.03
5/27/06		1.91	9.99	112.60	6.02	3.98
6/10/06		3.85	8.20	82.30	5.31	1.29
6/24/06		4.50	8.60	84.50		1.32
7/8/06		4.40	10.70	111.40	6.19	2.68
7/21/06		5.95	13.00	130.40	6.80	3.34
8/19/06		4.25	10.00	98.10		8.71
9/3/06		0.86	9.40	122.00	6.34	6.08
9/17/06		0.80	7.70	150.70	6.07	14.90
10/2/06		0.80	8.40	149.70	6.35	3.28
10/15/2006		0.80	7.70	99.30	5.55	11.50
10/29/2006		0.80	4.30	120.80	6.43	3.81
11/12/2006		0.80	2.70	130.20	5.61	16.20
12/10/2006		0.80	1.20	111.40		
12/24/2006		0.80	3.10	120.20	5.29	6.54
1/20/2007		4.19	2.10	73.20	6.56	23.50
2/4/2007		0.80	3.10	103.30	6.29	33.80
2/18/2007		1.29	3.30	103.90	4.94	50.10
3/4/2007	frozen					
3/20/2007	frozen					
4/1/2007	frozen					
4/15/2007		3.48	3.10	84.50	6.04	7.21
4/29/2007		1.74	5.60	144.40	6.30	7.36
5/12/2007		2.21	8.30	128.10	5.97	5.94
5/27/2007		3.07	7.90	100.10	5.47	6.47

6/9/2007		0.46	7.80	121.10	5.61	7.16
7/8/2007		0.80	10.30	16.18	5.89	8.03
7/23/2007		2.67	9.60	114.20	6.19	5.06
8/6/2007		0.90	10.00	123.50	5.46	3.00
8/20/2007		2.65	10.90	132.70	5.57	10.50
9/2/2007		0.97	9.90		5.61	4.70
9/15/2007		0.90	9.60	172.40	4.72	5.00
9/29/2007		1.10	8.20		5.01	3.40
10/13/2007		1.94	7.60	82.10	5.77	2.70
10/30/2007		2.16	7.10	97.10	5.37	1.90
11/11/2007		1.73	4.70	94.30	4.61	6.30
11/27/2007		1.37	4.50	112.50	5.15	25.50
12/11/2007		8.03	0.3	45.1	4.96	4.30
12/26/2007		1.42	2.2	110.0	5.81	2.66
1/7/2008	frozen					
1/21/2008	frozen					
2/2/2008	frozen					
2/16/2008	frozen					
3/4/2008		1.53	3.8	96.1	4.81	3
3/14/2008	frozen					
3/29/2008		1.60	4.0	100.4	4.57	2.7

Table S9: Water quality data for Church of Nazarene created wetland, site c.

CoNc	site	DO(mg/L)	T(^{o}C)	cond(uS/cm)	pH	turb(NTU)
7/21/04		6.43	16.30	149.10	6.65	5.71
7/28/04		5.89	15.40	123.70	6.88	4.99
8/6/04		5.74	15.70	137.20	6.70	4.97
8/11/04		6.94	17.30	143.40	6.80	4.76
8/18/04		5.88	17.10	150.30	6.63	4.04
8/29/04		5.43	14.50	137.80	6.54	4.73
9/8/04		4.38	12.90	134.20	6.50	11.90
9/26/04		4.11	9.90	110.70	6.63	33.80
10/23/04		2.30	6.40	114.80	6.01	21.80
11/13/05		3.96	5.10	116.70	6.17	30.60
1/23/05	frozen					
2/28/05		3.82	3.10	98.10	5.77	24.50
3/31/05		8.05	5.00	111.20	6.24	15.20
8/10/05		6.50	17.50	157.50	6.46	12.90
9/6/05		5.29	11.20	120.00	6.26	65.80
9/24/05		5.88	10.40	154.20	6.30	39.30
10/9/05		3.92	9.10	118.70	5.75	26.10
10/22/05		5.84	7.40	109.30	5.69	37.90
11/6/05		5.31	4.60	100.60		
11/26/05		7.21	6.30		4.74	21.40
12/10/05		5.24	3.70	86.30	5.23	26.20
12/26/06		1.89	5.30	107.50	5.55	3.64
1/14/06		1.75	3.20	90.40	5.72	8.86
1/28/06		5.16	1.80	104.00	5.90	134.00
2/11/06		5.62	3.30	117.20		80.60
2/25/06		4.46	2.70	106.20	5.89	200.00
3/11/06		2.74	3.10	122.60	5.80	200.00
3/28/06		6.11	4.10	114.30	6.34	256.00

4/8/06		7.31	6.90	127.40	5.71	77.80
4/27/06		4.05	6.40	128.40	6.86	49.70
5/14/06		9.60	9.50	100.00	6.20	24.00
5/27/06		8.06	15.30	156.00	6.67	9.93
6/10/06		7.70	13.80	142.70	6.53	9.32
6/24/06		8.85	12.30	142.10		6.10
7/8/06		7.62	14.70	153.80	6.82	8.68
7/21/06		7.88	14.20	150.80	6.89	6.92
8/19/06		5.12	10.90	117.60		32.00
9/3/06		5.54	11.20	113.30	6.78	37.30
9/17/06		2.77	9.40	122.70	6.44	43.80
10/2/06		4.53	9.40	102.50	6.34	30.60
10/15/2006		5.01	8.20	102.00	6.30	26.40
10/29/2006		5.52	5.20	90.20	6.54	32.20
11/12/2006		1.66	4.00	110.90	6.39	88.50
12/10/2006		2.64	3.10	107.30	6.51	32.80
12/24/2006		3.40	3.00	115.30	5.42	35.50
1/20/2007		6.80	2.80	103.90	5.27	28.30
2/4/2007		3.74	2.80	114.80	6.10	15.80
2/18/2007		3.38	2.90	126.10	5.00	27.80
3/4/2007	frozen					
3/20/2007	frozen					
4/1/2007		3.86	2.50	133.60	5.30	21.80
4/15/2007		8.39	4.20	107.70	6.29	27.80
4/29/2007		7.76	6.30	120.00	6.47	16.60
5/12/2007		7.43	8.50	117.80	6.34	16.10
5/27/2007		9.10	10.20	125.00	5.50	15.20
6/9/2007		7.87	12.80	139.70	6.30	11.40
7/8/2007		8.54	14.60	19.35	6.58	5.83
7/23/2007		6.13	13.40	134.40	6.65	12.10
8/6/2007		6.54	13.40	146.70	6.40	4.94
8/20/2007		9.58	14.20	153.10	6.30	10.10
9/2/2007		4.52	12.70		5.98	13.60
9/15/2007		3.00	11.20	184.30	5.45	28.90
9/29/2007		4.46	9.00		5.00	23.40
10/13/2007		5.31	7.80	106.80	6.27	20.40
10/30/2007		6.21	6.30	95.50	6.25	26.70
11/11/2007		4.75	4.40	103.30	4.79	20.30
11/27/2007		6.52	4.10	100.60	5.03	30.90
12/11/2007		3.06	3.2	108.1	5.09	16.80
12/26/2007		2.88	3.0	116.9	4.95	29.60
1/7/2008		1.57	2.9	122.1	4.97	24.40
1/21/2008		6.28	1.9	104.9	5.12	20.30
2/2/2008	frozen					
2/16/2008		4.91	2.3	107.8	4.28	21.40
3/4/2008		8.01	3.1	101.0	4.31	20.90
3/14/2008		6.73	3.4	99.9	5.97	15.80
3/29/2008		10.88	5.2	109.4	4.95	8.30

Table S10: Water quality data for Church of Nazarene created wetland, site 3.

CoN3		DO(mg/L)	T(^{o}C)	cond(uS/cm)	pH	turb(NTU)
10/13/01		6.04	7.90	200.00	6.55	20.90

1/3/02		2.27	3.40	121.40	6.24	15.00
5/14/02		9.40	8.10	168.30	5.00	13.10
10/15/02		5.55	8.10		6.13	39.90
10/23/02		6.12	9.20	98.80	5.84	42.40
11/21/02		6.90	5.00	94.70	6.29	25.80
12/18/02		5.74	4.10	100.40	6.33	30.90
1/31/03		3.29	3.50	105.20	4.88	11.18
3/10/03		2.72	4.20	106.30	5.11	19.30
4/3/03		5.40	4.60	110.40	5.80	16.30
5/3/03		10.02	11.10	129.80	6.61	15.70
6/3/03		8.73	14.70	127.90	6.95	9.93
7/21/03		6.43	15.00	138.00	7.06	5.81
10/4/03		3.95	9.90	119.90	5.93	36.10
11/5/03		3.67	4.20	109.70	6.97	21.00
12/12/03		2.05	3.70	117.60	6.21	11.20
1/11/04		3.21	3.30	119.20	5.65	14.30
2/10/04		7.03	2.50	80.60	5.70	32.30
3/20/04		4.40	7.90	105.50	6.12	21.00
5/15/04		10.15	15.00	140.13	7.08	8.10
6/10/04						
7/7/04		7.20	16.40	145.20	6.86	12.30
8/6/04		6.95	16.40	142.30	6.89	3.64
9/9/04			10.86	177.00	6.56	15.10
10/10/04		9.84	9.40	173.00	6.58	28.30
11/7/04						
12/5/04						
1/4/05		2.67	3.56	191.00	6.57	15.30
2/17/05		2.08	2.87	226.00	6.24	14.40
3/12/05		5.46	4.10	158.00	6.55	24.70
4/10/05		8.17	5.74	203.00	6.79	17.80
5/17/05		3.38	11.40	199.00	6.41	8.22
6/3/05		7.75	15.00	145.20	7.20	
8/10/05		7.15	18.60	161.40	6.66	13.00
9/6/05		5.13	11.20	121.20	6.53	67.70
9/24/05		5.23	10.10	113.00	6.10	46.10
10/9/05		3.97	9.00	118.80	6.41	22.60
10/22/05		5.95	7.30	109.30	5.79	28.90
11/6/05		5.39	4.60	101.30		
11/26/05		7.51	6.90		6.34	
12/10/05		7.40	3.80	138.30	4.38	32.10
12/26/05		6.17	4.30	97.60	6.26	22.70
1/14/06		6.95	3.00	109.20	7.03	41.90
1/28/06		1.56	3.60	104.80	5.94	36.90
2/11/06		5.88	3.20	124.90	6.54	36.20
2/25/06		5.44	3.20	120.60	6.04	84.10
3/11/06		3.41	3.20	124.20	6.15	21.40
3/28/06		6.67	4.20	121.70	6.45	26.30
4/8/06		5.67	6.10	125.70	5.72	13.30
4/27/06		4.90	6.60	128.80	6.82	25.70
5/14/06		9.06	9.30	100.00	6.08	23.70
5/27/06		8.06	15.30	156.00	6.67	9.93
6/10/06		8.00	14.10	143.50	6.64	10.00
6/24/06		9.04	12.40	143.10		6.13

7/8/06		7.70	14.80	154.70	6.74	7.87
7/21/06		7.65	14.30	151.90	6.10	6.44
8/19/06		5.15	10.90	118.00		33.90
9/3/06		5.54	11.10	113.30	6.77	39.50
9/17/06		2.94	9.50	123.00	6.44	43.80
10/2/06		4.71	9.40	101.80	6.41	31.70
10/15/2006		5.13	8.20	102.70	6.28	27.00
10/29/2006		5.70	53.00	91.10	6.76	48.40
11/12/2006		1.40	4.20	104.80	6.60	16.90
12/10/2006		2.70	3.10	108.20	6.52	28.70
12/24/2006		3.58	3.00	116.00	5.12	28.40
1/20/2007		7.14	2.80	103.70	6.13	28.90
2/4/2007		3.90	3.00	117.60	6.29	16.50
2/18/2007		3.90	2.80	125.20	5.46	28.20
3/4/2007		1.70	2.50	116.70		17.20
3/20/2007		1.32	2.20	138.70	5.24	12.70
4/1/2007		4.26	2.70	135.10	5.22	21.90
4/15/2007		8.62	4.20	110.40	6.55	23.40
4/29/2007		7.57	6.20	119.80	6.34	16.80
5/12/2007		7.60	8.60	117.50	6.40	16.10
5/27/2007		9.46	10.40	124.30	5.96	14.80
6/9/2007		8.03	12.70	139.70	6.25	11.40
7/8/2007		9.47	15.00	19.64	6.65	6.14
7/23/2007		6.61	13.60	133.10	6.80	13.40
8/6/2007		7.50	13.60	146.20	6.33	4.47
8/20/2007		10.69	14.60	153.10	6.36	8.91
9/2/2007		5.01	12.70		6.12	11.00
9/15/2007		3.70	11.20	186.60	5.45	34.80
9/29/2007		4.50	9.10		5.18	23.30
10/13/2007		5.17	7.90	107.60	6.70	21.80
10/30/2007		6.20	6.40	96.20	6.10	27.00
11/11/2007		4.45	4.60	105.40	5.72	17.90
11/26/2007		6.75	4.10	100.00	5.75	28.10
12/11/2007		4.1	2.8	107.20	5.48	20.90
12/26/2007		3.1	2.7	115.80	5.14	25.60
1/7/2008		1.4	2.6	124.60	5.40	12.00
1/21/2008		7.5	1.7	102.10	4.80	14.40
2/2/2008		1.2	2.7	100.00	5.30	9.50
2/16/2008		6.3	1.7	108.30	4.80	14.50
3/4/2008		10.0	2.5	102.60	5.17	14.00
3/14/2008		10.1	3.2	101.80	5.91	9.20
3/29/2008		11.2	4.8	108.70	5.75	7.80

Table S11: Water quality data for Allison Pond, site a.

APa		DO (mg/L)	T (^{o}C)	cond(μS/cm)	pH	turb(NTU)
7/21/04		6.95	16.8	146.3	6.67	5.61
7/28/04		6.08	16.6	135.1	6.94	7.78
8/6/04		6.37	16.1	135	6.88	3.91
8/11/04		7.92	17.8	142	6.93	3.7
8/18/04		6.18	17.2	147.9	6.77	4.2
8/29/04		5.83	14.9	134.1	6.79	4.46
9/8/04		5.18	12.6	120.8	6.5	16

9/26/04		4.77	9.8	100.7	6.92	31.4
10/23/04		3.05	4.6	107.4	6.11	31.9
11/13/04		3.96	4.7	113.5	6.32	25.2
1/28/05		0.97	2.4	130	6.11	16.8
2/28/05	frozen					
3/31/05		8.72	5.2	108.7	6.7	14.5
4/27/2006		4.99	6.8	117.1	6.95	27.5
5/14/2006		9.05	9	120.2	6.11	23.6
5/27/2006		8.61	16.4	159	6.94	11.4
6/10/2006		7.65	15.1	145.2	6.65	10.5
6/24/2006		9.6	12.7	140.7		6.87
7/8/2006		7.7	15.1	150.7	6.83	8.68
7/21/2006		8.2	14.3	145.6		7.83
8/19/2006		7.53	11.5	108.7		16.1
9/3/2006		5.48	11.4	105.9	6.72	35.1
9/17/2006		3.35	9.6	115.8	6.43	48.3
10/2/2006		3.25	9.2	95.5	6.07	34.2
10/15/06		3.05	8.1	101.7	6.47	27.5
10/29/06		3.81	4.8	83.9	6.32	40.8
11/12/06	frozen					
12/10/06		3.87	1.5	79.2	6.44	5.56
12/24/06	frozen					
1/20/07		4.37	1.4	44.1	6.06	9.29
2/4/07	frozen					
2/18/07	frozen					
3/4/07	frozen					
3/20/07	frozen					
4/1/07	frozen					
4/15/07		8.67	3	68.9	6.48	21.4
4/29/07		7.51	6.5	114.3	6.5	17.1
5/12/07		7.43	9	112.9	6.41	13.8
5/27/07		9.74	10.5	119.8	6.36	12.8
6/9/07		8.07	13.5	138.8	6.54	10.5
7/8/07		8.9	15.1	185	6.7	8.52
7/23/07		6.9	13.4	130.3	6.9	9.82
8/6/07		7.83	13.6	140.6	6.31	4.65
8/20/07		11.95	15	151.8	6.62	20.4
9/2/07		4.36	12.3		6.08	17.5
9/15/07		4.8	11.9	162.2	5.59	19.5
9/29/07		3.79	8.6		5.38	26.8
10/13/07		4.82	7.8	95	6.73	26.5
10/30/07		6.5	6.4	92.3	5.81	27.1
11/11/07		3.17	4.2	99.01	5.57	41.5
11/27/07		5.69	3.22	101.5	5.7	28.8
12/11/07	frozen					
12/26/07	frozen					
1/7/2008	frozen					
1/21/2008	frozen					
2/2/2008	frozen					
2/16/2008	frozen					
3/4/2008	frozen					
3/14/2008	frozen					
3/29/2008	frozen					

Table S12: Water quality data for Allison Pond, site b.

APa		DO (mg/L)	T (^oC)	cond(μS/cm)	pH	turb(NTU)
7/21/04		6.72	16.4	149.3	6.6	5.88
7/28/04		5.67	15.5	124.7	7.05	3.86
8/6/04		6.12	17.4	143.9	6.83	4.89
8/11/04		7.61	17.5	137	6.96	5.65
8/18/04		7.53	17.5	148.4	6.96	3.56
8/29/04		6.17	15.8	144.2	6.74	4.11
9/8/04		5.1	12.6	125	6.4	16.9
9/26/04		5.57	9.6	112.4	6.83	35.5
10/23/04		3.51	6	121.5	6.01	37.7
11/13/04		4.4	5.2	123.8	6.13	42.2
1/28/05	frozen					
2/28/05		4.92	2.5	81.5	5.97	21.6
3/31/05		9.09	4.9	107.8	6.92	22.4
4/27/06		5.68	6.9	120.2	5.7	27.7
5/14/06		9.43	9.1	120.9	6.14	23
5/27/2006		8.33	18	166.4	7.1	10.5
6/10/2006		8.64	16.3	152.4	6.67	9.94
6/24/2006		9.83	12.8	138.8		6.87
7/8/2006		8.28	15.2	152.3	6.41	8.09
7/21/2006		7.5	13.8	141.9	6.34	11.6
8/19/2006		4.28	11	120.7		30.4
9/3/2006		5.92	12	112	6.9	33.6
9/17/2006		2	9.9	131.1	6.13	35
10/2/2006		4.62	9.6	102	6.32	29.5
10/15/06		4.25	8.6	105.6	5.81	26.1
10/29/06		5.34	5.9	153.1	6.27	32
11/12/06		2.01	4.6	105.6	6.08	9.41
12/10/06	frozen					
12/24/06		4.91	3.2	103.1	5.38	9.13
1/20/07		6.75	2.8	99.2	6.48	23.9
2/4/07		3.44	2.3	92	6.36	10.3
2/18/07		3.07	3.2	117.4	4.94	13.4
3/4/07	frozen					
3/20/07	frozen					
4/1/07		2.88	3.6	110.6	4.95	3.87
4/15/07		8.94	4.1	102.5	6.48	21.4
4/29/07		8.32	6.3	119.6	5.59	19.8
5/12/07		8.9	9.8	120	6.2	14.4
5/27/07		9.16	10.1	119.7	5.75	16.7
6/9/07		8.95	15.5	151.5	6.74	10.3
7/8/07		9.35	15.2	195	6.75	5.93
7/23/07		7.37	13.8	120.9	6.86	10.5
8/6/07		7.95	13.4	145.3	6.3	6.04
8/20/07		10.83	14.8	151.4	6.41	10.8
9/2/07		6.54	15.2		6.29	16.3
9/15/07		7.2	11.5	162.3	5.65	27.9
9/29/07		4.98	9		5.45	24.8
10/13/07		5.64	8	102	5.9	23.1
10/30/07		6.88	6.6	94.2	4.95	20.6
11/11/07		4.6	5	108	5.39	19

11/27/07		5.78	4.9	104.5	4.9	14.9
12/11/07	frozen					
12/26/07	frozen					
1/7/2008	frozen					
1/21/2008	frozen					
2/2/2008	frozen					
2/16/2008	frozen					
3/4/2007	frozen					
3/14/2008	frozen					
3/29/2008		7.6	6.2	118.20	4.88	15.6