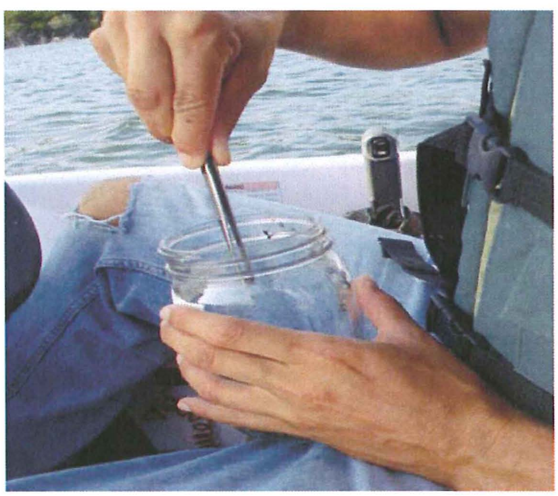
SQUAW CREEK RESERVOIR CHARACTERIZATION STUDY

Final Report






SUBMITTED TO:
ENERCON SERVICES, INC.
400 Valley Road, Suite 301
MT. Arlington, NJ 07856-2316

PREPARED BY:
BIO-WEST, INC.
1812 Central Commerce Court
Round Rock, Texas 78664
Ph: 512.990.3954
Fax: 512.990.5153

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INTRODUCTION

Squaw Creek Reservoir is a 3,272 acre impoundment located in Somervell County, Texas that functions as the primary source of cooling water for the Comanche Peak Steam Electric Station. The average depth of the reservoir is 14 meters (46 feet) with a maximum depth nearing 42 meters (135 feet). The reservoir was impounded in February 1977, and by May had filled to create a surface area of 1,324 hectares with a shoreline of 112.6 kilometers (km). Fish stocking began in 1979 by the Texas Parks and Wildlife Department (TPWD). Fish that were stocked in the impoundment included: smallmouth bass (*Micropterus dolomieu*), largemouth bass (*Micropterus salmoides*), Palmetto bass (*Morone saxatilis x Morone chrysops*), threadfin shad (*Dorosoma petenense*), channel catfish (*Ictalurus punctatus*), and walleye (*Sander vitreus*). Stocking ceased in 1996. The reservoir was closed to the public in 2001, and has not been reopened.

In February 2007, BIO-WEST initiated a four season ecological study to characterize the aquatic vegetation, fish, benthic, and plankton communities, and general water quality within Squaw Creek Reservoir. All field sampling efforts were completed on January 9, 2008 (Table 1). This report reflects the findings from all data gathered within this time period.

Table 1. Sampling dates in 2007 for Squaw Creek Reservoir.

Season	Sampling Date
Winter†	February 26 – 28
Spring	May 7 – 8
Summer	September 4 – 6
Fall	November 13 – 14

†An additional winter sampling trip was completed on January 9, 2008 to assess fish populations in the reservoir.

METHODS

Study Site

Seven sampling sites in the vicinity of Squaw Creek Reservoir were chosen based on information provided by Enercon Services professionals. Three of these sites were located in pelagic (open-water) areas, three in littoral (close to the bank) areas within Squaw Creek Reservoir, and one in Squaw Creek downstream of the reservoir (Figure 1). Sites were chosen in each section of the lake (lower, middle, upper) and were representative of habitats observed in the reservoir. All site locations were recorded on a handheld Garmin GPS unit, and fixed station photographs were taken with a digital camera at each site.

Pelagic sites were located in three regions running down the middle of the mainstem of Squaw Creek Reservoir. The upstream most site (SQP1) is located 123 meters (m) off the northern shore of the reservoir with depths of 9 – 11 m. The substrate at this site consists of deep silt. The site nearest the dam (SQP2) is 117 m from the shore just off of a shelf (6 – 9 m in depth) with depths of 16 – 22 m, and bedrock substrate. The third pelagic site (SQP3) is located near the power plant 85 m from the southern shore of the reservoir. Depths at the sampling location range from 8 – 11 m making it the shallowest pelagic site. The substrate here is dominated by bedrock and cobble (rip-rap).

Littoral sites were located within coves of the reservoir because these areas contained shallower depth habitats near the shoreline. Site SQL1 is located in the cove near the Squaw Creek Park, and is 157 m from the boat dock. The water depths at this site ranged from <1 m to 7 m. The substrate at this site consisted of clay and bedrock, with grasses and junipers dominating the shoreline. The second littoral site (SQL2) is found in a large cove located to the east of SQL1, where water depths ranged from <1 m to 5 m. The substrate at SQL2 consisted mainly of bedrock and the shoreline vegetation was also dominated by juniper and grasses, similar to site SQL2. However, this site also contained a large number of submerged trees throughout the cove. The final littoral site (SQL3) was located in a cove adjacent to the outflow of the power plant; however, it is upstream of the discharge site. This site had the lowest maximum depth of the littoral sites (2.5 m), and a shoreline also dominated by juniper trees. The substrate at this site was similar to other sites, consisting of clay and bedrock.

The seventh site (SQDS) was located approximately 1.4 km downstream of the dam in a stream environment. Since this is a stream site, approximately 55 m were sampled in order to accurately characterize the area. The downstream end of the site is delineated by a road where water is diverted into a culvert that passes underneath the road (during low-flows). Riparian vegetation is diverse with several tree and shrub species dominating the riparian zone along the stream banks. Substrates within the stream channel ranged from silt and detritus to large gravel, and habitats that were sampled included riffles, runs, and pools.

Aquatic and Terrestrial Vegetation

Since aquatic vegetation was sparse at all sites, dominant terrestrial vegetation species were identified at all littoral and stream sites. All vegetation was identified to species.

Fish Community

As directed by Enercon professionals, fish communities were sampled twice (winter and summer) in 2007. An additional sampling effort was conducted on January 9, 2008 at two sites (SQP3 and SQL3) to assess fish movement at these sites due to the low number of individuals captured during the summer sampling effort. Due to high total dissolved solids levels, variable mesh size gill netting was used as the primary means of sampling the fish community within the reservoir. These fishes were sampled at each site in the reservoir using a 38.1 m (125 ft) long experimental gill net with mesh sizes ranging from 2.5 to 7.6 centimeters (1.0 - 3.0 inches). Each net was set overnight for 14 – 17 hours. A backpack electrofisher and several types of seines (common sense, bag, etc.) with variable mesh sizes were used to sample fish communities in the stream site downstream of the reservoir (SQDS). Upon capture, fish were identified to species, and the total length (millimeters) and weight (grams) were recorded for each fish. All fish were released after measurements were taken. During the summer sampling effort, the stomachs of 12 fishes were excised to identify gut contents to assess food preferences of fishes in the reservoir.

Benthic Community

Benthic invertebrate communities were sampled utilizing several methods, with the intent to assess the taxa found within different habitats. At all pelagic sites, a three-grab composite Ponar sample was collected from the substrate at the bottom of the reservoir. At the littoral sites, a combination of a Ponar sample and a D-frame net sample (used to sample edge habitats) was collected to characterize benthic communities. A D-frame net was used to sample all habitats (edge, pool, woody debris, etc) throughout the stream site (SQDS) to create one composite sample. All samples were immediately stored in a 95% ethanol solution and identification of invertebrates was performed in the laboratory.

All insect taxa were enumerated and identified to genus. Non-insect taxa (annelids, amphipods, etc.) were identified to the lowest possible level.

Plankton Community

Plankton communities were sampled using a vertically towed Watermark® simple plankton net with 80-micron mesh. A single tow sample was collected at each site, as well as a duplicate sample at two of the seven sites for quality assurance measures. All samples were collected during daylight hours between 10:00 – 14:00 to minimize the effect of diurnal movements of zooplankton on the sampling design. In addition, during the summer sampling effort extra samples were taken to assess the golden algae (*Prymnesium parvum*) community within the reservoir. Samples were preserved in Lugol's solution and transported to the laboratory for identification and enumeration.

Water Quality

Data on water temperature (Celsius), pH, conductivity (microsiemens/cm), dissolved oxygen (DO, mg/L), and turbidity (NTU) were collected at the surface of each site using a handheld YSI multiparameter probe. Hardness (mg/L as Ca), alkalinity (mg/L), and total dissolved solids (TDS, mg/L) were determined in the laboratory from 500 mL surface water grab samples collected at each site. In addition, several surface water parameters (temperature, pH, conductivity, DO) were collected at three locations (DS, Mid, US) within the downstream site. A water column profile of temperature and DO was measured at all six reservoir sample sites, and one additional reservoir site, to assess changes in these parameters as they relate to depth. This site (DO Profile, Figure 1) was located in a pelagic region (26 m in depth) to assess DO and temperatures in deeper portions of the reservoir. Due to the influence of water temperature on biological and ecological responses in a cooling reservoir, a spatial surface profile of temperature was collected across 122 points (~31/season) in Squaw Creek Reservoir for all four seasonal efforts combined.

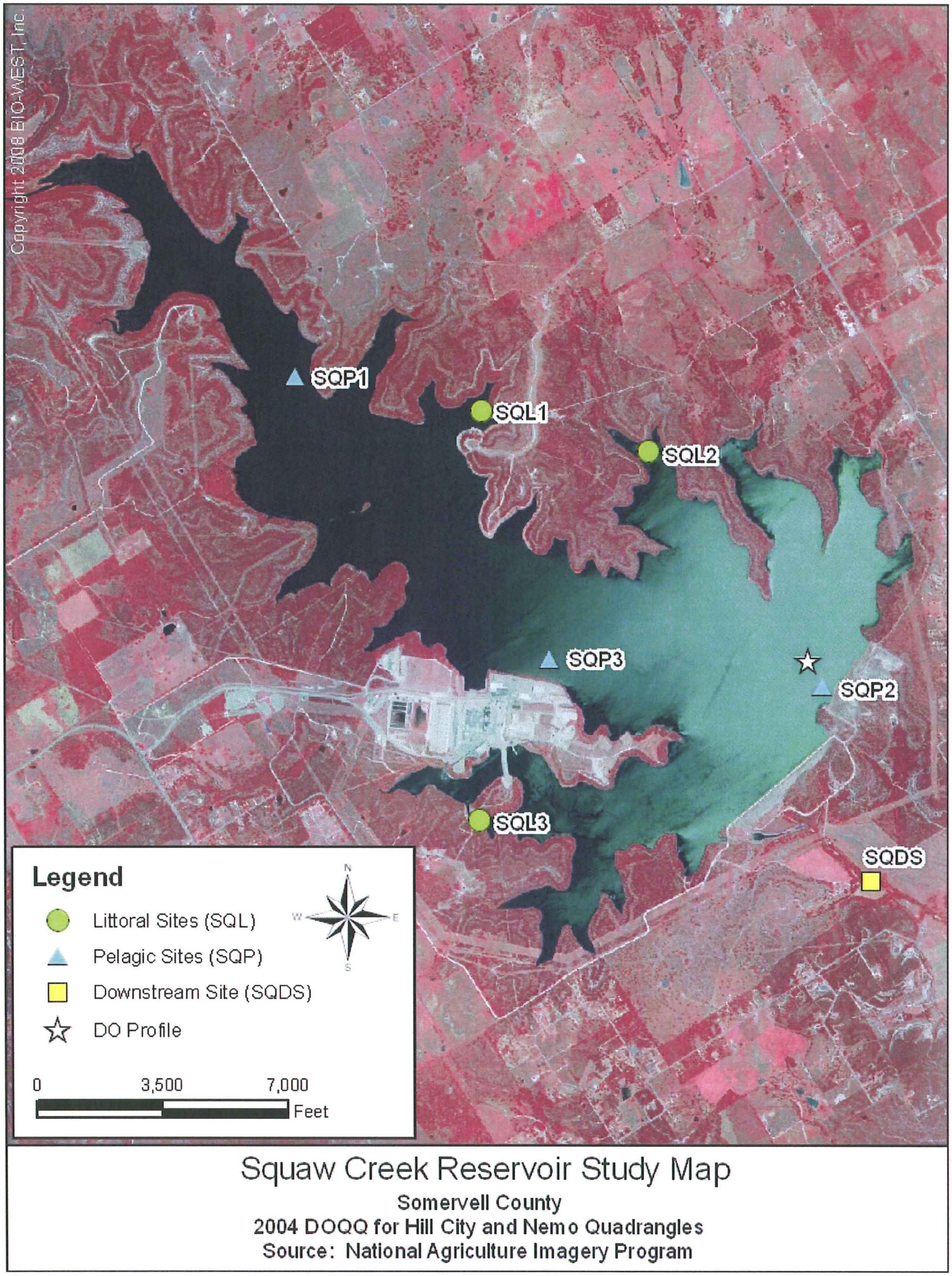

Figure 1. Location of seven study sites and a DO profile site in the Squaw Creek Reservoir study area.

RESULTS

Aquatic and Terrestrial Vegetation

Planktonic algae were the only vegetation type found at the pelagic (SQP 1-3) sites because water depths were too great (6 – 13 m) to support submerged or emergent vegetation. As a result, these sites were excluded from Table 2. The shoreline of Squaw Creek Reservoir is dominated by Ashe's juniper (*Juniperus ashei*) and grasses. Ashe's juniper was the most common plant found at the reservoir, and the only one found at all sites (excluding pelagic sites). These trees are commonly found on limestone hills throughout Texas. Bermuda grass (*Cynodon dactylon*) was observed at all littoral sites, however, it was absent during the winter sampling effort because the growing season had not commenced in this region. These two plants were the only ones common to all littoral sites.

All littoral sites are characterized by deep water close to the shoreline except site SQL3. This site is located at the most upstream end of a large cove in the southwestern region of the reservoir. With shallower depths, this site supported the only dominant aquatic vegetation in the reservoir. Cattail (*Typha* sp.) was dominant here during the winter sampling effort (and present during other efforts). It is an emergent plant that can tolerate extreme conditions in aquatic environments, and is common to many water bodies in Texas (Stutzenbaker 1999). Bermuda grass and Rooseveltweed (*Baccharis neglecta*) were also common plants found here through most of the year. Winter vetch (*Vicia villosa*) appeared as the growing season commenced at this site, but as temperatures warmed other plants outcompeted and became more dominant in the riparian zone. Spring herald (*Forestiera pubescens*) was another plant that appeared in the spring (SQL2), but by summer had ceased to be dominant on the shoreline of the reservoir. As the growing season progressed into fall there was little change in the dominant vegetation along the banks of Squaw Creek Reservoir.

Squaw Creek downstream of the dam is characterized by a relatively diverse riparian area. Bur oak (*Quercus macrocarpa*) and post oak (*Quercus stellata*) are the dominant oak species in the overstory at this site. Green ash (*Fraxinus pennsylvanica*), roughleaf dogwood (*Cornus drummondii*), and hackberry (*Celtis laevigata*) were also dominant in all seasons in this reach (though not growing as large as the oak trees). Poison-ivy (*Toxicodendron radicans*) was dominant in the understory during all seasons, and greenbriar (*Smilax* sp.) was dominant after the growing season commenced in spring. The only dominant aquatic vegetation at the downstream site in 2007 was filamentous algae. These plants were present throughout much of the water column in winter, and likely were flushed down from the dam during the higher flows. Johnsongrass (*Sorghum halepense*) and cuman ragweed (*Ambrosia psilostachya*) became a dominant part of the understory in the fall as other plants began to senesce as the growing season drew to a close. Although, many annual plants made their appearance in the riparian areas of the creek and reservoir, few were dominant and not discussed in this report. With Ashe's juniper and oaks dominating the overstory at the study sites, there was little seasonal change observed. Without major disturbance these plants will continue to dominate the shorelines and stream banks around Squaw Creek Reservoir.

Table 2. Dominant vegetation species encountered during all sampling efforts. Note: Pelagic sites (SQP1 – 3) were not included for lack of vegetation.

Site	Common Name	Scientific Name	Classification	Winter	Spring	Summer	Fall
SQDS	Post oak	*Quercus stellata*	Riparian	X	X	X	X
	Green ash	*Fraxinus pennsylvanica*	Riparian	X	X	X	X
	Roughleaf dogwood	*Cornus drummondii*	Riparian	X	X	X	X
	Hackberry	*Celtis laevigata*	Riparian	X	X	X	X
	Bur oak	*Quercus macrocarpa*	Riparian	X	X	X	X
	Western soapberry	*Sapindus drummondii*	Riparian			X	
	Greenbriar	*Smilax* sp.	Riparian		X	X	X
	Poison ivy	*Toxicodendron radicans*	Riparian	X	X	X	X
	Grape	*Vitis* sp.	Riparian			X	
	Johnsongrass	*Sorghum halepense*	Riparian				X
	Cuman ragweed	*Ambrosia psilostachya*	Riparian				X
	Filamentous algae	*Spirogyra, Anabaena* spp., etc.	Floating	X			
SQL1	Ashe's juniper	*Juniperus ashei* Buchh.	Riparian	X	X	X	X
	Bermuda grass	*Cynodon dactylon*	Riparian			X	X
	Gramma grass	*Bouteloua* sp.	Riparian		X		
SQL2	Ashe's juniper	*Juniperus ashei* Buchh.	Riparian	X	X	X	X
	Buttonbush	*Cephalanthus occidentalis*	Riparian			X	
	Rooseveltweed	*Baccharis neglecta*	Riparian	X	X	X	X
	Bermuda grass	*Cynodon dactylon*	Riparian		X	X	X
	Spring herald	*Forestiera pubescens*	Riparian		X		
SQL3	Ashe's juniper	*Juniperus ashei* Buchh.	Riparian	X	X	X	X
	Bermuda grass	*Cynodon dactylon*	Riparian		X	X	X
	Rooseveltweed	*Baccharis neglecta*	Riparian			X	X
	Winter vetch	*Vicia villosa*	Riparian		X		
	Common reed	*Phragmites australis*	Riparian			X	
	Cattail	*Typha* sp.	Emergent	X			
	Switchgrass	*Panicum virgatum*	Riparian				X

Fish Community

A total of 458 fishes representing 12 different species were captured at all sites combined in 2007 – 2008 (Table 3). The channel catfish was the most common fish captured in all seasons combined (270). It was more common at littoral (206) than pelagic (64) sites. Channel catfish are ubiquitous in rivers and lakes in Texas. Largemouth bass were also relatively common in the reservoir. Nearly all (43) were captured in littoral sites, with only 4 individuals collected in the pelagic zone of the reservoir. This fish was also found in the downstream site (2), but more were observed in the creek occupying habitats too deep to sample using conventional means (backpack electrofisher, seines). Gambusia (*Gambusia* sp.) were the most common fish in the downstream site (60), though they were only caught in February, they were observed to be occupying deeper habitats in September. Along with the inland silverside (*Menidia beryllina*), these fishes were only collected at the downstream site. Freshwater drum (*Aplodinotus grunniens*) were the most numerous fish (except for channel catfish) in the pelagic sites in Squaw Creek Reservoir (22 total in these three sites). These are another common fish found in lakes and rivers in Texas. Bluegill (*Lepomis macrochirus*) were the most common sunfish found at all sites in 2007 (24). These fish were found at the downstream and littoral sites. Common carp (*Cyprinus carpio*, Figure 2) were captured infrequently in Squaw Creek Reservoir even though they are very common in water bodies throughout Texas.

During the winter and spring sampling efforts, few benthic invertebrates were collected from the substrate in Squaw Creek Reservoir. Therefore, gut content analysis was performed on 12 fishes (7 channel catfish) during the summer sampling effort to get an idea of what organisms the fishes in the reservoir were feeding on. Of the excised stomachs, 5 had no identifiable remains in their stomachs. Contents found in other fish stomachs included insects (Coleopterans, chironomids), crayfish, mudcrabs, fish, worms, and algae. Parasites were also found in the stomachs of three fish. These results are not necessarily indicative of the feeding preferences of fishes in the reservoir. When stomachs were excised, water temperatures were extremely high (38.8 °C). When fishes are at or near their upper temperature tolerances, they are less likely to feed. To get a better understanding of feeding preferences, a greater number of fish's stomachs should be excised during all seasons.

The winter sampling effort was more productive with 75% of the fish caught, compared to 18% in the summer. Surface water temperatures were significantly cooler in winter (20.5 – 23.8 °C) than summer (32.8 – 38.8 °C). Site SQL3 exhibited the highest water temperature in summer (38.8 °C), and consequently no fish were caught at this site in September. This site was warmest in summer because it is the shallowest of the reservoir sites, and is also closest to the discharge of the plant. As a result, there are few cold-water refuges for the fishes in this area. Other littoral sites are much deeper and fishes were captured here in September in much greater numbers (compared to SQL3). Maximum temperature tolerances in fishes are important for growth and survival, and are often most important during the early life stages. The highest temperature and the time period that temperature is sustained (and access to cold water refuges) contributes in determining the species diversity of the reservoir. The extremely high water temperatures present in Squaw Creek Reservoir in summer is likely why many of the fish stocked previous to the power plant coming on-line are no longer present. For example, walleye have a maximum temperature tolerance of 32 °C, and 23 °C is the physiological optimum temperature for this coolwater fish (IDFG 1982). It is temperatures like these that have led to a natural distribution of these fish in the northern climes of North America. With temperatures in Squaw Creek Reservoir reaching well above 38 °C regularly in summer it is little wonder that these fish are no longer found. Other fishes stocked in the reservoir show similar tolerances. For smallmouth bass, water temperatures over 35 °C are considered stressful, and temperatures over 38 °C lethal (Moyle 2002). Largemouth bass can tolerate slightly higher temperatures (35.6 – 37.3 °C, Currie et al. 2004) and still exhibit growth. Channel catfish have even higher tolerances (38.5 – 39.6

°C, Currie et. al. 2004), which is why these fishes appear to be most common in the reservoir. Freshwater drum are less common and tolerate temperatures up to 32.8 °C (Cvancara 1975), but are commonly found at depths greater than 30 feet in reservoirs (Pflieger 1997). The combination of these maximum temperature tolerances, and the high summer water temperatures likely led these fishes to seek colder water refuges in the deeper portions of the lake. This is why so few fish (comparatively) were captured in the summer sampling effort. Fish species that cannot survive in temperatures exceeding 38 °C will seek out areas of greater depths (where temperatures are lower) than were sampled for this study. When temperatures decreased in winter, many fishes re-occupied areas that where they were not found in summer (SQL3 and SQP3). These movements by the fishes are tied to seasonal water temperature changes in most lakes and reservoirs, but with the extreme changes in this reservoir, these movements are more pronounced.

With water temperatures regularly climbing past 38 °C in summer in Squaw Creek Reservoir coolwater fishes like walleye and smallmouth bass will be unable to reproduce and survive. Warmer water fishes (largemouth bass, channel catfish, freshwater drum) can tolerate these temperatures, but still become stressed and growth is reduced. Stress of these fishes can lead to exposure to parasites (as seen in some fishes stomachs) that can kill fish. Reduction of water temperatures during spawning times, and the presence of cooler water refuges during summer will contribute greatly to the survival of these game species.

Figure 2. Common carp (*Cyprinus carpio*) captured in a gill net.

Table 3. Fish species collected during each season in Squaw Creek Reservoir during 2007 – 2008.

Site	Common Name	Scientific Name	Number Collected February	September	January[a]
SQDS	Gambusia	*Gambusia* sp.	60		
	Green sunfish	*Lepomis cyanellus*	1		
	Bluegill	*Lepomis macrochirus*	4	1	
	Sunfish	*Lepomis* sp.		1	
	Inland silverside	*Menidia beryllina*	6		
	Largemouth bass	*Micropterus salmoides*		2	
SQP1	Freshwater drum	*Aplodinotus grunniens*	3	2	
	Gizzard shad	*Dorosoma cepedianum*	1		
	Channel catfish	*Ictalurus punctatus*	25	12	
	Flathead catfish	*Pylodictis olivaris*	1		
SQP2	Freshwater drum	*Aplodinotus grunniens*	3		
	Threadfin shad	*Dorosoma petenense*	2		
	Channel catfish	*Ictalurus punctatus*	10		
	Green sunfish	*Lepomis cyanellus*	1		
SQP3	Freshwater drum	*Aplodinotus grunniens*	10		2
	Channel catfish	*Ictalurus punctatus*	12	3	2
	Bluegill	*Lepomis macrochirus*	3		
	Largemouth bass	*Micropterus salmoides*	4		
	Flathead catfish	*Pylodictis olivaris*	1		
SQL1	Freshwater drum	*Aplodinotus grunniens*	3	1	
	Channel catfish	*Ictalurus punctatus*	43	24	
	Green sunfish	*Lepomis cyanellus*		3	
	Bluegill	*Lepomis macrochirus*	1	3	
	Largemouth bass	*Micropterus salmoides*	15		
SQL2	Freshwater drum	*Aplodinotus grunniens*	1		
	Common carp	*Cyprinus carpio*	4	1	
	Gizzard shad	*Dorosoma cepedianum*	1		
	Channel catfish	*Ictalurus punctatus*	71	13	
	Green sunfish	*Lepomis cyanellus*		1	
	Bluegill	*Lepomis macrochirus*		12	
	Largemouth bass	*Micropterus salmoides*	1	3	
SQL3	Common carp	*Cyprinus carpio*	2		2
	Blue catfish	*Ictalurus furcatus*	1		1
	Channel catfish	*Ictalurus punctatus*	48		7
	Largemouth bass	*Micropterus salmoides*	5		17
Total			**343**	**82**	**31**

Benthic Community

The number of invertebrates collected in each season at each site is represented in Table 4, and family and genera of organisms found are shown in Appendix A. A total of 3,117 invertebrates representing at least 59 different genera were collected in Squaw Creek and Squaw Creek Reservoir in 2007. In every season chironomids (midges) were the most numerous (2,198 individuals) and most diverse (18 genera) invertebrates discovered in the study sites. Chironomids are a very diverse family and occupy a wide variety of habitats, which is why they are so numerous here. In addition, they can tolerate a wider range of water quality than most other invertebrates. *Parachironomus* were the most common genera in this family, and were found in each season except winter. Chironomids were also the only insects (and one mayfly) collected from the pelagic sites in the reservoir in 2007. Substrates in the pelagic sites vary from deep silt/mud (SQP1) to hard bedrock and cobble (SQP2 and SQP3), which is why so few insects were found here. In fact, no invertebrates were captured at site SQP2 during 2007. The only other benthic invertebrates collected in Ponar samples at these sites was the mud crab (*Rhithropanopeus* sp.) at site SQP3. These crabs are typically found in estuarine systems, but were first reported in Palo Pinto County in 1998, and were later discovered in Lake Granbury (Hood County) and Squaw Creek Reservoir. It is not understood how these organisms are able to live in these fresh water impoundments.

Diversity increased as habitat complexity increased leading to higher numbers of invertebrates at the littoral and downstream sites. Caddisflies (Hydroptilidae, Hydropsychidae, Leptoceridae) were most common at the downstream and littoral sites because of the increased number of available habitats. No stoneflies were collected at any of the sites in 2007. Mayflies (Baetidae and Caenidae) were predominantly found at the SQL3 and SQDS sites, but one *Caenis* was collected at site SQP3. These three orders (Plecoptera, Trichoptera, Ephemeroptera) are often used as indicators of healthy water bodies. The lack of diversity of these orders at Squaw Creek Reservoir indicates a less healthy system for invertebrates.

Total numbers of invertebrates were highest during the spring sampling effort. This indicates the first major reproductive cycle of the year in the stream and reservoir. Most of these organisms were collected at sites SQL3 and SQDS because of the higher habitat diversity found at each site. Site SQL3 is characterized by shallow water with bedrock/cobble substrate, with overhanging banks and floating vegetation along the shoreline. Site SQDS has undercut banks, pools, riffles, runs, and variable substrates (gravel, silt, etc.). The increased habitat diversity allows a larger number of species to occupy different niches. The pelagic sites are characterized by bedrock and cobble (and silt at site SQP1), and have little complexity to increase invertebrate numbers. Total numbers of invertebrates decreased by September when many hatched into adult forms and dispersed from the area. By fall, the adults of many different organisms had reproduced and eggs had hatched. As in spring, sites SQL3 and SQDS had the largest numbers of invertebrates collected.

Table 4. Total numbers of invertebrates collected at each site during each season in 2007.

Season	Site							Total
	SQP1	SQP2	SQP3	SQL1	SQL2	SQL3	SQDS	
Winter	37	0	4	88	93	62	280	564
Spring	3	0	2	55	105	266	601	1032
Summer	5	0	0	6	16	8	534	569
Fall	0	0	11	1	4	396	540	952

Plankton Community

The zooplankton community in Squaw Creek Reservoir varied in number based on reproductive cycles tied to the seasons. Rotifers were the most numerous organisms in all seasons except summer (Table 5). During the summer sampling effort rotifers decreased over five times from the spring effort. This was likely a result of decreased reproduction prior to September in the reservoir. The second most numerous organisms during every season were nauplii (larval form of calanoids and cyclopoids). The large number of larvae indicates that calanoids and cyclopoids are reproducing year round with a substantial decrease prior to May. Since adult cyclopoids are over ten times more common in the reservoir than adult calanoids, they likely make up the majority of the nauplii population. The relatively small number of adult cyclopoids in winter (and spring) led to decreased reproduction and fewer nauplii in spring. Increased reproduction when water temperatures increased in summer resulted in the highest number of adult cyclopoids and calanoids for the entire year (1,468 and 125, respectively). Daphniids (water fleas) experienced a reproductive peak between the spring and summer sampling periods resulting in a high number of adults in September (612). Clam shrimps (Conchostraca) were uncommon in plankton samples with the highest numbers present in fall (29). Bosminids (neo-natal crayfish) were infrequent organisms in samples, likely only picked up when the plankton net hit the bottom of the reservoir.

Golden algae (*Prymnesium parvum*) were first suspected to cause major blooms (and associated fish kills) in Texas in 1981. Though they have not been found in Squaw Creek Reservoir, nor have there been any reported major fish kills here, they have been reported in adjacent water bodies (Lake Granbury, Brazos River). In September, samples were taken at all seven sites to determine if this harmful alga was present in the reservoir. Golden algae were not found to be present at any of the sites. Since it has been documented from other nearby waters, absence of golden algae in samples from Squaw Creek Reservoir was somewhat surprising. However, most harmful golden algae blooms occur during cooler weather. Blooms are uncommon in the summer months because it is thought that green algae are more dominant when water temperatures are higher (Tiffany Morgan, Brazos River Authority, pers. comm. 2007). Considering water temperatures are extremely high in Squaw Creek Reservoir in summer, this is a plausible explanation. In addition, when previous golden algae blooms were identified at Lake Granbury (where water is imported to Squaw Creek Reservoir), water intake to the reservoir was shut off whenever possible, thereby reducing the potential for the algae to spread to Squaw Creek. As a result, close monitoring of blooms is necessary to ensuring healthy fish populations in Squaw Creek Reservoir.

Table 5. Numbers of different zooplankton present in Squaw Creek Reservoir in 2007.

Plankton Taxa	Number of Individuals			
	Winter	Spring	Summer	Fall
Cyclopoida	160	19	1468	446
Calanoida	2	9	125	20
Nauplii	1439	201	2486	1332
Rotifera	1900	2126	363	2436
Bosminidae	3	-	11	5
Daphniidae	47	1	612	11
Conchostraca	-	-	6	29

Water Quality

Water quality parameters collected from surface water at all sites and seasons can be found in Appendix A. With the exception of water temperature and DO, there was little variability in the other parameters between sites and seasons. Total dissolved solids were high in the reservoir (2690 – 3380 mg/L). It was similar between sites during each season, and mean TDS in winter (3327 mg/L) and spring (3324 mg/L) were higher than in the following summer and fall seasons (2764 and 2721 mg/L, respectively). These high TDS values are likely a result of surrounding geology (limestone), and the relative drainage size of Squaw Creek Reservoir. The lower values in summer and fall may be a result of fewer precipitation events bringing dissolved solids into the reservoir. Conductivity displayed a similar seasonal pattern. Although, mean conductivity was similar between sites during each season, it was highest in winter (567 µs/cm) and spring (538 µs/cm), and decreased by summer (491 µs/cm) and slightly more by fall (473 µs/cm). TDS and conductivity often mirror each other as they are both (directly or indirectly) measures of the amount of ions in the water.

There was little seasonal variation in surface water turbidity at all sites. However, turbidity was not measured during the summer sampling effort due to a faulty turbidity probe. Mean turbidity was lowest at the pelagic sites (2.5 NTU) compared to the downstream (3.3 NTU) and littoral (3.5 NTU) sites. Since pelagic sites are farther away from shore (compared to littoral), any dissolved solids brought into the reservoir from runoff are more diluted than sites nearer the shore. The pH of the surface water varied little during the year at all sites (8.2 – 9.0), and as a result, there were no clear seasonal changes for this parameter. These pH readings fall within the normal range of most freshwater lakes in North America (Kalff 2002). Alkalinity is the measure of the acid neautralizing capability of a water body. Like pH, alkalinity varied little seasonally in Squaw Creek Reservoir (180 – 230 mg/L). This is similar (though slightly higher) than the average alkalinity found in other water bodies with surrounding limestone geology (124 mg/L, Morrill et al. 2001). Relatively high alkalinities in the reservoir increase its ability to buffer the water and likely resulted in the minor changes in pH present in 2007. This buffering ability is important in keeping a relatively constant pH throughout the year. Hardness was more variable between sites, but did not show any site specific trends. As with conductivity and TDS, hardness decreased as the year progressed, with the lowest readings in fall (mean mg/L: winter – 845, spring – 793, summer – 700, fall – 680).

As expected, water temperatures varied seasonally and with depth (Appendix A, Figure 3). In all seasons, site SQL3 exhibited the highest surface water temperatures. This site is the shallowest of the reservoir sites, and is also nearest to the outflow from the power plant. The coolest surface water temperatures in each season were observed at site SQP1, which is the farthest upstream site, and therefore, less influenced by power plant operations. Mean temperatures across all sites in summer (36.4 °C) were 15 °C higher than in winter (21.4°C). As demonstrated by the fish populations in the reservoir, these high temperatures can affect movement and (likely) reproduction. Although surface water temperatures varied widely in 2007, the depth of the thermocline (metalimnion) changed little from season to season at the DO profile site (Figure 2). The most well defined thermocline occurred in summer (16 – 21 ft.) because summer winds were not powerful enough to mix the contrasting densities in the reservoir caused by the temperature stratification. The fall sampling effort also reflected a strong thermocline, but at a greater depth (20 – 24 ft.) than summer. In winter, surface water temperatures cooled and were more similar to temperatures at greater depths resulting in a poorly defined thermocline. In addition, increased wind action from storms during winter led to more mixing of water at greater depths.

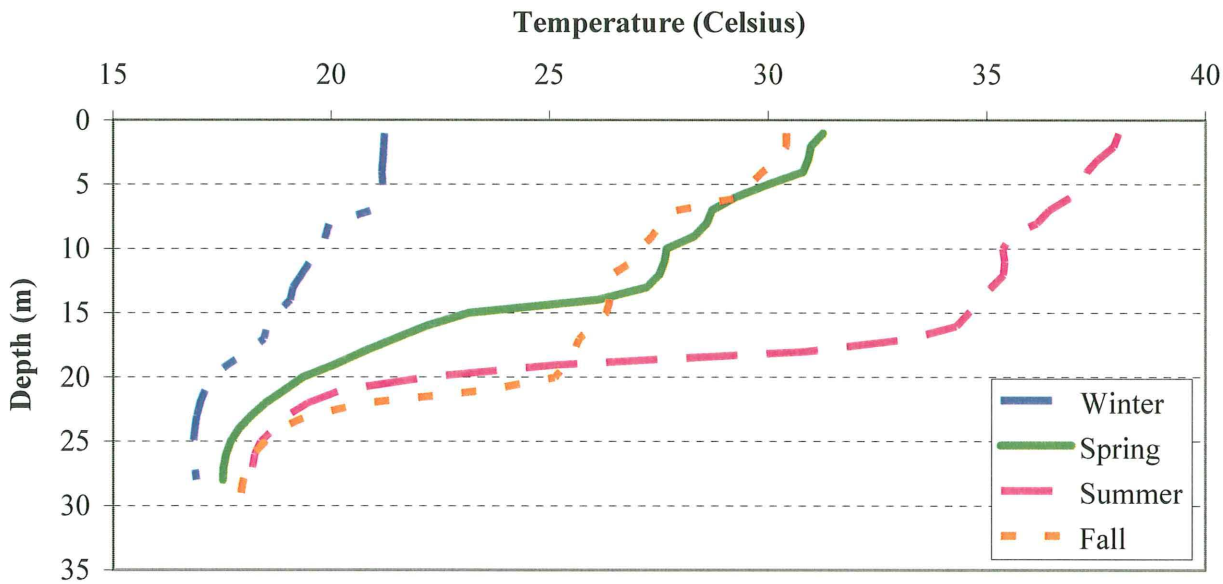

Figure 3. Water temperatures (Celsius) recorded at the DO Profile site in 2007.

Dissolved oxygen levels at all sites also reflect seasonal changes (Appendix A, Figure 3). Mean surface DO values were highest during winter (12.5 mg/L) and lowest in summer (7.1 mg/L). Colder water temperatures increase the ability of the water to absorb and retain oxygen molecules. Colder surface water temperatures combined with increased mixing due to higher winds during the winter months resulted in these high winter DO values. On average, the littoral sites had higher surface DO levels than the pelagic sites in the reservoir. In aquatic environments, light penetration and photosynthetic activity both decrease with depth, and respiration and decomposition by bacteria and other organisms increase oxygen demand in the lower water column. These processes result in a marked decline in DO at greater depths. This demand was met or exceeded in the spring and summer months at the DO Profile site in 2007 (Figure 4). With higher water temperatures prevalent during these months, there was less soluble oxygen available in the water column resulting in DO levels reaching 0 mg/L at greater depths. In fall, oxygen demand in the water column was high, but DO values did not reach zero. With lower water temperatures and increased atmospheric mixing due to winds occurring across the reservoir, DO values did not drop below 2.0 mg/L during the winter sampling effort.

Considering Squaw Creek Reservoir is being used as a cooling water reservoir for a power plant, water quality parameters should be closely monitored at regular intervals to understand the interaction between abiotic factors and the biota that depend on them. Water temperature and DO can have profound effects on the growth and survival of all organisms living in the reservoir and downstream. Being able to understand and predict significant changes in water quality parameters will increase the ability to manage and mitigate subsequent changes in the biota.

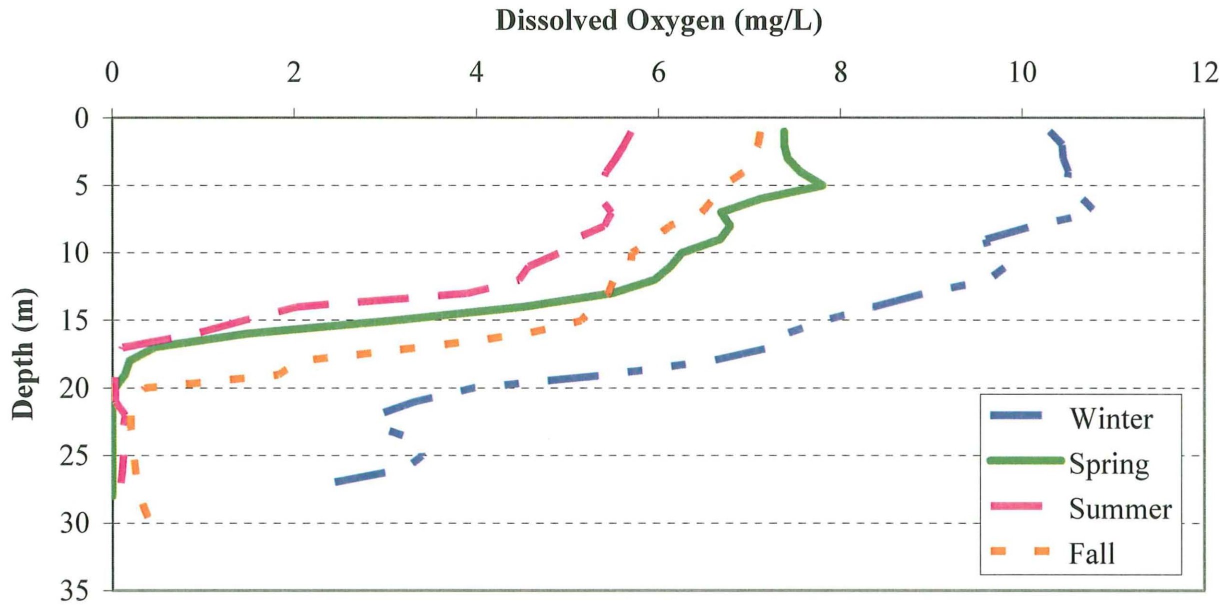

Figure 4. Dissolved oxygen levels (mg/L) recorded at the DO Profile site in 2007.

SUMMARY OF FINDINGS

This report summarizes the data collected from four seasonal sampling efforts on Squaw Creek Reservoir in 2007. Because this reservoir is used as cooling water for a large power plant, temperature effects are apparent in both the environment and the biological community. Although the water in the reservoir is relatively clear, it supports little aquatic vegetation (excluding phytoplankton), likely as a result of the steep dropoffs into deep water from coves along the banks. Where the water is more shallow in the reservoir (i.e. littoral zones), there are some aquatic macrophytes present, but none are considered dominant. The underlying geology and soils around the reservoir support a low species diversity of terrestrial vegetation. Ashe's juniper is the dominant tree species, while Bermuda grass covers much of the ground. A larger riparian zone along Squaw Creek allows more species diversity, and several species of oaks dominate the banks. There was little seasonal variation in the dominant vegetation types present at any of the sites. Zooplankton in the reservoir varied by season with summer being the most productive period, and nauplii and rotifers were the most numerous plankton throughout the year. Although golden algae were not detected in Squaw Creek Reservoir in 2007, constant monitoring of nearby water bodies (Lake Granbury, Brazos River) will be very beneficial in promoting a healthy system both within and downstream of the reservoir. Shutting off the intake water from Lake Granbury to Squaw Creek Reservoir during algal blooms in Lake Granbury will be beneficial in monitoring that this harmful species does not become established in Squaw Creek Reservoir. A reproductive peak following the spring sampling effort led to the highest numbers of plankton to be collected in summer. Benthic invertebrates were scarce at the pelagic sites in the reservoir (only chironomids were common). The littoral and downstream sites exhibited more insect diversity with a peak in numbers occurring in spring. This peak was likely a result of recent reproduction for many aquatic insects.

High total dissolved solids, and extremely high summertime water temperatures characterize the water quality in Squaw Creek Reservoir. While high TDS values are likely a result of underlying geology, the water temperatures are a by-product of the discharge water coming out of the plant. These temperatures can have a myriad of effects on the reservoir. When temperatures were highest (summer), oxygen became less soluble in water and DO dropped to its lowest level in 2007. Decreased DO (and high water temperatures) can adversely affect biological populations if there are no refuges for them to use. Large organisms like fish can easily move from low dissolved oxygen waters to areas with higher DO (provided they are present), however, animals with limited movement cannot. This may be a reason for the low species diversity of aquatic invertebrates in the reservoir (especially in the benthic region of the pelagic zones). Although, fishes can move out of these low quality waters, when temperatures are too high, growth may cease and stress can adversely affect the fish. Fishes with low tolerances of high temperatures (walleye, smallmouth bass, hybrid bass), have already been extirpated after stocking ceased in the reservoir. It is likely that extreme summer temperatures limited the ability of these fishes to grow or reproduce, and as a result could not sustain populations. Current fish populations in the reservoir appear to be stable, but with little data in the historical record it is very difficult to monitor changes. Continued monitoring of water quality and fish populations will serve to better understand the interactions between water quality and the biota. Because they are top predators, fish are good indicators of a reservoir's health and can warn managers of impending problems.

The primary function of Squaw Creek Reservoir is to act as cooling water for Comanche Peak Steam Electric Station. Although this reservoir will likely not support cooler water species of fish while the station is active, it can still be managed for warmer water species that are currently present. With yearly monitoring of the fish population, and monthly checks on water quality parameters, degradation of the aquatic environment and potential consequences to the biological community may be anticipated and acted upon in a timely manner. In addition, monitoring can provide valuable long-term data that would be beneficial to other power plants with cooling water reservoirs. With proper management, Squaw Creek Reservoir can exist primarily to provide energy for consumers, while providing ample habitat for aquatic organisms and a healthy ecosystem well into the future.

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Appendix A

Additional Data

Invertebrate taxa collected at all sites during the 2007 winter sampling period.

		Site							
Family	**Genus**	**SQP1**	**SQP2**	**SQP3**	**SQL1**	**SQL2**	**SQL3**	**SQDS**	**Total**
Caenidae	*Caenis*					2			**2**
Coenagrionidae	*Argia*				2			1	**3**
Coenagrionidae	*Enallagma*				1				**1**
Corixidae	*Trichocorixa*							160	**160**
Mesoveliidae	*Mesovelia*						2		**2**
Hydroptilidae	*Hydroptila*						1		**1**
Hydropsychidae	*Cheumatopsyche*					1		20	**21**
Hydropsychidae	*Hydropsyche*							4	**4**
Leptoceridae	*Oecetis*							1	**1**
Hydrophilidae	*Berosus*							4	**4**
Elmidae	*Stenelmis*							4	**4**
Simuliidae	*Simulium*							10	**10**
Chironomidae	*Chironomus*			2	35	87	17		**141**
Chironomidae	*Larsia*			2				1	**3**
Chironomidae	*Tanytarsus*	5						6	**11**
Chironomidae	Sp.	32			47	2		47	**128**
Ceratopogonidae	*Probezzia*				1	1			**2**
Hyalellidae	*Hyalella*						5	9	**14**
Physidae	*Physella*				2		37	13	**52**

Invertebrate taxa collected at all sites during the 2007 spring sampling period.

Family	Genus	Site SQP1	SQP2	SQP3	SQL1	SQL2	SQL3	SQDS	Total
Baetidae	*Callibaetis*						7	1	**8**
Caenidae	*Caenis*			1			7		**8**
Coenagrionidae	*Argia*								**0**
Coenagrionidae	*Enallagma*				1		1		**2**
Coenagrionidae	*Ischnura*						1		**1**
Coenagrionidae	Sp.						4	1	**5**
Hydropsychidae	*Cheumatopsyche*							38	**38**
Hydropsychidae	*Hydropsyche*							76	**76**
Hydroptilidae	*Ithytrichia*							3	**3**
Hydroptilidae	*Neotrichia*							3	**3**
Tricorythidae	*Trichorythodes*							1	**1**
Leptoceridae	*Oecetis*						2	4	**6**
Helophoridae	*Helophorus*						1		**1**
Hydrophilidae	*Berosus*				2			2	**4**
Elmidae	*Neoelmis*							1	**1**
Simuliidae	*Simulium*							70	**70**
Chironomidae	*Ablabesmyia*				1		5	2	**8**
Chironomidae	*Cardiocladius*							13	**13**
Chironomidae	*Chironomus*			1	8		84	93	**186**
Chironomidae	*Cryptochironomus*	1				14		5	**20**
Chironomidae	*Eukiefferiella*						53	6	**59**
Chironomidae	*Parachironomus*				28	61	98	59	**246**
Chironomidae	*Procladius*	2							**2**
Chironomidae	*Pseudochironomus*				4	2		19	**25**
Chironomidae	Sp.					3		6	**9**
Hyalellidae	*Hyalella*				11	25	10	199	**245**

Invertebrate taxa collected at all sites during the 2007 summer sampling period.

		Site							
Family	**Genus**	**SQP1**	**SQP2**	**SQP3**	**SQL1**	**SQL2**	**SQL3**	**SQDS**	**Total**
Baetidae	*Callibaetis*							5	**5**
Libellulidae	*Erythemis*							2	**2**
Coenagrionidae	*Argia*							3	**3**
Gomphidae	*Dromogomphus*							1	**1**
Hydrophilidae	*Paracymus*							3	**3**
Hydrophilidae	*Berosus*						1	20	**21**
Hydraenidae	*Helocharus*							2	**2**
Elmidae	*Stenelmis*							2	**2**
Belastomatidae	*Adebus*						1		**1**
Stratiomyidae	*Odontomyia*						3		**3**
Tabanidae	*Tabanus*							1	**1**
Tipulidae	sp.					1			**1**
Ceratopogonidae	*Culicoides*						2	6	**8**
Ceratopogonidae	*Probezzia*				1			2	**3**
Ceratopogonidae	*Sphaeromias*					1			**1**
Chironomidae	*Ablabesmyia*					12		162	**174**
Chironomidae	*Apedilum*							9	**9**
Chironomidae	*Brandiniella*							11	**11**
Chironomidae	*Chironomus*							26	**26**
Chironomidae	*Coelotanypus*	1							**1**
Chironomidae	*Parachironomus*					1	1	277	**279**
Chironomidae	*Polypedilum*				4				**4**
Chironomidae	*Tanypus*	4							**4**
Physidae	*Physella*							1	**1**
Annelida	sp.				1	1		1	**3**

Invertebrate taxa collected at all sites during the 2007 fall sampling period.

		Site							
Family	**Genus**	**SQP1**	**SQP2**	**SQP3**	**SQL1**	**SQL2**	**SQL3**	**SQDS**	**Total**
Baetidae	*Callibaetis*						2		**2**
Baetidae	*Caenis*						1		**1**
Libellulidae	*Libellula*							2	**2**
Libellulidae	*Sympetrum*						2		**2**
Coenagrionidae	*Enallagma*						53		**53**
Coenagrionidae	*Ischnura*						27		**27**
Coenagrionidae	sp.							2	**2**
Corixidae	*Trichorixa*							1	**1**
Mesoviliidae	*Mesovelia*						5		**5**
Hydroptilidae	*Hydroptila*							14	**14**
Naucoridae	*Ambrysus*						1		**1**
Hydrophilidae	*Paracymus*							1	**1**
Hydrophilidae	*Berosus*							14	**14**
Dytiscidae	*Agabus*							1	**1**
Belastomatidae	*Adebus*						2		**2**
Tipulidae	*Limonia*							13	**13**
Tipulidae	*Ormosia*							4	**4**
Tipulidae	*Rhabdomastix*							2	**2**
Ceratopogonidae	*Culicoides*							12	**12**
Ceratopogonidae	*Forcipomyia*						1	2	**3**
Chironomidae	*Ablabesmyia*						23		**23**
Chironomidae	*Chironomus*			6			90		**96**
Chironomidae	*Cryptochironomus*					3	4	13	**20**
Chironomidae	*Dicrotendipes*						7	80	**87**
Chironomidae	*Eukiefferiella*							65	**65**
Chironomidae	*Labrundinia*							3	**3**
Chironomidae	*Larsia*							12	**12**
Chironomidae	*Parachironomus*						114	179	**293**
Chironomidae	*Polypedilum*			1		1	6	4	**12**
Chironomidae	*Stictochironomus*						52		**52**
Chironomidae	*Tanypus*						4	19	**23**
Chironomidae	*Tanytarsus*			3				80	**83**
Physidae	*Physella*						2	17	**19**
Xanthidae	*Rhithropanopeus*			1	1				**2**

Water chemistry paramaters of surface water at sampling sites in 2007.

Sampling Period	Site						
	SQDS[a]	SQP1	SQP2	SQP3	SQL1	SQL2	SQL3
Temperature (C)							
Winter	21.8	20.5	21.2	20.7	20.8	20.9	23.8
Spring	31.0	28.5	31.7	29.3	28.5	30.1	31.9
Summer	35.3	35.2	38.0	35.8	35.7	36.1	38.8
Fall	28.5	27.7	30.5	28.8	28.4	29.2	31.2
Dissolved Oxygen (mg/L)							
Winter	12.2	11.9	10.3	12.1	14.1	12.2	14.6
Spring	8.2	8.7	9.5	8.8	8.8	10.0	8.4
Summer	8.6	7.3	5.6	6.5	7.5	7.4	7.1
Fall	7.5	7.5	6.9	7.5	8.3	8.5	8.4
pH							
Winter	9.0	8.8	8.8	8.8	8.9	8.9	8.9
Spring	8.2	8.7	8.7	8.7	8.7	8.8	8.7
Summer	8.8	8.8	8.7	8.8	8.8	8.8	8.8
Fall	9.0	8.7	8.9	8.9	9.0	8.9	8.9
Conductivity (µs/cm)							
Winter	565	566	566	568	565	565	571
Spring	530	537	542	538	537	541	541
Summer	493	491	492	488	490	490	493
Fall	476	473	465	474	474	474	475
Turbidity (NTU)							
Winter	3.5	2.8	2.3	2.3	3.8	3.3	3.0
Spring	3.3	2.2	2.2	<1.0	3.6	3.3	3.6
Summer[b]	-	-	-	-	-	-	-
Fall	3.2	2.8	3.5	3.2	3.2	3.9	3.5
Hardness (mg/L)							
Winter	848	857	848	847	845	833	839
Spring	795	805	764	801	796	797	794
Summer	706	687	701	717	689	696	705
Fall	692	672	699	683	685	664	662

[a]Temperature, DO, pH, Conductivity, and Turbidity are an average of three sites within the downstream site.

[b]No turbidity readings were recorded because of equipment malfunction.

Water chemistry paramaters of surface water at sampling sites in 2007.

Sampling Period	Site						
	SQDS	SQP1	SQP2	SQP3	SQL1	SQL2	SQL3
TDS (mg/L)							
Winter	3330	3380	3190	3350	3320	3360	3360
Spring	3320	3290	3310	3330	3320	3360	3340
Summer	2770	2770	2740	2740	2740	2800	2790
Fall	2700	2750	2690	2740	2740	2720	2710
Alkalinity (mg/L)							
Winter	210	230	230	220	220	220	220
Spring	210	220	210	220	220	210	210
Summer	180	190	200	190	190	190	190
Fall	200	200	200	200	200	200	200