TOTAL MAXIMUM DAILY LOAD
FOR DISSOLVED ZINC
IN LITTLE COTTONWOOD CREEK

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1.0 INTRODUCTION

This Total Maximum Daily Load (TMDL) study has been prepared for the reach of Little Cottonwood Creek (LCC) from its headwaters to its confluence with Red Pine Fork. An intensive monitoring program conducted by the Division of Water Quality and Salt Lake City in 1994 found that dissolved zinc concentrations in LCC in the study reach exceeded the established water quality criteria for this constituent for a cold water fishery, a designated beneficial use for LCC. As a result, the study reach of LCC was listed on the State's 303(d) list of impaired waters in 2000. Listing of this stream segment on the State's 303(d) list requires that a TMDL be completed to address the pollutant of concern in the watershed. The 2000 303(d) list designated LCC as a high priority for TMDL completion during the 2000-2002 time period. This TMDL study has been completed for this purpose.

1.1 Study Area

The LCC study area is located in LCC Canyon in Salt Lake County, about 8 miles east of Sandy, Utah (Figure 1.1). Land use in the study area includes the town of Alta and the Snowbird and Alta ski resorts. Historic mining activity in the canyon has left behind many mine features, such as mine shafts and adits, mine waste dumps (waste rock piles), mine drain tunnels and access roads. The numerous adits and waste rock piles are distributed throughout the LCC watershed, but are mainly concentrated near the town of Alta.

The most upstream drainage basin in the canyon is Grizzly Gulch, which is located on the north side of the canyon and contains a number of waste rock piles and adits. Other drainages located on the north side of the canyon that show historical mine impacts include the Flagstaff and Toledo Drainages, located above the town of Alta. The Flagstaff Drainage is one of the most prominent in the Canyon, in terms of mine drainage to LCC, as it contains the Howland Tunnel (also referred to as the Columbus-Rexall Tunnel). The Howland Tunnel is an uncontrolled discharge emanating from the north side of the canyon near the Peruvian Lodge (Figure 1.2). Water draining from the Howland Tunnel is typical of mine-impacted drainage, with a low pH and high sulfate and metals content.

Figure 1.1 Study Area

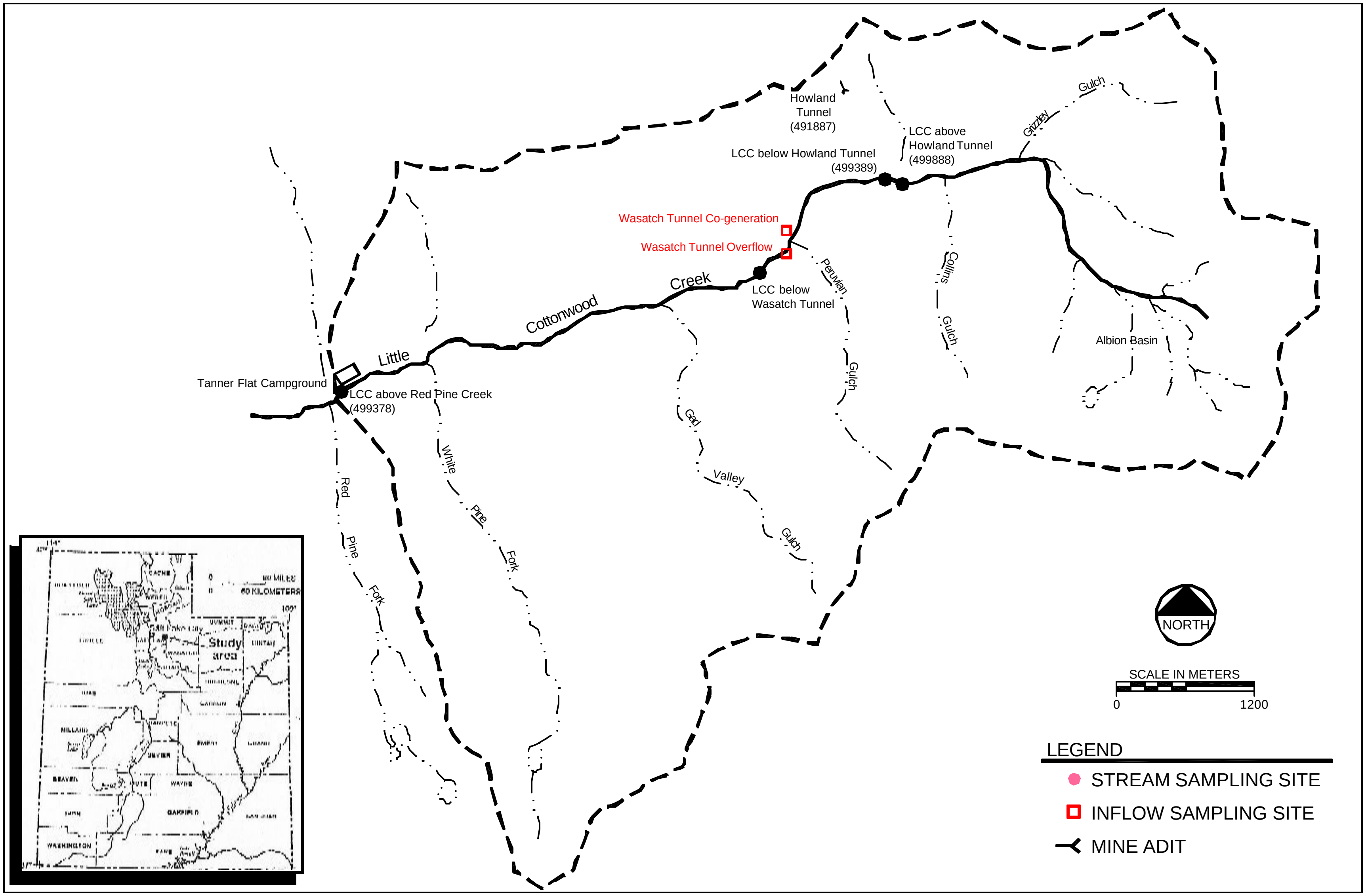
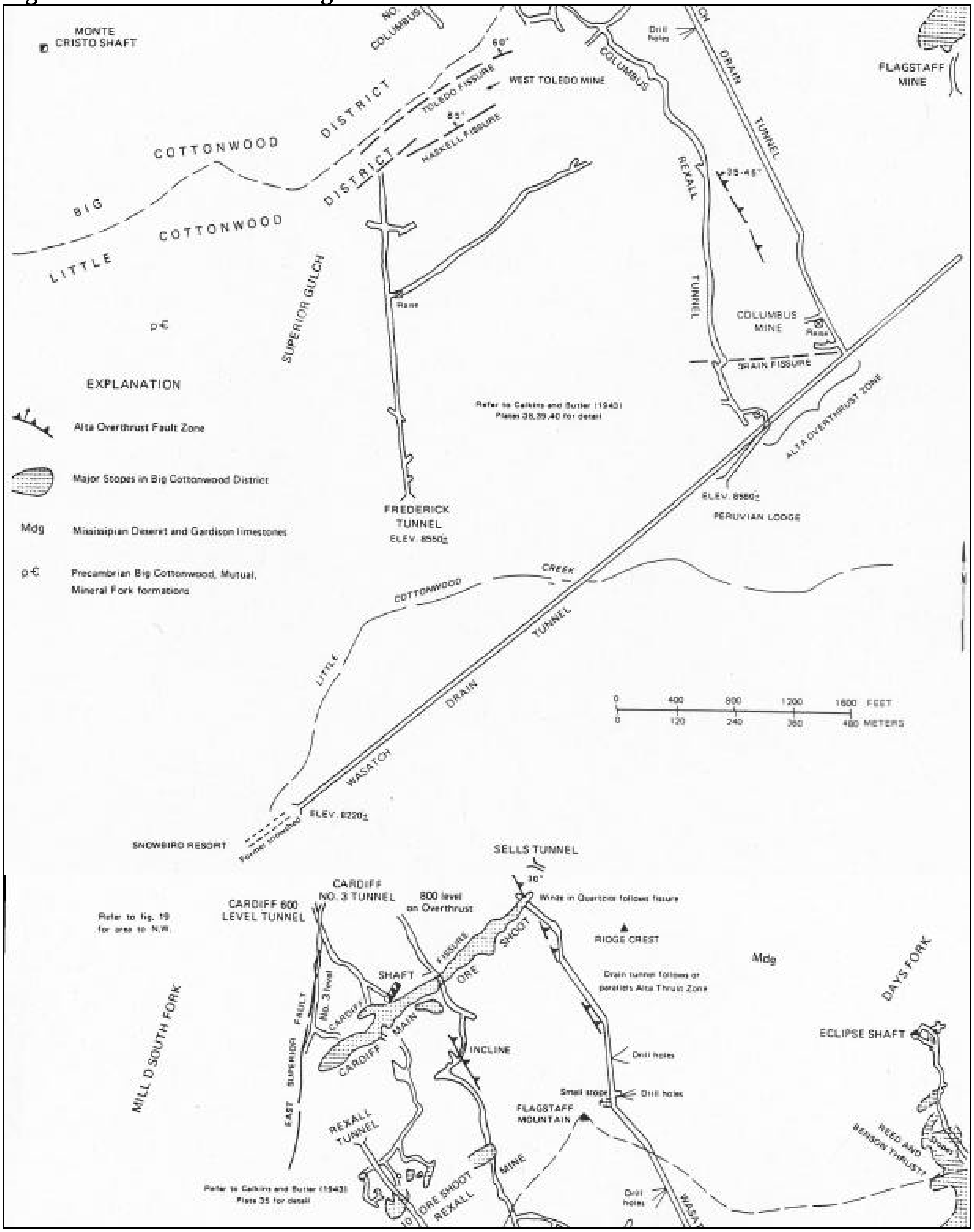


Figure 1.2 Tunnel Workings in Little Cottonwood District



The drainage basins located on the south side of the canyon above Alta are much less impacted, but still contain some mine adits and waste rock piles. These include Collins Gulch, which contains the South Hecla Mine and Quincy Mines; Albion Basin, which contains the Alta-Helena Tunnel; and Peruvian Gulch, which contains the Wasatch Drain Tunnel (Figure 1.2). The Wasatch Drain Tunnel, which is located on the south side of the canyon between Alta and Snowbird, was constructed between 1912 to 1916, and was later expanded under the canyon divide into Big Cottonwood Canyon, located north of LCC Canyon. The tunnel drained freely, until a plug (bulkhead) was installed in the tunnel opening in 1985. Water contained behind the bulkhead is currently used for domestic water supply, snowmaking, and as cooling water for the Snowbird co-generation plant. The Salt Lake County Service Area No. 3 operates the tunnel. Water from the Wasatch Drain Tunnel is discharged either directly to LCC, or indirectly through cooling water discharge from the Snowbird co-generation plant.

The Wasatch Drain Tunnel and Howland Tunnel have been identified as contributing the most metals load to LCC (Kimball, 2001).

1.2 LCC Canyon Geology and Soils

The Little Cottonwood Creek Canyon is located in the Wasatch Mountain Range, of the Middle Rocky Mountains physiographic province. Rock outcrops in LCC Canyon include Precambrian and Paleozoic metamorphic and sedimentary rocks (mainly quartzite and interbedded dolomite, limestone, shale, and sandstone units). Some of the glacial features in the canyon are acute, rugged mountain spurs, cirques, scoured rocks, and moraines. The soils in LCC Canyon include rock-dominated units and sandy loam units, which have developed on steep, recently glaciated terrain. They are generally thin and rocky, especially on the higher portions of the canyon. The upper portion of LCC Canyon was formed by recent (Pleistocene) glaciation.

1.3 LCC Canyon Vegetation

Vegetation in LCC Canyon includes forested (conifer parklands, spruce-fir, krummholz spruce-fir, mixed conifer, aspen, and mixed conifer-aspen) and non-forested (tall forb, short forb, rock/scree, mountain shrub, wetland/riparian, modified [including groomed or revegetated], and development) cover types.

1.4 General Meteorology and Climate

The climate at LCC Canyon is characterized as a mid-latitude, high elevation climate, typical of the mountain areas along the Wasatch Front, with warm summers and cold, early season winters. Precipitation occurs mainly as snow during the winter and rain during the summer. There are, on average, 100 days with snowfall greater than 0.1 inch at Alta. The average annual snowfall is about 519 inches. The average annual precipitation recorded for Alta is about 58.5 inches of water. (U.S. Forest Service, 1999).

1.5 Little Cottonwood Creek

Little Cottonwood Creek, originating near the Alta ski area and ending at the confluence with the Jordan River, has been classified as a third-order stream. Portions of LCC located downstream from the Wasatch Drain Tunnel and upstream from the Baby Thunder Lift are predominantly B3 stream types, typified by moderately entrenched systems with channel gradients of 2 to 4 percent. These type streams typically develop in very coarse alluvial fans, lag deposits from stabilized slide debris, rockfall talus, very coarse colluvial deposits, and structurally controlled drainage ways. They are dominated by cobble materials and characterized by a series of rapids with irregularly spaced scour pools. The average pool-to-pool spacing for the B3 stream type is three to four bank-full channel widths. In LCC, these pools are usually associated with coarse woody debris dams. (U.S. Forest Service, 1999).

Sections of LCC above the Wasatch Drain Tunnel and below the base of the Baby Thunder Lift have been categorized as A2 stream types. These stream types are characterized by steep, deeply entrenched, and confined channels that are associated with faults, scarps, folds, joints and other structurally controlled drainages. These steeply sloped channels exhibit step/pool bed features, and, in very steep sections (slope exceeding 10 percent), cascades and chutes. Channel materials are comprised of boulder-sized materials with lesser amounts of cobble and gravel. Because of their steep nature, these channels to not typically provide much holding habitat for fish populations. (U.S. Forest Service, 1999).

Much of the annual streamflow in LCC results from snowmelt, producing higher flows around May, June and July of each year. Lower flows are experienced in late fall and winter. Streamflow is also derived directly from precipitation and from groundwater inflow to the creek. The combination of shallow rocky soils in the steep and narrow LCC Canyon result in flow in LCC being highly responsive to precipitation events. (U.S. Forest Service, 1999).

2.0 WATER QUALITY STANDARDS AND TMDL TARGETS/ENDPOINTS

2.1 Pollutant of Concern

The reach of LCC that is the focus of this TMDL study is listed on Utah's 2000 303d list of impaired waters as a result of measured dissolved zinc concentrations in this reach. These dissolved zinc concentrations exceeded the water quality criteria established for this constituent for supporting a cold water fishery, a designated beneficial use for LCC.

Zinc is usually found in nature as the sulfide, and is often associated with sulfides of other metals, especially lead, copper, cadmium, and iron. Toxic concentrations of zinc compounds cause adverse changes in the morphology and physiology of fish. Acutely toxic concentrations may induce cellular breakdown of the gills of fish, and possibly the clogging of the gills with mucous. Chronically toxic concentrations of zinc compounds cause general enfeeblement and widespread histological changes to many organs, but not to gills. Growth and maturation are also retarded. (U.S. EPA, 1980).

In addition to adverse changes in the morphology and physiology of fish, increased zinc concentrations will also adversely impact macroinvertebrate populations in a stream. Macroinvertebrates, which are a necessary component of the fish food chain, have been shown to exhibit adverse impacts at zinc concentrations similar to those concentrations at which fish begin to exhibit adverse impacts. (U.S. EPA, 1980).

The toxicity of zinc compounds to aquatic life is dependent on several factors, particularly water hardness. The toxicity of zinc to aquatic life increases with a decrease in water hardness.

2.2 Water Quality Standards

As described in the following sections, the water quality standards applicable to LCC are comprised of designated uses and numerical criteria, and also include narrative standards. The State's antidegradation policy also applies to the study reach of LCC.

2.2.1 Use Designations

The Utah Division of Water Quality (DWQ) has classified the waters in the State of Utah so as to protect the beneficial uses designated within each class of waters. These classifications and associated beneficial uses are presented in Table 2.1. Use classifications assigned to LCC are Class 1C, Class 2B and Class 3A (Utah Administrative Code [UAC] R317-2-13.5.00).

Table 2.1 Utah Water Quality Classifications/Beneficial Uses

Class 1	Protected for uses as a raw water source for domestic water systems Class 1A: Reserved Class 1B: Reserved Class 1C: Protected for domestic purposes with prior treatment by treatment processes as required by the Utah Division of Drinking Water
Class 2	Recreational and aesthetic use Class 2A: Protected for primary contact recreation such as swimming Class 2B: Protected for secondary contact recreation such as boating, wading or similar uses
Class 3	Protected for use by aquatic wildlife Class 3A: Protected for cold water species of game fish and other cold water aquatic life, including the necessary aquatic organisms in their food chain Class 3B: Protected for warm water species of game fish and other warm water aquatic life, including the necessary aquatic organisms in their food chain Class 3C: Protected for non-game fish and other aquatic life, including necessary aquatic organisms in their food chain Class 3D: Protected for waterfowl, shore birds, and other water-oriented wildlife not included in Classes 3A, 3B or 3C, including the necessary aquatic organisms in their food chain Class 3E: Severely habitat-limited waters
Class 4	Protected for agricultural uses including irrigation of crops and stock watering
Class 5	The Great Salt Lake. Protected for primary and secondary contact recreation, aquatic wildlife, and mineral extraction

Source: Utah Administrative Code (UAC) R317-2-6

2.2.2 Numerical Criteria

Numeric criteria, set forth at UAC R317-2-14, have been promulgated for each of the beneficial use classes assigned to waters in the State. As described in this TMDL report, although limited exceedances of the applicable numeric criteria for other constituents have been noted from historical sampling of water quality in LCC, the constituent of concern (COC) is dissolved zinc. Of the three use classifications assigned to LCC, numeric criteria for dissolved zinc apply only for the protection of aquatic life (beneficial use classification 3A). These numeric criteria, which are hardness dependent, are calculated as:

4 day average concentration (chronic) = CF x $e^{(0.8473[\ln (hardness)]+07614}$

where: CF = conversion factor for ratio of total recoverable metals to dissolved metals = 0.986

1 hour average concentration (acute) = CF x $e^{(0.8473[\ln (hardness)] + 0.8604}$

where: CF = 0.978

Hardness, as used in the above equations, is expressed as mg/L of calcium carbonate ($CaCO_3$).

2.2.3 Narrative Standards

In addition to numeric criteria, narrative standards set forth at UAC R317-2-7.2 also apply to LCC. These narrative standards generally address the discharge or placement of wastes or other substances in a waterbody that are offensive, that will cause conditions that produce undesirable aquatic life or tastes in edible aquatic organisms, that result in undesirable physiological responses in aquatic life, or that produce undesirable human health effects.

2.2.4 Antidegradation Policy

The State's antidegradation policy is set forth at UAC R317-2-3. If a water body has a better water quality than necessary to support its designated uses, the antidegradation policy requirements dictate that the existing water quality shall be maintained and protected, unless the State finds that a lowering of water quality is necessary to accommodate important economic or social development in the area in which the water is located. The antidegradation policy applies to three categories of high quality waters designated by the State. One such category, High Quality Waters – Category 1, is defined at UAC R317-2-3.2 as: "Waters of high quality which have been determined … to be of exceptional recreational or ecological significance or have been determined to be a State or National resource requiring protection …." As mandated by the State's anti-degradation policy, new point source discharges of wastewater are prohibited in such waters, and diffuse sources of waste to these waters shall be controlled to the extent feasible through implementation of best management practices.

Waters in the State designated as High Quality Waters – Category 1 are listed at UAC R317-2-12.1. As set forth at UAC R317-2-12.1.1, these include all surface waters geographically located within the outer boundaries of the U.S. National Forests, whether on public or private lands, with limited exceptions. Little Cottonwood Creek is located within the outer boundary of the Wasatch-Cache National Forest and is, therefore, a designated Category 1, High Quality Water.

2.3 TMDL Target Sites and Target/Endpoints

This TMDL study establishes target sites where loading capacities for dissolved zinc are calculated and allocated to upgradient sources contributing zinc load to the target site. These target sites were selected to bracket the two significant sources of zinc loading to LCC, the Howland and Wasatch Drain Tunnels, that were identified during the study. The three selected target sites are:

- LCC below Columbus-Rexal Mine (STORET monitoring station No. 591886) – referred to in the remainder of this report as "LCC below Howland"
- LCC below Gold Cliff Discharge (a designated sampling site during the USGS 2001 water quality monitoring study) – referred to in the remainder of this report as "LCC below Wasatch"
- LCC above confluence with Red Pine Fork (STORET monitoring station No. 499378). – referred to in the remainder of this report as "LCC below Tanner Flat."

These target sites, which are shown on Drawing 1, were also chosen based on the amount of available water quality and flow data at and around these locations in LCC. Although no other significant sources of zinc loading contributing to water quality criteria exceedances have been identified below the Wasatch Drain Tunnel, the target site, LCC below Tanner Flat, has been established because historic measured dissolved zinc concentrations in LCC at this location lead to the 303d listing of LCC as an impaired water body.

Target/endpoints have also been established to indicate that water quality improvements are being achieved through the phased implementation of recommended water management and best management practices described in Section 5 of this report. These endpoints are: (1) reduced dissolved zinc concentrations in LCC at the three target sites to meet the dissolved zinc acute water quality criteria, expressed as an instantaneous measure of dissolved zinc concentration, and (2) macroinvertebrate populations in LCC below the Wasatch Drain Tunnel as an indicator of attaining the Class 3A beneficial use designated for LCC, protection for cold water species of game fish and other cold water aquatic life, including the necessary aquatic organisms in their food chain. Macroinvertebrate population has been selected as an endpoint because: (1) there remain unresolved questions regarding the suitability of the habitat in this reach of LCC to support a thriving fish population and, hence, the suitability of using fish population and size in LCC as an indicator of attaining a Class 3A beneficial use, (2) macroinvertebrate data can be obtained using more precise and consistent techniques than fish data collection techniques, which have been shown to undercount both the number and size of fish in a stream, and (3) the sensitivities of macroinvertebrates and fish to increased zinc concentrations are similar.

3.0 SOURCE ASSESSMENT

This section discusses the identification and assessment of individual zinc loading sources to LCC, which include point, non-point, and background. Available data and general LCC water chemistry is discussed first. Available data included LCC water chemistry and flow measurements, and biological data (fish habitat and abundance and macroinvertebrate populations). For completeness, the assessment of general water chemistry in LCC included a comparison of all measured constituents in LCC with the applicable water quality criteria for these constituents. The results of this general assessment show zinc to be the only constituent of concern in LCC.

An evaluation of zinc loading sources, including linkage analysis, follows the general assessment of LCC water chemistry. Two significant discrete (point) sources of zinc loading to LCC have been identified, the Howland Tunnel and Wasatch Drain Tunnel (comprised of discharge from the Snowbird co-generation plant and bypass flow). Diffuse non-point and background sources of zinc loading to LCC are also addressed. As discussed below, absent loading from these diffuse sources, the water quality criteria for dissolved zinc would still be exceeded in LCC downstream of the Howland and Wasatch Drain Tunnels as a result of water discharges from these two drainage tunnels.

3.1 Available Data

Data for this TMDL study were obtained from the following sources:

- United States Geological Survey (USGS)
- Utah Department of Environmental Quality, Division of Water Quality (UTDEQ)
- Salt Lake County (SLC), Public Works and Health Departments
- National Aquatic Monitoring Center, Utah State University
- United States Department of Agriculture (USDA), Wasatch-Cache National Forest, Salt Lake Ranger District (U.S. Forest Service).

Data from the USGS, UTDEQ, and SLC included LCC water quality and flow data. Data from the National Aquatic Monitoring Center included LCC macroinvertebrate monitoring data. Data from the U.S. Forest Service included results of LCC macroinvertebrate and fish habitat and abundance surveys.

3.1.1 Water Quality and Flow Data

The assembled water quality and flow data can be best classified as limited, one-time studies and long-term (but sporadic) monitoring. Table 3.1 summarizes the features of each data set that were pertinent to the TMDL study. Each data set is more fully described in the following sections.

Table 3.1 Analytical Data Available for TMDL Study

Data Set	Period of Record	Measured Parameters	Number of Sites/Samples
USGS Synoptic	September 1998	zinc(D), copper (D), hardness, and flow	81 Sites 1 Event
USGS 2001	April through July, 2001	zinc(D), copper (D), hardness\1, and Flow	3 Sites 10 Events
UTDEQ STORET	1975 - 2000	zinc(D), copper (D) hardness, and flow	1 Site 278 Events
UTDEQ 1998	May through August, 1998	zinc(D), copper (D), hardness	14 Sites 5 Events
UTDEQ 2001	September 2001	Zinc (D), copper (D)	6 Sites 1 Event
SLC – Wasatch Tunnel	1986 – 1996 2001	zinc (T), copper (T), and flow	1 Site 90 Events
SLC – Abandoned Mine Project	2001 - 2001	zinc (T), hardness, and Flow	2 Sites 2 Events
SLC – Fen Project	2000	zinc (T), copper (T)	1 Site 13 Events

Note: \1 Hardness calculated based on calcium and magnesium
(D) = dissolved, (T) = total

3.1.1.1 USGS Data

United States Geological Survey data for LCC included:

- Data from a synoptic survey of LCC performed in 1998
- Data collected in April, May, June, and July 2001, as a follow up to the 1998 synoptic study.

These data sets provided the most comprehensive collection of data for analysis of zinc loading to LCC.

3.1.1.1.1 1998 Synoptic Survey Data

The 1998 synoptic survey was the most extensive basin-wide study performed by the USGS. The survey was conduct in September 1998, during the seasonal low flow period in the LCC watershed, to evaluate the major metal loading sources to LCC. The study included measurements of flow and water chemistry. The study reach was 8,300 meters long, beginning above Grizzly Gulch and ending below the Tanner Flat area, just upstream of the confluence of LCC and Red Pine Fork. Stream sampling locations are shown on Drawing 1. These sampling locations were chosen to bracket 33 inflows and areas where subsurface inflow was considered likely. Table 3.2 summarizes the applicable data at each of the sampling locations. The results of the synoptic study are presented in "Quantification of Mine Drainage Inflows to Little Cottonwood Creek, Utah, Using a Trace-injection and Synoptic Sampling Study" (Kimball, 2001).

3.1.1.1.2 2001 Survey Data

The USGS measured flows and collected water quality samples at three locations in LCC in April through July 2001. Flows in LCC during this sampling period were representative of higher seasonal flow conditions in LCC. The three sampling locations were: (1) LCC below Howland (identified in the study data as Near Peruvian Lodge), (2) LCC below Wasatch (identified in the study data as LCC Below Gold Cliff Discharge), and (3) LCC below Tanner Flat. Flows were measured and water quality samples collected at LCC below Howland and LCC below Wasatch approximately every two weeks, between April 24 and July 25, 2001. Flows were measured and water quality samples collected at LCC below Tanner Flat every twelve hours starting on April 24, 2001, and continuing through May 25, 2001. After May 25, 2001, flows were measured and water quality samples collected at this location every two weeks, through July 2001. Table 3.3 summarizes the applicable data at each of the sampling locations.

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Table 3.2 Locations and Applicable Analytes, USGS 1998 Synoptic Study

Location Name	Distance Downstream From Injection Point	Analytes	Stream Type
Ab injection site	83	zinc (D), hardness, Flow	LCC
First site blw injection	263	zinc (D), hardness, Flow	LCC
Grizzly Gulch	282	zinc (D), hardness, Flow	Trib.
Ab culvert at jump	364	zinc (D), hardness, Flow	LCC
Blw culvert at jump	402	zinc (D), hardness, Flow	LCC
T1 stream site	572	zinc (D), hardness, Flow	LCC
Small inflow w/ Fe stain	686	zinc (D), hardness, Flow	Trib.
At end of willows	780	zinc (D), hardness, Flow	LCC
Ab Collins Gulch	933	zinc (D), hardness, Flow	LCC
Collins Gulch	955	zinc (D), hardness, Flow	Trib.
Blw Collins Gulch	1009	zinc (D), hardness, Flow	LCC
Blw Ski Bridge	1205	zinc (D), hardness, Flow	LCC
South Hecla Mine (Snowmaking)	1265	zinc (D), hardness, Flow	Trib.
Blw Hecla input	1375	zinc (D), hardness, Flow	LCC
Howland Drain Tunnel	1400	zinc (D), hardness	Trib.
Flagstaff drain	1401	zinc (D), hardness	Trib.
GMD lot drain	1402	zinc (D), hardness	Trib.
Combined Howland	1403	zinc (D), hardness, Flow	Trib.
Blw Howland Tunnel	1443	zinc (D), hardness, Flow	LCC
Spring by Peruvian Lodge	1490	zinc (D), hardness, Flow	Trib.
Nr Peruvian Lodge	1550	zinc (D), hardness, Flow	LCC
Blw Peruvian Lodge	1592	zinc (D), hardness, Flow	Trib.
T2 site at bridge	1742	zinc (D), hardness, Flow	LCC
Blw waterfall	1812	zinc (D), hardness, Flow	Trib.
Blw Hellgate Falls	1862	zinc (D), hardness, Flow	LCC
Hellgate spring	1874	zinc (D), hardness, Flow	Trib.
Large discharge spring	1899	zinc (D), hardness, Flow	Trib.
Blw Hellgate Spring	1959	zinc (D), hardness, Flow	LCC
Large spring	2003	zinc (D), hardness, Flow	Trib.
At footbridge	2063	zinc (D), hardness, Flow	LCC
Nr houses	2193	zinc (D), hardness, Flow	LCC
Nr Bedrock & houses	2433	zinc (D), hardness, Flow	LCC
Upper WT fractures	2470	zinc (D), hardness, Flow	Trib.
Blw fracture inflow	2590	zinc (D), hardness, Flow	LCC
Blw cascading reach	2890	zinc (D), hardness, Flow	LCC
Dilute inflow near Cliff parking	2892	zinc (D), hardness, Flow	Trib.
T3 ab thermal	2922	zinc (D), hardness, Flow	LCC
Cold inflow	2924	zinc (D), hardness	Trib.

Note: (D) = dissolved, (T) = total

Table 3.3 2001 USGS Sampling Data

Station Number (distance below 1998 Synoptic study injection point)	Period of Record	Measured Parameters Applicable to LCC TMDL Study
Near Peruvian Lodge/2	4/24/2001– 7/25/2001	zinc (D) 6 times hardness/1 9 times flow 9 times
LCC Blw Gold Cliff Discharge	4/24/2001– 7/25/2001	zinc (D) 7 times hardness/1 9 times flow 9 times
LCC Blw Tanner Flat/3	4/24/2001– 7/25/2001	zinc (D) 9 times hardness/1 65 times flow 66 times

Notes:/1 calculated based on calcium and magnesium or estimated based on sulfate
/2 Located in the approximate location of STORET monitoring station No. 591886
/3 In the approximate location of STORET monitoring station No. 499378
(D) = dissolved, (T) = total

3.1.1.2 UTDEQ Data

Data collected by the UTDEQ included: (1) water quality and flow at 19 stations located along the LCC, beginning in 1975 to the present (STORET data); (2) results of a metals loading reconnaissance of LCC performed in 1998; and (3) limited data collected in 2001 around the Tanner Flat Campground.

3.1.1.2.1 STORET Data

The STORET data set is comprised of water quality and flow at 19 monitoring stations located along the LCC. The locations and number designations of these monitoring stations are shown on Drawing 1. Three of these 19 monitoring stations (stations number 499370, 499366, and 499369) are located downstream of the LCC study reach (see Drawing 1). Station 499369 is the most downstream monitoring station, located just above the Murray City Water Intake. The 16 monitoring stations located in the study reach include nine located on LCC and seven located on tributaries to LCC.

While the STORET data were evaluated, their application to the TMDL was limited. The majority of the data were for monitoring station 499369, LCC above the Murray City Water Intake. The 16 stations located within the study area were sampled sporadically and only for a limited number of analytes, oftentimes not including any analyses for metals or flow. Table 3.4

summarizes the data at each of the 16 STORET monitoring stations located in the LCC study reach.

Table 3.4 STORET Analytical Data Summary

Station Number	Description	Period of Record	Measured Parameters Applicable to LCC TMDL Study[1]
499378	LCC ab CNFL / Red Pine Fork	2 times in 1978 2 times in 1994 2 time in 1995	Flow zinc and copper zinc and copper
499379	LCC bl White Pine Fork	2 time in 1978	Flow
499381	White Pine CK ab CNFL / LCC	2 time in 1978	Flow
499382	LCC bl Snowbird Rec Area	2 time in 1978	Flow
499386	LCC bl Hellgate Spring	2 time in 1978	Flow
499389	LCC bl Alta	1 time in 1978 1 time in 1985	Flow zinc, copper, hardness and Flow
499393	LCC ab Alta-under Sunnyside Ski Lift	4 time in 1986	zinc, copper, hardness and Flow
591886	LCC bl COL-REX Mine Q -0.1MI AB Alta Bridge	4 times in 1986	zinc, copper, hardness and Flow
591887	Columbus-Rexall Mine Outfall ab Peruvian Lodge	2 times in 1985 4 times in 1986	Zinc, copper, hardness and Flow Zinc, copper, hardness and Flow
591888	LCC ab Columbus-Rexall Mine Outfall	4 times in 1986	zinc, copper, hardness and Flow
591894	Grizzly Gulch at HWY U210 Culvert Outlet	4 time in 1985	Zinc, copper, hardness and Flow
591896	Live Yankee Huron Ravine Horizontal Opening 6	3 times in 1985 3 times in 1986	zinc, copper, hardness and Flow zinc, copper, hardness and Flow
591897	Live Yankee Huron Ravine Horizontal Opening 5	2 times in 1985 2 times in 1986	zinc, copper, hardness and Flow zinc, copper, hardness and Flow
591898	Live Yankee Huron Ravine Horizontal Opening 7	3 times in 1985 4 times in 1986	zinc, copper, hardness and Flow zinc, copper, hardness and Flow
591899	Grizzly Gulch Upper	1 time in 1985 2 times in 1986	zinc, copper, hardness and Flow zinc, copper, hardness and Flow
591902	LCC ab Grizzly Gulch	4 times in 1986	zinc, copper, hardness and Flow

Note: /1 Analytes are a mix of total and dissolved constituent concentrations.

3.1.1.2.2 1998 Reconnaissance Study

Sampling during the 1998 metals source loading reconnaissance of the LCC drainage basin was conducted at selected LCC and tributary drainage locations three times during dry weather (May, June, and July), and twice during storm events (July and August). Stream flows were not measured during the sampling events. Sampling locations are shown on Drawing 1. Table 3.5 summarizes the data at each of the sampling locations.

Table 3.5 UTDEQ 1998 Metals Loading Reconnaissance Data

Location	Period of Record	Measured Parameters Applicable to LCC TMDL Study
LCC at Sunnyside	May 1998 – July 1998	zinc (D), hardness
Grizzly Gulch	May 1998 –	zinc (D), hardness
Emma Ridge	July 21 1998 – July 27 1998	zinc (D), hardness
Collins Gulch	June 1998 – Aug 1998	zinc (D), hardness
Howland Drain Tunnel	May 1998 –Aug 1998	zinc (D), hardness
Flagstaff Mine Discharge (below Road)	July 21, 1998 – July 27, 1998	zinc (D), hardness
Flagstaff Drainage (Goldminer lot)	May 1998 – Aug 1998	zinc (D), hardness
Toledo Drainage	June 1998 – Aug 1998	zinc (D), hardness
LCC at Hellgate	May 1998 - July 1998	zinc (D), hardness
Peruvian Gulch	May 1998 - July 1998	zinc (D), hardness
Wasatch Drain Tunnel	July 21, 1998	zinc (D), hardness
Gad Valley	May 1998 - July 1998	zinc (D), hardness
White Pine	June 1998 - July 1998	zinc (D), hardness
LCC at Tanner Flat Campground	May 1998 - July 1998	zinc (D), hardness

Note: (D) = dissolved, (T) = total

3.1.1.2.3 2001 Data

Six water quality samples were collected for the UTDEQ in the Tanner Flat area in September 2001. These samples were collected to evaluate water quality (copper and zinc concentrations) in LCC, White Pine Fork, and an unnamed tributary flowing through Tanner Flat. This additional sampling was performed to confirm the presence of any zinc loading source in the Tanner Flat/White Pine Fork area because of the noted increase in zinc and copper concentrations in LCC below Tanner Flat reported in the USGS 1998 synoptic study results.

3.1.1.3 Salt Lake County Data

Information obtained from SLC included water quality and flow data for the Wasatch Drain Tunnel, water quality data from the Alta Abandoned Mine Monitoring Project, water quality data from the Alta Wetland Fen Pilot Project, and water quality and flow data from the Wasatch Watershed Monitoring Project.

Wasatch Drain Tunnel data were provided by Salt Lake County Service Area #3, which maintains and operates the water system. This tunnel was originally constructed in 1913 and was expanded as mining increased in the area. Long since abandoned as a mining operation, the Wasatch Drain Tunnel is now the primary water source at the Snowbird ski area. In 1985, a steel and concrete bulkhead structure was installed to backup water in the old mine workings to an elevation of zero to 400 feet of head. The water in the tunnel is used for domestic water supply, cooling the Snowbird natural-gas-fired co-generation plant, and snowmaking. Except for water used for domestic water supply and snowmaking, all of the water released from the tunnel flows to LCC, either as discharge from the co-generation plant, or directly through the tunnel bypass. The Wasatch Drain Tunnel data requested and provided by SLC covered a period from 1986 to 1996, and also included data for 2001. These data included flows from the tunnel, head behind the bulkhead, and tunnel water quality data. Water quality data included antimony, cadmium, copper, iron, lead, manganese, and zinc concentrations.

The Alta Abandoned Mine Project was established to investigate and monitor abandoned mine discharge into the upper segments of LCC from the Flagstaff, Howland, and Toledo drainage basins. The project was performed beginning the summer of 2000, through the summer of 2001. Automatic samplers were placed in the basin drainages during the spring and summer months, and were removed in the fall before the occurrence of heavy snows. The Alta Abandoned Mine Monitoring Project report for the 2000 monitoring season (Jensen, 2001a) provides analytical results of samples collected from the Flagstaff drainage during an August storm and results of samples collected from the Howland and Flagstaff drainages during a mid-October snowmelt event. These samples were analyzed for lead, copper, zinc, TSS, and hardness. No flow measurements were taken during the sampling events. No samples were obtained during the 2001 monitoring season.

As part of the Wasatch Watershed Monitoring Project, the SLC Health Department installed three automatic sampling stations in LCC Canyon to monitor flow, TSS, lead, and zinc during storm events. The three locations were LCC at Tanner Flat Campground (STORET monitoring station No. 499378), LCC at Hellgate Springs (STORET monitoring station No. 499386), and LCC at Sunnyside (STORET monitoring station No. 499393). The results of the 1990 monitoring season are provided in the Wasatch Watershed Water Quality 1990 Monitoring Season Summary (Jensen, 1991).

3.1.2 Biological Data

3.1.2.1 National Aquatic Monitoring Center Data

In 1997 and 1998, staff from the National Aquatic Monitoring Center, Utah State University, conducted macroinvertebrate sampling within the Weber River basin for the U.S. Forest Service, Wasatch-Cache National Forest. About half of the sampling sites in the study were located in LCC, the remainder in other sub-watersheds in the basin (Logan River in Cache County and Wheeler Creek in Weber County).

Results of the survey are reported in “Aquatic Macroinvertebrate Monitoring Report” (Vinson, 1999). The ten sample stations in LCC identified in the study report ranged from 1,841 meters to 2,926 meters in elevation. The approximate locations of these sampling stations are shown on Drawing 1. These sampling stations were located on Drawing 1 based on latitudinal and longitudinal data for each station and descriptions of each station provided with the study results. In many cases, plotted locations of the sampling stations, based on their reported latitude and longitude, did not fall in LCC. These locations were subsequently adjusted to fit in LCC, using best judgment.

Surveys were conducted in LCC in August 1998, and included three Surber samples (9 inch square sampler, covering 0.093 square meter each) at each sampling station. Data collected included number of individuals and taxa for four classifications of macroinvertebrates: (1) total, (2) Ephemeroptera+Plecoptera+Trichoptera combined (EPT), (3) Intolerant, and (4) Tolerant.

3.1.2.2 U.S. Forest Data

The U.S. Forest Service data reviewed for this study included macroinvertebrate, fish, and fish habitat data. In 1997, the Forest Service conducted electrofishing surveys on several streams in the Wasatch-Cache National Forest, including LCC (Cowley, 1977). Seven different sections of LCC were selected for survey. Five of these seven sections were located in the LCC study reach. These included: (1) the Tanner Flat campground area, (2) a section located just below the Baby Thunder Chair lift, (3) a section located above the bridge crossing downstream of the second entrance to the Snowbird ski area, (4) a section located just above the Wasatch Drain Tunnel, and (5) a section extending between the culvert at the Sugarloaf Lift of the Alta ski area and the base of the Albion lift.

In addition to the 1997 fish surveys, macroinvertebrate sampling at 16 locations in LCC was also conducted by the Forest Service in July 1997 (UTDEQ, 2001a). Ten of these 16 sampling stations were located in the LCC study reach; the remaining sampling stations were located downstream of the study reach. The data did not include surveyed locations of the sampling stations; however, written descriptions for the locations of five of the ten sampling stations located in the LCC study reach were provided. These five sampling locations were identified as: (1) Tanner Flat Campground, (2) just above White Pine Fork, (3) Snowbird ski area, (4) just below Wasatch Drain Tunnel, and (5) Alta ski Area. Although the locations of the remaining sampling stations could not be identified from the provided data, their relative locations (i.e., above or below the five described sampling locations) could be discerned. Data collected during the survey included number of individuals for four classifications of macroinvertebrates: (1) Diptera, (2) Ephemeroptera, (3) Plecoptera, and (4) Trichoptera.

It also appears that the Forest Service conducted a fish habitat survey in 1997. This survey was conducted from the lower boundary of Snowbird, upstream to the base facility for Alta. Although data from this survey were not available for review, summary results of the survey were provided in meeting minutes of the Little Cottonwood Canyon Group (UTDEQ, 2001b).

The Forest Service also conducted a fish habitat and abundance survey of LCC in the summer of 1999. The survey implemented the USDA Forest Service R1/R4 (Northern/Intermountain

Regions) Fish and Fish Habitat Standard Inventory, which provided quantitative estimates of fish abundance and fish habitat quality in each habitat type for each of five reaches of LCC studied. Only one of the five reaches studied was located in the LCC TMDL study area. This is the reach of LCC located between its confluence with White Pine Fork and Red Pine Fork. The remaining four study reaches were located downstream of the LCC TMDL study area.

The habitat assessment, based on the survey results, compared fish habitat quality measures against two sets of standards derived from USDA Forest Service publications: "natural condition descriptors" from "User's Guide to Fish Habitat: Descriptions that Represent Natural Conditions in the Salmon River Basin, Idaho" (Overton and others 1997), and the Inland Native Fish Strategy Environmental Assessment (INFISH) (USDA Forest Service 1995). Results of the survey are presented in "Little Cottonwood Creek Stream Survey Report" (Schwager and Crowley, 2001).

3.1.3 Data Limitations

The limited amount and inconsistencies in the water quality and flow data available for LCC required making interpretive judgements and assumptions for the TMDL analysis. These limitations and inconsistencies are a result of the data being collected by different entities and for different purposes, and include:

- Limited hardness data
- Limited flow data
- Chemical analysis (sample analytes) varying between sampling locations and sampling events
- Non-uniform sampling locations
- Metals analyses varying between dissolved, total recoverable, and total form.

Biological data is also limited, and two comments are made regarding this data. First, although macroinvertebrate data was analyzed as a qualitative measure of LCC water quality (see Section 3.3.3), the presence and diversity of macroinvertebrates can be very dependant on the microhabitats of a stream, and no descriptions of the microhabitats at each of the sampling locations were provided in the data so that macroinvertebrate data results could be assessed with respect to the specific microhabitats sampled. Accordingly, the previously measured variability in macroinvertebrate populations along the study reach of LCC cannot be conclusively attributed to dissolved zinc concentrations in LCC. Second, fish survey techniques used in data collection activities (i.e., electroshocking) have been shown to underestimate total fish count and size diversity in a stream reach, and habitat constraints do not appear to have been thoroughly addressed coincidentally with fish survey results. Accordingly, the previously measured variability in fish populations along the study reach of LCC cannot be conclusively attributed to dissolved zinc concentrations in LCC.

3.2 General Water Chemistry Assessment

A general assessment of LCC water chemistry was performed through review and analysis of the previously described water quality data. Although dissolved zinc concentrations in the study reach of LCC resulted in its listing as an impaired water body on the State's 303d list, water quality data for LCC was compared against all applicable water quality criteria for completeness. As discussed in the following sections, the evaluation of LCC water chemistry confirmed that dissolved zinc is the only constituent of concern in LCC.

3.2.1 Class 1C Criteria Exceedances

No exceedances of Class 1C criteria were noted in the water quality data for LCC. However, the concentrations of cadmium (0.0413 mg/L and 0.0308 mg/L) and lead (0.101 mg/L) in samples obtained from the Howland Tunnel by the UTDEQ in 1998 were measured above the Class 1C criteria for these constituents (0.01 mg/L and 0.05 mg/L, respectively). The concentration of cadmium (0.0295 mg/L) in a sample taken from White Pine Fork in 1998 also measured above the Class 1C criteria for this constituent (0.01mg/L).

3.2.2 Class 2B Criteria Exceedances

No exceedances of the Class 2B criteria were noted in the water quality data for LCC or any of its tributaries.

3.2.3 Class 3A Criteria Exceedances

Exceedances of the Class 3A criteria for both dissolved copper and dissolved zinc were noted in the water quality data for LCC. Because the toxicity of these dissolved metals to aquatic life is dependent on water hardness, the chronic and acute criteria of dissolved copper and zinc are calculated based on hardness-based equations. The hardness in LCC typically ranges from 50 to 200 mg/L and, as discussed in Section 4.1.3 of this report, is strongly related to river flow rate.

Since the criteria for dissolved copper and zinc are hardness-based, only those water quality measurements that included hardness data are discussed below.

3.3.3.1 Copper

The most comprehensive measurements of dissolved copper concentrations in LCC were completed during the 1998 USGS synoptic study. The results of this study show that copper levels in LCC remained below both the acute and the chronic criteria levels for the entire length of the creek, with the exception of the sampling location directly below the confluence of LCC and White Pine Fork. The concentration of copper in the sample taken at this location exceeded the chronic copper criteria (see Figure 3.1).

White Pine Fork, which drains an undisturbed mineralized area, appears to be a significant source of copper loading to LCC. As shown in Figure 3.2, copper concentrations in White Pine Fork have exceeded the acute and chronic standards for copper the three times that it was sampled for copper. These three sampling events were all completed in 1998, and include two samples collected by the UTDEQ and the USGS synoptic study sample.

Figure 3.1 LCC Dissolved Copper Concentrations and Criteria, USGS September 1998 Synoptic Study

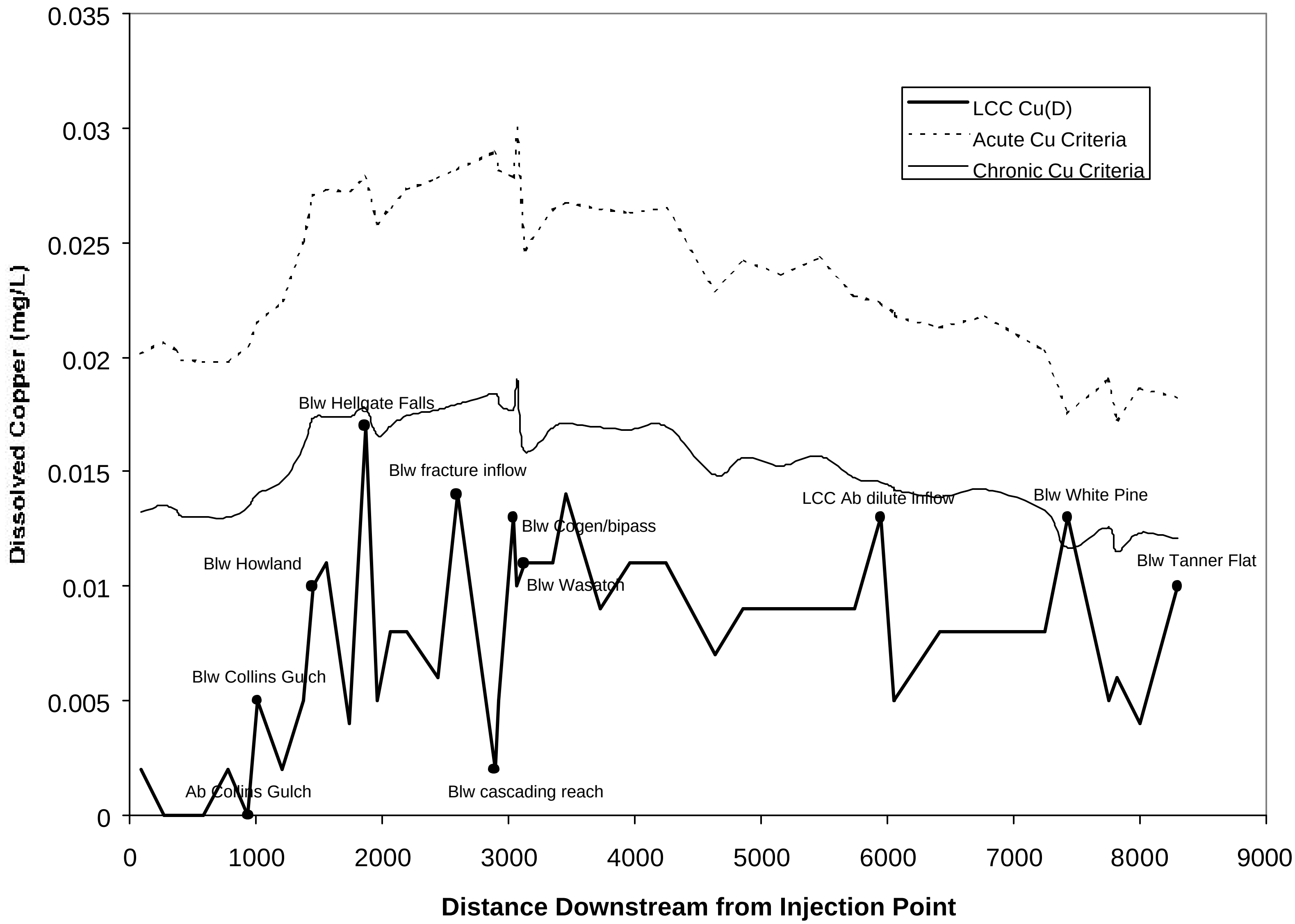
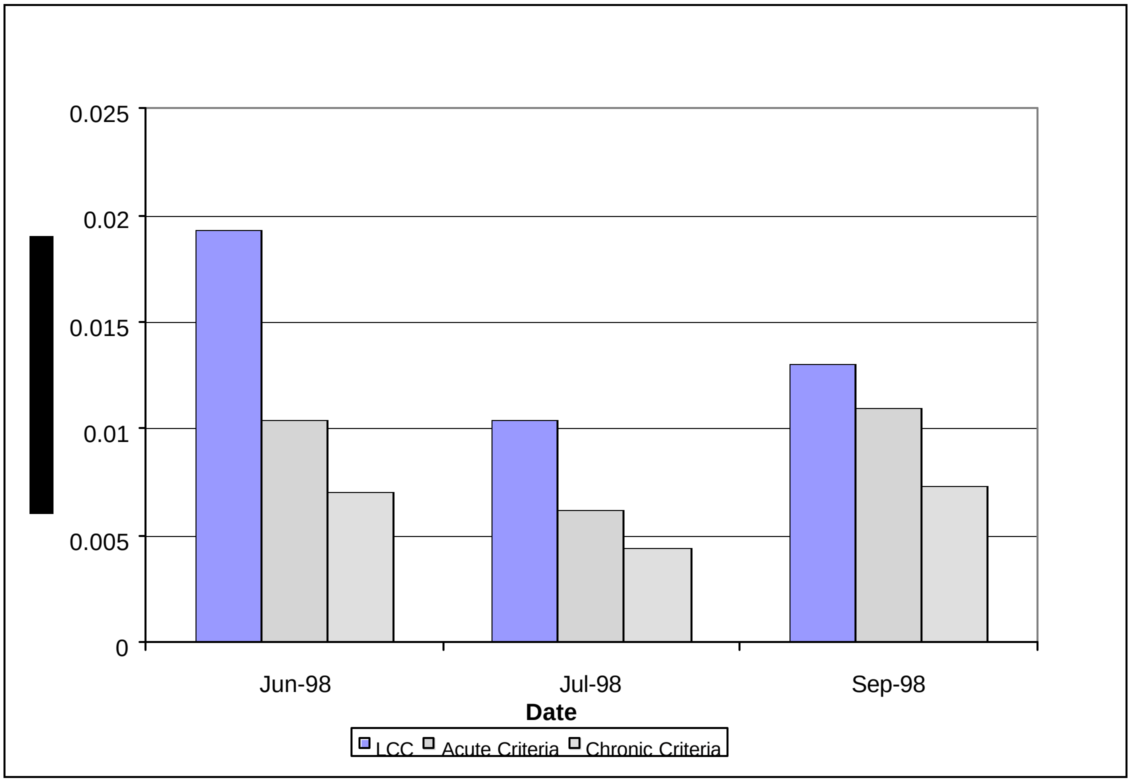


Figure 3.2 Dissolved Copper Concentrations in White Pine Fork compared to Class 3A Criteria



In addition to the measurements in White Pine Fork, copper measurements in LCC in the Tanner Flat area below White Pine Fork also show elevated dissolved copper concentration. Copper and hardness values have been measured in LCC in this area a total of 13 times since 1994 (Table 3.6). As shown in Table 3.6, the reported concentration of copper in two samples (May and June 1998) slightly exceeded the acute criteria for copper. The reported concentrations in four samples (May, June, and July 1998, and June 6, 2001) also exceeded the chronic criteria for copper. The reported copper concentrations for the May 1994, May 1995, and all but one of the seven 2001 samples were below the analytical method detection limit (MDL). Although measured copper concentrations in these samples were below the MDL, the results show that:

1. The concentration of dissolved copper in the May 1995 sample was clearly below the chronic criteria for copper

2. The dissolved copper concentrations in the two May 2001 samples were clearly below the chronic criteria for copper

3. The dissolved copper concentrations in the June 8 and June 29, 2001 samples and two July 2001 samples were clearly below the acute and chronic criteria for copper.

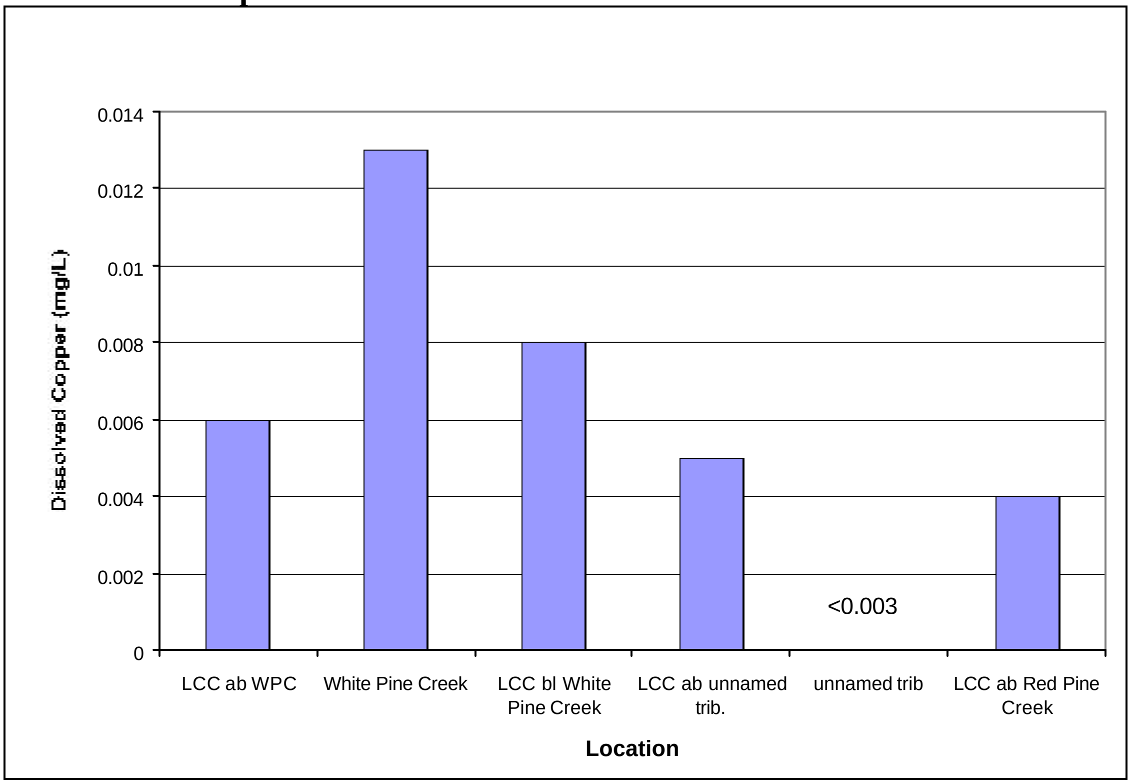
Six water quality samples were also collected for the UTDEQ in the Tanner Flat area in September 2001. Samples were taken in LCC, White Pine Fork, and an unnamed tributary flowing through Tanner Flat. As shown in Figure 3.3, the concentration of copper in White Pine Fork was elevated compared with measurements taken in LCC and the unnamed tributary.

Table 3.6 LCC Dissolved Copper Concentrations Compared to Class 3A Criteria, Tanner Flats

Location	Date	Hardness	Dissolved copper	Acute Criteria	Chronic Criteria
LCC ab CNFL / RED PINE CK (STORET # 499378)	May-94	63	<0.02	0.011	0.008
LCC ab CNFL / RED PINE CK (STORET # 499378)	May-95	100	<0.012	0.017	0.011
LCC at Tanner Flat Campground	May-98	90	0.0163	0.015	0.010
LCC at Tanner Flat Campground	Jun-98	71	0.0128	0.012	0.008
LCC at Tanner Flat Campground	Jul-98	66	0.00886	0.012	0.008
LCC Blw Tanner Flat	Sep-98	108	0.01	0.018	0.012
LCC Blw Tanner Flat	May16, 2001	59	<0.01	0.011	0.007
LCC Blw Tanner Flat	May 25, 2001	63	<0.009	0.011	0.008
LCC Blw Tanner Flat	June 6, 2001	83	0.013	0.015	0.010
LCC Blw Tanner Flat	June 18, 2001	93	<0.008	0.017	0.011
LCC Blw Tanner Flat	June 29, 2001	103	<0.009	0.018	0.012
LCC Blw Tanner Flat	July 11, 2001	122	<0.009	0.021	0.013
LCC Blw Tanner Flat	July 25, 2001	147	<0.008	0.025	0.016

Note: Shaded values represent exceedances of acute criteria

Figure 3.3 Dissolved Copper Concentrations in the White Pine and Tanner Flat Area, September 2001.



3.3.3.2 Zinc

The most comprehensive measurements of dissolved zinc concentrations in LCC were also completed during the 1998 USGS synoptic study. The results of this study show that zinc levels in LCC exceeded both the acute and chronic criteria, beginning below the Wasatch Drain Tunnel, to below White Pine Fork (See Figure 3.4). As shown in Figure 3.4, although the measured concentrations of zinc in this reach of LCC were above the acute and chronic criteria, and additional zinc loading is noted along the entire reach, the attenuation of zinc in LCC resulted in a downward trend of zinc concentrations through the reach. As a result of this attenuation, zinc concentrations fell below acute and chronic criteria levels just above Tanner Flat, with the measured concentration again rising above the criteria in LCC below Tanner Flat**.** (This increase in zinc concentration below Tanner Flat was noted in the synoptic study to be attributed to an apparent loading source in the Tanner Flat area. As discussed in Section 3.4.2 of this TMDL study report, additional sampling performed for the UTDEQ in 2001 did not confirm increased zinc concentrations through the Tanner Flat area.

Including the 1998 synoptic study, LCC has been sampled for zinc in the Tanner Flat area 13 times since 1994. As shown in Table 3.7 and Figure 3.5, the acute and chronic criteria for zinc were exceeded in six of these 13 samples.

Table 3.7 LCC Dissolved zinc Concentrations Compared to Class 3A Criteria, Tanner Flats

Location	Date	Hardness	Dissolved zinc	Acute Criteria	Chronic Criteria
LCC ab CNFL / RED PINE CK (STORET # 499378)	May-94	63	0.098	0.077	0.07
LCC ab CNFL / RED PINE CK (STORET # 499378)	May-95	100	0.13	0.11	0.10
LCC at Tanner Flat Campground	May-98	90	0.0616	0.10	0.10
LCC at Tanner Flat Campground	Jun-98	71	0.0902	0.086	0.08
LCC at Tanner Flat Campground	Jul-98	66	0.0561	0.080	0.07
LCC Blw Tanner Flat	Sep-98	108	0.126	0.12	0.11
LCC Blw Tanner Flat	5/16/01	58.72	0.065	0.07	0.07
LCC Blw Tanner Flat	5/25/01	63.16	0.084	0.08	0.07
LCC Blw Tanner Flat	6/6/01	83.0	0.14	0.10	0.09
LCC Blw Tanner Flat	6/18/01	93.1	0.082	0.11	0.10
LCC Blw Tanner Flat	6/29/01	103.3	0.088	0.12	0.11
LCC Blw Tanner Flat	7/11/01	122.2	0.093	0.14	0.13
LCC Blw Tanner Flat	7/25/01	146.7	0.12	0.16	0.15

Note: Shaded values represent exceedances of Acute Criteria

Figure 3.4 LCC Dissolved Zinc Concentrations Compared to Class 3A Criteria, USGS September 1998 Synoptic Study

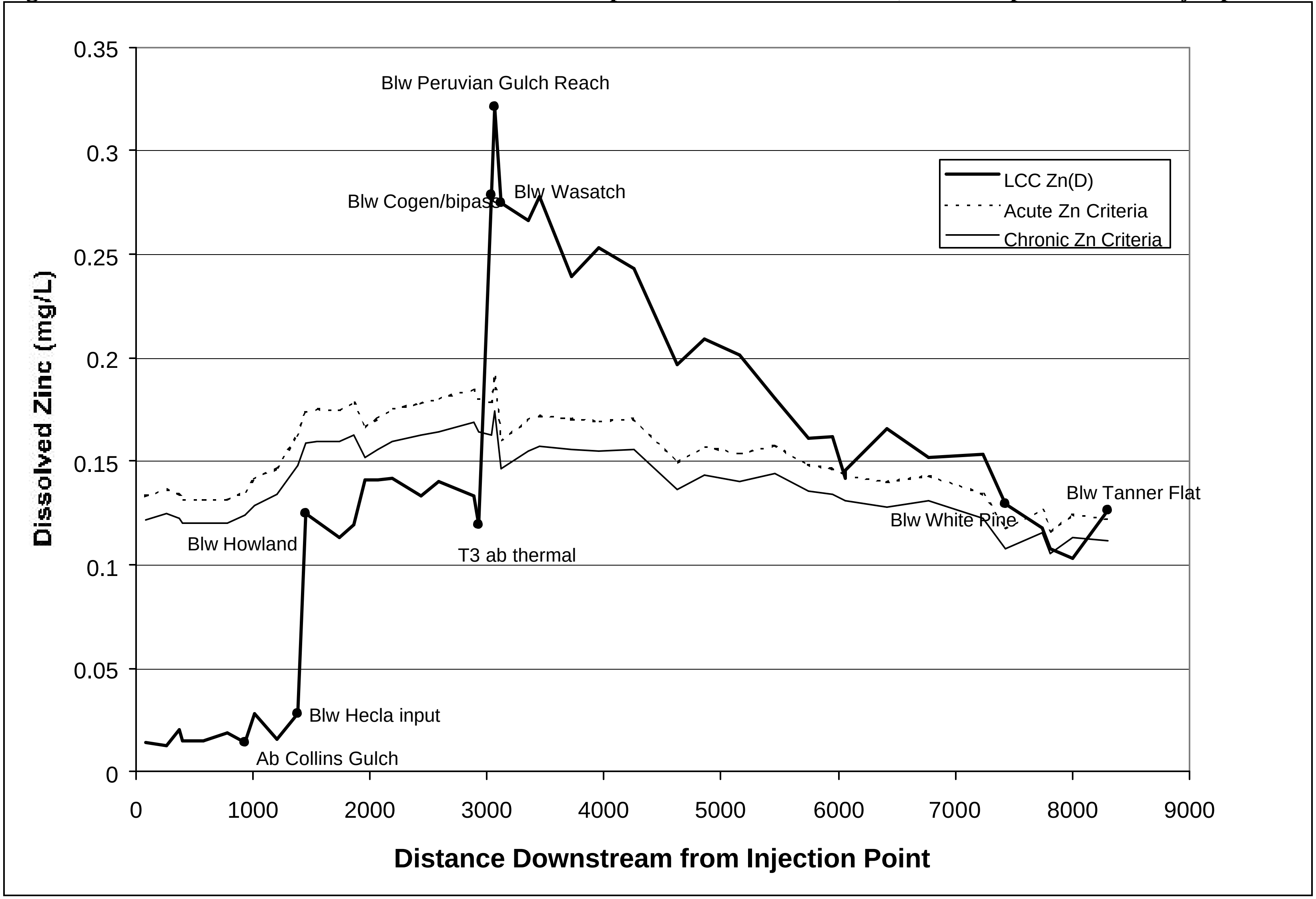
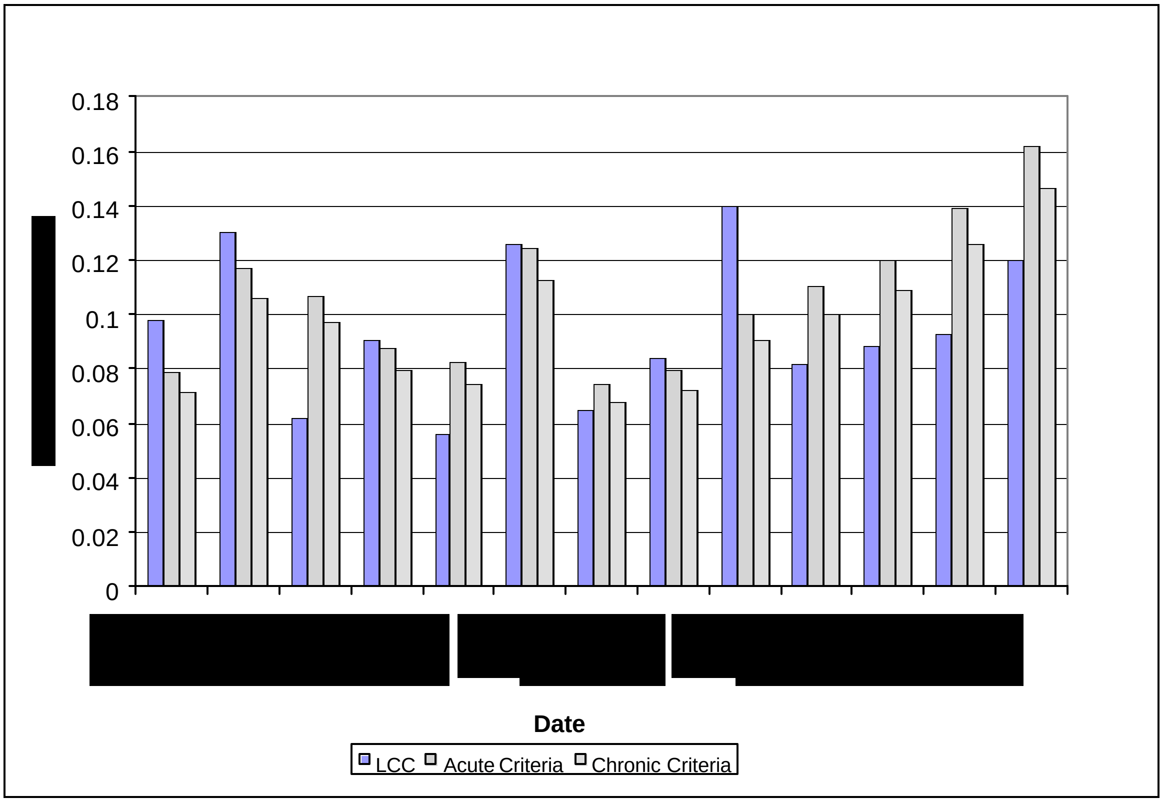


Figure 3.5 Dissolved Zinc Concentrations below Tanner Flat compared to Class 3A Criteria



Although not analyzed for dissolved zinc, total zinc concentrations in four samples taken in LCC below the Howland Tunnel area between July and October 1986 were measured above the acute criteria for dissolved zinc. Total zinc concentrations in samples taken in LCC above the tunnel during the same period measured below the criteria.

In addition to the zinc exceedances in LCC noted above, concentrations of dissolved zinc above the acute and chronic criteria have also been measured in flows from the Howland Tunnel, Flagstaff drainage, Toledo drainage, Wasatch Drain Tunnel, Gad Valley Drainage, and White Pine Fork. These data are presented in Table 3.8.

Table 3.8 Dissolved Zinc Concentration and Criteria in LCC Tributaries (excluding September 1998 Synoptic Survey)

Location	Date	Dissolved zinc	Acute Criteria	Chronic Criteria
Grizzly Gulch	5/11/98	0.124	0.14	0.12
Grizzly Gulch	6/16/98	0.0575	0.10	0.10
Grizzly Gulch	7/21/98	0.0224	0.07	0.07
Grizzly Gulch	7/27/98	0.0444	0.08	0.07
Grizzly Gulch	8/18/98	0.0519	0.13	0.12
GRIZZLY GULCH AT HWY U210 CULVERT OUTLET	9/16/86	0.025	0.14	0.12
Emma Ridge	7/21/98	0.0236	0.20	0.18
Emma Ridge	7/27/98	0.0431	0.19	0.18
Collins Gulch	6/16/98	0.0579	0.09	0.08
Collins Gulch	7/21/98	0.0208	0.12	0.11
Collins Gulch	7/27/98	0.0394	0.10	0.09
Collins Gulch	8/18/98	0.0454	0.17	0.16
Howland Drain Tunnel	5/11/98	0.441	0.07	0.06
Howland Drain Tunnel	6/16/98	0.181	0.06	0.05
Howland Drain Tunnel	7/21/98	5.66	0.39	0.36
Howland Drain Tunnel	8/18/98	4.51	0.44	0.40
Flagstaff Drainage (Goldminer lot)	5/11/98	0.161	0.14	0.13
Flagstaff Drainage (Goldminer lot)	6/16/98	0.103	0.11	0.10
Flagstaff Drainage (Goldminer lot)	7/21/98	0.0501	0.16	0.14
Flagstaff Drainage (Goldminer lot)	7/27/98	0.02	0.06	0.06
Flagstaff Drainage (Goldminer lot)	8/18/98	0.0726	0.12	0.11
Flagstaff Mine Discharge(below Road)	7/21/98	0.0433	0.16	0.14
Flagstaff Mine Discharge(below Road)	7/27/98	0.075	0.07	0.07
Toledo Drainage	16-Jun-98	0.0711	0.05	0.05
Toledo Drainage	27-Jul-98	0.0283	0.09	0.08
Toledo Drainage	18-Aug-98	0.635	0.15	0.13
Peruvian Gulch	11-May-98	0.0373	0.13	0.12
Peruvian Gulch	16-Jun-98	0.0479	0.11	0.10
Peruvian Gulch	21-Jul-98	0.0245	0.09	0.08
Wasatch Drain Tunnel	21-Jul-98	0.961	0.17	0.15
Gad Valley	5/11/98	0.0325	0.05	0.05
Gad Valley	6/16/98	0.0497	0.04	0.04
Gad Valley	7/21/98	0.0269	0.03	0.03
White Pine	16-Jun-98	0.125	0.07	0.06
White Pine	21-Jul-98	0.0313	0.04	0.04

Note: Shaded values represent exceedances of Acute Criteria

3.2.5 Summary

Although both zinc and copper concentrations in LCC have exceeded the Class 3A criteria for these constituents, zinc appears to be the only constituent of concern. This conclusion is based on the fact that dissolved zinc concentrations in LCC have been shown to exceed both the acute and chronic criteria over the entire length of LCC below the Wasatch Tunnel and in a number of tributary flows to LCC, whereas dissolved copper concentration in LCC only slightly exceeded the criteria for this constituent, and only in the Tanner Flat area. The exceedance of the copper criteria in this area can be attributed to natural loading from White Pine Fork. Also, although it is apparent from Figure 3.1 that copper loading occurs along the entire reach of LCC, rapid attenuation of copper in LCC prevents concentrations from exceeding the criteria for this constituent.

3.3 Biological Assessment

The biological assessment of LCC included a review of both fish habitat and macroinvertebrate data.

3.3.1 Fish Habitat

The U.S. Forest Service conducted fish habitat surveys in 1997 and 1999. The 1997 survey, briefly described in the April 9, 1998, meeting minutes of the Little Cottonwood Canyon Group (LCCG) (UTDEQ, 2001b), encompassed approximately 5024 feet of LCC from the lower boundary of Snowbird up to the base facility for Alta. Although data from this survey were not available for review for the TMDL study, the results of the survey, as reported in meeting minutes of the LCCG (UTDEQ, 2001b) indicated that there was enough room for fish in the studied reach, even during periods of low flow in LCC. Habitat indices, including percent of substrate fines, bank stability, percentage of undercut banks, percent of woody debris, and macroinvertebrate production sites were all reported as adequate. It was also noted in the meeting minutes that the ratio of turbulent water to pools was reported to be higher than optimal in the study reach, but the habitat was still considered sufficient to produce more than the noted 13 lbs./acre of fish biomass measured in this reach.

The U.S. Forest Service 1999 survey of fish habitat in LCC implemented the USDA Forest Service R1/R4 (Northern/Intermountain Regions) Fish and Fish Habitat Standard Inventory, which provided quantitative estimates of fish abundance and fish habitat quality. Of the five reaches of LCC surveyed, only one reach, located between the confluence of LCC with White Pine Fork and Red Pine Fork, was located in the TMDL study area. The remaining reaches were located downstream of the study area. The assessment compared fish habitat quality measures against two sets of standards derived from USDA Forest Service publications: (1) "natural condition descriptors" from "User's Guide to Fish Habitat: Descriptions that Represent Natural Conditions in the Salmon River Basin, Idaho" (Overton and others, 1997), and (2) the "Inland Native Fish Strategy Environmental Assessment" (INFISH) (USDA Forest Service 1995). Specific habitat measures in the R1/R4 Standard Inventory were assessed with respect to three standards: (1) pools per mile, (2) pool:riffle ratios, and (3) large woody debris per mile. The review of these study results gave no indication of significant anthropogenic impacts on fish populations in the surveyed reach of LCC located in the TMDL study area.

3.3.2 Fish Population

Fish population data appears to be inconclusive in terms of relating findings to LCC water quality. As reported in the 1998 LCCG meeting minutes (UTDEQ, 2001b), fish biomass surveyed by the U.S. Forest Service in 1997 was less than expected, compared with surveyed physical habitat quality. The results of this survey were also summarized in the "Final Environmental Impact Statement for the Snowbird Master Development Plan" (U.S. Forest Service 1999). As described, the results indicated that both rainbow and brook trout inhabit the stream. The most abundant fish populations were found in the reach of LCC approximately 200 to 300 meters downstream of the Wasatch Drain Tunnel. The sections of LCC immediately upstream and downstream of the tunnel were, however essentially devoid of fish.

3.3.3 Macroinvertebrate Population

Macroinvertebrate data included results of sampling in LCC performed by the National Aquatic Monitoring Center in 1998, and sampling conducted by the U.S. Forest Service in 1997.

Macroinvertebrate data was collected by the National Aquatic Monitoring Center at ten sample stations in LCC. These stations ranged from 1,841 meters to 2,926 meters in elevation. Surveys included three Surber samples (9-inch square sampler, covering 0.093 square meter each), each processed and reported separately. Data included number of individuals and taxa for four classifications: (1) total, (2) Ephemeroptera+Plecoptera+Trichoptera combined (EPT), (3) Intolerant, and (4) Tolerant. Survey results are plotted in Figures 3.6 and 3.7.

The EPT class included all taxa from three insect orders (mayflies, stoneflies, and caddisflies), which are considered relatively sensitive to pollution, and all of which are important food for fish. The Intolerant and Tolerant classes were designated based on the Hilsenhoff Biotic Index (HBI) rating for invertebrate families. The rating ranges 0 to 10, with 0 indicating taxa normally found only in high quality unpolluted water, and 10 indicating taxa found only in severely polluted waters. Taxa with HBI ratings of 0, 1, or 2 are included in the Intolerant class, and 8, 9, or 10 in the Tolerant class.

An HBI index was also calculated for each sample based on the HBI rating for each taxon weighted by the number of individuals in each taxon. This index was used to detect nutrient enrichment, high sediment loads, low dissolved oxygen, and thermal impacts. It is probably not a particularly good index for chemical pollution such as dissolved metal concentrations, but is likely suitable for physical disturbances in the watershed resulting in erosion and sediment transport. Samples with HBI values of 0-2 are considered clean, 2-4 slightly enriched, 4-7 enriched, and 7-10 enriched.

Additionally, two U.S. Forest Service Community Tolerant Quotient indices were computed. Each taxon was assigned a tolerant quotient, with possible values ranging from 2, for taxa found only in high quality unpolluted water, to 108, for taxa found in severely polluted water. The two quotients were CTQa and CTQd; the first essentially an average quotient for the sample, and the second a numbers-weighted quotient for the sample.

Figure 3.6 Total EPT and Taxa, Little Cottonwood Creek, August 1998

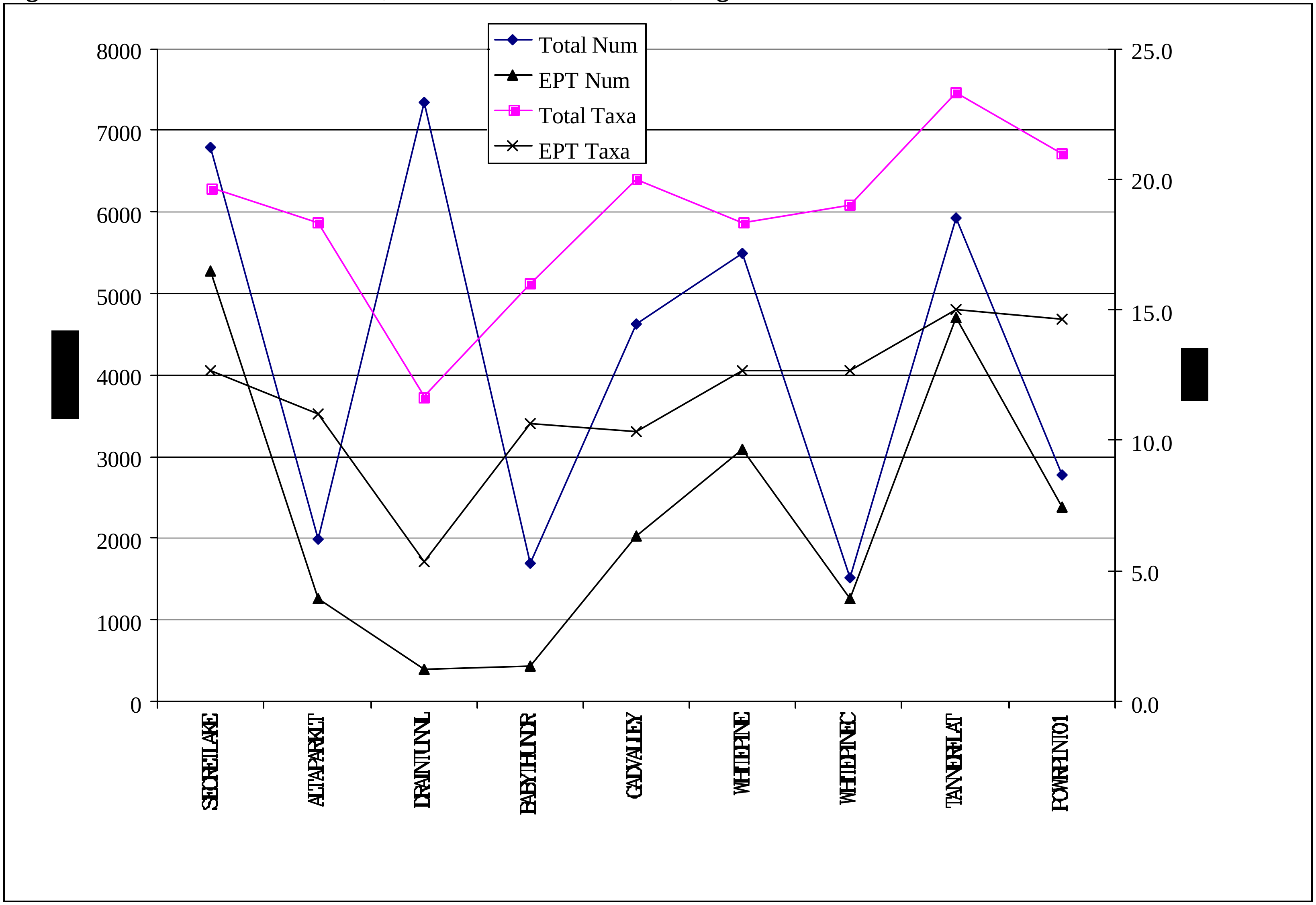
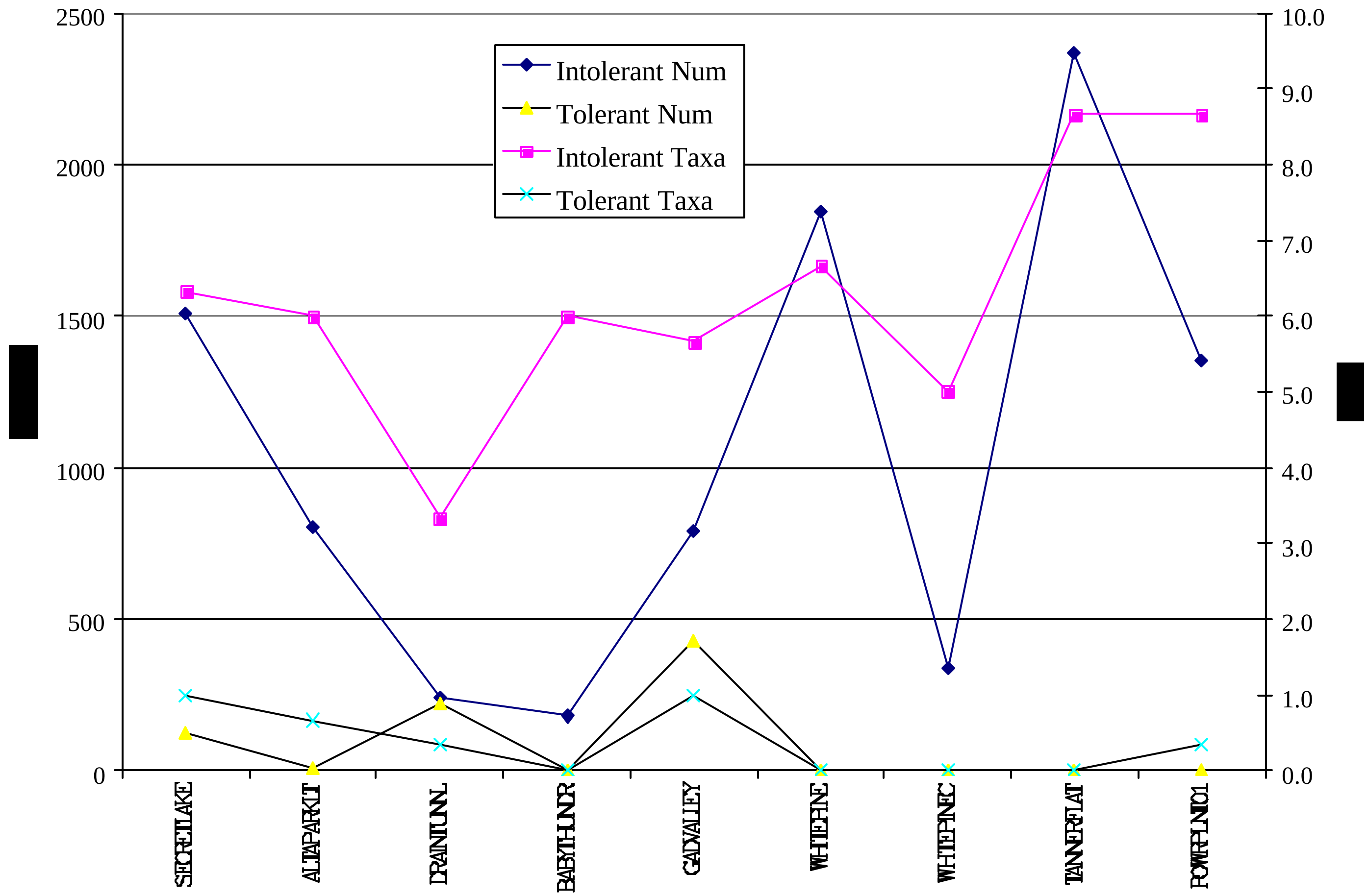


Figure 3.7 Total Tolerant and Intolerant and Taxa, Little Cottonwood Creek, August 1998



Data and indices for each replicate sample at each site are presented in Tables 3.9 and 3.10. Average values for each site were computed using these data. All results are compared with maximum, minimum, mean, standard deviation, mean plus standard deviation, and mean minus standard deviation for 331 samples taken at 147 stations in the Wasatch and Uinta Mountains ecoregion. The mean plus or minus one standard deviation is a useful range to assess whether particular values are "typical" of ecosystems in the region. Comparisons are summarized below:

- The mean total number of organisms at each site was lower than the mean for the ecoregion for 8 of the sites sampled. However, the number of organisms at each site were well within the Mean +/- SD interval, and 8 of the sites had a greater mean number of taxa than the mean for the ecoregion. Mean total number of invertebrate families among sites was close to the mean for the ecoregion; indicating that all sites were very typical for ecosystems in the region.

- The mean number of EPT individuals at each site were quite variable, ranging from 394 to 5267 per square meter; all were, however, within the Mean +/- SD interval for the ecoregion. As shown in Figure 3.6 and Table 3.9, the lowest number of EPT individuals and EPT taxa was found at the Wasatch Drain Tunnel site.

- The mean number of intolerant taxa individuals were within the interval for the ecoregion for all sites. The mean number of intolerant taxa for all ten sites were also within the interval for the ecoregion. As shown in Figure 3.7 and Table 3.9, the total number and taxa of intolerant individuals at the Wasatch Drain Tunnel site were some of the lower measured in the study reach.

- Only one site, Gad Valley, had mean number of tolerant individuals greater than the mean for the ecoregion, and five sites had no tolerant individuals at all (Table 3.9). It is noted that, although the average of tolerant individuals present at the Wasatch Drain Tunnel site was less than the mean for the ecoregion, a single sample at this location (the only one showing tolerant individuals out of three taken) showed more tolerant individuals than any other single sample at any other site during the study.

- Eight of the sites had mean HBI values with the 2-4 interval indicating "slightly enriched" (for nutrients), while two had values within the 4-7 interval indicating "enriched" (see Table 3.10). Five of the sites had values above the mean for the ecoregion, and two (Wasatch Drain Tunnel and Baby Thunder) had values greater than the Mean +/- SD interval for the ecoregion.

- Lower values of CTQd are indicative of better water quality. The Gad Valley and Wasatch Drain Tunnel site had CTQd values greater than the mean for the ecoregion, with the Wasatch Drain Tunnel site reporting the highest of all CTQd values.

Table 3.9 Numbers and Taxa, Little Cottonwood Creek, August 1998

Station	Elev	Rep	Tot Num	Tot Taxa	EPT Num	EPT Num %	EPT Taxa	EPT Taxa %	Tot Fam	Intolerant Taxa				Tolerant			
										Num	Num %	Taxa	Taxa %	Num	Num %	Taxa	Taxa %
GADVALLEY	2926	1	4527	21	2964	65.5	11	52.4	15	1240	27.4	6	28.6	444	9.8	1	4.8
		2	2570	19	1581	61.5	11	57.9	14	548	21.3	6	31.6	237	9.2	1	5.3
		3	6763	20	1548	22.9	9	45.0	16	581	8.6	5	25.0	602	8.9	1	5.0
		Avg	4620	20.0	2031	44.0	10.3	51.7	15.0	790	17.1	5.7	28.3	428	9.3	1.0	5.0
ALTAPARKLT	2908	1	1753	17	1151	65.7	10	58.8	13	688	39.2	5	29.4	22	1.3	1	5.9
		2	1720	19	1000	58.1	12	63.2	13	688	40.0	8	42.1	11	0.6	1	5.3
		3	2495	19	1613	64.6	11	57.9	15	1043	41.8	5	26.3	0	0.0	0	0.0
		Avg	1989	18.3	1255	63.1	11.0	60.0	13.7	806	40.5	6.0	32.7	11	0.6	0.7	3.6
SECRETLAKE	2816	1	13140	17	10151	77.3	11	64.7	12	2333	17.8	6	35.3	172	1.3	1	5.9
		2	4950	24	3821	77.2	16	66.7	17	1466	29.6	8	33.3	183	3.7	1	4.2
		3	2301	18	1828	79.4	11	61.1	13	731	31.8	5	27.8	22	1.0	1	5.6
		Avg	6797	19.7	5267	77.5	12.7	64.4	14.0	1510	22.2	6.3	32.2	126	1.8	1.0	5.1
DRAINTUNNL	2487	1	4803	11	258	5.4	5	45.5	10	186	3.9	4	36.4	0	0.0	0	0.0
		2	14043	10	796	5.7	5	50.0	8	495	3.5	3	30.0	0	0.0	0	0.0
		3	3161	14	129	4.1	6	42.9	12	43	1.4	3	21.4	656	20.8	1	7.1
		Avg	7336	11.7	394	5.4	5.3	45.7	10.0	241	3.3	3.3	28.6	219	3.0	0.3	2.9
BABYTHUNDR	2347	1	1849	18	452	24.4	12	66.7	13	151	8.2	7	38.9	0	0.0	0	0.0
		2	1430	14	172	12.0	9	64.3	11	75	5.2	5	35.7	0	0.0	0	0.0
		3	1785	16	667	37.4	11	68.8	12	312	17.5	6	37.5	0	0.0	0	0.0
		Avg	1688	16.0	430	25.5	10.7	66.7	12.0	179	10.6	6.0	37.5	0	0.0	0.0	0.0
WHITEPINE	2292	1	4742	17	3097	65.3	12	70.6	13	2061	43.5	6	35.3	0	0.0	0	0.0
		2	7054	19	3366	47.7	13	68.4	13	2054	29.1	8	42.1	0	0.0	0	0.0
		3	4692	19	2799	59.7	13	68.4	15	1427	30.4	6	31.6	0	0.0	0	0.0
		Avg	5496	18.3	3087	56.2	12.7	69.1	13.7	1847	33.6	6.7	36.4	0	0.0	0.0	0.0
WHITEPINEC	2268	1	1559	17	1333	85.5	12	70.6	14	247	15.8	5	29.4	0	0.0	0	0.0
		2	1656	22	1430	86.4	14	63.6	17	538	32.5	6	27.3	0	0.0	0	0.0
		3	1333	18	1022	76.7	12	66.7	14	226	17.0	4	22.2	0	0.0	0	0.0
		Avg	1516	19.0	1262	83.2	12.7	66.7	15.0	337	22.2	5.0	26.3	0	0.0	0.0	0.0

Table 3.9 Numbers and Taxa, Little Cottonwood Creek, August 1998 (continued)

Station	Elev	Rep	Tot Num	Tot Taxa	EPT Num	EPT Num %	EPT Taxa	EPT Taxa %	Tot Fam	Intolerant Taxa				Tolerant			
										Num	Num %	Taxa	Taxa %	Num	Num %	Taxa	Taxa %
TANNERFLAT	2188	1	7376	20	6183	83.8	13	65.0	15	2720	36.9	6	30.0	0	0.0	0	0.0
		2	7398	27	5763	77.9	17	63.0	17	3118	42.1	10	37.0	0	0.0	0	0.0
		3	2989	23	2194	73.4	15	65.2	16	1269	42.5	10	43.5	0	0.0	0	0.0
		Avg	5921	23.3	4713	79.6	15.0	64.3	16.0	2369	40.0	8.7	37.1	0	0.0	0.0	0.0
DISPCAMP01	2073	1	2871	23	2484	86.5	16	69.6	16	1376	47.9	10	43.5	0	0.0	0	0.0
		2	4602	19	4100	89.1	14	73.7	13	918	19.9	7	36.8	0	0.0	0	0.0
		3	3452	20	3097	89.7	14	70.0	13	2172	62.9	9	45.0	0	0.0	0	0.0
		Avg	3642	20.7	3227	88.6	14.7	71.0	14.0	1489	40.9	8.7	41.9	0	0.0	0.0	0.0
POWRPLNT01	1841	1	1269	19	914	72.0	12	63.2	14	538	42.4	9	47.4	0	0.0	0	0.0
		2	2183	22	1935	88.6	15	68.2	14	914	41.9	8	36.4	11	0.5	1	4.5
		3	4871	22	4315	88.6	17	77.3	13	2616	53.7	9	40.9	0	0.0	0	0.0
		Avg	2774	21.0	2388	86.1	14.7	69.8	13.7	1356	48.9	8.7	41.3	4	0.1	0.3	1.6
Wasatch and Uinta Mountains ecoregion		Max	138059	44	119476		29		31	19011		18		32860		2	
		Min	5	1	0		0		1	0		0		0		0	
		Mean	6358	17.8	3486		9.8		13.9	1110		5.3		398		0.6	
		SD	13429	8.2	9900		5.6		5.2	2602		3.7		2121		0.6	
		X+SD	19787	26.0	13386		15.4		19.1	3711		9.0		2518		1.2	
		X-SC	0	9.6	0		4.2		8.7	0		1.6		0		0.0	
Replicates Sites		Above	0	1	0		4		0	0		3		0		0	
		Below	0	0	0		0		1	0		0		0		0	
		Above	0	0	0		0		0	0		0		0		0	
		Below	0	0	0		0		0	0		0		0		0	

Table 3.10 Habitat Indices, Little Cottonwood Creek, August 1998

Station	Elev	Rep	HBI	CTQa	CTQd
GADVALLEY	2926	1	3.68	68	68
		2	3.47	68	70
		3	4.58	77	77
		Avg	3.91	71.0	71.7
ALTAPARKLT	2908	1	3.46	60	59
		2	3.43	55	56
		3	3.30	59	56
		Avg	3.40	58.0	57.0
SECRETLAKE	2816	1	2.56	57	56
		2	2.46	57	56
		3	2.30	59	54
		Avg	2.44	57.7	55.3
DRAINTUNNL	2487	1	5.74	70	73
		2	5.75	67	71
		3	6.24	76	82
		Avg	5.91	71.0	75.3
BABYTHUNDR	2347	1	5.17	59	64
		2	5.47	57	64
		3	4.38	53	58
		Avg	5.01	56.3	62.0
WHITEPINE	2292	1	3.39	51	52
		2	4.07	52	53
		3	3.63	58	56
		Avg	3.70	53.7	53.7
WHITEPINEC	2268	1	3.39	56	54
		2	2.86	61	59
		3	3.21	60	59
		Avg	3.15	59.0	57.3
TANNERFLAT	2188	1	2.91	55	54
		2	3.00	51	51
		3	3.29	51	49
		Avg	3.07	52.3	51.3
DISPCAMP01	2073	1	2.91	56	52
		2	2.03	48	50
		3	2.54	49	48
		Avg	2.49	51.0	50.0
POWRPLNT01	1841	1	3.07	57	56
		2	2.79	52	50
		3	2.70	46	43
		Avg	2.85	51.7	49.7

Table 3.10 Habitat Indices, Little Cottonwood Creek, August 1998 (continued)

Station	Elev	Rep	HBI	CTQa	CTQd
Wasatch and Uinta Mountains ecoregion		Max	9.00		108
		Min	0.40		21
		Mean	3.20		70
		SD	1.30		16.9
		X+SD	4.50		86.9
		X-SD	1.90		53.1
Replicates Sites		Above	6		0
		Below	0		9
		Above	2		0
		Below	0		3

The lower number and taxa of EPT individuals, lower number and taxa of intolerant individuals, and highest number of a single sample of tolerant individuals reported for the Wasatch Drain Tunnel Site may suggest some impairment in macroinvertebrate population at this location. However, because information on the microhabitat is lacking, and the total amount of microinvertebrate data is limited, it is inconclusive as to whether or not these numbers are reflective of water quality in the area or microhabitat quality.

The results of macroinvertebrate sampling of LCC performed by the U.S. Forest Service in July 1997 are shown in Figure 3.8. Data collected during the survey included number of EPT individuals. As previously discussed, ten of the 16 locations sampled during this event were located in the LCC TMDL study area. Although limited and inconclusive, the results do show decreased number of EPT individuals at sampling locations above the confluence of LCC and White Pine Fork.

3.4 Zinc Loading Sources

This section discusses the sources contributing zinc loads to LCC, including point (discrete), nonpoint (diffuse) and background. Based on the general assessment of LCC water chemistry, the Howland Tunnel and Wasatch Drain Tunnel (Snowbird co-generation plant discharge and bypass) have been identified as significant discrete sources of zinc loading to LCC. This is particularly represented in the graph of dissolved zinc concentrations measured in LCC during the 1998 synoptic study (Figure 3.4). Non-point sources of zinc loading to LCC are a combination of diffuse groundwater inflows and surface runoff to LCC during precipitation and snowmelt events. Background zinc loads to LCC are also a combination of diffuse groundwater and surface water flows, but are attributable to the natural mineralogy in the LCC canyon, as opposed to anthropogenic effects of past mining activity in the watershed.

3.4.1 Background Loads

The evaluation of natural background conditions in a historic mining area such as LCC Canyon can be difficult, because representative mineralized areas throughout the area have often been disturbed by mining activities. In such instances, actual background water quality conditions may occur only in non-mineralized areas, or high up a mineralized drainage, above disturbed areas.

For the TMDL study, the assumed natural background concentration for zinc was based on measured zinc concentrations in drainages having limited known mining activity. Within the study area, these drainages included White Pine Fork, Gad Valley Gulch, and Collins Gulch. Sampling of these drainages was primarily accomplished by the UTDEQ in 1998. Sampling locations in these drainages are shown in Drawing 1. Table 3.11 presents the measured zinc concentrations in samples taken at these locations. The average dissolved zinc concentration from these measurements is 0.04 mg/L, which is the assumed zinc background concentration in the LCC basin.

Figure 3.8 U.S. Forest Service 1997 Macroinvertebrate Sampling Results.

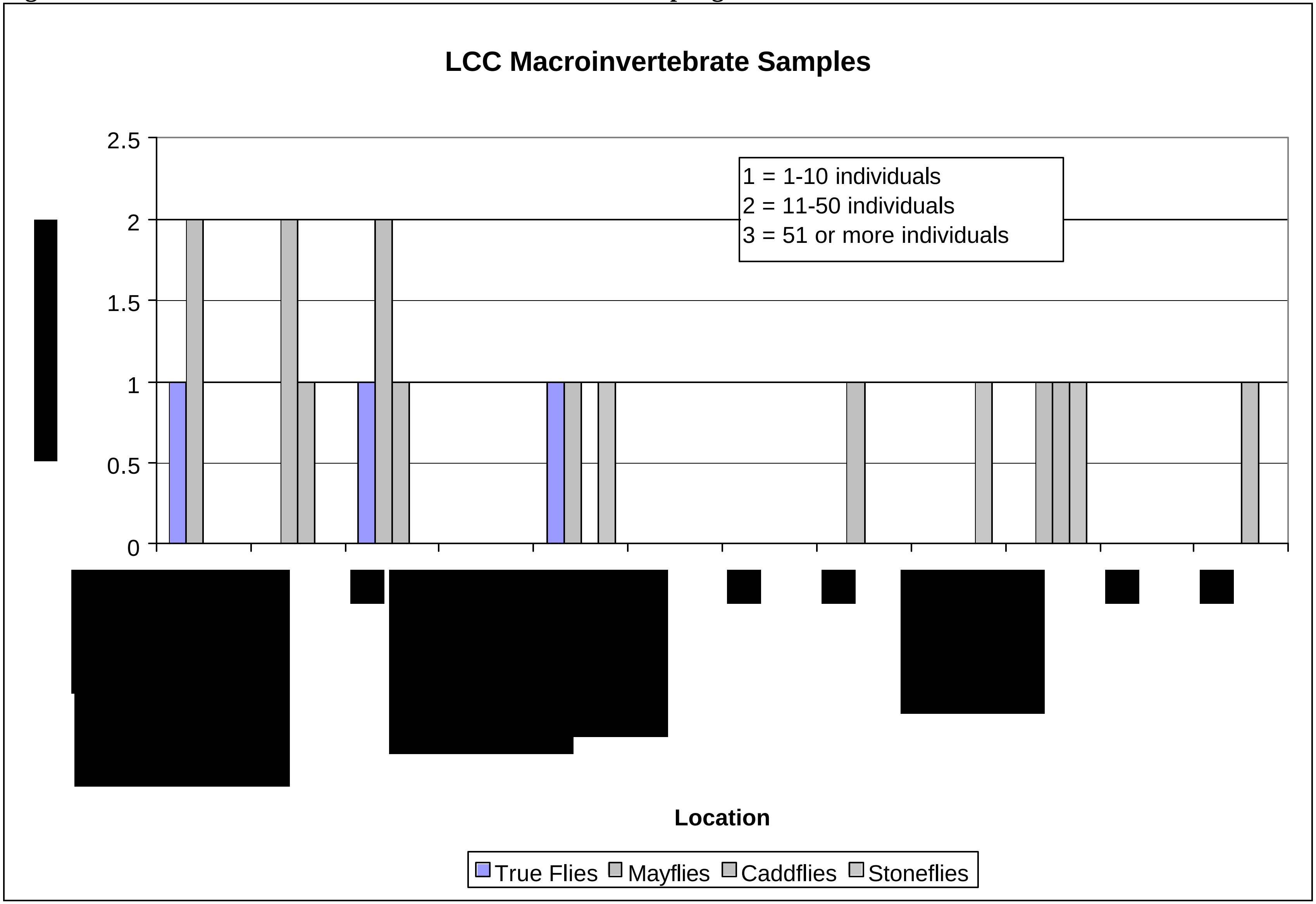


Table 3.11 Estimated Background zinc Concentrations in LCC Drainage

Location	Sample Date	Dissolved Zinc
Collins Gulch	6/16/1998	0.0579
	7/21/1998	0.0208
	7/27/1998	0.0394
	8/18/1998	0.0454
	9/1/1998	0.018
Gad Valley	5/11/1998	0.0325
	6/16/1998	0.0497
	7/21/1998	0.0269
	9/1/1998	0.011
White Pine Fork	6/16/1998	0.125
	7/21/1998	0.0313
	9/1/1998	0.032
	9/13/2001	0.024

Looking at the entire data set, it is noted that the reported dissolved zinc concentrations at a number of other sampling locations in the LCC study area were significantly less than the assumed background concentration of 0.04 mg/L. These included measured concentrations at sampling stations in the Albion Basin, which were sampled by the U.S. Forest Service in 1998. These data were supplied by the USGS with the 1998 synoptic study results. The sampling stations were identified as “Above Bog,” “At Bog,” and “Below Bog.” No information as to the location of these sampling stations was provided. The measured dissolved zinc concentrations at these three sampling stations were reported as 0.011, 0.014, and 0.006 mg/L, respectively. Lower zinc concentrations have also been measured at STORET monitoring stations number 591898 (Live Yankee Huron Ravine Horizontal Opening 7) and 591902 (LCC above Grizzly Gulch). As shown in Drawing 1, these monitoring stations are located in the upper reaches of the LCC drainage. Dissolved zinc concentrations measured at these two locations in September 1986 were 0.01 mg/L at station 591898 and 0.015 mg/L at station 591902.

The lower zinc concentrations in the Albion basin may be attributable to reducing conditions often found in natural bogs. The reasons for the lower zinc concentrations at the two STORET monitoring stations are not readily explained. Nonetheless, if the lower dissolved zinc concentrations measured in the Albion basin and at the STORET monitoring stations are representative of natural background conditions in the LCC, use of the assumed background concentration of 0.04 mg/L provides one element of the margin of safety for the LCC TMDL, in that the use of a higher background concentration will result in lower load allocations to point sources in the basin.

Calculation and allocation of natural background load to LCC is not possible because the diffuse flows contributing background loading to LLC could never be isolated and measured. At best, the assumed background dissolved zinc concentration of 0.04 mg/L was used in the TMDL study as the minimum concentration of zinc in LCC for allocating loads to discrete sources.

3.4.2 Non-point Source Loads

A significant number of diffuse, non-point sources of zinc loading to LCC exist in LCC Canyon. These include both surface and subsurface inflows to the creek. Surface inflows would include stormwater and snowmelt runoff to the creek. Subsurface inflows may include springs, seeps, and drainage from the numerous mine tunnel workings through fractures in the canyon formations. Evidence of zinc loading from subsurface inflows is apparent in the zinc concentrations measured in LCC during the 1998 USGS synoptic study. As shown in Figure 3.4, diffuse sources of zinc loading occur along the entire reach of LCC, as evidenced by the spikes in measured dissolved zinc concentrations that occur throughout the study reach.

Not all sources of loading identified in the synoptic study and represented in Figure 3.4 are characterized as non-point sources. These include: (1) the South Hecla Mine, (2) the combined flow into LCC from the Howland, Todedo, and Flagstaff Tunnels, (3) discharge from the Wasatch Drain Tunnel (Snowbird co-generation plant and bypass), and (4) White Pine Fork. As described in the 1998 synoptic study report, these surface water inflows accounted for approximately 52 percent of the zinc loading to LCC over the study period. The Wasatch Drain Tunnel accounted for 40 percent of the total load; the combined Howland, Toledo, and Flagstaff Tunnels accounted for 10 percent of the total load; the South Hecla Mine 1.3 percent; and White Pine Fork 0.3 percent. This TMDL study identifies the Howland Tunnel and Wasatch Drain Tunnel discharges as the most significant sources of zinc loading to LCC. These sources are discussed more fully in Section 3.4.3, below.

3.4.2.1 Groundwater Inflows

The additional zinc loading sources to LCC identified in the synoptic study can be characterized as diffuse, nonpoint subsurface inflows to the creek, as that study was performed during dry weather conditions over seasonal low flow conditions. These subsurface inflows to LCC accounted for approximately 48 percent of zinc loading to LCC over the study period. As reported in the synoptic study report, the minimum total loading to LCC from all sources was calculated to be approximately 236 mg/s or 45 lbs./ day over the study period. (The actual total load may have been greater, considering the loss of metal mass in the water column through attenuation). Accordingly, the minimum zinc loading to LCC from the diffuse subsurface inflows to LCC calculates to be approximately 22 lbs./day over the study period.

The data collected during the 1998 synoptic survey allowed for calculating the magnitude of these subsurface non-point source loads at discrete locations along LCC. Table 3.12 presents the dissolved zinc loads calculated for these inflows, including the surface flows identified above. The Tanner Flat area was identified in the synoptic study as a diffuse loading source contributing approximately 11 percent of the calculated total minimum zinc load to LCC over the study reach. As shown in Figure 3.4, zinc concentrations measured in LCC during the 1998 study increased from 0.108 mg/L at a sampling location above Tanner Flat to 0.126 mg/L below Tanner Flat. The sampling location downstream of the Tanner Flat area is located above monitoring station No. 499378 (LCC above confluence with Red Pine Fork). The 1998 data led to the conclusion in the study report that historic mill tailings in the Tanner Flat area may be contributing to significant zinc loading to LCC. However, subsequent sampling of LCC in the Tanner Flat area by the UTDEQ in September 2001 (during dry conditions and seasonal low flow in LCC) showed a decrease in zinc concentrations from upstream to downstream through the Tanner Flat area (Figure 3.9). The difference in zinc loads between the upstream and downstream samples could not be determined because flows were not measured for these samples.

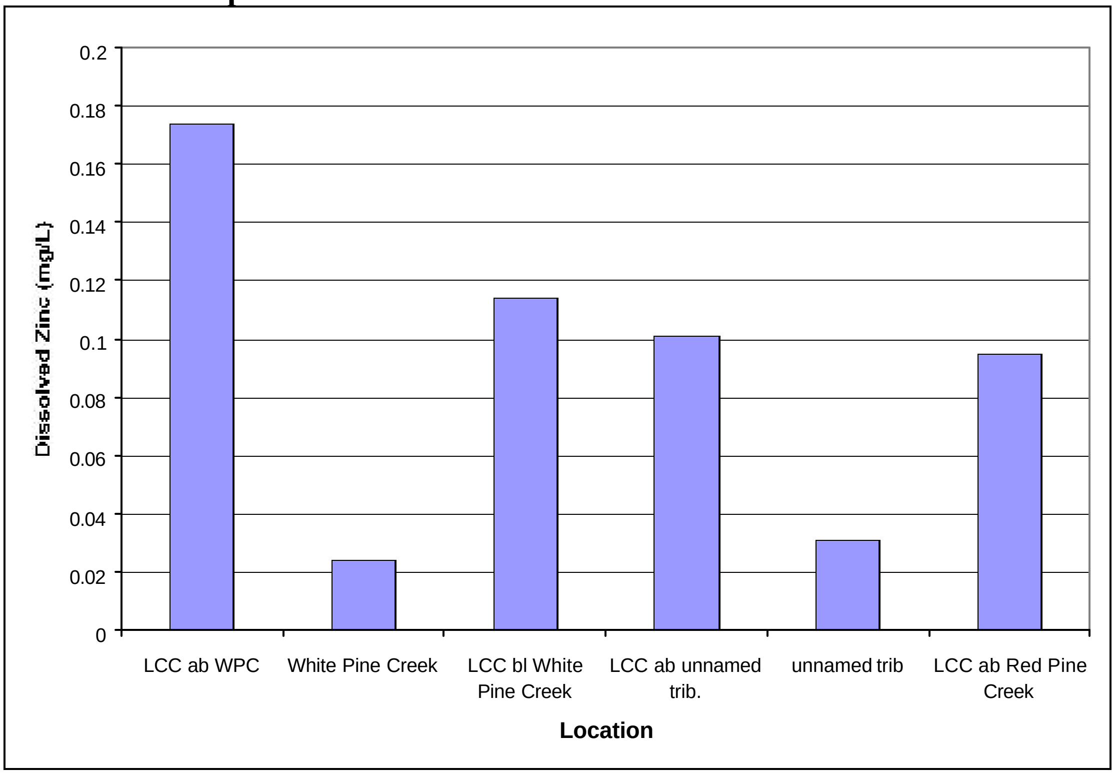
Table 3.12 Flow, Zinc, and Load, 1998 Synoptic Survey

Distance	Location Name	Trib	Flow (gpm)	Zinc(D) (mg/L)	Load (lb/day)
83	Ab injection site	LCC	706.9	0.014	0.119
263	First site blw injection	LCC	706.9	0.013	0.110
282	Grizzly Gulch	Trib	19	0.013	0.00297
364	Ab culvert at jump	LCC	725.9	0.02	0.174
402	Blw culvert at jump	LCC	727.5	0.015	0.131
572	T1 stream site	LCC	738.6	0.015	0.133
686	Small inflow w/ Fe stain	Trib	65	0.01	0.00781
780	At end of willows	LCC	803.6	0.019	0.183
933	Ab Collins Gulch	LCC	829	0.014	0.139
955	Collins Gulch	Trib	164.8	0.018	0.0357
1009	Blw Collins Gulch	LCC	993.8	0.028	0.334
1205	Blw Ski Bridge	LCC	1000.1	0.016	0.192
1265	South Hecla Mine (Snowmaking)	Trib	1348.8	0.038	0.616
1375	Blw Hecla input	LCC	2350.6	0.028	0.791
1400	Howland Drain Tunnel	Trib		3.9	
1401	Flagstaff drain	Trib		0.032	
1402	GMD lot drain	Trib		0.041	
1403	Combined Howland	Trib	1152.3	0.407	5.64
1443	Blw Howland Tunnel	LCC	3502.8	0.125	5.26
1490	Spring by Peruvian Lodge	Trib	152.2	0.028	0.0512
1550	LCC bl Alta	LCC	3655	0.121	5.32
1592	Blw Peruvian Lodge	Trib	226.7	0.023	0.0627
1742	T2 site at bridge	LCC	3881.7	0.113	5.27
1812	Blw waterfall	Trib	334.4	0.004	0.0161
1862	Blw Hellgate Falls	LCC	4216.1	0.119	6.03
1874	Hellgate spring	Trib	136.3	0.984	1.61
1899	Large discharge spring	Trib	136.3	0.245	0.401
1959	Blw Hellgate Spring	LCC	4488.7	0.141	7.61
2003	Large spring	Trib	302.7	0.138	0.502
2063	At footbridge	LCC	4791.5	0.141	8.12
2193	Nr houses	LCC	4935.7	0.142	8.42
2433	Nr Bedrock & houses	LCC	5208.3	0.133	8.33
2470	Upper WT fractures	Trib	84	0.346	0.349
2590	Blw fracture inflow	LCC	5290.7	0.14	8.90
2890	Blw cascading reach	LCC	5309.8	0.133	8.49
2892	Dilute inflow near Cliff parking	Trib	30.1	0.015	0.00543
2922	T3 ab thermal	LCC	5339.9	0.119	7.64
2924	Cold inflow	Trib		0.005	
2925	Cogenerator inflow	Trib		0.771	
2926	Wasatch Tunnel cogeneration	Trib	2236.4	0.732	19.7
3037	Blw Cogen blw bipass	LCC	7576.3	0.279	25.4
3047	Peruvian Gulch	Trib	370.9	0.006	0.0267
3067	Blw Peruvian Gulch	LCC	7947.2	0.321	30.7

Table 3.12 Flow, Zinc, and Load, 1998 Synoptic Survey (continued)

Distance	Location Name	Trib	Flow (gpm)	Zinc(D) (mg/L)	Load (lb/day)
3068	Wasatch Tunnel overflow	Trib	55.5	0.102	0.0680
3069	Overflow pipe	Trib	55.5	0.042	0.0280
3123	Blw Wasatch Tunnel	LCC	8056.6	0.275	26.6
3125	Cliff Lodge Grass inflow	Trib	71.3	0.122	0.105
3349	Blw Cliff Lodge inflow	LCC	8127.9	0.266	26.0
3351	Gold Cliff Mine discharge	Trib	22.2	0.025	0.00667
3451	LCC Blw Gold Cliff discharge	LCC	8150.1	0.278	27.2
3671	Swampy area blw SB Center	Trib	65	0.006	0.00469
3721	At bridge nr SB lot	LCC	8216.6	0.239	23.6
3961	Ab Wilbere Lift	LCC	8275.3	0.253	25.2
4251	Blw Wilbere Lift (cmnt pipe)	LCC	8546.3	0.243	25.0
4480	Gad Valley	Trib	122	0.011	0.0161
4630	Blw MidGad Bridge	LCC	8669.9	0.197	20.5
4861	At end of lower parking	LCC	8747.6	0.209	22.0
5161	Blw SB in cascades	LCC	8765	0.201	21.2
5281	LB with tarp from Baby Thunder	Trib	240.9	0.009	0.0261
5461	Nr bedrock outcrop	LCC	9006	0.18	19.5
5478	RB spring inflow	Trib	489.8	0.003	0.0177
5560	Spring at strm level	Trib	489.8	0.005	0.0294
5740	Blw RB seepage constricted	LCC	9985.5	0.161	19.3
5945	LCC Ab dilute inflow	LCC	10205.8	0.162	19.9
5955	Dilute inflow	Trib	328.1	0.01	0.0394
6055	T4 site replicate A	LCC	10533.9	0.142	18.0
6055	T4 site replicate B	LCC	10533.9	0.146	18.5
6415	LCC Blw transport site	LCC	10909.6	0.166	21.8
6775	LCC Nr highway ab falls	LCC	10827.1	0.152	19.8
7245	LCC Blw falls	LCC	11158.4	0.153	20.5
7250	White Pine	Trib	2375.9	0.032	0.914
7430	LCC Blw White Pine	LCC	13534.3	0.129	21.0
7750	LCC 300 Blw White Pine	LCC	13654.8	0.118	19.4
7770	RB inflow ab campground	Trib	199.7	0.011	0.0264
7820	LCC Ab Tanner Flat	LCC	13854.5	0.108	18.0
8000	LCC Nr middle Tanner Flat	LCC	14001.9	0.103	17.3
8040	RB stream from campgrnd	Trib	440.6	0.034	0.180
8300	LCC Blw Tanner Flat	LCC	14442.5	0.126	21.9

Figure 3.9 Dissolved Zinc Concentrations in the White Pine and Tanner Flat Area, September 2001.



It is noted that the Tanner Flat area was the location of the historic Jones and Pardee smelter, and was the subject of an investigation performed in 1996 by the UTDEQ, Division of Environmental Response and Remediation, to determine soils, groundwater and surface water impacts from these historic operations. It is understood that the Forest Service has conducted some remedial operations in the area (i.e., consolidation and covering of impacted surface soils) subsequent to this investigation. Although the extent of these activities and when these activities were conducted relative to the 1998 synoptic study could not be determined from available information, these activities may account for the differences in the trend in measured zinc concentrations in the Tanner Flats area between the 1998 study and 2001 sampling results. In summary, however, further sampling of the LCC above and below the Tanner Flats area would be required to determine the existence or non-existence of zinc loading sources in this area.

3.4.2.2 Surface Inflows

Limited data exists to characterize non-point source loads to LCC during precipitation and snowmelt events. These data include the results of stormwater monitoring performed by SLC in 1990, and sampling performed by UTDEQ in 1998.

In 1990, three automatic sampling stations were installed in LCC Canyon by SLC to monitor flow, TSS, lead, and zinc during storm events. The three locations were LCC at Tanner Flat Campground (STORET monitoring station No. 499378), LCC at Hellgate Springs (STORET monitoring station No. 499386), and LCC at Sunnyside (STORET monitoring station No. 499393). Three separate storm events were measured at the Hellgate Springs location: August 16, 1990, August 30, 1990, and November 11, 1990. The measured zinc concentrations in LCC over these storm events are shown in Figures 3.10, 3.11, and 3.12, respectively. The results of sampling over the August 16, 1990, event, show zinc concentrations increasing from 280 ug/L to a high of 320 ug/L, representing an increase of in-stream zinc load of approximately 18 percent (5 lbs./day to 5.9 lbs./day). Similarly, in-stream zinc load increased from 6 lbs./day to approximately 13 lbs./day (approximately 117 percent) during the August 30, event, and from a low of approximately 5 lbs./day to 6.6 lbs./day (approximately 32 percent) during the November 11, event. Although these results showed increased zinc load as a result of runoff into the creek, it is also noted that zinc concentrations dropped off through the events, which may be indicative of dilution of zinc following the initial flush of surface salts into the creek.

The August 30, 1990, event was also monitored at LCC below Sunnyside (see Figure 3.13). In-stream zinc loads increased at this location from approximately 2.2 lbs./day to 3.5 lbs./day (60 percent). However, zinc concentrations dropped over the peak runoff, indicating inflows of lower zinc concentrations above this location and subsequent dilution of zinc concentration in LCC.

Figure 3.10 Storm Event Zinc Concentrations and Flow at LCC at Hellgate Station, 8/16/90.

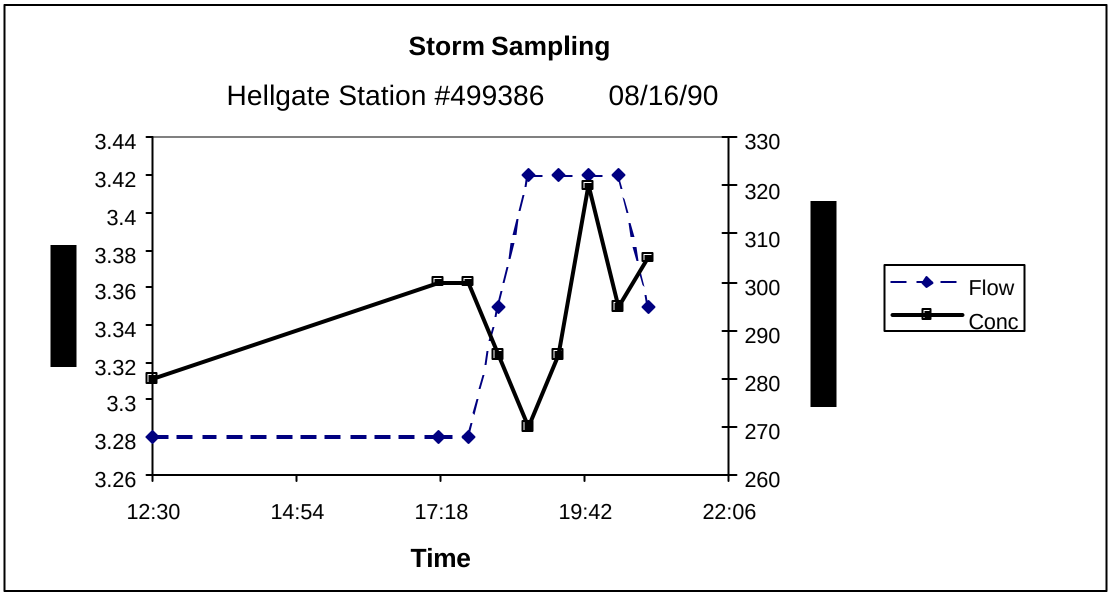


Figure 3.11 Storm Event Zinc Concentrations and Flow at LCC at Hellgate Station, 8/30/90.

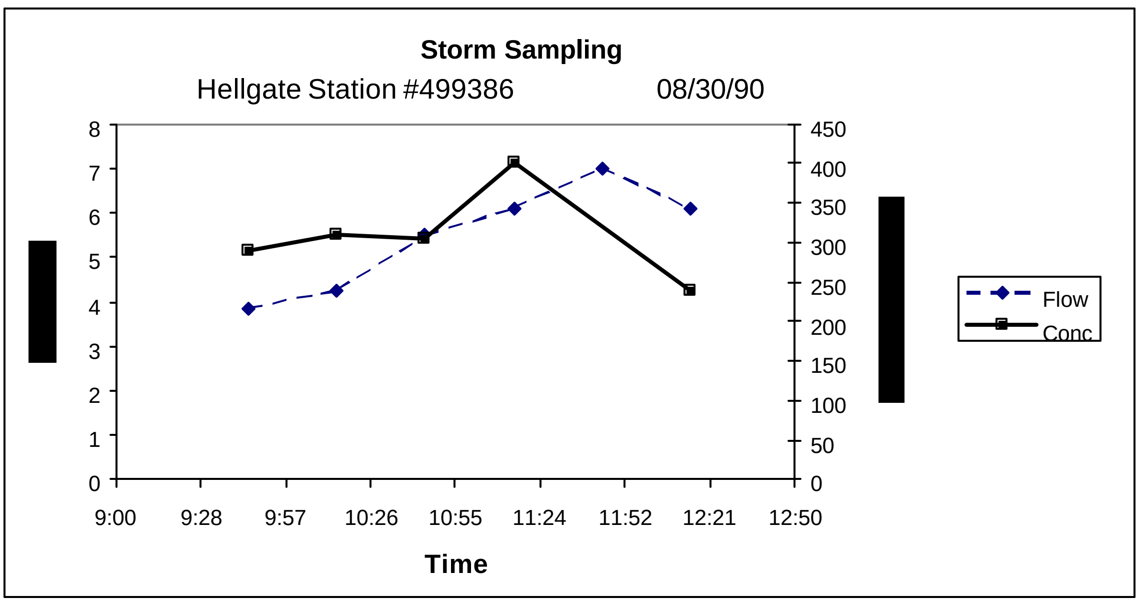


Figure 3.12 Storm Event Zinc Concentrations and Flow at Lcc at Hellgate Station, 11/19/90.

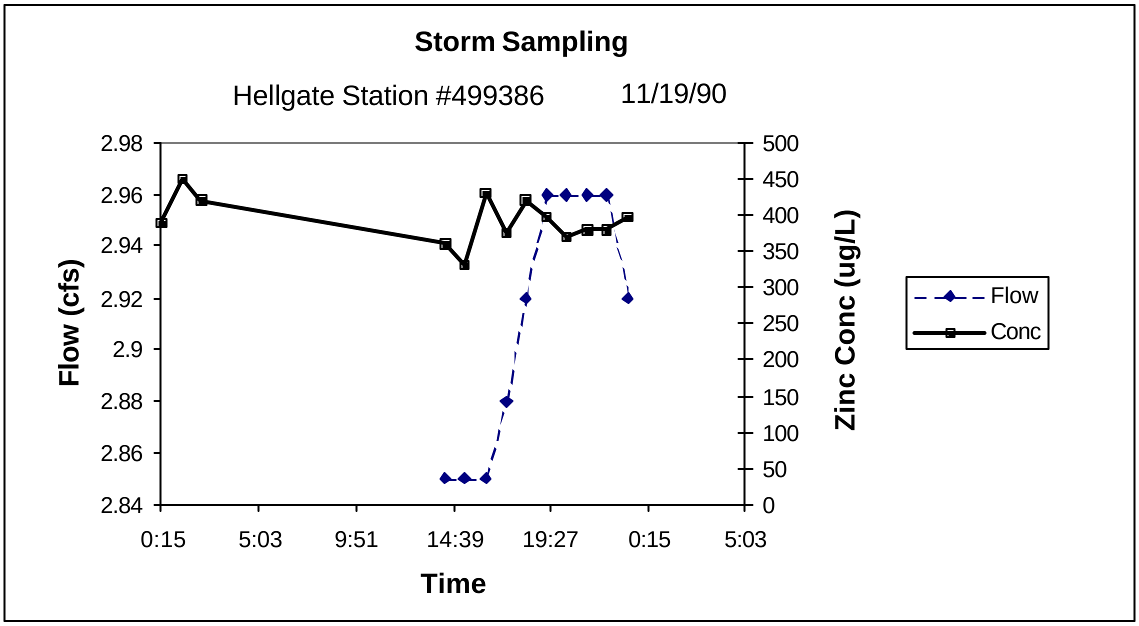
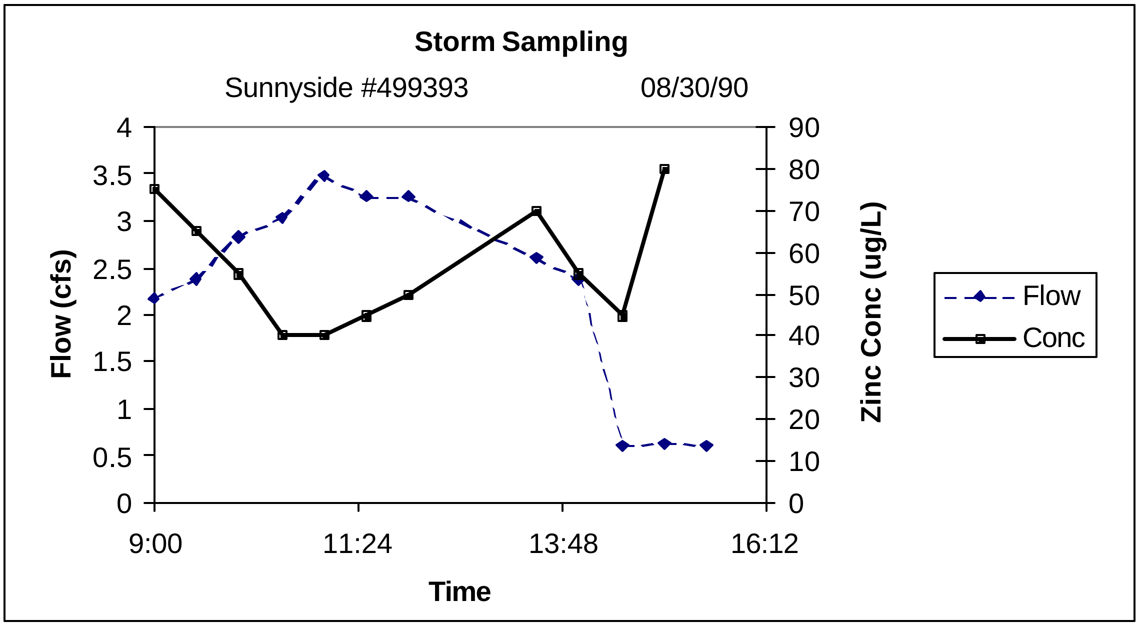


Figure 3.13 Storm Event Zinc Concentrations and Flow at LCC at Sunnyside Station, 8/30/90.



Zinc concentrations were also reported for the monitoring station at Tanner Flat for the August 16 and November 19, 1990, storm events (see Figures 3.14 and 3.15), and in-stream zinc loads also increased over these two storm events (approximately 10 percent and 53 percent, respectively). However, like LCC below Sunnyside, zinc concentrations dropped over the runoff events, also indicating inflows of lower zinc concentrations above this location

Figure 3.14 Storm Event Zinc Concentrations and Flow at LCC at Tanner Flat Station, 8/16/90.

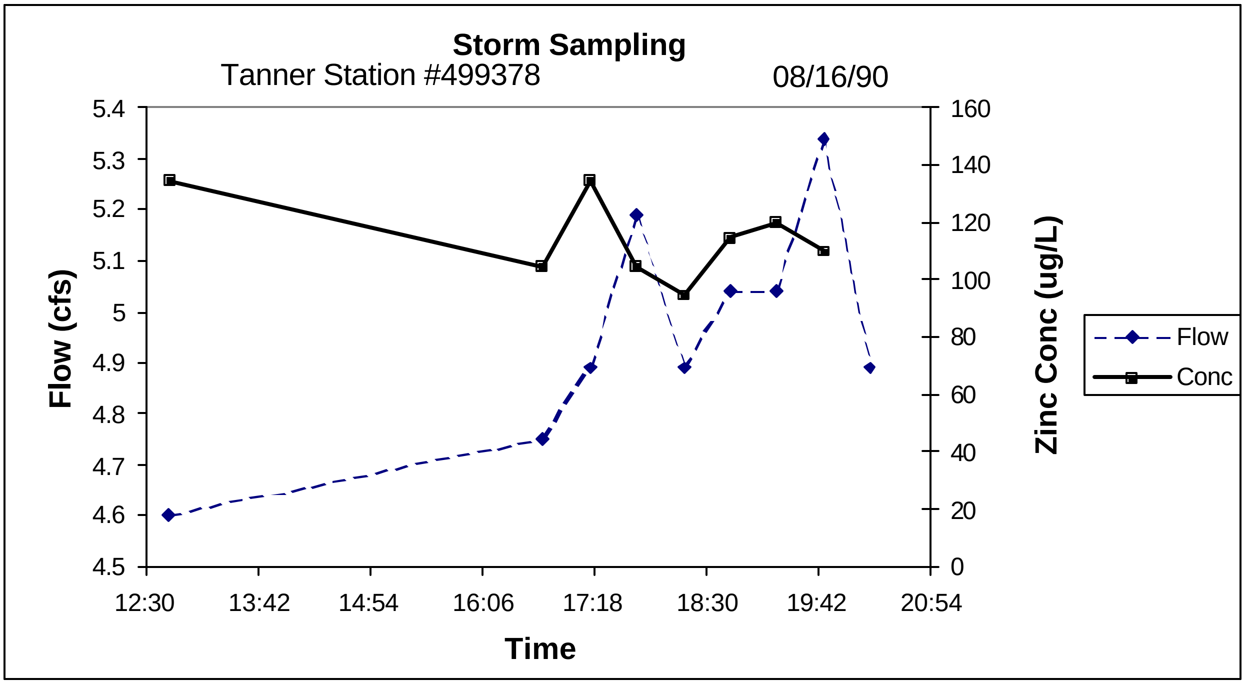
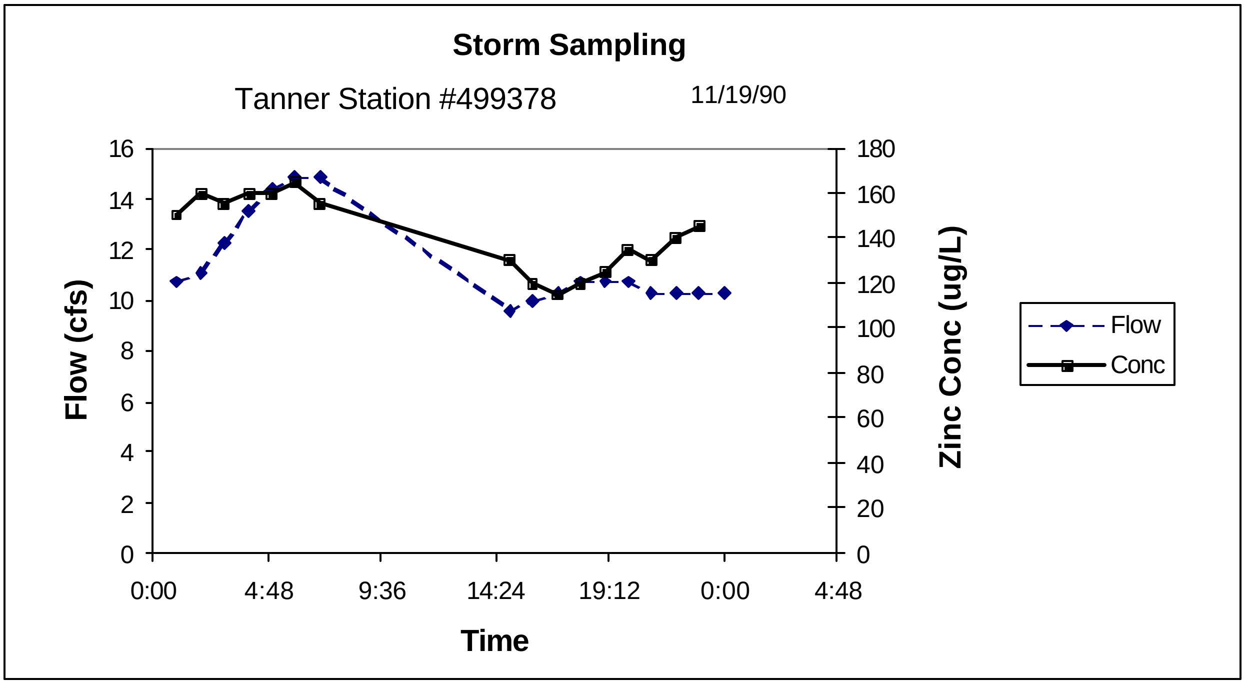


Figure 3.15 Storm Event Zinc Concentrations and Flow at LCC at Tanner Flat Station, 11/19/90.



Between May and August 1998, UTDEQ sampled water quality, but did not measure flows, at specific locations in the LCC watershed during both wet (precipitation) and dry conditions. While no samples were collected from LCC, samples were collected from some of the contributing drainages, including Grizzly Gulch, Toledo Drainage, and Collins Drainage. Results of these sampling events are shown in Table 3.13. Because of the length of time between sampling events, the comparison of measured zinc concentrations during wet and dry conditions is inconclusive. Nonetheless, results of sampling in Grizzly Gulch and Collins Drainage on July 21, and July 27, 1998, which represent dry and wet conditions, respectively, within a similar timeframe, may provide some indication of increased zinc concentrations during wet conditions, which may be attributable to surface runoff. It is also noted that, except for the sample taken in the Toledo Drainage on August 18, 1998, measured dissolved zinc concentrations in these drainages during both wet and dry conditions did not exceed the acute or chronic criteria for this constituent (see Table 3.8).

Table 3.13 Dry/Wet Periods, UTDEQ 1998 Sampling

Grizzly Gulch			Zn(D) (mg/L)	Zn(T) (mg/L)	TSS (mg/L)
5/11/1998		dry	0.124	0.0725	<3
6/16/1998		dry	0.0574	0.0591	<3
7/21/1998		dry	0.0224	0.0265	<3
7/27/1998		wet	0.0444	0.0507	<3
8/18/1998		wet	0.0519	0.0481	<3
Toledo Drainage			Zn(D)	Zn(T)	TSS(mg/L)
6/16/1998		dry	0.0711	0.0277	<3
7/27/1998		wet	0.0283	2.17	16.6
8/18/1998		wet	0.635	1.12	13.6
6/16/1998		dry	0.0579	0.0478	<3.00
7/21/1998		dry	0.0280	0.0299	<3.00
7/27/1998		wet	0.0394	0.0434	<3.00
8/18/1998		wet	0.0454	0.0368	<3.00

While the 1990 SLC data indicates increased zinc loading to LCC during storm events, which may be attributable to surface runoff, the limited data does not allow for the identification and characterization of specific areas or surface expressions of historic mining activity that may be contributing zinc loading during storm events. Nonetheless, this temporal component of zinc loading to LCC does not appear to be a significant factor in impairment of water quality in LCC.

3.4.3 Point Source Loads

The results of the USGS 1998 synoptic study of LCC clearly indicate that the Howland and Wasatch Drain Tunnels are the most significant sources of zinc loading to LCC. As described in the following sections, absent zinc loading from any other upstream sources, zinc water quality criteria would still be exceeded in LCC below these two discharges during lower flows in LCC. Aside from increased zinc concentrations in LCC below the Wasatch Drain Tunnel discharge (i.e., Snowbird co-generation plant and bypass discharges), data on macroinvertebrate population in LCC below this discharge may also indicate impairment of the Class 3A beneficial use designation for LCC in this reach of the creek.

3.4.3.1 Howland Tunnel Loads

Zinc loading from the Howland Tunnel discharge was evaluated using three different data sets: (1) results of UTDEQ sampling between July and October 1986, (2) the USGS 1998 synoptic study results, and (3) the USGS 2001 sampling results. Given the time frame of data collection, the data collected by the UTDEQ in 1986 is representative of decreasing seasonal low flow in LCC. The 1998 USGS data is also representative of seasonally low flow conditions in LCC, and the 2001 USGS data is representative of both increasing and decreasing flows in LCC that would be experienced along both the rising and falling limbs of the snowmelt runoff hydrograph of flows in LCC.

3.4.3.1.1 July – October 1986 Sampling Period

The UTDEQ 1986 sampling results include both flow and zinc concentrations measured in LCC above the Howland Tunnel discharge, flows from the Howland Tunnel, and in LCC below the Howland Tunnel discharge. These data allowed for performing a complete mass balance analysis of loading in this reach of LCC, the results of which are shown in Table 3.14. As shown in Table 3.14, the measured concentrations of zinc in LCC below the Howland Tunnel discharge were significantly higher than measured in LCC above the tunnel discharge. The increase in zinc concentration below the tunnel discharge is primarily attributed to the Howland Tunnel discharge, as the data show that the zinc load from the Howland Tunnel discharge exceeded the in-stream load in LCC above the tunnel discharge by over one to two orders of magnitude.

It is recognized that zinc loading was also occurring from diffuse inflows to the stream through this reach of LCC. For example, the difference in measured flows in LCC above and below the Howland Tunnel discharge in July was approximately 11,600 gpm. The measured flow from the Howland Tunnel during this same time was approximately 600 gpm, leaving approximately 11,000 in other inflows to the creek through this reach. These inflows would account for both background and nonpoint source loading to LCC through this reach. Even though the zinc load from these sources could not be quantified, their contribution is inherent in the measured zinc concentrations and in-stream loads calculated for LCC below the Howland Tunnel discharge.

Table 3.14 Water/Mass balance around the Howland Tunnel Area, 1986 Sampling.

Sample Date	LCC above Howland			LCC below Howland			Howland Tunnel			Acute Criteria Below Howland	Load Capacity at Criteria	Percent Reduction to Meet Criteria
	Flow (gpm)	Conc. (mg/L)	Load (lb/day)	Flow (gpm)	Conc. (mg/L)	Load (lb/day)	Flow (gpm)	Conc. (mg/L)	Load (lb/day)			
16-Jul-86	14,903	0.035	6.3	26,484	0.14	43	584	6.03	42	0.11	35	19%
07-Aug-86	2,065	0.035	0.87	4,130	0.27	13	404	4.82	23	0.14	6.7	27%
16-Sep-86	943	0.02	0.23	1,436	0.17	2.9	157	3.94	7.4	0.16	2.1	11%
24-Oct-86	943	0.03	0.34	2,918	0.24	8.4	63	4.30	3.2	0.15	5.0	104%

Note: zinc measurements are total, not dissolved.
Bold values are zinc measurements above the acute Criteria

As shown in Table 3.14, including zinc loading to LCC from diffuse sources through the study reach, the load from the Howland Tunnel would have to be reduced on the order of 11 to 27 percent in order to meet the zinc acute criteria in LCC below the Howland Tunnel. It is noted that the October 1986 results presented in Table 3.14 show that, even if the load from the Howland Tunnel were eliminated, the acute criteria for dissolved zinc would still be exceeded. Although this result could be attributed to increased zinc load to LCC from diffuse source inflows during this period, it is suspect, in that this result is inconsistent with all other mass balance calculations, including those using other data as discussed below.

<u>3.4.3.1.2 USGS 1998 Synoptic Study</u>

Flows from the Howland Tunnel were not measured during the USGS 1998 synoptic study. However, the combined Howland Tunnel flow, flow from the Toledo and Flagstaff drainages (Flagstaff Drain), and the flow from the Gold Miner's Daughter parking lot curtain drain (Curtain Drain) was measured. These combined flows enter LCC above STORET monitoring station No. 591886. The concentration of zinc in the Howland Tunnel drainage was measured at 3.9 mg/L during the 1998 study. The concentration of zinc in flow from the Flagstaff Drain was measured at 0.032 mg/L, and the concentration of zinc in flow from the Curtain Drain was measured at 0.041 mg/L. The concentration of zinc in the combined 1,152-gpm flow from these sources was also measured at 0.407 mg/L.

Using simplifying assumptions (i.e., assuming the concentrations of zinc in the Flagstaff Drain and Curtain Drain were the same – the average of the measured zinc concentrations in these flows), the estimated flow from the Howland Tunnel during the 1998 study was calculated as 111 gpm. As shown in Table 3.15, using this calculated flow, the total load from the Howland Tunnel discharge was calculated to be 5.2 lbs./day, which is consistent with the results obtained from the USDEQ data previously discussed. This load exceeded the calculated in-stream load in LCC above the tunnel discharge by one order of magnitude. Although the Howland Tunnel was calculated to be discharging a significant load to LCC during the study period, the measured zinc concentration in LCC below the Howland Tunnel discharge did not exceed the criteria for this constituent during the study. Therefore, no reduction in zinc load from the Howland Tunnel discharge would have been required to meet zinc criteria during this time.

Table 3.15 Water/Mass balance around the Howland Tunnel Area, 1998 Synoptic Sampling.

Sample Date	LCC above Howland			LCC below Howland			Howland Tunnel			Acute Criteria Below Howland	Load Capacity at Criteria	Percent Reduction to Meet Criteria
	Flow (gpm)	Conc. (mg/L)	Load (lb/day)	Flow (gpm)	Conc. (mg/L)	Load (lb/day)	Flow (gpm)	Conc. (mg/L)	Load (lb/day)			
Sept-1998	2,351	0.028	0.79	3,503	0.125	5.3	111	3.90	5.2	0.18	7.7	none

Note: Bold values are zinc measurements above the acute Criteria

3.4.3.1.3 USGS 2001 Study

Between April and July 2001, the USGS collected water quality samples and measured flows at three locations along LCC. These locations included a point downstream of the Howland Tunnel, a point downstream from the Wasatch Tunnel, and below Tanner Flat. Both dissolved zinc and flows were measured a total of nine times starting on April 24, 2001, and continuing through July 25, 2001.

As is shown in Table 3.16, zinc concentrations in LCC below the Howland Tunnel discharge exceeded the acute criteria for this constituent six out of the nine times measurements were taken. Measurements were not made from the Howland Tunnel or from an upstream point in LCC. However, assuming that the concentration of zinc in LCC above the Howland Tunnel discharge and in flows from the Curtain and Flagstaff drains were 0.03 mg/L (the average concentration of the combined LCC, Curtain Drain and Flagstaff Drain flows measured by the UTDEQ in 1986), and assuming the zinc concentration in the Howland Tunnel flows was 5 mg/L (the average of all measured zinc concentrations in the Howland Tunnel flows found in the available data), a mass balance can be performed for this reach of LCC to estimate Howland Tunnel flow during the 2001 sampling event.

As shown in Table 3.16, the estimated flows and loads from the Howland Tunnel are within the range of those measured in 1986. Based on meeting the acute criteria for zinc in LCC below the Howland Tunnel discharge, the data show that the load from the Howland Tunnel would have to have been reduced between 21 to 46 percent to meet the criteria, with the exception of the higher flow days (May 11 and May 25, 2001), during which the acute standard was not exceeded in LCC.

Table 3.16 Water/Mass balance around the Howland Tunnel Area, 2001 Sampling.

Sample Date	LCC below Howland			Howland Tunnel			Acute Criteria Below Howland	Load Capacity at Criteria	Percent Reduction to Meet Criteria
	Flow (gpm)	Conc. (mg/L)	Load (lb/day)	Flow (gpm)	Conc. (mg/L)	Load (lb/day)			
4/24/2001	1,257	0.085\1	1.3	14	5	0.84	0.18	2.8	none
5/4/2001	7,272	0.14\1	12	161	5	10	0.12	10.5	18%
5/16/2001	52,070	0.07	41	377	5	23	0.09	56.3	none
5/25/2001	35,103	0.07	29	275	5	17	0.09	40.6	none
6/6/2001	14,589	0.18	32	440	5	26	0.11	19.9	44%
6/18/2001	8,843	0.14	15	196	5	12	0.12	12.7	19%
6/29/2001	4,713	0.21	12	171	5	10	0.14	7.8	39%
7/11/2001	3,066	0.21	7.7	111	5	6.7	0.15	5.7	31%
7/25/2001	1,742	0.29	6.1	91	5	5.5	0.18	3.8	42%

Note: Bold values are zinc measurements above the acute Criteria
Balance based on assumed upstream concentration of 0.03 mg/L and Howland Tunnel concentration of 5 mg/L
/1 Total zinc, no dissolved zinc measured at this location

3.4.3.2 Wasatch Drain Tunnel Loads

Similar to the Howland Tunnel area, there is a scarcity of data available for use in mass balance calculation for the Wasatch Drain Tunnel area. During the 1986 sampling, discussed above, LCC water quality samples were only collected above the tunnel. The only data that do exist for LCC around the Wasatch Drain Tunnel area are that collected during the USGS synoptic study in September 1998 and during USGS sampling in 2001.

3.4.3.2.1 USGS 1998 Synoptic Study

The September 1998 sampling data includes results of LCC samples taken above and below the Wasatch Drain Tunnel area discharges, which include the tunnel discharges (Snowbird co-generation plant discharge and by-pass flows). The results of mass balance and loading calculations using these data are presented in Table 3.17, and show the Snowbird co-generation plant discharge to be a major source of loading to LCC in this area. It should be noted that the overflow was running at a reduced rate during the 1998 study, due to a pilot treatment project being conducted by Salt Lake County Service District No. 3. These calculations also show that the load from the Wasatch Drain Tunnel discharges would have to have been reduced by approximately 53 percent to meet the acute criteria for zinc in LCC below the tunnel discharges over the study period.

Table 3.17 Water/Mass balance around the Wasatch Tunnel Area, 1998 Synoptic and 2001 Sampling.

Sample Date	LCC above Wasatch			LCC below Wasatch			Wasatch Tunnel			Acute Criteria Below Wasatch	Load Capacity at Criteria	Percent Reduction to Meet Criteria
	Flow (gpm)	Conc. (mg/L)	Load (lb/day)	Flow (gpm)	Conc. (mg/L)	Load (lb/day)	Flow[1] (gpm)	Conc. (mg/L)	Load (lb/day)			
5/16/2001	52,070	0.066	41	130,176	0.08	125	736	1.80	16	0.10	156	none
5/25/2001	35,103	0.069	29	49,377	0.088	52	959	1.69	20	0.10	59	none
6/06/2001	14,589	0.18	32	25,407	0.18	55	1,100	1.55	21	0.12	37	89%
6/18/2001	8,843	0.14	15	13,601	0.15	25	1,021	1.41	17	0.13	21	20%
7/11/2001	3,066	0.21	7.7	7,811	0.18	17	886	1.04	11	0.16	15	17%
7/25/2001	1,742	0.29	6.1	4,130	0.21	10.4	816	1.02	9.99	0.17	8.9	17%
9/01/1998	3,655	0.12	5.3	8,150	0.28	27	2,236	0.73	20	0.17	17	53%

Notes:1 Wasatch Tunnel flow is based on monthly average flows
Bold values are zinc measurements above the acute Criteria

3.4.3.2.2 USGS 2001 Study

As previously mentioned, the USGS continued its evaluation of loading sources in LCC by collecting samples between April and July 2001 from three locations in LCC, including one upstream and one downstream of the Wasatch Drain Tunnel area. Wasatch Drain Tunnel discharges were not measured by the USGS during the 2001 sampling event. However, Salt Lake County Service Area No. 3 personnel were able to provide average monthly tunnel flow data and water quality for the sampling period. The provided flow measurements were a combination of water discharged from the co-generation plant and by-pass flows. The results of mass balance and loading calculations using these data are presented in Table 3.17. These results show that zinc loading from the Wasatch Drain Tunnel would have to have been reduced between 17 to 89 percent during this period to meet zinc water quality criteria in LCC below the tunnel discharge.

4.0 TMDL AND LOAD ALLOCATION

The elements for a TMDL for dissolved zinc in LCC include (1) water quality target sites and target/endpoints, (2) natural loading capacity at each of the target sites, (3) waste load allocations, (3) load allocations and (4) margin of safety. Zinc allocations have been derived for the two primary sources of zinc load to LCC, the Howland Tunnel and Wasatch Drain Tunnel discharges. These loading sources are located above water quality target sites LCC below Howland and LCC below Wasatch, respectively, which have been previously described in Section 2 of this report. As described in Section 2, a third water quality target site, LCC below Tanner Flat was also established at the end of the LCC study reach because measured zinc concentration in LCC at this location lead to the 303d listing of LCC. No other significant point sources of zinc loading to LCC exist between this target site and the two upstream target sites. Therefore, improvements in water quality attained at the two upstream target sites through application of water management and best management practices will also be reflected at this downstream target site, resulting in attainment of the dissolved zinc water quality criteria at this location. Accordingly, the derivation of the remaining TMDL elements focused on the two upstream target sites, LCC below Howland and LCC below Wasatch. As described in the following sections, these TMDL elements were derived based upon the results of the USGS 1998 synoptic study and 2001 sampling event.

4.1 Loading Capacities

Each of the target sites has a TMDL of dissolved zinc that can be carried before dissolved zinc criteria are exceeded. This TMDL is a function of the loading capacity at each of the target sites, which is calculated by multiplying the flow rate in the creek by the hardness dependant water quality criterion (acute) and applying an appropriate conversion factor to arrive at the loading capacity in pounds per day (lbs./day). The approach to evaluating loading capacities at each of the target sites is discussed below. Based on this approach, the flow based loading capacities at each of the target sites were calculated for the range of flows in LCC measured during the USGS 1998 synoptic study and 2001 sampling event. These results are shown in Table 4.1.

Table 4.1 Loading Capacity at Target Sites LCC bl Howland and LCC bl Wasatch

Sample Date	LCC bl Howland				LCC bl Wasatch			
	Flow (gpm)	Hardness[1] (mg/L)	Standard (mg/L)	Load Capacity (lb/day)	Flow (gpm)	Hardness[2] (mg/L)	Standard (mg/L)	Load Capacity (lb/day)
4/24/2001	1,257	163	0.18	2.7	4,489	162	0.18	9.5
5/04/2001	7,272	116	0.13	12	14,813	127	0.14	26
5/16/2001	52,070	64	0.08	50	130,176	63	0.08	125
5/25/2001	35,103	75	0.09	39	49,377	92	0.11	65
6/06/2001	14,589	98	0.11	20	25,407	111	0.13	39
6/18/2001	8,843	111	0.13	14	13,601	130	0.15	25
6/29/2001	4,713	128	0.14	8.2	11,761	134	0.15	21
7/11/2001	3,066	140	0.16	5.7	7,811	146	0.16	15
7/25/2001	1,742	155	0.17	3.5	4,130	165	0.18	8.9
9/01/1998	3,655	135	0.15	6.6	8,150	145	0.16	16

Notes: 1/ hardness at LCC bl Howland = -26.66 ln(flow) + 353.55

2/ hardness at LCC bl Wasatch = -29.377 ln(flow) + 408.76

Two potential approaches were considered to account for the variability of river flows and hardness levels that would directly affect the loading capacity of LCC at each of the target sites. Under the first approach, loading capacities would be determined for critical flows and hardness levels occurring during a particular season or seasons throughout the calendar year (e.g., summer, winter, spring-summer, or fall-winter). Under the second approach, loading capacities would be determined as a function of stream flow, regardless of season. This latter approach was chosen to derive loading capacities at each target site because: 1) data limitations precluded an analysis of LCC loading capacity on a seasonal basis, 2) available data and information indicate that flow conditions in LCC can vary widely during any particular season, and 3) good correlation between flow and hardness were derived for each of the target sites. The technical information and analysis used to establish the range of flows and hardness levels for determining loading capacities at the target sites using this approach are discussed below.

4.1.1 Range of Flows

Ideally, the range of flows that would occur at each of the target sites would be developed based on a statistically significant number of flow measurements representative of the entire range of flows occurring at each site. With such data, the loading capacity at each site could be evaluated based on a series of flow tiers (e.g., 7Q10 low flow, 10^{th} percentile of average daily flow, 50^{th}

percentile of average daily flow and 90th percentile of average daily flow). By addressing loading capacities within a series of flow tiers, added flexibility in allocating and addressing constituent loading to a stream may be realized. For example, controllable discharges to a stream may be scheduled when flow conditions in a stream provide higher loading capacity, and discharges reduced when flow conditions in a stream provide lower loading capacity.

Flow data at each of the target sites was limited. In an attempt to provide a more comprehensive understanding of the flow regimes at the target sites, an evaluation was performed to determine if an empirical relationship existed between flows in LCC at the target sites and flow in LCC at the Murray City Water Intake. A large historical record of flow measurements exists for LCC at the Murray City Water Intake (STORET monitoring station 499366), which is located approximately 5,400 meters downstream of the LCC study reach. The period of record for this monitoring station spans from 1975 to 1999. If a relationship existed between flow in LCC at the Murray City Water Intake and flows in LCC at the upstream target sites, a range of expected flows at each of the target sites could be extrapolated from the historical record of flows in LCC at the Murray City Water Intake. However, no such relationship was found.

Table 4.2 presents a series of flow measurements taken at LCC below Howland and LCC below Tanner Flat, and corresponding flows in LCC at the Murray Water Intake during these same periods. The calculated ratios of flows between the sites are also presented. If a definitive relationship existed between flow in LCC at the Murray Water Intake and flows in LCC at the upstream monitoring stations, the ratios of flows would be similar for all periods. The large variability in these calculated ratios shows that no such relationship exists. Accordingly, the limited flow data did not allow for the evaluation of flow tiers at the target sites. At best, hardness levels and loading capacities at each of the target sites could be evaluated within a limited range of flows. These were the flows measured by the USGS during the 1998 synoptic study and 2001 sampling event.

Table 4.2 Flow Measurements at LCC Below Howland, LCC Below Tanner Flat, and Corresponding Period Flows at Murray Water Intake

Location	Date	Measured Flow (gpm)	Flow at Murray Water Intake for Corresponding Period (gpm)	Ratio of Flows
LCC bl Howland (591886)	7/16/1986	26,484	136,280	0.19
LCC bl Howland (591886)	8/7/1986	4,130	95,980	0.043
LCC bl Howland (591886)	9/16/1986	1,436	22,707	0.063
LCC bl Howland (591886)	10/24/1986	2,918	13,965	0.21
LCC bl Tanner Flat (499378)	1/18/78	4,040	6,993	0.58
LCC bl Tanner Flat (499378)	4/19/78	628	23,799	0.026

4.1.2 Hardness and Water Quality Criteria

The chronic and acute cold water criteria for dissolved zinc are hardness dependent. Toxicity of metals to aquatic life increases as hardness decreases. For this reason, hardness-based water quality criteria are most stringent at low hardness levels. It was determined that hardness values at the LCC target sites varied between 59 and 147 mg/L. Therefore, a range of water quality criteria for dissolved zinc and, hence, loading capacities would apply at each of the target sites.

In some drainage systems, hardness levels may vary depending on river flow rates. Accordingly, hardness/flow relationships were investigated at each of the target sites in order to evaluate loading capacities at these sites over the range of measured flows. As shown in Figures 4.1 through 4.3, significant relationships were determined to exist between hardness values and flow in LCC at each of the target sites.

While investigating the hardness/flow relationships, it was determined that magnesium and calcium concentrations (used to calculate a hardness value) were not consistently measured at each of the target sites when flow measurements were taken. In order to maximize the data for developing the hardness/flow relationships presented in Figures 4.1 through 4.3 (more flow data existed than magnesium/calcium concentrations), relationships between more consistently monitored constituents and hardness were investigated. It was determined that sulfate concentrations correlated well with hardness at all three target sites with correlation coefficients (r^2) of 0.97, 0.99, and 0.99 calculated for the sulfate/hardness relationships at LCC below Tanner Flat, LCC below Wasatch, and LCC below Howland, respectively. These relationships were used to calculate hardness values at these sites for those times both flow and sulfate were measured at a site, but not calcium and magnesium. These calculated hardness values were also used in deriving the hardness/flow relationships shown in Figures 4.1 through 4.3. Based on the hardness/flow relationships, the applicable water quality criteria for zinc were calculated within the range of measured flows at each of the target sites.

Figure 4.1 Flow versus Hardness at LCC below Tanner Flats, April – June 2001.

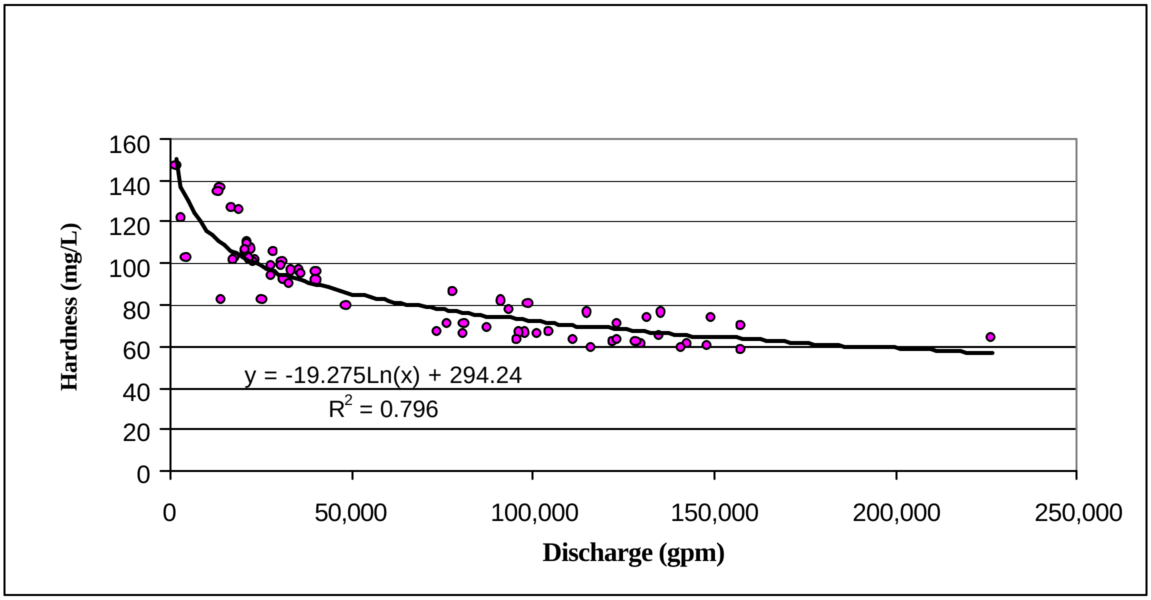


Figure 4.2 Flow versus Hardness at LCC below Wasatch, April – June 2001.

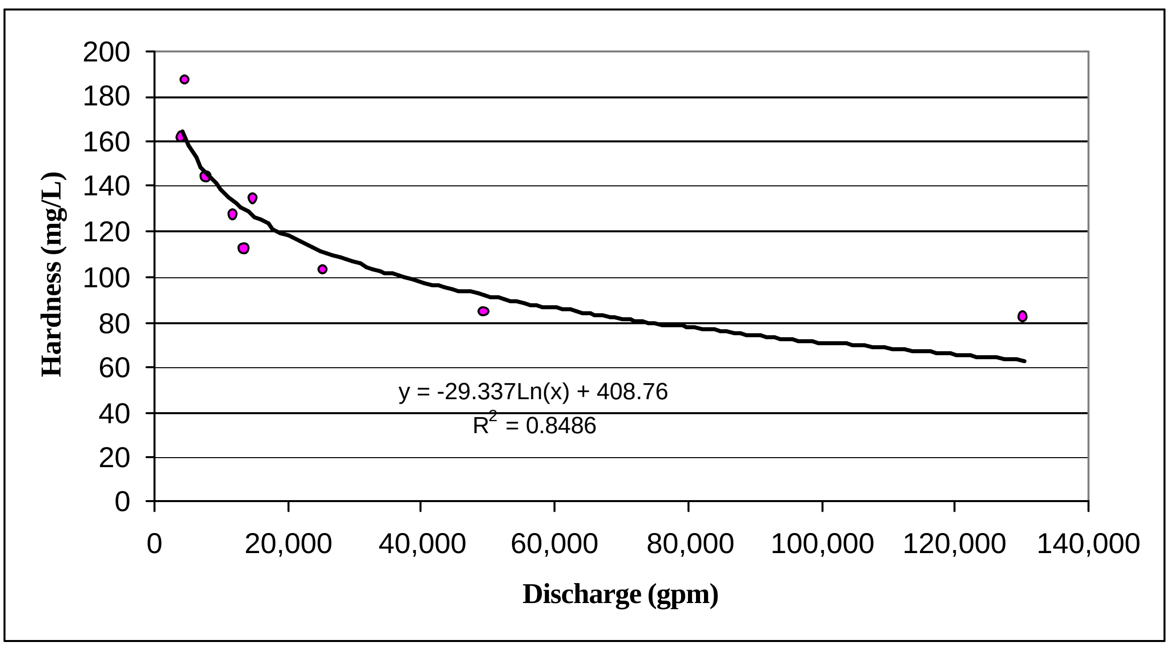
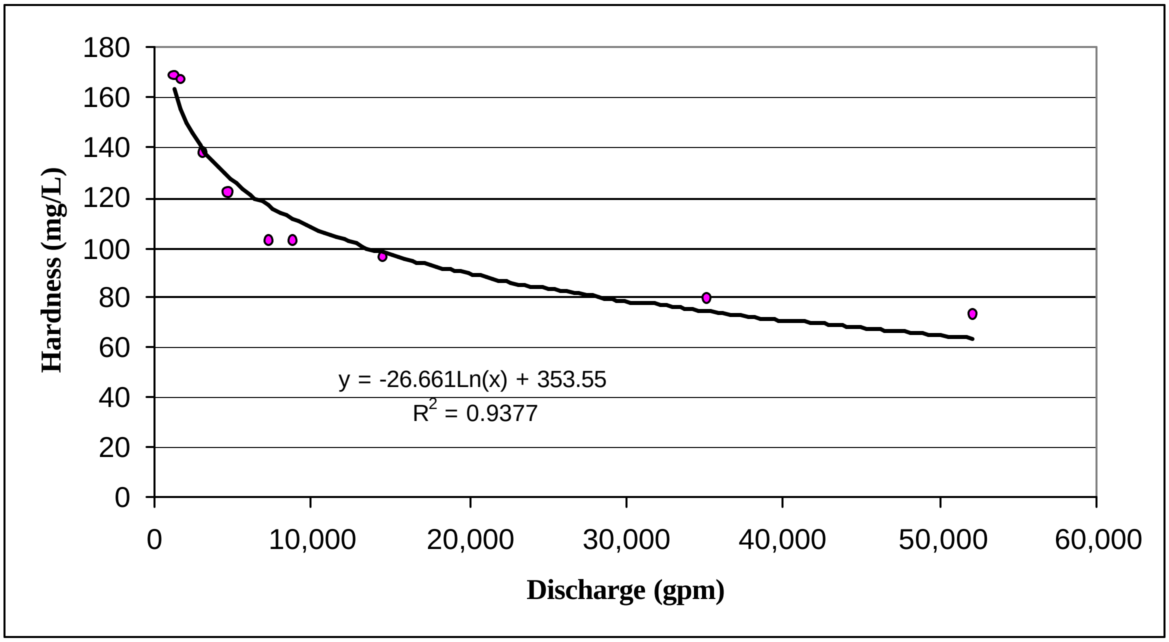


Figure 4.3 Flow versus Hardness at LCC below Howland, April – June 2001.



4.2 Load Allocations

Zinc load at each of the target sites includes contributions from both non-point sources and natural background load. Background load and non-point sources were previously discussed in Sections 3.4.1 and 3.4.2, respectively. The allocation of these loads at each of the target sites is discussed below.

4.2.1 LCC Below Howland

As described in Section 3.4.2, the data collected during the USGS 1998 synoptic study allowed for calculating the magnitude of non-point source loads to LCC at discrete locations along the study reach. These loads, and calculated concentrations of the inflows, are shown in Table 3.12. The concentrations of inflows above the target site, LCC below Howland (identified in the 1998 study and in Table 3.12 as "LCC bl Alta" – Distance 1550), ranged from 0.01 to 0.041 mg/L. These inflows, as measured during the synoptic study, would include background load. Since the calculated concentrations of the inflows were all at or below the assumed background concentration of 0.04 mg/L (see Section 3.4.1), the combined background and non-point source load at LCC below Howland was calculated as the measured flow at this site (less the flow at this location contributed by the Howland Tunnel discharge) multiplied by a concentration of 0.04 mg/L. The combined background and non-point source loads at LCC below Howland calculated using this procedure and used in deriving wasteload allocations from the Howland Tunnel are shown in Table 4.3.

As shown in Table 3.12, the calculated concentrations of the majority of inflows above the target site, LCC below Howland, were significantly less than 0.04 mg/L. The average concentration of all inflows is approximately 0.02 mg/L. Therefore, the use of 0.04 mg/L in calculating the combined non-point and background loads at LCC below Howland provides one aspect of the margin of safety for this TMDL.

Table 4.3 Waste Load Allocation Summary for LCC below Howland, which includes the Howland Tunnel

Date	Flow LCC bl Howland (gpm)	Load Capacity (lbs./day)	Background & Non-point Source Load (lb/day)	Margin of safety (lbs./day)	Waste Load Allocation (lbs./day)	Calculated Discharges from Howland (gpm)	Required Treatment Flow[/1] (gpm)
4/24/2001	1,257	2.7	0.60	0.27	1.8	11	0
5/4/2001	7,272	11.6	3.5	1.16	6.9	147	31
5/16/2001	52,070	50.2	25	5.02	20.2	273	0
5/25/2001	35,103	38.5	17	3.85	17.7	205	0
6/6/2001	14,589	20.2	7.0	2.02	11.2	412	227
6/18/2001	8,843	13.6	4.3	1.36	7.9	178	46
6/29/2001	4,713	8.2	2.3	0.82	5.1	162	78
7/11/2001	3,066	5.7	1.5	0.57	3.6	105	45
7/25/2001	1,742	3.5	0.84	0.35	2.3	88	50
9/1/1998	3,655	6.6	1.8	0.66	4.1	111	41

Note: /1 Potion of Howland Tunnel discharge required to be treated to meet the criteria. Assumed treatment results in reduction in dissolved zinc concentrations from 5 mg/L to 0.01 mg/L.

4.2.2 LCC Below Wasatch

The approach used to calculate background and non-point source load at the target site, LCC below Howland, was also used to calculate background and non-point source load at LCC below Wasatch. In this case, however, there were a number of additional non-point sources identified between these two target sites that had to be considered. These other non-point sources are identified in Table 3.12, and are those located between "LCC bl Alta" and "Blw Wasatch Tunnel." These inflows were calculated to contribute a total load of 3.2 lbs./day (1,825 gpm flow at an average concentration of 0.15 mg/L). Again, these inflows, as measured during the USGS 1998 synoptic study, would include background load. Based on this analysis, the combined background and non-point source load to the target site, LCC below Wasatch, was calculated as the product of inflows to LCC between target sites LCC below Howland and LCC below Wasatch (less the flow at this target site contributed by the Wasatch Drain Tunnel discharge) multiplied by a concentration of 0.15 mg/L. The combined background and non-point source loads at LCC below Wasatch calculated using this procedure and used in deriving wasteload allocations from the Wasatch Tunnel are shown in Table 4.4.

Using the results of the 1998 synoptic study (shown in Table 3.12), a mass balance performed using the calculated in-stream load of 5.3 lbs./day at LCC below Howland (identified in Table 3.12 as "LCC bl Alta"), background and non-point source load to LCC below Wasatch (3.2 lbs./day), load from the Wasatch Drain Tunnel (identified in Table 3.12 as "Wasatch Tunnel co-generation" – 19.7 lbs./day), and in-stream load at LCC below Wasatch (26.6 lbs./day) shows that there was a loss of load in this reach of LCC of approximately 1.6 lbs./day during the synoptic study. This loss is likely caused by the attenuation of dissolved zinc in the creek. Therefore, the use of 0.15 mg/L in calculating the combined non-point and background loads at LCC below Wasatch, and not considering attenuation, will provide another aspect of the margin of safety for this TMDL.

Table 4.4 Waste Load Allocation Summary for LCC below Wasatch, which includes the Wasatch Tunnel

Date	Flow (gpm)	Load Capacity (lbs./day)	In Stream Load Capacity at LCC below Howland (lbs./day)	Background and Non-point source Load at 0.15 mg/L (lbs./day)	Waste Load Allocation for Wasatch Tunnel (lbs./day)	Measured Discharge From Wasatch Tunnel (gpm)	Maximum Allowable Discharge to Meet Criterion (gpm)
5/16/2001	130,176	125	50.2	140	0	736	0
5/25/2001	49,377	65	38.5	24	2.5	959	101
6/6/2001	25,407	39.7	20.2	1.5	2	1100	76
6/18/2001	13,601	25	13.6	6.7	4.7	1021	205
6/29/2001	11,761	21	8.17	11	1.83	948	135
7/11/2001	7,811	15	5.7	6.96	2.34	886	196
7/25/2001	4,130	8.9	3.5	2.8	2.6	816	202
9/1/1998	8,150	16	6.6	4.1	5.3	2,236	566

4.3 Wasteload Allocations/Margin of Safety

4.3.1 LCC Below Howland

Wasteload allocations at the LCC below Howland target site were calculated as follows:

Step 1. Water hardness at the target site was determined based on the relationship between hardness and flow developed for this site.

Step 2. The loading capacity of the stream was calculated as the product of the hardness based dissolved zinc criterion (acute) and flow.

Step 3. Background and non-point source load was calculated as the product of flow in the stream (less that contributed by the Howland Tunnel discharge) and a dissolved zinc concentration of 0.04 mg/L.

Step 4. A margin of safety was calculated as 10 percent of the calculated loading capacity of the stream (Step 2).

Step 5. The wasteload allocation was calculated as the difference between stream loading capacity (Step 2) and background and non-point source load (Step 3) and margin of safety (Step 4).

Waste load allocations using this procedure for the range of flows and conditions encountered during the USGS 1998 synoptic study and 2001 sampling event are shown in Table 4.3. Table 4.3 also shows the calculated portion of the Howland Tunnel discharge that would have to be treated to attain the dissolved zinc water quality criterion at LCC below Howland over the range of flows and conditions encountered during the USGS 1998 synoptic study and 2001 sampling event. These calculated flows are based on the assumption that the treatment process could reduce the zinc concentrations in the treated discharge from 5 mg/L to 0.01 mg/L. This reduction in zinc concentration is deemed technically feasible and reasonable given the past performance of the Fen. (Jensen, 2001b).

The results show that no treatment of Howland Tunnel discharge would have been required to attain water quality criteria at LCC below Howland for those conditions existing during sampling on April 24, May 16, and May 25, 2001. Approximately 55 percent (227 gpm) of the Howland Tunnel drainage would have to have been treated to meet the load allocation for conditions existing on June 6, 2001. The amounts of Howland Tunnel discharge that would have to have been treated over other low flow conditions existing during the 1998 synoptic study and the 2001 sampling event ranged from 41 to 78 gpm.

4.3.2 LCC Below Wasatch

Wasteload allocations at the LCC below Wasatch target site were calculated as follows:

Step 1. Water hardness at the target site was determined based on the relationship between hardness and flow developed at this site.

Step 2. The loading capacity of the stream was calculated as the product of the hardness based dissolved zinc criterion (acute) and flow.

Step 3. Background and non-point source load was calculated as the product of calculated inflows to LCC between LCC below Howland and LCC below Wasatch (less the flow at this target site contributed by the Wasatch Drain Tunnel discharge) and a dissolved zinc concentration of 0.15 mg/L.

Step 4. The wasteload allocation was calculated as the difference between stream load capacity (Step 2) and background and non-point source load (Step 3) and in-stream load above the Wasatch Drain Tunnel discharge.

For purposes of the wasteload analysis, the in-stream load above the Wasatch Drain Tunnel discharge was calculated as the loading capacity of LCC calculated at LCC below Howland. This assumes that any treatment of Howland Tunnel discharge results in attainment of the water quality criteria at LCC below Howland only.

Waste load allocations using this procedure for the range of flows and conditions encountered during the USGS 1998 synoptic study and 2001 sampling event are shown in Table 4.4. One method of meeting the load allocations presented in Table 4.4 is to reduce the discharge from the Wasatch Drain Tunnel, as opposed to reducing zinc concentrations in the discharging waters. The calculated maximum allowable discharges from the Wasatch Drain Tunnel that would have resulted in attaining the dissolved zinc criteria at LCC below Wasatch over the range of flows and conditions encountered during the USGS 1998 synoptic study and 2001 sampling event are also shown in Table 4.4.

It should be noted that during the peak of the runoff period (conditions existing during sampling on May 16, 2001 and May 25, 2001), the calculated waste load allocation from the tunnel were zero and 2.5 lbs./day, respectively. These results are attributed to applying the concentration of 0.15 mg/L (see Section 4.2.2) to the calculated diffuse flows entering LCC between LCC below Howland and LCC below Wasatch. In reality, the high flows in LCC occurring during peak runoff periods are likely comprised of low-concentration snowmelt water, and a significant amount of water could be discharged from the Wasatch Drain Tunnel during peak runoff periods in LCC. This conclusion is based on the fact that the actual measured dissolved zinc concentration in LCC on May 16, 2001 and May 25, 2001 did not exceed the acute criteria (see Table 3.17).

The wasteload allocations shown in Table 4.4 were based on conservative assumptions that no attenuation of zinc concentration in LCC occurs through the study reach and that the concentration of dissolved zinc in all background and non-point source inflows is 0.15 mg/L. In order to determine the effect on calculated wasteload allocations using these assumptions, wasteload allocations were also determined based on the calculated in-stream load and Wasatch Tunnel discharge load using the data from the USGS 1998 synoptic study and 2001 sampling event. Inherent in using these data to calculate the wasteload allocations are attenuation of zinc loads in the creek and actual background and non-point source loads in LCC at the time of sampling. The resulting wasteload allocations using these data and as calculated above are compared in Table 4.5. Significantly, the wasteload allocations based on measured stream values are on average three times larger than the wasteload allocations calculated using conservative assumptions (excluding comparison of results based on the May 16 and 25, 2001 measurements). Therefore, the average of these two calculated wasteload allocations is suggested for use for this TMDL. These average wasteload allocations and calculated maximum allowable discharge from the Wasatch Drain Tunnel based on these allocations are shown in Table 4.5.

Table 4.5 Wasatch Tunnel Load Allocation – Method Comparison

Date	Actual Load	Allowable Load Calculated Based on Measured Stream Value (lbs./day)	Initial Calculated Allowable Load (lbs./day)	Average Allowable Load (lbs./day)	Maximum Allowable Discharge to Meet Criterion (gpm)
5/16/2001	16	45	0	22	1017
5/25/2001	20	28	2.1	15	739
6/6/2001	21	2.2	1.7	1.95	105
6/18/2001	17	14	4.4	9.2	543
6/29/2001	14	12	2.4	7.2	487
7/11/2001	11	9.1	2.5	5.8	464
7/25/2001	10	8.3	2.2	5.3	432
9/1/1998	20	9.1	3.9	6.5	741

5.0 TMDL IMPLEMENTATION

In the development of this TMDL, it has been noted that there is limited data available to completely characterize all of the components of the TMDL. Only one sampling event, the synoptic study conducted in September 1998 during the low-flow season, covered in detail the entire LCC study reach. The 2001 USGS data set, while not as detailed as the 1998 synoptic study, covered a period during the spring runoff and the beginning of the low flow season. The details omitted from the 2001 data set, such as direct measurements of flow and concentrations from the Howland and Wasatch Drain tunnels and measurements in LCC upstream of the Howland Tunnel drainage, required assumptions to be made that impact the TMDL wasteload allocations.

Given these data limitations, it is strongly suggested that further data be collected and the TMDL for LCC be refined, as appropriate, based on the results of additional analysis (a more complete data set would include monthly data over the entire year to better evaluate both high-flow and low-flow periods). Nonetheless, the results of this TMDL can provide a basis for future data collection and implementation of some of the actions and management measures required to implement the allocations provided in this report. As new data becomes available through monitoring efforts, elements of the TMDL may be changed to reflect this new information.

As discussed below, several implementation components directed towards reduction of zinc loads can be implemented while new data is being developed. It is noted, however, that uncertainties exist regarding the potential effectiveness of some of these recommended practices, and that implementation of the recommended practices may be constrained by other factors. Issues such as water rights, in-stream flows, and restrictions on land application will also need to be considered during the development of specific control programs. Alternative options to treat discharge waters may also be required if TMDL endpoints cannot be achieved through the current implementation strategy. These options will be evaluated at the appropriate time, after implementation of the current recommendations and collection of additional data.

The following strategy is recommended for implementing the TMDL.

5.1 Implementation Plan

The Little Cottonwood Watershed Group, with direct input and cooperation from Salt Lake County Service Area #3 and Snowbird, should prepare and submit within a reasonable time frame (6 months), a plan for implementing studies and activities addressing water management options for discharges to LCC and monitoring that would be required to evaluate management practices. All activities between SLC Service Area #3, Snowbird, SL County, and UTDEQ should be coordinated to ensure all conditions (e.g., discharge rates from the Wasatch Drain Tunnel) are documented during any monitoring or data collection activity in the LCC.

At a minimum, the implementation plan will address the implementation options listed below. Additional management or treatment options may also be considered (e.g., the proposed magnetic activated carbon treatment research project sponsored by the Utah Engineering Experiment Station) as the implementation plan is developed and refined during implementation of management activities.

5.1.1 Howland Tunnel

The Howland Tunnel contributes a significant zinc load to LCC, and efforts to begin treatment of the discharge have already begun by passing a portion of the Howland Tunnel discharge through the Fen. Additional efforts to meet the TMDL should include:

- Expanding the Alta Fen wasteland allocation for the Howland Tunnel to take additional flow, if not all of the flow, from the Howland Tunnel (the quantity of flow directed to the Fen can be based on the range of flows presented in Table 4.3)
- Creating a flow system that will prevent mixing of discharge from the Howland Tunnel with other waters, such as those in the Flagstaff or Toledo drainages, and that will direct only the Howland Tunnel discharge to the Fen
- Developing a flow delivery system that will allow the Fen to operate the entire year, not just during the summer months
- Establishing a program to monitor flows and chemistry from the Howland Tunnel and from the Fen over an entire year.

The expansion of the Fen should begin within the next year. Once the Fen has been expanded and operated with the maximum flows for one year, the TMDL can be revisited with the additional data to reevaluate this treatment option.

5.1.2 Wasatch Tunnel

Discharge from the Wasatch Drain Tunnel (Snowbird co-generation plant discharge and by-pass flows) also contributes a significant zinc load to LCC. It is evident that both reduction and timing of discharge are critical to meeting water quality standards in LCC below the tunnel discloses, and therefore, the initial implementation of the TMDL should include an evaluation of water management strategies addressing these issues.

The co-generation plant cooling water is one of the identified discharges from the Wasatch Drain Tunnel that causes zinc exceedances in LCC. There are several options to reduce the amount of co-generation cooling water discharges that can be evaluated. One option would be power plant modifications, such as additional cooling fins, that could result in less water required to cool the generators. Other options include re-circulating cooling water back to the tunnel or disposing of cooling waters through land application. These options can be evaluated based on the required reductions in discharge from the co-generation plant presented in Table 4.5

The timing of water releases from the Wasatch Tunnel are also critical in meeting the TMDL endpoints. The timing of release of water from the co-generation plant is not as flexible as direct discharge from the tunnel, since cooling water requirements are a function of plant use and seasonal temperature. The co-generation plant requires a large flow rate to maintain cooling of the turbines (700 gpm average) with the average peak flow of 900 gpm occurring in July. Discharge of cooling water at this rate following spring-runoff may cause an exceedance of the established TMDL since sufficient flow in LCC may not be available for dilution.

Wasatch Tunnel water is discharged directly to the stream during the spring-runoff period in order to maintain a pool level below 300 ft depth. Based on the 2001 USGS sampling, higher flows in LCC during spring runoff provide enough dilution to maintain zinc concentrations in LCC below the acute zinc water quality criteria. However, once the peak spring flows have passed, reduction in discharge from the Wasatch Drain Tunnel is required in order to maintain zinc concentrations in LCC below the acute zinc water quality criteria. One water management strategy that should be explored is rapidly reducing the mine pool during the peak runoff period, reducing direct discharges to LCC during lower flows. The evaluation of this option will require consideration and understanding of water chemistry changes that may occur from rapid draining of water from the tunnel. These changes, if any, could be evaluated based on on-going monitoring of responses during implementation of water management practices.

5.2 TMDL Monitoring Recommendations

A water-monitoring program needs to be conducted to further validate or define loading sources, and to monitor stream responses to implementation actions. The program will be designed to measure stream flows conditions over an entire year, encompassing both the spring-runoff period and the low flow period. At a minimum, dissolved zinc, hardness, and flow should be monitored at the target points (LCC below Howland, LCC below Wasatch, and LCC below Tanner Flat). Additional samples should also be collected from LCC above the Howland Tunnel, and from the Howland Tunnel and Wasatch Drain Tunnel discharge points (bypass and Snowbird co-generations plant) to quantify these specific loads. Monitoring should be performed on a monthly basis to better quantify the variability between high and low flow periods. All monitoring activities should be coordinated between SLC Service Area No. 3, Snowbird, SLC, and UTDEQ to ensure that all conditions (e.g., discharge rates from the Wasatch Drain Tunnel) can be documented during data collection activities. The load allocations set forth in Section 4 of this report should be refined if warranted by the results of this additional monitoring.

Macroinvertebrate populations will also be sampled on an annual basis as an additional gauge to stream response to implementation actions. Monitoring sites will be set up along the creek to match those sites that have been monitored historically. These same monitoring sites will also be evaluated for microhabitat during annual sampling, so that macroinvertebrate data can be developed that is consistent in both location and time.

A monitoring plan addressing the above recommendations, including funding and individual responsibilities, will be developed cooperatively by the members of the Little Cottonwood Canyon Watershed Group.

6.0 PUBLIC PARTICIPATION

With help from the Colorado Center for Environmental Management, a workgroup of local stakeholders was formed to investigate water quality concerns in the canyon and move towards possible solution. Representation on the workgroup, known as the Little Cottonwood Canyon Watershed Group, has included the following entities:

- Salt Lake County
- US Forest Service
- US Geological Survey
- Town of Alta
- Utah Division of Water Quality
- Salt Lake City
- Snowbird Resort
- Alta Lift Co.
- Salt Lake Co. Special Service District No. 3
- Metropolitan Water District of SLC
- Utah Division of Oil, Gas and Mining
- Utah Division of Drinking Water
- Save Our Canyons
- Trout Unlimited
- Environmental consultants
- Utah Mining Association
- Bureau of Land Management.

The Little Cottonwood Canyon Watershed Group, along with representatives from the Utah Department of Environmental Quality, have been meeting since 1998. More recently, two meetings were held in February and March 2001 to discuss the findings of the TMDL study with group members and other interested parties. Input received from participants on the draft TMDL has been incorporated into the final document. The Little Cottonwood Creek TMDL is also available for review on the Division of Water Quality's internet site.

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