PROVO RIVER DIVERSION DAMS EVALUATION

Final Draft Report

Prepared for:

Utah Reclamation Mitigation and Conservation Commission

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INTRODUCTION

Background

The Provo River in Utah is extensively used as a source of water for irrigation, hydropower, and domestic drinking water, and, in addition, supports a high quality sport fishery. The earliest water diversions on the Provo River date back to the mid-1800s, with formal water rights becoming established by the late 1800's. The lower portion of the Provo River between the mouth of Provo Canyon and Utah Lake is heavily diverted for irrigation water. Historically, this portion of the river provided spawning habitat for the June sucker (*Chasmistes liorus*), an endangered fish species. Due to the presence of diversion structures, this fish is currently restricted to spawning in the lowest 4.9 miles of the Provo River (USFWS 1999).

Authority

The Utah Reclamation Mitigation and Conservation Commission (Commission) was established as part of the Central Utah Project Completion Act (CUPCA) (Public Law 102-575, 1992). The Commission is responsible for mitigating the impacts to fish and wildlife resulting from construction of the Central Utah Project and other Federal Reclamation projects in Utah. As part of its mitigation program, the Commission is authorized to modify or construct diversion dams on the lower Provo River.

Scope and Purpose

The scope of this project encompasses eight diversion structures located along the lower portion of the Provo River between Utah Lake and Murdock Diversion (Figure 1). The purpose of this project is to evaluate these structures in terms of their ability to bypass instream flows, their impacts to fish migration, their effects on hydrology and sediment transport, and their effects on riparian vegetation. Results of the project will be used to assist in exploring possible modifications to the existing diversion system to benefit fish and wildlife resources. One specific fisheries goal is to expand the spawning area for the endangered June sucker and other fishes. Other goals include facilitating fish migration and providing a mechanism to ensure that minimum instream flows can bypass the diversion dams.

Definitions

Diversion Structure: Refers to the physical components of a diversion, including both the dam and canal headworks.

Dam: A structure that extends either partially or fully across the stream channel and functions to back up and direct water into a canal or ditch.

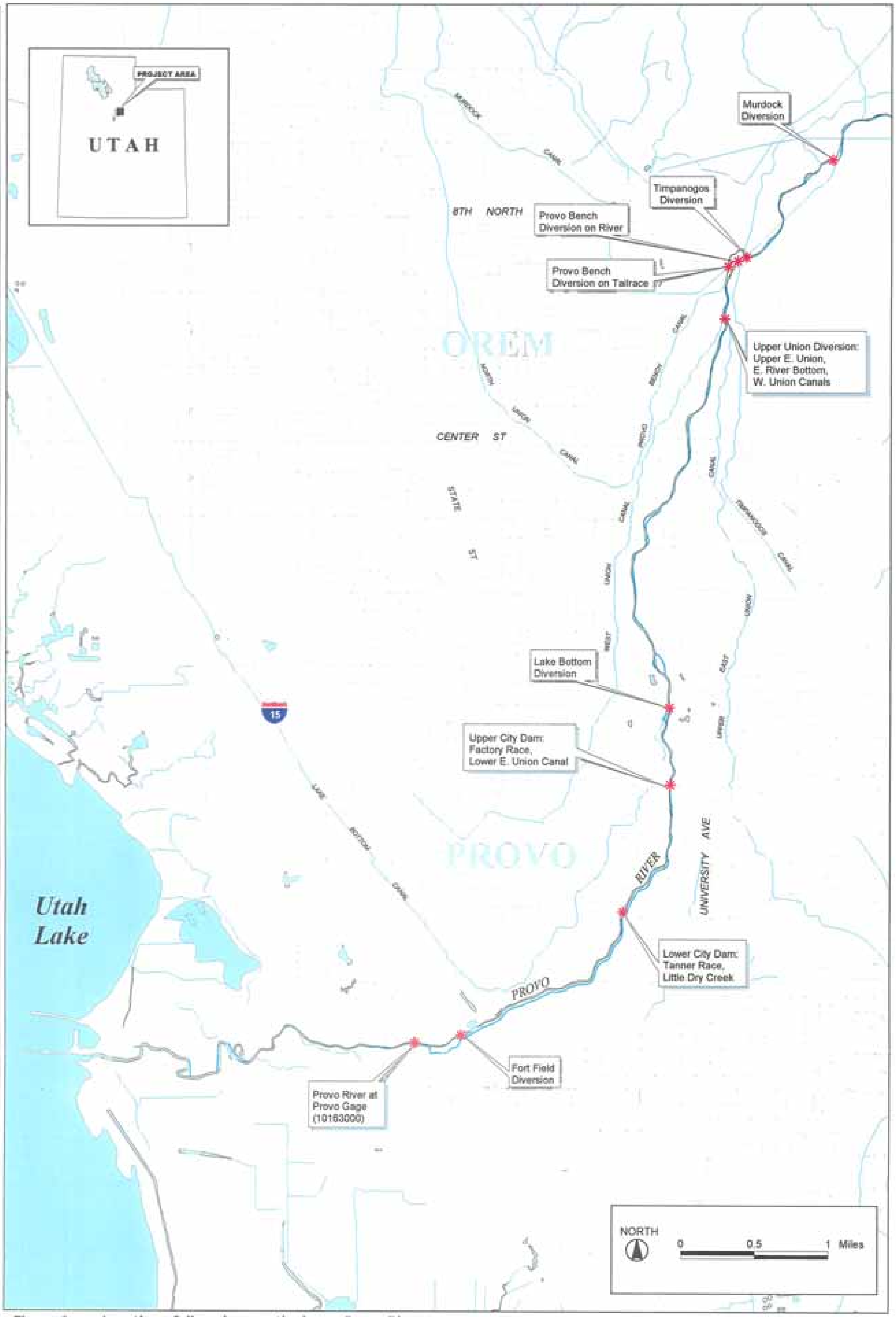

Figure 1. Location of diversions on the lower Provo River.

Kick-leg Dam:	A diversion dam structure that consists of hinged metal supports fitted with wooden boards placed horizontally across the channel. Kick-leg dams are typically installed in conjunction with concrete sidewalls and a concrete sill placed flush with the streambed.
Dry Dam:	The condition that exists when a diversion structure is used to divert all or nearly all the streamflow into a canal or ditch. Under dry dam conditions, the only water that remains in the channel downstream from the diversion is from seepage or leakage through/ under the dam.
Sluiceway:	An opening in a diversion dam, typically gated and located near the canal headworks, that is used to help maintain flow into the headworks and reduce the amount of bedload entering the headworks.

Methods

Hydrological and biological information about the lower Provo River was gathered from existing literature and discussions with relevant agency personnel. Diversion structures were initially visited on June 28, 2000 as part of a field meeting between BIO-WEST, the Commission, and the Provo River Commissioner. Following this initial meeting, specific diversion evaluation criteria were defined. Field evaluations of the diversion structures were completed by BIO-WEST on July 25, 2000.

DESCRIPTION OF EXISTING SYSTEM

Physical Setting and Hydrologic Characteristics

The Provo River originates in the Uinta Mountains at an elevation of approximately 10,800 feet and flows toward the west into Jordanelle Reservoir. From Jordanelle, the river flows south-southwest into Deer Creek Reservoir and through Provo Canyon. The study area for this project encompasses the lower-most 11 miles of the Provo River from Murdock Diversion (near the mouth of Provo Canyon) downstream to Utah Lake (Figure 1). The eight diversion structures evaluated are located within the upper 7.7 miles of this reach. This portion of the river is highly urbanized. The drainage area of the Provo River is 673 square miles at the USGS gage (gage # 10163000) located 2.1 miles upstream from Utah Lake.

Average annual precipitation in the study area ranges from approximately 21 inches at the Olmsted Power Plant near the mouth of Provo Canyon to 13 inches in downtown Provo (UDWR 1997). The majority of this precipitation comes in the form of snow during the winter months and melts/ runs off during the spring and early summer months. Flows within the study reach are primarily influenced by operations of Jordanelle and Deer Creek Reservoirs, and by water withdrawals at

Olmsted Diversion, a sizeable diversion located approximately 3.5 miles upstream from the Murdock Diversion Dam. Various additional diversion structures exist at points along the entire length of the river system upstream from Olmsted. Water is also imported to the Provo River above Jordanelle Dam via the Weber-Provo Canal and the Duchesne Tunnel; however, this imported water is typically re-diverted out of the Provo River at or upstream from Murdock Dam and therefore has limited influence on the hydrology of the study reach.

Water operations have altered the streamflow hydrograph within the study reach from natural historical conditions. Peak flows have been reduced by approximately 66% and occur approximately two weeks later than they would naturally (UDWR 1999). However, since 1994, attempts to operate the Provo River system to achieve flows more suitable for June sucker spawning and recruitment have been ongoing. New targets for springtime flow releases from Jordanelle and Deer Creek dams have recently been established in an attempt to more closely mimic the natural hydrograph for the benefit of June sucker. These target flow releases were implemented experimentally in spring 1999 and spring 2000 (C. Keleher 2000, pers. comm.). These flows were also implemented experimentally in 2001, although the target low water year peak flow was not achieved (CUWCD 2001).

Typical hydrographs at the USGS gages below Deer Creek Dam and at Provo are shown in Figure 2. Flows at the downstream Provo site are considerably lower than flows below Deer Creek during the summer irrigation season (Figure 2). The amount of water diverted between Deer Creek Dam and Utah Lake is substantial: the average annual flow for the period of record 1953-1999 at the USGS gage below Deer Creek Dam is 362 cfs, while the average annual flow for the same time period at the USGS gage at Provo is only 206 cfs. It is important to emphasize that neither gage site represents "natural" flow conditions. As discussed above, stream flows throughout the Provo River are affected by dam operations, water diversions, and water imports.

Currently, there are no legally-binding summer instream flow requirements for the lower Provo River. A wintertime minimum flow requirement of 25 cfs exists for the Provo River between Utah Lake and the Olmsted diversion (located approximately 5 miles upstream from the Murdock diversion). In the future, year-round minimum instream flows may become established on the lower Provo River. Section 302 of the Central Utah Project Completion Act (CUPCA) authorizes funding through the Utah Reclamation Mitigation and Conservation Commission for the Central Utah Water Conservancy District (CUWCD) to acquire water rights with the objective of providing a year-round minimum instream flow of 75 cfs (Public Law 102-575, 1992). The 75 cfs flow is established as an objective, not as a legally binding flow requirement. At present, this objective has not been met, although the CUWCD is in the process of acquiring water shares and water rights from willing sellers.

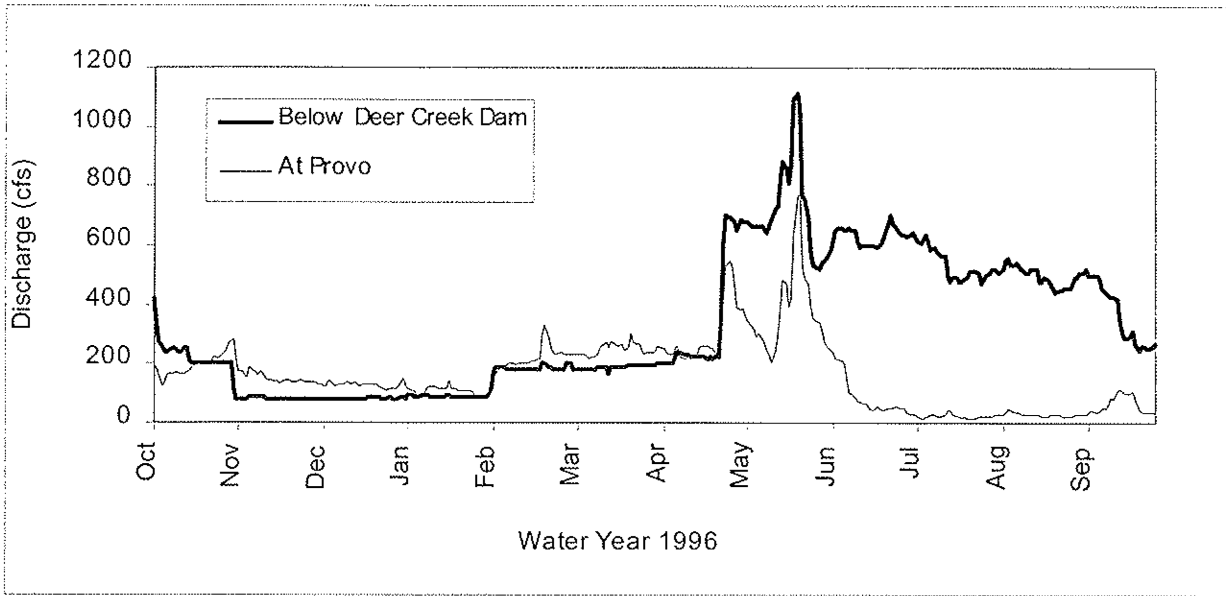

Figure 2. Typical hydrographs for the lower Provo River.

The portion of the Provo River within the study area is highly urbanized. The river has been channelized and leveed throughout this reach in order to eliminate flooding and accommodate residential, commercial, and industrial land uses. Because of these channel modifications, floodplain width is minimal, streambanks are overly steep and tall, and natural geomorphic processes such as point bar deposition and channel avulsion are limited. Although riparian vegetation is present along most of the reach and does provide some shading and bank protection, the width of the riparian corridor is typically narrow (less than 50 feet wide on either side of the stream), and recruitment of woody riparian species is lacking due to the limited floodplain functions within this channelized reach.

Biological Resources

The segment of the Provo River from Utah Lake upstream to Murdock Diversion provides a year-round fishery along the Wasatch Front for both cold water and warm water species as well as spawning habitat for the endangered June sucker. Additionally, the river corridor in this area is unique in the Wasatch Front portion of Utah County and provides riparian habitat for avian and small mammal species that occur in the area. Habitat for other fauna such as amphibians dependent upon riparian areas is present in limited amounts as well.

The Utah Division of Wildlife Resources (UDWR) has divided the lower Provo River (below Deer Creek Reservoir) into six management sections. Diversions structures evaluated for this report occur within the second and third sections of the lower Provo River with Section 1 beginning at the mouth of the Provo River and extending to the upstream extent of the Utah Lake backwater effect. Section 2 extends from the Utah Lake backwater upstream to State highway 91, and Section 3 extends from State highway 91 to Murdock Diversion. The Statewide Aquatic Habitat Classification System is used to rate stream sections and bodies of water according to aesthetics, availability, and productivity. Ratings for these categories are then totaled, weighted, and given a numerical rating of 1-6. Sections 1, 2, and 3 have been classified as Class 3, Class 4, and Class 3, respectively (UDWR 2000). A brief description of each class is as follows.

- **Class 1** waters are blue ribbon trout streams of the state which possess excellent productivity that supports large fish populations.

- **Class 2** waters also provide excellent fishing but are lacking in one category. Many of these waters are comparable to Class 1 waters, except are smaller in size. Water fluctuations may differentiate these waters from Class 1 streams.

- **Class 3** waters are very important because they comprise about half of the total stream fishery habitat and support the majority of recreational fishing pressure in Utah. These waters usually have good water quality, can be of any size, and have fairly good productivity in smaller streams and lower productivity in larger streams. Access is relatively good but likely requires walking, horseback, or off-road travel. Stocking may be required to maintain an acceptable fishery program.

- **Class 4** waters are usually poor in quality with limited fishery habitat. These waters are usually small and have poor scenic value with a short growing season and drawdown or dewatering may occur. Stocking of catchable sized fish are required to maintain a fishery.

- **Class 5** waters are of little value to the sport fishery due to the degradation of the natural environment from human development. A long term sport fishery cannot be established by natural or artificial means.

- **Class 6** waters are those streams that are dewatered for a significant period each year.

Utah streams are given a management classification in addition to the aquatic habitat classification. The management classification denotes how the stream is managed relative to fishing pressure, fish production of the system, and presence of wild fish, species of special concern, or trophy fishery conditions. Sections 1 and 2 of the Provo River are managed for June sucker (UDWR 2000). This management focuses on conservation and enhancement of the species relative to guidelines outlined in the June Sucker Recovery Plan (USFWS 1999). Additionally, Section 1 is managed as a Wildfish Water for white bass (*Morone chrysops*), black bass (*Microptrous sp.*), walleye (*Stizostedion vitreum vitreum*), and channel catfish (*Ictalurus punctatus*) and Section 2 is managed as a Wildfish Water for white bass, black bass, and brown trout *(Salmo trutta)*. Wildfish Waters are those that can be naturally sustained with the fish species and habitat that are presently in the system. The fishery is maintained exclusively via natural reproduction. Section 3 of the Provo

River is managed as an Intensive Yield Water for rainbow trout where 10,000 catchable trout are stocked annually. Intensive Yield Waters are those that provide fishing opportunities in areas where angling pressure is extensive or where habitat is marginal for fishery success (UDWR 2000).

The June sucker was federally listed as an endangered species on April 30, 1986. Critical habitat designated in the listing included the lower 7.8 km (4.9 miles) of the main channel of the Provo River from Tanner Race Diversion (Lower City Dam) downstream to Utah Lake. The documented wild population size at time of listing was less than 1,000 individual spawning adults with a current estimate of approximately 300 individual spawning adults (USFWS 1999).

The Provo River is used by adult June suckers for spawning in late May and June. After hatching, larvae drift downstream to Utah Lake at night. Due to this spawning migration, function of diversion structures within this section of the Provo River is important to recovery of the June sucker (USFWS 1999). Fort Field Diversion is approximately 3 miles upstream of the mouth of the Provo River and is likely a migration barrier during some spawning seasons (C. Thompson 2000, pers. comm.). Lower City Diversion, located at the upstream end of the section of the Provo River that is designated as critical habitat, is a barrier to migration at any flow due to a drop in elevation of approximately 8 feet.

Habitat conditions in Sections 1, 2, and 3 of the Provo River are greatly altered from natural conditions. The majority of the stream banks in these sections have been riprapped with concrete and rock boulders to prevent erosion and control flood waters. The resulting channelization has therefore limited the number of pools in these sections leaving riffles as the primary habitat type (UDWR 1976). Channelization has also virtually eliminated wetlands adjacent to the river providing habitat for river-influenced vegetation only along the raised berms on either side of the river. The majority of overstory vegetation types along side the river include cottonwood, willow, and elm trees with a smaller amount of tamarisk. Aquatic vegetation within the river is extensive during low flow periods and consists primarily of *Potamogeton sp.* Although this aquatic vegetation contributes to low oxygen levels at certain times of the year, it functions in a limited manner as habitat for juvenile and adult trout at a variety of flows.

Water quality data are collected by the Utah Division of Water Quality (DWQ) at the Provo River at Provo USGS gage site, and by the Central Utah Water Conservancy District at the Harbor Drive gage site. Although the Provo River is not included on Utah's year 2000 303(d) list of impaired water bodies, water quality is typically poor in the river's lower reaches during summer months due to low dissolved oxygen levels and elevated temperatures. Below Upper City Dam, polluted storm water runoff from urbanized areas contributes a large portion of the streamflow during storm events. Fish kills associated with polluted runoff are possible in the lower reaches of the river if these storm events occur during low flow periods (USFWS 1999).

Utah Division of Wildlife resources performed a fisheries inventory of several reaches in the project area during winter and spring 1975 (UDWR 1976). Electrofishing conducted 0.3 miles above Lower City Diversion sampled 793 fish which were comprised of 99.5 percent brown trout, 0.1 percent rainbow trout (*Oncorhynchus mykiss*), and 0.4 percent whitefish (*Prosopium williamsoni*). The population estimate for this section of river was 876 +- 36 and was among the highest of all sections sampled for the study. Nongame fish, identified during this sampling but not collected, included sculpin (*Cottus sp.*), mountain sucker (*Catostomus platyrhynchus*), and dace (*Rhinichthys sp.*). Game fish sampled in this section ranged from 235 mm to 272 mm in length and were among the highest total biomass for sections sampled in the study. The estimates may not have represented normal fish densities in this section because of a general downstream movement of fish and because Lower City Diversion serves as a barrier to upstream fish migration.

Additional sampling within the project area included two 0.1 mile sections of stream between Olmsted Power Plant and Murdock Diversion (UDWR 1976). Sampling in these two sections produced a total population estimate of 318 to 358 brown trout. Average length for brown trout from these two electrofishing stations was 236 mm with lengths ranging from 90 mm to 453 mm. Despite the occurrence of juvenile brown trout in this section it was assumed by the UDWR that these fish were recruited from upstream. The other species observed in this section included one 278 mm rainbow trout and sculpin.

Upstream of the project area (Murdock Diversion) UDWR has designated Sections 4, 5, and 6 of the Provo River as Murdock Diversion to Olmsted Diversion, Olmsted Diversion to Utah/Wasatch County line, and Utah/Wasatch County line to Deer Creek Dam, respectively. UDWR assigned sport fish classifications for Sections 4, 5, and 6 as 2, 1, and 1 respectively. Management classifications are designated as Wildfish for all three of the sections and species managed in these sections include rainbow trout, brown trout, and cutthroat trout. Additionally Sections 4, 5, and 6 provide the best spawning habitat and rearing areas in the lower Provo River and thereby provide lower sections with a substantial supply of trout for angler harvest. Tributaries including Deer Creek, South Fork Provo River, and North Fork Provo River add to spawning and rearing habitat in these sections as well.

Existing Diversions

Existing diversion structures on the lower Provo River are listed, from upstream to downstream, in Table 1, and their locations are shown in Figure 1.

The amount of water diverted from the river at each structure varies widely. Data on historical diversion amounts were obtained from the Division of Water Rights (DWRT) data base (DWRT 2000) and from the Provo River Commissioner (S. Roberts 2001, pers. comm.). In general, the greatest amount of water is removed at the Murdock diversion, and the least amount of water is removed at the Fort Field diversion (Figures 3 and 4). At all eight structures, June and July are typically the months when the greatest amount of water is diverted (Figure 3). The diversion season on the lower Provo River typically begins in April and ends in October, although in some years water is only diverted from May through September. The various diversions cumulatively deplete stream flows in the lower Provo River.

Figure 5 shows mean monthly stream flow for the Provo River between Upper Union diversion and the USGS gage near Utah Lake. Because stream flow is not directly measured upstream from the USGS gage, values were calculated by subtracting diversion amounts from the measured stream flow at the gage. Stream flows upstream from the Upper Union diversion are not presented here because reliable calculations were not possible due to the complexity of inflows and outflows in this segment of the river (see Figure 4).

Table 1. Summary of existing diversions on the lower Provo River.

DIVERSION	LOCATION	TYPE OF STRUCTURE DAM	 HEADWORKS	CANAL(S) SERVED
Murdock	SE 1/4, Sect.6, T6S, R3E	Concrete	radial gate in concrete	Murdock Canal
Timpanogos	NW 1/4, Sect.7, T6S, R3E	Kick-leg	radial gate in concrete	Timpanogos Canal
Provo Bench (River)	NW 1/4, Sect.7, T6S, R3E	Kick-leg	flashboard slot	Provo Bench Canal
Provo Bench (Tailrace)	NW 1/4, Sect.7, T6S, R3E	Concrete+ flashboards	radial gate in concrete	Provo Bench Canal
Upper Union	SW 1/4, Sect.7, T6S, R3E	Kick-leg	radial gate (2) in concrete	Upper E. Union, E. Riverbottom, Faucett Field, W. Union, W.Smith, Carter
Lake Bottom	NE 1/4, Sect.25, T6S, R2E	Rock/ rubble (partial)	metal slide gate (no concrete)	Lake Bottom
Upper City Dam	SE 1/4, Sect.25, T6S, R2E	Concrete +Kick-leg	metal slide gate in concrete	Factory Race, Lower E. Union
Lower City Dam	SW 1/4, Sect.36, T6S, R2E	Concrete +Kick-leg	metal slide gate in concrete	Tanner Race, Little Dry Creek
Fort Field	SW 1/4, Sect.2, T7S, R2E	Kick-leg	metal slide gate in concrete	Fort Field

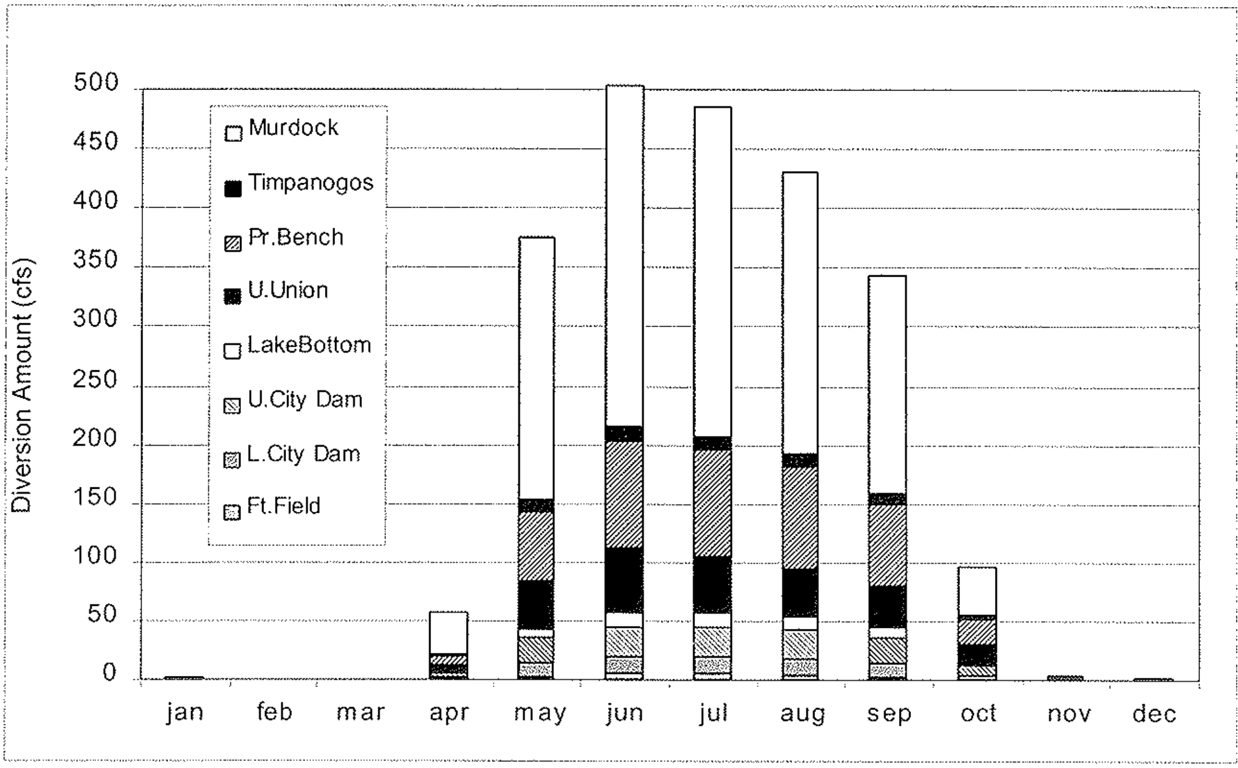

Figure 3. Mean monthly diversion amounts for the lower Provo River.

It is important to note that the diversion amounts depicted in Figures 3, 4, and 5 and listed in Tables 2 through 10 represent average values for the period of record 1950-1999. Substantial changes in the operations of the Provo River system have taken place since 1994. These changes have occurred as a result of the completion of Jordanelle Dam and also due to the 1994 Biological Opinion issued by the Fish and Wildlife Service requiring the Bureau of Reclamation to alter flow releases from Deer Creek Dam to benefit the June sucker (USFWS 1994, UDWR 1999). As discussed above, new target flow releases that mimic a more natural hydrograph have been established, and these flows were implemented experimentally in 1999 and 2000 (C. Keleher 2000, pers. comm). These flows were also implemented experimentally in 2001, although the target low water year peak flow was not achieved (CUWCD 2001). In order to better reflect these recent changes, average diversion amounts for the time period 1994-1999 were calculated for two representative dates: July 10 and August 10. Figure 6 shows average July 10 and August 10 daily stream flow and diversion values for the Provo River between Upper Union Diversion and the USGS gage near Utah Lake. Because stream flow is not directly measured upstream from USGS gage, values were calculated by adding diversion amounts to the measured stream flow at the gage. These calculated values do not account for storm drain inputs or groundwater seepage or inflow; therefore, potential inaccuracies exist. However, Figure 6 does provide a representation of how flows in the lower Provo River are affected by diversions, and this representation is as accurate as possible given the available flow and diversion data.

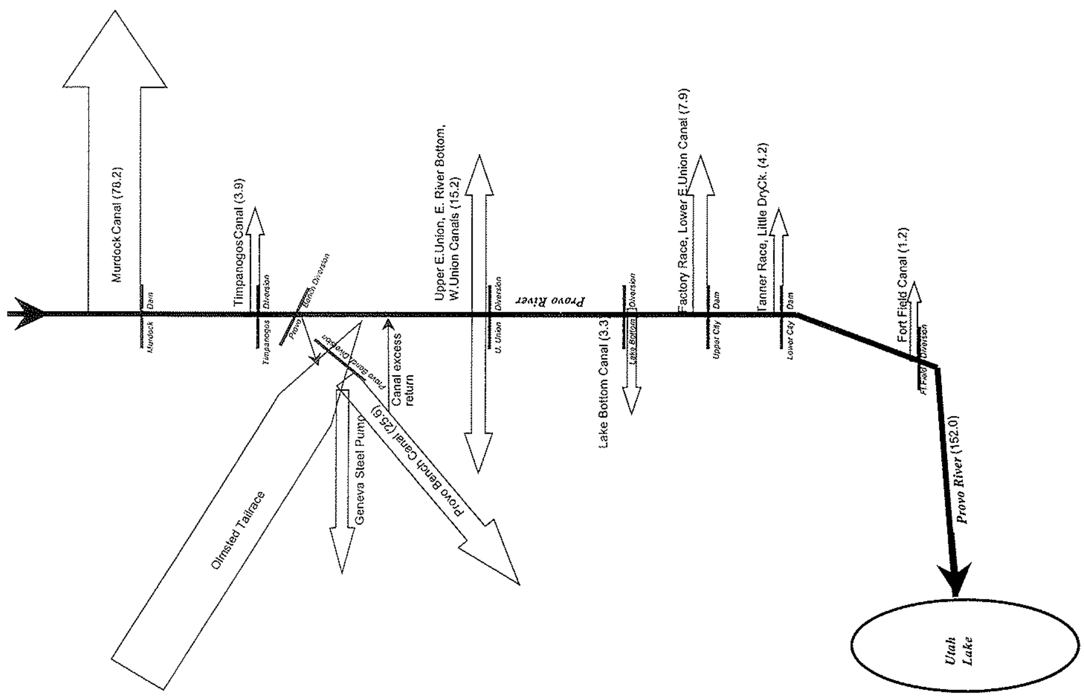

Figure 4. **Schematic diagram of diversions on the lower Provo River. Numbers in parentheses indicate average annual diversion or streamflow amount in 1,000 acre-feet for the period of record, 1950-1999.**

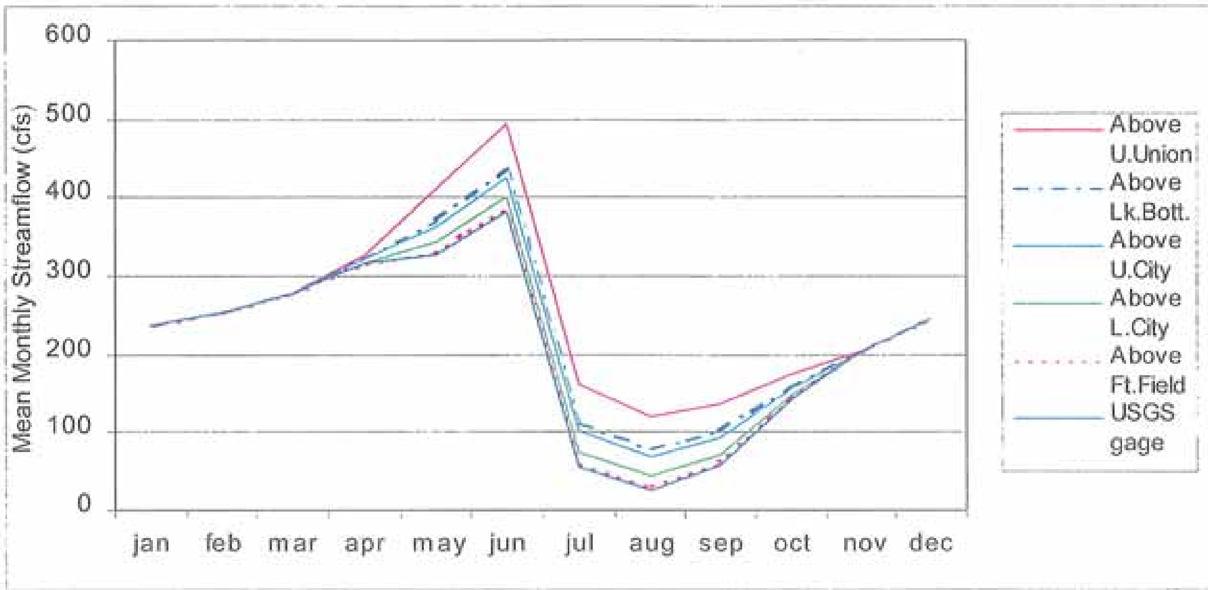

Figure 5. Mean monthly stream flow (water years 1950-1999) for the Provo River between Upper Union diversion and Utah Lake.

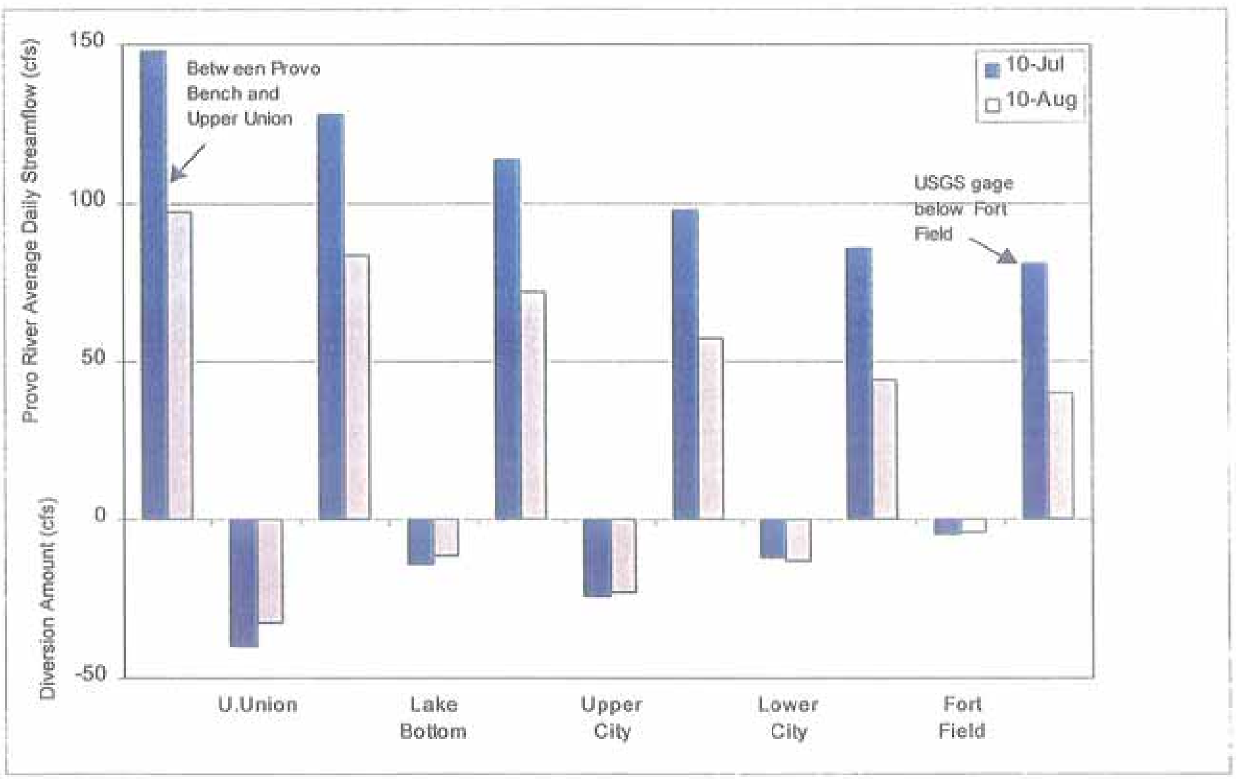

Figure 6. Average July 10 and August 10 streamflow and diversion values for water years 1994-1999. Data shown starting below the Provo Bench diversion and moving downstream to below the Fort Field diversion.

SUMMARY INFORMATION/ EVALUATION CRITERIA

Water Rights Information

Data on water rights, area served, and monthly canal flows were obtained from the Utah Division of Water Rights database (DWRT 2000), with review and additions by the Provo River Commissioner (S. Roberts 2001, pers. comm.). The water rights information presented in this report is not intended to be an exhaustive description of every water right and its priority; such information is beyond the scope of this project. The water rights information presented here is simply intended to provide an indication of the potential magnitude of water withdrawals at each diversion structure.

Water rights on the Provo River are highly complex, reflecting the long history of water diversion on the system. Over time, water rights have been transferred and segregated, points of diversion have been shifted or added, and new rights have been established. Water rights on the Provo River were first adjudicated in 1921 as the Provo River Decree, also known as the Morse Decree (JMM 1993). Within the Provo Division, which encompasses the Provo River between Deer Creek Reservoir and Utah Lake, water is divided into classes of rights from Class A (highest priority) through Class J (lowest priority). The majority of water rights listed in Tables 2 through 12 of this report are Class A water rights.

The water right values listed in Tables 2 through 12 represent the amount of water that a user can divert during the time period May 10 to June 20. Water rights on the lower Provo River are commonly bracketed into four time periods: May 10 to June 20; June 20 to July 20; July 20 to September 1; September 1 to May 10. The amount of the water right is greatest during the May 10 to June 20 time period and becomes incrementally smaller during the later time periods. The water right values for the May 10- June 20 period are presented as an indication of the relative water right magnitudes at the different diversion structures during the time period when June sucker spawning often occurs (UDWR 1999). These water right values do not represent the amount of water that is actually diverted in any given year. In wet water years, water users may be requested to divert a greater flow than their water right in order to alleviate the potential for downstream flooding.

Murdock (Provo Reservoir), Provo Bench, West Union, and East Riverbottom Canals are listed as points of re-diversion under several water rights held by the U.S. Bureau of Reclamation (BOR). For the most part, these water rights are associated with water imported via the Duchesne Tunnel or Weber-Provo Canal, or with water stored in Deer Creek Reservoir.

Dam Stability

Dam stability was rated as "good", "fair", or "poor" during the field evaluation conducted on 7/25/00. Diversion dam stability is important to fish and wildlife resources because dams that wash out frequently or require frequent maintenance work can cause habitat disruption in the vicinity of the structure. When a structure washes out, riparian vegetation may be lost and associated stream bank erosion could lead to increased sediment levels that can impair water quality and degrade spawning habitat. Maintenance and repair work often requires the instream use of heavy equipment, resulting in additional habitat disruption and adverse effects to fish and wildlife resources.

For this project, the stability rating was based on what would be considered good, fair, or poor stability for a given diversion structure type, rather than attempting to differentiate among different types of structures (i.e., the fact that a concrete dam is an inherently stronger structure than a kick-leg dam was not considered - it is assumed that the reader can determine this by comparing the information provided under the "dam type" category). Stability was considered "good" if a dam of a given type was in good condition, with little or no erosion of the structure. Stability was considered "fair" if the dam materials exhibited signs of wear, or if erosion was present. Dams rated "fair" for stability are considered stable under regularly occurring flow levels (i.e., flows with recurrence intervals of 1 to 2 years), but vulnerable to being undermined or extensively damaged by larger floods. The "poor" stability category was reserved for structures that would be vulnerable to being washed out by regularly-occurring flows (i.e. the annual spring flood), and require frequent, major repairs. None of the structures evaluated on the lower Provo received a rating of "poor" for stability.

Headworks Stability

The stability of canal headworks is of concern to fish and wildlife resources for the same reasons described above for dam stability. Headworks with "good" stability were made of materials that were in good condition with little chance of being undermined or washed out by regularly-occurring floods (i.e., floods with recurrence intervals of less than 20 years). Headwork stability was considered "fair" if headworks materials showed substantial signs of wear, or if they were vulnerable to erosion. The "poor" category was reserved for headworks at high risk of being washed out by annual floods. Again, none of the structures evaluated received a "poor" rating.

Monthly Canal Flows

Daily records of canal flows for the period of record 1950-1999 were obtained from the Utah Division of Water Rights database (DWRT 2000). These data were sorted by month and year, and the monthly mean flows were calculated for the period of record. For each year of data, the highest and lowest daily values recorded in each month were identified and then averaged for the period of record to derive "minimum mean" and "maximum mean" monthly flows. Please note that the flow and water rights data used in this evaluation and presented in this report were derived from the best available information; however, no other claim to its accuracy or validity is implied by BIO-WEST, the Commission, or the Provo River Commissioner.

Fish Migration Barrier

Criteria for evaluation of diversion structures as migration barriers included assessment of height of diversion structure, ratio of height of diversion versus depth of plunge pool, and presence or absence (and resulting function) of an apron downstream of the structure. Bjorn and Reiser (1991) reviewed spawning migration related literature and reported that brown trout had maximum jumping heights of 0.8 m. Also, they referenced a laboratory study that identified leaping conditions as ideal for fish when the ratio of height of falls to depth of pool below falls is 1:1.25. Therefore, those structures that did not favor these dimensions were deemed unpassable by brown trout and other salmonid species. Aprons directly below diversions further reduced the ability of a structure to be fish passable. At lower flows aprons generally have a shallow depth of water passing over them and therefore do not provide the ideal height of falls to depth of pool ratio.

Migration barrier evaluation criteria for June sucker were more stringent due to the decreased swimming efficiency of the species as compared to salmonids. No literature was found regarding the leaping ability (or lack thereof) of June sucker. However, the cui-ui (*Chasmistes cujus*) is a sucker species of the same genus as June sucker and has a similar life history that has been studied more extensively. Research indicates that the cui-ui has no leaping ability and if passage is made difficult they will abandon spawning and try again the following year. Also, older individual cui-ui are less tolerant of difficult migration conditions with respect to velocity and barriers (G. Scoppettone 2001, pers. comm.). While the spawning situation is somewhat different for June sucker, given the above information it is likely that obstructions even very minimal in height would not be ascendable. Therefore, those diversion structures that could not be taken down to streambed level during the spawning migration were deemed impassable for June sucker.

Fish Entrainment Potential

Entrainment of fish into canals is the act of fish either passively or actively entering a canal from the river. Size of fish present in the river (i.e. larvae, juvenile, adult) and the size of the canal opening or screen on the canal determined whether entrainment was possible. Because fish were not physically sampled as part of this project, it was not possible to confirm whether or not fish were present in canals; therefore, evaluation of this criteria was based on whether or not the potential for fish entrainment existed at a given diversion structure.

Diversion Operated as Dry Dam

Diversions may potentially be operated as dry dams during times of low flow. Under this condition, all or nearly all of the flow in the river is diverted into a canal, potentially causing the channel to be dewatered for some distance downstream from the structure. On the lower Provo River, leakage or seepage through the diversion dams generally provides some water downstream, even if flows are not passed downstream intentionally. Therefore, what is termed a "dry dam" for the purposes of this report generally results in "semi-dry" downstream conditions. However, leakage flows may be still be too low to provide usable habitat, and fish may become stranded in isolated pools. Frequent dewatering of a stream reach also has the potential to adversely affect water-dependent macroinvertebrate species, riparian vegetation species, and associated wildlife. The evaluation of whether or not structures are operated as dry dams was based on discussions with the Provo River Commissioner as well as field observations made during the 7/25/00 evaluation effort.

Flow Bypass Capability

Legally, a diversion structure may only divert water up to the amount of its established water right, and must allow water that belongs to downstream users to bypass the structure. Ideally, each diversion structure would have a mechanism to ensure that a set amount of water is bypassed downstream. Such a mechanism would include devices to accurately measure the amount of water being diverted as well as the amount of water being bypassed downstream. On the lower Provo River, the ability for diversion structures to bypass a set amount of water will become increasingly important as instream flow rights are acquired by the CUWCD.

Diversion Structure Trapping Bedload

Depending on the type and size of a diversion dam, the structure may either trap bedload sediment or allow it to pass downstream. Structures that trap bedload can cause fine sediments to accumulate in the reach above the diversion, embedding the substrate and adversely affecting aquatic habitat. Structures that trap sediment may also periodically require maintenance to remove accumulated material and restore diversion capacity. Maintenance activities that require the instream use of heavy equipment are disruptive and can have adverse effects on water quality, bank erosion, and riparian vegetation. The evaluation of whether or not diversion structures trap bedload was based on field observations made during the 7/25/00 evaluation effort. Structures were examined for evidence of fine sediment accumulation above the structure, and for evidence of bedload movement over the structure (i.e., gravel accumulation on the downstream sill or apron of the diversion dam).

Streambed Degradation

The presence of a diversion structure can lead to degradation of the streambed downstream from the structure. There are various processes that may contribute to degradation of the channel. Diversions that trap bedload above the structure and reduce the downstream sediment load can lead to bed erosion because there is less sediment available for transport and the water has more energy available to scour the channel bed. During high flows, the downward energy of water flowing over a diversion dam can scour the bed immediately downstream. Upstream-migrating headcuts are another process that may be responsible for channel degradation in the Provo River. The main problem associated with streambed degradation in the vicinity of diversion structures is the potential for the degradation to undermine the structure and cause it to fail. When a structure fails, riparian vegetation may be lost and associated streambank erosion could lead to increased sediment levels that can impair water quality, degrade spawning habitat, and limit macroinvertebrate production. Maintenance and repair work often requires the instream use of heavy equipment, resulting in additional habitat disruption and adverse effects to fish and wildlife resources. Streambed elevation differences above and below each diversion structure were measured in the field using a clinometer and stadia rod. A bed elevation difference of less than 2 ft. was considered "slight"; a difference of 2-5 ft. was considered "moderate"; and a difference greater than 5 ft. was considered "substantial".

Canal Intercepting Bedload

Certain types of diversion structures are designed to prevent bedload sediment from entering the canal headworks, while other structures allow bedload to pass into the canal. From a water use standpoint, bedload sediment that enters a canal can become problematic if it accumulates and reduces canal conveyance capacity or clogs irrigation works. From a fish and wildlife resource standpoint, diversions that prevent sediment from entering canals can be problematic because downstream flows are reduced but the sediment load is not. This can cause bed aggradation and accumulation of fine sediments downstream from the diversion structure and potentially degrade spawning habitat. During the 7/25/00 field evaluation effort, diversions were examined for evidence of bedload passing into canals, and it was noted whether or not the diversion included a structure to prevent bedload from entering the canal.

Canal Substrate Material

The type of canal substrate material was noted for each diversion structure. This information is important from a water efficiency standpoint. Canals with bed and banks composed of natural sediments typically have fairly high leakage and surface evaporation rates. Concrete-lined canals have lower leakage rates. Canals that are piped have low leakage rates as well as much lower evaporation rates. Delivering a required amount of water to a downstream user through a canal with a high loss rate may require the water to be initially diverted at a higher rate than the actual consumptive use rate. In contrast, water diverted through a pipe can be delivered at essentially the same rate it is diverted. Water efficiency improvements from lining or piping canals can benefit fish and wildlife resources because more water can be kept in the natural stream. However, canals with natural bed and bank materials commonly support riparian vegetation and provide habitat for riparian-dependent fauna. These habitat benefits are not as great for concrete-lined canals or pipes.

Impact to Riparian Vegetation

The condition of riparian vegetation in the vicinity of each diversion was noted during the July, 2000 field evaluation. Diversion structures have the potential to directly and indirectly affect riparian vegetation. Direct impacts occur when riparian vegetation is removed during installation of a diversion structure or during maintenance activities. Indirect effects due to flow depletions can also occur in the channel reach downstream from diversions. Reduced flow levels can result in increased riparian vegetation density if plants encroach onto newly-exposed channel surfaces. However, if flow depletions are extreme, riparian vegetation density may decrease downstream due to dessication of plants. At each diversion structure evaluated on the lower Provo River, riparian vegetation density was similar upstream and downstream from the structure, suggesting that flow depletions have not had a measurable adverse impact on riparian vegetation. Impacts appear to be limited to small areas where vegetation was removed in order to install the diversion dam sidewalls and canal headgates. Vegetation impacts from maintenance activities are minimal due to the low maintenance requirements of lower Provo River diversion structures. As discussed previously, however, the overall quality and functional health of the riparian corridor within the study area is limited due to the channelized condition of the lower Provo River.

EVALUATION RESULTS

This section presents a description of each of the eight diversion structures previously listed and the results of the evaluation based on the criteria described above. Photographs and summary tables are provided. These descriptions and evaluation results are based on site visits made in June and July, 2000, discussions with the Provo River Commissioner, and information obtained from the Utah Division of Water Rights database (DWRT 2000) and the CUWCD Draft Technical Memorandum (JMM 1993). Additional reference materials that were consulted are listed at the end of this document.

Again, BIO-WEST emphasizes that the water rights information presented in this report is not intended to be an exhaustive description of every water right and its priority. The information presented and evaluated was obtained from the best available sources; however, no other claim to its accuracy or validity is implied by BIO-WEST, the Commission, or the Provo River Commissioner.

Brief lists of recommendations for diversion improvements are provided following the description of each diversion structure. A number of these recommendations are general items that are listed for all structures. One common recommendation is to make the diversion structures fish passable for salmonids and June sucker. These fishes are specifically identified because June sucker and brown trout are the two species that currently have the highest management priorities in the Provo River. Although the endangered June sucker's habitat is currently restricted to the portion of the Provo River below Lower City Dam, access to upstream areas may become important for species recovery once rearing conditions in Utah Lake and the lower river are improved. Therefore, provision of passage for June sucker is included as a long-term recommendation for all diversion structures that are currently migration barriers.

A second recommendation common to all structures is to investigate the need to prevent entrainment of larval, juvenile, and adult fish in canals. This recommendation is made because, although assessment of the potential for entrainment was completed as part of this study, more detailed physical sampling is needed to quantify the extent of the problem for different species and sizes of fish.

A final general recommendation involves provision of minimum instream flows and installation of flow bypass and flow measurement devices on diversion structures. As previously discussed, the CUWCD is currently pursuing the objective of providing a year-round minimum instream flow of 75 cfs. As instream flow water rights are acquired, bypass devices capable of passing a measured flow amount downstream will be needed on the lower Provo River diversion structures.

Murdock Diversion

Summary information and photographs of the Murdock Diversion are provided in Table 2 and Photos 1-1 through 1-6.

The existing diversion structure is in good condition and consists of a concrete dam with a radial gated sluiceway on the south (river left) side of the dam. The headworks to the Murdock Canal consist of a metal radial gate installed on the south (river left) side of the dam and sluiceway.

During the diversion season (generally from April through October), the sluiceway gate is kept closed and bypass flows that pass over the dam are measured using an automated stage reader operated by the Provo Reservoir Water Users Company. Accurate measurements of flows that bypass Murdock Dam are not available for the winter or spring months (S. Roberts 2000, pers. comm.). Murdock is not operated as a dry dam because 12 cfs must be bypassed downstream to meet water rights at the Timpanogos diversion. This 12 cfs is typically bypassed through a pipe located in the sidewall of the Murdock Canal that returns water from the canal to the river below the dam. Therefore, water may not always spill over the crest of the dam, but instream flows are always present in the river below the dam.

Murdock Dam creates a complete barrier to upstream fish migration at all flows, and the 3 inch spacing of the trash grate located at the canal entrance is inadequate to prevent fish from becoming entrained in the canal. The initial portion of Murdock Canal consists of a concrete-lined channel, but shortly downstream the canal enters a pipe and passes under the highway.

Provo River Water Users Association (PRWUA) operates and maintains the Murdock (Provo Reservoir) Canal and Murdock Diversion. The facilities lie on land owned in fee title or easement by the U.S. Bureau of Reclamation. Water diverted at the Murdock Diversion can either be PRWUA water stored in Deer Creek Reservoir or Provo Reservoir Water Users Company water that can include stored water or direct flow water rights.

Recommendations

- Investigate need to prevent larval, juvenile, and adult fish entrainment. Devise and implement preventative measures as appropriate.
- Install device to measure flows that are bypassed downstream during winter and spring months - may be possible to use existing sluiceway.
- Provide passage for salmonids, June sucker, and other fish species.

Table 2. Murdock Diversion Summary and Evaluation.

Characteristic/Criterion	Data/Comment		
General			
Location:	SE 1/4, Sect.6, T6S, R3E		
Canal(s) Served:	Murdock (also known as Provo Reservoir Canal)		
Total Acres Served:	not available		
Total Water Right (cfs):	252.357 (5/10-6/20) plus appx. 2,630 cfs BOR re-diversion rights		
Known Water Right Numbers:	35-8737, -8756; 43-341,-343,-344; 55-262,-295,-7060,-7061,-7899		
Diversion Structure			
Dam Type:	Concrete		
Dam Stability:	Good. No evidence of erosion or cracking of structure		
Headworks Type:	Metal radial gate set in concrete; opens at bottom		
Headworks Stability:	Good		
Flow Bypass Device:	Radial-gated sluiceway, dam spillway, canal bypass pipe		
Flow Measuring Device (Canal):	15 ft. Parshall Flume		
Diversion Record Summary			
Period Covered		1950-1997[1]	
Monthly Flow Data (cfs)	Minimum Mean	Mean	Maximum Mean
January	0	0	0
February	0	0	0
March	0	0	0.03
April	0.3	35.5	140.7
May	113.2	222.3	307.1
June	209.8	288.2	337.4
July	196.9	278.7	319.4
August	186.6	238.7	277.5
September	124.1	184.8	235.5
October	2.1	40.5	126.2
November	0	0.2	0.45
December	0	0.01	0.2

[1] No data available for 1990

Table 2 (cont.). Murdock Diversion summary and evaluation.

Characteristic/Criterion	Data/Comment
Evaluation Criteria	
Fish migration barrier	**Yes** (all flows). Water surface elevation difference above and below structure is approximately 11.9 feet
Fish entrainment potential	**Yes.** Trash grate (3" wide slots) at entrance to canal ineffective as fish barrier. Large volume of water entering canal makes entrainment likely.
Diversion structure operated as a dry dam	**No.** Flows bypassed to meet water rights at Timpanogos diversion.
Flow bypass capability	**Yes.** Flows can by bypassed over the dam spillway, through the radial gated sluiceway, and/or through the small release pipe (approximate diameter 9-12") that conveys water from the canal back into the river below the dam.
Diversion structure trapping bedload	**No**. Very little fine sediment evident on stream bed above diversion structure.
Streambed degradation (elevation differences above and below structure)	**Slight**. Bed elevation difference approximately 1.5 ft. Deep pool is present above structure.
Canal intercepting bedload	**Yes**. No structure present to prevent bedload from entering canal, although 3" grate prevents large rocks from entering.
Canal substrate material	Initial ~1,000' section has concrete bed and banks, then piped under road, then enters open canal again >1 mile downstream from diversion.
Impact to riparian vegetation	**Minimal**. Impact limited to dam and headgate locations.

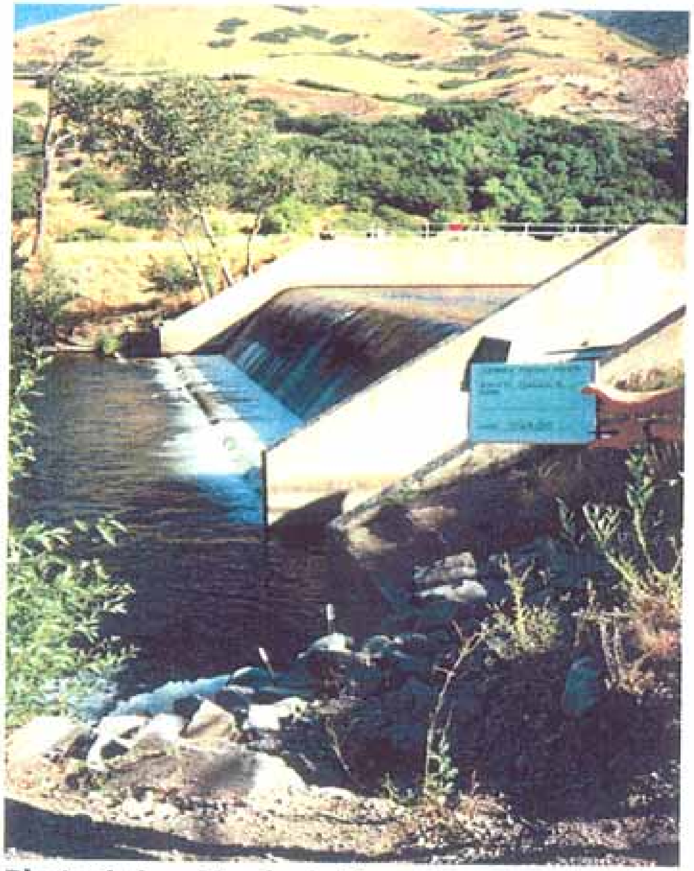

Photo 1-1. Murdock Diversion structure.

Photo 1-2. Murdock Diversion: view of structure and radial-gated sluiceway.

Photo 1-3. Murdock Diversion: grate at canal headworks.

Photo 1-4. Murdock Diversion: upstream view of headworks canal.

Photo 1-5. Murdock Diversion: channel upstream from structure.

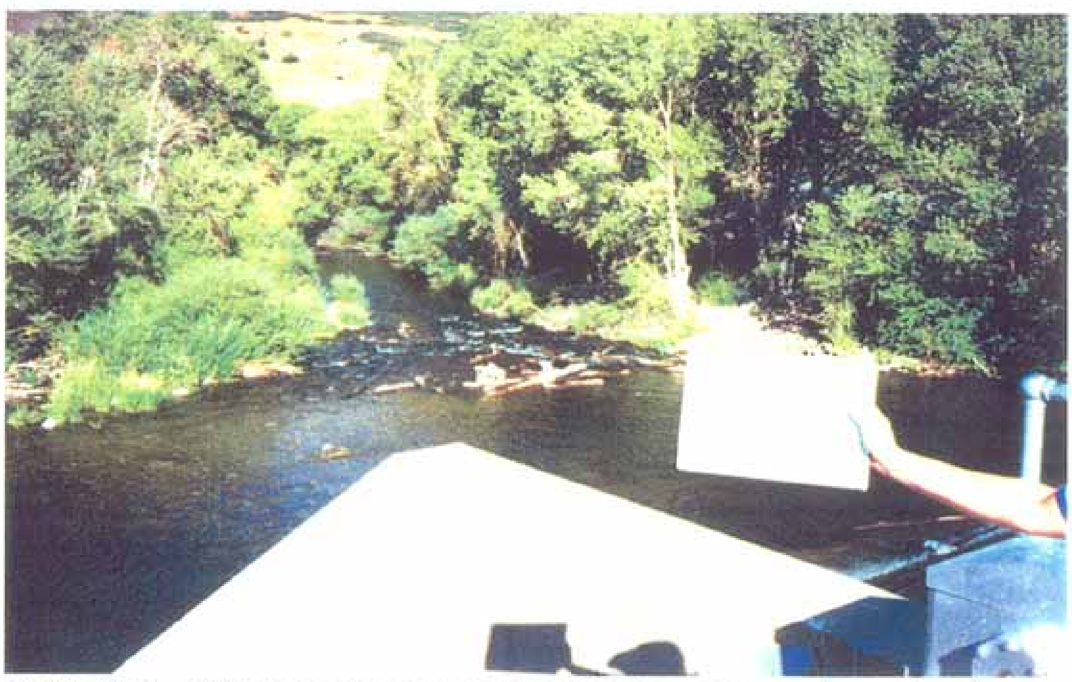

Photo 1-6. Murdock Diversion: channel downstream from structure.

Timpanogos Diversion

Summary information and photographs of the Timpanogos Diversion are provided in Table 3 and Photos 2-1 through 2-5.

The existing diversion structure is in good condition and consists of a kick-leg dam installed with concrete sidewalls and a flat concrete sill that lies flush with the streambed. No flow bypass device is present. During high flow years, the dam is taken down so that it will not be damaged. The Provo River Commissioner estimated that the dam has been removed and re-assembled 3 or 4 times in the last 10 years (S. Roberts 2000, pers. comm.). The canal headworks consist of a metal radial gate set in concrete. The initial section of the canal is approximately 300 feet long and has bed and banks made of natural materials. After this initial section, the canal is piped. A mechanical moving screen has recently been installed at the entrance to the piped section of the canal. The CUWCD has recently purchased water shares associated with this canal, and in the future instream flows will be provided below this structure. Based on Division of Water Rights records, the average maximum canal flows during May, June, and July exceed the legal water right of 14.12 cfs (Table 3).

Under most flow conditions, the diversion structure acts as a barrier to upstream migrating fish, and fish moving downstream have the potential to become entrained in the initial section of the Timpanogos canal. The Timpanogos diversion is commonly operated as a dry dam, dewatering an 800 foot-long reach downstream to the confluence of the Provo River with the Olmsted tailrace. This practice does not appear to have adversely affected riparian vegetation in the dewatered reach. Healthy stands of willows and box elders were observed both above and below the diversion.

Recommendations

- Investigate need to prevent larval, juvenile, and adult fish entrainment. Devise and implement preventative measures as appropriate. This may involve screening at headgate on river, or providing bypass pipe upstream of mechanical moving screen to return larval, juvenile, and adult fish to river from canal.
- Provide minimum instream flows below the structure.
- Provide fish passage for salmonids, June sucker, and other fish species.
- Install bypass device and measurement device to ensure instream flows are provided.

Table 3. Timpanogos Diversion summary and evaluation.

Characteristic/Criterion	Data/Comment		
General			
Location:	NW 1/4, Sect.7, T6S, R3E		
Canal(s) Served:	Timpanogos		
Total Acres Served:	847.0		
Total Water Right (cfs):	14.12 (5/10-6/20)		
Known Water Right Numbers:	55-11006		
Diversion Structure			
Dam Type:	Kick-leg		
Dam Stability:	Good. Kick-leg boards and metal supports are in good condition		
Headworks Type:	Metal radial gate set in concrete; opens at bottom		
Headworks Stability:	Good		
Flow Bypass Device:	None		
Flow Measuring Device (Canal):	4 ft. Parshall Flume		
Diversion Record Summary			
Period Covered	1954-1998[1]		
Monthly Flow Data (cfs)	Minimum Mean	Mean	Maximum Mean
January	0.7	0.9	1.2
February	0.6	0.6	0.7
March	0.4	0.6	0.8
April	0	1.4	3.8
May[2]	4.2	10.1	14.8
June[2]	8.4	12.7	15.7
July[2]	8.0	11.3	14.6
August	8.1	10.1	12.1
September	6.4	8.9	11.4
October	1.8	4.7	8.6
November	1.0	1.5	2.3
December	1.0	1.3	1.5

[1] No data available for 1985,1986,1988,1990,1991,1992,1993,1995
[2] Flows in these months sometimes exceed water right due to diversions to reduce downstream flooding

Table 3 (cont.). Timpanogos Diversion summary and evaluation.

Characteristic/Criterion	Data/Comment
Evaluation Criteria	
Fish migration barrier	**Yes** (at most flows). Water surface elevation difference above and below structure is greater than 3 feet under low flow conditions; at high flows, increased standing wave height may enable migration
Fish entrainment potential	**Yes** (for 1st 100 yds). Trash grate (3" wide slots) at entrance to canal ineffective as fish barrier. Fish may be entrained in first 100 yards of canal before canal is piped and passage blocked by mechanical moving fish screen.
Diversion structure operated as a dry dam	**Yes.** According to the River Commissioner, the Provo River has been frequently dewatered in the past between Timpanogos and the Olmstead Tailrace (a distance of about 800 feet).
Flow bypass capability	**No.** The diversion structure does not have a mechanism to ensure a set amount of water is bypassed.
Diversion structure trapping bedload	**No.** Very minor accumulation of fines evident above structure; fines flushed when structure is removed during high runoff years
Streambed degradation (elevation differences above and below structure)	**Slight.** Bed elevation difference approximately 0.8 ft.
Canal intercepting bedload	**Yes.** No structure present to prevent bedload from entering canal; canal substrate material similar to natural channel substrate.
Canal substrate material	Natural bed and banks for 1st 100 yards, then piped.
Impact to riparian vegetation	**Minimal.** Impact limited to dam and headgate locations.

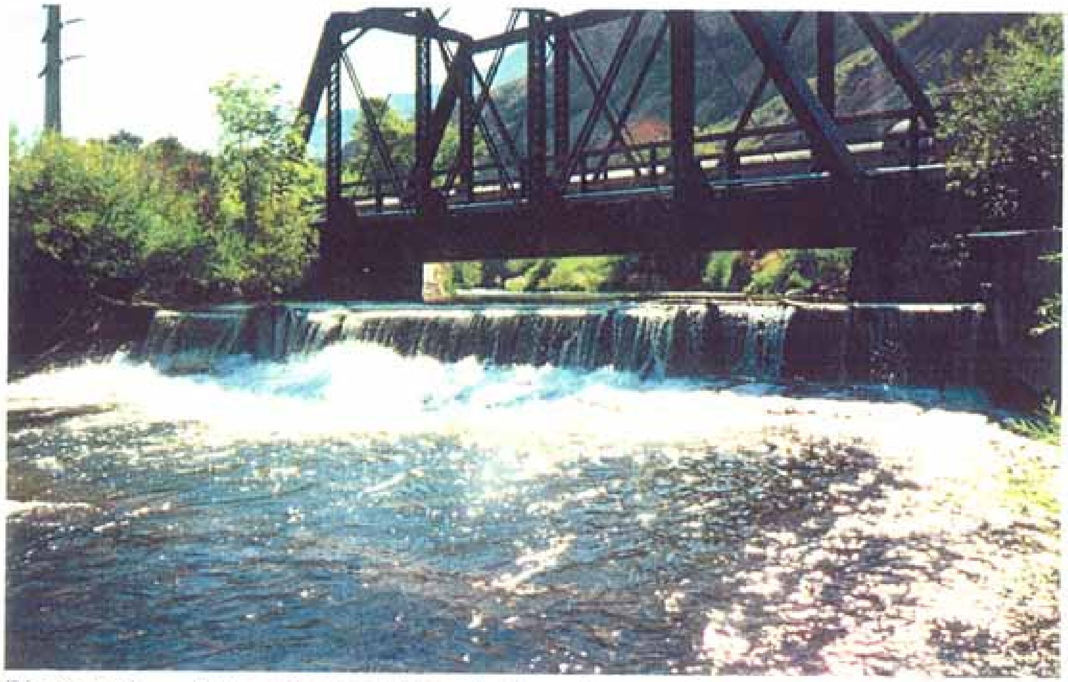

Photo 2-1. Timpanogos Diversion: upstream view.

Photo 2-2. Timpanogos Diversion: downstream view.

Photo 2-3. Timpanogos Diversion: kick-leg structure.

Photo 2-4. Timpanogos Diversion: canal headworks.

Photo 2-5. **Timpanogos Diversion: mechanical moving fish screen at pipe entrance.**

Provo Bench Diversion

The Provo Bench diversion consists of two separate diversion structures: one on the Provo River itself, and one on the Olmsted Tailrace (Figures 1 and 4). Both of these structures can be used to divert flows into the Provo Bench Canal. The diversion structure on the river is used to augment the flow in the Tailrace for subsequent diversion by the Provo Bench diversion structure on the tailrace. Typically, during the summer irrigation season, flows in the tailrace are much greater than in the river, and the structure on the river is often not used because the channel is commonly dewatered below the Timpanogos Diversion just upstream[1]. The two Provo Bench structures were evaluated separately.

Structure on River

Summary information and photographs of the Provo Bench - diversion on river are provided in Table 4 and Photos 3-1 to 3-5.

The existing diversion structure is in fair condition and consists of a kick-leg dam installed with concrete sidewalls and a flat concrete sill. This concrete sill lies flush with the streambed above the dam, but below the dam considerable scour has occurred at the base of the sill (Photo 3-1). Rip rap has been placed below the sill and this appears to have halted the scour/ undercutting process; however, the potential exists for further undercutting to occur during high flow events. No flow bypass device exists for this structure. The diversion feeds a short section of canal that connects to the Olmsted tailrace. The entrance to this canal consists of openings between concrete footbridge pillars. Although no defined headgate is present, the entrance to the canal could be blocked by placing flashboards in vertical slots between the pillars.

The channel is periodically dewatered both upstream and downstream from this structure due to Timpanogos Canal diversions, but this condition does not appear to have adversely affected riparian vegetation. Healthy, dense stands of willows are present both above and below the structure. The diversion creates a barrier to fish migration at all flows, both because of the height of the structure and because flows are thinly spread out across the full width of the structure.

Recommendations

- Because flows in the Olmsted Tailrace are typically sufficient to meet Provo Bench Canal water rights, the entrance to the "connector" canal between the river and tailrace should be kept closed (expect for occasional times when power plant is not operating and supplemental flows are needed). This will prevent fish from becoming entrained in the canal.[1]

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[1]The Olmsted Power Plant is currently operated under an Agreement with the United States whereby excess capacity in the Olmsted flowline, if available, can be used to transport water for electrical generation at the Olmsted Power Plant, through 2014. Operation of the Olmsted Power Plant will likely change because of this

- Investigate need to prevent larval, juvenile, and adult fish entrainment. Devise and implement preventative measures as appropriate. This may involve installation of fish screen at the "connector canal" entrance to prevent larval, juvenile, and adult fish entrainment during times when supplemental flows are diverted.
- Install measurement device in connector canal to accurately measure diversion amount.
- Provide fish passage for salmonids, June sucker, and other fish species. This may require narrowing the structure in order to concentrate flows into a bypass "notch" and maintain adequate water depths for passage.
- Install measurement device on bypass "notch" to ensure instream flows are provided.

Agreement in the future, and sufficient flows may not be available from the tailrace to meet Provo Bench Canal water rights. Diversions from the Provo River to meet the water rights may be required in the future.

Table 4. Provo Bench - Diversion on River: summary and evaluation.

Characteristic/Criterion	Data/Comment
General	
Location:	NW 1/4, Sect.7, T6S, R3E
Canal(s) Served:	Provo Bench Canal, Geneva Steel Pipeline
Total Acres Served:	4332.53
Total Water Right (cfs):	95.63 (5/10-6/20) plus appx. 2,630 cfs BOR re-diversion rights
Known Water Right Numbers:	55-11007, 55-278
Diversion Structure	
Dam Type:	Kick-leg
Dam Stability:	Fair. Considerable scour has occurred at base of concrete sill; placed rip rap now preventing further scour/ undercutting
Headworks Type:	Concrete bridge pillars with slots for flashboards
Headworks Stability:	Good. Some minor erosion at base of concrete pillars
Flow Bypass Device:	None
Flow Measuring Device (Canal):	14.25 foot rect. suppressed weir

Diversion Record Summary

Period Covered: 1952-1999[1]

Monthly Flow Data (cfs)[2]	Minimum Mean	Mean	Maximum Mean
January	0.0	0.0	0.0
February	0.0	0.0	0.0
March	0.0	0.0	0.0
April	0.0	6.4	20.7
May	20.4	58.2	89.5
June[3]	68.5	90.2	104.0
July[3]	78.5	91.1	101.0
August	74.6	86.7	93.7
September	46.0	68.3	82.0
October	3.0	20.0	49.1
November	0.0	0.0	0.0
December	0.0	0.0	0.0

[1] No data available for 1986,1988,1990,1992,1993
[2] Data presented for Provo Bench Canal only (pumping by Geneva Steel not accounted for)
[3] Flows in these months sometimes exceed water right due to diversions to reduce downstream flooding

Table 4(cont.). Provo Bench - Diversion on River: Summary and Evaluation.

Characteristic/Criterion	Data/Comment
Evaluation Criteria	
Fish migration barrier	**Yes (most flows).** Water surface elevation difference above and below structure is approximately 5 feet under low flow conditions
Fish entrainment potential	**Yes.** No screen or grate present
Diversion structure operated as a dry dam	Channel periodically dewatered upstream and downstream from structure due to Timanogos Canal diversions.
Flow bypass capability	**No.** The diversion structure does not have a mechanism to ensure a set amount of water is bypassed.
Diversion structure trapping bedload	**No**. No evidence of fine sediment accumulating above structure
Streambed degradation (elevation differences above and below structure)	**Moderate**. Bed elevation difference approximately 5 ft.
Canal intercepting bedload	**Yes**. No structure present to prevent bedload from entering canal; canal substrate material similar to natural channel substrate.
Canal substrate material	Natural bed; rock wall banks to Olmstead Tailrace
Impact to riparian vegetation	**Minimal**. Impact limited to dam and headgate locations.

Photo 3-1. **Provo Bench - diversion on river: upstream view of structure.**

Photo 3-2. **Provo Bench - diversion on river: downstream view of structure.**

Photo 3-3. Provo Bench - diversion on river: kick-leg dam structure.

Photo 3-4. Provo Bench - diversion on river: canal head works.

Photo 3-5. Provo Bench - diversion on river: channel upstream from structure.

Structure on Tailrace

Summary information and photographs of the Provo Bench tailrace diversion are provided in Table 5 and Photos 4-1 to 4-4.

The existing diversion structure is in good condition, and consists of flashboards on top of a concrete dam. The flashboards are fitted in slots between metal footbridge supports (Photo 4-1). Some minor scour has occurred at the base of the concrete dam, but the stability of the structure remains good. No flow bypass device is present.

The dam diverts flows from the Olmstead Tailrace into the Provo Bench Canal and into the Geneva pumping plant. The canal headworks has a metal radial gate to control flow, but no screen or grate is present.

A portion of the flows diverted into the Provo Bench Canal are commonly returned to the Provo River via a return channel located approximately 500 feet downstream from the tailrace diversion structure (Figure 4).

Considerable leakage through and under the flashboards was observed during the July 2000 field evaluation. Therefore, even if the structure is operated as a dry dam, it is unlikely that the downstream reach would be dewatered. However, the structure is tall enough that it acts as a barrier to upstream fish migration under most flow conditions. At high flows when water depths are greater, it appears that fish migration may be possible if flow velocities are not too great. However, an objective field evaluation would be needed to confirm this.

Recommendations

- No improvements needed if the recommendations described above for the Provo Bench diversion structure on the river are implemented.

Table 5. Provo Bench - Diversion on tailrace: summary and evaluation.

Characteristic/Criterion	Data/Comment		
General			
Location:	NW 1/4, Sect.7, T6S, R3E		
Canal(s) Served:	Provo Bench Canal, Geneva Steel Pipeline		
Total Acres Served:	4332.53		
Total Water Right (cfs):	95.63 (5/10-6/20) plus appx. 2,630 cfs BOR re-diversion rights		
Known Water Right Numbers:	55-11007, 55-278		
Diversion Structure			
Dam Type:	Concrete dam with flashboard slots between footbridge pillars		
Dam Stability:	Good. Some scour has occurred at base of concrete sill, but stability remains good		
Headworks Type:	Metal radial gate set in concrete; opens at bottom		
Headworks Stability:	Good. Some minor erosion of concrete box near gate		
Flow Bypass Device:	None		
Flow Measuring Device (Canal):	14.25 foot rect. suppressed weir		
Diversion Record Summary			
Period Covered		1952-1999[1]	
Monthly Flow Data (cfs)[2]	Minimum Mean	Mean	Maximum Mean
January	0.0	0.0	0.0
February	0.0	0.0	0.0
March	0.0	0.0	0.0
April	0.0	6.4	20.7
May	20.4	58.2	89.5
June [3]	68.5	90.2	104.0
July [3]	78.5	91.1	101.0
August	74.6	86.7	93.7
September	46.0	68.3	82.0
October	3.0	20.0	49.1
November	0.0	0.0	0.0
December	0.0	0.0	0.0

[1] No data available for 1986,1988,1990,1992,1993
[2] Data presented for Provo Bench Canal only (pumping by Geneva Steel not included in table)
[3] Flows in these months sometimes exceed water right due to diversions to reduce downstream flooding

Table 5 (cont.). Provo Bench - Diversion on Tailrace: summary and evaluation.

Characteristic/Criterion	Data/Comment
Evaluation Criteria	
Fish migration barrier	**Yes (low flow) Possibly (high flow).** Water surface elevation difference above and below structure is approximately 2.5 feet under low flow conditions
Fish entrainment potential	**Yes.** No screen or grate present
Diversion structure operated as a dry dam	**No.** Water is typically passed to meet downstream water rights. There is also considerable leakage under flashboards.
Flow bypass capability	**No.** The diversion structure does not have a mechanism to ensure a set amount of water is bypassed.
Diversion structure trapping bedload	**No.** No evidence of fine sediment accumulating above structure
Streambed degradation (elevation differences above and below structure)	**Moderate.** Bed elevation difference approximately 3.6 ft.
Canal intercepting bedload	**Yes.** No structure present to prevent bedload from entering canal; canal substrate material similar to natural channel substrate.
Canal substrate material	Natural bed and banks for initial portion; according to River Commissioner, a downstream portion of the canal is concrete-lined.
Impact to riparian vegetation	**Minimal.** Impact limited to dam and headgate locations.

Photo 4-1. **Provo Bench - diversion on tailrace: flashboard and concrete structure.**

Photo 4-2. **Provo Bench - diversion on tailrace: canal headworks.**

Photo 4-3. **Provo Bench - diversion on tailrace: headworks to pumping station.**

Photo 4-4. **Provo Bench - diversion on tailrace: view of tailrace above structure.**

Upper Union Diversion

Summary information and photographs of the Upper Union diversion are provided in Table 6 and Photos 5-1 to 5-5.

The existing Upper Union diversion structure is in fair condition and consists of a kick-leg dam installed with concrete sidewalls and a flat concrete sill. This concrete sill lies flush with the streambed above the dam, but below the dam considerable scour has occurred at the base of the sill (Photo 5-1). At the present time, this scour has not caused the structure to become unstable; however, the potential exists for further scour and undercutting to occur during high flow events. No flow bypass device is present. Three separate canal headgates are associated with this structure. A metal radial gate on the east (river left) side of the dam feeds the Upper East Union and East Riverbottom canals. A metal radial gate on the west (river right) side of the dam feeds the West Union canal. A third, smaller metal slide gate on the west (river right) side of the dam is the headworks to the Park Nuttal Canal/ Barton Young ditch. This canal system was discontinued in the 1970's and the headworks are now kept closed.

The existing diversion dam creates a fish migration barrier at all flows, and fish may be entrained in either of the two active canals as no screens or grates are present. A moderate accumulation of fine sediment and dense macrophyte growth are present above the dam, indicating that the structure traps a portion of the bedload. The fine sediment has caused the substrate above the dam to become embedded, reducing the habitat value of this portion of the channel.

This structure is not operated as a dry dam under typical operating conditions. On rare occasions while upstream or downstream flow adjustments are made, the Upper Union structure may be operated as a dry dam for a brief period (several hours to one day). On these infrequent occasions, leakage through the kick-leg boards would provide some flow downstream.

Recommendations

- Investigate need to prevent larval, juvenile, and adult fish entrainment. Devise and implement preventative measures as appropriate.
- Provide fish passage for salmonids, June sucker, and other fish species. This may require narrowing the structure in order to concentrate flows and maintain adequate water depths for passage.
- Periodically (approximately once every three years) dismantle kick-leg structure during high spring flows to flush out sediment that accumulates behind dam.
- Acquire water rights to provide minimum instream flows below structure.
- Install flow bypass device and measurement device to ensure instream flows are provided.

Table 6. Upper Union Diversion: Summary and evaluation.

Characteristic/Criterion	Data/Comment		
General			
Location:	SW 1/4, Sect.7, T6S, R3E		
Canal(s) Served:	Upper E. Union, E. Riverbottom, Faucett Field, W. Union, W. Smith, Carter		
Total Acres Served:	2673.31		
Total Water Right (cfs):	50.01 (5/10-6/20) plus appx. 2,630 cfs BOR re-diversion rights		
Known Water Right Numbers:	55-11008, 55-11011, 55-11017, 55-6581, 55-11018, 55-11019		
Diversion Structure			
Dam Type:	Kick-leg		
Dam Stability:	Fair. Considerable scour has occurred at base of concrete sill, creating potential for undercutting		
Headworks Type:	2 metal radial gates (6' and 8' wide) set in concrete; gates open at bottom		
Headworks Stability:	Good. Some minor erosion of concrete near gate on river left		
Flow Bypass Device:	None		
Flow Measuring Devices (Canals):	7-foot and 12-foot rect. suppressed weirs		
Diversion Record Summary			
Period Covered		1953-1999[1]	
Monthly Flow Data (cfs)[2]	Minimum Mean	Mean	Maximum Mean
January	0.1	0.1	0.1
February	0.1	0.1	0.1
March	0.1	0.2	0.4
April	0.3	7.0	20.0
May	21.0	41.8	61.4
June[3]	42.0	56.1	67.6
July[3]	38.2	47.8	59.5
August	34.0	41.2	47.2
September	29.1	37.0	44.6
October	6.5	16.6	34.0
November	0.7	1.8	35.7
December	0.1	0.1	0.1

[1] No data available for 1985,1986,1988,1990,1992,1993
[2] Values represent sum of recorded flows in Upper E. Union, E. River Bottom, and W. Union canals
[3] Flows in these months sometimes exceed water right due to diversions to reduce downstream flooding

Table 6 (cont.). Upper Union Diversion: Summary and Evaluation.

Characteristic/Criterion	Data/Comment
Evaluation Criteria	
Fish migration barrier	**Yes** (all flows). Water surface elevation difference above and below structure is approximately 3.9 feet under low flow conditions
Fish entrainment potential	**Yes.** No screen or grate present
Diversion structure operated as a dry dam	**No**, not generally. On rare occasions may be operated as dry dam for several hours as upstream and downstream flow adjustments are made.
Flow bypass capability	**No.** The diversion structure does not have a mechanism to ensure a set amount of water is bypassed.
Diversion structure trapping bedload	**Yes**. Moderate accumulation of fine sediment and dense macrophyte growth above structure
Streambed degradation (elevation differences above and below structure)	**Moderate**. Bed elevation difference approximately 4.3 ft.
Canal intercepting bedload	**Yes**. No structure present to prevent bedload from entering canal; canal substrate material similar to natural channel substrate.
Canal substrate material	Natural bed and banks
Impact to riparian vegetation	**Minimal.** Impact limited to dam and headgate locations.

Photo 5-1. Upper Union Diversion: upstream view of structure.

Photo 5-2. Upper Union Diversion: downstream view of structure.

Photo 5-3. Upper Union Diversion: kick-leg dam structure.

Photo 5-4. Upper Union Diversion: headworks to Upper East Union / East Riverbottom canals.

Photo 5-5. Upper Union Diversion: headworks to West Union Canal/West Smith Ditch (large headgate). Small headgate on right is no longer in use.

Lake Bottom Diversion

Summary information and photos of the Lake Bottom diversion are provided in Table 7 and Photos 6-1 to 6-4.

The existing diversion structure is in fair condition and consists of a low-elevation rubble and rock dam that extends partially across the channel. This dam directs flow into a diversion pipe with a metal slide headgate. After a distance of approximately 20 feet, the pipe outlets into an open canal with bed and banks made of natural materials. The diversion dam and canal headworks both received ratings of "fair" for stability because the structures are stable under regularly occurring flows, but susceptible to large floods (i.e., floods with recurrence intervals of 25 years or greater).

Because the structure does not fully extend across the channel, it does not act as a barrier to fish migration, and it can not be operated as a dry dam. No device is present to measure the amount of flow bypassing the diversion; however, the canal headworks can be operated to allow a set amount of water to be diverted. No screen is present at the canal headgate; however, the likelihood of fish becoming entrained is relatively small due to the small size of the headworks pipe. Maximum mean flows recorded in the Lake Bottom Canal exceed the legal water right during June and July (Table 7).

Recommendations

- Investigate need to prevent larval, juvenile, and adult fish entrainment. Devise and implement preventative measures as appropriate.
- Line or pipe Lake Bottom Canal to reduce conveyance losses; then conserved water could be left undiverted in the river.

Table 7. Lake Bottom Diversion: Summary and Evaluation.

Characteristic/Criterion	Data/Comment		
General			
Location:	NE 1/4, Sect.25, T6S, R2E		
Canal(s) Served:	Lake Bottom		
Total Acres Served:	1196.00		
Total Water Right (cfs):	14.95 (5/10-6/20)		
Known Water Right Numbers:	55-11013		
Diversion Structure			
Dam Type:	Rock/ rubble (partial)		
Dam Stability:	Fair. Structure vulnerable to large floods, but stable under regularly occurring flows		
Headworks Type:	4-ft. wide metal slide gate (no concrete); opens at bottom		
Headworks Stability:	Fair. Potential exists for erosion around/ behind headgate		
Flow Bypass Device:	None		
Flow Measuring Devices (Canals):	4 foot Parshall flume		
Diversion Record Summary			
Period Covered		1953-1999[1]	
Monthly Flow Data (cfs)	Minimum Mean	Mean	Maximum Mean
January	0.0	0.0	0.0
February	0.0	0.0	0.0
March	0.0	0.0	0.0
April	0.0	0.4	1.1
May	2.3	7.4	12.6
June[2]	7.9	12.5	15.4
July[2]	8.7	12.5	15.2
August	7.5	10.7	13.2
September	4.7	7.6	10.8
October	0.7	2.5	5.6
November	0.0	0.2	0.5
December	0.0	0.0	0.0

[1] No data available for 1959, 1985, 1986, 1988, 1990, 1992, 1993
[2] Flows in these months sometimes exceed water right due to diversions to reduce downstream flooding

Table 7(cont.). Lake Bottom Diversion: Summary and Evaluation.

Characteristic/Criterion	Data/Comment
Evaluation Criteria	
Fish migration barrier	**No.** Partial rock/ rubble dam does not block passage.
Fish entrainment potential	**Yes.** No screen or grate present
Diversion structure operated as a dry dam	**No.** Not possible to divert entire flow with existing structure.
Flow bypass capability	**No.** The diversion structure does not have a mechanism to ensure a set amount of water is bypassed.
Diversion structure trapping bedload	**No.** Partial dam does not trap bedload.
Streambed degradation (elevation differences above and below structure)	**Not applicable.** Structure does not dam full width of channel.
Canal intercepting bedload	**Yes.** No structure present to prevent bedload from entering canal; however, amount intercepted would be small due to small size of pipe that forms entrance to canal
Canal substrate material	Initial 20 feet piped, then natural bed and banks
Impact to riparian vegetation	**Minimal.** Impact limited to dam and headgate locations.

Photo 6-1. **Lake Bottom Diversion: view of partial rock/rubble dam.**

Photo 6-2. **Lake Bottom Diversion: canal headworks.**

Photo 6-3. Lake Bottom Diversion: view of channel downstream from structure.

Photo 6-4. Lake Bottom Diversion: view of channel upstream from structure.

Upper City Dam

Summary information and photos of the Upper City Dam diversion are provided in Table 8 and Photos 7-1 to 7-5.

The existing diversion structure is in good condition and consists of a kick-leg structure installed on top of a concrete dam. Some minor scour has occurred at the base of the concrete dam, but this has not adversely affected the stability of the structure. A radial-gated sluiceway is present on the east (river left) side of the dam, and a metal slide gate set in concrete that controls flow into the Factory Race and Lower East Union Canals is located adjacent to (east of) the sluiceway. Water for Factory Race and Lower East Union is initially diverted into a single channel that splits into two separate canals farther downstream. Prior to 2000, Upper City Dam provided water to the City Race canal also; currently this canal is no longer in use (S. Roberts 2000, pers. comm.).

The gated sluiceway could be operated to provide bypass flows downstream; however, no flow measurement device is currently installed. This structure is not operated as a dry dam under typical operating conditions. On rare occasions while upstream or downstream flow adjustments are made, the Upper City structure may be operated as a dry dam for a brief period (several hours to one day). On these infrequent occasions, leakage through the kick-leg boards would provide some flow downstream.

Upper City Dam acts as a complete barrier to upstream fish migration at all flows, and no screen is present at the canal headworks to prevent fish from becoming entrained in the canal. An accumulation of fine sediment (1 to 2 inches deep) and dense macrophyte growth are present above the dam, indicating that the structure traps a portion of the bedload. The fine sediment has caused the substrate above the dam to become embedded, reducing the habitat value of this portion of the channel.

Recommendations

- Investigate need to prevent larval, juvenile, and adult fish entrainment. Devise and implement preventative measures as appropriate.
- Provide fish passage for salmonids, June sucker, and other fish species.
- Periodically (approximately once every three years) dismantle kick-leg structure during high spring flows to flush out sediment that accumulates behind dam.
- Acquire water rights to provide minimum instream flows below structure.
- Install measurement device on sluiceway to ensure instream flows are bypassed.

Table 8. Upper City Dam: Summary and Evaluation.

Characteristic/Criterion	Data/Comment
General	
Location:	SE 1/4, Sect.25, T6S, R2E
Canal(s) Served:	Factory Race, Lower E. Union, City Race[1]
Total Acres Served:	more than 2058.6
Total Water Right (cfs):	62.62 (5/10-6/20)
Known Water Right Numbers:	55-11001, 55-11002, 55-11003
Diversion Structure	
Dam Type:	Kick-leg on top of concrete dam
Dam Stability:	Good. Minor scour at base of concrete dam.
Headworks Type:	8-ft. wide metal slide gate set in concrete; opens at bottom
Headworks Stability:	Good
Flow Bypass Device:	sluiceway with 8.5-ft. wide radial gate
Flow Measuring Devices (Canals):	4-ft. Parshall flume (Lower E. Union); 2-ft .Parshall Flume (Factory Race)

Diversion Record Summary

Period Covered Monthly Flow Data (cfs)[3]	Minimum Mean	1954-1999[2] Mean	Maximum Mean
January	0.0	0.0	0.0
February	0.0	0.0	0.0
March	0.0	0.0	0.0
April	0.7	3.8	9.5
May	10.4	21.1	28.6
June	17.1	25.3	32.5
July	16.9	24.8	30.3
August	17.4	24.8	30.2
September	13.8	21.7	27.4
October	1.1	7.7	19.1
November	0.0	0.0	0.0
December	0.0	0.0	0.0

[1] City Race discontinued in 2000
[2] No data available for 1985, 1986, 1988, 1990, 1992
[3] Values represent sum of recorded flows in Lower E. Union, Factory Race, and City Race canals

Table 8 (cont.). Upper City Dam: Summary and Evaluation.

Characteristic/Criterion	Data/Comment
Evaluation Criteria	
Fish migration barrier	**Yes (all flows).** Water surface elevation difference above and below structure is approximately 8.5 feet under low flow conditions
Fish entrainment potential	**Yes.** No screen or grate present at canal entrance.
Diversion structure operated as a dry dam	**No**, not generally. On rare occasions may be operated as dry dam for several hours as upstream and downstream flow adjustments are made.
Flow bypass capability	**Yes.** The diversion structure has a radial gated sluiceway that could be used to bypass flow. No measurement device currently installed.
Diversion structure trapping bedload	**Yes.** Structure appears to trap a portion of the bedload. Observed dense macrophyte coverage and 1-2" thick deposit of fine sediment above structure. Also observed accumulation of cobbles on sill of concrete dam, indicating that the structure allows a portion of the bedload to pass.
Streambed degradation (elevation differences above and below structure)	**Substantial.** Bed elevation difference is 7.5 ft.
Canal[1] intercepting bedload	**Yes.** No structure present to prevent bedload from entering canal; gravel deposit present on bottom of concrete flume in canal.
Canal substrate material	Natural bed with concrete/ rip rap banks for initial 30 ft; then piped under road; then open for appx. 50 ft.; then piped again.
Impact to riparian vegetation	**Minimal.** Impact limited to dam and headgate locations.

[1] Evaluation performed on initial canal section shared by Factory Race and Lower East Union.

Photo 7-1. Upper City Dam: upstream view of structure.

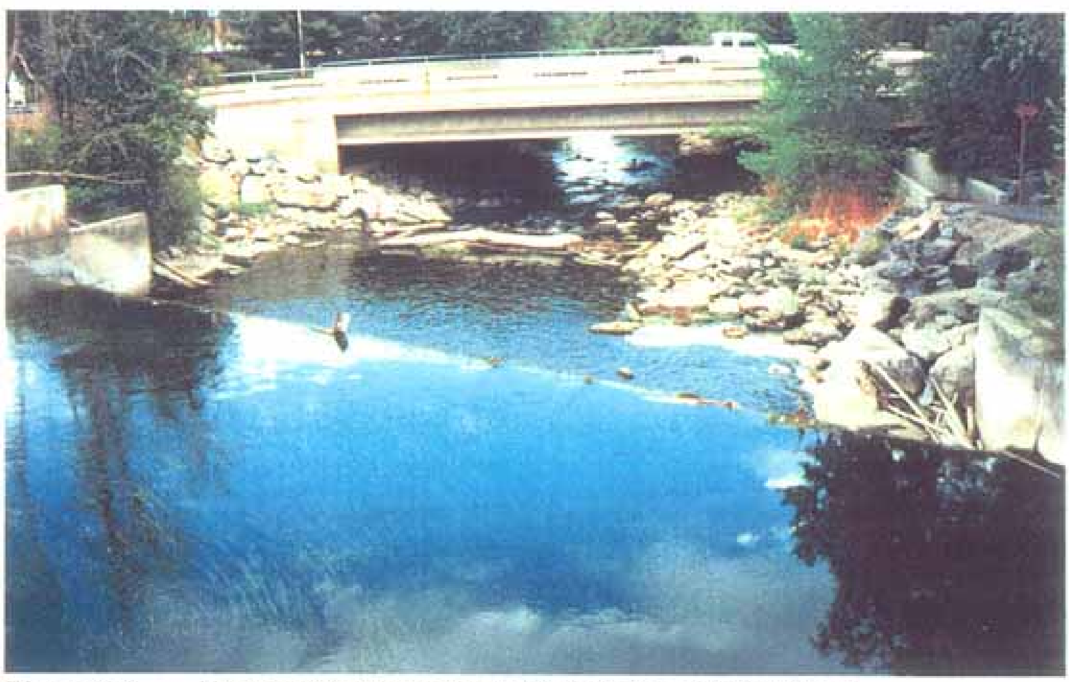

Photo 7-2. Upper City Dam: downstream view of structure.

Photo 7-3. Upper City Dam: headworks to Lower East Union/Factory Race canals.

Photo 7-4. Upper City Dam: radial gated sluiceway.

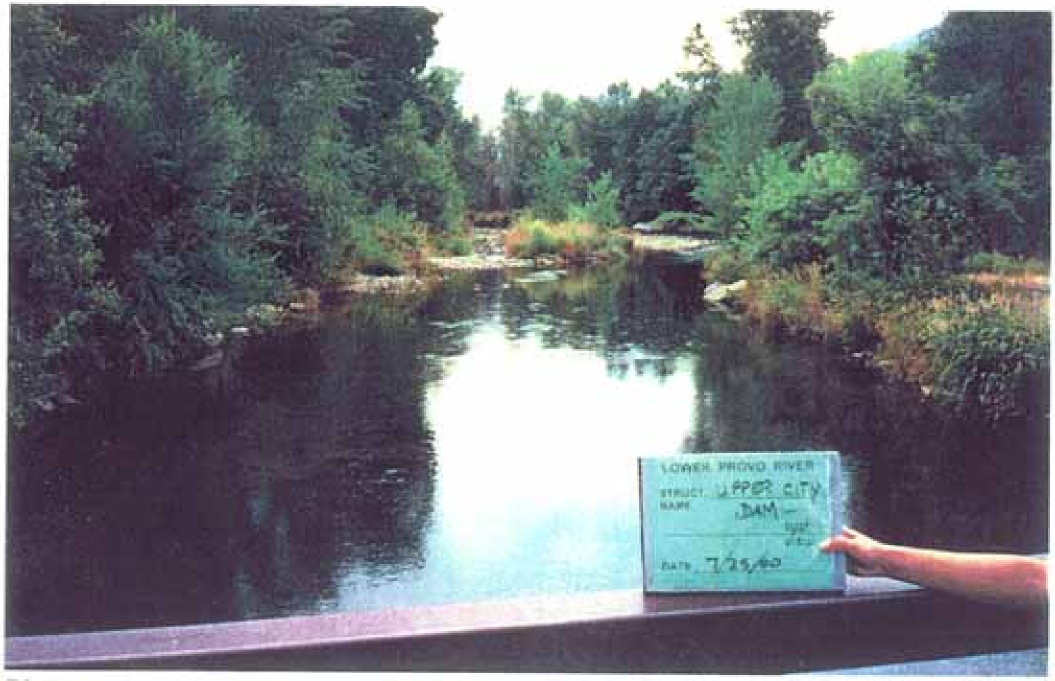

Photo 7-5. Upper City Dam: view of channel upstream from structure.

Lower City Dam

Summary information and photographs of the Lower City Dam diversion are provided in Table 9 and Photos 8-1 to 8-7.

The existing diversion structure is in good condition and is very similar to the Upper City Dam structure. Lower City Dam consists of a kick-leg structure installed on top of a concrete dam, with a radial gated sluiceway on the east (river left) side of the dam. The headworks to Tanner Race/ Little Dry Creek Canal consist of a metal slide gate installed in the east (river left) concrete sidewall of the dam.

A 3-foot wide metal slot (Photo 8-7) designed to pass 25 cfs downstream has been installed by the Provo River Commissioner on the west side of the kick-leg structure (S. Roberts 2001, pers. comm.). The gated sluiceway on the east side of the structure could also potentially be operated to provide bypass flows downstream. The Provo River Commissioner attempts to adjust flow withdrawals in order to pass water downstream through the metal bypass slot. However, the Lower City diversion is periodically operated as a dry dam. For example, during the July 2000 evaluation, no flow was passing over the top of the kick-leg structure or through the metal slot, and the sluiceway gate was closed. However, a significant amount of seepage through and under the kick-leg boards prevents the downstream channel from being completely dewatered under dry dam conditions. Riparian vegetation does not appear to have been adversely affected by the reduced flows below the structure: healthy, mature stands of box elder and cottonwood trees are present both above and below the dam.

Of the nine diversion structures evaluated, Lower City Dam had the greatest accumulation of fine sediment and most dense macrophyte coverage above the structure. This fine sediment has caused the substrate above the dam to become embedded, reducing the habitat value of this portion of the channel. The diversion creates a complete barrier to upstream fish migration at all flows, and no screen is present at the canal headworks to prevent fish from being entrained in the canal.

Recommendations

- Investigate need to prevent larval, juvenile, and adult fish entrainment. Devise and implement preventative measures as appropriate.
- Provide fish passage for salmonids, June sucker, and other fish species.
- Periodically (approximately once every three years) dismantle kick-leg structure during high spring flows to flush out sediment that accumulates behind dam.
- Acquire water rights to provide minimum instream flows below structure.
- Install measurement device on sluiceway to ensure instream flows are bypassed.

Table 9. Lower City Dam: Summary and Evaluation.

Characteristic/Criterion	Data/Comment		
General			
Location:	SW 1/4, Sect.36, T6S, R2E		
Canal(s) Served:	Tanner Race, Little Dry Creek		
Total Acres Served:	more than 877.47		
Total Water Right (cfs):	78.23 (5/10-6/20)		
Known Water Right Numbers:	55-11009, 55-11012, 55-11001, 55-11002, 55-11003		
Diversion Structure			
Dam Type:	Kick-leg on top of concrete dam		
Dam Stability:	Good. Minor scour at base of concrete dam.		
Headworks Type:	6-ft. wide metal slide gate set in concrete; opens at bottom		
Headworks Stability:	Good		
Flow Bypass Device:	metal slot in kick-leg structure passes 25 cfs		
Flow Measuring Devices (Canals):	3 foot Parshall flume (Little Dry Creek); 7-ft. rect. weir (Tanner Race)		
Diversion Record Summary			
Period Covered		1953-1999[1]	
Monthly Flow Data (cfs)[2]	Minimum Mean	Mean	Maximum Mean
January	0.0	0.0	0.0
February	0.0	0.0	0.0
March	0.0	0.0	0.0
April	0.0	1.4	4.8
May	4.1	11.4	16.2
June	8.4	13.8	18.0
July	9.3	13.8	17.6
August	8.9	13.4	16.9
September	7.5	11.8	15.3
October	0.1	3.5	10.8
November	0.0	0.0	0.0
December	0.0	0.0	0.0

[1] No data available for 1985, 1986, 1988, 1990, 1992
[2] Values represent sum of recorded flows in Tanner Race and Little Dry Creek canals

Table 9 (cont.). Lower City Dam: Summary and Evaluation.

Characteristic/Criterion	Data/Comment
Evaluation Criteria	
Fish migration barrier	**Yes (all flows).** Water surface elevation difference above and below structure is approximately 7.8 feet under low flow conditions
Fish entrainment potential	**Yes.** No screen or grate present at canal entrance.
Diversion structure operated as a dry dam	**Yes.** At time of evaluation, no flow was passing over top of kick-leg boards; all downstream flow was leakage under/ through boards.
Flow bypass capability	**Yes.** The diversion structure has a radial gated sluiceway that could be used to bypass flow. No measurement device currently installed.
Diversion structure trapping bedload	**Yes.** Observed dense macrophyte coverage and accumulation of fine sediment above structure.
Streambed degradation (elevation differences above and below structure)	**Substantial.** Bed elevation difference is approximately 7 ft.
Canal intercepting bedload	**Yes.** No structure present to prevent bedload from entering canal; gravel deposits present on bottom of concrete-lined canal.
Canal substrate material	Concrete bed and banks
Impact to riparian vegetation	**Minimal.** Impact limited to dam and headgate locations.

Photo 8-1. Lower City Dam: upstream view of structure.

Photo 8-2. Lower City Dam: downstream view of structure.

Photo 8-3. **Lower City Dam: view of kick-leg structure and canal headworks.**

Photo 8-4. **Lower City Dam: view of radial-gated sluiceway.**

Photo 8-5. **Lower City Dam: view of channel upstream from structure.**

Photo 8-6. **Lower City Dam: view of channel downstream from structure.**

Photo 8-7. Upstream view of Lower City Dam. At the left side of the photo, note the 3-foot-wide metal slot designed to pass 25 cfs.

Fort Field Diversion

Summary information and photos of the Fort Field Diversion are provided in Table 10 and Photos 9-1 to 9-4.

The existing diversion structure is in fair condition and consists of a kick-leg dam installed with concrete sidewalls and a flat concrete sill that lies flush with the bed of the stream. Several of the metal kick-leg supports are bent or missing, and consequently several wooden boards inadequately supported (Photo 9-3). However, despite the poor condition of the kick-leg materials, the overall stability of the structure remains fair. The concrete sidewalls and concrete sill are in good condition and would remain stable during high flows, even if the kick-leg was damaged. The headworks to the Fort Field Canal consist of a metal slide gate set in the eastern (river left) sidewall of the dam.

The Fort Field Diversion creates a barrier to upstream fish migration during low flow conditions. The structure is periodically operated as a dry dam, although seepage through and under the kick-leg boards provides some flow downstream from the structure. However, these flows can become very low during dry years: flows as low as 3 cfs have been recorded at the USGS gage near Utah Lake. Under these low flow conditions, fish become stranded in isolated pools, aquatic habitat becomes extremely limited, and poor water quality conditions exist.

No screen is present at the canal headgate; however, the likelihood of fish becoming entrained is relatively small due to the small size of the headworks pipe. Dense macrophyte growth and a minor accumulation of fine sediment were observed above the structure. This fine sediment has caused the substrate above the dam to become slightly embedded, decreasing the habitat value of this portion of the channel.

Recommendations

- Explore feasibility of permanently removing structure and meeting water rights via diversions at Lower City Dam.
- If permanent removal is not feasible, provide fish passage for salmonids, June sucker, and other fish species. As an interim measure, the kick-leg structure could be temporarily dismantled during critical spawning periods and reassembled for use during the summer.
- If permanent removal is not feasible, investigate need to prevent larval, juvenile, and adult fish entrainment. Devise and implement preventative measures as appropriate.

Table 10. Fort Field Diversion: Summary and Evaluation.

Characteristic/Criterion	Data/Comment		
General			
Location:	SW 1/4, Sect.2, T7S, R2E		
Canal(s) Served:	Fort Field		
Total Acres Served:	877.47		
Total Water Right (cfs):	15.61 (5/10-6/20)		
Known Water Right Numbers:	55-11009, 55-11012		
Diversion Structure			
Dam Type:	Kick-leg		
Dam Stability:	Fair. Several metal supports are bent/ missing; structure vulnerable to being washed out in large flood event		
Headworks Type:	2.5-ft. wide metal slide gate set in concrete; opens at bottom		
Headworks Stability:	Good		
Flow Bypass Device:	None		
Flow Measuring Devices (Canals):	2 foot Parshall flume		
Diversion Record Summary			
Period Covered		1953-1999[1]	
Monthly Flow Data (cfs)	Minimum Mean	Mean	Maximum Mean
January	0.0	0.0	0.0
February	0.0	0.0	0.0
March	0.0	0.0	0.0
April	0.0	0.1	0.3
May	0.4	2.5	6.0
June	2.4	4.9	8.7
July	2.2	5.3	8.5
August	1.5	4.3	7.7
September	0.9	2.5	5.0
October	0.1	0.5	1.1
November	0.0	0.1	0.2
December	0.0	0.0	0.0

[1] No data available for 1959, 1965, 1966, 1967, 1985, 1986, 1988, 1990, 1992, 1993

Table 10 (cont.). Fort Field Diversion: Summary and Evaluation.

Characteristic/Criterion	Data/Comment
Evaluation Criteria	
Fish migration barrier	**Yes (low flow) No (high flow).** Water surface elevation difference above and below structure is approximately 1.8 feet under low flow conditions
Fish entrainment potential	**Yes.** No screen or grate present at canal entrance.
Diversion structure operated as a dry dam	**Yes.** At time of evaluation, no flow was passing over top of kick-leg boards; all downstream flow was leakage under/between boards.
Flow bypass capability	**No.** The diversion structure does not have a mechanism to ensure a set amount of water is bypassed.
Diversion structure trapping bedload	**Yes.** Structure appears to trap a portion of the bedload. Observed dense macrophyte coverage and minor accumulation of fine sediment above structure. Also observed accumulation of cobbles on concrete sill below kick-leg structure, indicating that the structure allows a portion of the bedload to pass.
Streambed degradation (elevation differences above and below structure)	**Moderate.** Bed elevation difference is approximately 2 ft.
Canal intercepting bedload	**No.** Slight potential exists, but amount probably insignificant due to small size of pipe opening and position of headgate relative to dominant flow direction.
Canal substrate material	Piped for first 500 ft., then open canal with natural substrate and rock bank
Impact to riparian vegetation	**Minimal.** Impact limited to dam and headgate locations.

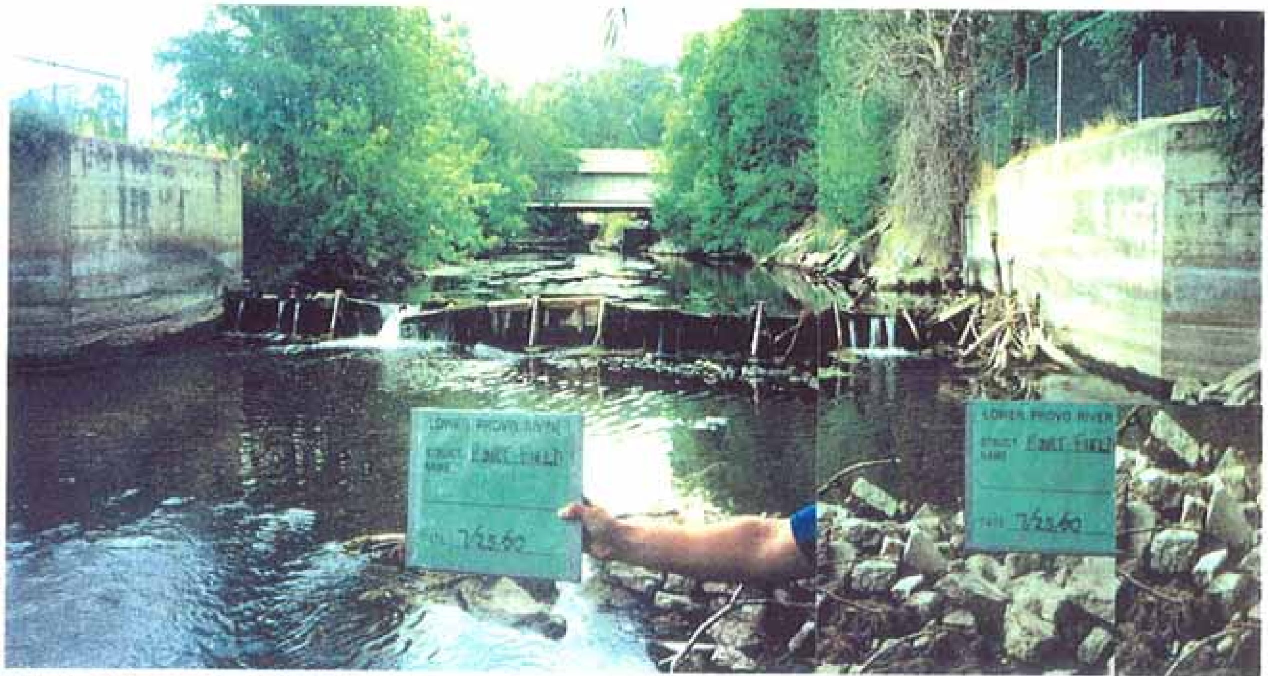

Photo 9-1. **Fort Field Diversion: upstream view of structure.**

Photo 9-2. **Fort Field Diversion: downstream view of structure.**

Photo 9-3. **Fort Field Diversion: kick-leg structure.**

Photo 9-4. **Fort Field Diversion: canal headworks.**

Summary

A summary of the evaluation results for all the diversion structures on the lower Provo River is provided in Table 11. A summary of water rights information used in this evaluation is provided in Table 12.

RECOMMENDATIONS

Recommendations specific to each individual diversion structure are listed briefly in the Evaluation Results section of this document. The following section provides a broader discussion of recommendations for diversion improvements for the lower Provo River system as a whole.

Potential Diversion Improvements Relative to General Fishery Health

Currently, June sucker and brown trout are the two species that have the highest management priorities in the Provo River. If a wild reproducing population of cutthroat trout can be established in the upper reaches of the lower Provo as well, then this species may be managed similar to brown trout. Thus, improvements to diversion structures and adjoining canals should focus on improving life history function of these three species with emphasis placed first on June sucker due to its endangered status (USFWS 1999).

A warm water hatchery for production of June sucker and other Utah species of special concern is planned to be brought on-line in approximately 5 years (URMCC 1998, URMCC 2001). Also, additional studies are currently being conducted that will examine methods to improve young June sucker survivability during the larval and juvenile stages of development. Once a hatchery facility is actively stocking June sucker and rearing conditions in Utah Lake and the lower river are improved, the number of spawners will increase and the need for additional suitable spawning habitat in the Provo River may be critical to the recovery of June sucker. Assuming this scenario develops as described, it will then be necessary to make upper reaches of the lower Provo River more accessible during the June sucker spawning season.

Fort Field Diversion is the first barrier that should be made 100 percent passable. Past observations of June sucker spawning runs have identified this diversion as a barrier at low flows (C. Thompson 2000, pers. comm.). Likewise it is possible that during high water years when spawning does occur above the diversion, the canal entrance located above the structure could entrain larval June sucker as they drift downstream. One potential way to alleviate this problem may be to meet the water right of the Fort Field canal by piping water from the Lower City Diversion, and then permanently dismantling the Fort Field structure and closing off the canal. If this approach is not economically feasible then another approach would be to lower the diversion completely at the time of spawning, and close the canal headgate at times when larvae are most likely to be drifting downstream. At the very least, a few of the top kick-leg boards could be removed at the stream thalweg to provide some type of plume so fish could ascend the structure. However, the potentially limited swimming abilities of June sucker and the high velocities of a concentrated plume may make this option unfavorable. Additionally, operation of the canal headgate would still have to take into account drifting larval June sucker.

Diversions upstream of Fort Field Diversion should be made June sucker passable if increased numbers of these fish begin to frequent Provo River during the spawning season. Different structures will need different approaches because of the wide range of drops associated with each. The Murdock, Upper City, and Lower City Diversions comprise those which have the largest drops and therefore would need fish ladders for ascension by June sucker. At those structures that have less drop it may be possible to build one or a succession of pools that would allow for fish passage. However, before design and construction could commence, information such as June sucker swimming efficiency and speed, jumping abilities, migration capacity criteria, and resulting design requirements should be quantified. Likewise, accommodation of downstream passage requirements for June sucker as well as entrainment prevention requirements for exclusion of larvae and adult post-spawners from canal intakes should be addressed. One of the first steps in dealing with entrainment issues should be to assess the severity of the problem. The extent of the problem should be quantified for salmonid species, June sucker, and other fish species of all size classes including larvae, juveniles, and adults. Once it has been established that there is a problem that needs further action, several options should be considered including screening, timing of canal operation, and partitioning of the diversion area to exclude species or size classes at risk of entrainment.

As explained previously, the cui-ui is a lake sucker species of the same genus as June sucker and has similar life history characteristics. Cui-ui spawning runs historically occurred from Pyramid Lake into the Truckee River ascending the river as much as 70 km. After substantial reductions in flow and subsequent lake level lowering during the mid 1900's, fish passage problems arose and were dealt with using various passage devices. Much of the information assimilated in the process of successfully solving the cui-ui passage problems could be very applicable to the June sucker passage problem and therefore should be reviewed when passage solutions are devised (Scoppettone and Vinyard 1991).

Diversion improvements for sportfish could likely be accommodated into designs for June sucker fish passage. Access to upstream spawning areas for all trout species could increase reproductive success for those species. Securing migration routes for fall spawning brown trout and spring spawning cutthroat trout would be critical to these species. Fish passage structures could be designed to accommodate both trout species and June sucker. Likewise, structures will have to safely pass other fish species in the upstream and downstream directions.

Table 11. Diversion structure evaluation summary and recommended improvements.

Diversion	Evaluation Criteria								Recommended Improvements		
	Dam Stability	Flow Bypass Capability	Operated as Dry Dam	Fish Migration Barrier (flow level)	Fish Entrainment Potential	Structure Trapping Bedload	Streambed Degradation	Canal Intercepting Bedload	Canal	Flow Bypass	Fish Passage
Murdock	Good	Yes	No	Yes (all)	Yes	No	Slight	Yes	Screen to prevent fish entrainment[1]	Install measurement device on sluiceway	Install fish ladder
Timpanogos	Good	No	Yes	Yes (most)	Yes	No	Slight	Yes	Screen to prevent fish entrainment	Install bypass device	Install pool sequence or other passage structure
Provo Bench-River	Fair	No	Yes	Yes (most)	Yes	No	Moderate	Yes	Keep closed when tailrace flows sufficient	Install bypass device	Install pool sequence or other passage structure
Provo Bench-Tailrace	Good	No	No	Yes (most)	Yes	No	Moderate	Yes	-	-	-
Upper Union	Fair	No	No	Yes (all)	Yes	Yes	Moderate	Yes	Screen to prevent fish entrainment	Install bypass and measurement devices	Install pool sequence or other passage structure
Lake Bottom	Fair	No	No	No	Yes	No	N/A	Yes (minor)	Screen to prevent fish entrainment	-	-
Upper City	Good	Yes	No	Yes (all)	Yes	Yes	Substantial	Yes	Screen to prevent fish entrainment	Install measurement device on sluiceway	Install fish ladder
Lower City	Good	Yes	Yes	Yes (all)	Yes	Yes	Substantial	Yes	Screen to prevent fish entrainment	Install measurement device on sluiceway	Install fish ladder
Fort Field	Fair	No	Yes	Yes (low)	Yes	Yes	Moderate	No	Keep closed during critical periods for June sucker	Permanently remove dam[2] or install bypass device	Permanently remove dam or provide passage structure

[1] For all structures, this recommendation should be implemented only if additional studies demonstrate that fish entrainment is a significant problem.
[2] The Fort Field Irrigation Company's water right (#55-11012) can also be legally diverted at Lower City Dam; therefore, it may be possible to remove the Fort Field structure, divert the water right upstream, and modify the delivery system to meet water users' needs.

Table 12. Water rights information for diversions on the lower Provo River.[a]

DIVERSION STRUCTURE	CANAL	WATER RIGHT NUMBER	AMOUNT OF WATER RIGHT	WATER RIGHT OWNER
Murdock	Murdock (Provo Reservoir)	55-7899	252.357 cfs	Provo Reservoir Water Users Co.
Murdock	Murdock (Provo Reservoir)	55-67	30 cfs	Provo Reservoir Water Users Co.
Murdock	Murdock (Provo Reservoir)	35-8737[b]	1000 cfs	U.S. Bureau of Reclamation
Murdock	Murdock (Provo Reservoir)	35-8756[b]	1000 cfs	U.S. Bureau of Reclamation
Murdock	Murdock (Provo Reservoir)	43-341[b]	550 cfs	U.S. Bureau of Reclamation
Murdock	Murdock (Provo Reservoir)	43-343[b]	50 cfs	U.S. Bureau of Reclamation
Murdock	Murdock (Provo Reservoir)	43-344[b]	21 cfs	U.S. Bureau of Reclamation
Murdock	Murdock (Provo Reservoir)	55-262[b]	30,000 acre feet	U.S. Bureau of Reclamation
Murdock	Murdock (Provo Reservoir)	55-295[b]	100,000 acre feet	U.S. Bureau of Reclamation
Murdock	Murdock (Provo Reservoir)	55-7060[b]	7.9 cfs	U.S. Bureau of Reclamation
Murdock	Murdock (Provo Reservoir)	55-7061[b]	1.43 cfs	U.S. Bureau of Reclamation
Timpanogos	Timpanogos	55-11006	14.12 cfs	Timpanogos Canal Co.
Provo Bench	Provo Bench (N. Union)	55-11007	76.01 cfs	Provo Bench Canal & Irrigation Co.
Provo Bench	Geneva pump	55-278	19.62 cfs	Geneva Steel Co.
Union	Upper E. Union	55-11008	13.07 cfs	Upper E. Union Irrigation Co.
Union	E. Riverbottom	55-11011	6.96 cfs	E. Riverbottom Water Co.
Union	Carter Ditch	55-11018	0.78 cfs	Carter Ditch Co.
Union	Carter, W. Union, E. Riverbottom	55- 6581	0.76 cfs	Riverside Country Club
Union	Faucett Field	55-11019	2.09 cfs	Faucett Field Ditch Co.
Lake Bottom	Lake Bottom	55-11013	14.95 cfs	Lake Bottom Irrigation Co.
Upper City	Lower E. Union/Factory Race	55-11001[c]	36.12 cfs	Provo City Corporation
Upper City	Lower E. Union/Factory Race	55-11002[c]	10.0 cfs	Provo City Corporation
Upper City	Lower E. Union/Factory Race	55-11003[c]	16.5 cfs	Provo City Corporation
Lower City	Little Dry/Tanner Race	55-11001[c]	36.12 cfs	Provo City Corporation
Lower City	Little Dry/Tanner Race	55-11002[c]	10.0 cfs	Provo City Corporation
Lower City	Little Dry/Tanner Race	55-11003[c]	16.5 cfs	Provo City Corporation
Lower City	Little Dry	55-11009	8.43 cfs	Ft. Field-Little Dry Ck. Water Users
Lower City	Little Dry	55-11012[c]	7.18 cfs	Fort Field Irrig. Co.
Ft. Field	Ft. Field	55-11012[c]	7.18 cfs	Fort Field Irrig. Co.

[a] Please note that the water rights data presented in this report were derived from the best available information; however, no other claim to their accuracy or validity is implied by BIO-WEST, the Commission, or the Provo River Commissioner.
[b] These water rights list Murdock, Provo Bench, W. Union, and E. Riverbottom canals as re-diversion points; for simplicity these water right numbers are listed only for the Murdock diversion structure in this table.
[c] Water right has more than one diversion point and is listed more than once in this table

Currently, brown trout spawning in UDWR management sections 5 and 6 likely accounts for production of all brown trout in the lower Provo River. Young are produced upstream and then drift downstream to occupy new habitats. It is likely that as these fish move downstream, some are becoming entrained into canals and are then separated from the angling public as well as the natural habitat in the river. Fish entrainment in canals statewide has been a longtime problem and was mentioned in year-end reports of Utah state game and fish wardens from the late 1890's through 1960 (Musser 1897, Sharp 1899, Crane 1960). Although several generalized claims were made in these reports as to specific losses, more information should be gathered to determine to what degree entrainment occurs on the Provo River and which size classes of fish are most affected. Specifically, canals should be sampled to determine the number and sizes of fish present in various canals during different times of the year. After this information is gathered and if entrainment prevention is necessary, screening of the appropriate size or other devices should be installed to protect salmonids starting with the canal entrances at the most upstream diversion structures (Olmsted Diversion) and progressively moving downstream. The screen size used or method employed should be determined by the size of fish being lost in canals, and should also consider larval fish needs. It may be impractical to screen for larval fish, but it is possible that canal and diversion operational changes could be used to alleviate larval entrainment.

Observation of the endless belt traveling screen at the Timpanogos Diversion determined that it would likely do a satisfactory job of preventing entrainment of juvenile and adult fish into the piped portion of the canal. However, because the screen is approximately 100 feet down the canal from the point where water is diverted, fish can become entrained in this unscreened section. In addition, because there is no bypass back to the river for these fish, once they are entrained they must move up-current in the canal to return to the river. Future projects should consider locating entrainment prevention devices closer to the headgate of the canal and incorporating a bypass weir and piping back to the river below the diversion.

Potential Improvements in Hydrologic Management of the Lower Provo River

The structural improvements to diversions discussed above will prove effective only if adequate instream flows are present in the river. As previously mentioned, the CUWCD is currently in the process of acquiring water shares from willing sellers with the objective of providing a year-round minimum instream flow of 75 cfs. However, the 75 cfs objective is not a legally-binding flow requirement, and the time frame for acquiring water rights for instream flows is indefinite. This instream flow objective was initially established in 1992, and as of Fall 2000, instream flows have not yet been provided in the lower Provo River. The stream is commonly dewatered between Timpanogos Dam and the Olmsted tailrace/ Provo River confluence. At the USGS gage near Utah Lake, average August streamflow is only 24.9 cfs, and flows below 10 cfs are common. To the extent possible, efforts to acquire and implement instream flow water rights should be accelerated in order to improve summertime flow conditions.

Once water rights for instream flows are obtained, flow bypass devices should be installed at diversion structures on the lower Provo River so that instream flows can be bypassed downstream. Ideally, devices would also be installed to measure the amount of flow bypassed and ensure that water designated for instream flow purposes is not inadvertently diverted. Currently, the USGS gage near Utah Lake (Figure 1) is the only location in this section of river where stream flow is directly measured. The closest upstream gage is located below Deer Creek Dam. Flows passing over the Murdock Dam spillway are measured by the CUWCD, but accurate data are not available during times when the dam is not spilling. The possibility of using the existing radial-gated sluiceways at Murdock Dam, Upper City Dam, and Lower City Dam to bypass and measure flows should be explored. Installation of a flow measurement device at the Upper Union diversion is also recommended. If flows were measured at these four structures, flow values at the Timpanogos, Provo Bench, Lake Bottom, and Fort Field diversions could be calculated by subtracting measured canal flows.

The existing legal framework surrounding water rights on the lower Provo River is complex and dynamic. Multiple water rights owned by multiple entities are associated with many of the individual diversion structures (see Table 12). Over the last several decades, the demand for water in the Provo area has been shifting from agricultural to urban uses, and this trend can be expected to continue. Because of this shift in demand, water rights are frequently transferred and segregated, and points of diversion associated with specific rights also change. Some water rights are designated in terms of an allowable rate of diversion (in cfs), while others are designated in terms of diversion volume (in acre-feet) or irrigable land area (in acres). Because of these complexities, it is difficult to obtain an accurate representation of the maximum total legal diversion rate at a given structure. This information is essential from a fishery standpoint, because fish and other aquatic species are directly affected by the amount of water flowing in a stream at any given point in time. Therefore, diversion rates (in cfs) are more relevant from a fisheries standpoint than diversion volumes. At each structure, a maximum total legal diversion rate (in cfs) should be quantified. The legal means of accomplishing this will require further study.

Because the Provo River is a resource that is utilized and affected by many diverse entities, a working group should be established to oversee and coordinate efforts to improve diversion structures on the lower Provo River. At a minimum, this working group should include the Provo River Commissioner, individual water users, representatives from relevant municipalities, canal companies, and water conservancy districts, and representatives from the Utah Division of Wildlife Resources, the U.S. Fish and Wildlife Service, the Utah Reclamation Mitigation and Conservation Commission, and the U.S. Bureau of Reclamation. Coordination among these groups is essential so that individual actions do not work at cross-purposes and opportunities to work together are fully utilized.

Because acquiring water rights is an expensive, time-consuming process, additional means of providing instream flows in the lower Provo River should be explored. Possibilities include implementing water conservation programs or canal-lining/ piping projects. Conserved water could be returned to the stream, possibly by transferring unneeded water shares or water rights to the Utah Division of Wildlife Resources to be held as instream flow rights. Another possibility would be to transfer these shares or rights to the U.S. Bureau of Reclamation, who could make downstream flows available as needed from storage in Jordanelle Reservoir or Deer Creek Reservoir.

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