Utah Lake Drainage Basin
Water Delivery System
Bonneville Unit, Central Utah Project

Draft Environmental Impact Statement

Draft
Aquatic Resources Technical Report

March 2004

UTAH RECLAMATION
MITIGATION
AND CONSERVATION
COMMISSION

Utah Lake Drainage Basin Water Delivery System
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Prepared by
Central Utah Water Conservancy District

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Chapter 1
Introduction

1.1 Purpose and Organization

This *Aquatic Resources Technical Report* (TR) analyzes potential impacts on aquatic resources from the construction, operation and maintenance of the Utah Lake Drainage Basin Water Delivery System (ULS). This analysis is based on flow projections as described in detail in the Draft Surface Water Hydrology Technical Report for the Utah Lake Drainage Basin Water Delivery System (CUWCD 2004a).

This TR addresses issues raised during the public and agency scoping process for the ULS and provides baseline information to support the ULS Draft Environmental Impact Statement (DEIS) being prepared in compliance with the National Environmental Policy Act (NEPA). Related information on threatened and endangered and sensitive aquatic resources is presented in the DEIS, Chapter 3, Section 3.9 Threatened and Endangered Species, and Section 3.10 Sensitive Species.

This TR is organized by the following chapters:

Chapter 1 – An outline of the TR and a summary description of the Preferred Alternative and other alternatives

Chapter 2 – Methodology used in the analysis of aquatic resources

Chapter 3 – Existing Environment (Baseline Conditions)

Chapter 4 – Analysis of environmental consequences (impacts)

Chapter 5 – Mitigation and monitoring for significant impacts identified in the analysis

Chapter 6 – Unavoidable adverse impacts

Chapter 7 – Cumulative impacts of the ULS and related actions

1.2 Description of Preferred Alternative and Other Alternatives

This section serves as an overview of the ULS alternatives for this technical report.

1.2.1 Spanish Fork Canyon–Provo Reservoir Canal Alternative (Preferred Alternative)

Table 1-1 presents the Preferred Alternative features. This alternative has a total transbasin diversion of 101,900 acre-feet, which consists of the following amounts of water: 30,000 acre-feet of municipal and industrial (M&I) secondary water to southern Utah County, 30,000 acre-feet of M&I water to Salt Lake County, 1,590 acre-feet of M&I water already contracted to the southern Utah County cities, and 40,310 acre-feet of M&I water to Utah Lake for exchange to Jordanelle Reservoir. It would involve constructing five new pipelines: 1) from the mouth of Diamond Fork Canyon to the mouth of Spanish Fork Canyon; 2) from the mouth of Spanish Fork Canyon to Santaquin in southern Utah County; 3) from Santaquin to Mona Reservoir; 4) from the mouth of Spanish Fork Canyon to Hobble Creek along the Mapleton-Springville Lateral alignment; and 5) from the mouth of Spanish Fork Canyon to the Provo Reservoir Canal and Jordan Valley Aqueduct. Under this alternative, the Department of the Interior (DOI) would acquire approximately 57,000 acre-feet of the Central Utah Water Conservancy District's (District) secondary water rights in Utah Lake as part of the project water supply. Two power generating facilities would be constructed in the Diamond Fork System under this alternative.

Table 1-1
Construction Features of Utah Lake Drainage Basin Water Delivery System Alternatives

Feature	Spanish Fork Canyon – Provo Reservoir Canal Alternative (Preferred Alternative)	Bonneville Unit Water Alternative	No Action Alternative
Sixth Water Power Facility and Transmission Line	45 MW generator and 12.9 miles of overhead transmission line upgraded to 138 kV from Sixth Water Power Facility to Highway 6	45 MW generator and 12.9 miles of overhead transmission line upgraded to 138 kV from Sixth Water Power Facility to Highway 6	Not constructed
Upper Diamond Fork Power Facility and Underground Cable	5 MW generator and 1.6 miles of 25 kV underground cable (existing) through Tanner Ridge Tunnel to Sixth Water Transmission Line	5 MW generator and 1.6 miles of 25 kV underground cable (existing) through Tanner Ridge Tunnel to Sixth Water Transmission Line	Not constructed
Spanish Fork Canyon Pipeline	7.0 mile steel pipeline, 84-inches diameter from Spanish Fork Flow Control Structure at mouth of Diamond Fork Creek to Moark Junction	7.0 mile steel pipeline, 72-inches diameter from Spanish Fork Flow Control Structure at mouth of Diamond Fork Creek to Moark Junction	Not constructed
Spanish Fork-Santaquin Pipeline	17.5 mile steel pipeline, ranging from 60- to 36-inches diameter, from terminus of Spanish Fork Canyon Pipeline to Santaquin	17.5 mile steel pipeline, ranging from 48- to 30-inches diameter, from terminus of Spanish Fork Canyon Pipeline to Santaquin (CUPCA Section 207 feature)	Not constructed
Santaquin-Mona Reservoir Pipeline	7.7 mile steel pipeline, 24-inches diameter, from terminus of Spanish Fork-Santaquin Pipeline to Mona Reservoir	Not constructed	Not constructed
Mapleton-Springville Lateral Pipeline (CUPCA Section 207)	5.7 mile steel pipeline, ranging from 48- to 30-inches diameter from terminus of Spanish Fork Canyon Pipeline to Hobble Creek	5.7 mile steel pipeline, ranging from 48- to 30-inches diameter, from terminus of Spanish Fork Canyon Pipeline to Hobble Creek	Not constructed
Spanish Fork – Provo Reservoir Canal Pipeline	19.7 mile steel pipeline, ranging from 60- to 48 inches diameter, from terminus of Spanish Fork Canyon Pipeline to Provo Reservoir Canal and Jordan Valley Aqueduct	Not constructed	Not constructed

The following summarizes the Preferred Alternative operation.

- 30,000 acre-feet of M&I water would be conveyed to Salt Lake County through the new pipelines and a combination of existing facilities (Jordan Aqueduct and Provo Reservoir Canal conveyance facilities) to water treatment plants for treatment and culinary supply.

- 30,000 acre-feet of M&I water would be conveyed through the new pipelines to the South Utah Valley Municipal Water Association (SUVMWA) member cities in southern Utah County.

- 1,590 acre-feet of Bonneville Unit water already contracted would continue to be used by SUVMWA member cities as M&I water.

- 40,310 acre-feet of project M&I water would be delivered to Utah Lake for exchange to Jordanelle Reservoir. This water would consist of the following: an average of 16,273 acre-feet would be released for in-stream flows in Sixth Water Creek (8,773 acre-feet through the Strawberry Tunnel) and Diamond Fork Creek (7,500 acre-feet released from the Diamond Fork Flow Control Structure) and flow down the Spanish Fork River to Utah Lake mainly during the winter months; an average of 16,000 acre-feet would be conveyed through the Spanish Fork–Provo Reservoir Canal Pipeline and discharged to the Provo River to assist in meeting in-stream flows when water is being delivered from Strawberry Reservoir to Utah Lake for exchange up to Jordanelle Reservoir; and about 8,037 acre-feet would be conveyed through the Mapleton-Springville Lateral Pipeline and released to Utah Lake via Hobble Creek. All of this water would be subsequently exchanged from Utah Lake to Jordanelle Reservoir.

- Up to 10,200 acre-feet of Strawberry Valley Project (SVP) water shares held by SUVMWA would be conveyed to member cities through the new ULS pipelines in southern Utah County on a space-available basis.

- Hydroelectric project power would be generated and contracted to the Western Area Power Administration (see Table 1-1 for generating capacities).

- By implementing Section 207 Water Conservation Program projects, at least 12,000 acre-feet of project water would be provided for in-stream flow purposes to assist in meeting the flows necessary for recovery of the June sucker. Of this amount, at least 4,000 acre-feet would be obtained from projects in southern Utah County to be released down Hobble Creek, and at least 8,000 acre-feet would be obtained from projects in north Utah County to be released and conveyed through the lower Provo River.

- As allowed under the Jordanelle-Deer Creek Operating Agreement, an average annual 12,165 acre-feet of project water would be provided as flows for June sucker spawning and rearing in the lower Provo River to assist in meeting the June Sucker Recovery Implementation Program (JSRIP) goals. Of this amount 4,165 acre-feet has already been obtained, and as indicated above, at least an additional 8,000 acre-feet would be obtained from new section 207 projects in north Utah County and released through the lower Provo River.

- Approximately 3,300 acre-feet of lower Provo River summer irrigation water rights already purchased by the Mitigation Commission would flow undiverted to Utah Lake, thereby increasing the summertime flow in the lower Provo River.

- An average of 12,037 acre-feet of water would be available through the Mapleton-Springville Lateral pipeline to Hobble Creek for June sucker spawning and rearing flows to meet JSRIP goals and to provide

other fish and wildlife benefits throughout the year. This water would be subsequently exchanged from Utah Lake to Jordanelle Reservoir. Of the 12,037 acre-feet, 4,000 acre-feet would be provided in every year that it is needed. The remaining 8,037 acre-feet only would be provided when water is being delivered from Strawberry Reservoir to Utah Lake for exchange up to Jordanelle Reservoir. Hobble Creek supplemental water would not be delivered during high runoff years when Utah Lake is above "Compromise Level" (4,489.045 feet mean sea level). The high runoff years correspond with years when natural runoff would be sufficient to attract June sucker spawning.

1.2.2 Bonneville Unit Water Alternative

Table 1-1 presents the features of this alternative. This alternative has a total transbasin diversion of 101,900 acre-feet which consists of: 15,800 acre-feet of M&I secondary water to southern Utah County, 1,590 acre-feet of M&I water already contracted to the southern Utah County cities, and 84,510 acre-feet of M&I water to Utah Lake for exchange to Jordanelle Reservoir. It would involve constructing three of the new pipelines as described for the Preferred Alternative: 1) from the mouth of Diamond Fork Canyon to the mouth of Spanish Fork Canyon; 2) from the mouth of Spanish Fork Canyon to Santaquin in southern Utah County; and 3) from the mouth of Spanish Fork Canyon to Hobble Creek along the Mapleton – Springville Lateral alignment. The Spanish Fork Canyon Pipeline would be a federally funded ULS feature; the other two pipelines would be constructed as combined ULS and Section 207 Water Conservation Program features. Under this alternative, two power generating facilities would be constructed in the Diamond Fork System; the DOI would acquire approximately 15,000 acre-feet of District secondary water rights in Utah Lake as part of the project water supply; and no M&I water would be conveyed to Salt Lake County.

The following summarizes the Bonneville Unit Water Alternative operation:

- 15,800 acre-feet of additional Bonneville Unit M&I water would be delivered to SUVMWA member cities through the Spanish Fork-Santaquin Pipeline in southern Utah County under a contract with SUVMWA.

- 1,590 acre-feet of Bonneville Unit water already contracted would continue to be used by SUVMWA member cities as M&I water.

- 84,510 acre-feet of project M&I water minus conveyance losses would be delivered to Utah Lake for exchange to Jordanelle Reservoir. This water would consist of the following: an average of 16,273 acre-feet would be released for in-stream flows in Sixth Water Creek (8,773 acre-feet through the Strawberry Tunnel) and Diamond Fork Creek (7,500 acre-feet released from the Diamond Fork Flow Control Structure) and flow down the Spanish Fork River to Utah Lake mainly during the winter months; 48,727 acre-feet would be released from the Spanish Fork Flow Control Structure to be conveyed down the Spanish Fork River to Utah Lake; and 19,510 acre-feet would be conveyed through the Mapleton-Springville Lateral Pipeline and released to Utah Lake via Hobble Creek. All of this water would be subsequently exchanged from Utah Lake to Jordanelle Reservoir.

- Up to 10,200 acre-feet of Strawberry Valley Project (SVP) water shares held by SUVMWA would be conveyed to member cities through the new ULS pipelines in southern Utah County.

- Hydroelectric project power would be generated from the M&I water conveyance and contracted to the Western Area Power Administration (see Table 1-1 for generating capacities).

- By implementing Section 207 Water Conservation Program projects, at least 12,000 acre-feet of project water would be provided for in-stream flow purposes to assist in meeting the flows necessary for recovery of the June sucker. Of this amount, at least 4,000 acre-feet would be obtained from projects in southern Utah County to be released down Hobble Creek, and at least 8,000 acre-feet would be obtained from projects in north Utah County to be released and conveyed through the lower Provo River.

- As allowed under the Jordanelle-Deer Creek Operating Agreement, an average annual 12,165 acre-feet of project water would be provided as flows for June sucker spawning and rearing in the lower Provo River to assist in meeting the June Sucker Recovery Implementation Program (JSRIP) goals. Of this amount 4,165 acre-feet has already been obtained, and as indicated above, at least an additional 8,000 acre-feet would be obtained from new section 207 projects in north Utah County and released through the lower Provo River.

- Approximately 3,300 acre-feet of lower Provo River summer irrigation water rights already purchased by the Mitigation Commission would flow undiverted to Utah Lake, thereby increasing the summertime flow in the lower Provo River.

- An average of 23,510 acre-feet of water would be conveyed through the Mapleton-Springville Lateral pipeline to Hobble Creek for June sucker spawning and rearing flows to meet JSRIP goals and to provide other fish and wildlife benefits throughout the year. This water would be subsequently exchanged from Utah Lake to Jordanelle Reservoir. Of the 23,510 acre-feet, 4,000 acre-feet would be provided in every year that it is needed. The remaining 19,510 acre-feet only would be provided when water is being delivered from Strawberry Reservoir to Utah Lake for exchange up to Jordanelle Reservoir. Hobble Creek supplemental water would not be delivered during high runoff years when Utah Lake is above Compromise Level The high runoff years correspond with years when natural runoff would be sufficient to attract June sucker spawning.

1.2.3 No Action Alternative

No new water conveyance features would be constructed under the No Action Alternative. The 86,100 acre-feet of Bonneville Unit M&I water, minus the 1,590 acre-feet of Bonneville Unit water already contracted for by SUVMWA member cities, would be conveyed from Strawberry Reservoir through the existing Diamond Fork System and discharged into the Spanish Fork River at the mouth of Diamond Fork Canyon, as described in the 1999 Diamond Fork FS_FEIS. All of this water would be exchanged from Utah Lake to Jordanelle Reservoir.

The following summarizes the No Action Alternative operation.

- 86,100 acre-feet of project M&I water minus conveyance losses would be delivered to Utah Lake for exchange to Jordanelle Reservoir. This water would consist of the following: an average of 16,273 acre-feet would be released for in-stream flows in Sixth Water Creek (8,773 acre-feet through the Strawberry Tunnel) and Diamond Fork Creek (7,500 acre-feet released from the Diamond Fork Flow Control Structure) and flow down the Spanish Fork River to Utah Lake mainly during the winter months; and 69,827 acre-feet would be released from the Spanish Fork Flow Control Structure. Of the 69,827 acre-feet, 1,590 acre-feet would be delivered to SUVMWA member cities under existing contracts, and the remaining 68,237 acre-feet would be conveyed through the Spanish Fork River to Utah Lake throughout the year. All of this water would be subsequently exchanged from Utah Lake to Jordanelle Reservoir.

- 1,590 acre-feet of Bonneville Unit water already contracted would continue to be used by SUVMWA member cities as M&I water.

- As allowed under the Jordanelle-Deer Creek Operating Agreement, an average annual 12,165 acre-feet of project water would be provided as flows for June sucker spawning and rearing in the lower Provo River to assist in meeting the June Sucker Recovery Implementation Program (JSRIP) goals. Of this amount 4,165 acre-feet has already been obtained, and as indicated above, at least an additional 8,000 acre-feet would be obtained from new section 207 projects in north Utah County and released through the lower Provo River.

- Approximately 3,300 acre-feet of lower Provo River summer irrigation water rights already purchased by the Mitigation Commission would flow undiverted to Utah Lake, thereby increasing the summertime flow in the lower Provo River.

1.3 Scoping Issues

1.3.1 Issues Raised in Scoping Meetings

The following aquatic resource issues were raised during the public and agency scoping process:

- What would be the impacts of high flows in the Provo River on aquatic resources and recreational fishing?

- Would the timing of demand for M&I water be compatible with instream flows for stream habitats, particularly protection of spawning habitats, etc.?

- What would be the impacts on Utah Lake from a pipeline rupture, since the area is in a zone of high earthquake risk?

- What would be the short-term impacts of pipeline construction on riparian areas, wildlife habitats and critical spawning periods for aquatic species?

- What would be the impacts on aquatic habitats if all available ULS capacity were needed for M&I peak demands during the summer season?

- What would be the impacts of pipeline construction on streams and wetlands in Daniels Canyon?

- What would be the potential impacts on channel stability, stream habitats and fishability from higher flows in the Provo River below Deer Creek Reservoir?

- What would be the impacts on flows and fish habitat in Hobble Creek to Utah Lake?

- What would be the impacts of possible catastrophic failure of the pipeline through Utah Lake?

- What would be the impacts on each of the ULS concepts from aquatic nuisance species such as the zebra mussel?

- What would be the impacts of the ULS water delivery concepts on:
    - Pollution of surface water and groundwater
    - Habitat destruction, fragmentation and alteration (aquatic and terrestrial)
    - Groundwater depletion
    - Loss of species diversity (aquatic and terrestrial)
- What would be the impacts on the endangered June sucker and Bonneville cutthroat trout from any of the ULS concepts?
- What would be the impact on Utah Lake biota from constructing a pipeline across Utah Lake?
- What would be the impacts on wetlands, aquatic life and T&E species from overuse of groundwater?

1.3.2 Scoping Issues Eliminated From Further Consideration

What would be the impact on Utah Lake biota from constructing a pipeline across Utah Lake?

What would be the impacts of possible catastrophic failure of the pipeline through Utah Lake?

What would be the impacts on Utah Lake from a pipeline rupture, since the area is in a zone of high earthquake risk?

The Spanish Fork-Bluffdale Alternative, which included the construction of a pipeline across Utah Lake, was eliminated from consideration (see EIS Chapter 1, Section 1.11.1).

What would be the impacts on wetlands, aquatic life and T&E species from overuse of groundwater?

The ULS project does not involve any features that require the pumping of groundwater. The pumping of groundwater is controlled by the Utah State Engineer and would continue with or without the construction of the ULS project.

What would be the impacts on the endangered June sucker and Bonneville cutthroat trout from any of the ULS concepts?

The impacts on June Sucker (a threatened and endangered species) and Bonneville cutthroat trout (a sensitive species) are covered in the Threatened, Endangered and Sensitive Species Technical Report (CUWCD 2004b) and in EIS sections 3.9 and 3.10.

What would be the impacts on the Daniels Creek fishery from the Strawberry Reservoir - Deer Creek Reservoir Alternative?

What would be the opportunities for and impacts of the Strawberry Reservoir - Deer Creek Reservoir Alternative on the roadside put-and-take fishery conditions in Daniels Canyon?

What would be the impacts of pipeline construction on streams and wetlands in Daniels Canyon?

The Strawberry Reservoir–Deer Creek Reservoir Alternative was eliminated from detailed analysis. Please see EIS Chapter 1, Section 1.11.8.

1.3.3 Scoping Issues Addressed in the Technical Report

All issues in Section 1.3.1 are addressed in the impact analysis, with the exception of those listed in Section 1.3.2.

1.4 Impact Topics

- Habitats
- Fish populations
- Benthic macroinvertebrates populations

Chapter 2
Methodology

2.1 Assumptions

- Wetted perimeter and macroinvertebrate habitat are directly related; thus, increases in wetted perimeter were assumed to result in increased habitat for macroinvertebrates.
- Data from river cross sections collected in the Spanish Fork River immediately downstream of the Diamond Fork River confluence were assumed to be representative of the Spanish River sections downstream of the Spanish Fork Diversion Dam.
- Cross-sectional information gathered at USGS gages was assumed to be representative of the entire reach that they are located in, for each analysis.
- In the Provo River below Deer Creek Reservoir, the baseline condition was assumed to be the habitat conditions published in the M&I FEIS (Reclamation 1979). While trout biomass in the Provo River was estimated in 1979, more recent habitat surveys from 2000 to 2001 (UDNR 2003) provided slightly different biomass estimates using the Habitat Quality Index (HQI) Model II (Binns 1982). It was assumed that the more recent estimates provided a more accurate description of the trout populations and these data were used to estimate baseline trout standing crop in the Provo River.
- The Spanish Fork River baseline conditions were updated with modeled flows from 1950 to 1999 and habitat conditions published in the Diamond Fork System FEIS (CUWCD 1999).

2.1 Impact Analysis Methodology

2.2.1 Baseline Conditions

The description of baseline habitat conditions in this region was complex. Baseline conditions of habitat were determined through a combination of hydrologic modeling, direct field observations and sampling, literature review, and agency file data on resources in the area, and discussions with knowledgeable state and federal agency representatives. Baseline flow conditions for all rivers and streams were obtained from the Draft Surface Water Hydrology Technical Report for the Utah Lake Drainage Basin Water Delivery System (CUWCD 2004a). In the Provo River below Deer Creek Reservoir, the baseline condition was assumed to be the habitat conditions published in the M&I FEIS (Reclamation 1979). However, since Binns HQI habitat ratings were not available in the M&I FEIS, Binns HQI habitat surveys from 2000 to 2001 were used to determine baseline conditions. The baseline condition for the Jordan River was based on hydrologic modeling. The Spanish Fork River baseline conditions were updated with modeled flows from 1950 to 1999 and habitat conditions published in the Diamond Fork System FEIS (CUWCD 1999).

2.2.1.1 Fish

A comprehensive list of native and game fish species with the potential to occur within the project surface waters was compiled after consulting with the U.S. Fish and Wildlife Service (FWS), Utah Division of Wildlife Resources, Natural Heritage Program (NHP), and the Uinta National Forest (UNF). Fish species that occupied

similar habitat niches were grouped for habitat modeling on the Provo River. Population abundance data were obtained from existing documents and/or Utah Division of Wildlife Resources fisheries survey data.

Data on spawn timing and water temperatures associated with spawning activity for game and non-game fishes were compiled from scientific literature (Table 2-1). This information was used in conjunction with projected changes in flow quantity and timing to determine potential impacts on fish.

Table 2-1
Spawning Period and Water Temperatures Associated with Spawning For Fish Species Potentially Affected by the ULS Project Alternatives[1]

Common Name	Spawning Period/Water Temperature
Game Fish	
Brown trout	October-December, 45-50 °F
Cutthroat trout*	Late-spring, 42-48 °F
Rainbow trout	Late-spring, ~50 °F
Channel catfish	Late-spring, early summer, 72-75 °F
Black bullhead	May-July, 65-70 °F
Walleye	Late-spring, 38-48 °F
White bass	Spring, 58-66 °F
Mountain Whitefish	Mid-November-December, 40-45 °F
Non-game Fish	
Leatherside chub*	June-August, 60-68 °F
Utah chub*	June-July, 52-68 °F
Speckled dace*	June-August, ~65 °F
Longnose dace	June-September, nr
Fathead minnow	May-August, ~64°F
Common carp	Spring, 58-67°F
Redside shiner*	April-June, ~50°F
Mountain sucker*	June-July, ~50°F
Mottled sculpin*	February-May, nr
Utah sucker*	Spring, ~60°F

* Native Species
[1]Spawning period and water temperatures associated with spawning reported by Sigler and Sigler (1987).
nr = not reported

2.2.1.1.1 Provo River IFIM and PHABSIM. The Instream Flow Incremental Methodology (IFIM) was used in this analysis to assess the effects of flow manipulation in the Provo River on fish habitat (BIO-WEST 2003b; Radant and Shirley 1987). IFIM is composed of a suite of analytical procedures that describe habitat features resulting from a specific flow scenario (Bovee et al. 1998). One of these procedures is the microhabitat model component of the IFIM known as the Physical Habitat Simulation (PHABSIM). In a recent study by BIO-WEST (2003a, 2003b), the PHABSIM component of the IFIM was used to predict the amount of fish habitat for fish species under a range of possible flows in the Provo River. The major premise of the PHABSIM procedure is that the suitability of a species' habitat can be described by measuring selected physical variables in a stream. To address this assumption, an extensive search of published and unpublished physical habitat relationships for the

species of interest in this analysis was conducted (e.g. Radant et al. 1987). Additional research was conducted for some fishes in the Provo River to measure or validate their requirements for depth, velocity and substrate (Bio-West 2003b; Belk and Elsworth 2000). After these values were determined, the biological data were linked with the physical and hydraulic properties of the river. The physical habitat features of the river were determined by overlaying substrate maps with detailed digital terrain models developed for each site. The river's hydraulic properties were then simulated using a two-dimensional (quasi-three-dimensional) hydraulic model (a version of STAGR, modified by Craig Addley, Utah State University) (BIOWEST 2003a, 2003b) of each study site. The hydraulic model calculates depth and velocity at hundreds of nodes within the study site mesh, at different discharge values. Linking the biological data to the hydraulic values was used to estimate the relationship between habitat availability and flow within study reaches. The following methods are summarized from BIO-WEST 2003a and 2003b.

To evaluate habitat availability in the Provo River between Deer Creek Reservoir and Utah Lake, selected habitat parameters for the PHABSIM analysis were measured at eight study sites (Table 2-1 and 2-2). Two modeling approaches were used during this study to estimate habitat availability for fishes in the Provo River. In the first approach, a PHABSIM model was applied to multiple life stages of game fishes for which models were available including brown trout, cutthroat tout, rainbow trout and mountain whitefish. These models combined site-specific habitat and flow data with requirements of depth, velocity, and substrate for each species and life stage considered to predict how fish habitat would change with increased or decreased flows. Habitat availability was determined for each species and life stage and for all trout under alternative flow scenarios.

A second modeling approach was used to evaluate flow effects on niche habitats because data on specific habitat requirements for some species were limited. Fish species with similar habitat requirements were grouped together into 7 distinct habitat niches (Table 2-2). This approach provided a more coarse measure of habitat usage than the habitat suitability by species model. A given habitat niche may be the only one used by a certain life stage of a species or may represent only partial use. In addition, any one niche can be used by multiple species and life stages. Habitat availability was determined for each niche for each alternative.

After the integration of biological and physical habitat components, projected habitat availability was simulated in terms of weighted usable area (WUA). For these purposes, WUA can be defined as the total area per unit length of river that would be expected to provide usable habitat for a selected species/life stage or habitat niche. Habitat was modeled as WUA (ft^2) per 1,000 linear feet of stream. In this analysis, a modeled average monthly flow generated a monthly WUA value. Average monthly flows under a project alternative were used to predict a corresponding value of monthly WUA for each modeled species/life stage or habitat niche during the 50-year period (1950-1999). An average WUA for each month over the period of record (1950-1999) was then calculated for alternative comparison. WUA was the measure of habitat used to assess potential impacts on fish habitat under the project alternatives.

Table 2-2
Fish Species Use of Provo River Habitat Niches

Page 1 of 2

Niche	Species	Life Stage	Use*
(1) Backwater/Edge	Mountain whitefish	Fry	Partial (1,5)
	Mountain sucker	juvenile, YOY	full
	Utah sucker	YOY	full
	Speckled dace	YOY	full
	Longnose dace	YOY	full
	Leatherside chub	adult, juvenile, YOY	full
	Redside shiner	adult, juvenile, YOY	full

Table 2-2
Fish Species Use of Provo River Habitat Niches

Niche	Species	Life Stage	Use*
(2) Slow/Shallow	Brown trout	Spawning	Partial (2,3,5)
	all trout	juvenile, fry, spawning	partial (2,3,5)
	mountain sucker	adult	partial (2,3,4,5,6)
	mottled sculpin	adult, juvenile	partial (2,3,4)
	mottled sculpin	YOY	full
	speckled dace	Adult	partial (2,3)
	speckled dace	Juvenile	full
	longnose dace	Adult	partial (2,3,5)
	longnose dace	Juvenile	full
(3) Moderate/Shallow	Brown trout	Spawning	Partial (2,3,5)
	all trout	juvenile, fry, spawning	partial (2,3,5)
	mountain sucker	adult	partial (2,3,4,5,6)
	mottled sculpin	adult, juvenile	partial (2,3,4)
	speckled dace	adult	partial (2,3)
	longnose dace	adult	partial (2,3,5)
(4) Fast/Shallow	Mountain sucker	Adult	Partial (2,3,4,5,6)
	Mottled sculpin	adult, juvenile	partial (2,3,4)
(5) Moderate/Mid-depth	Brown trout	adult, juvenile, fry	full
	Brown trout	spawning	partial (2,3,5)
	all trout	adult	full
	all trout	juvenile, fry, spawning	partial (2,3,5)
	June sucker	spawning	full
	Mountain whitefish	adult	partial (5,7)
	Mountain whitefish	juvenile, spawning	full
	Mountain whitefish	fry	partial (1,5)
	Mountain sucker	adult	partial (2,3,4,5,6)
	Utah sucker	adult	partial (5,7)
	Utah sucker	juvenile	full
	Longnose dace	adult	partial (2,3,5)
(6) Fast/Mid-Depth	Mountain sucker	Adult	Partial (2,3,4,5,6)
(7) Moderate/Deep	Mountain whitefish	Adult	Partial (5.7)
	Utah sucker	Adult	partial (5.7)

*full = best habitat suitability within niche; partial = best habitat suitability shared between niches (shared niches are listed in parentheses)

2.2.1.1.1.1 Verification and Calibration. As part of the IFIM study, BIO-WEST performed a sensitivity analysis to compare the habitat suitability by species/life stage to the habitat niche approach. This was done by modeling several species using both methods and comparing the relationships between the two model results. Results indicated that relationships were similar for all species evaluated, while the total amount of habitat availability calculated under the two approaches differed. This was as expected, because the habitat niche approach is a more general measure than the species-specific habitat suitability method.

2.2.1.1.1.2 Data Analysis and Application. WUA values were calculated for each month in the 50-year period of record for each of the 19 species/life stage/niche categories for baseline and each alternative, for each study site. The resulting abundance of data was analyzed several ways.

1. A habitat-time series graph was plotted for each species/life stage/niche category in each river reach over the entire 50-year timeframe to examine temporal patterns in habitat availability for baseline and each alternative. This first step in the evaluation process identified where specific areas of focus for additional analysis might be appropriate. For instance, a pattern of repeated low habitat availability during certain months or frequency and duration of very low habitat availability would be apparent with this graph and would lead to a closer examination of those trends.

2. A habitat duration graph was plotted for each species/life stage/niche category in each river reach during the entire 50-year period of record for baseline and each alternative. This type of graph provided an overview of the proportion of time each WUA value was met over the time period analyzed. However, this type of graph does not show some important information such as the timing and repetition of low WUA values. For instance, a particular graph may show that a WUA of zero occurs only 1 percent of the time during the 50-year period of record, but does not indicate whether the occurrences of low WUA were all at one time in one year or repeatedly for a short period in a number of years. It does not indicate what time of year the low WUA value occurs. Timing of these low WUA value occurrences can be determined visually through examination of the time-series graph produced from method (1) above, but does not provide summary statistics of those occurrences.

3. While the two analyses described above provide a complete look at the conditions experienced under a given alternative flow regime for an individual species/life stage/niche category at a river reach, this type of analysis does not lend itself well to comparison of alternatives because the results are somewhat subjective. For comparisons, summary statistics are essential. Therefore, additional analyses were conducted. Along with typical measures of mean, median, and ranges of the entire dataset, three index values were used for the DEIS: the mean of the 10 to 90 percent exceedance values; the mean of the 50 to 90 percent exceedance values; and the mean of the 50 to 100 percent exceedance values. At the upper end of the WUA range, high values can have a disproportionate effect on the overall mean. Biotic communities (e.g. fish populations) may not be able to respond to sudden, short-term increases in WUA from one month to the next. Having higher WUA (better conditions for that type of organism) for only one or two months out of 24, for instance, may not result in any appreciable positive influence on that organism because the timeframe is too short for the organism to respond (e.g. to reproduce or put on a substantially greater increment of growth, for example). Additionally, sudden short-term declines in WUA can have adverse effects on organisms that may be manifested in only a period of a month or two (lower growth rates, stress caused by competition or predation risk may lead to higher mortality). Including the lowest WUA values was considered important for this analysis, to be consistent with the conservative approach applied in this DEIS. Therefore, evaluating only the lowest half of the exceedance values (50 to 100 percent) reduces the influence of very high WUA values and provides a more accurate measure of true differences. This index was chosen as the primary means of comparing alternatives. Because the 50 to 100 percent interval consists of trimming all of the habitat values above the median and averaging the habitat values between the median and minimum, it is equivalent to evaluating only the troughs in the habitat time series. The ranges associated with this index value (median and minimum from entire dataset) are considered to identify potential differences in two datasets that have the same mean index value.

4. Analysis method (3) might not provide the resolution necessary to identify differences that may occur on a smaller temporal scale (i.e., across years or seasonally). Therefore, a comparison at a finer scale of resolution was conducted for selected categories. The 50 to 100 percent index value was calculated for this additional analysis on an annual basis using only the months (May through August) when hydrology would fluctuate rapidly (>20 percent change from one month to the next).

All datasets were evaluated using each method (1, 2 and 3) described above with additional analysis described in method (4) conducted on selected datasets. Unless otherwise noted, the results reported in this technical report are as described under method (3). The reported results of comparing alternatives were determined by using the 50 to 100 percent index value for the entire 50-year period for a given category under baseline conditions at a particular site.

2.2.1.1.1.3 Binns Habitat Quality Index. Potential impacts on aquatic resources were estimated with the Habitat Quality Index (or Binns HQI) Model II, a method to evaluate the quality of the habitat of trout-supporting, cold-water river systems. Analysis output for the HQI is expressed in terms of standing crop of trout, where trout are used as an indicator species for the coldwater aquatic ecosystem. The Binns HQI Model II was used to calculate the net increase, or decrease, in trout standing crop based on streamflow and other specific habitat variables. Binns HQI Model II attribute rating summary sheets are included in Appendix A.

In the Provo River below Deer Creek Reservoir, a projected trout standing crop was established from the M&I FEIS (Reclamation 1979). Although estimates of fish biomass were presented in the M&I EIS (Reclamation 1979), Binns HQI Model II habitat ratings were not provided. More recent data on fish resources in the Provo River have been collected by the Utah Division of Wildlife Resources at nine sites in the Provo River below Deer Creek Reservoir, including individual habitat ratings and estimates of fish standing crop. Data from the 2000 and 2001 Binns HQI habitat surveys were used as the starting point for biomass determinations. Data from four of the Utah Division of Wildlife Resources sites were combined to estimate the baseline biomass for the Murdock Diversion Dam to Interstate 15. These sites were: Murdock Diversion Dam to Spanish Fork-Provo Reservoir Canal Pipeline Discharge; Spanish Fork-Provo Reservoir Canal Pipeline Discharge to Riverside Country Club; Riverside Country Club to Tanner Race Diversion Dam; and Tanner Race Diversion Dam to Fort Field Diversion. Data from the Fort Field Diversion to Utah Division of Wildlife Resources weir was used for the Interstate 15 to Utah Lake reach (ending at the weir). To estimate trout standing crop, these data were then adjusted for the surface water hydrology that was projected for baseline and alternative conditions. A final calculation, multiplying an estimate of standing crop (pounds per acre) by the total available area (acres) was used to generate total biomass (pounds). The net increase or decrease in predicted trout biomass under each alternative was compared to baseline conditions to determine whether changes were beneficial or adverse to game fish. This same protocol was used to estimate trout standing crop and biomass for the Spanish Fork River and Hobble Creek.

2.2.1.1.2 Hobble Creek Geomorphic Survey. Baseline geomorphic condition, and its relationship to altered flows in Hobble Creek, was determined with assessment methodologies adapted from Rosgen. The focus of this task was to assess overall existing channel stability, identify point sources of lateral bank erosion and channel incision and identify sediment deposition zones. These data were extrapolated using estimated average monthly flow to assess changes associated with the proposed alternatives. Knowledge of the relationships between discharge, channel geometry and hydraulics were used to relate movement of substrate material to a measure of stream power or average bed shear stress. Then, the effects of altered flow on substrate movement conditions were evaluated.

Initially, a Level 1 (pre-field) characterization of historical and existing channel and riparian condition of the affected reach was conducted. This characterization was made from reviews of topographic maps, aerial photography, flow data, channel and aquatic habitat surveys and land management information. The product of this characterization was a delineation of valley type, landform, and channel type, and provided a framework for conducting a field survey.

The second step under this task was to conduct a field survey through the reach to verify the Level 1 morphological characterization of channel types and channel processes, characterize bank and channel bed stability, and identify active and/or potential erosion sources and sediment deposition within the Hobble Creek channel. The survey included reconnaissance-level collection of data on channel dimension, plan form, profile, substrate, composition of bank materials, value of habitat, and effects on water quality. A unit file was prepared

for both the stream classification and erosion surveys. Data were analyzed to qualitatively evaluate the potential effects on channel form, including sediment erosion and deposition, and potential effects on fish habitat.

In addition to field surveys of channel condition, a river analysis model (HEC-RAS) was used to assess effects related to changes in wetted channel width, maximum channel depth, wetted perimeter, and mean channel velocity in Hobble Creek under the alternative flow regimes. The model was used to simulate steady flow conditions and to simulate backwater effects that could occur in Hobble Creek from Utah Lake. A diversion structure approximately 800 feet downstream of the I-15 crossing prevented an analysis of backwater effects upstream of this point. Data inputs into the model included 60 habitat cross-sections and baseline and alternative flows described in MWH 2003b. Data outputs from the model were analyzed to determine potential effects on Hobble Creek aquatic habitat under each alternative.

2.2.1.1.2.1 Verification and Calibration. Qualitative calibration of the HEC-RAS model was performed. The survey data from BIO-WEST included the water level and a flow measurement and a calibrated Manning's number. Velocities and Froude numbers were checked in the model. These data were used to confirm approximate accuracy of the geometric data.

2.2.1.1.3 Spanish Fork River. Stage-discharge relationships and baseline modeled flows were used to estimate habitat impacts in Spanish Fork River. Hydrologic relationships from two cross-sections immediately downstream of the Diamond Fork Creek confluence with the Spanish Fork River were used during the analysis (CUWCD 1999). The location of the cross-sections is provided in Appendix A, Section C. The two cross-sections differed in channel morphology. Stage-discharge relationships derived from habitat cross-sections were not available for the reaches below the Spanish Fork Diversion Dam, therefore these two habitat cross-sections were considered to be representative of channel morphology in the entire section of the Spanish Fork River downstream of this reach.

2.2.1.1.4 Water Quality. The results of the water resource and water quality analyses were reviewed to determine potential changes in stream flow and water quality. The analysis covered the following water quality constituents: temperature, pH, nutrient levels, dissolved oxygen, salinity (as TDS) and trace metals. Additional information on aquatic habitat and water quality was obtained from related regulatory documents and information from the Utah Department of Water Quality, in addition to ratings from the Binns Habitat Quality Index (HQI) Model II, where available.

2.2.1.1.5 Additional Surveys. Reconnaissance level surveys of rivers and streams within the potential area of impact were conducted to qualitatively evaluate potential effects from project alternatives. These surveys provided a general description of existing stream habitat conditions in and around proposed construction areas (e.g., riparian corridor, stream gradient, spawning habitat, existing flows) to supplement existing data and support impact assessment.

2.2.1.2 Macroinvertebrates

Where information was available, macroinvertebrates in the affected environment were described in two ways: by providing a discussion of the community in terms of the number and groups of taxa, and by estimating the density of macroinvertebrates indirectly through habitat ratings. Descriptions of taxa were obtained from various sources including previously published reports (BIO-WEST 2003b; Reclamation 2001; CUWCD 1997), unpublished data (Gray 2003), and the EPA STORET database (USEPA 2003). Habitat ratings were obtained from previously performed Binns HQI analyses (UDNR 2003; CUWCD 1999; CUWCD 1998). The Binns HQI Model II method evaluates a number of factors that can be used to estimate the quantity of trout in a stream (Binns 1982). One of these factors, submerged aquatic vegetation, can be used as an indicator of the density of macroinvertebrates. Surveyors qualitatively rank the density of submerged aquatic vegetation on a discrete scale from 0 to 4 that corresponds to a density range of macroinvertebrates per square foot (Table 2-3).

Table 2-3 Binns HQI Ratings for Submerged Aquatic Vegetation (and Corresponding Macroinvertebrate Density)			
Rating	**Vegetation Characteristic**	**Expected Macroinvertebrate Density (#/ft^2)**	**Description of Population Status**
0	Submerged aquatic vegetation lacking	<25	Poor
1	Little submerged aquatic vegetation	25-99	Fair
2	Occasional patches of submerged aquatic vegetation	100-249	Moderate
3	Frequent patches of submerged aquatic vegetation	250-500	Good
4	Well developed and abundant submerged aquatic vegetation	>500	Excellent

To evaluate impacts, channel morphology data and flow data were obtained for the Provo River, Hobble Creek, Spanish Fork River, and Jordan River from USGS gage data (USGS 2003). A discussion of gage locations by reach is provided in the following subsections. Cross-sectional information gathered at these gages was assumed to be representative of the entire reach for each analysis. Macroinvertebrate habitat quantity was assumed to be related to flow and/or wetted perimeter. Hydrologic modeling provided baseline and estimated flows under each of the alternatives. Directional impacts on macroinvertebrates in project-affected rivers and reservoirs were assessed based on the correlation between habitat and wetted perimeter and/or discharge. Wetted width and stream depths were assumed to have a direct relationship with discharge during calculation of wetted perimeter. Increases in wetted perimeter were assumed to result in increased habitat for macroinvertebrates. Descriptions of macroinvertebrate diversity and density from the affected environment were used to support the assessment of directional (i.e., increase or decrease) impacts on macroinvertebrate communities and aid in the evaluation of macroinvertebrates with respect to significance criteria. Hydrology was used in combination with water quality data to estimate the likely impact of flow scenarios on water quality parameters that may affect aquatic resources including macroinvertebrates.

2.2.1.2.1 Provo River From Deer Creek Reservoir Outlet to North Fork of Provo River. In 2000, existing macroinvertebrate habitat was evaluated in this reach of the Provo River, approximately 1 mile upstream of the North Fork of the Provo River at the trestle (UDNR 2003).

Cross-section data obtained from the USGS Gage 10159500, downstream of Deer Creek Reservoir, was used to model potential changes in macroinvertebrate habitat from proposed ULS alternatives (USGS 2003).

2.2.1.2.2 Provo River From North Fork of Provo River to Olmsted Diversion Dam. Binns HQI surveys were conducted at Vivian Park in 2000. Conditions were assumed to be similar to those at the survey location in the upstream reach (see Section 2.2.1.2.1).

No USGS gages are in this reach. It was assumed that channel morphology in this reach was similar to the area between Deer Creek Reservoir and North Fork of Provo River, therefore the cross-section data obtained from the USGS gage 10159500 below Deer Creek Dam was used to model channel characteristics (see Section 2.2.1.2.6).

2.2.1.2.3 Provo River From Olmsted Diversion Dam to Murdock Diversion Dam. In 2000, existing macroinvertebrate habitat was evaluated using Binns HQI at two locations in this reach: Bridal Veil Falls and the Squaw Peak turnoff (UDNR 2003).

No USGS gages occur in this reach. As in the reach between North Fork of Provo River and Olmsted Diversion, it was assumed that channel morphology in this reach was similar to the area between Deer Creek Reservoir and North Fork of Provo River, therefore the cross-section data obtained from the USGS gage 10159500 below Deer Creek Dam was used to model channel characteristics (see Section 2.2.1.2.1).

2.2.1.2.4 Provo River From Murdock Diversion Dam to Interstate 15. The description of macroinvertebrate habitat conditions was based on Binns HQI data obtained in 2000 at three sample locations in this reach located: about 400 yards downstream of the Murdock Diversion, in Orem at the 800 South Bridge, and in Provo downstream of 1400 North (UDNR 2003).

No USGS gages occur in this reach. It was assumed that channel morphology in this reach was similar to the reach downstream between Interstate 15 and Utah Lake, therefore the cross-section data obtained from the USGS gage 1016300 in the Provo City reach was used to estimate flow and channel relationships (USGS 2003).

2.2.1.2.5 Provo River From Interstate 15 to Utah Lake. Intermittent historical data from EPA's STORET database was used to describe macroinvertebrate community composition. These data were available for one monitoring station in this reach of the Provo River (USEPA 2003). The long-term sampling station was at the road crossing for Highway 114 near the river's confluence with Utah Lake. Samples were taken on 11 dates during 1991-1995.

For impact analysis, channel morphology and flow relationships in this reach were calculated based on channel cross-section data at USGS gage 10163000 about two miles upstream of Utah Lake (USGS 2003).

2.2.1.2.6 Hobble Creek. Macroinvertebrate community diversity information was not available for this reach. Binns HQI ratings of macroinvertebrate density were based on 1998 surveys at two locations.

Change in wetted perimeter for Hobble Creek under the ULS alternatives was calculated using data from the Hobble Creek Geomorphic Survey, rather than using USGS gage data.

2.2.1.2.7 Spanish Fork River. The baseline condition of the Spanish Fork River is more similar to conditions that were described in the Diamond Fork System FS-FEIS (CUWCD 1999) than to existing conditions. Descriptions of macroinvertebrate community composition are therefore taken from field sampling described in that document that took place in 1980 above the Spanish Fork Diversion Dam.

Binns HQI ratings were assigned to more than 9 locations on the Spanish Fork River based on surveys in 1997 (CUWCD 1998). Four of these stations occurred in the reach between Diamond Fork Creek and Spanish Fork Diversion Dam, two were situated in the reach between Spanish Fork Diversion Dam and East Bench Canal, and three were between the East Bench and Mill Race canals. Additional assessments were conducted in the area downstream of Mill Race Canal.

Only one USGS gage (#10150500) is located in the Spanish Fork River between Diamond Fork Creek and the Lakeshore Gage. Data obtained from cross-sections at this gage, near the Spanish Fork Diversion Dam (Castilla Gage) were used to model potential changes in macroinvertebrate habitat under the ULS alternatives (USGS 2003). Data from this gage were assumed to be representative of channel characteristics for the entire reach between Diamond Fork Creek and the Lakeshore Gage.

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Chapter 3
Affected Environment (Baseline Conditions)

3.1 Impact Area of Influence

Map 3-1 shows the overall ULS project impact area of influence. Within that area, the aquatic resources impact area of influence includes the following:

- Rivers, streams and creeks in the Utah Lake drainage basin that support aquatic species and have the potential to be directly impacted by water withdrawal or flow alterations
- Rivers and streams affected by the construction of pipelines, access roads, pressure management structures, power lines, power facilities, in-stream water delivery and water diversions

3.2 Overview

This chapter specifically addresses game fish (brown trout, cutthroat trout, rainbow trout, channel catfish, and black bullhead) because they indicate the overall health of an aquatic system and have recreational and economic value (Table 3-1). Information on native fish is incorporated.

Table 3-1
Fish Species Potentially Affected by the ULS Project Alternatives

Game Fish		Non-game Fish	
Common Name	**Scientific Name**	**Common name**	**Scientific Name**
Brown trout	*Salmo trutta*	Leatherside chub*	*Gila copei*
Cutthroat trout*	*Oncorhynchus clarki*	Utah chub*	*Gila atraria*
Rainbow trout	*Oncorhynchus mykiss*	Speckled dace*	*Rhinichthys osculus*
Channel catfish	*Ictalurus punctatus*	Longnose dace	*Rhinichtys cataractae*
Black bullhead	*Ictalurus melas*	Fathead minnow	*Pimephales promelas*
Walleye	*Stizostedion vitreum*	Common carp	*Cyprinus carpio*
White bass	*Morone chrysops*	Redside shiner*	*Richardsonius balteatus*
Mountain Whitefish	*Prosopium williamsoni*	Mountain sucker*	*Catostomous platyrhynchus*
		Mottled sculpin*	*Cottus bairdi*
		Utah sucker*	*Catostomouss ardens*
*Native Fish			

The abundance and diversity of aquatic macroinvertebrate species can be an indicator of water quality and aquatic ecosystem health. Common and scientific names of taxa discussed in this chapter are shown in Table 3-2.

Table 3-2
Common Name and Taxa for Macroinvertebrates Potentially Affected by the ULS Project Alternatives[1,2]

Family	Related Taxon	Common Name
Baetidae, Cinygmula	Ephemeroptera	mayflies
Chironomid	Diptera	midges
Simuliidae	Diptera	black flies
Optioservus, Elmidae	Coleoptera	beetles
Hydropsyche, Hydroptilidae	Trichoptera	caddisflies
--	Plecoptera (Order)	stoneflies
Orthocladiinae	Diptera (Order)	true flies
--	Isopoda (Order)	isopods, aquatic sow bugs
--	Amphipoda (Order)	amphipods, scuds
Tubificidae	Oligochaeta (Subclass)	earthworms
Planariidae	Turbellaria (Class)	flat worms
Hydracarina	Acari (Subclass)	water mites
--	Copepoda (Order)	copepods
--	Ostracoda (Order)	seed shrimp

[1] List of macroinvertebrate taxa derived from a review of available macroinvertebrate habitat, distribution, and abundance data.
[2]Harrington and Born 2000
-- not identified

3.3 Habitats

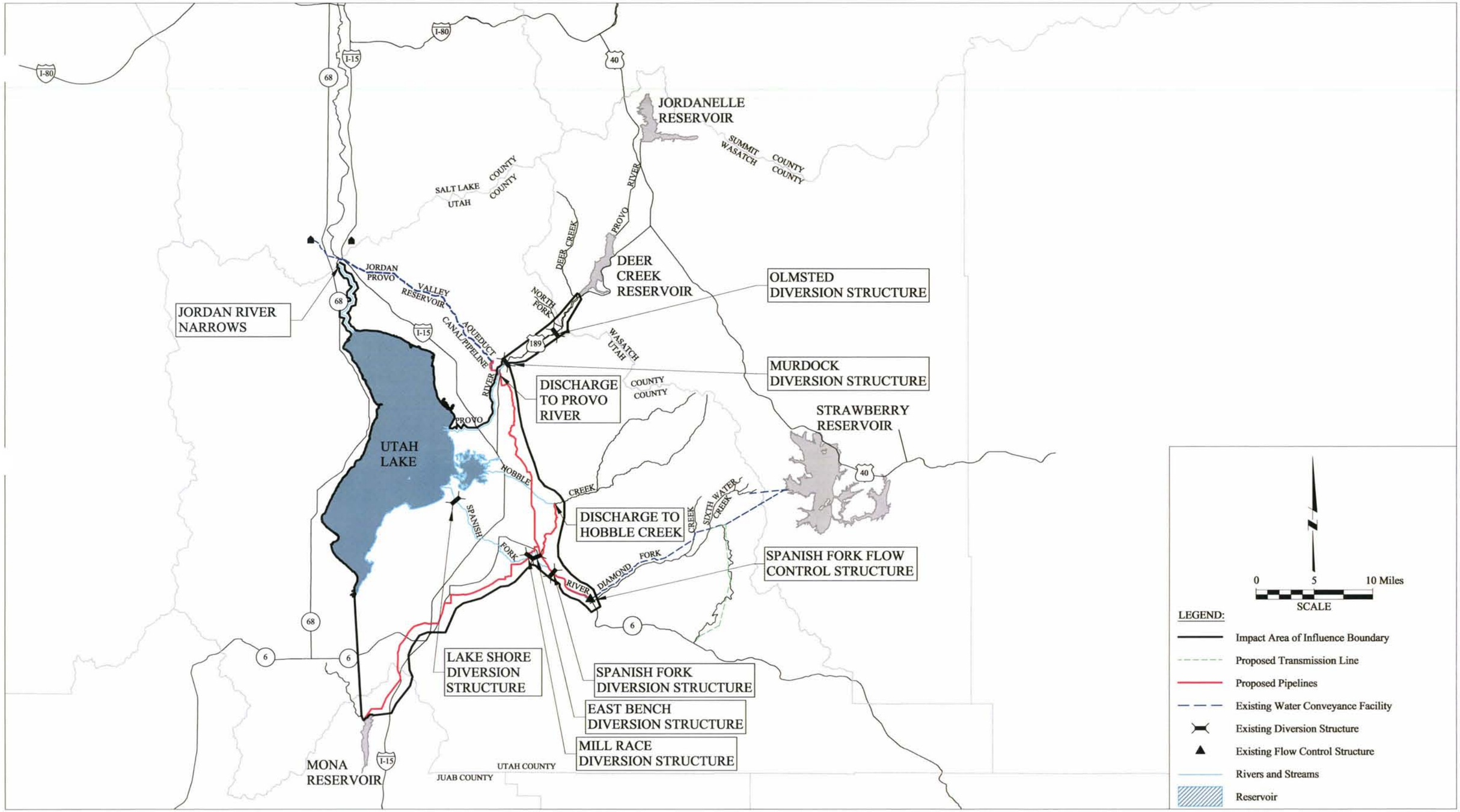
3.3.1 Provo River

The Provo River originates high in the western portion of the Uinta Range and terminates at Utah Lake near the City of Provo. This important river is impounded by two major reservoirs, Jordanelle and Deer Creek. The total stream length from Jordanelle Reservoir to Utah Lake is approximately 35 miles. Provo River has been extensively modified and diverted for irrigation since the mid-1850s. It contains a variety of habitats typical of large gravel/cobble-bedded pool-riffle streams, and includes a restored meandering channel and floodplain from Jordanelle Reservoir to Deer Creek Reservoir, a geologically confined channel that parallels Highway 189 through Provo Canyon, and a highly channelized channel from Provo Canyon to Utah Lake as it flows through the suburban cities of Orem and Provo.

3.3.1.1 Provo River From Deer Creek Reservoir Outlet to North Fork of Provo River

This reach flows through the upstream portion of Provo Canyon. In this reach, the river has been channelized and levied to enable highway, trail, and railroad construction (BIO-WEST 2003b). Stream width ranges between 41 and 89 feet (UDNR 2003).

Flows are controlled by releases from Deer Creek Dam, inputs from tributary streams, and major irrigation diversions. Springtime peak flows have been reduced from historical levels, and summer flow releases are artificially high because the river is used as a water delivery conduit to supply downstream users and irrigators (BIO-WEST 2003b). Monthly average baseline flows range from 110 to 871 cfs (Table 3-3). The year-round minimum in-stream flow, established as a CUP environmental commitment, is 100 cfs (BIO-WEST 2003b).



Map 3-1
Aquatic Resources
Impact Area of Influence

Table 3-3 Baseline Average Monthly Flows in Provo River From Deer Creek Reservoir to North Fork of Provo River	
Month	**Average Monthly Flow (cfs)**
October	147
November	110
December	112
January	132
February	138
March	205
April	279
May	743
June	871
July	628
August	568
September	440
Average	**365**

Water quality in this reach was assessed as meeting its beneficial uses (UDEQ 2003a). Low dissolved oxygen measurements have been documented in a small area immediately below Deer Creek dam and appear to be related to releases of deep, anoxic reservoir water from Deer Creek Reservoir (BIO-WEST 2003b). Operation of Deer Creek Reservoir has the potential to affect water quality in the lower Provo River, as tributary inputs to the reservoir can be high in phosphorus (BIO-WEST 2003b). Water quality in this reach has not been considered limiting to fish and other aquatic species (UDEQ 2003a). The river and its tributaries have not been listed as impaired by the State of Utah.

The reach between Deer Creek Reservoir and North Fork of Provo River is classified as a Class 1 (highest) category for stream fisheries and accounts for about 5 percent of Utah's total mileage with this designation. The sport fishery is dominated by trout, primarily brown trout (Wiley and Thompson 1998). Since 1975, the Utah Division of Wildlife Resources began managing for wild fish with the discontinuation of hatchery stocking. Rainbow trout were stocked extensively prior to 1975, but wild populations of this species have produced fewer numbers and less biomass of fish than the thriving brown trout. Much less abundant are the native game fish, Bonneville cutthroat trout and mountain whitefish.

As many as 13 species of native fishes occurred in the Provo River, although most are now uncommon to rare. The presence of abundant piscivorus brown trout is likely a factor (Belk and Elsworth 2000). Limited information is available on native fishes in Provo Canyon as few native fishes have been collected or recorded in this reach, except the mottled sculpin that is frequently recorded in large numbers during Utah Division of Wildlife Resources surveys.

3.3.1.2 Provo River From North Fork of Provo River to Olmsted Diversion Dam

Habitat in this reach is similar to that described in Section 3.3.1.1. Springtime peak flows have been reduced from historical levels, and summer flow releases are artificially high because the river is used as a water delivery

conduit to supply downstream users and irrigators (BIO-WEST 2003b). Baseline flows are shown in Table 3-4. The year-round minimum in-stream flow, established as a CUP environmental commitment, is 100 cfs (BIO-WEST 2003b).

Water quality typically meets state standards, although occasional exceedances have occurred in total phosphorus, dissolved oxygen, and bacteria levels (BIO-WEST 2003b). Water quality concerns in this reach are similar to the reach from Deer Creek Reservoir to the North Fork of Provo River (Section 3.3.1.1).

The reach between North Fork of Provo River and Olmsted Diversion Dam is classified as a Class 1 (highest) category for stream fisheries and accounts for about 5 percent of Utah's total mileage with this designation. The fish community is similar to that described for the reach upstream.

Table 3-4
Baseline Average Monthly Flows in Provo River From North Fork of the Provo River to Olmsted Diversion

Month	Average Monthly Flow (cfs)
October	161
November	125
December	123
January	143
February	148
March	216
April	300
May	801
June	938
July	674
August	595
September	461
Average	**392**

3.3.1.3 Provo River From Olmsted Diversion Dam to Murdock Diversion Dam

The Provo River from Olmsted Diversion Dam to Murdock Diversion Dam is a large, low to moderate gradient stream. Habitat, fisheries, and water quality in this reach are similar to that described in Section 3.3.1.2, however the channel includes both moderate and high gradient reaches (BIO-WEST 2003b). Geologic controls such as landslide deposits and steep canyon walls provides for steeper, boulder-bedded, cascading habitat conditions for a portion of this reach near Bridal Veil Falls. Stream width is fairly uniform throughout this reach. The substrate consists mostly of fine sands and silts deposited over cobble, rubble and boulder-sized rock in the channel (Reclamation 2001). Some sections have overhanging vegetation and subsequent input of organic matter to the river (Reclamation 2001). The reach was highly channelized and modified to accommodate residential, commercial, and industrial land uses (BIO-WEST 2003b).

Flows are controlled by releases from Deer Creek Dam, inputs from tributary streams, and water withdrawals from Olmsted Diversion. Average monthly flows range from 54 to 859 cfs (Table 3-5). Diversions trap sediment

and prevent natural hydrologic and geomorphic processes (BIO-WEST 2003b). Water quality concerns are similar to the reach from Deer Creek Reservoir to the North Fork of the Provo River described in Section 3.3.1.1.

Table 3-5
Baseline Average Monthly Flows in Provo River From Olmsted Diversion Dam to Murdock Diversion Dam

Month	Average Monthly Flow (cfs)
October	137
November	70
December	57
January	54
February	68
March	145
April	243
May	740
June	859
July	472
August	386
September	344
Average	**299**

3.3.1.4 Provo River From Murdock Diversion Dam to Interstate 15

The portion of the river between Murdock Diversion and Interstate 15 has been channelized and levied to allow for residential and commercial development across the historic floodplain and terraces (BIO-WEST 2003b). Because of these channel modifications, the floodplain width is minimal, streambanks are overly steep and tall, and natural geomorphic processes such as point bar deposition and channel avulsion are limited. Sediment supply is limited to bed erosion and nonpoint source inputs since upstream sources have been cut off by Murdock diversion, Olmsted diversion, and Deer Creek Dam. The banks for the most part are lined with rock rip-rap to protect against erosion. Channel substrate is coarse consisting primarily of cobble (bowling ball) size particles.

In addition to being controlled by Deer Creek Dam releases and withdrawals at Salt Lake Aqueduct and Olmsted Diversion upstream, streamflows in this reach are affected by 7 additional diversion structures: Murdock Diversion, Timpanogos Diversion, Provo Bench Diversion, Upper Union Diversion, Lake Bottom Diversion, Upper City Dam, and Lower City Dam (also known as Tanner Race) (BIO-WEST 2001). Murdock Diversion (also known as Provo Reservoir Canal Diversion) is the most significant of these diversions, typically removing 200 to 300 cfs from Provo River during the irrigation season. In combination, the other six diversions remove an additional 150 to 200 cfs. Because of these diversions, flows in this reach are significantly lower than in Provo Canyon between April and October. Currently, there are no legally-binding summer in-stream flow requirements for the lower Provo River. A wintertime minimum flow requirement of 25 cfs exists for the Provo River between Olmsted Diversion and Utah Lake.

The State of Utah does not operate any water quality monitoring stations between Murdock Diversion and Interstate 15; therefore, little is known about water quality in this reach. Average monthly flows range from 55 to

527 cfs (Table 3-6). Portions of the river between diversion structures are dewatered in some years (BIO-WEST 2001).

Although channelized and levied, the game and non-game fisheries conditions in this reach are similar to those described in Section 3.3.1.3.

Table 3-6
Baseline Average Monthly Flows in Provo River From Murdock Diversion Dam to Interstate 15

Month	Average Monthly Flow (cfs)
October	88
November	72
December	59
January	55
February	70
March	147
April	199
May	476
June	527
July	182
August	149
September	134
Average	**180**

Water quality in this reach is typically poor during summer because of low dissolved oxygen levels and elevated water temperatures. Nutrient and sediment inputs, combined with warm temperatures and shallow-water depths, contribute to increased algae and macrophytes during the summer (BIO-WEST 2003b). Increased aquatic vegetation from associated nutrient inputs has the potential to cause armoring of spawning gravels and accumulations of fine sediments that degrade spawning habitat quality. Fish kills have been associated with polluted runoff during low-water periods (FWS 1999).

3.3.1.5 Provo River From Interstate 15 to Utah Lake

Channel morphology in this reach is similar to that described in Section 3.3.1.4, however the channel flattens near the historic river/lake interface (BIO-WEST 2003b). The lowermost 1.6 miles of Provo River (Utah Lake State Park Marina to the Utah Division of Wildlife Resources fish weir) is all channelized "lake habitat" even though the trapezoidal shape gives it the appearance of a river. Water depths in the lowermost 1.6 miles of the Provo River are primarily controlled by Utah Lake water levels. Substrate material is finer-grained, consisting primarily of gravel-sized material rather than the large cobbles that dominate the reach between Murdock Diversion and Interstate 15 because of the flatter stream gradient between Interstate 15 and Utah Lake.

General streamflow patterns are similar to those described in Section 3.3.1.4, except that flows are even further depleted during the irrigation season by withdrawals at Fort Field Diversion, which is located just downstream from Interstate 15 (BIO-WEST 2001). Average monthly flows during summer are as low as four cfs (Table 3-7).

Water quality data are collected by the Utah Division of Water Quality and by the District near Harbor Drive. Water quality is typically poor in the river's lower reaches during summer months because of low dissolved oxygen levels and elevated water temperatures. 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 (FWS 1999). Nutrient and sediment inputs, combined with warm water temperatures and shallow water depths, contribute to summertime build-ups of algae and macrophytes within the channel. This aquatic vegetation can cause armoring of spawning gravels and accumulations of fine sediments that degrade spawning habitat quality.

This reach is designated as Critical Habitat for the June sucker. This reach is used by adult June sucker for spawning in late May and June. After hatching, larvae drift downstream to Utah Lake. See the *Threatened and Endangered Species Technical Report* for more information on the June sucker.

In addition to the species mentioned above, surveys in this reach have documented rainbow trout, mountain whitefish, mottled sculpin, mountain sucker, longnose dace, and speckled dace.

Table 3-7
Baseline Average Monthly Flows in Provo River From Interstate 15 to Utah Lake

Month	Average Monthly Flow (cfs)
October	32
November	76
December	56
January	51
February	64
March	142
April	168
May	347
June	374
July	42
August	4
September	6
Average	**114**

3.3.2 Hobble Creek From Springville Mapleton Lateral to Utah Lake

Hobble Creek originates in the canyons of the Wasatch Front in northern Utah. Hobble Creek discharges to Utah Lake near the City of Springville. As the creek descends into the City of Springville, the majority of the stream is surrounded by private land (UDNR 2003). Irrigation diversions and dams are common in Hobble Creek below the small flood control reservoir in the mouth of Hobble Canyon (UDNR 2003). In Hobble Creek below the reservoir, bank vegetation is very dense and grown over the stream in residential areas. As the creek flows west toward Utah Lake, agricultural land and industrial areas are more predominant and streamside vegetation decreases. Riparian vegetation consists of cottonwood, willow, dogwood, rose, and box elder (UDNR 2003).

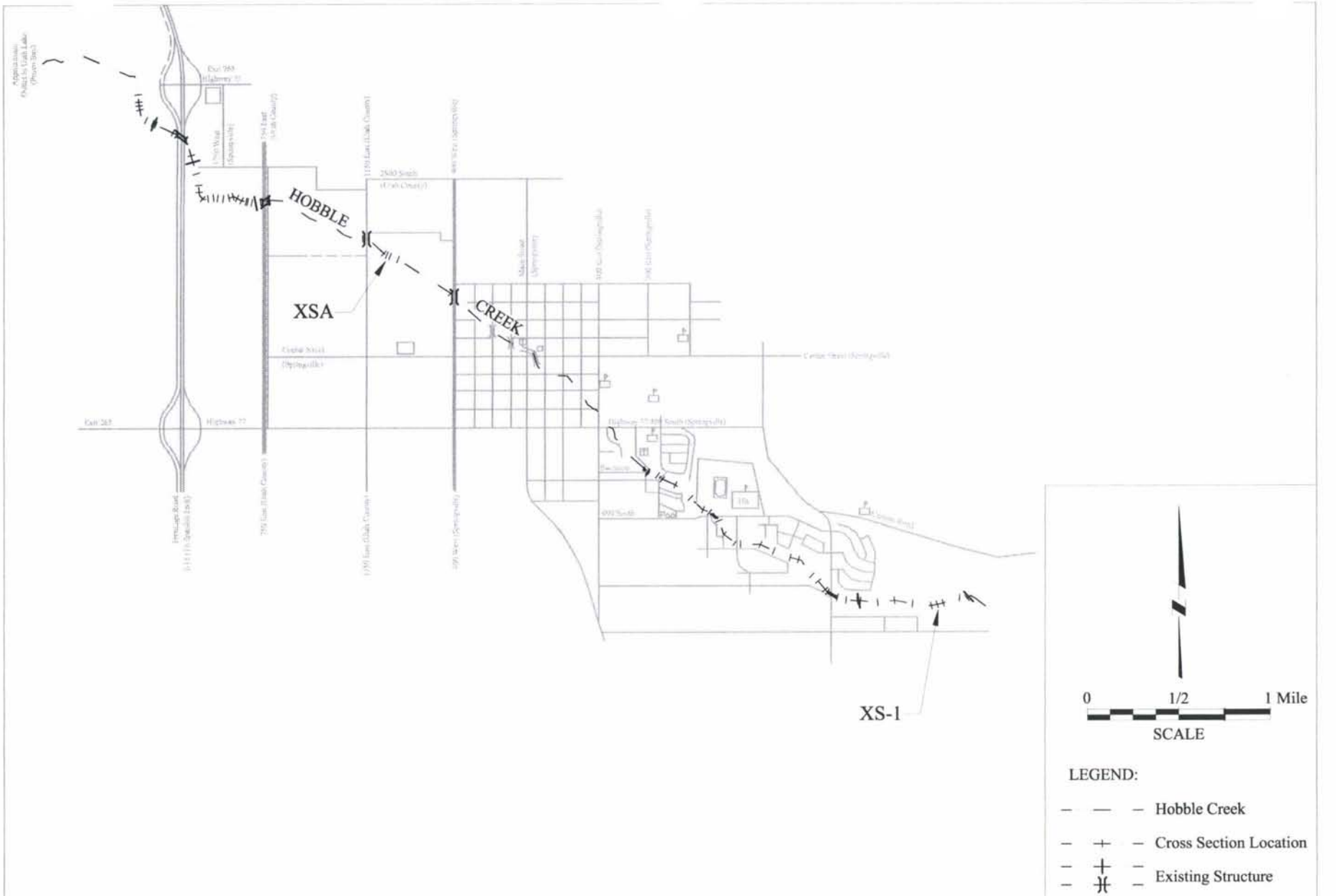
The reach of Hobble Creek downstream of the Mapleton Lateral is cobble and gravel dominated, and the lower reach is sand dominated with small gravel sub-dominant. Median (D_{50}) sizes of surface substrate decreased from about 51 mm upstream, to 23 mm at the middle reach cross section, to less than 1mm at the lower cross section (see Map 3-2). Field geomorphology indicated that more than 90 percent of banks surveyed in upper and lower Hobble Creek are stable. In addition, sediment modeling indicated that bedload transport in Hobble Creek was initiated when flows exceeded 95 cfs.

Baseline flows in Hobble Creek indicate that the discharge is relatively uniform during November through March (Table 3-8). In spring months, precipitation and snowmelt from the Wasatch Mountains cause monthly average flows to increase, with flows exceeding 95 cfs in May. Flow is limited in Hobble Creek during July-October.

Historic data indicated that water temperature occasionally exceeded water quality standards. Water temperature exceeded the related criterion five percent of the time in Hobble Creek. With one exception, water temperature exceedances occurred at a station at the lower end of Hobble Creek near Utah Lake.

Table 3-8
Baseline Average Monthly Flows in Hobble Creek From Mapleton Springville Lateral to Utah Lake

Month	Average Monthly Flow (cfs)
October	7
November	25
December	23
January	22
February	26
March	38
April	60
May	109
June	38
July	4
August	1
September	1
Average	**30**



Hobble Creek Cross-Sections

Map 3-2

3.3.3 Spanish Fork River

3.3.3.1 Spanish Fork River From Diamond Fork Creek to Spanish Fork Diversion Dam

This reach is low-gradient and heavily disturbed by man-made features that encroach on the stream channel and floodplain. Much of the reach was altered by railroad and road grades that parallel the river. A variety of channel types are present including meandering stream through floodplain and highly channelized sections with riprap banks. Approximately 20 percent of the reach is channelized. The amount of riparian vegetation is highly variable. A few short segments of the reach contain up to 70 percent mature riparian vegetation throughout the floodplain, while other segments are characterized by a low percentage of riparian habitat (less than 10 percent). The substrate in this reach is primarily dominated by gravel, followed by sand and silt. The reach is dominated by riffle-run habitat types and contains very few pools. Overall, the current habitat condition of this reach is poor (CUWCD 1998).

Streamflow is comprised of water from the upper Spanish Fork basin and inflow from Diamond Fork Creek. During most of the year, the majority of flow is from the upper basin. In the summer when irrigation needs are highest, flow releases from Strawberry Reservoir via Diamond Fork Creek account for most of the flow. Average monthly flows range from 158 to 740 cfs and are highest during April-August (Table 3-9).

Table 3-9
Baseline Average Monthly Flows in the Spanish Fork River From Diamond Fork Creek to Spanish Fork Diversion Dam

Month	Average Monthly Flow (cfs)
October	158
November	191
December	201
January	215
February	248
March	285
April	425
May	740
June	645
July	546
August	457
September	258
Average	**365**

Water quality is adequate to meet the standards for its beneficial uses (UDEQ 2003a). High turbidity occurs from Diamond Fork irrigation releases and tributaries to the Spanish Fork River during storm events (CUWCD 1998), but historic levels of total dissolved solids in the Spanish Fork River have only exceeded significance criteria (>1,200 ppm) twice (1 percent) within the last five years. Water temperature exceeded state standards

approximately five percent of the time. Based on the available information, water quality is adequate to support aquatic resources.

3.3.3.2 Spanish Fork River From Spanish Fork Diversion Dam to East Bench Diversion

Habitat and water quality in this reach of the Spanish Fork River is similar to that described in Section 3.3.3.1. Baseline average monthly flows range from 58 to 339 cfs and were highest during May-June, with the lowest flows occurring from September to December (Table 3-10). Within this reach of the Spanish Fork River, the Spanish Fork Diversion Dam affects the amount of flow. In the winter, most flow is diverted for power generation except for a small amount of leakage that disappears in a few hundred feet from the diversion dam (CUCWD 1998). In the summer, 20 to 50 cfs is released from the diversion dam to supply the East Bench Canal.

Table 3-10
Baseline Average Monthly Flows in the Spanish Fork River From Spanish Fork Diversion Dam to East Bench Diversion

Month	Average Monthly Flow (cfs)
October	58
November	109
December	130
January	143
February	163
March	160
April	190
May	339
June	242
July	176
August	134
September	88
Average	**161**

3.3.3.3 Spanish Fork River From East Bench Diversion to Mill Race Canal

Habitat and water quality in this reach of the Spanish Fork River is similar to that described in Section 3.3.3.1. Average monthly flows are highest during April through June, with the lowest flows occurring during August through October (Table 3-11). Springs discharge to the river about 300 yards below the dam, and these discharges provide about five cfs in the 2.8 miles of river below the East Bench Diversion (CUWCD 1998).

Table 3-11 Baseline Average Monthly Flows in the Spanish Fork River From East Bench Diversion to Mill Race Canal	
Month	**Average Monthly Flow (cfs)**
October	54
November	109
December	130
January	143
February	163
March	159
April	182
May	295
June	187
July	127
August	93
September	70
Average	**143**

3.3.3.4 Spanish Fork River From Mill Race Canal to Lakeshore Gage

This reach has low-gradient, deep, and slow-moving water that flows primarily through agricultural land. Much of the reach was altered by railroad and road grades that parallel the Spanish Fork River. This reach of river occurs between the entrance of the Mill Race Canal and Utah Lake. A thin strip of riparian vegetation exists along portions of the stream. The substrate in this reach is dominated by sand and silt, although some areas contain suitable spawning gravel (CUWCD 1998).

During the irrigation season, typically April 15 to October 15, streamflow below the Strawberry Diversion Dam is largely diverted at intervals by adjacent landowners for agricultural purposes. Summer flows can be comprised largely from seepage, irrigation return flows, and septic tanks (CUWCD 1998). Average monthly flows decrease to 86 cfs in September (Table 3-12).

Water quality in this reach of the Spanish Fork River is adequate to meet the standards for its beneficial uses (UDEQ 2003a). Water quality fluctuates significantly from season to season and deteriorates considerably during the summer (CUWCD 1999). This reach of the Spanish Fork River experiences high water temperatures, high total dissolved solid levels and nutrient levels with periodic increases in biological oxygen demand and coliform levels (CUWCD 1998). Agricultural and urban runoff contributes to the pollutant load of this reach. Despite numerous water quality conditions that have the potential to limit fish production, water quality is adequate to support aquatic resources in most areas.

Table 3-12 Baseline Average Monthly Flows in the Spanish Fork River From Mill Race Canal to Lakeshore Gage	
Month	**Average Monthly Flow (cfs)**
October	131
November	194
December	205
January	219
February	252
March	289
April	389
May	471
June	257
July	149
August	113
September	86
Average	**229**

3.3.4 Jordan River From Utah Lake to Jordan Narrows

The Jordan River originates at the north end of Utah Lake and flows north for approximately 35 miles before discharging into the Great Salt Lake. The upper 10-mile stretch of the river to the Jordan Narrows is slow and meandering. The river carries a high silt and nutrient load and the substrate is adobe clay, with silt in the backwaters. Silt, sand, and gravel are the predominant substrates, with silt increasing in prevalence as the river flows north. The river is characterized by silty water, relatively warm temperatures, and low current velocities (CUWCD 1998). Overall, the aquatic habitat in the Jordan River from the outlet of Utah Lake to Jordan Narrows is considered low quality.

Flow in the Jordan River is regulated by irrigation and flood control structures at Utah Lake. The outflow from Utah Lake to the Jordan Narrows includes releases to meet historical irrigation and industrial demands in northern Utah County and Salt Lake County. Spills or flood releases occur when the lake reaches and exceeds compromise level. Estimated baseline average monthly flows are provided in Table 3-13. The largest agricultural diversions occur at the Jordan Narrows, an area approximately 10 miles north of Utah Lake near the Utah County and Salt Lake County line (CUWCD 1998).

Table 3-13 Baseline Average Monthly Flows in the Jordan River From Outlet of Utah Lake to Jordan Narrows	
Month	**Average Monthly Flows (cfs)**
October	251
November	155
December	196
January	248
February	314
March	435
April	566
May	849
June	922
July	919
August	792
September	584
Average	**520**

Dissolved solids were identified as water quality parameter of concern in the Jordan River from historic data. Dissolved solids exceeded the agricultural water quality standard 31 percent of the time.

Water quality at the Jordan Narrows is controlled primarily by the water quality of Utah Lake (CUWCD 1998). In 2002, one reach of the upper Jordan River was documented as not supporting the aquatic life beneficial use support designation. The Jordan River from Bluffdale to the Narrows exceeded the temperature for a class 3A water (cold-water game fish). Storm-water runoff was attributed as the cause of low dissolved oxygen concentrations in the lower Jordan River (UDEQ 2003a). Despite water quality problems in these areas, water quality in the Jordan River is adequate to support aquatic resources.

3.3.5 Utah Lake

Utah Lake was developed as a storage reservoir in 1872 when gates were placed at the Jordan River outlet. Its storage serves to supplement flows lost to irrigation diversions in the Jordan River. The control gate structure at the Utah Lake outlet and hydraulic restrictions of the Jordan River have resulted in flooding around the lake during some years. A pumping plant at the outlet permits lowering of the lake below its natural outlet to a potential elevation of 9 to 10 feet below the compromise elevation. Reservoir levels are highest during spring, and then decline as the summer progresses (Table 3-14). The lake is used for boating and recreation and provides a warmwater commercial and recreational fishery.

Table 3-14 Baseline Reservoir Volume for Utah Lake	
Month	**Average Volume (1000 acre-feet)**
October	576
November	614
December	654
January	696
February	737
March	771
April	789
May	790
June	754
July	670
August	601
September	566
Average	**685**

Utah Lake evaporates nearly as much water as it releases to the Jordan River each year, primarily because of its high surface area relative to its volume. This high evaporation rate results in high total dissolved solids (TDS) levels, because the salt in the lake inflows is concentrated. Twelve samples were collected from Utah Lake on 9 days during the 1990 to 1999 period. The TDS concentration exceeded the agricultural use criterion of 1,200 mg/L on one day during the 9 days that samples were collected and analyzed.

The aquatic habitat of Utah Lake and its water quality is closely related to its water level and fluctuations throughout the year. In 2002, Utah Lake was assigned the status of "partially supporting" with respect to water quality criteria (UDEQ 2003a). A designation of "partially supporting" was assigned because a pollutant or stressor exceeded water quality standards in more than 10 percent but fewer than or equal to 25 percent of the measurements. The reservoir has been assigned this designation since 1994. Utah Lake is currently on the State of Utah's 303(d) list. Blue green algae abundance, trophic state index levels, and total phosphorus levels exceeded standards during some periods (UDEQ 2003a). In spite of stressor exceedances, water quality in the lake is adequate to support aquatic resources.

3.4 Game Fish Biomass

3.4.1 Provo River

3.4.1.1 Provo River From Deer Creek Reservoir Outlet to North Fork of the Provo River

The fish community in this reach of the Provo River has been extensively studied because of its importance as a trout fishery. At least seven exotic game fish have been introduced into the Provo River, including rainbow trout, brown trout, brook trout, smallmouth and largemouth bass, walleye, and yellow perch (Thompson et.al. 2003).

Dominant game fish species that have been documented in this reach of the Provo River include brown trout, rainbow trout, cutthroat trout, smallmouth bass, and mountain whitefish (CUWCD 1997; BIO-WEST 2003b).

Fisheries assessments using the Binns HQI Model II have been used to estimate the trout standing crop in this reach. In 1979, a fishery assessment was conducted to estimate the trout standing crop in the reach of the Provo River between Deer Creek Dam and Olmsted Diversion.

In 2001, additional habitat surveys using the Binns HQI Model II methodology in this reach of the Provo River indicate that non-native brown trout are highly abundant and trout densities are slightly lower than historical estimates. Habitat data from a site upstream of the North Fork confluence supported an estimated trout standing crop of 675 pounds per acre, with a total estimated biomass of 15,728 pounds. The site was located near a railroad trestle approximately 0.5 miles upstream of the North Fork confluence with the Provo River.

3.4.1.2 Provo River From North Fork of the Provo River to Olmsted Diversion Dam

Game fish community composition is similar to communities described in Section 3.4.1.1.

The 1979 fishery assessment estimated the trout standing crop in the reach of the Provo River between the Olmsted Diversion and the Olmsted Power Plant. The distance of this reach is approximately five miles.

In September 2000, additional habitat data were collected by Utah Division of Wildlife Resources near Vivian Park, located below the confluence of the North Fork with the Provo River. The current estimated standing crop of trout, based on the Binns HQI Model II, is 506 pounds per acre, with a total estimated biomass of 16,091 pounds.

3.4.1.3 Provo River From Olmsted Dam to Murdock Diversion Dam

Game fish community composition is similar to that described in Section 3.4.1.1.

In September 2000, Utah Division of Wildlife Resources collected fish and aquatic habitat data from two locations in this reach of the Provo River. Habitat data in the upper location were collected near Bridal Veil Falls. Habitat data in the lower location were collected near the Squaw Peak Road intersection with U.S. Highway 189. The current estimated standing crop of trout for this reach, based on the mean of two representative modeled reaches using the Binns HQI Model II, is 545 pounds per acre, with a total biomass of 8,339 pounds.

3.4.1.4 Provo River From Murdock Diversion Dam to Interstate 15

Game fish community composition is similar to that described in Section 3.4.1.1.

In 2000, game fish habitat was assessed by the Utah Division of Wildlife Resources. The current Binns HQI Model II estimates an average trout standing crop of 173 pounds per acre with a total biomass of 5,919 pounds in this reach of the Provo River.

3.4.1.5 Provo River From Interstate 15 to Utah Lake

Game fish community composition is similar to that described in Section 3.4.1.1.

In 2000, game fish habitat condition was assessed by the Utah Division of Wildlife Resources. Habitat data was input into the Binns HQI Model II. The current Binns HQI Model II estimates a trout standing crop of 86 pounds per acre with a total biomass of 714 pounds in this reach of the Provo River.

3.4.2 Hobble Creek

Hobble Creek supports brown trout populations (UDNR 2003). Bonneville cutthroat trout and rainbow trout are found in the headwater reaches of Hobble Creek (FWS 2001). Before settlement of Utah valley, Hobble Creek provided suitable spawning habitat for June Sucker (FWS 1999).

Remnant populations of Bonneville cutthroat trout have been documented in the right and left forks of Hobble Creek. These populations are upstream of the impact area of influence and several miles above a small flood control dam in the mouth of Hobble Canyon east of Springville, Utah.

Based on Utah Division of Wildlife Resources fisheries surveys conducted in 1998 and updated Binns HQI Model II results, Hobble Creek above Kolob Park in Springville, Utah has an estimated trout standing crop of 10 pounds per acre with a total biomass of 56 pounds, and lower Hobble Creek (Kolob Park to Utah Lake) has an estimated standing crop of 15 pounds per acre and a total biomass of 132 pounds.

Spawning cutthroat trout prefer clear, cold, and shallow riffles with course gravel substrates (Sigler and Sigler 1987). These habitats were historically most prevalent upstream of the interface between the river and backwater from Utah Lake. Reconnaissance surveys of channel geomorphology indicated that gravel/cobble habitat is available upstream of lowest surveyed reach, although the quality of the spawning gravel increased in upper reaches. The prevalence of sand and silt in the lowest Hobble Creek reaches indicated sub-optimal or unsuitable spawning habitat for trout.

3.4.3 Spanish Fork River

3.4.3.1 Spanish Fork River From Diamond Fork Creek to Spanish Fork Diversion Dam

This 4.2-mile reach of the Spanish Fork River supports a fishery dominated by brown trout. Other fish species documented in the reach include rainbow trout and rainbow/cutthroat trout hybrids (CUWCD 1998).

In 1984, the Binns HQI Model II was used to estimate the trout standing crop in this reach of the Spanish Fork River. Trout standing crop was estimated for the section of the upper Spanish Fork River between the confluence of Diamond Fork Creek and the Spanish Fork Diversion Dam (Reclamation 1984). The current Binns HQI Model II estimates a trout standing crop of 151 pounds per acre with a total biomass of 4,002 pounds.

3.4.3.2 Spanish Fork River From Spanish Fork Diversion Dam to East Bench Diversion

Below the Spanish Fork Diversion Dam, fisheries are affected by low flows throughout most of the year. This reach of the Spanish Fork River supports marginal brown trout and cutthroat fisheries and a population of leatherside chub (Sakaguchi 1994; Shirley 1994).

Trout standing crop was estimated with the Binns HQI Model II for the section of the upper Spanish Fork River between the Spanish Fork Diversion Dam and East Bench Diversion (CUWCD 1999). The current Binns HQI Model II estimates a trout standing crop of 348 pounds per acre and a total biomass of 2,888 pounds.

3.4.3.3 Spanish Fork River From East Bench Diversion to Mill Race Canal

Fisheries in this reach are affected by low flows throughout most of the year. This reach of the Spanish Fork River supports marginal brown trout and cutthroat trout fisheries. Other game species documented in the reach include

walleye and largemouth bass (IABAT 1990). Trout habitat is this reach is expected to improve with increased flows resulting from interim operation of the Diamond Fork System.

Under the Proposed Action in the Diamond Fork System FEIS and as adjusted by modeled average monthly flows increased under Diamond Fork System operation, the current Binns HQI Model II estimates the trout standing crop at 348 pounds per acre with a total biomass of 3,793 pounds in this reach.

3.4.3.4 Spanish Fork River From Mill Race Canal to Lakeshore Gage

Fisheries in this reach are affected by low flows throughout most of the year. Under the Proposed Action in the Diamond Fork System FEIS and as adjusted by modeled average monthly flows, the current Binns HQI Model II estimates the trout standing crop at 126 pounds per acre with a total biomass of 7,623 pounds in this reach.

3.4.4 Jordan River From Utah Lake to Jordan Narrows

The fish community in the Jordan River is dominated by non-native warmwater fish species. Fish documented in the Jordan River included walleye and rainbow trout (IABAT 1988). Other species preset include carp, white bass, walleye, yellow perch, green sunfish, black bullhead, channel catfish, largemouth bass, Utah sucker, and brown trout. Fish abundance appears to be limited more by physical habitat than by water quality as fish are most numerous where riprap on the stream banks provides cover (Filbert and Holden 1992). Areas where accretion flows input to the Jordan River have supported trout in the upper section, but the lack of year-round flows that lower water temperatures was considered a limiting factor for trout and other aquatic biota in the upper Jordan River (CUWCD 1998). Data were not available to evaluate the population sizes of fish species found in the Jordan River.

3.4.5 Utah Lake

Utah Lake supports a fish community dominated by non-native warmwater species. Game fish documented in Utah Lake include white bass, walleye, largemouth bass, brown trout, and rainbow trout. Carp are the most prevalent species, followed by white bass, walleye, black bullhead, and channel catfish. Additional non-game species are present in lower numbers (Table 3-15). Recent data are not available to characterize the diversity and abundance of game fish species in Utah Lake.

Table 3-15 Fish Species Abundance in Utah Lake[a,b]		
Fish Species	**Percentage of Total Number**	**Percentage by Weight**
Carp	66.2	90.9
White bass	26.7	4.2
Walleye	2.0	2.6
Black bullhead	1.4	0.7
Channel catfish	0.8	0.7
Largemouth bass	0.1	0.2
Bluegill	0.3	0.1
Yellow perch	0.3	0.1
Fathead minnow	1.6	T[b]
Sucker[c]	0.4	0.5
Black crappie	T	T
Golden shiner	T	T
Brown trout	T	T
Rainbow trout	T	T
Green sunfish	T	T
Redside shiner	T	T
Utah sucker	T	T

[a] For adult fish in combined net catches, 1978-1979
[b] T = less than 0.1 percent
[c] Utah sucker (*Catostomous ardens*) and June sucker (*Chasmistes liorus*)
Source: IABAT 1988

3.5 Non-Game Fish Populations

3.5.1 Provo River

3.5.1.1 Provo River From Deer Creek Reservoir Outlet to Utah Lake

Thirteen native non-game species have been documented in the Provo River drainage (Table 3-16). Data on non-game fish were limited for this reach of the Provo River. The composition of the fish community in this reach of the Provo River is assumed to be similar to communities in the Provo River between River Ditch and Snake Creek. Fisheries surveys conducted in 1993 in this reach of the Provo River documented the presence of longnose dace, mountain sucker, leatherside chub, Utah sucker, and sculpin (CUWCD 1997). Longnose dace, sculpin, and mountain sucker were most abundant with few individual leatherside chub and Utah sucker documented (CUWCD 1997). Carp, June sucker and Utah sucker are present seasonally in the lowest portions of the Provo River just upstream of the Utah Lake interface.

Table 3-16
Non-Game Fish Species used in PHABSIM Niche Analysis in Provo River Drainage

Common Name	Scientific Name
Utah chub	*Gila atraria*
Leatherside chub	*Gila copei*
Longnose dace	*Rhinichthys cataractae*
Mottled sculpin	*Cottus bairdi*
Mountain whitefish	*Prosopium williamsoni*
Utah sucker	*Catostomus ardens*
June sucker	*Chasmistes liorus*
Mountain sucker[c]	*Catostomus platyrhynchus*
Speckled dace	*Rhinichthys osculus*
Redside shiner	*Richarsonius balteatus*
Least chub	*Iotichthys phlegethontis*

3.5.2 Hobble Creek

Limited information is available for non-game species in Hobble Creek. In addition to the game species described in Section 3.4.3, sculpin and mountain sucker have been documented in Hobble Creek (UDNR 2003).

3.5.3 Spanish Fork River

Data are not available to estimate population sizes of non-game fish species in the Spanish Fork River. Non-game fish species reported in the Spanish Fork drainage include leatherside chub, mountain sucker, mottled sculpin, Utah chub, fathead minnow, golden shiner, and redside shiner (IABAT 1990; Sakaguchi 1994, 1995; CUWCD 1998). Other non-native warmwater fish, such as carp, yellow perch, bluegill, green sunfish, and white bass have been documented (IABAT 1990; Sakaguchi 1994, 1995; CUWCD 1998).

3.5.4 Jordan River From Utah Lake to Jordan Narrows

Limited information is available for non-game species in the Jordan River. In the upper river above the Jordan Narrows, Utah sucker and carp have been documented (IABAT 1988).

3.5.5 Utah Lake

Surveys performed in 1978 and 1979 (see Table 3-15) in Utah Lake indicated that carp make up 66 percent of the total number of fish in Utah Lake and 91 percent of the biomass. Other non-game species such as yellow perch, fathead minnow, and Utah sucker were documented in lower numbers. These three species make up approximately two percent of the total number of fish in the lake and less than one percent of the biomass. A few individuals of black crappie, golden shiner, green sunfish, and redside shiner were documented.

3.6 Macroinvertebrate Populations and Communities

3.6.1 Provo River

3.6.1.1 Provo River From Deer Creek Reservoir Outlet to North Fork of Provo River

This reach of the Provo River supports an abundant standing crop of benthic macroinvertebrates (Provo River Interagency Study Team 1989). Primary benthic macroinvertebrate taxa inhabiting the river include caddisflies, stoneflies, mayflies, true flies, isopods, amphipods, earthworms, mussel shrimp, flat worms and water mites (Reclamation 2001).

Based on surveys performed in 2000, conditions in this reach was assigned a Binns HQI rating of 4, indicating the presence of well-developed and abundant submerged aquatic vegetation that could be expected to support greater than 500 macroinvertebrates per square foot (UDNR 2003). This population level is considered to be excellent.

3.6.1.2 Provo River From North Fork of Provo River to Olmsted Diversion Dam

This reach of the Provo River supports an abundant standing crop of benthic macroinvertebrates (Provo River Interagency Study Team 1989). Mean abundance estimates for macroinvertebrates ranged from 2,700 to 5,000 per square foot, comprised of all taxa listed in Section 3.6.1.1 (Reclamation 2001).

In 2000, existing macroinvertebrate habitat was evaluated in this reach at Vivian Park. This site was assigned a Binns HQI Model II rating of 3, indicating the presence of frequent patches of submerged aquatic vegetation that could be expected to support between 250 and 500 macroinvertebrates per square foot (UDNR 2003). This population level is considered to be good.

3.6.1.3 Provo River From Olmsted Diversion Dam to Murdock Diversion Dam

This reach of the Provo River supports an abundant standing crop of benthic macroinvertebrates (Provo River Interagency Study Team 1989). Mean abundance estimates for macroinvertebrates ranged from 2,700 to 5,000 per square foot, comprised of all taxa listed in Section 3.6.1.1 (Reclamation 2001).

Both sites surveyed in this reach in 2000 were assigned a Binns HQI Model II rating of 4, indicating the presence of well-developed and abundant submerged aquatic vegetation that could be expected to support greater than 500 macroinvertebrates per square foot (UDNR 2003). This population level is considered to be excellent.

3.6.1.4 Provo River From Murdock Diversion Dam to Interstate 15

The macroinvertebrate community was evaluated during surveys at two locations in this reach between 1999 and 2001. Macroinvertebrates from 38 taxa were collected at Canyonview Park and macroinvertebrate from 39 taxa were collected from Riverwoods (Gray 2003). Fewer taxa and fewer individuals were captured at each station as the surveyors continued sampling downstream (Gray 2003).

In 2000, macroinvertebrate habitat was given a Binns HQI rating of 4 at three sites in this reach, indicating frequent to well developed patches of submerged vegetation and greater than 500 individuals per square foot (UDNR 2003). This population level is considered to be excellent.

3.6.1.5 Provo River From Interstate 15 to Utah Lake

Surveys during 1991 through 1995 indicated that the macroinvertebrate community was by dominated by pollution-tolerant midges (28 percent) and other taxa characteristic of silty substrates. Other dominant taxa in this reach included isopods (17 percent) and earthworms (29 percent). Between 1999-2001, macroinvertebrates from 31 taxa were collected at Exchange Park in the lower Provo River (Gray 2003). Fifteen of these taxa were considered rare. At the furthest downstream site near Geneva Road, a similar number of taxa were collected. At this site, 16 macroinvertebrate taxa were considered rare. Fewer taxa and fewer individuals were captured at each station as the surveyors sampled downstream (Gray 2003).

In 2000, surveys at two locations resulted in Binns HQI Model II ratings of 4, indicating frequent to well-developed patches of submerged vegetation and greater than 500 macroinvertebrates per square foot (UDNR 2003). This population level is considered to be excellent.

3.6.2 Hobble Creek

Information on macroinvertebrate community diversity was not available for Hobble Creek.

Surveys in 1998 resulted in a Binns HQI rating of 1 between the Forest Boundary and Springville. This indicates the presence of little submerged aquatic vegetation and corresponds to an estimated macroinvertebrate population level of 25 to 99 individuals per square foot. This population level is considered to be fair. Between Springville and Utah Lake, the submerged aquatic vegetation was assigned a rating of 2. This rating is assigned for areas with occasional patches of submerged vegetation and predicts an estimated number of between 100 and 249 macroinvertebrates per square foot. This population level is considered to be moderate. Frequent de-watering of the stream from irrigation diversions likely results in conditions supporting fair to moderate macroinvertebrate abundance.

3.6.3 Spanish Fork River

3.6.3.1 Spanish Fork River From Diamond Fork Creek to Spanish Fork Diversion Dam (Castilla Gage)

In 1980, field sampling during summer in this reach of the Spanish Fork River indicated that the river has a high number of species and greater density from macroinvertebrate drift associated with flow releases from Strawberry Reservoir compared to other parts of the year. Taxa historically present during the summer included amphipods, copepods, seed shrimp, caddisflies, and black flies. The dominant invertebrate taxa during the rest of the year included several genera of mayflies, stoneflies, caddisflies, and midges (CUWCD 1999).

Macroinvertebrate population conditions at four stations in this reach were assigned Binns HQI Model II ratings of 1 in 1997. This indicates the presence of little submerged vegetation that would be expected to support a fair population size of 25 to 99 macroinvertebrates per square foot (CUWCD 1998).

3.6.3.2 Spanish Fork River From Spanish Fork Diversion Dam to East Bench Canal

Field information was not available to evaluate the diversity of macroinvertebrate taxa in this reach of the Spanish Fork River. It is assumed that macroinvertebrate communities in this reach would be similar in composition to those in the reach between Diamond Fork Creek and the Spanish Fork Diversion Dam (see Section 3.6.3.1).

Existing macroinvertebrate population conditions at two stations in this reach were assigned Binns HQI Model II ratings of 1 in 1997. This indicates the presence of little submerged vegetation that would be expected to support a fair population size of 25 to 99 macroinvertebrates per square foot (CUWCD 1998).

3.6.3.3 Spanish Fork River From East Bench Diversion to Mill Race Canal

Field information was not available to evaluate the diversity of macroinvertebrate taxa in this reach of the Spanish Fork River. It is assumed that macroinvertebrate communities in this reach would be similar in composition to those in the reach between Diamond Fork Creek and the Spanish Fork Diversion Dam (see Section 3.6.3.1).

Macroinvertebrate population conditions at three stations in this reach were assigned Binns HQI Model II ratings of 1 in 1997. This indicates the presence of little submerged vegetation that would be expected to support a fair population size of 25 to 99 macroinvertebrates per square foot (CUWCD 1998).

3.6.3.4 Spanish Fork River From Mill Race Canal to Lakeshore Gage

Field information was not available to evaluate the diversity of macroinvertebrate taxa in this reach of the Spanish Fork River. It is assumed that macroinvertebrate communities in this reach would be similar in composition to those in the reach between Diamond Fork Creek and the Spanish Fork Diversion Dam (see Section 3.6.3.1).

Macroinvertebrate population conditions in this reach were assigned Binns HQI Model II ratings of 1. This indicates the presence of little submerged vegetation that would be expected to support a fair population size of 25 to 99 macroinvertebrates per square foot.

3.6.4 Jordan River From Utah Lake to Jordan Narrows

The most recent characterization of macroinvertebrates in the Jordan River was published in 1987. At this time, the substrate between Utah Lake and the Narrows was described as being mostly silty and supporting a benthic macroinvertebrate population predominately composed of earthworms and midges. Less-common riffle habitats were found to support filter-feeding macroinvertebrates, including midge and caddisfly larvae. Densities of macroinvertebrates in this upstream section of the Jordan River were much higher than in those found in areas further downstream, specifically, north of the City of Riverton below the Narrows (CUWCD 1998).

Ratings from the Binns HQI Model II were not available to evaluate macroinvertebrate habitat in the Jordan River.

3.6.5 Utah Lake

No recent surveys of macroinvertebrates in Utah Lake have been performed or documented. The most current information about the conditions of Utah Lake macroinvertebrates dates from a 1982 study by the Eyring Institute and Brigham Young University (CUWCD 1998). Oligochaetes (earthworms) and chironomids (midge larvae) were identified as the dominant benthic macroinvertebrates. The highest density of these benthic organisms was found in the mud layer in Goshen Bay at the south end of Utah Lake, with Provo Bay exhibiting much lower densities. Goshen Bay was found to support high densities of other macroinvertebrates in various rocky and emergent vegetation habitats. Lake margins characterized by sandy shores were found to have lower densities of macroinvertebrates than rockier areas (CUWCD 1998).

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Chapter 4
Environmental Consequences (Impacts)

4.1 Significance Criteria

The following significance criteria were used to determine if operation of the alternatives might have a significant impact on aquatic biota or its habitat. An impact was considered significant if one of the following potential changes was likely to occur.

4.1.1 Fish

- A long-term (more than one year) change in sport fish numbers and/or biomass that was likely to occur in an affected stream section as a result of change in habitat conditions (quantity and quality of instream flows).

- A long-term change in native fish species numbers or habitat that was likely to occur as a result of change in habitat conditions (quantity and quality of instream flows).

- The Utah Water Quality Standards for protection of aquatic life were likely to be exceeded because surface water classified as 3A (protected for coldwater fish) had temperatures exceeding 68°F (81°F for surface water classified 3B [warmwater fisheries]) (UDNR 2003). If existing temperatures were estimated to periodically exceed this standard, the assessment of impact significance was based on the frequency and duration.

- The Utah Water Quality Standards for protection of aquatic life were exceeded because surface water classified as 3A had dissolved oxygen concentrations of less than a 30-day average of 6.5 ppm, a seven-day average greater than 5.0 ppm or less than 9.5 ppm, or a one-day average greater than 4.0 ppm or less than 8.0 ppm (UDEQ 2003b). For surface water classified as 3B, the dissolved oxygen standards are a 30-day average of 5.5 ppm, a seven-day average of 4.0 to 6.0 ppm, and a one-day average of 3.0 to 5.0 ppm (UDEQ 2003b).

- Operations were to cause surface water supporting trout to exceed 2,000 ppm TDS or were to cause surface water supporting fish other than trout to exceed 5,000 ppm TDS (this is a professional judgment standard based on McKee and Wolf (1963). The State of Utah has not adopted water salinity standards for protection of fisheries (UDEQ 2003b). The Utah water quality standard for agricultural use is 1,200 mg/L.

4.1.2 Macroinvertebrates

Three categories of "potential for impact" were developed for macroinvertebrate habitat. Habitat was categorized according to the following criteria and professional judgment:

Low Potential

- Low to moderate potential for impact was based on fluctuations in stream discharge that correspondingly resulted in altered habitat availability. Low effects were considered if habitat availability of affected rivers changed by <5 percent compared to baseline values.

- Low to moderate potential for impact was based on low magnitude, short-term changes of water quality parameters beyond their natural range in project surface water. Low to moderate potential was considered if water quality parameters change less than 10 percent compared to natural range of values in project surface water.

Moderate Potential

- Moderate to high potential for impact was based on fluctuations in stream discharge that correspondingly resulted in altered habitat availability. Moderate to high impacts were considered if habitat availability of affected rivers changed between 5 and 40 percent compared to baseline values.

- Moderate to high potential for impact was based on moderate magnitude, short- or long-term changes of water quality parameters 10 and 30 percent beyond their natural range in project surface water.

High Potential

- High potential for impact was based on fluctuations in stream discharge that correspondingly resulted in altered habitat availability. Moderate to high impacts were considered significant if habitat availability of affected rivers changed more than 40 percent compared to baseline values.

- High potential for impact was based on high magnitude, short- or long-term changes of water quality parameters greater than 30 percent beyond their natural range in project surface water.

4.2 Potential Impacts Eliminated From Further Analysis

4.2.1 Nuisance Species

The inter-basin delivery of water and flow alterations that affect aquatic environments posed the risk of transporting or facilitating the expansion of non-indigenous or exotic nuisance species (e.g., crayfish, carp, water flea). Based on a literature review, it was concluded that there are no nuisance species present in Colorado River water stored in Strawberry Reservoir that are likely to be transferred to the Utah Lake drainage basin.

4.2.2 Construction Impacts

Assuming adherence to the SOPs, design, and construction techniques for facilities described in EIS Chapter 1, Section 1.8.8, there would be minimal to no impact on aquatic resources from any of the project construction activities under all of the alternatives.

Therefore, the following sections discuss only potential impacts that may occur from the operation of the Preferred Alternative and other alternatives.

4.2.3 Operational Impacts in Utah Lake

Impacts on aquatic resources from changes in the lake level of Utah Lake have been eliminated from further analysis. The changes in reservoir storage volume and stage are shown in the EIS, Chapter 3, Section 3.2.8.2.6, Surface Water Hydrology. The incremental changes would be small relative to baseline reservoir operations and would be within the normal historic fluctuations that these reservoirs experience on a yearly basis. As a result, there would be minimal change in aquatic habitat, and therefore, no impact on aquatic species populations and

communities from changes in water level. There could be potential for impacts on aquatic resources as a result of changes in water quality, however, so these potential impacts are considered.

4.2.4 Jordan River From Utah Lake to Jordan Narrows

The Jordan River would experience a maximum decrease in average monthly flow of about 90 cfs in August (-11 percent) from 792 to 702 cfs under the Preferred Alternative. Flow changes in the Bonneville Unit Alternative and No Action Alternative would be minimal and not expected to significantly alter hydraulic conditions in the Jordan River. This reach of the river is wide and slow moving. An analysis of wetted perimeter changes under the proposed flow regime under all alternatives showed that wetted perimeter would vary less than 2 percent from baseline conditions. Small changes in water surface elevations from proposed flows under all alternatives likely would have minimal to negligible impacts on habitat, and therefore fish or macroinvertebrate populations and communities. Significant changes to water quality in this reach would not be expected to occur under this alternative. Because of this, the Jordan River is eliminated from further analysis in this TR.

4.3 Spanish Fork Canyon–Provo Reservoir Canal Alternative (Preferred Alternative)

4.3.1 Habitat

Operational impacts on aquatic resources would be related to changes in stream flows, water surface elevations, and reservoir volumes associated with water supply operations. Altering the supply of water in rivers has the potential to impact aquatic resources by changing water velocities, inundating or stranding riparian habitat, altering natural geomorphic processes, and/or shifting the structure and quantity of existing habitat niches. For reservoirs, it was assumed that the amount of aquatic habitat was correlated with the amount of available surface water during an average water year. Directional impacts on aquatic habitat in project-affected rivers and reservoirs were assessed based on these assumptions.

4.3.1.1 Provo River

4.3.1.1.1 Provo River From Deer Creek Reservoir Outlet to North Fork of Provo River. In the reach of the Provo River immediately below Deer Creek Reservoir, the average monthly flows proposed under this alternative would decrease in six out of twelve months (Table 4-1). The largest deviations in average monthly flows from baseline conditions would occur during spring. Provo River discharge during this period would increase up to 55 cfs (7 percent) compared to baseline conditions. The largest proportional decreases in average monthly flow would occur in January (-20 percent) and February (-14 percent) and the largest proportional increases would occur in April (9 percent) and October (12 percent). These flow changes reflect project operations that support the recovery goals of the June sucker Recovery Implementation Program by storing (winter) and releasing (spring) water acquired to assist June sucker spawning in the lower Provo River (see the Draft Threatened and Endangered Species and Sensitive Species Technical Report for the Utah Lake Drainage Basin Water Delivery System (CUWCD 2004b).

Table 4-1
Estimated Baseline and Proposed Monthly Average Flow (cfs)
in Provo River From Deer Creek Reservoir Outlet to North Fork of Provo River (Preferred Alternative)

	Month											
	Oct	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
Baseline	147	110	112	132	138	205	279	743	871	628	568	440
Proposed	165	106	105	105	119	186	305	798	904	648	542	448
% Change	12	-4	-6	-20	-14	-9	9	7	4	3	-5	2

Habitat modeling results indicated that proposed flow under the Preferred Alternative would reduce habitat availability (1 to 16 percent) for all game species (Table 4-2). The spawning life stage of rainbow trout would experience the largest projected habitat decrease (15 percent), followed by decreases in spawning cutthroat trout (3 percent). Estimated habitat availability for all life stages of brown trout was projected to decrease between 1-2 percent under the Preferred Alternative. Although habitat availability was projected to be lower for all trout species, these decreases would be minor. Thus, the slight, long-term decreases in habitat availability in this reach would not significantly impact habitat for brown trout or other game fish.

Under the Preferred Alternative, flow changes likely would not affect critical spawning periods of game species. The largest proportional decreases in monthly flow occur during January through March in an average water year (9 to 20 percent). Flow decreases during this period are outside critical spawning periods for rainbow trout and cutthroat trout in the Provo River (Table 2-1). Moderate increases in flow in September (2 percent) and October (12 percent) would occur before the primary spawning period of mountain whitefish and brown trout (Table 2-1). Modeling of game fish life stages supports the idea that flow changes would not affect game fish spawning, as habitat availability for this life stage would be expected to change between 1 and 15 percent from baseline conditions for brown trout, rainbow trout, and cutthroat trout.

Habitat niche modeling projected decreases in habitat availability between Deer Creek Dam and the North Fork of the Provo River. Most of the habitat decreases would be small, 10 percent or less, and would not be expected to have a significant impact on non-game fish. Estimated habitat decreases would be 1 to 3 percent in slow-flow niches, 4 to 5 percent in moderate-flow niches, and 10 to 16 percent in fast-flow niches. Moderate decreases in fast/shallow and mid-depth habitats could impact habitat availability for adult mountain sucker, longnose dace, and Utah sucker (Table 2-2). Small decreases in the amount of low-velocity, backwater habitats could adversely impact juvenile and young-of-year life stages of non-game species such as mountain sucker, speckled dace, longnose dace, and redside shiner (Table 2-2). Although estimated habitat in all niches would experience minimal decreases under the Preferred Alternative, these changes are relatively minor and likely would not result in a long-term change in non-game fish abundance or fish community structure. However, small losses in slow- and moderate-flow niches combined with a moderate decrease (10 percent) in the fast/mid-depth habitat niche (16 percent) could result in a significant loss of available habitat for mountain sucker in this reach. Overall, projected long-term decreases in habitat availability for non-game species were relatively small and would not be expected to have significant impacts on fish habitat.

Table 4-2
PHABSIM Predictions for Proposed Flows in the Provo River From Deer Creek Reservoir Outlet to North Fork of Provo River Under the Preferred Alternative[a,b,c]

	Site 6		
Species and Life Stages	**Total Habitat Area Under Baseline Conditions**	**Total Habitat Area Under Spanish Fork-Provo Reservoir Canal Alternative**	**Percent Change**
Brown Trout-Adult	13,639	13,425	-2
Brown Trout-Juvenile	12,374	12,195	-1
Brown Trout-Spawn	26,313	26,146	-1
Brown Trout-Fry	4,847	4,763	-2
All Trout-Juvenile	17,750	17,404	-2
Cutthroat Trout-Spawn	586	571	-3
Rainbow Trout-Spawn	4,917	4,159	-15
Habitat Niches			
Backwater/Edge	3,009	2,972	-1
Slow/Shallow	5,749	5,587	-3
Mod/Shallow	7,006	6,705	-4
Fast/Shallow	2,356	1,973	-16
Mod/Mid-Depth	10,501	10,257	-2
Fast/Mid-Depth	3,344	3,002	-10
Mod/Deep	543	517	-5

[a] WUA results were expressed as square feet per 1,000 feet of river
[b] WUA was calculated as a weighted average based on the lengths of Reach Types 5 and 6 from Deer Creek Reservoir to the North Fork confluence
[c] Total Habitat Area derived from a mean of 50-100% WUA exceedance values

Based on hydraulic modeling and channel cross-section data at USGS Gage 10159500, the Preferred Alternative would result in small increases and decreases in wetted perimeter during at various times of the year (Table 4-3). Habitat was projected to decrease 1 to 3 percent during November through March and increase 1 to 3 percent during April through July and in October. Estimated flow changes under the Preferred Alternative would result in a low impact on macroinvertebrate habitat compared to baseline conditions.

Table 4-3
Estimated Change in Wetted Perimeter in the Provo River From Deer Creek Reservoir to North Fork of Provo River Using Data From USGS Gage 10159500 (Preferred Alternative)

Month	Baseline Wetted Perimeter (feet)	Estimated Wetted Perimeter under Preferred Alternative (feet)	Percent Change
Jan	56.2	54.5	-3.0
Feb	56.5	55.4	-1.9
Mar	59.6	58.8	-1.3
Apr	62.2	62.9	1.2
May	71.4	72.1	1.0
June	73.1	73.5	0.5
July	69.7	70.0	0.5
Aug	68.7	68.2	-0.7
Sep	66.2	66.4	-0.3
Oct	57.0	57.9	1.6
Nov	54.9	54.6	-0.5
Dec	55.0	54.5	-0.8

Based on model projections, water temperature, dissolved oxygen, and total dissolved solids changes in this reach would not be significant under the Preferred Alternative. The change in water releases to this reach would not significantly impact water quality.

4.3.1.1.2 Provo River From North Fork of Provo River to Olmsted Diversion Dam. Operational impacts on monthly flow for this reach of the Provo River (Table 4-4) would be similar to the Provo River reach between the Deer Creek Reservoir outlet and the North Fork of the Provo River (Section 4.3.1.1.1). Stream discharge during spring would increase by up to 55 cfs (7 percent) compared to baseline conditions. The largest proportional decreases in average monthly flow would occur in January (20 percent) and February (13 percent) and the largest proportional increases would occur in April (9 percent) and October (11 percent).

Table 4-4
Estimated Baseline and Proposed Monthly Average Flow (cfs) in Provo River From North Fork of Provo River to Olmsted Diversion (Preferred Alternative)

	Month											
	Oct	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
Baseline	161	125	123	143	148	216	300	801	938	674	595	461
Proposed	178	121	117	115	129	197	327	856	972	694	569	469
% Change	11	-3	-5	-20	-13	-9	9	7	4	3	-4	2

Operational impacts on habitat availability in modeled niches and species' life stages would be similar to the Provo River reach between the Deer Creek Reservoir outlet and the North Fork of the Provo River (Section 4.3.1.1.1). Modeling results indicated that proposed flow would lower habitat availability for all adult game species and life stages (Table 4-5). The spawning life stage of rainbow trout would experience the largest projected habitat decrease (15 percent), followed by spawning cutthroat trout (2 percent). Estimated habitat for all other game species and life stages were projected to decrease between 1 to 2 percent under the Preferred Alternative. Estimated habitat decreases of 2 to 4 percent in moderate flow habitats could impact habitat availability for adult trout, while a projected decrease of 3 percent in the slow/shallow habitat niche could affect the spawning life stage of trout. Although habitat availability would be lower for all trout species and life stages, most of these decreases would be small (less than 2 percent change from baseline conditions). Overall the long-term, small decreases in habitat availability in this reach would not significantly impact habitat for brown trout or other game fish.

Under the Preferred Alternative, flow changes likely would not affect critical spawning periods of game species. The moderate percent change estimated for rainbow trout spawning habitat could have localized negative impact for spawning rainbow trout located in this reach. However, this reach of the Provo is managed primarily for brown trout (BIO-WEST 2003a). Rainbow trout are stocked annually into lakes, reservoir, and stream sections within the Provo River to support sport fishing activities. Thus, even a moderate decrease in rainbow trout spawning habitat in this reach would not be likely to significantly affect the fishery.

Additionally, the largest proportional decreases in monthly flow occur during January through March in an average water year (9 to 20 percent). Flow decreases during this period are outside critical spawning periods for rainbow trout and cutthroat trout in the Provo River (Table 2-1). Moderate increases in flow in September (2 percent) and October (11 percent) would occur before the primary spawning period of mountain whitefish and brown trout (Table 2-1). Modeling of game fish life stages supports the idea that flow changes would not significantly affect game fish spawning, as habitat availability for this life stage would be expected to change between 1 and 18 percent from baseline conditions for brown trout, rainbow trout, and cutthroat trout.

Habitat availability in all modeled niches was projected to decrease in this reach. Most of the decreases would be small, less than 10 percent, and would not be expected to have a significant impact on non-game fish. Estimated habitat decreases would be approximately 1 to 3 percent in slow-flow niches, 2 to 4 percent in moderate-flow niches, and 10 to 16 percent in fast-flow niches. The moderate decreases estimated for fast/shallow and mid-depth habitats could impact habitat availability for adult mountain sucker, mottled sculpin, longnose dace, and Utah sucker (Table 2-2). Decreases in the amount of low-velocity, backwater habitats would be minor and not likely to impact juvenile and young-of-year life stages of non-game species such as mountain sucker, speckled dace, longnose dace, and redside shiner (Table 2-2). Estimated habitat in all niches would experience minimal decreases under the Preferred Alternative and likely would not result in a long-term change in non-game abundance or fish community structure. Small losses in slow- and moderate-flow niches combined with a moderate decrease (16 percent) in the fast/shallow habitat niche could result in a significant loss of available habitat for mountain sucker and mottled sculpin in this reach. Overall, projected long-term decreases in habitat availability for non-game species would be relatively small and would not be expected to have significant impacts on fish habitat.

Table 4-5
PHABSIM Predictions for Proposed Flows in the Provo River From North Fork of Provo River to Olmsted Diversion Dam Under the Preferred Alternative[a,b,c]

	Site 5		
Species and Life Stages	**Total Habitat Area Under Baseline Conditions**	**Total Habitat Area Under Spanish Fork-Provo Reservoir Canal Alternative**	**Percent Change**
Brown Trout-Adult	14,290	14,065	-2
Brown Trout-Juvenile	13,161	12,984	-1
Brown Trout-Spawn	26,116	25,951	-1
Brown Trout-Fry	5,191	5,101	-2
All Trout-Juvenile	18,706	18,366	-2
Cutthroat Trout-Spawn	634	623	-2
Rainbow Trout-Spawn	5,061	4,319	-15
Habitat Niches			
Backwater/Edge	3,242	3,203	-1
Slow/Shallow	6,041	5,877	-3
Mod/Shallow	6,960	6,666	-4
Fast/Shallow	2,248	1,885	-16
Mod/Mid-Depth	11,005	10,745	-2
Fast/Mid-Depth	3,184	2,857	-10
Mod/Deep	738	701	-5

[a] WUA results were expressed as square feet per 1,000 feet of river
[b] WUA was calculated as a weighted average based on the lengths of Reach Types 5 and 6 from the North Fork confluence to the Olmsted Diversion
[c] Total Habitat Area derived from a mean of 50-100% WUA exceedance values

Impacts on macroinvertebrate habitat in this reach would be similar to those occurring upstream in the reach between Deer Creek Reservoir and North Fork of the Provo River (see Section 4.3.1.1.1). Based on hydraulic modeling and channel cross-section data at USGS Gage 10159500, the Preferred Alternative would result in small increases and decreases in wetted perimeter at various times of the year (Table 4-6). Projected decreases would be generally greater than increases, though neither would be very large in magnitude (less than 3 percent). Estimated flow changes would result in a low impact on macroinvertebrate habitat compared to baseline conditions.

Table 4-6
Estimated Change in Wetted Perimeter in the Provo River From North Fork of Provo River to Olmsted Diversion Dam Using Data From USGS Gage 10159500 (Preferred Alternative)

Month	Baseline Wetted Perimeter (feet)	Estimated Wetted Perimeter under Preferred Alternative (feet)	Percent Change
Jan	56.8	55.2	-2.8
Feb	57.1	56.0	-1.8
Mar	60.0	59.3	-1.2
Apr	62.8	63.5	1.2
May	72.2	72.9	1.0
June	73.9	74.2	0.5
July	70.4	70.7	0.4
Aug	69.1	68.7	-0.6
Sep	66.7	66.8	0.2
Oct	57.7	58.5	1.4
Nov	55.8	55.6	-0.4
Dec	55.7	55.3	-0.7

Based on model projections, water temperature, dissolved oxygen, and total dissolved solids changes in this reach would not be significant under the Preferred Alternative. The change in water releases in this reach would not significantly impact water quality.

4.3.1.1.3 Provo River From Olmsted Diversion Dam to Murdock Diversion Dam. The average monthly flows proposed under this alternative would represent an increase over baseline conditions during the winter and a decrease during the summer (Table 4-7). In average water years, flow decreases of between 5 and 23 percent would occur during June through September. Small flow increases would occur in January through March, and May (1 to 6 percent), with larger proportional increases projected to occur in April (18 percent).

Table 4-7
Estimated Baseline and Proposed Monthly Average Flow (cfs) in Provo River From Olmsted Diversion Dam to Murdock Diversion Dam (Preferred Alternative)

	Month											
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Baseline	137	70	57	54	68	145	243	740	859	472	386	344
Proposed	113	70	57	55	72	148	287	765	813	430	299	281
% Change	-18	0	0	2	6	2	18	3	-5	-9	-23	-18

Habitat availability for game species in this reach was not estimated to change substantially (less than 11 percent) from baseline conditions. Modeling results indicated that proposed flows would provide low to moderate gains in

habitat availability for all game species except brown trout fry (5 percent decrease), spawning cutthroat trout (3 percent decrease), and spawning rainbow trout (5 percent decrease) (Table 4-8). Habitat availability in modeled habitat niches used by game species was estimated to change somewhat more substantially. The greatest projected change in a habitat niche used by game fish was a 12 percent decrease in the backwater/edge niche. This niche is used by mountain whitefish fry but is only a partial-use niche. Overall, projected habitat changes for game fish would be long-term, but they would be expected to be small enough that they would not likely have any significant impact.

Under the Preferred Alternative, flow changes likely would not affect game species that spawn in the autumn, and could provide a slight benefit to spring spawners. In an average water year, the largest decreases in monthly flow would occur during June through October and the largest increases would occur from December through April. Moderate decreases in flow during October would occur before the primary spawning period of mountain whitefish and brown trout (Table 2-1). Small to moderate increases in flow in April and May would occur during the spawning period of rainbow trout (Table 2-1). Modeling of game fish life stages supports the determination that flow changes would not significantly affect game fish spawning, as habitat availability for this life stage would be expected to change less than 11 percent from baseline conditions. Under the Preferred Alternative, the highest risk to game fishes would occur during the summer in an average flow year. Reductions in flow of 18 to 23 percent during late summer could affect the quantity and quality of in-stream habitat in this reach of the Provo River.

Habitat availability for non-game species would increase in all modeled habitat niches except the backwater/edge habitat type (12 percent decrease). The greatest change in a niche used by non-game fish was an estimated 79 percent increase in the fast/shallow niche. Although the percent increase would be high for the fast/shallow niche, the total available habitat under baseline conditions would be low at 351 square feet per 1,000 linear feet and the increase would likely result in fewer than 300 square feet per 1,000 linear feet being added to this niche. This niche provides partial habitat availability to mountain sucker and mottled sculpin (Table 2-2). Given the small change in total available habitat and the partial use of this habitat by game fishes, this increase would not be expected to have substantial impact on non-game fish (Table 4-8 and Table 2-2). Fast/mid-depth habitats, used primarily by mountain sucker, are estimated to increase by 17 percent. Habitat increases in other niches of less than 11 percent (shallow niches and moderate/mid-depth niches) would benefit juvenile and adult native species including mottled sculpin, Utah sucker, longnose dace, and speckled dace (see Table 2-2). The increase of habitat in these niches would benefit some of the species affected by loss of backwater/edge habitat, but at different life stages. The backwater/edge habitat type was projected to decrease by 12 percent. This habitat niche is used by mountain whitefish fry, young-of-year Utah sucker, specked dace, and longnose dace, and multiple life stages of redside shiner. Although a minor decrease in the backwater/edge habitat niche was projected under the Preferred Alternative, habitat increases in other modeled niches would offset these habitat losses and would provide a significant long-term benefit to many species of non-game fish in this reach of the Provo River.

Table 4-8
PHABSIM Predictions for Proposed Flows in the Provo River From Olmsted Diversion Dam to Murdock Diversion Dam (Preferred Alternative)[a, b, c]

	Site 3		
Species and Life Stages	**Total Habitat Area Under Baseline Conditions**	**Total Habitat Area Under Spanish Fork-Provo Reservoir Canal Alternative**	**Percent Change**
Brown Trout-Adult	6,502	6,648	2
Brown Trout-Juvenile	6,097	6,134	1
Brown Trout-Spawn	19,835	21,985	11
Brown Trout-Fry	2,439	2,309	-5
All Trout-Juvenile	10,605	10,750	1
Cutthroat Trout-Spawn	768	745	-3
Rainbow Trout-Spawn	4,481	4,253	-5
Habitat Niche			
Backwater/Edge	725	642	-12
Slow/Shallow	5,348	5,424	1
Mod/Shallow	3,791	4,217	11
Fast/Shallow	351	627	79
Mod/Mid-Depth	3,895	4,149	7
Fast/Mid-Depth	1,449	1,692	17

[a] WUA results were expressed as square feet per 1,000 feet of river
[b] Results from Site 3 were extrapolated to represent habitat throughout this Provo River reach
[c] Total Habitat Area derived from a mean of 50-100% WUA exceedance values

This alternative would result in small increases and decreases in wetted perimeter at various times of the year (Table 4-9). Projected increases and decreases would be generally comparable in magnitude, although all values would change by less than 4 percent. The greatest increase (3.4 percent) was estimated to occur in January and the greatest decrease would occur in August (3.5 percent). During June through October, wetted perimeter was estimated to decrease between 1 and 4 percent, with habitat increases estimated during the rest of the year. Estimated flow changes in this reach would result in a low impact on macroinvertebrate habitat compared to baseline conditions.

Table 4-9
Estimated Change in Wetted Perimeter in the Provo River From Olmsted to Murdock Diversion Dams Using Data From USGS Gage 10159500 (Preferred Alternative)

Month	Baseline Wetted Perimeter (feet)	Estimated Wetted Perimeter under Preferred Alternative (feet)	Percent Change
Jan	50.1	51.7	3.4
Feb	51.6	52.8	2.4
Mar	56.9	57.4	0.9
Apr	61.0	62.4	2.3
May	71.3	71.7	0.5
June	72.9	72.3	-0.8
July	66.9	66.0	-1.3
Aug	65.0	62.8	-3.5
Sep	64.0	62.2	-2.8
Oct	56.5	55.1	-2.4
Nov	51.7	52.2	0.9
Dec	50.4	51.7	2.7

Based on model projections, water temperature, dissolved oxygen, and total dissolved solids changes in this reach would not be significant under the Preferred Alternative. The change in water releases in this reach would not significantly impact water quality.

4.3.1.1.4 Provo River From Murdock Diversion Dam to Interstate 15. The average monthly flows proposed under this alternative would represent an increase over baseline conditions in all months (Table 4-10). Greater flow releases below the Murdock Diversion Dam during the year would provide additional habitat for aquatic resources in the reach. Moderate flow increases (23 to 47 percent) would occur during two distinct periods, during July through February and in April (26 percent increase) and May (16 percent increase). Minor flow increases of seven percent would occur during March and June.

Table 4-10
Estimated Baseline and Proposed Monthly Average Flow (cfs) in Provo River From Murdock Diversion Dam to Interstate 15 (Preferred Alternative)

	Month											
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Baseline	88	72	59	55	70	147	199	476	527	182	149	134
Proposed	129	90	77	74	86	158	251	553	563	231	196	182
% Change	47	25	31	35	23	7	26	16	7	27	32	36

In the upper portion of the reach (Site 2a), habitat modeling results indicated that proposed flows would cause habitat decreases estimated at 8 percent for brown trout juveniles, 32 percent for brown trout fry, as well 20 percent for all trout juveniles (Table 4-11). Habitat would be increased for brown trout adults (3 percent) and brown trout spawning (378 percent). More moderate increases would be evident for brown trout adults (47 percent) and juveniles (36 percent) in the middle part of this reach (Site 2b). In the lower end of the reach (Site 2c), habitat modeling results showed that proposed flows would provide additional brown trout adult (167 percent) and brown trout juvenile (154 percent) habitat (Table 4-11). The modeled category for all trout juveniles was projected to experience a net increase under the Preferred Alternative (Table 4-11). Modeled habitat availability for spawning cutthroat, rainbow, and brown trout was minimal throughout this reach of the Provo River. Overall, however, habitat increases for modeled game fish species and life stages would represent a significant benefit to game fish in this reach.

Habitat availability in niches used by game fish varied throughout the reach, with slow flow niches (backwater/edge and slow/shallow) exhibiting decreases as large as 43 percent and moderate flow niches experiencing very large increases in habitat. The greatest increase in a niche used by game fish was projected to occur in the moderate/shallow and moderate/mid-depth niches (17 to 452 percent). These niches are used by juvenile, fry, spawning, and adult life stages of all trout (Table 2-2). Smaller decreases in slow/shallow habitat availability would affect juvenile, fry, and spawning stages for all trout, but this is only one of several habitat niches used by these trout. A decrease in the amount of backwater/edge habitat under this alternative that could adversely impact mountain whitefish fry would be compensated for by greater increases in the moderate/mid-depth niche (see Table 2-2). Net habitat increases for game fish would compensate for small losses and would be a significant benefit to game fish in this reach.

For non-game fish, the greatest increase in habitat availability would be in the fast/shallow (91 to 5,207 percent) and fast/mid-depth (215 to 49,498 percent) habitat niches. These niches provide suitable habitat for mountain sucker and mottled sculpin, and thus these species would benefit by increased habitat associated with this alternative (see Table 2-2). Large proportional increases were estimated for these two habitat niches because only small amounts of habitat (as low as 1 ft^2 and up to 602 ft^2 per 1,000 feet of river) are available in this reach under baseline conditions (Table 4-11). Moderate flow habitat niches were estimated to increase under the Preferred Alternative. Habitat increases in the moderate/shallow and moderate/mid-depth habitat niche would benefit adult mountain sucker, mottled sculpin, speckled and longnose dace, and Utah sucker. Juvenile sculpin and Utah sucker would benefit by projected habitat increases in moderate flow niches. The moderate/shallow habitat niche was projected to increase by as much as 452 percent in this reach. A similar trend was estimated for the moderate/mid-depth habitat niche that was estimated to increase 428 percent in the lower portion of the reach and 17 to 97 percent in the upper and middle portions respectively. Smaller decreases in habitat availability were estimated to occur in backwater/edge and slow/shallow (19 and 1 percent [Site 2c lower], 29 and 43 percent [Site 2b middle], and 10 and 32 percent [Site 2a upper]). A moderate decrease in the availability of backwater/edge habitats under this alternative could adversely impact young-of-year suckers and dace, and all life stages of redside shiner; at these life stages these species utilize this habitat exclusively. Decreased slow/shallow habitat availability potentially could affect juvenile longnose dace and young-of-year mottled sculpin, which use this habitat niche exclusively. Overall, decreased slow water habitat availability could have a significant, long-term adverse impact on habitats for non-game fishes. Increases in moderate and fast water habitats would help to offset the losses and would provide benefits to mountain sucker, mottled sculpin and dace, but redside shiner would still be subject to significant losses in available habitat.

Table 4-11
PHABSIM Predictions for Proposed Flows in the Provo River
From Murdock Diversion Dam to Interstate 15 (Preferred Alternative)[a,b,c]

	Site 2c			Site 2b			Site 2a		
Species and Life Stages	**Total Habitat Area Under Baseline Conditions**	**Total Habitat Area Under Spanish Fork-Provo Reservoir Canal Alternative**	**Percent Change**	**Total Habitat Area Under Baseline Conditions**	**Total Habitat Area Under Spanish Fork-Provo Reservoir Canal Alternative**	**Percent Change**	**Total Habitat Area Under Baseline Conditions**	**Total Habitat Area Under Spanish Fork-Provo Reservoir Canal Alternative**	**Percent Change**
Brown Trout-Adult	4,220	11,258	167	8,040	11,826	47	11,462	11,829	3
Brown Trout-Juvenile	4,901	12,427	154	9,475	12,918	36	12,697	11,619	-8
Brown Trout-Spawn	0	5.8	--	0	6.6	--	4	19	378
Brown Trout-Fry	2,985	3,328	12	3,786	3,056	-19	3,404	2,326	-32
All Trout-Juvenile	13,234	23,355	76	21,600	23,355	8	22,615	18,185	-20
Cutthroat Trout-Spawn	0	0	--	0	0	--	0	0	--
Rainbow Trout-Spawn	0	0	--	0	0	--	0	0	--
Habitat Niches									
Backwater/Edge	1,270	1,028	-19	1,311	933	-29	860	772	-10
Slow/Shallow	10,013	9,879	-1	14,139	8,112	-43	5,964	4,044	-32
Mod/Shallow	1,422	7,853	452	3,887	8,597	121	8,139	9,752	20
Fast/Shallow	7.4	395	5,207	55	477	764	416	795	91
Mod/Mid-Depth	1,468	7,755	428	3,807	7,514	97	7,195	8,427	17
Fast/Mid-Depth	1.1	565	49,498	14.1	753	5,223	602	1,899	215
Mod/Deep	0	0	--	0	0	--	0	0	--

[a] WUA results were expressed as square feet per 1,000 feet of river
[b] Results from Site 2a, 2b, and 2c were extrapolated to represent habitat throughout this Provo River reach
[c] Total Habitat Area derived from using a mean of 50-100% WUA exceedance values

This alternative would result in small increases in wetted perimeter in this reach during all months (Table 4-12). The greatest increase (7.3 percent) was estimated to occur in October, with increases in other months ranging from 1 to 6 percent. The Preferred Alternative would have a low to moderate potential to impact macroinvertebrate habitat in this reach.

Table 4-12
Estimated Change in Wetted Perimeter in the Provo River From Murdock Diversion Dam to Interstate 15 Using Data From USGS Gage 10163000 (Preferred Alternative)

Month	Baseline Wetted Perimeter (feet)	Estimated Wetted Perimeter under Preferred Alternative (feet)	Percent Change
Jan	44.0	46.5	5.6
Feb	46.0	47.8	3.8
Mar	52.7	53.4	1.3
Apr	55.7	58.2	4.4
May	65.5	67.3	2.8
June	66.7	67.5	1.2
July	54.8	57.3	4.5
Aug	52.9	55.6	5.2
Sep	51.8	54.8	5.8
Oct	48.0	51.5	7.3
Nov	46.3	48.2	4.2
Dec	44.6	46.8	5.0

Water quality changes in dissolved oxygen, total dissolved solids, and water temperature would occur under the Preferred Alternative. Water delivered from Strawberry Reservoir is expected to increase the concentration of dissolved oxygen by up to 15 percent during September in the reach below Murdock Diversion. Concentrations of total dissolved solids are projected to decrease under this alternative. On average the total dissolved solids in the lower Provo would decrease up to 12 percent remaining well below state standards for aquatic life. Water temperatures would decrease during summer months and increase during the winter months as a result of the Preferred Alternative. Estimated monthly temperature changes would be small (less than 2 degrees) and would not change water temperatures beyond state standards for aquatic life. Overall, the water quality impacts on aquatic life are not expected to be significant under the Preferred Alternative.

4.3.1.1.5 Provo River From Interstate 15 to Utah Lake. The average monthly flows proposed under the Preferred Alternative would represent an increase over baseline conditions in all months (Table 4-13). This reach of the Provo River would receive its largest proportional increase in flows compared to baseline conditions in July (68 cfs), August (57 cfs), and September (56 cfs). Proportional flow increases during other months would range between 8 and 141 percent compared to baseline conditions.

Table 4-13
Estimated Baseline and Proposed Monthly Average Flow (cfs)
in Provo River From Interstate 15 to Utah Lake (Preferred Alternative)

	Month											
	Oct	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
Baseline	32	76	56	51	64	142	168	347	374	42	4	6
Proposed	77	94	75	69	81	153	222	445	433	110	61	62
% Change	141	24	34	35	27	8	32	28	16	162	1425	933

Modeling results indicated that proposed flows would provide higher habitat availability for all game species and life stages modeled compared to the baseline condition (Table 4-14). Projected habitat increases for game fish in this reach would range from 51 to 302 percent. The estimated net increase in habitat for game species throughout the entire reach would be a significant benefit to game fish within this reach.

Projected changes in availability of habitat niches used by game species would vary. Habitat availability for all niches used by game species was estimated to increase substantially compared to baseline under this alternative. The greatest increase in a niche used by game fish (1,294 percent) would occur in the moderate/shallow niche, which is used by trout in juvenile, fry, and spawning life stages. The increases in habitat for game fish would be a significant benefit to game fish within this reach.

All habitat niches were estimated to increase (49 to 7,868 percent). The greatest proportional increase in habitat availability would be associated with the fast/shallow habitat niche (7,868 percent), which is used by adult mountain sucker and adult and juvenile mottled sculpin. The large proportional increase would occur in this niche because only 2 ft^2 per 1,000 linear feet of river was estimated under baseline conditions, compared with 137 ft^2 per 1,000 linear feet of river under the Preferred Alternative. A similar magnitude habitat increase would occur in the moderate/deep habitat niche, which accounts for the large proportional increase (1,071 percent) projected by the PHABSIM model. These moderate to large increases in habitat availability would provide benefits in habitat availability to mountain sucker, mottled sculpin, redside shiner, and longnose and speckled dace and would be a significant benefit to non-game fishes within this reach.

Table 4-14 PHABSIM Predictions for Proposed Flows in the Provo River From Interstate 15 to Utah Lake (Preferred Alternative)[a,b,c]			
	Site 1		
Species and Life Stages	Total Habitat Area Under Baseline Conditions	Total Habitat Area Under the Preferred Alternative	Percent Change
Brown Trout-Adult	4,677	17,528	275
Brown Trout-Juvenile	4,960	18,812	279
Brown Trout-Spawn	20,617	31,134	51
Brown Trout-Fry	3,746	5,991	60
All Trout-Juvenile	8,911	29,734	234
Cutthroat Trout-Spawn	320	524	63
Rainbow Trout-Spawn	1,219	4,906	302
June Sucker-Spawn	7	236	3,374
Habitat Niches			
Backwater/Edge	1,278	1,904	49
Slow/Shallow	3,133	10,686	241
Mod/Shallow	426	5,938	1,294
Fast/Shallow	2	137	7,868
Mod/Mid-Depth	1,533	9,769	537
Fast/Mid-Depth	0	83	--
Mod/Deep	11	126	1,071

[a] WUA results were expressed as square feet per 1,000 feet of river
[b] Results from Site 1 were extrapolated to represent habitat throughout this Provo River reach
[c] Total Habitat Area derived from a mean of 50 to 100% WUA exceedance values

Wetted perimeter would increase in all months (Table 4-15). Increases would be substantial in some months, particularly August (63.8 percent) and September (52.7 percent). During November through June, projected increases in wetted perimeter would be less than 6 percent. These changes could cause a moderate to high increase in macroinvertebrate habitat compared to baseline conditions. There is high potential to improve macroinvertebrate habitat in this reach.

Table 4-15 Estimated Change in Wetted Perimeter in the Provo River From Interstate 15 to Utah Lake Using Data From USGS Gage 10163000 (Preferred Alternative)			
Month	**Baseline Wetted Perimeter (feet)**	**Estimated Wetted Perimeter under Preferred Alternative (feet)**	**Percent Change**
Jan	43.4	45.9	5.7
Feb	45.3	47.3	4.4
Mar	52.4	53.1	1.4
Apr	54.0	56.9	5.3
May	61.8	64.7	4.7
June	62.6	64.3	2.7
July	41.9	50.0	19.2
Aug	27.4	44.9	63.8
Sep	29.5	45.0	52.7
Oct	39.9	46.8	17.4
Nov	46.7	48.6	4.0
Dec	44.2	46.6	5.5

Based on model projections, water temperature, dissolved oxygen, and total dissolved solids changes in this reach would not be significant under the Preferred Alternative. The delivery of ULS Bonneville Unit water to this reach would not significantly impact water quality.

4.3.1.2 Hobble Creek

Under baseline conditions, monthly average flows in Hobble Creek range from 1 to 109 cfs with the peak average monthly flow occurring in May (Table 4-16). Under the Preferred Alternative, additional water would be delivered to Hobble Creek. This additional water would be supplied to enhance potential June sucker spawning habitat in lower Hobble Creek and would result in increased flows in Hobble Creek in all months. The greatest proportional flow increases would occur from August to October with increases greater than 100 percent. During April through early June, flows would be sustained above 85 cfs. Projected flows in May would average 145 cfs and likely would be accompanied by bedload transport.

Table 4-16
Estimated Baseline and Proposed Monthly Average Flow (cfs) in Hobble Creek Under the Preferred Alternative

	Month											
	Oct	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
Baseline	7	25	23	22	26	38	60	109	38	4	1	1
Proposed	20	35	32	32	35	46	111	145	65	13	10	10
% Change	186	40	39	45	35	21	85	33	71	225	900	900

Hydraulic modeling (HEC-RAS) of Hobble Creek estimated habitat impacts on wetted width, maximum channel depth and water velocities in the main river channel (Table 4-17). Detailed information on hydraulic modeling was provided in Section 2.2.1.1.2. Hydraulic modeling of steady-state conditions in Hobble Creek indicated that wetted widths would increase between 4 and 71 percent under the Preferred Alternative. Maximum channel depth would increase between 8 and 124 percent and mean main channel velocity would increase by 10 to 367 percent. Increased habitat availability from increased flows during all months would provide a significant long-term benefit to fishes in Hobble Creek.

Water depth and wetted perimeter in Hobble Creek would increase under this alternative (MWH 2003a). Thus it is reasonable to assume that the total area of aquatic habitat would increase. Specific changes in habitat would be expected with sustained near bank-full flows from April through mid-June as detailed in Table 4-17. Bank-full flows would be greater than 200 cfs.

Table 4-17
Estimated Changes in Wetted Width and Maximum Channel Depth in Hobble Creek From HEC-RAS Modeling Under the Preferred Alternative

	Month											
% Change	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
Wetted Perimeter	28	8	7	8	6	4	12	7	13	33	71	63
Maximum Channel Depth	50	13	13	14	11	8	22	12	22	58	124	108
Mean Main Channel Velocity	71	18	18	19	14	10	24	23	26	104	367	329

As a result of flow increases in Hobble Creek, water velocities were estimated to increase. Estimated mean channel velocities at proposed average monthly flows would range from 0.4 to 6.6 feet per second under this alternative. The average channel velocity in Hobble Creek would increase by approximately 0.5 feet per second during April through June. Mean channel velocity at individual cross section locations would increase from baseline conditions by less than 1 foot per second during spring. Water velocity at individual cross sections would have a gradient of values, with the highest velocities mid-channel and lower velocities near stream margins.

Results of the channel stability study indicated that sustained flows from April through mid-June would have the potential to result in bedload movement, especially when flows are greater than 95 cfs. Sustained higher flow in these months could wash fine sediments and small gravel downstream. Fine sediment and gravel would likely build up behind existing irrigation diversion structures in Hobble Creek, thus preventing natural processes of gravel recruitment downstream of the dams. Over time, periodic flushing of fine sediment and gravels has the potential to result in heavily armored substrates that would be unsuitable for fish production. Geomorphology results indicate that flows exceeding 95 cfs would redistribute spawning gravels for cutthroat trout and other game fishes, especially within the reach of Hobble Creek immediately below the Mapleton Lateral. Based on 2003 field surveys, this reach of Hobble Creek contained the most suitable spawning habitat for cutthroat trout and other trout species. Projected flows in May would average 145 cfs and thus may frequently result in rapid bedload transport. This alternative has the potential to impact substrates in Hobble Creek that are important for trout spawning, however, a net loss of suitable habitat is not expected with flow under bankfull width (<200 cfs).

Based on hydraulic modeling and estimated average monthly flows, habitat for macroinvertebrates in Hobble Creek would increase under the Preferred Alternative because flow would increase in all months. Water depth and wetted perimeter in Hobble Creek would increase under this alternative. These changes could cause a moderate to high increase in macroinvertebrate habitat compared to baseline conditions. There is a high potential to improve macroinvertebrate habitat in this reach.

Based on model projections, the water temperature would decrease under the Preferred Alternative. The likelihood of water temperatures exceeding state standards is expected to decrease. Thus, the increase flows to Hobble Creek during low flow periods would result in significant benefits to aquatic resources as a result of improved water temperature. Based on water quality modeling, dissolved oxygen would increase and total dissolved solids would decrease. The Preferred Alternative would not have significant impacts on TDS and dissolved oxygen in this reach. The water quality impacts of delivering Bonneville Unit water to Hobble Creek are described in the Draft Surface Water Quality Technical Report (CUWCD 2004c).

4.3.1.3 Spanish Fork River

The following aquatic resources impact analysis for the Spanish Fork River is based on operation of the Preferred Alternative by the District. Impacts are described as changes between the Preferred Alternative and baseline conditions.

4.3.1.3.1 Diamond Fork Creek to Spanish Fork Diversion Dam. The average monthly flows proposed under the Preferred Alternative for this reach were projected to decrease by 15 to 44 percent compared to baseline conditions (Table 4-18). The largest proportional flow decreases would occur from December to March, decreasing by approximately 40 percent. The remaining months would experience moderate proportional flow decreases (15 to 35 percent).

Table 4-18
Estimated Baseline and Proposed Monthly Average Flow (cfs)
in the Spanish Fork River From Diamond Fork Creek to Lakeshore Gage (Preferred Alternative)

	Month											
	Oct	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
Diamond Fork Creek to Spanish Fork Diversion Dam												
Baseline	158	191	201	215	248	285	425	740	645	546	457	258
Proposed	134	130	124	125	138	171	296	578	452	356	305	180
% Change	-15	-32	-38	-42	-44	-40	-30	-22	-30	-35	-33	-30
Spanish Fork Diversion Dam to East Bench Diversion												
Baseline	58	109	130	143	163	160	190	339	242	176	134	88
Proposed	34	48	53	54	53	46	60	189	99	54	43	29
% Change	-41	-56	-59	-62	-67	-71	-68	-44	-59	-69	-68	-67
East Bench Diversion to Mill Race Canal												
Baseline	54	109	130	143	163	159	182	295	187	127	93	70
Proposed	31	48	53	54	53	46	53	147	51	17	14	15
% Change	-43	-56	-59	-62	-67	-71	-71	-50	-73	-87	-85	-79
Mill Race Canal to Lakeshore Gage												
Baseline	131	194	205	219	252	289	389	471	257	149	113	86
Proposed	108	133	128	130	143	175	260	324	121	38	35	31
% Change	-18	-31	-38	-41	-43	-39	-33	-31	-53	-74	-69	-64

Stage-discharge relationships derived from two cross-sections in this reach varied because of different channel morphology. In one portion of this reach, represented by MWH Cross Section 1, flow was contained within a v-shaped channel at the deepest part of the river. In the other part of this reach, MWH Cross Section 2, the channel was trapezoidal, with in-channel variation in water surface elevation and complex habitats including side channels, islands, and oxbow habitats at flows less than 500 cfs. These two habitat cross-sections were assumed to be representative of channel morphology throughout the reach.

Based on modeled flows in this reach of the Spanish Fork River and channel configuration data, declines in discharge greater than 100 cfs would occur from February through August and would result in water surface elevations that are decreased by approximately six inches, thus decreasing the area of in-channel aquatic habitat available for aquatic species. In the part of the reach with a v-shaped channel, this decrease in water surface elevation would not be expected to have substantial effects, other than a general reduction in total area of in-stream habitat. Water elevation decreases in areas with trapezoidal channel morphology have the potential to confine water to the deepest part of the main channel during May through July. This would result in a decrease in overall habitat availability as well as a decrease in availability of some off-channel habitats that are used by brown trout and other game species during these months. Reduced spring and fall flows and associated decreases in habitat have the potential to significantly impact rainbow trout spawning in March and April and brown trout spawning in October and November. Modeled flows indicated that decreases in wetted width associated with trapezoidal channel morphology would occur only in May through July, while wetted width would decrease during all months in parts of the reach with a v-shaped channel. Projected flow decreases in the Spanish Fork River likely would result in small, long-term, and significant impacts on game and non-game fish habitats under the Preferred Alternative.

Based on channel cross-section data (USGS gage 10150500 at Castilla), the Preferred Alternative would result in small changes to wetted perimeter during all months. Wetted perimeter would decrease of 2 to 7 percent during the year (Table 4-19). Long-term but small decreases in wetted perimeter would be expected to have a low potential to impact macroinvertebrate habitat.

Table 4-19
Estimated Change in Wetted Perimeter in the Spanish Fork River From Diamond Fork Creek to Spanish Fork Diversion Dam Using Data From USGS Gage 10150500 (Preferred Alternative)

Month	Baseline Wetted Perimeter (feet)	Estimated Wetted Perimeter under Bonneville Unit Alternative (feet)	Percent Change
Jan	53.6	52.6	-1.9
Feb	54.9	52.4	-4.5
Mar	55.2	52.1	-5.6
Apr	55.7	52.2	-6.3
May	56.6	52.8	-6.8
June	57.6	54.1	-6.0
July	60.6	57.9	-4.4
Aug	65.0	63.0	-3.2
Sep	63.9	61.0	-4.5
Oct	62.5	59.2	-5.3
Nov	61.1	58.1	-4.9
Dec	56.9	54.5	-4.3

Under the Preferred Alternative, decreased flow in this reach of the Spanish Fork River would not significantly impact water quality. Only small changes in water temperatures, dissolved oxygen, and total dissolved solids would be expected because water quality conditions for aquatic resources would be very similar to baseline conditions. Water quality modeling estimated that the addition of less water under the Preferred Alternative would result in lower temperatures compared to baseline conditions because a greater proportion of water in the reach would originate from tributaries. Flow changes in this reach are not projected to affect total dissolved solids, dissolved oxygen, or water temperature to the point of exceeding state standards and thus would not impact aquatic resources in this reach. Other water quality changes are described in the Draft Surface Water Quality Technical Report (CUWCD 2004c).

4.3.1.3.2 Spanish Fork Diversion Dam to East Bench Diversion. Stage-discharge relationships derived from habitat cross sections were not available for this reach of the Spanish Fork River. Although these data were not available, evaluating directional habitat impacts from changes in average monthly flow would be similar to those described for the reach between Diamond Fork Creek and the Spanish Fork Diversion Dam. Monthly average flows in this reach would decrease by 41 to 71 percent (Table 4-18). Declines in flow of approximately 50 cfs during winter would result in a small reduction in the amount of aquatic habitat under this alternative, regardless of stream channel type. This habitat reduction would be greatest in May when flow decreases would be 150 cfs (see Table 4-18). Projected flow decreases in the Spanish Fork River likely would result in small, long-term, and significant impacts on habitat under the Preferred Alternative.

Based on channel cross-section data (USGS gage 10150500 at Castilla), this alternative would result in small to moderate decreases in wetted perimeter of 6 to 14 percent during all months (Table 4-20). Long-term but small decreases in wetted perimeter would be expected to have moderate potential to impact macroinvertebrate habitat.

Table 4-20
Estimated Change in Wetted Perimeter in the Spanish Fork River From Spanish Fork Diversion Dam to East Bench Diversion Using Data From USGS Gage 10150500 (Preferred Alternative)

Month	Baseline Wetted Perimeter (feet)	Estimated Wetted Perimeter under Bonneville Unit Alternative (feet)	Percent Change
Jan	47.7	44.9	-5.9
Feb	51.3	46.7	-9.0
Mar	52.4	47.2	-9.9
Apr	53.0	47.3	-10.7
May	53.8	47.2	-12.3
June	53.7	46.5	-13.5
July	54.8	47.9	-12.7
Aug	58.9	54.8	-6.9
Sep	56.5	50.7	-10.1
Oct	54.3	47.3	-12.9
Nov	52.6	46.1	-12.3
Dec	50.1	44.1	-11.9

Water quality impacts in this reach would be similar to the reach between Diamond Fork Creek to Spanish Fork Diversion Dam (Section 4.3.1.3.1)

4.3.1.3.3 East Bench Diversion to Mill Race Canal. The difference between proposed average monthly flows and baseline would be similar in most months to those in the reach between Spanish Fork Diversion Dam and East Bench Diversion (Table 4-18). Summer time flow decreases proportional to total flow would be greater in this reach compared to the reach between Spanish Fork Diversion Dam and East Bench Diversion. Habitat impacts from changes in average monthly flow would be similar to those described for the reach between Spanish Fork Diversion Dam and East Bench Diversion (Section 4.3.1.3.1).

Based on channel cross-section data (USGS gage 10150500 at Castilla), this alternative would result in small to moderate decreases in wetted perimeter of from 6 to 21 percent during all months (Table 4-21). Long-term but small decreases in wetted perimeter would be expected to have moderate potential to impact macroinvertebrate habitat.

Table 4-21 Estimated Change in Wetted Perimeter in the Spanish Fork River From East Bench Diversion to Mill Race Canal Using Data From USGS Gage 10150500 (Preferred Alternative)			
Month	**Baseline Wetted Perimeter (feet)**	**Estimated Wetted Perimeter under Bonneville Unit Alternative (feet)**	**Percent Change**
Jan	47.3	44.4	-6.1
Feb	51.3	46.7	-9.0
Mar	52.4	47.2	-9.9
Apr	53.0	47.3	-10.7
May	53.8	47.2	-12.3
June	53.7	46.5	-13.4
July	54.5	47.2	-13.4
Aug	57.9	53.2	-8.1
Sep	54.7	47.0	-14.1
Oct	52.3	41.6	-20.5
Nov	50.4	40.7	-19.3
Dec	48.7	41.0	-15.9

Water quality impacts would be similar to the reach between Diamond Fork Creek to Spanish Fork Diversion Dam (Section 4.3.1.3.1).

4.3.1.3.4 Mill Race Canal to Lakeshore Gage. Monthly average flows in this reach would decrease by 18 to 74 percent (Table 4-18), with the highest proportional decreases projected to occur in the summer during July through September. Although channel morphology information was not available, declines in flow would reduce the amount of aquatic habitat under this alternative, regardless of stream channel type. Habitat impacts from changes in fall, winter, and spring flows (October through May) would be similar to those described for the reach between Diamond Fork Creek and the Spanish Fork Diversion Dam (Section 4.3.1.3.1). Impacts from summer flow changes (June through September) would be similar to those described for the reach from Spanish Fork Diversion Dam to the East Bench Diversion (Section 4.3.1.3.2).

Based on channel cross-section data (USGS gage 10150500 at Castilla), this alternative would result in small to moderate decreases in wetted perimeter of from 2 to 15 percent during all months (Table 4-22). Long-term but small decreases in wetted perimeter would be expected to have low to moderate potential to impact macroinvertebrate habitat.

Table 4-22 Estimated Change in Wetted Perimeter in the Spanish Fork River From Mill Race Canal to Lakeshore Gage Using Data From USGS Gage 10150500 (Preferred Alternative)			
Month	**Baseline Wetted Perimeter (feet)**	**Estimated Wetted Perimeter under Bonneville Unit Alternative (feet)**	**Percent Change**
Jan	52.4	51.3	-2.3
Feb	55.0	52.5	-4.4
Mar	55.3	52.3	-5.5
Apr	55.8	52.4	-6.1
May	56.7	53.0	-6.6
June	57.7	54.3	-5.9
July	59.9	57.0	-4.9
Aug	61.4	58.5	-4.6
Sep	56.9	52.0	-8.7
Oct	53.3	45.5	-14.6
Nov	51.5	45.0	-12.6
Dec	49.9	44.4	-11.0

Water quality impacts would be similar to the reach between Diamond Fork Creek to Spanish Fork Diversion Dam (Section 4.3.1.3.1).

4.3.2 Game Fish Biomass and Communities

4.3.2.1 Provo River

4.3.2.1.1 Provo River From Deer Creek Reservoir Outlet to North Fork of Provo River. Standing crop estimates from the Binns HQI Model II indicate that game fish biomass and total biomass would remain the same as baseline. Although the improved flow in late summer and reductions in annual stream flow variation should benefit game fish production, winnowing of substrate would be expected in this reach (BIO-WEST 2003b) and would reduce the flow benefit. This prediction from the Binns HQI Model II indicates a nonsignificant increase in game fish numbers and/or biomass would be expected in this reach.

4.3.2.1.2 Provo River From North Fork of Provo River to Olmsted Diversion Dam. Standing crop estimates from the Binns HQI Model II indicate that game fish biomass and total biomass would remain the same as baseline. Although the improved flow in late summer and reductions in annual stream flow variation should benefit game fish production, winnowing of substrate would be expected in this reach (BIO-WEST 2003b) that could affect spawning substrate. The Binns HQI Model II results indicate that a nonsignificant decrease in game fish numbers and/or biomass would be expected in this reach.

4.3.2.1.3 Provo River From Olmsted Diversion Dam to Murdock Diversion Dam. Standing crop estimates from the Binns HQI Model II indicate that game fish biomass would increase by 118 pounds per acre. Total game fish biomass was estimated to increase by 1,805 pounds. This increase reflects a reduction in annual stream flow

variation, which would improve game fish habitat quality. This prediction from the Binns HQI Model II suggests a significant increase in game fish numbers and/or biomass would be expected in this reach.

4.3.2.1.4 Provo River From Murdock Diversion Dam to Interstate 15. Standing crop estimates from the Binns Model II indicated that game fish biomass would increase by 497 pounds per acre in this reach. Total biomass was estimated to increase by 13,545 pounds. This increase is reflective of improved flow in late summer, reduction in annual stream flow variation, increased fish cover, improved substrate, and higher water velocities compared to baseline conditions. This prediction from the Binns HQI Model II suggests a significant increase in game fish numbers and/or biomass would be expected in this reach.

4.3.2.1.5 Provo River From Interstate 15 to Utah Lake. Standing crop estimates from the Binns HQI Model II indicated that game fish biomass would increase by 329 pounds per acre in this reach. Total biomass was estimated to increase by 2,731 pounds. This increase reflects improved flows in late summer and reductions in annual stream flow variation. This prediction from the Binns HQI Model II suggests a significant increase in game fish numbers and/or biomass would be expected in this reach.

4.3.2.2 Hobble Creek

Higher springtime flows would increase total available aquatic habitat and thereby benefit game fish in Hobble Creek (see Section 4.3.1.2). Standing crop estimates from the Binns HQI Model II indicated that game fish biomass would increase by 344 pounds per acre in upper (Mapleton-Springville Lateral Discharge to Kolob Park in Springville) Hobble Creek. Total biomass was estimated to increase by 1,926 pounds in upper Hobble Creek. In the lower section (Kolob Park in Springville to Utah Lake) of Hobble Creek, standing crop estimates from the Binns Model II indicated that game fish biomass would increase by 388 pounds per acre. Total biomass was estimated to increase by 3,414 pounds in lower Hobble Creek. These increases reflect improved flow in late summer, reductions in annual stream flow variation, lower water temperatures, decreased nitrate concentrations, and improved substrate conditions. These predictions from the Binns HQI Model II suggest a significant increase in game fish numbers and/or biomass would be expected in Hobble Creek.

4.3.2.3 Spanish Fork River

4.3.2.3.1 Diamond Fork Creek to Spanish Fork Diversion Dam. Flow-related habitat changes in this reach of the Spanish Fork River could reduce game-fish habitat and have potential to reduce habitat complexity, however, the flow changes would not result in changes in Binns HQI Model II flow ratings. Game fish standing crop was projected to increase by 8 pounds per acre in the reach from the Diamond Fork Creek confluence to Spanish Fork Diversion Dam. Total biomass in this reach was estimated to increase by 212 pounds. The small increased biomass reflects decreased stream width under the Preferred Alternative. Overall, a small net long-term increase in fish numbers and/or biomass would be expected for game species in this reach of the Spanish Fork River.

4.3.2.3.2 Spanish Fork Diversion Dam to East Bench Diversion. Game fish standing crop in this reach of the Spanish Fork River was projected to increase by 17 pounds per acre. Total biomass in this reach was estimated to increase by 142 pounds. This small increase in biomass reflects decreased stream width under the Preferred Alternative. Overall, a net long-term small increase in fish numbers and/or biomass would be expected for game species in this reach of the Spanish Fork River.

4.3.2.3.3 East Bench Diversion to Mill Race Canal. In contrast to the reach of the Spanish Fork River from the Diamond Fork confluence to East Bench Diversion, game fish standing crop was projected to decrease by 43 pounds per acre. Total biomass in this reach was estimated to decrease by 468 pounds. This small decrease in biomass reflects a decrease in late summer stream flow. Overall, a non-significant long-term decrease in fish numbers and/or biomass would be expected for game species in this reach of the Spanish Fork River.

4.3.2.3.4 Mill Race Canal to Lakeshore Gage. Game fish standing crop was projected to decrease by 63 pounds per acre. Total biomass in this reach was estimated to decrease by 3,811 pounds. Decreased game fish biomass would result from decreased late summer stream flow and increased summer water temperatures. Overall, a significant long-term decrease in fish numbers and/or biomass would be expected for game species in this reach of the Spanish Fork River.

4.3.3 Non-Game Fish Populations and Communities

4.3.3.1 Provo River

4.3.3.1.1 Provo River From Deer Creek Reservoir Outlet to North Fork of Provo River. Non-game fish would be expected to experience mostly small decreases in habitat availability (see Section 4.3.1.1.1). However, a moderate decrease in habitat availability would be expected for the fast/shallow habitat. This habitat is only a partial use habitat for sucker and sculpin. Thus, the projected habitat availability change likely would not result in population changes for mountain sucker and mottled sculpin. Other non-game species habitat availability changes would be relatively minor and likely would not result in a long-term change in abundance and/or biomass for non-game fishes.

4.3.3.1.2 Provo River From North Fork of Provo River to Olmsted Diversion Dam. Mountain sucker and mottled sculpin would be expected to experience moderate decreases in habitat availability for fast water habitats (see Section 4.3.1.1.2). These projected habitat availability changes may result in population changes for mountain sucker and mottled sculpin. Other non-game species habitat availability changes would be relatively minor and likely would not result in a long-term change in abundance and/or biomass for non-game fishes.

4.3.3.1.3 Provo River From Olmsted Diversion Dam to Murdock Diversion Dam. Mountain sucker, mottled sculpin, longnose dace, speckled dace, and Utah sucker would be expected to experience moderate to high increases in habitat availability (see Section 4.3.1.1.3). Therefore, these species likely would increase in numbers and/or biomass in this reach. Projected decreases in the backwater habitat (12 percent) could result in small changes in populations of young-of-year Utah sucker, speckled dace, longnose dace, and multiple life stages of redside shiner. A loss of backwater habitat would have the potential to impact young-of-the-year fish numbers and/or biomass. However since the flow regime in the Preferred Alternative has been designed toward more natural flow levels in the lower Provo River for enhancement of June sucker spawning and rearing, the significance of the loss of backwater habitat in the middle and lower Provo River must be considered concurrently with the habitat gains created lower in the system (Section 4.3.3.1.5). In addition, net habitat increases in other modeled niches would be expected to provide significant long-term benefits for populations of non-game fish in this reach of the Provo River.

4.3.3.1.4 Provo River From Murdock Diversion Dam to Interstate 15. Habitats for juvenile and adult mountain sucker, mottled sculpin, longnose dace, and Utah sucker would experience moderate to high increases in habitat availability (see Section 4.3.1.1.4). Therefore, these species likely would increase in numbers and/or biomass in this reach. Young-of-the-year Utah sucker, speckled dace, longnose dace, and all stages of redside shiner likely would experience moderate decreases in habitat availability of the backwater/edge and slow/shallow habitats. A loss of slow water habitats would have the potential to impact young-of-the-year non-game fish numbers and/or biomass. However, since the flow regime in the Preferred Alternative has been designed toward more natural flow levels in the lower Provo River for enhancement of June sucker spawning and rearing, the significance of the loss of backwater and slow/shallow habitat in the middle and lower Provo River must be considered concurrently with the habitat gains created lower in the system (Section 4.3.3.1.5). In addition, net habitat increases in other modeled niches would be expected to provide significant long-term benefits for populations of non-game fishes in this reach of the Provo River.

4.3.3.1.5 Provo River From Interstate 15 to Utah Lake. Because all habitat niches are projected to experience substantial increases, it would be expected that all non-game species populations may benefit from increases in habitat availability under the Preferred Alternative (see Section 4.3.1.1.5). However, large increases in habitat suitability for predatory game fish (Section 4.3.1.1.5) may dampen the actualized benefit for non-game species.

4.3.3.2 Hobble Creek

Sculpin and mountain sucker are non-game fish species that may benefit by flow related increases in habitat availability. No other game species are documented in Hobble Creek. Increased habitat availability from increased flows during all months would provide a significant long-term benefit to non-game species in Hobble Creek.

4.3.3.3 Spanish Fork River

Impacts on non-game fish populations and communities in each of the four reaches of the Spanish Fork River were considered similar. Therefore, the impact assessment for non-game fish was combined to represent a geographic area between Diamond Fork Creek and the Lakeshore gage.

Although field surveys have indicated that brown trout dominate the fish community in the Spanish Fork River, non-game species have the potential to be impacted by flow related habitat changes under this alternative. Flow decreases during all months in all four of the reaches likely would result in a significant impact on non-game fish populations and could result in long-term decreases in fish numbers and/or biomass in each of the four reaches. The potential for this significant impact to occur is small because the river flows that were projected to occur as baseline conditions under the ULS (the same as river flows under the Interim Proposed Action in the Diamond Fork System FS-FEIS (CUWCD 1999)) are not expected to occur. This is because the District would continue to release the Bonneville Unit water to the Spanish Fork River only during the winter months when gates at the downstream irrigation dams are not diverting river flows. Therefore, the potential significant impact on non-game fish populations likely would occur on paper but not occur within the river.

4.3.4 Macroinvertebrate Populations and Communities

4.3.4.1 Provo River

4.3.4.1.1 Provo River From Deer Creek Reservoir Outlet to North Fork of Provo River. Impacts on macroinvertebrates in this reach would not be expected to be substantial under this alternative because the change in habitat is not projected to exceed 3 percent (see Section 4.3.1.1.1). The Preferred Alternative has a low potential to impact macroinvertebrate populations in this reach.

4.3.4.1.2 Provo River From North Fork of Provo River to Olmsted Diversion Dam. Impacts on macroinvertebrates in this reach would not be expected to be substantial under this alternative because the change in habitat is not projected to exceed 3 percent (see Section 4.3.1.1.2). The Preferred Alternative has a low potential to impact macroinvertebrate populations in this reach.

4.3.4.1.3 Provo River From Olmsted Diversion Dam to Murdock Diversion Dam. Although projected changes in macroinvertebrate habitat are slightly more in this reach than in further upstream reaches, the magnitude of change in habitat would not significantly alter macroinvertebrate populations and communities in this reach (see Section 4.3.1.1.3). The Preferred Alternative has a low potential to impact macroinvertebrate populations in this reach.

4.3.4.1.4 Provo River From Murdock Diversion Dam to Interstate 15. Projected increases in macroinvertebrate habitat (up to 7.3 percent) in this reach may be large enough to benefit macroinvertebrate populations and communities (see Section 4.3.1.1.4). Macroinvertebrate diversity and population size in this reach is relatively low (see Section 3.6.2.4). The Preferred Alternative has a moderate potential to increase macroinvertebrate populations in this reach.

4.3.4.1.5 Provo River From Interstate 15 to Utah Lake. Increases in aquatic habitat (up to 64 percent) would have a high potential to increase macroinvertebrate populations. This reach supports a low diversity of pollution-tolerant macroinvertebrates. Based on Binns HQI Model II ratings for submerged aquatic vegetation, the macroinvertebrate population is estimated to be very high under the Preferred Alternative. Project operations under this alternative are not likely to improve diversity but may increase populations to even greater levels. The Preferred Alternative has a high potential to increase macroinvertebrate populations in this reach compared to baseline conditions.

4.3.4.2 Hobble Creek

A moderate to high potential for benefit would be realized for macroinvertebrate populations during all months because increased aquatic habitat (up to 71 percent) would be available. A high potential for positive impact would occur during summer (July through September) when additional flow would be provided to Hobble Creek for the benefit of potential June sucker habitat.

4.3.4.3 Spanish Fork River

Impacts on macroinvertebrate populations and communities in each of the four reaches of the Spanish Fork River were considered similar. Therefore, the impact assessment for macroinvertebrates was combined to represent a geographic area between Diamond Fork Creek and Lakeshore gage.

Small changes in wetted perimeter (decreases of up to about 20 percent in the reach from East Bench Diversion to Mill Race Canal) (see Section 4.3.1.3.1) would occur, and the Preferred Alternative would result in a low potential impact on macroinvertebrates in the Spanish Fork River. This area currently supports a fair population of macroinvertebrates (see Section 3.6.4), and the Preferred Alternative likely would not substantially reduce the population size or diversity.

4.3.5 Summary of Alternative Impacts

4.3.5.1 Habitat

Estimated change in habitat is variable for the areas of impact and by habitat type. In the Provo River slow and backwater habitats generally would decrease while moderate and fast water habitats would increase. One notable exception is the lowest reach of the Provo River where large increases in all habitats would be expected. Projected increases in habitat likely would provide a significant benefit to aquatic species in Hobble Creek. Although a net loss would not be expected, high spring flows in Hobble Creek pose a risk to trout spawning habitat. Projected flow decreases in the Spanish Fork River would decrease habitat complexity for fishes and macroinvertebrates.

4.3.5.2 Game Fish Biomass

Game fish biomass and total biomass are projected to increase substantially because of increases in available habitat on the Provo River downstream of the Olmsted Diversion Dam. Trout standing crop and total biomass are projected to decrease compared to baseline conditions in two of four reaches in the Spanish Fork River. Impacts on game fish in the Spanish Fork River would be compounded by a loss in available habitat and would likely have

Habitat modeling results indicated that proposed flow under the Bonneville Unit Water Alternative would increase habitat availability for most game fish and life stages. In the lower portion of the reach (Site 2c), PHABSIM results indicated that proposed flows would substantially increase habitat availability for brown trout juveniles and adults (by 105 to 106 percent) (Table 4-25). More moderate increases would be evident for the middle part of this reach (Site 2b: 19 to 23 percent increases). Habitat availability was estimated to decrease slightly (3 percent) for brown trout juveniles in the upper part of the reach (Site 2a). Habitat availability for brown trout fry would decrease by 5 to 20 percent in the middle and upper portions of this reach. However, habitat availability increases in the lower end (27 percent) should offset these losses. Spawning habitat for brown trout was identified only in the upper part of this reach and would be expected to increase slightly from 4.1 to 4.7 ft^2 per 1,000 ft of river (14 percent). No cutthroat or rainbow trout spawning habitat has been identified in this reach (BIO-WEST 2002). Estimated habitat changes would generally result in significant improvements in game fish habitat.

Habitat niche modeling estimated increases in moderate- and fast-water habitats with decreases expected for slow- and backwater habitats. The backwater/edge niche was projected to decrease by 4 to 13 percent. This decrease could adversely impact juvenile and young-of-year mountain sucker, young-of-year dace and various life stages of redside shiner that utilize this habitat exclusively. Slow shallow habitat would increase at the lower end but decrease in the upper sections of the reach resulting in a small net decrease in slow shallow habitat between Murdock Diversion and Interstate 15. Decreased slow/shallow habitat availability potentially would affect adult and juvenile specked and longnose dace, various life stages of mottled sculpin, and mountain sucker adults. Juvenile dace would experience a net negative effect, as they use slow/shallow habitats exclusively. Impacts on other species that utilize this habitat niche would be offset by greater increases in habitat availability in other niches.

In contrast to slow water habitats, moderate flow niches would experience small to very large increases in habitat availability (3 to 230 percent). Increases in moderate flow niches would benefit numerous non-game species. The greatest increase in habitat would be associated with the fast/shallow (21 to 992 percent) and fast/mid-depth (32 to 1995 percent) habitat niches (Table 4-25). These niches provide suitable habitat for mountain sucker and mottled sculpin, which would therefore be expected to benefit from implementation of this alternative (Table 2-2). Overall, the increases in habitat availability would be expected to result in significant gains for non-game fish habitat.

This alternative would result in small increases in wetted perimeter during all months (Table 4-26). The greatest increase (3.7 percent) was estimated to occur in April. These changes are small and would be expected to have low potential for significant impact on macroinvertebrate habitat.

Table 4-25
PHABSIM Predictions for Proposed Flows in the Provo River
From Murdock Diversion Dam to Interstate 15 Bonneville Unit Water Alternative[a,b,c]

	Site 2c			Site 2b			Site 2a		
Species and Life Stages	**Total Habitat Area Under Baseline Conditions**	**Total Habitat Area Under Bonneville Unit Water Alternative**	**Percent Change**	**Total Habitat Area Under Baseline Conditions**	**Total Habitat Area Under Bonneville Unit Water Alternative**	**Percent Change**	**Total Habitat Area Under Baseline Conditions**	**Total Habitat Area Under Bonneville Unit Water Alternative**	**Percent Change**
Brown Trout-Adult	4219.5	8666.2	105	8039.8	989036	23	11462.1	11481.1	0
Brown Trout-Juvenile	4900.9	10113.8	106	9475.2	11263.7	19	12697.9	12322.7	-3
Brown Trout-Spawn	0.0	0.0	--	0.0	0.0	--	4.1	4.7	14
Brown Trout-Fry	2984.7	3803.2	27	3785.6	3605.8	-5	3404.4	2720.7	-20
All Trout-Juvenile	13234.3	22190.4	68	21599.6	23082.2	7	22615.2	20876.5	-8
Cutthroat Trout-Spawn	0.0	0.0	--	0	0	--	0.0	0.0	--
Rainbow Trout-Spawn	0.0	0.0	--	0	0	--	0.0	0.0	--
Habitat Niches									
Backwater/Edge	1269.6	1221.5	-4	1311.5	1136.1	-13	859.9	819.2	-5
Slow/Shallow	10013.1	12774.2	28	14139.1	11625.7	-18	5964.4	4986.1	-16
Mod/Shallow	1421.6	4517.2	218	3887.2	6126.5	58	8138.7	8385.3	3
Fast/Shallow	7.4	81.3	992	55.3	187.8	240	415.7	501.1	21
Mod/Mid-Depth	1467.6	4848.8	230	3806.8	5603.8	47	7195.2	7414.6	3
Fast/Mid-Depth	1.1	23.9	1995	14.1	148.0	904	601.9	794.6	32
Mod/Deep	0.0	0.0	--	0.0	0.0	--	0.0	0.0	--

[a] WUA results were expressed as square feet per 1,000 feet of river
[b] Results from Site 2a, 2b, and 2c were extrapolated to represent habitat throughout this Provo River reach
[c] Total Habitat Area derived from using a mean of 50-100% WUA exceedance values

Table 4-26
Estimated Change in Wetted Perimeter in the Provo River From Murdock Diversion Dam to Interstate 15 Using Data From USGS Gage 10163000 Under the Bonneville Unit Water Alternative

Month	Baseline Wetted Perimeter (feet)	Estimated Wetted Perimeter Under the Bonneville Unit Water Alternative (feet)	Percent Change
Jan	44.0	44.2	0.3
Feb	46.0	46.4	0.8
Mar	52.7	52.9	0.4
Apr	55.7	57.8	3.7
May	65.5	66.4	1.4
June	66.7	67.1	0.6
July	54.8	56.4	2.9
Aug	52.9	53.9	2.0
Sep	51.8	52.6	1.5
Oct	48.0	48.5	1.0
Nov	46.3	46.3	0.0
Dec	44.6	44.6	0.0

Based on model projections, water temperature, dissolved oxygen, and total dissolved solids changes in this reach would not be significant under the Bonneville Unit Water Alternative.

4.4.1.1.2 Provo River From Interstate 15 to Utah Lake. The average monthly flows proposed under this alternative would represent an increase over baseline conditions in all months except for November and December (Table 4-27). Under this alternative, this reach of the Provo River would receive significantly increased flows in August (650 percent increase) and September (333 percent increase) compared to baseline conditions.

Table 4-27
Estimated Baseline and Proposed Monthly Average Flow (cfs) in Provo River From Interstate 15 to Utah Lake Under the Bonneville Unit Water Alternative

	Month											
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Baseline	32	76	56	51	64	142	168	347	374	42	4	6
Proposed	41	76	56	52	68	145	213	404	414	93	30	26
% Change	28	0	0	2	6	2	27	16	11	121	650	333

PHABSIM results indicate that proposed flows would provide moderate to substantially higher habitat availability for all game species and life stages modeled compared to the baseline condition (Table 4-28). Spawning habitat indices for brown trout, cutthroat trout, and rainbow trout would increase 37 to 354 percent under the Bonneville Unit Water Alternative. Juvenile and fry habitat availability would be expected to increase by 84 to 219 percent.

Projected changes in habitat niches would vary by niche and location within the reach from Interstate 15 and Utah Lake. All habitat niches were estimated to increase. The greatest proportional increase in habitat availability would be associated with the fast/shallow habitat niche (1,097 percent), which is used by adult mountain sucker and adult and juvenile mottled sculpin.

Table 4-28
PHABSIM Predictions for Proposed Flows in the Provo River From Interstate 15 to Utah Lake Under the Bonneville Unit Water Alternative [a,b,c]

	Site 1		
Species and Life Stages	**Total Habitat Area Under Baseline Conditions**	**Total Habitat Area Under Bonneville Unit Water Alternative**	**Percent Change**
Brown Trout-Adult	4677.7	13800.3	195
Brown Trout-Juvenile	4960.8	15379.0	210
Brown Trout-Spawn	20617.7	28193.4	37
Brown Trout-Fry	3746.4	6908.4	84
All Trout-Juvenile	8911.9	28470.5	219
Cutthroat Trout-Spawn	320.6	876.1	173
Rainbow Trout-Spawn	1219.3	5538.5	354
June sucker-Spawn	6.8	207.7	2960
Habitat Niches			
Backwater/Edge	1278.0	2475.0	94
Slow/Shallow	3132.9	14478.7	362
Mod/Shallow	425.8	1975.4	365
Fast/Shallow	1.7	20.6	1097
Mod/Mid-Depth	1532.5	5834.4	281
Fast/Mid-Depth	0.0	1.4	--
Mod/Deep	10.7	52.7	391

[a] WUA results were expressed as square feet per 1,000 feet of river
[b] Results from Site 1 and 2a were extrapolated to represent habitat throughout this Provo River reach
[c] Total Habitat Area derived from a mean of 50-100% WUA exceedance values

Wetted perimeter would increase in all months (Table 4-29). Increases would be substantial in some months, particularly August (44.0 percent) and September (30.4 percent). These changes would be expected to have moderate to high potential to increase macroinvertebrate habitat.

Table 4-29
Estimated Change in Wetted Perimeter in the Provo River From Interstate 15 to Utah Lake Using Data from USGS Gage 10163000 Under the Bonneville Unit Water Alternative

Month	Baseline Wetted Perimeter (feet)	Estimated Wetted Perimeter under Alternative 3 (feet)	Percent Change
Jan	43.4	43.6	0.4
Feb	45.3	45.8	1.1
Mar	52.4	52.6	0.4
Apr	54.0	56.4	4.5
May	61.8	63.5	2.8
June	62.6	63.8	1.9
July	41.9	48.5	15.6
Aug	27.4	39.4	44.0
Sep	29.5	38.4	30.4
Oct	39.9	41.8	4.6
Nov	46.7	46.7	0.0
Dec	44.2	44.2	0.0

Based on model projections, water temperature, dissolved oxygen, and total dissolved solids changes in this reach would not be significant under the Bonneville Unit Water Alternative.

4.4.1.2 Hobble Creek

Under baseline conditions, monthly average flows in Hobble Creek range from 1 to 109 cfs, with the peak average monthly flow occurring in May (Table 4-30). Under the Bonneville Unit Water Alternative, additional water would be delivered to Hobble Creek. This additional water would be supplied to enhance potential June sucker habitat in lower Hobble Creek and would result in increased flows in Hobble Creek in all months. Flows are projected to increase by more than 100 percent from July through February with the greatest proportional flow increases occurring from July through October. During April through early June flows would be sustained above 85 cfs. Projected flows in May would average 147 cfs and likely would be accompanied by bedload transport.

Table 4-30
Estimated Average Hobble Creek Flows From Mapleton Lateral to Utah Lake Under the Bonneville Unit Water Alternative Compared to Baseline Conditions (flows in cfs)

	Month											
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Baseline	7	25	23	22	26	38	60	109	38	4	1	1
Alternative	38	55	53	52	56	68	102	147	72	35	33	32
% Change	443	120	130	136	115	79	70	35	89	775	3200	3100

Hydraulic modeling (HEC-RAS) of Hobble Creek estimated habitat impacts on wetted width, maximum channel depth and water velocities in the main river channel (Table 4-31). Detailed information on hydraulic modeling was provided in Section 2.2.1.1.2. Hydraulic modeling of steady-state conditions in Hobble Creek indicated that wetted widths would increase between 7 and 111 percent under the Bonneville Unit Water Alternative. Maximum channel depth would increase between 12 and 218 percent and mean main channel velocity would increase by 25 to 757 percent. Increased habitat available during all months would provide a significant benefit for game fish habitat as compared to baseline conditions.

Water depth and wetted perimeter in Hobble Creek would increase under the Bonneville Unit Water Alternative (MWH 2003a). Thus it is reasonable to assume the total area of aquatic habitat would increase. Specific changes in habitat are anticipated with sustained near bank-full flows from April through mid-June as described below.

Table 4-31
Estimated Changes to Wetted Width and Maximum Channel Depth in Hobble Creek From HEC-RAS Modeling Under the Bonneville Unit Water Alternative

	Month											
% Change	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
Wetted Perimeter	45	17	16	17	16	14	12	7	15	58	111	110
Maximum Channel Depth	87	32	28	30	30	24	23	12	26	110	218	214
Mean Main Channel Velocity	132	43	39	42	40	29	25	28	32	214	757	737

As a result of flow increases in Hobble Creek, water velocities were estimated to increase. During April through June, estimated mean channel velocities at proposed average monthly flows would range from 2.7 to 3.4 feet per second in this alternative. The average channel velocity in Hobble Creek would increase by approximately 0.5 feet per second during April through June. Mean channel velocity at individual cross section locations would increase from baseline conditions by less than 1 foot per second during spring. Water velocity at individual cross sections showed a gradient of values, with the highest velocities mid-channel and lower velocities near stream margins.

The PHABSIM modeling completed for the Provo River modeled cutthroat trout habitat with water velocities ranging up to approximately 3 feet per second (BIO-WEST 2003b). Cutthroat trout in Hobble Creek are assumed to have similar habitat suitability requirements to those in the Provo River. Average channel velocities in the baseline condition for Hobble Creek were estimated at 3.1 feet per second in May (MWH 2003a). This is higher than for cutthroat trout from existing habitat suitability curves (3 feet per second). Although water velocity in Hobble Creek would increase in this alternative and average water velocities in the main channel would be higher than preferred values, the magnitude of the increases from baseline conditions do not suggest that habitat would be unsuitable for cutthroat trout and other trout species that may be present. Cutthroat trout have persisted in Hobble Creek under the current flow regime. It is expected that habitat between the thalweg and the stream margins would contain lower velocity areas suitable for trout during April through June when ULS Bonneville Unit water would be discharged into Hobble Creek.

Results of the channel stability study indicated that sustained flows from April through mid-June have the potential to result in bedload movement, especially when flows are greater than 95 cfs. Sustained higher flow in these months could wash fine sediments and small gravel downstream. Fine sediment and gravel would likely build up behind existing irrigation diversion structures in Hobble Creek, thus preventing natural processes of gravel recruitment downstream of the dams. Over time, periodic flushing of fine sediment and gravels has the potential to result in heavily armored substrates that would be unsuitable for fish production. Geomorphology results indicate that flows exceeding 95 cfs would redistribute spawning gravels for cutthroat trout and other game fishes, especially within the reach of Hobble Creek immediately below the Mapleton Lateral. Based on 2003 field surveys, this reach of Hobble Creek contained the most suitable spawning habitat for cutthroat trout and other trout species. This alternative has the potential to impact substrates in Hobble Creek that are important for trout spawning, however a net loss of suitable habitat is not anticipated with stream flow under bank full width conditions.

Based on hydraulic modeling and estimated average monthly flows, habitat for macroinvertebrates in Hobble Creek would increase under the Bonneville Unit Water Alternative because flow would increase in all months. Water depth and wetted perimeter in Hobble Creek would increase. These changes could cause a moderate to high increase in macroinvertebrate habitat compared to baseline conditions.

Based on model projections, water temperature would decrease under the Bonneville Unit Water Alternative. The likelihood of water temperatures exceeding significance criteria would be expected to decrease. Thus, increased flows to Hobble Creek during low flow periods could result in significant benefits for aquatic resources as a result of improved water temperatures. The Bonneville Unit Water Alternative would not have significant impacts on total dissolved solids and dissolved oxygen in this reach. The delivery of water to this reach would not significantly impact water quality.

4.4.1.3 Spanish Fork River

4.4.1.3.1 Diamond Fork Creek to Spanish Fork Diversion Dam. As compared to baseline conditions, the average monthly flows proposed under the Bonneville Unit Water Alternative would represent moderate (2 to 35 percent) decreases from April to September and moderate increases (3 to 34 percent) from October to March. The modeled average monthly flows proposed under this alternative are shown in Table 4-32.

Table 4-32
Estimated Baseline and Proposed Monthly Average Flow (cfs)
in the Spanish Fork River From Spanish Fork Diversion Dam to Lakeshore Gage
Under the Bonneville Unit Water Alternative

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	Month											
	Oct	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
Diamond Fork Creek to Spanish Fork Diversion Dam												
Baseline	158	191	201	215	248	285	425	740	645	546	457	258
Proposed	192	256	246	247	272	293	417	578	452	356	305	180
% Change	22	34	22	15	10	3	-2	-22	-30	-35	-33	-30
Spanish Fork Diversion Dam to East Bench Diversion												
Baseline	58	109	130	143	163	160	190	339	242	176	134	88
Proposed	93	174	175	175	187	168	181	189	99	54	43	29
% Change	60	60	35	22	15	5	-5	-44	-59	-69	-68	-67

Table 4-32
Estimated Baseline and Proposed Monthly Average Flow (cfs)
in the Spanish Fork River From Spanish Fork Diversion Dam to Lakeshore Gage
Under the Bonneville Unit Water Alternative

	Month											
	Oct	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**
East Bench Diversion to Mill Race Canal												
Baseline	54	109	130	143	163	159	182	295	187	127	93	70
Proposed	90	174	175	175	187	168	174	147	51	17	14	15
% Change	67	60	35	22	15	6	-4	-50	-73	-87	-85	-79
Mill Race Canal to Lakeshore Gage												
Baseline	131	194	205	219	252	289	389	471	257	149	113	86
Proposed	167	259	250	252	276	297	381	324	121	38	35	31
% Change	27	34	22	15	10	3	-2	-31	-53	-74	-69	-64

Stage-discharge relationships derived from two cross sections indicated that such moderate change in flow under this alternative would not be expected to have substantial effects, other than a general reduction in total area of in-stream habitat. A general reduction of in-stream habitat during spring could lead to reduced levels of spawning, rearing, or holding habitat for rainbow trout species. In contrast, higher flow and increased habitat from October to December could benefit any spawning brown trout.

Based on channel cross-section data (USGS gage 10150500 at Castilla), this alternative would result in small changes to wetted perimeter during the year. Wetted perimeter would have a maximum decrease of approximately 5 percent during July and August in this reach (Table 4-33). These changes would have a low potential for impacting macroinvertebrate habitats.

Table 4-33
Estimated Change in Wetted Perimeter in the Spanish Fork River From Diamond Fork Creek to Spanish Fork Diversion Dam Using Data From USGS Gage 10150500 Under the Bonneville Unit Water Alternative

Month	Baseline Wetted Perimeter (feet)	Estimated Wetted Perimeter under Bonneville Unit Alternative (feet)	Percent Change
Jan	55.7	56.6	1.7
Feb	56.6	57.3	1.1
Mar	57.6	57.8	0.4
Apr	60.6	60.4	-0.2
May	65.0	63.0	-3.1
June	63.9	61.0	-4.4
July	62.5	59.2	-5.2
Aug	61.1	58.1	-4.9
Sep	56.9	54.6	-4.0
Oct	53.6	54.9	2.4
Nov	54.9	56.9	3.6
Dec	55.2	56.6	2.5

Under the Bonneville Unit Water Alternative, projected flow changes in this reach of the Spanish Fork River would not significantly impact water quality. Only small changes in water temperatures and dissolved oxygen would be expected. Dissolved oxygen levels may drop below the state standard for aquatic life but would be expected to return to within criteria because of re-aeration at riffles and diversion dams. Water quality modeling estimated that the addition of less water under the Bonneville Unit Alternative would result in lower temperatures compared to baseline conditions because a greater proportion of water in the reach would originate from tributaries. Flow in this reach is not projected to alter total dissolved solids, dissolved oxygen, or water temperature sufficiently to increase the likelihood of exceeding state standards and thus would not impact aquatic resources in this reach.

4.4.1.3.2 Spanish Fork Diversion Dam to East Bench Diversion. Stage-discharge relationships derived from habitat cross sections were not available for this reach of the Spanish Fork River. Compared to baseline conditions, flow changes in this reach would vary widely from a 60 percent increase in October and November to a 69 percent decrease in July (see Table 4-32). Decreases in late spring and summer flow by 44 to 69 percent would likely have negative impacts on fish spawning during that period. In contrast, greater flows during October through December should increase habitat and benefit any brown trout spawning in this reach.

Based on channel cross section data, this alternative would result in small to moderate changes in wetted perimeter during the year. Wetted perimeter would have a maximum decrease of approximately 13 percent during July in this reach (Table 4-34). These changes would have a low to moderate potential for impacting macroinvertebrate habitats.

Table 4-34
Estimated Change in Wetted Perimeter in the Spanish Fork River From Spanish Fork Diversion Dam to East Bench Diversion Using Data From USGS Gage 10150500 Under the Bonneville Unit Water Alternative

Month	Baseline Wetted Perimeter (feet)	Estimated Wetted Perimeter under Bonneville Unit Alternative (feet)	Percent Change
Jan	53.0	54.3	2.4
Feb	53.8	54.7	1.7
Mar	53.7	54.1	0.7
Apr	54.8	54.5	-0.5
May	58.9	54.9	-6.7
June	56.5	50.8	-10.0
July	54.3	47.4	-12.7
Aug	52.6	46.5	-11.7
Sep	50.1	44.7	-10.6
Oct	47.7	50.4	5.6
Nov	51.3	54.3	5.7
Dec	52.4	54.3	3.6

Water quality impacts in this reach would be similar to the reach between Diamond Fork Creek to Spanish Fork Diversion Dam (Section 4.4.1.3.1).

4.4.1.3.3 East Bench Diversion to Mill Race Canal. Compared to baseline conditions, flow changes in this reach would vary widely from a 67 percent increase in October to an 87 percent decrease in July. The difference between proposed average monthly flows and baseline during October through April would be similar to those in the reach between Spanish Fork Diversion Dam and East Bench Diversion (Table 4-32). Decreases in late spring and summer flow by 49 to 86 percent would likely have negative impacts on aquatic habitats and fish spawning during that period. In contrast, greater flows during October through December should increase habitat and benefit any brown trout spawning in this reach.

Based on channel cross section data (USGS gage 10150500 at Castilla), this alternative would result in small changes in wetted perimeter during the year. Wetted perimeter would have a maximum decrease of 20 percent during August in this reach (Table 4-35). These changes would have a low to moderate potential for impacting macroinvertebrate habitats.

Table 4-35
Estimated Change in Wetted Perimeter in the Spanish Fork River From East Bench Diversion Dam to Mill Race Canal Using Data From USGS Gage 10150500 Under the Bonneville Unit Water Alternative

Month	Baseline Wetted Perimeter (feet)	Estimated Wetted Perimeter under Bonneville Unit Alternative (feet)	Percent Change
Jan	53.0	54.3	2.4
Feb	53.8	54.7	1.7
Mar	53.7	54.0	0.7
Apr	54.5	54.3	-0.5
May	57.9	53.3	-7.9
June	54.7	47.2	-13.7
July	52.3	41.8	-20.0
Aug	50.4	41.6	-17.5
Sep	48.7	42.3	-13.2
Oct	47.3	50.2	6.1
Nov	51.3	54.3	5.7
Dec	52.4	54.3	3.6

Water quality impacts would be similar to the reach between Diamond Fork Creek to Spanish Fork Diversion Dam (Section 4.4.1.3.1).

4.4.1.3.4 Mill Race Canal to Lakeshore Gage. Habitat changes associated with changing flows in this reach would be similar to the reach between Diamond Fork Creek and Spanish Fork Diversion Dam (Section 4.4.1.3.1) during October through April. From May to September, the impacts would be similar to those described for the reach from the Spanish Fork Diversion Dam to the East Bench Diversion Dam.

Based on channel cross-section data (USGS gage 10150500 at Castilla), this alternative would result in small changes in wetted perimeter during the year. Wetted perimeter would have a maximum decrease of approximately 14 percent during July in this reach (Table 4-36). These changes would have a low to moderate potential for impacting macroinvertebrate habitats.

Table 4-36 Estimated Change in Wetted Perimeter in the Spanish Fork River From Mill Race Canal to Lakeshore Gage Using Data From USGS Gage 10150500 Under the Bonneville Unit Water Alternative			
Month	**Baseline Wetted Perimeter (feet)**	**Estimated Wetted Perimeter under Bonneville Unit Alternative (feet)**	**Percent Change**
Jan	55.8	56.7	1.7
Feb	56.7	57.1	0.7
Mar	57.7	57.9	0.3
Apr	59.9	59.7	-0.3
May	61.4	58.6	-4.5
June	56.9	52.1	-8.5
July	53.3	45.7	-14.1
Aug	51.5	45.3	-12.1
Sep	49.9	45.0	-9.8
Oct	52.4	54.0	2.9
Nov	55.0	56.9	3.6
Dec	55.3	56.7	2.4

Water quality impacts would be similar to the reach between Diamond Fork Creek to Spanish Fork Diversion Dam (Section 4.4.1.3.1).

4.4.2 Game Fish Biomass

4.4.2.1 Provo River

The game fish biomass changes for the following reaches would be the same as under the Preferred Alternative.

- Provo River from Deer Creek Reservoir to North Fork of Provo River – Section 4.4.2.1.1
- Provo River from North Fork of Provo River to Olmsted Diversion Dam – Section 4.4.2.1.2
- Provo River from Olmsted Diversion Dam to Murdock Diversion Dam – Section 4.4.2.1.3
- Spanish Fork River from Mill Race Diversion to Utah Lake – Section 4.3.2.3.3

4.4.2.1.1 Provo River From Murdock Diversion Dam to Interstate 15. Standing crop estimates from the Binns Model II indicate that game fish biomass would increase by 186 pounds per acre in this reach. Total biomass was estimated to increase by 6,371 pounds. This increase reflects improved critical low flows in late summer and reductions in annual stream flow variation. This prediction from the Binns HQI Model II suggests a significant increase in game fish biomass would be expected in this reach.

4.4.2.1.2 Provo River From Interstate 15 to Utah Lake. Standing crop estimates from the Binns Model II indicated that game fish biomass would increase by 184 pounds per acre in this reach. Total biomass was

estimated to increase by 1,527 pounds. This increase reflects improved critical low flows in late summer and reduction in annual stream flow variation. This prediction from the Binns HQI Model II suggests a significant increase in trout biomass would be expected in this reach.

4.4.2.2 Hobble Creek

4.4.2.2.1 Hobble Creek From Mapleton-Springville Lateral to Kolob Park. Standing crop estimates from the Binns HQI Model II indicate that game fish biomass would increase by 437 pounds per acre. Total biomass was estimated to increase by 2,447 pounds. Based on changes in habitat availability and standing crop estimates estimated from the Binns HQI Model II, a significant long-term increase in game fish biomass would be expected in this reach.

4.4.2.2.2 Hobble Creek From Kolob Park to Utah Lake. The Binns HQI Model II projected game fish standing crop to increase by 493 pounds per acre. Total biomass was estimated to increase by 4,338 pounds. Based on changes in habitat availability and standing crop estimates estimated from the Binns HQI Model II, a significant long-term increase in game fish biomass would be expected in this reach.

4.4.2.3 Spanish Fork River

4.4.2.3.1 Spanish Fork River From Diamond Fork to Spanish Fork Diversion Dam. The Binns HQI Model II estimated that there would be no change from baseline conditions for pounds per acre biomass or total biomass.

4.4.2.3.2 Spanish Fork River From Spanish Fork Diversion Dam to East Bench Dam. The Binns HQI Model II projected trout standing crop to decrease by 57 pounds per acre. Total biomass is projected to decrease by 473 pounds. This decrease would be caused by decreased late summer flows. The Binns HQI Model II results suggest a long-term decrease in game fish biomass would be expected in this reach.

4.4.2.3.3 Spanish Fork River From East Bench Dam to Mill Race Diversion. The Binns HQI Model II projected trout standing crop to decrease by 182 pounds per acre. Total biomass is projected to decrease by 1,984 pounds. This decrease would be caused by decreased late summer flows. The Binns HQI Model II output suggest a long-term decrease in game fish biomass would be expected in this reach.

4.4.3 Non-Game Fish Populations and Communities

The non-game fish changes for the following reaches would be the same as under the Preferred Alternative.

- Provo River from Deer Creek Reservoir to North Fork of Provo River – Section 4.3.1.1.1
- Provo River from North Fork to Olmsted Diversion Dam – Section 4.3.1.1.2
- Provo River from Olmsted Diversion Dam to Murdock Diversion Dam – Section 4.3.1.1.3

4.4.3.1 Provo River

4.4.3.1.1 Provo River From Murdock Diversion Dam to Interstate 15. Mountain sucker and mottled sculpin would be expected to experience large projected increases in habitat availability, which may result in increases in population size (see Section 4.4.1.1.4). Other non-game species that would be expected to experience large increases in habitat availability are speckled and longnose dace and Utah sucker. Young-of-the-year sucker and dace and all life stages of redside shiner likely would experience smaller decreases in availability of backwater/edge habitat, the only niche utilized by these life stages. A loss of backwater habitats would have the

potential to impact young-of-the-year non-game fish numbers and/or biomass. However, since the flow regime in the Bonneville Unit Water Alternative has been oriented toward more natural flow levels in the lower Provo River for improvement of June sucker spawning and rearing habitat, the significance of the loss of backwater habitat in the middle and lower Provo River must be considered concurrently with the habitat gains created lower in the river system (Section 4.3.3.1.5). In addition, net habitat increases in other modeled niches would be expected to provide significant long-term benefits for populations of non-game fish in this reach of the Provo River.

4.4.3.1.5 Provo River From Interstate 15 to Utah Lake. Because most habitat niches are projected to experience substantial increases, it would be expected that all non-game species populations may benefit associated with increased habitat availability under the Bonneville Unit Water Alternative (see Section 4.4.1.1.5). However, large increases in habitat suitability for predatory game fish (Section 4.4.1.1.5) may dampen the actualized benefit for non-game species.

4.4.3.2 Hobble Creek

Sculpin and mountain sucker are the non-game fish species that may benefit by flow related increases in habitat availability, especially during the summer months. These habitat benefits would result in a significant increase in non-game fish population in Hobble Creek.

4.4.3.4 Spanish Fork River

Impacts on non-game fish populations and communities in each of the four reaches of the Spanish Fork River were considered similar. Therefore, the impact assessment for non-game fish was combined to represent a geographic area between Diamond Fork Creek and Lakeshore gage.

Although field surveys have indicated that brown trout dominate the fish community in the Spanish Fork River, non-game species present in the system have the potential to be impacted by flow related habitat changes under this alternative. Flow decreases during summer in the upper two reaches would increase the likelihood of exceeding water temperature criteria. Low to moderate summer flow decreases could negatively impact non-game fish species because less habitat would be available during spawning. The increased potential for exceedance of water temperature criteria represents a significant impact on non-game fishes and could result in long-term decreases in fish numbers and/or biomass.

4.4.4 Macroinvertebrate Populations and Communities

The macroinvertebrate population changes for the following reaches would be the same as under the Preferred Alternative.

- Provo River from Deer Creek Reservoir to North Fork of Provo River – Section 4.3.1.1.1
- Provo River from North Fork to Olmsted Diversion Dam – Section 4.3.1.1.2
- Provo River from Olmsted Diversion Dam to Murdock Diversion Dam – Section 4.3.1.1.3

4.4.4.1 Provo River

4.4.4.1.1 Provo River From Murdock Diversion Dam to Interstate 15. The increases in habitat, approximately 4 percent, may be large enough to provide a benefit to macroinvertebrate populations and communities to a small degree in this reach (see Section 4.4.1.1.1). Macroinvertebrate diversity and population size in this reach is relatively low (see Section 3.6.1.4). Project operations under this alternative are not likely to improve diversity

but may slightly increase population size. Flow induced habitat changes have low potential to benefit macroinvertebrate populations and communities in this reach.

4.4.4.1.2 Provo River From Interstate 15 to Utah Lake. This alternative would have a moderate to high potential to benefit macroinvertebrate communities. This reach supports a low diversity of pollution-tolerant macroinvertebrates (see Section 3.6.2.5). Based on measurements taken for the Binns HQI Model II analysis for submerged aquatic vegetation, the population size of macroinvertebrates is estimated to significantly increase. Project operations under the Bonneville Unit Water Alternative are not likely to improve diversity but should increase population size to even greater levels (see Section 4.4.1.1.2).

4.4.4.2 Hobble Creek

A moderate to high benefit would be realized for macroinvertebrate populations during all months because increased habitat would be available. The Bonneville Unit Water Alternative would have a high potential to result in positive impacts during summer (July through September) when additional flow would be provided to Hobble Creek for the benefit of potential June sucker habitat.

4.4.4.3 Spanish Fork River

Impacts on macroinvertebrate populations and communities in each of the four reaches of the Spanish Fork River were considered similar. Therefore, the impact assessment for macroinvertebrates was combined to represent a geographic area between Diamond Fork Creek and Lakeshore gage.

Wetted perimeter habitat changes would vary with the season (see Section 4.4.1.3). Small improvements in the winter likely would not be large enough to impact macroinvertebrate populations and communities. Moderate losses in the summer have greater potential to impact macroinvertebrates. Macroinvertebrate diversity and population size in this reach is relatively low (see Section 3.6.4). Project operations under the Bonneville Unit Water Alternative would have low to moderate potential to have impacts on macroinvertebrate populations and communities.

4.4.5 Summary of Alternative Impacts

4.4.5.1 Habitat

Large increases in habitat availability would be expected in the lower Provo River. The greatest increases would be expected to occur downstream of the Murdock Diversion Dam reach and should improve game and non-game fish habitats. In the Spanish Fork River, habitat is projected to increase and decrease seasonally. The greatest potential loss would occur during summer months and could have significant impacts on non-game spawning habitat. Hobble Creek habitat is projected to increase significantly under the Bonneville Unit Water Alternative.

4.4.5.2 Game Fish Biomass

Game fish biomass may be expected to increase (Table 4-37) as a result of habitat increases in the Provo River downstream of the Olmsted Diversion Dam to the Murdock Diversion Dam reach. Game fish populations in the Spanish Fork River would decrease because of decreases in late summer flows. In Hobble Creek, game fish populations and total biomass would experience significant long-term increases. Overall, the Bonneville Unit Water Alternative would result in an increase of 10,220 pounds of fish biomass.

Table 4-37
Summary of Estimated Trout Standing Crop (lb/acre) and Biomass (lbs)[1]
Under the ULS EIS Bonneville Unit Water Alternative

		Baseline Conditions		Bonneville Unit Water Alternative	
Waterbody	**Reach Description**	**Standing Crop (lbs/acre)**	**Biomass (lbs)**	**Standing Crop (lbs/acre)**	**Biomass (lbs)**
Spanish Fork River Above Spanish Fork Diversion Dam					
Reach 1	Diamond Fork Creek confluence to Spanish Fork Diversion Dam	151	4,002	151	4,002
Spanish Fork River Below Spanish Fork Diversion Dam					
Reach 1	Spanish Fork Diversion Dam to East Bench Dam	348	2,888	291	2,415
Reach 2	East Bench Dam to Mill Race Diversion	348	3,793	166	1,809
Reach 3	Mill Race Diversion to Utah Lake	126	7,623	63	3,812
Hobble Creek Above Kolob Park in Springville					
Reach 1	Mapleton – Springville Lateral Discharge to Kolob Park in Springville	10	56	447	2,503
Hobble Creek Below Kolob Park in Springville					
Reach 1	Kolob Park in Springville to Utah Lake	15	132	598	4,470
Provo River Above Olmsted Diversion Dam					
Reach 1	Deer Creek Dam outlet to North Fork of Provo River	675	15,728	675	15,728
Reach 2	North Fork of Provo River to Olmsted Diversion Dam	506	16,091	506	16,091
Provo River Below Olmsted Diversion Dam					
Reach 1	Olmsted Diversion Dam to Murdock Diversion Dam	545	8,339	663	10,144
Reach 2	Murdock Diversion Dam to Interstate 15	173	5,919	359	12,290
Reach 3	Interstate 15 to Utah Lake	86	714	270	2,241
Total			**65,285**		**75,505**

[1]Standing crop and biomass predictions rounded to nearest pound.

4.4.5.3 Non-game Fish

Non-game fish may experience small losses associated with decreases in slow flow and backwater habitats in the Provo River. However many of the same species would benefit at different life stages from increased availability of moderate and fast water habitats. Furthermore, the lowest reach of the Provo River would have habitat improvements that should result in a large net benefit for non-game populations. In the Spanish Fork River,

reduced summer time flows would have the potential to adversely impact any spawning populations of non-game fish. In Hobble Creek, non-game fish populations would experience significant long-term increases.

4.4.5.4 Macroinvertebrates

Macroinvertebrate populations would be expected to experience habitat changes that have moderate to high potential to benefit populations in the Provo River between Murdock Diversion Dam and Interstate 15. Flow decreases in the Spanish Fork River would be expected to result in low to moderate impacts on macroinvertebrates. There is a moderate to high potential for benefits to macroinvertebrates in Hobble Creek.

4.5 No Action Alternative

There would be no change in habitat, standing crop per acre or total biomass, and macroinvertebrate populations and communities from baseline in the following reaches:

- Spanish Fork River from Diamond Fork to Utah Lake
- Hobble Creek from Mapleton-Springville Lateral discharge to Utah Lake
- Provo River from Deer Creek Reservoir to Olmsted Diversion

The change in habitat, standing crop per acre, total biomass, and macroinvertebrate populations and communities would be the same as under the Bonneville Unit Water Alternative for the following reaches:

- Provo River from Olmsted Diversion to Murdock Diversion
- Provo River from Murdock Diversion to Interstate 15
- Provo River from Interstate 15 to Utah Lake

The No Action Alternative would result in an overall increase of 9,703 pounds of game fish biomass. This increase in game fish biomass would result from flow changes that would occur in the lower Provo River because of summer river flows provided for June sucker spawning and rearing habitat.

Chapter 5
Mitigation and Monitoring

The decreased flows in the Spanish Fork River from Diamond Fork Creek confluence to Utah Lake under the Preferred Alternative and Bonneville Unit Water Alternative would cause decreased fish habitat and decreased fish biomass, resulting in significant impacts. The decreases in fish habitat and biomass would be offset by increases in Hobble Creek and lower Provo River. Additionally, mitigation for these significant impacts would be provided by the improved fish habitat and increased biomass gained for the same suite of aquatic resources in Diamond Fork Creek between Monks Hollow and Three Forks and in Sixth Water Creek, based on the impact analyses performed in the Diamond Fork System FS-FEIS (CUWCD 1999).

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Chapter 6
Unavoidable Adverse Impacts

To supply necessary water to Hobble Creek and the lower Provo River would require a reduction in summer time flows in the Spanish Fork River. Summer time flow reductions would be substantial enough (up to 86 percent) to potentially impact habitat and perhaps populations and communities of non-game fishes. These impacts would be considered unavoidable and adverse.

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Chapter 7
Cumulative Impacts

Net cumulative impacts on aquatic habitats would be positive with increased flows for the Provo River and Hobble Creek from ULS along with implementation of the June Sucker Recovery Implementation Program (JSRIP), and Lower Provo River Diversion Dam Modifications. The Preferred Alternative would provide sufficient flows into the lower Provo River and Hobble Creek to support improved aquatic resources. The JSRIP will provide for management and habitat development actions that will improve conditions for native fishes such as assessing means of controlling nonnative predatory fishes and evaluating potential habitat improvements and/or restoration in lower Hobble Creek. In addition, the Lower Provo River Diversion Dam would improve physical habitat conditions by reducing or eliminating fish passage barriers and restoring a more natural river condition to the lower Provo River. The Provo River Parkway Trail upgrade and proposed Hobble Creek Trail could increase the potential for trout and other fish harvest in these reaches once the Bonneville Unit flows were provided and fish populations became established. These potential cumulative impacts cannot be quantified because the impacts of the trail projects have not yet been analyzed.

The Provo Reservoir Canal Enclosure, Utah Lake Wetland Preserve, Interstate 15 Widening from Point of the Mountain through Utah County, State Route 52 Upgrade from Geneva Road to U.S. Highway 189, Diamond Fork Campground, and Temporary Supplemental Irrigation Water would have no known cumulative impacts with the Preferred Alternative and Bonneville Unit Water Alternative on aquatic resources in the impact area of influence.

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Glossary

Acre-feet. The volume of water that would cover one acre of land to a depth of one foot.

Affected Environment. That part of the environment that changes from a proposed change in the operation or management.

Alkalinity. The capacity of water to neutralize acid is termed alkalinity. Alkalinity represents the presence of carbonates, bicarbonates, hydroxides, and occasionally the borates, silicates, and phosphates in the water.

Attribute. In the Binns HQI model, a characteristic of the aquatic habitat (e.g., late summer stream flow, eroding channel banks) that is given a numerical rating based on a field evaluation and then used in the computation of an HQI score.

Average annual flow. Average annual flow (the sum of all monthly average flows for a 12-month period) can be calculated for one year, or as an average of all the years in the period of record.

Bankfull Depth. The water surface depth of a stream flowing at channel capacity. Often the maximum stream depth corresponding to the annual peak flows.

Bankfull Width. The water surface width of a stream flowing at channel capacity. Often the maximum stream width corresponding to the annual peak flows.

Base Flows. Typical flow during the low flow months of the year. It is usually comprised of subsurface and groundwater inflow to a stream channel during periods of minimal surface water inflow.

Baseline. The set of starting conditions from which changes and impacts are quantified.

Benthic Macroinvertebrates. A group of small-sized aquatic insects, crustaceans, and worms typically found in the substrate (mud, sand, silt, gravel, cobble, and boulders) of a stream or water body.

Benthos. Organisms that live on or in the bottom of bodies of water.

Biochemical Oxygen Demand. A measurement of dissolved oxygen consumption in water as a result of organic material decomposition.

Biomass. A measurement of the weight of living organisms per unit area.

Biota. The plant and animal life of a region or ecosystem, as in a stream or other body of water.

Coliforms. Several types of bacteria that are somewhat harmless in themselves, but are used as pollution indicators. Total coliforms include all types. Fecal coliforms are the types that grow on a fecal matter.

Complexity. The diversity and variability in stream habitat. The presence of different kinds of structure in a stream (e.g., root wads, logs, cover and depth) that contribute towards increased habitat diversity.

Compromise (or Compromise Elevation). The elevation of Utah Lake at which the outlet gates must be fully opened to avoid inundation of lands around the Lake. Established as 4,489.045 feet above mean sea level.

Cubic Feet Per Second. A measurement of discharge: volume/time, in English units (cfs).

Discharge. The amount of water taken out of a hydrologic system or feature.

Dissolved Oxygen. The concentration of oxygen in a volume of water, normally expressed as milligrams of oxygen per liter of water.

Electroshocking. A sampling technique for collecting fish in streams using electric current to temporarily stun the fish and allow its capture.

Gaging Station. A permanent facility on a stream that measures the depth (also called stage) of the water in the river. Depths are then converted to flows using a stage-discharge equation that was developed for that particular site.

Geomorphic. Relating to the form of the earth or its solid surface features.

Gradient. The slope of a stream bed.

Habitat. The place or type of site where a plant or animal naturally or normally lives and grows.

Irrigation Season. The period of April 15 to October 15 when water is usually released from high country reservoirs for the purpose of irrigating croplands in the valley.

Riparian. Refers to features of the environment (e.g., vegetation types) living in, or located on, the bank of a natural watercourse such as a stream or river.

Reaches. A specified section of river or a pipeline.

Salinity. The concentration of dissolved "salts" in the water, measured by total dissolved solids (TDS).

Sedimentation. The introduction of sediment material from an erosional source into a water body, stream or lake.

Siltation. The process of introducing fine particle materials to a stream and the subsequent deposition of these fine particles and covering larger substrate particles. Often quality gravel substrate that is critical for trout habitat.

Standing Crop. The minimum biomass of fish typically found in a given stream. The common assumption is that this minimum biomass occurs in early fall after angler harvest and low summer flows have minimized the fish population. The stream or lake bottom materials (silt, sand, rock, wood) within a wetted area.

Substrate. Those sediment particles that make up the stream or lake bottom. The classification or categorization of sediment particles present within a stream, lake or body of water includes; silt, sand, gravel, cobble, and boulders.

Taxa. Refers to a specific type, or group, of organisms.

Total Dissolved Solids. The mass of dissolved ionic compounds in water per a volume of water, usually expressed in mg/L or equivalently parts per million. Often used as a measurement of salinity.

Transbasin Diversion. A water diversion from one hydrologic drainage basin to another.

Transects. A cross-section of a stream channel that is oriented perpendicular to the primary direction of flow.

Tributary. A stream that flows into a large stream, river, or other body of water.

Trout Production. A measurement of the amount of trout biomass produced per unit area of a stream or water body. Production is also usually stated in terms of an element of time (e.g., pounds of trout per acre per year).

Water Diversion. A place where water is diverted from a river, pipeline, or reservoir. Also defined as the quantity of water diverted.

Wetted Channel. That portion of the streambed that conveys water.

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Abbreviations and Acronyms

Abbreviation/ Acronym	Meaning/Description
ac-ft	acre-foot/feet
Binns	Binns Method Habitat Quality Index (HQI)
BOD	biochemical oxygen demand
cfs	cubic feet per second
Cm	Centimeter
CUP	Central Utah Project
CUPCA	Central Utah Project Completion Act
CUWCD	Central Utah Water Conservancy District
CVWRP	Central Valley Water Reclamation Project
°	Degree
DEIS	Draft Environmental Impact Statement
EIS	Environmental Impact Statement
EPA	Environmental Protection Agency
F	Fahrenheit
fps	feet per second
HQI	Habitat Quality Index (Binns)
IABAT	Interagency Aquatic Biological Assessment Team
IFIM	Instream Incremental Flow Methodology
mg/L	milligrams per liter
N	Nitrogen
NEPA	National Environmental Protection Agency
pH	Measure of acidity/alkalinity
PHABSIM	Physical Habitat Simulation
ppm	parts per million
PRRP	Provo River Restoration Project
SFN System	Spanish Fork Canyon-Nephi Irrigation System
TDS	total dissolved solids
UDNR	Utah Department of Natural Resources
Reclamation	U.S. Bureau of Reclamation
FWS	U.S. Fish and Wildlife Services
USGS	U.S. Geological Survey
WCWEP	Wasatch County Water Efficiency Project

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Utah Lake Drainage Basin Water Delivery System

Draft Aquatic Resources

Technical Report

Appendix A
Technical Data

Section A
Hobble Creek Geomorphology Field Survey

INTRODUCTION

A geomorphic reconnaissance was conducted in Hobble Creek to assess how increases of flows from the Mapleton Lateral discharge would affect channel stability. Proposed additional flows from the Mapleton Lateral discharge is estimated at 6,000 acre-feet per year during the period from April to June. This equates to approximately 33 cubic feet per second (cfs) for a three-month duration, 50 cfs for a two-month duration, or about 100 cfs for a one-month duration. Results from the study would be used with analyses from other resource investigations to evaluate the impacts of alternatives on fish and other aquatic communities.

For this effort, the Hobble Creek study area extended from the Mapleton Lateral discharge to Provo Bay. The Mapleton Lateral enters Hobble Creek about 1.2 miles downstream of a flood control Reservoir, which, apart from its intended design, also functions to intercept bed material routed from upstream sources.

APPROACH

The approach used to assess effects of increased flows on channel stability was to relate channel geomorphic conditions with an estimated critical shear stress that would be required to initiate channel bed incision.

Information was collected to provide information on current channel conditions and how these values may change over time under different flow scenarios. Existing channel data were supplemented with on-site observations and measurements to derive stage-discharge relations, calculate bed shear stress, and obtain reasonable approximations of flows that would be required to initiate bed material transport for a range of bed material sizes. In the absence of bed material recruitment sources, flows calculated as sufficient to initiate and maintain bed material transport would effectively cause channel instability through vertical and lateral incision. Such flows, then, would be used as an approximation of the upper limit of artificially induced flows into the reach that would not adversely affect channel stability.

METHODS

Pre-field Work

Prior to conducting field reconnaissance, recent cross section data were obtained from surveys conducted by BioWest and MWH. The BioWest surveys were made in representative reaches downstream of the town of Springville, and the MWH surveys were made from central Springville to the Mapleton Lateral discharge area. Cross section data for three representative reaches were plotted, and a determination was made of field data that would need to be collected for hydraulic models and to derive shear stress estimates.

Field Work

Field reconnaissance efforts focused on assessing channel geomorphic conditions in the three representative sub-reaches of the study reach. The upper site was in the siphon reach, about 1,000 feet downstream of the Mapleton Lateral (MWH cross section No. 27). An intermediate site was

about 930 feet upstream of the S. 1150 East Street, downstream of town (BioWest cross section A). A downstream site was about 390 feet downstream of the Frontage Road (BioWest cross section 2A).

At each cross section pebble counts were made of 100 surface layer particles following the methodology of Wolman (1954). The length of the median diameter of each particle was measured and assigned to a size class. Water surface slope was measured through each section using stadia rod and hand level. Evidence for bankfull discharge was identified at each cross section. A measure was made of bankfull width and of bankfull elevation relative to channel thalweg. Estimates of channel roughness at the bankfull stage were made using the formula proposed by Cowan (1956) supplemented by tables of values from Aldridge and Garrett (1973).

In addition to data collected at each of three cross section locations, representative sections of channel were surveyed to document evidence for stability and instability. The siphon reach was surveyed from the Mapleton Lateral downstream about 1,000 feet to the cross section location used in this geomorphic assessment. The reach having the lower most cross section was surveyed from the Frontage Road west of the railroad switchyard downstream about 3,600 feet to the I-15 crossing. Evidence of channel bed stability included vegetated gravel bars, angular large bed particles, densely packed large bed particles, bed pavement of large particles, and moss growth on bed sediment. Channel bank failure types were noted, along with failure dimension, soils, and trigger mechanisms.

Field Data Analysis

Pebble count data from the three cross section sites were analyzed, and particle size distributions calculated.

The WinXSPRO program was used to perform hydraulic and bedload transport modeling at the cross section in the siphon reach. The purpose of the modeling was to determine the flows that would initiate transport of bed material for various sized particles. Hydraulic information was obtained from existing cross section data and measurements taken during the field reconnaissance. Measured data included the particle size distributions, measured water surface slope, and estimates of channel roughness. Hydraulic modeling was performed using the Manning's resistance equation, with verification of the estimated roughness coefficient compared to roughness derived using the equation of Jarrett (1984). A bedload rating curve was calculated in the WinXSPRO program using the Parker (1990) formula.

RESULTS

Channel Morphology

Geomorphic Setting

Hobble Creek emerges from a narrow valley below a flood control reservoir onto an alluvial apron of the East Bench, and drops into the Utah Lake basin. Soils are generally composed of alluvial fill, and at the time of survey groundwater contribution to the channel was appreciable. Through much of its six-mile journey from the Mapleton Lateral to Provo Bay of Utah Lake the channel has been straightened and artificially confined by a constructed levee. The levee material appears to have been constructed from river material, likely dredged from the natural Hobble Creek channel. The material is largely composed of gravel- and cobble-sized rounded rock, but includes boulder-sized

material in places. Estimated bankfull discharge in the upper portion of the project reach is 140 to 150 cfs.

Channel Form

Overall channel gradient is about 0.008, exceeding 0.01 in the upper reach and less than 0.002 in the lower reach. The lower portion of the project reach (downstream of the Frontage Road) appears to be influenced by backwater during periods when lake levels or flows are high. Due to artificial straightening, overall channel sinuosity (ratio length of channel to valley length) is generally less than 1.2. In-channel habitat is dominated by riffle and glide in the upper portion of the project reach, and by glide and infrequent riffle in the lower portion. Pool habitat was observed as infrequent everywhere, being controlled mostly by instream obstructions such as woody debris, or by large boulder below culvert outfalls or road crossings. The habitat variability is primarily limited by the straight and confined nature of the reach. Floodplain area is also very limited by the levees; entrenchment ratio (width of floodprone area as defined as water surface width at an elevation twice the maximum bankfull depth, divided by bankfull width) is generally less than 1.4. In natural channels, the floodprone area width relates approximately to the 50-year flood recurrence interval.

Channel Stability

Siphon Reach

A 1,000-foot sample reach was surveyed in the siphon reach from the Mapleton Lateral discharge to the cross section to document channel bed and bank stability. Two areas of direct bank instability were noted. The first was about 490 feet downstream of the siphon. Unconsolidated fill had been placed on hydraulic right bank in a pool to riffle transition area of the channel. Dimensions of the fill were estimated at 75 feet length along the channel, about 10 feet from water surface to top of bank, and having about a 60° slope (Photo No. 1, Attachment B). This bank is subject to surface erosion from sheet wash, and undercutting of the bank toe by high velocity scour.

A second area of bank instability was noted about 908 feet downstream of the siphon on hydraulic left bank in a riffle section (Photo No. 2A and 2B, Attachment B). This failure occurred in the levee (constructed of alluvial soils) and measured approximately 25 feet in length, was 8 feet high, and 2 to 3 feet deep. The likely trigger for this failure was flow stress.

Assuming that the bank fill observed at station 0+490 was placed to fill an area of instability, then about 10% by length of the channel banks in the 1,000-foot sample reach are unstable. The channel bed was determined to be stable, in that no indicators of vertical scour were observed. Indicators would have included undercut banks below water line and exposed roots.

The Reach Through Springville

Based on reconnaissance of the channel from observations at bridge crossings, channel banks in the reach of Hobble Creek through Springville appears to be heavily armored with boulder and concrete, and no failures were observed. An estimate of vertical incision could not be made due to water depth, but no indications of vertical instability were observed.

The Middle Reach Upstream of the S. 1150 East Street

Only minor bank erosion was observed along the approximately 1200 feet of channel walked upstream of the S. 1150 East Street. Small areas of instability were associated with livestock crossings. Otherwise, the levees on both sides of the channel were moderately well vegetated and no signs of bank failure attributable to flow stress were observed.

No indications of vertical instability were observed; rather, indicators of vertical stability were observed. These include angular and densely packed large gravel- and cobble-sized substrate with moss attached to the substrate.

The Lower Reach Downstream of the Frontage Road to I-15 Crossing

Channel banks in the upper half of this sample reach are composed of boulder and silt. Bank instability was estimated at less than 10% by length. Principal indicators of instability included the presence of sloughed, grass-vegetated bank material in the channel. One the other hand, lateral bars in the channel were vegetated, indicating relatively good stability. Sloughing may be attributable to pore water release following saturation from backwater.

Channel banks in the lower half of this sample reach are composed of gravel and silt. Bank instability was estimated at about 15%. As with the upper half of the reach, instability may be attributable to pore water release following saturation from backwater. In addition, vegetative cover on these banks was much more sparse, composed mostly of sparse grass and small brush.

Sediment

Coarse sediment recruitment into the project reach is limited, primarily due to trapping efficiency of the flood control reservoir upstream of the reach. Some sources of sediment recruitment were noted downstream of the reservoir and through the siphon reach (to the North Main Street crossing). These sources of sediment recruitment are related to streamside landowner management (see photos No. 1 and No. 3, Attachment B), and to bank scour (photo No. 2, Attachment B). In the absence of adequate recruitment of sediment, available mobile-sized bed material is likely winnowed from the bed leaving a dominantly coarse fraction of lag material. Very little gravel recruitment was noted in the downstream reaches.

The distribution of particle sizes measured at each of the three cross sections is displayed in Attachment A. Median (D_{50}) sizes of surface substrate decreased from about 51 mm upstream, to 23 mm at the middle reach cross section, to less than 1mm at the lower cross section (Attachment A). These size distributions generally confirm the qualitative assessment of substrate sizes observed during the survey; the siphon reach appeared to be cobble and gravel dominated, the middle reach appeared to be gravel and cobble dominated, and the lower reach appeared to be sand dominated with small gravel sub-dominant.

Sediment Transport Modeling

Cross section data from MWH section No. 27 in the siphon reach was analyzed, and supplemented with data collected during the field reconnaissance to model sediment transport. In particular, the modeling was conducted to answer the key question: What predicted flows in Hobble Creek would

mobilize bed material (assuming that incipient motion would be required to induce vertical channel incision)?

Channel cross section data and sediment transport modeling was performed using the WinXSPRO program. Details of the modeling results are provided in Attachment C. The cross section data was analyzed using the Manning's resistance equation to derive flow velocity relative to stage in half-foot increments, and then compute a stage – discharge relationship and calculate the boundary shear stress. As a check on estimates of Manning's roughness used in the model, a roughness coefficient was derived using Jarrett's (1984) equation for roughness, which relates roughness to other hydraulic parameters. Manning's roughness coefficient was estimated in the field for the bankfull stage at 0.057; roughness derived from Jarrett's (1984) equation was calculated at 0.062 for the bankfull stage, providing good agreement.

Bedload transport was modeled using the Parker (1990) function. This function was chosen because it is one of few functions using particle sizes of the surface layer of bed material. Results relate bedload in pounds per second as a function of discharge. Modeling at the riffle transect indicates that transport initiates at about 95 cfs, and increases rapidly between flows of about 145 and 210 cfs (Attachment C).

Preliminary data presented by BioWest (May 2003) related historic hydrographs for Hobble Creek. The median flows in early April were about 40 cfs, rising to about 160 cfs in early May, and falling back to below 40 cfs by early July. During the period from mid April to late May flows exceed 100 cfs.

DISCUSSION

Geomorphic reconnaissance of the Hobble Creek project reach indicates that the channel is relatively stable through much of its length, particularly in its middle reaches. The upper reach is likely to be more susceptible than the lower reaches to instability caused by increases of flows over the historic flows, primarily due to its much steeper slope (the depth – slope product heavily influences critical shear stress, which influences initiation of bed material transport for given grain sizes).

The addition of sustained flows meeting or exceeding the historic bankfull discharge should be approached with caution. The bankfull discharge is generally accepted as the discharge that maintains channel form. Sustained flows that exceed the bankfull flow may initiate channel instability in the upper reach, depending on the difference in magnitude. Sustained flows exceeding the historic bankfull flow would likely winnow fine material from the surface layer of substrate, leaving a coarse lag fraction that would be detrimental to some aquatic organisms.

REFERENCES

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Cowan, W.L. 1956. Estimating hydraulic roughness coefficients. Agricultural Engineering, Vol. 37, No. 7, pp. 473-475.

Jarrett, Robert D. 1984. Hydraulics of high-gradient streams. Journal of Hydraulic Engineering, Am. Soc. Civil Engr., Vol. 110, No. 11, pp. 1519-1539.

Parker, Gary. 1990. Surface-based bedload transport relation for gravel rivers. Journal of Hydraulic Research, IAHR, Vol. 28, No. 4.

Wolman, M. Gordon. 1954. A method of sampling coarse river-bed material. Transactions of the American Geophysical Union, Vol. 35, No. 6, pp. 951-956.

Attachment A—Pebble Counts for MWH Hobble Creek Cross-Sections

Pebble Count Worksheet

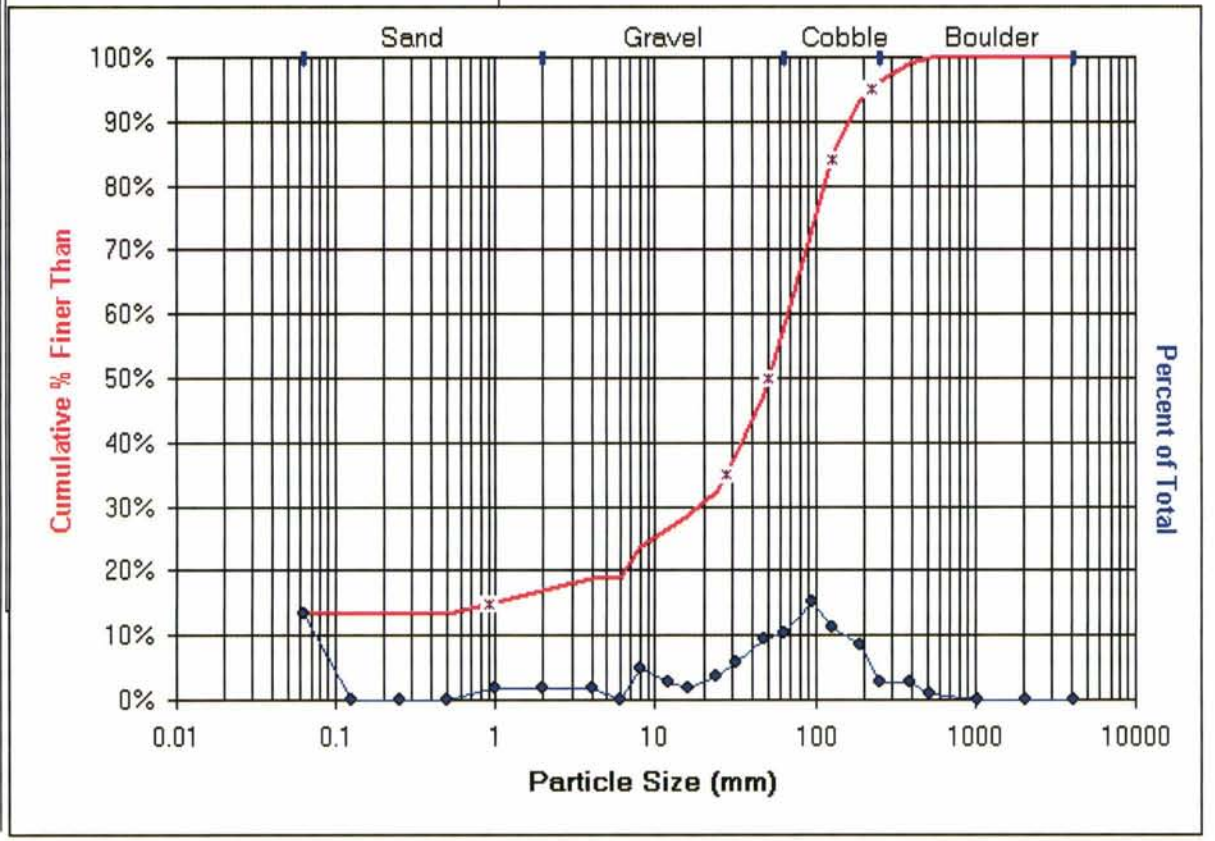
COMMENTS: Cross Section 1, about 1,000 feet downstream of siphon

Particle Size (mm)	% finer than	Total Count
<0.062	13%	14
0.062 - 0.125	13%	0
0.125 - 0.25	13%	0
0.25 - 0.5	13%	0
0.5 - 1.0	15%	2
1 - 2	17%	2

STREAM NAME: Hobble Ck XS-1
USGS # :
FWS # :

DATE: 5/19/2003
CREW: cec, tlb

Particle Size Distribution (mm)	D15	D35	D84	D95
	0.9	27.4	125.6	227.1



Pebble Count Worksheet

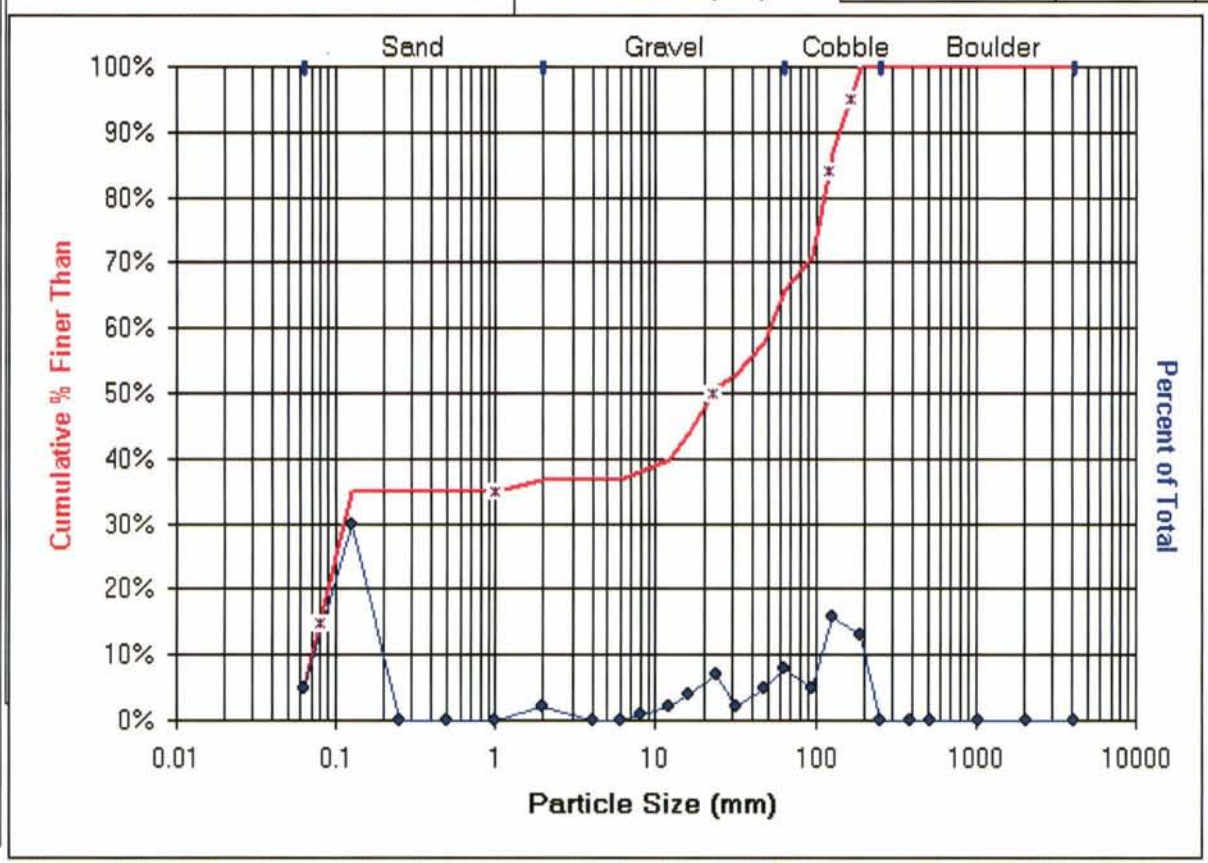
COMMENTS: Cross Section A, upstream from 1150 East

Particle Size (mm)	% finer than	Total Count
<0.062	5%	5
0.062 - 0.125	35%	30
0.125 - 0.25	35%	0
0.25 - 0.5	35%	0
0.5 - 1.0	35%	0
1 - 2	37%	2

STREAM NAME: Hobble Ck XS-A
USGS # :
FWS # :

DATE: 5/20/2003
CREW: cec, tlb

Particle Size Distribution (mm)	**D15**	**D35**	**D50**	**D84**	**D95**
	0.1	**1.0**	**22.6**	**121.3**	**164.3**



Pebble Count Worksheet

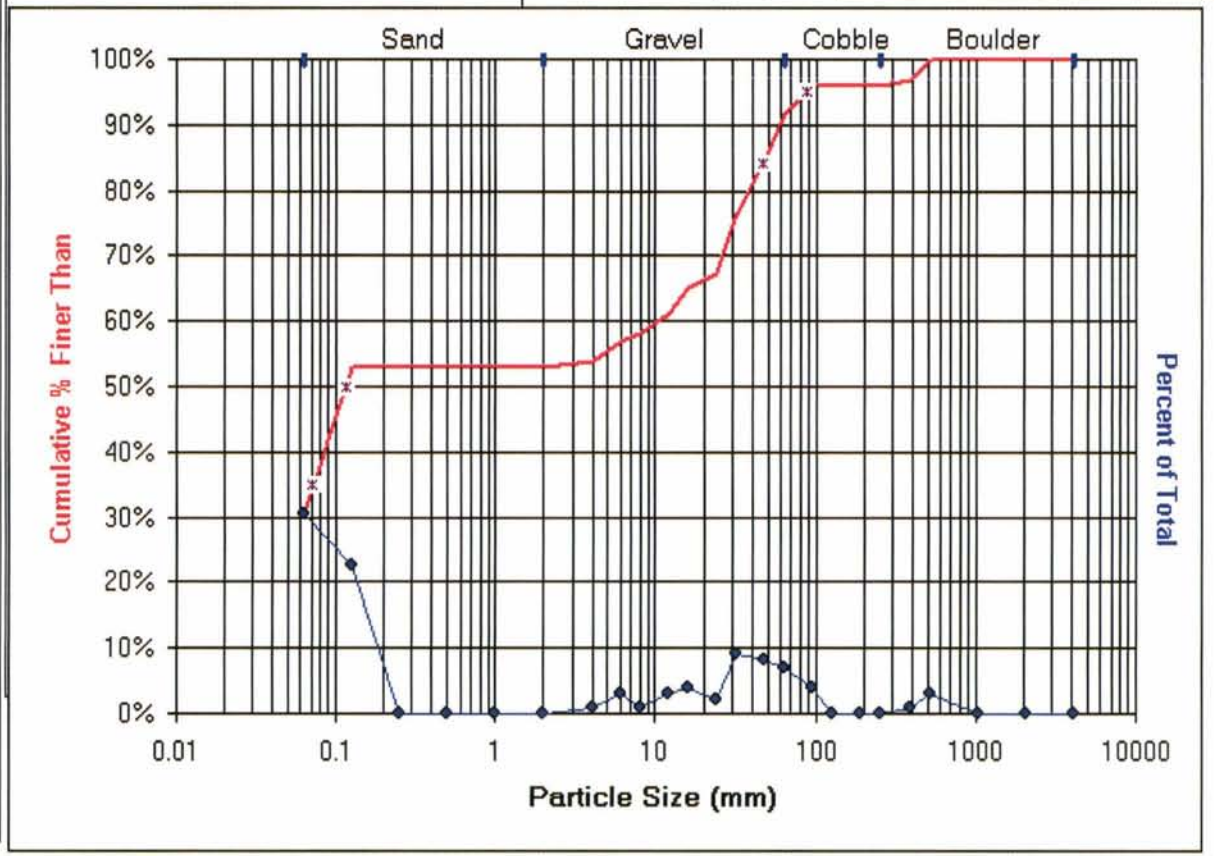
COMMENTS: Cross Section 2A, located downstream from crossing west of RR

Particle Size (mm)	% finer than	Total Count
<0.062	31%	30
0.062 - 0.125	53%	22
0.125 - 0.25	53%	0
0.25 - 0.5	53%	0
0.5 - 1.0	53%	0
1 - 2	53%	0

STREAM NAME: Hobble Ck XS-2A
USGS # :
FWS # :

DATE: 5/21/2003
CREW: cec, tlb

Particle Size Distribution (mm)	D15	D35	D50	D84	D95
		0.1	0.1	46.4	87.6



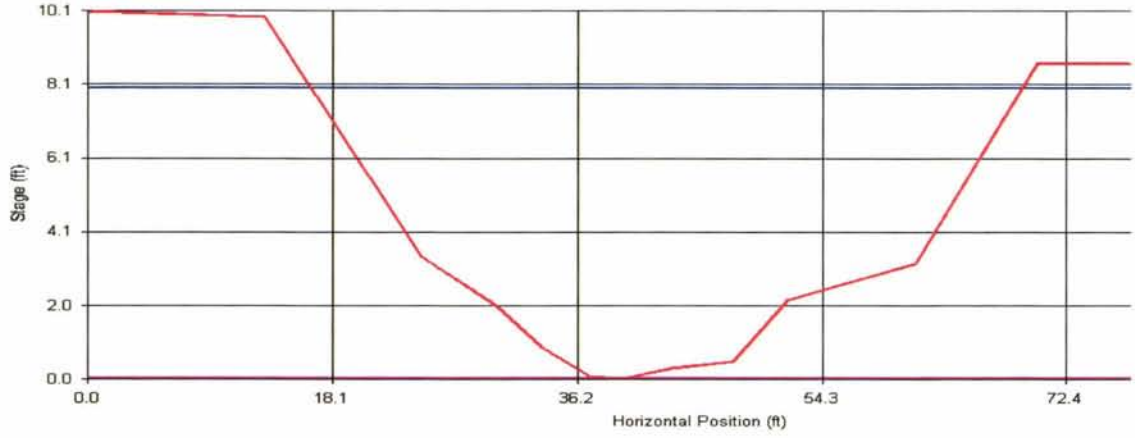
Attachment B—Hobble Creek Photos

Photo No. 1. Raw fill on hydraulic right bank about 490 feet downstream of the Mapleton Lateral discharge.

Photo No. 2A (top) and 2B (bottom). Detail of bank failure on hydraulic left bank about 908 feet downstream of the Mapleton Lateral discharge. Dimensions of the failure are approximately 25' length, 8' height, and 2 ½ ' deep.

Photo 3. One of only a few sources of gravel recruitment into the upper Hobble Creek project reach. This site is upstream of the reach and downstream of the reservoir at the Oak Leaf Lane crossing off 3400 East. (Another source of gravel recruitment is shown in Photo No. 1.).

HOBBLE CREEK CROSS SECTION AND DATA (XS-1 ABOUT 1,000 FEET DOWNSTREAM OF SIPHON)

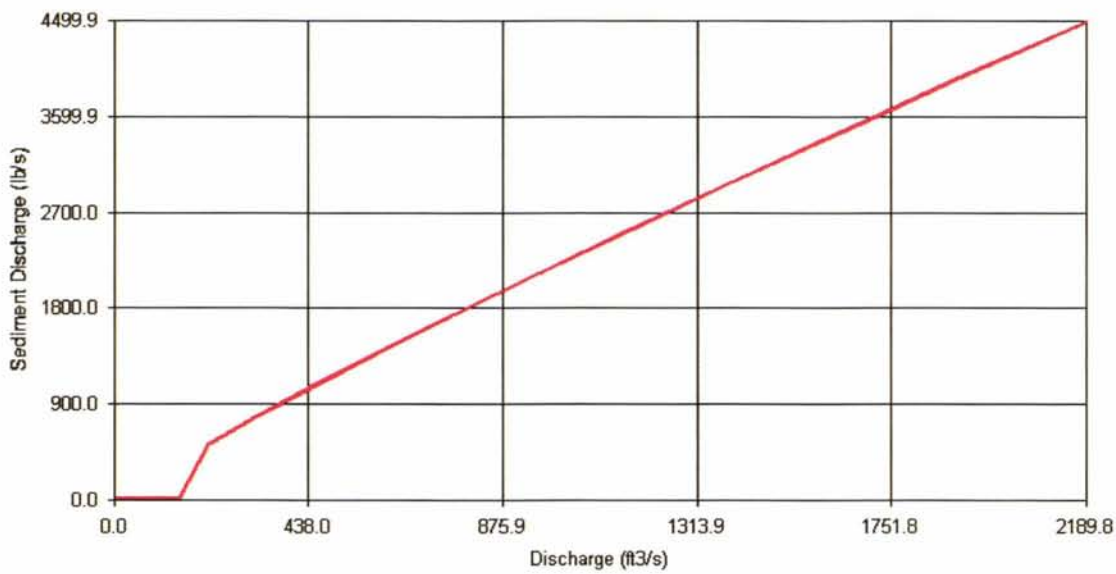



```
*******************************WinXSPRO*********************************
xslqman.out
Input File:              C:\WXSPRO20\XS1QMAN.DAT
Run Date:                08/02/03
Analysis Procedure:      Hydraulics
Cross Section Number:    1
Survey Date:             05/19/03
Relates to XS 27, ~ 1,000 ft d.s. of siphon

Subsections/Dividing stations
A

Resistance Method:       Manning's n
          SECTION          A
     Low Stage n          0.057
     High Stage n         0.057
```

STAGE (ft)	#SEC	AREA (sq ft)	PERIM (ft)	WIDTH (ft)	R (ft)	DHYD (ft)	SLOPE (ft/ft)	n	VAVG (ft/s)	Q (cfs)	SHEAR (psf)
0.50	T	3.33	12.57	12.50	0.27	0.27	0.011	0.057	1.13	3.77	0.18
1.00	T	10.42	15.97	15.74	0.65	0.66	0.011	0.057	2.06	21.49	0.45
1.50	T	18.96	18.84	18.43	1.01	1.03	0.011	0.057	2.75	52.21	0.69
2.00	T	28.85	21.71	21.12	1.33	1.37	0.011	0.057	3.31	95.59	0.91
2.50	T	40.62	27.43	26.72	1.48	1.52	0.011	0.057	3.56	144.66	1.02
3.00	T	55.66	34.25	33.46	1.63	1.66	0.011	0.057	3.79	210.93	1.12
3.50	T	73.63	38.29	37.32	1.92	1.97	0.011	0.057	4.24	312.18	1.32
4.00	T	92.71	40.26	39.01	2.30	2.38	0.011	0.057	4.78	443.28	1.58
4.50	T	112.64	42.23	40.71	2.67	2.77	0.011	0.057	5.27	594.00	1.83
5.00	T	133.42	44.20	42.41	3.02	3.15	0.011	0.057	5.73	764.05	2.07
5.50	T	155.05	46.17	44.10	3.36	3.52	0.011	0.057	6.15	953.30	2.31
6.00	T	177.53	48.14	45.80	3.69	3.88	0.011	0.057	6.54	1161.76	2.53
6.50	T	200.85	50.11	47.49	4.01	4.23	0.011	0.057	6.92	1389.48	2.75
7.00	T	225.02	52.08	49.19	4.32	4.57	0.011	0.057	7.27	1636.61	2.97
7.50	T	250.04	54.05	50.89	4.63	4.91	0.011	0.057	7.61	1903.31	3.18
8.00	T	275.91	56.02	52.58	4.93	5.25	0.011	0.057	7.94	2189.80	3.38

STAGE	ALPHA	FROUDE
0.50	1.00	0.39
1.00	1.00	0.45
1.50	1.00	0.48
2.00	1.00	0.50
2.50	1.00	0.51
3.00	1.00	0.52
3.50	1.00	0.53
4.00	1.00	0.55
4.50	1.00	0.56
5.00	1.00	0.57
5.50	1.00	0.58
6.00	1.00	0.59
6.50	1.00	0.59
7.00	1.00	0.60
7.50	1.00	0.61
8.00	1.00	0.61

BEDLOAD RATING CURVE (PARKER) AT XS-1 FOR D_{50} = 51MM



BEDLOAD RATING CURVE DATA (PARKER) AT XS-1 FOR D_{50} = 51MM

Bedload Computation
xslqman.p90
Input File: XS1QMAN.OUT
Run Date: 08/02/03
Analysis Procedure: xslqman.p90 Parker 1990

Stage (ft)	#Sec	Width (ft)	Shear (psf)	Q (cfs)	Bedload (lb/s)
0.50	T	12.50	0.18	3.77	0.00
1.00	T	15.74	0.45	21.49	0.00
1.50	T	18.43	0.69	52.21	0.05
2.00	T	21.12	0.91	95.59	2.52
2.50	T	26.72	1.02	144.66	9.38
3.00	T	33.46	1.12	210.93	516.95
3.50	T	37.32	1.32	312.18	761.85
4.00	T	39.01	1.58	443.28	1057.07
4.50	T	40.71	1.83	594.00	1381.72
5.00	T	42.41	2.07	764.05	1736.56
5.50	T	44.10	2.31	953.30	2121.65
6.00	T	45.80	2.53	1161.76	2536.90
6.50	T	47.49	2.75	1389.48	2982.31
7.00	T	49.19	2.97	1636.61	3457.89
7.50	T	50.89	3.18	1903.31	3963.71
8.00	T	52.58	3.38	2189.80	4499.92

Stage ft	Q ft3/Sec	Bedload lb/Sec
0.50	3.77	0.00
1.00	21.49	0.00
1.50	52.21	0.05
2.00	95.59	2.52
2.50	144.66	9.38
3.00	210.93	516.95
3.50	312.18	761.85
4.00	443.28	1057.07
4.50	594.00	1381.72
5.00	764.05	1736.56
5.50	953.30	2121.65
6.00	1161.76	2536.90
6.50	1389.48	2982.31
7.00	1636.61	3457.89
7.50	1903.31	3963.71
8.00	2189.80	4499.92

Section B
Hobble Creek HEC-RAS Modeling Technical Memo

MWH
MONTGOMERY WATSON HARZA

MEMORANDUM

To: ULS EIS Team

From: Will Elledge

Date: August 20, 2003

Subject: Hobble Creek HEC-RAS Model Results

BACKGROUND

This HEC-RAS analysis of Hobble Creek was done as part of the development of the EIS for the Utah Lake Drainage Basin Water Delivery System (ULS). The intent of this analysis is to show any potential impacts on wetted channel top width and maximum channel depth in Hobble Creek as a result of different flows. The baseline flow and alternative flows are described in "ULS Surface Water Hydrology Results: Simulated Spanish Fork Streamflows by Ownership" dated August 2003. The analysis further describes any impacts on Hobble Creek water levels resulting from different Utah Lake water surface elevations.

1. SUMMARY

Hobble Creek has several inline structures including irrigation diversion structures, culverts, bridges, and contractions. Diversion structures have a tremendous impact on the water surface in Hobble Creek. These impacts are described in section 5.1 because operations of the diverions are likely to change with higher flows and these operational changes cannot be quantified.

The model was used to simulate *steady flow conditions*. These results are summarized in section 6.2 using cross sectional plots showing the water level for each of the flows described above. A key map is provided to locate each cross section.

Additionally, the model was used to simulate *backwater effects* occurring in Hobble Creek due to different Utah Lake water surface elevations. These results are summarized in section 7.2 with cross section plots showing the flow conditions with and without the backwater effect. These plots are repeated for three different Utah Lake water surface elevations.

2. DATA SOURCES

Cross sectional data came from two different surveys. Robinson, Biehn, and Biehn (RBB) completed a survey on March 26, 2003 of the upper portion of Hobble Creek (cross sections 250.75 and higher). The remaining cross section data was gathered from a BioWest survey dated 12-5-02 that included three typical cross sections (52.93, 97.55, and 142.75) and channel flowline slope (cross sections 44.75-164.42).

Data regarding diversion structures (weirs/dam) and bridges/culverts were gathered using field visits and photographs. Relative invert elevations of diversion pipes and ditches are unknown.

3. KNOWN DATA DEFICIENCIES

Just upstream of cross section 104.12 there is an area where Hobble Creek widens and contains a substantial island. There is no surveyed geometric data for this area so no data could be reported on water surface elevations in this region.

The results summarized in the cross sectional plots only contain water surfaces assuming the diversion structures operate at one known height. This height is based on field observations and is correct so long as the diversions operate as such. The diversions however are likely to be operated at different heights on different days throughout the irrigation season.

There is an additional dam near 252.00-254.00 that is essentially a large pile a stick, branches, and lumber. It was likely placed by local residents. This dam has a backwater effect of about 2 feet in height and less than 100 feet upstream. The dam was not modeled because it has relatively little impact on water surface and it is difficult to locate without additional survey data.

4. SUMMARY OF FLOWS

The following flows have been summarized from the "ULS Surface Water Hydrology Results: Simulated Spanish Fork Streamflows by Ownership" dated August 2003 and approved by the Department of the Interior (DOI) on Wednesday, August 13, 2003.

Hobble Creek	Average Monthly Flows (cfs)												Average
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	
Baseline	7	25	23	22	26	38	60	109	38	4	1	1	30
Alternative 1	21	36	33	32	35	47	100	145	65	16	13	11	46
Alternative 2	21	36	33	32	35	47	100	145	65	16	13	11	46
Alternative 3	38	55	53	52	56	68	102	147	72	35	33	32	62
Alternative 4 (No Action)	7	25	23	22	26	38	60	109	38	4	1	1	30

5. EFFECTS OF STRUCTURES

5.1 Irrigation Diversion Structures

The water surface elevation is affected not only by the ULS alternative flows, but also by the operations of the diversion structures. It is likely that different flows would cause adjustments in the operations of the diversions, thereby changing the water surface elevations in a manner counter to changes in flow. This means that the cross section plots for cross sections affected by diversion backwater will also depend on the operations of the diversion structures. The cross sections impacted by diversion backwater are listed in sections 5.1.1-5.16.

Each diversion is non-permanent; they create backwater by adding a number of 2x10's with a tarp between two concrete structures to create the backwater elevation necessary for irrigation. Each diversion could have backwater depths that vary on a daily basis. The various heights and length of time at a given height are unknown, but it is generally assumed that the diversions would only create backwater during the irrigation season (April to October).

5.1.1 Diversion at 55.53

The diversion structure at 55.53 has a maximum possible height of about 6 feet. It was found to be in place during each site visit, but operated at different levels on different days. The backwater effect can reach as far as the 2800 South Diversion and even 100-500 feet further upstream if the 2800 South Diversion is not in place. This backwater affects the following cross sections: 56.06, 61.53, and 70.71.

5.1.2 2800 South Diversion at 72.73

The 2800 South diversion structure at 72.73 has a maximum possible height of about 3 to 4 feet. It was found to be in place only during certain field visits. The backwater effect can reach 500 to 1700 feet upstream depending on the flows. This backwater affects the following cross sections: 76.22, 79.64, 81.67, 83.95, 85.65, 87.26, and 88.45.

5.1.3 Packard Dam at 99.92

Packard Dam (at 99.92) has a maximum possible height of about 6 to 7 feet. It was found to operate at one level during all site visits. The backwater effect can reach at least 800 feet and as much as 1400 feet. This backwater affect cross sections 101.40 and 104.12. The backwater continues through a series of bridges including the 750 East bridge at the downstream end and the 800 East bridge at the upstream end. An old railroad bridge located at 103.43 is partially submerged at flows over about 100 cfs because of the backwater effect caused by Packard Dam. The backwater further affects a large divided flow area (an island just upstream of the 800 East bridge) that can not be modeled because it was not surveyed.

5.1.4 Diversion at 247.75

The diversion structure at 247.75 has a maximum possible height of about 4 feet. It is just upstream of the Swenson St. Bridge and only operates on certain days. The backwater effect can reach near 500 feet. This backwater does not affect any reported cross sections.

5.1.5 Diversion at 323.60

No conclusions could be drawn about when backwater was created due to the operation of the diversion structure at 323.60. It has a maximum possible height of about 4-5 feet. The backwater effect can reach 450-550 feet. This backwater affects cross sections 323.75 and 328.75.

5.1.6 Diversion at 355.75

No conclusions could be drawn about when backwater was created due to the diversion structure at 355.75. It has a maximum possible height of about 3-5 feet. The upstream limit of the backwater effect is a 2-foot tall cobble dam located about 150 feet upstream of the diversion. This dam is about 20-30 feet upstream of the Mapleton Lateral. This diversion structure does not affect any reported cross sections.

5.2 Bridges and Culverts

There are several bridges and culverts on Hobble Creek. These structures cause localized backwater that is only slightly amplified by increases in flow. Even at the highest flows backwater is restricted to a few inches in height and less than 100 feet upstream. Most of the bridges have a decrease in water surface of a few inches inside the bridge. Changes in flow do not affect this decrease in water surface.

The bridge at 103.43 is submerged at flows greater than about 100 cfs due to backwater caused by Packard Dam (99.92).

6. STEADY FLOW ANALYSIS

6.1 METHODS

6.1.1 Geometry Data

The cross-sections were compiled in AutoCAD and imported into HEC-RAS. The Manning's coefficient for roughness was estimated to be 0.035 for most of the main channel. Extreme Manning's values ranged from 0.013-0.075. Main channel bank stations were estimated to relate to channel geometry and variations in Manning's number.

Inline structures on Hobble Creek typically have a tremendous impact on the water levels. The diversion structures were modeled as weirs even though water does not flow over the diversion but rather through holes in the tarps and wood. Crest elevations were slightly adjusted when necessary to mimic upstream depths measured during field observations.

6.1.2 Flow Data

The water levels were analyzed for several different flows that encompass the range of flows in Hobble Creek. A mixed flow condition was modeled using normal depth as the upstream and the downstream boundary condition.

6.1.3 Model Calibration

Calibration of this model is qualitative, not quantitative. The survey data from Bio-West included the water level and a flow measurwment as well as a calibrated Mannings number. Velocities and Froude numbers were checked in the model. These data were used to confirm approximate accuracy of the geometric data.

6.2 SUMMARY OF STEADY FLOW RESULTS

The results are first summarized below in brief format indicating the general range of values of the following variable: maximum channel depth, wetted top width, mean cross section velocity, and velocity distribution throughout the cross section.

The attachments in Section 8.2 show the cross section plots indicating cross section geometry and water surface for a range of flows.

The attachments in Section 8.4 further summarize (in a series of tables) the increase in flow for each average monthly flow and the accompanying increases in hydraulic depth, maximum channel depth, wetted top width, wetted perimeter, and mean main channel velocity as a percentage increase from the baseline value. The values for hydraulic depth are on occasion negative; this value can be negative even with an increasing water surface if the channel is broadening rapidly enough because hydraulic depth is the wet cross sectional area divided by the wetted top width. All of the other variables follow relative increases in comparison to the increases in flow. The increases were summarized for Alternative 1 and 2 together because the monthly flows are identical in Alternatives 1 and 2. Alternative 4 flows are identical to baseline flows so they were not calculated as they would all be zero.

The attachments in Section 8.5 summarize velocity values in fps for each cross section for critical months. The table shows the velocity for each of the cross section under the different alternatives.

6.2.1 Upstream Portion (cross sections 250.75-355.25)

The low flow depths are less than 1 foot without ponding and up to 5 feet in ponds. The high flow depths range from 1 to 3 feet without ponding and up to 7 feet in ponds. Top widths range from 4 to 25 feet during low flows and 15 to 50 feet at high flows. Mean cross section velocities in the upper portion range from 0 to 2 fps for low flows and from 1 to 6 fps for high flows. The distribution of cross sectional velocities range from 0 to 4 fps at the edges and from 1 to 12 fps in the middle for high flows. The distribution of cross sectional velocities range from 0 to 1 fps at the edges and from 1 to 3 fps in the middle for low flows.

6.2.2 Downstream Portion (cross sections 44.75-167.42)

The low flow depths are less than 1 foot without ponding and up to 5 feet in ponds. The high flow depths range from 2 to 4 feet without ponding and up to 7 feet in ponds. Low flow top widths range from a few feet to 40 feet. High flow top widths range from a 25 to 40 feet. Mean cross section velocities range from 0 to 1 fps for low flows and from 1 to 4 fps for high flows. The distribution of cross sectional velocities range from 0 to 3 fps at the edges and from 1 to 6 fps in the middle for high flows. The distribution of cross sectional velocities range from 0 to 1 fps at the edges and from 1 to 3 fps in the middle for low flows.

7. BACKWATER ANALYSIS

Under baseline conditions, the water surface elevation of Utah Lake fluctuates between about 4481 feet and about 4493 while the average water surface elevation is approximately 4487 feet. This data comes from the "ULS Surface Water Hydrology Results: Simulated Streamflows and Reservoir Levels" dated April 2004. These elevations were used to model the backwater effect of Utah Lake on Hobble Creek.

7.1 METHODS

The backwater analysis used the same methods as the steady state analysis with the exception of the downstream boundary condition. To model the elevation in Utah Lake, a known water surface was used as the downstream boundary condition.

7.2 SUMMARY OF BACKWATER RESULTS

7.2.1 UTAH LAKE WSE AT 4487 (NEAR AVERAGE)

For the cross sections surveyed, there is no backwater effect in Hobble Creek due to a Utah Lake water surface elevation near the average level of Utah Lake.

7.2.2 UTAH LAKE WSE AT 4490 (ABOUT HALF WAY BETWEEN AVERAGE AND MAXIMUM UTAH LAKE WSE)

The backwater effect in Hobble Creek approximately extends to the diversion at 55.53 (about 800 feet downstream of the I-15 crossing).

The lowest modeled flows in Hobble Creek (1-5 cfs) have a 1 foot channel depth increase resulting from Utah Lake backwater. The highest modeled flow in Hobble Creek (160 cfs) have negligible increases in water surface elevation as a result of Utah Lake backwater effect.

The lowest modeled flows in Hobble Creek (1-5 cfs) have a channel top width increase of about 4 feet. The highest modeled flows in Hobble Creek (160 cfs) have negligible increases in channel top width resulting from Utah Lake backwater effect.

7.2.4 UTAH LAKE WSE AT 4492 (NEAR HIGHEST LEVEL)

The backwater effect in Hobble Creek approximately extends to the diversion at 55.53 (about 800 feet downstream of the I-15 crossing).

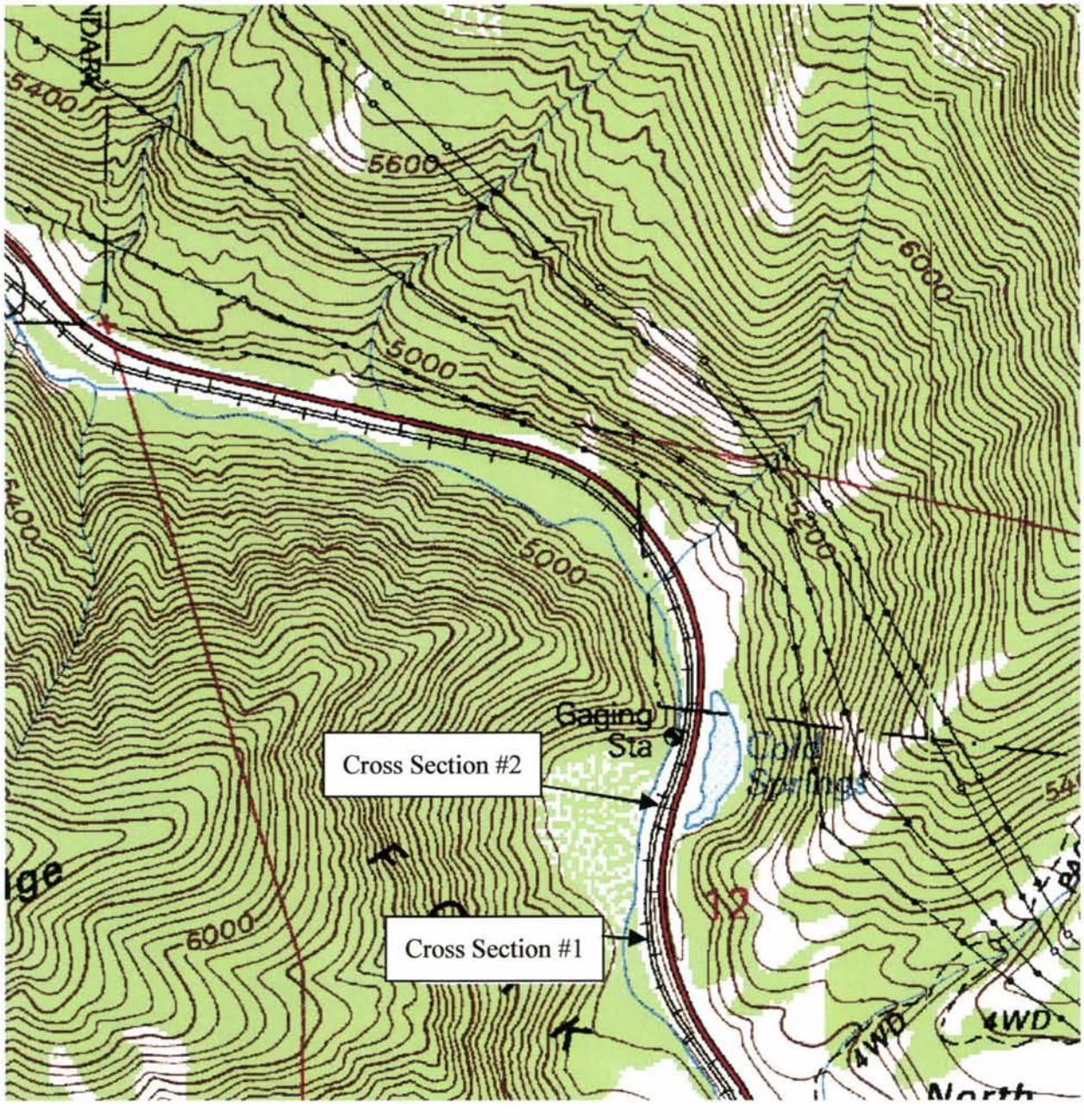
The lowest modeled flows in Hobble Creek (1 to 5 cfs) have a channel depth increase of 3 feet resulting from Utah Lake backwater effect. The highest modeled flow in Hobble Creek (160 cfs) have a channel depth increase of 1 foot resulting from Utah Lake backwater effect.

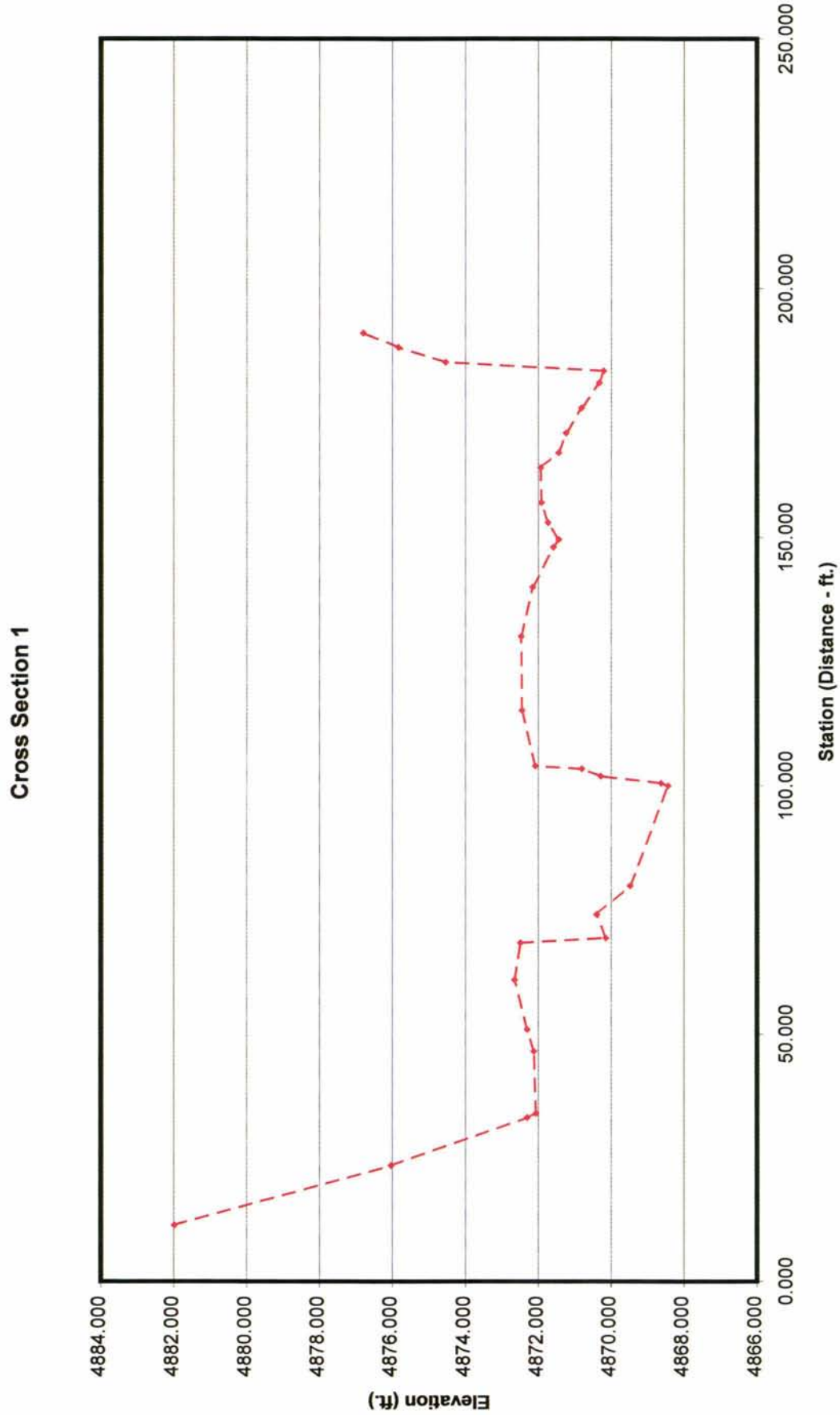
The lowest modeled flows in Hobble Creek (1-5 cfs) have a channel top width increase resulting from Utah Lake backwater ranging from 5-10 feet. The highest modeled flow in Hobble Creek (160 cfs) have a negligible channel top width increase resulting from Utah Lake backwater effect.

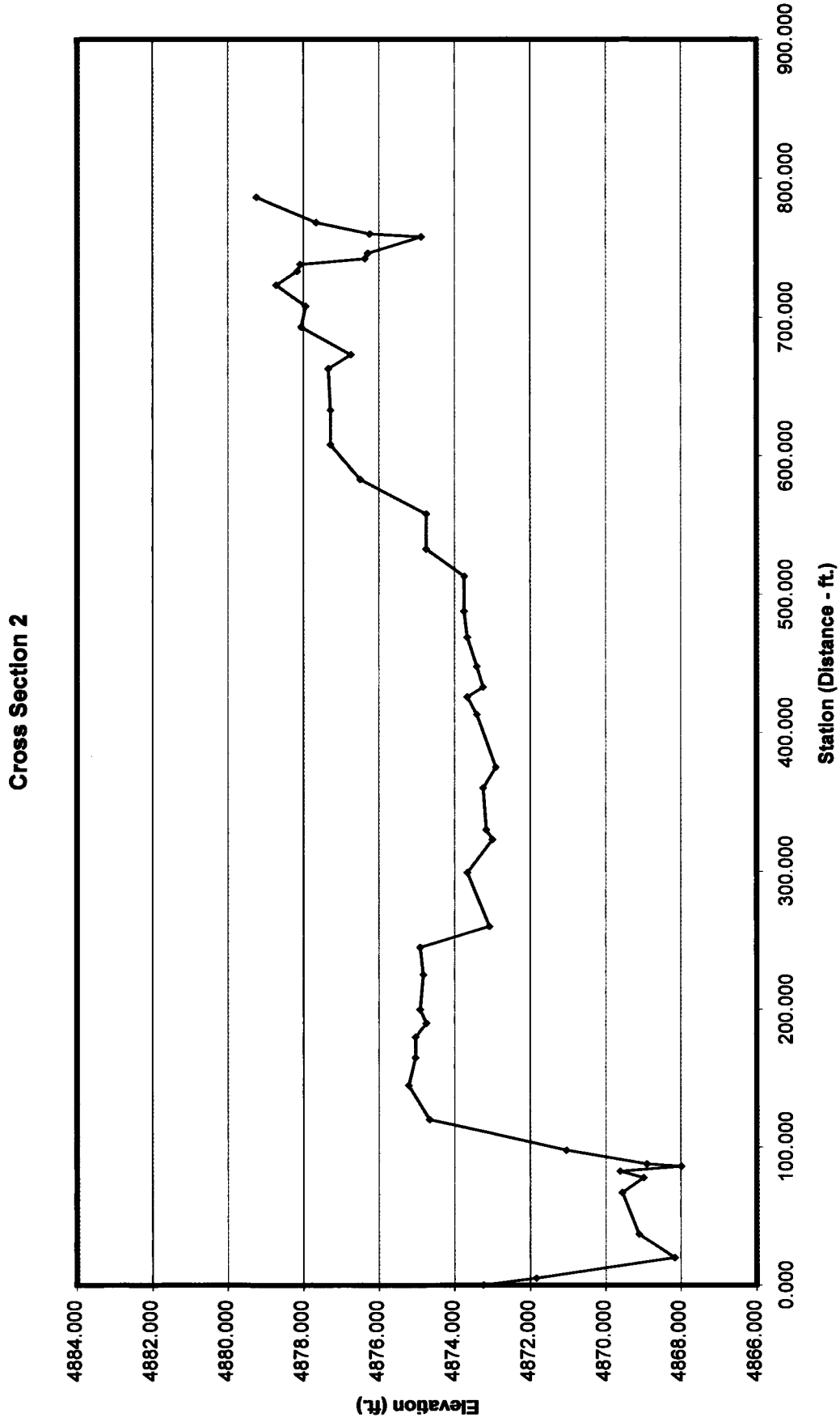
If the diversion at 55.53 is not operated at observed heights the backwater effect in Hobble Creek extends to approximately cross section 72.71 (about 800 feet upstream of the I-15 crossing).

Section C
Spanish Fork Hydraulic Transects

Location of Cross-Sections




Cross Section 1
Elevation (ft.)
4884.000
4882.000
4880.000
4878.000
4876.000
4874.000
4872.000
4870.000
4868.000
4866.000
0.000
50.000
100.000
150.000
200.000
250.000
Station (Distance - ft.)


Cross Section 2
Elevation (ft.)
4884.000
4882.000
4880.000
4878.000
4876.000
4874.000
4872.000
4870.000
4868.000
4866.000
0.000
100.000
200.000
300.000
400.000
500.000
600.000
700.000
800.000
900.000
Station (Distance - ft.)

Section D
Binns HQI Model II Data Sheets

Habitat Quality Index (Model II) Attribute Rating Summary Sheet

Stream:	Provo River Baseline	Location:	Deer Creek Dam to North Fork
Date Data Collection:	August 2001; 1990 to 1999; 2004	HQI Score:	675 lbs/acre
Trout Standing Crop:	lbs/acres		729 trout habitat units
	(cyanide sample or other method)		

Attribute (Symbol)	(name)	Data	Rating	Data Sources
X_1	late summer stream flow (critical period stream flow - CPSF)	Gauge location: ADF = 365 cfs; Avg CPF = 504 cfs Avg CPF/ADF = 138% ADF	4	ULS Surface Water Hydrology Technical Report 2004
X_2	annual stream flow variation	ASFV Ratio = 7.9	4	ULS Surface Water Hydrology Technical Report 2004
X_3	maximum summer stream temperature	64 degrees F	4	Psomas Tech Memo to MWH 2004
X_4	nitrate nitrogen	0.15 mg/l (data source)	4	Utah Division of Wildlife Resources Field Data 2001
X_5	fish food abundance	>500 organisms/square foot, only used in Model I, but same as X_9 in Model II	N/A	Utah Division of Wildlife Resources Field Data 2001
X_6	fish food diversity	D_s = XX, only used in Model I	N/A	
X_7	cover	23 (% cover)	1	Utah Division of Wildlife Resources Field Data 2001
X_8	eroding stream banks (bank stability)	Estimated at 2 (% eroding)	4	Utah Division of Wildlife Resources Field Data 2001
X_9	substrate	Same as X_5 (Estimated)	4	Utah Division of Wildlife Resources Field Data 2001
X_{10}	water velocity	Time of Travel = 1.8 ft/sec	4	Utah Division of Wildlife Resources Field Data 2001
X_{11}	stream width	50 feet	2	Utah Division of Wildlife Resources Field Data 2001

$S = (X_7)(X_8)(X_{11})$ = shelter index		$\log(Y+1) = (-0.903)+(0.807)\log(X_1+1)+(0.877)\log(X_2+1)+(1.233)\log(X_3+1)+(0.631)\log(F+1)+(0.182)\log(S+1)$	
$F = (X_3)(X_4)(X_9)(X_{10})$ = food index		Y = predicted trout standing crop (lbs/acre)	
X_1+1	5	log(Y+1) =	2.830235
X_2+1	5	Y =	675 lbs/acre
X_3+1	5		
F+1	257		
S+1	9		

Habitat Quality Index (Model II) Attribute Rating Summary Sheet

Stream:	Provo River Preferred Alternative	Location:	Deer Creek Dam to North Fork
Date Data Collection:	August 2001; 1990 to 1999; 2004	HQI Score:	675 lbs/acre
Trout Standing Crop:	lbs/acres		729 trout habitat units
	(cyanide sample or other method)		

Attribute (Symbol)	(name)	Data	Rating	Data Sources
X_1	late summer stream flow (critical period stream flow - CPSF)	Gauge location: ADF = 370 cfs; Avg CPF = 495 cfs Avg CPF/ADF = 134% ADF	4	ULS Surface Water Hydrology Technical Report 2004
X_2	annual stream flow variation	ASFV Ratio = 8.6	4	ULS Surface Water Hydrology Technical Report 2004
X_3	maximum summer stream temperature	64 degrees F	4	Psomas Tech Memo to MWH 2004
X_4	nitrate nitrogen	0.15 mg/l (data source)	4	Utah Division of Wildlife Resources Field Data 2001
X_5	fish food abundance	>500 organisms/square foot, only used in Model I, but same as X_9 in Model II	N/A	Utah Division of Wildlife Resources Field Data 2001
X_6	fish food diversity	D_s = XX, only used in Model I	N/A	
X_7	cover	23 (% cover)	1	Utah Division of Wildlife Resources Field Data 2001
X_8	eroding stream banks (bank stability)	Estimated at 2 (% eroding)	4	Utah Division of Wildlife Resources Field Data 2001
X_9	substrate	Same as X_5 (Estimated)	4	Utah Division of Wildlife Resources Field Data 2001
X_{10}	water velocity	Time of Travel = 1.8 ft/sec	4	Utah Division of Wildlife Resources Field Data 2001
X_{11}	stream width	50 feet	2	Utah Division of Wildlife Resources Field Data 2001

$S = (X_7)(X_8)(X_{11})$ = shelter index	$\log(Y+1) = (-0.903)+(0.807)\log(X_1+1)+(0.877)\log(X_2+1)+(1.233)\log(X_3+1)+(0.631)\log(F+1)+(0.182)\log(S+1)$
$F = (X_3)(X_4)(X_9)(X_{10})$ = food index	Y = predicted trout standing crop (lbs/acre)
X_1+1 5	log(Y+1) = 2.830235
X_2+1 5	Y = 675 lbs/acre
X_3+1 5	
F+1 257	
S+1 9	

Habitat Quality Index (Model II) Attribute Rating Summary Sheet

Stream:	Provo River Baseline	Location:	North Fork to Olmsted Div. Dam
Date Data Collection:	August 2001; 1990 to 1999; 2004	HQI Score:	506 lbs/acre
Trout Standing Crop:	lbs/acres		547 trout habitat units
	(cyanide sample or other method)		

Attribute (Symbol)	(name)	Data	Rating	Data Sources
X_1	late summer stream flow (critical period stream flow - CPSF)	Gauge location: ADF = 392 cfs; Avg CPF = 528 cfs Avg CPF/ADF = 135% ADF	4	ULS Surface Water Hydrology Technical Report 2004
X_2	annual stream flow variation	ASFV Ratio = 7.6	4	ULS Surface Water Hydrology Technical Report 2004
X_3	maximum summer stream temperature	64 degrees F	4	Psomas Tech Memo to MWH 2004
X_4	nitrate nitrogen	0.19 mg/l (data source)	4	Utah Division of Wildlife Resources Field Data 2001
X_5	fish food abundance	310 organisms/square foot, only used in Model I, but same as X_9 in Model II	N/A	Utah Division of Wildlife Resources Field Data 2001
X_6	fish food diversity	D_s = XX, only used in Model I	N/A	
X_7	cover	11 (% cover)	1	Utah Division of Wildlife Resources Field Data 2001
X_8	eroding stream banks (bank stability)	Estimated at 4 (% eroding)	4	Utah Division of Wildlife Resources Field Data 2001
X_9	substrate	Same as X_5 (Estimated)	3	Utah Division of Wildlife Resources Field Data 2001
X_{10}	water velocity	Time of Travel = 2.2 ft/sec	4	Utah Division of Wildlife Resources Field Data 2001
X_{11}	stream width	89 feet	1	Utah Division of Wildlife Resources Field Data 2001

$S = (X_7)(X_8)(X_{11})$ = shelter index	$\log(Y+1) = (-0.903)+(0.807)\log(X_1+1)+(0.877)\log(X_2+1)+(1.233)\log(X_3+1)+(0.631)\log(F+1)+(0.182)\log(S+1)$
$F = (X_3)(X_4)(X_9)(X_{10})$ = food index	Y = predicted trout standing crop (lbs/acre)
X_1+1 5	log(Y+1) = 2.705295
X_2+1 5	Y = 506 lbs/acre
X_3+1 5	
F+1 193	
S+1 5	

Habitat Quality Index (Model II) Attribute Rating Summary Sheet

Stream:	Provo River Preferred Alternative	Location:	North Fork to Olmsted Div. Dam
Date Data Collection:	August 2001; 1990 to 1999; 2004	HQI Score:	506 lbs/acre
Trout Standing Crop:	lbs/acres		547 trout habitat units
	(cyanide sample or other method)		

Attribute (Symbol)	(name)	Data	Rating	Data Sources
X_1	late summer stream flow (critical period stream flow - CPSF)	Gauge location: ADF = 396 cfs; Avg CPF = 519 cfs Avg CPF/ADF = 131% ADF	4	ULS Surface Water Hydrology Technical Report 2004
X_2	annual stream flow variation	ASFV Ratio = 8.5	4	ULS Surface Water Hydrology Technical Report 2004
X_3	maximum summer stream temperature	64 degrees F	4	Psomas Tech Memo to MWH 2004
X_4	nitrate nitrogen	0.19 mg/l (data source)	4	Utah Division of Wildlife Resources Field Data 2001
X_5	fish food abundance	310 organisms/square foot, only used in Model I, but same as X_9 in Model II	N/A	Utah Division of Wildlife Resources Field Data 2001
X_6	fish food diversity	D_s = XX, only used in Model I	N/A	
X_7	cover	11 (% cover)	1	Utah Division of Wildlife Resources Field Data 2001
X_8	eroding stream banks (bank stability)	Estimated at 4 (% eroding)	4	Utah Division of Wildlife Resources Field Data 2001
X_9	substrate	Same as X_5 (Estimated)	3	Utah Division of Wildlife Resources Field Data 2001
X_{10}	water velocity	Time of Travel = 2.2 ft/sec	4	Utah Division of Wildlife Resources Field Data 2001
X_{11}	stream width	89 feet	1	Utah Division of Wildlife Resources Field Data 2001

$S = (X_7)(X_8)(X_{11})$ = shelter index		$\log(Y+1) = (-0.903)+(0.807)\log(X_1+1)+(0.877)\log(X_2+1)+(1.233)\log(X_3+1)+(0.631)\log(F+1)+(0.182)\log(S+1)$	
$F = (X_3)(X_4)(X_9)(X_{10})$ = food index		Y = predicted trout standing crop (lbs/acre)	
X_1+1	5	log(Y+1) =	2.705295
X_2+1	5	Y =	506 lbs/acre
X_3+1	5		
F+1	193		
S+1	5		

Habitat Quality Index (Model II) Attribute Rating Summary Sheet

Stream:	Provo River Baseline	Location:	Olmsted DD to Murdock DD 1
Date Data Collection:	August 2001; 1990 to 1999; 2004	HQI Score:	594 lbs/acre
Trout Standing Crop:	lbs/acres		641 trout habitat units
	(cyanide sample or other method)		

Bridal Veil Falls

Attribute (Symbol)	(name)	Data	Rating	Data Sources
X_1	late summer stream flow (critical period stream flow - CPSF)	Gauge location: ADF = 299 cfs; Avg CPF = 365 cfs Avg CPF/ADF = 122% ADF	4	ULS Surface Water Hydrology Technical Report 2004
X_2	annual stream flow variation	ASFV Ratio = 15.9	3	ULS Surface Water Hydrology Technical Report 2004
X_3	maximum summer stream temperature	64 degrees F	4	Psomas Tech Memo to MWH 2004
X_4	nitrate nitrogen	0.19 mg/l (data source)	4	Utah Division of Wildlife Resources Field Data 2001
X_5	fish food abundance	>500 organisms/square foot, only used in Model I, but same as X_9 in Model II	N/A	U.S. Bureau of Reclamation 2001
X_6	fish food diversity	D_s = XX, only used in Model I	N/A	
X_7	cover	13 (% cover)	1	Utah Division of Wildlife Resources Field Data 2001
X_8	eroding stream banks (bank stability)	0 (% eroding)	4	Utah Division of Wildlife Resources Field Data 2001
X_9	substrate	Same as X_5 (Estimated)	4	U.S. Bureau of Reclamation 2001
X_{10}	water velocity	Time of Travel = 2.0 ft/sec	4	Utah Division of Wildlife Resources Field Data 2001
X_{11}	stream width	42 feet	3	Utah Division of Wildlife Resources Field Data 2001

$S = (X_7)(X_8)(X_{11})$ = shelter index	$\log(Y+1) = (-0.903)+(0.807)\log(X_1+1)+(0.877)\log(X_2+1)+(1.233)\log(X_3+1)+(0.631)\log(F+1)+(0.182)\log(S+1)$
$F = (X_3)(X_4)(X_9)(X_{10})$ = food index	Y = predicted trout standing crop (lbs/acre)
X_1+1 5	log(Y+1) = 2.774311
X_2+1 4	Y = 594 lbs/acre
X_3+1 5	
F+1 257	
S+1 13	

Habitat Quality Index (Model II) Attribute Rating Summary Sheet

Stream:	Provo River Preferred Alternative	Location:	Olmsted DD to Murdock DD 1
Date Data Collection:	August 2001; 1990 to 1999; 2004	HQI Score:	722 lbs/acre
Trout Standing Crop:	lbs/acres		780 trout habitat units
	(cyanide sample or other method)		

Bridal Veil Falls

Attribute (Symbol)	(name)	Data	Rating	Data Sources
X_1	late summer stream flow (critical period stream flow - CPSF)	Gauge location: ADF = 283 cfs; Avg CPF = 290 cfs Avg CPF/ADF = 102% ADF	4	ULS Surface Water Hydrology Technical Report 2004
X_2	annual stream flow variation	ASFV Ratio = 14.8	4	ULS Surface Water Hydrology Technical Report 2004
X_3	maximum summer stream temperature	64 degrees F	4	Psomas Tech Memo to MWH 2004
X_4	nitrate nitrogen	0.19 mg/l (data source)	4	Utah Division of Wildlife Resources Field Data 2001
X_5	fish food abundance	>500 organisms/square foot, only used in Model I, but same as X_9 in Model II	N/A	U.S. Bureau of Reclamation 2001
X_6	fish food diversity	D_s = XX, only used in Model I	N/A	
X_7	cover	13 (% cover)	1	Utah Division of Wildlife Resources Field Data 2001
X_8	eroding stream banks (bank stability)	0 (% eroding)	4	Utah Division of Wildlife Resources Field Data 2001
X_9	substrate	Same as X_5 (Estimated)	4	U.S. Bureau of Reclamation 2001
X_{10}	water velocity	Time of Travel = 2.0 ft/sec	4	Utah Division of Wildlife Resources Field Data 2001
X_{11}	stream width	42 feet	3	Utah Division of Wildlife Resources Field Data 2001

$S = (X_7)(X_8)(X_{11})$ = shelter index	$\log(Y+1) = (-0.903)+(0.807)\log(X_1+1)+(0.877)\log(X_2+1)+(1.233)\log(X_3+1)+(0.631)\log(F+1)+(0.182)\log(S+1)$
$F = (X_3)(X_4)(X_9)(X_{10})$ = food index	Y = predicted trout standing crop (lbs/acre)
X_1+1 5	log(Y+1) = 2.859301
X_2+1 5	Y = 722 lbs/acre
X_3+1 5	
F+1 257	
S+1 13	

Habitat Quality Index (Model II) Attribute Rating Summary Sheet

Stream:	Provo River Baseline	Location:	Olmsted DD to Murdock DD 2
Date Data Collection:	August 2001; 1990 to 1999; 2004	HQI Score:	495 lbs/acre
Trout Standing Crop:	lbs/acres		535 trout habitat units
	(cyanide sample or other method)		

Squaw Peak Road

Attribute (Symbol)	(name)	Data	Rating	Data Sources
X_1	late summer stream flow (critical period stream flow - CPSF)	Gauge location: ADF = 299 cfs; Avg CPF = 365 cfs Avg CPF/ADF = 122% ADF	4	ULS Surface Water Hydrology Technical Report 2004
X_2	annual stream flow variation	ASFV Ratio = 15.9	3	ULS Surface Water Hydrology Technical Report 2004
X_3	maximum summer stream temperature	64 degrees F	4	Psomas Tech Memo to MWH 2004
X_4	nitrate nitrogen	0.19 mg/l (data source)	4	Utah Division of Wildlife Resources Field Data 2001
X_5	fish food abundance	>500 organisms/square foot, only used in Model I, but same as X_9 in Model II	N/A	U.S. Bureau of Reclamation 2001
X_6	fish food diversity	D_s = XX, only used in Model I	N/A	
X_7	cover	13 (% cover)	1	Utah Division of Wildlife Resources Field Data 2001
X_8	eroding stream banks (bank stability)	Estimated at 5 (% eroding)	4	MWH Field Data 2000
X_9	substrate	Same as X_5 (Estimated)	4	U.S. Bureau of Reclamation 2001
X_{10}	water velocity	Time of Travel = 2.8 ft/sec	3	Utah Division of Wildlife Resources Field Data 2001
X_{11}	stream width	41 feet	3	Utah Division of Wildlife Resources Field Data 2001

$S = (X_7)(X_8)(X_{11})$ = shelter index	$\log(Y+1) = (-0.903)+(0.807)\log(X_1+1)+(0.877)\log(X_2+1)+(1.233)\log(X_3+1)+(0.631)\log(F+1)+(0.182)\log(S+1)$
$F = (X_3)(X_4)(X_9)(X_{10})$ = food index	Y = predicted trout standing crop (lbs/acre)
X_1+1 5	log(Y+1) = 2.69583
X_2+1 4	Y = 495 lbs/acre
X_3+1 5	
F+1 193	
S+1 13	

Habitat Quality Index (Model II) Attribute Rating Summary Sheet

Stream:	Provo River Preferred Alternative	Location:	Olmsted DD to Murdock DD 2
Date Data Collection:	August 2001; 1990 to 1999; 2004	HQI Score:	603 lbs/acre
Trout Standing Crop:	lbs/acres		651 trout habitat units
	(cyanide sample or other method)		

Squaw Peak Road

Attribute (Symbol)	(name)	Data	Rating	Data Sources
X_1	late summer stream flow (critical period stream flow - CPSF)	Gauge location: ADF = 283 cfs; Avg CPF = 290 cfs Avg CPF/ADF = 102% ADF	4	ULS Surface Water Hydrology Technical Report 2004
X_2	annual stream flow variation	ASFV Ratio = 14.8	4	ULS Surface Water Hydrology Technical Report 2004
X_3	maximum summer stream temperature	64 degrees F	4	Psomas Tech Memo to MWH 2004
X_4	nitrate nitrogen	0.19 mg/l (data source)	4	Utah Division of Wildlife Resources Field Data 2001
X_5	fish food abundance	>500 organisms/square foot, only used in Model I, but same as X_9 in Model II	N/A	U.S. Bureau of Reclamation 2001
X_6	fish food diversity	D_s = XX, only used in Model I	N/A	
X_7	cover	13 (% cover)	1	Utah Division of Wildlife Resources Field Data 2001
X_8	eroding stream banks (bank stability)	Estimated at 5 (% eroding)	4	MWH Field Data 2000
X_9	substrate	Same as X_5 (Estimated)	4	U.S. Bureau of Reclamation 2001
X_{10}	water velocity	Time of Travel = 2.8 ft/sec	3	Utah Division of Wildlife Resources Field Data 2001
X_{11}	stream width	41 feet	3	Utah Division of Wildlife Resources Field Data 2001

$S = (X_7)(X_8)(X_{11})$ = shelter index		$\log(Y+1) = (-0.903)+(0.807)\log(X_1+1)+(0.877)\log(X_2+1)+(1.233)\log(X_3+1)+(0.631)\log(F+1)+(0.182)\log(S+1)$	
$F = (X_3)(X_4)(X_9)(X_{10})$ = food index		Y = predicted trout standing crop (lbs/acre)	
X_1+1	5	log(Y+1) =	2.78082
X_2+1	5	Y =	603 lbs/acre
X_3+1	5		
F+1	193		
S+1	13		

Habitat Quality Index (Model I) Attribute Rating Summary Sheet

Stream:	Provo River Baseline	Location:	Murdock DD to I-15 1
Date Data Collection:	August 2001; 1990 to 1999; 2000; 2004	HQI Score:	641 lbs/acre
Trout Standing Crop:	lbs/acres		692 trout habitat units
	(cyanide sample or other method)		

400 yards below Murdock DD

Attribute (Symbol)	(name)	Data	Rating	Data Sources
X_1	late summer stream flow (critical period stream flow - CPSF)	Gauge location: ADF = 180 cfs; Avg CPF = 142 cfs Avg CPF/ADF = 79% ADF	4	ULS Surface Water Hydrology Technical Report 2004
X_2	annual stream flow variation	ASFV Ratio = 9.6	4	ULS Surface Water Hydrology Technical Report 2004
X_3	maximum summer stream temperature	65 degrees F	4	ULS Surface Water Quality Technical Report 2004
X_4	nitrate nitrogen	0.37 mg/l (data source)	3	ULS Surface Water Quality Technical Report 2004
X_5	fish food abundance	>500 organisms/square foot, only used in Model I, but same as X_9 in Model II	N/A	U.S. Bureau of Reclamation 2001
X_6	fish food diversity	D_s = XX, only used in Model I	N/A	
X_7	cover	59 (% cover)	4	Utah Division of Wildlife Resources Field Data 2001
X_8	eroding stream banks (bank stability)	Estimated at 5 (% eroding)	4	MWH Field Data 2000
X_9	substrate	Same as X_5 (Estimated)	4	U.S. Bureau of Reclamation 2001
X_{10}	water velocity	Time of Travel =1.0 ft/sec	3	Utah Division of Wildlife Resources Field Data 2001
X_{11}	stream width	34 feet	3	Utah Division of Wildlife Resources Field Data 2001

$S = (X_7)(X_8)(X_{11})$ = shelter index	$\log(Y+1) = (-0.903)+(0.807)\log(X_1+1)+(0.877)\log(X_2+1)+(1.233)\log(X_3+1)+(0.631)\log(F+1)+(0.182)\log(S+1)$
$F = (X_3)(X_4)(X_9)(X_{10})$ = food index	Y = predicted trout standing crop (lbs/acre)
X_1+1 5	log(Y+1) = 2.807334
X_2+1 5	Y = 641 lbs/acre
X_3+1 5	
F+1 145	
S+1 49	

Habitat Quality Index (Model II) Attribute Rating Summary Sheet

Stream:	Provo River Preferred Alternative	Location:	Murdock DD to I-15 1
Date Data Collection:	August 2001; 1990 to 1999; 2000; 2004	HQI Score:	641 lbs/acre
Trout Standing Crop:	lbs/acres		692 trout habitat units
	(cyanide sample or other method)		

400 yards below Murdock DD

Attribute (Symbol)	(name)	Data	Rating	Data Sources
X_1	late summer stream flow (critical period stream flow - CPSF)	Gauge location: ADF = 216 cfs; Avg CPF = 189 cfs Avg CPF/ADF = 88% ADF	4	ULS Surface Water Hydrology Technical Report 2004
X_2	annual stream flow variation	ASFV Ratio = 7.6	4	ULS Surface Water Hydrology Technical Report 2004
X_3	maximum summer stream temperature	60 degrees F	4	ULS Surface Water Quality Technical Report 2004
X_4	nitrate nitrogen	0.34 mg/l (data source)	3	ULS Surface Water Quality Technical Report 2004
X_5	fish food abundance	>500 organisms/square foot, only used in Model I, but same as X_9 in Model II	N/A	U.S. Bureau of Reclamation 2001
X_6	fish food diversity	D_s = XX, only used in Model I	N/A	
X_7	cover	59 (% cover)	4	Utah Division of Wildlife Resources Field Data 2001
X_8	eroding stream banks (bank stability)	Estimated at 5 (% eroding)	4	MWH Field Data 2000
X_9	substrate	Same as X_5 (Estimated)	4	U.S. Bureau of Reclamation 2001
X_{10}	water velocity	Time of Travel = 1.0 ft/sec	3	Utah Division of Wildlife Resources Field Data 2001
X_{11}	stream width	34 feet	3	Utah Division of Wildlife Resources Field Data 2001

$S = (X_7)(X_8)(X_{11})$ = shelter index		$\log(Y+1) = (-0.903)+(0.807)\log(X_1+1)+(0.877)\log(X_2+1)+(1.233)\log(X_3+1)+(0.631)\log(F+1)+(0.182)\log(S+1)$	
$F = (X_3)(X_4)(X_9)(X_{10})$ = food index		Y = predicted trout standing crop (lbs/acre)	
X_1+1	5	log(Y+1) =	2.807334
X_2+1	5	Y =	641 lbs/acre
X_3+1	5		
F+1	145		
S+1	49		

Habitat Quality Index (Model II) Attribute Rating Summary Sheet

Stream:	Provo River BUW Alternative	Location:	Murdock DD to I-15 1
Date Data Collection:	August 2001; 1990 to 1999; 2000; 2004	HQI Score:	641 lbs/acre
Trout Standing Crop:	lbs/acres		692 trout habitat units
	(cyanide sample or other method)		

400 yards below Murdock DD

Attribute (Symbol)	(name)	Data	Rating	Data Sources
X_1	late summer stream flow (critical period stream flow - CPSF)	Gauge location: ADF = 194 cfs; Avg CPF = 156 cfs Avg CPF/ADF = 80% ADF	4	ULS Surface Water Hydrology Technical Report 2004
X_2	annual stream flow variation	ASFV Ratio = 9.7	4	ULS Surface Water Hydrology Technical Report 2004
X_3	maximum summer stream temperature	60 degrees F	4	ULS Surface Water Quality Technical Report 2004
X_4	nitrate nitrogen	0.34 mg/l (data source)	3	ULS Surface Water Quality Technical Report 2004
X_5	fish food abundance	>500 organisms/square foot, only used in Model I, but same as X_9 in Model II	N/A	U.S. Bureau of Reclamation 2001
X_6	fish food diversity	D_s = XX, only used in Model I	N/A	
X_7	cover	59 (% cover)	4	Utah Division of Wildlife Resources Field Data 2001
X_8	eroding stream banks (bank stability)	Estimated at 5 (% eroding)	4	MWH Field Data 2000
X_9	substrate	Same as X_5 (Estimated)	4	U.S. Bureau of Reclamation 2001
X_{10}	water velocity	Time of Travel = 1.0 ft/sec	3	Utah Division of Wildlife Resources Field Data 2001
X_{11}	stream width	34 feet	3	Utah Division of Wildlife Resources Field Data 2001

$S = (X_7)(X_8)(X_{11})$ = shelter index	$\log(Y+1) = (-0.903)+(0.807)\log(X_1+1)+(0.877)\log(X_2+1)+(1.233)\log(X_3+1)+(0.631)\log(F+1)+(0.182)\log(S+1)$
$F = (X_3)(X_4)(X_9)(X_{10})$ = food index	Y = predicted trout standing crop (lbs/acre)
X_1+1 5	log(Y+1) = 2.807334
X_2+1 5	Y = 641 lbs/acre
X_3+1 5	
F+1 145	
S+1 49	

Habitat Quality Index (Model II) Attribute Rating Summary Sheet

Stream:	Provo River Baseline	Location:	Murdock DD to I-15 2
Date Data Collection:	August 2001; 1990 to 1999; 2004	HQI Score:	105 lbs/acre
Trout Standing Crop:	lbs/acres		114 trout habitat units
	(cyanide sample or other method)		

Orem 800 South Bridge

Attribute (Symbol)	(name)	Data	Rating	Data Sources
X_1	late summer stream flow (critical period stream flow - CPSF)	Gauge location: ADF = 114 cfs; Avg CPF = 5 cfs Avg CPF/ADF = 4.4% ADF	0	ULS Surface Water Hydrology Technical Report 2004
X_2	annual stream flow variation	ASFV Ratio = 93.5	2	ULS Surface Water Hydrology Technical Report 2004
X_3	maximum summer stream temperature	65 degrees F	4	ULS Surface Water Quality Technical Report 2004
X_4	nitrate nitrogen	0.37 mg/l (data source)	3	ULS Surface Water Quality Technical Report 2004
X_5	fish food abundance	>500 organisms/square foot, only used in Model I, but same as X_9 in Model II	N/A	Utah Division of Wildlife Resources Field Data 2001
X_6	fish food diversity	D_s = XX, only used in Model I	N/A	
X_7	cover	52 (% cover)	3	Utah Division of Wildlife Resources Field Data 2001
X_8	eroding stream banks (bank stability)	0 (% eroding)	4	Utah Division of Wildlife Resources Field Data 2001
X_9	substrate	Same as X_5	4	Utah Division of Wildlife Resources Field Data 2001
X_{10}	water velocity	Time of Travel =2.6 ft/sec	3	Utah Division of Wildlife Resources Field Data 2001
X_{11}	stream width	44 feet	3	Utah Division of Wildlife Resources Field Data 2001

$S = (X_7)(X_8)(X_{11})$ = shelter index	$\log(Y+1) = (-0.903)+(0.807)\log(X_1+1)+(0.877)\log(X_2+1)+(1.233)\log(X_3+1)+(0.631)\log(F+1)+(0.182)\log(S+1)$
$F = (X_3)(X_4)(X_9)(X_{10})$ = food index	Y = predicted trout standing crop (lbs/acre)
X_1+1 1	log(Y+1) = 2.026501
X_2+1 3	Y = 105 lbs/acre
X_3+1 5	
F+1 145	
S+1 37	

Habitat Quality Index (Model II) Attribute Rating Summary Sheet

Stream:	Provo River Preferred Alternative	Location:	Murdock DD to I-15 2
Date Data Collection:	August 2001; 1990 to 1999; 2004	HQI Score:	535 lbs/acre
Trout Standing Crop:	lbs/acres		578 trout habitat units
	(cyanide sample or other method)		

Orem 800 South Bridge

Attribute (Symbol)	(name)	Data	Rating	Data Sources
X_1	late summer stream flow (critical period stream flow - CPSF)	Gauge location: ADF = 157 cfs; Avg CPF = 62 cfs Avg CPF/ADF = 40% ADF	3	ULS Surface Water Hydrology Technical Report 2004
X_2	annual stream flow variation	ASFV Ratio = 7.9	4	ULS Surface Water Hydrology Technical Report 2004
X_3	maximum summer stream temperature	60 degrees F	4	ULS Surface Water Quality Technical Report 2004
X_4	nitrate nitrogen	0.34 mg/l (data source)	3	ULS Surface Water Quality Technical Report 2004
X_5	fish food abundance	>500 organisms/square foot, only used in Model I, but same as X_9 in Model II	N/A	Utah Division of Wildlife Resources Field Data 2001
X_6	fish food diversity	D_s = XX, only used in Model I	N/A	
X_7	cover	>55 (% cover)	4	Utah Division of Wildlife Resources Field Data 2001
X_8	eroding stream banks (bank stability)	0 (% eroding)	4	Utah Division of Wildlife Resources Field Data 2001
X_9	substrate	Same as X_5	4	Utah Division of Wildlife Resources Field Data 2001
X_{10}	water velocity	Time of Travel = 2.7 ft/sec	3	Utah Division of Wildlife Resources Field Data 2001
X_{11}	stream width	44 feet	3	Utah Division of Wildlife Resources Field Data 2001

$S = (X_7)(X_8)(X_{11})$ = shelter index	$\log(Y+1) = (-0.903)+(0.807)\log(X_1+1)+(0.877)\log(X_2+1)+(1.233)\log(X_3+1)+(0.631)\log(F+1)+(0.182)\log(S+1)$
$F = (X_3)(X_4)(X_9)(X_{10})$ = food index	Y = predicted trout standing crop (lbs/acre)
X_1+1 4	log(Y+1) = 2.729128
X_2+1 5	Y = 535 lbs/acre
X_3+1 5	
F+1 145	
S+1 49	

Habitat Quality Index (Model II) Attribute Rating Summary Sheet

Stream:	Provo River BUW Alternative	Location:	Murdock DD to I-15 2
Date Data Collection:	August 2001; 1990 to 1999; 2004	HQI Score:	331 lbs/acre
Trout Standing Crop:	lbs/acres		357 trout habitat units
	(cyanide sample or other method)		

Orem 800 South Bridge

Attribute (Symbol)	(name)	Data	Rating	Data Sources
X_1	late summer stream flow (critical period stream flow - CPSF)	Gauge location: ADF = 135 cfs; Avg CPF = 28 cfs Avg CPF/ADF = 21% ADF	2	ULS Surface Water Hydrology Technical Report 2004
X_2	annual stream flow variation	ASFV Ratio = 15.9	3	ULS Surface Water Hydrology Technical Report 2004
X_3	maximum summer stream temperature	65 degrees F	4	ULS Surface Water Quality Technical Report 2004
X_4	nitrate nitrogen	0.37 mg/l (data source)	3	ULS Surface Water Quality Technical Report 2004
X_5	fish food abundance	>500 organisms/square foot, only used in Model I, but same as X_9 in Model II	N/A	Utah Division of Wildlife Resources Field Data 2001
X_6	fish food diversity	D_s = XX, only used in Model I	N/A	
X_7	cover	52 (% cover)	3	Utah Division of Wildlife Resources Field Data 2001
X_8	eroding stream banks (bank stability)	0 (% eroding)	4	Utah Division of Wildlife Resources Field Data 2001
X_9	substrate	Same as X_5	4	Utah Division of Wildlife Resources Field Data 2001
X_{10}	water velocity	Time of Travel = 2.6 ft/sec	3	Utah Division of Wildlife Resources Field Data 2001
X_{11}	stream width	44 feet	3	Utah Division of Wildlife Resources Field Data 2001

$S = (X_7)(X_8)(X_{11})$ = shelter index		$\log(Y+1) = (-0.903)+(0.807)\log(X_1+1)+(0.877)\log(X_2+1)+(1.233)\log(X_3+1)+(0.631)\log(F+1)+(0.182)\log(S+1)$	
$F = (X_3)(X_4)(X_9)(X_{10})$ = food index		Y = predicted trout standing crop (lbs/acre)	
X_1+1	3	log(Y+1) =	2.521109
X_2+1	4	Y =	331 lbs/acre
X_3+1	5		
F+1	145		
S+1	37		

Habitat Quality Index (Model II) Attribute Rating Summary Sheet

Stream:	Provo River Baseline	Location:	Murdock DD to I-15 3
Date Data Collection:	August 2001; 1990 to 1999; 2004	HQI Score:	118 lbs/acre
Trout Standing Crop:	lbs/acres		127 trout habitat units
	(cyanide sample or other method)		

Provo 1400 North

Attribute (Symbol)	(name)	Data	Rating	Data Sources
X_1	late summer stream flow (critical period stream flow - CPSF)	Gauge location: ADF = 114 cfs; Avg CPF = 5 cfs Avg CPF/ADF = 4.4% ADF	0	ULS Surface Water Hydrology Technical Report 2004
X_2	annual stream flow variation	ASFV Ratio = 93.5	2	ULS Surface Water Hydrology Technical Report 2004
X_3	maximum summer stream temperature	65 degrees F	4	ULS Surface Water Quality Technical Report 2004
X_4	nitrate nitrogen	0.37 mg/l (data source)	3	ULS Surface Water Quality Technical Report 2004
X_5	fish food abundance	>500 organisms/square foot, only used in Model I, but same as X_9 in Model II	N/A	Utah Division of Wildlife Resources Field Data 2000
X_6	fish food diversity	D_s = XX, only used in Model I	N/A	
X_7	cover	32 (% cover)	2	Utah Division of Wildlife Resources Field Data 2000
X_8	eroding stream banks (bank stability)	0 (% eroding)	4	Utah Division of Wildlife Resources Field Data 2000
X_9	substrate	Same as X_5	4	Utah Division of Wildlife Resources Field Data 2000
X_{10}	water velocity	Time of Travel = 1.7 ft/sec	4	Utah Division of Wildlife Resources Field Data 2000
X_{11}	stream width	40 feet	3	Utah Division of Wildlife Resources Field Data 2000

$S = (X_7)(X_8)(X_{11})$ = shelter index	$\log(Y+1) = (-0.903)+(0.807)\log(X_1+1)+(0.877)\log(X_2+1)+(1.233)\log(X_3+1)+(0.631)\log(F+1)+(0.182)\log(S+1)$
$F = (X_3)(X_4)(X_9)(X_{10})$ = food index	Y = predicted trout standing crop (lbs/acre)
X_1+1 1	log(Y+1) = 2.073877
X_2+1 3	Y = 118 lbs/acre
X_3+1 5	
F+1 193	
S+1 25	

Habitat Quality Index (Model II) Attribute Rating Summary Sheet

Stream:	Provo River Preferred Alternative	Location:	Murdock DD to I-15 3
Date Data Collection:	August 2001; 1990 to 1999; 2004	HQI Score:	609 lbs/acre
Trout Standing Crop:	lbs/acres		658 trout habitat units
	(cyanide sample or other method)		

Provo 1400 North

Attribute (Symbol)	(name)	Data	Rating	Data Sources
X_1	late summer stream flow (critical period stream flow - CPSF)	Gauge location: ADF = 157 cfs; Avg CPF = 62 cfs Avg CPF/ADF = 40% ADF	3	ULS Surface Water Hydrology Technical Report 2004
X_2	annual stream flow variation	ASFV Ratio = 7.9	4	ULS Surface Water Hydrology Technical Report 2004
X_3	maximum summer stream temperature	60 degrees F	4	ULS Surface Water Quality Technical Report 2004
X_4	nitrate nitrogen	0.34 mg/l (data source)	3	ULS Surface Water Quality Technical Report 2004
X_5	fish food abundance	>500 organisms/square foot, only used in Model I, but same as X_9 in Model II	N/A	Utah Division of Wildlife Resources Field Data 2000
X_6	fish food diversity	D_s = XX, only used in Model I	N/A	
X_7	cover	48 (% cover)	3	Utah Division of Wildlife Resources Field Data 2000
X_8	eroding stream banks (bank stability)	0 (% eroding)	4	Utah Division of Wildlife Resources Field Data 2000
X_9	substrate	Same as X_5	4	Utah Division of Wildlife Resources Field Data 2000
X_{10}	water velocity	Time of Travel = 1.7 ft/sec	4	Utah Division of Wildlife Resources Field Data 2000
X_{11}	stream width	40 feet	3	Utah Division of Wildlife Resources Field Data 2000

$S = (X_7)(X_8)(X_{11})$ = shelter index	$\log(Y+1) = (-0.903)+(0.807)\log(X_1+1)+(0.877)\log(X_2+1)+(1.233)\log(X_3+1)+(0.631)\log(F+1)+(0.182)\log(S+1)$
$F = (X_3)(X_4)(X_9)(X_{10})$ = food index	Y = predicted trout standing crop (lbs/acre)
X_1+1 4	log(Y+1) = 2.785288
X_2+1 5	Y = 609 lbs/acre
X_3+1 5	
F+1 193	
S+1 37	

Habitat Quality Index (Model II) Attribute Rating Summary Sheet

Stream:	Provo River BUW Alternative	Location:	Murdock DD to I-15 3
Date Data Collection:	August 2001; 1990 to 1999; 2004	HQI Score:	369 lbs/acre
Trout Standing Crop:	lbs/acres		399 trout habitat units
	(cyanide sample or other method)		

Provo 1400 North

Attribute (Symbol)	(name)	Data	Rating	Data Sources
X_1	late summer stream flow (critical period stream flow - CPSF)	Gauge location: ADF = 135 cfs; Avg CPF = 28 cfs Avg CPF/ADF = 21% ADF	2	ULS Surface Water Hydrology Technical Report 2004
X_2	annual stream flow variation	ASFV Ratio = 15.9	3	ULS Surface Water Hydrology Technical Report 2004
X_3	maximum summer stream temperature	65 degrees F	4	ULS Surface Water Quality Technical Report 2004
X_4	nitrate nitrogen	0.37 mg/l (data source)	3	ULS Surface Water Quality Technical Report 2004
X_5	fish food abundance	>500 organisms/square foot, only used in Model I, but same as X_9 in Model II	N/A	Utah Division of Wildlife Resources Field Data 2000
X_6	fish food diversity	D_s = XX, only used in Model I	N/A	
X_7	cover	32 (% cover)	2	Utah Division of Wildlife Resources Field Data 2000
X_8	eroding stream banks (bank stability)	0 (% eroding)	4	Utah Division of Wildlife Resources Field Data 2000
X_9	substrate	Same as X_5	4	Utah Division of Wildlife Resources Field Data 2000
X_{10}	water velocity	Time of Travel = 1.7 ft/sec	4	Utah Division of Wildlife Resources Field Data 2000
X_{11}	stream width	40 feet	3	Utah Division of Wildlife Resources Field Data 2000

$S = (X_7)(X_8)(X_{11})$ = shelter index		$\log(Y+1) = (-0.903)+(0.807)\log(X_1+1)+(0.877)\log(X_2+1)+(1.233)\log(X_3+1)+(0.631)\log(F+1)+(0.182)\log(S+1)$	
$F = (X_3)(X_4)(X_9)(X_{10})$ = food index		Y = predicted trout standing crop (lbs/acre)	
X_1+1	3	log(Y+1) =	2.568485
X_2+1	4	Y =	369 lbs/acre
X_3+1	5		
F+1	193		
S+1	25		

Habitat Quality Index (Model II) Attribute Rating Summary Sheet

Stream:	Provo River Baseline	Location:	Murdock DD to I-15 4
Date Data Collection:	August 2001; 1990 to 1999; 2003; 2004	HQI Score:	69 lbs/acre
Trout Standing Crop:	lbs/acres		74 trout habitat units
	(cyanide sample or other method)		

Provo 600 West 600 North

Attribute (Symbol)	(name)	Data	Rating	Data Sources
X_1	late summer stream flow (critical period stream flow - CPSF)	Gauge location: ADF = 114 cfs; Avg CPF = 5 cfs Avg CPF/ADF = 4.4% ADF	0	ULS Surface Water Hydrology Technical Report 2004
X_2	annual stream flow variation	ASFV Ratio = 93.5	2	ULS Surface Water Hydrology Technical Report 2004
X_3	maximum summer stream temperature	65 degrees F	4	ULS Surface Water Quality Technical Report 2004
X_4	nitrate nitrogen	0.37 mg/l (data source)	3	ULS Surface Water Quality Technical Report 2004
X_5	fish food abundance	375 organisms/square foot, only used in Model I, but same as X_9 in Model II	N/A	MWH Field Data 2003
X_6	fish food diversity	D_s = XX, only used in Model I	N/A	
X_7	cover	20 (% cover)	1	Utah Division of Wildlife Resources Field Data 2001
X_8	eroding stream banks (bank stability)	10 (% eroding)	3	Utah Division of Wildlife Resources Field Data 2001
X_9	substrate	Same as X_5 (Estimated)	3	MWH Field Data 2003
X_{10}	water velocity	Time of Travel = 1.0 ft/sec	3	Utah Division of Wildlife Resources Field Data 2001
X_{11}	stream width	37 feet	3	Utah Division of Wildlife Resources Field Data 2001

$S = (X_7)(X_8)(X_{11})$ = shelter index	$\log(Y+1) = (-0.903)+(0.807)\log(X_1+1)+(0.877)\log(X_2+1)+(1.233)\log(X_3+1)+(0.631)\log(F+1)+(0.182)\log(S+1)$
$F = (X_3)(X_4)(X_9)(X_{10})$ = food index	Y = predicted trout standing crop (lbs/acre)
X_1+1 1	log(Y+1) = 1.844881
X_2+1 3	Y = 69 lbs/acre
X_3+1 5	
F+1 109	
S+1 10	

Habitat Quality Index (Model II) Attribute Rating Summary Sheet

Stream:	Provo River Preferred Alternative	Location:	Murdock DD to I-15 4
Date Data Collection:	August 2001; 1990 to 1999; 2003; 2004	HQI Score:	539 lbs/acre
Trout Standing Crop:	lbs/acres		582 trout habitat units
	(cyanide sample or other method)		

Provo 600 West 600 North

Attribute (Symbol)	(name)	Data	Rating	Data Sources
X_1	late summer stream flow (critical period stream flow - CPSF)	Gauge location: ADF = 157 cfs; Avg CPF = 62 cfs Avg CPF/ADF = 40% ADF	3	ULS Surface Water Hydrology Technical Report 2004
X_2	annual stream flow variation	ASFV Ratio = 7.9	4	ULS Surface Water Hydrology Technical Report 2004
X_3	maximum summer stream temperature	60 degrees F	4	ULS Surface Water Quality Technical Report 2004
X_4	nitrate nitrogen	0.34 mg/l (data source)	3	ULS Surface Water Quality Technical Report 2004
X_5	fish food abundance	>500 organisms/square foot, only used in Model I, but same as X_9 in Model II	N/A	MWH Field Data 2003
X_6	fish food diversity	D_s = XX, only used in Model I	N/A	
X_7	cover	33 (% cover)	2	Utah Division of Wildlife Resources Field Data 2001
X_8	eroding stream banks (bank stability)	10 (% eroding)	3	Utah Division of Wildlife Resources Field Data 2001
X_9	substrate	Same as X_5 (Estimated)	4	MWH Field Data 2003
X_{10}	water velocity	Time of Travel = 1.5 ft/sec	4	Utah Division of Wildlife Resources Field Data 2001
X_{11}	stream width	37 feet	3	Utah Division of Wildlife Resources Field Data 2001

$S = (X_7)(X_8)(X_{11})$ = shelter index	$\log(Y+1) = (-0.903)+(0.807)\log(X_1+1)+(0.877)\log(X_2+1)+(1.233)\log(X_3+1)+(0.631)\log(F+1)+(0.182)\log(S+1)$
$F = (X_3)(X_4)(X_9)(X_{10})$ = food index	Y = predicted trout standing crop (lbs/acre)
X_1+1 4	log(Y+1) = 2.732609
X_2+1 5	Y = 539 lbs/acre
X_3+1 5	
F+1 193	
S+1 19	

Habitat Quality Index (Model II) Attribute Rating Summary Sheet

Stream:	Provo River BUW Alternative	Location:	Murdock DD to I-15 4
Date Data Collection:	August 2001; 1990 to 1999; 2003; 2004	HQI Score:	218 lbs/acre
Trout Standing Crop:	lbs/acres		235 trout habitat units
	(cyanide sample or other method)		

Provo 600 West 600 North

Attribute (Symbol)	(name)	Data	Rating	Data Sources
X_1	late summer stream flow (critical period stream flow - CPSF)	Gauge location: ADF = 135 cfs; Avg CPF = 28 cfs Avg CPF/ADF = 21% ADF	2	ULS Surface Water Hydrology Technical Report 2004
X_2	annual stream flow variation	ASFV Ratio = 15.9	3	ULS Surface Water Hydrology Technical Report 2004
X_3	maximum summer stream temperature	65 degrees F	4	ULS Surface Water Quality Technical Report 2004
X_4	nitrate nitrogen	0.37 mg/l (data source)	3	ULS Surface Water Quality Technical Report 2004
X_5	fish food abundance	375 organisms/square foot, only used in Model I, but same as X_9 in Model II	N/A	MWH Field Data 2003
X_6	fish food diversity	D_s = XX, only used in Model I	N/A	
X_7	cover	20 (% cover)	1	Utah Division of Wildlife Resources Field Data 2001
X_8	eroding stream banks (bank stability)	10 (% eroding)	3	Utah Division of Wildlife Resources Field Data 2001
X_9	substrate	Same as X_5 (Estimated)	3	MWH Field Data 2003
X_{10}	water velocity	Time of Travel = 1.0 ft/sec	3	Utah Division of Wildlife Resources Field Data 2001
X_{11}	stream width	37 feet	3	Utah Division of Wildlife Resources Field Data 2001

$S = (X_7)(X_8)(X_{11})$ = shelter index	$\log(Y+1) = (-0.903)+(0.807)\log(X_1+1)+(0.877)\log(X_2+1)+(1.233)\log(X_3+1)+(0.631)\log(F+1)+(0.182)\log(S+1)$
$F = (X_3)(X_4)(X_9)(X_{10})$ = food index	Y = predicted trout standing crop (lbs/acre)
X_1+1 3	log(Y+1) = 2.33949
X_2+1 4	Y = 218 lbs/acre
X_3+1 5	
F+1 109	
S+1 10	

Habitat Quality Index (Model II) Attribute Rating Summary Sheet

Stream:	Provo River Baseline	Location:	I-15 to Utah Lake
Date Data Collection:	August 2001; 1990 to 1999; 2004	HQI Score:	86 lbs/acre
Trout Standing Crop:	lbs/acres		93 trout habitat units
	(cyanide sample or other method)		

1/2 mile above weir

Attribute (Symbol)	(name)	Data	Rating	Data Sources
X_1	late summer stream flow (critical period stream flow - CPSF)	Gauge location: ADF = 114 cfs; Avg CPF = 5 cfs Avg CPF/ADF = 4.4% ADF	0	ULS Surface Water Hydrology Technical Report 2004
X_2	annual stream flow variation	ASFV Ratio = 93.5	2	ULS Surface Water Hydrology Technical Report 2004
X_3	maximum summer stream temperature	65 degrees F	4	ULS Surface Water Quality Technical Report 2004
X_4	nitrate nitrogen	0.37 mg/l (data source)	3	ULS Surface Water Quality Technical Report 2004
X_5	fish food abundance	>500 organisms/square foot, only used in Model I, but same as X_9 in Model II	N/A	Utah Division of Wildlife Resources Field Data 2001
X_6	fish food diversity	D_s = XX, only used in Model I	N/A	
X_7	cover	56 (% cover)	4	Utah Division of Wildlife Resources Field Data 2001
X_8	eroding stream banks (bank stability)	0 (% eroding)	4	Utah Division of Wildlife Resources Field Data 2001
X_9	substrate	Same as X_5	4	Utah Division of Wildlife Resources Field Data 2001
X_{10}	water velocity	Time of Travel = 0.5 ft/sec	2	Utah Division of Wildlife Resources Field Data 2001
X_{11}	stream width	40 feet	3	Utah Division of Wildlife Resources Field Data 2001

$S = (X_7)(X_8)(X_{11})$ = shelter index		$\log(Y+1) = (-0.903)+(0.807)\log(X_1+1)+(0.877)\log(X_2+1)+(1.233)\log(X_3+1)+(0.631)\log(F+1)+(0.182)\log(S+1)$	
$F = (X_3)(X_4)(X_9)(X_{10})$ = food index		Y = predicted trout standing crop (lbs/acre)	
X_1+1	1	log(Y+1) =	1.938534
X_2+1	3	Y =	86 lbs/acre
X_3+1	5		
F+1	97		
S+1	49		

Habitat Quality Index (Model II) Attribute Rating Summary Sheet

Stream:	Provo River Preferred Alternative	Location:	I-15 to Utah Lake
Date Data Collection:	August 2001; 1990 to 1999; 2004	HQI Score:	415 lbs/acre
Trout Standing Crop:	lbs/acres		448 trout habitat units
	(cyanide sample or other method)		

1/2 mile above weir

Attribute (Symbol)	(name)	Data	Rating	Data Sources
X_1	late summer stream flow (critical period stream flow - CPSF)	Gauge location: ADF = 157 cfs; Avg CPF = 62 cfs Avg CPF/ADF = 40% ADF	3	ULS Surface Water Hydrology Technical Report 2004
X_2	annual stream flow variation	ASFV Ratio = 7.9	4	ULS Surface Water Hydrology Technical Report 2004
X_3	maximum summer stream temperature	60 degrees F	4	ULS Surface Water Quality Technical Report 2004
X_4	nitrate nitrogen	0.34 mg/l (data source)	3	ULS Surface Water Quality Technical Report 2004
X_5	fish food abundance	>500 organisms/square foot, only used in Model I, but same as X_9 in Model II	N/A	Utah Division of Wildlife Resources Field Data 2001
X_6	fish food diversity	D_s = XX, only used in Model I	N/A	
X_7	cover	56 (% cover)	4	Utah Division of Wildlife Resources Field Data 2001
X_8	eroding stream banks (bank stability)	0 (% eroding)	4	Utah Division of Wildlife Resources Field Data 2001
X_9	substrate	Same as X_5	4	Utah Division of Wildlife Resources Field Data 2001
X_{10}	water velocity	Time of Travel = 0.8 ft/sec	2	Utah Division of Wildlife Resources Field Data 2001
X_{11}	stream width	42 feet	3	Utah Division of Wildlife Resources Field Data 2001

$S = (X_7)(X_8)(X_{11})$ = shelter index	$\log(Y+1) = (-0.903)+(0.807)\log(X_1+1)+(0.877)\log(X_2+1)+(1.233)\log(X_3+1)+(0.631)\log(F+1)+(0.182)\log(S+1)$
$F = (X_3)(X_4)(X_9)(X_{10})$ = food index	Y = predicted trout standing crop (lbs/acre)
X_1+1 4	log(Y+1) = 2.618958
X_2+1 5	Y = 415 lbs/acre
X_3+1 5	
F+1 97	
S+1 49	

Habitat Quality Index (Model II) Attribute Rating Summary Sheet

Stream:	Provo River BUW Alternative	Location:	I-15 to Utah Lake
Date Data Collection:	August 2001; 1990 to 1999; 2004	HQI Score:	270 lbs/acre
Trout Standing Crop:	lbs/acres		292 trout habitat units
	(cyanide sample or other method)		

1/2 mile above weir

Attribute (Symbol)	(name)	Data	Rating	Data Sources
X_1	late summer stream flow (critical period stream flow - CPSF)	Gauge location: ADF = 135 cfs; Avg CPF = 28 cfs Avg CPF/ADF = 21% ADF	2	ULS Surface Water Hydrology Technical Report 2004
X_2	annual stream flow variation	ASFV Ratio = 15.9	3	ULS Surface Water Hydrology Technical Report 2004
X_3	maximum summer stream temperature	65 degrees F	4	ULS Surface Water Quality Technical Report 2004
X_4	nitrate nitrogen	0.37 mg/l (data source)	3	ULS Surface Water Quality Technical Report 2004
X_5	fish food abundance	>500 organisms/square foot, only used in Model I, but same as X_9 in Model II	N/A	Utah Division of Wildlife Resources Field Data 2001
X_6	fish food diversity	D_s = XX, only used in Model I	N/A	
X_7	cover	56 (% cover)	4	Utah Division of Wildlife Resources Field Data 2001
X_8	eroding stream banks (bank stability)	0 (% eroding)	4	Utah Division of Wildlife Resources Field Data 2001
X_9	substrate	Same as X_5	4	Utah Division of Wildlife Resources Field Data 2001
X_{10}	water velocity	Time of Travel = 0.5 ft/sec	2	Utah Division of Wildlife Resources Field Data 2001
X_{11}	stream width	40 feet	3	Utah Division of Wildlife Resources Field Data 2001

$S = (X_7)(X_8)(X_{11})$ = shelter index	$\log(Y+1) = (-0.903)+(0.807)\log(X_1+1)+(0.877)\log(X_2+1)+(1.233)\log(X_3+1)+(0.631)\log(F+1)+(0.182)\log(S+1)$
$F = (X_3)(X_4)(X_9)(X_{10})$ = food index	Y = predicted trout standing crop (lbs/acre)
X_1+1 3	log(Y+1) = 2.433142
X_2+1 4	Y = 270 lbs/acre
X_3+1 5	
F+1 97	
S+1 49	

Habitat Quality Index (Model II) Attribute Rating Summary Sheet

Stream:	Hobble Creek Baseline	Location:	F.S. Boundary to Averette Ave.
Date Data Collection:	8/5/98; WQ 1990-1999	HQI Score:	10 lbs/acre
Trout Standing Crop:	lbs/acres		11 trout habitat units
	(cyanide sample or other method)		

Attribute (Symbol)	(name)	Data	Rating	Data Sources
X_1	late summer stream flow (critical period stream flow - CPSF)	Gauge location: ADF = 30 cfs; Avg CPF = 1 cfs Avg CPF/ADF = 3.3% ADF	0	ULS Surface Water Hydrology Technical Report 2004
X_2	annual stream flow variation	ASFV Ratio = 109	1	ULS Surface Water Hydrology Technical Report 2004
X_3	maximum summer stream temperature	74 degrees F	2	ULS Surface Water Quality Technical Report 2004
X_4	nitrate nitrogen	0.7 mg/l (data source)	2	ULS Surface Water Quality Technical Report 2004
X_5	fish food abundance	38 organisms/square foot, only used in Model I, but same as X_9 in Model II	N/A	Utah Division of Wildlife Resources Field Data 1998
X_6	fish food diversity	D_s = XX, only used in Model I	N/A	
X_7	cover	47 (% cover)	3	Utah Division of Wildlife Resources Field Data 1998
X_8	eroding stream banks (bank stability)	0 (% eroding)	4	Utah Division of Wildlife Resources Field Data 1998
X_9	substrate	Same as X_5	1	Utah Division of Wildlife Resources Field Data 1998
X_{10}	water velocity	Time of Travel = 2.4 ft/sec	4	Utah Division of Wildlife Resources Field Data 1998
X_{11}	stream width	22 feet	4	Utah Division of Wildlife Resources Field Data 1998

$S = (X_7)(X_8)(X_{11})$ = shelter index		$\log(Y+1) = (-0.903)+(0.807)\log(X_1+1)+(0.877)\log(X_2+1)+(1.233)\log(X_3+1)+(0.631)\log(F+1)+(0.182)\log(S+1)$	
$F = (X_3)(X_4)(X_9)(X_{10})$ = food index		Y = predicted trout standing crop (lbs/acre)	
X_1+1	1	log(Y+1) =	1.033323
X_2+1	2	Y =	10 lbs/acre
X_3+1	3		
F+1	17		
S+1	49		

Habitat Quality Index (Model II) Attribute Rating Summary Sheet

Stream:	Hobble Creek Preferred Alternative	Location:	F.S. Boundary to Averette Ave.
Date Data Collection:	8/5/98; WQ 1990-1999	HQI Score:	354 lbs/acre
Trout Standing Crop:	lbs/acres		382 trout habitat units
	(cyanide sample or other method)		

Attribute (Symbol)	(name)	Data	Rating	Data Sources
X_1	late summer stream flow (critical period stream flow - CPSF)	Gauge location: ADF = 46 cfs; Avg CPF = 10 cfs Avg CPF/ADF = 21.7% ADF	2	ULS Surface Water Hydrology Technical Report 2004
X_2	annual stream flow variation	ASFV Ratio = 14.5	4	ULS Surface Water Hydrology Technical Report 2004
X_3	maximum summer stream temperature	58 degrees F	4	ULS Surface Water Quality Technical Report 2004
X_4	nitrate nitrogen	0.5 mg/l (data source)	3	ULS Surface Water Quality Technical Report 2004
X_5	fish food abundance	250 organisms/square foot, only used in Model I, but same as X_9 in Model II	N/A	Estimated based on ULS Field Studies 2003
X_6	fish food diversity	D_s = XX, only used in Model I	N/A	
X_7	cover	47 (% cover)	3	Utah Division of Wildlife Resources Field Data 1998
X_8	eroding stream banks (bank stability)	0 (% eroding)	4	Utah Division of Wildlife Resources Field Data 1998
X_9	substrate	Same as X_5	3	Utah Division of Wildlife Resources Field Data 1998
X_{10}	water velocity	Time of Travel = 2.7 ft/sec	3	ULS Field Studies 2003
X_{11}	stream width	22 feet	4	Utah Division of Wildlife Resources Field Data 1998

$S = (X_7)(X_8)(X_{11})$ = shelter index		$\log(Y+1) = (-0.903)+(0.807)\log(X_1+1)+(0.877)\log(X_2+1)+(1.233)\log(X_3+1)+(0.631)\log(F+1)+(0.182)\log(S+1)$	
$F = (X_3)(X_4)(X_9)(X_{10})$ = food index		Y = predicted trout standing crop (lbs/acre)	
X_1+1	3	log(Y+1) =	2.550095
X_2+1	5	Y =	354 lbs/acre
X_3+1	5		
F+1	109		
S+1	49		

Habitat Quality Index (Model II) Attribute Rating Summary Sheet

Stream:	Hobble Creek BUW Alternative	Location:	F.S. Boundary to Averette Ave.
Date Data Collection:	8/5/98; WQ 1990-1999	HQI Score:	447 lbs/acre
Trout Standing Crop:	lbs/acres		482 trout habitat units
	(cyanide sample or other method)		

Attribute (Symbol)	(name)	Data	Rating	Data Sources
X_1	late summer stream flow (critical period stream flow - CPSF)	Gauge location: ADF = 62 cfs; Avg CPF = 33 cfs Avg CPF/ADF = 53.2% ADF	3	ULS Surface Water Hydrology Technical Report 2004
X_2	annual stream flow variation	ASFV Ratio = 4.6	4	ULS Surface Water Hydrology Technical Report 2004
X_3	maximum summer stream temperature	58 degrees F	4	ULS Surface Water Quality Technical Report 2004
X_4	nitrate nitrogen	0.4 mg/l (data source)	3	ULS Surface Water Quality Technical Report 2004
X_5	fish food abundance	250 organisms/square foot, only used in Model I, but same as X_9 in Model II	N/A	Estimate based on ULS Field Studies 2003
X_6	fish food diversity	D_s = XX, only used in Model I	N/A	
X_7	cover	47 (% cover)	3	Utah Division of Wildlife Resources Field Data 1998
X_8	eroding stream banks (bank stability)	0 (% eroding)	4	Utah Division of Wildlife Resources Field Data 1998
X_9	substrate	Same as X_5	3	Utah Division of Wildlife Resources Field Data 1998
X_{10}	water velocity	Time of Travel = 2.8 ft/sec	3	ULS Field Studies 2003
X_{11}	stream width	22 feet	4	Utah Division of Wildlife Resources Field Data 1998

$S = (X_7)(X_8)(X_{11})$ = shelter index		$\log(Y+1) = (-0.903)+(0.807)\log(X_1+1)+(0.877)\log(X_2+1)+(1.233)\log(X_3+1)+(0.631)\log(F+1)+(0.182)\log(S+1)$	
$F = (X_3)(X_4)(X_9)(X_{10})$ = food index		Y = predicted trout standing crop (lbs/acre)	
X_1+1	4	log(Y+1) =	2.650921
X_2+1	5	Y =	447 lbs/acre
X_3+1	5		
F+1	109		
S+1	49		

Habitat Quality Index (Model II) Attribute Rating Summary Sheet			
Stream:	Hobble Creek Baseline	Location:	Averette Ave. to Utah Lake
Date Data Collection:	8/5/98; WQ 1990-1999	HQI Score:	15 lbs/acre
Trout Standing Crop:	lbs/acres		16 trout habitat units
	(cyanide sample or other method)		

Attribute (Symbol)	(name)	Data	Rating	Data Sources
X_1	late summer stream flow (critical period stream flow - CPSF)	Gauge location: ADF = 30 cfs; Avg CPF = 1 cfs Avg CPF/ADF = 3.3% ADF	0	ULS Surface Water Hydrology Technical Report 2004
X_2	annual stream flow variation	ASFV Ratio = 109	1	ULS Surface Water Hydrology Technical Report 2004
X_3	maximum summer stream temperature	74 degrees F	2	ULS Surface Water Quality Technical Report 2004
X_4	nitrate nitrogen	0.7 mg/l (data source)	2	ULS Surface Water Quality Technical Report 2004
X_5	fish food abundance	143 organisms/square foot, only used in Model I, but same as X_9 in Model II	N/A	Utah Division of Wildlife Resources Field Data 1998
X_6	fish food diversity	D_s = XX, only used in Model I	N/A	
X_7	cover	53 (% cover)	3	Utah Division of Wildlife Resources Field Data 1998
X_8	eroding stream banks (bank stability)	0 (% eroding)	4	Utah Division of Wildlife Resources Field Data 1998
X_9	substrate	Same as X_5	2	Utah Division of Wildlife Resources Field Data 1998
X_{10}	water velocity	Time of Travel = 2.26 ft/sec	4	Utah Division of Wildlife Resources Field Data 1998
X_{11}	stream width	23.6 feet	3	Utah Division of Wildlife Resources Field Data 1998

$S = (X_7)(X_8)(X_{11})$ = shelter index	$\log(Y+1) = (-0.903)+(0.807)\log(X_1+1)+(0.877)\log(X_2+1)+(1.233)\log(X_3+1)+(0.631)\log(F+1)+(0.182)\log(S+1)$
$F = (X_3)(X_4)(X_9)(X_{10})$ = food index	Y = predicted trout standing crop (lbs/acre)
X_1+1 1	log(Y+1) = 1.192889
X_2+1 2	Y = 15 lbs/acre
X_3+1 3	
F+1 33	
S+1 37	

Habitat Quality Index (Model II) Attribute Rating Summary Sheet

Stream:	Hobble Creek Preferred Alternative	Location:	Averette Ave. to Utah Lake
Date Data Collection:	8/5/98; WQ 1990-1999	HQI Score:	403 lbs/acre
Trout Standing Crop:	lbs/acres		435 trout habitat units
	(cyanide sample or other method)		

Attribute (Symbol)	(name)	Data	Rating	Data Sources
X_1	late summer stream flow (critical period stream flow - CPSF)	Gauge location: ADF = 46 cfs; Avg CPF = 10 cfs Avg CPF/ADF = 21.7% ADF	2	ULS Surface Water Hydrology Technical Report 2004
X_2	annual stream flow variation	ASFV Ratio = 14.5	4	ULS Surface Water Hydrology Technical Report 2004
X_3	maximum summer stream temperature	58 degrees F	4	ULS Surface Water Quality Technical Report 2004
X_4	nitrate nitrogen	0.5 mg/l (data source)	3	ULS Surface Water Quality Technical Report 2004
X_5	fish food abundance	250 organisms/square foot, only used in Model I, but same as X_9 in Model II	N/A	Estimate based on ULS Field Studies 2003
X_6	fish food diversity	D_s = XX, only used in Model I	N/A	
X_7	cover	53 (% cover)	3	Utah Division of Wildlife Resources Field Data 1998
X_8	eroding stream banks (bank stability)	0 (% eroding)	4	Utah Division of Wildlife Resources Field Data 1998
X_9	substrate	Same as X_5	3	Utah Division of Wildlife Resources Field Data 1998
X_{10}	water velocity	Time of Travel = 2.3 ft/sec	4	ULS Field Studies 2003
X_{11}	stream width	24 feet	3	Utah Division of Wildlife Resources Field Data 1998

$S = (X_7)(X_8)(X_{11})$ = shelter index	$\log(Y+1) = (-0.903)+(0.807)\log(X_1+1)+(0.877)\log(X_2+1)+(1.233)\log(X_3+1)+(0.631)\log(F+1)+(0.182)\log(S+1)$
$F = (X_3)(X_4)(X_9)(X_{10})$ = food index	Y = predicted trout standing crop (lbs/acre)
X_1+1 3	log(Y+1) = 2.606099
X_2+1 5	Y = 403 lbs/acre
X_3+1 5	
F+1 145	
S+1 37	

Habitat Quality Index (Model II) Attribute Rating Summary Sheet

Stream:	Hobble Creek BUW Alternative	Location:	Averette Ave. to Utah Lake
Date Data Collection:	8/5/98; WQ 1990-1999	HQI Score:	508 lbs/acre
Trout Standing Crop:	lbs/acres		549 trout habitat units
	(cyanide sample or other method)		

Attribute (Symbol)	(name)	Data	Rating	Data Sources
X_1	late summer stream flow (critical period stream flow - CPSF)	Gauge location: ADF = 62 cfs; Avg CPF = 33 cfs Avg CPF/ADF = 53.2% ADF	3	ULS Surface Water Hydrology Technical Report 2004
X_2	annual stream flow variation	ASFV Ratio = 4.6	4	ULS Surface Water Hydrology Technical Report 2004
X_3	maximum summer stream temperature	58 degrees F	4	ULS Surface Water Quality Technical Report 2004
X_4	nitrate nitrogen	0.4 mg/l (data source)	3	ULS Surface Water Quality Technical Report 2004
X_5	fish food abundance	250 organisms/square foot, only used in Model I, but same as X_9 in Model II	N/A	Estimate based on ULS Field Studies 2003
X_6	fish food diversity	D_s = XX, only used in Model I	N/A	
X_7	cover	53 (% cover)	3	Utah Division of Wildlife Resources Field Data 1998
X_8	eroding stream banks (bank stability)	0 (% eroding)	4	Utah Division of Wildlife Resources Field Data 1998
X_9	substrate	Same as X_5	3	Utah Division of Wildlife Resources Field Data 1998
X_{10}	water velocity	Time of Travel = 2.4 ft/sec	4	ULS Field Studies 2003
X_{11}	stream width	24.5 feet	3	Utah Division of Wildlife Resources Field Data 1998

$S = (X_7)(X_8)(X_{11})$ = shelter index		$\log(Y+1) = (-0.903)+(0.807)\log(X_1+1)+(0.877)\log(X_2+1)+(1.233)\log(X_3+1)+(0.631)\log(F+1)+(0.182)\log(S+1)$	
$F = (X_3)(X_4)(X_9)(X_{10})$ = food index		Y = predicted trout standing crop (lbs/acre)	
X_1+1	4	log(Y+1) =	2.706925
X_2+1	5	Y =	508 lbs/acre
X_3+1	5		
F+1	145		
S+1	37		

Habitat Quality Index (Model II) Attribute Rating Summary Sheet

Stream:	Spanish Fork River Baseline	Location:	Dia. Fk. to Span. Fk. Div. Dam
Date Data Collection:	1990 to 1999; DF FS-FEIS	HQI Score:	151 lbs/acre
Trout Standing Crop:	lbs/acres (cyanide sample or other method)		163 trout habitat units

Attribute (Symbol)	(name)	Data	Rating	Data Sources
X_1	late summer stream flow (critical period stream flow - CPSF)	Gauge location: ADF = 365 cfs; Avg CPF = 358 cfs Avg CPF/ADF = 98% ADF	4	ULS Surface Water Hydrology Technical Report 2004
X_2	annual stream flow variation	ASFV Ratio = 4.7	4	ULS Surface Water Hydrology Technical Report 2004
X_3	maximum summer stream temperature	58 degrees F	4	ULS Surface Water Quality Technical Report 2004
X_4	nitrate nitrogen	0.19 mg/l (data source)	4	ULS Surface Water Quality Technical Report 2004
X_5	fish food abundance	25 to 99 organisms/square foot, only used in Model I, but same as X_9 in Model II	N/A	MWH Field Data 1998, Diamond Fork FS-FEIS 1999
X_6	fish food diversity	D_s = XX, only used in Model I	N/A	
X_7	cover	10 to 25 (% cover)	1	MWH Field Data 1998, Diamond Fork FS-FEIS 1999
X_8	eroding stream banks (bank stability)	50 to 74 (% eroding)	1	MWH Field Data 1998, Diamond Fork FS-FEIS 1999
X_9	substrate	Same as X_5	1	MWH Field Data 1998, Diamond Fork FS-FEIS 1999
X_{10}	water velocity	Time of Travel = 3.2 ft/sec	2	MWH Field Data 1998, Diamond Fork FS-FEIS 1999
X_{11}	stream width	52 feet	2	MWH Field Data 1998, Diamond Fork FS-FEIS 1999

$S = (X_7)(X_8)(X_{11})$ = shelter index	$\log(Y+1) = (-0.903)+(0.807)\log(X_1+1)+(0.877)\log(X_2+1)+(1.233)\log(X_3+1)+(0.631)\log(F+1)+(0.182)\log(S+1)$
$F = (X_3)(X_4)(X_9)(X_{10})$ = food index	Y = predicted trout standing crop (lbs/acre)
X_1+1 5	log(Y+1) = 2.180914
X_2+1 5	Y = 151 lbs/acre
X_3+1 5	
F+1 33	
S+1 3	

Habitat Quality Index (Model II) Attribute Rating Summary Sheet

Stream:	Spanish Fork River Preferred Alternative	Location:	Dia. Fk. To.Span. Fk. Div. Dam
Date Data Collection:	1990 to 1999; DF FS-FEIS	HQI Score:	159 lbs/acre
Trout Standing Crop:	lbs/acres (cyanide sample or other method)		172 trout habitat units

Attribute (Symbol)	(name)	Data	Rating	Data Sources
X_1	late summer stream flow (critical period stream flow - CPSF)	Gauge location: ADF = 250 cfs; Avg CPF = 243 cfs Avg CPF/ADF = 97% ADF	4	ULS Surface Water Hydrology Technical Report 2004
X_2	annual stream flow variation	ASFV Ratio = 4.7	4	ULS Surface Water Hydrology Technical Report 2004
X_3	maximum summer stream temperature	60 degrees F	4	ULS Surface Water Quality Technical Report 2004
X_4	nitrate nitrogen	0.17 mg/l (data source)	4	ULS Surface Water Quality Technical Report 2004
X_5	fish food abundance	25 to 99 organisms/square foot, only used in Model I, but same as X_9 in Model II	N/A	MWH Field Data 1998, Diamond Fork FS-FEIS 1999
X_6	fish food diversity	D_s = XX, only used in Model I	N/A	
X_7	cover	10 to 25 (% cover)	1	MWH Field Data 1998, Diamond Fork FS-FEIS 1999
X_8	eroding stream banks (bank stability)	50 to 74 (% eroding)	1	MWH Field Data 1998, Diamond Fork FS-FEIS 1999
X_9	substrate	Same as X_5	1	MWH Field Data 1998, Diamond Fork FS-FEIS 1999
X_{10}	water velocity	Time of Travel = 3.2 ft/sec	2	MWH Field Data 1998, Diamond Fork FS-FEIS 1999
X_{11}	stream width	47 feet	3	MWH Field Data 1998, Diamond Fork FS-FEIS 1999

$S = (X_7)(X_8)(X_{11})$ = shelter index		$\log(Y+1) = (-0.903)+(0.807)\log(X_1+1)+(0.877)\log(X_2+1)+(1.233)\log(X_3+1)+(0.631)\log(F+1)+(0.182)\log(S+1)$	
$F = (X_3)(X_4)(X_9)(X_{10})$ = food index		Y = predicted trout standing crop (lbs/acre)	
X_1+1	5	log(Y+1) =	2.203653
X_2+1	5	Y =	159 lbs/acre
X_3+1	5		
F+1	33		
S+1	4		

Habitat Quality Index (Model II) Attribute Rating Summary Sheet

Stream:	Spanish Fork River BUW Alternative	Location:	Dia. Fk. To Span. Fk. Div. Dam
Date Data Collection:	1990 to 1999; DF FS-FEIS	HQI Score:	151 lbs/acre
Trout Standing Crop:	lbs/acres		163 trout habitat units
	(cyanide sample or other method)		

Attribute (Symbol)	(name)	Data	Rating	Data Sources
X_1	late summer stream flow (critical period stream flow - CPSF)	Gauge location: ADF = 316 cfs; Avg CPF = 244 cfs Avg CPF/ADF = 77% ADF	4	ULS Surface Water Hydrology Technical Report 2004
X_2	annual stream flow variation	ASFV Ratio = 3.2	4	ULS Surface Water Hydrology Technical Report 2004
X_3	maximum summer stream temperature	61 degrees F	4	ULS Surface Water Quality Technical Report 2004
X_4	nitrate nitrogen	0.20 mg/l (data source)	4	ULS Surface Water Quality Technical Report 2004
X_5	fish food abundance	25 to 99 organisms/square foot, only used in Model I, but same as X_9 in Model II	N/A	MWH Field Data 1998, Diamond Fork FS-FEIS 1999
X_6	fish food diversity	D_s = XX, only used in Model I	N/A	
X_7	cover	10 to 25 (% cover)	1	MWH Field Data 1998, Diamond Fork FS-FEIS 1999
X_8	eroding stream banks (bank stability)	50 to 74 (% eroding)	1	MWH Field Data 1998, Diamond Fork FS-FEIS 1999
X_9	substrate	Same as X_5	1	MWH Field Data 1998, Diamond Fork FS-FEIS 1999
X_{10}	water velocity	Time of Travel = 3.3 ft/sec	2	MWH Field Data 1998, Diamond Fork FS-FEIS 1999
X_{11}	stream width	51 feet	2	MWH Field Data 1998, Diamond Fork FS-FEIS 1999

$S = (X_7)(X_8)(X_{11})$ = shelter index	$\log(Y+1) = (-0.903)+(0.807)\log(X_1+1)+(0.877)\log(X_2+1)+(1.233)\log(X_3+1)+(0.631)\log(F+1)+(0.182)\log(S+1)$
$F = (X_3)(X_4)(X_9)(X_{10})$ = food index	Y = predicted trout standing crop (lbs/acre)
X_1+1 5	log(Y+1) = 2.180914
X_2+1 5	Y = 151 lbs/acre
X_3+1 5	
F+1 33	
S+1 3	

Habitat Quality Index (Model II) Attribute Rating Summary Sheet

Stream:	Spanish Fork River Baseline	Location:	Span. Fk. Div. Dam to E. Bench
Date Data Collection:	1990 to 1999; DF FS-FEIS	HQI Score:	348 lbs/acre
Trout Standing Crop:	lbs/acres		376 trout habitat units
	(cyanide sample or other method)		

Attribute (Symbol)	(name)	Data	Rating	Data Sources
X_1	late summer stream flow (critical period stream flow - CPSF)	Gauge location: ADF = 161 cfs; Avg CPF = 111 cfs Avg CPF/ADF = 69% ADF	4	ULS Surface Water Hydrology Technical Report 2004
X_2	annual stream flow variation	ASFV Ratio = 5.8	4	ULS Surface Water Hydrology Technical Report 2004
X_3	maximum summer stream temperature	58 degrees F	4	ULS Surface Water Quality Technical Report 2004
X_4	nitrate nitrogen	0.19 mg/l (data source)	4	ULS Surface Water Quality Technical Report 2004
X_5	fish food abundance	100 to 249 organisms/square foot, only used in Model I, but same as X_9 in Model II	N/A	MWH Field Data 1998, Diamond Fork FS-FEIS 1999
X_6	fish food diversity	D_s = XX, only used in Model I	N/A	
X_7	cover	10 to 25 (% cover)	1	MWH Field Data 1998, Diamond Fork FS-FEIS 1999
X_8	eroding stream banks (bank stability)	25 to 49 (% eroding)	2	MWH Field Data 1998, Diamond Fork FS-FEIS 1999
X_9	substrate	Same as X_5	2	MWH Field Data 1998, Diamond Fork FS-FEIS 1999
X_{10}	water velocity	Time of Travel = 2.7 ft/sec	3	MWH Field Data 1998, Diamond Fork FS-FEIS 1999
X_{11}	stream width	24 feet	3	MWH Field Data 1998, Diamond Fork FS-FEIS 1999

$S = (X_7)(X_8)(X_{11})$ = shelter index		$\log(Y+1) = (-0.903)+(0.807)\log(X_1+1)+(0.877)\log(X_2+1)+(1.233)\log(X_3+1)+(0.631)\log(F+1)+(0.182)\log(S+1)$	
$F = (X_3)(X_4)(X_9)(X_{10})$ = food index		Y = predicted trout standing crop (lbs/acre)	
X_1+1	5	log(Y+1) =	2.543356
X_2+1	5	Y =	348 lbs/acre
X_3+1	5		
F+1	97		
S+1	7		

Habitat Quality Index (Model II) Attribute Rating Summary Sheet

Stream:	Spanish Fork River Preferred Alternative	Location:	Span. Fk. Div. Dam to E. Bench
Date Data Collection:	1990 to 1999; DF FS-FEIS	HQI Score:	365 lbs/acre
Trout Standing Crop:	lbs/acres		394 trout habitat units
	(cyanide sample or other method)		

Attribute (Symbol)	(name)	Data	Rating	Data Sources
X_1	late summer stream flow (critical period stream flow - CPSF)	Gauge location: ADF = 64 cfs; Avg CPF = 36 cfs Avg CPF/ADF = 56% ADF	4	ULS Surface Water Hydrology Technical Report 2004
X_2	annual stream flow variation	ASFV Ratio = 6.5	4	ULS Surface Water Hydrology Technical Report 2004
X_3	maximum summer stream temperature	60 degrees F	4	ULS Surface Water Quality Technical Report 2004
X_4	nitrate nitrogen	0.17 mg/l (data source)	4	ULS Surface Water Quality Technical Report 2004
X_5	fish food abundance	100 to 249 organisms/square foot, only used in Model I, but same as X_9 in Model II	N/A	MWH Field Data 1998, Diamond Fork FS-FEIS 1999
X_6	fish food diversity	D_s = XX, only used in Model I	N/A	
X_7	cover	10 to 25 (% cover)	1	MWH Field Data 1998, Diamond Fork FS-FEIS 1999
X_8	eroding stream banks (bank stability)	25 to 49 (% eroding)	2	MWH Field Data 1998, Diamond Fork FS-FEIS 1999
X_9	substrate	Same as X_5	2	MWH Field Data 1998, Diamond Fork FS-FEIS 1999
X_{10}	water velocity	Time of Travel = 2.7 ft/sec	3	MWH Field Data 1998, Diamond Fork FS-FEIS 1999
X_{11}	stream width	22 feet	4	MWH Field Data 1998, Diamond Fork FS-FEIS 1999

$S = (X_7)(X_8)(X_{11})$ = shelter index		$\log(Y+1) = (-0.903)+(0.807)\log(X_1+1)+(0.877)\log(X_2+1)+(1.233)\log(X_3+1)+(0.631)\log(F+1)+(0.182)\log(S+1)$	
$F = (X_3)(X_4)(X_9)(X_{10})$ = food index		Y = predicted trout standing crop (lbs/acre)	
X_1+1	5	log(Y+1) =	2.563221
X_2+1	5	Y =	365 lbs/acre
X_3+1	5		
F+1	97		
S+1	9		

Habitat Quality Index (Model II) Attribute Rating Summary Sheet

Stream:	Spanish Fork River BUW Alternative	Location:	Span. Fk. Div. Dam to E. Bench
Date Data Collection:	1990 to 1999; DF FS-FEIS	HQI Score:	291 lbs/acre
Trout Standing Crop:	lbs/acres		314 trout habitat units
	(cyanide sample or other method)		

Attribute (Symbol)	(name)	Data	Rating	Data Sources
X_1	late summer stream flow (critical period stream flow - CPSF)	Gauge location: ADF = 130 cfs; Avg CPF = 38 cfs Avg CPF/ADF = 29% ADF	3	ULS Surface Water Hydrology Technical Report 2004
X_2	annual stream flow variation	ASFV Ratio = 6.1	4	ULS Surface Water Hydrology Technical Report 2004
X_3	maximum summer stream temperature	61 degrees F	4	ULS Surface Water Quality Technical Report 2004
X_4	nitrate nitrogen	0.20 mg/l (data source)	4	ULS Surface Water Quality Technical Report 2004
X_5	fish food abundance	100 to 249 organisms/square foot, only used in Model I, but same as X_9 in Model II	N/A	MWH Field Data 1998, Diamond Fork FS-FEIS 1999
X_6	fish food diversity	D_s = XX, only used in Model I	N/A	
X_7	cover	10 to 25 (% cover)	1	MWH Field Data 1998, Diamond Fork FS-FEIS 1999
X_8	eroding stream banks (bank stability)	25 to 49 (% eroding)	2	MWH Field Data 1998, Diamond Fork FS-FEIS 1999
X_9	substrate	Same as X_5	2	MWH Field Data 1998, Diamond Fork FS-FEIS 1999
X_{10}	water velocity	Time of Travel = 2.7 ft/sec	3	MWH Field Data 1998, Diamond Fork FS-FEIS 1999
X_{11}	stream width	24 feet	3	MWH Field Data 1998, Diamond Fork FS-FEIS 1999

$S = (X_7)(X_8)(X_{11})$ = shelter index		$\log(Y+1) = (-0.903)+(0.807)\log(X_1+1)+(0.877)\log(X_2+1)+(1.233)\log(X_3+1)+(0.631)\log(F+1)+(0.182)\log(S+1)$	
$F = (X_3)(X_4)(X_9)(X_{10})$ = food index		Y = predicted trout standing crop (lbs/acre)	
X_1+1	4	log(Y+1) =	2.46515
X_2+1	5	Y =	291 lbs/acre
X_3+1	5		
F+1	97		
S+1	7		

Habitat Quality Index (Model II) Attribute Rating Summary Sheet

Stream:	Spanish Fork River Baseline	Location:	E. Bench Div. to Mill Race Div.
Date Data Collection:	1990 to 1999; DF FS-FEIS	HQI Score:	348 lbs/acre
Trout Standing Crop:	lbs/acres (cyanide sample or other method)		376 trout habitat units

Attribute (Symbol)	(name)	Data	Rating	Data Sources
X_1	late summer stream flow (critical period stream flow - CPSF)	Gauge location: ADF = 143 cfs; Avg CPF = 82 cfs Avg CPF/ADF = 57% ADF	4	ULS Surface Water Hydrology Technical Report 2004
X_2	annual stream flow variation	ASFV Ratio = 5.5	4	ULS Surface Water Hydrology Technical Report 2004
X_3	maximum summer stream temperature	58 degrees F	4	ULS Surface Water Quality Technical Report 2004
X_4	nitrate nitrogen	0.19 mg/l (data source)	4	ULS Surface Water Quality Technical Report 2004
X_5	fish food abundance	100 to 249 organisms/square foot, only used in Model I, but same as X_9 in Model II	N/A	MWH Field Data 1998, Diamond Fork FS-FEIS 1999
X_6	fish food diversity	D_s = XX, only used in Model I	N/A	
X_7	cover	10 to 25 (% cover)	1	MWH Field Data 1998, Diamond Fork FS-FEIS 1999
X_8	eroding stream banks (bank stability)	25 to 49 (% eroding)	2	MWH Field Data 1998, Diamond Fork FS-FEIS 1999
X_9	substrate	Same as X_5	2	MWH Field Data 1998, Diamond Fork FS-FEIS 1999
X_{10}	water velocity	Time of Travel = 1.4 ft/sec	3	MWH Field Data 1998, Diamond Fork FS-FEIS 1999
X_{11}	stream width	24 feet	3	MWH Field Data 1998, Diamond Fork FS-FEIS 1999

$S = (X_7)(X_8)(X_{11})$ = shelter index		$\log(Y+1) = (-0.903)+(0.807)\log(X_1+1)+(0.877)\log(X_2+1)+(1.233)\log(X_3+1)+(0.631)\log(F+1)+(0.182)\log(S+1)$	
$F = (X_3)(X_4)(X_9)(X_{10})$ = food index		Y = predicted trout standing crop (lbs/acre)	
X_1+1	5	log(Y+1) =	2.543356
X_2+1	5	Y =	348 lbs/acre
X_3+1	5		
F+1	97		
S+1	7		

Habitat Quality Index (Model I) Attribute Rating Summary Sheet

Stream:	Spanish Fork River Preferred Alternative	Location:	E. Bench Div. to Mill Race Div.
Date Data Collection:	1990 to 1999; DF FS-FEIS	HQI Score:	305 lbs/acre
Trout Standing Crop:	lbs/acres		329 trout habitat units
	(cyanide sample or other method)		

Attribute (Symbol)	(name)	Data	Rating	Data Sources
X_1	late summer stream flow (critical period stream flow - CPSF)	Gauge location: ADF = 49 cfs; Avg CPF = 15 cfs Avg CPF/ADF = 31% ADF	3	ULS Surface Water Hydrology Technical Report 2004
X_2	annual stream flow variation	ASFV Ratio = 10.5	4	ULS Surface Water Hydrology Technical Report 2004
X_3	maximum summer stream temperature	60 degrees F	4	ULS Surface Water Quality Technical Report 2004
X_4	nitrate nitrogen	0.17 mg/l (data source)	4	ULS Surface Water Quality Technical Report 2004
X_5	fish food abundance	100 to 249 organisms/square foot, only used in Model I, but same as X_9 in Model II	N/A	MWH Field Data 1998, Diamond Fork FS-FEIS 1999
X_6	fish food diversity	D_s = XX, only used in Model I	N/A	
X_7	cover	10 to 25 (% cover)	1	MWH Field Data 1998, Diamond Fork FS-FEIS 1999
X_8	eroding stream banks (bank stability)	25 to 49 (% eroding)	2	MWH Field Data 1998, Diamond Fork FS-FEIS 1999
X_9	substrate	Same as X_5	2	MWH Field Data 1998, Diamond Fork FS-FEIS 1999
X_{10}	water velocity	Time of Travel = 1.3 ft/sec	3	MWH Field Data 1998, Diamond Fork FS-FEIS 1999
X_{11}	stream width	22 feet	4	MWH Field Data 1998, Diamond Fork FS-FEIS 1999

$S = (X_7)(X_8)(X_{11})$ = shelter index		$\log(Y+1) = (-0.903)+(0.807)\log(X_1+1)+(0.877)\log(X_2+1)+(1.233)\log(X_3+1)+(0.631)\log(F+1)+(0.182)\log(S+1)$	
$F = (X_3)(X_4)(X_9)(X_{10})$ = food index		Y = predicted trout standing crop (lbs/acre)	
X_1+1	4	log(Y+1) =	2.485014
X_2+1	5	Y =	305 lbs/acre
X_3+1	5		
F+1	97		
S+1	9		

Habitat Quality Index (Model II) Attribute Rating Summary Sheet

Stream:	Spanish Fork River BUW Alternative	Location:	E. Bench Div. to Mill Race Div.
Date Data Collection:	1990 to 1999; DF FS-FEIS	HQI Score:	166 lbs/acre
Trout Standing Crop:	lbs/acres		179 trout habitat units
	(cyanide sample or other method)		

Attribute (Symbol)	(name)	Data	Rating	Data Sources
X_1	late summer stream flow (critical period stream flow - CPSF)	Gauge location: ADF = 115 cfs; Avg CPF = 16 cfs Avg CPF/ADF = 14% ADF	1	ULS Surface Water Hydrology Technical Report 2004
X_2	annual stream flow variation	ASFV Ratio = 12.4	4	ULS Surface Water Hydrology Technical Report 2004
X_3	maximum summer stream temperature	61 degrees F	4	ULS Surface Water Quality Technical Report 2004
X_4	nitrate nitrogen	0.20 mg/l (data source)	4	ULS Surface Water Quality Technical Report 2004
X_5	fish food abundance	100 to 249 organisms/square foot, only used in Model I, but same as X_9 in Model II	N/A	MWH Field Data 1998, Diamond Fork FS-FEIS 1999
X_6	fish food diversity	D_s = XX, only used in Model I	N/A	
X_7	cover	10 to 25 (% cover)	1	MWH Field Data 1998, Diamond Fork FS-FEIS 1999
X_8	eroding stream banks (bank stability)	25 to 49 (% eroding)	2	MWH Field Data 1998, Diamond Fork FS-FEIS 1999
X_9	substrate	Same as X_5	2	MWH Field Data 1998, Diamond Fork FS-FEIS 1999
X_{10}	water velocity	Time of Travel = 1.4 ft/sec	3	MWH Field Data 1998, Diamond Fork FS-FEIS 1999
X_{11}	stream width	24 feet	3	MWH Field Data 1998, Diamond Fork FS-FEIS 1999

$S = (X_7)(X_8)(X_{11})$ = shelter index		$\log(Y+1) = (-0.903)+(0.807)\log(X_1+1)+(0.877)\log(X_2+1)+(1.233)\log(X_3+1)+(0.631)\log(F+1)+(0.182)\log(S+1)$	
$F = (X_3)(X_4)(X_9)(X_{10})$ = food index		Y = predicted trout standing crop (lbs/acre)	
X_1+1	2	log(Y+1) =	2.222219
X_2+1	5	Y =	166 lbs/acre
X_3+1	5		
F+1	97		
S+1	7		

Habitat Quality Index (Model I) Attribute Rating Summary Sheet

Stream:	Spanish Fork River Baseline	Location:	Mill Race Div. to Utah Lake
Date Data Collection:	1990 to 1999; DF FS-FEIS	HQI Score:	126 lbs/acre
Trout Standing Crop:	lbs/acres		136 trout habitat units
	(cyanide sample or other method)		

Attribute (Symbol)	(name)	Data	Rating	Data Sources
X_1	late summer stream flow (critical period stream flow - CPSF)	Gauge location: ADF = 229 cfs; Avg CPF = 100 cfs Avg CPF/ADF = 44% ADF	3	ULS Surface Water Hydrology Technical Report 2004
X_2	annual stream flow variation	ASFV Ratio = 5.5	4	ULS Surface Water Hydrology Technical Report 2004
X_3	maximum summer stream temperature	61 degrees F	4	ULS Surface Water Quality Technical Report 2004
X_4	nitrate nitrogen	0.64 mg/l (data source)	2	ULS Surface Water Quality Technical Report 2004
X_5	fish food abundance	100 to 249 organisms/square foot, only used in Model I, but same as X_9 in Model II	N/A	MWH Field Data 1998, Diamond Fork FS-FEIS 1999
X_6	fish food diversity	D_s = XX, only used in Model I	N/A	
X_7	cover	10 to 25 (% cover)	1	MWH Field Data 1998, Diamond Fork FS-FEIS 1999
X_8	eroding stream banks (bank stability)	50 to 74 (% eroding)	1	MWH Field Data 1998, Diamond Fork FS-FEIS 1999
X_9	substrate	Same as X_5	2	MWH Field Data 1998, Diamond Fork FS-FEIS 1999
X_{10}	water velocity	Time of Travel = 0.9 ft/sec	2	MWH Field Data 1998, Diamond Fork FS-FEIS 1999
X_{11}	stream width	52 feet	2	MWH Field Data 1998, Diamond Fork FS-FEIS 1999

$S = (X_7)(X_8)(X_{11})$ = shelter index	$\log(Y+1) = (-0.903)+(0.807)\log(X_1+1)+(0.877)\log(X_2+1)+(1.233)\log(X_3+1)+(0.631)\log(F+1)+(0.182)\log(S+1)$
$F = (X_3)(X_4)(X_9)(X_{10})$ = food index	Y = predicted trout standing crop (lbs/acre)
X_1+1 4	log(Y+1) = 2.102707
X_2+1 5	Y = 126 lbs/acre
X_3+1 5	
F+1 33	
S+1 3	

Habitat Quality Index (Model II) Attribute Rating Summary Sheet

Stream:	Spanish Fork River Preferred Alternative	Location:	Mill Race Div. to Utah Lake
Date Data Collection:	1990 to 1999; DF FS-FEIS	HQI Score:	63 lbs/acre
Trout Standing Crop:	lbs/acres		68 trout habitat units
	(cyanide sample or other method)		

Attribute (Symbol)	(name)	Data	Rating	Data Sources
X_1	late summer stream flow (critical period stream flow - CPSF)	Gauge location: ADF = 135 cfs; Avg CPF = 33 cfs Avg CPF/ADF = 24% ADF	2	ULS Surface Water Hydrology Technical Report 2004
X_2	annual stream flow variation	ASFV Ratio = 10.5	4	ULS Surface Water Hydrology Technical Report 2004
X_3	maximum summer stream temperature	68 degrees F	3	ULS Surface Water Quality Technical Report 2004
X_4	nitrate nitrogen	0.87 mg/l (data source)	2	ULS Surface Water Quality Technical Report 2004
X_5	fish food abundance	100 to 249 organisms/square foot, only used in Model I, but same as X_9 in Model II	N/A	MWH Field Data 1998, Diamond Fork FS-FEIS 1999
X_6	fish food diversity	D_s = XX, only used in Model I	N/A	
X_7	cover	10 to 25 (% cover)	1	MWH Field Data 1998, Diamond Fork FS-FEIS 1999
X_8	eroding stream banks (bank stability)	50 to 74 (% eroding)	1	MWH Field Data 1998, Diamond Fork FS-FEIS 1999
X_9	substrate	Same as X_5	2	MWH Field Data 1998, Diamond Fork FS-FEIS 1999
X_{10}	water velocity	Time of Travel = 0.8 ft/sec	2	MWH Field Data 1998, Diamond Fork FS-FEIS 1999
X_{11}	stream width	50 feet	2	MWH Field Data 1998, Diamond Fork FS-FEIS 1999

$S = (X_7)(X_8)(X_{11})$ = shelter index	$\log(Y+1) = (-0.903)+(0.807)\log(X_1+1)+(0.877)\log(X_2+1)+(1.233)\log(X_3+1)+(0.631)\log(F+1)+(0.182)\log(S+1)$
$F = (X_3)(X_4)(X_9)(X_{10})$ = food index	Y = predicted trout standing crop (lbs/acre)
X_1+1 3	log(Y+1) = 1.80631
X_2+1 5	Y = 63 lbs/acre
X_3+1 4	
F+1 25	
S+1 3	

Habitat Quality Index (Model II) Attribute Rating Summary Sheet

Stream:	Spanish Fork River BUW Alternative	Location:	Mill Race Div. to Utah Lake
Date Data Collection:	1990 to 1999; DF FS-FEIS	HQI Score:	63 lbs/acre
Trout Standing Crop:	lbs/acres		68 trout habitat units
	(cyanide sample or other method)		

Attribute (Symbol)	(name)	Data	Rating	Data Sources
X_1	late summer stream flow (critical period stream flow - CPSF)	Gauge location: ADF = 202 cfs; Avg CPF = 34 cfs Avg CPF/ADF = 17% ADF	2	ULS Surface Water Hydrology Technical Report 2004
X_2	annual stream flow variation	ASFV Ratio = 12.4	4	ULS Surface Water Hydrology Technical Report 2004
X_3	maximum summer stream temperature	66 degrees F	3	ULS Surface Water Quality Technical Report 2004
X_4	nitrate nitrogen	0.69 mg/l (data source)	2	ULS Surface Water Quality Technical Report 2004
X_5	fish food abundance	100 to 249 organisms/square foot, only used in Model I, but same as X_9 in Model II	N/A	MWH Field Data 1998, Diamond Fork FS-FEIS 1999
X_6	fish food diversity	D_s = XX, only used in Model I	N/A	
X_7	cover	10 to 25 (% cover)	1	MWH Field Data 1998, Diamond Fork FS-FEIS 1999
X_8	eroding stream banks (bank stability)	50 to 74 (% eroding)	1	MWH Field Data 1998, Diamond Fork FS-FEIS 1999
X_9	substrate	Same as X_5	2	MWH Field Data 1998, Diamond Fork FS-FEIS 1999
X_{10}	water velocity	Time of Travel = 0.9 ft/sec	2	MWH Field Data 1998, Diamond Fork FS-FEIS 1999
X_{11}	stream width	51 feet	2	MWH Field Data 1998, Diamond Fork FS-FEIS 1999

$S = (X_7)(X_8)(X_{11})$ = shelter index	$\log(Y+1) = (-0.903)+(0.807)\log(X_1+1)+(0.877)\log(X_2+1)+(1.233)\log(X_3+1)+(0.631)\log(F+1)+(0.182)\log(S+1)$
$F = (X_3)(X_4)(X_9)(X_{10})$ = food index	Y = predicted trout standing crop (lbs/acre)
X_1+1 3	log(Y+1) = 1.80631
X_2+1 5	Y = 63 lbs/acre
X_3+1 4	
F+1 25	
S+1 3	