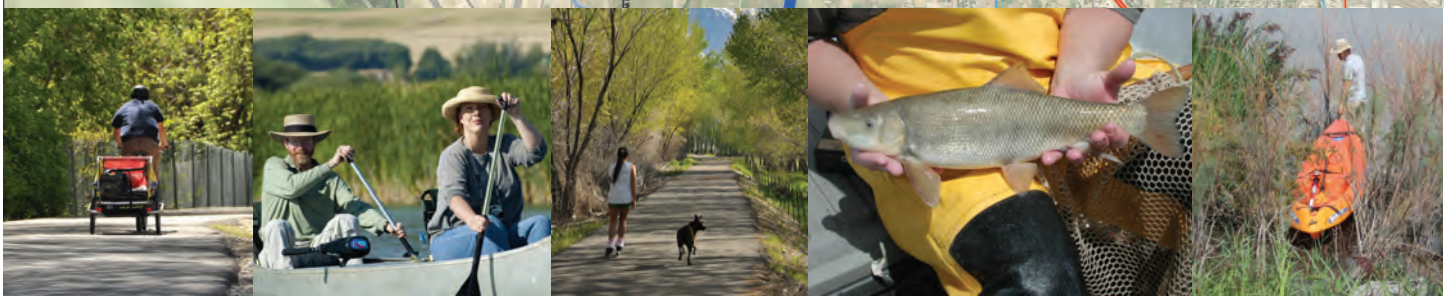
PROVO RIVER DELTA RESTORATION PROJECT

Alternatives Development Technical Memorandum

in Support of the Draft Environmental Impact Statement



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UTAH RECLAMATION MITIGATION AND CONSERVATION COMMISSION

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CENTRAL UTAH WATER CONSERVANCY DISTRICT

JUNE SUCKER RECOVERY IMPLEMENTATION PROGRAM

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1.0 INTRODUCTION

The June sucker (*Chasmistes liorus*) is listed as an endangered species under the Endangered Species Act (ESA) (51 FR 10857, April 30, 1986). In conjunction with the listing, the lower 4.9 miles of the Provo River, from Utah Lake upstream to the Tanner Race Diversion Dam, was designated as critical habitat.

The June Sucker Recovery Implementation Program (JSRIP) is a collaborative effort between local, state, and federal partners to recover the June sucker while allowing water development and operations to continue. The JSRIP was established in 2002 and has implemented recovery actions based on the June Sucker Recovery Plan (USFWS 1999a). Under the ESA, recovery plans delineate reasonable actions that are believed to be required to recover and/or protect listed species. The June Sucker Recovery Plan outlines the steps and actions needed to achieve recovery and delist the June sucker.

The proposed Provo River Delta Restoration Project (proposed project) is an essential component of the ongoing effort to recover June sucker. The proposed project would restore a delta ecosystem on the lower Provo River at Utah Lake. This delta ecosystem would be designed to suit June sucker spawning and rearing needs. The proposed project would accommodate a distributary channel form and active channel migration, which are common to natural river deltas. In addition, the proposed project would enhance the recreational opportunities associated with lower Provo River and Utah Lake. Where necessary, existing levees would be removed to create the new habitat complex, and new levees would be constructed to protect existing development outside the project area from flooding.

The proposed project would represent a significant federal action and therefore requires preparation of an Environmental Impact Statement (EIS) under the National Environmental Policy Act (NEPA) (42 USC § 4321 et seq.). The joint lead agencies (JLAs) preparing the EIS for the proposed project are the Utah Reclamation Mitigation and Conservation Commission (Mitigation Commission), the U.S. Department of the Interior's (DOI) Central Utah Project Completion Act (CUPCA) Office, and the Central Utah Water Conservancy District (CUWCD).

This Technical Memorandum is intended to inform the NEPA process by incorporating comments received through the scoping process into the process of identifying a range of alternatives that meet the purpose and need of the proposed project. This memorandum is anticipated to become the basis for the description of "Alternatives Advanced and Alternatives Considered but Eliminated from Detailed Analysis" in Chapter 2 of the EIS document.

2.0 PROJECT BACKGROUND

June sucker are native to and occur naturally only in the Utah Lake system. Figure 1 illustrates the Utah Lake study area, including all major tributaries. At the time of the June sucker's ESA listing in 1986, habitat alteration, presence of nonnative fishes, and water development were identified as the major threats to the June sucker. The lower Provo River represented the only known spawning location for the species at the time of listing. By 1998 the wild June sucker

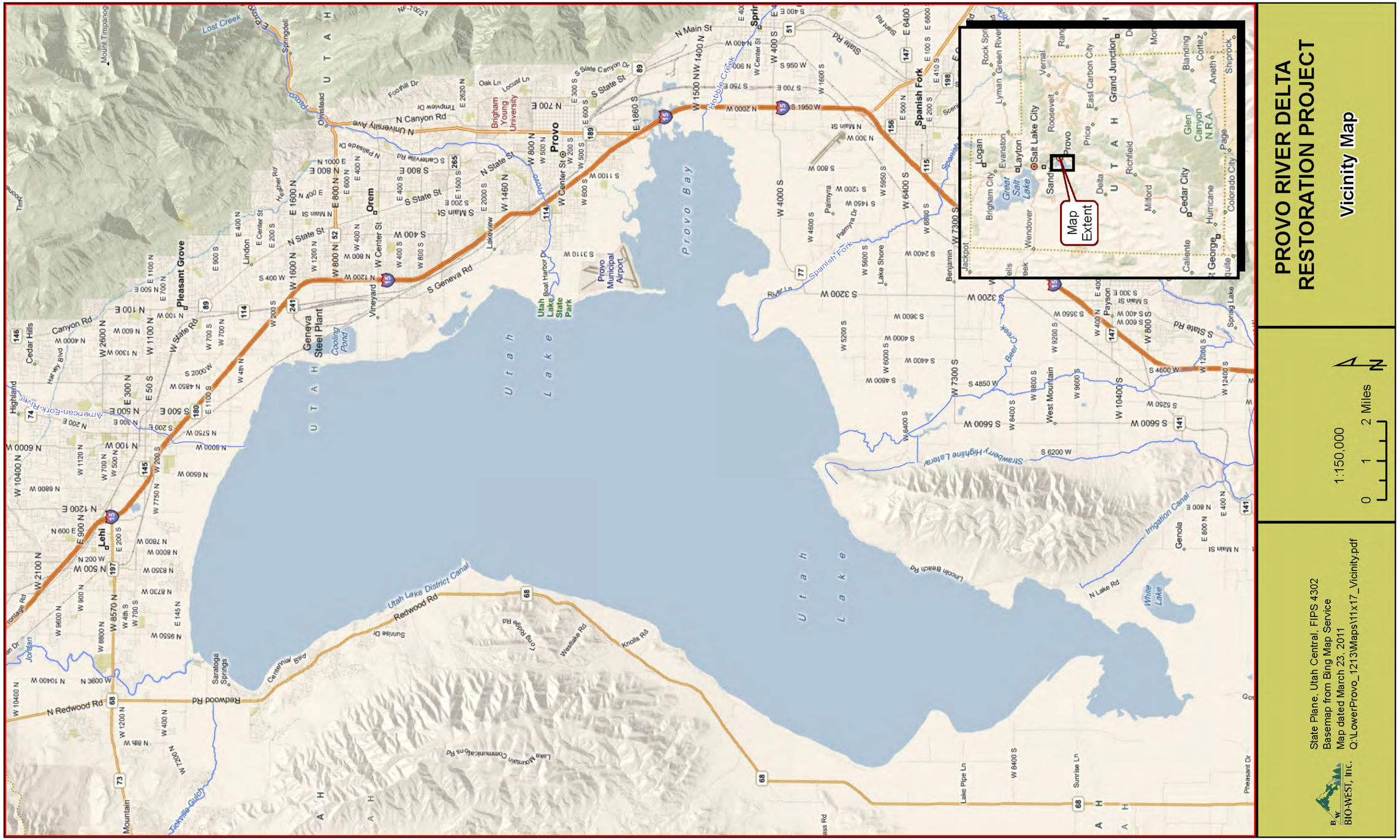

Figure 1. Vicinity map of Utah Lake and tributaries.

spawning population was estimated to consist of only approximately 300 individuals (Keleher et al. 1998).

Significant monitoring and research efforts have gone into the determination that restoration of a naturally functioning Provo River delta is necessary for achieving downlisting and eventual delisting of the species. As noted, the June Sucker Recovery Plan (USFWS 1999a) includes a series of actions that are intended to (first) prevent extinction and then to allow downlisting of the species to threatened status, and finally to achieve delisting of the June sucker. As outlined in the Recovery Plan, the June sucker may be downlisted to threatened status if the following criteria are met:

1. *Provo River flows essential for June sucker spawning and recruitment are protected,*

2. *habitat* ***in the Provo River and Utah Lake*** *has been enhanced and/or established to provide for the continued existence of all life stages, (****emphasis added****)*

3. *nonnative species which present a significant threat to the continued existence of June sucker are reduced or eliminated from Utah Lake, and*

4. *an increasing self sustaining spawning run of wild June sucker resulting in significant recruitment over ten years has been re-established* ***in the Provo River****. (****emphasis added****)*

The next section provides the background to understand the challenges facing June sucker and why the proposed project is an integral part of a systematic approach to recovery.

2.1 Challenges to June Sucker Recovery

Monitoring data indicate that June sucker experience a “recruitment bottleneck”. Monitoring efforts in Utah Lake have not documented the recruitment of wild June sucker from the larval to juvenile to adult stages (Rader et al. 2010), and research suggests that larval fish generally do not survive longer than about 20 days after hatching, in the Provo River (Ellsworth et al. 2010). However, each spring in the lower Provo River, adult fish are observed spawning, and significant numbers of recently hatched larvae are subsequently monitored drifting downstream. This discrepancy implies that the larval fish die before reaching suitable lake habitat and are thus unable to grow and recruit to the adult population. A recent study suggests that starvation due to low water temperature and channel morphology contribute to the demise of the larval fish in Provo River (Ellsworth et al. 2010). Larval June sucker are also highly vulnerable to predation because the existing habitat lacks vegetative cover. These mortality factors are linked to the altered habitat conditions at the existing river-lake interface.

Historical photographs show that a broad area of floodplain (with cottonwoods, willows, etc.) once dominated the lower Provo River delta. The riverine corridor was supported by the Provo River migrating back and forth across a very wide floodplain over long periods of time in response to natural forces. The historic floodplain extended over all of the land north of Provo Bay. This floodplain built up over time as the Provo River cut its way through alluvial deposits at the mouth of Provo Canyon. These deposits were left behind by Lake Bonneville when that much larger lake encompassed both Utah Lake and the Great Salt Lake. Alluvial deposits picked up by the Provo River dropped out as the river lost elevation near the mouth at Utah Lake. This caused the river to fan out into multiple channels and to migrate over the landscape. Today the majority of the historic floodplain of the Provo River has been developed, and the Provo River corridor is limited to less than 130 feet due to the presence of constructed levees along either side of the Provo River.

Historically, the Provo River delta was a much more complex system as it entered Utah Lake. The historic river channels most likely provided a diversity of habitat suitable for different age classes of June sucker under different runoff regimes. The same is likely true for most other tributaries of Utah Lake. Today, like most tributaries, the Provo River consists of a single, trapezoidal-shaped channel as it enters the lake, which has reduced rearing habitat for June sucker larvae and juveniles. It also likely has improved the ability of nonnative fish predators to exploit these early life stages (Olsen et al. 2002).

The mouth and lower section of the Provo River has been channelized, straightened, and deepened by dredging, and its longitudinal connectivity to the lake has been significantly altered. The result is a straightened and confined channel that has little habitat diversity. The existing river/lake interface consists of deep water, has a trapezoidal-shaped channel, and is void of shallow, vegetated habitat. Conditions in the lowermost 1.6 miles of the river are largely controlled by the Utah Lake backwater rather than river flows. Except in high-water runoff years, velocities in this reach are slow to stagnant, causing larval fish to become “trapped” in the channelized river mouth and unable to reach shallower, warmer, more productive lake habitats. As a result, larvae cannot reach Utah Lake in most years. Instead, as they drift downstream, they come in contact with the slack-water interface created by Utah Lake, which causes water to backup into the lower Provo River. Ellsworth suggests that recruitment failure may be caused by larvae not being able to reach the warm, shallow areas of Utah Lake with higher zooplankton densities before they deplete their yolk reserves. This results in their starvation (Ellsworth et al. 2010).

The current character of the lower river is primarily the result of human influences during the past 100 years to reduce flooding for agricultural uses and development. Water diversion features associated with a variety of projects prevent spawning June sucker from moving upstream in Provo River as they did historically.

One of the largest projects affecting the Provo River is the Central Utah Project (CUP). Congress authorized the CUP through enactment of the Colorado River Storage Project Act of 1956 (43 USC § 620 et seq.). This law authorized Federal funds to assist the State of Utah to develop a portion of Utah’s share of water from the Upper Colorado River system, according to interstate compact. The CUP provided for construction of Jordanelle Dam, guaranteed minimum stream

flows on all river reaches below Jordanelle Dam, and provided a mechanism for acquisition of additional water supplies to provide supplemental flows to assist with June sucker recovery and other environmental purposes.

In summary, a variety of factors have contributed to the June sucker's inability to survive to adulthood. In particular, June sucker have limited and altered spawning habitat and lack the historic complex delta ecosystem that provided habitat for juveniles. As a result, extensive monitoring of Utah Lake over the last 25 years has not documented the existence of naturally recruited June sucker.

2.2 Importance of the Provo River to Recovery

The June Sucker Recovery Plan identifies the need for habitat enhancement on Provo River and Utah Lake. The proposed project has developed over the past several years through efforts by the JSRIP and its member federal, state and local entities, including the JLAs, to investigate and determine the mechanisms needed to meet recovery criteria according to the June Sucker Recovery Plan and JSRIP.

As the site of the primary June sucker spawning run, Provo River has been the focus of extensive recovery measures for decades. To this end, millions of dollars have been spent to acquire water and manage flows for spawning and larval transport in the lower Provo River, studies on spawning and rearing habitat requirements, flow recommendations, removal of fish passage barriers in the critical habitat reach, genetic testing, hydraulic analysis, biological research and monitoring efforts, and others.

The lower 4.9 miles of Provo River, from Utah Lake upstream to the Tanner Race Diversion Dam, is designated as critical habitat for June sucker. Critical habitat is defined as a geographical area occupied by the species at the time it is listed and on which are found those physical and biological features "essential to the conservation of the species" and which "may require special management considerations or protections" (16 USC § 1532(5)).

When the June sucker was listed as endangered and the June Sucker Recovery Plan was written, the Provo River was the only tributary to Utah Lake known to be successfully used by June sucker for spawning. Adult June sucker were observed exhibiting pre-spawning/staging behavior at the mouth of the Spanish Fork River, the second largest Utah Lake tributary, but no larval fish or actual spawning activity were observed (Radant and Sakaguchi 1981, Radant and Shirley 1987). Historically, June sucker most likely spawned in multiple tributaries to Utah Lake, but alterations associated with flow withdrawals, diversion structures, and channelization have greatly limited or precluded access to suitable spawning habitat in tributaries other than the Provo River. Even in its current altered condition, the section of the lower Provo River designated as critical habitat provides the greatest, though limited, habitat suitable for spawning in the Utah Lake system. But very limited rearing and nursery habitat is available.

The Provo River is the largest tributary to Utah Lake. Its average annual streamflow is 200 cubic feet per second (cfs) (USGS 2011), which is two times the annual flow of the next largest

tributary, Spanish Fork River (Stamp et al. 2002). Because of its size, the Provo River historically provided the most reliable flows from year to year to support June sucker spawning. The Provo River channel is also the widest of the Utah Lake tributaries, and with the 2010 completion of the Fort Field diversion modification project (URMCC 2008), it provides a length of 4.9 miles of accessible river habitat for June sucker spawning. On other tributaries such as Spanish Fork, Hobble Creek, and American Fork, diversion dams and other structures currently limit readily accessible river lengths to 2.7, 1.5, and 1.8 miles, respectively (Stamp et al. 2002). Numerous irrigation diversions withdraw water from American Fork and commonly dewater the river during the summer months and sometimes dewater the lower river during the spring spawning period. In three out of five years during the 2002–2006 monitoring period, the Utah Division of Wildlife Resources was unable to complete surveys on American Fork because the river was either dry or too shallow for snorkeling (UDWR 2003, UDWR 2004, UDWR 2005, UDWR 2006, UDWR 2007). Spanish Fork River is also heavily used for irrigation. Gage records indicate that June flows on Spanish Fork are less than 5 cfs about 50% of the time (Stamp et al. 2002). No instream flow protections are known to have been established for the lower portions of either of these tributaries, and therefore there is little assurance that water would consistently be available each year to support June sucker spawning and recruitment.

For more than 15 years, efforts have been underway to secure water rights to support year-round instream flows to the lower Provo River. To date more than 13,000 acre-feet of water have been acquired annually on a permanent basis for lower Provo River streamflows under Section 207 and Section 302 of the Central Utah Project Completion Act (CUPCA). These flows have been used almost exclusively to benefit June sucker spawning and larval transport. Efforts to acquire additional instream water rights remain ongoing. The Utah Lake Drainage Basin Water Delivery System (ULS) project, as authorized by the CUPCA, includes an environmental commitment to supplement Provo River stream flows to assist with June sucker recovery. When operational and under full water delivery conditions, the ULS project is projected to deliver on average approximately 16,000 acre-feet of supplemental water annually (CUWCD 2004). In addition, about 12,165 acre-feet of water will be dedicated annually specifically for flows in the lower Provo River and the June sucker. Efforts through the water conservation program (authorized in Section 207 of CUPCA) to acquire additional instream water are ongoing. It is anticipated that a firm supply of up to 20,000 acre-feet may ultimately be available annually for controlled release in direct support of June sucker spawning and larval transport in the Provo River.

In summary, the lower Provo River is essential to the recovery of June sucker, and is the tributary on which to focus recovery efforts because:

- the lower Provo River serves as the primary June sucker spawning location and is the only Utah Lake tributary where successful reproduction has been observed each year since the 1980s (Ellsworth et al. 2010);

- the lower Provo River is protected as critical habitat under the ESA;

- efforts to secure instream flows on the lower Provo River have been successfully underway for 15 years and flows for the future are assured;

- other tributaries to Utah Lake are much smaller and have more factors limiting June sucker recovery than the Provo River;

- millions of dollars have been expended and are committed to future expenditure for studies, habitat improvements, and the securing and provision of water to the lower Provo River because of its identified importance for June sucker as a result of prior Section 7 ESA consultation on projects affecting the Utah Lake Drainage Basin; and

- a downlisting criteria of the June Sucker Recovery Plan is the enhancement of the habitat in Provo River and Utah Lake for all life stages of the June sucker.

2.3 Form and Functions of Natural River Delta Ecosystems

River deltas are depositional features that form where a river enters a terminal water body such as a lake, reservoir, or ocean (Penland and Kulp 2005). These specific landforms received the name "delta" because of their triangular shape similar to the upper-case Greek letter, "delta" or Δ. Deltaic sedimentation and evolution were first described by G. K. Gilbert (Gilbert 1877) in his study of Lake Bonneville (Ritter 1986). Deltas around the world, including ones occurring in Utah, vary in size, shape, function, and complexity depending on many factors such as river discharge, quantity and size distribution of sediment transported in the river, near shoreline topography, lake water level fluctuations, and external forces such as wind. A reasonable question to ask for this project is how much room does a delta need and what will the delta do with the space? Recent research and modeling results (Geleynse et al. 2011) provide a framework for physics-based delta design under various environmental conditions (Figure 2). This tool along with other research and observations (Appendix A) allows plausible explanations for expected patterns and shapes of a natural delta at Utah Lake.

Natural delta systems include various zones distinguished by the relative influences of lentic (lake) versus lotic (riverine) processes. Under natural conditions, each zone provides a diverse array of habitat features formed and maintained by a specific set of geomorphic processes. Delta zones applicable to this project area are illustrated in Figure 3 and the habitats they support are described in more detail below.

2.3.1 Dynamic River/Riparian Floodplain

This portion of the delta ecosystem lies above any lentic influence, and habitat conditions are controlled by riverine processes. In natural alluvial settings free from significant geologic controls, rivers are free to erode and deposit, migrate, and flood overbank as they transport water and sediment delivered from upstream.

Dynamic rivers provide in-channel habitats with diverse hydraulic conditions including slow, deep pools and runs; shallow, slow backwaters; and fast, shallow riffles. Pools form by scour or impoundment at in-channel obstructions such as woody debris jams or at constrictions such as point bars (Swanston 1991). In terms of June sucker life-cycle requirements, slower-velocity habitats such as pools provide important resting or staging areas for spawning adults. Successful

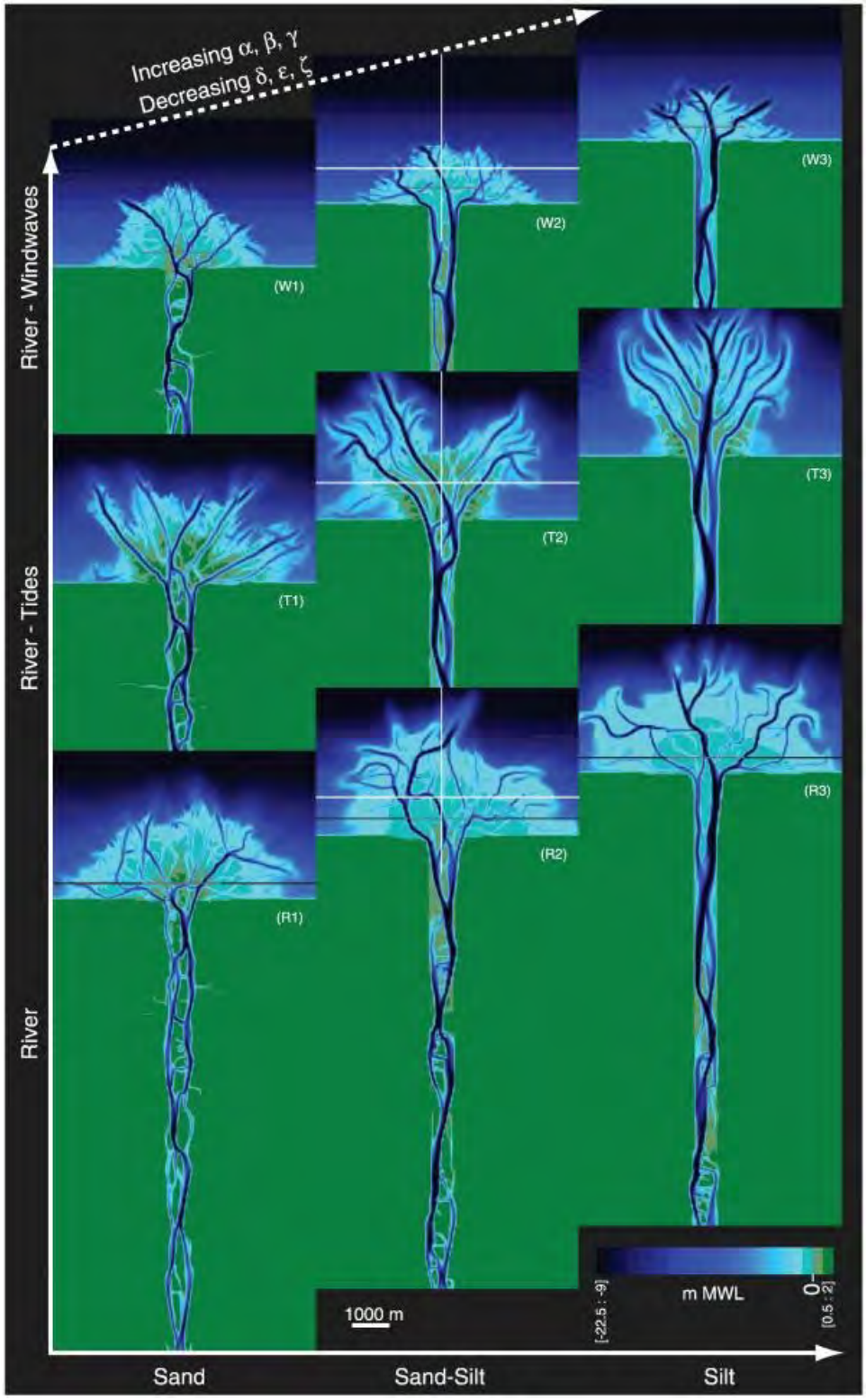

Figure 2. **Delta modeling results described in Geleynse et al. (2011) for various types of sediment, water movement, and wind action (driving forces), for a given point in time (image produced at Delft University of Technology, The Netherlands).**

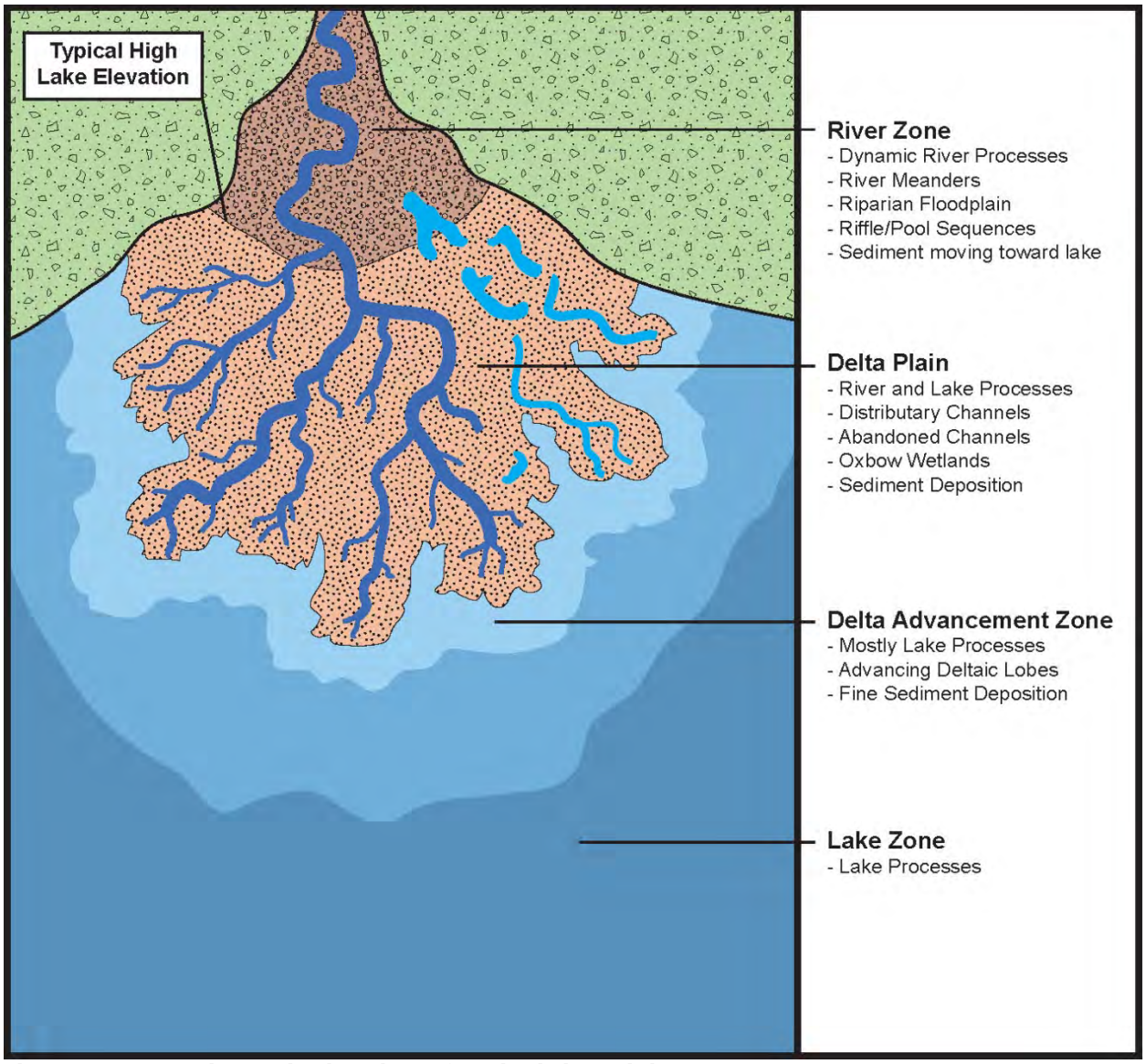

Figure 3. Schematic drawing of typical river delta zones.

spawning also requires the presence of clean gravel and small cobble substrate close to staging/resting pools. These substrates typically form at riffle-pool transitions, which commonly occur at meander bends and point bar deposits (Chamberlain et al. 1991). Spawning substrates can also occur as deposits behind woody debris obstructions. Long-term maintenance of spawning substrates and pool habitats require ongoing recruitment of riparian shrubs and trees to supply woody debris to the channel; sediment and flow regimes adequate to support erosion and deposition; and lateral space to accommodate channel migration and meander formation (Table 1).

Table 1. Selected geomorphic features, processes, and habitats associated with natural river delta ecosystems.

GEOMORPHIC FEATURE	FORMATION PROCESS	MAINTENANCE PROCESSES	JUNE SUCKER HABIBAT OR LIFE STAGE SUPPORTED
Pool-riffle sequence	Scour or ponding at obstruction or constriction	Riparian recruitment to supply woody debris; erosion/bar deposition; channel migration; flushing flows	Spawning gravel and staging pool (spawning)
Oxbow/ meander scar	Channel avulsion or meander cutoff	Periodic high-magnitude overbank flooding ; riparian recruitment to supply woody debris	Submergent marsh (nursery/rearing/over-wintering)
Shallowly inundated floodplain/ delta plain	Overbank flow onto connected floodplain	Flow and sediment regime adequate to regularly inundate a hydraulically connected floodplain	Warmer-water productive marsh; hydraulic refuge (nursery/rearing)
Topographically diverse floodplain/ delta plain	Floodplain scour and deposition	Periodic high-magnitude overbank flooding	Warmer-water productive marsh; hydraulic refuge; cover (nursery/rearing)
Active distributary channel(s)	Channel bifurcation at a river mouth bar	Longitudinal river-lake connectivity; active sediment transport and deposition	Warmer-water riverine habitat; spawning gravel (spawning, larval transport, rearing)
Abandoned distributary channel(s)	Channel avulsion	Sediment accretion/natural levee formation; access to lower-elevation flow path; riparian recruitment to supply woody debris	Warmer-water productive marsh; hydraulic refuge; cover (nursery/rearing)

In addition to supporting diverse, in-channel habitats critical for spawning, the river zone of the delta ecosystem also provides important floodplain habitats. Natural alluvial rivers are connected to broad floodplain surfaces that are regularly inundated during flood events. Shallowly inundated portions of the floodplain provide high-quality nursery habitat for fishes. These areas serve as hydraulic refuge from powerful in-channel flood flows. They are also productive food sources due to their warmer water temperatures and lower turbidity relative to the main channel (Opperman et al. 2010). During large flood events, floodplain sediments are scoured and deposited, resulting in an uneven, topographically diverse surface. In turn, this unevenness leads to the development of diverse vegetation patches associated with variable moisture and inundation regimes (Opperman et al. 2010). Fresh floodplain sediment deposits are also an essential element of successful riparian cottonwood recruitment (Scott et al. 1993), while erosive processes (such as channel avulsions and meander cutoffs) create productive marsh habitats in the form of oxbow ponds and overbank secondary channels. When floodplain width and connectivity are constrained by levees, this diversity of floodplain habitats is reduced (Figure 4). Also, without periodic large floods to “reset” conditions and create bare surfaces, vegetative succession would ultimately lead to a homogenous mature riparian community. These large floods are high-energy events that can result in significant infrastructure damage if sufficient lateral space is not provided adjacent to the river channel (Kline and Cahoon 2010).

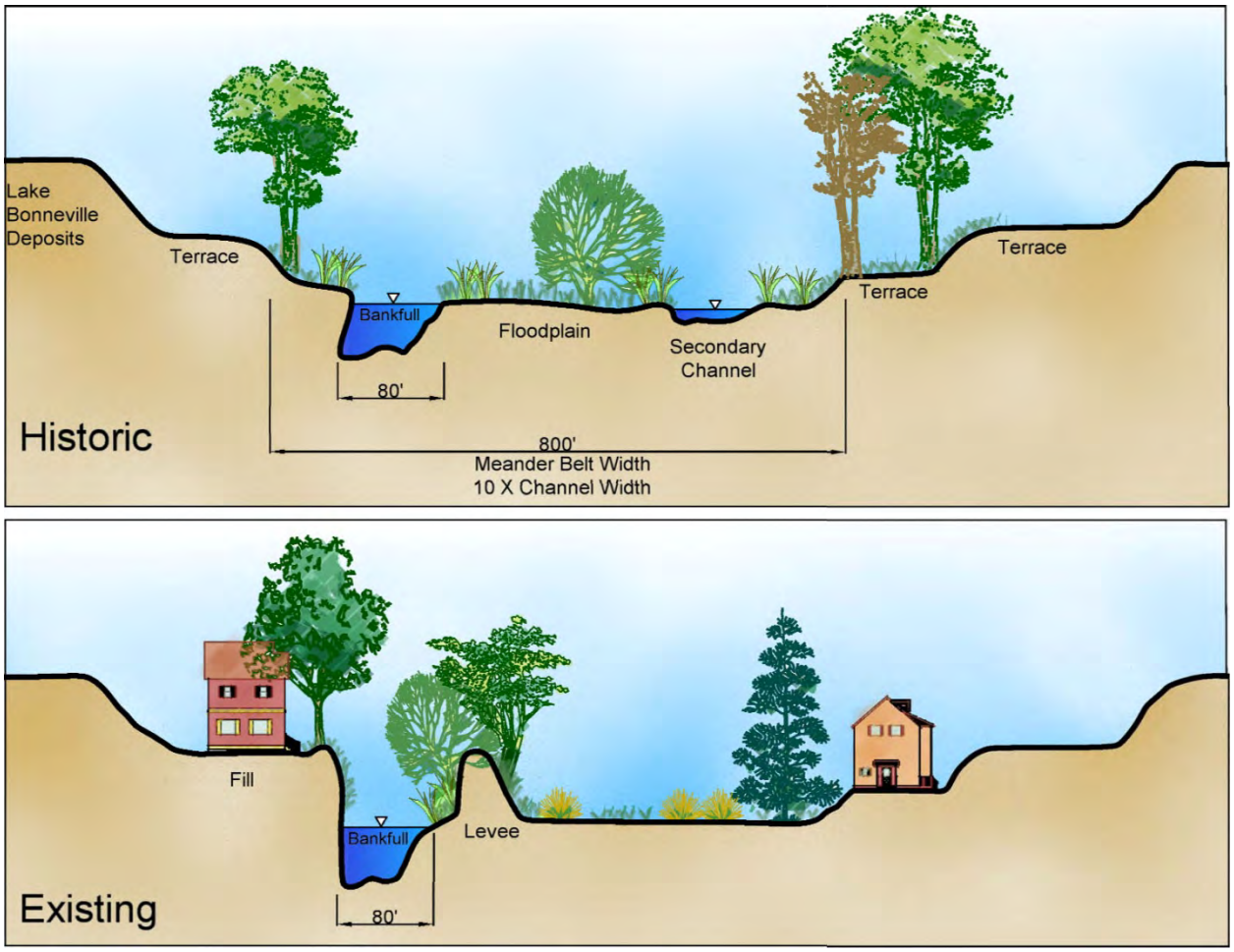

Figure 4. Schematic cross sections comparing historic channel and riparian corridor/floodplain to existing levee-constrained channel.

2.3.2 Delta Plain

The delta plain zone of a delta ecosystem includes the portion of the river mouth between the high and low elevations of the terminal water body (Figure 3). Habitat conditions in the delta plain are controlled by both riverine and lentic processes. As a flowing river approaches standing water such as a lake, slope and velocity decrease and transported sediment begins to deposit. These deposits commonly take the form of "river mouth bars" that can block the center of the channel and cause it to split into multiple distributary channels (Edmonds and Slingerland 2007). These distributary channels are typically bordered by natural levees formed by sediment deposition during floods. The network of distributary channels of varying sizes and their natural levees creates complex topography and an associated diversity of vegetation communities and habitats.

As a delta evolves through time, sediment accretion will eventually obstruct the active distributary channels to such an extent that they become abandoned in favor of a new flow path along topographically lower areas, or where the river is forced to go. Because of this process,

most delta plains include both active and abandoned distributary channel networks. Abandoned channels may become oxbow-type ponds deep enough to support submergent/emergent marsh wetlands (Figure 3). The presence of both active and inactive distributary networks further enhances the diversity of inundation depths and habitat types available under various combinations of river flow and lake level (Figure 5). Without adequate lateral space, the dynamic delta plain formation processes of channel bifurcation, avulsion, and abandonment will be limited in terms of stability diversity, and habitat quality and quantity will be correspondingly reduced (Table 1).

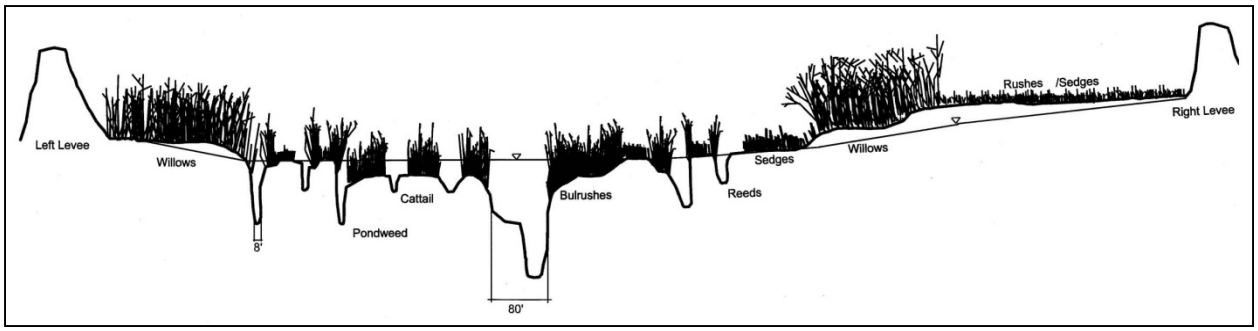

Figure 5. Schematic cross session of a distributary channel network supporting a diversity of inundation depths and habitat types.

The channel shifting processes that were described in the previous paragraphs typically occur within or on the margins of the active portion of the delta. There are typically a diversity of active and inactive (unstable and stable) portions of river deltas. Shifting events typically occur on a relatively frequent basis, but tend to be somewhat localized in nature. In addition to these localized shifting events, large-scale shifting of deltaic lobes also occurs on an episodic basis. During such events, the entire active area of the delta moves to a new location and the previous active area becomes somewhat abandoned from active fluvial process for a period of time. Several examples of these major shifting events are illustrated in Figure 5a (modified from Wicander and Monroe 1993), which shows the major deltaic lobes of the Mississippi River Delta over the past several thousand years. The figure demonstrates that the entire active portion of the delta has shifted many times in the past. These shifting events are inevitable over long time periods, given the continual deposition of sediment that eventually blocks the path of the flowing water.

2.3.3 Delta Advancement Zone

The delta advancement zone is the underwater portion of the delta below the low elevation limit of the terminal water body (Figure 3). Habitat conditions in this zone are predominantly controlled by lentic processes, but are influenced by the influx of fine-grained sediments and nutrients from the river mouth, also wind action from the lake.

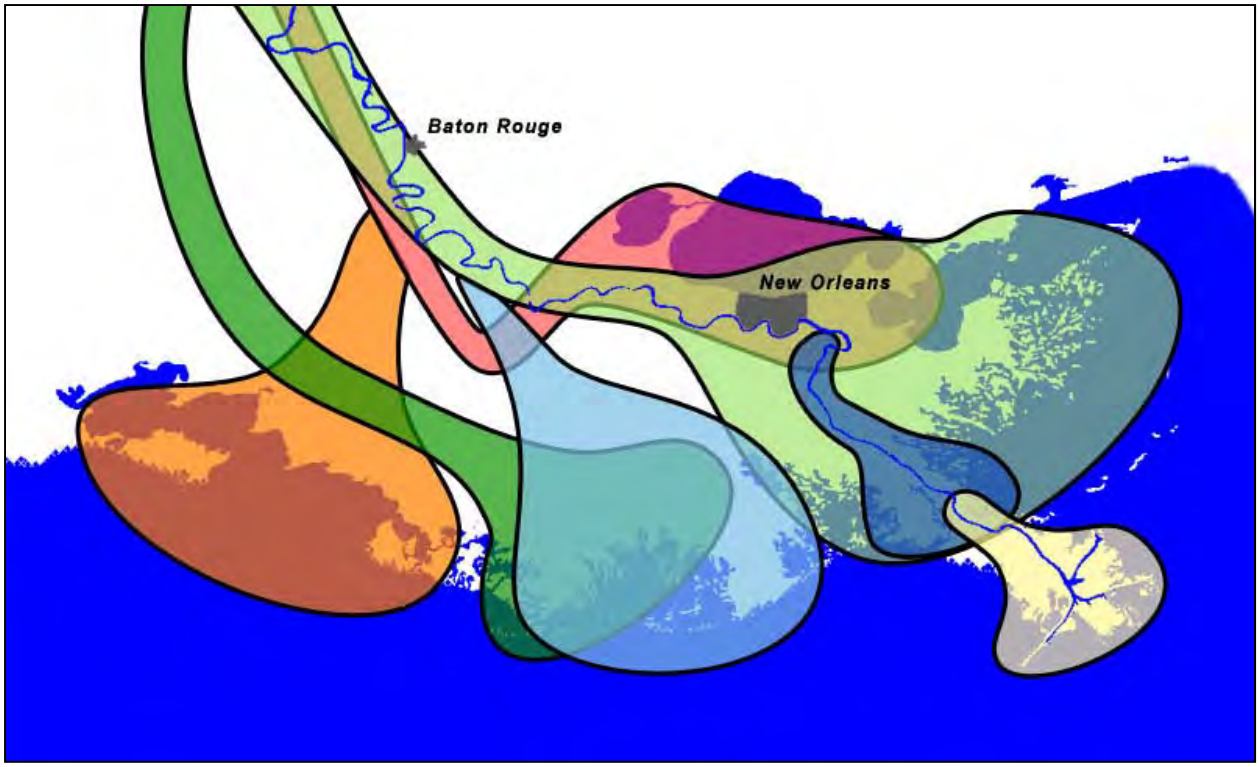

Figure 5a. Major deltaic lobes of the Mississippi River Delta over the past several thousand years (modified from Wicander and Monroe 1993).

2.4 Biological Importance of Delta Ecosystems

Various biological studies have documented the significance of delta habitats to aquatic ecosystems and fish populations. Delta habitats provide unique conditions that can support large numbers of species and life stages, presumptively through habitat diversity and the associated increases in niche availability. One example of this concept has been reported by Kaemingk et al. (2007). These authors describe the importance of deltas as they serve to maintain natural river function and "ecological hotspots" within the highly modified Missouri River system. They hypothesize that the diversity of habitats found within river deltas in turn, leads to increases in fish species diversity, particularly though the maintenance of native fishes and the habitats to support native fishes (Kaemingk et al. 2007).

In 2008, large-scale efforts to restore delta habitat diversity were implemented on the Williamson River delta where it enters Upper Klamath Lake in Oregon (Erdman and Hendrixson 2010). This project, which initially began around 1996, has focused on restoring complex marsh/rearing habitat to improve survival and recruitment of larval and juvenile shortnose and Lost River suckers (endangered fish species with life history characteristics similar to June sucker). The recent phase of the Williamson project involved breaching several miles of constructed levees to facilitate the restoration of 7,500 acres of wetlands. Post-project biological monitoring indicates that larval suckers appear to prefer the restored delta habitats over pre-existing wetlands along the lake shore (Erdman and Hendrixson 2010). Also, the abundance of larval fish captured in the

restored delta in 2009 was greater than those captured along the shoreline of the lake (Burdick and Brown 2010, Erdman and Hendrixson 2010). Monitoring data also indicate that newly hatched larval suckers primarily utilize vegetated and unvegetated shallow water (less than 3 feet deep) environments in May and early June but then transition to deeper open water habitat by late July into August and September (Burdick and Brown 2010). Data from 2009 and 2010 found that the average density of suckers caught in shallow habitats was 4.3 fish per cubic meter (Erdman and Hendrixson 2010, C. Erdman, TNC, Pers. Comm. 2011).

From the perspective of a different endangered fish species, another example highlighting the importance of river/lake interface features can readily be observed in Lake Mead, Nevada-Arizona. Albrecht et al. (2010a) demonstrated that vegetative cover and turbidity commonly associated with areas of Lake Mead that have inflow features (e.g., confluences of the Virgin River and Las Vegas Wash with Lake Mead proper) have supported the only remaining, self-sustaining, and naturally recruiting population of razorback sucker (*Xyrauchen texanus*) within the Colorado River Basin. Wild recruitment of this unique species has been documented through direct capture of small, juvenile individuals as well as through nonlethal aging techniques. Lake Mead is the only currently known location that this life stage of razorback sucker continues to be collected (Albrecht et al. 2010a). Recently, a new population of razorback sucker has been found in Lake Mead at the Colorado River inflow, further underscoring the importance of river/lake interface areas for this highly rare species (Albrecht et al. 2010b). Lake Mead is a very real and functioning example of how, given appropriate habitat features, a highly sensitive species can persist despite major habitat modifications and competition and predation pressure from a thriving nonnative sportfish population (Albrecht et al. 2010a, 2010b).

Other biological research has focused more specifically on the use of off-channel floodplain habitats by larval and juvenile fish. In a delta ecosystem, these types of habitats are available both within the river/riparian floodplain zone and within the delta plain zone (Figure 3). One study (Killgore and Baker 1996) that examined larval fish abundance on a river system in Arkansas, demonstrated a positive link between abundance of larval fish and the areal extent of inundated riparian floodplain. Other research has found that growth rates of juvenile salmon are substantially greater for fish that rear in inundated floodplain habitats versus habitats within the main river channel (Sommer et al. 2001).

Improved larval growth , development, and abundance of shortnose and Lost River suckers (*Chasmistes* species similar to June sucker) have been documented in fish utilizing emergent macrophyte habitats rather than open water or submergent vegetation (Cooperman and Markle 2004). Laboratory experiments using June sucker indicate that warmer water temperatures are linked to improved growth rates and survival of larval fish (Kappenman et al. 2010). At the Williamson River delta, the observed seasonal shifts in habitat use by larval fish (Burdick and Brown 2010) suggest that access to habitats that provide a mix of vegetation types and inundation depths may be essential for fish to successfully transition through their early life stages.

Collectively, these various studies demonstrate that when larval fish are able to access shallow, warm, productive habitats, their likelihood of successfully recruiting to the adult population will be maximized. Furthermore, the larger the areal extent of such habitats, the greater the anticipated abundance of young fish would be. In the specific case of June sucker, shallow, warm, productive rearing habitat is currently lacking at the Provo River mouth. Modeling studies (Belk et al. 2004) indicate that June sucker population numbers may be particularly sensitive to the abundance and survivorship of June sucker during their first year of life. Relative to model runs of improved survival during later life stages, model runs of improved year-one survival predict population increases that are approximately three to four times greater (Belk et al. 2004). These modeling results suggest that investing in the maximum possible amount of restored rearing habitat may be highly worthwhile in terms of population growth and ultimate species recovery.

2.5 Suitable Habitat Characteristics for June Sucker

Based on the physical and biological characteristics of a naturally functioning river delta, discussed in the previous two sections, and essential components of June sucker spawning and rearing habitat determined through previous feasibility studies, the lead agencies developed a list of suitable habitat characteristics.

2.5.1 Suitable Spawning Habitat Characteristics

Characteristics of suitable spawning habitat are described below.

1. Adult fish spawn in river areas over large deposits of clean, coarse gravel and small cobble substrate in run and riffle habitats. Suitable spawning areas are characterized by:

    A. water velocities up to 3.2 feet per second;
    B. water temperatures ranging from 52–60 degrees Fahrenheit; and
    C. water depths between 1–3 feet.

2. Adult fish also need low velocity deep pool resting habitat near spawning areas.

3. Staging pools in and around the river mouth where adult fish aggregate prior to the spawn.

4. Lack of barriers or large obstacles in the river channel that would prevent access upstream to the spawning habitat areas.

2.5.2 Suitable Rearing Habitat Characteristics

June sucker eggs hatch approximately 7–10 days following spawning (depending on temperature); newly hatched larvae remain among the cobble and gravel for another 7–10 days; then they swim up into the water column (primarily during nighttime hours), where the emergent June sucker larvae drift downstream (Shirley 1983).

During this rearing period, habitat needs of the larvae include the following:

1. Low-velocity pools in the river channel where larvae are sometimes found during the day when drifting downstream.

2. Shallow, vegetated habitat at the river/lake interface, which harbors an abundance of small zooplankton food resources.

3. Water depths ranging from 0.1–3.0 feet at the mouth of the river, which provides a variety of emergent and submergent vegetation types varying by turbidity, substrate, and lake level. This variety of depth provides a combination of emergent and submergent vegetation types, lateral water temperature gradients, and cover to escape from predators.

2.6 Related Provo River Actions

The JSRIP, Mitigation Commission, DOI, CUWCD, and other entities have implemented numerous complimentary recovery efforts on the lower Provo River, and such efforts are anticipated to continue into the future. As noted previously, an intensive effort to acquire in-stream flows to benefit June sucker is ongoing (CUWCD 2004a, Stamp et al. 2008).

Detailed flow recommendations for the Provo River to help guide the delivery of the ULS supplemental flows was completed in 2008 (Stamp et al.). An interagency June Sucker Flow Workgroup was established in 1994 and meets each spring to evaluate anticipated runoff conditions based on snowpack conditions, reservoir storage, etc. The June Sucker Flow Workgroup uses a consensus-based approach to determine the timing and quantity of dedicated flows to be released from the dams on the Provo River that will best support June sucker spawning success.

In 2009 modifications to the Fort Field Diversion to improve fish passage were completed. Prior to construction of the modified structure, this diversion (the first upstream barrier to upstream migration) impeded June sucker access to the upper 1.1 miles of designated critical habitat in all but very wet water years (USFWS 1999a). Fort Field diversion modifications completed in 2009 culminated a 5-year effort involving planning, NEPA compliance, design, and construction. Initial evaluations of fish passage conditions at lower Provo River diversion structures were completed more than 10 years ago (BIO-WEST 2001).

As the location of the primary June sucker spawning run, Provo River has been the focus of extensive biological research and monitoring efforts for decades. The river has served as the source of fish for genetic testing and development of hatchery broodstock. A flushing flow study was completed in 1996 (Olsen et al. 1996) to evaluate the effects of flow patterns on hydraulic habitat availability and spawning substrate maintenance.

2.7 Other Recovery Actions

The JSRIP involves six major recovery elements. These elements are listed below, and some specific examples are provided for each element. More comprehensive information can be found in the JSRIP program document and the annual JSRIP Annual Accomplishment reports (JSRIP 2011, JSRIP 2009b), and Provo River-specific examples listed above.

2.7.1 Nonnative and Sportfish Management

The introduction of nonnative fish species to Utah Lake and associated impacts from predation, competition, and habitat alteration contributed significantly to the decline of June sucker (USFWS 1999a). The current focus of the nonnative and sportfish management recovery element is on removing common carp (*Cyprinus carpio*) from Utah Lake. The carp population has been estimated to be 5.8 million carp of age 2 or older (Valdez 2006), which represents more than 90 percent of Utah Lake's fish biomass (JSRIP 2011). The carp removal effort under the JSRIP began in September 2009 with the goal of removing 5 million pounds of carp annually for a period of six consecutive years.

2.7.2 Habitat Development and Maintenance

This recovery element is focused on enhancing and protecting the habitats that June sucker rely on for all stages of their life cycle. Efforts include the 2008 lower Hobble Creek restoration project. Additional work in progress on Hobble Creek upstream of the restoration project includes evaluations of the feasibility of removing or modifying diversion structures to improve access to spawning habitat and NEPA analyses for additional stream restoration work. This proposed project represents a substantial portion of the needed work under this recovery element.

2.7.3 Water Management and Protection

This element focuses on protecting in-stream flows sufficient to provide for June sucker recruitment while allowing for continued development of water resources for human use. Specific efforts have included acquisition of in-stream flow water rights and related water conservation projects, development of target hydrographs (Keleher 1999), and annual Flow Workgroup meetings to assess how well targets are being met. Most recently, comprehensive flow recommendations have been developed for Provo River (Stamp et. al. 2008) and Hobble Creek (Stamp et al. 2009).

2.7.4 Genetic Integrity and Augmentation

This recovery element involves ongoing efforts to develop and implement a captive breeding program to augment the June sucker population to prevent extinction. Specific efforts have included collection and development of broodstock, development of warmwater hatchery facilities and refuge populations, and stocking of hatchery-raised June sucker back into Utah Lake.

2.7.5 Research, Monitoring and Data Management

This recovery element involves conducting and supporting research and monitoring efforts to better understand June sucker life history and habitat requirements in support of recovery implementation. Monitoring efforts also allow for the evaluation of previously implemented recovery actions and provide feedback to guide future recovery efforts. The JSRIP Technical Committee meets approximately bi-monthly to review, guide, and synthesize these efforts. The JSRIP has contracted or helped to fund annual monitoring and JSRIP element research, which has resulted in more than 56 reports and 12 peer-reviewed scientific articles since its inception in 2002. A database is being developed to help organize June sucker literature and facilitate information sharing and adaptive management strategies.

2.7.6 Information and Education

This recovery element focuses on promoting education and outreach efforts to increase public awareness and understanding of June sucker and the Utah Lake ecosystem and to encourage involvement in program activities. Specific efforts include the annual Utah Lake Symposium, annual Utah Lake Festival, preparing and distributing a school curriculum about Utah Lake, conducting public opinion surveys, and publishing the book *Utah Lake: Legacy* and documentary, which describe the region's history.

2.8 Relationship of Proposed Project to Water Development and Growth in Utah

In addition to ensuring water supplies for continued growth and development, the CUPCA also includes wildlife mitigation and conservation requirements. Under Section 301 of CUPCA, the Mitigation Commission was created to coordinate, plan, and administer implementation of fish, wildlife, and recreation mitigation and conservation measures for the CUP and other federal water development projects in Utah. Section 301(g)(4)(A) of the CUPCA directs the Mitigation Commission to:

> …restore, maintain, or enhance the biological productivity and diversity of natural ecosystems within the State [and] which have substantial potential for providing fish, wildlife, and recreation mitigation and conservation opportunities.

By enacting CUPCA in 1992, the U.S. Congress reaffirmed the commitment of the federal government to mitigate impacts to fish, wildlife, and recreation resources in Utah caused by construction and operation of the Bonneville Unit of CUP. While substantial progress has been made throughout the CUP area, several mitigation measures remain to be completed, including measures to aid in the recovery of June sucker within Provo River and Utah Lake.

As implementation of CUPCA has proceeded, numerous mitigation efforts have focused on recovery of the endangered June sucker. The environmental commitments of the JLAs associated with Provo River, Utah Lake, and June sucker are extensive. The Biological Assessment

prepared for the ULS EIS (CUWCD 2004) summarizes the many commitments to June sucker recovery:

- The JLAs will identify, acquire and permanently provide a block of water for flows in the lower Provo River through critical habitat, in perpetuity, for June sucker.

- The District, in cooperation with the other Provo River water users, the U.S. Fish and Wildlife Service (USFWS) and other members of the Provo River Flows Workgroup, will agree on operational scenarios that mimic dry, moderate and wet years. The District, with the support of the JLA and Provo River water users, will apply operational scenarios to the annual Provo River operation to benefit June sucker.

- The JLA, in cooperation with the State of Utah and the USFWS, will work toward establishment of a refugium in Red Butte Reservoir for June sucker.

- The JLA will participate in the development of a RIP for June sucker.

- Any future development of the Bonneville Unit of the CUP will be contingent on the RIP making sufficient progress towards recovery of June sucker.

- Provide 12,165 acre-feet of water to be regulated annually from Deer Creek Reservoir to the lower Provo River for June sucker spawning and rearing flows.

- The Mitigation Commission and the District will continue to acquire water shares from irrigation companies to provide flows in the lower Provo River to meet the 75 cfs target flow.

- Provide 3,300 acre-feet of irrigation company shares of water to flow unregulated toward the 75 cfs target flow in the lower Provo River.

- An annual average of 16,000 acre-feet of Bonneville Unit water would be delivered to the lower Provo River through the Spanish Fork-Provo Reservoir Canal Pipeline, when water is needed in Utah Lake for exchange to Jordanelle Reservoir, and when the lower Provo River is below the 75 cfs target flow.

- An annual average of 12,037 acre-feet of water, of which 4,000 acre-feet will be available annually, would be regulated out of Strawberry Reservoir through the Mapleton-Springville Lateral Pipeline to Hobble Creek to Utah Lake for June sucker spawning and rearing in Hobble Creek.

- The JLAs, in cooperation with the JSRIP and USFWS, have initiated a study to determine the feasibility of providing fish passage or removing the Fort Field Diversion Dam on the lower Provo River for June sucker spawning and rearing.

3.0 PROJECT CONTEXT

The previous section provided a review of background information that led up to the Provo River Delta Restoration Project. This section discusses the specific problem to be addressed by the proposed project. The statements of the proposed project purposes and the project need form the basis for screening of potential alternative courses of action suggested by the public, cooperating agencies, and the project design team.

The ESA provides strong protections for the June sucker and its critical habitat within the Provo River at its interface with Utah Lake. The listing of June sucker as endangered under the ESA, the designation of the lower 4.9 miles of the Provo River as critical habitat, and the June Sucker Recovery Plan (USFWS 1999a) all point to the necessity of modifying the lower Provo River in order to ensure the recovery of the species.

3.1 Project Need

The need for the proposed project is to restore a delta ecosystem at the Provo River interface with Utah Lake that would provide more naturally functioning habitat conditions, which are essential for spawning, hatching, larval transport, survival, rearing, and recruitment of the endangered June sucker on a self-sustaining basis.

3.2 Project Purposes

The specific purposes to be supported by the proposed project are as follows:

- to expedite recovery of the endangered June sucker by re-establishing essential June sucker habitat through restoring the lower Provo River ecosystem, at the Provo River/Utah Lake interface, to a more natural condition;
- to preserve and improve other fish, wildlife, riparian, and wetland habitats at the lower Provo River and its interface with Utah Lake;
- to provide recreational improvements and opportunities associated with the habitat restoration project; and
- to provide for continued development of the Central Utah Project (CUP).

3.3 Public and Agency Coordination

An Interdisciplinary Team (IDT) of resource specialists comprised of the Mitigation Commission, DOI, CUWCD, JSRIP, contractor BIO-WEST, Inc. (BIO-WEST), and other agencies conducted background research and initial site visits during fall 2008 and spring 2009 to identify potential resource impact issues and alternative concepts. The IDT identified potential issues by analyzing a variety of initial concepts for implementing the proposed project. The IDT

made extensive efforts to involve agencies, the public, and stakeholder groups early in the process to help identify potential issues, project needs, and alternatives.

A public scoping meeting was held on March 25, 2010, and was attended by 37 individuals. The public scoping comment period extended until April 30, 2010. Seventeen comment forms, letters, or e-mail messages were received during this period.

Additional public and agency comments were obtained through a series of meetings with key stakeholders during the scoping period, including the following:

- March 25, 2010; meeting with Utah Lake Commission
- April 6, 2010; presentation to Provo City Municipal Council Study Meeting
- April 27, 2010; presentation at annual assessment meeting of JSRIP
- April 28, 2010; meeting with Provo City Mayor, staff and Mr. Dale Despain, landowner
- April 28, 2010; meeting with John McMullin, Utah County Engineering Division

Prior to the formal scoping period, informal meetings and data gathering sessions were held as follows:

- January 21, 2009; IDT/agency pre-planning meeting

- April 20, 2009; meeting with Provo City Mayor and staff

- May 20, 2009; meeting with Provo City department staff (public works, recreation, airport, water)

- May 26, 2009; meeting with Utah Department of Natural Resources and Division representatives

- October 1, 2009, meeting with Utah County Commissioners

- November 17, 2009; meeting with Mountainland Association of Governments

- November 23, 2009; meeting with Utah Department of Transportation

- February – March 2010; met with or discussed the project with numerous landowners north of North Boat Harbor Drive (Harbor Drive) and West of 3110 West

- March 9, 2010; meeting with Provo City Mayor and staff

A Technical Assistance Team (TAT) was formed to assist in the development of project alternatives and to establish criteria to evaluate alternatives. This group was composed of individuals from federal, state, local, and private organizations with special knowledge or expertise related to the study area and June sucker recovery.

The TAT met twice as an entire group to review the project purpose and need and the range of alternatives. Through these meetings and follow-up individual meetings, the TAT helped define the project purposes, the range of alternatives, and criteria for evaluating alternatives.
In addition to the TAT and informal consultations with agency personnel, a request for formal comments regarding potential project issues was sent to regulatory agencies that may have an interest in the project. These included the U.S. Army Corps of Engineers (Corps), U.S. Environmental Protection Agency, U.S. Fish and Wildlife Service (USFWS), Federal Emergency Management Agency, and State of Utah resource agencies.

3.4 Potential Issues

The coordination efforts described in the previous section were aimed at identifying significant issues to be addressed in the EIS process. Significant issues are those with environmental effects that warrant resolution either through development of alternatives that reduce adverse impacts while achieving the project's purpose and need, through application of mitigation measures, or both. Issues that have been identified for the proposed project (URMCC 2010) include potential effects of project actions on the following:

- economic values derived from existing land uses and land ownership;
- private land acquisition;
- changes to the floodplain and flood control facilities;
- changes and future use of the abandoned portion of the Provo River;
- control of nuisance species such as mosquitoes and invasive weeds;
- local land use planning including Provo City streets, Provo Airport, and Utah County trails;
- water rights (e.g., wells, points of diversion) and public utilities;
- recreation resources including trails, sport fishing, Utah Lake State Park;
- cultural/historic resources;
- endangered species;
- wetland impacts;
- water quality;
- impacts/changes to existing infrastructure; and
- impacts to airport operations (bird strikes).

All of these issues were considered during the alternatives development process in order to address avoidance of impacts wherever possible. Where impacts would be unavoidable, analysis completed as part of the EIS will determine the level of impact, as well as discuss possible mitigation measures.

4.0 ALTERNATIVE DEVELOPMENT

The JLAs sought to identify a broad range of alternatives in the early stages of the EIS process. Following the official scoping comment period, all suggested ideas for alternatives were assembled in a "master list" of potential project alternatives. Some suggestions were not alternatives in themselves, but rather design considerations that might apply to any project

alternative. Complete project alternatives are presented in Section 4.1 and potential design considerations are presented in Section 4.2.

4.1 Suggested Project Concepts

After compiling the master list of project suggestions, the JLAs determined that there were 12 concepts for project alternatives, including the No-Action Alternative. These suggested concepts are:

1. Create rearing habitat between the existing channel and the north end of the Provo Municipal Airport, and connect with spawning habitat in the Provo River.

2. Create rearing habitat in the agricultural fields between the existing channel and Harbor Drive, and connect with spawning habitat in the Provo River.

3. Create rearing habitat in the agricultural fields north of the existing river channel, and connect with spawning habitat in the Provo River.

4. Divert the river to the south and into Provo Bay, create more spawning habitat in the River, and increase and improve existing rearing habitat in Provo Bay.

5. Improve the habitat quality of the existing Provo River channel.

6. Use a different tributary than Provo River for creating habitat (e.g., American Fork, Spanish Fork, or Mill Race Creek).

7. Use Mona Reservoir and Currant Creek to create habitat or try a “test” delta project there first.

8. Use other strategies such as reducing predatory fish populations, habitat improvement in Provo Bay, and carp removal to support June sucker recovery instead of rerouting and expanding the Provo River delta.

9. Create an “artificial” habitat area by pumping lake water into a restoration area, thus leaving the existing Provo River channel unaffected.

10. Develop a different habitat improvement project, such as improving/dredging Provo Bay, that would also have other benefits for fishing, boating, and recreating.

11. Divert the Provo River to the north of the existing channel and develop a new narrow corridor to accommodate meandering prior to the river’s terminus at Utah Lake north of the Utah Lake State Park.

12. Take “No-Action” with respect to the stated project need.

4.2 Design Considerations

Some of the suggestions provided by agencies and the public were design considerations rather than complete alternatives. The JLAs reviewed suggested design considerations and determined whether each suggestion would be possible to include with any of the project alternatives. These determinations are summarized in Table 2.

Table 2. Proposed design considerations.

DESIGN SUGGESTIONS	HOW WAS THIS ADDRESSED?
Provide Public Access.	This suggestion was considered in developing potential concepts.
Maintain or enhance recreational uses of lower Provo River.	This suggestion was considered in developing potential concepts.
Utilize all or portions of the existing Provo River channel as part of the design, improve habitat quality to better support June sucker rearing and/or spawning.	This suggestion was considered in developing potential concepts.
Include an outlet through the harbor at Utah Lake State Park to improve water quality and fishery conditions there which would support recreational fishing.	This suggestion was considered in developing potential concepts.
Route the proposed new channel through existing low areas and wetlands to minimize impacts to landowners.	This suggestion was considered in developing potential concepts.
Utilize existing canals and drainage ditches to transport fish.	This suggestion was considered in developing potential concepts.
Protect and enhance Provo City's conservation easement within the study area.	This suggestion was considered in developing potential concepts.
Coordinate with Provo City regarding plans for the proposed Northwest Connector road.	This suggestion was considered in developing potential concepts.
Consider the needs of the Provo City Municipal airport during planning of the proposed project.	This suggestion was considered in developing potential concepts.
Consider plans for the Utah County trail system during planning of the proposed project.	This suggestion was considered in developing potential concepts.
Consider allowing sport fishers to take walleye during their spawning run to reduce predation on juvenile June sucker.	This suggestion is beyond the scope of the project.
Consider facilitating populations of gizzard shad as an alternative food source for predatory fish to reduce predation on juvenile June sucker.	This suggestion is beyond the scope of the project.

5.0 LEVEL 1 SCREENING

The NEPA requires that an EIS "rigorously explore and objectively evaluate all reasonable alternatives to the proposed action," and that it devote "substantial treatment to each alternative considered in detail," (40 C.F.R. § 1502.14). "Screening" is the process whereby concepts are narrowed down to the range of reasonable alternatives that will be studied in detail in the EIS. For the alternatives "which were eliminated from detailed study," the EIS must "briefly discuss the reasons for their having been eliminated."

The JLAs used an iterative 3 level screening process that progressively narrowed the criteria used to evaluate the range of alternatives. If an alternative adequately met the Level 1 screening it was advanced to the next level of screening for further consideration. The ultimate goal was to identify those alternatives that best meet the purpose and need for the project and the issues raised by the public and agencies. The alternatives that are advanced through all three levels of screening will be advanced for detailed analysis in the EIS.

In the initial screening of alternatives, the JLAs considered whether suggested alternatives could meet the need for the project. Under NEPA, only alternatives that meet the "need" for the project should be carried forward for analysis. The degree to which each of the selected alternatives meet the need and the various purposes for the project are assessed in the EIS, and may ultimately form the bases for making a decision on which alternative to implement.

5.1 Evaluation Criteria

Based on the purpose and need of the proposed project, the JLAs screened all of the 12 initially suggested project concepts for their ability to meet the need for the project:

- **Delta Restoration:** Would the concept restore a naturally functioning delta ecosystem?

- **Self-sustaining Habitat:** Would the concept provide sufficient habitat for June sucker for spawning, hatching, larval transport, survival, rearing, and recruitment on a self-sustaining basis?

Concepts that would not meet both criteria were eliminated from further design and consideration. The following subsections provide a brief discussion of concept details and a determination of why they did or did not meet the Level 1 screening criteria.

5.2 Evaluation of Concepts

5.2.1 Create Habitat North of the Provo Airport

The concept would be to create rearing habitat between the existing Provo River channel and the north end of the Provo Airport and then to connect this delta area with spawning habitat in the Provo River. This concept would involve utilizing the existing channel of the Provo River with habitat improvements made in the lands immediately north and east of the newly expanded Provo Municipal Airport runway.

Determination: After developing a preliminary design, it became apparent that this concept would not meet either of the Level 1 criteria. It would not be possible to establish a naturally functioning delta ecosystem in this vicinity because of the narrow "bottleneck" between Utah Lake State Park and the airport runway. This concept would not be able to provide habitat sufficient for a self-sustaining population of June sucker because there is insufficient geographic area available where the necessary life-cycles of June sucker could occur. In particular, this concept could not provide additional spawning habitat or aid in hatching and larval transport.

Given its small geographic area and bottleneck between the airport runway and the Utah Lake State Park, it is not anticipated that this concept could provide adequate area to supply the missing rearing habitat required for a self-sustaining population. Of particular concern is the fact that the majority of problems facing juvenile June sucker take place upstream from this section of river. As a result, the lead agencies determined that this concept does not meet the Level 1 screening criteria and will not be considered further.

5.2.2 Create Habitat South of Harbor Drive

This concept would create rearing habitat in the agricultural fields between the existing river channel and Harbor Drive and then to connect with spawning habitat higher up in the Provo River channel. This concept would involve utilizing the existing channel of the Provo River with habitat improvements in the lands immediately north of the existing channel and south of Harbor Drive in the lower mile of the Provo River. The concept proposes widening a section of river that would likely be inundated during flood events to provide for June sucker rearing habitat while utilizing existing spawning habitat.

Determination: This concept does not meet either of the Level 1 criteria. After brief analysis it is clear that this concept would not be able to restore a naturally functioning delta ecosystem and is actually proposed in an area in which dredging has essentially turned the historic river channel into lake. This concept would not be able to provide habitat sufficient for a self-sustaining population of June sucker because there is insufficient geographic area available where the necessary life-cycles of June sucker could occur. In particular, this concept fails to provide adequate additional spawning habitat or aid in hatching and larval transport. Given its small geographic area and bottleneck between the airport runway and the Utah Lake State Park, it is not anticipated that this concept would provide adequate area to supply the missing rearing habitat required for a self-sustaining population. Of particular concern for this concept is the fact that the majority of problems facing juvenile June sucker starts taking place upstream from this section of river. As a result, the lead agencies have determined that this concept does not meet the need for the proposed project and will not be considered further.

5.2.3 Create Habitat in Agricultural Fields North of Existing River

This concept would create rearing habitat in the agricultural fields north of the existing Provo River channel by removing the existing lake shore levee north of Utah Lake State Park and connect with spawning habitat in the Provo River. This concept would involve diverting the Provo River into the agricultural area north of the existing river channel to increase both spawning and rearing habitat. The channel would be restored as far to the east as possible (approximately 3110 West) to enhance spawning habitat and the riparian ecosystem just upstream of the historic river-lake interface. The existing lake shore levee north of Utah Lake State Park Camping site would be partially removed to restore the connection between Skipper Bay and Utah Lake. Without the levee and with Provo River entering Skipper Bay, a delta would be created in a manner that would allow the river to spread out and slow down at the river/lake interface (at an approximate elevation of 4,489 feet). Existing levees would be breached to flood areas historically inundated by lake water. Complex habitats providing for a variety of June

sucker life stages would be created and maintained. There is sufficient area at this location that recreational use consistent with the ecological objectives of the proposed project could be encouraged through a variety of means.

Determination: This concept potentially meets both of the Level 1 criteria. Specifically, there is likely to be ample geographic area and adequate slope to enhance existing spawning habitat and restore a naturally functioning delta ecosystem at the historic river/lake interface. In addition, this concept potentially meets the second criterion in that it would likely provide a geographic area of enough size to construct the habitats and habitat features required in the various June sucker life-cycle stages on a self-sustaining basis, and has geographic area necessary for providing recreational opportunities in the study area, parking, and facilities if desired. As a result, the lead agencies determined that this concept would meet the need for the proposed project and will be evaluated further.

5.2.4 Divert the River South and into Provo Bay

This concept would divert Provo River to the south west of U.S. Interstate 15 (I-15) near Fort Field Diversion and into Provo Bay, create more spawning habitat in Provo River, and increase and improve existing rearing habitat in Provo Bay. This concept would involve diverting the Provo River immediately west of I-15 into the residential, commercial, and agricultural area south of the existing river channel to increase both spawning and rearing habitat. A delta would be constructed in a manner that would allow the river to spread out and slow down at the river/lake interface at Provo Bay. Complex habitats providing for a variety of June sucker life stages would be created and maintained. Recreational use of the area would be encouraged through a variety of means.

Determination: This concept potentially meets both of the Level 1 criteria. Specifically, there is likely to be ample geographic area and adequate slope to enhance existing spawning habitat and restore a naturally functioning delta ecosystem. In addition, this concept potentially meets the second criterion in that it likely provides a geographic area of enough size to construct the habitats and habitat features required in the various June sucker life-cycle stages on a self-sustaining basis. As a result, the lead agencies determined that this concept would meet the need of the proposed project and will be evaluated further.

5.2.5 Improve Habitat Quality within Existing River Channel

This concept would improve the habitat quality of the existing Provo River channel**.** This concept was suggested in the context of minimizing land acquisition necessary for accomplishing the project purpose and need. The concept would involve creating artificial in-stream habitat structures to provide cover and structure for June sucker larvae and young of the year fish.

Determination: This concept does not meet either of the Level 1 criteria. After brief analysis it is clear that this concept would not be able to restore a naturally functioning delta ecosystem because it lacks sufficient land area, lacks sufficient slope characteristics, and is actually proposed in an area in which dredging has essentially turned the historic river channel into a

channelized lake. It is unclear what actions could be taken to improve the existing river channel habitat quality, and how this concept would remedy the water temperature/productivity issues in this trapezoidal channel. The existing river channel resides in an aggressively managed channel, similar to a large canal. This prevents the river from overflowing its banks during high flows but eliminates the possibility of dynamic habitat capable of supporting the necessary life-cycles of June sucker. In particular, this concept could not provide additional spawning habitat or aid in hatching and larval transport. Given its small geographic area, it is not anticipated that this concept could provide adequate area to supply the missing rearing habitat required for a self-sustaining population. As a result, the lead agencies have determined that this concept does not meet the need for the proposed project and will not be considered further.

5.2.6 Use a Different Tributary

This concept would use a tributary other than the Provo River for creating habitat, such as American Fork, Spanish Fork, or Mill Race Creek. This concept would include creating a delta ecosystem to increase spawning and rearing habitat on a tributary to Utah Lake other than Provo River. A delta would be constructed in a manner that would allow the river to spread out and slow down at the river/lake interface. Complex habitats providing for a variety of June sucker life stages would be created and maintained. Recreational use of the area would be encouraged through a variety of means.

Determination: The JLAs have determined that implementing a restoration project on another Utah Lake tributary instead of Provo River would not fulfill the responsibilities and commitments of the JLAs under CUPCA and the JSRIP. Nonetheless, the JLAs have evaluated the other tributaries to Utah Lake. A feasibility study was conducted in 2002 (Stamp et al. 2002) to evaluate the potential of every tributary to Utah Lake for June sucker spawning and rearing.

Historically, June sucker most likely spawned in multiple tributaries to Utah Lake, but alterations associated with flow withdrawals, diversion structures, and channelization have greatly limited or precluded access to suitable spawning habitat in tributaries other than the Provo River. Ultimately the Hobble Creek restoration project was successfully implemented in 2009 to serve as a location of a second spawning run to fulfill another June Sucker Recovery Plan requirement. That study eliminated all other tributaries except Spanish Fork River and American Fork River from detailed consideration due to one or more of the following factors: lack of stream flows during most of the year including during June sucker transport and rearing periods; inadequate or incorrect substrate for spawning; low potential to create or restore spawning habitat; no interface with Utah Lake; constraints by adjacent developments; poor water quality. The other tributaries also have little or no documented history of June sucker use.

Regarding American Fork and Spanish Fork rivers, they often lack water altogether during the June sucker spawning period. Spanish Fork River is heavily used for irrigation. Gage records indicate that June flows on Spanish Fork are less than 5 cubic feet per second (cfs) about 50 percent of the time (Stamp et al. 2002). In 2002 when the study was completed, the Spanish Fork River was still under consideration as a potential stream to have instream flows restored under the Utah Lake System of the CUP. Subsequently the decision was made to not deliver instream

flow water and/or exchange water to Utah Lake via the Spanish Fork River, but to utilize Provo River and Hobble Creek for that purpose [cite ULS RODs]. Numerous irrigation diversions withdraw water from American Fork and commonly dewater the river during the summer months and sometimes dewater the lower river during the spring spawning period. In three out of five years during the 2002–2006 monitoring period, the Utah Division of Wildlife Resources was unable to complete surveys on American Fork because the river was either dry or too shallow for snorkeling (UDWR 2003, UDWR 2004, UDWR 2005, UDWR 2006, UDWR 2007). No instream flow protections are known to have been established for the lower portions of either of these tributaries, and therefore there is little assurance that water would consistently be available each year to support June sucker spawning and recruitment.

Powell Slough Waterfowl Management Area was also mentioned in public scoping as a potential alternative location for the Proposed Project. This area is a shoreline wetland area that does not connect to any tributaries of Utah Lake. It therefore does not provide connectivity to spawning habitat and consequently also does not have potential to provide nursery/rearing habitat. (Another concept was to route the Provo River through Powell Slough, which is discussed under Concept 11 below.)

Every documented guidance from the U.S. Fish and Wildlife Service and other members of the June Sucker Recovery Team since the JS was listed as endangered in 1986 has emphasized the need for successful recruitment from the Provo River spawning run to recover the June sucker. The June Sucker Recovery Plan (USFWS 1999a) requires improvement of Provo River and Utah Lake habitats to support self-sustaining June sucker populations. While restoring a delta ecosystem on a tributary other than Provo River may also be of some benefit to June sucker and the Utah Lake ecosystem, it will not meet the June Sucker Recovery Plan requirement nor the June Sucker Recovery Implementation Program commitments to recover the June sucker by restoring suitable habitat conditions in Provo River and its interface with Utah Lake. It is not reasonable for the JLAs to propose an action which would not further recovery objectives nor result in continued findings by the FWS that “sufficient progress” is being met by the JSRIP.

Even in its current altered condition, the section of the lower Provo River designated as critical habitat provides the greatest, though limited, habitat suitable for spawning in the Utah Lake system. As the site of the primary June sucker spawning run, Provo River has been the focus of extensive recovery measures for decades. To this end, millions of dollars have been spent to acquire water and manage flows for spawning and larval transport in the lower Provo River, to conduct studies on spawning and rearing habitat requirements to guide flow recommendations, on removal of fish passage barriers in the critical habitat reach, and other measures.

For more than 15 years, efforts have been underway to secure water rights to support year-round instream flows to the lower Provo River. To date more than 13,000 acre-feet of water have been acquired annually on a permanent basis for lower Provo River streamflows under Section 207 and Section 302 of the Central Utah Project Completion Act (CUPCA). These flows have been used almost exclusively to benefit June sucker spawning and larval transport. Efforts to acquire additional instream water rights remain ongoing. The Utah Lake Drainage Basin Water Delivery System (ULS) project, as authorized by the CUPCA, includes an environmental commitment to supplement Provo River stream flows to assist with June sucker recovery. When operational and

under full water delivery conditions, the ULS project is projected to deliver on average approximately 16,000 acre-feet of supplemental water annually (CUWCD 2004). In addition, about 12,165 acre-feet of water will be dedicated annually specifically for flows in the lower Provo River and the June sucker. Efforts through the water conservation program (authorized in Section 207 of CUPCA) to acquire additional instream water are ongoing. It is anticipated that a firm supply of up to 20,000 acre-feet may ultimately be available annually for controlled release in direct support of June sucker spawning and larval transport in the Provo River.

In summary, restoration of the lower Provo River and its interface with Utah Lake is essential to the recovery of June sucker, and is the most important area to focus recovery efforts because:

- the lower Provo River serves as the primary June sucker spawning location and is the only Utah Lake tributary where successful reproduction has been observed each year since the 1980s (Ellsworth et al. 2010);

- the lower Provo River is protected as critical habitat under the ESA;

- efforts to secure instream flows on the lower Provo River have been successfully underway for 15 years;

- other tributaries to Utah Lake are much smaller and have more factors limiting June sucker recovery than the Provo River;

- millions of dollars have been expended and are committed to future expenditure for studies, habitat improvements, and the securing and provision of water to the lower Provo River because of its identified importance for June sucker as a result of prior Section 7 ESA consultation on projects affecting the Utah Lake Drainage Basin.

Pursuit of a different tributary (not Provo River) to restore spawning and rearing conditions to recover June sucker would not replace the need to restore suitable spawning and rearing conditions in the Provo River/Utah Lake system. Although restoring a delta ecosystem on another tributary might be additive in its effects and might be a desirable endeavor for the future under the JSRIP, the JLAs recognize the restoration of the Provo River at its interface with Utah Lake as a required and essential step towards recovery.

These factors lead to the determination that this concept would not be considered further.

5.2.7 Use Mona Reservoir and Currant Creek

This concept suggests the use of Mona Reservoir and Currant Creek to create habitat, or to try a “test” delta project there first. This concept would involve creating a delta at the Currant Creek/Mona Reservoir interface to increase both spawning and rearing habitat. Complex habitats providing for a variety of June sucker life stages would be created and maintained. Recreational use of the area would be encouraged through a variety of means.

Determination: The concept does not meet either of the Level 1 criteria developed for the proposed project. It should be noted that Mona Reservoir and Currant Creek has no historical June sucker use and are not part of the Utah Lake system. After brief analysis it is clear that this concept does not restore or create suitable spawning or rearing habitat in a tributary of Utah Lake. Creating a delta restoration project to support June sucker spawning and recruitment at Currant Creek and Mona Reservoir would be problematic. Efforts to introduce June sucker into Mona Reservoir have been undertaken by the JSRIP, and are still considered experimental. Success of those efforts is still being evaluated. Attempts to further "test" the success of a potential Currant Creek delta restoration project would be many years in the future, if at all, because June sucker have yet to establish an adult population in Mona Reservoir that would be capable of sustaining a spawning run. The small size of Currant Creek would not likely provide sufficient flows or have sufficient use by June sucker if they were to be established in Mona Reservoir to constitute much of a sustainable population.

The JSRIP has already undertaken a "test" project involving the restoration of river/lake interface area, which occurred on Hobble Creek in 2009. While not a true delta restoration, the project involved many of the same goals and design characteristics that are proposed for the Provo River and is considered a successful "test" of the overall delta restoration concept. Indeed, the Hobble Creek project represents a smaller example of how restoration activities could provide greater benefits if they are of appropriate magnitude.

The lead agencies determined that this concept does not meet the need for the proposed project and will not be considered further.

5.2.8 Use Strategies/Actions Other Than Habitat Creation

This concept would use other strategies (e.g., reducing predatory fish populations, habitat improvement in Provo Bay, and carp removal) to support June sucker recovery instead of rerouting and expanding the Provo River delta. This concept attempts to find a separate idea or set of ideas that would accomplish the same purposes as the proposed project. A variety of options exist in this regard.

Determination: The concept does not meet either of the Level 1 criteria developed for the project. In particular, the concept would not provide a naturally functioning delta, nor would it provide sufficient habitat for a self-sustaining population of June sucker in Provo River and Utah Lake. However, it is acknowledged that the need for delta restoration and reestablishment of suitable nursery habitat to support a self-sustaining population of June sucker does not exist in isolation. Indeed, the needs proposed to be met by the proposed concept are being addressed under the JSRIP and June Sucker Recovery Plan. The June Sucker Recovery Plan and the JSRIP are inclusive of a variety of strategies and projects required to meet the goals of June sucker recovery(JSRIP 2002–2009). These strategies, or recovery program elements, include the items listed in Section 2.0 of this document. To that end, the concept that other ideas may meet the needs of the proposed project is included in the No-Action Alternative for the proposed project because they would be pursued with or without the proposed project's implementation.

Because these other ideas do not meet the Level 1 criteria, and because they would likely be implemented anyway as part of the overall recovery and mitigation effort, the lead agencies have determined that this concept does not meet the need for the proposed project and will not be considered further.

5.2.9 Create an Artificial Habitat Area

This concept would create an "artificial" habitat area by pumping lake water into a restoration area, thus leaving the existing Provo River channel unaffected. This concept would involve leaving the existing Provo River as it is now and using a series of pumps to transport lake water to an area that could be created or restored for the purposes of recovering June sucker.

Determination: This concept does not meet either of the Level 1 criteria. This concept would not be able to restore a naturally functioning delta ecosystem because it would rely on mechanical means of transporting water. In addition, costs associated with operating and maintaining a pumping system of adequate size would likely exceed reasonable thresholds. The extensive reliance on artificial and mechanical means of water transport associated with this concept fail to meet the second criteria of achieving a self-sustaining population of June sucker.

The JSRIP partners have some experience with maintaining artificial habitats and/or refugia populations at Camp Creek Reservoir, Red Butte Reservoir, and Arrowhead and Teal Ponds similar to this concept. They have been developed and are continuing to be maintained for the primary purpose to prevent extinction of June sucker. Because neither of the criteria can be met, the lead agencies determined that this concept does not meet the need for the proposed project and will not be considered further.

5.2.10 Provo Bay Habitat Improvement

This concept would develop a different habitat improvement project, such as improving/dredging Provo Bay, that would also have other benefits for fishing, boating, and recreating. This concept would primarily include intensive management of habitat within Provo Bay to help optimize its use by a variety of fish species, including June sucker and sportfish species.

Determination: This concept does not meet either of the Level 1 criteria. No restoration of a delta ecosystem is included in the concept and no provision would be made to provide for a self-sustaining population of June sucker since it does not connect adequate spawning and rearing habitat necessary for successful recruitment. It should be noted that past studies have noted the availability of June sucker habitat within Provo Bay. However, this concept does not address how juvenile June sucker would access this habitat under existing conditions in the Provo River where they are either preyed upon or starve to death. Because neither of the criteria can be met, the lead agencies determined that this concept does not meet the need of the proposed project and will not be considered further.

5.2.11 Divert the Provo River to the North into a Narrow Corridor

This concept would divert all or a portion of the Provo River to the north of the existing channel and develop a new narrow corridor to accommodate meandering prior to the river's terminus at Utah Lake north of the Utah Lake State Park. This concept was suggested in the context of minimizing land acquisition necessary for accomplishing the project purpose and need. The concept would basically provide a narrow strip of land (approximately 200 feet) through the area north of the existing channel for a new channel to have some ability to meander and migrate as it moves towards Utah Lake. The concept would not include additional width for a delta, but would be aimed at trying to provide habitat for June sucker spawning and rearing within a narrow riverine corridor.

Determination: This concept does not meet either of the Level 1 criteria. After brief analysis it is clear that this concept would not be able to restore a naturally functioning delta ecosystem because it is intentionally designed under the premise that June sucker could utilize riverine habitats for both spawning and rearing. Nearly all literature and studies to date acknowledge that riverine habitat alone would be unable to provide June sucker rearing habitat. Indeed, current conditions in the Provo River and lack of rearing habitat make this point abundantly clear. The lack of delta ecosystem components in this concept does little to alter current conditions within the existing Provo River channel. The concept effectively eliminates the possibility of the dynamic habitat required to support the critical lifecycles of June sucker. In particular, this concept would not provide additional rearing habitat as the channel would require periodic dredging to maintain capacity for high flow events given a lack of floodplain capacity in a "narrow corridor" similar to the existing channel and floodplain. Given the narrowness of the geographic area, it is not anticipated that this concept could provide adequate habitat to supply the missing rearing habitat required for a self-sustaining population. As a result, the lead agencies have determined that this concept does not meet the need of the proposed project and will not be considered further.

5.2.12 No-Action Alternative

Consideration of a No-Action Alternative is required in regulations for implementing NEPA (40 CFR 1502.14). This alternative considers the consequences of taking "no action" with respect to the purpose and need of the proposed project. It also provides the baseline condition for comparing expected environmental outcomes of the potential build alternatives. Under the No-Action Alternative, the proposed project would not be constructed.

Determination: Even though it does not meet the Level 1 criteria, the No-Action Alternative is being carried forward for detailed study in the EIS, in accordance with CEQ regulations. Potential impacts of failing to meet these needs will be evaluated in the Draft EIS along with other identified impacts of the No-Action Alternative.

5.3 Level 1 Screening Summary

Table 3 summarizes the Level 1 screening process. Two concepts and the No-Action alternative were advanced for additional development and screening:

- Create habitat in the agricultural fields north of the existing Provo River (see Section 5.2.3).
- Divert the Provo River south and into Provo Bay as described in Section 5.2.4.
- The No-Action Alternative (see Section 5.2.12) was also advanced as required by NEPA.

Table 3. Level 1 screening summary.

CONCEPT	LEVEL 1 SCREENING CRITERIA	
	DELTA RESTORATION	SELF-SUSTAINING POPULATION
1. Create rearing habitat between the existing channel and the north end of the Provo Airport and connect with spawning habitat in the Provo River.	☒	☒
2. Create rearing habitat in the agricultural fields between the existing channel and Harbor Drive and connect with spawning habitat in the Provo River.	☒	☒
3. Create rearing habitat in the agricultural fields north of the existing river channel and connect with spawning habitat in the Provo River.	☑	☑
4. Divert the river to the south and into Provo Bay; create more spawning habitat in the River, increase and improve existing rearing habitat in Provo Bay.	☑	☑
5. Improve the habitat quality of the existing Provo River channel.	☒	☒
6. Use a different tributary than the Provo River for creating habitat such as American Fork, Spanish Fork, or Mill Race Creek.	☑	☒
7. Use Mona Reservoir and Currant Creek to create habitat or try a "test" delta project there first.	☑	☒
8. Use other strategies such as reducing predatory fish populations, habitat improvement in Provo Bay, and carp removal to support June sucker recovery instead of rerouting and expanding the Provo River delta.	☒	☒
9. Create an "artificial" habitat area by pumping lake water into a restoration area, thus leaving the existing Provo River channel unaffected.	☒	☒
10. Develop a different habitat improvement project, such as improving/dredging Provo Bay, that would also have other benefits for fishing, boating, and recreating.	☒	☒
11. Divert the Provo River to the north of the existing channel and develop a new narrow corridor to accommodate meandering prior to the river's terminus at Utah Lake north of the Utah Lake State Park.	☒	☒
12. No-Action Alternative	☒	☒

☑ Would meet the project needs. ☒ Would not meet the project needs.

6.0 LEVEL 2 SCREENING

Under CUPCA and in accordance with the June Sucker Recovery Plan, and numerous commitments as a result of consultation with USFWS as required under Section 7 of ESA, the JLAs have legal responsibilities and commitments specific to the recovery of June sucker. To ensure that the proposed concepts would enable the JLAs to meet these responsibilities and commitments, while simultaneously meeting the demands of NEPA and the Clean Water Act, additional screening was developed.

The JLAs have a long history of cooperating on various agreements and efforts to recover June sucker. These efforts and agreements have, in part, been stipulated by CUPCA (P.L. 102-575 as amended), the ESA, the Fish and Wildlife Coordination Act, and similar laws that require consultation and coordination when planning and implementing water development projects. Title II of CUPCA authorized funds for completion of the Diamond Fork System and for construction of facilities and features under the Utah Lake Drainage Basin Water Delivery System. Title III of CUPCA created the Mitigation Commission and established standards and requirements for completing environmental mitigation measures adopted pursuant to the National Environmental Policy Act on a priority basis (CUPCA Section 301(f)(3)), among other things. Title III also required that environmental mitigation projects "…restore, maintain, or enhance the biological productivity and diversity of natural ecosystems within the State…", [are] "…based on, and supported by, the best available scientific knowledge;", and "… complement the existing and future activities of the Federal and State fish, wildlife, and recreation agencies…" (CUPCA Section 301(g)(4)).

June sucker recovery has been a focus of mitigation efforts by the JLAs primarily as a result of environmental commitments adopted pursuant to NEPA decisions on the Diamond Fork System and the ULS of the Central Utah Project (see Section 2.8). The JLAs have consulted with the U.S. Fish and Wildlife Service while planning those projects, as required by the ESA. In its Biological Opinion issued on the 1999 Diamond Fork Final Supplement to the Final Environmental Impact Statement, the USFWS was specific in its recommendation as to how the JLAs should accomplish habitat development for June sucker:

> The JLA, in cooperation with the FWS and the June sucker Technical Workgroup, should determine the feasibility of restoring the lower Provo River to obtain past habitat characteristics and complexity. The lower Provo River historically had a complex delta system, which provided braided, slow, meandering channels. This delta system provided low velocity habitat as a refuge and rearing habitat for larval and juvenile June sucker. Re-establishment of the delta system may provide habitat needed by larval and juvenile June sucker to obtain sized needed to reduce predation by nonnative fishes. (USFWS 1999b)

Ultimately, the JLAs and USFWS concurred that making a commitment to implement such a project, which in and of itself would require the preparation of an EIS, was problematic to adopt as a commitment in the Records of Decision for the ULS System. The JLAs instead made the

commitment that future development of the Bonneville Unit of the CUP will be contingent on the RIP making sufficient progress towards recovery of June sucker. The ULS Biological Assessment for the ULS Final Environmental Impact Statement includes a thorough history and discussion of the consultation history regarding June sucker by the JLAs and other Federal cooperators.

In an effort to make sufficient progress toward recovery, the JLAs were instrumental in the formation of the JSRIP in 2002. One of the goals of the JSRIP is to recover June sucker so that it no longer requires protection under the ESA. The June Sucker Recovery Plan and the JSRIP recovery elements recognize the need for habitat development and maintenance of the lower Provo River and Utah Lake.

Concepts that do not allow the JLAs to meet these commitments and recommendations will not be considered further.

In addition to meeting specific commitments under the CUPCA and the JSRIP, the JLAs must meet the requirements of NEPA and the Clean Water Act. Under NEPA, alternatives must be considered to be "reasonable." Reasonable alternatives must meet the purpose and need of the proposed project and be implementable. The proposed concepts will be evaluated to ensure that they are actually implementable within the study area.

In addition to the NEPA reasonableness standard, projects with impacts to waters of the United States must also meet the "practicability" standard under Section 404 of the Clean Water Act (40 CFR 230). Although adherence to this standard is applied by the Corps in review of proposed projects, it provides a useful tool in evaluating whether a particular concept may be permitable under the act. Alternatives are considered practicable under Section 404 when they are "available and capable of being done after taking into consideration cost, existing technology, and logistics in light of overall project purposes."

As such, the remaining concepts will be evaluated to ensure that they meet both the reasonableness standard and the practicability standard. Concepts that do not meet both of the standards will not be considered further.

6.1 Evaluation Criteria

To address the responsibilities and commitments of the JLAs and the standards of both NEPA and the CWA, two additional criteria were developed to ensure that concepts advanced beyond this point would be capable of meeting basic standards of implementation and permitablility. These criteria are:

- ***Regulatory Commitments:*** Would the concept fulfill the responsibilities and commitments of the JLAs under CUPCA and the JSRIP?

- ***Reasonable and Practicable:*** Would the concept be considered reasonable under NEPA and Practicable under Section 404 of the Clean Water Act?

6.2 Evaluation of Concepts

The two remaining concepts were evaluated to determine if they met the Level 2 screening criteria. Consistent design standards were used for both alternatives to provide a fair comparison.

6.2.1 Create Habitat in Agricultural Fields North of the Existing River

This concept would create rearing habitat in the agricultural fields north of the existing river channel by removing the existing lake shore levee north of Utah Lake State Park. This would restore a small bay (historically known as Skipper Bay) that would be connected with spawning habitat in the realigned Provo River. This concept was developed further in an effort to more fully understand and evaluate its potential impacts. Numerous preliminary concepts were developed for this potential study area. An example preliminary design is illustrated in Figure 6.

Determination: This concept would be consistent with the commitments and obligations of the JLAs under CUPCA and the JSRIP. Specifically, the concept has the potential to accomplish the goals and objectives outlined in the June Sucker Recovery Plan and is in keeping with the recommendations of the numerous Biological Opinions issued by the USFWS as discussed previously.

In addition, evaluation of the concept regarding reasonableness under NEPA and practicability under Section 404 of the Clean Water Act indicate that the concept is likely both reasonable and practicable. Under NEPA, a concept is determined to be reasonable if it potentially meets the purpose and need and is considered implementable. The concept was determined to potentially meet the purpose and need of the proposed project as discussed under Level 1 screening. Analysis under Level 2 screening also indicates that it is likely implementable. Specifically, the land north of the existing river channel is largely undeveloped agricultural land. Although the land is separated into different parcels with a variety of landowners, very few improvements or structures have been made in the area. Another attribute of this area is that much of it is currently protected by levees and below the level of the lake. This facilitates implementation because it aids in the establishment of a delta ecosystem. As a result, the JLAs feel that the concept represents a unique situation that facilitates the needs of the proposed project and have determined the concept to be potentially implementable and thus, reasonable under NEPA.

Practicability under Section 404 of the Clean Water Act is determined by taking into account costs, existing technology, and logistics. Analysis of the costs associated with this concept indicates that there is no reason for the JLAs to believe that there is anything about the concept that would increase costs over and above what is expected for this type of project. It would also appear that the technology to complete this concept is existing and readily available. In addition, there are likely only minor logistical details for consideration. These include multiple landowners, likely impacts to existing structures, resources of concern for resource agencies, and the possibility of some historic water conveyance structures. Because these issues could be addressed by a variety of means, the JLAs have determined that this concept is both reasonable and practicable and will be advanced to a higher level of design and level 3 screening.

Figure 6. Preliminary northern concept, level 2 screening.

6.2.2 Divert the River South and into Provo Bay

This concept would divert Provo River to the south west of I-15 near Fort Field Diversion and into Provo Bay, create more spawning habitat in the Provo River, and increase and improve existing rearing habitat in Provo Bay. This concept was developed further in an effort to more fully understand and evaluate its potential impacts. Only one site along the river west of I-15 afforded the topography and slope for this concept to function. To minimize and avoid potential impacts, the hypothetical path for the concept was routed through areas with minimal development to the extent possible. Standards used in creating this hypothetical route through southwest Provo were consistent with the needs of the proposed project and with the standards utilized for evaluation of the other concept being evaluated under level 2 screening. A preliminary design illustrating this concept is illustrated in Figure 7.

Determination: This concept would be consistent with the commitments and obligations of the JLAs under CUPCA and the JSRIP. Specifically, the concept has the potential to accomplish the goals and objectives outlined by the JSRIP and is in keeping with the recommendations of the Biological Opinion as discussed previously. However, evaluation of the concept regarding reasonableness under NEPA and practicability under Section 404 of the Clean Water Act indicate that the concept is likely neither reasonable nor practicable.

Under NEPA, a concept is determined to be reasonable if it potentially meets the purpose and need and is considered implementable. Although the concept would meet the purpose and need of the proposed project, it is highly unlikely that it is actually implementable. Specifically, a variety of factors indicate the concept would result in clear and broad impacts. These impacts are of such a magnitude that they would result in broad societal and infrastructure changes, disproportionately high costs, and political ill will. Analysis indicates that this concept would require the relocation of at least 134 homes, 6 businesses, a 15-acre park, and large tracts of agricultural land. Existing transportation infrastructure would be altered to the extent that several roads would likely be closed or turned into cul-de-sacs, and three major bridge structures totaling 3,795 feet would need to be constructed to accommodate existing collector roads. In addition, nine potential hazardous waste sites would be disturbed, existing bus routes and stops would be removed, and 3.7 acres of a known archeological site would be impacted. Impacts to structures would likely include a number of properties eligible for the National Register of Historic Places in accordance with Section 106 of the National Historic Preservation Act. In addition, analysis also indicates that this concept could impact a minority population with regard to Executive Order 12898. Discussions with Provo City representatives have indicated that the concept is contrary to longstanding planning for the area and that the resulting broad impacts to the southwestern Provo community would not be acceptable. Provo City also owns and manages the airport and has expressed concern about ecosystem restoration and a probable subsequent increase in bird use along flight paths adjacent to this concept. Because of the magnitude of impacts projected with this concept, the JLAs determined that it is basically not implementable and therefore not reasonable under NEPA.

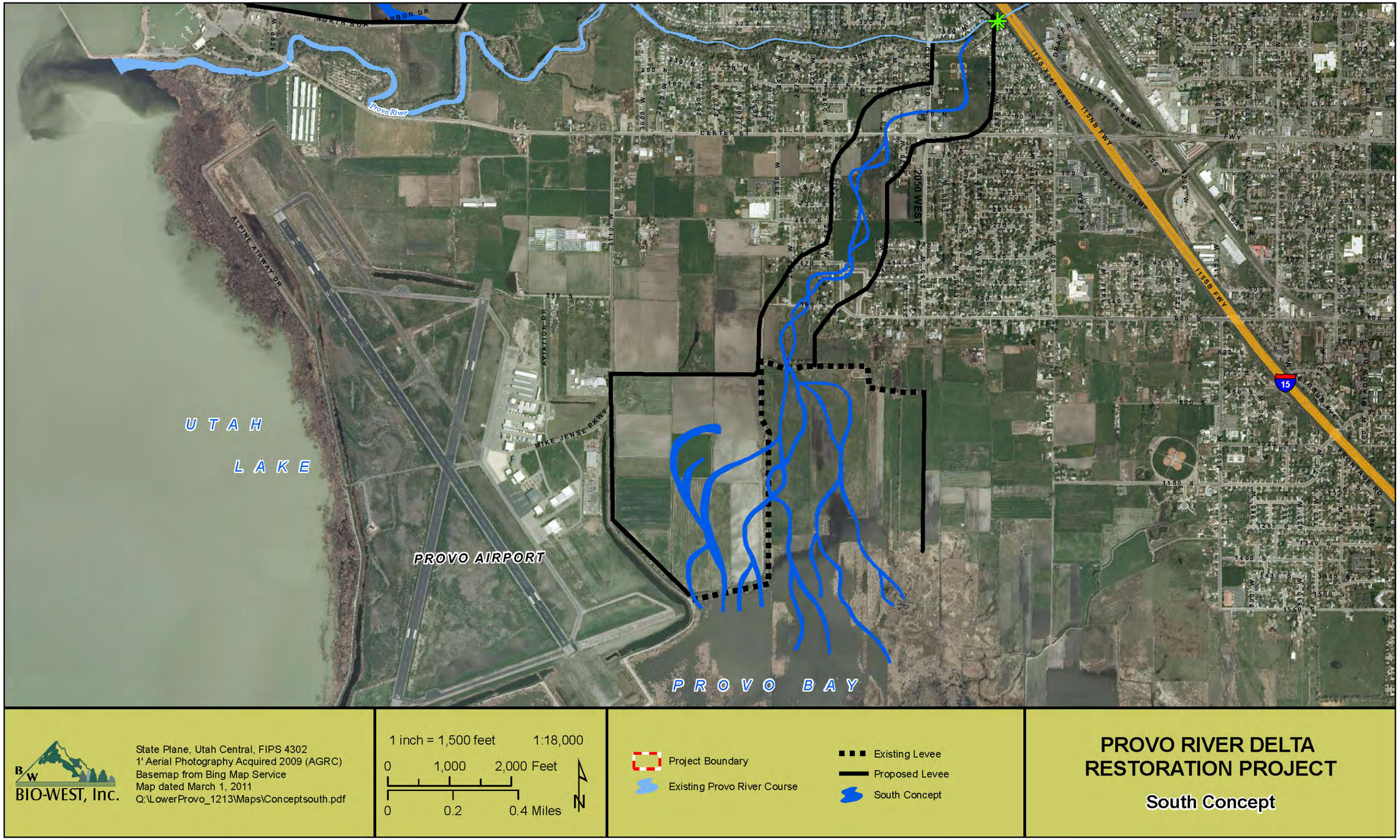

Figure 7. Preliminary southern concept, level 2 screening.

As noted, practicability under Section 404 of the Clean Water Act is determined by taking into account costs, existing technology, and logistics. In considering the impacts noted above, particularly the residential and commercial relocations and the required bridge structures, the resulting costs associated with this concept would represent expenditures over and above what is expected for this type of project and would not be practicable. In fact, if a conservative estimate of $200 per square foot for bridge structure costs alone were utilized (Barton J. 2011, pers. comm.), the resulting costs would constitute an additional $51 million. Although existing technology is likely adequate to actually construct the proposed concept, the magnitude of the impacts described above also make the concept not practicable logistically. From myriad logistical standpoints including regulatory requirements (Section 106, Environmental Justice), broad land use changes, infrastructure requirements, community impacts, and political concerns, it is clear to the JLAs that the concept, when coupled with extraordinary costs, is not practicable.

Because the concept was determined neither reasonable nor practicable, the concept has been eliminated from further consideration.

6.3 Level 2 Screening Summary

One concept was advanced for additional development and screening; the No-Action Alternative was also advanced:

- Create rearing habitat in the agricultural fields north of the existing river channel and connect with spawning habitat in the Provo River.
- The No-Action Alternative was also advanced as required by NEPA.

Table 4 summarizes the level 2 screening process.

Table 4. Level 2 screening summary.

CONCEPT	LEVEL 2 SCREENING PROCESS	
	REGULATORY COMMITTMENTS	REASONABLE AND PRACTICABLE
1. Create rearing habitat in the agricultural fields north of the existing river channel and connect with spawning habitat in the Provo River.	☑	☑
2. Divert the river to the south and into Provo Bay; create more spawning habitat in the River, increase and improve existing rearing habitat in Provo Bay.	☑	☒

☑ Would meet the project needs. ☒ Would not meet the project needs.

With only one concept advancing beyond level 2 screening, the lead agencies determined that it was appropriate to obtain more detailed information about the natural resource context of the project area and to use that information to develop multiple potential site designs. These more-detailed designs could then be evaluated in level 3 screening to determine which designs would have the greatest potential to meet the need and purposes the proposed project. This level 3 screening would determine the alternatives to be evaluated in detail in the EIS.

7.0 PROPOSED PROJECT AREA CONTEXT

The remaining potential site for the proposed project after level 2 screening was the undeveloped area north of the existing Provo River channel (hereafter, the project area). The project area is shown in Figure 8 with an approximate delineation of the historic Provo River delta. The project area would constitute less than 25 percent of the historic delta area (Figure 8).

The JLAs obtained detailed information about the project area in order to develop potential designs for the project that could be assured of meeting the project needs, avoiding resource impacts to the extent practicable, and responding to public-identified issues to the extent practicable. This included detailed topography using light detection and ranging technology (LIDAR), detailed information about the project area, Provo River, and Utah Lake hydrology, wetlands, soils, land ownership/use, vegetation, and wildlife. Existing and planned land uses, water rights, and public utilities were also mapped in order to evaluate potential conflicts and possible avoidance.

7.1 Topography

7.1.1 Project Area Topography

Accurate elevation data within the project area is critically important for developing design concepts and evaluating how they would function both ecologically and to benefit June sucker. BIO-WEST contracted with Utah State University to provide detailed bare surface elevation data using LIDAR technology. The coordinate system and datum used for this survey were NAD 83 State Plane Utah Central Zone (feet, horizontal), NGVD 29 (feet, vertical). The vertical datum of 1929 was used to be consistent with the datum used to report Utah Lake water elevation data. On September 28, 2010, the project area was over flown and LIDAR data collected. Target panels were installed prior to the LIDAR flight and XYZ coordinates surveyed on the ground by Nolte, Inc.,(Nolte) to verify LIDAR accuracy. The LIDAR elevation data is verified to plus or minus 0.7 inches (1-sigma) in accuracy. Horizontal resolution of 3 feet was obtained. With this data, ground elevation data accurate within a single inch is available for every 3-foot by 3-foot square, and detailed contours, such as those shown in Figure 9, were generated. Many additional survey control points were established in the project area by Nolte to assist with on-the-ground channel and lake surveys.

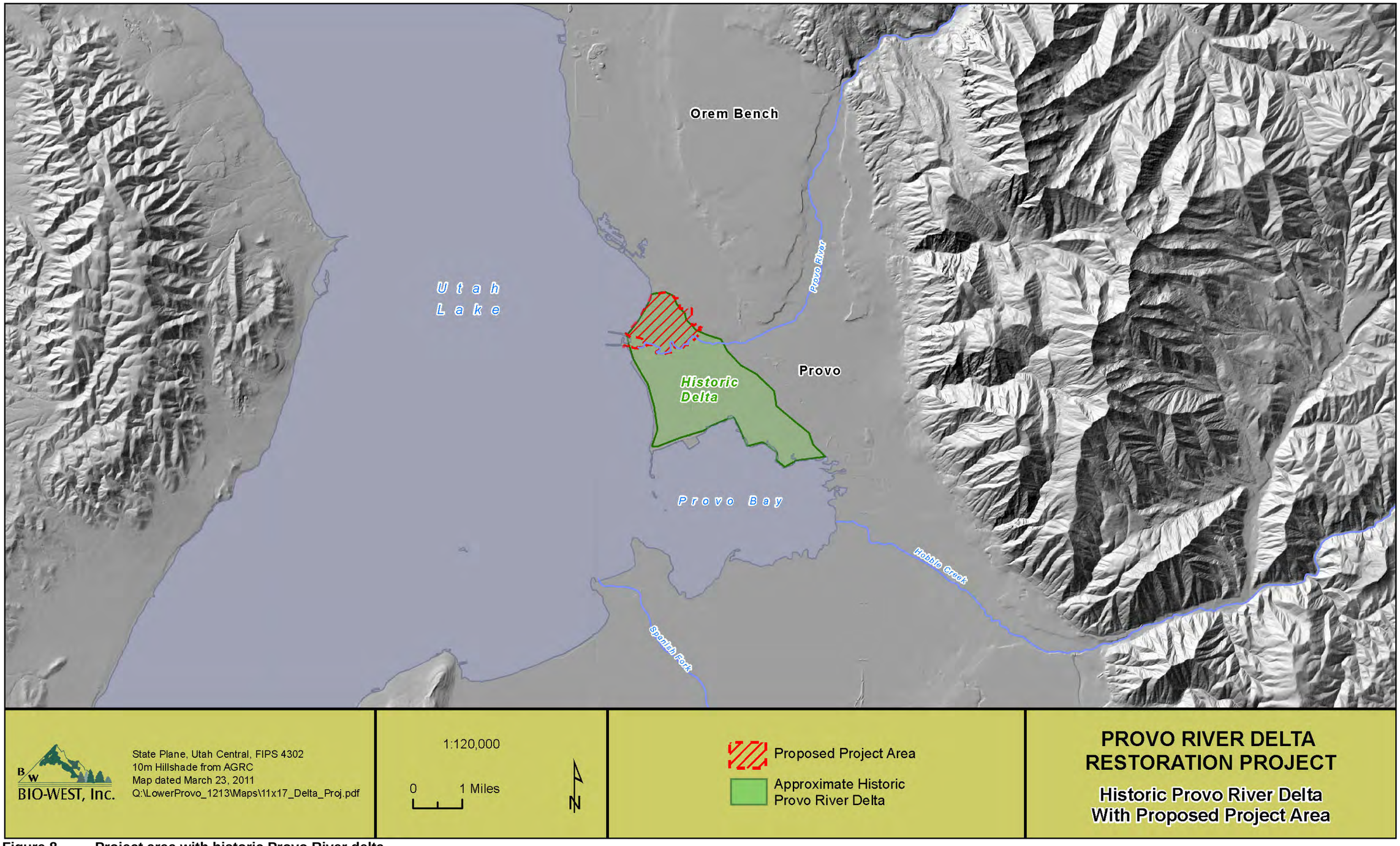

Figure 8. Project area with historic Provo River delta.

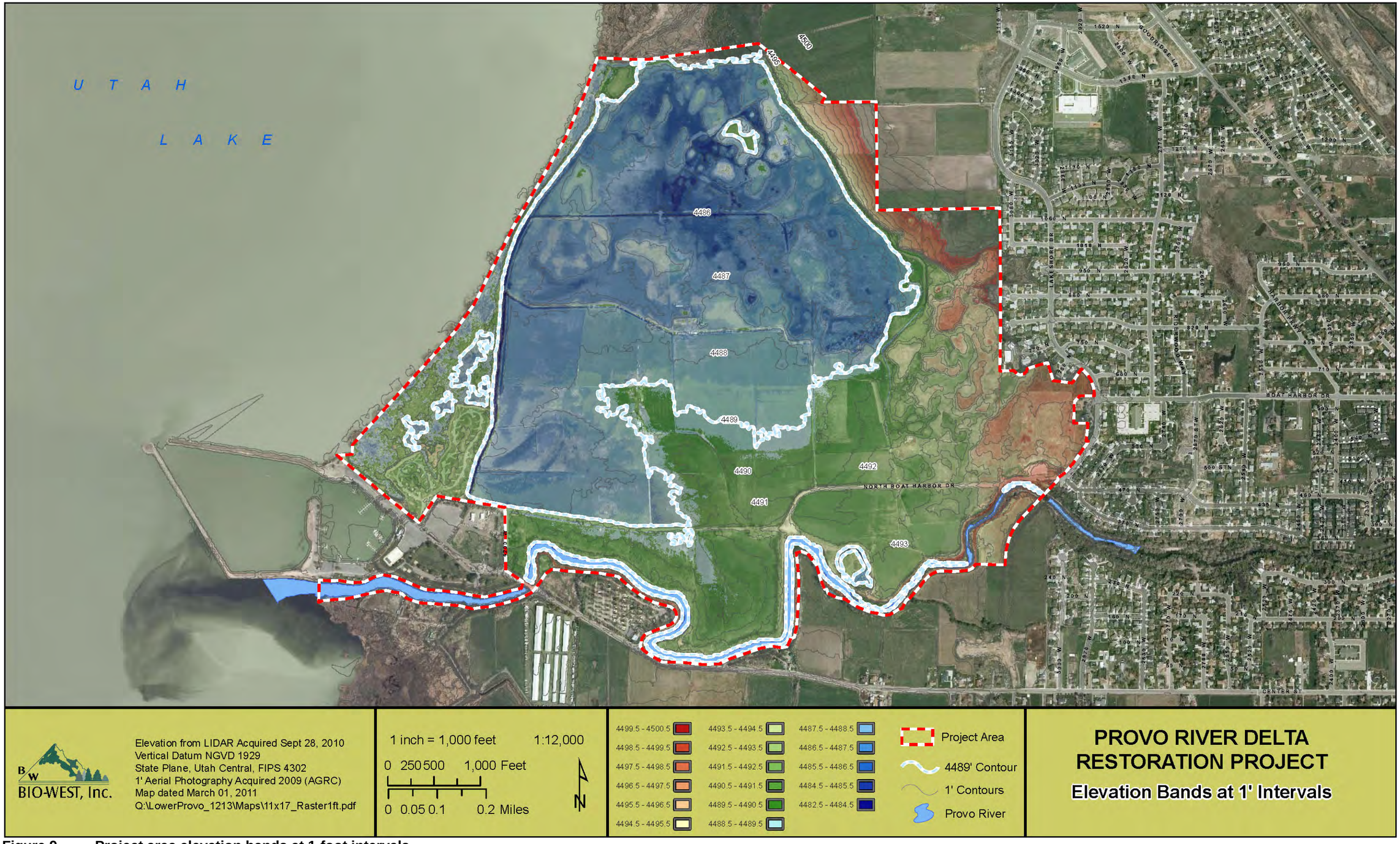

Figure 9. Project area elevation bands at 1-foot intervals.

7.1.2 Provo River In-Channel Topography

To obtain accurate in-channel topographic information and to assist with hydraulic modeling of the Provo River, cross sections of the lower river were surveyed with a total station in December 2010 and January 2011. Surveys were completed at 23 locations (Figure 10). The upstream cross sections (XS32 to XS18) are spaced relatively tightly and are situated at hydraulic control features (e.g., riffle heads, gravel bars) to facilitate development of an accurate hydraulic model for the project area. Downstream from the fish weir (XS18), hydraulic control features are lacking because the gradient becomes very flat, stage is influenced by Utah Lake, and habitat is essentially one long, deep run or pool. Because of this lack of diversity, the spacing between surveyed cross sections was greater below the fish weir. Cross section endpoint elevations were tied in to control points to within 0.05 foot vertical accuracy. The horizontal positions of the cross sections were approximated on field maps of high resolution aerial imagery. For each cross section, points were collected between the tops of the levees on the south and north banks of the river and features such as edge of water and floodplain surfaces were noted.

Much of the lower river exhibits a trapezoidal cross-sectional form entrenched between steep levees. The shape of XS31 (Figure 11) is typical of about half the surveyed cross sections. In these areas habitat diversity is lacking, and during high flows the channel cannot access broad floodplain surfaces due to its confinement between the levees. Instead, most of the increased flow is accommodated by increased depth and velocity. In other portions of the lower river, some relatively narrow floodplain surfaces or small islands are present between the levees. This typically occurs at bends in the river. The shape of XS25 (Figure 12) illustrates this condition. For the 23 surveyed transects, average width between tops of levees is 98 feet and ranges from 73 to 128 feet.

7.1.3 Provo River Hydraulic Conditions

The cross section data were used to create a HEC-RAS hydraulic model of the existing river channel. Cross sections above the fish weir (XS18) were surveyed at hydraulic controls. Downstream of the fish weir, the channel is deep, directly affected by the backwater from Utah Lake, and lacks obvious hydraulic controls. In this area, channel cross section shape plays little role in determining the water surface elevation, thus fewer cross sections were surveyed below the weir. If additional data are deemed necessary in the future, supplemental cross sections can easily be surveyed and added at a later date.

Distances between cross sections were measured digitally using geographic information system (GIS) technology and then entered into the HEC-RAS model. Similarly, coordinates of the channel centerline were determined by digitizing them in a GIS system. Cross section endpoint positions, which had been noted on high-resolution field maps, were digitized and entered into the model to allow for proper display of the modeled reach on available aerial images.

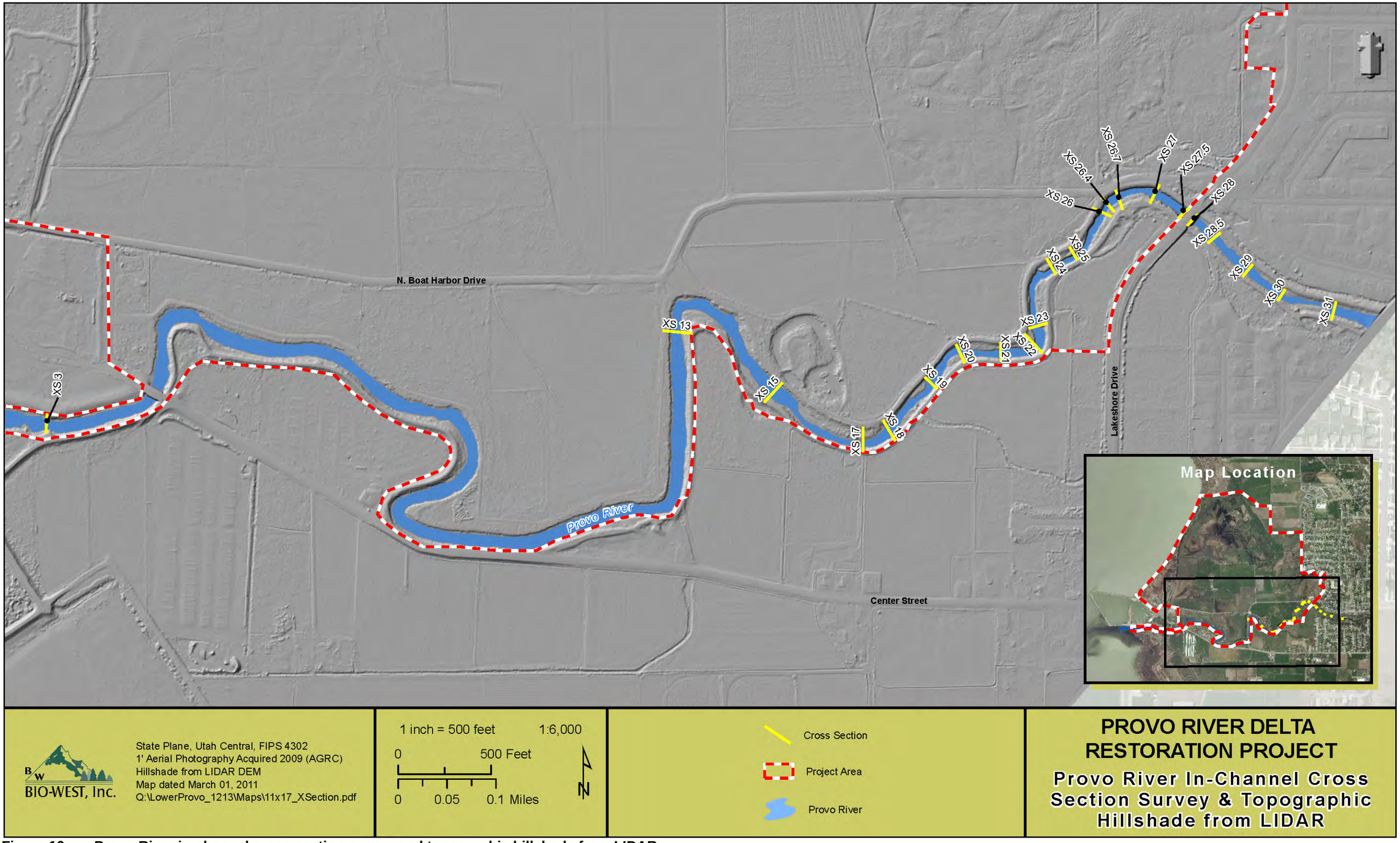

Figure 10. Provo River in-channel cross section survey and topographic hillshade from LIDAR.

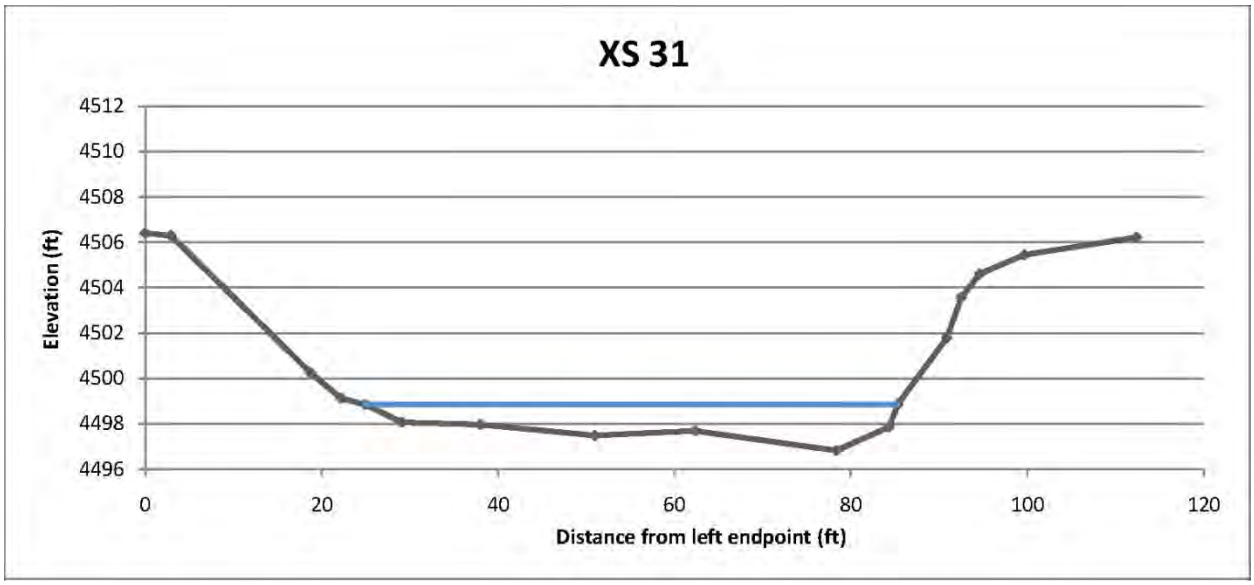

Figure 11. **Plot of cross section 31, illustrating trapezoidal channel form common to the lower Provo River. Blue line indicates surveyed water surface at 176 cubic feet per second (cfs).**

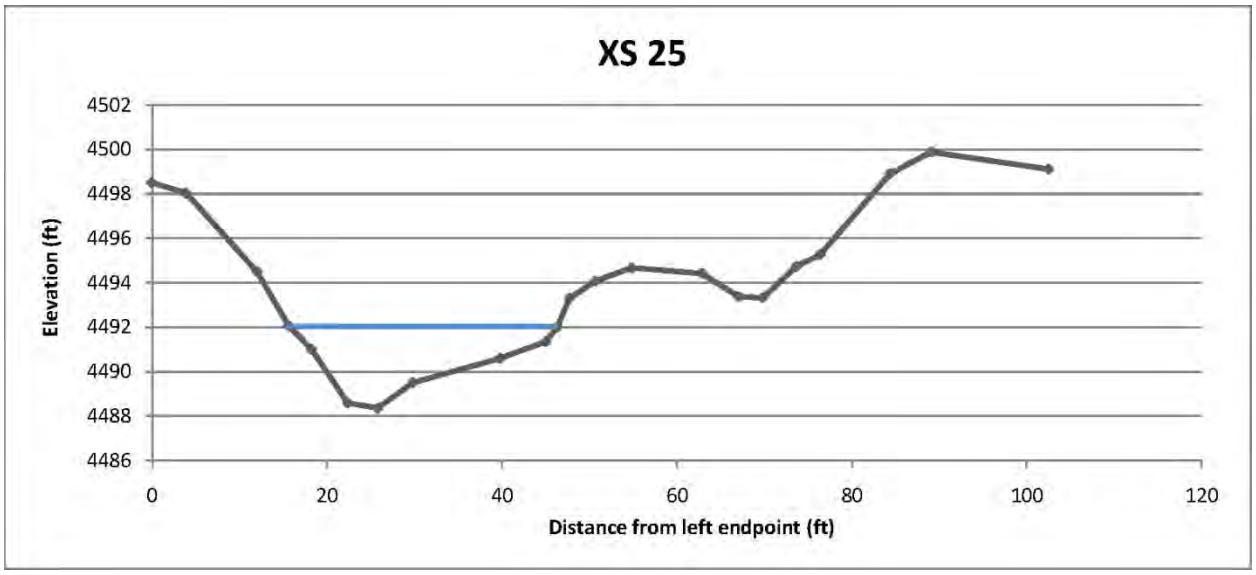

Figure 12. **Plot of cross section 25, illustrating and flooplain surface that has developed on the inside of a bend. Blue line indicates surveyed water surface at 173 cubic feet per second (cfs).**

River discharge varied during the time period when cross section surveys were completed, but most of the data were collected when the discharge was approximately 175 cfs. Roughness values for Manning's "n" were estimated at n=0.04 for the channel. A higher roughness value of n=0.06 was used for the overbank areas, based on estimates of the increased roughness from vegetation. Using these inputs, an initial run was completed for calibration of the model. A lake level of 4487.447feet was used for the calibration run because that was the level of the lake when the field surveys were completed.

The HEC-RAS model results from the calibration run clearly show the backwater effect from the lake (Figure 13). At the calibration discharge of 175 cfs, water surface elevations for the lower 7400 feet of the river channel (the area below the fish weir) are determined by the lake level, not by the cross section shape. In fact, the modeled water surface elevation at a distance of 7407 feet up the channel is less than 0.1 feet higher than the lake, meaning that the slope of the lower section of channel is very nearly zero (slope = 0.00001).

The roughness values selected for the model runs provide results that are reasonably close to the observed water surface elevations shown in Figure 13. The modeled water surface is higher than observed in some locations and lower in others. As such, no further adjustments were made to the roughness values used in the model. If additional water surface elevations are measured at a higher discharge, roughness values could be adjusted in the future, however, these results appear to be accurate enough to answer many questions about the existing hydraulic conditions the river channel over a reasonable range of discharge.

Additional model runs were completed to assess water surface elevation at discharges of 2,500 cfs, 2,000 cfs, 1,800 cfs, 1,500 cfs, 1,200 cfs, 1,000 cfs, 500 cfs, 300 cfs, 200 cfs, and 100 cfs. Discharges of 287 cfs and 175 cfs were also included for calibration purposes. Additionally, a discharge of 1 cfs was used to model extreme low flow conditions.

Selected results from these early model runs of existing river conditions are shown in Figure 14. Water surface elevations through much of the project area are far more dependent on the water level in Utah Lake than on the discharge of the river, although flows over 500 cfs clearly raise the water surface elevation even in the lower part of the reach.

This HEC-RAS model has been prepared to answer specific questions that may arise during the planning process. As such, it is a work in progress that can be added to and fine tuned in the future, in order to provide insight for planners and managers. To date, a range of flows have been modeled, and others can easily be added, as needed, for future analyses to assess a wide range of river discharge and lake level combinations.

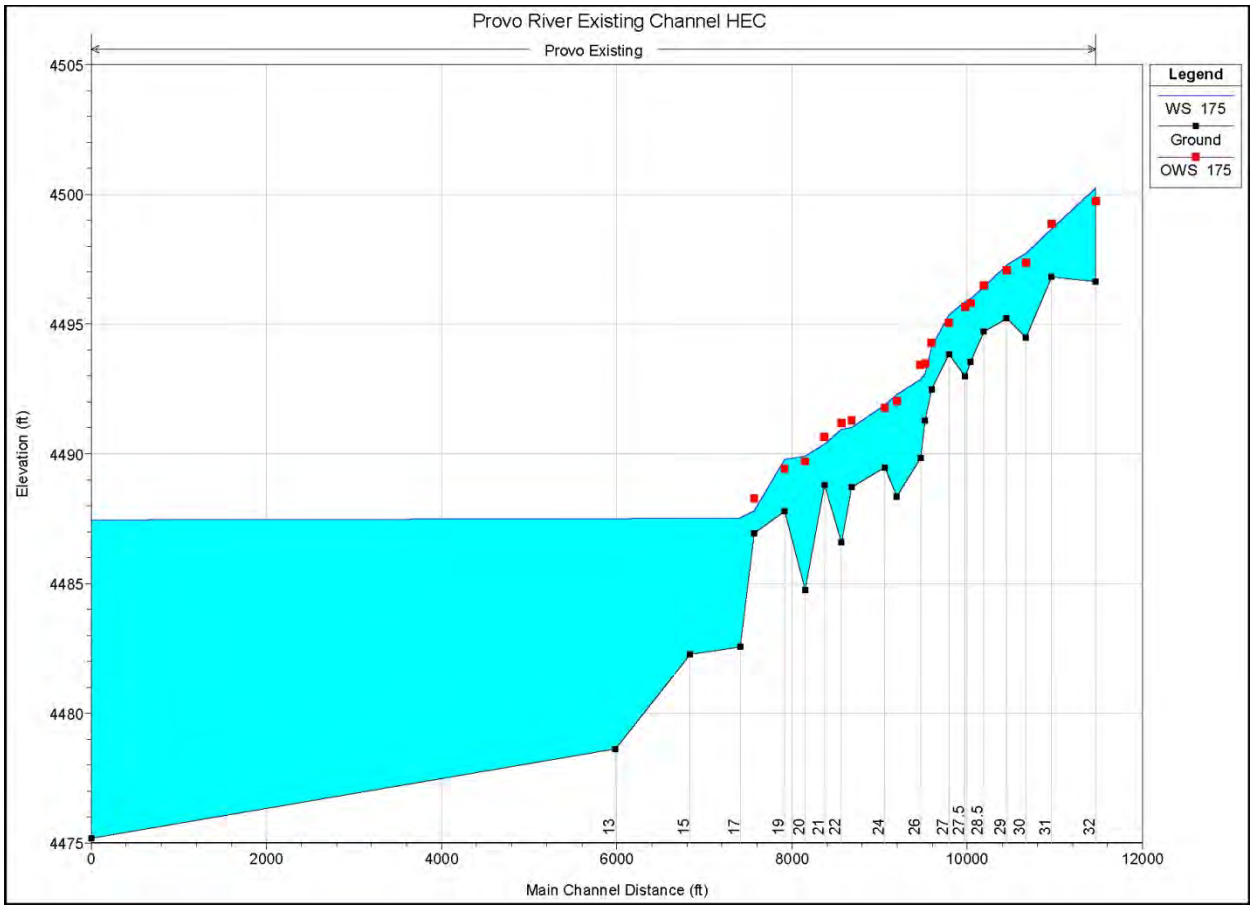

Figure 13. HEC-RAS model results from calibration run at river discharge of 175 cubic feet per second (cfs) and a lake level of 4,487.447. The modeled water surface elevation is shown in blue and the observed water surface elevations are shown with red dots.

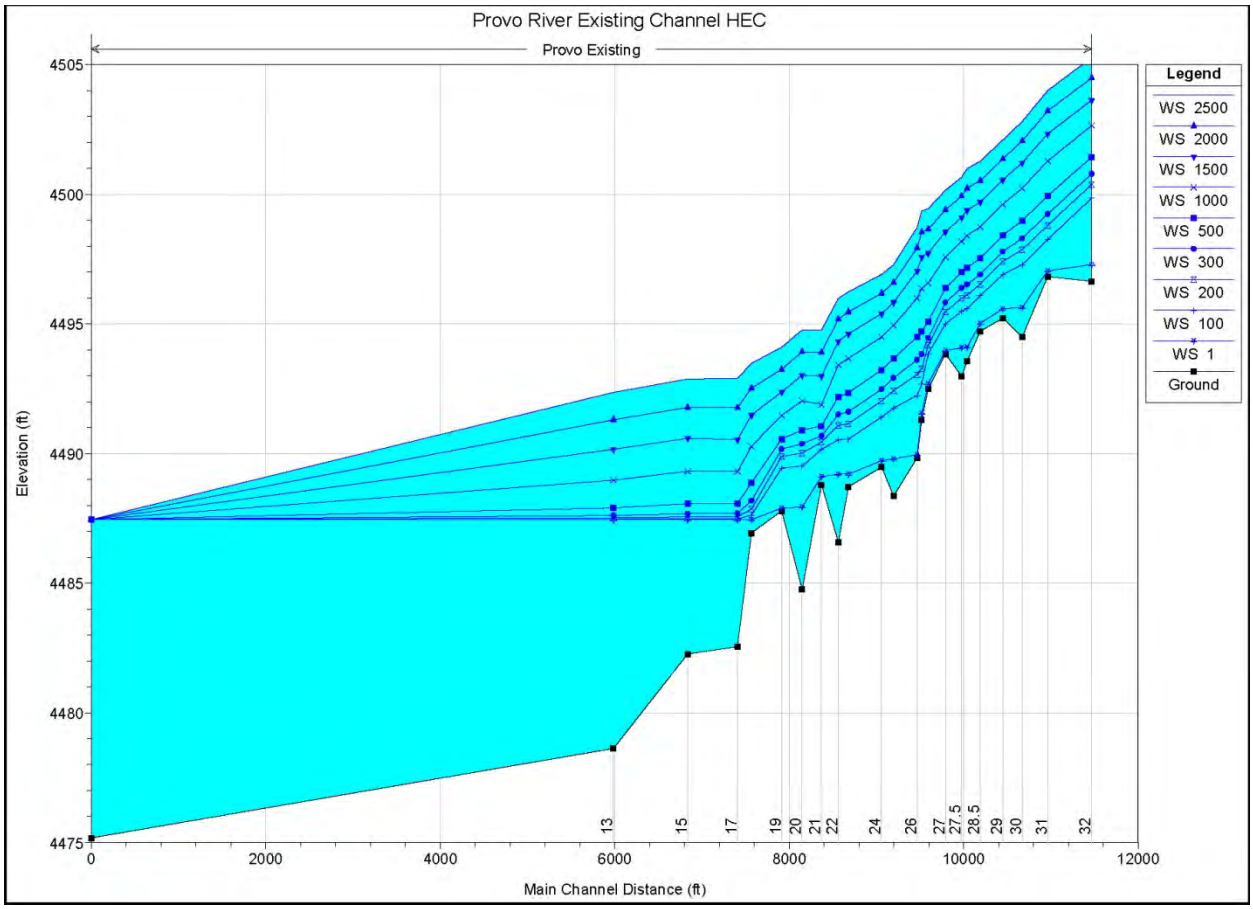

Figure 14. HEC-RAS model output for a range of discharges from 1 to 2,500 cubic feet per second (cfs) at a lake level of 4,487.447.

7.2 Hydrology

7.2.1 Provo River

USGS Gage Data

The historic streamflow of the lower Provo River is well documented. The United States Geological Survey (USGS) currently maintains a streamflow gage on the Lower Provo River (Provo River at Provo, Utah; Station Number 10163000) that has recorded streamflow data continuously since 1937. This gage is located approximately 0.7 miles downstream of the I-15 crossing in Provo. This gage provides an excellent long-term record of the discharge in Provo River over the last 70 years. Prior to 1937, limited data are available, although some records exist for years 1903, 1904, 1905, 1933, and 1934. These early data are discontinuous and are of limited usefulness for determining streamflow conditions and variability.

The USGS gage record includes two basic types of information: (1) daily mean discharge data and, (2) instantaneous peak discharge data. Both records were obtained from the USGS, for the period of record, and were used for the hydrologic analyses that follow.

Over the period of record, many human activities have occurred in the basin that have influenced the hydrology of the river, including construction of two large dams (i.e., Deer Creek and Jordanelle) and many smaller diversions, trans-basin importation of water from the Weber River and Duchesne River, urbanization of portions of the drainage basin, livestock grazing, and channelization of major segments of the river, to name only a few.

Historical Average Streamflow Conditions

Daily Mean Streamflow. The entire record of daily mean streamflow was analyzed to determine average conditions of the river over time. The overall average of all daily mean streamflow data for the period of record is slightly over 194.3 cfs. Further information is presented in Figure 15, which shows the annual mean, annual minimum, and annual maximum, daily mean discharges in the Lower Provo River for the time period between 1937 and 2010. Earlier years are not shown because the data for those years were incomplete.

Low mean streamflow years appear to be more common after the extremely high flow period in the mid-1980s. Annual mean flows below 100 cfs were recorded nine times during the 23-year period between 1987 and 2010, but occurred only six times during the 50-year period between 1937 and 1987. However, streamflow under 5 cfs was quite common during the early part of the historic record, but these extremely low flows occurred less frequently in recent years, due in part to current efforts by JSRIP partners to maintain streamflow during dry periods.

The daily mean discharge of the lower Provo River rarely exceeds 2,000 cfs, although a daily mean discharge of 2,420 cfs occurred in 1952. Mean daily streamflow also exceeded 2,000 cfs during the large floods of 1983.Provo City planners and engineers strive to maintain a channel capacity of about 2,300 cfs through Provo City (G. Beckstrom 2008, pers. comm.). Water managers strive to keep flows less than that level to reduce potential flooding risk.

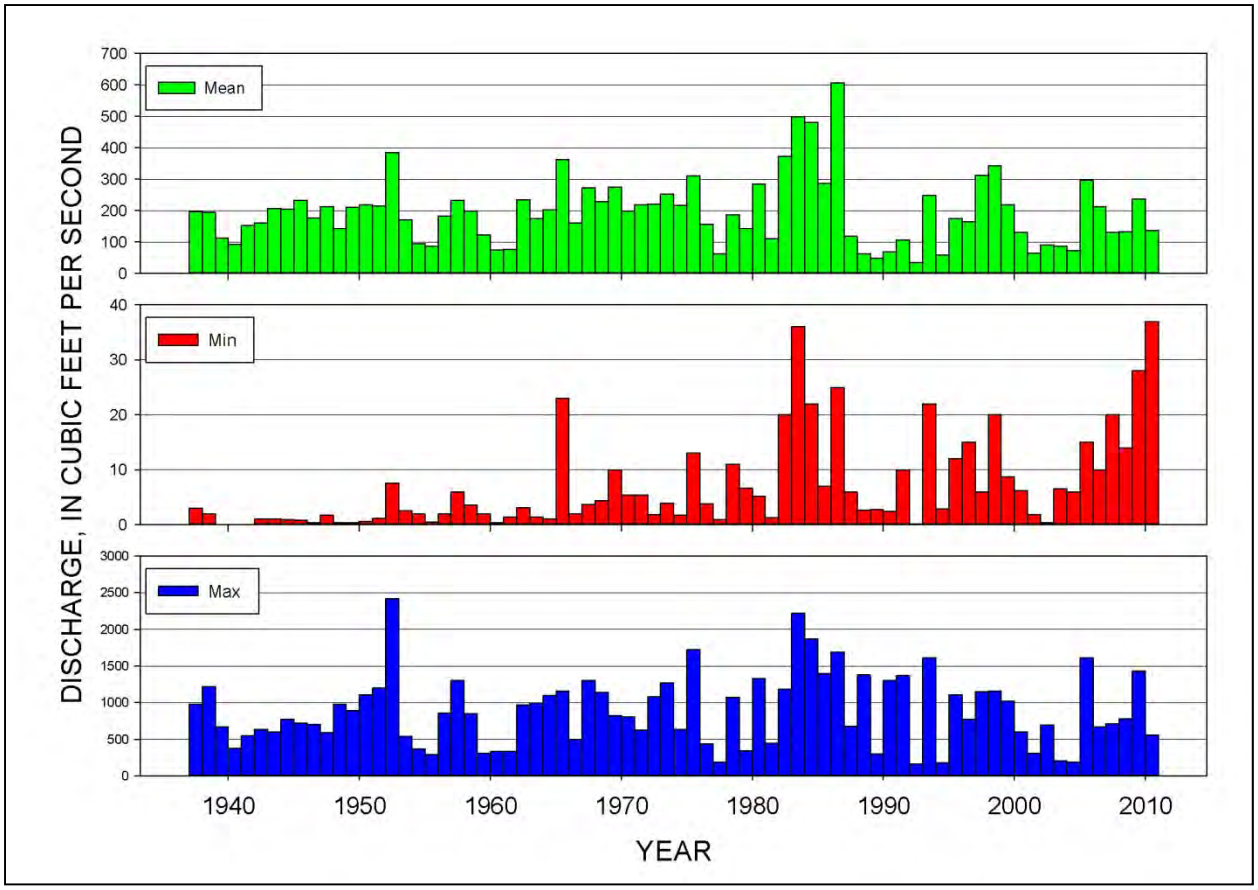

Figure 15. Time series of mean, minimum, and maximum discharge, for the Provo River at Provo, Utah

Streamflow in the Provo River is largely driven by snowmelt. As such, the daily mean streamflow varies seasonally throughout the year. A plot of the monthly distribution of streamflow for the Lower Provo River is shown in Figure 16. Streamflow is highest during the months of May and June, when snowmelt runoff is at its peak. Low flow months include July, August, and September, when diversion for irrigation is high. Zero flow has occurred at least once in every month between April and October, but never between November and March.

Monthly Mean Streamflow. Monthly mean streamflow was computed for every month of the historic record. These data are characterized in Figure 17. Although streamflow has never remained at zero for an entire month, extremely low flows have occurred for extended time periods. For example, the months from April through October have all experienced monthly mean flows of 3 cfs or less. However, the months from November through March have never had monthly mean discharges less than 10 cfs. The lowest recorded monthly mean for December was more than 39 cfs.

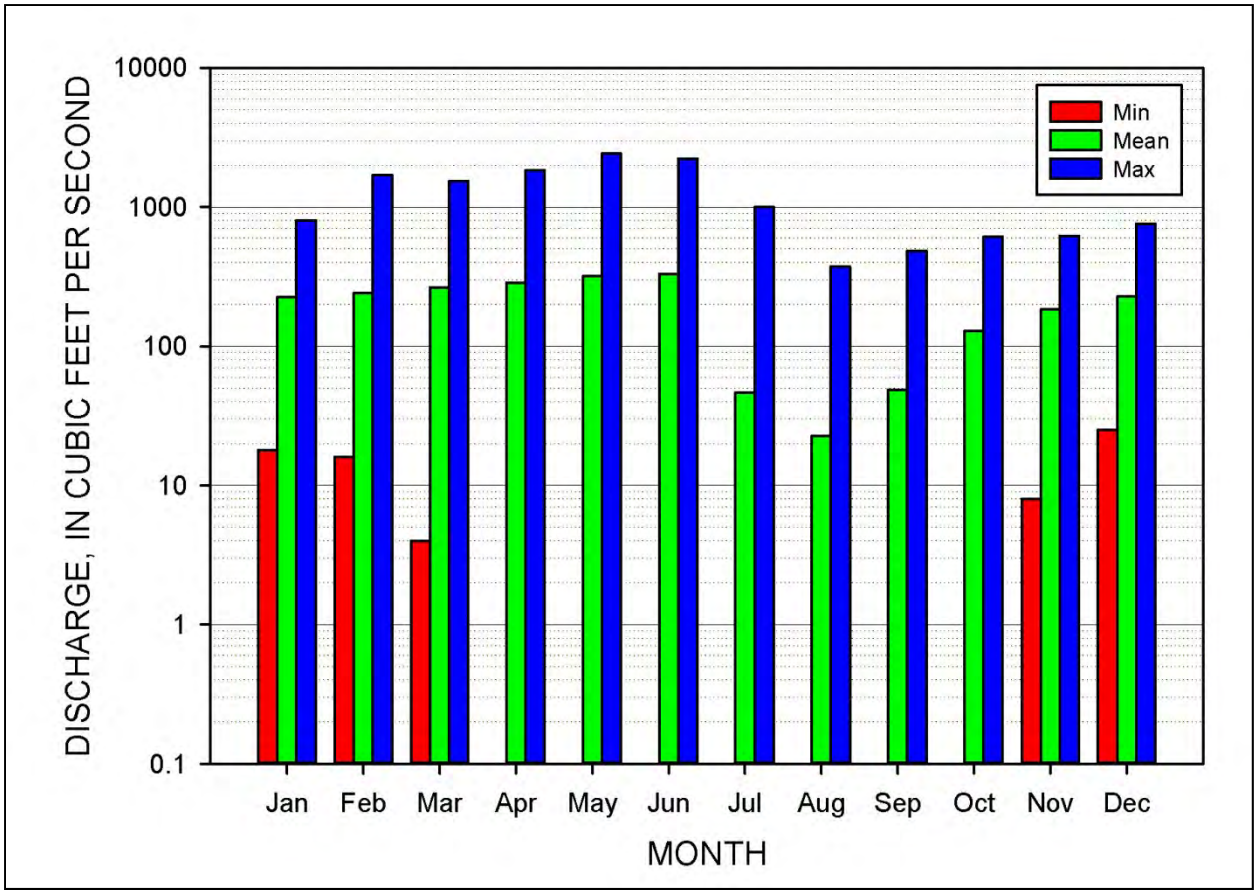

Figure 16. Mean, minimum, and maximum daily mean discharges for the Provo River at Provo, Utah. Minimum daily mean flow for April through October reach zero, and therefore cannot be seen on the plot.

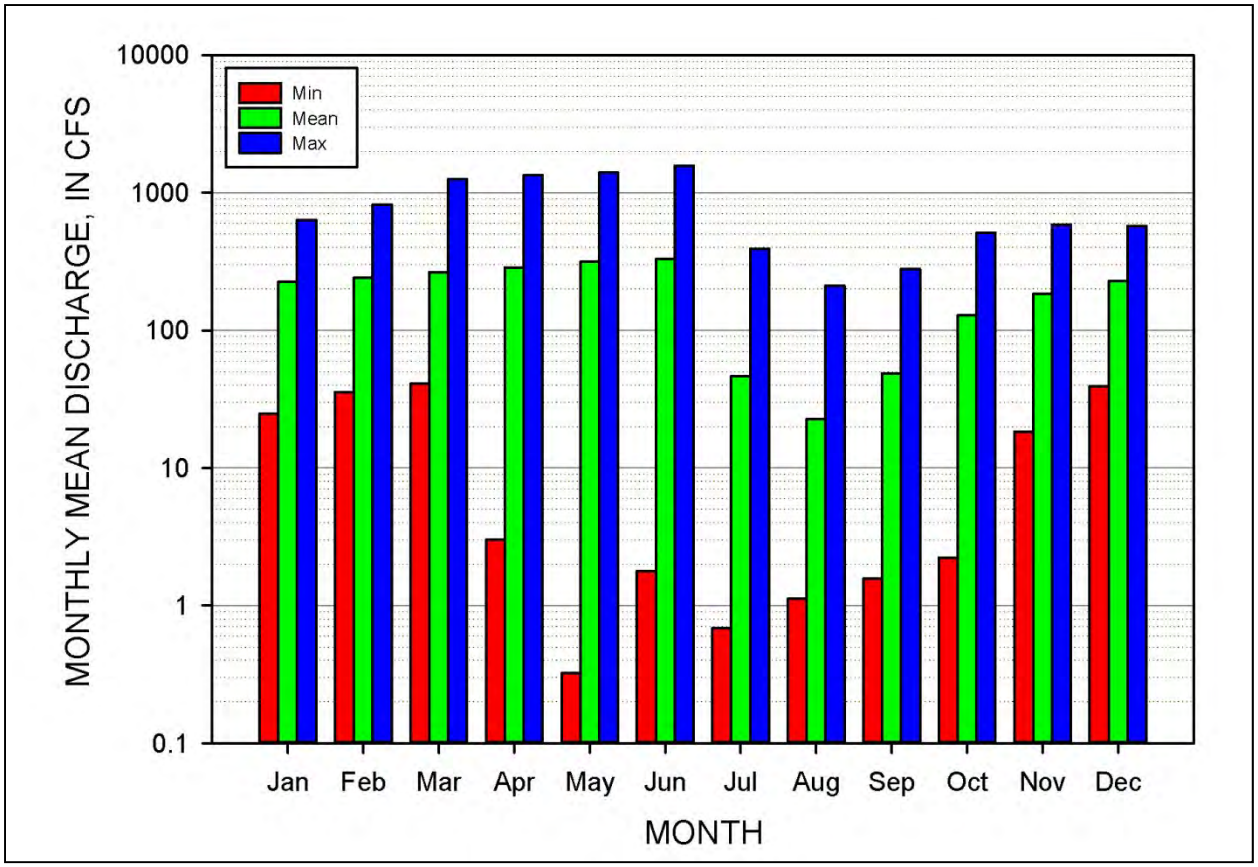

Figure 17. Distribution of monthly mean discharges for the Provo River at Provo, Utah. Discharge was averaged for each individual month in the record. Means, minimums, and maximum values are shown.

Streamflow Duration. A standard flow duration relation (curve) was developed for the lower Provo River by analyzing gage data for the entire period of record, which includes mean daily discharge for 27,865 days (Figure 18). This flow duration curve plots the mean daily streamflow against the percent of time that the given streamflow has been equaled or exceeded during the period of record. This curve provides a great deal of information on the range of streamflow for the Provo River. Daily mean streamflow has varied from a high of 2,420 cfs to a low of 0 cfs. In addition to illustrating the entire range of streamflow present in the Lower Provo River, Figure 18 also provides detailed information on the duration of that streamflow. Examination of the relation shows that a discharge of 131 cfs was exceeded 50 percent of the time, whereas discharges of 2.8 cfs and 577 cfs were exceeded 95 percent and 5 percent of the time, respectively.

When plotted in log space, the flow duration relation also clearly illustrates the frequent occurrence of very low flows on the Lower Provo River (Figure 19). A streamflow of 20 cfs or less occurred approximately 20 percent of the time (80.248 percent exceedance); an average of over 73 days per year. A streamflow of 5 cfs or less occurred approximately 9 percent of the time (91.046 percent exceedance); an average of almost 33 days per year. And, a streamflow of 1 cfs or less occurred approximately 1.5 percent of the time (98.440 percent exceedance); an average of almost 5.5 days per year. Table 5 provides selected data on a range of discharges and their associated exceedance percentages.

Magnitude of Peak Flows. Instantaneous peak flows have been recorded on the lower Provo River gage continuously since 1937. Prior to that peaks were recorded in 1903 and 1934. The history of annual peak discharge is shown in Figure 20.The highest peak of 2,520 cfs occurred in 1952. Only two other years in the historic record (1983 and 1984) had peak discharges more than 2,000 cfs.

The recurrence interval for peak flows was determined using a standard Log-Pearson Type III distribution (IACWD 1982). The results of these computations are shown in Figure 21 for the USGS gage (Provo River at Provo, Utah). Standard Weibull plotting positions are also shown. The 2-year recurrence interval discharge is computed to be approximately 859 cfs; the 10-year recurrence is 1,722 cfs; and the 100-year recurrence is 2,752 cfs.

Although the applicability of the Log-Pearson method to rivers that have been subject to hydrologic alteration can be problematic, it is possible to compare standard Weibull plotting position estimates against the Log-Pearson estimates to check the fit of the Log-Pearson curve, thus ensuring that the computed distribution represents the data reasonably well. In this case the Log-Pearson curve follows the Weibull data quite well despite the hydrologic changes that have occurred in the basin over time (Figure 21).

Timing of Peak Flows. Several descriptors of the timing of peak flows in the Provo River are shown in Figure 22. Peak flows occur most frequently during the months of May and June, although annual peaks have occurred all months except July and August. The peaks that occur in May and June are snowmelt runoff peaks, which average over 1,150 cfs. These peaks tend to be larger than peaks that occur at other times of the year.

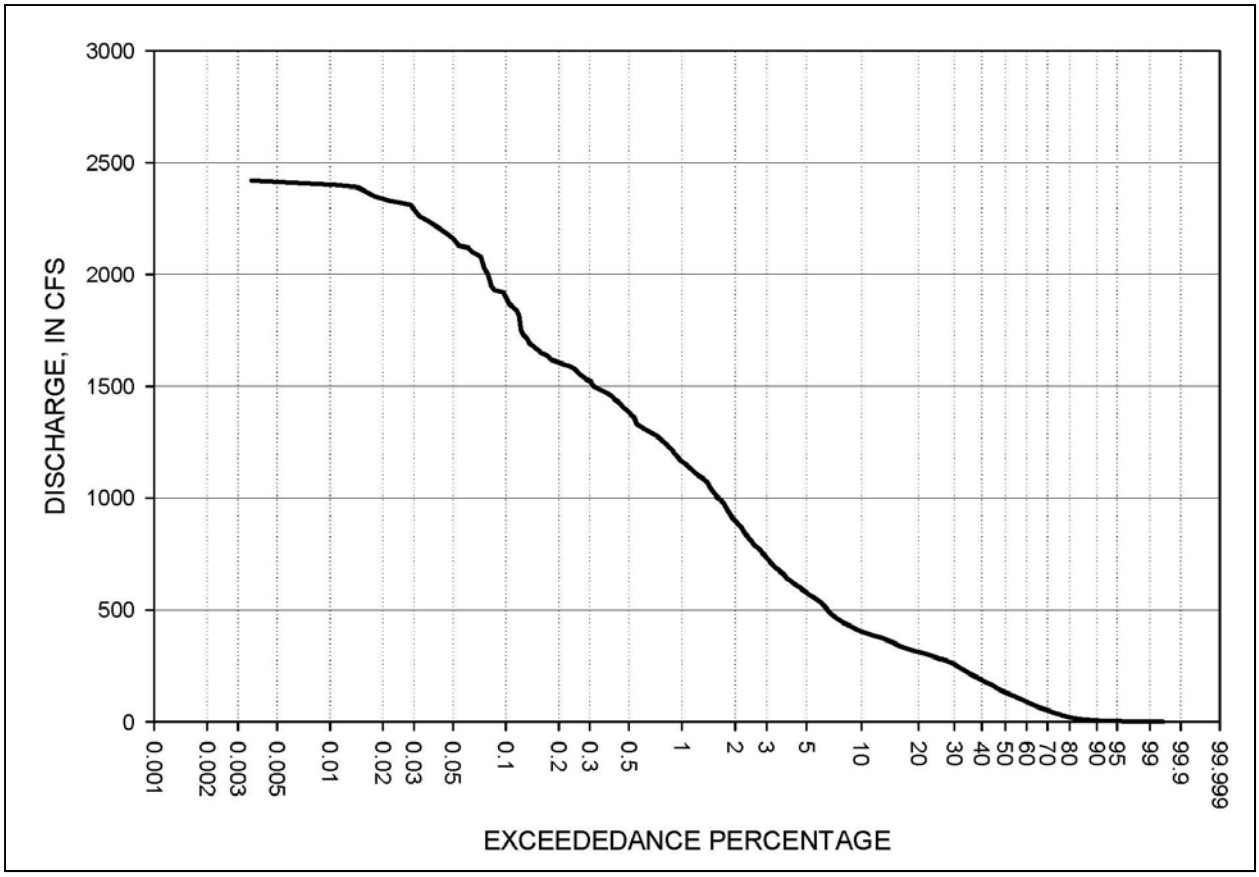

Figure 18. Flow duration relation for USGS Station Number 10163000 (Provo River at Provo, Utah).

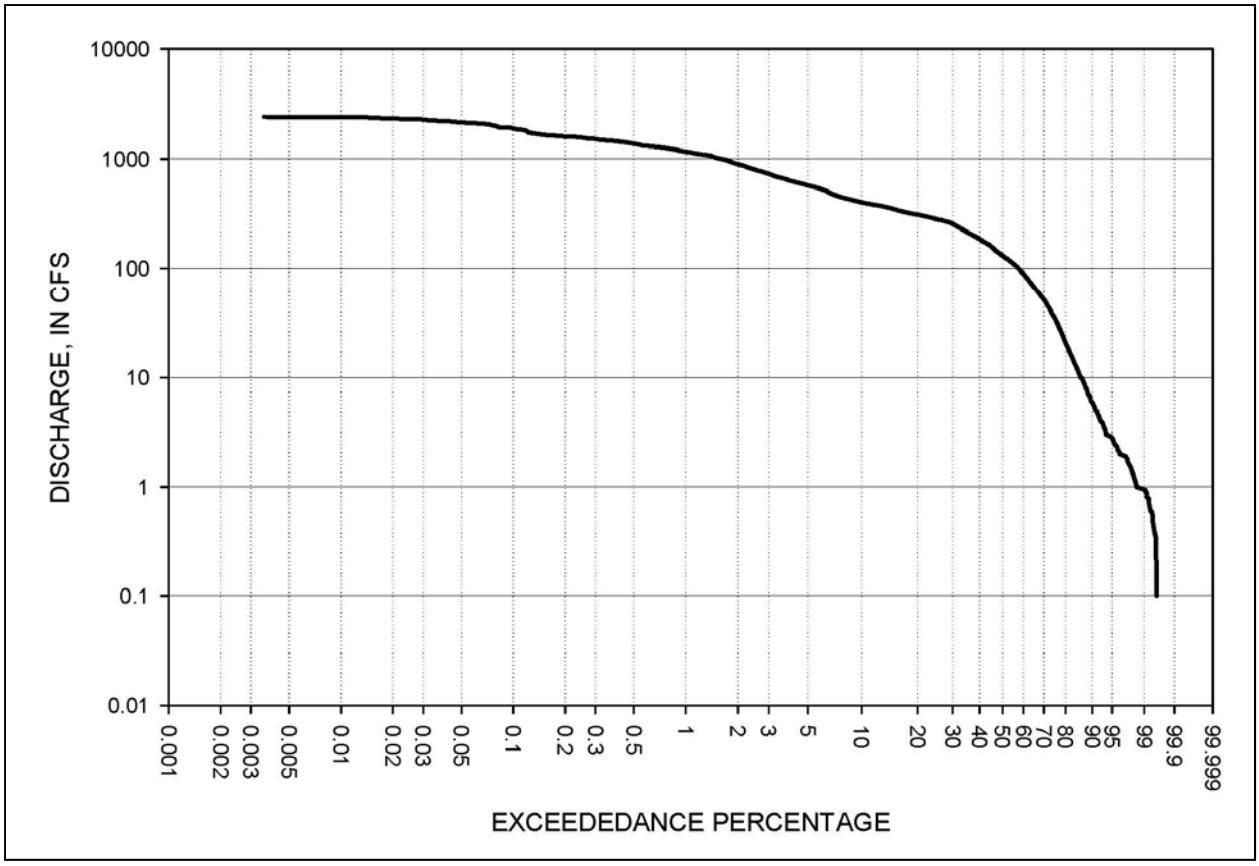

Figure 19. Flow duration relation for USGS Station Number 10163000 (Provo River at Provo, Utah). This is the same as Figure 18, but with a log discharge axis.

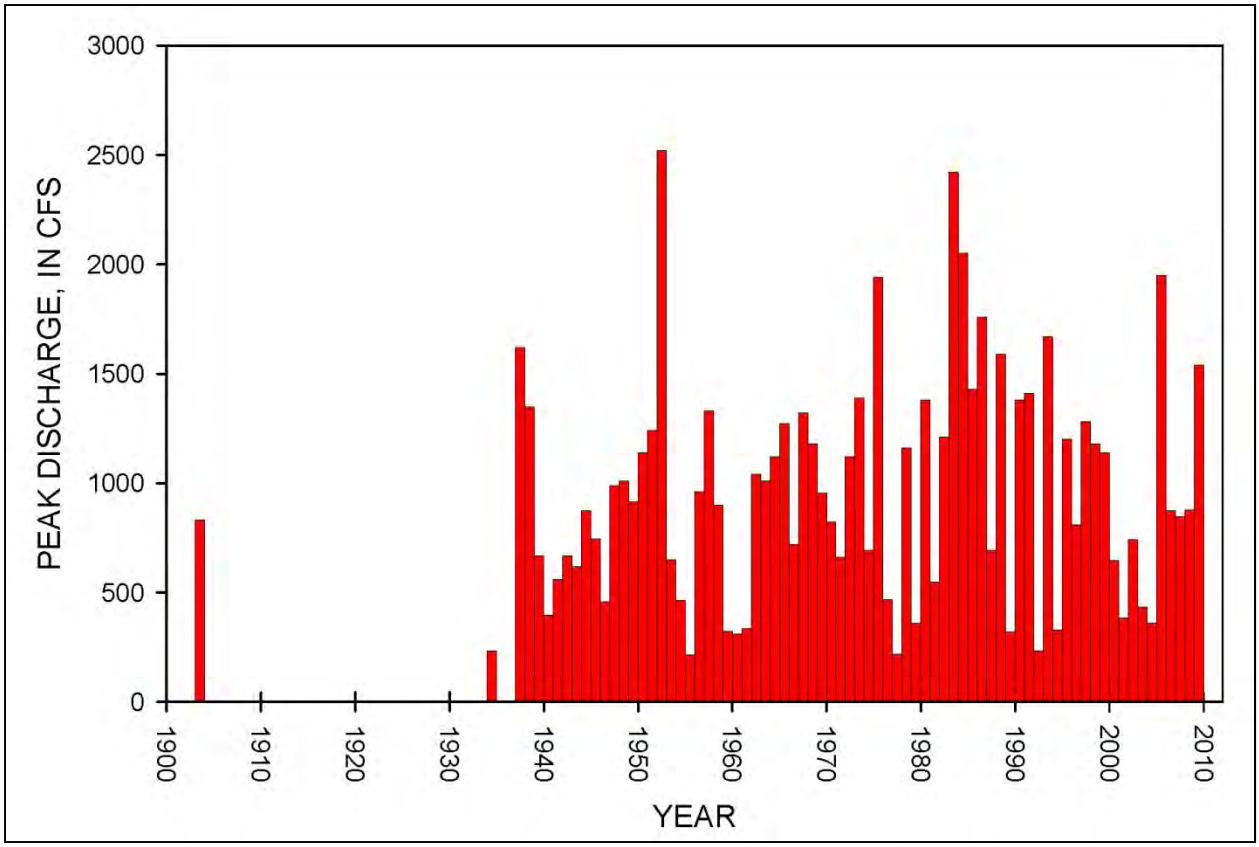

Figure 20. History of peak streamflow for USGS Station Number 10163000 (Provo River at Provo, Utah.

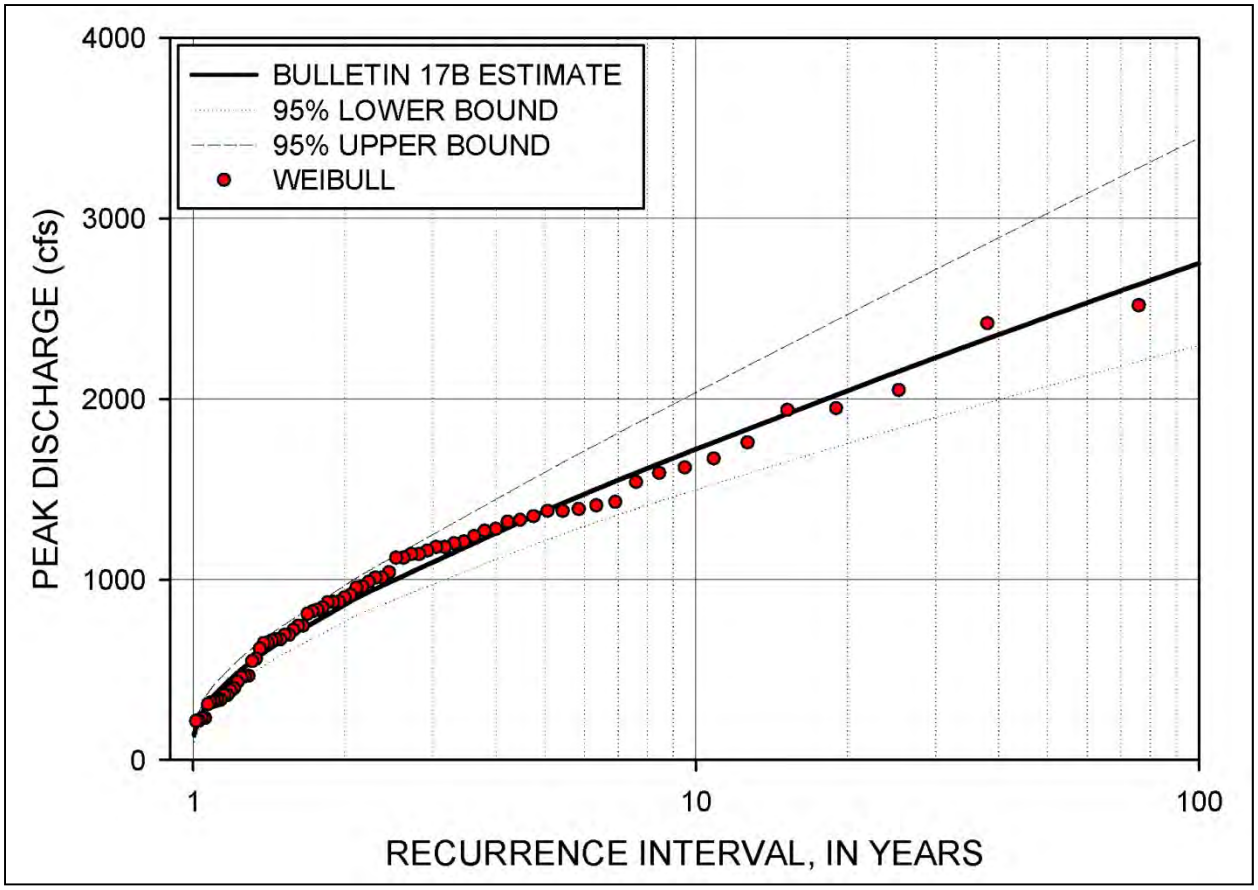

Figure 21. Log Pearson flood frequency distribution for USGS Station Number 10163000 (Provo River at Provo, Utah). Weibull plotting positions are also shown.

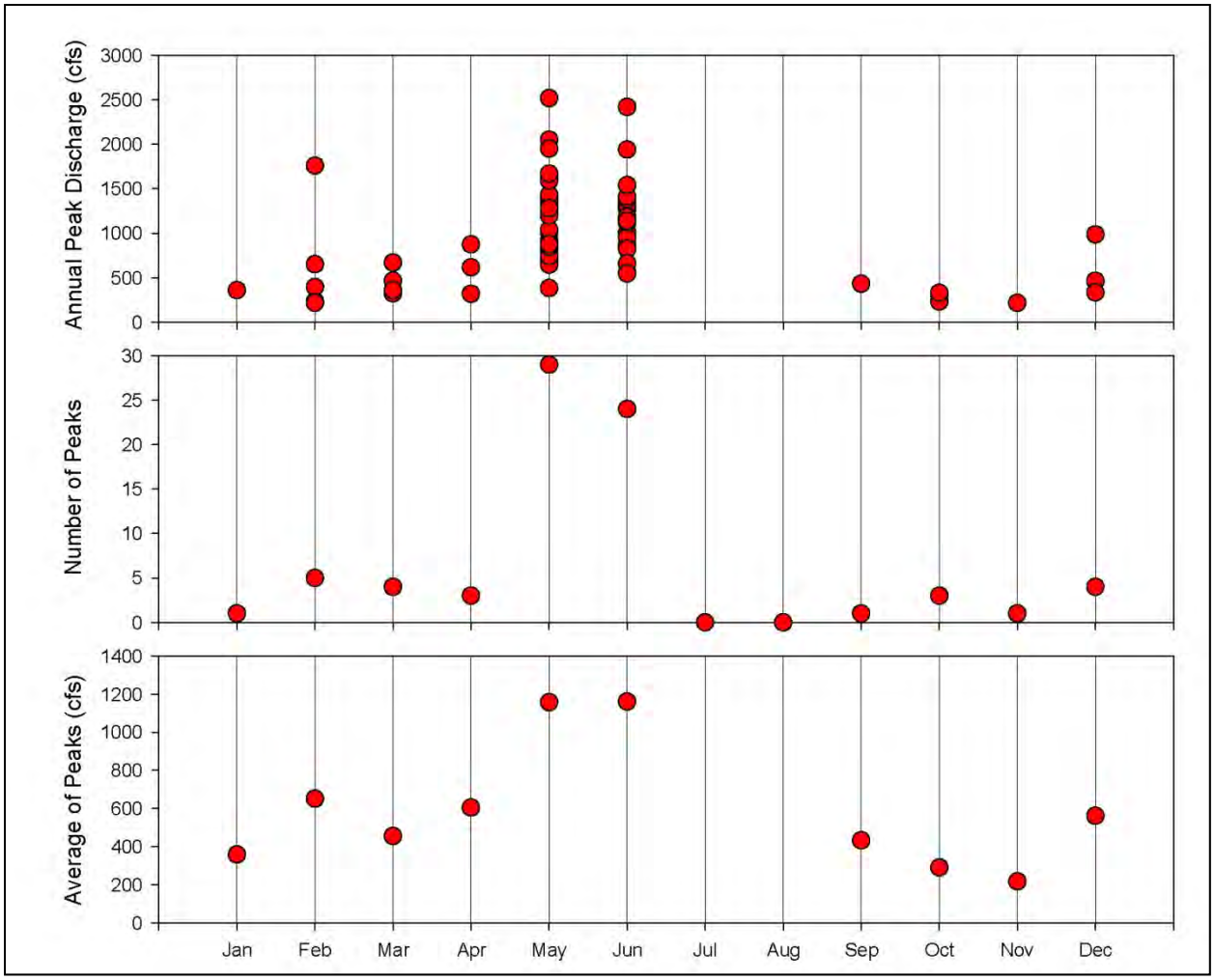

Figure 22. Monthly summary of peak flows for USGS Station Number 10163000 (Provo River at Provo, Utah). The plots include peaks versus month (top), number of peaks versus month (middle), and average of peaks versus month (bottom).

Table 5. Selected discharges and associated exceedance percentages.

DAILY MEAN DISCHARGE (CUBIC FEET PER SECOND)	EXCEEDANCE PERCENTAGE
2,420	0.004
2,000	0.079
1,500	0.316
1,000	1.579
500	6.520
200	37.723
100	57.719
50	70.624
40	73.495
30	76.760
20	80.248
10	86.037
5	91.046
2	96.386
1	98.460
0.1	99.573
0	99.577

7.2.2 Utah Lake

Utah Lake is a shallow, freshwater lake that that drains northward into the Salt Lake valley via the Jordan River. Its surface area is approximately 150 square miles (CUWCD 2004b). Utah Lake is a natural water body, but the lake is used as an irrigation storage reservoir, with water levels and flow releases manipulated via gates and a pumping station at the lake's outlet to the Jordan River. Historically, there have been disputes between Utah and Salt Lake counties over management of the lake. Farmers in Utah County wanted to maintain lower lake levels to expose more agricultural land, while Salt Lake county interests wanted the ability to maintain high lake levels to maximize water storage for downstream deliveries. Following lawsuits associated with this conflict and flooding in the early 1980s, a new legal "compromise" level for Utah Lake was established at 4,489.045 feet. Above this level, the control gates at the lake outlet must be left fully open (DWRT 1993).

Utah Lake water levels fluctuate seasonally and year to year depending on climatic conditions and water storage and release operations. Typically, lake levels are highest in the spring and lowest in the fall (CUWCD 2004b). As part of planning and analyses for the Utah Lake System project, baseline monthly Utah Lake water levels were simulated using current/planned water operations and water year 1950–1999 hydrologic conditions (CUWCD 2004b). Using these simulation results, plots and summaries of lake levels for different time frames were prepared. Based on the entire (full-year) data set, lake levels average about 1.5 feet below compromise but range by 11 feet over the simulated 50-year time period (Table 6, Figure 23). During May and June, the time period when June sucker spawn, lake levels are typically higher and less variable, averaging about 0.7 feet below compromise (Figure 23). The growing season is another time

Table 6. Summary of predicted Utah Lake water levels for various seasons of interest. Data based on current/planned water operations simulated for water years 1950–1999 (CUWCD 2004b).

MEASUREMENT	UTAH LAKE WATER LEVEL (FEET, NGVD 29 DATUM)		
	ENTIRE YEAR	GROWING SEASON (APRIL–OCTOBER)	SPRING RUNOFF (MAY AND JUNE)
Minimum	4481.25	4481.25	4483.00
Maximum	4492.55	4492.55	4492.55
Average	4487.57	4487.53	4488.35
50th Percentile	4487.95	4487.80	4488.55

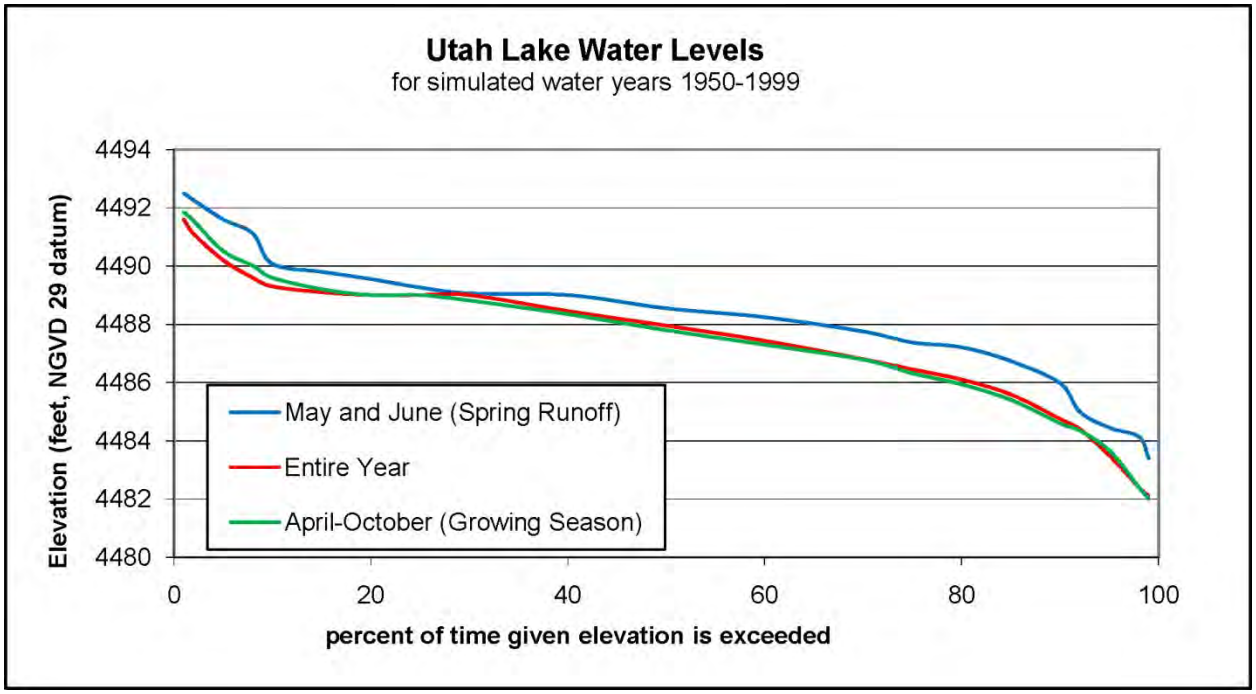

Figure 23. Elevation duration curves of predicted Utah Lake water levels for various seasons of interest. Data based on current/planned water operations simulated for water years 1950–1999 (CUWCD 2004b).

period of interest because it determines the types of plant communities that develop around the lake shore. Lake levels for the April through October growing season are very similar but slightly lower, on average, than those predicted using data for the entire year (Figure 23, Table 6).

The CUWCD operates a gauging station that records Utah Lake levels near the lake's outlet at Jordan Narrows. This gauging station uses two pressure transducers that record lake levels. These paired transducers provide a redundant check of the recorded lake levels which helps to bolster the accuracy of the historic record. The elevation of the transducers has not been

surveyed independently, but rather the transducers are calibrated to match a stage plate that is located nearby at the pumping station.

Due to Utah Lake's large size and exposure to prevailing westerly winds, large waves are common, and monitoring suggests that lake levels can become "perched" or super-elevated in the Provo Bay area on the east side of the lake. Therefore, water levels measured at Jordan Narrows, at the north end of the lake, may not always match water levels on the east side of the lake. To assess whether perching occurs north of Provo Bay within the proposed project area, a Solinst level logger was installed at the Utah Lake marina in November 2010. The logger was tied in to established control benchmarks to within 0.05 foot vertical accuracy and calibrated using a paired logger set to record barometric pressure. This set up allowed lake levels at the marina to be recorded in real-world elevations comparable to those collected at Jordan Narrows.

The Solinst datalogger recorded lake elevations at the marina every 15 minutes for a 29-day period, from November 5, 2010, through December 3, 2010, when it was removed to prevent ice damage. The recorded lake elevations were used to compute daily average lake elevations, which are shown in Table 7 along with the recorded elevations from the CUWCD gage and the computed difference between the recorded values. A comparison plot of the two records is shown in Figure 24.

Recorded lake levels at the marina match those recorded at the CUWCD gage reasonably well, although there appears to be a small systematic difference between the two sites, according to the surveys. The table includes a column with computed differences between the data sources. The mean and median of the differences are 0.16 feet and 0.15 feet respectively. There were 8 days when the difference was 0.10 feet or less; 8 days when the difference was 0.20 feet or more; and 13 days when the difference was between 0.10 and 0.20 feet. Notice that the data logger always recorded lake levels that were slightly higher than the CUWCD gage. These data suggest that the lake level at the marina may be slightly higher than the recorded level at the narrows, or that the surveyed elevations at the two sites differ slightly. The recorded lake level data at the marina are smoother and appear to be more consistent than the CUWCD gage, which jumped up and down a bit. The CUWCD gage is located at the end of the lake and is likely affected more by wind conditions than the recorder in the marina, which is closer to the mid-line of the lake. It is also possible that the marina provided wind and wave protection that helped to smooth measurements at the marina.

Given the similarity between the measured lake elevations, the historic lake levels from the CUWCD gage appear to be adequate to use for detailed designs, although additional comparisons over a longer time period should be made to ensure that designers have the proper lake elevation history to use for development of desired habitats within the project area.

Table 7. Recorded lake levels from two stage recorders on Utah Lake.

DATE	LAKE LEVEL (SOLINST) AT UTAH LAKE MARINA (FEET)	LAKE LEVEL RECORDED BY CUWCD AT JORDAN NARROWS (FEET)	DIFFERENCE (FEET)
11/5/2010	4487.08	4486.97	0.11
11/6/2010	4487.09	4486.99	0.10
11/7/2010	4487.09	4487.03	0.06
11/8/2010	4487.15	4486.89	0.26
11/9/2010	4487.17	4486.89	0.28
11/10/2010	4487.15	4487.00	0.14
11/11/2010	4487.17	4486.89	0.29
11/12/2010	4487.17	4487.01	0.15
11/13/2010	4487.18	4486.99	0.19
11/14/2010	4487.18	4487.03	0.15
11/15/2010	4487.21	4487.02	0.20
11/16/2010	4487.25	4487.02	0.22
11/17/2010	4487.23	4487.10	0.13
11/18/2010	4487.22	4487.16	0.06
11/19/2010	4487.23	4487.17	0.06
11/20/2010	4487.31	4487.26	0.05
11/21/2010	4487.32	4487.16	0.16
11/22/2010	4487.33	4487.20	0.13
11/23/2010	4487.33	4487.21	0.12
11/24/2010	4487.35	4487.06	0.30
11/25/2010	4487.34	4487.17	0.18
11/26/2010	4487.33	4487.18	0.16
11/27/2010	4487.32	4487.16	0.17
11/28/2010	4487.36	4487.06	0.30
11/29/2010	4487.38	4487.05	0.33
11/30/2010	4487.36	4487.23	0.13
12/1/2010	4487.34	4487.26	0.08
12/2/2010	4487.35	4487.28	0.07
12/3/2010	4487.33	4487.29	0.04

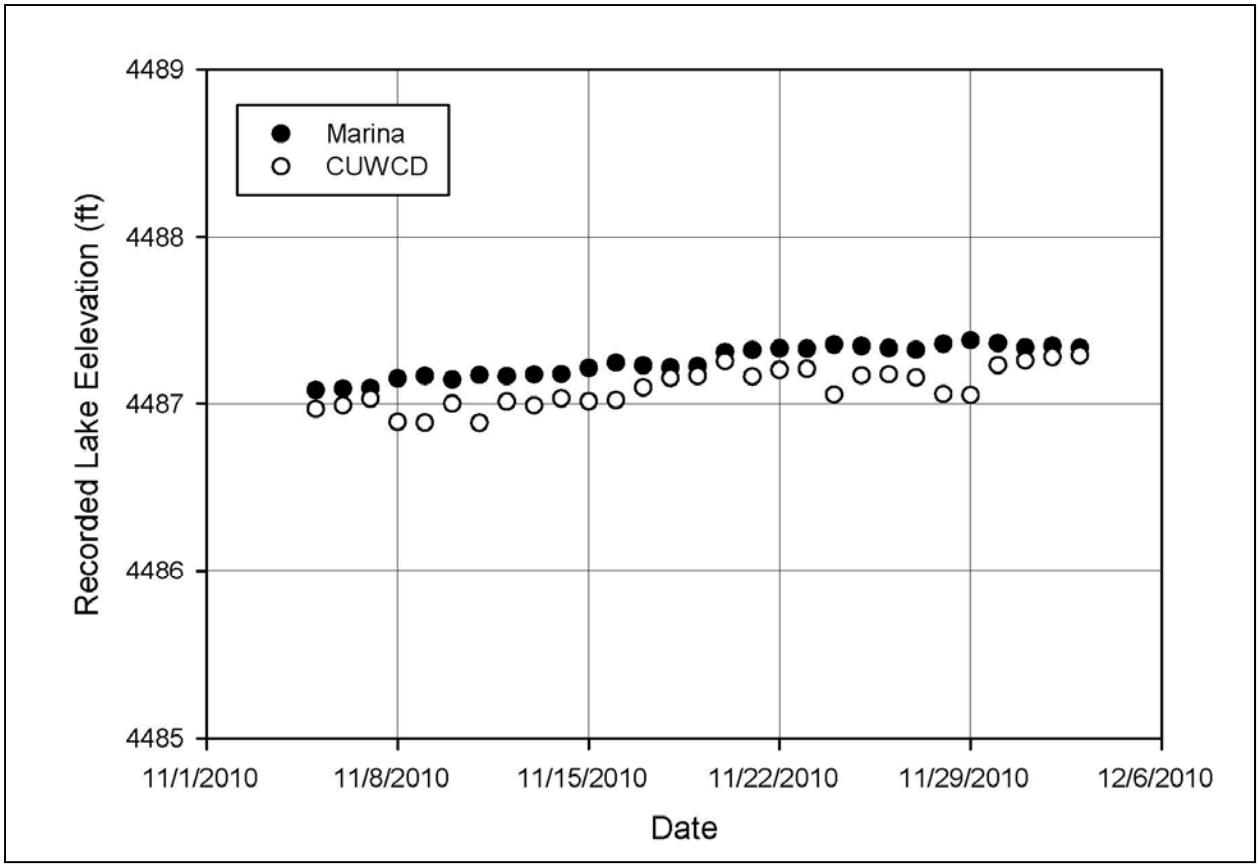

Figure 24. Plot of Utah Lake water surface elevations for a 29-day period in late 2010. The plot compares elevations recorded at the marina to those recorded by Central Utah Water Conservancy District (CUWCD) near the lake's outlet at Jordan Narrows.

7.3 Floodplains

Boundaries of legally defined floodplains in the project area were determined from the current Flood Insurance Rate Map available from Utah County updated most recently in 1982. The flood map in Figure 25 shows the majority of the project area as floodplain being affected by the 100-year flood. The eastern edge of the project area near 3110 West, along with some of the development east of 3110 West, is mapped as a 500-year flood area. FEMA is in the process of updating the floodplain map in this area. Preliminary drafts of this new map extend the 100-year flood area to the east including the entire project area and a much larger portion of the development east of 3110 West.

7.4 Wetlands and Soils

The discharge of dredged or fill material into wetlands and other waters of the U.S. are regulated by the Corps under Section 404 of the Clean Water Act. The proposed project would likely require an individual permit under Section 404 because it would affect existing wetlands and waters of the U.S. The Corps requires that, prior to submitting a permit application, a wetland delineation is performed. During the course of the wetland delineation, the landowner of the northern half of the project area denied site access. This approximately 200-acre area was assessed remotely using existing information, and is referred to as the Wetland Approximation Area. Soils within the project area were assessed as part of the Wetland Delineation and the Wetland Approximation Area. The proposed project involves removal of the existing flood-control levee separating Utah Lake from the project area. The removal of the levee would allow Utah Lake to flood portions of the project area during high-water events, thus restoring the surface hydrologic connection. Historic Utah Lake water level data and LIDAR survey data were used to determine the frequency, depth, and duration of inundation within the project area. Based on this information, the response of vegetation communities to the removal of the existing levee was predicted. . This analysis is referred to as the Predicted Wetland Response.

7.4.1 Wetland Delineation

A project area inspection was conducted on August 23–25, 2010, to delineate jurisdictional wetland boundaries. Wetland boundaries were identified in accordance with the *U.S. Army Corps of Engineers Wetlands Delineation Manual* (Environmental Laboratory 1987). In addition, the *Regional Supplement to the Corps of Engineers Wetland Delineation Manual: Arid West Region* (Research and Development 2008) was used for regional specificity. In areas where one or more wetland parameters may have been absent or misleading, mapping was completed using mainly soil characteristics, landscape position, remnant hydrophytic vegetation, and/or persistent hydrological indicators, as specified by the manual.

Twenty-nine sample points were established within the project area to describe existing conditions. These sample points were established as pairs along the wetland boundary with one sample point representing the wetland and another sample point representing the upland. Existing hydrological, soil, and vegetative conditions were examined and recorded at all sample points. Wetland boundaries were delineated based on observations at each sample point.

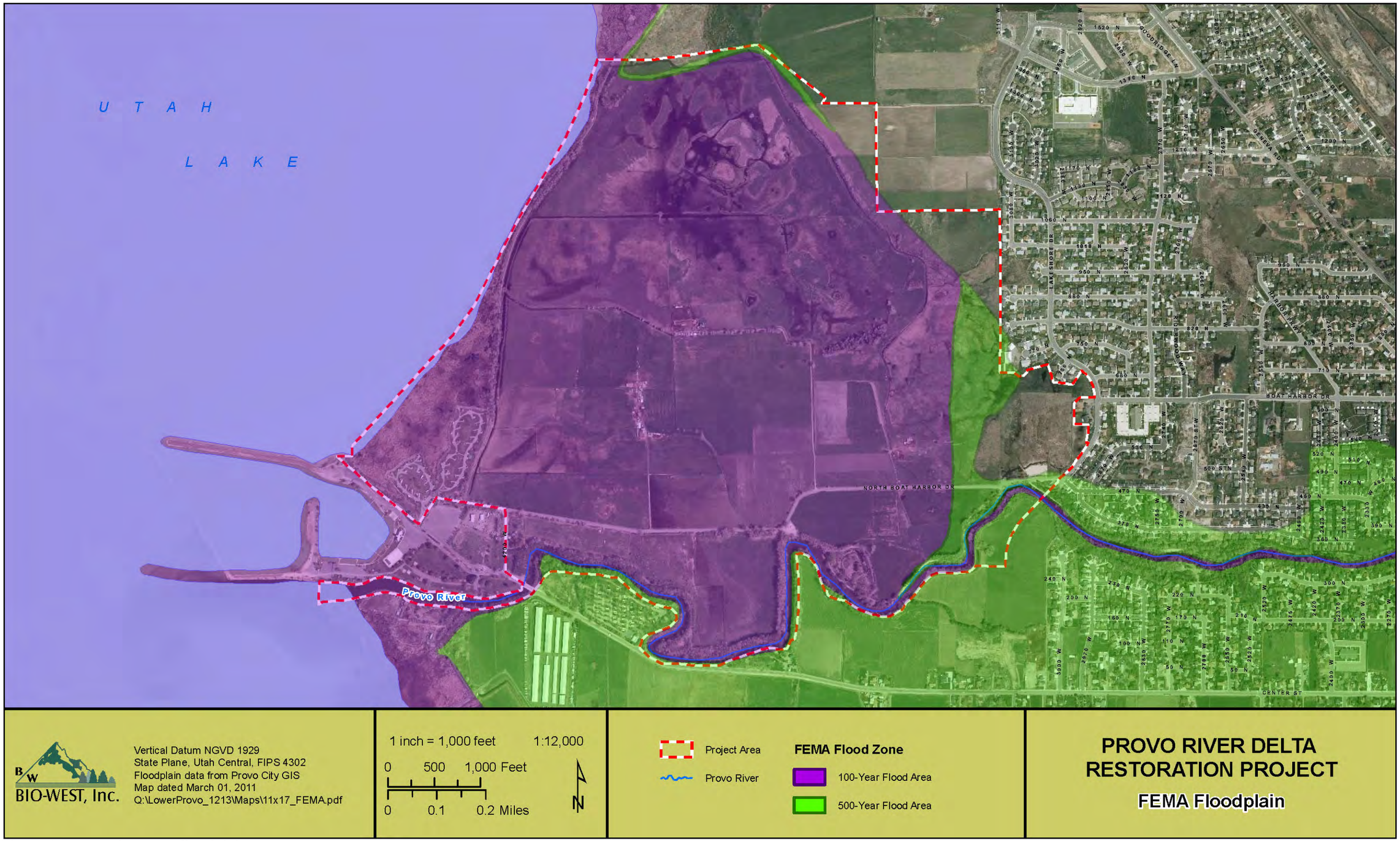

Figure 25. Project area floodplain.

Arid west region wetland delineation data forms were used to record conditions at sample points. Plant species were recorded, along with their relative abundance in the vicinity of each sample point according to procedure outlined in the 1987 *Manual*. Vegetation strata were used to determine the sampling-plot radius using the sampling point as the center. Trees and woody vines within a 30-foot radius of each sample point were recorded. Saplings, shrubs, and herbaceous vegetation within a 5-foot radius of each sample point were recorded. Those plant species considered dominant within each strata were used to determine wetland or upland classification. Species comprising 20 percent or more of the total areal cover per stratum were considered dominant. The wetland-indicator status of dominant plants was noted according to the *National List of Vascular Plant Species that Occur in Wetlands: 1996 National Summary* (USFWS 1997).

The vegetation-indicator status estimates the probability of a particular plant species occurring in a wetland. Of the dominant plant species recorded, more than 50 percent must have a vegetation-indicator status of facultative (34–66 percent probability of occurring in wetlands), facultative wetland (67–99 percent probability of occurring in wetlands), or obligate wetland (more than 99 percent probability of occurring in wetlands) for a sample point to be classified as having hydrophytic vegetation for wetland delineation purposes.

The presence or absence of hydrological indicators was examined and recorded at each sample point. The determination of wetland hydrology was based on the presence of at least one positive primary indicator or two positive secondary indicators of a prolonged period of saturation. Primary indicators include observation of the following: surface water, high water table, saturation, watermarks (nonriverine), debris deposits (nonriverine), sediment deposits (nonriverine), surface soil cracks, inundation visible on aerial imagery, water-stained leaves, salt crust, biotic crust, aquatic invertebrates, hydrogen sulfide odor, oxidized rhizospheres along living roots, the presence of reduced iron, or recent iron reduction in plowed soils. Secondary indicators include watermarks (riverine), sediment deposits (riverine), drift deposits (riverine), drainage patterns, dry season water table, thin muck surface, crayfish burrows, saturation visible on aerial imagery, shallow aquitard, or hydrophytic results from the facultative-neutral test. Environmental changes and the topographic position of the sample points relative to observed water tables were also noted.

Soil pits were dug at each sample point to a depth of at least 18 inches to characterize soil profiles and soil/water conditions. At least one positive hydric soil indicator was required at each sample point to classify a soil as hydric. For example, soils in prolonged anaerobic conditions undergo chemical reduction, thereby producing lighter soil colors. During the field survey, the colors of the soil profile matrix and mottles were identified using Munsell® soil color charts (Kollmorgen Instruments 1990). Soil horizon, texture, moisture content, and depth-to-soil saturation and/or standing water were noted. The presence or absence of particulate organic matter, organic matter staining, concretions, mottling, and gleying was also noted.

Standard wetland delineation procedures require comparison of soil profiles observed in the field with the United States Department of Agriculture, National Resource Conservation Service (NRCS), soil maps. The Utah County soil survey was accessed using the NRCS Web Soil Survey (NRCS 2010). Project area soils are further described in the Soils section of this report.

Wetland boundaries were determined from sample points and vegetation communities. The approximate locations of delineated wetland boundaries and sample points were surveyed using a sub-meter accurate GPS. The survey data were downloaded into a computer-aided drafting and design program to produce a map illustrating wetland boundaries. The wetland boundaries and sample points were marked in the field with pin flags. The results of the wetland delineation are illustrated in Figure 26.

7.4.2 Wetland Approximation Area

Access to approximately 200 acres of the project area was denied for wetland delineation purposes. To provide preliminary existing conditions data for the next level of alternatives development, approximate wetland boundaries within this area were estimated (Figure 26). The wetland approximation utilized existing data to remotely define approximate wetland boundaries.

The existing data utilized for the wetland approximation included aerial photography, Utah Lake level records, LIDAR ground elevation data, National Wetland Inventory (NWI) Data, and USDA soil maps. These data were reviewed for similar characteristics that indicated the existence of wetlands. These observations were used to create the wetland boundaries within the wetland approximation area. The wetlands illustrated in the wetland approximation area have one or more of the following attributes: they are located at low elevations within the surrounding landscape, are frequently inundated, contain hydric soils described by the USDA soil data, and/or have been identified and mapped as wetlands by the NWI.

The wetland approximation is a useful preliminary planning tool as the wetland approximation boundaries are generally representative of existing conditions; however, it must be noted that this area was not delineated in the field and the Corps had not verified the wetland boundaries depicted at the time this Technical Memorandum was written.

7.4.3 Existing Wetland Conditions

Using a combination of wetland delineation results and wetland approximation results, project area wetlands are described in Table 8. These results are illustrated in Figure 26.

Table 8. Existing wetlands.

WETLAND TYPE	EXISTING ACRES
Wet Meadow / Emergent Marsh Complex	187.8
Emergent Marsh (*Phragmites* dominant)	38.2
Saline Wet Meadow	4.5
Emergent Marsh	3.8
Freshwater Wet Meadow	0.3
Total Wetland Acres	234.6

Figure 26. Project area existing wetlands.

The majority of the existing wetlands located within the project area are described as wet meadow/emergent marsh complex. This mixed classification was used because of the existence of the flood control levee, agricultural drainage ditches, and the incised condition of the Provo River. Historically, project area wetlands would have been inundated seasonally by the Provo River and Utah Lake. The lack of inundation, combined with agricultural drainage, has degraded project area wetlands and caused a transition to drier site conditions. The majority of the project area wetlands contain a mosaic of habitat types with characteristics of both wet meadow and emergent marsh.

The wet meadow/emergent marsh complex wetlands can be further classified as hydrologically altered peatlands due to the presence of peat soils. Peatlands exhibit anaerobic, acidic, and nutrient poor conditions that lead to the extensive accumulation of partially decayed organic matter (Chadde 1998). The unique suite of environmental factors present within peatlands can support rare species that are specially adapted to survive under these conditions (Conservation Data Center 1992). The hydrologic alteration of the project area peatlands has likely resulted in drier conditions than those under which the peat soils formed. The decreased flooding and increased aeration of peatland soils results in increased rates of vegetation decomposition, preventing the formation of new peat soils. In addition, the heavy grazing of peatlands reduces available organic matter for peat formation.

Wet meadows are typically flooded on a seasonal basis. These areas commonly dry up during late summer. Wet meadows within the project area are hydrologically supported by a seasonally high groundwater table that, under normal conditions, does not drop below 18 inches from the ground surface. Wet meadows are important foraging habitat for migratory waterfowl. They are also important breeding areas for reptiles and amphibians. These areas serve a flood storage role and allow for valuable groundwater recharge. These wetlands also serve an important role in the filtration of agricultural pollutants.

Freshwater wet meadow wetlands within the project area are grazed, mowed, or hydrologically altered for agricultural practices. Species present include Nebraska sedge (*Carex nebrascensis*), common ragweed (*Ambrosia artemisiifolia*), Arctic rush (*Juncus arcticus*), chairmaker's bulrush (*Schoenoplectus americanus*), redtop (*Agrostis gigantea*), spike rush (*Eleocharis* spp.), common paintbrush (*Castilleja exilis*), reed canarygrass (*Phalaris arundinacea*), Nuttall's sunflower (*Helianthus nuttallii*), and scratchgrass (*Muhlenbergia asperifolia*).

The 4.5-acre saline wet meadow present within the project area has been ditched for agricultural drainage. This drainage ditch diverts surface water flow away from the wetland to the adjacent canal. This diverted surface water flow prevents normal flushing of the wetland, and saline conditions are present. As a result the wetland is dominated by salt tolerant species including pickleweed (*Salicornia rubra*) and saltgrass (*Distichlis spicata*).

Emergent marsh wetlands within the project area are flooded or saturated to the surface of the ground on a permanent basis. It is common for these areas to be inundated with several feet of water in spring and early summer. Emergent marsh areas within the project area are hydrologically connected to the groundwater table and historically exhibited surface water connections to the Provo River and Utah Lake. These areas serve similar functions to the wet

meadow environment; however, they provide benefits to aquatic species for longer periods because of prolonged saturation and inundation.

Emergent marsh wetlands located behind the flood-control levee within the project area are grazed, mowed, or hydrologically altered for agricultural practices. Typical species present include hard stem bulrush (*Schoenoplectus acutus*), Olney's bulrush (*Schoenoplectus americanus*), cattail (*Typha latifolia*), and common reed (*Phragmites australis*). The 38.2 acres of emergent marsh that is located outside of the flood-control levee on Utah Lake is dominated by common reed, an invasive emergent weed.

The wetland approximation area and the project area contain two parcels that are currently protected as wetland mitigation areas. These parcels provide wetland mitigation for past wetland impacts associated with off-site projects. The Provo City, Utah wetland mitigation area is located within the wetland approximation area and contains approximately 18 acres of wet meadow / emergent marsh complex and uplands (K.A. Smith Consulting Inc. 2009). The BLB Drywall parcel, presumably an active mitigation site, is located on the eastern edge of the project area and contains approximately 5 acres of wet meadow/emergent marsh complex and uplands.

7.4.4 Predicted Wetland Response

An analysis of the predicted wetland response due to levee removal was requested by the Corps. This task was accomplished by comparing historic Utah Lake surface elevations and existing LIDAR elevation data. Historic lake water surface elevation data from 1949–2009 indicates that during the growing season Utah Lake has a 50 percent probability of having a water surface elevation of 4,487.8 feet or higher. This lake surface elevation can be compared with the existing project area ground surface elevations from the LIDAR survey to predict water levels and wetland types on the project area after levee removal. This analysis assumes that the project area surface water and groundwater levels will be directly represented by Utah Lake water surface elevations after levee removal.

Areas where groundwater remains 1-foot or more below the surface throughout the growing season will typically have upland communities. Wetland communities typically form when the water level is at most 1-foot below the ground surface for at least two weeks during the growing surface. Areas with more than 2 feet of standing water throughout the growing season will develop into deepwater communities. These generalized water depth ranges combined with the LIDAR survey data of the project area and the historic Utah Lake water surface elevation data were used to predict wetland response to the proposed levee removal.

The predicted wetland types and the associated water levels are described in Table 9. The results of the analysis indicate that removal of the existing flood-control levee would result in the enhancement and restoration of approximately 395 acres of wetlands (Table 10). These areas are currently a mosaic of grazed wetlands and uplands. The results of the predicted wetland response are illustrated in Figure 27.

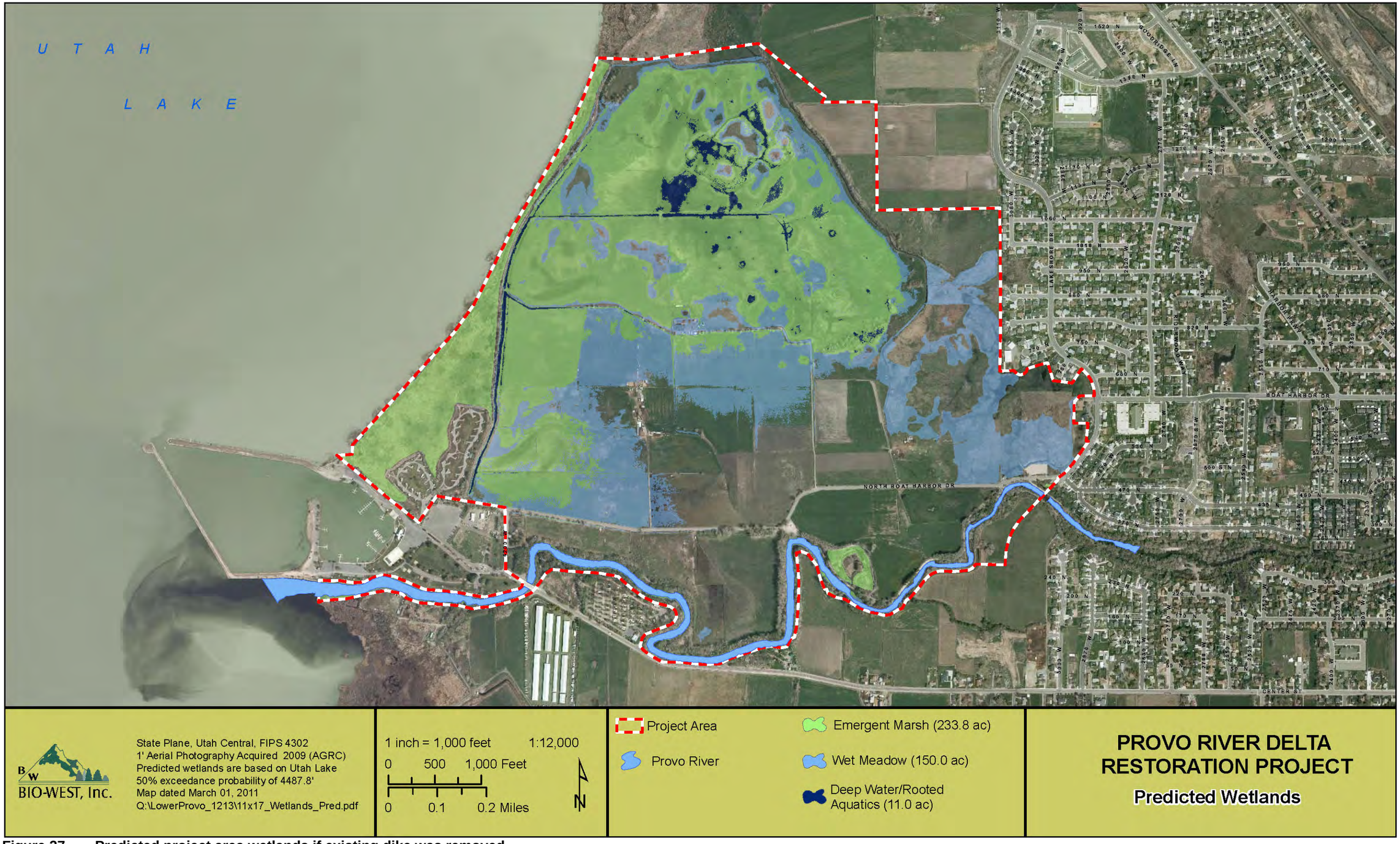

Figure 27. Predicted project area wetlands if existing dike was removed.

Table 9. Predicted wetland types.

PREDICTED WETLAND TYPE	WATER LEVELS
Uplands	Utah Lake level lower than 1 foot below ground surface
Freshwater wet meadow	Utah Lake level equal to ground surface to 1 foot below ground surface
Emergent marsh	Utah Lake level equal to ground surface to 2 feet above ground surface
Deepwater / Rooted Aquatics	Utah Lake level greater than 2 feet above ground surface

Table 10. Predicted wetland responses.

WETLAND TYPE	PREDICTED ACRES [a]
Emergent Marsh	233.8
Wet Meadow	150.0
Deep Water with Rooted Aquatics	11.0
Total Wetlands	394.8

[a] Based on historic Utah Lake water surface elevations (50% exceedance probability) and project area topography from LIDAR.

Removal of the existing levee would restore the surface water hydrologic connection between the project area and Utah Lake. Existing wetlands within the project area would be enhanced and large areas of upland pasture would be restored to historic wetland conditions. Existing wetland functions and services within the project area would be enhanced through levee removal. Management of the developing wetland vegetation community would be required to prevent further spread of invasive common reed within the project area. Figure 28 illustrates both existing and predicted wetlands in the project area.

7.4.5 Soils

A field examination of soils was performed during the project area visit. The NRCS Web Soil Survey(USDA NRCS 2010) map of the project area was reviewed and used as a reference while on site. Fourteen soil types were mapped within the project area (Table 11). All soils defined by NRCS within the project area are listed as hydric soils. Project area soils were formed within lacustrine sediments and/or in association with alluvial deposits (USDA NRCS 2010).

Soils within the project area that are not geographically extensive include Holdaway silt loam, McBeth silt loam, and Peteetneet peat. Peat soils support rare wetland vegetation communities as described in Section 7.4.3, Existing Wetland Conditions.

Peat soils within the project area were formed as dead marsh vegetation was deposited into standing water on the edge of Utah Lake. Anaerobic conditions within the marsh kept the organic matter from fully decaying. This organic matter deposition and accumulation over thousands of years formed the existing peat soils on the project area.

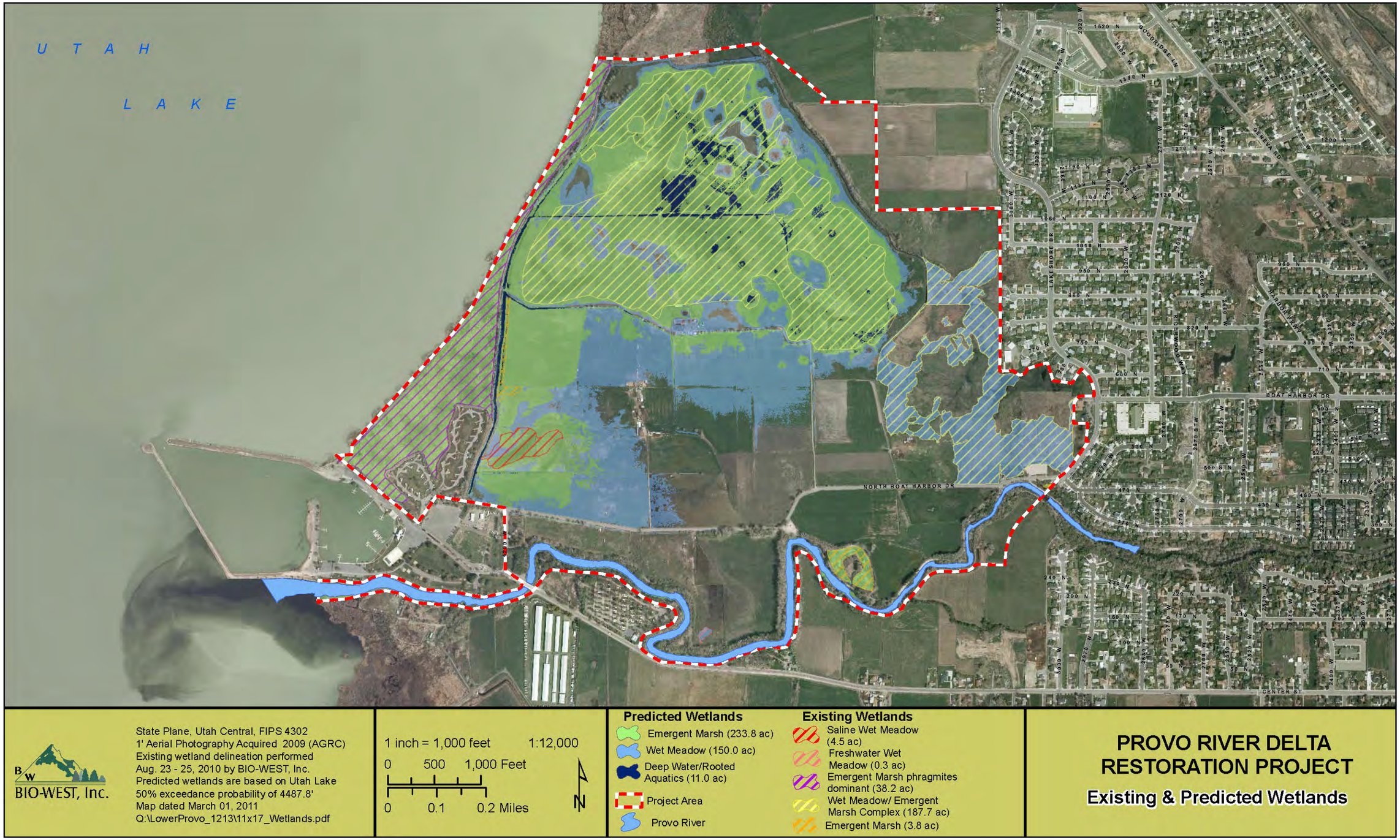

Figure 28. Existing and predicted project area wetlands.

Table 11. Project area soils.

MAP SYMBOL	MAP UNIT NAME	HYDRIC SOIL	FORMED	OCCURRENCE
Br	Bramwell silty clay loam	Yes	silty alluvium and lacustrine sediments	moderately extensive
Bs	Bramwell silty clay loam, drained	Yes	silty alluvium and lacustrine sediments	moderately extensive
Ch	Chipman loam	Yes	lacustrine sediments	moderately extensive
Ck	Chipman silty clay loam	Yes	lacustrine sediments	moderately extensive
Cm	Chipman silty clay loam, moderately deep water table	Yes	lacustrine sediments	moderately extensive
Cn	Chipman silty clay loam, moderately saline	Yes	lacustrine sediments	moderately extensive
CU	Cobbly alluvial land	Yes	alluvium	N/A
Hr	Holdaway silt loam	Yes	lacustrine sediments	inextensive
Lo	Logan silty clay loam	Yes	alluvium and lacustrine sediments	moderately extensive
Mh	McBeth silt loam	Yes	stratified alluvium	inextensive
Mn	McBeth silt loam, moderately saline	Yes	stratified alluvium	inextensive
MU	Mixed alluvial land	Yes	alluvium	N/A
Pf	Peteetneet peat	Yes	lacustrine	inextensive
Pg	Peteetneet-Holdaway complex	Yes	lacustrine	inextensive

Source: USDA NRCS 2010

7.5 Ute Ladies'-Tresses

The Ute ladies'-tresses (*Spiranthes diluvialis*), or ULT, is a white-flowered orchid that occurs in low- to mid-elevation wetlands and riparian zones in the central Rocky Mountains. The ULT was listed as threatened under the ESA on January 17, 1992, because of its rarity, low population sizes, and threats of loss or modification of riparian habitats (USFWS 1992). All ULT have been found on wetland sites that remain moist throughout the growing season (USFWS 1992). In Utah, ULT is most often found along old stream channels and on recently deposited material in floodplains of adjacent rivers (UNHP 1994). Both ground and river water contribute to the wetland hydrology of such sites. The ULT plants have been observed in inundated conditions and in merely moist conditions (Gecy 1994, Riedel et al. 1994).

Vegetation associated with ULT is variable, but its physiognomy is consistent. Canopy cover above 5 feet is sparse, while canopy cover below this height includes mixed densities of other species. The most important environmental parameter, apart from soil moisture, appears to be exposure to sunlight. Ute ladies'-tresses thrive in full sunlight or partial shade (USFWS 1992).

The ULT flowering period normally occurs from late July through mid-to-early October. The ULT is difficult to identify and survey in the vegetative stage because the leaves are small and easily blend with surrounding vegetation. A project area ULT survey was therefore scheduled during estimated peak bloom time for the most accurate identification and count. The ULT survey was conducted by BIO-WEST from August 23–August 25, 2010, to determine the

presence/absence of ULT in the project area. A nearby reference population was visited prior to the survey to confirm potential bloom time prior to the survey.

Nonlinear, meandering surveys were conducted through habitat thought to be appropriate or marginally appropriate for ULT in the project area. A cursory survey was conducted through all wetlands delineated in the project area, with a more intensive search effort focused on areas with appropriate conditions for supporting ULT. Upon discovery of ULT populations, data were collected, including the following: number of individuals in a population, phenology, age class, associated species and their percent aerial coverage, soil texture and moisture, and disturbance level. To incorporate data from multiple strata layers, absolute cover percentages were collected; these often totaled more than 100 percent cover to reflect species overlap in strata layers. The ULT individuals and habitat were photo documented and miscellaneous notes were taken concerning overall ecological conditions, as well as agricultural and grazing impacts.

Three populations of ULT were found within the project area during the 2010 survey. All three populations were found within the Fisher Lake Farm property north of 4200 West on the east end of the project area. This property was being lightly grazed by horses at the time the survey was conducted. Most of the area within proximity to the ULT populations is considered wet meadow habitat with some scattered emergent marsh habitat as well as upland berms and knolls.

The first population found (occurrence 1) consisted of 23 individuals with 10 percent fruiting and 90 percent flowering. The population was found within wet to marginally wet meadow habitat with soil moist to the surface. The surrounding vegetation consisted almost entirely of Nebraska sedge (*Carex nebrascensis)* and common ragweed (*Ambrosia artemisiifolia*). There appeared to be a higher concentration of ULT along livestock trails and areas with a more open canopy. Other associated species included arctic rush(10%), Olney's bulrush (10%), redtop (10%), reed canarygrass (*Phalaris arundinacea*) (5%), Nuttall's sunflower (*Helianthus nuttallii*) (5%), and scratchgrass (5%).

The second and largest population found (occurrence 2) consisted of 147 individuals. This site differed from occurrence 1 in that it was slightly more open canopy with small moist depressions. It is located east of a mowed hay field with an emergent marsh community to the north and an upland community to the southeast. Soils were a loam that was moist to saturated to the surface. A slight concentration of ULT in this population occurred adjacent to the emergent marsh community, though not within it, and along a small toe slope leading to the upland community. These concentrated areas may have been the result of a more open canopy in these transition zones. About 20 percent of the population was fruiting with 80 percent flowering. Like the previous population, the understory was thick with a sparser overstory of common ragweed (15%), and Nuttall's sunflower (5%). The understory was diverse in species composition and included; Nebraska sedge (20%), redtop (20%), spike rush (*Eleocharis* spp.) (15%), arctic rush (15%), reed canarygrass (10%), Olney's bulrush (5%), field bindweed (*Convolvulus arvensis*) (5%), and common paintbrush (*Castilleja exilis*) (5%).

The third and smallest population found (occurrence 3) consisted of 10 individuals. The ULT occurred at the very northern end of a hay field which had been mowed early in the 2010 growing season. This third population was to the northwest of occurrences one and two. The

vegetation was recovering from the mow but was still less thick than vegetation in adjacent areas not mown. The area where the ULT were growing had thicker and higher vegetation than the rest of the field as well as moister soil conditions. Associated species in the area included spikerush (30%), Nebraska sedge (20%), arctic rush (15%), redtop (10%), common ragweed (10%), common paintbrush (10%), and yellow sweetclover (5%). Of the ten individuals 10 percent were fruiting and 90 percent were flowering.

Permission was not granted for access to all properties within the project area. Specifically, the same property that was not surveyed in the wetlands delineation, which comprises a large percentage of the central to northern portion of the project area, was not surveyed. According to a Provo City Wetland Mitigation Monitoring report prepared by K.A. Smith Consulting, Inc., and submitted to the Utah Natural Heritage Program, ULT are found on the Provo city wetland mitigation site within this property (K.A. Smith Consulting Inc. 2009). Based on aerial photo interpretation, NWI maps and the ULT occurrence found within the property it is likely that additional ULT populations exist in areas not surveyed. This cannot be verified without a thorough survey of all appropriate habitats for ULT in the project area.

ULT occurrence is known to fluctuate from year to year, sometimes drastically. This tendency may be exacerbated by unsuitable environmental factors such as drought, altered hydrology, invasive species competition, and disturbance level including mowing and grazing (Fertig et al. 2005). With project implementation, degraded wetlands in the area have the potential to be restored and to support additional ULT populations. Conversely, some existing agricultural practices such as light-to-moderate grazing and mowing likely have had positive effects on ULT occurrence by reducing competition from overstory species (see Arft 1995). Given these variable factors, additional surveying and monitoring of ULT populations within the project area is advisable.

7.6 Public Utilities and Water Rights

Public utilities within the project area were identified and mapped in order to assess constraints on project design and construction. Entities with utilities and infrastructure in the area include Provo City, Utah County, Questar Gas, Utah Lake State Park, and Rocky Mountain Power. Water right points of diversion were identified in consultation with the Utah Division of Water Rights. Figure 29 illustrates the known utilities and water rights in the project area.

Irrigation water in the project area is supplied by a mix of underground wells, diverted surface water, and pumped surface water conveyed through a network of ditches. Within the project area, only one surface water point of diversion is noted in the Utah water rights database (DWRT 2011a). This point of diversion, associated with water right number 55-500, change number a16279, consists of a pump in the Provo River about 700 feet downstream from the Center Street Bridge and adjacent to Utah Lake State Park (Figure 29). Water rights WR 55-1349 and 55-1350 divert surface water east of the project area but have shared rediversion points from ditches within the project area. The source for WR 55-1349 is listed as “Unnamed stream,” while the source for WR55-1350 is listed as Provo River (DWRT 2011a). The remaining points of diversion listed for the project area are associated with underground water wells (Table 12).

Figure 29. Project area utilities and water rights.

Table 12. Water rights listed in the Utah Water Rights Database as having points of diversion within or immediately adjacent to the project area.

WATER RIGHT NUMBER	OWNER	AMOUNT (CFS)	AF [a]	SOURCE
55-1038	B. A. BROCKBANK	1	N/A	Underground Water Well
55-110	REED J. KNUDSEN	1	223.4	Underground Water Well
55-1349	ALFRED MADSEN	2	N/A	Unnamed Stream Rediversion
55-1350	DUN ROAMIN CORPORATION	3	N/A	Provo River Rediversion
55-1608	DONALD D. & DOROTHY C. REESE	0.267	N/A	Underground Water Well
55-2051	ELTON L. AND ETHEL S. TAYLOR	0.334	N/A	Underground Water Well
55-2058	ISAAC B. NELSON	0.446	N/A	Underground Water Well
55-2283	REED J. KNUDSEN	0.446	N/A	Underground Water Well
55-2284	REED J. KUNDSEN	0.134	N/A	Underground Water Well
55-2285	REED J. KNUDSEN	0.156	N/A	Underground Water Well
55-2301	CHARLES MADSEN	1.114	N/A	Underground Water Well
55-2302	CHARLES MADSEN	0.446	N/A	Underground Water Well
55-2303	CHARLES MADSEN	0.668	N/A	Underground Water Well
55-2357	DUN ROAMIN CORPORATION	0.446	N/A	Underground Water Well
55-2363	L. A. ADAMS	0.167	N/A	Underground Water Well
55-2364	L. A. ADAMS	0.679	N/A	Underground Water Well
55-2365	L. A. ADAMS	0.045	N/A	Underground Water Well
55-2945	FISHER LAKE FARM LIMITED PARTNERSHIP	0.455	N/A	Underground Water Well
55-3138	J. W. HOWE	0.78	N/A	Underground Water Well
55-3145	MATHEW AND DANA MANSFIELD REVOCABLE LIVING TRUST	N/A	40	Underground Water Well
55-3146	NELLIE B. EDWARDS REVOCABLE TRUST AGREEMENT	0.011	N/A	Underground Water Well
55-3147	PHIL & NELLIE EDWARDS	0.129	55.66	Underground Water Well
55-3148	NELLIE B. EDWARDS REVOCABLE TRUST AGREEMENT	N/A	80.45	Underground Water Well
55-3149	DANA MANSFIELD REVOCABLE LIVING TRUST	0.78	200	Underground Water Well (Abandoned)
55-3149	JACKIE LYNN EDWARDS AND R. DIANE EDWARDS REVOCABLE LIVING TRUST	0.78	200	Underground Water Well
55-3152	PAUL S. DIXON	0.189	N/A	Underground Water Well
55-3153	PAUL S. DIXON	0.446	N/A	Underground Water Well
55-3259	JAMES FISHER	0.553	N/A	Underground Water Well
55-424	FISHER LAKE FARM LIMITED PARTNERSHIP	0.75	N/A	Underground Water Well
55-483	HEBER A. KNUDSEN	1	N/A	Underground Water Well
55-500	STATE OF UTAH DIVISION OF PARKS & RECREATION	0.247	N/A	Underground Water Well
55-500 (a16279)	STATE OF UTAH DIVISION OF PARKS & RECREATION	0.247	38.58	Provo River
55-5439	DEAN N. MASON	0.015	N/A	Underground Water Drain
55-5669	ELTON L. AND ETHEL S. TAYLOR	1.37	N/A	Underground Water Drain
55-589	DUN ROAMIN CORP.	0.809	N/A	Underground Water Well
55-590	CHARLES MADSEN	0.752	N/A	Underground Water Well
55-736	B. A. BROCKBANK	1	N/A	Underground Water Well
55-737	B. A. BROCKBANK	4	N/A	Underground Water Drain
55-8033	RUDOLPH P. REESE	0.002	N/A	Underground Water Well
55-8034	RUDOLPH P. REESE	0.018	N/A	Underground Water Well

[a] N/A = not available or not applicable.

Well depths average about 140 feet and range from 114 feet to 250 feet deep (DWRT 2011b). It is possible that additional points of diversion exist within the project area but have not been updated in the available water rights database information. For example, a large pump is visible on the south side of Provo River downstream from the fish weir, but it is not listed as a point of diversion in the state database. It is not known whether the pump is active or how it is operated.

7.7 Land Use and Parcel Ownership

The project area is located in Utah County and is adjacent to land in Provo City. Ownership of lands in the project area is a mix of private, municipal, state, and federal. For purposes of coordinating with landowners in the project area, parcel ownership data was obtained from Utah County. Figure 30 illustrates parcels and owners within the project area.

The largest project alternative (see Section 8.1.1: Full Alternative) is 564.3 acres. The majority of land within this area, 475 acres, is privately owned. Land use is primarily agricultural, including livestock grazing and growing grass hay. Distributions of grazing and hay production likely change year to year and season to season. In addition, two wetland mitigation areas are present as discussed in Section 7.4.3. Approximately 231 acres of the project area is held in the Despain Ranch and Bird Refuge Easement purchased in 2000 with help from the LeRay McAllister Critical Land Conservation Fund. The land is privately owned, and the easement is held by Provo City. The conservation easement was set up for scenic quality, wildlife habitat, recreation, and agricultural land.

The United States and the State of Utah recently reached a settlement regarding ownership of certain lands around Utah Lake (U.S. District Court, District of Utah, Central Division, March 3, 2011 (Civil No. 2:97CV 0927K)). This settlement of a lawsuit filed in 1997 involves several land parcels within the project area. Approximately 84 acres of land previously reflected on Utah County records as private property was in fact withdrawn from the public domain by the United States in 1889. These lands are owned by the United States (Figure 30), having never been patented out of federal ownership. The United States is currently moving forward with appropriate actions to demonstrate title.

8.0 LEVEL 3 SCREENING

As noted in the previous section, prior to level 3 screening, the JLAs collected more detailed information on the project area. The purpose of gathering this detailed information is to use it in conjunction with the scoping comments to develop alternatives north of the existing river channel that would maximize the functionality of the delta ecosystem while minimizing impacts. To this end, a variety of alternative configurations of land area associated with different possible river delta alignments were considered within the greater concept of using the area north of the existing river channel. Although these alternative designs provide greater detail, they are still conceptual in nature and do not necessarily dictate exact positions of river channels or other concept particulars.

BIO-WEST, Inc.

State Plane, Utah Central, FIPS 4302
1' Aerial Photography Acquired 2009 (AGRC)
Parcel data from Provo City
Map dated March 01, 2011
Q:\LowerProvo_1213\Maps\11x17_Ownership.pdf

1 inch = 1,000 feet 1:12,000

0 500 1,000 Feet

0 0.1 0.2 Miles

N

Project Area

Parcel Boundary

PROVO RIVER DELTA RESTORATION PROJECT

Parcel Ownership

Figure 30. Project area parcel ownership.

In addition to gathering needed information on the project area, criteria for evaluating alternatives were also developed. Geomorphic criteria (Appendix A) were developed by geomorphologists on the project team, whereas biological criteria (Appendix B) were developed in a workshop of experts lead by the Mitigation Commission.

8.1 Description of Alternatives

Within the area north of the existing river channel, a variety of alternative designs were developed to help determine the most appropriate place for a river diversion, length of restored river channel, and delta configuration. As noted, these alternatives were developed to a higher level of detail and design to facilitate evaluation of which ones would best meet project need and purposes.

The technical nature of the proposed project dictates that specific actions must be common to all of the alternatives to ensure the operational integrity and viability of the project. Some of the commonalities are discussed briefly below:

- All alternatives include full or partial removal of the existing shoreline levee and trail that extend northward from the campground at Utah Lake State Park. The low-elevation areas east of the levee were formerly part of Utah Lake, but are isolated from the lake by the levee. When the levee is removed, all areas lower than the compromise elevation of the lake (4,489.045 feet) will be flooded during most years, unless new levees are constructed to keep "lake water" out of specific locations.

- All alternatives include an array of geomorphic features that are common in the river delta environment, including a distributary channel form with alternating bars, mid-channel bars, and mouth bars. Other features common in the delta environment include abandoned channels, oxbow wetlands, natural levees, etc. Natural levees form along the margins of rivers when suspended sediment falls out of the water onto the floodplain. Natural levees should not be confused with constructed levees, which are created by humans.

- All alternatives would include a number of recreation components that would allow for public use of substantial portions of the project area. Each alternative would minimally include a new trail system that would connect with the existing river trail.

- All alternatives would alter the lower portion of the existing Provo River channel. There are a variety of options for the existing channel that can be considered. The existing channel could be filled, abandoned, or possibly provided with minimal flow to maintain water quality and possibly provide public recreational uses. If maintained as a channel, a barrier could be placed at the mouth of the existing river, near the State Park, or the river channel could be left open to water from Utah Lake backing up into it.

The alternatives were given alphabetical designations for tracking and discussion purposes as well as descriptive titles. A total of seven designs were developed. The first design, designated the "Full Alternative," utilized the entire area north of the existing river channel and west of existing development. The other six designs fell into two categories, referred to as the "variations on the full alternative" category, and the "4,489 alternatives" category.

8.1.1 Full Alternative

Alternative A – Full. Alternative A includes the entire agricultural area north of the existing river channel and west of existing development (Figure 31). It is the largest alternative under consideration in terms of land area. It includes all lands below the compromise elevation, and additional lands that would flood only during extremely wet periods when the lake exceeds the compromise elevation. This alternative maximizes the available area for June sucker habitat, and provides a considerable amount of additional area for restoration of the delta ecosystem (e.g., wetlands, uplands, and riparian areas) and recreational uses. Alternative A is bounded by a natural topographic rise along much of the northern and eastern margin. This topographic feature would allow the project area to be confined in many areas, without the need for artificial levees. Existing levees along the south side of the Provo River channel would define much of the southern boundary without additional levee construction. Alternative A includes the removal of Harbor Drive.

8.1.2 Variations on the Full Alternative

Each of these three designs represent a reduction in overall acreage from the full alternative in an effort to avoid key resources and/or reduce the amount of agricultural land required to be purchased from private landowners.

Alternative B – North. Alternative B was designed to preserve the existing condition of Harbor Drive and some agricultural lands located just north of Harbor Drive (Figure 32). This alternative includes a levee along the south boundary, but would use the topography to define much of the northern and eastern boundary, similar to Alternative A. This alternative lacks the topographic diversity that exists elsewhere in the project area. It primarily includes peat wetland areas that are low in elevation. In addition, the channel excavation would occur largely within jurisdictional wetlands. This alternative allows Harbor Drive to remain in place, but would require construction of a bridge over the new river channel.

Alternative C – Middle. Alternative C was designed to avoid the existing Provo City wetland mitigation site and additional wetlands to the south and east of the mitigation site, as well as some agricultural lands adjacent to Harbor Drive (Figure 33). This alternative includes a considerable amount of levee construction, much of which would occur within jurisdictional wetlands. In addition, a pumping system (similar to the pumping system located east of the existing levee) would be installed to protect the areas behind the levee from flooding. This alternative includes removal of a section of Harbor Drive, and replacement with a new section (the exact route of which is yet to be determined).

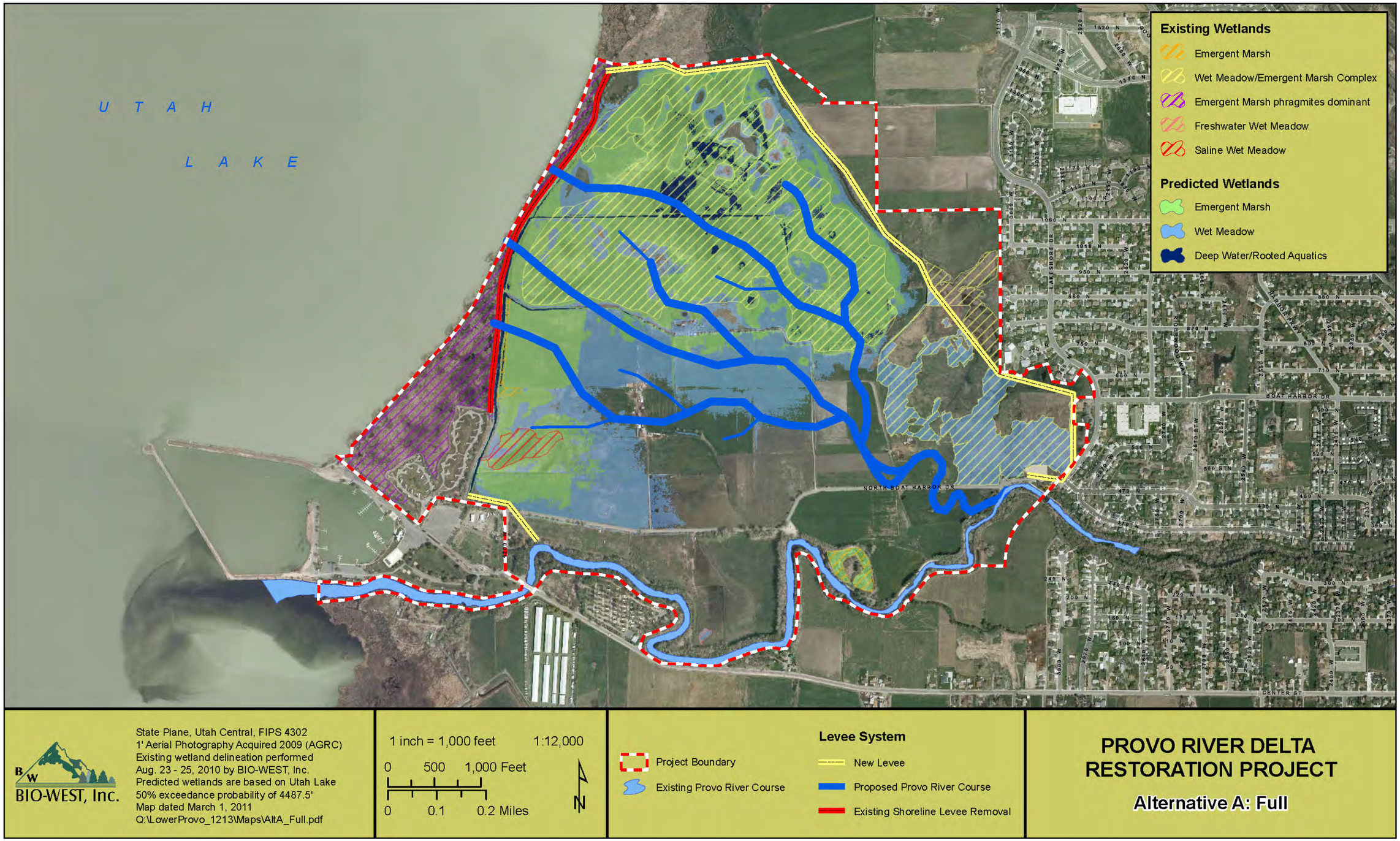

Figure 31. Alternative A – Full.

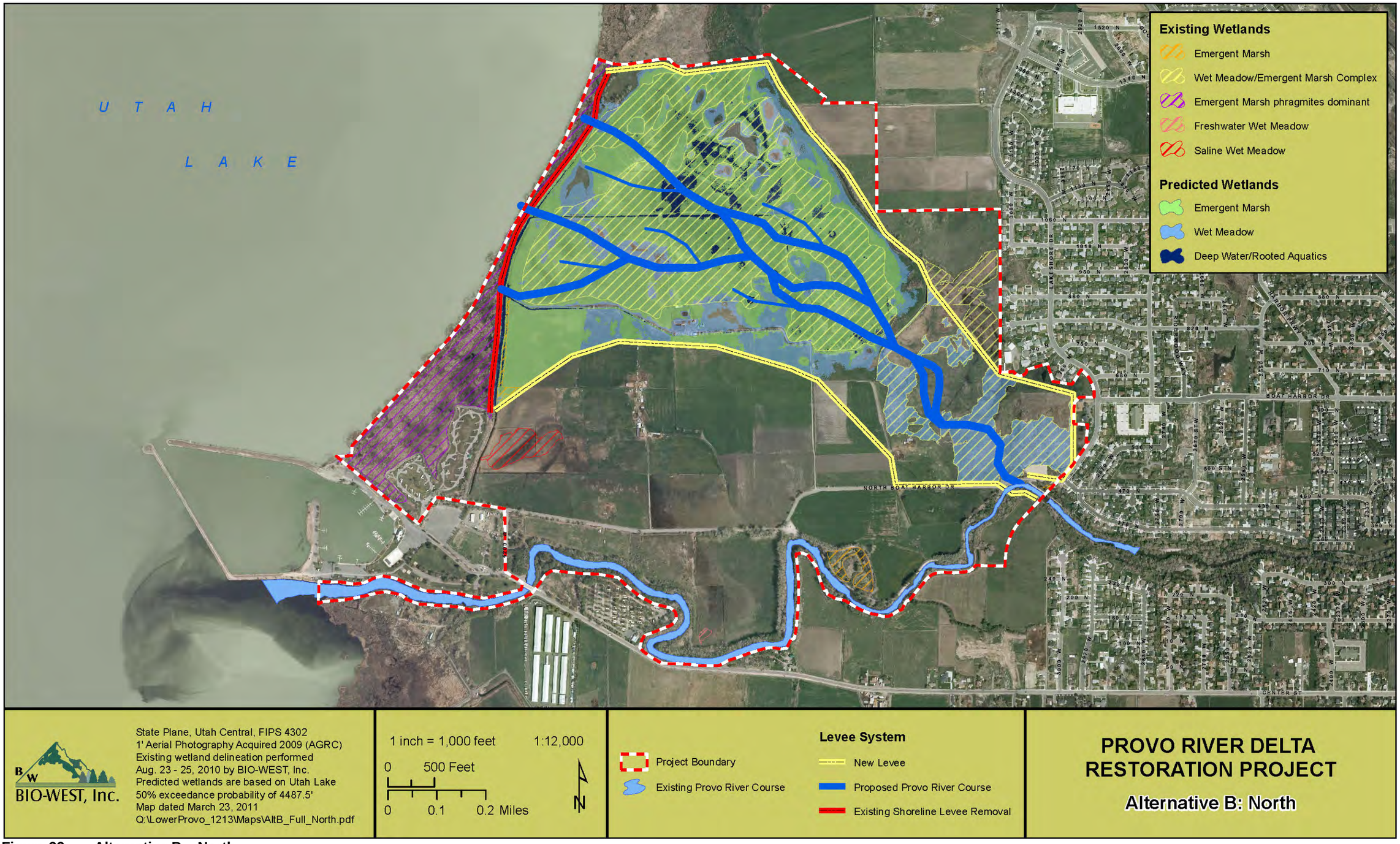

Figure 32. Alternative B – North.

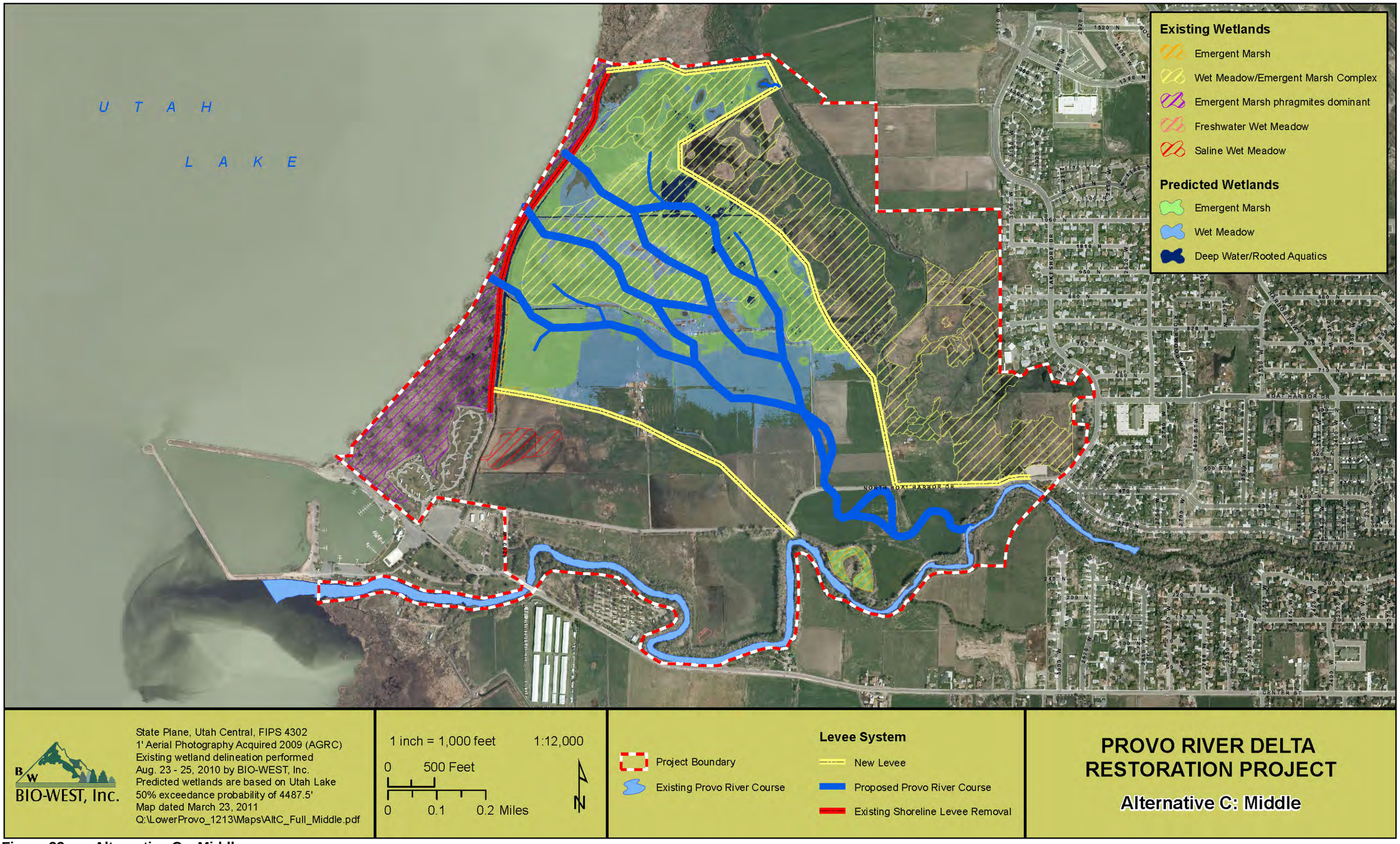

Figure 33. Alternative C – Middle.

Alternative D – South. Alternative D was designed to avoid the existing Provo City wetland mitigation site and surrounding peat wetlands located to the east and south of the mitigation site (Figure 34). This alternative includes a considerable amount of levee construction, but would reduce the amount to be constructed in jurisdictional wetlands as compared to the Middle Alternative. In addition, a pumping system (similar to the pumping system located east of the existing levee) would be installed to protect the areas behind the levee from flooding. This alternative includes removal of a section of Harbor Drive, and replacement with a new section (the exact route of which is yet to be determined).

8.1.3 4,489 Alternatives

As an approach consistent with the managed high-water level of Utah Lake, approximately 4,489 feet, Alternatives E through G were designed to encompass all lands below that elevation in the project area. Alternatives E through G vary in the routes they propose to connect the Provo River and Utah Lake.

Alternative E – 4,489 North. Alternative E was designed to preserve the existing condition of Harbor Drive, as well as agricultural lands to the north of Harbor Drive that are higher than 4,489 (Figure 35). This alternative maximizes the available rearing habitat for June sucker while keeping some private lands outside of the project area. Some levees would be required, though most would not have water against the base on a frequent basis, due to their location above compromise elevation. As such, pumping behind the levees would be minimal. Harbor Drive could remain in place, but a new bridge over the relocated Provo River channel would be required.

Alternative F – 4,489 Middle. Alternative F was designed to preserve the existing condition of some lands north of Harbor Drive that are higher than 4,489 and some agricultural lands adjacent to Harbor Drive below that elevation (Figure 36). This alternative maximizes the available rearing habitat for June sucker while keeping some private lands outside of the project area. Some levees would be required, although most would not have water against the base on a frequent basis, due to their location above compromise elevation. As such, pumping behind the levees would be minimal. Portions of Harbor Drive could remain in place or be rerouted, but a new bridge over the relocated Provo River channel would be required.

Alternative G – 4,489 South. Alternative G was designed to preserve the existing condition of lands north of the river channel as well as some lands north of Harbor Drive that are higher than 4,489 (Figure 37). This alternative maximizes the available rearing and spawning habitat for June sucker, while keeping some private lands outside of the project area. Some levees would be required, although most would not have water against the base on a frequent basis, due to their location above compromise elevation. As such, pumping behind the levees would be minimal. Portions of Harbor Drive could remain in place or be rerouted, but a new bridge over the relocated Provo River channel would be required.

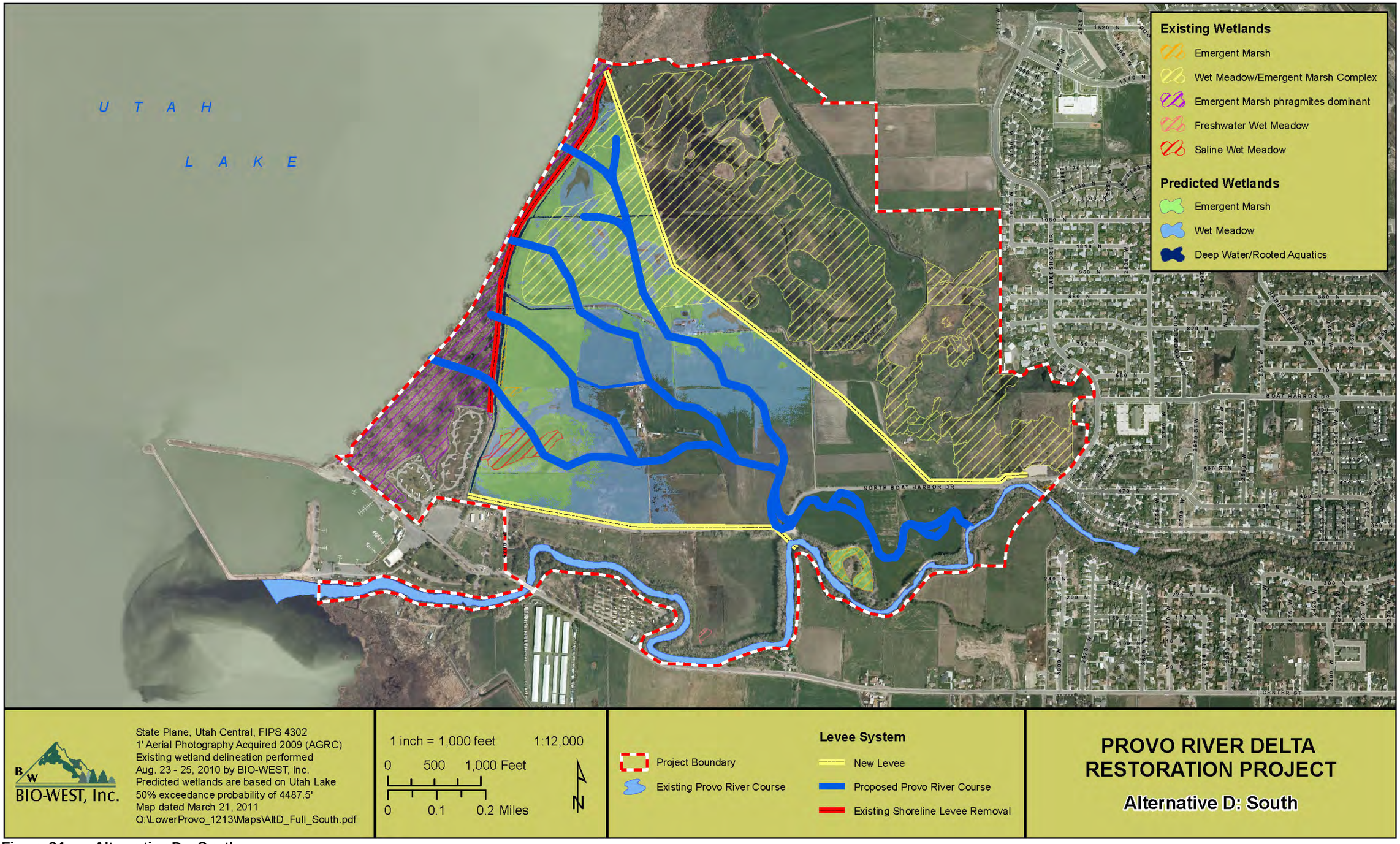

Figure 34. Alternative D – South.

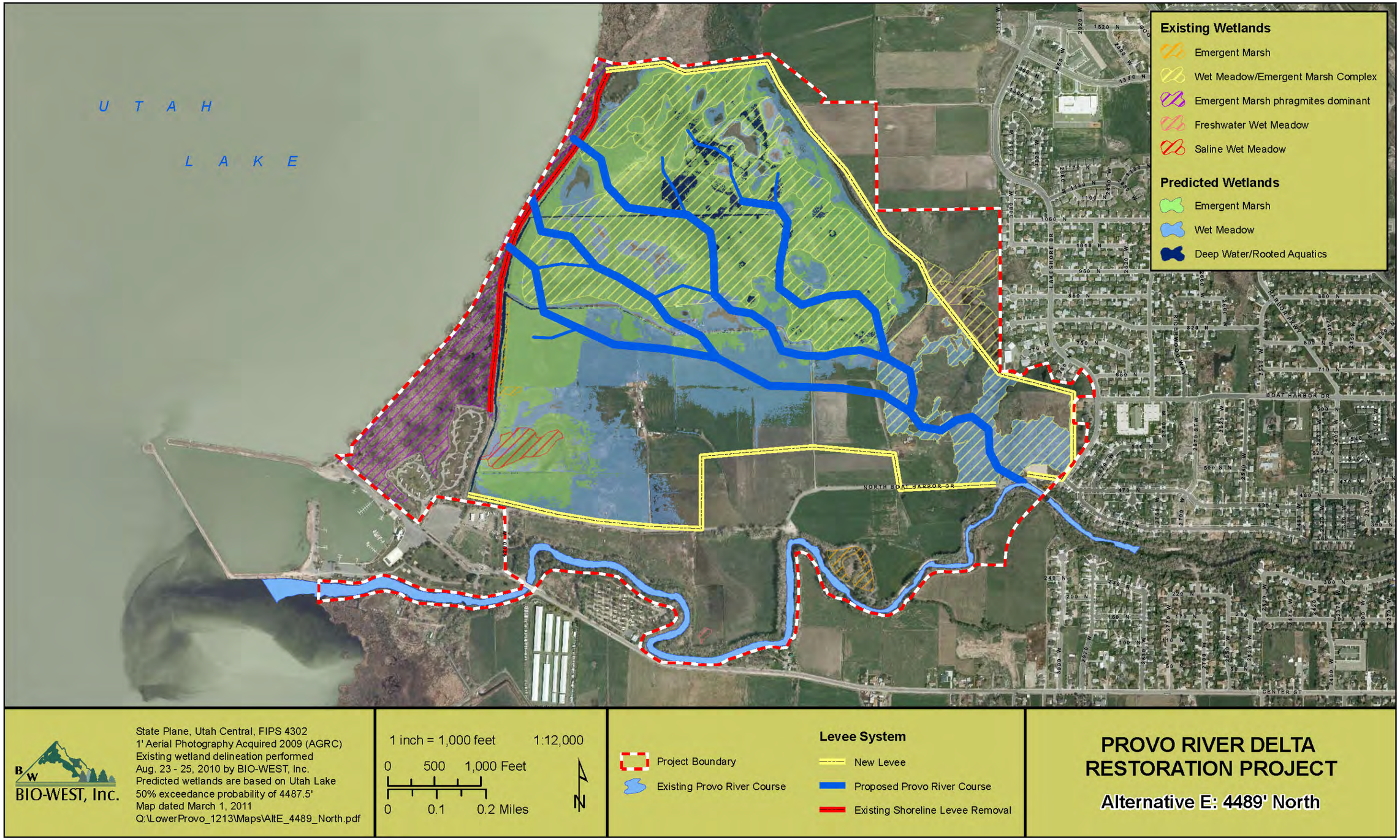

Figure 35. Alternative E – 4,489 North.

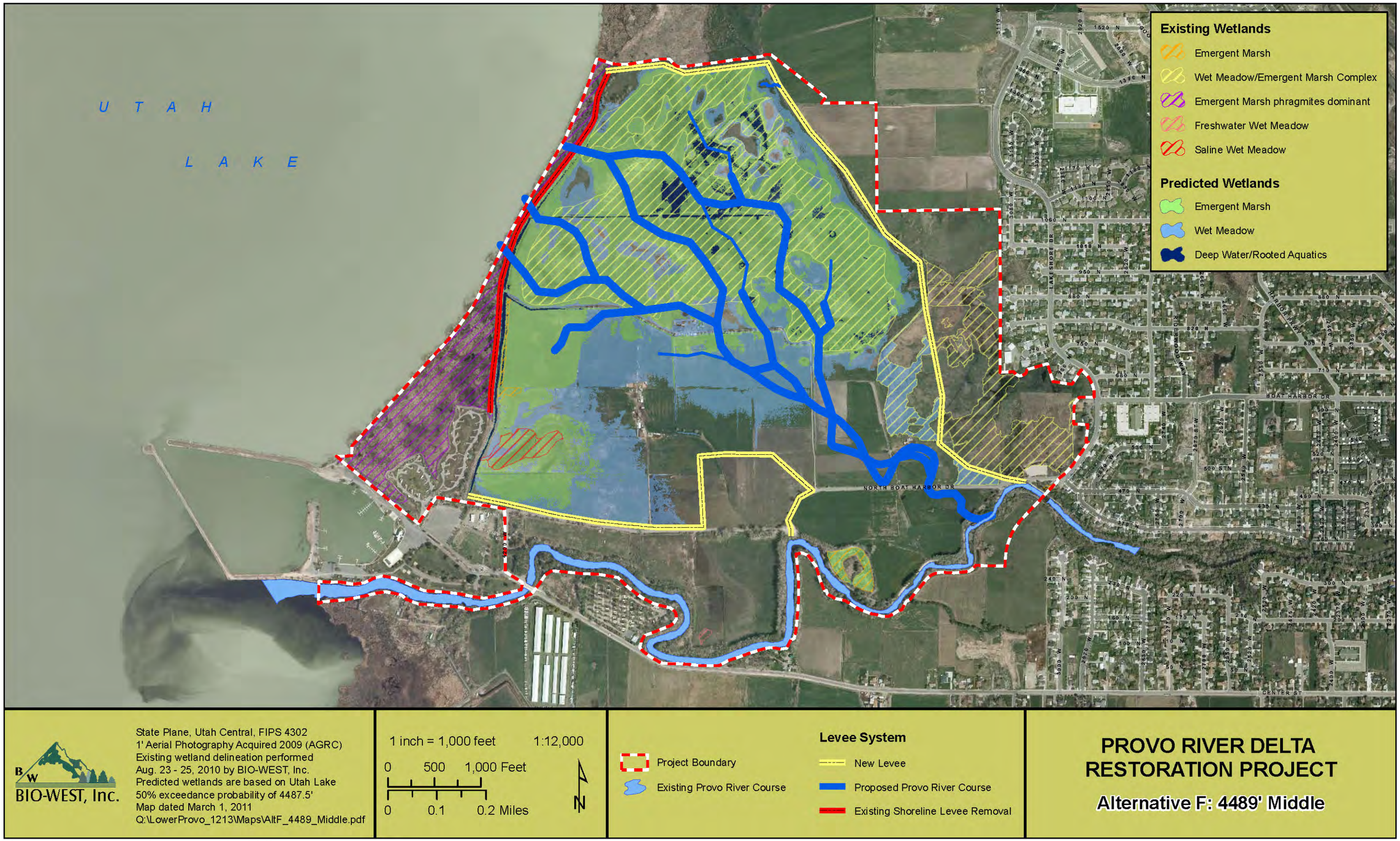

Figure 36. Alternative F – 4,489 Middle.

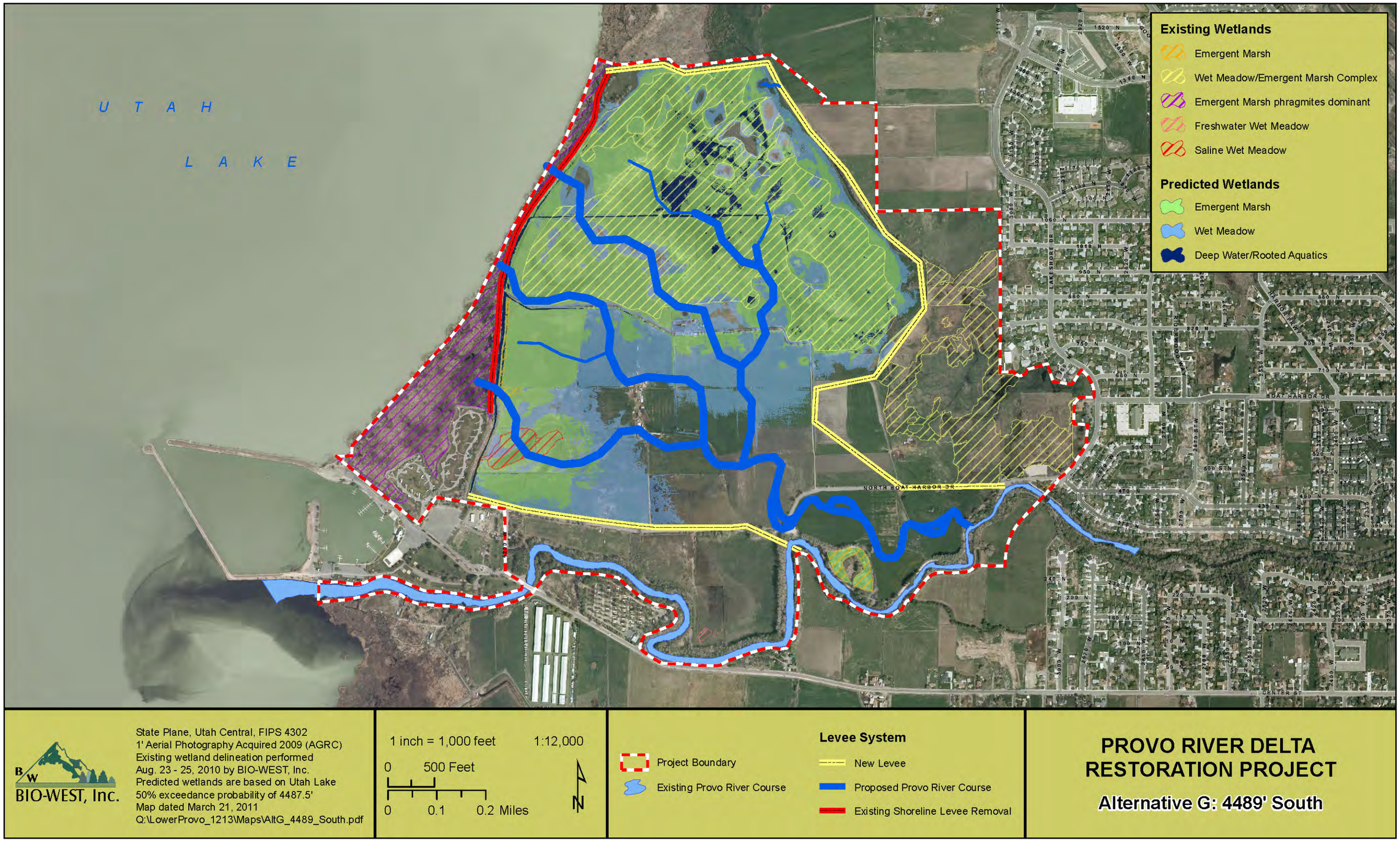

Figure 37. Alternative G – 4,489 South.

8.2 Evaluation Criteria

Because of the technical nature of the proposed project, there are specific criteria that must be met in order for the project to succeed. In addition, there are criteria that must be met in order to meet the commitments and agreements that have preceded this project. These criteria are described below and are inclusive of the biological, physical, recreational, and operational elements that would allow the proposed project to function as intended. These criteria are as follows:

- ***Width of Floodplain/Riparian Corridor in Spawning Reach:*** Would the concept allow restoration of a floodplain/riparian corridor for natural meander patterns? The recommended floodplain width for the lower Provo River would equal or exceed 800 feet according to Appendix A.

- ***Size of Delta in Rearing Reach:*** Would the concept allow restoration of a delta at the river/lake interface of sufficient size to support a distributary channel form and other ecosystem features? The recommended delta plain width in Utah Lake is 6,000 feet according to Appendix A.

- ***Abundance of Shallow Wet Meadow Aquatic Habitat (0–2 feet):*** How much shallow wet meadow aquatic habitat would the concept provide at a lake level of 4,489 feet?

- ***Abundance of Deep Emergent Aquatic Habitat (2–4 feet):*** How much deep emergent aquatic habitat would the concept provide at a lake level of 4,489 feet?

- ***Abundance of Deep Submergent Aquatic Habitat (4+ feet):*** How much deep submergent aquatic habitat would the concept provide at a lake level of 4,489 feet?

- ***Water Depth Ranges at a Typical Low Lake Elevation:*** How many acres of shallow (under 2 feet), medium (2–4 feet), and deep (greater than 4 feet) water would exist under a typical low water condition (4,487 feet) in Utah Lake?

- ***Water Depth Ranges at a Typical High Lake Elevation:*** How many acres of shallow (under 2 feet), medium (2–4 feet), and deep (greater than 4 feet) water would exist in the project area under a high water condition (4,491 feet) in Utah Lake?

- ***Isolated Habitat Avoidance:*** Would the concept avoid the creation of isolated habitats that would not be accessible to June sucker?

- ***Wetlands:*** Would the concept result in an increase of wetland habitat function?

- ***Recreation:*** Would the concept allow for expansion or improvement of existing recreational resources within the project area?

- ***Avoidance of Key Resources:*** Would the concept allow for avoidance of filling or excavating on or near (within 50 feet) existing key resources such as jurisdictional wetlands, Ute ladies'-tresses populations, and archeological/cultural resources?

- ***Levee Length:*** How much new levee length and subsequent maintenance would the concept require?

- ***Existing Infrastructure Impacts:*** What impacts would the concept have on existing infrastructure?

- ***Long-term Costs:*** What long-term costs not associated with achieving the proposed project's purpose and need would be required for implementation of the concept?

- ***Length of Enhanced Spawning Habitat:*** How many feet of enhanced spawning habitat would be provided by the concept?

- ***Area Available for Project Implementation:*** How much area does the concept provide to meet the needs of the proposed project?

- ***Private Landowner and Land Acquisition Impacts:*** How many individual private landowners would be impacted by property acquisition and how many private land acres would be required to implement the alternative?

8.3 Evaluation of Alternatives

In an effort to identify which concepts would best meet the screening criteria, qualitative values were used to score each concept. Each concept was scored on a scale from 0 to 3, with 0 representing a concept not meeting a criterion and 3 representing a concept meeting a particular criterion well. A score of 1 or 2 would indicate meeting a criterion at respectively lower levels. It should be noted that not all criteria have equal weight or importance. Thus, the designation of 1 for one criterion may not be analogous to the designation of a 1 for a different criterion. The numerical designations are only provided to determine how a given concept compares to other concepts for that criterion only and are not intended to be summed or weighted. Detailed evaluation and discussion of how well the alternatives meet the level 3 screening criteria is provided in each of the subsequent subsections. A level 3 screening summary is provided at the end.

8.3.1 Width of Floodplain/Riparian Corridor in Spawning Reach

Each alternative was evaluated to determine how well the concept would restore a floodplain/riparian corridor with sufficient width for natural meander patterns. Research has indicated that the meander belt width should be approximately 800 feet to accommodate an actively migrating and meandering channel, including its associated floodplain and riparian corridor that supports in-stream habitat for June sucker spawning (Appendix A). For this criterion, all of the alternatives were given a rating of 3. All of the alternatives met this criterion

well because the alternatives were designed with adequate width as a necessary component of a successful project.

Alternative A – Full. Alternative A was designed specifically to accommodate the 800-foot belt width and was given a rating of 3 because it met the criterion well.

Alternative B – North. Alternative B was designed specifically to accommodate the 800-foot belt width and was given a rating of 3 because it met the criterion well.

Alternative C – Middle. Alternative C was designed specifically to accommodate the 800-foot belt width and was given a rating of 3 because it met the criterion well.

Alternative D – South. Alternative D was designed specifically to accommodate the 800-foot belt width and was given a rating of 3 because it met the criterion well.

Alternative E – 4,489 North. Alternative E was designed specifically to accommodate the 800-foot belt width and was given a rating of 3 because it met the criterion well.

Alternative F – 4,489 Middle. Alternative F was designed specifically to accommodate the 800-footbelt width and was given a rating of 3 because it met the criterion well.

Alternative G – 4,489 South. Alternative G was designed specifically to accommodate the 800-foot belt width and was given a rating of 3 because it met the criterion well.

8.3.2 Size of Delta in Rearing Reach

Each alternative was evaluated to determine how well the concept would allow restoration of a delta at the river/lake interface of sufficient size to support a distributary channel form and other ecosystem features. Research has indicated that the delta width should be 6,000 feet to allow the dynamic processes inherent in delta ecosystems to support June sucker during critical life stages (Appendix A). This delta width recommendation represents the most narrow fan shape found in nature, keeping as many variables the same as Utah Lake. A larger width would support a greater distribution of habitat for critical June sucker life stages at various lake levels.

Alternative A – Full. Alternative A would utilize the maximum extent of the project area to create a delta and was given a rating of 3 because it met the criterion well.

Alternative B – North. Alternative B would utilize a portion of the project area but the resulting delta would be narrower and more confined before spreading out to its full extent on the west side of the project area. Alternative B was given a rating of 1 because it met the criterion poorly.

Alternative C – Middle. Alternative C would utilize a portion of the project area but the resulting delta would be narrower and more confined before spreading out to its full extent on the west side of the project area. Alternative C was given a rating of 1 because it met the criterion poorly.

Alternative D – South. Alternative D would utilize a portion of the project area but the resulting delta would be narrower and more confined before spreading out to its full extent on the west side of the project area. Alternative D was given a rating of 1 because it met the criterion poorly.

Alternative E – 4,489 North. Alternative E would utilize the maximum extent of the project area to create a delta and was given a rating of 2 because it met the criterion moderately well.

Alternative F – 4,489 Middle. Alternative F would utilize the maximum extent of the project area to create a delta and was given a rating of 2 because it met the criterion moderately well.

Alternative G – 4,489 South. Alternative G would utilize the maximum extent of the project area to create a delta and was given a rating of 2 because it met the criterion moderately well.

8.3.3 Abundance of Shallow Wet Meadow Nursery Habitat (0–2 feet)

Each alternative was evaluated to determine, based on existing topography without earthwork other than shoreline levee removal, how well the concept would provide shallow wet meadow nursery habitat at a lake level of 4,489 feet. Table 13 shows the amount of shallow wet meadow nursery habitat that would be provided under each alternative.

Table 13. Shallow wet meadow nursery habitat (in acres) predicted under each alternative.

WATER DEPTH ATCOMPROMISE (+/- 6 INCHES)	ALT A – FULL	ALT B – NORTH	ALT C – MIDDLE	ALT D – SOUTH	ALT E – 4,489 NORTH	ALT F – 4,489 MIDDLE	ALT G – 4,489 SOUTH	VEGETATION TYPE PREDICTED
0 to <2	181.8	78.5	108.5	141.0	174.0	174.0	174.0	Wet Meadow

Alternative A – Full. Alternative A would provide the greatest amount of shallow wet meadow nursery habitat. Alternative A was given a rating of 3 because it met this criterion well.

Alternative B – North. Alternative B would provide a modest amount of shallow wet meadow nursery habitat. Alternative B was given a rating of 1 because it met this criterion poorly.

Alternative C – Middle. Alternative C would provide a modest amount of shallow wet meadow nursery habitat. Alternative C was given a rating of 2 because it met this criterion moderately well.

Alternative D – South. Alternative D would provide a large amount of shallow wet meadow nursery habitat. Alternative D was given a rating of 3 because it met this criterion well.

Alternative E – 4,489 North. Alternative E would provide a large amount of shallow wet meadow nursery habitat. Alternative E was given a rating of 3 because it met this criterion well.

Alternative F – 4,489 Middle. Alternative F would provide a large amount of shallow wet meadow nursery habitat. Alternative F was given a rating of 3 because it met this criterion well.

Alternative G – 4,489 South. Alternative G would provide a large amount of shallow wet meadow nursery habitat. Alternative G was given a rating of 3 because it met this criterion well.

8.3.4 Abundance of Deep Emergent Nursery Habitat (2–4 feet)

Each alternative was evaluated to determine, based on existing topography without earthwork other than shoreline levee removal, how well the concept would provide deep emergent nursery habitat at a lake level of 4,489 feet. Table 14 shows the amount of shallow deep emergent nursery habitat that would be provided under each alternative.

Table 14. Shallow deep submergent nursery habit (in acres) predicted under each alternative.

WATER DEPTH ATCOMPROMISE (+/- 6 INCHES)	ALT A – FULL	ALT B – NORTH	ALT C – MIDDLE	ALT D – SOUTH	ALT E – 4,489 NORTH	ALT F – 4,489 MIDDLE	ALT G – 4,489 SOUTH	VEGETATION TYPE PREDICTED
2 to <4	172.1	159.7	117.6	95.2	171.1	171.1	171.1	Emergent Marsh

Alternative A – Full. Alternative A would provide the greatest amount of deep emergent nursery habitat. Alternative A was given a rating of 3 because it met this criterion well.

Alternative B – North. Alternative B would provide a large amount of deep emergent nursery habitat. Alternative B was given a rating of 3 because it met this criterion well.

Alternative C – Middle. Alternative C would provide a moderate amount of deep emergent nursery habitat. Alternative C was given a rating of 2 because it met this criterion moderately well.

Alternative D – South. Alternative D would provide a moderate amount of deep emergent nursery habitat. Alternative D was given a rating of 2 because it met this criterion moderately well.

Alternative E – 4,489 North. Alternative E would provide a large amount of deep emergent nursery habitat. Alternative E was given a rating of 3 because it met this criterion well.

Alternative F – 4,489 Middle. Alternative F would provide a large amount of deep emergent nursery habitat. Alternative F was given a rating of 3 because it met this criterion well.

Alternative G – 4,489 South. Alternative G would provide a large amount of deep emergent nursery habitat. Alternative G was given a rating of 3 because it met this criterion well.

8.3.5 Abundance of Deep Submergent Nursery Habitat (4+ feet)

Each alternative was evaluated to determine, based on existing topography without earthwork other than shoreline levee removal, how well the concept would provide deep submergent nursery habitat at a lake level of 4,489 feet. Deep submergent habitat is limited within the project area, but particularly important for early June sucker life stages. Table 15 shows the amount of deep submergent nursery habitat that would be provided under each alternative. None of the alternatives met this criterion well or moderately well.

Table 15. Deep submergent nursery habitat (in acres) predicted under each alternative.

WATER DEPTH ATCOMPROMISE (+/- 6 INCHES)	ALT A – FULL	ALT B – NORTH	ALT C – MIDDLE	ALT D – SOUTH	ALT E – 4,489 NORTH	ALT F – 4,489 MIDDLE	ALT G – 4,489 SOUTH	VEGETATION TYPE PREDICTED
4 to <6	5.9	5.6	3.8	3.1	5.9	5.9	5.9	Submergent

Alternative A – Full. Alternative A would provide a modest amount of deep submergent nursery habitat. Alternative A was given a rating of 1 because it met this criterion poorly.

Alternative B – North. Alternative B would provide a modest amount of deep submergent nursery habitat. Alternative B was given a rating of 1 because it met this criterion poorly.

Alternative C – Middle. Alternative C would provide a modest amount of deep submergent nursery habitat. Alternative C was given a rating of 1 because it met this criterion poorly.

Alternative D – South. Alternative D would provide a modest amount of deep submergent nursery habitat. Alternative D was given a rating of 1 because it met this criterion poorly.

Alternative E – 4,489 North. Alternative E would provide a modest amount of deep submergent nursery habitat. Alternative E was given a rating of 1 because it met this criterion poorly.

Alternative F – 4,489 Middle. Alternative F would provide a modest amount of deep submergent nursery habitat. Alternative F was given a rating of 1 because it met this criterion poorly.

Alternative G – 4,489 South. Alternative G would provide a modest amount of deep submergent nursery habitat. Alternative G was given a rating of 1 because it met this criterion poorly.

8.3.6 Water Depth – Low Lake Elevation

Each Alternative was evaluated for the range of water depths it would provide under a typical low lake elevation. A low lake elevation of 4,487 was selected because it represents the median (50th percentile) of Utah Lake elevation during September, which generally has the lowest lake levels of the year.

As shown in Table 16, none of the alternatives have deep water areas (>4 feet) under a typical low lake elevation, and depths of 2–4 feet would also be limited. These figures are based on existing topography and do not include the possibility of excavation to obtain greater depths. None of the alternatives would provide very much medium and deep water area without excavation.

Table 16. Acres of inundation in the project area by depth ranges at a typical low-lake elevation (4,487 feet) for Utah Lake.

WATER DEPTH RANGE	ALT A – FULL	ALT B – NORTH	ALT C – MIDDLE	ALT D – SOUTH	ALT E – 4,489 NORTH	ALT F – 4,489 MIDDLE	ALT G – 4,489 SOUTH
Shallow, Under 2 feet	172.1	159.6	117.6	69.9	170.9	172.0	172.0
Medium, 2-4 feet	6.0	5.5	3.8	2.2	5.9	6.0	5.8
Deep, Over 4 feet	0	0	0	0	0	0	0
Total Acreage	178.0	165.1	121.3	72.2	176.9	177.9	177.7

Alternative A – Full. Alternative A would provide the most acres of shallow-depth water under this low-lake-elevation condition. There would be very little medium-depth and no deep water at this lake level. As a result, Alternative A was given a rating of 2 because it met this criterion moderately well.

Alternative B – North. Alternative B would provide nearly the same amount of shallow-depth water at this low lake elevation condition. As a result, Alternative B was given a rating of 2 because it met this criterion moderately well.

Alternative C – Middle. Alternative C would provide much less shallow-depth water under the low lake condition, compared to Alternative A. Alternative C was given a rating of 1 because it met this criterion poorly.

Alternative D – South. Alternative D would provide much less shallow-depth water under the low lake condition, compared to Alternative A. Alternative D was given a rating of 1 because it met this criterion poorly.

Alternative E – 4,489 North. Alternative E would provide nearly the same amount of shallow-depth water as Alternative A at this low lake elevation condition. As a result, Alternative E was given a rating of 2 because it met this criterion moderately well.

Alternative F – 4,489 Middle. Alternative F would provide nearly the same amount of shallow-depth water as Alternative A at this low lake elevation condition. As a result, Alternative F was given a rating of 2 because it met this criterion moderately well.

Alternative G – 4,489 South. Alternative G would provide nearly the same amount of shallow-depth water as Alternative A at this low lake elevation condition. As a result, Alternative G was given a rating of 2 because it met this criterion moderately well.

8.3.7 Water Depth – High Lake Elevation

Each Alternative was evaluated for the range of water depths it would provide under a high lake elevation. A high lake elevation of 4,491 feet was selected because it represents the 20th percentile of Utah Lake elevation during the critical spawning month of June, which generally has the highest lake levels of the year.

As shown in Table 17, during high lake elevations the distribution of water depths changes considerably when compared to medium (4,489) and low (4,487) lake elevations. Alternatives were compared and scored based on their total respective acreage of inundation.

Alternative A – Full. Alternative A would provide the greatest amount of inundated area with the most acres of all water depths under this high lake elevation condition. In particular, shallow-depth water is more than double any other alternative. As a result, Alternative A was given a rating of 3 because it met this criterion well.

Table 17. Acres of inundation in the project area by depth ranges at a high-lake elevation (4,491 feet) for Utah Lake.

WATER DEPTH RANGE	ALT A – FULL	ALT B – NORTH	ALT C – MIDDLE	ALT D – SOUTH	ALT E – 4,489 NORTH	ALT F – 4,489 MIDDLE	ALT G – 4,489 SOUTH
Shallow, Under 2 feet	92.2	17.0	36.4	45.1	35.4	42.4	45.5
Medium, 2-4 feet	181.8	78.5	108.5	136.1	173.9	174.5	174.5
Deep, Over 4 feet	178.0	165.1	121.3	72.2	176.9	177.9	177.7
Total Acreage	452.0	260.6	266.3	253.3	386.2	394.9	397.6

Alternative B – North. Alternative B would provide diminished amounts of varying water depths at this high lake elevation condition. In particular, Alternative B lacks shallow and medium water depths. As a result, Alternative B was given a rating of 1 because it met this criterion poorly.

Alternative C – Middle. Alternative C would provide diminished amounts of varying water depths at this high lake elevation condition. In particular, Alternative C lacks shallow and deep water depths. As a result, Alternative C was given a rating of 1 because it met this criterion poorly.

Alternative D – South. Alternative D would provide diminished amounts of varying water depths at this high lake elevation condition. In particular, Alternative D lacks shallow and deep

water depths. As a result, Alternative D was given a rating of 1 because it met this criterion poorly.

Alternative E – 4,489 North. Alternative E would provide diminished amounts of shallow water depths at this high lake elevation condition. As a result, Alternative E was given a rating of 2 because it met this criterion moderately well.

Alternative F – 4,489 Middle. Alternative F would provide diminished amounts of shallow water depths at this high lake elevation condition. As a result, Alternative F was given a rating of 2 because it met this criterion moderately well.

Alternative G – 4,489 South. Alternative G would provide diminished amounts of shallow water depths at this high lake elevation condition. As a result, Alternative G was given a rating of 2 because it met this criterion moderately well.

8.3.8 Isolated Habitat Avoidance

Each alternative was evaluated to determine how well the concept would avoid the creation of isolated habitats that would not be accessible to June sucker. Isolated habitat would result from design and topographic constraints. This criterion underscores the need for June sucker to be able to access habitats that are created for their use during various life stages.

Alternative A – Full. Alternative A would utilize the entire area and could potentially provide June sucker access to all habitat areas. Alternative A was given a rating of 3 because it met the criterion well.

Alternative B – North. Alternative B would utilize the entire area and could potentially provide June sucker access to all habitat areas. Alternative B was given a rating of 3 because it met the criterion well.

Alternative C – Middle. Alternative C would provide a delta shape that partially isolates some habitat in the extreme north end of the alternative. Alternative C was given a rating of 2 because it met the criterion moderately well.

Alternative D – South. Alternative D would provide a delta shape that partially isolates some habitat in the extreme north end of the alternative. Alternative D was given a rating of 2 because it met the criterion moderately well.

Alternative E – 4,489 North. Alternative E would provide a delta shape that leaves some isolated habitat areas in the extreme south portions of the alternative. Alternative E was given a rating of 2 because it met the criterion moderately well.

Alternative F – 4,489 Middle. Alternative F would provide a delta shape that leaves some isolated habitat areas in the extreme south portions of the alternative. Alternative F was given a rating of 2 because it met the criterion moderately well.

Alternative G – 4,489 South. Alternative G utilizes the entire area and could provide June sucker access to all habitat areas. Alternative G was given a rating of 3 because it met the criterion well.

8.3.9 Recreation

Each alternative was evaluated to determine how well the concept would allow for expansion or improvement of existing recreational resources within the project area. In general, alternatives with larger areas were perceived to be able to provide greater options and improvements; given the project area topography, smaller-acreage alternatives would not be able to accommodate the same recreation opportunities without compromising project habitat objectives. For example, a smaller alternative might require use of a potential habitat area to provide parking for recreational users, where a larger alternative could utilize upland areas to provide parking.

Alternative A – Full. Alternative A would maximize the area available for providing recreational activities because it utilizes the entire project area. Of particular potential value for recreational purposes is the land located between the existing river channel and Harbor Drive. Alternative A was given a rating of 3 because it met the criterion well.

Alternative B – North. Alternative B substantially reduces the area available for providing additional recreational activities compared to Alternative A. Alternative B was given a rating of 1because it met the criterion poorly.

Alternative C – Middle. Alternative C reduces the area available for providing additional recreational activities. Alternative C was given a rating of 2 because it met the criterion moderately well.

Alternative D – South. Alternative D reduces the area available for providing additional recreational activities. Alternative D was given a rating of 2 because it met the criterion moderately well.

Alternative E – 4,489 North. Alternative E reduces the area available for providing additional recreational activities. Alternative E was given a rating of 2 because it met the criterion moderately well.

Alternative F – 4,489 Middle. Alternative F reduces the area available for providing additional recreational activities. Alternative F was given a rating of 2 because it met the criterion moderately well.

Alternative G – 4,489 South. Alternative G reduces the area available for providing additional recreational activities. Alternative G was given a rating of 2 because it met the criterion moderately well.

8.3.10 Avoidance of Key Resources

Each alternative was evaluated to determine how well the concept would avoid filling or excavating on or near (within 50 feet) existing key resources such as jurisdictional wetlands, Ute Ladies'-Tress populations, and archeological/cultural resources. Jurisdictional wetlands have been delineated and approximated for land within the project area. Populations of ULT have also been identified and mapped. In addition, archeological and cultural resources are known to exist in the western portions of the project area.

Alternative A – Full. Alternative A would be routed to avoid both the wetlands and ULT populations on the eastern side of the project area. New channel excavation and levee construction would minimize impacts to wetlands and ULT by not requiring construction of levees in these areas. Alternative A was given a rating of 3 because it met the criterion well.

Alternative B – North. Alternative B would be routed through the middle of existing wetlands and ULT populations on the eastern side of the project area. The new channel excavation would impact wetlands and ULT, but levee construction would be located to reduce the impact on wetlands and ULT to the extent possible. Alternative B was given a rating of 2 because met the criterion moderately well.

Alternative C – Middle. Alternative C would be routed to avoid existing wetlands and ULT on the eastern side of the project area. However, a new levee would be constructed through the wetland and ULT complexes on the western side of the project area. Alternative C was given a rating of 0 because it did not meet the criterion.

Alternative D – South. Alternative D would be routed to exclude from the project area existing wetlands and ULT in the northeast portion of the project area. However, to exclude those areas, a new levee would be constructed through wetlands on the western side of the project area. Therefore, Alternative D was given a rating of 0 because it did not meet the criterion.

Alternative E – 4,489 North. Alternative E would be routed through the middle of existing wetlands and ULT populations on the eastern side of the project area. The new channel excavation would impact wetlands and ULT, but impacts would be minimized from levee construction. Alternative E was given a rating of 2 because it met the criterion moderately well.

Alternative F – 4,489 Middle. Alternative F would be routed to avoid existing wetlands on the eastern side of the project area. However, new levees would be routed directly through wetlands and areas of known ULT, though for a shorter length than alternatives C and D. Alternative F was given a rating of 1 because it met the criterion poorly.

Alternative G – 4,489 South. Alternative G would be routed to avoid both the wetlands and ULT populations on the eastern side of the project area. New channel excavation and levee construction would minimize impacts to wetlands and ULT. Alternative G was given a rating of 3 because it met the criterion well.

8.3.11 Levee Length

Each alternative was evaluated to determine the required length of new levee construction and subsequent maintenance. Table 18 describes the length of levee required for each alternative. Less levee construction is considered a positive attribute of the Alternatives.

Alternative A – Full. Alternative A would require the least amount of new levee. Alternative A was given a rating of 3 because it met the criterion well.

Alternative B – North. Alternative B would require a large amount of new levee to be constructed and maintained. Alternative B was given a rating of 1 because it met the criterion poorly.

Alternative C – Middle. Alternative C would require a large amount of new levee to be constructed and maintained. Alternative C was given a rating of 1 because it met the criterion poorly.

Alternative D – South. Alternative D would require a moderate amount of new levee to be constructed and maintained. Alternative D was given a rating of 2 because it met the criterion moderately well.

Table 18. Length of required levee for each alternative (in feet).

ALTERNATIVE	NEW LEVEE LENGTH (FEET) [a]
Alternative A – Full	6,489
Alternative B – North	12,304
Alternative C – Middle	13,053
Alternative D – South	10,558
Alternative E – 4,489 North	12,362
Alternative F – 4,489 Middle	10,215
Alternative G – 4,489 South	10,261

[a] The levee systems for these alternatives contain a naturally occurring high bench approximately 2,600 feet in length. The "New Levee Length" listed for these alternatives represents only those portions of the levee system that do not exist currently (total levee length minus the 2,600-foot natural levee).

Alternative E – 4,489 North. Alternative E would require a large amount of new levee to be constructed and maintained. Alternative E was given a rating of 1 because it met the criterion poorly.

Alternative F – 4,489 Middle. Alternative F would require a moderate amount of new levee to be constructed and maintained. Alternative F was given a rating of 2 because it met the criterion moderately well.

Alternative G – 4,489 South. Alternative G would require a moderate amount of new levee to be constructed and maintained. Alternative G was given a rating of 2 because it met the criterion moderately well.

8.3.12 Existing Infrastructure Impacts

Each alternative was evaluated to determine whether it avoids impacts to existing infrastructure. Existing infrastructure within the project area includes Harbor Drive, agricultural structures, a cabin, the Provo City stormwater system, and other water conveyance structures.

Alternative A – Full. Alternative A would likely impact all of the existing infrastructure in the project area. Alternative A was given a rating of 0 because it did not meet the criterion.

Alternative B – North. Alternative B would impact much of the existing infrastructure including portions of the Provo City stormwater system, the cabin, and a portion of Harbor Drive. Several agricultural structures and water conveyance structures in the southern portion of the project area would not be impacted. Alternative B was given a rating of 2 because it met the criterion moderately well.

Alternative C – Middle. Alternative C would impact much of the existing infrastructure including agricultural structures, the cabin, and Harbor Drive. Some existing water conveyance structures and most of the Provo City stormwater system would not be impacted. Alternative C was given a rating of 2 because it met the criterion moderately well.

Alternative D – South. Alternative D would impact much of the existing infrastructure including agricultural structures, the cabin, and some existing water conveyance structures. Most of the Provo City stormwater system and most of Harbor Drive would not be impacted. Alternative D was given a rating of 2 because it met the criterion moderately well.

Alternative E – 4,489 North. Alternative E would impact much of the existing infrastructure including agricultural structures, the cabin, the Provo City stormwater system, and some of Harbor Drive. Alternative E was given a rating of 1 because it met the criterion poorly.

Alternative F – 4,489 Middle. Alternative F would impact much of the existing infrastructure including agricultural structures, the cabin, the Provo City stormwater system, and some of Harbor Drive. Alternative F was given a rating of 1 because it met the criterion poorly.

Alternative G – 4,489 South. Alternative G would impact much of the existing infrastructure including agricultural structures, the cabin, and some existing water conveyance structures. Most of the Provo City stormwater system and most of Harbor Drive would not be impacted. Alternative G was given a rating of 2 because it met the criterion moderately well.

8.3.13 Long-term Costs

Each alternative was evaluated to determine what long-term costs would be required that are not associated with achieving the proposed project's purpose and need. Specifically, it is assumed that there would be increased maintenance costs associated with levees and the probable requirement to pump water from behind the levees in some portions of the project area. This would be especially true where levees would retain lake waters.

Alternative A – Full. Alternative A would require the least amount of new levees and would likely not require pumping behind most of the new levees. Alternative A was given a rating of 3 because it met this criterion well.

Alternative B – North. Alternative B would require a moderate amount of new levees. However, most of the levees would not likely require pumping. Alternative B was given a rating of 2 because it met this criterion moderately well.

Alternative C – Middle. Alternative C would require a significant amount of new levees. In addition, many of these levees would require pumping and maintenance in the long term. Alternative C was given a rating of 0 because it did not meet the criterion.

Alternative D – South. Alternative D would require a significant amount of new levees. In addition, many of these levees would require pumping and maintenance in the long term. Alternative D was given a rating of 0 because it did not meet the criterion.

Alternative E – 4,489 North. Alternative E would require a moderate amount of new levees. However, most of the levees would not likely require pumping. Alternative E was given a rating of 2 because it met this criterion moderately well.

Alternative F – 4,489 Middle. Alternative F would require a moderate amount of new levees. However, most of the levees would not likely require pumping. Alternative F was given a rating of 2 because it met this criterion moderately well.

Alternative G – 4,489 South. Alternative G would require a moderate amount of new levees. However, most of the levees would not likely require pumping. Alternative G was given a rating of 2 because it met this criterion moderately well.

8.3.14 Length of Enhanced Spawning Habitat

Each alternative was evaluated to determine how many feet of enhanced spawning habitat would be provided. Enhanced spawning habitat was assessed from the existing Lakeshore Drive Bridge to the point where the longest conceptual channel would cross 4,489 feet for each of the alternatives. Table 19 describes the lengths of enhanced spawning habitat for each alternative.

Table 19. Length of enhanced spawning habitat for each alternative (in feet).

ALTERNATIVE	PROPOSED RIVER LENGTH (FEET) [a]
Alternative A – Full	4,180.5
Alternative B – Full North	2,933.7
Alternative C – Full Middle	4,484.5
Alternative D – Full South	6,583.5
Alternative E – 4,489 North	2,913.2
Alternative F – 4,489 Middle	4,164.7
Alternative G – 4,489 South	6,299.2

[a] Proposed river lengths calculated along each alternative's longest main river channel beginning at the bridge on Lakeshore Drive (southeast corner of the project area) to the 4,489-foot contour derived from LIDAR data acquired September 28, 2010.

Alternative A – Full. Alternative A would provide a moderate amount of enhanced spawning habitat. Alternative B was given a rating of 2 because it met the criterion moderately well.

Alternative B – North. Alternative B would provide a small amount of enhanced spawning habitat. Alternative B was given a rating of 1 because it met the criterion poorly.

Alternative C – Middle. Alternative C would provide a moderate amount of enhanced spawning habitat. Alternative C was given a rating of 2 because it met the criterion moderately well.

Alternative D – South. Alternative D would provide a significant amount of enhanced spawning habitat. Alternative D was given a rating of 3 because it met the criterion well.

Alternative E – 4,489 North. Alternative E would provide a small amount of enhanced spawning habitat. Alternative E was given a rating of 1 because it met the criterion poorly.

Alternative F – 4,489 Middle. Alternative F would provide a moderate amount of enhanced spawning habitat. Alternative F was given a rating of 2 because it met the criterion moderately well.

Alternative G – 4,489 South. Alternative G would provide a significant amount of enhanced spawning habitat. Alternative G was given a rating of 3 because it met the criterion well.

8.3.15 Area Available for Project Implementation

Each alternative was evaluated to determine how much area would be provided to meet the needs of the project. This criterion was developed based on the fact that more area has the potential to provide more habitat (including uplands) and improvement for June sucker and other ecosystem values, as well as recreational needs. The number of acres of potential habitat under each of the alternatives is described in Table 20.

Table 20. Area of potential habitat for each alternative (in acres).

ALTERNATIVE	POTENTIAL HABITAT (ACRES)
Alternative A – Full	572.3
Alternative B – North	328.0
Alternative C – Middle	312.8
Alternative D – South	335.1
Alternative E – 4,489 North	453.4
Alternative F – 4,489 Middle	463.2
Alternative G – 4,489 South	434.7

Alternative A – Full. Alternative A would provide the greatest number of acres available for potential habitat and recreational needs. Alternative A was given a rating of 3 because it met this criterion well.

Alternative B – North. Alternative B would provide a modest amount of acreage for potential habitat and recreational needs. Alternative B was given a rating of 1 because it met this criterion poorly.

Alternative C – Middle. Alternative C would provide a modest amount of acreage for potential habitat and recreational needs. Alternative C was given a rating of 1 because it met this criterion poorly.

Alternative D – South. Alternative D would provide a modest amount of acreage for potential habitat and recreational needs. Alternative D was given a rating of 1 because it met this criterion poorly.

Alternative E – 4,489 North. Alternative E would provide a moderate amount of acreage for potential habitat and recreational needs. Alternative E was given a rating of 2 because it met this criterion moderately well.

Alternative F – 4,489 Middle. Alternative F would provide a moderate amount of acreage for potential habitat and recreational needs. Alternative F was given a rating of 2 because it met this criterion moderately well.

Alternative G – 4,489 South. Alternative G would provide a moderate amount of acreage for potential habitat and recreational needs. Alternative G was given a rating of 2 because it met this criterion moderately well.

8.3.16 *Private Landowner and Land Acquisition Impacts*

Alternatives were evaluated for the number of private landowners impacted relative to the acreage of private land acquisition that would be required to implement the alternative. Table 21 provides this comparison. This criterion is concerned with rating the alternatives in terms of minimization of these impacts.

Table 21. Land owners and private land acquisition required by alternative.

LAND OWNERSHIP ASPECT	ALT A – FULL	ALT B – NORTH	ALT C – MIDDLE	ALT D – SOUTH	ALT E – 4,489 NORTH	ALT F – 4,489 MIDDLE	ALT G – 4,489 SOUTH
Number of private landowners	20	14	10	12	17	13	14
Number of private parcels	45	24	28	31	31	35	34
Acres of privately owned land acquired	475	238	236	252	365	370	351

Alternative A – Full. Alternative A would affect the largest number of landowners and would require the largest acreage of private land acquisition. Alternative A was given a rating of 1 because it met this criterion poorly.

Alternative B – North. Alternative B would affect fewer landowners and would acquire substantially less acres of private land compared to Alternative A. Alternative B was given a rating of 2 because it met this criterion moderately well.

Alternative C – Middle. Alternative C would affect fewer landowners and would acquire substantially less acres of private land compared to Alternative A. Alternative C was given a rating of 2 because it met this criterion moderately well.

Alternative D – South. Alternative D would affect fewer landowners and would acquire substantially less acres of private land compared to Alternative A. Alternative D was given a rating of 2 because it met this criterion moderately well.

Alternative E – 4,489 North. Alternative E would affect fewer landowners and would acquire somewhat less acres of private land compared to Alternative A. Alternative E was given a rating of 2 because it met this criterion moderately well.

Alternative F – 4,489 Middle. Alternative F would affect fewer landowners and would acquire somewhat less acres of private land compared to Alternative A. Alternative F was given a rating of 2 because it met this criterion moderately well.

Alternative G – 4,489 South. Alternative G would affect fewer landowners and would acquire somewhat less acres of private land compared to Alternative A. Alternative G was given a rating of 2 because it met this criterion moderately well.

8.4 Level 3 Screening Summary

Although a variety of potential alternative designs meet the general purpose and need of the project, only a few are well suited to the detailed requirements of June sucker and ecosystem restoration. Indeed, when evaluating the alternatives during level 3 screening, significant differences became apparent regarding how well or poorly the alternatives fulfill the criteria, as summarized in Table 22. The most favorable results within each criterion (table row) are highlighted in green.

Table 22. Level 3 screening summary.

LEVEL 3 CRITERIA	ALTERNATIVES						
	ALT. A – FULL	ALT. B – NORTH	ALT. C – MIDDLE	ALT. D – SOUTH	ALT. E – 4,489 NORTH	ALT. F – 4,489 MIDDLE	ALT. G – 4,489 SOUTH
Technical/Ecological Criteria							
Size of Delta in Rearing Reach	**3**	1	1	1	2	2	2
Abundance of Shallow Wet Meadow Nursery Habitat at Average Lake Elevation	**3**	1	2	**3**	**3**	**3**	**3**
Range of Water Depths at a High Lake Elevation	**3**	1	1	1	2	2	2
Range of Water Depths at a Low Lake Elevation	**2**	**2**	1	1	**2**	**2**	**2**
Length of Enhanced Spawning Habitat	2	1	2	**3**	1	2	**3**
Width of Floodplain/Riparian Corridor in Spawning Reach	**3**	**3**	**3**	**3**	**3**	**3**	**3**
Avoidance of Key Resources	**3**	2	0	0	2	1	**3**
Area Available for Project Implementation	**3**	1	1	1	2	2	2
Abundance of Deep Emergent Nursery Habitat at Average Lake Elevation	**3**	**3**	2	2	**3**	**3**	**3**
Abundance of Deep Submergent Nursery Habitat at Average Lake Elevation	1	1	1	1	1	1	1
Isolated Habitat Avoidance	**3**	**3**	2	2	2	2	**3**
Socioeconomic Criteria							
Private Landowner and Land Acquisition Impacts	1	**2**	**2**	**2**	**2**	**2**	**2**
Existing Infrastructure Impacts	0	**2**	**2**	**2**	1	1	**2**
Recreation Opportunity	**3**	1	2	2	2	2	2
Long-term Costs	**3**	2	0	0	2	2	2
Levee Length	**3**	1	1	2	1	2	2

8.4.1 Alternative A – Full

Alternative A scores well in nearly every criteria with the exception of impacts to existing infrastructure. Because this alternative utilizes the entire project area for purposes of enhanced habitat and recreation, avoidance of infrastructure was not possible with this design.

8.4.2 Alternative B – North

Alternative B scores well in some specific criteria, but does not provide a large delta or shallow nursery habitat. In addition, it requires longer levees and provides only a small amount of enhanced spawning habitat. Alternative B provides a wide floodplain and riparian corridor and avoids impacts to existing infrastructure in the south end of the project area.

8.4.3 Alternative C – Middle

Alternative C is remarkable for not scoring particularly well for many criteria. It does not avoid key resources and would likely have higher long-term costs. While Alternative C avoids some existing infrastructure, it does not avoid key resources and scores low on several project priorities including providing spawning and rearing habitat.

8.4.4 Alternative D – South

Alternative D rated well for some criteria, particularly length of spawning habitat and abundance of shallow, wet-meadow nursery habitat. While avoiding impacts to existing infrastructure, it includes long lengths of new levee with potential resource conflicts.

8.4.5 Alternative E – 4,489 North

Alternative E scores particularly well in terms of enhancing habitat, with the exception of spawning habitat. In general, Alternative E is moderate in that it scores down the middle for most criteria. However, it does not provide enhanced spawning habitat and requires longer levees.

8.4.6 Alternative F – 4,489 Middle

Alternative F, like alternative E, scores well in terms of enhancing habitat. It does a poor job of avoiding key resources and existing infrastructure, but scores moderately well for other criteria.

8.4.7 Alternative G – 4,489 South

Alternative G is similar to Alternative A in that it scores well or moderately well for most resources. In contrast, Alternative G better avoids impacts to existing infrastructure and provides a greater length of spawning habitat. It also requires longer levees and has less land area for recreational activities.

9.0 RECOMMENDATIONS

As stated in section 3.4, a variety of issues were derived from public and agency scoping for the project. Among these issues were some that are logically addressed through designs that avoid and minimize impacts. Because alternatives were designed to address the issues derived in the scoping process, alternatives that were able to successfully avoid and minimize impacts while still meeting the screening criteria are considered the best candidates for detailed analysis in the EIS. It is also desirable/required to analyze a reasonable range of alternatives, e.g. from large to small. So while the ranking above is helpful in guiding the selection of detailed alternatives, it is not strictly a numeric conclusion.

Three categories of alternatives were evaluated in this technical memo including utilizing the entire project area (Alternative A), utilizing portions of the project area and avoiding other specific areas (Alternatives B, C, and D), and utilizing lands primarily below the managed lake elevation of 4,489 feet (Alternatives E, F, and G). In comparing alternatives within the categories for meeting the screening criteria, it is clear that there are distinct differences between some alternatives while others performed similarly. Alternatives that do not represent significant changes in impacts or benefits or that do not address substantially different issues when compared to another alternative are not recommended for detailed analysis in the EIS. The alternatives are discussed briefly below with specific recommendations as to why they should or should not be evaluated in detail in the EIS.

9.1 Alternative A – Full

Alternative A is different from all of the other alternatives in that it would utilize the entire project area and represents the maximum project size possible with greatest ecological benefits. It also represents the largest potential impact on private landowners by including the most private land. In general, it meets the technical screening criteria well as noted in Section 8.4. Alternative A is unique in its design, the manner in which it would address issues, and in how it meets the screening criteria. As a result, Alternative A is recommended for inclusion in the EIS for detailed analysis.

9.2 Alternative B – North

Alternative B is similar to alternatives C and D in that it represents a portion of the entire project area. However, Alternative B was designed to avoid the acquisition of agricultural lands in the southern part of the project area. This alternative meets some of the screening criteria moderately well overall (Section 8.4). Alternative B is unique in its northerly design and addresses the important issue of minimizing private land acquisition. As a result, Alternative B is recommended for inclusion in the EIS for detailed analysis.

9.3 Alternative C – Middle

Alternative C is similar to alternatives B and D in that it represents a portion of the entire project area. However, Alternative C was designed to avoid some acquisition of agricultural lands in the central part of the project area and some peat wetlands in the north western part of the project area. As noted in Section 8.4, Alternative C does not score particularly well for many criteria. Alternative C appears "split the difference" between Alternatives B and D and does not meet the identified issues well, particularly land acquisition and avoidance of key resources. Alternative C offers little that is not offered by another alternative while maintaining poor performance regarding screening criteria. As a result, Alternative C is not recommended for inclusion in the EIS for detailed analysis.

9.4 Alternative D – South

Alternative D is similar to alternatives B and C in that it represents a portion of the entire project area. However, alternative D was designed to avoid impacts to peat wetlands in the northern part of the project area. This alternative meets the screening criteria moderately well overall (Section 8.4). Although Alternative D would impact some existing wetlands, it is the only alternative that isolates and completely excludes a sizable portion of the peat wetland complex located on the east and north edges of the project area, from the project. As a result, Alternative D is recommended for inclusion in the EIS for detailed analysis.

9.5 Alternative E – 4,489 North

Alternative E is similar to alternatives F and G in that it represents utilization of the area primarily below the compromise elevation of 4,489 feet. Like all of the 4,489 alternatives, this design focuses restoration efforts on lands that would be regularly inundated within the project area. Alternative E was designed to focus the alignment of the project to the northern part of the project area. As noted in Section 8.4, Alternative E scores well and moderately well for most criteria. However, Alternative E has direct effects on key resources and offers little that is not offered by the other 4,489 alternatives. As a result, Alternative E is not recommended for inclusion in the EIS for detailed analysis.

9.6 Alternative F – 4,489 Middle

Alternative F is similar to alternatives E and G in that it represents utilization of the area primarily below the compromise elevation of 4,489 feet. Like all of the 4,489 alternatives, this design focuses restoration efforts on lands that would be regularly inundated within the project area. Alternative F was designed to focus the alignment of the project to the central part of the project area. As noted in Section 8.4, Alternative F scores well and moderately well for most criteria. However, Alternative F has direct impacts on key resources and offers little that is not offered by the other 4,489 alternatives. As a result, Alternative F is not recommended for inclusion in the EIS for detailed analysis.

9.7 Alternative G – 4,489 South

Alternative G is similar to alternatives E and F in that it represents utilization of the area primarily below the compromise elevation of 4,489 feet. Like all of the 4,489 alternatives, this design focuses restoration efforts on lands that would be regularly inundated within the project area. Alternative G was designed to focus the new channel alignment of the project to the southern part of the project area. As noted in Section 8.4, Alternative G scores well for most criteria. In fact, Alternative G consistently scores the best of all of the 4,489 alternatives. Screening criteria indicate that the 4,489 alternatives, despite small differences, actually have little meaningful differences with the exception of Alternative G. As such, Alternative G avoids direct effects to most key resources, offers everything alternatives E and F offer, and more. As a result, Alternative G is recommended for inclusion in the EIS for detailed analysis.

10.0 CONCLUSIONS

10.1 Alternatives Advanced For Detailed Analysis

Four designs represent a reasonable range of alternatives that address identified issues and would meet the need of the project. These are alternatives A, B, D, and G. The alternatives at this stage of development reflect only a cursory consideration of some issues and ideas. Detailed analysis in the EIS will further detail consideration of mitigation strategies, recreational features, boundaries, planned features, and others.

10.2 Additional Design Considerations for Alternatives Advanced

Design considerations identified through public scoping and coordination with the TAT were discussed in Section 4.2. These considerations were considered throughout each of the design levels leading up to the alternatives selected for detailed analysis. Some design considerations remain unresolved and will be further considered through the EIS planning and analysis process. These considerations include:

- What would happen with North Boat Harbor Drive?
- What would be the future uses of the existing river channel below the diversion point?
- What enhanced recreation opportunities would be compatible with each alternative?
- How would the project be compatible with Provo City's planned Northwest Connector roadway?

The sections below summarize the conclusions of this Technical Memorandum with regard to how the JLAs intend to address these issues through the EIS planning and analysis process.

10.2.1 North Boat Harbor Drive (Harbor Drive)

Harbor Drive is a paved east-west road providing access to agricultural properties between Lakeshore Drive and Utah Lake State Park. Provo City also considers this roadway important as a secondary (emergency) access to and from the State Park without crossing Provo River. All of the action alternatives realign Provo River to the north allowing Center Street access without crossing the river.

A decision to be made for any of the action alternatives is whether or not to keep Harbor Drive. If Harbor Drive is kept, it would be necessary to determine how to connect Harbor Drive with a Provo City road to the east of the project area without affecting the habitat quality of the restored river channel and adjacent wetlands.

Eliminating Harbor Drive and incorporating agricultural lands between the drive and the existing river channel could be advantageous for the project purposes. The lands in this area are relatively high in elevation and have good riparian habitat potential as connected upland habitat with mature trees. Any action alternative could potentially utilize these lands as part of the project.

If all of the lands adjacent to Harbor Drive are utilized as habitat, it would not be compatible to maintain Harbor Drive as a public access roadway. Access to Utah Lake State Park for emergency vehicles could potentially be provided along a new levee or by modifying the existing levee along the north side of the existing river channel.

These options should be evaluated in the EIS. During the process of evaluating alternatives in detail, the JLAs will continue to gather information about Harbor Drive primarily from the State of Utah, Utah County, Provo City and the local community and will continue coordination activities with the TAT and local landowners.

10.2.2 Future Use of the Existing River Channel

Another decision to be made through the EIS process will be what to do with the existing lower Provo River channel if an action alternative is selected. The TAT and JLAs have discussed potential future uses of the river channel below the diversion point. The existing river channel could potentially continue to support existing recreational uses and habitat values.

Filling-in the old channel may be an option. Alternatively, providing some flow in the channel during all or part of the year may be a design option with any action alternative. In the EIS analysis it will be necessary to determine how much water, if any, could be available for this purpose.

Further analysis in the EIS should assess maintaining existing recreational and habitat values including the potential for water quality changes and nuisance species. The EIS impact assessment will evaluate both positive and negative environmental consequences of alternative future uses of the existing channel. The JLAs will continue coordination with the TAT and with potentially affected landowners, Utah County, and Provo City through this process.

10.2.3 Enhanced Recreation Opportunities

As discussed in Section 2.8, under CUPCA, enhanced recreational improvements and opportunities will be provided as part of the proposed restoration project.

Existing recreation opportunities associated with the lower Provo River are sport fishing, boating, wildlife viewing, and a nonmotorized trail. In addition to a marina, Utah Lake State Park has a visitor center/museum and provides areas for swimming, camping, picnicking, and fishing. A privately owned facility along the existing river channel provides boating activities and has a ropes course.

Recreation improvements and opportunities can be accommodated with any of the action alternatives. Alternatives with larger land areas, particularly areas that would remain upland, would provide more options.

The JLAs and TAT have discussed potential recreation opportunities that might be accommodated with implementation of an action alternative. In discussions with Utah County it seems that the project can have a benefit in expanding the County trail system. Levees created as a part of this project may provide new routes for connecting existing trails. Under any scenario, it will be necessary to maintain connectivity of the County trail system beyond the project area including connectivity to Utah Lake State Park.

Potential activities discussed in TAT meetings have included wildlife viewing, boating, fishing, waterfowl hunting, and upland game bird hunting. Other potential recreation opportunities offered as suggestions for the project area include small parks and recreation areas, a beach, ATV riding, and other activities not directly related to fish and wildlife habitat. Although the range of potential recreation opportunities is fairly broad, selected features will ultimately need to be consistent with the ecological objectives of the project area. The EIS analysis will evaluate public access to the area and the types of recreational activities supported. The TAT also discussed whether or not there would be opportunities to support JSRIP information and education objectives. For example, it may be possible to accommodate project area access or interpretive facilities associated with the State Park campground that would provide the public with an opportunity to learn about June sucker and the recovery program. The potential to accommodate a nature center will also be evaluated (the actual construction of a nature center, and its ongoing operation and maintenance, would need to come from other funding sources and partners).

Consideration will be given to which agencies would support and manage these activities and facilities (e.g., parking, restrooms, access trails).

10.2.4 Earthwork and Excavation

Abundance of shallow-, medium-, and deep-water habitats described in Sections 8.3.3 through 8.3.7 were determined using existing topography and ground elevations throughout the project area based on the newly acquired LIDAR data using GIS. All alternatives include earthwork and

excavation to re-establish a distributary channel system as illustrated in Figure 5. Additional earthwork and excavation is possible to re-establish oxbow and meander scar features for the purpose of further enhancing specific and critical habitat conditions for all alternatives, keeping in mind construction costs and available area. The size and location of additional excavation to re-establish these features will occur at the next level of design.

10.2.5 Provo City's Northwest Connector Roadway

The JLAs coordinated with Provo City regarding their planned Northwest Connector roadway early in the process of developing the project concepts evaluated in this Technical Memorandum. The JLAs will continue coordination with Provo City as alternatives for both projects are developed and evaluated.

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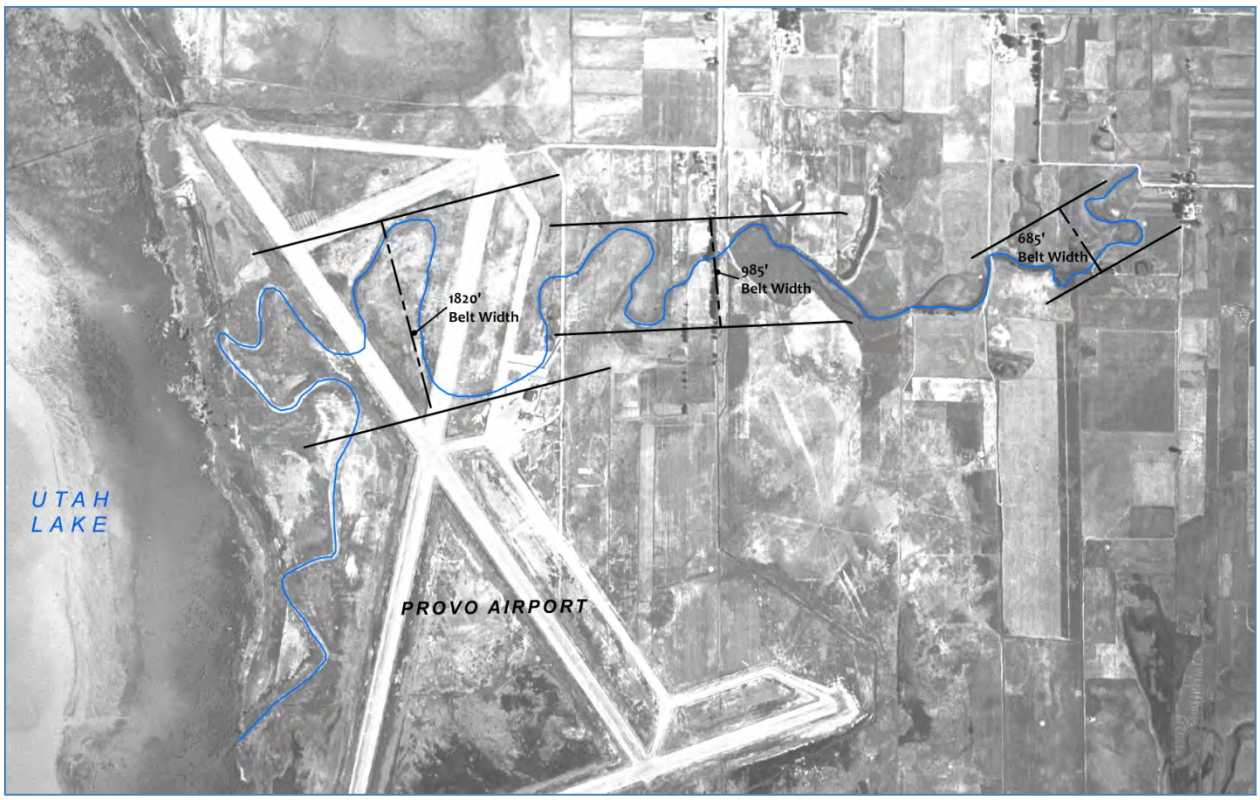
APPENDIX A: GEOMORPHIC MEMORANDUM

PROVO RIVER DELTA RESTORATION PROJECT

Appendix A: Lower Provo River Channel, Floodplain, and Provo River Delta at Utah Lake Design Dimensions Geomorphic Memorandum

By Darren Olsen, Tyler Allred, and Melissa Stamp



UTAH RECLAMATION MITIGATION AND CONSERVATION COMMISSION

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INTRODUCTION

The purpose of this memorandum is to describe geomorphic design considerations for the lower Provo River Delta Restoration Project (PRDRP). The PRDRP involves restoration of both spawning and rearing habitat for the endangered June sucker (*Chasmistes liorus*). June sucker spawn in riffles with gravel-cobble substrate—habitat that generally occurs in the lower Provo River above the Utah Lake interface, where riverine processes dominate. Habitat needs for rearing include shallow, productive areas with a mix of vegetation types—habitat that under natural conditions would occur largely within the Utah Lake-influenced portion of the lower Provo River delta system. This memo provides background and summarizes research regarding recommended design dimensions for the lower Provo River channel, riparian area and floodplain (spawning), and delta (rearing) habitats.

RIVERINE FLOODPLAIN WIDTH

Empirical Channel and Meander Geometry Relationships

In natural alluvial settings, free from significant geologic controls, rivers are free to erode and deposit, migrate, and flood overbank as they transport water and sediment delivered from upstream. Under these conditions, rivers predominantly display a meandering plan form (Leopold 1994). Although specific dimensions may vary substantially, studies have documented common patterns among channel size and meander geometry that can be useful when developing design parameters for channel and floodplain restoration. Langbein and Leopold (1966) found that meander geometry can be well approximated by a sine curve function of the distance along the channel. Empirical studies of meanders in flumes and alluvial rivers of varying sizes have generated a variety of equations relating meander geometry variables (Table 1, Figure 1). More recent publications (FISRWG 1998; Soar and Thorne 2001) have reviewed these past studies and summarize the results into a general range of expected relationships (Table 1).

The lateral distance between the outer banks of successive meander bends is known as the meander belt width (Williams 1986) (Figure 1). In natural settings, the land areas contained within successive meander bends typically function as active floodplains that are commonly inundated during high-flow events and provide important low-velocity habitats for fish and other aquatic organisms. Thus, the meander belt width dimension can serve as an approximation of floodplain width; however, belt width does not take into account areas beyond the outer banks of meander bends that may also provide floodplain habitats associated with abandoned channel scars or important upland fringe habitats. Therefore, estimates of meander belt width should be considered as minimum dimensions for floodplain design. The State of Vermont has used this approach in their recently adopted policy of delineating fluvial erosion hazard areas to establish development setback requirements (Kline and Cahoon 2010). Specifically, fluvial erosion hazard areas are determined by delineating a river corridor equal to eight times the bankfull channel width; this includes the meander belt width estimated at six times channel width plus an additional channel width added to each side as a buffer (Kline and Cahoon 2010).

Table 1. Selected publications describing empirical relationships between bankfull channel width (W), meander belt width (B), meander wavelength (L), and meander amplitude (A).

PUBLICATION	DATA SET OR REFERENCE	ORIGINAL EQUATION(S)	EQUATION CONVERTED TO BELT WIDTH FORM
Inglis (1949)	Jefferson data as cited in Leopold and Wolman (1960)	$A = 18.6W^{0.99}$	$B = W+18.6W^{0.99}$
Inglis (1949)	Bates data as cited in Leopold and Wolman (1960)	$A = 10.9W^{1.04}$	$B = W+10.9W^{1.04}$
Leopold and Wolman (1960)	Flumes, large and small rivers, gulf stream, glacier ice	$A = 2.7W^{1.1}$	$B = W+2.7W^{1.1}$
Zeller (1967)	Meanders of Swiss rivers (50 reaches), Leopold and Wolman (1960) data, ice meanders, and other data sets	$B=4.5W^{1.00}$	
Williams (1986)	153 data points from various sources; primarily rivers of varying sizes	$B=4.3W^{1.12}$	
Carlston (1965)	Jefferson 1902 data set as cited in Soar and Thorne (2001)	A=17.6W	B=18.6W
Soar and Thorne (2001); FISRWG (1998)	Leopold (1994); FISRWG (1998)	10W<=L<=14W 0.5L<=A<=1.5L	6W<=B<=22W

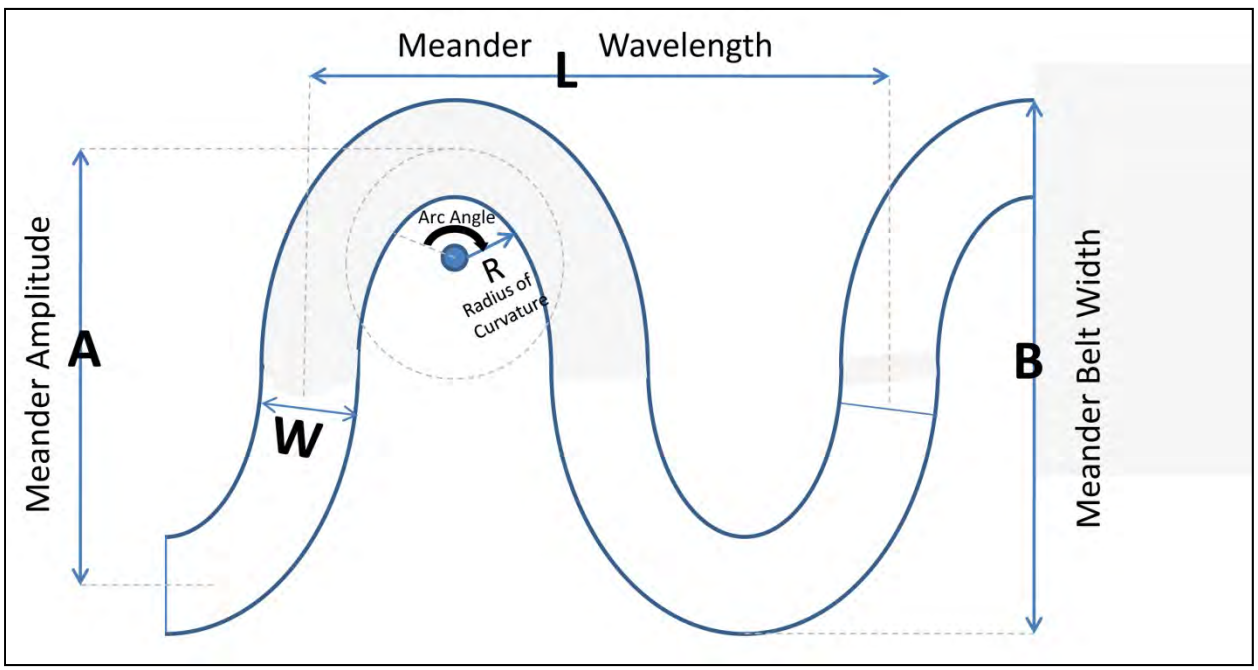

Figure 1. Plan view sketch of river meander dimensions (adapted from Williams 1986). W = bankfull channel width.

River Channel Width

In order to use the empirical relationships described above to estimate a possible range of appropriate meander belt width/floodplain width values for a specific river, an appropriate bankfull channel width value must first be selected. Based on various sources of information (Table 2), a design bankfull width of 80 to 100 feet was selected for the lower Provo River.

Table 2. Summary of information used to select an appropriate design dimension for bankfull channel width for the Provo River delta Restoration Project (PRDRP).

SOURCE	METHOD	ESTIMATED BANKFULL WIDTH (FEET)
Cross section field surveys completed in 2010 by BIO-WEST, Inc.	Width between tops of levees at 23 transects in existing lower Provo River.	73–128 (width between levees)
Figure 7-2 of Rosgen (1996), after Dunne and Leopold 1978, using approximate lower Provo River drainage area of 700 square miles.	Regional regression curves relating bankfull width to drainage area for four Intermountain West regions in the United States.	80–150
D. Olsen (pers. comm.).	Regional regression curves relating bankfull width to drainage area for streams in the vicinity of Provo Canyon, Utah.	90–100
Figure 9 of Leopold and Maddock (1953), using approximate lower Provo River mean annual discharge of 200 cubic feet per second.	Curves developed for various U.S. river systems relating downstream hydraulic geometry to mean annual discharge.	60–100
HEC-RAS hydraulic model developed by T. Allred, using cross section surveys of existing lower Provo River channel.	Average width for the modeled reach at a flow of 1,000 cubic feet per second, which approximates the 2.3-year recurrence interval flood for lower Provo River.	74
Aerial photographs of Provo River above Jordanelle Reservoir.	Measure channel width apparent on image.	100–150 (active channel width)

Longitudinal Patterns in River Geometry

Stream channels experience changes in both process and form as they flow from headwaters to mouth. Channel width and depth typically increase in the downstream direction due to increases in drainage area and associated increases in discharge. Related structural changes also occur in the channel, floodplain, and transitional upland fringe, and in processes such as erosion and deposition. Even among different types of streams, a common sequence of structural changes is generally observable from headwaters to mouth (FISRWG 1998).

The overall longitudinal profile of most streams can be roughly divided into the following three zones: (1) the headwaters, (2) the transfer zone, and (3) the depositional zone (Schumm 1977). Some of the typical characteristics of these zones are described below and are illustrated in Figures 2 and 3.

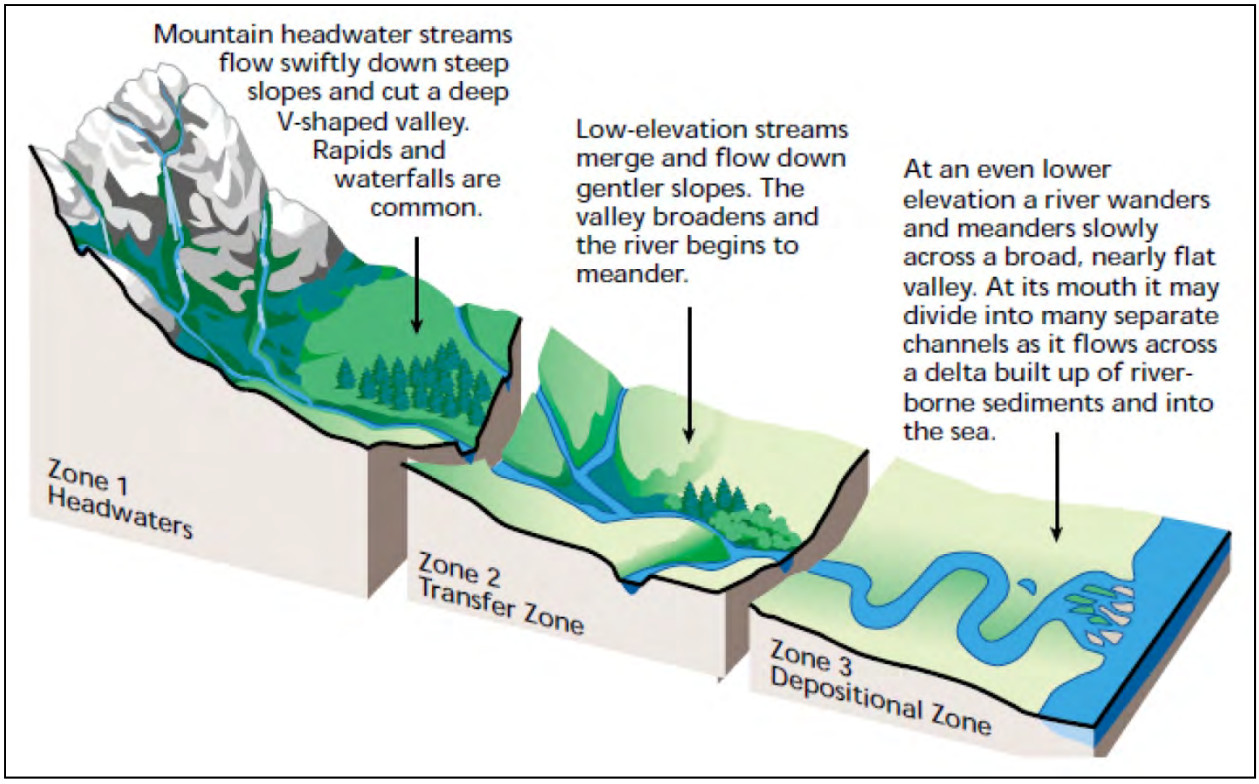

Figure 2. Three longitudinal profile zones. Channel and floodplain characteristics change as rivers travel from headwaters to mouth. Source: Miller (1990)

Zone 1 (headwaters). Zone 1 usually has the steepest gradient and thus the highest erosion rates. The rapid erosion often leads to V-shaped valleys. Streams in this zone are frequently straighter than other zones because the steep slopes limit meander formation. Sediment erodes from side slopes within this zone of the watershed and is transported downstream.

Zone 2 (transfer zone). In this zone, eroded material from the headwaters is transported downstream. Temporary storage of material is common in this zone, but the primary process is one of transport through the reach. This zone is usually characterized by wide floodplains and meandering channel patterns.

Zone 3 (depositional zone). In this zone, the gradient flattens even further and the decreasing slope causes a reduction in sediment transport competence that leads to large-scale deposition of transported material (FISRWG 1998). Stream channels in Zone 3 tend to have more pronounced meanders than in other zones.

Figures 2 and 3 show general patterns and changes that are applicable to most watersheds, even those with relatively small topographic relief from the headwaters to mouth. It is important to note that the processes of erosion, transfer, and deposition occur in all zones, but the figures highlight the most dominant process in each area (FISRWG 1998).

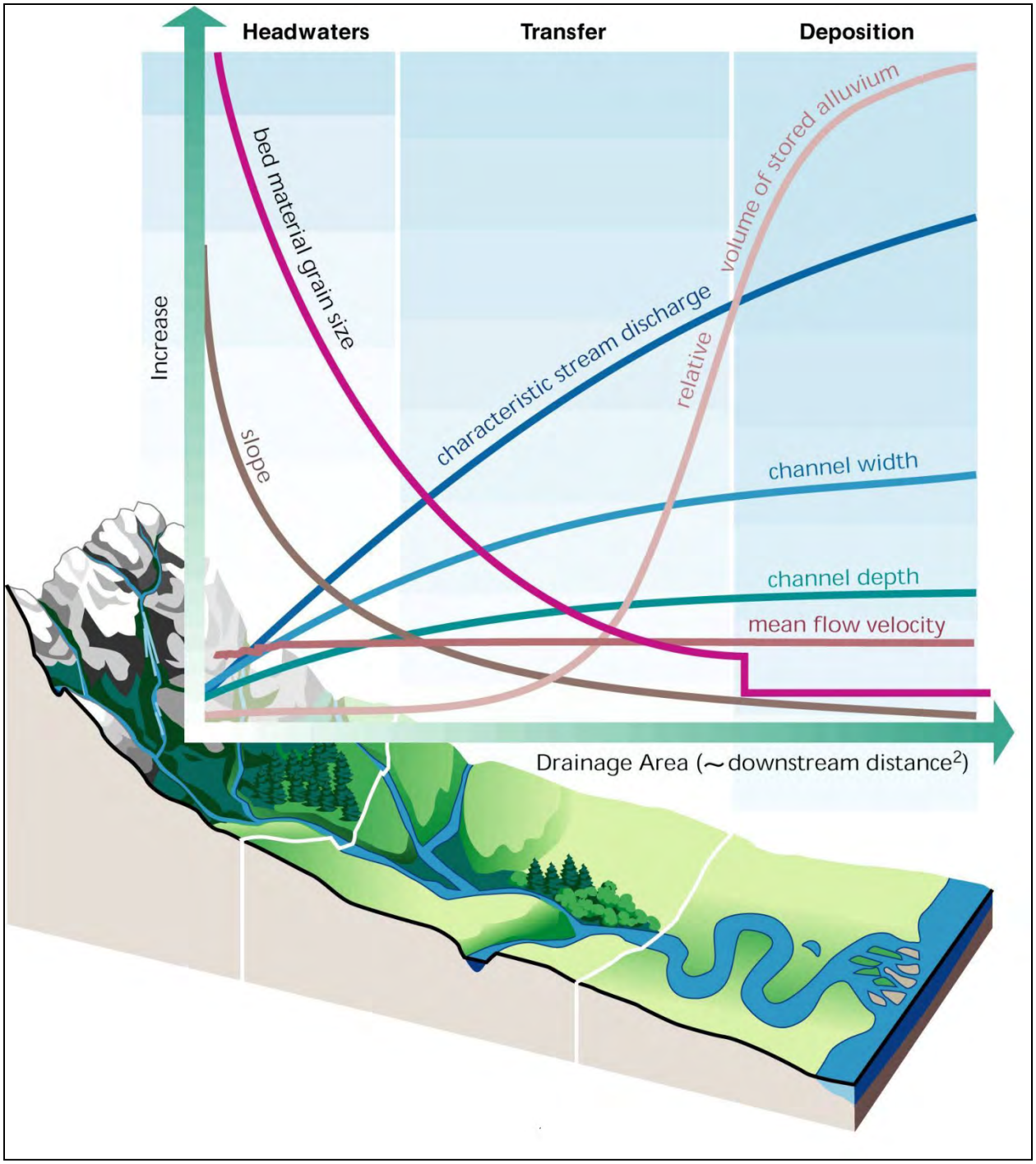

Figure 3. **Changes in the channel in the three zones. Flow, channel size, and sediment characteristics change throughout the longitudinal profile from headwaters to mouth. Source: FISRWG (1998)**

Longitudinal Changes in Channel Form

The form of a given channel typically changes as it moves through the three longitudinal zones. "Sinuosity" is a term indicating the amount of curvature in the channel. The sinuosity of a reach is computed by dividing the channel centerline length by the length of the valley. If the ratio of channel length to valley length is more than 1.3, the stream is considered to have a meandering form (FISRWG 1998). Sinuosity is generally determined by discharge, gradient, and bed material. Low to moderate levels of sinuosity (less than 1.4) are typically found in Zones 1 and 2 of the longitudinal profile. Higher levels of sinuosity (more than 1.4) often occur in the broad, flat valleys of Zone 3.

The Lower Provo River in the Project Area

The lower Provo River in the PRDRP project area is situated at the downstream end of the depositional zone (Zone 3), in which Utah Lake represents an effective base level control. As such, the expected condition of the channel differs somewhat from conditions that would be expected in a typical alluvial setting. The channel of the lower Provo River would be expected to have a high sinuosity when compared to stream sections that are in Zones 1 and 2, and those not affected by a nearby base level control. The increase in sinuosity would directly influence the amount of space that is needed for natural functioning of the river corridor. This means that the restored meander belt width in the lower Provo River should increase in a westward direction as the river position gets closer to Utah Lake, and ultimately trend toward the upper end of the ranges expected based on empirical relationships (Table 1), as the river transitions into the delta/lake.

Dimensions Evident in Historical Provo River Imagery

Available historical evidence suggests that the Provo River near Utah Lake utilized a relatively wide floodplain and belt width without the constraints of roads, bridges, levees, marinas, and airports. A 1946 photo of the lower Provo River shows a previous river alignment south of the current channel in the vicinity of Provo Airport (Figure 4). The meander scars are very evident in this imagery, indicating a progressively wider meander belt width and greater sinuosity in the lower Provo River as the river position becomes closer to Utah Lake. Specifically, within about 3.5 miles of the lake shore, the river channel's belt width increases from 685 feet wide to 1,820 feet (Figure 4).

This historic "airport alignment" of the lower Provo River predates settlement in Utah Valley, construction of dams in the Jordan River near Utah Lake, implementation of the Utah Lake Jordan River Flood Management Plan, the Central Utah Project, and other water management activities in the State of Utah. Therefore, the meander patterns exhibited in Figure 4 would be positioned (relative to current water elevations in Utah Lake) a few feet lower in elevation and, therefore, farther to the west, since Utah Lake water levels were historically lower than they have been under more recent management, since Salt Lake County first constructed a dam at the Jordan Narrows in 1872 (Hooton 1989).

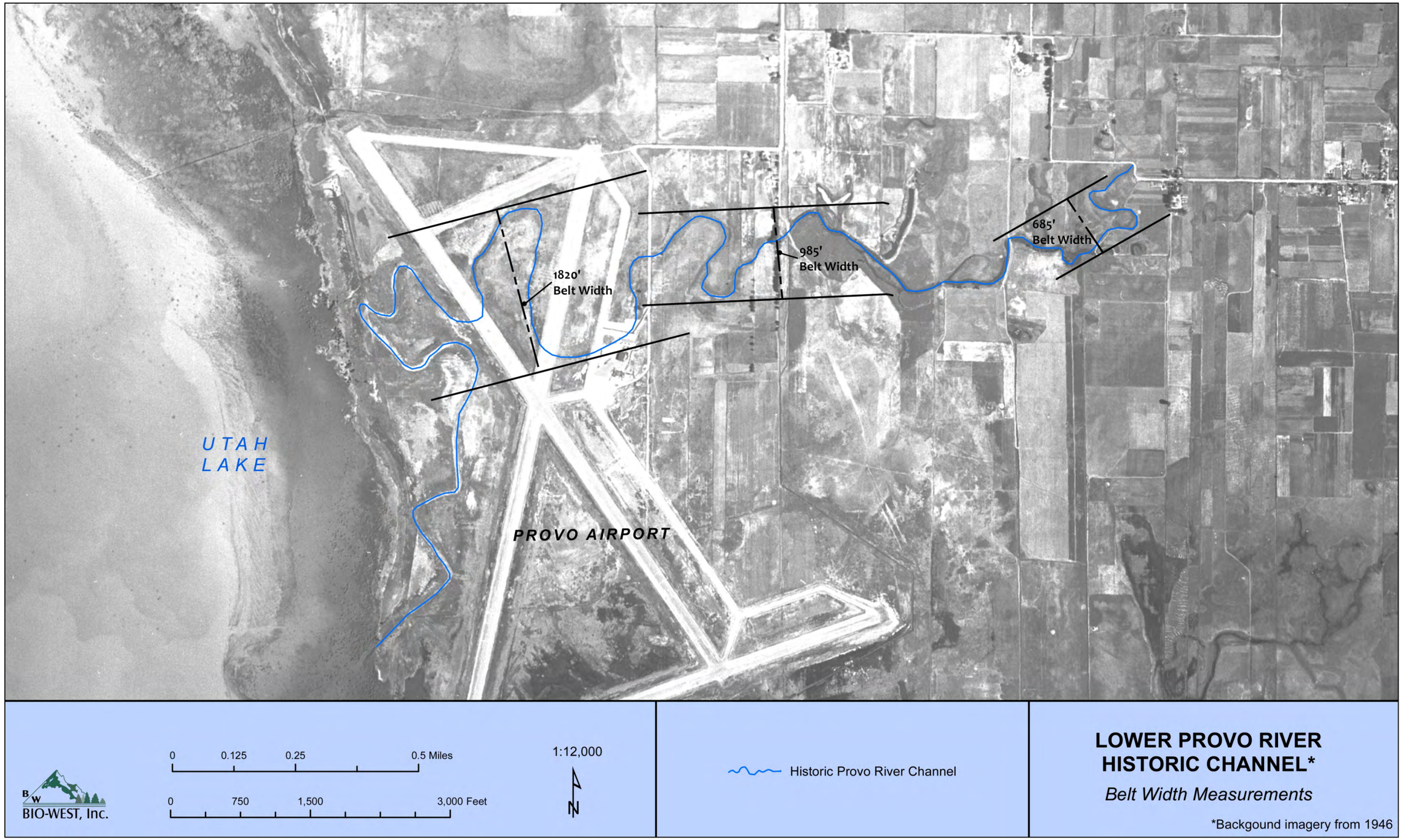

Figure 4. **Historical imagery of meander scars of the lower Provo River showing a progressively wider meander belt width from east to west as the river approaches Utah Lake.**

Floodplain Width Evident in Geology Map

The surficial geology of Utah was mapped between 1977 and 1984 (USGS 1992). Alluvial deposits (Qf) in the form of an ancient river delta are shown to be approximately 10 miles wide (north to south) and 4 miles long (east to west) at the mouth of Provo Canyon where the Provo River once entered Lake Bonneville (Figure 5). This is a complex delta that formed more than 14,500 years ago. Since then the Provo River has cut through and eroded portions of the remnant Lake Bonneville delta and established a new channel alignment, floodplain, and delta relative to water surface elevations in Utah Lake.

The most recent floodplain width as measured by the width of Holocene alluvium (Qa) is approximately 2,500 feet in the valley bottom west of U.S. Interstate 15, and then increases to approximately 4,000 feet at the current shoreline of Utah Lake (Figure 5). This alluvium is surrounded to the north and south by other recent deltaic and lacustrine deposits (Qc) of clay, silt and sand (including local peat beds and matted plant materials from marsh deposits). The relatively recent, fine-grained, deltaic, and lacustrine deposits (Qc) extend several miles north and south of the current channel alignment (Skipper Bay to Provo Bay), presumably burying alluvium from older channel alignments, floodplains, and active deltas such as the Provo River alignment shown in Figure 4.

Recommended PRDRP Floodplain Design Dimensions

The range of meander belt width and floodplain dimensions derived using the above information is summarized in Table 3. Values range from a minimum of 360 feet to a maximum of 2,200 feet, with an overall average of about 1,000 feet. Based on these various sources of information, a design floodplain width of 800 to 1,200 feet was selected for the lower Provo River within the project area.

DELTA SIZE

River Delta Form and Function

A delta is a landform that is formed at the mouth of a river where that river flows into an ocean, sea, estuary, lake, reservoir, flat arid area, or another river. Deltas are formed from the deposition of the sediment carried by the river as the flow leaves the mouth of the river. Over long periods of time, this deposition builds the characteristic geomorphic pattern of a river delta.

River deltas are defined in the scientific literature (Wright 1977) as:

> Coastal accumulations, both subaqueous and subaerial, of river-derived sediments adjacent to, or in close proximity to, the source stream, including the deposits that have been secondarily molded by various marine agents, such as waves, currents, or tides.

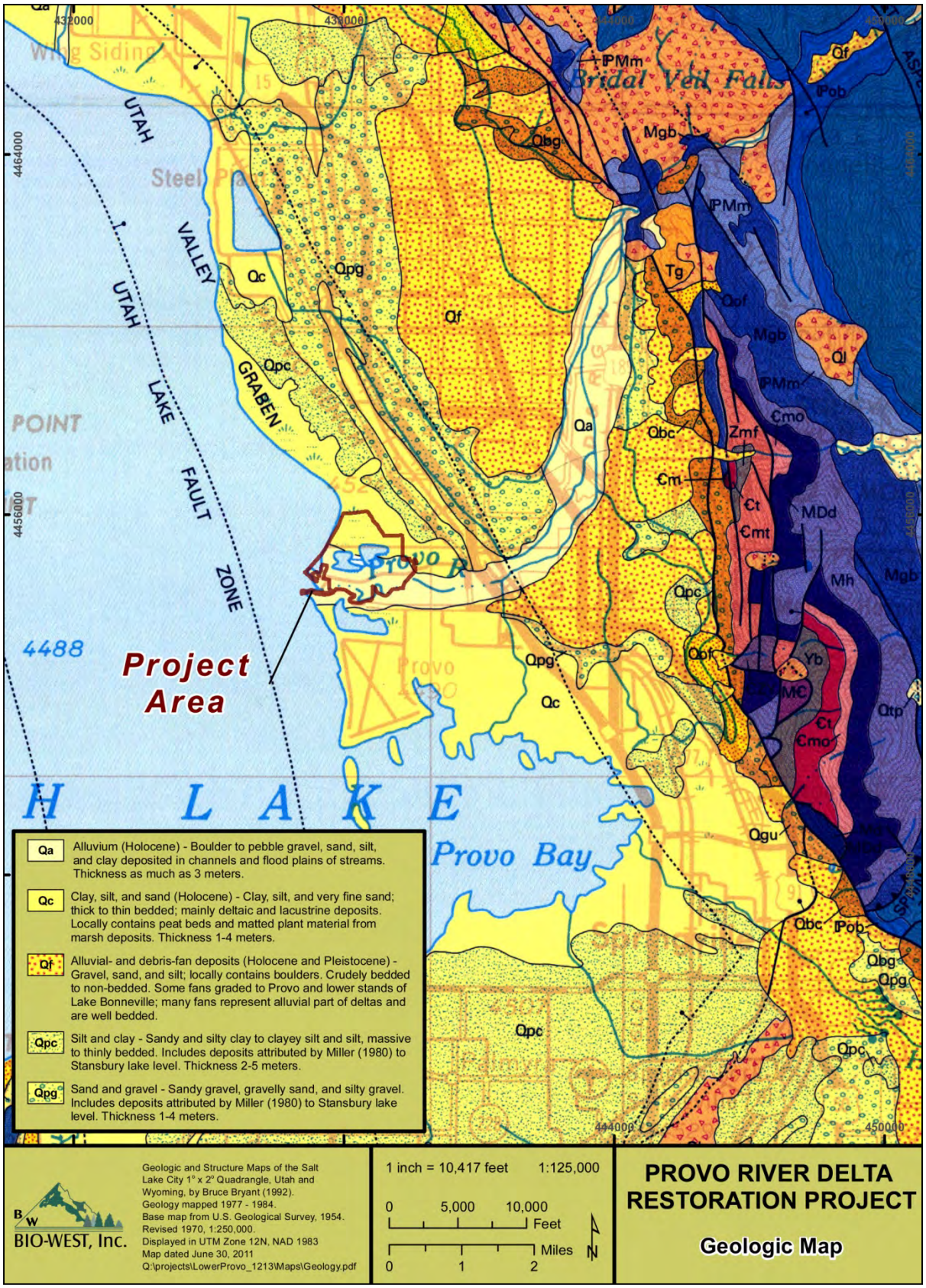

Figure 5. **Historical imagery of meander scars of the lower Provo River showing a progressively wider meander belt width from east to west as the river approaches Utah Lake.**

Table 3. Summary of meander belt and floodplain width dimensions derived from empirical relationships and historical information.

TYPE OF INFORMATION	PUBLICATION OR DATA SOURCE	EQUATION OR RELATIONSHIP [a]	BELT WIDTH OR FLOODPLAIN WIDTH (FEET)	
			LOW ESTIMATE (USING W [a] = 80 FEET)	HIGH ESTIMATE (USING W = 100 FEET)
Empirical relationship	Inglis 1949	$B = W+18.6W^{0.99}$	1,504	1,876
Empirical relationship	Inglis 1949	$B = W+10.9W^{1.04}$	1,119	1,410
Empirical relationship	Leopold and Wolman 1960	$B = W+2.7W^{1.1}$	415	528
Empirical relationship	Zeller 1967	$B=4.5W^{1.00}$	360	450
Empirical relationship	Williams 1986	$B=4.3W^{1.12}$	582	747
Empirical relationship	Carlston 1965	B=18.6W	1,488	1,860
Empirical relationship	Soar and Thorne 2001; FISRWG 1998	6W<=B<=22W	480 to 1,760	600 to 2,200
River corridor setback guideline	Kline and Cahoon 2010	8 times bankfull channel width	640	800
Historical aerial imagery	1946 aerial photo	Not applicable	685	1,820
MINIMUM			360	450
MAXIMUM			1,760	2,200
AVERAGE			903	1,229
COMBINED AVERAGE			1,066	

[a] W = bankfull channel width, B=meander belt width.

Delta Form, Formation, and Maintenance Processes

The processes of deposition that build river deltas are generally well understood. However, many factors influence the form of a given delta over time, including water and sediment supply, sediment size distribution, shoreline shape, wave action, shore currents, tidal currents, etc. The complex interactions between these factors can lead to a myriad of delta shapes and sizes. Common delta types include the following:

Lobate or Arcuate (fan-shaped) Delta. This delta type has many active, short distributaries conveying sediment to their mouths. The receiving (ambient) waters are rather shallow and have relatively even wave action arriving perpendicular to the shore with minimal longshore current. As the sediment exits the many distributary mouths, the waves push it back, so the coastline is rather smooth.

Elongate or Bird-foot (shaped like a bird foot) Delta. These deltas tend to have one or a very few major distributaries near their mouths. The receiving basin has currents that carry the sediment away as it exits the distributary mouth. There is a broad, shallow shelf that deepens abruptly, so the trend is to grow long and thin like a bird's toe.

Cuspate (tooth-shaped) Delta. This delta type usually has one distributary emptying into a flat coastline with wave action hitting it head-on. This tends to push the sediment back on both sides of the mouth, with a "tooth" growing out onto the shelf.

Estuarine Delta. This type of delta has a river that empties into a long, narrow estuary that eventually becomes filled with sediment (inside the coastline).

Gilbert Delta. A Gilbert delta (named after Grove Karl Gilbert) is a specific type of delta that is formed by coarse sediments entering a fresh water lake, as opposed to gently-sloping muddy deltas such as that of the Mississippi. For example, a mountain river depositing sediment into a freshwater lake would form this kind of delta. Gilbert used deltas that formed around Lake Bonneville for this description. Gilbert deltas tend to have a somewhat lobate form.

Major processes that govern the form of a given delta have been described by Galloway (1975), who suggested that three major processes combine to determine the general form of a given delta, as follows: (1) river processes that build the delta (primarily flow and sediment), (2) wave processes that erode the delta, and (3) tidal processes that redistribute deltaic deposits, which are not a factor in Utah Lake (Figure 6). The relative importance and interactions between each of these processes dictate the forms of a delta. Figure 6 shows many of the delta types that were described previously.

Another diagram describing delta form as a function of driving processes was provided by Antonov (2011), who showed delta form as a balance between fluvial processes and marine processes (Figure 7). This diagram provides a useful way of thinking about processes that shape and reshape a delta.

When flow that is transporting sediment enters the backwater area of a standing water body, it experiences a decrease in flow velocity, which reduces its competence to transport sediment. When the velocity decreases enough, the shear stress is no longer of sufficient magnitude to transport the coarse sediment that is moving as bedload, and it stalls on the bed of the channel. As velocity decreases further, suspended sediment also drops out of the flow and deposits, sometimes forming natural levees along the margins of the main channel. Over time, the channel will build a deposit called a "deltaic lobe" that pushes out into the standing water body. As this lobe builds, the energy within the river channel decreases further. This happens because the slope is decreased due to the added channel length. If the slope of the river channel continues to decrease, the system becomes unstable and begins to seek a new equilibrium (incoming sediment loads = outgoing sediment loads).

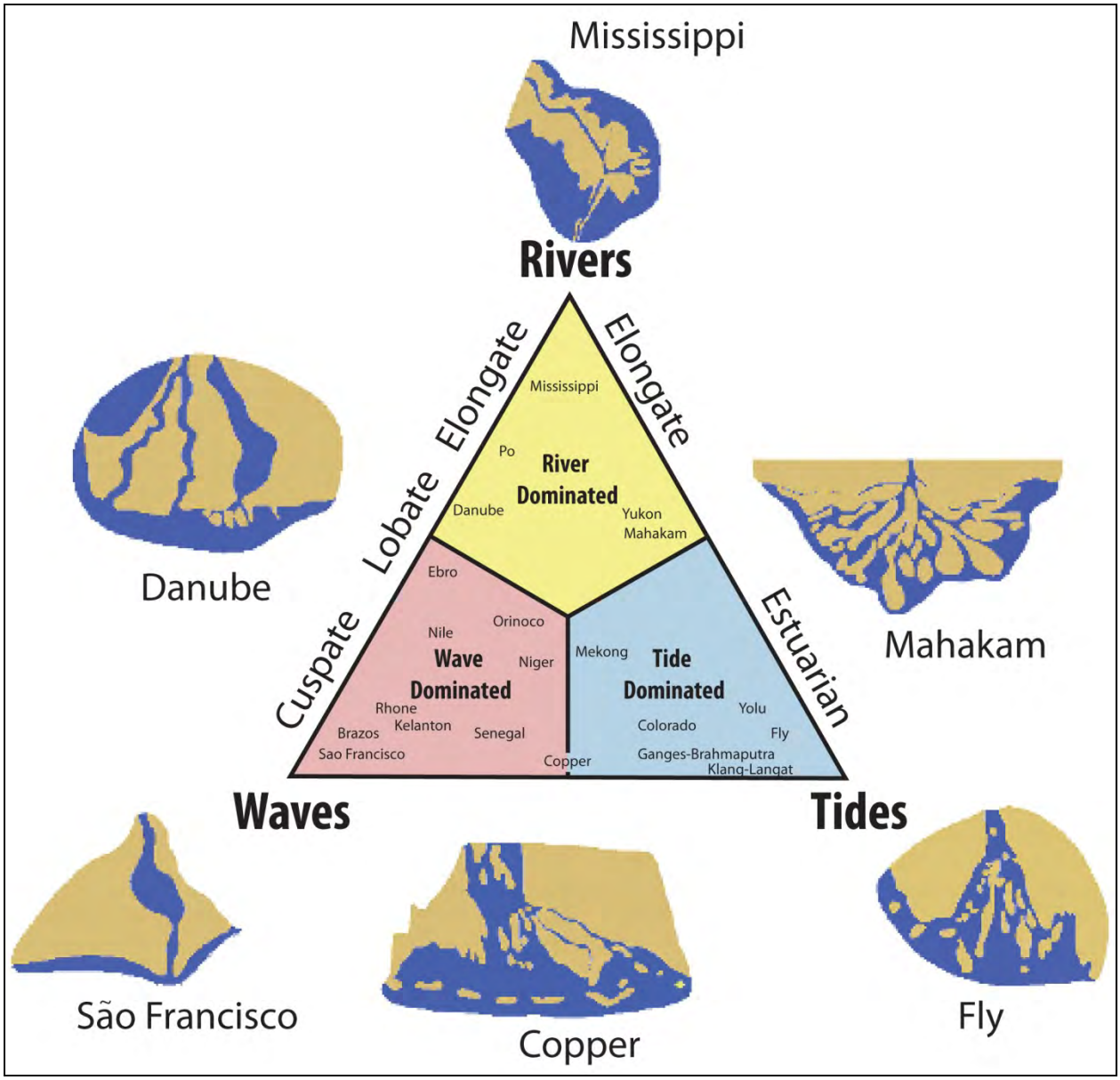

Figure 6. **Triangular diagram for classifying river deltas according to the relative influence of the three major factors affecting their development: the river, waves, and tides. Source: Galloway (1975)**

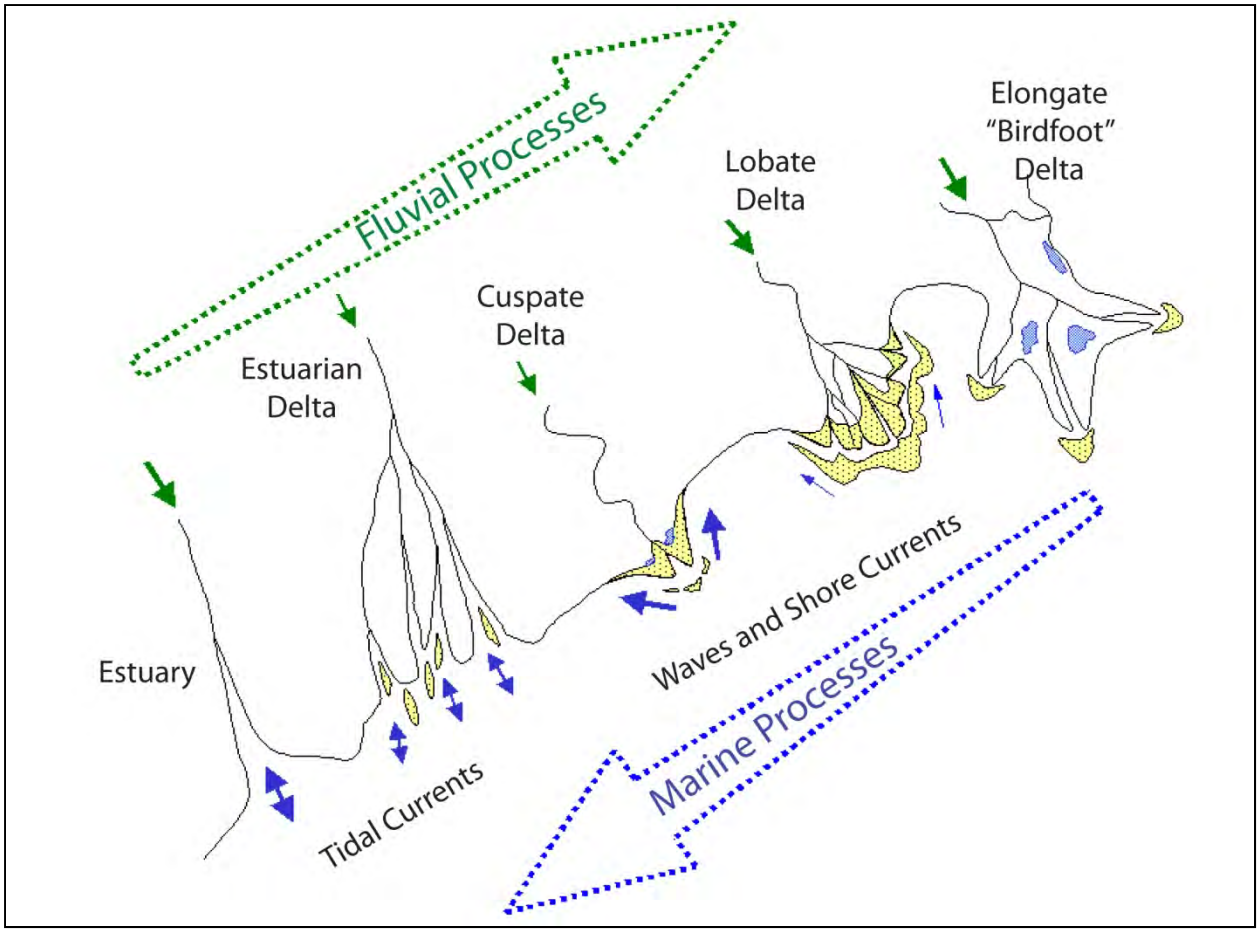

Figure 7. Delta form as a function of dominant processes. Source: Antonov (2011)

The instability is a direct result of the reduction in slope, which has two primary effects that promote channel movement. First, the decreasing slope reduces the shear stress within the channel that is available for transporting sediment. This reduction in transport capacity increases the likelihood of large-scale deposition within the channel, which reduces overall channel capacity and promotes rapid lateral shifting generally when sediment transport rates are at their highest. Second, the decreasing slope raises the water stage and increases the likelihood that the water will be forced out of the channel and subsequently find a new, steeper path into the water body.

If river processes were the only forces acting on a delta, the result would be elongated deltas that reach far out into water bodies. However, wave action and tidal forces combine to disperse the sediment that is delivered into the standing water body. The importance of these dispersal processes on the form of the delta has been clearly described by Wright and Nittouer (1995). They used examples from six deltas that have very different forms because the dispersal processes at each location differ. They also identified these four important stages of sediment dispersal: (1) supply via plumes, (2) initial deposition, (3) resuspension and transport by marine processes, and (4) long-term accumulation. Some water bodies have periods of sufficient energy to mobilize sediment that has been deposited in the delta. Wind driven waves are the primary

mechanism for mobilization in most inland lakes, although along-shore currents can also be important in some settings. In oceans, waves and tides combine as the primary mechanism for dispersal. Utah Lake is very shallow and often windy. Therefore, wind likely has a role in limiting the extent of the delta formation west into the lake from Provo River.

Lateral Instability in Deltas

There are two main processes that promote rapid adjustments in river deltas. First, water that is acted upon by gravity will seek the shortest course down a slope. As the deltaic lobe advances, it eventually reaches an unstable condition that cannot be maintained because the energy gradient (slope) decreases as a result of sediment deposition, breaches its natural levees, and finds a shorter and steeper route to the water body as described in the previous section. This process leads to a steeper slope and a more stable condition. However, within the new channel, the process of deposition leading to instability begins anew. Second, as slope decreases, the available shear stress on the bed also decreases, which promotes deposition of coarse sediment directly on the bed of the channel. This sediment deposition causes the channel bed to rise relative to the surrounding floodplain, eventually becoming perched slightly higher than surrounding areas. This process increases the likelihood of a natural levee breach. When breaches occur, some of the flow often remains in the previously active channel. When these channel switching and dividing events occur over a long enough period of time, a mature river delta will form that exhibits a classic distributary form.

Lateral instability can come from another process. Mid-channel bars that form when rivers enter standing water bodies are often called mouth bars. When these bars are deposited at the mouth of a river, the flow must find another route to the standing water body. Normally, the flow is simply forced laterally around the sides of the bar, which effectively extends the length of channel and lowers the slope. These bars also create an upstream backwater effect that reduces shear stress and leads to additional deposition upstream of the bar. This added deposition frequently divides the river into two distributary channels, thus further accentuating the distributary channel form.

The processes outlined above illustrate an important characteristic of river deltas: they are dynamic in nature and require a significant amount of space to accommodate the natural deltaic processes. Deposition of sediment in any given location cannot continue for long periods of time without causing lateral instability. Thus river channels in a delta environment will adjust laterally in order to accommodate a continuous supply of sediment that is delivered by the river. It is this constant shifting of channel location over time that leads to the classic delta form. However, delta landforms and distributary channel networks are generally large enough to include a range of stability across the delta plain; one particular channel or portion of the delta may be experiencing lateral instability while at the same time another channel or other portions of the delta are very stable. This range of stability across a single landform provides great diversity. Restricting of the lateral extent of a delta diminishes its ability to function naturally and may lead to instability that may affect upstream and surrounding areas.

Predictive Methods

Deltas are extremely dynamic by nature, and as such, they require a substantially increased width when compared to the rivers that enter them. Delta widths are typically many times wider than the active floodplain width of the rivers that feed into them. They are nearly always fan shaped to a certain degree, due in large part to the lateral instability that the depositing sediment creates.

Despite the scientific work that has been directed toward river deltas, no precise predictive models exist that can be used to determine the expected size of a river delta in a given setting. Deltas are constantly shifting and reshaping themselves, and the complexity of the interactions between driving forces is hard to model. Computer models have been developed that can be used to simulate the delta processes (Figure 8), but their usefulness as a predictive tools is limited, largely due to the lack of detailed field data that can be used to calibrate these models (Gouw 2007). Although precise predictive tools are not available to determine the exact delta size, several techniques can be employed to guide restoration efforts in the Provo River delta at Utah Lake. These include examination of historical evidence from the lower Provo River at Utah Lake, and also examination of evidence from other similar rivers and lakes.

Provo River Delta at Utah Lake Dimensions Evident in Historical Imagery

In addition to the general relationships between floodplain width and delta width, historical data can be used to examine the remnants of deltas that have been altered by human activities. Using available digital elevation information, a hillshade image of the eastern portion of Utah Lake was developed (Figure 9). In this image, a significant landform is evident protruding into the lake and into Provo Bay; through geologic time this feature formed through sediment deposition by the Provo River. The full extent of this historic Provo River delta in Utah Lake spans a lateral distance of more than 4 miles or more than 21,000 feet (Figure 9), less than half the size of the Provo River delta in Lake Bonneville. Furthermore, only a portion of this area would have been active at any given time, and the full extent of the feature is most likely the product of several major river channel shifts related to different historic periods. The historic Provo River delta in Utah Lake also built up while the Provo River remained unregulated; today the river's sediment load and flood flows are substantially reduced by dams and diversions. Transbasin water imports also have influenced the hydrological patterns and annual quantities of water entering Utah Lake via Provo River. Currently, all of the land area of the historic delta has been developed for agricultural, commercial, industrial, and residential land uses except for the portion of the historic delta immediately north of the current channel alignment.

Provo River Delta at Jordanelle Reservoir

Jordanelle Dam is located on the Provo River approximately 35 miles upstream of Utah Lake. The dam was constructed in 1992 and the Reservoir filled by 1996. Since dam closure, a new Provo River delta has formed in Jordanelle Reservoir at the inflow (Figures 10 and 11). The date of the aerial photograph used for Figure 8 is October 2006; therefore, this particular delta (Figure 10) has formed a fairly extensive distributary network of channels and has started building a "classic" delta plain landform over a relatively short, 10-year period.

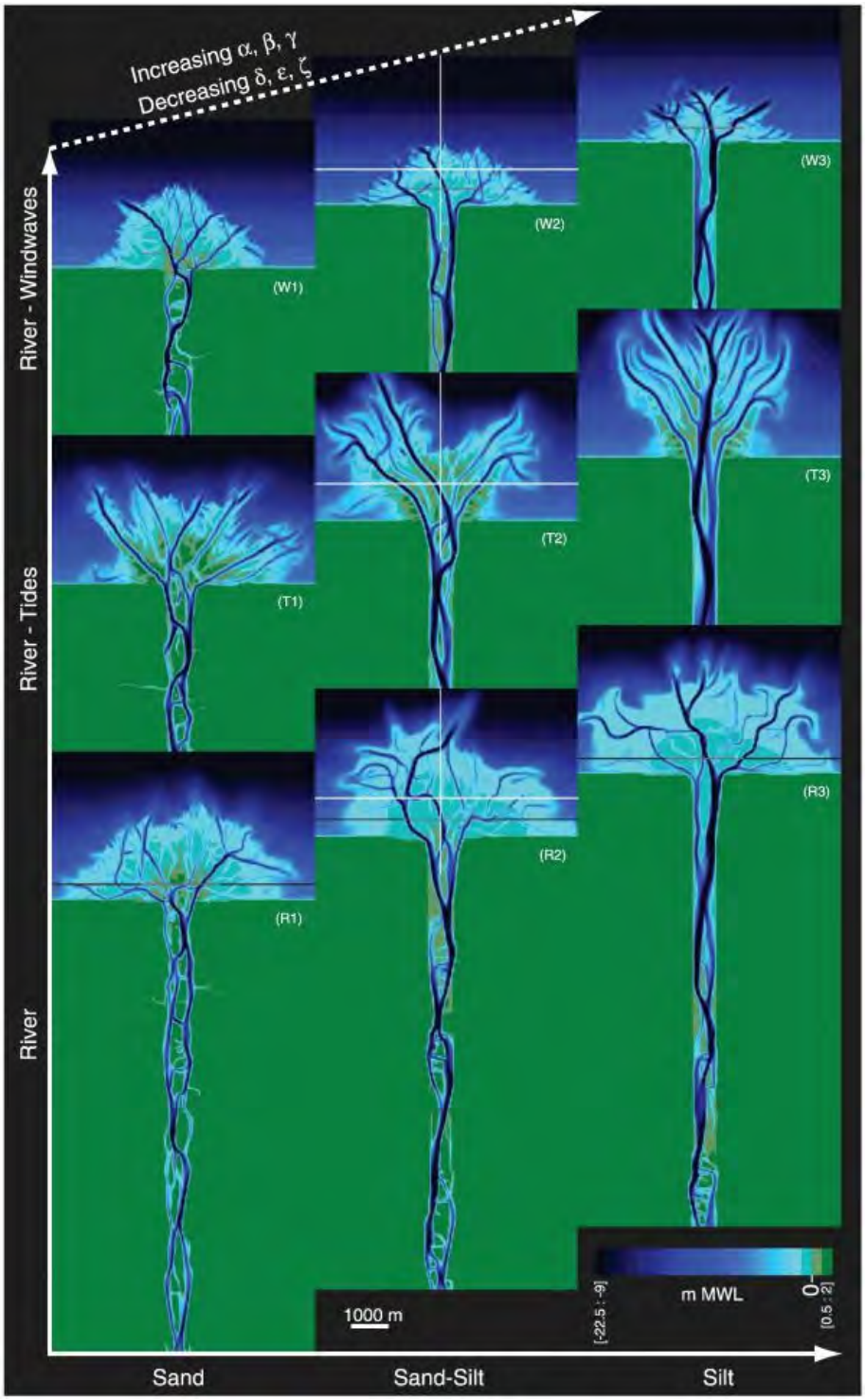

Figure 8. **Modeling results described in Geleynse et al. (2010) for various types of sediment and water movement (driving forces), for a given point in time (image produced at Delft University of Technology, Netherlands).**

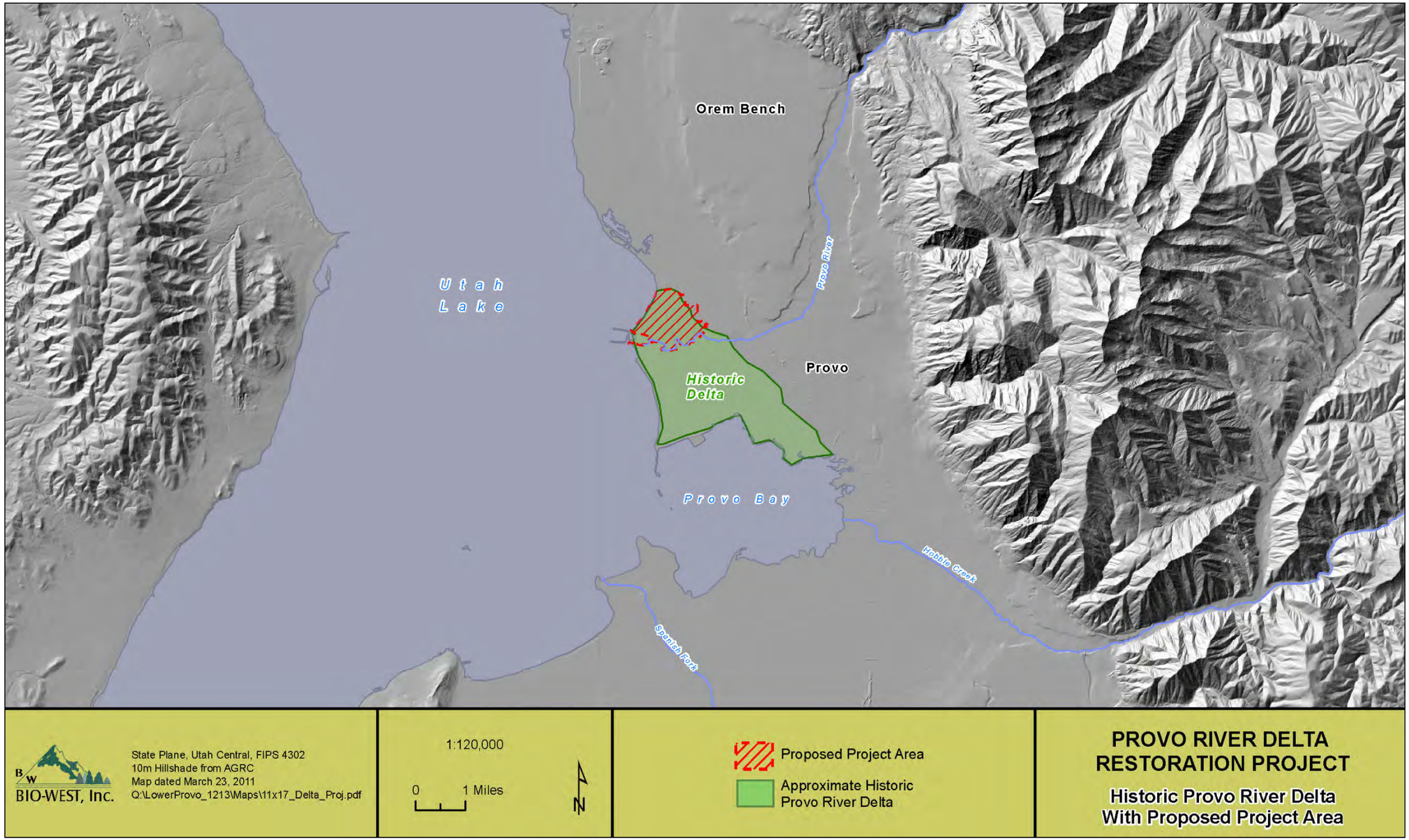

Figure 9. **Project area with historic Provo River delta.**

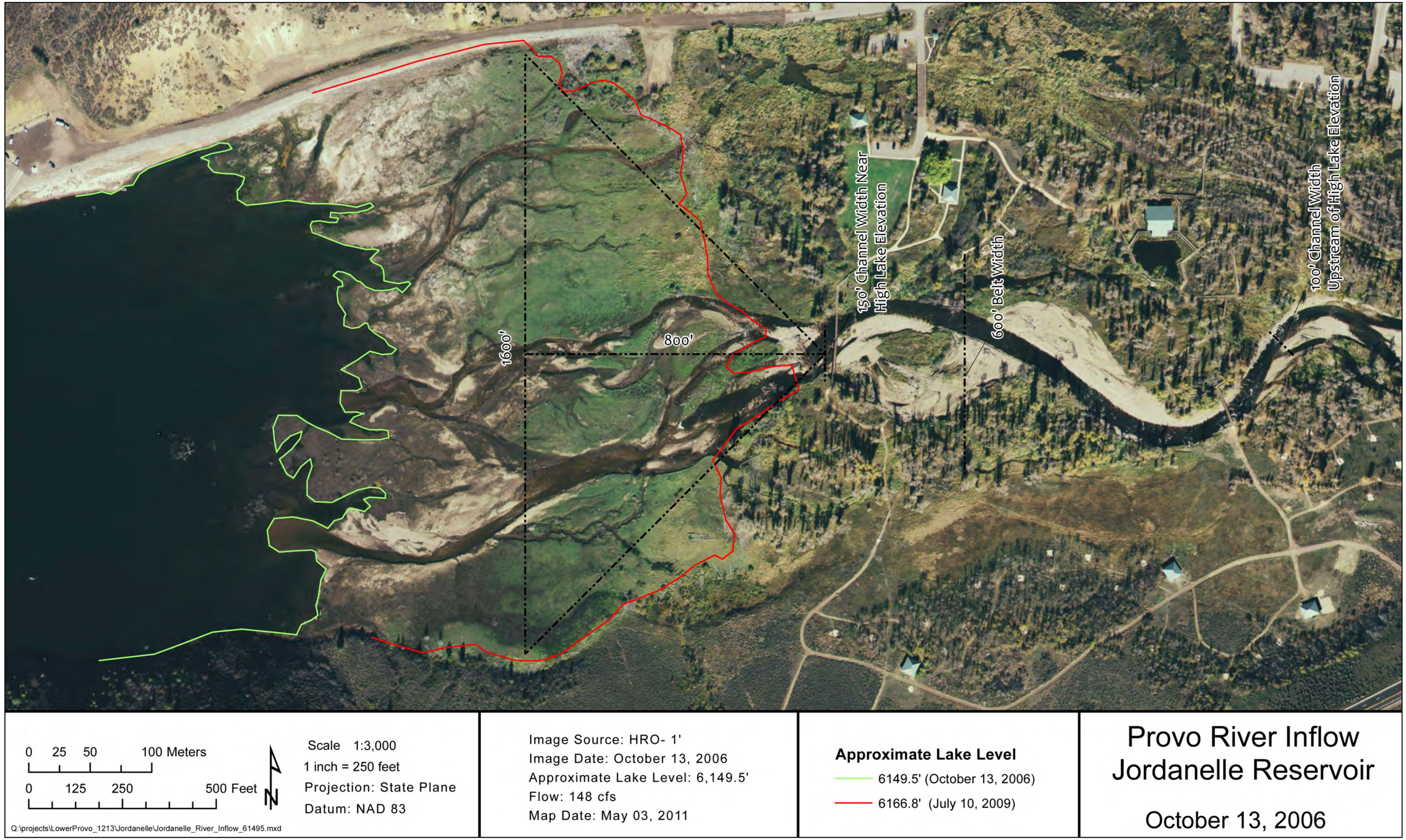

Figure 10. Provo River delta at Jordanelle Reservoir when reservoir levels were low.

Figure 11. Provo River delta at Jordanelle Reservoir when reservoir levels were high.

Provo River flows into Jordanelle Reservoir in an area that would be characterized as Zone 2 (the transfer zone, as described above and in Figures 2 and 3) in the overall longitudinal profile for Provo River. The primary physical differences between the Jordanelle inflow and the inflow at Utah Lake are related to the fact that the Jordanelle inflow (Zone 2) is steeper and more geologically confined between side hills, and not as flat and wide as the Utah Lake inflow area which is in Zone 3 of the overall longitudinal profile. In addition, Jordanelle Reservoir typically fluctuates approximately 15 feet annually, whereas Utah Lake only fluctuates approximately 3 feet annually.

The size and shape of a river delta in this setting is largely controlled by water and sediment supply, sediment size distribution, shoreline shape, and wave action. The U.S. Geologic Survey (USGS) gaging data and field observations indicate that peak flows, sediment supply, and sediment particle sizes are greater in the Provo River at the Jordanelle inflow than at Utah Lake. The delta at Jordanelle is also confined to a width of around 1,600 feet due to the influence of side hills. With these differences, the Jordanelle delta would generally be much more dynamic with regard to lateral instability, and the delta plain formation would extend over a greater elevation range than the Utah Lake delta. For example, Figure 10 shows the initial fan spreading from 150 feet wide just above high lake elevation to 1,600 feet wide over an approximate horizontal distance of 800 feet and vertical drop of approximately 7 feet. This drop is much steeper than anything around Utah Lake. The fan width of the Jordanelle delta is confined by the geologic controls of the side hills, and would otherwise be significantly wider before reaching the low lake level. It is important to note that a significantly sized mouth bar has formed at this river/lake interface in just over a decade (Figure 11), extending under a bridge and approximately 300 feet upstream of the shoreline at high lake level. While the Jordanelle delta formation is illustrative, it has limitations for developing design guidelines for the lower Provo River at Utah Lake because of differences in formative variables.

River Delta Dimensions Evident in Other Similar Lakes

The Provo River delta that recently formed in Jordanelle Reservoir is evidence of current formative processes in a relatively undeveloped section of this riverine system, however finding examples of delta dimensions in a setting similar to Utah Lake (Zone 3) would better define design parameters for the Provo River delta at Utah Lake. Fortunately, satellite and aerial imagery (from sources such as Google Earth) now allows easy access to current and historic aerial photography across the western United States and the world, available anywhere at the touch of a button. Only a few years ago this type of imagery search and landform measurements would have been infeasible.

A total of four river deltas were identified and evaluated in terms of riverine channel and floodplain widths compared to delta size. Three were found in Utah and one in Oregon. An extensive search was performed to find a larger sample size in the western United States, which produced additional example deltas like the Provo River delta at Jordanelle Reservoir, but there were too many differences in formative variables (primarily annual lake level fluctuations) to be considered similar to Utah Lake. Channel width, meander belt width, and delta plain width were measured using aerial photography, first in Google Earth and then confirmed using ArcGIS. The

measurements were performed at a fairly large scale based on available imagery of the area. In addition, lake elevation, average annual discharge (river flow), and average annual lake water level fluctuation were determined using available gauging data for the following "Zone 3" river deltas (Table 4):

1. Provo River delta at Utah Lake (Figure 12)
2. Weber River delta in the Great Salt Lake (Figure 13)
3. Sevier River delta in Sevier Lake (Figure 14)
4. Williamson River delta in Upper Klamath Lake (Figure 15)

Table 4. Summary of channel width, meander belt width, and delta plain width for four river deltas in the western United States with similar average annual discharge, and average annual lake water level fluctuations.

DELTA NAME	CHANNEL WIDTH (FEET)	MEANDER BELT WIDTH (FEET)	DELTA PLAIN WIDTH (FEET)	AVERAGE ANNUAL DISCHARGE (CUBIC FEET PER SECOND)	AVERAGE ANNUAL LAKE WATER FLUCTUATION (FEET)	LAKE ELEVATION ABOVE NGVD 1,929 (FEET)	DRAINAGE AREA (SQUARE MILES)
Provo River delta at Utah Lake	80	1,000	12,000	200	3	4,489	673
Sevier River delta at Sevier Lake	100	1,200	25,000	239	2	4,600	5,966
Weber River delta at Great Salt Lake	120	1,600	25,000	465	2	4,200	2,081
Williamson River delta at Upper Klamath Lake	180	1,700	36,000	164	4	4,098	1,290

The four river deltas used in this analysis illustrate that there is a reasonable correlation between channel width, meander belt width, and the width of the delta plain. The size and shape of each example delta plain is very discernable using aerial photography, even though there is a significant difference in levels of floodplain and delta plain development between sites. The Provo River and Williamson River deltas have been developed similarly for agricultural purposes, whereas the Weber River delta has been developed for wildlife purposes, and the Sevier River delta is entirely undeveloped.

Delta zones applicable to Provo River delta at Utah Lake (Figure 16) are approximated for each example delta (Figures 12 through 15). The abrupt transition in riparian/wetland width between the river zone and the delta plain zone is apparent at each river/lake interface. The actual position of this transition appears to occur just upstream of the normal high lake elevation, probably as remnant mouth bar(s) formed during extreme high lake levels. An example of this type of bar forming event occurred during the floods of 1983 and 1984 in the lower Provo River, and then subsequently dredged (Stream Alteration Permits #86-55-0011 and #87-55-0001). Dredging and further channelization continues to be necessary in the lower Provo River presumably to maintain channel capacity and prevent lateral instability as described in previous sections of this document.

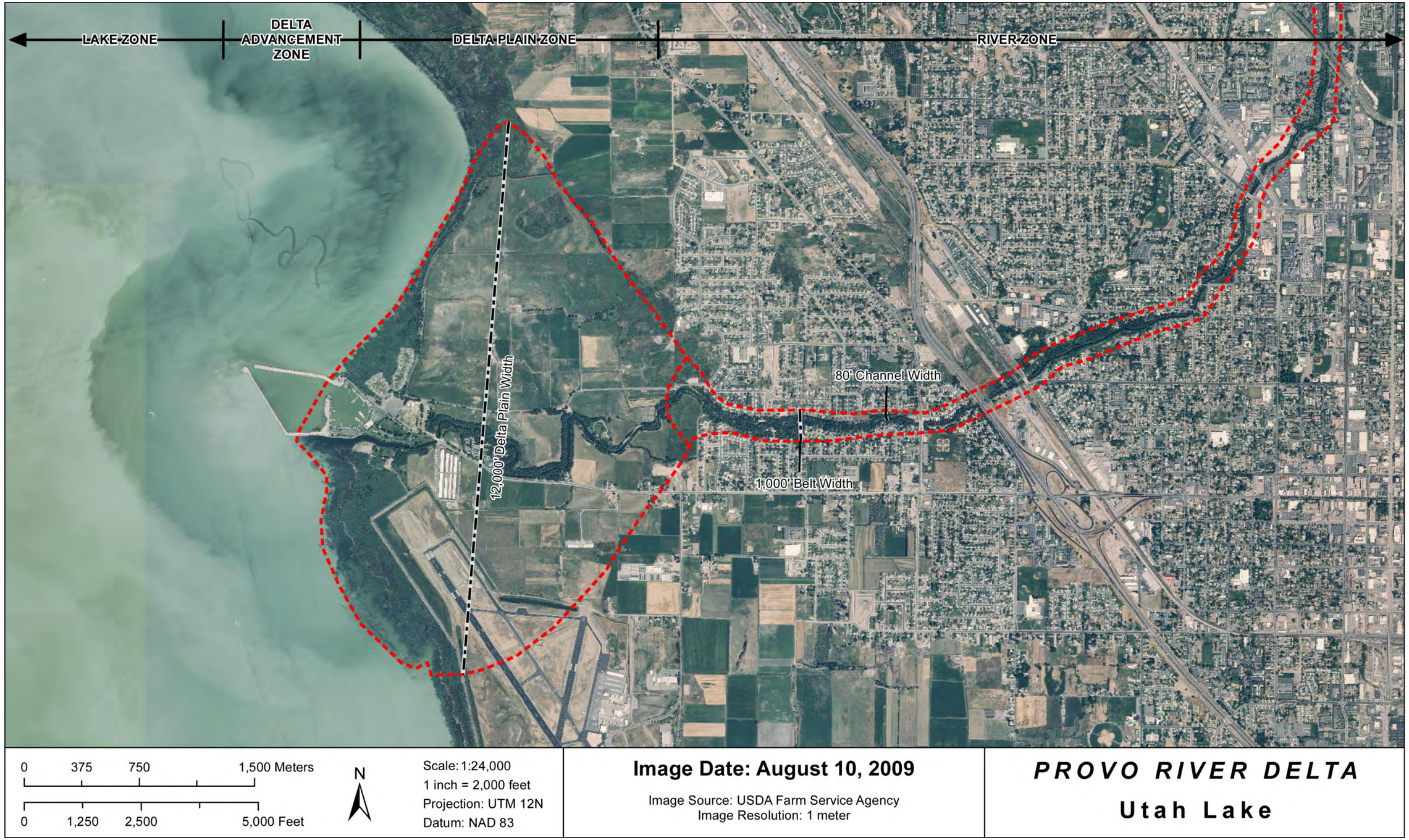

Figure 12. Provo River delta at Utah Lake.

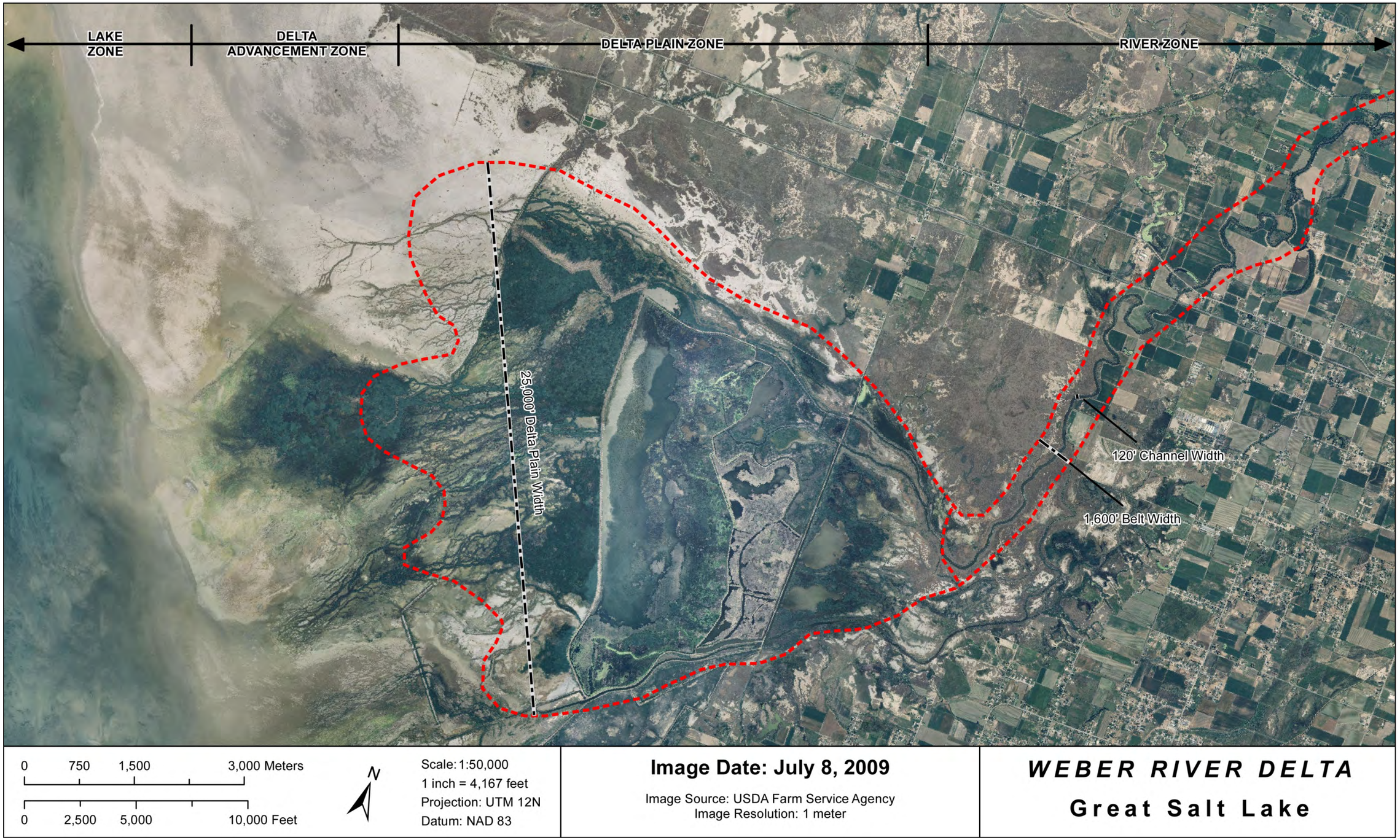

Figure 13. Weber River delta at Great Salt Lake.

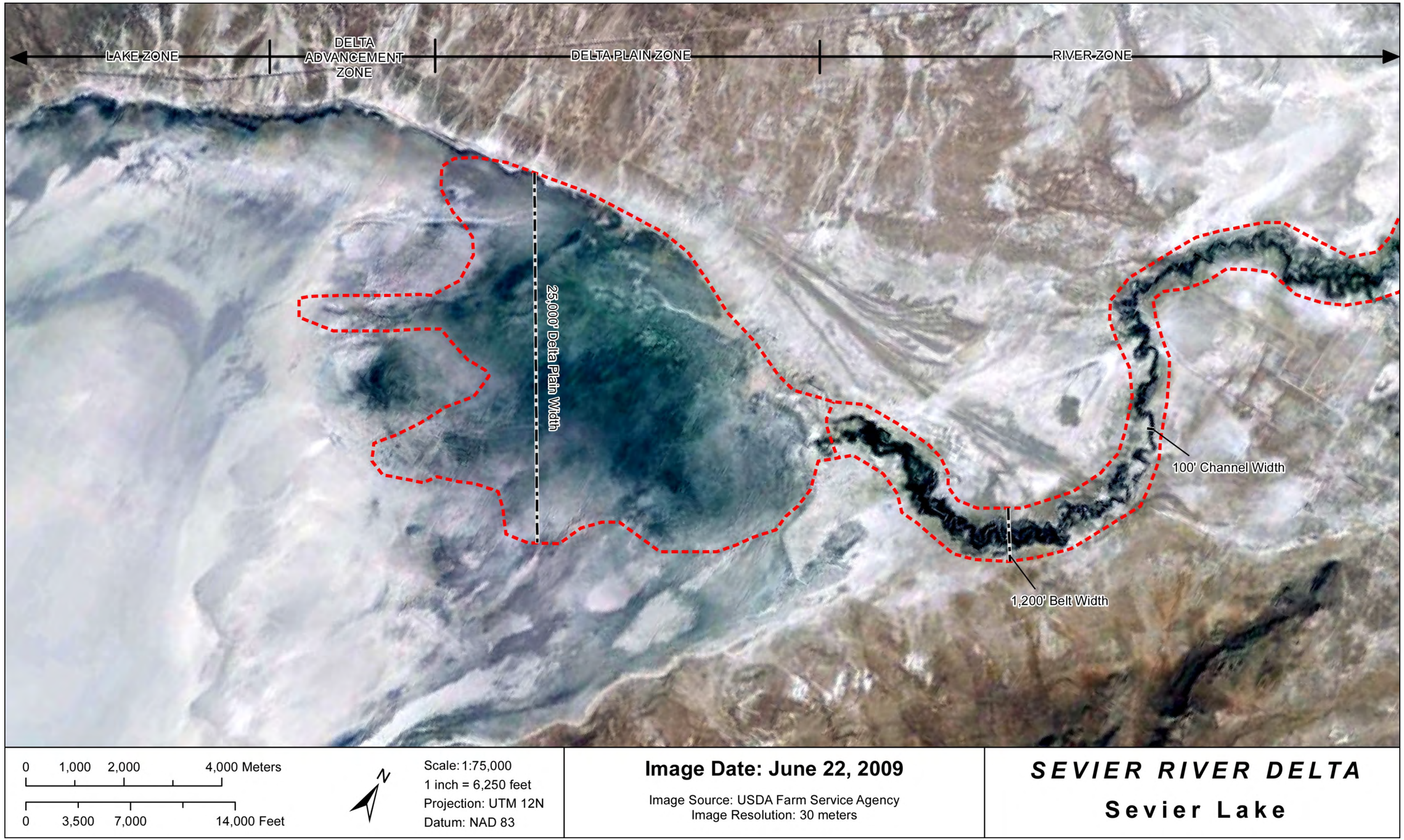

Figure 14. Sevier River delta at Sevier Lake.

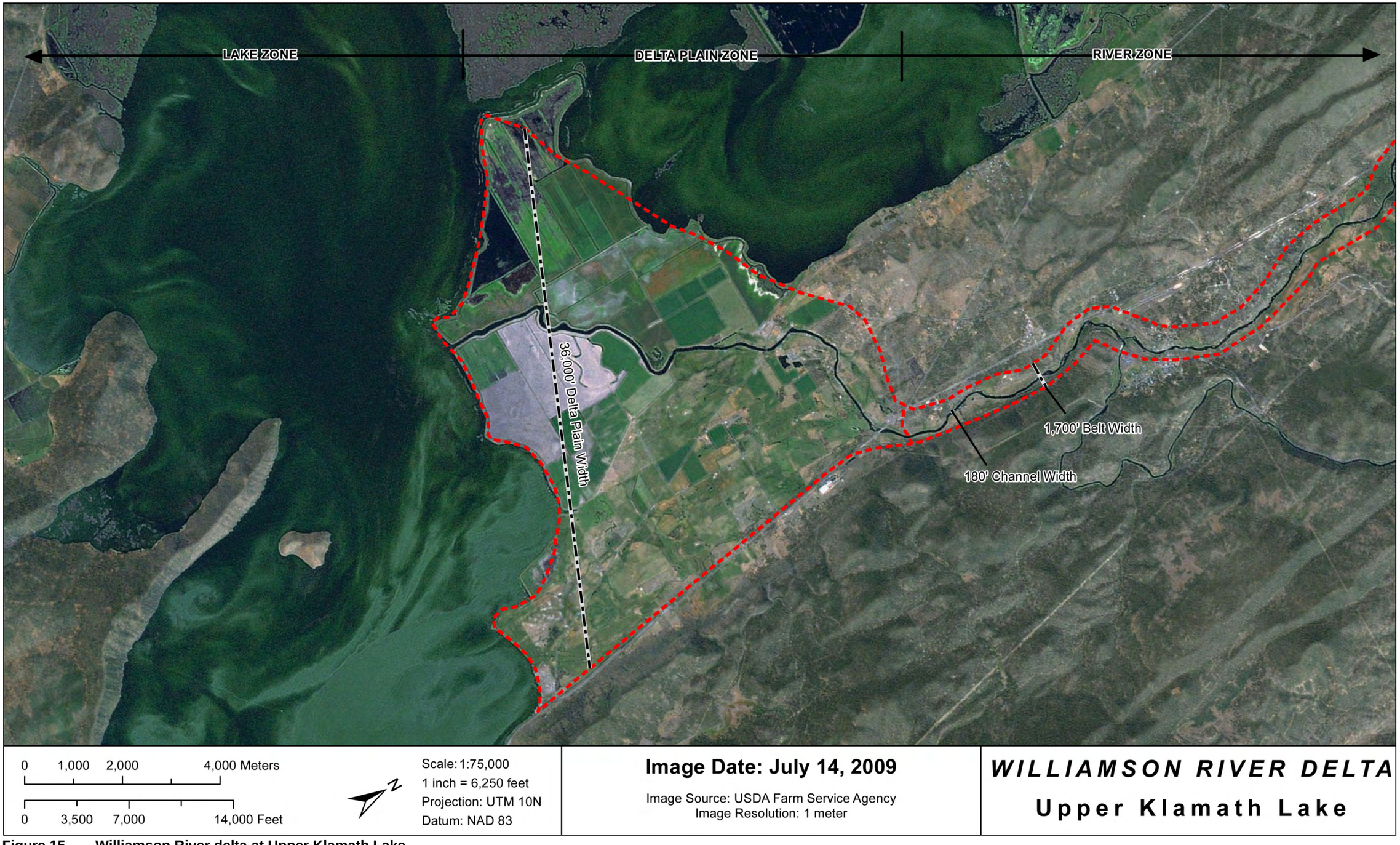

Figure 15. Williamson River delta at Upper Klamath Lake.

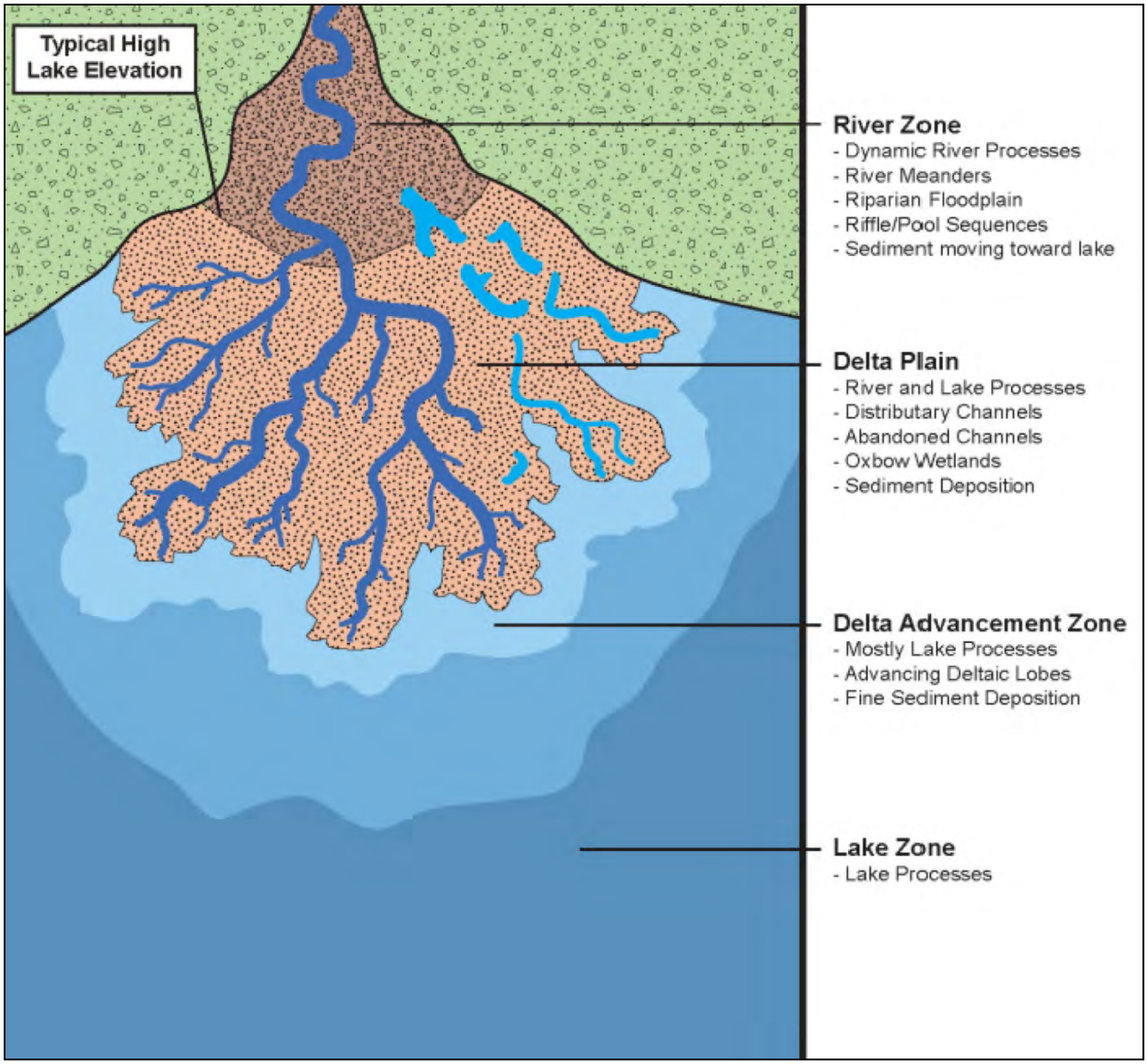

Figure 16. Typical zones of river deltas forming in a lake.

The shape of the four example deltas are remarkably similar, all lobate, all resembling a duck foot. They would all be classified as a Gilbert Delta, exhibiting a distinct fan shape. The angles of outside boundaries of the fan shape of these deltas are all acute (less than 90 degrees), ranging from 30–60 degrees relative to a straight line starting at the center of channel/meander belt at the boundary of the river/delta plain zones, and drawn through the middle of the delta plain (as illustrated in Figure 10). Therefore, the total flare or shape of the entire fan of these example deltas (both sides of the fan relative to a straight line drawn through the middle) ranges from 60–120 degrees (Figure 17). It is reasonable therefore to conclude that a Gilbert-type delta will form naturally in lakes similar to Utah Lake with fan angles as low as 30 degrees.

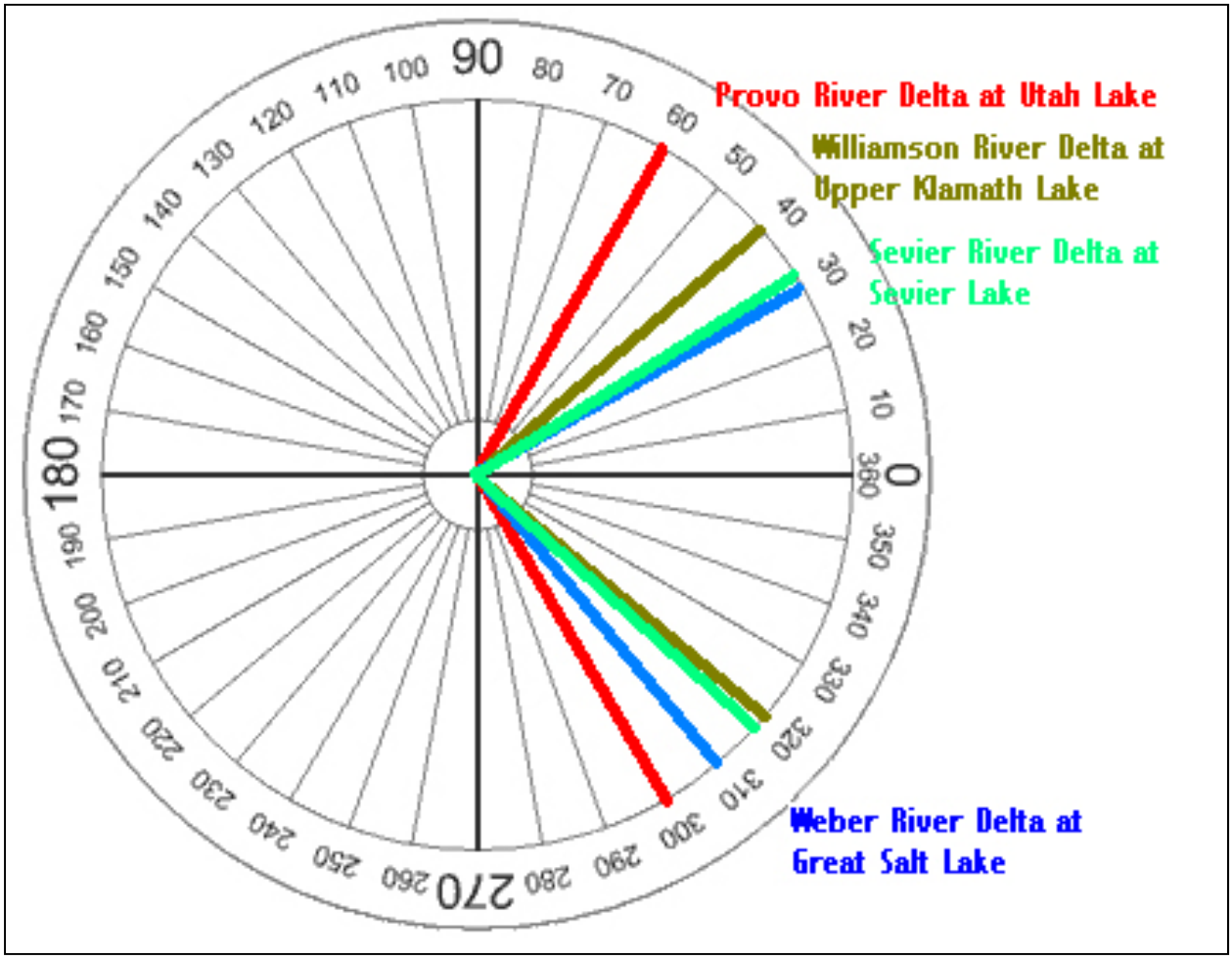

Figure 17. General fan shapes in similar river deltas in lakes with low annual water level water fluctuations.

The straight-line distance through the Provo River delta at Utah Lake (Figure 12) is approximately 1 mile (5,280 feet) as measured from normal high lake elevation of 4,489 feet NGVD 1929 in the existing Provo River channel stretching west to the lake. The minimum angle from the four reference deltas is 30 degrees on each side of that straight line; therefore, the minimum width of a delta plain at the lake interface would approximately equal 6,096 feet (tan 30 degrees times delta length times 2), which is almost exactly one half the width of the "modern" delta plain landform in the lower Provo River as delineated on Google Earth.
The modern delta plain landform in the lower Provo River delineated in Figure 12 (12,000 feet) is much smaller than the full delta shown in Figure 9 (21,000 feet). Lake Bonneville drained approximately 14,500 years ago. The full delta shown in Figure 9 is likely a product of several major river channel shifts related to different historic periods since the draining of Lake Bonneville. The modern delta width is a product of the lower Provo River essentially in its current alignment, yet without the constraints of channelization and development in the area. The minimum angle approach used in this analysis produces a delta plain width of 6,096 feet primarily as a function of delta length. Given the lobate shape of the boundary between the delta plain zone and the delta advancement zone, delta length does not change very much, even if the channel direction changes from a directly western direction to more of a northwestern or southwestern direction. The delta length (and therefore delta width) would be affected if water elevations in the lake change significantly (up or down), mostly depending on the gradient or slope of the distributary channel system at the new river/lake interface.

Biological Information

Additional design guidance regarding appropriate PRDRP delta design dimensions can be found in the biological literature and in biological monitoring results from other delta restoration projects. In 2008, large-scale efforts to restore delta habitat diversity were implemented on the Williamson River delta where it enters Upper Klamath Lake in Oregon (Erdman and Hendrixson 2010). This project, which initially began around 1996, has focused on restoring complex marsh/rearing habitat to improve survival and recruitment of larval and juvenile shortnose sucker (*Chasmistes brevirostris*) and Lost River sucker (*Deltistes luxatus*), which are endangered fish species with life history characteristics similar to those of the June sucker. The recent phase of the Williamson project involved breaching several miles of constructed levees to facilitate the restoration of 7,500 acres of wetlands. Post-project biological monitoring indicates that larval suckers appear to prefer the restored delta habitats over pre-existing wetlands along the lake shore (Erdman and Hendrixson 2010). Also, the abundance of larval fish captured in the restored delta in 2009 was greater than abundance along the shoreline of the lake (Burdick and Brown 2010; Erdman and Hendrixson 2010). Monitoring data also indicate that newly-hatched larval suckers primarily utilize vegetated and unvegetated shallow-water (less than 3 feet deep) environments in May and early June but then transition to deeper open water habitat by late July into August and September (Burdick and Brown 2010). Data from 2009 and 2010 found that the average density of suckers caught in shallow habitats was 4.3 fish per cubic meter.

Other biological research has focused more specifically on the use of off-channel floodplain habitats by larval and juvenile fish. In a delta ecosystem, these types of habitats are available both within the river/riparian floodplain zone and within the delta plain zone (Figure 16). One

study (Killgore and Baker 1996) that examined larval fish abundance on a river system in Arkansas, demonstrated a positive link between abundance of larval fish and the areal extent of inundated riparian floodplain. At the Williamson River delta, the observed seasonal shifts in habitat use by larval fish (Burdick and Brown 2010) suggest that access to habitats that provide a mix of vegetation types and inundation depths may be essential for fish to successfully transition through their early life stages.

Collectively, these various studies demonstrate that when larval fish are able to access shallow, warm, productive habitats, their likelihood of successfully recruiting to the adult population will be maximized. Furthermore, the larger the areal extent of such habitats, the greater the anticipated abundance of young fish. In the specific case of June sucker, shallow, warm, productive rearing habitat is currently lacking at the Provo River mouth. Modeling studies (Belk et al. 2004) indicate that June sucker population numbers may be particularly sensitive to the abundance and survivorship of June sucker during their first year of life. Models show that improved year-one survival rates of juvenile June sucker result in population increases that are approximately three to four times greater than comparable improved survival rates during later life stages. These modeling results suggest that investing in the maximum possible amount of restored rearing habitat may be highly worthwhile in terms of population growth and ultimate species recovery.

Recommended PRDRP Design Dimensions

As discussed above, deltas are extremely dynamic by nature, and as such, they require a substantially increased width to properly function both physically and biologically relative to the rivers that enter them. Based on examples of similar river deltas as described above, a delta plain width of 6,000 feet is recommended for the Provo River delta at Utah Lake. This width is appropriate for the size, shape and flow of the lower Provo River including the anticipated water levels in Utah Lake, and is based on a number of applicable examples of other deltas that have formed under similar conditions. This recommended delta width would likely allow for all formative and maintenance processes common to delta plains including deposition of alluvial sediments, and provides a large area of complex habitat for fish and wildlife.

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APPENDIX B: BIOLOGICAL MEMORANDUM

April 19, 2011

Memo to Project File, Provo River Delta Restoration Project

From Maureen Wilson, Utah Reclamation Mitigation and Conservation Commission

Subject: Development of Biological Screening Criteria for June Sucker Habitat-Workshop held February 23, 2011. Provo River Delta Restoration Project

Attending: C. Keleher, Utah Department of Natural Resources; C. Landress and K. Wilson, Utah Division of Wildlife Resources; M. Mills, Central Utah Water Conservancy District; M. Capone, U.S. Fish and Wildlife Service; K. Sim and B. Albrecht, Bio-West; R. Mingo, M. Wilson and M. Holden, Utah Reclamation Mitigation and Conservation Commission.

The workshop was held to develop biological screening criteria for the Provo River Delta Restoration Project alternatives. That is, based on June sucker recovery, how best to measure the degree to which different alternatives meet the Project purpose and need. Alternatives will be evaluated against the screening criteria, and those alternatives that rate high based on the screening criteria and that are also responsive to issues raised during public scoping, are recommended to be included for detailed analysis in the Environmental Impact Statement (EIS). Information discussed at the meeting may also be used into the design process.

Additional information from the Williamson River Delta Restoration Project in the Klamath Lake system, the June sucker life stage model developed by Belk et al (2004), the June sucker bioenergetics model from Landom et al (2010) and Utah Division of Wildlife Resources stocking records was also considered in the screening criteria development.

Background information

The restoration of larval and juvenile June sucker habitat in the lower Provo River was identified as a recovery action to minimize factors limiting recruitment of June sucker in the June Sucker Recovery Plan (USFWS 1999). Low-velocity, vegetated habitats have been identified as important for June sucker larval growth and survival. The development of these types of habitats on the tributary Hobble Creek, and in the Klamath Lake system, on the Williamson River delta for related lake suckers has resulted in increased larval growth and survival.

The Hobble Creek restoration project was completed in 2009. Hobble Creek monitoring data was discussed. The monitoring data represents a very small data set. Twelve ponds were evaluated: of these, 5 ponds were grouped based on the fish community present, and timing of connection to the main channel. June sucker were found in 3 of the 5 ponds. Timing of connectivity to the stream was seen as the most important variable for June sucker. The best sites for June sucker were ponds that were connected during larval drift in June, but disconnected from late June though mid-July. These ponds had submerged and emergent vegetation and woody debris. Vegetative cover was considered to

be intermediate or about 50% cover. The ponds are up to 6 feet deep; those that were at least 3 feet deep overwintered fish. Of the cover types, submerged vegetation was considered to be of most value to larval June sucker.

The Hobble Creek project focused on restoring a functioning river channel and connecting it to the lake and is most comparable to the portion of the proposed Provo River Delta Restoration project above the 4489 ft elevation. Here, the oxbow ponds, side channels, and off channel wetlands that have been successful at Hobble Creek should be incorporated. The 50:50 shallow-deep habitat ratio applies very well to this portion of the project, where shallow, warmer areas along with deeper areas with submerged vegetation to provide refuge and overwintering habitat are desired.

From the Williamson River delta monitoring reports, it is observed that the sucker larvae transition from near shore to open water offshore habitats at a standard length range of 40-90 mm. June sucker are observed to display schooling behavior at 20-40 mm.

Williamson River Delta Restoration Project Information

One of the biggest differences in sucker capture data noted since the Williamson River Delta Restoration has been the shift of larval suckers during the outmigration period from existing lakeshore fringe wetlands to the restored delta area wetlands. Sampling by pop up nets was done at depths up to ~ 1 m only. Based on sampling results for 2006-2010 period, larval suckers appear to prefer shallow water habitat types (<0.5 m depth, From C. Erdman, The Nature Conservancy). Within the upper Klamath Lake age-0 juvenile suckers were found to be habitat generalists that use vegetated and unvegetated shallow water habitats (0.5-3 m) (Burdick and Brown 2010). They frequently use shallow water (<1 m) in May and early June but moved to water 1.5-2.0 m deep in late July as the lake elevation declined. The deepest median water depth occupied by age-1 suckers was around 2 m (Burdick and Brown 2010). Survival of juvenile to spawning adult suckers (age 6-14 years) in this system is unknown.

Acres of anticipated wetland types based on water depths for the Provo River Delta Restoration Project alternatives are provided in Table 1. It should be noted that the data are based on existing topography from removing the dike along Utah Lake at the west edge of the Project Area, with a lake level of 4,498 feet Mean Sea Level (msl). The total area for the Provo River Delta Restoration Project full option is 700 acres (ac). The acreage for the 2009 Hobble Creek restoration project is 21 ac. By comparison, the Williamson River Delta restoration project in the Klamath River system, Oregon is a 7,500 wetland acre restoration project[1].

[1] The Williamson River Delta restoration project, undertaken by The Nature Conservancy and its partners since 2003, has restored wetlands and reconnected the lower six miles of the river to its former delta. This project was undertaken in part, to aid in the recovery of the endangered shortnose and Lost River suckers, lake suckers with life histories similar to the June sucker.

Table 1. Wetland area by project draft alternative at Utah Lake elevation of 4,489 feet msl.

Water Depth at Compromise		Project Draft Alternative							Vegetation Type Predicted
feet (+ or - 6")	meters (+ or - 0.155 m)	Full	North	Middle	South	4489 North	4489 Middle	4489 South	
0	0	67.8	18.2	41.5	52.9	67.8	67.8	67.8	wet meadow
1	0.3	114.2	60.4	67.4	89.7	114.2	114.2	114.2	wet meadow
2	0.6	132.5	120.1	93.4	80.1	132.5	132.5	132.5	emergent marsh
3	0.9	39.8	39.5	24.6	15.2	39.8	39.8	39.8	emergent marsh
4	1.2	4.8	4.7	3	2.1	4.8	4.8	4.8	submergent
5	1.5	1.1	0.9	0.8	1	1.1	1.1	1.1	submergent

<u>Extrapolation of restored Williamson River Delta area catch data</u>

shallow habitat available after restoration (m^2), with Upper Klamath Lake elevation of 41.41 feet: 4,294,896

mean depth of this area (m): 0.55

mean density of larval suckers (age 0) in this habitat type (2009 and 2010; suckers/m^3): 4.3

rough estimate of larval suckers occupying delta after restoration per year: 10,157,429 (C. Erdman, TNC 2011 pers. comm.).

The mean sucker density value of 4.3 larval suckers/ m^3 was used to estimate potential June sucker larval fish numbers, based on the acres of wetlands (water depths <0.5 m [1.6 ft], Table 1) for the Provo River Delta restoration alternatives[2]. Those alternatives with the maximum available shallow water

[2] The Williamson River Delta system does not have the fish predator pressure that Utah Lake does, so the application of the Williamson River Delta larval sucker density values to the Utah Lake system should be made with caution. These values may represent an overestimate for actual June sucker larval fish production, but they do identify those alternatives that have the potential for higher production than others.

habitat have the potential to support the highest number of larval June sucker: Full and all 4489 alternatives, North, South and Middle, respectively (see Table 2).

Table 2. Estimates of potential June sucker larval production, based on habitat area provided by project draft alternative.

Project Draft Alternative	Area with <0.5 m depth*		Mean Depth*	Mean sucker density	Estimated larval sucker production/year
	Acres	Meter^2	Meter	Number/m^3	
Full	246.7	998,360.36	0.45	4.3	1,931,827.3
North	180.5	730,458.23	0.45	4.3	1,413,436.7
Middle	160.8	650,735.09	0.45	4.3	1,259,172.4
South	169.8	687,156.83	0.45	4.3	1,329,648.5
4489 North	246.7	998,360.36	0.45	4.3	1,931,827.3
4489 Middle	246.7	998,360.36	0.45	4.3	1,931,827.3
4489 South	246.7	998,360.36	0.45	4.3	1,931,827.3

*This mean depth is based on the average depth of areas 1 and 2 ft deep at Utah Lake compromise level (4498 ft elevation msl) from Table 1.

June sucker life stage model

A sensitivity analysis of a June sucker life stage based matrix model was conducted to determine the influence of each component of the model to June sucker population growth (Belk et al 2004). The life stage model used 7 stages to characterize the June sucker life cycle. These stages were based on size, but also corresponded to age or age classes (Belk et al 2004). The sensitivity analysis results indicated that the transition probability (survival) for stage 1 (age-1, see Table 3) June sucker is the most influential on population growth rate followed by the survival probability of the last stage (ages 20+). Efforts directed toward increasing survival of the youngest and oldest age classes will yield the largest proportional increases in population growth rate. (Belk et al 2004).

It should be noted that the life stage model has no predictive power. That is, it should not be used to extrapolate to an end population number with any confidence (Mark Belk BYU, 2011 pers. comm.) It

was used to evaluate the population response, with manipulation of survivability rates or other parameters, such as a starting population number, given actions such as habitat improvement.

Table 3. June sucker life stage model definitions and survival rates used in this discussion.

Model life stage	Age class	Assigned survival rate
Stage 0	From egg to July – Aug, age-0 (ie, first 1-2 months); larval sucker (see Shirley 1983)	0.0005, consistent with Klamath system and cui ui sucker estimates
Stage 1	July-Aug, age-0 until May-June of the next year, age-1; juvenile sucker (see Shirley 1983)	0.3459

The life stage model size-specific fecundity rates used are from razorback sucker data and were 75,000 eggs/female for ages 12-19 and 82,000 eggs/female for ages 20+ (Belk et al 2004).

If there is a starting population N vector of 1.9 million age-1 suckers (from Table 2 above, and based on a lake level at 4489 ft elevation, msl), with the model survival rates, and if there is a stable age distribution, then the model indicates that it would take approximately 48,000 reproducing adults to produce 1.9 million offspring.

With an increase in rearing habitat quantity, one would expect an increase in the survival rate of Stage 1. When adjusted survivability rate-based scenario model runs are made, if small increases are made to the Stage 1 survival rate, then the population growth rate, λ, increases to a positive value (ie., > 1)and June sucker population increases may be observed. However, as the June sucker is a long-lived, slow growing fish, population responses will take time. Without population augmentation through stocking of 8 inch (200 mm) fish, no rapid growth rate of the population is expected to occur.

Bioenergetics model estimate

A model estimate of June sucker populations based on catch per unit estimates of fish sampled in Utah Lake (Landom et al 2010) indicates that there may be, at present, approximately 170,000 adult June sucker in Utah Lake. According to Division of Wildlife Resources records, over 255,000 8 inch June sucker have been stocked into Utah Lake since 1994 and of these, over 204,000 have been stocked since 2007, after the new recirculation system and diet improvements were implemented (DWR Stocking Records, Fisheries Experiment Station, 2011).

Recommendations

Based on the group discussion and the additional information described above, the workshop participants support and recommend the screening criteria presented in Table 4. The project focus should be on providing habitat for the larval and juvenile life stages (model Stage 0 and Stage 1 as defined in Table 3); this is where the June sucker population bottleneck exists. Overall, the recommendation was made to maximize opportunities within the Project Area.

The consensus of the group was that a full build out use of the 700 ac would not provide enough habitat to support a self-sustaining June sucker population on its own. Connectivity of the restored delta area to the extant Utah Lake is vital to allow stage 1 June sucker access to reach deeper water habitats as they increase in size. Habitat development should also incorporate seasonal variation: early in the year – shallow, warmer areas are of higher value. Later in the year, the June sucker need increased water depths with increased dissolved oxygen levels. Annual variability should also be incorporated to include a suite of habitats. There is a need to use the maximum area available to provide this habitat heterogeneity.

Generally, a preferred June sucker-habitat model pattern was described as one that would support larval June sucker drifting downstream from spawning/incubation sites (ie. Stage 0), and being pushed out into emergent shallow warm temperature areas to maximize early growth, with access to deeper areas with submerged vegetation for cover. The group concurred that 5-7 foot water depths are also important. If not available within the restored delta itself then they would need to be available-with connection to the lake as it recedes through the growing season. If deeper water ponds are constructed within the delta restoration area, depths adequate to overwinter fish, with some inflow, are preferable.

Of the habitats available under project alternative options, the wet meadow with water depths of 0 at Utah Lake compromise (elevation 4,489 feet msl, Table 1) is seen to have the least value for June sucker recovery. Turbidity levels are much lower in the restored areas of Hobble Creek than in Utah Lake. In the proposed project, where emergent vegetation can be established, the water would be expected to be less turbid as well.

Table 4. Recommended biological screening criteria for development of Provo River Delta Restoration alternatives.

Criteria description	**Application of criteria to considered alternatives, or basis of ranking**
Abundance of shallow habitats (water depths <2 feet)	Alternatives with the greatest abundance of these habitats, and the ability to maintain them through the summer given receding lake levels, should be ranked higher and recommended for detailed analysis in the EIS.
Abundance of deeper habitats (water depths ≥ 2 feet, with submerged vegetation)	Alternatives with the greatest abundance of these habitats, and the ability to maintain them through the summer given receding lake levels, should be ranked higher and recommended for detailed analysis in the EIS.
Abundance of deeper habitats (water depths ≥ 2 feet, with emergent vegetation)	Alternatives with the greatest abundance of these habitats, and the ability to maintain them through the summer given receding lake levels, should be ranked higher and recommended for detailed analysis in the EIS.
Connectivity of shallow and deeper habitats	Alternatives with the highest amount of connectivity of all habitat types, or the least amount of habitat isolation should be ranked higher and recommended for detailed analysis in the EIS.
Delta width or area	Those alternatives with the best ability to provide a mosaic or variety of the above habitat types under a range of water year conditions should be ranked higher and recommended for detailed analysis in the EIS.

Note that the habitat abundance recommendations apply to the delta area that is located below the 4489 ft elevation msl, at compromise.

Design Considerations

There is a general lack of deeper habitat in the mid to southern end of the Provo River Delta Restoration project area. Any alternative that does not include the northern portion of the project area may need to include the excavation of deeper areas. It is very important that suckers have the ability to leave the

delta area and enter the lake---but it is not clear what the connection between the delta and lake will be. It is important that cover be provided within the connection (eg., channel) to provide protection from predators as the suckers leave the delta and enter the lake.

The question of whether the delta could be perched above the lake, as Provo Bay is, and may retain some water levels as the lake level recedes was discussed. The question posed was, would this be a good option? If the water levels retained by a perched delta as the lake recedes provide the connectivity to deeper water areas for maturing June sucker discussed above, it would be a preferred option.

Other considerations to be made: trail system, the existing channel, aesthetics of the area. It was determined that the use of the existing channel would not benefit June sucker and sport fish use may be of higher value to the local community.

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