DRAFT

Environmental Restoration and Protection Areas Feasibility Study: Comal Springs

Prepared for:

Edwards Aquifer Recovery Implementation Program
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1.0 INTRODUCTION

The Edwards Aquifer Recovery Implementation Program (EARIP) is pursuing a Habitat Conservation Plan (HCP) for the protection of the threatened and endangered species in the Comal and San Marcos springs/river ecosystems. To ensure the protection of these species in the wild, EARIP will likely need to consider measures above and beyond currently established practices. One such measure is Environmental Restoration and Protection Areas (ERPAs) within the Comal and San Marcos springs/river ecosystems. Formerly termed "Intensive Management Areas (IMAs)", the name was changed to be more representative of the function of the measure. An ERPA consists of both restoration and protection activities pursuant to the threatened and endangered species and their habitats in these aquatic ecosystems.

Guyton (2004) took a cursory look at several measures for maintaining habitat for the threatened and endangered species during times of severely reduced recharge. Several strategies appeared promising but the response of the biological community is often unpredictable, and thus without adequate study it was not possible based on Guyton (2004) to determine the impacts and benefits of such alternatives to protect habitat for these species. This feasibility study evaluates several alternatives in greater detail with a focus on the following three key components that are imperative in the EARIP decision making process.

1) *In-situ* refugia – maintain habitat and endangered species within the springs/river ecosystem(s) under severely reduced recharge conditions;
2) Adaptive management – conduct applied research to explore low and high flow responses of the endangered species and their habitats, in order to better inform future (adaptive) management decisions; and
3) Mitigation – restore and maintain habitats that will be or have been historically reduced for some reason, as a trade-off for some level of take that may occur as part of the proposed HCP action.

Unless considerable reductions in groundwater withdrawal can be accomplished during extensive drought periods, *in-situ* refugia may provide one of the best measures for protection of the species and their habitat in the wild during these extreme conditions. Applied research will prove extremely valuable and informative for the EARIP adaptive management plan and continued re-evaluation of HCP measures and groundwater withdrawal requirements. The low-flow response of the threatened and endangered species and their habitat in the wild is a critical question that remains unanswered because biological data under extremely low-flow conditions in these systems are non-existent. Restoration of habitat in particular areas of these systems in advance of any extreme periods is a form of mitigation that will enhance the opportunity for habitat maintenance and survival of the species in the wild when such extreme periods occur. Therefore, ERPAs are directly applicable to EARIP decision making as it is evident that under the proposed bottom-up approach additional measures (beyond springflow reductions) will be required to protect species and their habitat in the wild.

The purpose of this feasibility study is not to implement a pilot project or research effort, but to conduct the necessary steps to evaluate an ERPAs probability of success both biologically and economically. As groundwater modeling results continue to demonstrate that the most severe reductions to flow under the current Senate Bill 3 (SB3) legislation will occur at Comal Springs, the focus of the feasibility study is on the Comal Springs/River ecosystem. However, during the EARIP process it was also determined that a cursory evaluation of potential ERPAs at San Marcos Springs/River would be conducted in this assessment and included as a separate section. The Comal Springs/River detailed evaluation focuses on existing conditions (Section 2); stakeholder interaction (Section 3); system-wide evaluation (Section 4); component description and conceptual design (Section 5); alternatives formulation and evaluation (Section 6); and concludes with recommendations (Section 7). Section 8 presents a cursory evaluation of the potential for ERPAs in the San Marcos Springs/River ecosystem with the focus on need and biological feasibility.

All analysis and recommendations presented in this feasibility study are based on the proposed EARIP flow regime as follows. The EARIP flow regime is presented as an overlay on historical flow conditions with permitted pumping which is forced to maintain a 30 cubic feet per second (cfs) daily minimum not to exceed 6 months with 80 cfs daily minimum flows for 2 to 3 months following each extended low-flow event. Additionally, this overlay assumes that these low-flow conditions would only happen periodically over time and not be repeated every few years. We are also making the assumption that to balance this minimum flow condition, a long-term average flow condition (yet to be determined) will be incorporated into the flow regime with the goal of maintaining or increasing populations or habitat over time. This long-term average is not the EARIP Science Subcommittee (SSC) long-term average recommendation at this time, as the SSC recommendation did not include any management or mitigation measures beyond the status quo (SSC 2009). Finally, the evaluated EARIP flow regime in this analysis is NOT the EARIP bottom-up approach discussed at the January 2011 EARIP Steering Committee meeting. The EARIP bottom-up approach when modeled using historical hydrology and fully authorized pumping does create a hydrological time series over the period of record, which could be considered a flow regime. HDR has modeled this scenario and provided monthly results to the EARIP. Additional analysis is currently underway to assess the bottom-up approach and resulting hydrological time series and will be reported on in the EARIP HCP.

2.0 ENVIRONMENTAL BACKGROUND

Comal Springs gush forth from the Edwards Aquifer through a series of spring openings located along the Balcones Escarpment near New Braunfels, Texas. Collectively, Comal Springs represent the largest spring system in Texas, and have the greatest mean discharge of any springs in the southwestern United States with an average annual discharge of approximately 284 cfs (USFWS 1996). Comal Springs has stopped flowing only one time in recorded history, from June 13 to November 4, 1956, during the most severe drought recorded for this region (USFWS 1996). The perennial flow of constant temperature water (≈23˚C) emanating from these springs has created a diverse and unique ecosystem in the relatively arid environment of central Texas. Due to the island-like uniqueness of this habitat, many of the species found in Comal Springs are not found elsewhere. In fact, four Federally-listed endangered species and an endemic salamander are found within the Comal Springs/River ecosystem.

2.1 FOUNTAIN DARTER - ENDANGERED

The fountain darter *Etheostoma fonticola* is a small fish endemic to the upper San Marcos and Comal Rivers. Fountain darters are one of the smallest darter species, with adults averaging approximately one inch (25 mm) in standard length. They feed on small aquatic insects and crustaceans. Fountain darters spawn adhesive eggs which are attached to submerged vegetation. Spawning occurs year around with peaks in reproduction occurring seasonally. Fountain darters are thought to have been extirpated from the Comal River when the springs ceased flowing during the 1950's. However, 457 individuals from the San Marcos River population were reintroduced in the mid 1970's (Schenck and Whiteside 1976, Linam et al. 1993). Currently, fountain darters occupy the entire Comal River from its headwaters near Landa Lake to its confluence with the Guadalupe River. However, habitat conditions vary throughout the system, with certain areas harboring higher densities of fountain darters than others. Substantial information on habitat use of fountain darters has been gained during the 10-year ongoing Edwards Aquifer Authority (EAA) Variable Flow Study (BIO-WEST 2000a,b – 2010a,b).

In the Comal Springs/River ecosystem, fountain darter populations are largely influenced by aquatic vegetation. Density of fountain darters varies widely across vegetation types. Native vegetation such as bryophytes and filamentous algae which provide thick cover near the substrate tend to yield the highest fountain darter densities (Figure 1). These vegetation types also harbor high densities of amphipods and other aquatic invertebrates, which are the main food source of fountain darters. Fountain darters are also common in other native vegetation types with complex leaf structures such as *Ludwigia* and *Cabomba*. Exotic vegetation types (*Hygrophila* and *Ceratopteris*), and native plants with simple leaf structures (*Vallisneria* and *Sagittaria*) harbor fewer darters. Fountain darters are seldom found over open substrate with no aquatic vegetation.

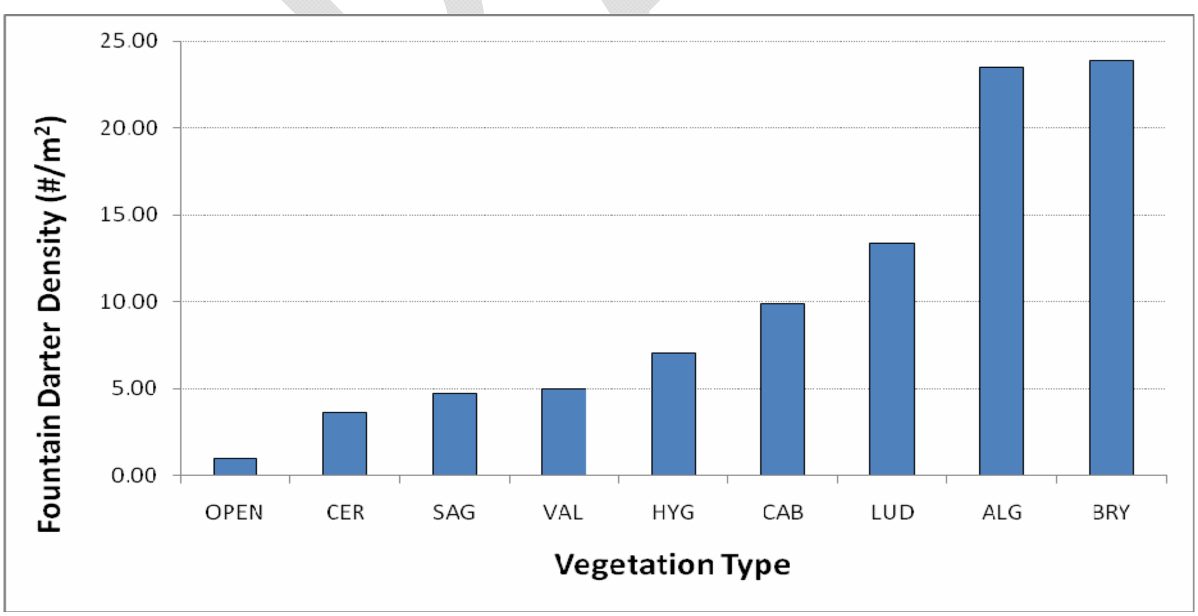


Figure 1. Density of fountain darters collected by vegetation type in the Comal Springs/River ecosystem from 2000-2009. CER – *Ceratopteris*, SAG – *Sagittaria,* VAL – *Vallisneria*, , HYG – *Hygrophila*, CAB – *Cabomba*, LUD – *Ludwigia*, ALG – Filamentous Algae, BRY – Bryophytes.

Throughout the 10-year EAA Variable Flow study, aquatic vegetation has remained abundant in most study reaches, with the largest impacts resulting from scouring associated with sporadic flood events. This scouring is intensified in areas where the channel is constricted (i.e., Upper Spring Run and New Channel), and is less severe in areas where flow is dispersed laterally (i.e., Landa Lake). The vegetation types that are the most susceptible to scouring are those that are not strongly rooted, such as filamentous algae and bryophytes. Unfortunately, these vegetation types also support the highest densities of fountain darters. However, scouring typically results in a temporary reduction in total aquatic vegetation coverage after which many plant types quickly respond with rapid re-growth during the period of higher flows following a flood event.

Low flows have been uncommon during the 10-year study period. However, from 2007 to 2009 central Texas experienced an extreme drought that resulted in a Critical Period Low Flow sampling event on the Comal River in 2009. The lowest total discharge recorded during 2009 was 158 cfs, and flows were below 200 cfs for 83 consecutive days. This resulted in the lowest flows experienced since late summer 2000. The most obvious effect of sustained low springflows on fountain darter habitat conditions was the proliferation of green algae in the Upper Spring Run reach. Areas typically occupied by bryophytes under higher flows became blanketed by green algae. Despite the less-than-optimal habitat conditions observed in summer 2009, no drastic changes in fountain darter abundance or density were noted (BIO-WEST 2010a).

2.2 COMAL SPRINGS RIFFLE BEETLE

The Comal Springs riffle beetle *Heterelmis comalensis* is a small (≈ 1/8 inch long) aquatic beetle in the family Elmidae found at Comal Springs and San Marcos Springs (Arsuffi 1993). It inhabits gravel and cobble substrates within and around spring openings, where it is thought to feed on periphyton and attached algae. Larvae of the Elmidae family create terrestrial pupal chambers in soil and detritus. After emergence adults reenter the water and reproduction usually occurs subsequently (Arsuffi 1993). Other genera in this family are able to tolerate environmental extremes (low dissolved oxygen and high temperature). Such tolerance may have contributed to survival of the Comal Springs riffle beetle during the drought of the 1950's, when Comal Springs stopped flowing for several months (Arsuffi 1993). Based on laboratory observations, Comal Springs riffle beetles are also known to retreat into interstitial spaces within the substratum as upwelling flows decrease (BIO-WEST 2002c). This may have also contributed to their survival during the drought of record.

As part of the EAA Variable Flow study, the Comal Springs riffle beetle population is monitored at three spring upwelling areas in and around Landa Lake. Riffle beetle monitoring occurs in spring seeps within Spring Run 3, in several springs along the western shoreline of Landa Lake, and near springs upstream of Spring Island. To monitor riffle beetles, a cotton lure is placed near spring upwellings, covered with several large rocks, and left out for four weeks. Attached algae and various microorganisms which grow on the lure attract riffle beetles and other invertebrates. After four weeks, the lures are removed and invertebrates are identified. Table 1 shows the total number of Comal Springs riffle beetles captured per cotton lure during each sampling event from 2004 through 2010. Similar to fountain darter abundance data, this data is variable across sampling events. However, data suggests a relatively stable long-term trend in abundance.

Table 1. Total number of Comal Springs riffle beetles (*Heterelmis comalensis*) collected with cotton lures (adults and larvae) for each EAA Variable Flow sampling date from 2004 – 2010.

Sample Period	Spring Run 3	Western Shore	Spring Island	Total
May-June 2004	88	83	122	**293**
August 2004	169	143	90	**402**
Nov-Dec 2004	170	175	146	**491**
April 2005	119	121	121	**361**
Nov-Dec 2005	262	201	185	**648**
May-June 2006	256	195	160	**611**
Nov-Dec 2006	185	92	125	**402**
May-June 2007	59	161	119	**339**
Nov-Dec 2007	204	83	132	**419**
May-June 2008	155	139	156	**450**
Nov-Dec 2008	144	133	227	**504**
May-June 2009	136	226	74	**436**
Nov-Dec 2009	72	56	198	**326**
May-June 2010	53	110	20	**183**
Nov-Dec 2010	298	264	104	**666**
Total	**2,370**	**2,182**	**1,979**	**6,531**
Average	158.0	145.5	131.9	458.3

2.3 COMAL SPRINGS DRYOPID BEETLE

The Comal Springs dryopid beetle *Stygoparnus comalensis* is the only stygobiontic (subterranean aquatic) beetle in the Dryopidae (long-toed water beetles) family. They are small weakly pigmented beetles (≈ 1/8 inch long) with non-functional eyes and thin skin. Comal Springs dryopid beetles have been collected from Comal Springs, Comal County and Fern Bank Springs in Hays County. The feeding and reproductive habits of this organism are unknown. Adults are thought to feed on biofilms scraped from various surfaces. The extent of their range in the subterranean realm of the aquifer is not well understood, but based on the fact that the beetles have not been collected from deep wells, they may be confined to small areas of the aquifer near spring openings. These beetles use atmospheric oxygen to produce a bubble that is used to breathe (act as a gill) underwater. Dissolved oxygen (DO) from the water diffuses into this bubble allowing the beetles to remain underwater for extended periods of time (Arsuffi 1993). As a result, DO levels in the water can have an impact on their survival. The surrounding terrestrial environment may also be important because the larvae are thought to inhabit soil and debris near the subterranean orifices (Arsuffi 1993). Since this species is subterranean and the EARIP flow regime being considered maintains springflow at all times, proposed ERPA's are not designed to influence Comal Springs dryopid beetle habitat or populations. Although uncertainty exists in dealing with rare subterranean species, maintenance of sufficient springflow and protection of aquifer water quality is thought to provide sufficient subterranean aquatic habitat for persistence of this species (SSC 2008, 2009).

2.4 PECK'S CAVE AMPHIPOD

Peck's cave amphipod *Stygobromus pecki* is a subterranean aquatic crustacean in the family Crangonyctidae. This species, which has no eyes and no pigment, has only been collected from Comal Springs and nearby Hueco Springs. Similar to the Comal Springs dryopid beetle, the extent of their habitat in the subterranean realm of the aquifer is unknown, but they have only been collected near spring openings. There is very little data on this species, but some things may be inferred from other species of amphipods with a subterranean life cycle. Although its feeding habits are unknown, it likely feeds on dead organic matter transported from above ground areas (Arsuffi 1993). Cold-water species of amphipods exhibit long life cycles and reduced fecundity (Thorp and Covich 1991) and do not likely survive for long, once outside the aquifer. Since this is a subterranean species, ERPA's are not designed to influence the Peck's Cave amphipod. Although uncertainty exists in dealing with rare subterranean species, maintenance of sufficient springflow and protection of aquifer water quality is thought to provide sufficient subterranean aquatic habitat for persistence of this species (SSC 2008, 2009).

2.5 COMAL SPRINGS SALAMANDER

Although not Federally-listed, the Comal Springs salamander *Eurycea* sp. is a small (adults are approximately 60 mm [2.4 inches]) aquatic salamander species endemic to Comal Springs. Like other species of *Eurycea*, they are neotenic, meaning that they remain in the larval condition with external gills throughout their life, and never metamorphose into a lunged terrestrial form. The Comal Springs salamander was once considered the same species as the endangered San Marcos salamander *Eurycea nana*. Comal Springs salamanders are only found in close proximity to spring upwellings in the vicinity of Landa Lake, and in the spring runs above Landa Lake. They are typically found hiding under larger rocks, and are most abundant in spring areas containing attached bryophytes. Siltation of spring areas usually leads to a decrease in the number of salamanders observed. Although no detailed life history studies have been conducted on the Comal Springs salamander, the closely related San Marcos salamander feeds on aquatic insect larvae, small crustaceans, and small snails, and is thought to reproduce year around with a possible peak in the spring. Although manipulating habitat for the Comal Springs salamander is not the direct focus of ERPAs, this species occupies habitats in close association with the Comal Springs riffle beetle. During opportunities to create habitat or research opportunities for the Comal Springs riffle beetle, the requirements for the Comal Springs salamander should also be explored.

3.0 STAKEHOLDER INTERACTION

As part of the ERPA feasibility study, BIO-WEST was charged with informing, seeking input from, and updating EARIP stakeholders as the feasibility study was conducted. Stakeholder meetings were held, site visits were conducted, and several presentations were given to a variety of EARIP stakeholders as summarized in Table 2. At each initial stakeholder meeting, the project team presented a description of what the feasibility project entailed, answered questions to the degree possible, and sought input regarding existing conditions or additional items for consideration.

The activities in Table 2 led to excellent discussions, information being provided to the project team and questions being asked that guided the overall analysis of feasibility. Examples of some specific concerns and questions brought to the project team's attention at these meetings included:

- Could water be supplemented from wells during prolonged drought periods?
- Concern about the potential for increased gill parasite concentrations within the ERPAs during periods of low-flow.
- How would security for any constructed structures be addressed?
- How could the experimental component of ERPAs be used to guide adaptive management decisions both before and after experimentation?
- What water rights permits, if any, would be needed for ERPAs?
- How would ERPAs potentially affect population genetics of the endangered species?
- How would the endangered invertebrates be protected during times of extreme drought?
- Would water temperatures significantly increase in any pipelines used?
- Would carbon dioxide (CO_2) need to be added to any re-circulated water for aquatic vegetation growth?
- What damage would flooding as experienced in June 2010 cause to the proposed ERPAs?

During meetings with the City of New Braunfels and New Braunfels Utilities important information was gathered regarding the existing property, management of flows, and structures within the project area that might be used for future supplementation or manipulation of spring flows in the Comal system.

3.1 UPPER SPRING RUN HEADWATERS

New Braunfels Utilities owns a parcel of land at the headwaters of the Comal River that is being considered for education outreach purposes. This site also contains 3 wells with a cumulative pumping capacity of a few cfs.

Table 2. List of Stakeholder meetings, site visits, and presentations during the Study Period.

Stakeholders	Activity	Date	Location
Schlitterbahn	Stakeholder Meeting	September 18, 2009	New Braunfels
U.S. Fish and Wildlife Service - National Fish Hatchery and Technology Center	Site Visit	January 26, 2010	New Braunfels
San Antonio Water System	Stakeholder Meeting	February 17, 2010	San Antonio
U.S. Fish and Wildlife Service Texas Parks and Wildlife Department Habitat Conservation Plan Project Team San Antonio Water System Guadalupe/Blanco River Authority San Marcos River Foundation	Discussion following Habitat Conservation Plan Biological Modeling Group Meeting	February 18, 2010	San Marcos
City of New Braunfels	Site Visit / Stakeholder Meeting	February 25, 2010	New Braunfels
Guadalupe/Blanco River Authority	Stakeholder Meeting	March 8, 2010	Seguin
New Braunfels Utilities	Stakeholder Meeting	March 26, 2010	New Braunfels
Edwards Aquifer Authority	Stakeholder Meeting	April 13, 2010	San Antonio
City of New Braunfels	Stakeholder Meeting	July 19, 2010	New Braunfels
EARIP Steering Committee	Presentation	March 11, 2010	San Antonio
EARIP Steering Committee	Discussion	June 29, 2010	Kerrville
EARIP Steering Committee	Presentation	July 28, 2010	San Antonio
EARIP Science Subcommittee	Presentation	September 1, 2010	San Marcos
Technical Advisory Group	Presentation	September 2, 2010	San Antonio
U.S. Fish and Wildlife Service Texas Parks and Wildlife Department	Site Visit / Stakeholder Meeting	October 13, 2010	New Braunfels
U.S. Fish and Wildlife Service Texas Parks and Wildlife Department	Stakeholder Meeting	November 30, 2010	San Marcos

3.2 SWIMMING POOLS NEAR LANDA LAKE

The City of New Braunfels operates two swimming pools near Landa Lake at the head of the Old Channel. One pool is supplied with water from the City system, while the other uses spring water sourced from Landa Lake. Both pools have a typical annual operating period between May 1 and October 1. Once filled, the spring fed pool maintains approximately 5 cfs of flow-through during normal operations. Water is discharged from the spring fed pool through a 36" diameter culvert with gate valve directly into the Old Channel. The natural unlined pool bottom often leads to the pool water getting turbid during periods of heavy use. Water temperature because of solar insolation is affected by the wide shallow geometry of the water body. During once-per-week (Tuesday or Wednesday) pool draining and cleaning operations, the pool is drained (over the course of a couple hours), scrubbed, filled, drained, and re-filled for use on the following day. The pool is not chlorinated and approved chemicals/neutralizers are used in the cleaning operation. Some consideration of unknown levels of components in the pool discharge water (e.g., suntan lotion or other products used by outdoor swimmers) may be warranted as part of the future permitting-level environmental assessment.

3.3 OLD CHANNEL CULVERTS

Landa Lake is connected to the Old Channel by a 48-inch culvert (Figure 2), and two 24-inch Culverts (Figure 3). The lake-side invert elevation of the 48-inch culvert is approximately 611.4 feet (ft) and the two 24-inch culverts are installed at a lake-side invert elevation of approximately 618 ft (Guyton 2004). A fourth smaller culvert directs flow into the flowthrough swimming pool, and ultimately into Old Channel as described above. The dual 24-inch culverts were the sole source of water directly into the Old Channel until the late 1990's and have a capacity of approximately 40-50 cfs. The new 48-inch culvert was installed at upstream invert 614.00 ft and downstream invert of 611.14 ft. The additional capacity (Figure 2) of the new culverts allows for considerably higher flows to the Old Channel. At this time, no active flow management occurs except for cleaning of culvert inlet screens. Flow through the culverts can be impacted by vegetation accumulation on upstream grates. The City of New Braunfels clears vegetation and trash from the culvert gates approximately once per week from March through October and on an as needed basis the remainder of the year. The June 2010 flooding has caused considerable erosion around the culvert openings that will need attention to ensure the proper continued operation of these structures (Figure 4).

Figure 2. New 48-inch culvert from Landa Lake to the Old Channel

Figure 3. Old set of 24-inch culverts with limited capacity in the Old Channel.

Figure 4. Damage to new culvert from June 2010 flood (photo courtesy of Nathan Pence).

3.4 NEW CHANNEL STRUCTURES

The LCRA weir (Figure 5) which includes a bypass culvert is located across from the City of New Braunfels Park office. The elevation of the weir is 619.28 ft and no active flow management occurs at the weir and gate valve. The gate valve does have 80-90 cfs capacity to pass water but the valve is typically closed. As the lake stage becomes lower, flow is naturally controlled by these outlet elevations in the Old and New Channels. Comal spring flow would stop at New Channel dam first (at 619.28 ft) and then flow would be directed towards the lower Old Channel culverts (Guyton 2004).

New Braunfels Utilities own the dam/hydropower unit in the old mill race (just above the confluence with Dry Comal Creek). If managed, this facility can back up water in the New Channel to the LCRA weir. The hydropower facility was taken offline during the 1980s primarily because pulling weeds off of intake rake was too labor intensive compared to generation capacity. The facility needs approximately 100 cfs to generate with a capacity of 300 cfs at full operation.

Figure 5. Reconstructed LCRA weir across from Landa Park office.

3.5 EARIP ERPA FUTURE SUBCOMMITTEE OR REVIEW TEAM

During the October 13th site visit with USFWS and TPWD agency personnel, BIO-WEST proposed the concept of an EARIP ERPA subcommittee or review team to oversee ERPA activities. A concern repeatedly raised since the concept of *in-situ* refugia, IMAs, and ERPAs was first proposed, and raised again during the October 13th site visit is: If ERPAs are established and proven to be successful, what would keep the water users from pumping down to these levels at all times? First of all, if ERPAs were established and proven to be successful, the added protection to the species and knowledge learned through applied research would both greatly benefit the very species the EARIP stakeholders are charged with protecting. Secondly, the concern regarding massive water withdrawals following such establishment and proof of success is completely unwarranted for the following reasons. In order for the USFWS to approve an HCP, one would assume that a flow regime that would "protect" the threatened and endangered species and their habitat would need to be obtainable. One would also assume based on EARIP SSC guidance that this flow regime would be a regime and not just a minimum flow. Additionally, allowing some sort of maximum pumping at all times completely contradicts the reason that ERPAs are being developed in the first place. ERPAs are additional protection measures during periods of extreme conditions to allow a measure of safety. They are not designed, nor proposed as a continuous measure.

Additionally, concerns have been raised by EARIP stakeholders and reiterated at the site visit regarding the nature of the studies, who would do the work, and who would interpret the results.

It is anticipated that the HCP applicant(s) would be responsible for the implementation of the HCP components and adaptive management plan. It is also anticipated that the EARIP SSC would remain in some fashion to peer review future work being conducted or proposed associated with the HCP and adaptive management plan. In addition to those entities, it may be valuable to have an ERPA subcommittee or third-party independent review team consisting of scientists thoroughly familiar with the specific systems and the scientific process of applied research. Anticipated roles for this group would include overseeing activities/studies to be conducted at any implemented ERPAs as well as being the first entity to review and interpret study results from any applied research activities. Subsequently, this subcommittee was discussed at the November 11, 2010 Steering Committee meeting but was not formally established. An informal gathering of stakeholders interested in discussing the potential ERPA subcommittee or review team met with BIO-WEST on November 30, 2010.

4.0 ERPA SYSTEM EVALUATION

Determining the best locations for placement of potential ERPAs or various ERPA components in the complex and highly modified Comal Springs/River ecosystem required careful consideration of numerous factors. Before design details could be discussed, a systematic process for evaluating feasible locations of various ERPA components included a system-wide analysis of several key factors including but not limited to habitat abundance and quality, recreation, flooding, land ownership, and security. The Comal system ERPA analysis focuses on habitat restoration and protection for the fountain darter and Comal Springs riffle beetle. Habitat conditions for each species in each major section of the system are discussed below, along with notes regarding recreational impacts and flooding.

4.1 COMAL SPRINGS/RIVER SECTIONS

4.1.1 Upper Spring Run Reach

At times, large numbers of fountain darters inhabit the Upper Spring Run Reach, which extends from the mouth of Blieders Creek to the Spring Island area (Figure 6). Bryophytes located in the upper portion of this reach often contain relatively high densities of fountain darters under typical flow conditions. However, the springs at the top of this reach are at the highest elevation of any of the major springs, and are the first to stop flowing as aquifer levels decline. Since these springs are the first to be affected, habitat conditions can suffer during lower than average flow periods, as witnessed in summer 2009 when most of the high-quality bryophyte habitat within this reach was covered with green algae. No Comal Springs riffle beetles have been collected from this reach.

Flooding resulting from localized runoff rushing down Blieders Creek can also significantly alter habitat conditions within this reach. During the June 2010 flood event, high flows from Blieders Creek resulted in intense scouring within this reach. All aquatic vegetation (except for a few small patches of strongly-rooted *Sagittaria*) was removed during this event, leaving only bare gravel substrate. Low to moderate amounts of recreational activity (mainly swimming and fishing) occur within this reach. Heidelberg Lodges, located at the junction of Blieders Creek and the Upper Spring Run Reach allows swimming and fishing, and local homeowners are often seen canoeing, kayaking, or fishing. However, since there is no public access to this reach, recreational impacts are relatively minor compared to areas further downstream.

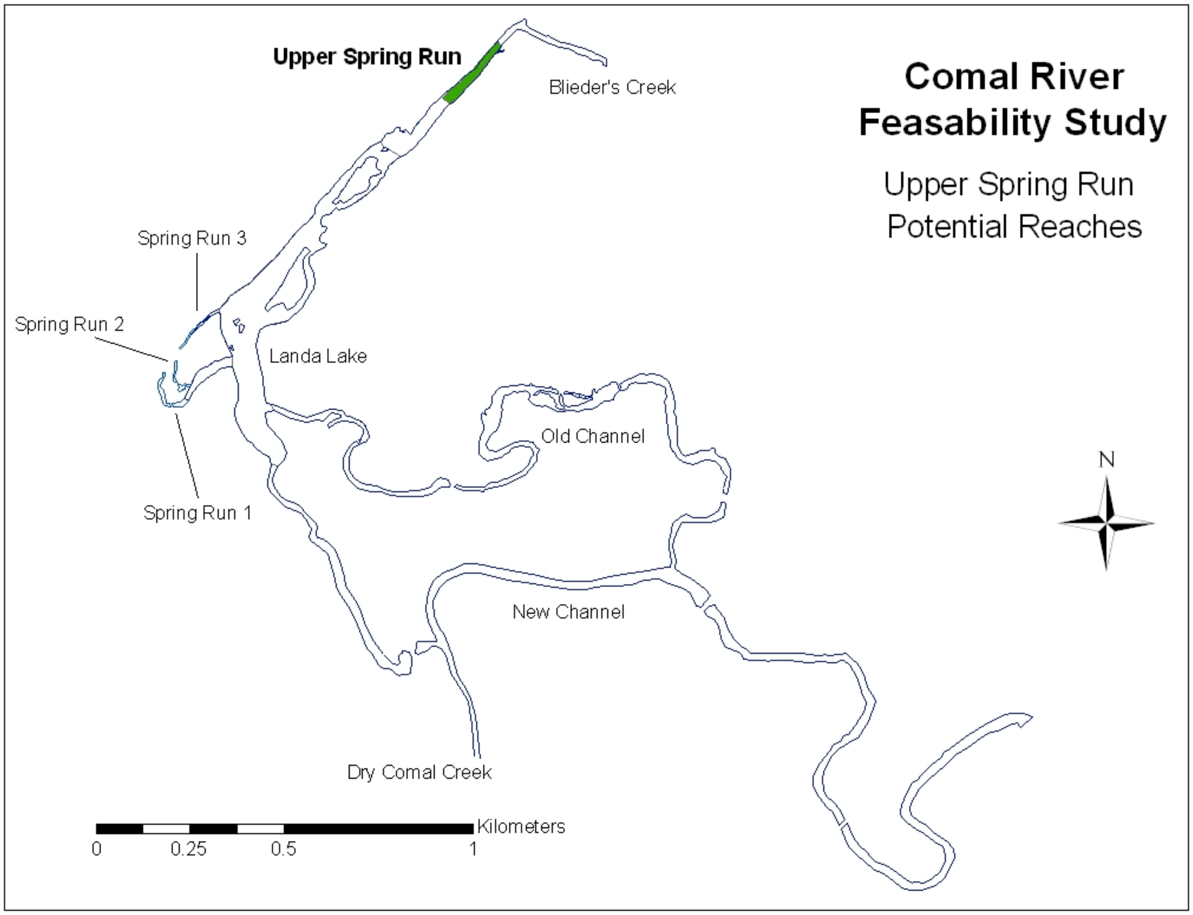


Figure 6. Upper Spring Run Reach – Comal System

4.1.2 Landa Lake (Spring Island Area to Landa Lake)

The upper portion of Landa Lake is labeled Spring Island with the main portion of the lake being labeled Landa Lake (Figure 7). The Spring Island area contains high-quality habitat for both fountain darters and Comal Springs riffle beetles. Although fountain darters are found throughout this area, the highest densities are found in the bryophyte covered gravel immediately upstream of Spring Island. Several spring upwellings are located on the stream bed in this location, which also provide habitat for Comal Springs riffle beetles and Comal Springs salamanders. Spring upwellings are also located in the eastern channel of the river, and two small spring runs emerge from a spring located on the main island. Although habitat quality will likely decline in this reach under critically low flows, the additional springs and upwellings in this area will maintain quality conditions longer than in the Upper Spring Run Reach.

Flooding from Blieders Creek can also have significant impacts on the Spring Island area. During the June 2010 flood event, significant scouring occurred in the area upstream of Spring Island, and debris washing down from Blieders Creek resulted in significant damage to the recreational area on the island. Recreational activity is moderately high in this area. Although there is no public access, Spring Island serves as a park for local homeowners, and the eastern channel of the river is used as a wading/swimming area. Canoes are available for homeowners to access the area around Spring Island.

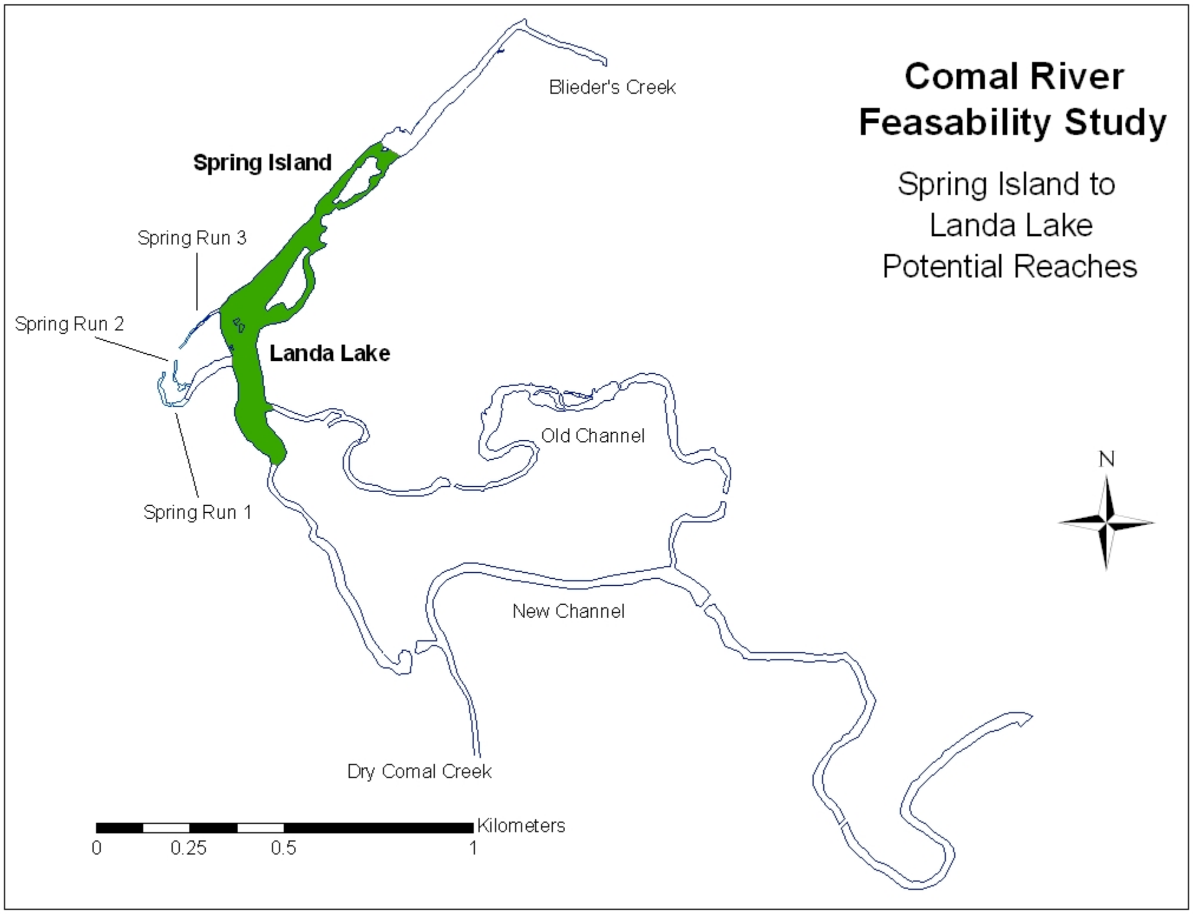


Figure 7. Landa Lake proper and Spring Island area – Comal System

Landa Lake proper provides a large area of high quality habitat for fountain darters. Although it is variable across vegetation type, overall density of darters here is greater than in any other sample reach. Due to the abundance of springs along the lake bottom and flow entering the lake from the various spring runs, annual temperature variation in Landa Lake is less than 1˚C. A diverse vegetation community exists in Landa Lake, including large expanses of bryophytes near the upper end of the lake which harbor large numbers of fountain darters. Comal Springs riffle beetles are routinely captured at several small springs located along the western shoreline of Landa Lake. Due to the hydraulic control of the dam, the width of the wetted channel, and the relatively low and flat nature of the terrain surrounding Landa Lake, scouring as a result of flood waters from Blieders Creek have minimal impact to habitats within the lake. During the June 2010 flood event, only minimal scouring of bryophytes along the upper east side of Landa Lake was evident, despite extreme scouring of vegetation in the more channelized Upper Spring Run and Spring Island areas.

Landa Lake is designated as an environmentally sensitive area, and therefore, no swimming or kayaking is allowed in the lake. The only recreational watercraft allowed on Landa Lake are paddle-boats available for rent from the City of New Braunfels. Fishing is allowed from the banks. However, neither of these activities has a significant impact to endangered species habitats, and therefore, recreation is currently not an issue in Landa Lake proper.

4.1.3 Spring Runs

Three major spring runs occur along the western edge of Landa Lake (Figure 8). Spring Run 1 is supported by a large spring that erupts on the west side of Landa Park Drive. Spring Run 2 emerges a few yards east of Spring Run 1 along the east side of Landa Park Drive, flows through a small wading pool, and merges with Spring Run 1 before it enters Landa Lake. Spring Run 3 emerges a few yards northeast of Spring Run 2, and follows a separate course to its juncture with Landa Lake near the gazebo in Landa Park. Spring Run 1 is the highest elevation, and the first spring run to go subsurface under critically low flows, whereas, Spring Run 3 is the last spring run to go subsurface. Localized rainfall can cause flooding in the area of the spring runs. In the June 2010 flood event, flood waters moving down the steep terrain of Panther Canyon caused significant damage to bridges and other structures near Spring Runs 1 and 2, whereas impacts to Spring Run 3 were relatively minor. Comal Springs riffle beetles are known to occur in all three spring runs, however, long-term monitoring has focused on Spring Run 3. Fountain darters are occasionally seen in all three Spring Runs, however, they are not particularly abundant in the swift rocky habitats of the spring runs. No swimming or wading is legal in Spring runs 1 or 3 (although frequently observed). Spring Run 2 has a small wading pool just above the confluence with Spring Run 1 where wading is allowed resulting in heavy recreational use of this area.

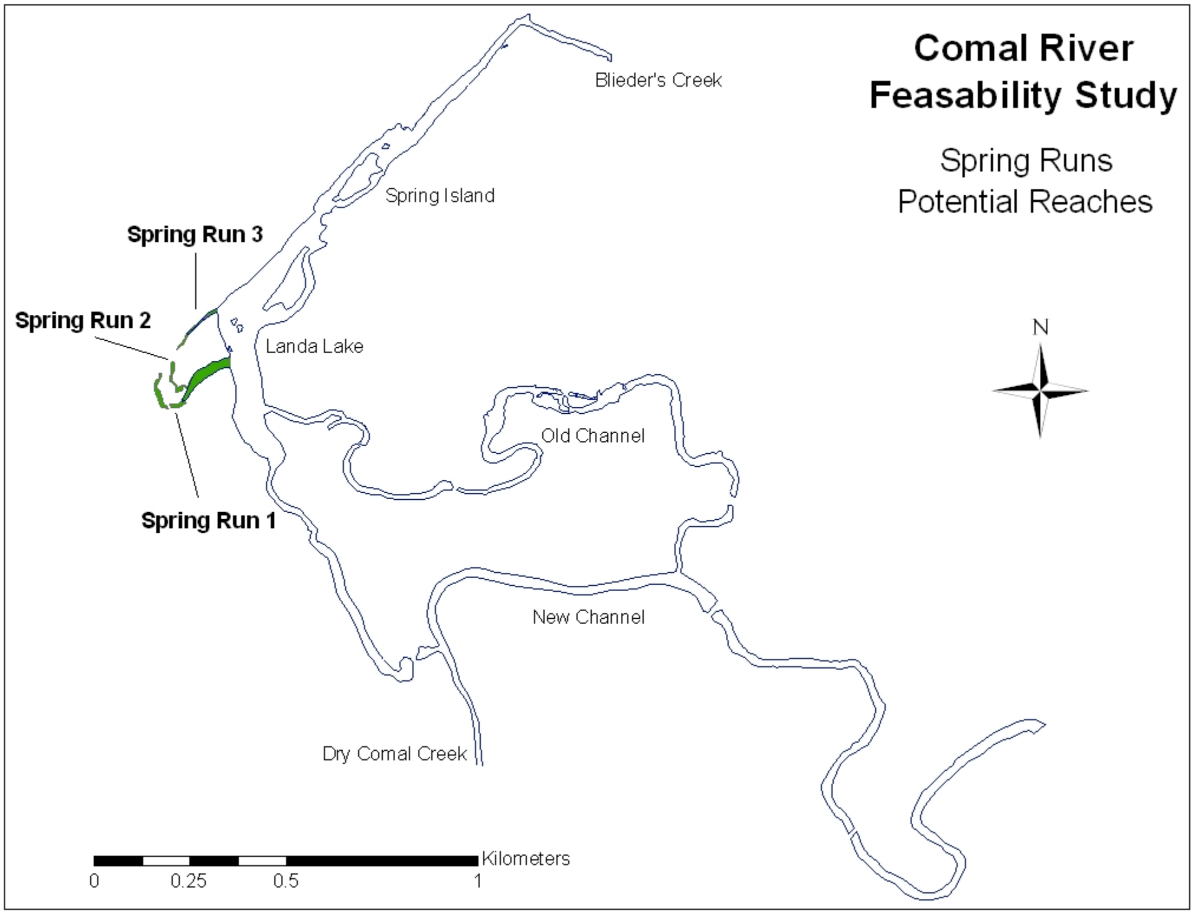


Figure 8. Three main Spring Runs – Comal System

4.1.4 New Channel (Above and below Dry Comal Creek

The new channel emerges from the southern end of Landa Lake near the Landa Park Drive bridge and flows several hundred yards downstream before it merges with Dry Comal Creek immediately past the old NBU Hydrogeneration facility (Figure 9). This artificially dredged channel is deep (>6 ft. in most areas) and highly channelized. There are substantial amounts of aquatic vegetation here (mainly *Sagittaria* and *Vallisneria*), which provide limited fountain darter habitat. The deep nature of the channel here would make any kind of experimentation difficult without major channel modifications. Comal Springs riffle beetles have not been collected from this reach. Vegetation within this upper area is not routinely mapped, and therefore, information on scouring after flood events is primarily anecdotal.

After the confluence of Dry Comal Creek, the New Channel flows past the Wurstfest grounds, under the Union Pacific Railroad bridge, and by Hinman Island Park before its confluence with the Old Channel immediately above the tube chute. This section of the New Channel is extremely channelized with concrete walls or bulkheads on both sides in many places. The lower portion of this section is greater than six feet deep in most places. Aquatic vegetation in this reach includes primarily *Cabomba*, *Hygrophila*, and *Ludwigia* which does provide habitat for fountain darters. Comal Springs riffle beetles have not been collected from this area.

Coverage of vegetation within this reach is extremely variable due to significant scouring after sporadic large flood events coming down Dry Comal Creek. Due to the intense flows coming from the steep watershed of Dry Comal Creek during rainfall events, this reach witnesses the worst scouring of any of the sample reaches. This area is also the put-in location for several local tubing businesses, and receives intense recreational pressure, especially on summer weekends.

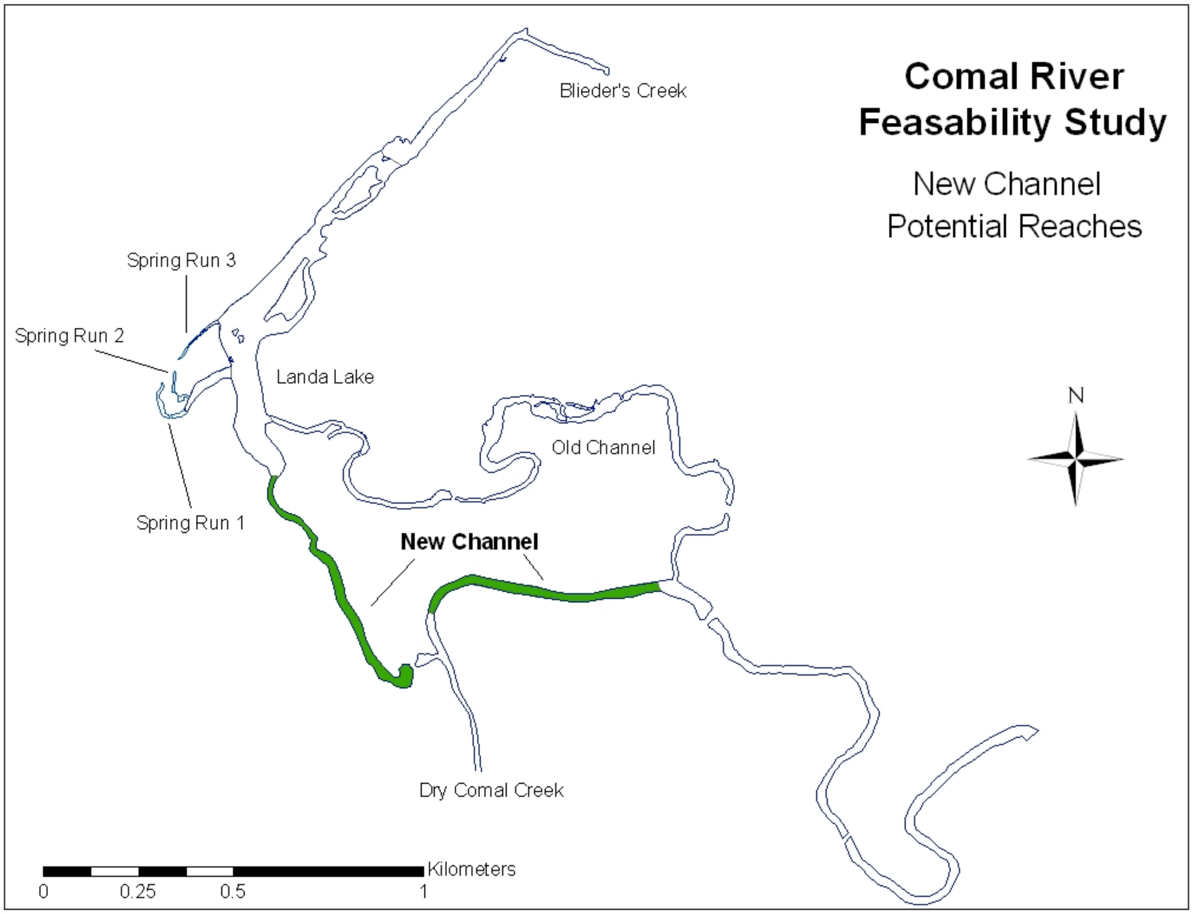


Figure 9. New Channel – Comal System

4.1.5 Old Channel (Reach 1 [below Landa Lake], Reach 2 [near Schlitterbahn], and Reach 3 [below Hinman Island Drive])

The old channel emerges from the southeastern portion of Landa Lake (Figure 10) through three sets of culverts. Two sets of culvert send water directly into the old channel near tee box #2 on the city golf course. An additional culvert directs water through the City of New Braunfels swimming pool before rejoining the old channel below the pool area. The Old Channel below Landa Lake is a fairly natural channel with a diversity of habitat for aquatic organisms. Fountain darters are moderately abundant throughout the majority of the Old Channel. Prior to the installation of the new, higher capacity culvert and subsequent high flow period, fountain darter habitat was outstanding throughout sections of the Old Channel. However, the removing of native vegetation from higher flow conditions, followed by the establishment of non-native aquatic vegetation species have led to reduced habitat conditions in the Old Channel at this time relative to what it had been in the early 2000s. Although many aquatic invertebrates including a species of riffle beetle are present in the Old Channel, no Comal Springs riffle beetles have been documented in the Old Channel below Landa Lake. The three reaches shown in Figure 10 were evaluated because they maintain quality fountain darter habitat and relatively high numbers of darters. Reach 1 (just below Landa Lake) is tucked between the City swimming pool and the riparian zone that separates the river from the golf course. As such, Reach 1 is very protected and not used for recreational purposes. Reach 2 is located downstream below Elizabeth Street and encompasses one of the long-term monitoring reaches of the EAA Variable Flow study. This area is located on City of New Braunfels property and is adjacent to the golf course on the south. As such, this reach is also well protected and not heavily used for recreation. Schlitterbahn does use the adjacent area to the north of the river for a parking lot when the park is open. The third reach is located downstream of Hinman Island. This area maintains quality fountain darter habitat but is not well protected and heavily used for recreational purposes. This reach also experiences the highest level of disturbance following flood events that come down Dry Comal Creek and back water up into this area.

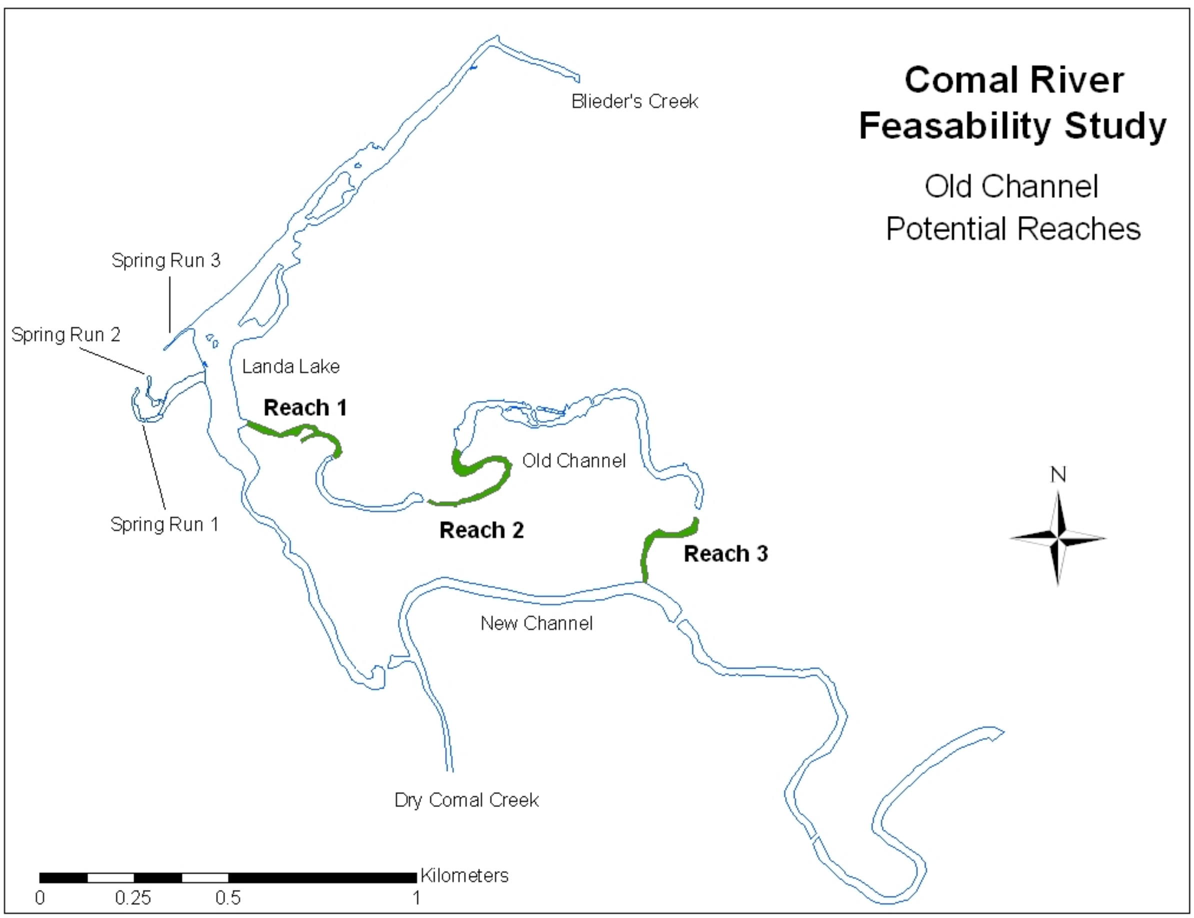


Figure 10. Old Channel Reaches – Comal System

4.1.6 Comal River below confluence

Below the confluence of the Old and New channels (Figure 11), the amount and quality of fountain darter habitat decreases although darters are still collected in this section. There has been no Comal Springs riffle beetles documented in this reach. This area is also highly recreated and routinely scoured by high flow events.

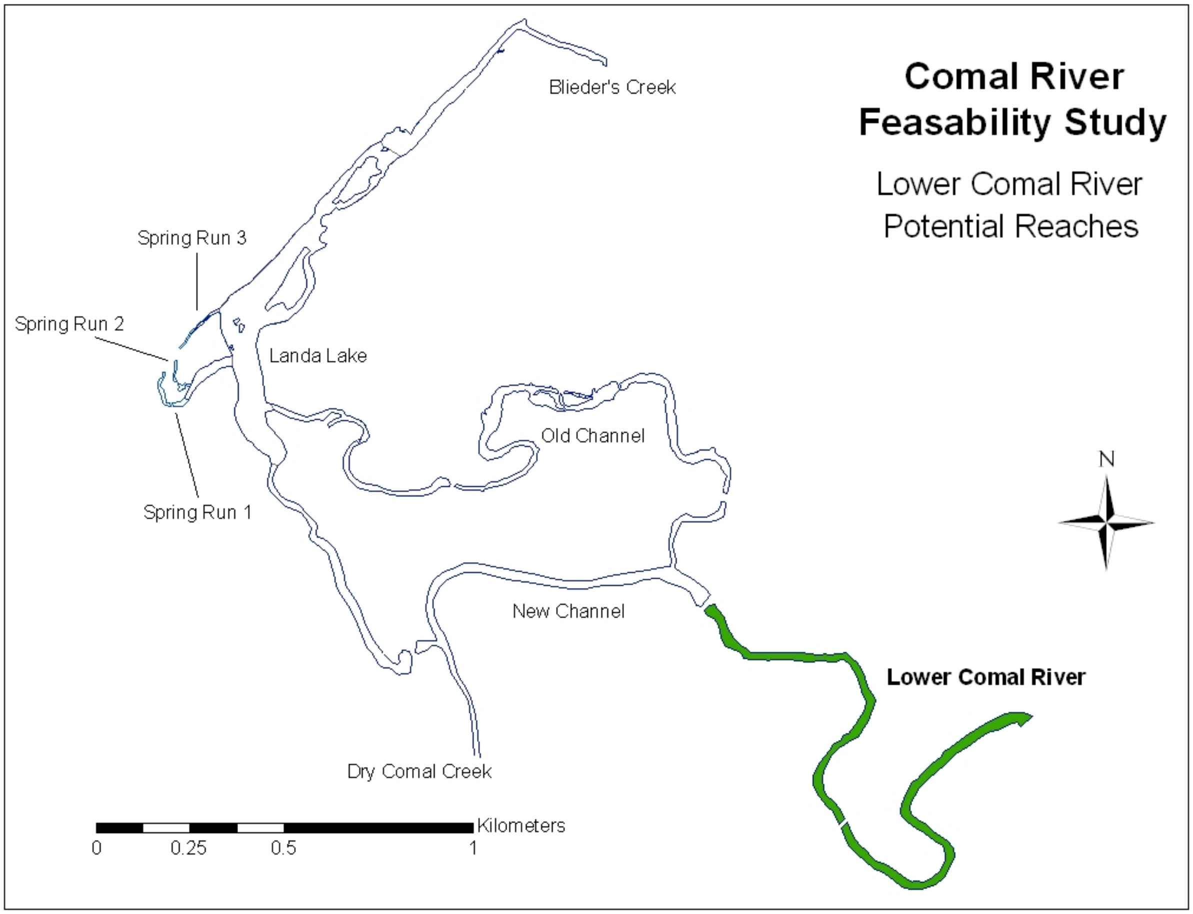


Figure 11. Comal River below confluence of Old and New channels

4.2 STUDY REACH EVALUATION

Table 3 provides a summary of several key evaluation measures for the reaches described above. Key biological measures evaluated were whether or not fountain darters and Comal Springs riffle beetles are present and if so, what quality of habitat is found in these areas. Life history data and habitat requirements of the unique biological communities within the Comal Springs/River ecosystem indicate certain locations that are important to the survival of these species during severe low recharge to the aquifer. Additionally, elevation and hydrology information was evaluated to assess at what total Comal springflow these reaches maintain surface water flow. Finally, additional items were evaluated including potential recreational, flooding, and security risks that might be associated with each of these locations.

Table 3. Reach Selection Evaluation Matrix

Comal River Section	*Fountain Darter Presence / Habitat Quality*		*Comal Springs Riffle Beetle Presence / Habitat Quality*		*Maintain surface flow during drought (Total Comal Springflow cfs)*					*Recreation Activity*	*Flooding impacts*	*Security Risk*
	Pres.	*Qual.*	*Pres.*	*Qual.*	*30 cfs*	*60 cfs*	*90 cfs*	*120 cfs*	*150 cfs*			
Upper Spring Run												
Blieders Creek to above Spring Island	√	*Mod*							√	*Low*	*High*	*Mod*
Landa Lake												
Spring Island	√	*High*	√	*High*	√	√	√	√	√	*Mod*	*Mod*	*Mod*
Landa Lake proper	√	*High*	√	*High*	√	√	√	√	√	*Low*	*Low*	*Low*
Spring Runs												
Run 1	√	*Low*	√	*High*				√	√	*Low*	*Mod*	*Mod*
Run 2	√	*Low*	√	*Mod*				√	√	*High*	*High*	*High*
Run 3	√	*Low*	√	*High*			√	√	√	*Low*	*Low*	*Mod*
New Channel												
Lake to NBU hydro	√	*Mod*			√	√	√	√	√	*Low*	*Low*	*High*
Below NBU hydro	√	*Low*			√	√	√	√	√	*High*	*High*	*High*
Old Channel												
Reach 1 (below Landa Lake)	√	*Mod*			√	√	√	√	√	*Low*	*Low*	*Low*
Reach 2 (near Schlitterbahn)	√	*Mod*			√	√	√	√	√	*Low*	*Low*	*Low*
Reach 3 (Hinman Island)	√	*Mod*			√	√	√	√	√	*High*	*High*	*High*
Comal River												
(below confluence)	√	*Low*			√	√	√	√	√	*High*	*High*	*High*

When total Comal Springs flow falls below approximately 150 cfs, the springs upstream of Spring Island cease to flow and that area may become stagnant resulting in elevated water temperatures and a higher potential for decreased dissolved oxygen (DO) levels. As a result, fountain darters will likely move downstream to where the springs are still flowing and water quality is more suitable. In addition, the Comal Springs riffle beetle is not found in the Upper Spring Run Reach (length of river upstream of Spring Island), therefore at low recharge this area is not considered crucial for the survival of any endangered species. As mentioned in Section 3.1, New Braunfels Utilities owns a parcel of land at the headwaters of the Comal River that is being considered for education outreach purposes. This site contains 3 wells with a cumulative pumping capacity of a few cfs that could be used to support a research facility. This property might be considered for further evaluation if no other feasible locations are identified for the Comal system. At this time, this location was not carried further in the analysis since a completely new research facility would need to be constructed at this location requiring significant costs. Also, being located at the headwaters of the Comal Springs/River ecosystem might prove problematic if unexpected flooding or unforeseen accidents caused spills or exotic species (being used in applied research) releases at this most upstream locale.

All three spring runs provide Comal Springs riffle beetle habitat to varying degrees but limited fountain darter habitat. Spring Run 1 is the highest elevation and the first spring run to go subsurface under critically low flows while also being susceptible to intense flooding coming down Panther Canyon. Spring Run 2 is highly susceptible to flooding coming down Panther Canyon, has the lowest quality riffle beetle habitat and is highly recreated in the kiddie pool. Spring Run 3 is the last spring run to go subsurface, less impacted by flooding, and has the highest quality riffle beetle habitat. As such, Spring Run 3 was selected for further evaluation.

The areas with the highest quality habitat for fountain darters and potential for protecting habitat during severely low-flows are Landa Lake and the Spring Island area. These areas also maintain high quality riffle beetle habitat along the western shoreline of Landa Lake and in the Spring Island area. However, for this feasibility study we are not evaluating measures that could be used below 30 cfs total Comal Springflow because that minimum has preliminarily been determined necessary for threatened and endangered species survival (SSC 2009, Hardy 2011). Modeling suggests that at 30 cfs total Comal Springflow, Landa Lake and Spring Island area will remain wetted with sufficient springflow to support aquatic habitat and water quality parameters. As such, these areas were only selected to evaluate for restoration activities and potential water quality improvements, but not selected for specific ERPA project evaluation.

Although DO and water temperatures may remain suitable in the New Channel downstream of Landa Lake during a period of low recharge, physical conditions within this reach results in lower quality habitat for fountain darters. In addition, no Comal Springs riffle beetles are found in the New Channel. As such, the new channel was not carried forward for evaluation. For the Old Channel, Reaches 1, 2, and 3 all provide quality fountain darter habitat but varying levels of other conditions. During the site visit, Nathan Pence of the City of New Braunfels requested that Reach 3 be removed from consideration as it is too impacted by recreation during the summer months (most likely time of low recharge) to make this reach feasible. Therefore, in the Old Channel only Reaches 1 and 2 were carried forward for evaluation.

In summary, based on the evaluation, Landa Lake (including Spring Island and Landa Lake proper), Spring Run 3, and the Old Channel (reaches 1 and 2) were carried forward for additional analysis.

5.0 ERPA COMPONENT DESCRIPTION AND CONCEPTUAL DESIGN

To preserve endangered riffle beetle and fountain darter populations and habitat during low-flow drought conditions, ERPAs or specific drought management measures are proposed for the area encompassing Comal Springs, Landa Lake and the Old Channel of the Comal River. These measures would be implemented to protect endangered species populations and habitat as spring flow drops below threshold levels. The impetus for this project is concern for species survival in the wild during an extreme drought condition similar to that exhibited in the 1950s. Of particular concern are conditions similar to those in 1956 where aquifer levels in the Landa Park well dropped below 622 ft causing Spring Runs 1 and 2 to cease surface flow and then continued to drop below 620 ft causing Spring Run 3 to cease surface flow (total spring flows were approximately 35 cfs). In 1956, aquifer levels continued to drop below 619 feet, causing springs emitting into the lake to cease resulting in total spring flows of zero. This last stage is outside the bounds of the ERPA analysis as the underlying assumption for all ERPA analyses herein is that a minimum 30 cfs daily average total Comal discharge will be maintained.

The objective of this feasibility study is to identify more specifically what structures or practices are needed to implement potential management measures, then to evaluate benefits, concerns, and constraints for each measure. Considering the reaches carried forward there are several measures to be evaluated that could potentially provide sufficient habitat for fountain darters and Comal Springs riffle beetles during extremely low recharge within the Comal Springs/River ecosystem.

The key components to any ERPA include Restoration, Protection, and Applied Research. The following outline provides a guide for each component:

- Restoration
  - Re-establishment of native vegetation
- Protection
  - Native aquatic vegetation maintenance
  - Flow Split Management
  - Decaying Vegetation Removal for maintenance of dissolved oxygen at low-flow (if necessary)
  - Spring Run 3 connectivity
  - Old channel ERPA
  - Landa Lake Barriers for water temperature control
- Applied Research
  - Old Channel ERPA – channel creation and establishment of Comal Springs riffle beetle habitat
  - Spring Run 3 – observation well

5.1 RESTORATION

It has been documented over the past decade of EAA Variable Flow study monitoring that native aquatic vegetation plays a key role in supporting the native fish assemblages including the fountain darter. Native vegetation restoration consists of the establishment of native aquatic vegetation within key, sustainable reaches of the Comal River. This includes planting native vegetation in unoccupied areas and the establishment of native vegetation in previously occupied non-native aquatic vegetation, with the latter obviously requiring non-native vegetation removal first. In either instance, the 2-D models developed for the EARIP should be used to evaluate the potential for success of the native vegetation establishment. This evaluation should consider the depth, velocity, and substrate conditions present in the proposed areas along with what non-native vegetation is thriving in these areas. If the area is bare, is there a reason it is bare? (i.e. recent flood scour, or unsuitable depth, velocity or substrate conditions). Following an evaluation of the physical habitat model, an evaluation of water quality conditions should also be conducted. In particular, understanding whether the native plant being considered for establishment is a carbon dioxide (CO_2) obligate species and if so, what are the CO_2 concentrations in the water column under varying flow conditions at the proposed establishment locations? Additionally, restoration will involve acquiring local, disease and pathogen-free plant material that will either be removed from adjacent habitat or propagated off-site with material removed from the Comal system. When non-native species are removed, they will need to be disposed of properly. Finally, federal and state permits will be required for potential "take" of fountain darters and for removal of non-native species that are on the TPWD prohibited list.

The EARIP has established restoration subcommittees for both the Comal and San Marcos Rivers and as such, this report will not go into specifics regarding native vegetation establishment or costs associated with these activities. In general, however, it is recommended that the focus be on key, sustainable areas. For the Comal system, this includes Landa Lake and the Old Channel. As positive as it sounds to conduct restoration activities throughout the entire system, the factors that shape these areas (floods, recreation, etc) discussed above need to be factored into the cost/benefit and potential success component of this decision. A few examples that should prove valuable would be replacing the non-native *Hygrophila* with native *Ludwidgia* in Landa Lake and the Old Channel. This would be a positive step in habitat creation/enhancement in both areas. Establishing additional *Cabomba* along the eastern shoreline area of Landa Lake would also create valuable fountain darter habitat.

5.2 PROTECTION

Restoring native vegetation within the Comal system is likely to have benefits to the aquatic species, but will be unsuccessful or likely very limited if it is not monitored and protected over time. Similarly, any restoration activities or ERPA components that are simply constructed and left unattended will likely fail. One-time restoration contradicts the purpose for these activities which is to provide better habitat conditions for the ecological community over time and in particular, upon entering into critical low-flow periods. To maintain these conditions prior to entering into these periods both native aquatic vegetation maintenance in Landa Lake and the Old Channel, along with a flow-split management for the Old and New channels are recommended for implementation.

5.2.1 Native aquatic vegetation maintenance.

Native aquatic vegetation maintenance consists of actively monitoring and maintaining planted stands of native vegetation. Temporal monitoring should incorporate some form of quantitative measurement system to assess whether plantings are increasing, decreasing or remaining stable. Additionally, intensive non-native vegetation control in the adjacent areas may be required until the native vegetation is well-established. Maintenance will also likely include additional activities following natural disturbances such as floods, periods of limited recharge, and/or herbivory, as well as anthropogenic disturbances such as recreation or vandalism. Anytime a disturbance is observed the monitoring/maintenance schedule may need to be increased temporarily in order to provide the stability for the native vegetation re-establishment. Regardless of how successful the initial establishment of native aquatic vegetation may seem to have gone, the continued maintenance/control of non-native vegetation will likely be required in order to protect the restoration efforts and keep them viable over time.

5.2.2 Flow-split management in the Old and New channels.

Flow-split management using the culverts at the head of the Old Channel is also a key tool for the protection of native aquatic vegetation proposed for re-establishment in the Old Channel. A second, but possibly more important function of flow-split management is to maximize (to the extent possible) the quality of habitat in the Old Channel. This could be accomplished by 1) providing a level of flow variability during average to high flow conditions, and 2) allowing proportionally more water to go through the Old Channel versus the New Channel during periods of critically low-flow with the ultimate goal of preserving high quality fountain darter habitat within the Old Channel in wait of the rains necessary to recharge the aquifer.

Table 4 presents the amount of available fountain darter habitat in the Old Channel relative to flow as predicted by the 2-D modeling conducted by the River Systems Institute (Hardy 2011). The physical habitat information along with the temperature modeling conducted during this project and confirmed by the update temperature modeling in Hardy (2011), and professional judgment of the authors who have spent the last decade monitoring the changes within the Old Channel were used to formulate the proposed flow-split recommendation.

Table 4. Fountain Darter Weighted Usable Area in Old Channel (Hardy 2011)

Old Channel Flow (cfs)	Proposed Old Channel ERPA WUA (m^2)	Total Old Channel WUA (m^2)
10	777	18,471
20	833	19,931
30	879	21,837
40	908	22,595
45	924	22,984
50	935	23,291
55	949	23,902
60	956	24,287
70	975	27,109
80	987	27,783

Hardy (2011) describes that from 40 cfs to 80 cfs in the top section of the Old Channel (proposed Old Channel ERPA) greater than 90% of the total available habitat is maintained and water temperature conditions in this reach are not projected to exceed threshold levels. Based on our experience with this reach over the past decade, flows over 80 cfs start to initiate scour of native vegetation (BIO-WEST 2007c). Therefore, the desired goal for maximizing fountain darter habitat in the Old Channel ERPA at all time is to maintain 40-80 cfs of flow. Extremely uniform suitable habitat is present in the New Channel under modeled (10 to 300 cfs) flows (Hardy 2011). Table 5 describes a proposed flow-split for total Comal springflow conditions. During average to high flow conditions (200 to 350+ cfs) the focus is on a seasonal flow split in order to optimize habitat conditions in the Old Channel over time. Slightly higher flows during the fall and winter should provide some channel maintenance benefit while not hindering overall fountain darter habitat. Optimal habitat conditions are proposed for spring and summer to provide the best opportunity for fountain darter recruitment.

Table 5. Proposed Flow-split management for Old and New channels.

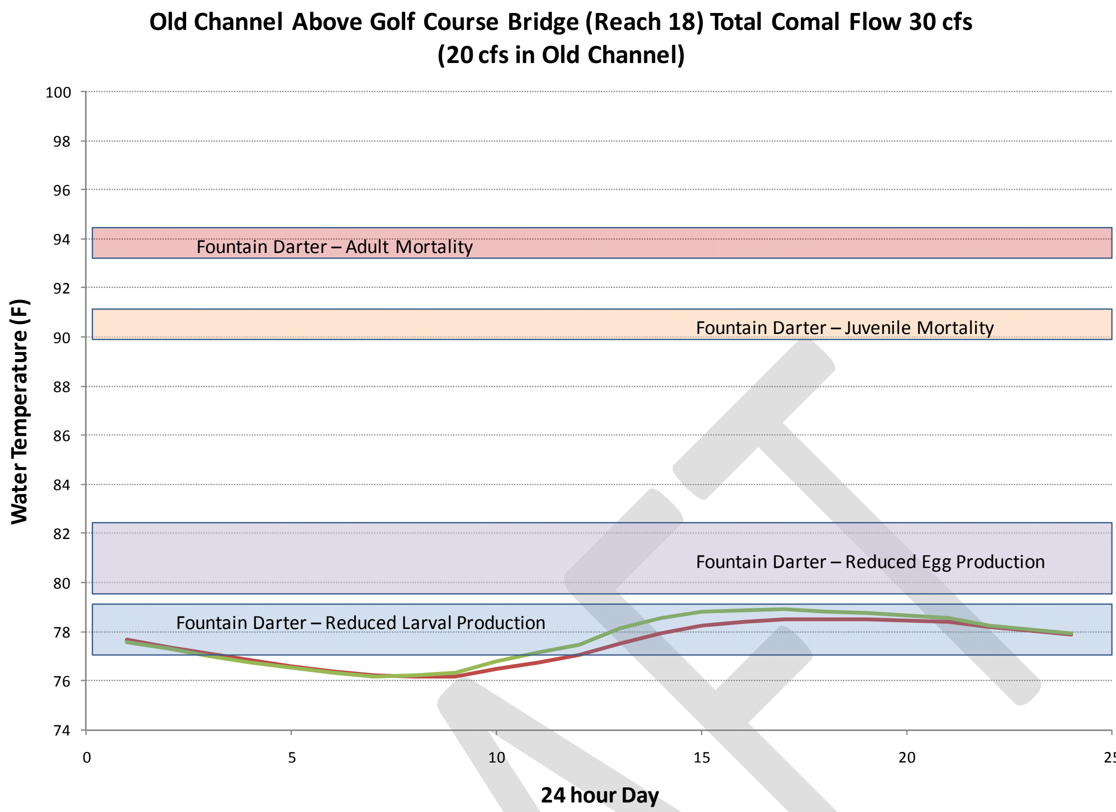
Total Comal Springflow (cfs)	Old Channel (cfs)		New Channel (cfs)	
	Fall, Winter	Spring, Summer	Fall, Winter	Spring, Summer
350+	80	60	270+	290+
300	80	60	220	240
250	80	60	170	190
200	70	60	130	140
150	60		90	
100	60		40	
80	50		30	
70	50		20	
60	40		20	
50	40 / (30*)		10 / (20)	
40	30 / (30*)		10	
30	20 / (20*)		10	

(*) Potentially supplemented to 40 cfs with ERPA recirculation

When total Comal springflow flows drops to 150 cfs the flow split is shifted to protecting the maximum amount of habitat within the Old Channel year round, while continuing to provide flow in the New Channel at all times (Table 5). As discussed in Hardy (2011), 20 cfs in the Old Channel will provide approximately 75% of the maximum available fountain darter habitat in the Old Channel from a physical habitat perspective. In addition to physical habitat, four checkpoint temperature ranges have been identified as critical to the fountain darter life cycle: at and above 77 to 79 (°F) there is reduction in fountain darter larval production; between 79 and 82 (°F) and above there is a reduction in egg production, and at approximately 91 (°F) and 94 (°F) larval and adult thermal death can be expected based on laboratory studies (Brandt et al. 1993, Bonner et al. 1998, McDonald et al. 2007). At 20 cfs, under the extreme ambient temperature conditions modeled in Hardy (2011), the proposed Old Channel ERPA area (Landa Lake to Golf Course Road, [Model Segment 18 – Hardy 2011], Figure 12) is projected (model results) to maintain water temperature below three of the four temperature threshold ranges at all times. Reduced larval production (up to 63%) has the potential to occur for portions of the day based on laboratory results from McDonald et al (2007). Hardy (2011) shows that the lower portion of the next modeled segment downstream (Reach 19 – Old Channel above Elizabeth Street – Figure 12) is projected to have water temperatures high enough during portions of the day to cause reduction in egg production as well, as do all subsequent downstream Old Channel segments. However, it should be reiterated that even at 20 cfs, nowhere in the Old Channel during the extreme conditions modeled, are water temperatures projected to exceed levels necessary for adult or juvenile survival (Hardy 2011).

5.2.3 Decaying Vegetation removal.

Hardy (2011) highlights the uncertainty surrounding the potential effect of extended low-flow periods on aquatic vegetation dynamics within the Comal system as neither the hydraulic and habitat modeling, nor water quality modeling conducted address this issue. As such, Hardy (2011) recommends further study (for which we support) of this important topic. The main concern is that dying vegetation will start to decay subsequently requiring a large amount of dissolved oxygen (DO) during the decay process. This in turn could cause large swings in the DO concentration within Landa Lake which depending on the severity could affect the biological community including the endangered species. The concern is likely limited to the lake portions of the system as the culverts and weirs present at the upper most portions of the Old and New channels would likely provide sufficient re-aeration to compensate most events. However, within the lake environment problems could occur. A possible solution is to establish water quality monitoring stations within the lake where 24-hour probes could be placed and monitored as flow conditions fall below 80 cfs (total Comal springflow). The focus would be to closely monitor the DO (and other water quality parameters) as flows start to decrease to these flow conditions that have been infrequent in history. Should aquatic vegetation start to die-off and DO concentrations start to show large swings, a vegetation removal program should be initiated. The program would identify areas of dying and/or decaying vegetation and remove the vegetation from the lake with the minimal amount of disturbance possible. This would likely entail using rakes/pitch forks and a jon boat to transfer material to the banks for subsequent disposal.



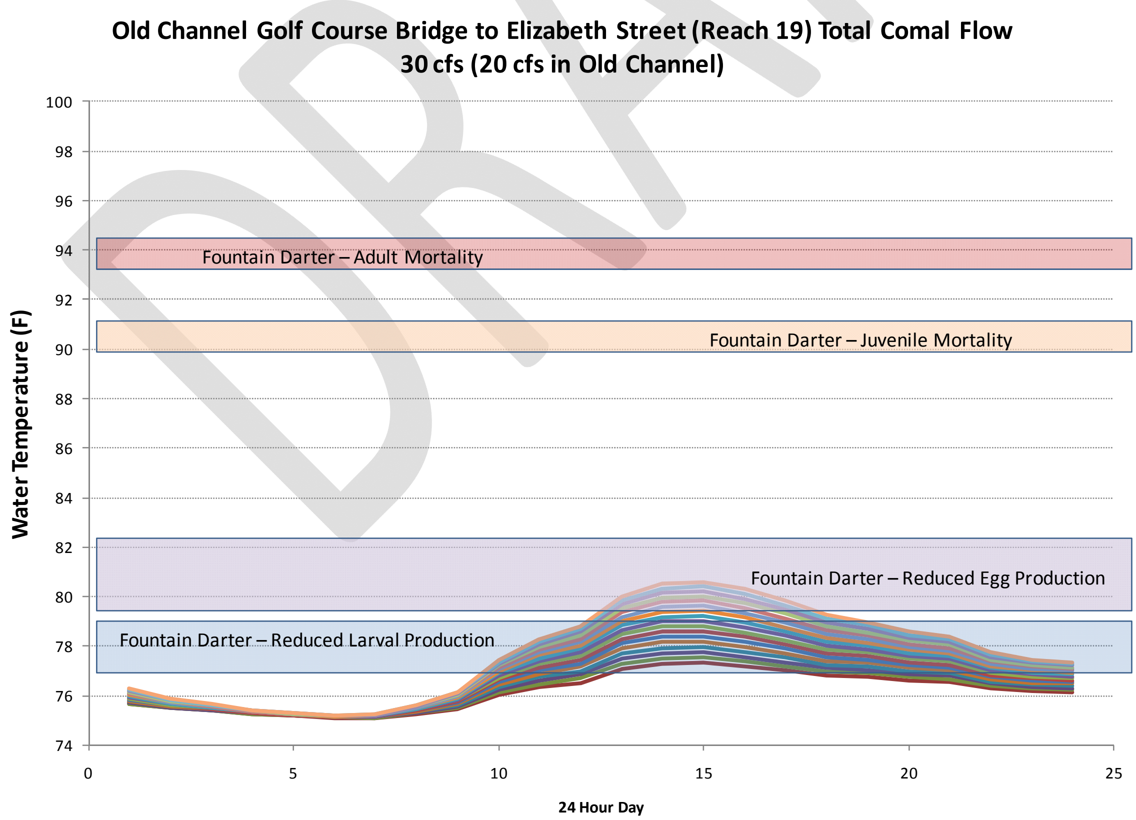


Figure 12. Modeled water temperatures in Reach 18 (top) and Reach 19 (bottom) (Hardy 2011)

5.2.4 Spring Run 3 connectivity

Hardy (2011) states, "We believe the empirical data on riffle beetles demonstrates their persistence within the Landa Lake and spring runs over the past two decades strongly supports that they should be adequately protected over the proposed flow regime being considered by the EARIP." As introduced in Section 1.0, the proposed EARIP flow regime is described as an overlay on historical flow conditions with permitted pumping which is forced to maintain a 30 cfs daily minimum not to exceed 6 months with 80 cfs daily minimum flows for 2 to 3 months following each extended low-flow event. Additionally, this overlay assumes that these low-flow conditions would only happen periodically over time and not be repeated every few years. We concur that the Comal Springs riffle beetle would be protected with the described EARIP flow regime as described in Hardy (2011) and presented throughout this document, as long as it is balanced with a long-term average flow condition suitable for maintaining or increasing populations and habitat over time.

Comal Springs riffle beetles (adults and larvae) have been collected at least semi-annually over the past 7 years via a cotton lure methodology employed for the EAA Variable Flow study. The details of the sampling protocol and results can be found in BIO-WEST 2005a – 2010a). In summary, three main areas are sampled in the Comal Springs system including Spring Run 3, a portion of the western shoreline of Landa Lake, and the Spring Island area. Table 1 (Section 2.0) shows the total number of Comal Springs riffle beetles (adult and larvae) collected per event over this time period. Figure 13 shows the breakdown of Comal Springs riffle beetle density (#/lure) collected during this same time period for the three locations and overlaid on the total Comal springflow observed over this period. Table 1 and Figure 13 show that the total numbers collected and density's observed has been similar across all three locations. However, the difference is that the area sampled along the western shoreline and Spring Island area are smaller areas in proportion to the total available habitat in those areas, as compared to the proportion of sample area to total available habitat in Spring Run 3. Figures 14 through 16 are intended to put the size of the areas into perspective with approximate sampling locations laid over aerial photography.

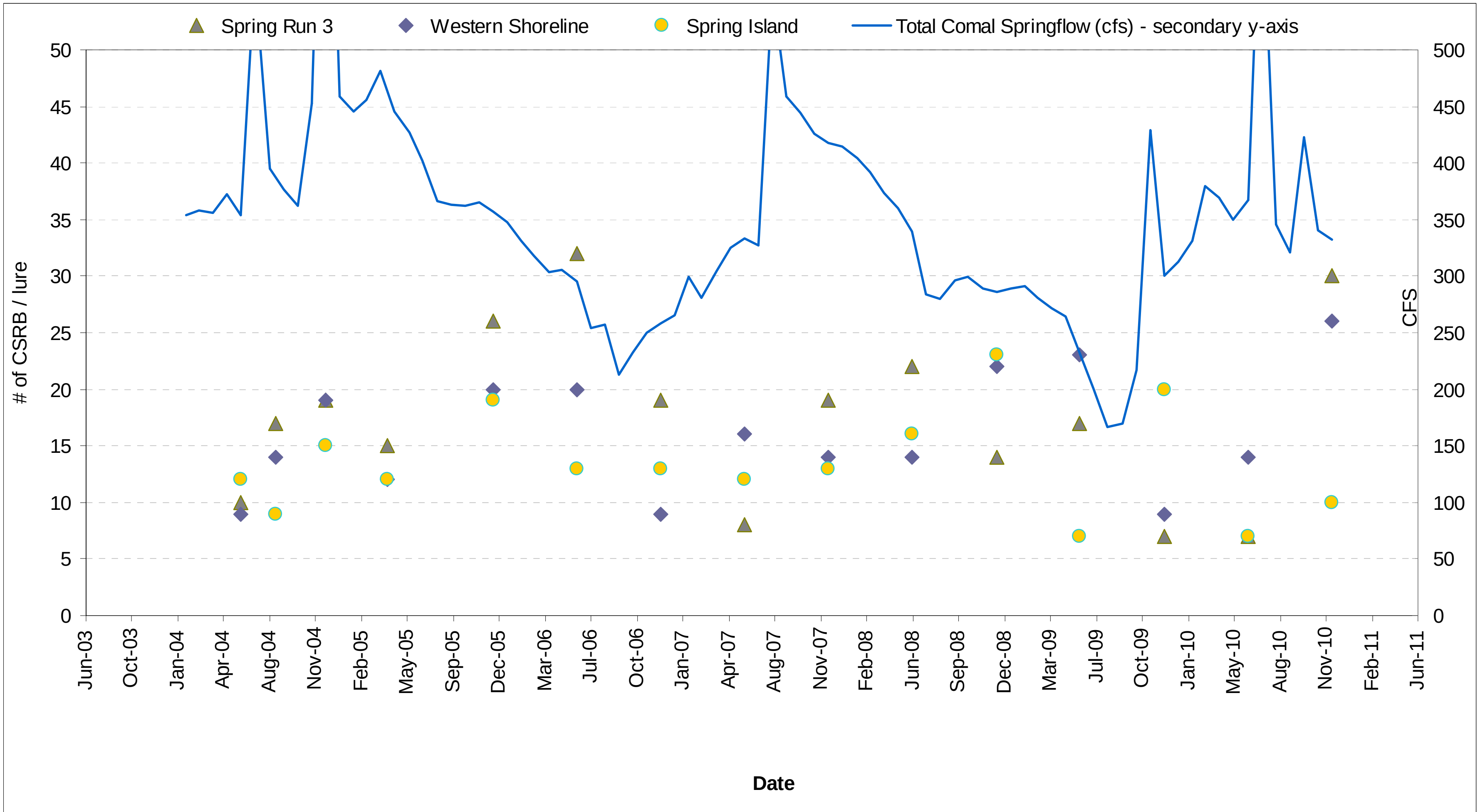


Figure 13. Density of Comal Springs riffle beetles (#/cotton lure) from 2004 to 2010 – EAA Variable Flow Study.

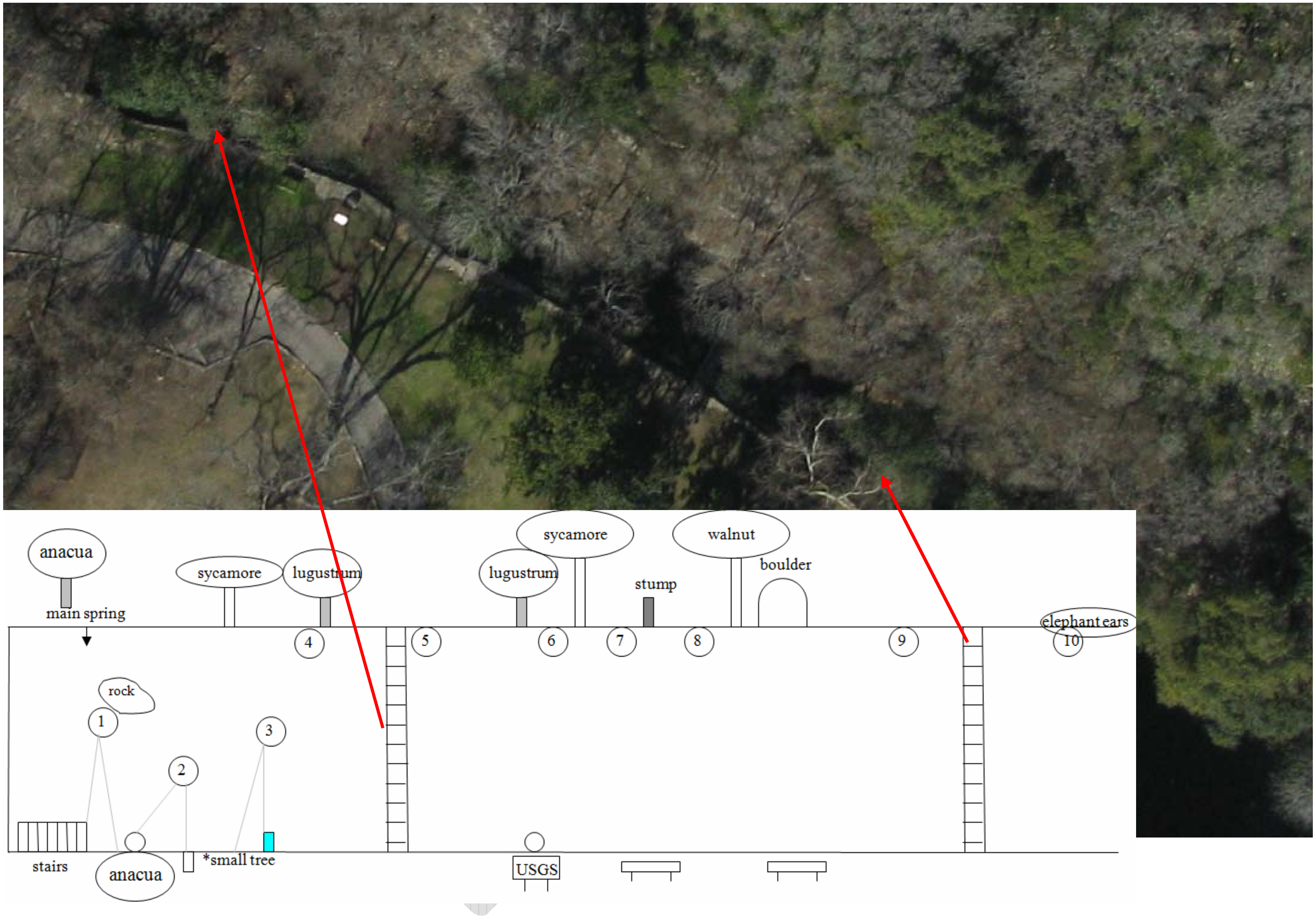


Figure 14. Spring Run 3 Cotton Lure sampling area – EAA Variable Flow Study

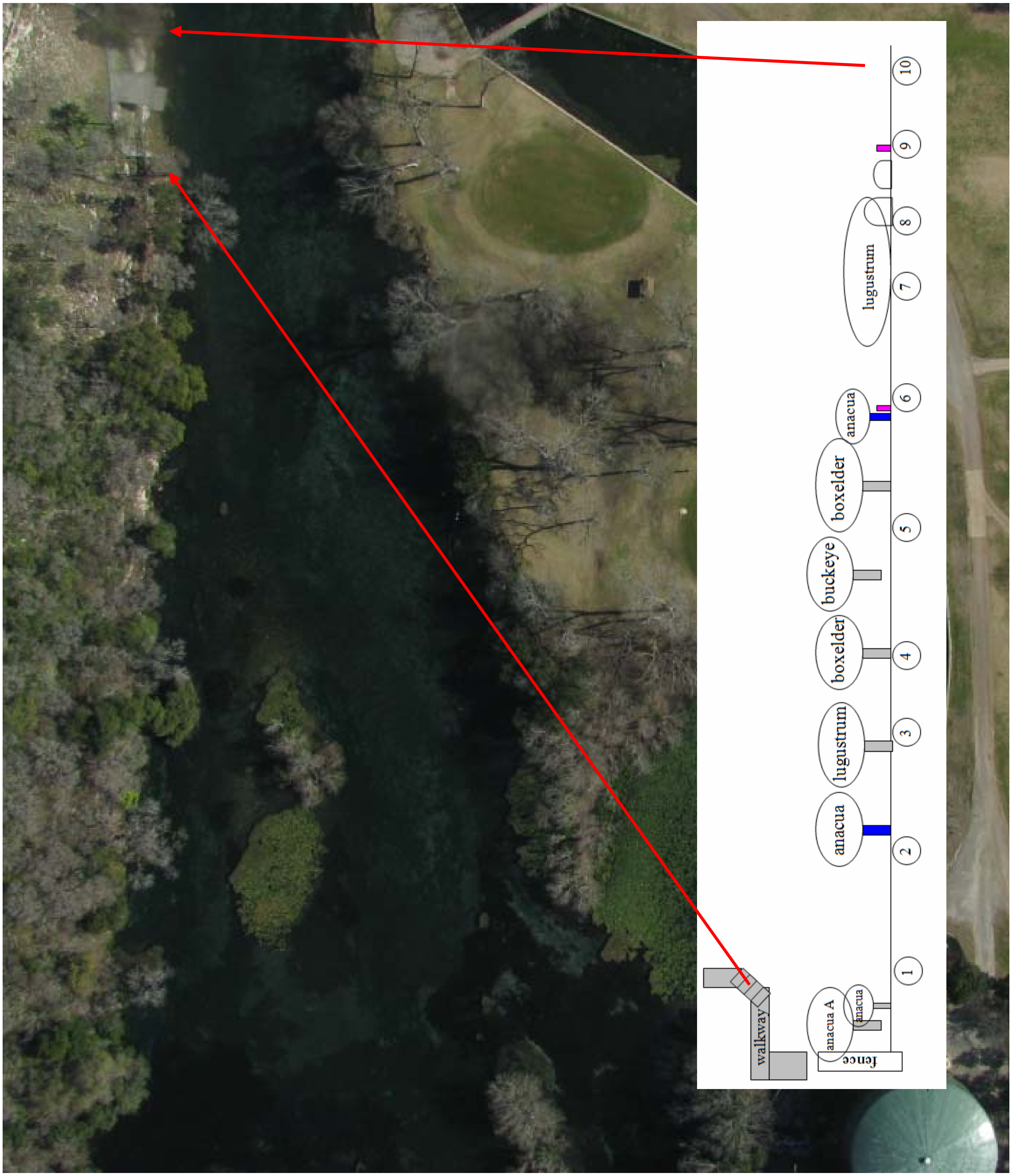


Figure 15. Western Shoreline of Landa Lake Cotton Lure sampling area – EAA Variable Flow Study

Figure 16. Spring Island Cotton Lure sample locations (red circles) – EAA Variable Flow Study

A close examination of Figure 13 shows that a lagged response to total Comal springflow appears evident at all three locations. Why this is happening has not been determined. A closer look at 2009 shows fewer riffle beetles were collected at Spring Run 3 and the Western Shoreline in December as compared to June, but more riffle beetles were collected at Spring Island in December compared to June. One explanation might be that the riffle beetle population fluctuates with total springflow. Most of the springs sampled in the Spring Island area are upwellings on the lake bottom and possibly less susceptible to the effects of drought than seeps along the margins of the lake; some of which had no measurable flow in June. However, many *Heterelmis* were collected on the lures along the Western Shoreline in June 2009. Another possible explanation is that riffle beetles in edge habitat retreat further into the lake or spring run or go subsurface during lower flow conditions. This would also explain fewer numbers recorded during lower flow conditions. During 2010, increases in Comal Springs riffle beetle densities were recorded at all sites as flows returned above historical average conditions.

Hardy (2011) states that the Spring Island portions of Landa Lake and the Western Shoreline will remain inundated at 30 cfs whereas Spring Run 3 would likely go subsurface except for near the terminus into Landa Lake. This is shown in Figure 17 which was provided by Dr. Hardy upon request of the project team. Overall, during 30 cfs total Comal springflow approximately 2/3 of these three main (sampled) areas would likely sustain riffle beetle habitat. Based on this amount of remaining habitat, coupled with the ability of the beetles to use subsurface habitat in the spring runs and increased flows to 80 cfs for a few months following each low-flow event (re-wetting surface water habitat in Spring Run 3 (Hardy 2011), and the fact that the Comal Springs riffle beetle survived after 6 months of zero flow in the 1950s, we have confidence that the Comal Springs riffle beetle should survive the described EARIP flow regime.

Although confident in the statement concerning the described EARIP flow regime, there remains considerable uncertainty regarding the ability to meet the flow targets specified. Additionally, there is very little known about the Comal Spring riffle beetle response to low-flow events in the wild. As such, we propose an ERPA within Spring Run 3 that would maintain spring run connectivity to surface water flow during the periods of minimum flow (30 cfs) in the system. The following is a description of a proposed ERPA to evaluate the concept of spring run connectivity.

The goal of the proposed measure is to provide a constant source of water to flow over the Spring Run 3 edge habitat used by riffle beetles during times when the surface flow in Spring Run 3 ceases. The concept for testing is whether a constant flow of water over detritus and other surface materials might provide a continued food source to riffle beetles that had retreated to subsurface habitats. It would also allow edge habitat to remain wet or moist which in of itself may sustain riffle beetles for some period of time. For instance, during the Spring 2009 EAA Variable Flow study sampling (May 21 to June 19 – standard 4 week retrieval period), total Comal springflow dropped from 223 to 199 cfs and the lake depth lowered slightly around Site 1 (Figure 15, Western Shoreline) leaving the cotton lure in just a moist spot along the bank. Additionally, Site 2 (Figure 15, Western Shoreline) was located in an area with no detectible flow at the conclusion of the survey. However, at the conclusion of the survey, the Site 1 lure contained 26 adult Comal Springs riffle beetles and 5 larvae, while the Site 2 lure contained 25 adults.

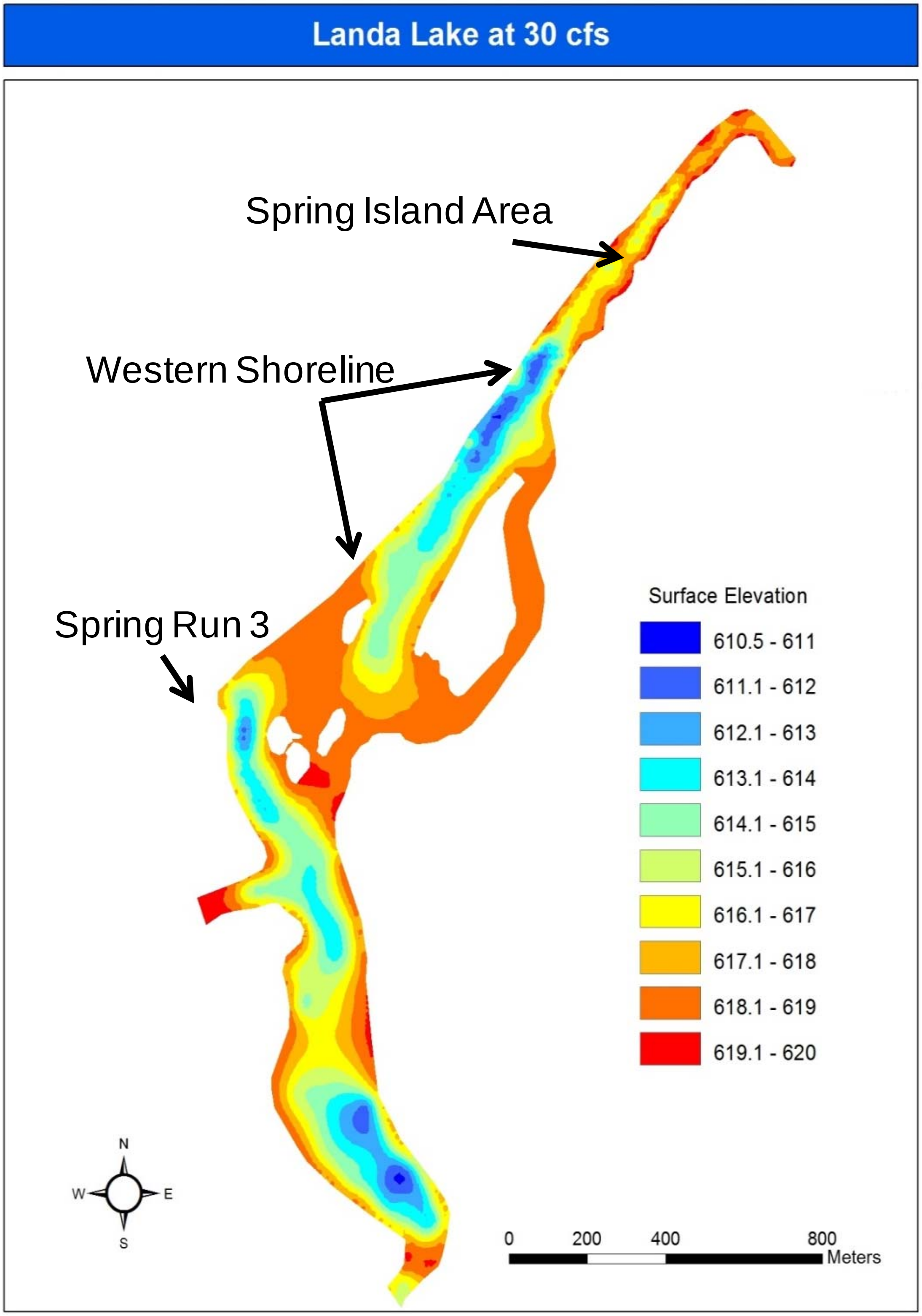


Figure 17. Inundation of Landa Lake at 30 cfs model flow (Hardy 2011)

The proposed ERPA would involve taking Landa Lake water from the immediate terminus of Spring Run 3 and recirculating that water to Spring Run 3 during times when aquifer levels decrease below 620 feet (Landa Park Well) (Figure 18). As aquifer levels decrease to 620 feet, spring flow decreases then ceases surface flow in the spring runs. Temporary wetting of surface areas and connectivity to the subsurface water at documented riffle beetle habitat would be provided along the river left edge of Spring Run 3 (Figure 18) by trickling water from the ground surface down through riffle beetle habitat areas. A temporary submersible pump (or a pump with submersible intake screen) would be deployed across from the existing gazebo. The pump (estimated to have capacity of approximately 2 cfs) would draw water from the lake and discharge into a pipe along the length of the north shoreline of Spring Run 3. Diffusers attached or integral to the pipe would be used to supplement riffle beetle habitat (Figure 19 shows a simple, conceptual perforated pipe design) that would emit water through existing high quality riffle beetle habitat (Figure 20). If implemented, a means for testing the success of the measure would also need to be developed. This would likely include the presence of riffle beetles (adult and larvae) but may also involve some form of habitat assessment.

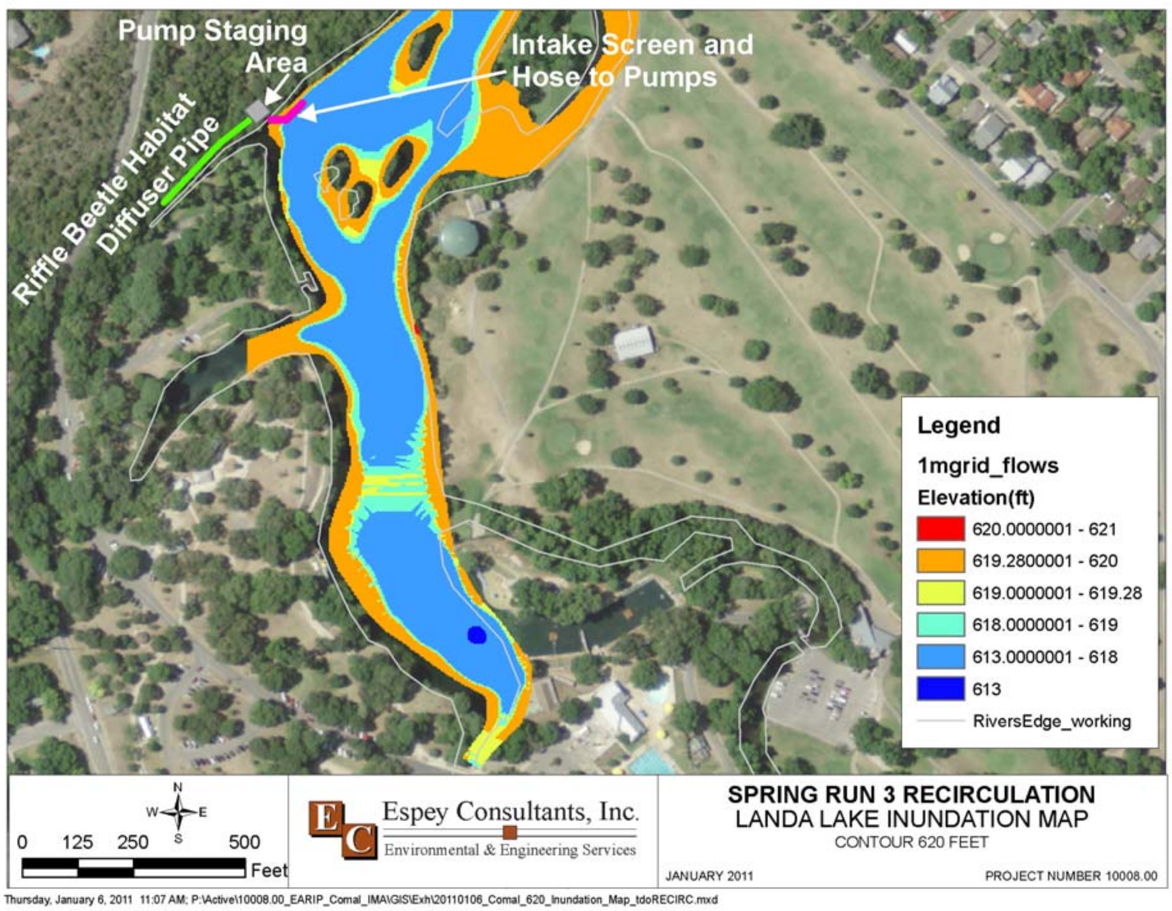


Figure 18. Spring Run 3 Connectivity conceptual design

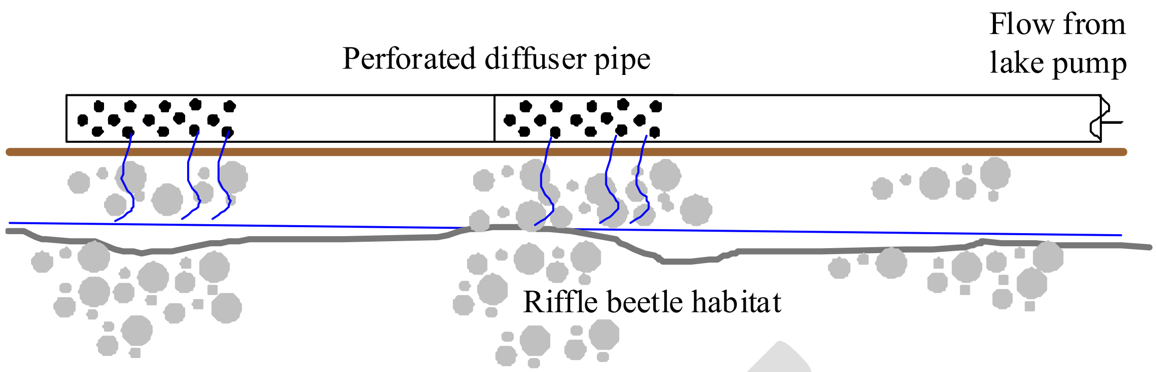


Figure 19. Spring Run 3 - Riffle Beetle diffuser pipe

Figure 20. Picture of Riffle Beetle edge habitat in Spring Run 3.

Since use of a gas or diesel pump in this sensitive area is not preferred, installation of a 480v 3-phase electrical service would be needed to run an electric 1,000-2,000 gpm pump. Rather than using a permanently installed pump within a pump-house, a temporary rental pump is recommended to avoid maintenance costs associated with cleaning and servicing a pump used irregularly (e.g, once every 10+ years). Similarly, piping and intakes are envisioned as temporary. Any temporary equipment would need to be secured and/or anchored to prevent theft, vandalism and/or disturbance during weather events. However, permanent structures could be constructed to house temporary pumps rented during an operational event.

Consideration to the aesthetics of the system is critical since the area is visited for its natural beauty. An outlet box placed on the northern shoreline (across the channel) with a temporary submersible pump and camouflaged perforated pipe along the northern shoreline is proposed to minimize any aesthetic issues. An informational kiosk is also proposed near the Gazebo across the channel from the outlet box that describes the purpose and goal of the Spring Run 3 connectivity project. It must be remembered that during these very infrequent events, all three main spring runs will be mostly dry, causing an aesthetically unpleasing scene for park visitors. Observing an attempt to protect endangered species habitat during these time periods might even be considered a positive aesthetic appeal. Permanent structures may offer more benefits to aesthetics despite being infrequently used and more expensive than temporary installations. Construction of a permanent intake structure and pump house is possible but with increased costs. However, attempting to bury the diffuser pipe along the northern edge is NOT recommended as this would involve considerable disturbance to the existing Comal Springs riffle beetle habitat and/or flow patterns that this project would be trying to protect.

Spring Run 3 ceases surface flow at park well level 620 ft (approx 35 cfs total spring flow), so operationally, this measure should begin operation in advance at approximately 50-60 cfs total spring flows. Permitting of the recirculation component would need to be further evaluated if this option is chosen. Texas Commission of Environmental Quality (TCEQ) water rights permitting staff have indicated the possibility that Spring Run 3 could be designated as a water course where a bed and banks permit may be needed to withdraw and discharge. Additionally, permitting for construction of permanent facilities may need approval of regulatory entities including the city of New Braunfels or TCEQ.

Estimated cost for purchase of necessary site equipment and installation is $87,000, which includes installation of a 480V 3-phase service at $32,500 (Table 6). Estimated monthly operations cost totals $12,600 per month (Table 7) for a rental pump and hoses ($7,300) and for electrical power ($5,300).

Table 6. Spring Run 3 - Construction and materials cost estimate

Infrastructure and Purchased Equipment

Description	Quantity	Unit	Unit Price	Total
Mobilization	1	LS	$2,000	$2,000
Pipe Manifold Structure	1	LS	$2,000	$2,000
12" Gate Valve	1	EA	$1,500	$1,500
12" 20-slot SS Well Screen, 20-ft Joint	1	EA	$2,500	$2,500
Screen Assembly	1	EA	$750	$750
12" PVC Pipe and Installation	300	LF	$90	$27,000
Diffuser assemblies	10	EA	$250	$2,500
Revegetation	1200	SY	$1.50	$1,800
Electrical Service Line	500	LF	$65	$32,500
Subtotal				$72,550
Contingencies	20	%		$14,510
Total				**$87,000**

Table 7. Spring Run 3 - Monthly operations cost estimate

Rental Equipment

Description	Quantity	Unit	Unit Price	Total
100-hp Trailer-Mounter Pump with Noise Abatement	1	Mo	$7,000	$7,000
12-in Flexible Suction Hose	50	LF/Mo	$6	$300
12-in Flexible Discharge Hose	20	LF/Mo	$2	$40
Total per month				**$7,300**

Electric Power Cost

Description	Quantity	Unit	Unit Price	Total
Electricity	40267.8	kWh	$0.084	$3,400
Demand Charge (3 months)	168	kW	$3.75	$1,888
Total per month				**$5,300**

5.2.5 Old Channel ERPA.

As discussed in Section 4.0 and highlighted in Table 3, the Old Channel below Landa Lake is a suitable location to construct and maintain an ERPA for the protection and enhancement of fountain darter and potentially riffle beetle habitat during extended drought conditions. Similar to the Comal Springs riffle beetle conclusions presented, Hardy (2011) also concludes that the fountain darter in the Comal system will be protected by the EARIP flow regime as previously described. We concur with the Hardy analysis for the fountain darter relative to the described EARIP flow regime, but again are concerned with several components of ecological uncertainty raised by the EARIP SSC, and the uncertainty surrounding any management approach to truly meet the flow requirements as specified in the described regime. An Old Channel ERPA, as described below, would provide an additional measure of safety in the event that all does not go as planned or that some of the underlying assumptions founding the Hardy (2011) analysis are proven to be not completely accurate. Additionally, the Old Channel ERPA presented below would serve as an on-site facility to conduct applied research on the concerning assumptions and many unknowns that continue to cloud our judgment on what is truly necessary to protect the ecological community (including the endangered species) within the Comal Springs/River ecosystem. The applied research component is discussed in detail in Section 5.3.1.

To summarize the Hardy (2011) findings, at 30 cfs total Comal springflow (20 cfs – Old Channel, 10 cfs – New Channel), physical habitat and water quality conditions throughout Landa Lake proper, the Old Channel and New Channel are sufficient to support adult and juvenile fountain darters and recruitment in key but limited areas. At 80 cfs, which are the flows prescribed for a few months following a maximum 6-month flow of 30 cfs minimum daily flows, suitable conditions are extended into the spring runs and further downstream in the Old and New Channels (Hardy 2011). Three main concerns noted in Hardy (2011) regarding this flow regime were 1) the potential for aquatic vegetation die-off and subsequent dissolved oxygen (DO) problems in Landa Lake, 2) the reduction in larval production of fountain darters that would likely be experienced, and 3) the potential for cool water inflows from springs along the western margin of Landa Lake flowing down the New Channel instead of entering the Old Channel. As supported in Hardy (2011), the aquatic vegetation question remains unanswered and we agree it should be explored further through applied research on-site (see Section 5.3.1). The reduction in larval production has been thoroughly documented in laboratory studies (Bonner et al. 1998, McDonald et al. 2007) and can be assumed to occur at these flow conditions in the wild based on temperature modeling (as no water quality data is available at 30 cfs total Comal springflow). Therefore, based on the temperature modeling, at 30 cfs total Comal springflow, only the upper portion of the Old Channel (proposed Old Channel ERPA and the upper portion of Hardy 2011 – Reach 19) (Figure 12) and possibly pockets of cooler water along the bottom of Landa Lake (Hardy 2011) are projected to remain below three of the four temperature threshold ranges at all times. At this flow level, reduction in larval fountain darter production is possible in these segments during portions of the day (Figure 12). All other areas of the system are projected to experience reductions in fountain darter larval and egg production (Hardy 2011). It needs to be clear, that at these flow levels, temperatures throughout most all of the Comal system are still below conditions necessary for survival of adult and juvenile fountain darters and a reduction in larval production within the threshold range (77 to 79 °F) does not equivocate to "total" larval mortality (projected as up to 63% in McDonald et al. 2007). The third concern is directly related to uncertainty associated with the temperature modeling and will require additional hydrodynamic modeling with follow-up water temperature modeling in addition to intensified spatial monitoring during low-flow events. These activities are all supported and will be proposed in the HCP.

At 80 cfs, the majority of Landa Lake proper and an extended portion of the Old Channel (Hardy 2011) are not predicted to experience any reductions in fountain darter larval production. Based on the maximum 6-month duration at 30 cfs daily flows, the few months at 80cfs following the minimum periods, and the available darter habitat and reproduction availability within the system, we concur with Hardy (2011) that under the described EARIP flow regime, the fountain darter population and habitat will be supported in a condition that can recover to pre-drought conditions. With this said, it is easy to start asking what if questions, such as what if aquatic vegetation in the Lake does crash?; Would we come to the same conclusion if fountain darter habitat going into the drought is in really poor condition because of a recent flood or human disturbance?; What if predation and competition in the remaining high quality habitat is so great that fountain darters are drastically reduced by this biological pressure?; What if the proposed EARIP flow regime cannot be met for whatever reason?, etc. etc. These are the types of questions asked in the development of the proposed Old Channel ERPA. The primary function of the Old Channel ERPA (as described below) will be to maintain high quality fountain darter habitat within the main channel through restoration and protection, in order to ensure that habitat quality going into a drought is always high in this area. Should model assumptions relative to the biology and/or hydrology be wrong, this area could be operated with the goal of protecting the fountain darter population and habitat in the wild for some period of time. The phrase "some period of time" is used because at this time, this concept is only at the feasibility stage and would need to be implemented, tested, and no doubt adjusted and improved over time to maximize its ability to sustain fountain darters and their habitat in the wild.

Figure 21 shows the proposed Old Channel ERPA location. As discussed in Section 4.0, flow from Landa Lake into the swimming pool and the Old Channel can be controlled by existing culverts in the system (Figure 22). Figure 23 shows the topography for the proposed Old Channel ERPA which extends from Landa Lake to the Golf Course road. One alternative is that the flow in this area be controlled by the existing culverts and actively restoring and maintaining fountain darter habitat within this reach. Figure 24 shows the aquatic vegetation communities within this reach in Spring 2010, prior to the June flood. If one simply takes the average fountain darter densities per aquatic vegetation type (recorded over the past 10 years of the EAA Variable Flow study) and multiplies that number by the amount of each type of vegetation in this reach and then sums it up, one would predict that at that particular time, that reach maintained a fountain darter population of approximately 8,500 fountain darters.

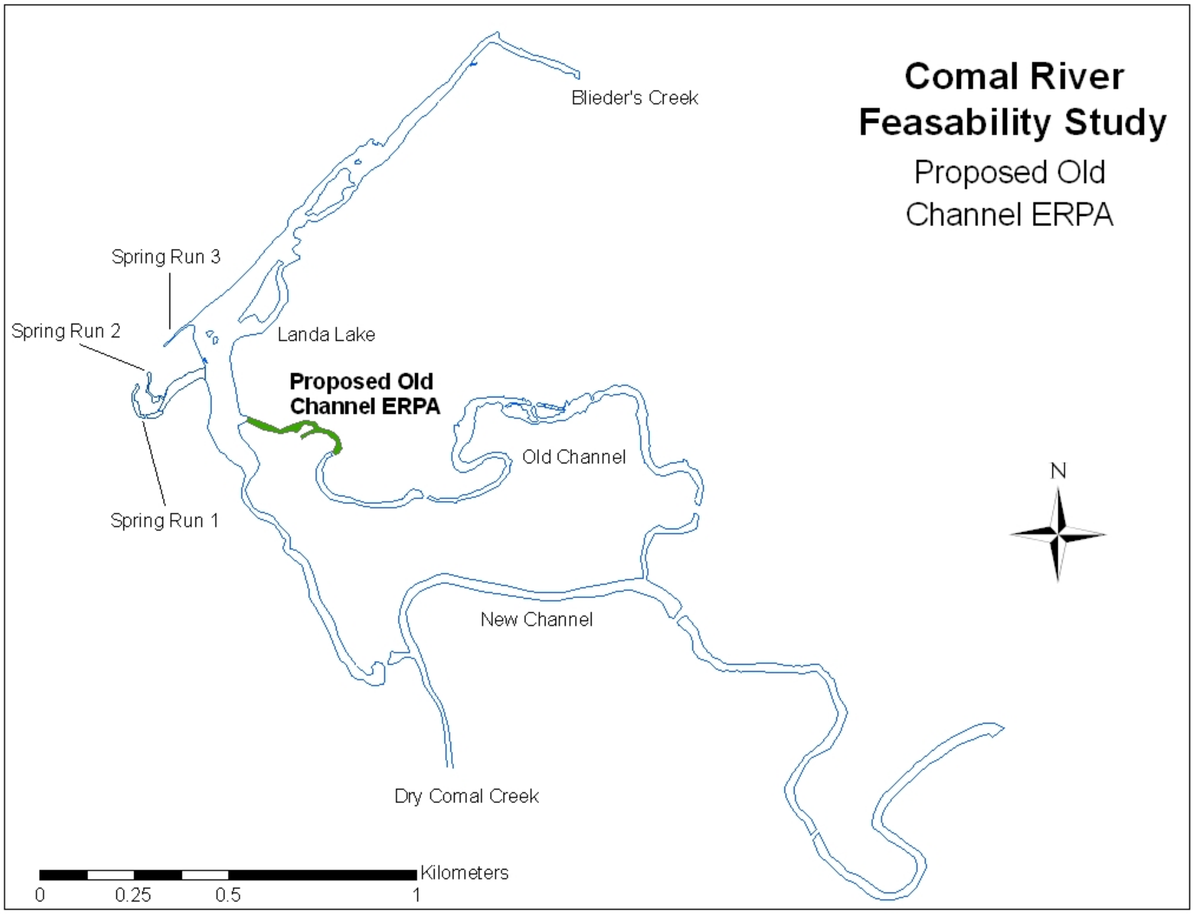


Figure 21. Proposed Old Channel ERPA location.

Figure 22. Landa Lake and culverts going to swimming pool and Old Channel

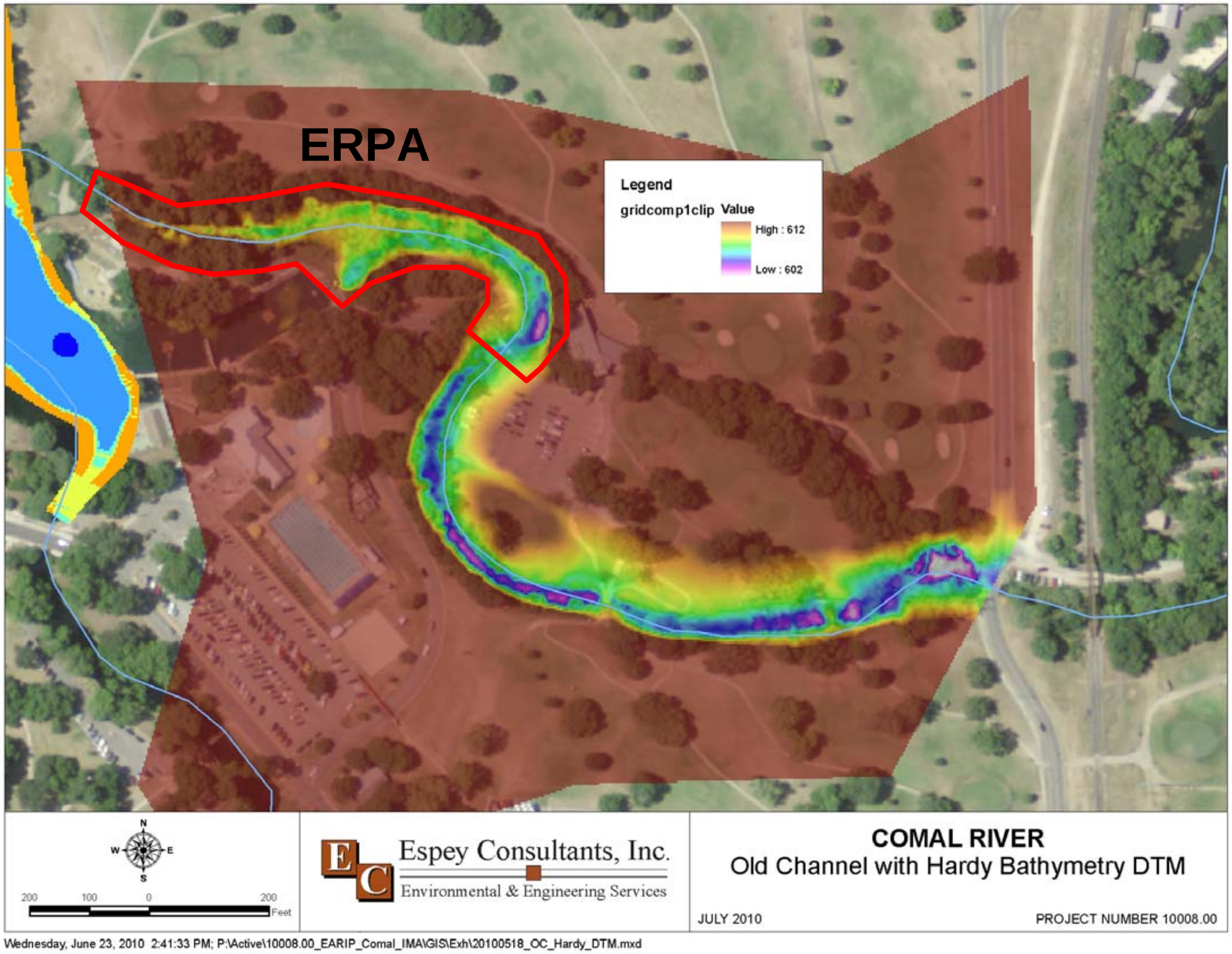


Figure 23. Old Channel ERPA below Landa Lake. Data sources: Topography – City of New Braunfels two-foot topographic contours from LIDAR data Bathymetry – (Hardy 2009)

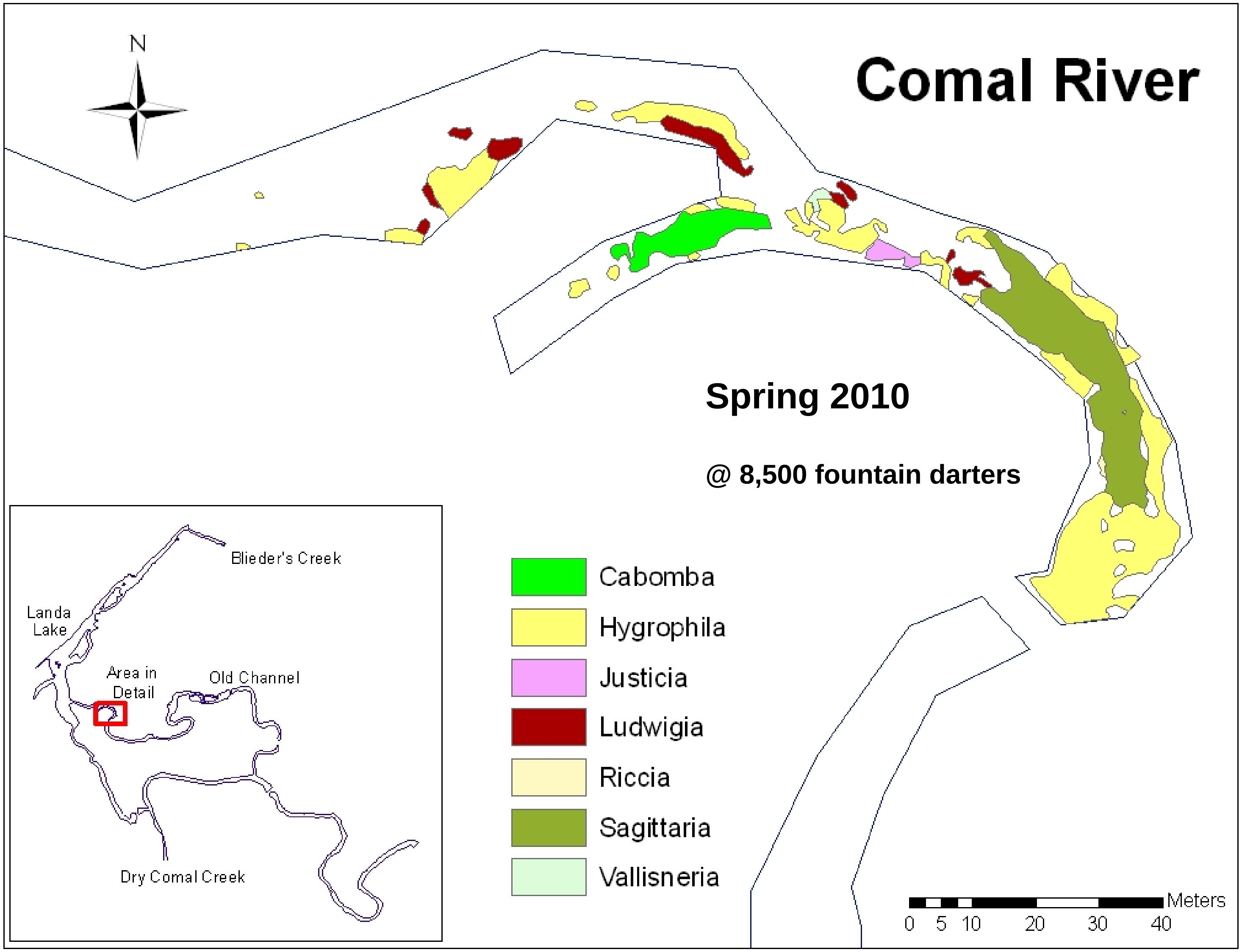


Figure 24. Aquatic vegetation in proposed Old Channel ERPA – Spring 2010

Figure 25 shows the same area with an example of a recommended aquatic vegetation restoration and maintenance effort. Under this scenario, the same fountain darter population calculation as presented above would yield approximately 28,000 fountain darters within this reach. Clearly this is an oversimplification, but is used to provide an example of what might be possible to maintain within this reach under high quality habitat conditions. Based on the habitat modeling conducted by Hardy (2011), Old Channel flows between 40 and 80 cfs support high quality habitat conditions. By only operating the culverts at Landa Lake, maintaining these conditions at all times would be impossible for the following reasons. At higher total Comal spring flows, the amount of water coming through the Old Channel is often in the 80 to 110 cfs range in order to alleviate the pressure on the dam above the swimming pool, and thus, would be anticipated to continue unless dam improvements were made or a flow by-pass around the ERPA was constructed. Secondly, the EARIP described flow regime proposes flow to go as low as 20 cfs within the Old Channel which again strays from a high quality habitat condition, should only the culverts be used to control flow. In order to increase flows back to more optimal conditions within the Old Channel ERPA, some sort of recirculation scheme would need to be implemented. Bottom-line, it is currently not possible to maintain optimal conditions in the Old Channel via the existing culvert operation and restoration of aquatic vegetation alone.

Figure 26 shows the conceptual design for the complete ERPA package being discussed in this report. The design incorporates a diversion structure used to take water from the main channel and either bypass the ERPA (blue line, Figure 26) or divert water into the experimental channel (described later in this section). To accommodate the significant slope in the Old Channel and to facilitate diversion, a control structure similar to a cross-vane weir (Figure 27) is proposed to provide head to deliver water to the bypass or experimental channel while controlling impact to the existing Old Channel. Rock cross vane weirs have been used for this similar purpose in the South Fork of the Platte River in Colorado (Figure 28) and elsewhere to provide head for an irrigation diversion. With the inclusion of the experimental channel, this structure would be located at the presented location, whereas if the experimental channel was not constructed, this structure would be better suited closer to the main portion of the ERPA. For this discussion, the entire package including the experimental channel is described.

Having the ability to bypass water around the ERPA during higher flow conditions is only one part of the protection necessary to allow the continued maintenance of high quality fountain darter habitat conditions at all times. The second component is the ability to recirculate up to 20 cfs in the same pipeline (blue line, Figure 26). While the experimental channels would be permanently installed (discussed later) and likely used continuously, the recirculation appurtenances are anticipated to be used only during severe drought conditions. Recirculated water would be used to augment flow within the ERPA area. For example, under the 30 cfs EARIP minimum total Comal springflow (20 cfs in the Old Channel) approximately 40 cfs flow (20 cfs continually coming from Landa Lake plus 20 cfs being recirculated) could be maintained within the Old Channel ERPA despite only 20 cfs flowing into the ERPA from Landa Lake and discharging out of the downstream end. Water volume necessary to augment flow within the ERPA would start to be withdrawn (smaller quantities at first) from the river and recirculated at around 50 to 60 cfs to minimize impact to downstream water users.

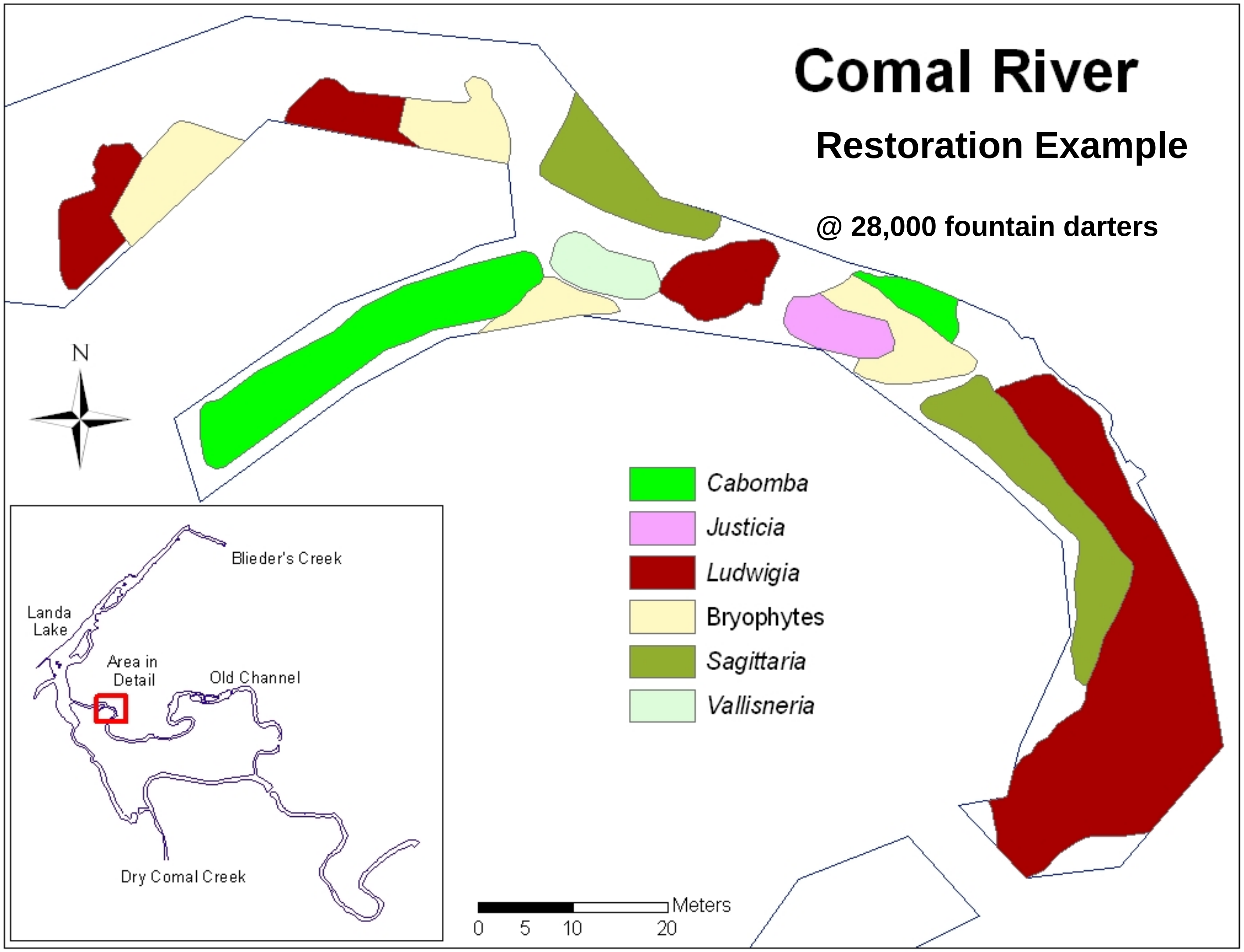


Figure 25. Potential Aquatic vegetation community following restoration in proposed Old Channel ERPA.

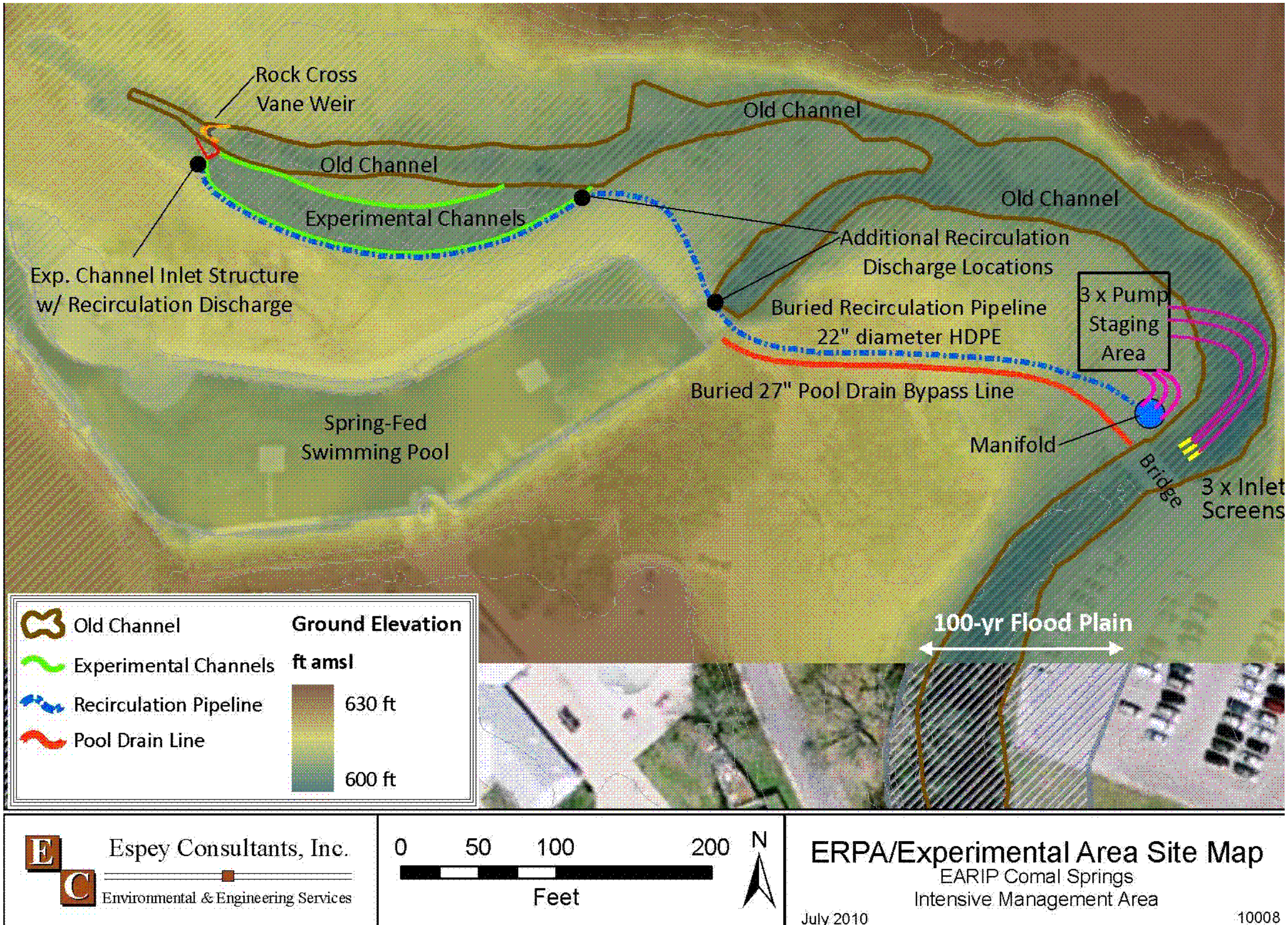


Figure 26. Conceptual Old Channel ERPA and Experimentation area

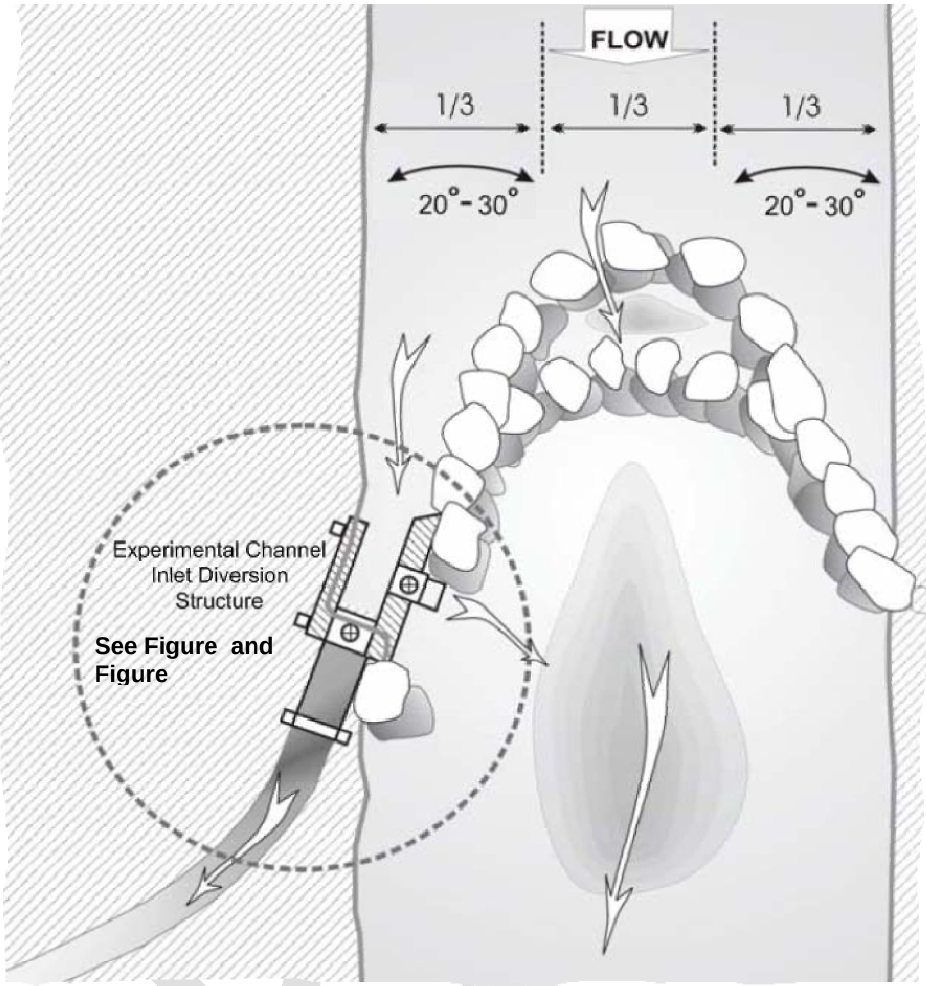


Figure 27. Rock Cross Vane Weir with Diversion Structure

Figure 28. Rock cross vane weir, South Fork Platte River, Colorado

Since the recirculation system would only be used only during severe droughts, a combination of permanently installed and temporary rental components is proposed to avoid maintenance and testing that would be necessary for critical components of a seldom-used dedicated permanent system. Underground piping to transfer water from downstream pumps to the upstream end of the recirculation area is proposed to be permanent, while the pumps themselves and the in-channel intake structures are proposed to be rented and/or temporarily placed (Figure 26).

The primary challenge with flow recirculation involves the means to divert and pump up to 50% of the flow in the channel into a pipe under low flow conditions. The option presented here is the use of wire-wrapped well screen deployed horizontally in the channel at least 6 inches or more above the channel bottom (Figure 29). Wire-wrapped well screen offers a relatively large open area to limit entrance velocities, but the aperture of the opening is very small to limit intake of sediment and other materials in the channel. Well screen is readily available, easy to deploy, durable and can easily be modified for use in the channel. Drawing water over the relatively large intake area also serves to minimize impact or disturbance to the channel, thereby preventing scour or other impacts that may be caused by a more typical single intake located near the channel bank.

The conceptual design (Figure 29) is to use an 8.5 ft segment of 12-inch diameter, 20-slot (0.020-inch) stainless steel well screen connected to a trailer-mounted 100-hp pump by a 12-inch flexible suction hose. This configuration will be capable of diverting nearly 3,000 gpm while limiting the entrance velocity at the well screen to 1.5 fps. If required, lower entrance velocities can be achieved by using longer sections of well screen or wider screen openings. To achieve the target recirculation of 20 cfs (~9,000 gpm) at 1.5 fps entrance velocity, a total of three (3) well screen and pump units are necessary.

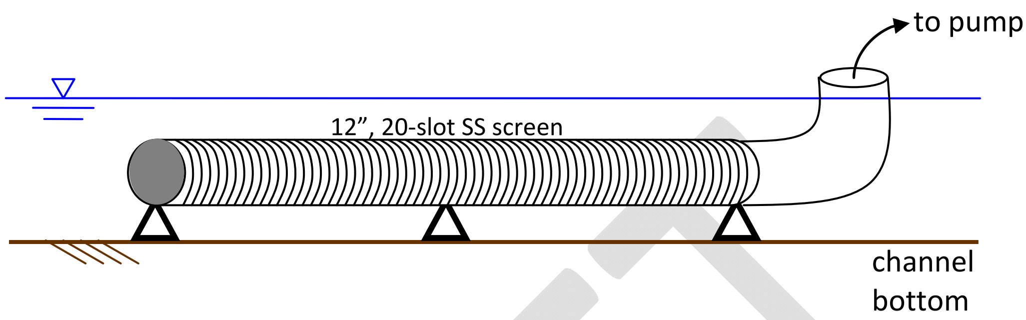


Figure 29. Recirculation Intake Screen

The discharge line from each pump will be connected to an aboveground manifold that directs the flow into an underground 22-inch (or 24-inch) SDR-17 HDPE pipe (Figure 30 and Figure 31). The pipe conveys the recirculated water upstream to the discharge location (Figure 26). The conceptual design presented here assumes the recirculation project is constructed with the diversion project so that the discharge of the recirculation pipe is integrated into the diversion structure at the upstream end of the constructed channels (Figure 26).

In addition to recirculation, the project allows for bypass of pool cleanout water around the ERPA area (red line, Figure 26). A pipeline buried in the same trench as the recirculation pipe would be used to collect pool flow-through and once-weekly pool clean out water and direct this water to discharge downstream of the existing low-water bridge. This configuration would prevent pool waters with potentially high temperatures and potentially including contaminants (e.g., suntan lotion) from entering the ERPA area and from being continuously recirculated through the system. Two pool drain configurations are considered. To drain the pool in approximately four hours using gravity, a 27” diameter pipe is estimated to be required. Another alternative is to rent a pump and discharge into a smaller diameter pipeline.

Recirculation features would be activated when total Comal spring flow is reduced below approximately 60 cfs. Recirculation to augment within ERPA flows by 20cfs (40 cfs total) would be maintained to protect the ERPA down to a condition of low flows of approximately 20 cfs entering and leaving the ERPA. The exact flow rates would be determined by additional future study; this study has identified the level of infrastructure necessary to maintain these features.

An additional concern raised with the Old Channel ERPA is the potential for “take” associated with native vegetation restoration activities and potential impingement/entrainment from recirculation strategies. At the flow levels being considered, take will be considerable throughout the Comal system and additional take will likely occur from these activities. During the permitting and environmental documentation component of this project (should it move forward), all efforts should be made to design restoration strategies and recirculation structures to minimize take to the degree practicable. However, it needs to be reiterated that the goal of the ERPA is to promote survival in the wild. At this time, we believe that the benefits from the ERPA far outweigh concerns regarding "take" that may occur as a result of implementation and management of the ERPA.

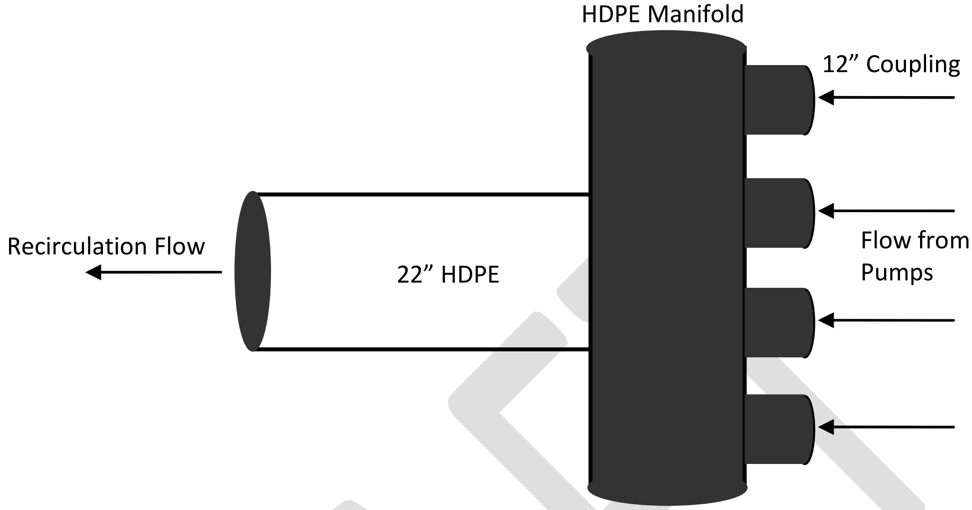


Figure 30. Recirculation Manifold-Plan

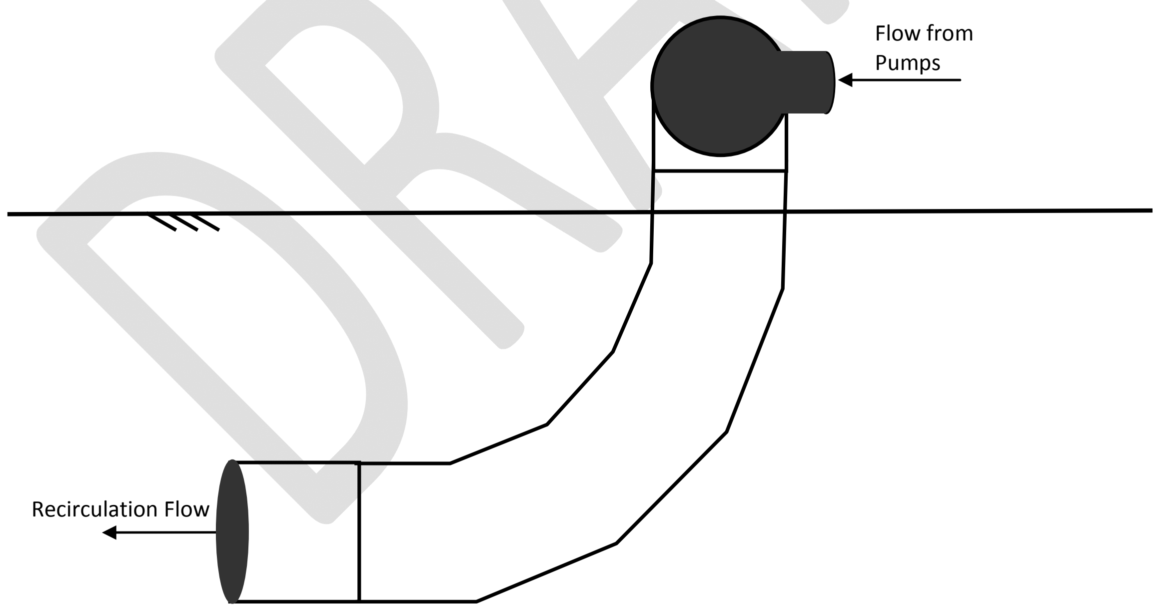


Figure 31. Recirculation Manifold-Profile

Costs were estimated for a recirculation system capable of a sustained flow of 20 cfs (Table 8). The cost estimate includes the installation cost of the HDPE pipeline. Operations costs are tabulated per month (assuming a 3-month operation period) and include equipment rental and fuel/power costs. The total cost of construction and fabrication of permanent infrastructure and equipment is about $167,000. The rental cost of one electric-powered pump unit, required pump intake/discharge hoses, and electricity is approximately $12,400 per month; because 3 pump units are required to achieve the desired recirculation flow of 20 cfs, the total monthly cost is about $35,000. These costs assume 3-phase electrical service is available near the project site.

Use of diesel pumps are not recommended because of the potential of spills associated with the need to handle approximately 7,500 gallons of diesel fuel per month adjacent to sensitive endangered species protection areas during critical time periods. Additionally, the operation cost could be significantly higher than electric, outweighing savings offered by eliminating the need for installing an electrical service. Estimated cost totals approximately $11,000 per month for electric pumps, compared to approximately $26,500 per month for diesel-fueled pumps operating under the same conditions. Specific details related to operations procedures, security, fencing and exact placement of all structures and components of this ERPA would need to be identified in subsequent phases of this project.

5.2.5.1 *Temperature Modeling Overview – Old Channel ERPA*

Water temperature has been identified as a critical habitat component for the fountain darter in the Comal system. Under extreme low flow conditions, temperature of the lake and stream reaches are most impacted because of slow circulation and water clarity. Since extreme low flow conditions are anticipated to correspond with high summer temperatures, the worst-case condition is identified as high ambient air temperatures, coupled with clear skies and low spring flows. For this assessment, water clarity is assumed to be consistently good (clear) under all flow conditions and scenarios. As previously described, four checkpoint temperature ranges have been identified as critical to the fountain darter life cycle: at and above 77 to 79 (°F) there is reduction in fountain darter larval production; between 79 and 82 (°F) and above there is a reduction in egg production, and at approximately 91 (°F) and 94 (°F) larval and adult thermal death can be expected based on laboratory studies (Brandt et al. 1993, Bonner et al. 1998, McDonald et al. 2007). Model scenarios considering potential Old Channel/New Channel flow splits were evaluated to assess impacts to temperature (Section 5.2.2). Additionally, potential impact of the Old Channel ERPA was evaluated to determine whether the recirculation component will have a significant temperature impact (increase).

The original QUAL2E model developed by Dr. Hardy in the late 1990s was used as a basis for new modeling work. The overall spatial extents and model framework were preserved for the new model. However, revisions were made to the model geometry, parameters and boundary conditions to reflect the present status of the system. Following this extensive set of revisions, the new QUAL2E model was calibrated using real-time data collected during the low flow conditions exhibited during July 2009. Upon new model calibration, three variations of the QUAL2E model were used in this evaluation: (1) Landa Lake with New Channel model; (2) Old Channel model and (3) Landa Lake flow screens model. Additionally, a new Water quality Analysis and Simulation Program (WASP) model was developed specifically for this project to evaluate impacts to temperature caused by recirculating water within the Old Channel ERPA.

Table 8. ERPA Old Channel Recirculation measures, estimated costs

Infrastructure and Purchased Equipment

Description	Quantity	Unit	Unit Price	Total
Mobilization	1	LS	$5,000	$5,000
Clear and Grub	0.25	Ac	$5,000	$1,250
22" HDPE SDR 17 Pipe and Installation	740	LF	$80	$59,200
Pipe Manifold Structure	1	LS	$2,000	$2,000
12" Gate Valve	4	EA	$1,500	$6,000
24" Gate Valve	1	EA	$15,000	$15,000
12" 20-slot SS Well Screen, 20-ft Joint	2	EA	$2,500	$5,000
Screen Assembly	3	EA	$750	$2,250
6" PVC Pipe and Installation	300	LF	$30	$9,000
Revegetation	1200	SY	$1.50	$1,800
Electrical Service Line	500	LF	$65	$32,500
Subtotal				$139,000
Contingencies	20	%		$27,800
Total				**$167,000**

Rental Equipment

Description	Quantity	Unit	Unit Price	Total
100-hp Trailer-Mounted Pump with Noise Abatemen	9	Mo	$7,000	$63,000
12-in Flexible Suction Hose	150	LF/Mo	$6	$8,100
12-in Flexible Discharge Hose	60	LF/Mo	$2	$1,080
Total				**$72,200**
Per Month				**$24,100**

Fuel Cost (Diesel)

Description	Quantity	Unit	Unit Price	Total
Fuel (Diesel, 3.5 gph, 3 pumps, 3 months)	22680	Gal	$4	$79,380
Per Month				**$26,500**

Electric Power Cost

Description	Quantity	Unit	Unit Price	Total
Electricity	362410	kWh	$0.084	$30,400
Demand Charge (3 months)	168	kW	$3.75	$1,888
Total				**$32,300**
Per Month				**$10,800**

Total (Diesel)	**$280,000**
Total (Electricity)	**$272,000**
Operations Total Per Month (Diesel)	**$50,600**
Operations Total Per Month (Electricity)	**$34,900**

It should be noted that Hardy (2011) presents an updated QUAL 2E water quality model, based on additional input modifications and adjustments to boundary conditions. As the results of our updated QUAL2E model and the subsequently revised Hardy (2011) QUAL2E model are nearly identical, we refer to Hardy (2011) for the detailed modeling evaluation of water temperature at low flows in Landa Lake and various Old / New Channel flow splits as opposed to repeat the methodology, calibration, and results section herein.

In summary, when total spring flow drops below approximately 100 cfs and Spring Runs 1 and 2 cease surface flow, temperature in the lake begins to increase. Temperature of receiving streams (Old Channel and New Channel), are impacted both by source water (lake water) temperature and ambient environmental conditions; however, because of the short distance from the lake to the habitat areas of interest, the lake temperature has a significant impact on stream temperatures. At 30 cfs total Comal springflow, diurnal variations in temperature are considerable, but even under the worst-case conditions modeled, night-time temperatures are often below all temperature checkpoint ranges. However, during day-time under typical sun and shade conditions, temperatures in Landa Lake, New Channel and Old Channel (lower portions of Reach 19 [Hardy 2011: Old Channel – Golf Course bridge to Elizabeth Street]) exceed checkpoint ranges for reduction in larval and egg production. Both models used indicate that diurnal temperature conditions are established as soon as flow levels become established; maximum temperatures for each scenario are typically reached after two days and do not continue to increase. A large factor in this relates to the spring source water temperature that remains constant across the entire range of conditions (74.3 °F [23.5°C] was assumed for all modeling scenarios). In the New Channel under flow management conditions where flow is completely cut off, fountain darter mortality temperatures are reached in one segment and temperature in all segments exceeds 90°F (30°C) during the day. As such, the flow-split management recommendations (discussed in Section 5.2.2) were made to maintain at least 10 cfs through the New Channel. The full set of updated temperature model runs can be found in Hardy (2011).

WASP modeling was conducted to specifically assess potential impacts in the Old Channel ERPA (Figure 32). It needs to be noted that the WASP model calibration uses our updated and calibrated QUAL2E results for boundary conditions and input into WASP. Hardy (2011) results were not available at the time of our analyses. As results for our updated QUAL2E model and the revised Hardy (2011) model are nearly identical, we are confident in using these results as input parameters to the WASP model for this feasibility report. However, because of the additional updates to the QUAL2E model (HARDY 2011), the feasibility report should be considered preliminary and additional WASP runs conducted based on the Hardy (2011) QUAL2E model during the permitting and environmental documentation phase of this project, should it move forward.

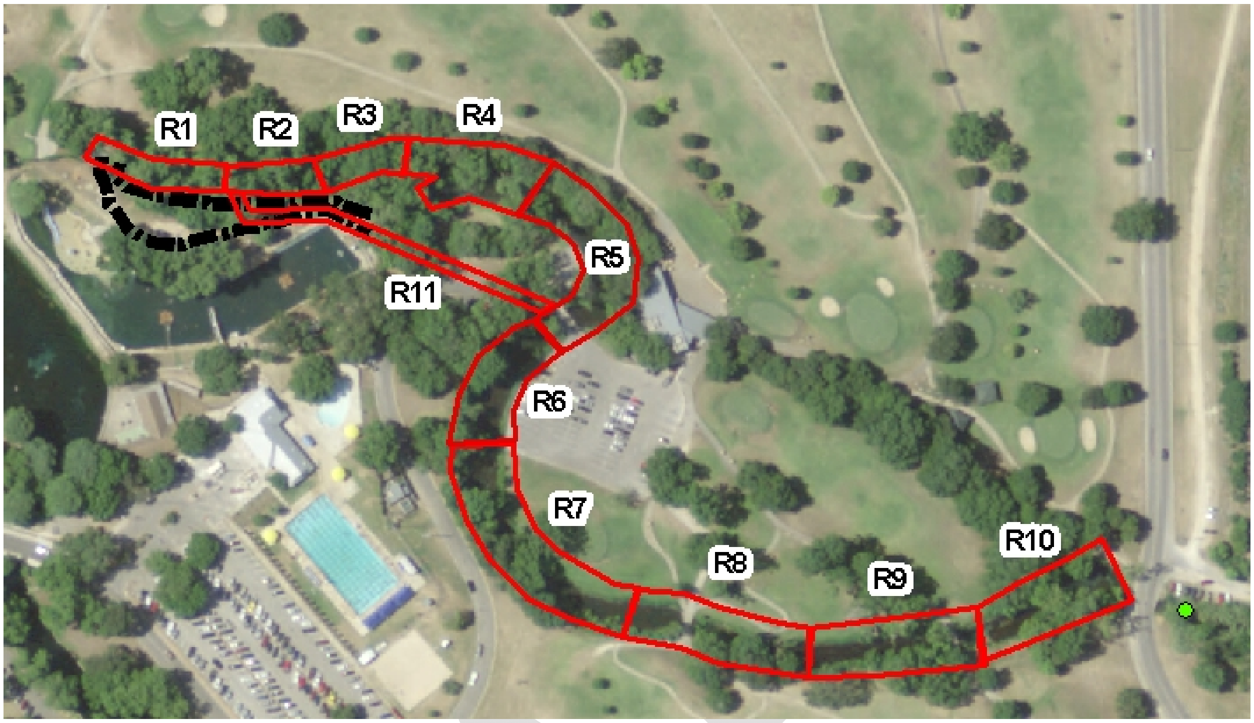


Figure 32. WASP segmentation, Old Channel ERPA recirculation

Figure 33 shows the WASP water temperature model results for July 2009 worst case ambient air temperature modeled conditions. Landa Lake maximum (80.6 °F) input temperatures were used based on QUAL2E results. As evident in Figure 33, diurnal fluctuations in water temperature are evident and range between approximately 76 and 81 °F (similar to shown in Figure 12). The purple line in Figure 33 represents when the recirculation pump was turned on (July 10) in the model with the full 20 cfs being recirculated at that time. Figure 33 indicates that because of the continuous input of 20 cfs from Landa Lake, recirculating 20 cfs for a total Old Channel flow of 40 cfs through the ERPA does not measurably increase water temperatures in this reach (Figure 33).

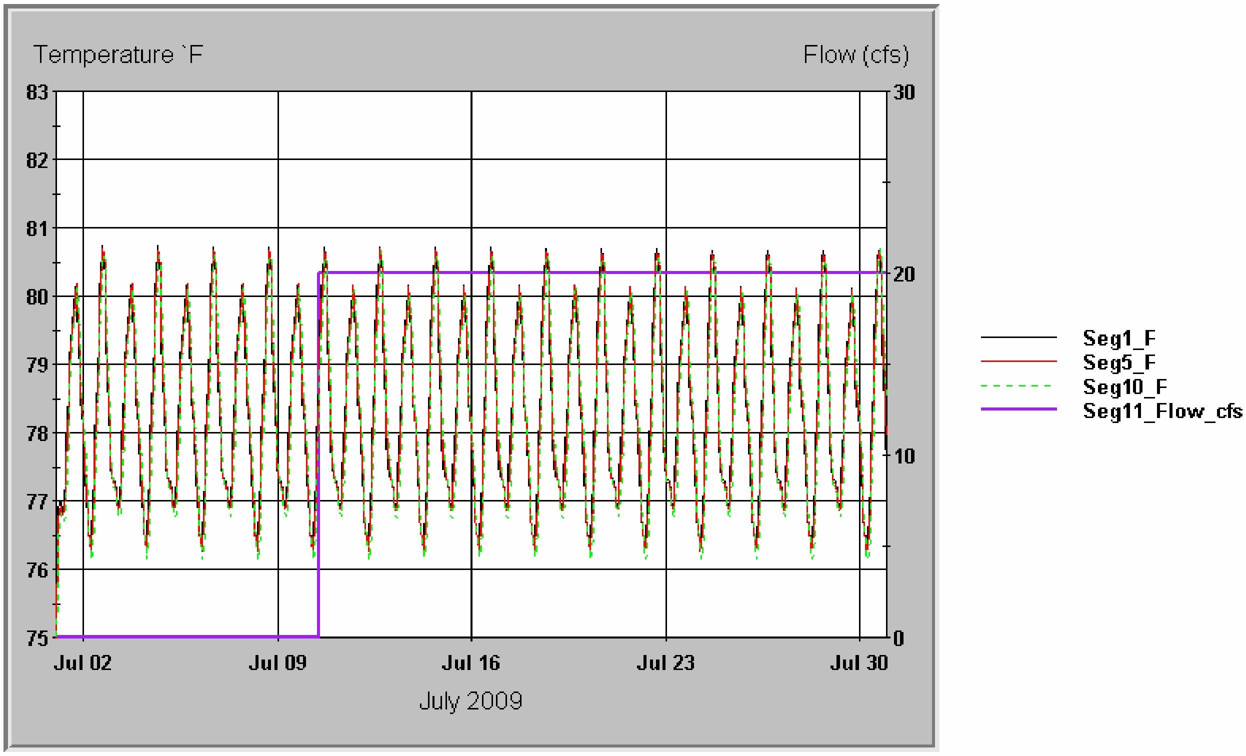


Figure 33. WASP temperature model results for the Old Channel ERPA recirculation. Purple line represents when 20 cfs recirculation was started (July 10) in model simulation.

5.2.5.2 *Old Channel proposed permanent experimentation channel*

A key component of the proposed Old Channel ERPA is the incorporation of a permanent area to use for applied research. Applied research specifically considered in the development of this conceptual design is discussed in Section 5.3. The proposed experimentation area consists of two parallel channels, constructed in an area just below Landa Lake and adjacent to the existing Old Channel (Figure 26). The purpose of the constructed research channel is to provide the ability to experiment with flow conditions to evaluate potential impacts to endangered species and their habitats.

The constructed research channel is envisioned as two permanent channels, each approximately 13-foot wide and 230 feet long, constructed parallel to the Old Channel (Figure 34). The southern (right) bank of the diversion channel runs alongside an existing low concrete wall adjacent to the swimming pool. For construction of the channel, an engineered segmental masonry unit retaining structure that varies in height from 3 to 7 feet is proposed to be constructed 5 feet north of the existing concrete wall with a shorter retaining structure proposed as the northern bank of the channel (Figure 35). The existing and proposed topography of the area with the diversion channels will necessitate some cut and fill (Figure 36).

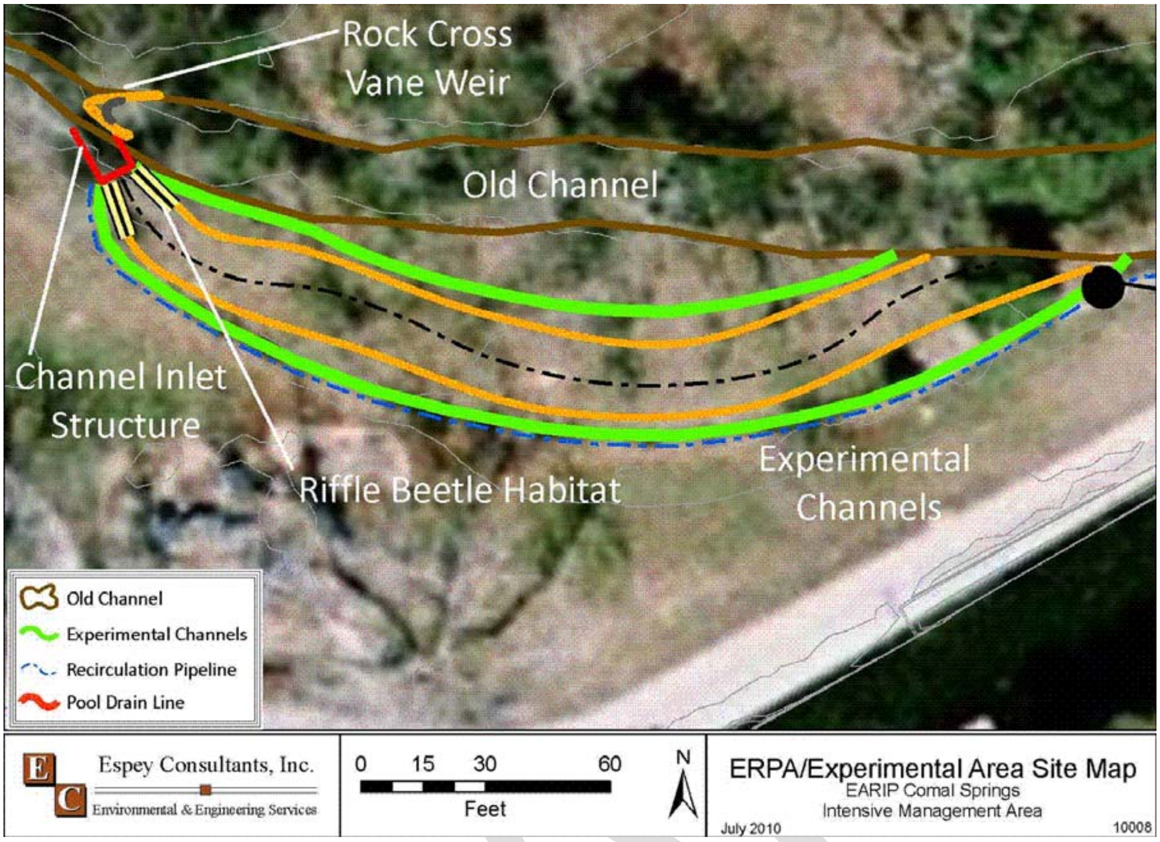


Figure 34. Old Channel ERPA and experimental channels, aerial photo

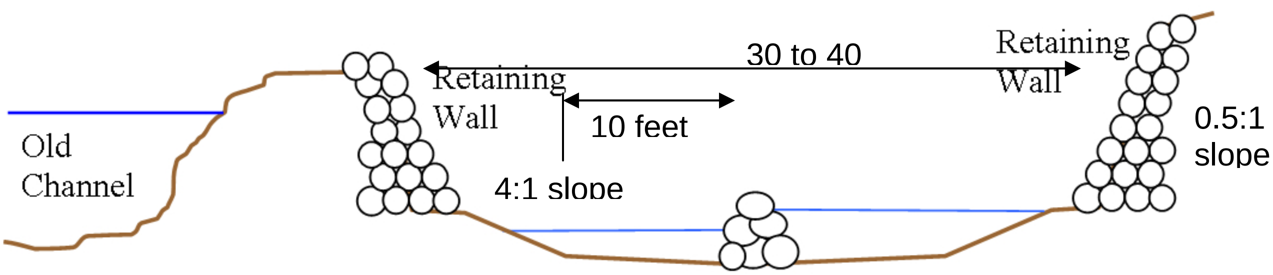


Figure 35. Typical Experimental Channel Cross-section

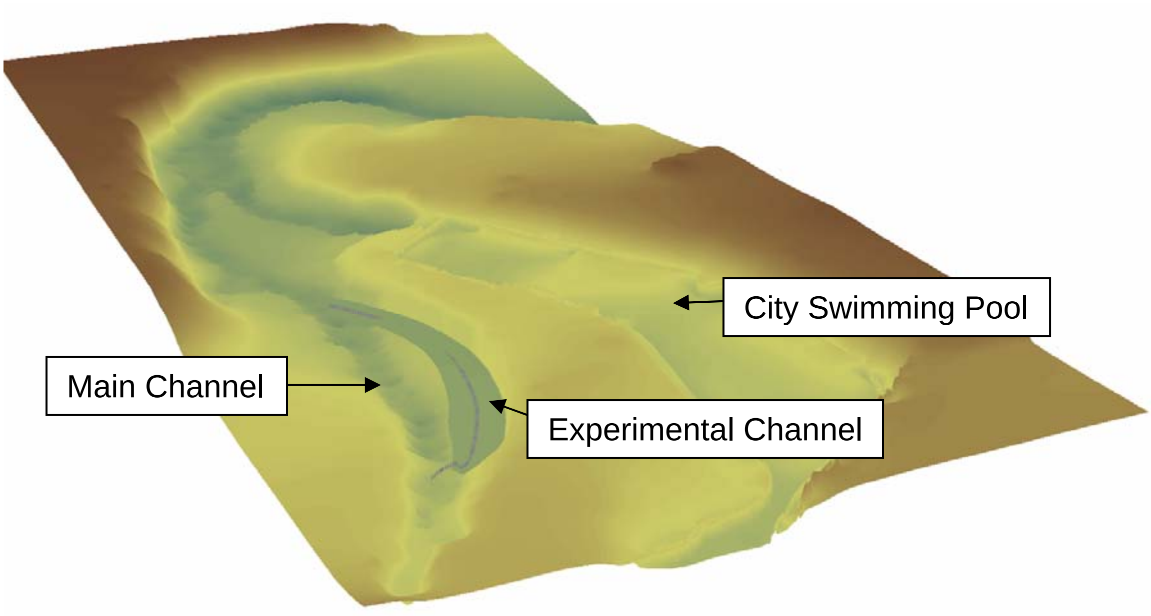


Figure 36. Old channel topographic scene, with experimental channels

Figure 37 shows the approximate location of the experimental channel on recent aerial photography. There has been considerable discussion regarding the aesthetics of the proposed channel. It needs to be clear that the proposed area is tucked between the existing retaining wall from the swimming pool that has a chain link fence on top of it and the actual river channel itself. The location is currently wooded with understory vegetation and not visible from the Golf Course road. The area would only be visible from within the swimming pool area and from the Golf Course looking across the existing Old Channel. The experimental channel would be designed considering aesthetics with boulder formed retaining structures and natural substrates. Coupled with an educational kiosk within the swimming pool area to explain the purpose of the experimental channel, endangered species protected, and applied research being conducted, we believe this would be a very positive upgrade to the current land use in this area.

The experimental channel will be unlined as the point is to use natural substrate and vegetation features to mimic the preferred habitat of the fountain darter. These features will serve to increase the channel roughness and limit flow velocities. A Manning's n value for the channels of 0.045 for a winding sand or gravel channel with vegetation is an assumed roughness value; a slope of 0.0011 is consistent with the energy slope of the water in the Old Channel just upstream of the golf course bridge. This slope is anticipated to provide sufficient flexibility to incorporate riffles and runs and pools into the experimental channel, but should be further evaluated before final design is completed. The slopes, depths of flow, and velocities for a range of discharges are given in

Table 9 assuming channel geometry similar to that shown in (Figure 35).

Figure 37. Proposed Old Channel Experimental Channel Location

Table 9. Old channel experimental channels, hydraulic design parameters

Slope	Q (cfs)	Average Velocity (fps)	Average Depth (ft)
0.0005	10	0.7	1.0
0.0005	20	0.9	1.4
0.0011	**5**	**0.7**	**0.56**
0.0011	**10**	**0.9**	**0.81**
0.0011	**20**	**1.2**	**1.17**
0.0011	**35**	**1.4**	**1.55**
0.0022	10	1.2	0.68
0.0022	20	1.5	0.98

The northern channel will be approximately 210 ft long along the channel centerline while the southern channel will be about 260 ft long. The downstream terminus of each channel will be at the same elevation as the base of the Old Channel to allow the channels to act as an extension of the Old Channel habitat. The approximate profile of the channels is shown in Figure 38. At the greatest depth, the channel bottom is approximately 7 feet below the existing ground surface elevation and typical excavation is between 2 and 5 feet below existing natural ground level. Because of the limited distance available between the Old Channel and the pool, the use of boulder formed retaining structures bordering the channels will be necessary.

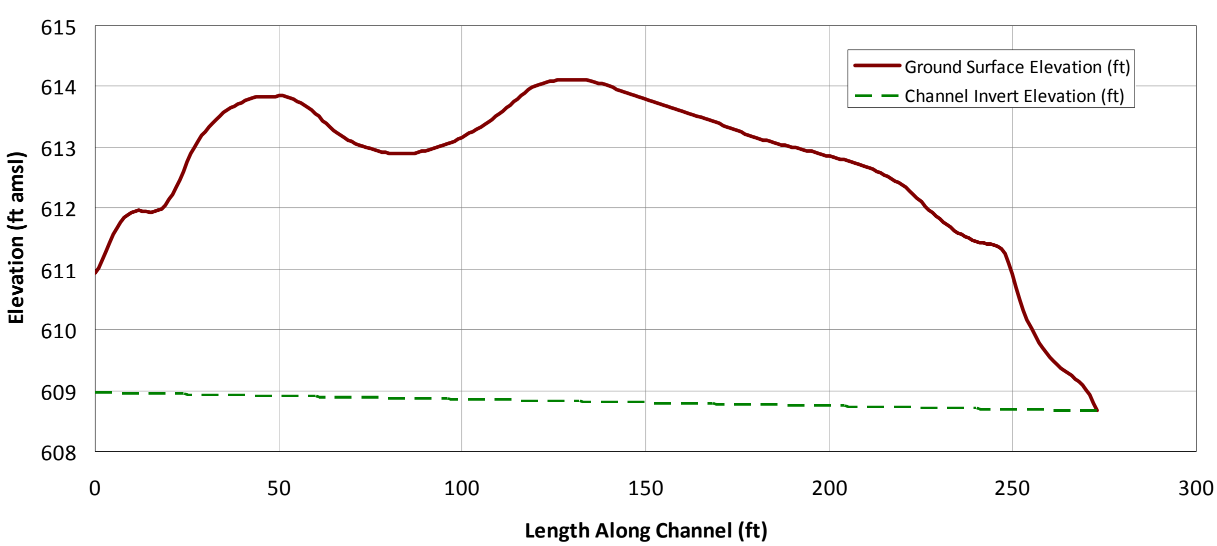


Figure 38. Proposed profile of experimental channel

The channel slope of the experimental channel is proposed to be significantly less than in the adjacent section of Old Channel; therefore, a drop inlet structure will be required at the head of the channels as previously described. A rock cross-vane weir (Figure 27) is proposed to provide head to deliver water to the head gates of the diversion channels (Figure 39 and Figure 40) and to control impact to the existing Old Channel. Near the upstream end of the experimental channels and the control structure, constructed riffle beetle habitats are proposed. These consist of a pipe buried beneath native rock or gravel substrate similar to substrate where beetles are found; the pipe will percolate or upwell water through the rocks to mimic flow of water through natural habitats (Figure 39 and Figure 40).

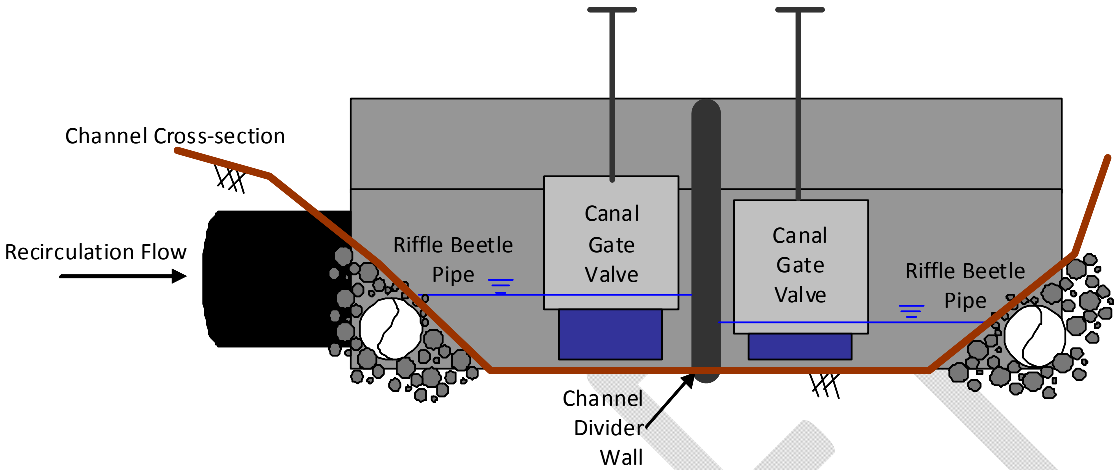


Figure 39. Headgate Structure-Section

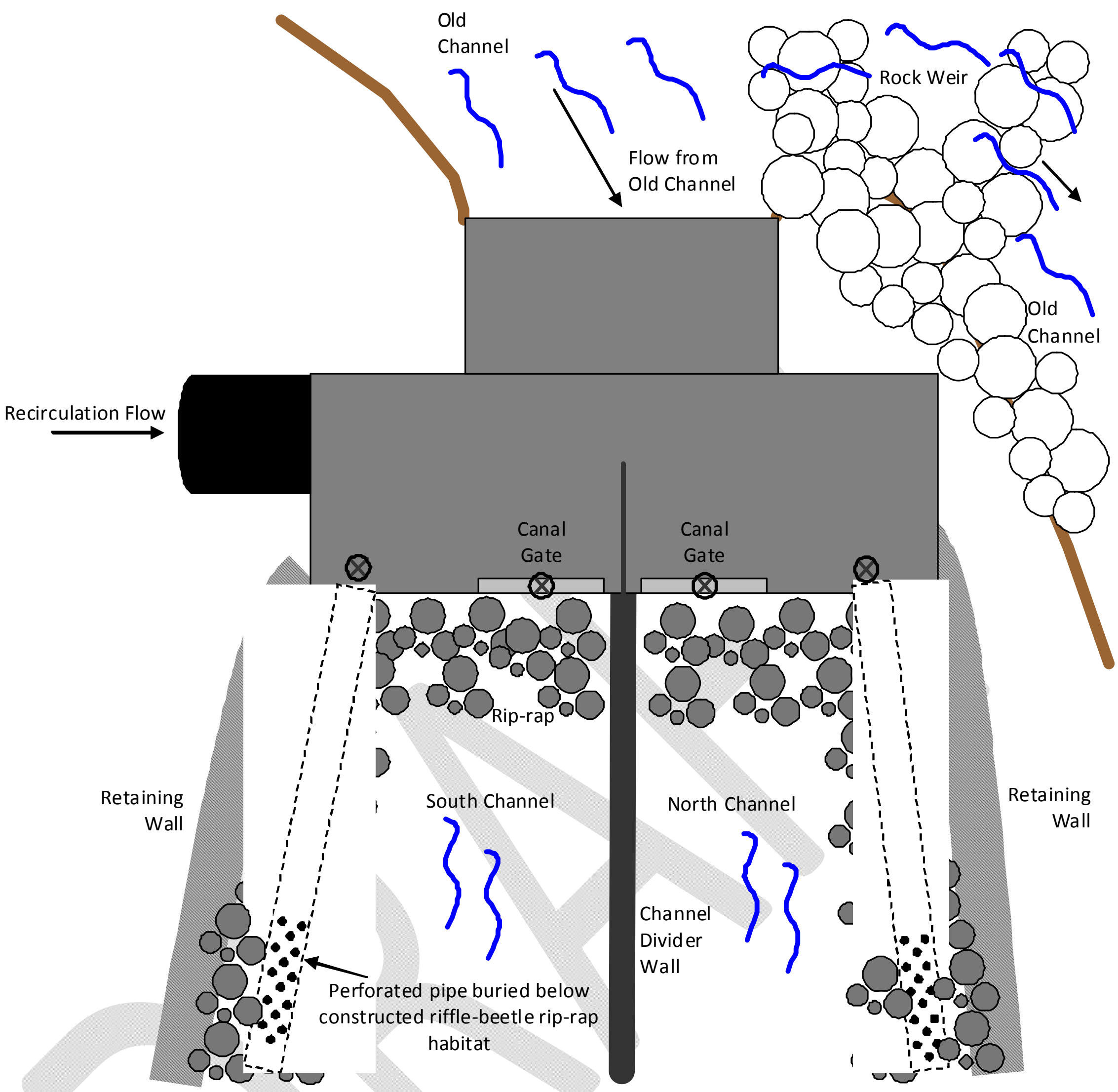


Figure 40. Headgate Structure-Plan

The cost to construct the proposed permanent experimental diversion channel, including the control structure and rough in-channel grading but excluding vegetation and habitat final in-channel grading, is estimated at approximately $265,000 (Table 10).

Table 10. Experimental channel estimated construction cost

Description	Unit	Quantity	Unit Price	Total
Mobilization	1	LS	$15,000	$15,000
Clear and Grub	0.50	Ac	$5,000	$2,500
Excavation and Grading	1300	CY	$15	$19,500
Segmental Masonry Unit Wall	3100	SF	$25	$77,500
Rock Vane Weir	50	LF	$240	$12,000
Headgate Structure	1	LS	$15,000	$15,000
Riffle beetle upwelling habitat	2	LS	$2,000	$4,000
Channel Lining Gravel/Rip Rap	170	CY	$100	$17,000
Channel divider wall	26	CY	$1,000	$25,556
Surveying	1	LS	$5,000	$5,000
Channel Construction	520	LF	$50	$26,000
Subtotal				$219,056
Contingencies	20	%		$43,811
Total				**$262,867**

Alternate configurations of the experimental channel or the recirculation system could provide similar benefits. These alternate configurations were not discussed in detail because of additional cost of constraints; however, these could be investigated as part of the environmental documentation and final design phase of the project. The proposed experimental channel configuration is constrained by existing walls that outline the perimeter of the spring-fed swimming pool. If some of the pool area could be re-purposed and dedicated to the experimental channel area, the channels could be augmented to be wider. More sinuous, wider channels would allow more flexibility in design of natural habitat. Widening the existing configuration by approximately 10 to 15 feet would improve the design presented in this report.

The proposed recirculation system is based upon temporarily installing rented pumps. Aesthetics, noise and security were among some concerns of stakeholders, particularly the City of New Braunfels. Additional options related to purchase and installation of permanent pumps in a dedicated structure could be investigated, as could installation of permanent intake structures. Another option is to construct a permanent housing for temporary rented pumps; this may address some concerns while not necessitating a long-term maintenance program for infrequently-used, expensive pumping equipment.

5.2.5.3 *Old Channel ERPA Permitting*

Permitting requirements will depend on the exact component configuration, but it is anticipated that an evaluation of any in-channel structure (e.g., the old channel ERPA) would require flood evaluation. This would require FEMA flood permitting with the need for updated flood maps through the FEMA process.

It is also anticipated that a water rights permit would be required through TCEQ. On May 21, 2010, the project team met with Chris Loft (TCEQ water rights permitting section manager). Mr. Loft indicated that a bed and banks authorization would need to be granted for diverting water from the old channel, as proposed for the ERPA recirculation option. Mr. Loft recommended a pre-application meeting with TCEQ staff in the permitting, environmental and water quality sections. Additional staff could be assembled from the 401 certification group at the same time. We recommend that such a meeting be scheduled if this project moves past the feasibility stage and as details are further developed. Additionally, should the project move forward, a permittee would need to be identified and evaporation losses would need to be identified as well as operational aspects and reliability. An existing water right holder would need to contract water to cover the evaporation losses since the Comal River system is currently fully appropriated.

The amount of water to be impounded by this project within the recirculation system is anticipated to be less than 1 acre-foot. That volume could be achieved during higher flow (e.g., 60 cfs total Comal spring flow) conditions by diverting and recirculating an increasing amount of water over an extended period of time; for example, the diversion rate could be increased from 0 to 4 cfs over the course of 24 hours, thus achieving a full 20 cfs over the course of 5 days. Since the recirculation system will be operating, impact on flow at downstream user diversion points could be minimized to less than 1 cfs on any given day.

5.2.5.4 *Old Channel Reach 2 ERPA*

There is also the potential for high quality fountain darter habitat present in Reach 2 (Old Channel within Schlitterbahn loop, Figure 10) of the Old Channel which makes it favorable for ERPA consideration should the Reach 1 site not be acceptable to stakeholders. However, this area is not favorable for providing riffle beetle habitat because of the distance from typical beetle habitats near Landa Lake. Additionally, this area exhibits low hydraulic gradient (0.0001 ft/ft) which makes it less flexible for experimentation compared to Reach 1 near Landa Lake. To control flow and experiment within this reach, pumps would be required and this would considerably increase the cost associated with this option. The proposed Old Channel experimental channel (Reach 1) is proposed to have a slope of 0.0011. Although, the Reach 1 location is remotely located and not visible from the Golf Course road, the Reach 2 location is even more remote being tucked in behind the railroad tressle in an area used primarily as a parking lot for Schlitterbahn employees when the park is in operation. One idea for future consideration might be discussions with the City of New Braunfels and Schlitterbahn regarding an educational facility to be constructed in cooperation with a research channel within this reach.

5.2.6 Landa Lake – Temporary flow screens

A primary concern expressed by the EARIP SSC has been the potential for increased temperature conditions in Landa Lake and subsequently to downstream locations. Hardy (2011) describes the temperature modeling conducted to assess this concern. Because of the original concern, we evaluated whether alterations of flow patterns within Landa Lake would be successful in reducing water temperatures during extreme drought conditions. One option is to cut off shallow areas entirely, restricting water only to deeper areas within the lake. Another option investigated in this project is to install temporary baffles or screens to direct flow to deeper areas (Figure 41). This was proposed to reduce retention time and keep lake temperatures low, particularly in areas where water is diverted into the Old Channel. Temporary, quickly-deployable structures are proposed in lieu of permanent structures. A survey was completed to identify potential products/technologies that would be suitable and cost-effective. From this survey, cost estimates are developed for two candidate technologies, water-inflatable cofferdams Figure 42) and floating baffles (Figure 43).

The concept of temporary structures allows for some limited water exchange from one side of the screen to the other to prevent complete dead zones on the non-flow side of the baffles. Exchange may be either through holes in the screen, by the material itself or by gaps between the buoys on top or weights at bottom. Exchange across the screen would need to be minimized to the avoid short-circuiting that would make ineffective their main purpose to direct flow.

Water-inflatable cofferdams appear to be the well-suited for deployment in Landa Lake, are simple and quick to install, and are low-cost. Aqua Dam, Inc. (www.waterstructures.com) inflatable dams are shown on a water-inflatable dam deployed in an Idaho stream to limit the channel width to increase the depth of flow and allow salmon passage over a riffle (Figure 42). Water-inflatable cofferdams offer the following benefits: durability (can be reused multiple times), ease of installation and removal, no permanent structures required and safe. Depending on the depth of water for the installation, a crew of 4 to 6 can install a 100-foot dam in less than one hour. The cost of the inflatable dams is estimated assuming a water surface elevation of 620 ft in Landa Lake. The total cost of the inflatable dams is approximately $126,000 (Table 11). The estimated cost to install the dams is $11,200, and the cost of removal is $13,200 (Table 11).

An alternative to the water-inflatable dams is the use of custom-manufactured floating baffles (Figure 43). The use of floating baffles would require installation of permanent anchor structures at the endpoints of each baffle along the shoreline and in the lake. However, once the anchor points are installed, deployment and removal of the floating baffles would be very fast and straight forward. Unit cost for 3 ft to 6 ft baffle curtains constructed of 45 mil reinforced polypropylene is $36 per linear foot (provided by Layfield Environmental Systems Corporation). The estimated cost for a floating baffle system for Landa Lake, including installation of permanent anchor points along the shore and in the lake, is approximately $67,000 (Table 12). The cost to deploy the baffles (included in the total above) is about $4,600 (Table 12).

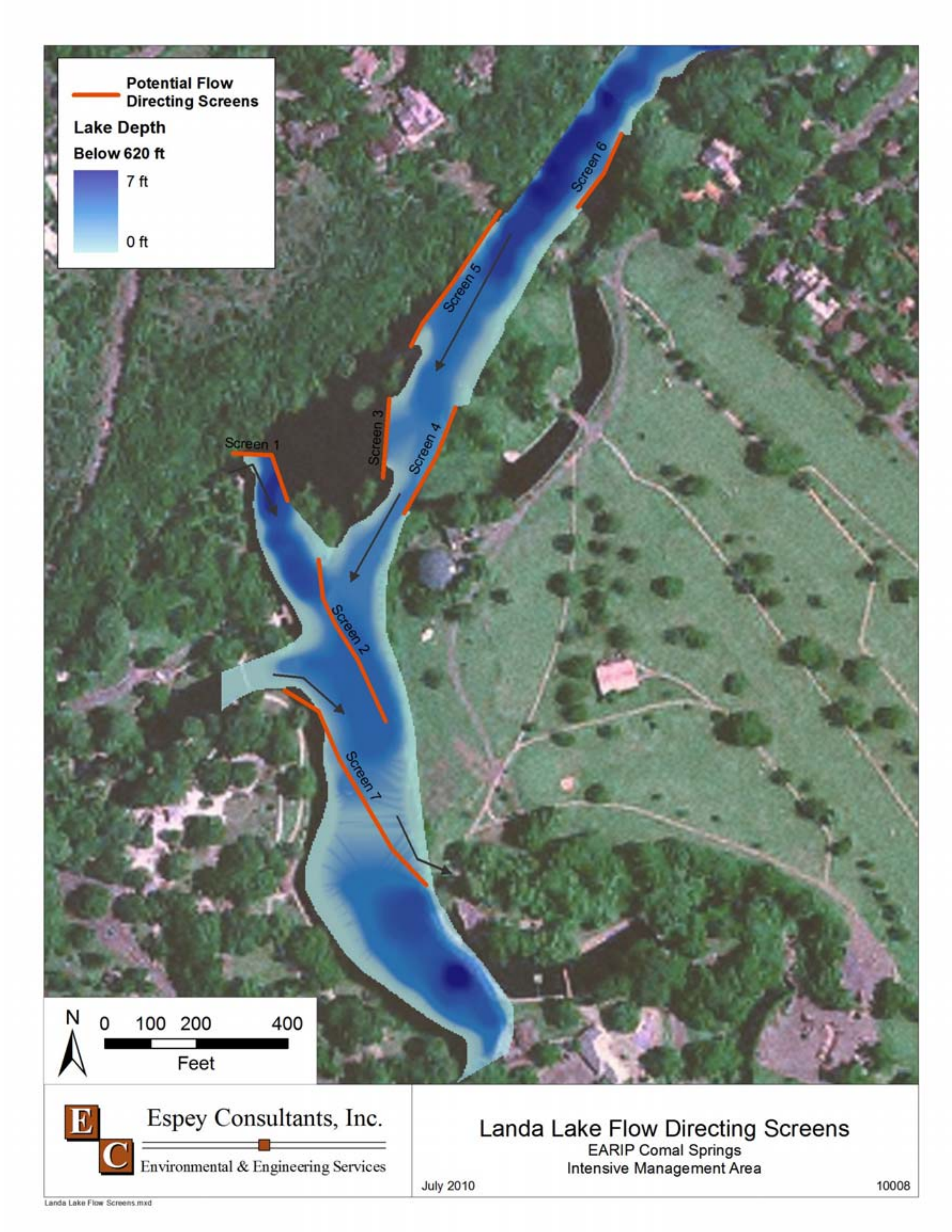


Figure 41. Landa Lake flow screens

Figure 42. Aqua Dam inflatable cofferdams

Table 11. Inflatable cofferdam estimated costs

Description	Unit	Quantity	Unit Price	Total	
Inflatable Dams	1	LS	$75,750	$75,750	
Miscellaneous Equipment	1	LS	$2,500	$2,500	ropes, waders, knives, winches
Portable Pumps (One Week Rental)	2	Ea	$1,000	$2,000	
Installation Labor	112	Hr	$100	$11,200	assume 1-hour per 100-ft
Removal Labor	132	Hr	$100	$13,200	includes 20 additional hours for re-rolling dams
Subtotal				$104,650	
Contingencies	20	%		$20,930	
Total				**$126,000**	

Inflatable Dams and Labor Quantity Estimates

Line	Depth Range	Design Depth (in)	Length (ft)	Dam (ft)	Unit Cost ($/ft)	Cost	Crew Number	Time (hr)	Total Time (hr)
1	0-6	72	50	8	125	$6,250	6	4	24
2	0.9-4.25	51	120	6	250	$37,500	5	5	25
3	0-3	36	45	4	50	$2,500	4	3	12
4	1-3	36	80	4	50	$5,000	4	3	12
5	0-3.25	39	90	5	70	$7,000	5	3	15
6	0-3	36	60	4	50	$5,000	4	3	12
7	0-3	36	135	4	50	$7,500	4	3	12
Subtotal						$70,750			112
Shipping						$5,000			
Dams Total						**$75,750**			

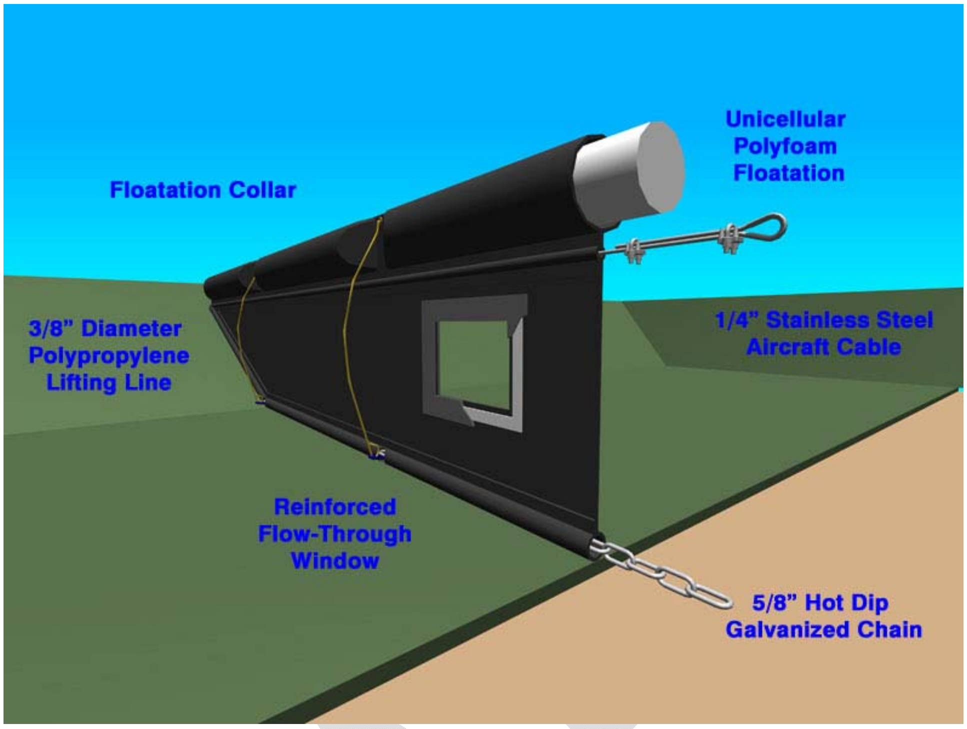


Figure 43. Environetics floating baffles (flow screens)

Table 12. Flow screen (baffle) estimated costs

Description	Unit	Quantity	Unit Price	Total	
Floating Baffles	1	LS	$26,600	$26,600	
Miscellaneous Equipment	1	LS	$1,500	$1,500	waders, winches, etc.
Shore Anchorage Points	3	Ea	$2,500	$7,500	assume 6" steel bollard buried at least 48", set in concre
Lake Anchorage Points	11	Ea	$1,000	$11,000	
Baffle Installation Labor	46	Hr	$100	$4,600	assume 2-hours per baffle
Baffle Removal Labor	46	Hr	$100	$4,600	same as installation
Subtotal				$55,800	
Contingencies	20	%		$11,160	
Total				**$67,000**	

Floating Baffles and Labor Quantity Estimates

Line	Depth Range (ft)	Design Depth (in)	Length (ft)	Unit Cost ($/ft)	Cost	Crew Number	Time (hr)	Total Time (hr)
1	0-6	72	50	36	$1,800	3	2	6
2	0.9-4.25	51	120	36	$5,400	4	2	8
3	0-3	36	45	36	$1,800	3	2	6
4	1-3	36	80	36	$3,600	3	2	6
5	0-3.25	39	90	36	$3,600	3	2	6
6	0-3	36	60	36	$3,600	3	2	6
7	0-3	36	135	36	$5,400	4	2	8
Subtotal					$25,200			46
Shipping					$1,400			
Baffles Total					$26,600			

The flow screens were then evaluated for potential benefits from the partitioning of Landa Lake (Figure 44). The original QUAL2E model with modifications noted in Section 5.2.5.1 was calibrated to July 2009 conditions. Air temperature during this period was very hot (100 to 104 degrees), conditions were sunny, and spring flow conditions are somewhat low (160 cfs).

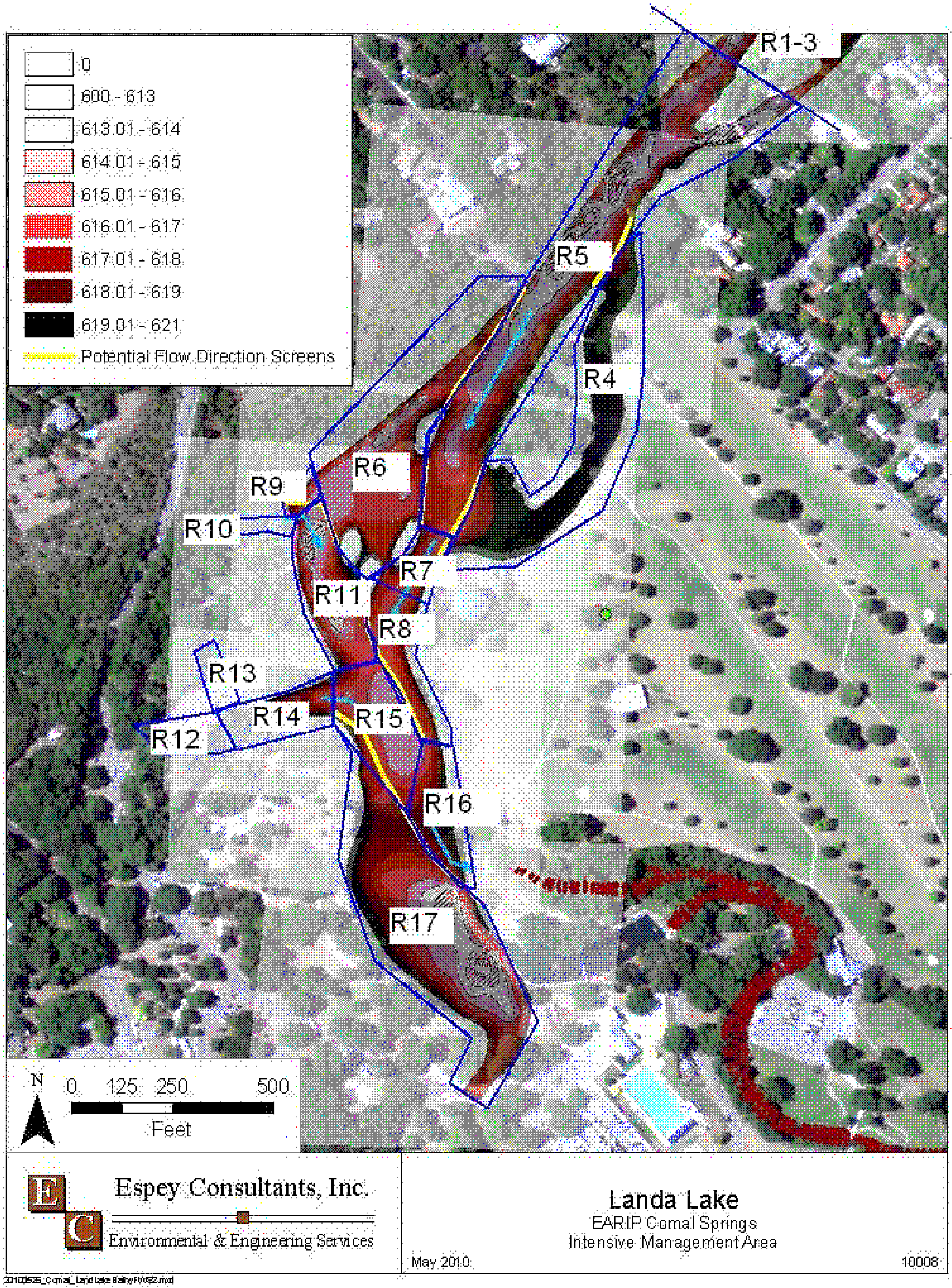


Figure 44. QUAL2E segmentation, Landa Lake with flow screens

Temperature modeling shows that implementing the flow direction screen strategy within the lake does have a considerable impact on lake temperature with limited effect downstream. The reduction in residence time resulting from partitioning of the lake reduces maximum day-time lake temperatures in some areas by 6° to 7°F; however, the partitioning also creates lake areas with limited circulation and results in temperatures increases of up to 10°F (91°F in some areas). Lake temperature reductions resulting from installation of flow screens do not significantly impact temperature within the Old Channel.

Deployment of temporary flow baffles or screens within Landa Lake to direct flow away from shallow areas was hypothesized to reduce temperature within the lake and flowing into the Old Channel. It appears that positive effects occur in protected portions of the Lake, but are not extended downstream to the Old Channel. No significant improvements to temperature in the Old Channel coupled with the potential negative impacts within portions of the lake makes this strategy unfeasible in our opinion. As such, we do not recommend this alternative for further consideration.

5.3 APPLIED RESEARCH

Perhaps the most valuable component of the ERPA concept over the lifespan of the HCP (and definitely during the first phase) will be the applied research that can be conducted to better understand the ecological dynamics of the Comal system, particularly under low flow conditions.

5.3.1 Old Channel ERPA experimental channel

The experimental channel proposed in the Old Channel ERPA was specifically designed to address the key unknowns repeatedly discussed by the EARIP SSC and also reiterated by Hardy (2011). Based on the comments received to date, and several misunderstandings about the experimental channel, we think it prudent to first describe what it IS and what it is NOT (Table 13).

Table 13. Old Channel ERPA Experimental Channel Description

Old Channel ERPA Experimental Channel Description	
IS	**Is NOT**
for Applied Research to guide HCP phase 2 development and the adaptive management plan.	*to recirculate water through to keep endangered species alive during the drought.* Note: Maintaining a viable population of fountain darters during drought is the purpose of optimizing habitat conditions in the ERPA reach of the MAIN channel of the existing river at all times.
a small, constructed channel split in two to provide an experimental control and is proposed to be constructed in a remote area	*some giant structure located along a visible roadway*
constructed with boulder designed walls and earthen bottom	*a concrete lined ditch*
designed to tie back into the main channel in a non-intrusive manner limiting the potential for any downstream erosional impacts or channel modification.	*in a highly erodible area or frequently disturbed area from flooding, as it is located immediately below the dam.* Note: in the 10 year Variable Flow study, only the June 2010 flood was significant enough to cause major damage in this stretch of river.

Several comments have also been received questioning the need to conduct field experiments, with the argument that all necessary studies could be conducted in a laboratory (i.e. the San Marcos National Fish Hatchery and Technology Center [NFH&TC]). Other comments agree that on-site is the appropriate place to conduct the studies but would prefer to conduct any research in the Upper Spring Run reach, Landa Lake or main channel of the river as opposed to an experimental channel. Table 14 provides the key studies envisioned for the Old Channel ERPA based on unknowns identified by researchers over the years and repeatedly discussed by the EARIP SSC and EARIP steering committee during HCP development. The table compares which studies could be conducted in the laboratory and which ones could be conducted in the main lake or river portions of the Comal system.

Upon review of Table 14, it is evident that the key unknowns simply can’t be addressed in a laboratory setting. It would require a living stream to be created that essentially simulates the conditions of the natural environment. This would require an enormous effort to create, and amount of water and electricity to maintain and still would likely fall short relative to simulating conditions field conditions. For instance, stakeholders have commented that the NFH&TC has wells in the Edwards so the water would be identical. The wells statement is correct, but the water in the natural environment (other than at the immediate spring openings) is different both chemically and biologically than direct aquifer water. The chemical and biological processes that are undergone in Landa Lake clearly change the make-up of the water before entering the Old Channel.

Table 14. Applied Research Components and Facility/Area Comparison

Applied Research Components - Comal Springs	Facility or Area				
	Laboratory	Upper Spring Run Reach	Landa Lake	Within Old Channel	ERPA Experimental Channel
RESTORATION / HABITAT CREATION					
Evaluate transplant methodologies for various types of native aquatic vegetation	No	Not Recommended - frequent disturbance	Yes	Yes	Yes
Evaluate success of transplants over extended time period	No	Not Recommended - frequent disturbance	Yes	Yes	Yes
Track maintenance required to keep exotic species from re-establishing	No	Not Recommended - frequent disturbance	Yes	Yes	Yes
Channel manipulation - depth, width, slope, substrate, cutbanks, woody debris, etc.	No	Not Recommended - frequent disturbance	No	Yes	Yes
LOW-FLOW DURATIONAL RESEARCH					
Evaluate potential aquatic vegetation decay (both surface [stem and leaves] and subsurface [roots] plant biomass.	Possibly in a living stream, but very difficult to simulate Landa Lake inflow	Yes - but only possible when total flow is near or below 150 cfs.	Yes - but only possible when total flow is near or below 60 cfs	Yes at all flows - but a flow by-pass would be necessary and you would need to allow take of fountain darter habitat.[1]	Yes at all flows - "take"[2] only in research channel - not in main channel
Evaluate potential changes in physicochemical parameters (i.e., water temperature, dissolved oxygen, carbon dioxide, etc.)	see above	same as above	same as above	Again, you would need to allow parameters to exceed conditions suitable for fountain darters in the main channel to test effects.[1]	same as above
Low-flow effects on fountain darter reproduction	No	same as above	same as above	same as above	Yes
Low-flow effects on fountain darter movement	No	same as above	same as above	same as above	Yes
Low-flow effects on fountain darter clumping and potential predation or competition	No	same as above	same as above	same as above	Yes
Low-flow effects on fountain darter population size	No	same as above	same as above	same as above	Yes
Low-flow effects of gill parasites on fountain darters	No	same as above	same as above	same as above	Yes

[1] - this option is also possible with only manipulation of existing culverts. However, under this option, take of fountain darter habitat would extend to a larger portion of the Old Channel. If you do not allow take of habitat, you would not reach the point of learning about decaying and dying aquatic vegetation.

[2] - Take is put in " " in the ERPA column because this is created habitat and may not be considered actual take of fountain darter habitat.

Table 14. continued Applied Research Components and Facility/Area Comparison

Applied Research Components - Comal Springs	Facility or Area				
	Laboratory	Upper Spring Run Reach	Landa Lake	Within Old Channel	ERPA Experimental Channel
GENERAL					
Effect of Snail Removal on parasite control	No	Yes	Yes	Yes	Yes
COMAL SPRINGS RIFFLE BEETLE					
Establish sustainable riffle beetle population in upwelling and spring run habitats in the upper portion of the old channel	No	No	No	Potentially with channel manipulation, unproven	Potentially, but unproven
IF CSRB successfully established in Old Channel					
Effect of CSRB movement with flow	No	No	No	Potentially with channel manipulation and flow by-pass	Yes, the CSRB area would be designed specifically to test these components.
Low-flow effect on CSRB movement	No	No	No	same as above	same as above
Low-flow effect on CSRB population size	No	No	No	same as above	same as above
FLOW-RELATED COMPONENTS DESCRIBED ABOVE					
Track condition of the system entering into and recovery following the low-flow condition	No	Yes	Yes	Yes	Yes
Evaluate repeated durations within a relatively short time-period (a few years).	No	No	No	Yes, with take in the main channel	Yes with "take"[2] only in the research channel
Evaluate cumulative impacts from repeat low-flow conditions.	No	No	No	Yes, with take in the main channel	Yes with "take"[2] only in the research channel

[2] - Take is put in " " in the ERPA column because this is created habitat and may not be considered actual take of fountain darter habitat.

Secondly, the Upper Spring Run reach and Landa Lake would make good research areas for most components were there not a few fatal flaws. The first is there is no flow control for either area and, thus the researcher would need to wait for the conditions to happen naturally. This would require flows near or below 150 cfs in the Upper Spring Run reach and near or below 60 cfs to be meaningful in Landa Lake. For example, 150 cfs has only been seen twice in the past decade for a short period of time and 60 cfs has not been observed since the early 1980's. Thus, experiments designed for evaluation of durational low-flow conditions are not feasible in these locations. Additionally, the Upper Spring Run reach can be drastically affected by even modest flooding in Blieders Creek which has happened numerous times over the past decade.

The main portion of the Old Channel has also been mentioned as a "better" research area and was considered for inclusion early on in the ERPA design. As discussed previously, flows within the Old Channel have the ability to be controlled via the culverts at Landa Lake at this time. However, without some type of flow-bypass around the Old Channel ERPA (in this example – simply restored and maintained habitat in the ERPA) optimal habitat would not be maintainable during higher than average or lower than average conditions as discussed in Section 5.2.5. Additionally, without the bypass, any flow manipulations to the Old Channel for experimental purposes would affect the entire Old Channel and not just the ERPA making this alternative undesirable. Should a flow-bypass be constructed, experiments could be conducted within the main channel ERPA. However, this also poses several practical issues for consideration. For instance, in order to test the effects/impacts of low flow (extended and repeated durations), experiments in the main channel would need to allow habitat to degrade to beyond the condition that would be considered "take" for the fountain darter. If you only experimented to the point of initial impact and not beyond, there is no way to quantify the full effect these types of events would have. This issue is highlighted here because the same entities recommending research in the main channel have also publicly stated that no "take" of fountain darters or habitat should be allowed in existing habitats. This severely limits the utility of applied research in the main system and essentially turns this option into a monitoring effort that can go slightly beyond the bounds of what would have occurred anyway.

Should a flow-bypass be installed and take be allowed in the main channel, meaningful experiments could be conducted. However, this again is not without some drawbacks. The first drawback is that experimenting in the area that is supposed to be protected at all times, contradicts the point of maintaining optimal fountain darter habitat in the ERPA at all times. As such, experiments would likely only be feasible when flow conditions are average or above, and as soon as drought is predicted (likely some established flow trigger), this area would need to be restored to optimal conditions regardless of what stage the experiment was in. In our opinion, recreating optimal habitat prior to each drought is not considered equivalent in protection of the species as maintaining optimal habitat at all times. Additionally, another drawback is that the main channel is just one channel. So, unless one was to go in and physically create separate channels (either temporarily or permanently), or deem an area downstream in the Old Channel a suitable reference point, you would only have one data point. It is very difficult to tease out potential impacts when you have no reference or control.

In summary, we recommend an experimental channel with a built-in reference over attempting to conduct applied research within the main channel or attempting to develop some elaborate, more expensive scheme in an off-site laboratory. We also recommend that monitoring be conducted in the main ERPA channel, as well as in the Upper Spring Run reach and Landa Lake so that when lower flow conditions do occur, there is background data to compare against. Additionally, we recommend specifically targeted research within the latter two areas, should total Comal springflow fall to near 150 cfs (Upper Spring Run reach) or 60 cfs (Landa Lake).

5.3.2 Spring Run 3 Riffle Beetle Permanent Observation Area

A second consideration for applied research would be a permanent observation well constructed near the edge of Spring Run 3 to enable sub-surface observation of riffle beetle habitat and movements. One current hypothesis is that as surface springs cease emitting, riffle beetles move to habitat areas deeper underground. This concept is supported by a laboratory study (BIO-WEST 2002c) but has yet to be documented in the wild. The proposed well would be approximately 15 feet deep from ground level, to allow for observation below elevation 615 feet and for screening (if necessary) down to 612 feet. A mobile camera would be inserted or permanently installed to monitor riffle beetle activity. The monitoring activity would be used to assess how riffle beetles utilize karst habitat and whether drought management measures near the surface (e.g., recirculation and diffusers) are effective or necessary.

The well could be 8-inch diameter uncased to allow observation and migration of beetles along the rock face. A 6 inch well head with lock and water-tight seal should be installed with annular grout to promote security and minimize contamination. An alternate but less preferable method could be to make the casing of this observation well plexiglass to enable viewing of the beetles. Native gravel similar to that found in adjacent Spring Run 3 riffle beetle habitats would be used as necessary in the annular area between the casing and existing rock. Perforated casing or screen should be installed at a level deeper than anticipated habitat viewing; the screen may be useful for cycling water through the annular gravel for cleaning following installation or for flushing sediment accumulations in viewing area.

Investigation of suitable camera types and lights would be necessary to ensure viewing of beetles is possible across a range of conditions. Additionally, permitting requirements of this observation well with TCEQ, EAA, and USFWS would need further discussion.

A preliminary cost estimate is $7,000 to drill a 25 foot deep 8” well in rock using a rotary drill, including mobilization, site access with a truck-mounted rig (e.g., F550 dually truck with derrick) and completion as described above. There would be an additional $5,000 to $10,000 upfront cost for cameras evaluation, selection, and placement.

6.0 ALTERNATIVES FORMULATION AND EVALUATION

The project team evaluated the ERPA components discussed above to formulate alternatives for comparison in order to provide the EARIP with information for consideration in the HCP. The following alternatives are identified for further consideration and three of them contain a package of ERPA components that were deemed "feasible" for the Comal system based on analysis conducted for this study. Four alternatives (A, B, C, D) are presented for comparison, costing, and evaluation purposes fully understanding that there are a lot of additional combinations of ERPA components that could be packaged together or taken individually and considered by the EARIP. All four alternatives are first described and then evaluated for biological risk relative to the described EARIP flow regime. Again, this regime allows for a minimum daily total Comal springflow of 30 cfs (20 cfs Old Channel, 10 cfs New Channel) for a maximum of 6 months followed by 2-3 months of 80 cfs (50 cfs Old Channel, 30 cfs New Channel). Additionally, these low-flow events are assumed to be rare events with the main occurrence taking place during a repeat of conditions similar to the drought of record.

6.1 ALTERNATIVES

6.1.1 Alternative A - No action

The No Action alternative (A) considers moving forward according to Senate Bill 3 (SB3) with only existing management and monitoring activities currently in place. This alternative does not include any of the ERPA components discussed above or EARIP Comal restoration subcommittee proposed restoration/mitigation actions.

6.1.2 Alternative B - No ERPA structure

Alternative B includes all existing management and monitoring activities that are not superseded by the following ERPA components:

- re-establishment of native vegetation in Landa Lake and Old Channel,
- active flow-split management,
- expanded monitoring program for water quality conditions in Landa Lake relative to low-flow impacts to water temperature and dissolved oxygen, and
- a decaying vegetation removal program.

In addition to the ERPA components, the following EARIP Comal restoration subcommittee recommendations are also included.

- Control of harmful exotics
- Optimization of fountain darter habitat in the Old Channel of the Comal River. *Note: Although proposed by the subcommittee, we do not recommend habitat enhancement in the New Channel.*
- Evaluation and control of the gill parasite. *Note: This did not make the final list for the subcommittee but we recommend its inclusion.*

These above stated Comal restoration subcommittee recommendations are included in all of the following alternatives and thus, will serve as a background which is equal for all but the No Action alternative.

6.1.3 Alternative C - Old Channel ERPA (Temporary)

Alternative C includes all components of Alternative B, with the addition of the Old Channel ERPA. The Old Channel ERPA for this comparison includes the main channel ERPA with recirculation along with the proposed experimental channel described in Section 5.2.5. Configurations of this package that could be considered are as follows:

- Old Channel ERPA (with recirculation) – temporary infrastructure, including experimental channel. (*ALTERNATIVE C1*)
- Old Channel ERPA (with recirculation) – permanent infrastructure, including experimental channel. (*ALTERNATIVE C2*)
- The flow-by pass only option, with the rock vane weir moved downstream closer to the main channel ERPA.
- The flow-by pass and recirculation option, with the rock vane weir moved downstream closer to the main ERPA.
- The flow-by pass option, with the experimental channel; or
- Just the experimental channel alone.

For costing and comparison purposes, we selected C1 - Old Channel ERPA (with recirculation), temporary infrastructure and experimental channel as we feel this option package provides the components necessary to achieve the purpose of guiding phase 2 of the HCP development and adaptive management.

6.1.4 Alternative D - Old Channel ERPA (Permanent) Plus

Alternative D includes both Alternative C options (C1 and C2) and adds the Spring Run 3 connectivity component along with the Spring Run 3 observation well.

6.2 ANALYSIS

The initial step in the alternatives analysis was to conduct an evaluation of biological risk. This exercise examined what risk would be associated with the No Action alternative (A) relative to SB3 modeled flow regime with the other three alternatives (B, C, and D) evaluated against the EARIP flow regime as discussed throughout this report. Based on continuing feedback, we also looked at biological risk associated at 60 cfs and 80 cfs as minimums. Table 15 shows the biological risk assigned to each alternative resulting from this exercise.

Table 15. Biological Risk Evaluation

Alternative	Springflow Protection	BIOLOGICAL RISK[1,2]					
		30 CFS		60 CFS		80 CFS	
		Fountain Darter	CS Riffle Beetle	Fountain Darter	CS Riffle Beetle	Fountain Darter	CS Riffle Beetle
A - No Action	SB 3	No springflow guarantee - BIOLOGICAL RISK - DETRIMENTAL					
B - No ERPA Structure	EARIP Flow Regime[3]	SEVERE[4]	High	High	High	Moderate	Moderate
C - Old Channel ERPA (temporary)	EARIP Flow Regime[3]	High / Moderate[5] / Low	High / Moderate[6]	Moderate[5] / Low	High / Moderate[6]	Full Alternative not necessary but experimental channel still recommended	
D - Old Channel ERPA (permanent), SR3 connectivity and observation well	EARIP Flow Regime[3]	High / Moderate[5] / Low	High / Moderate[6] / Low[7]	Moderate[5] / Low	High / Moderate[6] / Low[7]	Full Alternative not necessary but experimental channel still recommended	

[1] Biological Risk categories - Detrimental, Severe, High, Moderate, Low

[2] Assessment conducted as if the EARIP flow regime would support the minimum 6 month daily flow levels specified in the table.

[3] EARIP Flow Regime defined as the minimum total Comal springflow not occuring for greater than 6 months with flows of 80 cfs for 2-3 months following those events.

[4] Severe based on no mechanism to protect a designated area in the Comal system. Should model projections be wrong, off-site refugia is the only option.

[5] Moderate based on having the ability to maintain optimal habitat under most conditions; potential for Low pending testing and proven success of the ERPA.

[6] High based on unproven concepts. Potential for Moderate following testing and proven success of CS Riffle Beetle establishment in of the ERPA.

[7] High based on unproven concepts. Potential for Low following testing and proven success of spring run connectivity.

The biological risk categories used in Table 15 include the following with associated definitions for this evaluation:

- Detrimental (Jeopardy)
    - likely to cause extirpation of the species
- Severe
    - major impact to habitat and populations throughout the system
    - Low potential for full recovery of habitat and populations throughout the entire range
- High
    - major impact to habitat in extents of available habitat
    - moderate impact to habitat in optimal habitat areas
    - population reduction but not to the jeopardy level
    - Full recovery of habitat and populations throughout system to pre-drought condition possible with human intervention.
- Moderate
    - major impact to habitat in extents of available habitat
    - minor impact to habitat in optimal habitat areas
    - population reduction but to a lesser degree than High
    - Full recovery of habitat and populations throughout system to pre-drought condition possible with less human intervention than High.
- Low
    - major impact to habitat in extents of available habitat
    - limited to no impact to habitat in optimal habitat areas
    - population reduction but to a lesser degree than Moderate
    - Full recovery of habitat and populations throughout system to pre-drought condition possible with less human intervention than Moderate.

The first point to understand regarding the biological risk definitions is that they are created for the extreme event. Even under the highest flow (80 cfs) scenario presented in Table 15, there will be major habitat impacts in portions of the Comal system. At 80 cfs, a good portion of Spring Runs 1 and 2 will be subsurface, the Upper Spring Run reach will have been stagnant for a considerable amount of time with water quality and habitat degradation implications, and the New Channel and lower portion of the Old Channel will experience water temperatures high enough to cause reduced fountain darter larval and egg production. All these conditions will increase in impact as total Comal springflows decrease. As such, both the fountain darter and Comal Springs riffle beetle populations will likely decline under all scenarios. However, the key is the amount of habitat decline in high quality habitat areas, the degree of overall population decline, and the potential for full recovery following the drought event. An additional key is the ability to protect and maintain high quality habitat in some portion of the system under all circumstances, even if the bulk of assumptions underpinning the hydraulic, habitat, and water quality modeling conducted to date are proven false when a severe drought happens. It also needs to be clear that we are not talking about the ability of the EARIP bottom up flow regime to meet the flows required as that is a separate issue. We are assuming that the daily minimum flows and durations targeted in Table 15 will be met.

The assumptions in the biological modeling and the biological unknowns are what have driven this whole ERPA feasibility evaluation. The ability to protect and maintain high quality habitat in some portion of the system under all circumstances and the ability to learn from applied research throughout the adaptive management program are the true benefits of the proposed ERPA alternatives.

6.2.1 Alternative A

Returning to the biological risk assigned to each Alternative in Table 15, the No-Action alternative (A) does not ensure spring flow and, thus is given a Detrimental ranking.

6.2.2 Alternative B

Alternative B is focused on the fountain darter, has some very positive features and is the least expensive of the alternatives. However, biological risk for the fountain darter is ranked Severe at 30 cfs because there is no protection of a designated area of high quality habitat under all circumstances. Through restoration and maintenance of aquatic vegetation one can get optimal conditions for fountain darter habitat going into the drought, but if the drought continues and you have 6 months of 20 cfs going down the old channel, it is very unlikely that you will maintain high quality conditions throughout this time period. This is especially true if our assumptions about aquatic vegetation are inaccurate and we start experiencing die-offs in Landa Lake with decaying organic matter being transported to and settling out in the Old Channel. Another downside to Alternative B is there is no applied research proposed with this Alternative which is the foundation for understanding a lot of the unknowns (especially aquatic vegetation response to low flow) that continue to dominate discussions on this topic.

Alternative B receives a High ranking for the Comal Springs riffle beetle based on the fact that Spring Run 3 will be subsurface for 6 continuous months. Populations will likely decline but we do not anticipate past the point at which the population could recover. These conditions have been experienced on more than one occasion in the historical record and over 6,500 Comal Springs riffle beetles have been collected from 2004-2010 via the cotton lure methodology and twice a year sampling at the three locations described in Section 5.2.4.

At 60 cfs, the Alternative B fountain darter ranking switches to High because 40 cfs would be transferred through the Old Channel at the lowest flow condition which would likely facilitate the maintenance of high quality fountain darter habitat. The Comal Springs riffle beetle ranking remains the same at 60 cfs as Spring Run 3 would still not be experiencing complete surface flow. At 80 cfs, both species receive a Moderate ranking under Alternative B as conditions for the darter are improved in both the Old and New Channels and Spring Run 3 would now support surface flow for the majority of the run.

6.2.3 Alternative C

Alternative C focuses on both the fountain darter and Comal Springs riffle beetle. The biological risk for the fountain darter at 30 cfs is assigned a High/Moderate/Low ranking. The High ranking is because the ERPA has yet to be proven successful at any level. Moderate, because our analysis shows that the ERPA would likely provide a protected area of the system under most all conditions. It is also possible that the ranking could be shifted to a Low if the ERPA proves to be effective for longer periods than originally projected. An additional benefit of Alternative C is it allows for applied research to be conducted to address biological unknowns. Similar to Alternative B, Alternative C receives a High ranking for Comal Springs riffle beetle because the ERPA components for the beetle are unproven. It has the potential for Moderate if populations of riffle beetles could be established and protected in the headwaters of the experimental channel. However, even if reproducing populations of the riffle beetle cannot be successfully established, applied research targeted at movement and habitat preferences might still be practical in the experimental channel. Comal Springs riffle beetles can survive in an aquarium at the NFH&TC, so it is anticipated that researchers might still be able to conduct experiments on riffles beetles translocated to this area. If it turns out the water quality is not amenable and needs to be direct Edwards Aquifer water (as is present in spring orifices and used at the NFH&TC) then consideration should be given to drilling a well near the research channel and providing direct Edwards Aquifer water to the research area for experimentation during average and above total Comal springflow conditions.

At 60 cfs, the Alternative C fountain darter ranking switches to Moderate because 40 cfs would be transferred through the Old Channel at the lowest flow condition which would likely facilitate the maintenance of high quality fountain darter habitat. What would happen is that the infrequently used recirculation portion of the ERPA at 30 cfs would now rarely if ever be required, but would be available as a safety measure should unknowns be encountered. With the ERPA in place, the potential for shift to a Low ranking for the fountain darter exists. The Comal Springs riffle beetle ranking for Alternative C at 60 cfs does not change as habitat conditions do not significantly improve. At 80 cfs guaranteed daily minimum flow, the full Alternative C would not be necessary as flows in the Old Channel would support themselves and Spring Run 3 would be inundated. However, we recommend that the experimental channel still be implemented even at these flow minimums.

6.2.4 Alternative D

Alternative D maintains the same rankings as Alternative C for the fountain darter as the only difference is the permanent vs. temporary infrastructure associated with the ERPA. The one addition for the Comal Springs riffle beetle is the potential to go to a Low ranking should the spring run connectivity concept be tested and proven effective. Another potential advantage of Alternative D would be knowledge gained via the observation well. As with Alternative C, Alternative D maintains the same rankings at 60 cfs, and the full alternative is not necessary at 80 cfs guaranteed minimum daily spring flow.

Table 16 shows the ERPA associated cost ranges for each of the alternatives. No costs were calculated for the No Action as it contains no ERPA activities. Although, several recommendations of the EARIP Comal ecosystem restoration subcommittee were discussed above, no costs were assigned to those activities as that cost would remain the same across Alternatives B, C, and D. As expected, cost for Alternative B (with few components and no structural components) is the least expensive, followed by Alternative C with temporary structures in the Old Channel ERPA, followed by Alternative D with the permanent Old Channel ERPA structures and the addition of Spring Run 3 connectivity structures and the observation well.

The infrastructure, environmental documentation, permitting, routine maintenance, and applied research costs can all be summed up to get a total cost for each alternative minus the actual operational costs during drought. The operational costs (Monthly when used column, Table 16) would need to have some constant assumption behind it to calculate how often it would be in operation. This could be done by examining the final EARIP bottom-up approach hydrology and determining how many months each option would be in operation. This exercise was not conducted for this study as the final EARIP bottom-up approach has not been determined.

Table 16. Estimated Cost Ranges for Alternatives evaluated

ALTERNATIVE	COST RANGE[1]				
	Upfront	Operation	Maintenance	Applied Research	
	Infrastructure / Env. Doc. / Permitting	Monthly when in use	Routine Annual	Upfront	Annual
A - No Action	N/A	N/A	N/A	N/A	N/A
B - No ERPA Structure	$150,000 - $175,000	N/A	$15,000 - $25,000	N/A	N/A
C - Old Channel ERPA (temporary)	$500,000 - $950,000	$50,000 - $65,000	$15,000 - $25,000	$150,000	$100,000 - $250,000[2]
D - Old Channel ERPA (permanent), SR3 connectivity and observation well	$1,750,000 - $2,750,000	$30,000 - $40,000	$50,000 - $75,000	$200,000	$125,000 - $300,000[3]

[1] EARIP Comal Restoration subcommittee recommendations were not costed as they would be the same for all alternatives

[2] Assumed $250,000 per year for Phase 1 (7 years), then $100,000 per year for Phase 2 (8 years if a 15 year HCP term)

[3] Assumed $300,000 per year for Phase 1 (7 years), then $125,000 per year for Phase 2 (8 years if a 15 year HCP term)

Table 17 shows a biological risk and feasibility level comparison between alternatives. The biological risk comparison was described above. The costs were ranked as Low (Alternative B), moderate (Alternative C), and High (Alternative D). Permitting and environmental documentation was also ranked in order of difficultly. As Alternative B has no structural components to be installed and does not affect downstream water distribution, there would be no USACE, TCEQ, or EAA permits required. Federal and state scientific collection permits would likely require modification or special approvals granted by USFWS and/or TPWD for the applicant to remove non-native vegetation and re-establish native vegetation. Alternative C would require considerably more complex environmental documentation and permitting. A TCEQ water rights permit, and 401 certification would likely be required. A USACE 404 permit would likely be required for the placement of the rock vane weir, and construction of the experimental channel. Again, federal and state scientific collection permits would need to modified or granted by USFWS and/or TPWD in order to conduct applied research on federally listed species. Alternative D would require the greatest level of environmental documentation as well as permitting complexity. Again a USACE 404 permit, and associated TCEQ 401 water quality certification would be required for the Old Channel ERPA and potentially the Spring Run 3 connectivity project. A TCEQ water rights permit would likely be required for both the Old Channel ERPA and Spring Run 3 connectivity project. Additional City permits and possibly a State Historical Preservation Office permit would be required for both Alternatives C and D.

Table 17. Feasibility Evaluation

ALTERNATIVE	ERPA ALTERNATIVES FEASIBILITY[1]								
	BIOLOGICAL RISK[2]						COST	PERMITTING / ENV. DOC.	INTANGIBLES[3]
	30 cfs		60 cfs		80 cfs				
	FD	RB	FD	RB	FD	RB			
A - No Action							N/A	N/A	N/A
B - No ERPA Structure									
C - Old Channel ERPA (temporary)					N/A	N/A			
D - Old Channel ERPA (permanent), SR3 connectivity and observation well					N/A	N/A			

[1] Biological Rank / Feasibility Level /
- Detrimental / Fatal Flaw
- Severe / Extremely Difficult
- High / Difficult
- Moderate / Moderate
- Low / Easy

[2] FD = Fountain Darter, RB = Comal Springs Riffle Beetle

[3] Main intangibles include City of New Braunfels concern regarding aesthetics and TPWD's reluctancy to support the Old Channel ERPA concept

The final column in Table 17 relates to intangibles that may impede the ability to move forward with a given alternative. It is unlikely that there would be much opposition to Alternative B based on stakeholder meetings and feedback received to date on this study. There has been considerable feedback from the City of New Braunfels regarding the aesthetic value of Landa Park and noise, etc. that might be caused by the implementation and operation of ERPA components. This issue would need to be discussed in greater detail with the City of New Braunfels should the EARIP choose to move forward with an ERPA alternative or component. With today's technology and naturally friendly designs, we do not feel this intangible is detrimental to the project; it just needs to be diligently addressed so that all parties are comfortable with the end result.

A second intangible is the reluctance being put forth by TPWD staff regarding conducting research in an experimental channel adjacent to the Old Channel as proposed. Based on recent TPWD feedback, it does appear TPWD supports many of the activities presented in Table 14 and addressing these questions in an experimental research channel rather than a laboratory environment. However, TPWD opposes the proposed Old Channel research channel on the Comal System, and recommends investigating potential research facilities at other locations in the Comal and/or San Marcos systems. To protect the endangered species going into the future with the EARIP described flow regime, we strongly feel that applied research needs to be conducted on-site. We are not opposed to evaluating other options within the Comal or San Marcos systems in greater detail, as where the research is done is less critical than that it is done. However, in contrast to TPWD, we do feel the proposed Old Channel research facility is feasible.

The third and likely most difficult intangible is TPWD's opposition to the Old Channel ERPA for the protection of endangered species habitat. We respectfully disagree with TPWD on this issue as we believe ensuring a protected reach of high quality habitat under all conditions is vital to the fountain darters continued existence in the wild at Comal Springs. It is our hope that further discussions with TPWD or the formation of an EARIP ERPA subcommittee or special review team may alleviate some or all of TPWD's staff concerns. However, should concerns not be alleviated, this may prove to be a difficult intangible for the project.

7.0 RECOMMENDATIONS

Considering all aspects, our current recommendation to the EARIP is Alternative C. The value gained by minimizing biological risk and the potential further reduction of biological risk should conceptual ideas be tested and proven, coupled with the ability to learn via applied research throughout the HCP adaptive management process outweighs the slightly higher costs and potential difficulties with permitting and intangibles. We rank Alternative D a very close second. It is second only based on costs and increased time that may be necessary to address all permitting requirements. Alternative D is the most complete package with the greatest potential to minimize biological risk for both the fountain darter and the Comal Springs riffle beetle. However, costs are high primarily because of permanent structures that would be required to house or support equipment that may not ever be used. Permanent structures for this alternative are driven by aesthetics and possibly through discussions with the City of New Braunfels cost saving options might be available that would reduce these costs. The additional components in Spring Run 3 would be valuable as an additional safety measure and research tool should Alternative D or the Spring Run 3 components of it be selected. One solution to the potential for the increased time this alternative might require because of permitting complexities is to phase the implementation of Alternative D components. Finally, we are uncomfortable with Alternative B relative to the described EARIP flow regime as it puts a lot of pressure on the hydrological modeling and predictions of maintaining flows at the recommended levels, in addition to allowing very little flexibility should some of the assumptions used in the biological and water quality modeling prove to be incorrect.

In summary, Alternative B, C, and D all appear feasible and capable of providing benefits at varying levels to the EARIP. It is our professional judgment that Alternative C or D would meet or exceed the goals of the HCP for consideration with the described EARIP flow regime (assuming flows met the regime described in this report). We are supportive of Alternative B as an alternative should the minimum flow levels be raised from 30 cfs daily average flow to 60 cfs daily average flow, but would still highly recommend the addition of an experimental channel to be included with that alternative.

Finally, should the EARIP decide to move forward with an ERPA or components thereof, we recommend that the formation of an EARIP ERPA subcommittee or some form of third-party independent review team be assembled to oversee the ERPA implementation and studies conducted during the adaptive management phase of the HCP.

8.0 SAN MARCOS EVALUATION

8.1 INTRODUCTION AND ENVIRONMENTAL BACKGROUND

During the course of the Comal feasibility study the EARIP requested that a preliminary evaluation of the San Marcos system also be conducted. As such, this section addresses the San Marcos system but with less detail than provided for the Comal system above. The foundational concept of evaluating an ERPA remains the same as for the Comal system. Designated areas within the San Marcos Springs/River ecosystem were evaluated considering the potential to restore and protect habitat for the threatened and endangered species that inhabit those areas. Differences in the evaluation stem from the threatened and endangered species present, the existing habitat conditions, system-specific anthropogenic factors such as recreation, and the proposed EARIP flow regime for the San Marcos system.

The proposed EARIP flow regime evaluated is the same one identified in Hardy (2011) for the protection of the threatened and endangered species during a repeat of conditions similar to the drought of record. The evaluated flow regime includes a minimum daily average springflow of 45 cfs for a period not to exceed 6 months, followed by 2 to 3 months of springflow at 80 cfs minimum daily average. It is also assumed that conditions similar to the drought of record are infrequent events.

The focus of the preliminary ERPA evaluation of the San Marcos system is on the fountain darter, San Marcos salamander (*Eurycea nana*), and Texas wild-rice (*Zizania texana*). The Comal Springs riffle beetle is also present in Spring Lake as is the Texas Blind salamander (*Eurycea rathbuni*). However, the Comal Springs riffle beetle was not examined as it appears that the evaluated EARIP flow regime provides enough spring flow through Spring Lake to maintain Comal Springs riffle beetle Spring Lake habitat. The Texas Blind salamander is an aquifer dwelling species and similar to the Peck's Cave amphipod and Comal Springs dryopid beetle in the Comal system, is a subterranean species. As such, it was assumed that maintaining a minimum of 45 cfs daily average would be protective of this aquifer dwelling species. A thorough description of each of the San Marcos threatened and endangered species, their existing habitat and known life history requirements is presented in SSC (2008, 2009).

8.1.1 Spring Lake

The existing habitat in the San Marcos system differs from the Comal system in several ways. Spring Lake is located at the headwaters of the San Marcos River similar to Landa Lake, but is considerably deeper than Landa Lake. Spring Lake provides high quality habitat for both the fountain darter and San Marcos salamander. At the evaluated flow regime (Hardy 2011) of 45 cfs minimum daily average spring flow for a period of 6 months, followed by 2 to 3 months of 80 cfs daily average springflow, it is not anticipated that the fountain darter or salamander habitat within Spring Lake would be affected to the degree necessary for active management through some type of ERPA. However, it would be a valuable exercise to evaluate the aquatic gardening practices in Spring Lake conducted by Texas State University (TSU) to see if adjustments to any of those practices during low-flow events might be beneficial to existing high quality habitat. Although not evaluated in this investigation, should the temperature model (Hardy 2011) be proven to be inaccurate or the evaluated flow regime not be met, another option that has been discussed has been to coffer off the slough arm of Spring Lake in order to facilitate the turnover of lake water more rapidly potentially allowing cooler temperatures to move downstream.

8.1.2 San Marcos River

The Upper San Marcos river channel starts below Spring Lake Dam where water spills through the western and eastern spillways (Figure 45) moving downstream until it is joined by Blanco River flows near the eastern part of town. A high level evaluation of the Upper San Marcos River was conducted with the best potential ERPA location being identified just below Spring Lake Dam. Best potential refers to the ability of a proposed ERPA to protect high quality habitat in the wild during periods of extreme drought, but also considers overall costs, species present, permitting and environmental documentation feasibility, and intangibles. At Spring Lake Dam, the Salt Grass restaurant is adjacent to the western spillway with the Riverside apartments adjacent to the eastern spillway. The eastern spillway is the only location in the San Marcos River that supports quality habitat for all three species (fountain darter, San Marcos salamander, and Texas wild-rice) focused on in this assessment. The area below Spring Lake Dam is highly recreated during the summer months, with increased recreation in the eastern spillway during lower flows. There are several old pilings in the eastern spillway channel that are broke off and sharp and extremely difficult to see during average to higher flow conditions. Swimming and wading in this area during average to higher flows is difficult and dangerous because of these obstacles and thus, this area is typically not used to the same degree as during lower flows when the obstacles can easily be seen and avoided.

The eastern spillway has a lot of potential for an ERPA because all three aforementioned threatened and endangered species reside in this reach. The main difference, from an ERPA perspective, between the eastern spillway and the Old Channel ERPA proposed for the Comal system is the amount of recreation that takes place in the eastern spillway. This area would not be a good choice for an ERPA if recreation was not controlled. If recreation was controlled, then restoration and protection of fountain darter and San Marcos salamander habitat, as well as protection and enhancement of Texas wild-rice plants would be beneficial in this area. As mentioned for the Comal system, restoration or enhancement is only one component as protection of the restored or enhanced areas would need to follow. Fortunately, flow over Spring Lake dam can be manipulated to travel down the western spillway or eastern spillway. Additional structures may be necessary to achieve the purposes of an ERPA but with the correct setup, a flow-split management scheme could be implemented for the protection of restored habitat. Currently, under higher than average conditions, flows through the eastern spillway scour out Texas wild-rice plants, and limit the suitability of fountain darter and San Marcos salamander habitat because of extreme velocities. Additionally, with the proper structure(s), flow could potentially be controlled and provided for experimentation within the eastern spillway.

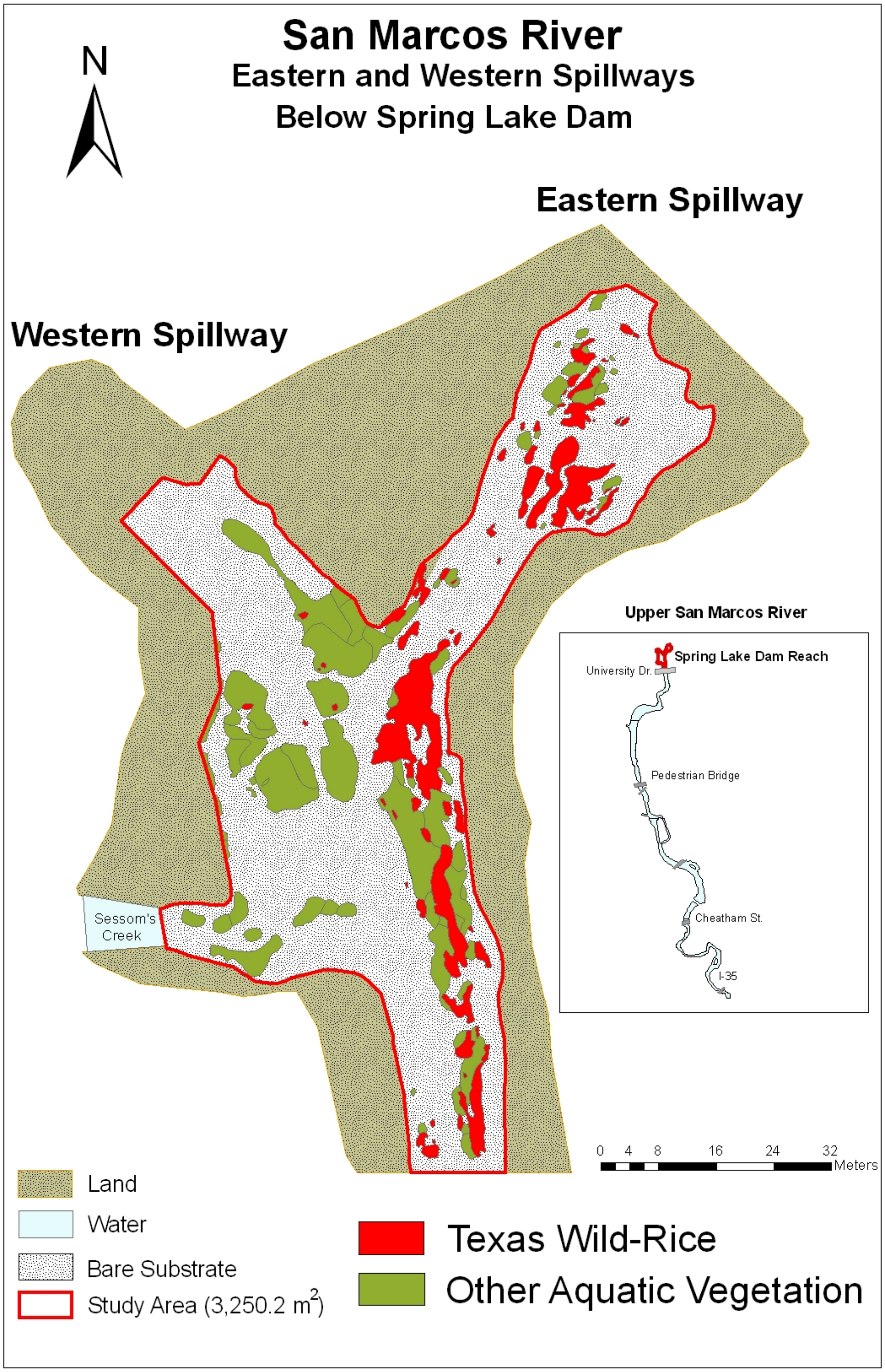


Figure 45. San Marcos River from Spring Lake Dam to University Avenue.

When considering the evaluated flow regime described above for the San Marcos system, it does not appear that an ERPA in the eastern spillway below Spring Lake dam would be mandatory for the survival of these three species during conditions similar to a repeat of the drought of record. However, restoration and protection (both from flow and recreation) would provide an additional level of protection for future unknown hydrological conditions. Additionally, the potential for applied research in the reach is also very intriguing and we recommend further evaluation of this important aspect.

Although not an ERPA in the sense of the projects described for the Comal system and above for the eastern spillway, a restoration/enhancement component that we feel does warrant further evaluation and ultimate implementation for the adaptive management component of the HCP is the restoration and enhancement of Texas wild-rice stands within high quality habitat. Texas wild-rice within the San Marcos River has been steadily increasing over the past two decades, with minor setbacks following floods and impacts associated with low flow conditions (Figure 46).

Since the original ERPA analysis (later in this section), the concept of enhancement of Texas wild-rice plants during low flow conditions has received a lot of positive feedback from the EARIP and City of San Marcos. To be fair, it has also received some skepticism and as such Hardy (2011) conducted some additional analysis as presented in his report. We will not repeat the Hardy (2011) evaluation in this report, nor do we present the later analysis in contradiction to any of the additional work that Dr. Hardy has provided. Both sets of analyses relay the same message which is encouraging relative to the potential ability to maintain Texas wild-rice stands in high quality habitat during low-flow conditions, with the potential for expansion of these stands.

Regarding Texas wild-rice, Hardy (2011) concludes,

> "Physical habitat simulations within the San Marcos River for TWR based on occupied optimal habitat areas indicate that the proposed flow regime within the San Marcos River being considered by the EARIP will provide adequate quantity and quality habitat to sustain this species during a repeat of the drought of record provided effective recreation control can be implemented. Analyses examining the potential benefit from removal of non-native vegetation within mixed stands of TWR in optimal areas and removal of non-natives within a 2 meter buffer of occupied optimal TWR stands can substantially increase aerial coverage of TWR."

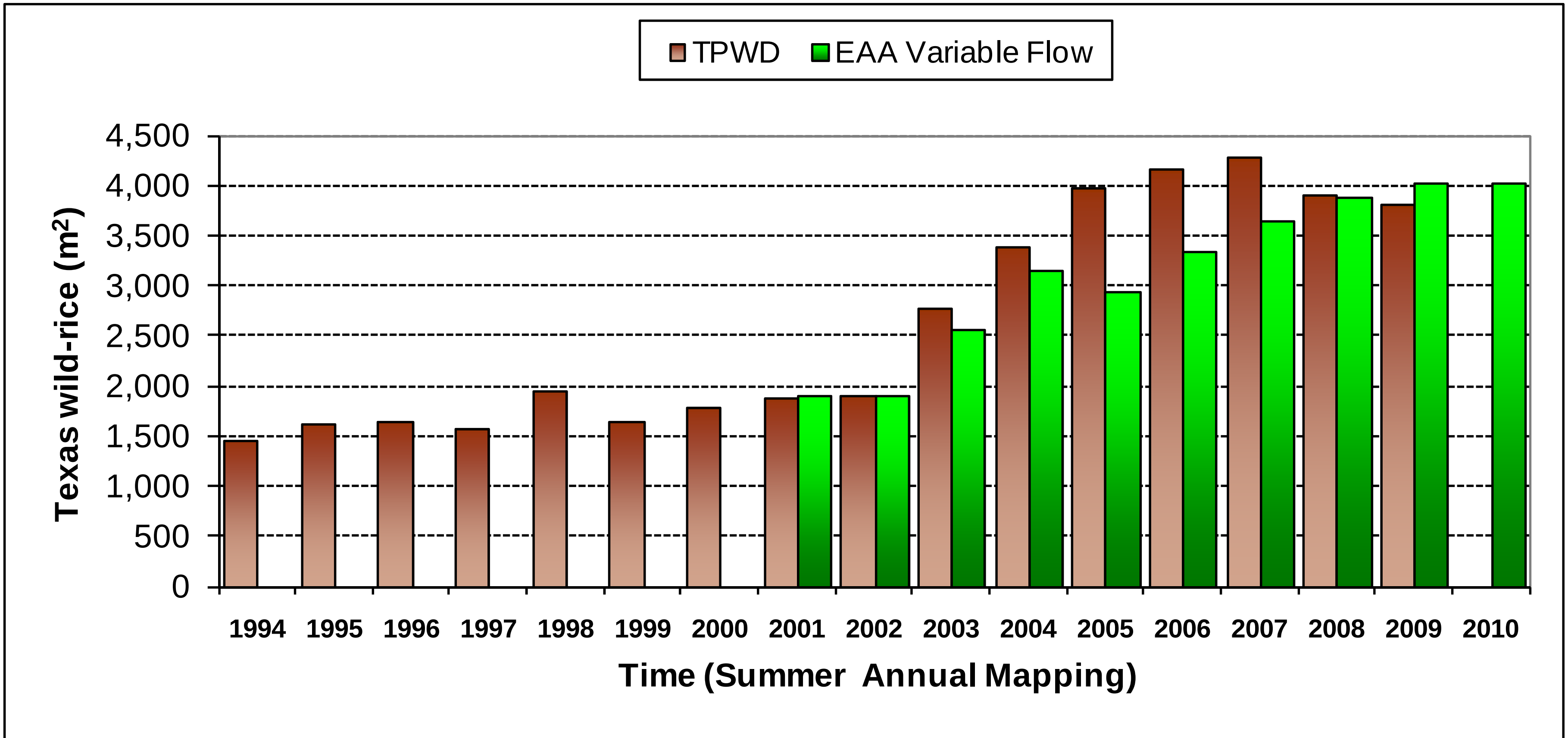


Figure 46. Total coverage (m^2) of Texas wild-rice measured in the San Marcos River during annual summer monitoring.

Table 18 is taken directly from Hardy (2011) and shows the rationale behind that conclusion. Based on existing Texas wild-rice data collected by TSU in 2009, coupled with modeling data at 45 cfs, approximately 1,500 m^2 of Texas wild-rice is projected to remain in optimal habitat areas, with approximately 1,200 m^2 in suboptimal areas. So, even if all the Texas wild-rice in suboptimal areas would be eliminated (which is highly unlikely), and only 75% (which is again likely an overestimate of loss, since it is optimal habitat) of the Texas wild-rice in optimal areas be sustained, over 1,100 m^2 of Texas wild-rice would remain in the San Marcos River. This amount is still greater than the total river population in 1989.

Table 18. Hardy (2011) Texas wild-rice modeled Weighted Usable Area available and occupied based on 2009 vegetation mapping.

Table 15. Predicted optimum TWR areas (m^2) [not necessarily occupied], 2009 mapped TWR predicted within optimum/suboptimum areas, additional areas with removal of H. verticillata and H. polysperma within TWR patches and a 2 meter buffer around TWR patches in the San Marcos River. Note that the sum of columns 3 and 4 is the total of occupied 2009 TWR habitat mapped by Texas State.

Discharge (cfs)	Optimum area (>75% suitable)	Optimum area (>75% suitable)	Suboptimum area (<75% suitable)	*H. verticillata* *H. polysperma* Removal in TWR patches	2 m buffer TWR patches
30	21,709	1,246	1,486	594	779
45	26,785	1,518	1,224	1,134	1,292
50	29,087	1,596	1,146	1,269	1,452
55	29,182	1,603	1,134	1,345	1,527
60	31,049	1,630	1,113	1,423	1,585
70	33,667	1,675	1,068	1,499	1,673
80	34,730	1,678	1,057	1,548	1,748
90	36,274	1,667	1,087	1,564	1,793
100	37,142	1,635	1,100	1,572	1,827
120	37,407	1,542	1,199	1,219	1,795
140	36,957	1,428	1,308	1,345	1,722
160	36,077	1,288	1,451	1,278	1,663
180	35,366	1,144	1,592	1,212	1,614
200	33,294	980	1,760	1,074	1,515
220	31,875	781	1,954	958	1,371
240	30,226	615	2,121	840	1,201
260	28,043	482	2,250	741	1,083

With the control of recreation in the river as proposed by Hardy (2011) and supported by this report, it is very likely that some Texas wild-rice in suboptimal areas will survive as well as more than 75% of the Texas wild-rice in optimal areas. So, based on the evaluated EARIP flow regime, with only recreation control, it is possible that over 2,000 m^2 of Texas wild-rice might survive following a repeat of conditions similar to those experienced during the drought of record. Hardy (2011) goes on to show (Table 18) that an additional 2,200 m^2 could potentially be established in optimal habitat areas should the exotic *Hygrophila* and *Hydrilla* be removed from a 2-meter buffer surrounding existing Texas wild-rice plants.

We concur with Hardy (2011) that the proposed EARIP flow regime will be sufficient for the survival of Texas wild-rice assuming the effective implementation of recreational control during low flow periods. We also agree that non-native vegetation removal adjacent to and downstream of Texas wild-rice plants should be conducted in order to let the Texas wild-rice stands expand into these areas.

To be consistent with our biological risk analysis conducted for the Comal system (extreme conditions evaluation), we assigned the 45 cfs minimum daily average flow condition within the context of the EARIP flow regime as Moderate risk. Texas wild-rice in suboptimal areas will be impacted through drying of wetted area, increased recreational activity and herbivory during these times. However, with the amounts preserved in optimal habitat areas and the potential for additional Texas wild-rice in these areas via non-native vegetation removal, recovery to pre-drought conditions is expected.

The analysis presented below was originally conducted in summer 2010 to evaluate minimum flows that may be acceptable for the survival of Texas wild-rice during a repeat of hydrological conditions similar to the drought of record. The analysis was completed with the updated Hardy (2011) model. However, to be clear about its use in this report, this analysis is not provided to refute minimum flows (as we are supportive of the EARIP flow regime as described in Hardy 2011 and this report). The analysis is presented herein to assess increases in biological risk as springflow decreases below 45 cfs and to support Texas wild-rice enhancement activities. For this exercise, fall 2009 Texas wild-rice mapping conducted for the EAA Variable Flow study was used. The total extent of Texas wild-rice in the San Marcos River was mapped in November 2009 using real-time Trimble® GPS equipment (BIO-WEST 2010b). A total of 3,350 m^2 of Texas wild-rice stand area was mapped, with most of the stands located upstream of the I-35 bridge. Although not evident in the annual mapping data presented in 2009 (Figure 46), recreational impacts during the low flow conditions experienced in 2009 did impact the amount of Texas wild-rice in the river in the summer and fall 2009, and this total represented the lowest areal coverage of Texas wild-rice observed since 2006. Therefore, we chose this period as an added level of conservatism. As a follow-up, annual mapping in summer 2010 shows that Texas wild-rice has expanded to back over 4,000 m^2.

Additionally for the analysis, data from the TSU aquatic vegetation mapping effort of the entire San Marcos River in 2009 was used. Due to potential errors associated with satellite coverage, tree cover along the river banks, and GPS accuracy during the field mapping efforts, there may be some errors in evaluating the overlapping areas of the habitat model and the location of mapped vegetation areas. To determine potential quality habitat for Texas wild-rice at low-flow conditions, the habitat model results from the Hardy (2011) 30 cfs model run were overlaid on the current mapped vegetation in the San Marcos River. Model nodes with habitat suitability results higher than 0.75 were analyzed first to identify areas that 1) currently have Texas wild-rice growing in them, and 2) do not have Texas wild-rice growing in them, but have another type of vegetation or bare substrate. To add an additional level of conservatism, we classified optimal habitat as needing a suitability of 1.0 and only carried forward that analysis at 30 cfs.

Results of the 30 cfs model run predict there are 1,679 m^2 of optimal quality (all 1.0 suitability) Texas wild-rice habitat, of which 233 m^2 currently (based on 2009 mapping) have Texas wild-rice growing in them (Figures 47 through 50). Under a hypothetical situation in which all Texas wild-rice stands except those located in optimal (1.0 suitability) quality habitat (233 m^2 predicted at 30 cfs) were lost under low-flow conditions, we attempted to look at potential scenarios for the conservation and re-establishment of Texas wild-rice in other areas of predicted high quality habitat. We then evaluated the remaining areas of predicted optimal quality (1.0 suitability) habitat to determine if it would be feasible to plant all or part of the remaining predicted 1,446 m^2 of high quality habitat with Texas wild-rice. Four main areas for planting are apparent from the map analysis – a portion of the river in Sewell Park where Texas wild-rice is currently abundant (Figure 47), two areas that are downstream of City Park and are downstream of current wild-rice stands, and an area upstream of Rio Vista Park that does not currently support wild-rice (Figure 49). The area of these optimal quality Texas wild-rice habitats and their associated mapped vegetation types is presented in Table 19.

Table 19. Predicted high quality (1.0 suitability) Texas wild-rice habitats in the upper San Marcos River at 30 cfs modeled flow conditions that do not currently have Texas wild-rice.

Vegetation	**Area**
Cabomba caroliniana	18.13 m^2
Colocasia esculenta	45.75 m^2
Hydrilla verticillata	984.11 m^2
Hygrophila polysperma	143.92 m^2
Potamogeton illinoensis	18.45 m^2
Sagittaria platyphylla	6.79 m^2
Substrate (unvegetated)	228.85 m^2
Total	**1,446 m^2**

If additional Texas wild-rice were planted and successful in the bare areas (half of which are close to existing stands), it would add approximately 229 m^2 of Texas wild-rice area. If Texas wild-rice were transplanted into areas currently supporting *Hydrilla* and *Hygrophila* plants, it could add approximately 1,100 m^2. *Hydrilla* and *Hygrophila* are invasive non-native plants and removing them would likely have additional ecosystem benefits. The analysis would be incomplete if one did not go back and evaluate what would be the suitability of these newly established areas during average flow conditions. Therefore, we examined the 1,679 m^2 of optimal quality (all 1.0 suitability) Texas wild-rice habitat predicted under 30 cfs flow conditions at 170 cfs (slightly higher than historical average springflows). This follow-up analysis showed that this area has a predicted average habitat suitability of 0.64 at 170 cfs. As such, non-native vegetation removal and Texas wild-rice establishment or enhancement appears feasible for when flow conditions return to average. The existing modeling tools should be used to maximize the potential for success by first attempting these activities in optimal (1.0) suitability areas at both the low flow target and the average flow condition.

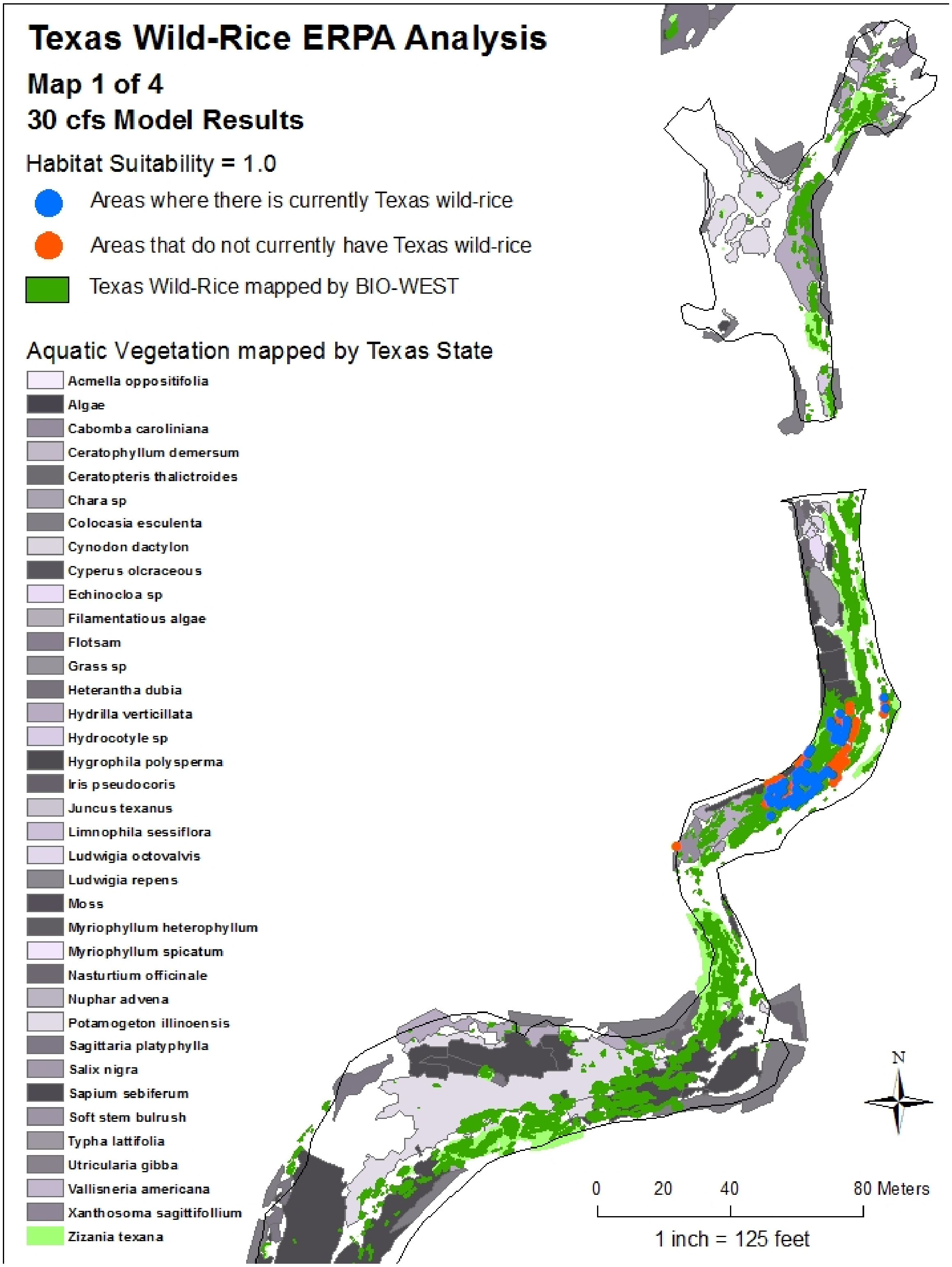


Figure 47. Texas wild-rice ERPA Analysis – 30 cfs model results (1.0 suitability) - Map 1

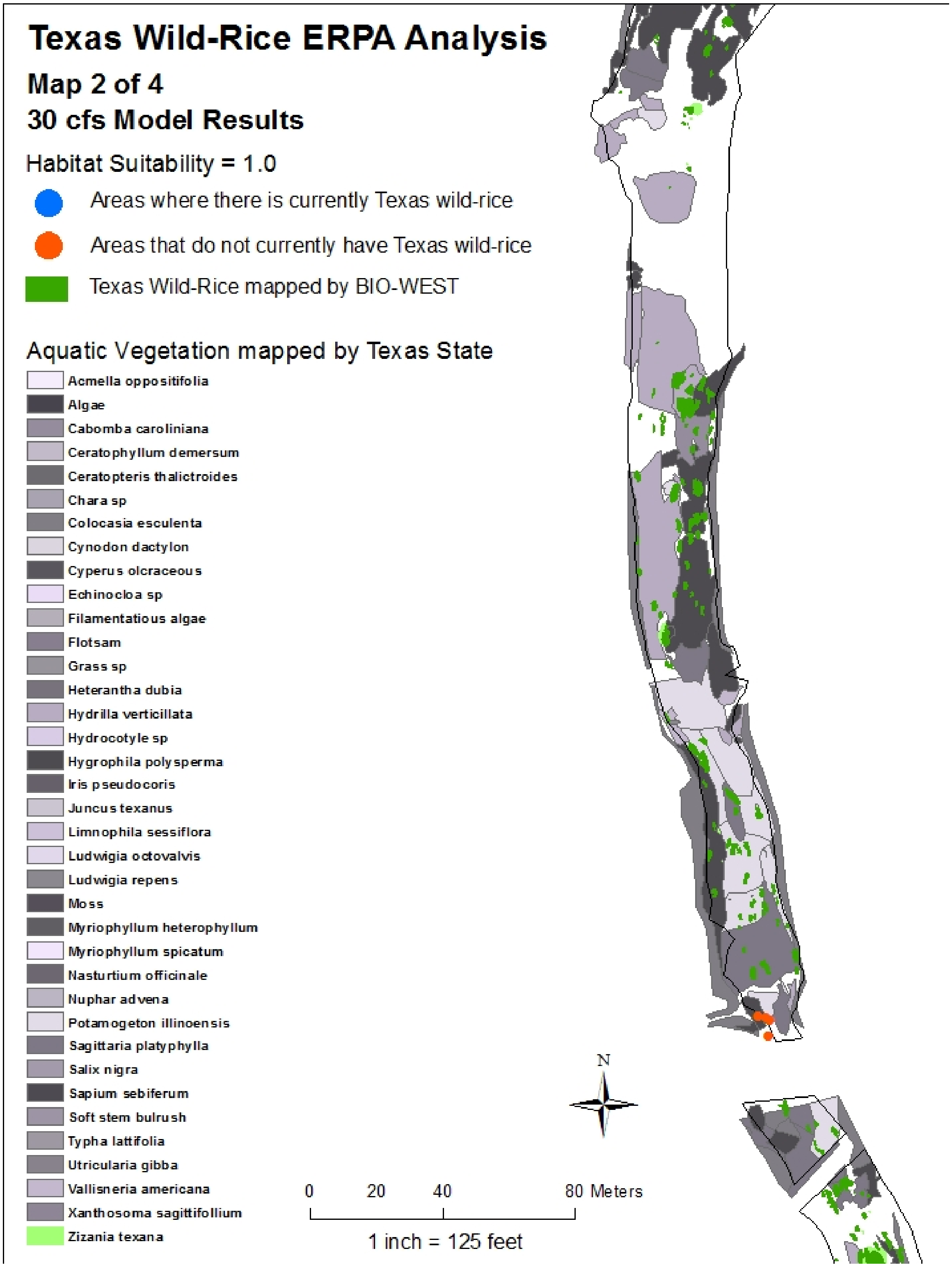


Figure 48. Texas wild-rice ERPA Analysis – 30 cfs model results (1.0 suitability) - Map 2

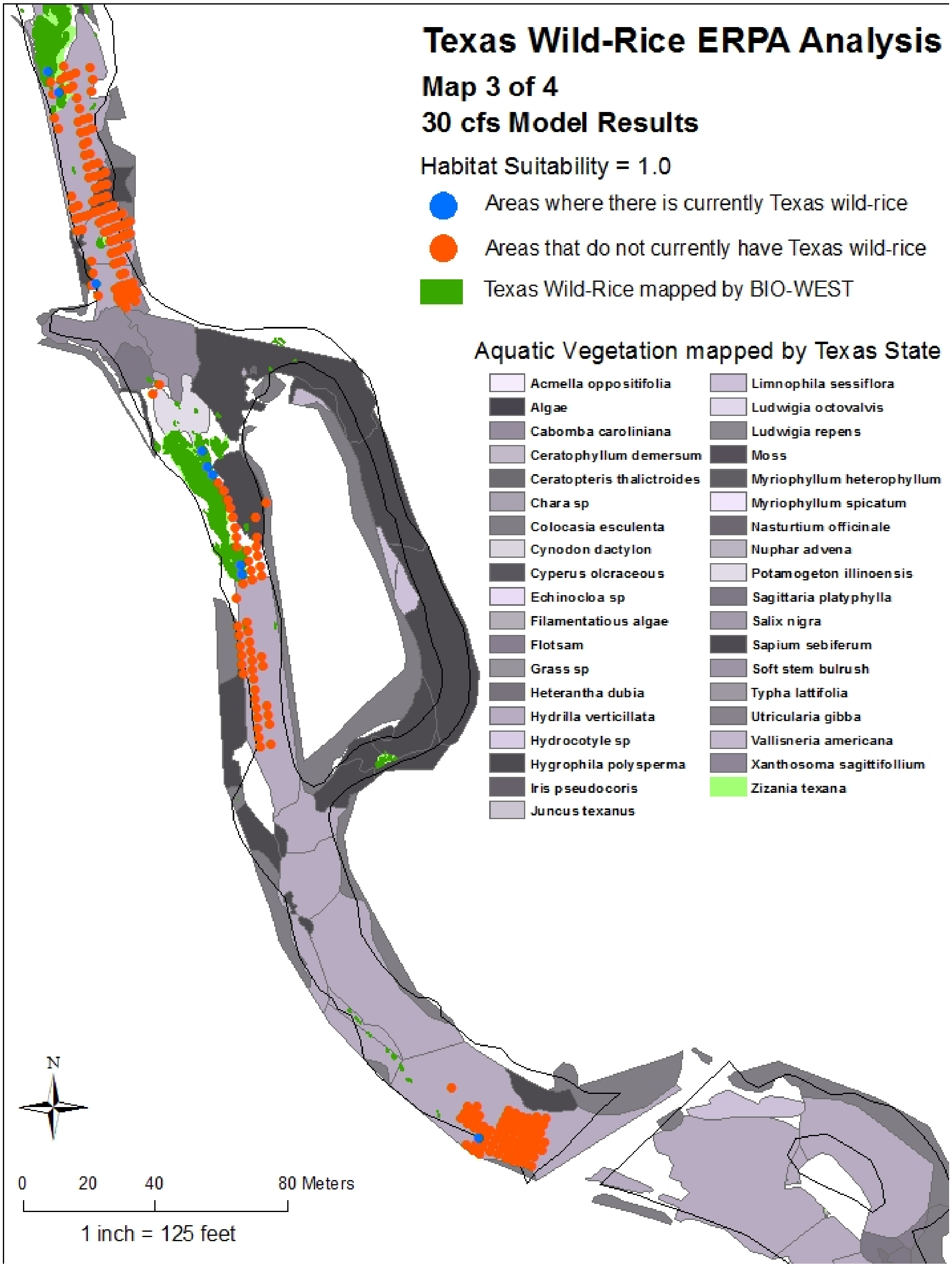


Figure 49. Texas wild-rice ERPA Analysis – 30 cfs model results (1.0 suitability) - Map 3

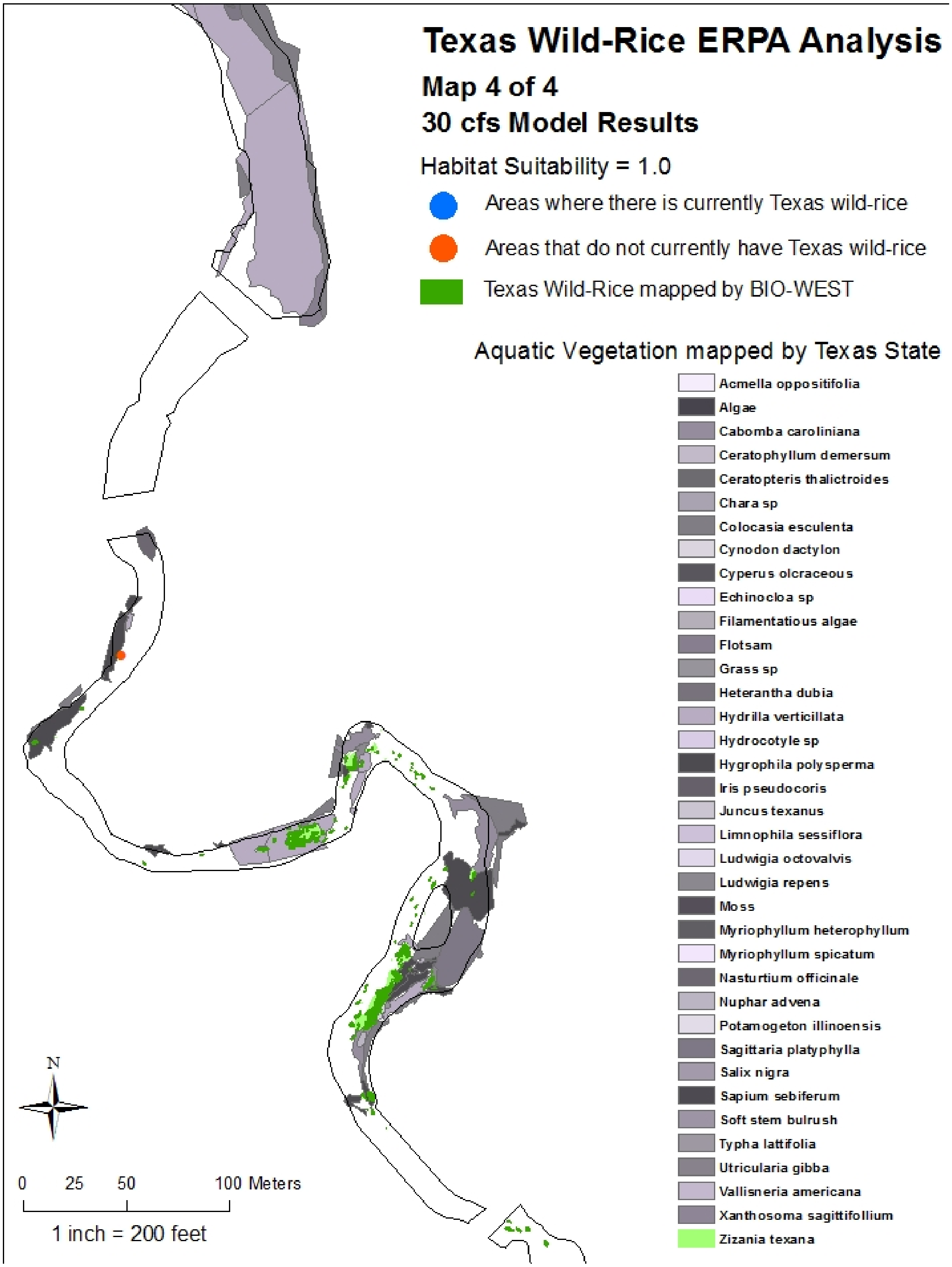


Figure 50. Texas wild-rice ERPA Analysis – 30 cfs model results (1.0 suitability) - Map 4

A comparison of 30 cfs from Hardy (2011) shows that using a suitability value of 0.75 as optimal predicts approximately 1,200 m^2 of occupied Texas wild-rice area in optimal areas; approximately 1,500 m^2 of occupied Texas wild-rice in suboptimal areas; and the potential for approximately 1,300 m^2 to be gained if *Hydrilla* and *Hygrophila* were removed (Table 18). Based on both these analyses, we conclude that biological risk at 30 cfs inserted into the evaluated EARIP flow regime would shift to High (extreme biological risk assessment categories as discussed in Comal) as more areas would be impacted. The potential for recovery still appears possible. However, at 30 cfs versus the recommended 45 cfs minimum, there would be much greater pressure on successful recreation control over broader areas as well as successful removal of non-native vegetation in optimal Texas wild-rice habitat areas, followed by successful expansion or re-introduction of Texas wild-rice.

Finally, we evaluated the results of the 15 cfs model run to assess increased biological risk to Texas wild-rice. It quickly became evident that only small amounts of optimal (1.0 suitability) Texas wild-rice habitat remains at this flow level with less than 100 m^2 predicted to be occupied. Therefore, we expanded our analysis to include what we term quality (>0.75) habitat. Results of the 15 cfs model run predict 2,564 m^2 of quality (>0.75 suitability) Texas wild-rice habitat, of which 238 m^2 currently (2009 mapping) have wild-rice growing in it (Figure 51 – only the uppermost segment is shown because it quickly became evident that this flow level would be Detrimental to Texas wild-rice).

There are two main differences in the predicted habitat for Texas wild-rice between the 30 cfs and 15 cfs model results. First, the 15 cfs habitat results in this comparison include somewhat lower habitat quality values (0.79-1.0 values). Second, is the location of the areas that are predicted as quality habitat. Results of the habitat model under 15 cfs flow conditions show the predicted quality habitat is in areas that are currently unvegetated, too deep and typically have too high velocities to support Texas wild-rice stands at average flows. The total area of good quality habitats and their associated mapped vegetation types are presented in Table 20. Even if one could be successful in going in under low flow conditions and transplanting Texas wild-rice in these bare areas (which we don't recommend because of stress on the plants and slim chance of success), when the river returned to average conditions all that restoration would be blown out.

Table 20. Predicted good quality (>0.75 suitability) habitats in the upper San Marcos River at 15 cfs modeled flow conditions that do not currently have Texas wild-rice.

Vegetation	Area
Colocasia esculenta	16.97 m^2
Grass	9.08 m^2
Hydrilla verticillata	211.19 m^2
Hygrophila polysperma	40.25 m^2
Nasturtium officinale	27.87 m^2
Potamogeton illinoensis	13.40 m^2
Sagittaria platyphylla	28.05m^2
Substrate (unvegetated)	1,979.19 m^2
Total	**2,326 m^2**

Based on the 15 cfs evaluation it is clear that these flow levels would be Detrimental and likely cause jeopardy to Texas wild-rice populations in the San Marcos River, even with extensive recreation control.

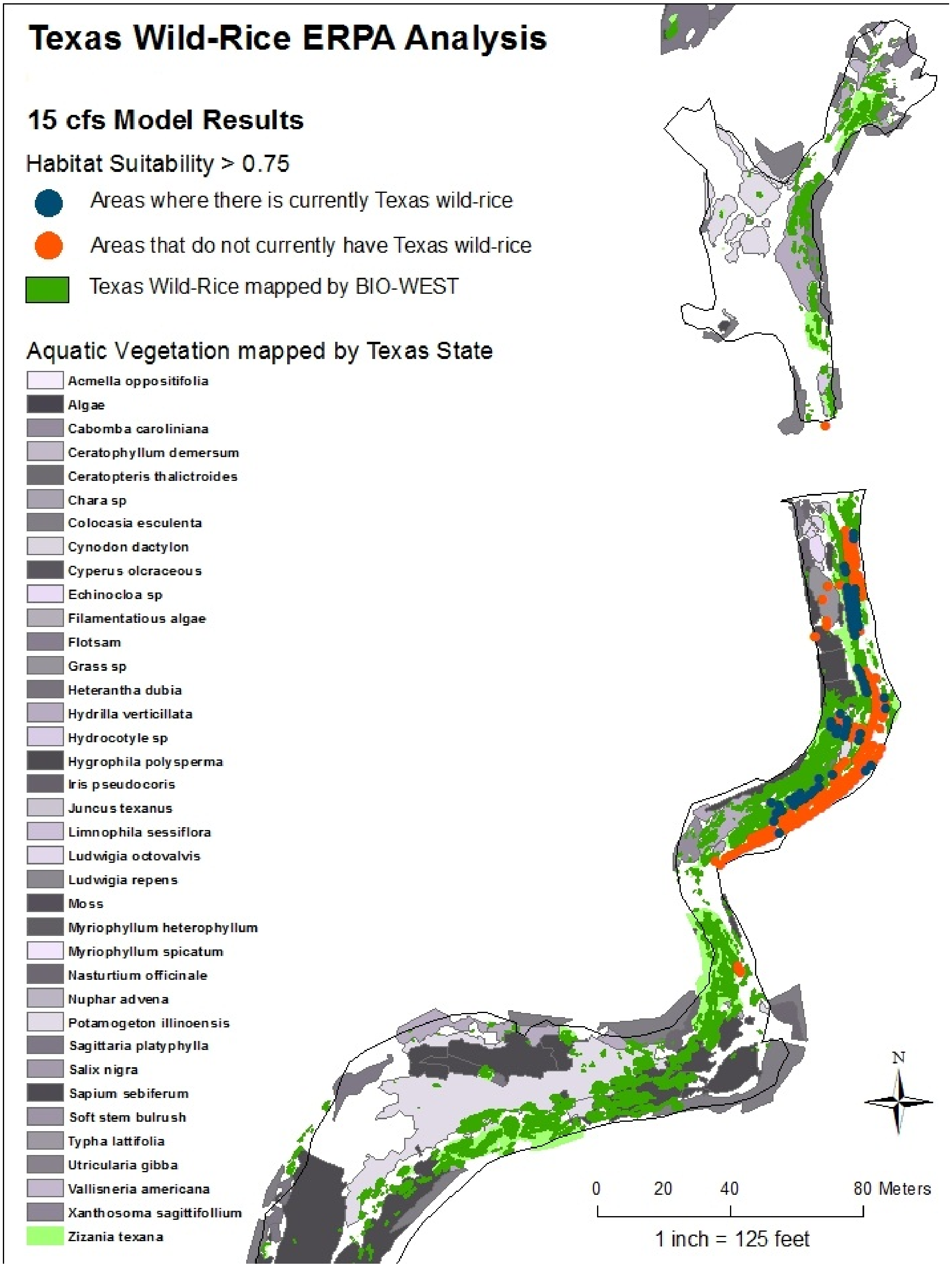


Figure 51. Texas wild-rice ERPA Analysis – 15 cfs model results (> 0.75 suitability)

8.2 SAN MARCOS RECOMMENDATIONS

Based on our preliminary assessment of ERPA's in the San Marcos system, we conclude that the evaluated EARIP flow regime as described in this document is sufficient to sustain the threatened and endangered species in this system without the necessity of a specific ERPA. However, we reiterate that the eastern spillway has a lot of potential for an ERPA. Should model assumptions be proven wrong, flows required to meet the evaluated EARIP flow regime not be deemed feasible, or if an added measure of safety is determined necessary by the EARIP or the USFWS during HCP review, further evaluation of this area would be warranted. Additionally, the eastern spillway has the potential to be converted into an applied research area that might greatly increase the understanding of the threatened and endangered species and their habitat during low flows. Regardless if the eastern spillway is turned into an ERPA or an applied research location, we recommend that this area be restricted from all recreational activities. This alone will greatly enhance the protection of these three species and their habitat in this reach.

TPWD has recently recommended an evaluation of some additional San Marcos locations to conduct endangered species research with on-site experimental channels. These include designing and building experimental channels at Aquarena Springs in the location of existing buildings to be torn down; the existing TSU raceways; and/or the slough arm of the San Marcos River in relation to a proposed fish bypass (or ladder) at Rio Vista Dam. Although none of these locations meet the criteria for an ERPA as defined, they are potential applied research locales and we are supportive of further evaluation of research activities at any or all of these locations.

We concur with the Hardy (2011) analysis regarding 45 cfs and the protection of Texas wild-rice in the San Marcos River. We also concur with the first recommendation in Hardy (2011) which promotes Texas wild-rice enhancement activities. Expansion or enhancement could first be observed through the reduction of non-native aquatic vegetation surrounding Texas wild-rice stands (adjacent to or downstream). We recommend caution regarding removing any aquatic vegetation from just upstream of established Texas wild-rice plants as this could drastically increase the effects of scour on the Texas wild-rice root wads. Additionally, establishment of Texas wild-rice stands in areas modeled to be high quality habitat during low-flow conditions is also recommended. In either case, protection (in this case, recreation control) of these areas would also need to occur to improve the chances for success. We echo Hardy (2011) by stressing that activities associated with Texas wild-rice enhancement need to be initiated early on in the first phase of the EARIP adaptive management program. If one waits to attempt this work during low flow conditions, the stress on the plants associated during those conditions will significantly decrease the success of any such activity.

As recommended for the Comal system, should the EARIP decide to move forward with an ERPA or components thereof for the San Marcos system, we recommend that the formation of an EARIP ERPA subcommittee or some form of third-party independent review team be assembled to oversee the ERPA implementation and studies conducted during the adaptive management phase of the HCP. Should the EARIP decide to only pursue Texas wild-rice enhancement, these activities could likely be overseen by the San Marcos River ecosystem restoration subcommittee.

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