Title
A Conceptual Restoration Plan and Tidal Hydrology Assessment for Reconnecting Spring Branch Creek to Suisun Marsh, Solano County, California

Author
Olson, Jessica J.

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A Conceptual Restoration Plan and Tidal Hydrology Assessment for Reconnecting Spring Branch Creek to Suisun Marsh, Solano County, California

By

Jessica J. Olson

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requirements for the degree of

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Committee in charge:
Professor G. Mathias Kondolf, Chair
Professor Katharine Nash Suding
Matt Ferner, Ph.D., Client

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And the sea lends large, as the marsh: lo, out of his plenty the sea
Pours fast: full soon the time of the flood-tide must be:
Look how the grace of the sea doth go
About and about through the intricate channels that flow

Here and there,
Everywhere,

Till his waters have flooded the uttermost creeks and the low-lying lanes,
And the marsh is meshed with a million veins,
That like as with rosy and silvery essences flow

In the rose-and-silver evening glow.
Farewell, my lord Sun!

The creeks overflow: a thousand rivulets run
'Twixt the roots of the sod; the blades of the marsh-grass stir;
Passeth a hurrying sound of wings that westward whirr;
Passeth, and all is still; and the currents cease to run;
And the sea and the marsh are one.

From the Marshes of Glynn
Sidney Lanier (1878)

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Thank you to National Estuarine Research Reserve, Solano Land Trust, California State Coastal Conservancy for allowing me to develop the restoration plan for this important site. Thank you Phil Williams, Michelle Orr, and Ben Wallace for helpful comment on previous drafts. Thank you Lisa Schile, Peter Baye, Phil Williams, Christina Toms, Brenda Grewell, Christine Whitcraft, Stuart Siegel, and Reza Ghezelbash for providing data, equipment, and/or help analyzing and interpreting data. Thank you to Richard Hobbs for your inspiring ideas and for helpful comments on my final presentation. Thank you Louise Mozingo for help on graphics, writing, and for helpful critiques on previous drafts. Thanks to lonely hearts thesis club and my EP sweeties. Last but not least, thanks to Brian Anacker for your love, support, and R skills and thanks to Pickleweed for sitting next to me while I endlessly click away on the computer.

1. INTRODUCTION

After 150 years of disking, diking and filling wetlands since colonization in San Francisco Bay, the first formal protection of wetlands in San Francisco Bay was enacted 1965 with the McAteer-Petris Act and the establishment of Bay Conservation and Development Commission (BCDC) (Williams and Faber 2001; Zedler 2001). However, by that time 90% of wetlands had already been lost (Dahl 1990), spurring an interest to begin restoring what was lost (Goals Project 1999) (Figure 1). In the past 30 years, over 75 major tidal wetland restoration or enhancement projects have been designed and implemented in San Francisco Bay, totaling more than 6,000 hectares (SF Bay Joint Venture 2012, Williams and Faber 2001). Today, there are more than 50 active projects in San Francisco Bay, that will result in an additional 8,000 HA of tidal wetland restoration or enhancement (SF Bay Joint Venture 2012). However, wetland restoration can be extremely complex, especially for tidal wetlands because global warming and sea level rise may compromise the long-term success of restoration efforts (Zedler 2001, Orr 2003, Callaway et al. 2011). Tidal marsh restoration projects that accommodate the process of estuarine transgression, defined as net migration of tidal marshes and other coastal features inland with rising sea level, may be the highest priority projects to undertake in the San Francisco Bay (Goals Project 1999). However, very little opportunity exists to accommodate space for estuarine transgression in the San Francisco Bay, threatening to further reduce wetland habitat (Goals Project 1999). By removing berms and ditches that currently impede exchange of flows, sediments, wildlife, nutrients and seeds, Spring Branch Creek is one location in the San Francisco Bay Estuary where estuarine transgression may be possible. The Spring Branch Creek Restoration Plan offers a rare opportunity to reconnect an alluvial fan to one of the largest intact brackish wetlands in western United States, allowing room for water, plants, and wildlife to migrate landward as sea level rises.

The purpose of this Professional Report is to develop a restoration plan for Spring Branch Creek in the context of 10 over-arching goals as defined by landowner Solano Land Trust. Goals relate to the associated ecosystem, organisms, invasive species, future change adaptation, uncertainties, grazing, public use, education and outreach, science, and administration (Table 1.1). The primary restoration actions proposed in the Spring Branch Creek Restoration Plan include levee and berm removal in order to reinitiate the exchange of flows, sediments, wildlife, nutrients and seeds. Secondary actions include non-native species removal and native plant revegetation within tidal and seasonal wetlands, and upland to wetland transition zone.

The report is organized in four sections. Section one describes relevant ecological restoration theory, the intended audience and planning framework. Section two describes the conceptual model for site conditions following removal of a berm and levee. Section three consists of a tidal hydrology analysis before and after removal of a berm and levee for Federally listed plant species soft bird's beak (*Chloropyron molle* ssp. *molle*, syn. *Cordylanthus mollis* ssp. *mollis*). Section four is a conceptual restoration design and a monitoring and adaptive management program for the restoring Spring Branch Creek.

Table 1.1 Project Goals

Category	Goal
1 Ecosystem	Conserve the dynamic extensive Holocene-epoch Rush Ranch tidal marsh and slough complexes, upland grasslands, and their continuous wetland ecotones, featuring them as outstanding scarce representative examples of portions of the Suisun Marsh ecosystem that are minimally influenced by dikes.
2 Organisms	Conserve populations of regionally rare, declining, distinctive, or unique native species inhabiting Rush Ranch.
3 Invasive species	Eliminate, control, or adapt to significant ecological threats to the site from introductions of non-native invasive plants and animals.
4 Future Change Adaptation	Adapt to future changes in environmental conditions: climate change (sea level rise, storms, air and water temperature, ancillary effects), large-scale regional tidal restoration, reduced regional sediment supply, local land use change
5 Uncertainties	Address uncertainties in site management, enhancement, and restoration by implementing these processes in an adaptive management context.
6 Grazing	Maintain an economically viable livestock grazing operation representative of cultural agricultural landscapes in Suisun Marsh, adapted to facilitate biological conservation goals and minimize ecological impacts.
7 Public Use	Promote and provide for public use of the site within the context of site conservation goals.
8 Education & Outreach	Promote and provide opportunities for public education and outreach on the site that enhance public understanding and appreciation of the site's past, present, and future ecology and human uses.
9 Science	Promote and support scientific research that contributes to conservation goals and improves the scientific understanding and management of the site and region.
10 Administration	Establish and maintain sustainable levels of staffing, financing, and legal protection to implement restoration project at Spring Branch Creek.

Notes: Goals were provided by Solano Land Trust as part of the Rush Ranch Management Plan update. Goals are not listed in order of importance.

1.1. Applicable Restoration Ecology Theory

There are aspects of restoration ecology theory that can inform the Spring Branch Creek Restoration Plan from setting goals, objectives, and restoration targets, to formulating actions and predicting outcomes.

Restoration Goals, Objectives, and Restoration Targets

The formulation of restoration goals, objectives, and restoration targets is an important step in developing a successful restoration plan (Zedler 2001; Clewell and Aronson 2007; Williams and Faber 2001). The development of measurable, explicit restoration targets (or performance standards) is especially important in developing a monitoring and adaptive management program (Clewell and Aronson 2007). By comparing monitoring results to the original targets (or performance standards), one should be able to determine whether the site has been successfully restored (Clewell and Aronson 2007). For this reason, the planning framework for the Spring Branch Creek project is set up to explicitly link the restoration objectives to measurable targets.

Table 1.2 Definitions (As Used In This Report)

Term	Definition
Adaptive Management	Long term management that changes iteratively based on monitoring results
Adaptive Restoration	Restoration actions undertaken in an experimental context
Alternative Stable States	An environment that can support two or more different stable (self-replacing) assemblages
Goal	Over-arching plan vision
Objective	Site specific project goals
Outcomes	Measured result of restoration actions
Resilience	The amount of change a system can undergo and retain the same structure, function, and feedbacks
Restoration Target	Measurable standards used in project monitoring
Thresholds	Point in environmental conditions that cause change of system state
Trajectories	The direction or path of site evolution
Trigger	A temporary event that causes long-term impact to the system

The Society of Ecological Restoration (SER) published a Restoration Primer in 2004 to introduce restoration principles and define how they are planned, conducted, and evaluated (SER 2004). According to the Primer, a restored site should have nine attributes that fall into the broader categories of diversity, community structure, and ecological processes. One can infer that a successful restoration plan should include goals relating to achieving these nine attributes. Ruiz-Jaen and Aide (2005) used the Primer attributes to evaluate how restoration projects measure success. Their results indicate that most restoration projects only measure one of three of the broader-category attributes, making it difficult to evaluate success (Ruiz-Jaen and Mitchell Aide 2005). Therefore, in order to be successful, the Spring Branch Creek plan includes measurable objectives related to all nine attributes (Table 1.3).

Table 1.3 Society Of Ecological Restoration Primer Attributes And Related Project Objectives

FORM	Diversity and Community Structure	SBC Objectives (Table 4.1)
1	Similar diversity and structure to reference system	3-5
2	Presence of indigenous species	3-6
3	Presence of functional groups necessary for long-term stability	3-6
FUNCTION	Ecological and Landscape Processes	
4	Capacity of the physical environment to sustain populations	1-2
5	Normal functioning	1-2
6	Integration with the landscape	1-2

7	Elimination of potential threats	1-3
8	Resilience to natural disturbances	1-2
9	Self-sustaining	1-2

Intended Actions

The relationship between how restoration actions achieve restoration targets should be made explicitly clear (Clewell and Aronson 2007). In formulating site-specific actions, restoration ecology theory pertaining to population, community and ecosystem perspectives may be relevant (Zedler 2001). Falk, Palmer and Zedler (2006) identified example ecological restoration questions and the theory related to each question (Falk, Palmer, and Zedler 2006) (Table 1.4). These types of questions along with the relevant restoration ecology theory is further developed in the restoration design and adaptive management sections of the plan.

Table 1.4. Example Restoration Questions And Applicable Restoration Ecology Theory (Falk, Palmer, and Zedler 2006)

Restoration Question	Ecology Theory
What propagule sources and numbers should be introduced?	Population and ecological genetics
How should sites be managed to exclude undesired species?	Invasive species and community invasibility, trait-based plant selection
How can sites be modified to enhance species diversity?	Fine scale habitat heterogeneity
What assemblages will persist in each part of restored site? In what order should they be introduced?	Community ecology

Predicted Outcomes

Like many restoration projects, the intended outcome of the Spring Branch Creek Restoration Plan is to create a resilient, self-sustaining system. However, predicting the outcome or trajectory of a restoration site is difficult (Suding 2011; Zedler 2001; Clewell and Aronson 2007). Instead, viewing restoration success as a dynamic concept, where multiple outcomes, or a range of conditions, are possible across time and space may be better than assuming a single outcome or trajectory (Suding and Hobbs 2009; Poole et al. 2004).

Evaluating the thresholds or triggers that can change an ecosystem state is another important step determining what the outcome or trajectory of a site will be following restoration. State transition models apply in restoration ecology because in restoring an ecosystem, we are trying to shift the ecosystem state, from an undesirable condition to a desirable one. The process of evaluating what triggers or thresholds apply to a site also uncovers whether restoration actions are necessary (Suding and Hobbs 2009). In examining the possible state-transition models for Spring Branch Creek following removal of berms and levees, there are many options for site evolution (Figure 2). The site could experience gradual change in shifting from one state to another. Alternatively it may reach some environmental threshold (certain tidal regime), which may cause a shift in the vegetation. Another alternative is that two alternative stable states may be able to persist for the same environment). Alternative stable sites are possible within the same environmental condition due to site history. In particular, site history can vary in terms of species colonization (what species are first to colonize), dispersal (some species are dispersal limited), and disturbance. Site history plays a significant role in shaping the restoration trajectory (Suding and Hobbs 2009). Although there may be uncertainty as to what state and transition model applies best to the Spring Branch Creek site, Suding and Hobbs 2009 offer a framework to help managers better understand what ecosystem dynamic models may be applicable to their site. Framework includes (1) understanding the temporal and spatial patterns of change, (2) identifying the broad-scale processes that can affect resilience and act as triggers to thresholds, (3) determining feedback mechanisms that have the potential to cause rapid change, (4) developing tests of the framework using adaptive management focused on experiments and scenario model building (Suding and Hobbs 2009). Monitoring actions and the adaptive restoration framework are set up to understand patterns of change, processes that act as triggers, and feedback mechanisms to change (see section 4.2 and 4.3) and the adaptive restoration framework (see section 4.2) explicitly sets up experiments to test how well restoration methods work.

1.2. Intended Audience

This project is intended to benefit the landowner Solano Land Trust (SLT) and partner San Francisco Bay National Estuarine Research Reserve (NERR). The conceptual restoration design allows SLT and NERR to apply for permits and funding necessary to develop final designs and construct the project. The project is also applicable to the larger restoration community within the estuary. Specifically, the project has relevance in Suisun Marsh where the Suisun Marsh Plan calls for 5,000 to 7,000 acres of tidal marsh restoration over the next 30 years. The Spring Branch Creek project could be considered a case study on removing small levees in order to prepare for estuarine transgression and see level rise and improve the ecological function of tidal wetland and seasonal wetland while also protecting and expanding habitat for rare and special status species. Further, the adaptive management framework and performance measures could be used by agencies implementing the restoration projects. As a National Estuarine Research Reserve site, the project could have relevance to other NERR sites implementing adaptive management. Further, if the Spring Branch Creek project uses the same monitoring protocols as other NERR sites, as part of a national effort and mandate to develop "Sentinel Site" monitoring, comparisons of site evolution and change in relation to climate change could be made across sites.

1.3 Related Plans

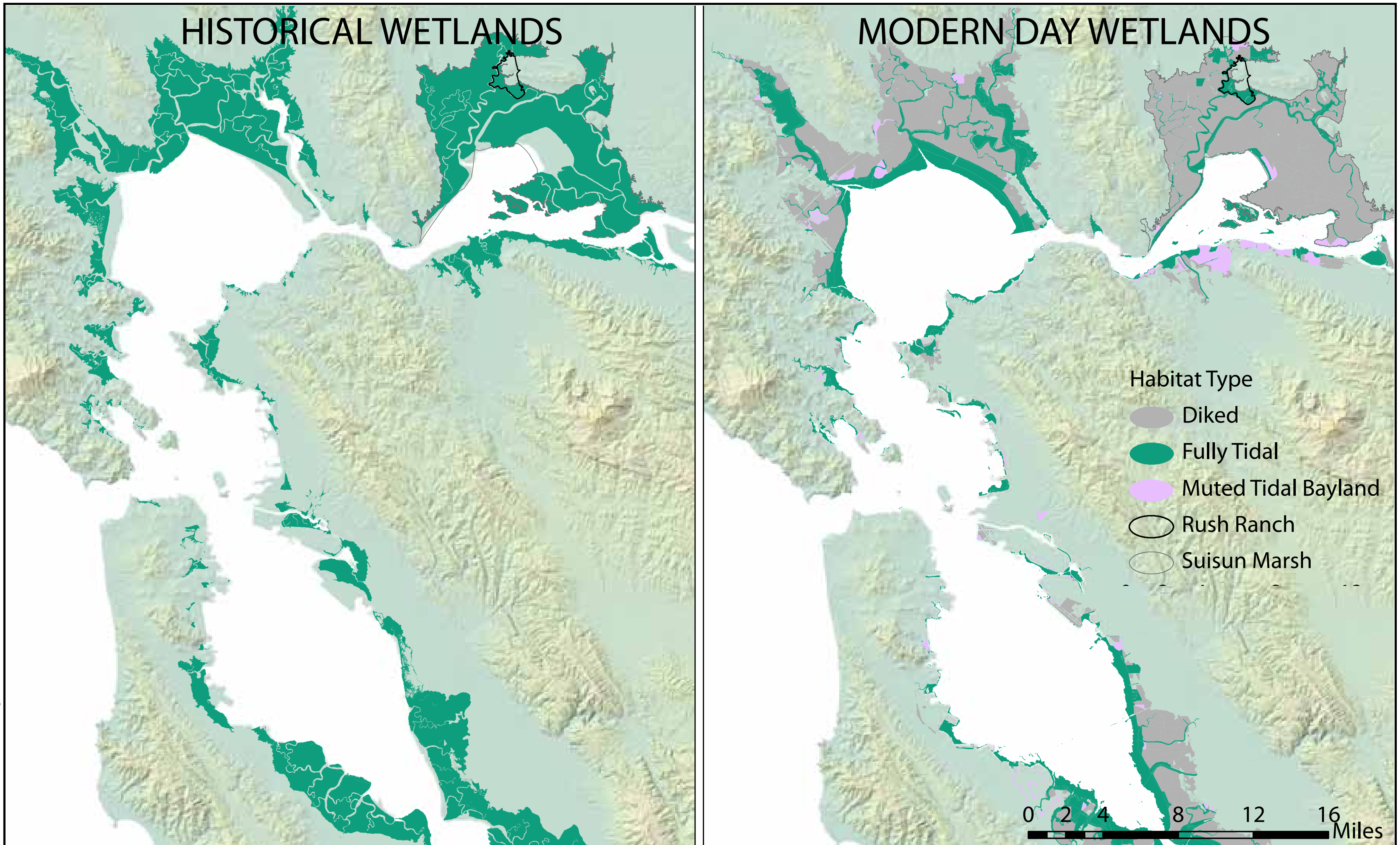
The Spring Branch Creek Restoration Plan is part of Solano Land Trust's underway Rush Ranch Management Plan update. The 1990 Rush Ranch Management Plan, written by WRA Environmental Consultants, guided ecological preservation and restoration, public use, grazing and land management for the past decade. In the ensuing years, the plan became outdated as a result of new issues related to invasive species, increased visitor use, and increased agricultural use. Further, an increase in demand to accept mitigation funds to implement restoration projects generated the need to identify and prioritize restoration and enhancement projects. In 2008, Solano Land Trust received a grant from the California State Coastal Conservancy (SCC) for preparation of a revised management plan. The management plan consists of an Existing Conditions Report, a Master Plan, Management, Enhancement, and Restoration (MER) Recommendations, Land Stewardship Program, and Restoration Designs. Solano Land Trust hired Wetlands and Water Resources (WWR) in 2009 to develop the Existing Conditions Report, the Management, Enhancement, and Restoration (MER) Recommendations, and three restoration designs. This report, the Spring Branch Creek Restoration Plan, is a fourth restoration design as required by SCC. Solano Land Trust authors the underway Master Plan, Land Stewardship Program, and a fifth restoration design.

The Land Stewardship Program has particular relevance to the Spring Branch Creek plan. In particular, the underway Rush Ranch Stewardship Program, in consultation with a science advisory group, defines weed control methods and related performance measures for each weed species of concern. For this reason, the Spring Branch Creek Restoration Plan does not include details on weed control methods and performance measures. The final restoration design (outside the scope of this project) incorporates information from the Rush Ranch Stewardship Program and defines weed control methods and performance measures more specifically.

WWR's Existing Conditions Report and MER Recommendations lay a solid scientific foundation for the Spring Branch Creek Restoration Design. The Existing Conditions Report summarizes and synthesizes existing data related to environmental conditions at Rush Ranch. The MER Recommendations identify the restoration priorities and describe the basic goals, objectives and actions for restoration and management at Rush Ranch.

1.4. Planning Framework

Restoration of Spring Branch Creek is a priority restoration project according to WWR's MER Recommendations. While the MER Recommendations set up the initial goals, objectives, and actions for restoration, this report develops specific project objectives and measurable targets that are explicitly linked to restoration actions in order to help develop an adaptive management framework in the planning process (Suding and Hobbs 2009; Clewell and Aronson 2007; Williams and Faber 2001; Zedler 2001). The planning framework for the Spring Branch Creek Restoration Plan is designed to explicitly link the restoration goals to site-specific objectives, measurable targets, and specific on-the-ground actions (Figure 3). This over-arching framework informs each plan section (Site Assessment, Site Analysis, and Restoration Design) and each section informs the over-arching framework. The resulting objectives, measurable targets, and restoration actions are reflective of this framework and are included in the restoration design (see section 4).



WETLAND LOSS IN SAN FRANCISCO BAY

Notes: Map created by Jessie Olson using ESRI and Adobe Illustrator software. Data source Ecoatlas, SFEI wetland files over laid on CalATLAS hillshade.

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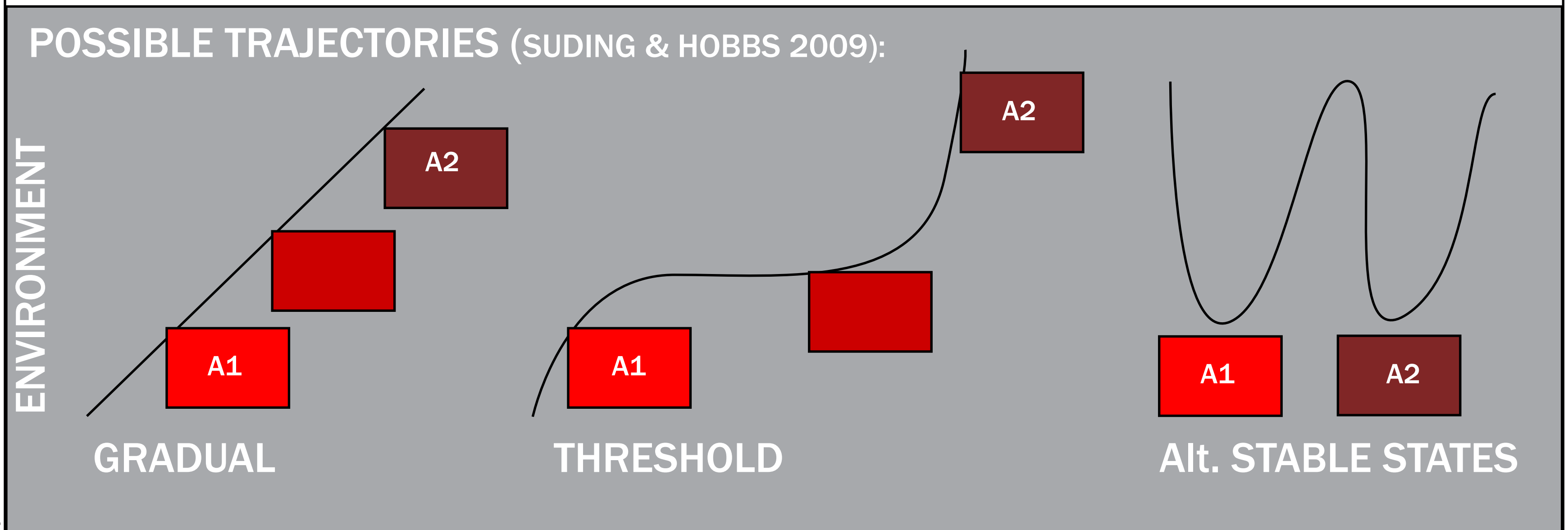
Figure 1



STATE TRANSITION MODELS

Notes: Figure created by Jessie Olson. In examining the possible state-transition models for Spring Branch Creek following removal of berms and levees, there are many possibilities for site evolution. The site could experience gradual change in shifting from one state to another. Alternatively it may reach some environmental threshold (certain tidal regime), which may cause a shift in the vegetation. Another alternative is that two alternative stable states may be able to persist for the same environment (Suding and Hobbs 2009).

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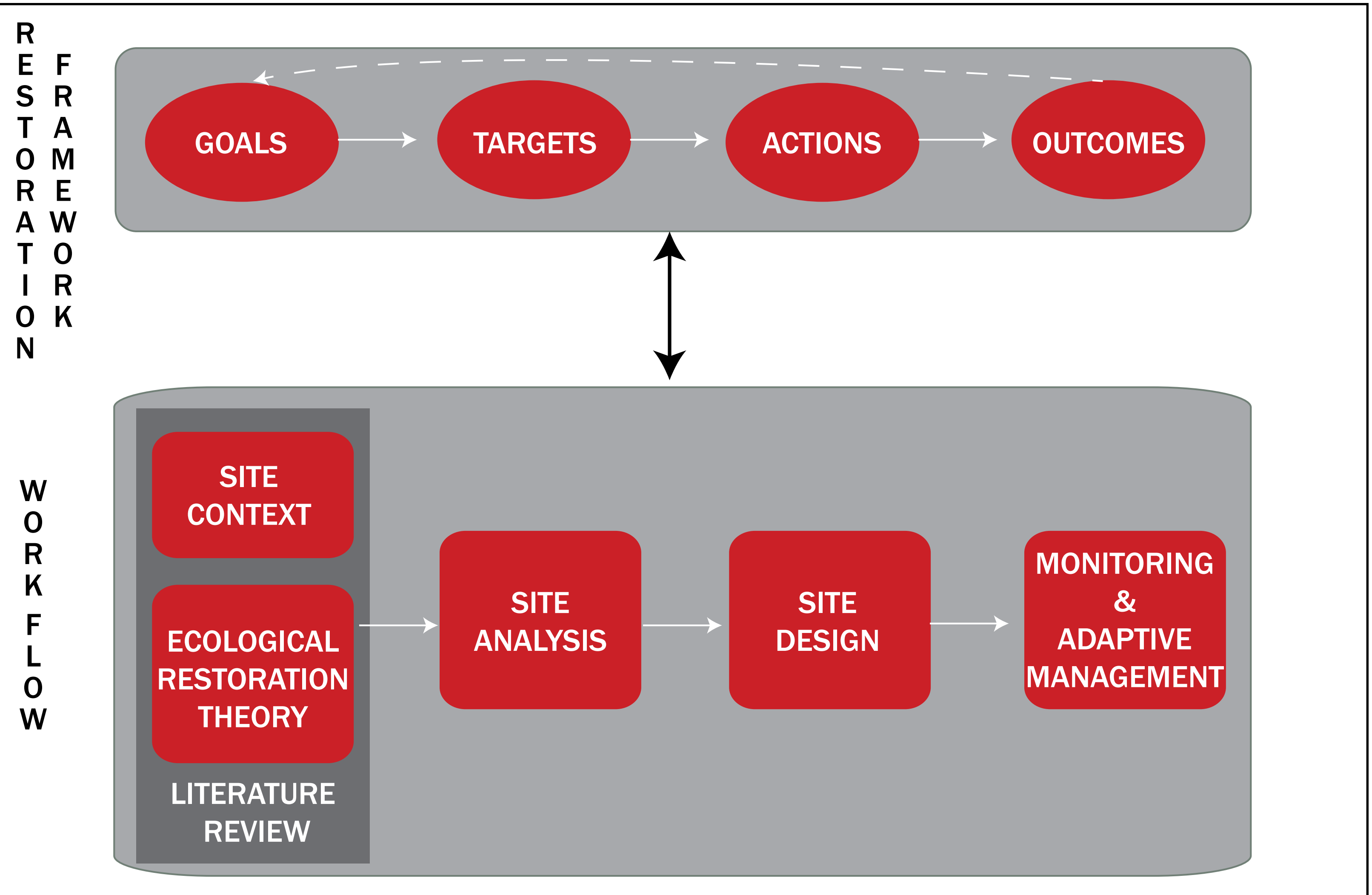
Figure 2



PLANNING FRAMEWORK

Notes: Figure created by Jessie Olson. The planning framework for the Spring Branch Creek Restoration Project is set up to link the restoration goals to site specific objectives to measureable targets to specific on the ground actions (Figure 3). This overarching framework informs each plan section (Site Assessment, Site Analysis, and Restoration Design) and each section informs the over-arching framework.

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Figure 3

2. SPRING BRANCH CREEK SITE ASSESSMENT

The purpose of the Spring Branch Creek Site Assessment is to describe the ecological, physical, and social components of the project site, Lower Spring Branch Creek, in order to understand the main ecological drivers of the site and how the site will respond following reconnection. While restoration frequently implies restoration back to a previous state, restoring back to a certain point in history is not relevent because the present day conditions have changed due to climate change, land use changes, species invasions, and changes in disturbance regimes (Hobbs et al. 2009). Therefore, the site assessment does not to evaluate reference site conditions from a static moment in time. Instead, the site assessment describes the ecological drivers and other site components in relation to the past, present and potential future conditions of Spring Branch Creek.

First, the site introduction describes the basic site components, including the project boundary and landscape context. Next, a conceptual model describes the relationship between modifying topography (the main physical action of the proposed project) and each aspect of the site. Descriptions of past, present and potential future conditions of the site are based on existing literature and studies. In addition the opportunities and constraints of other potential restoration and monitoring actions are highlighted throughout.

2.1. Introduction To Site

Rush Ranch is a 2000-acre property in Suisun Marsh, located in the San Francisco Bay estuary in Solano County, California (Figure 1 and 4). Owned and managed by Solano Land Trust since 1988, it was purchased with support from the California State Coastal Conservancy. Rush Ranch is also a San Francisco Bay National Estuarine Research Reserve (SF Bay NERR). The SF Bay NERR is part of a network of 28 reserves across the United States established to implement long-term research, education and stewardship. The legislative purpose of the NERR system is to improve understanding and management of the nation's estuaries.

The average annual rainfall is 23 inches; average high temperature is 73 degrees Fahrenheit and an average low of 47 degrees Fahrenheit (NCDC). The tidal marsh at Rush Ranch is home to a suite of threatened, endangered or rare plants and animals including the Suisun thistle *(Cirsium hydrophilum* var. *hydrophilum*), soft bird's beak (*Chloropyron molle* ssp. *molle*, syn. *Cordylanthus mollis* ssp. *mollis*), salt marsh harvest mouse (*Reithrodontomys raviventris*), and California black rail (*Laterallus jamaicensis*) (WWR 2010). First Mallard Slough, a natural drainage pathway for the entire Spring Branch Creek Watershed, has been shown to harbor among the highest counts of splittail (*Pogonichthys macrolepidotus*) and tule perch (*Hysterocarpus traski*) in Suisun Marsh (Teejay and Moyle 2008).

Project Boundary & Justification

Spring Branch Creek has two reaches within the Rush Ranch property. Solano Land Trust (SLT) refers to the reach between the levee road and Grizzly Island Road as "Lower Spring Branch Creek" and the reach between Grizzly Island Road and the eastern property boundary as "Upper Spring Branch Creek". The reach outside the Solano Land Trust property between the property boundary and the headwaters at Potrero Hills Landfill is the headwaters reach (Figure 5).

The restoration project boundary for this project consists of lower Spring Branch Creek, or the area between the levee road and Grizzly Island Road (Figure 5). Restoration designs for upper Spring Branch Creek, east of Grizzly Island Road, are outside the scope of this plan. In order to fully realize the ecological benefits of restoration, restoration of lower Spring Branch Creek should occur in concert with upper Spring Branch Creek. However, there are justifiable ecological benefits to restore lower Spring Branch Creek independent of the upper Spring Branch Creek project. The short-term ecological benefit of the lower Spring Branch Creek restoration project may be small when the berm and levee removal only occurs in lower Spring Branch Creek. However, long-term benefit is large considering the low gradient slope of Spring Branch Creek is one location with the possibility to accommodate estuarine transgression (Figure 6).

Ecological Drivers

Like many estuarine-fluvial systems, the main ecological drivers of the site are vegetation, hydrology, and soils. Together this can be classified into ecogeomporphic units (Figure 7). Present-day ecogeomporphic units are a result of historical land use changes (Figure 8). Draining a 2,670-acre watershed, Spring Branch Creek flows through a geologically-controlled valley to deposit onto its alluvial fan built out into Suisun Marsh. Alluvial fans are depositional features with a network of small distributary channels which fill with sediments, causing flow to shift to other channels (WWR 2010). The lower reaches of Spring Branch Creek transition into a first order tidal creek (First Mallard Slough). Approximately 75 years ago (in the 1930s), a farm levee road was constructed across the Spring Branch Creek channel by digging a borrow pit upstream of the levee. In addition, a berm was constructed by digging an adjacent borrow ditch. The berm and levee, which cut off tidal flows that historically reached above Grizzly Island road, were intended to impound a stockpond for cattle. An additional levee, constructed to create a stockpond in upper Spring Branch Creek, prevents a greater volume of freshwater flows from entering lower Spring Branch Creek. The present-day alluvial fan and seasonal wetland within lower Spring Branch Creek is a result of this altered hydrology from the berm levee construction within lower and upper Spring Branch Creek (Brenda Grewell pers. comm, December 2011). In the 1990s, SLT installed two four-foot culverts beneath the levee road in an attempt to partially restore the exchange of tidal water with fresh water. However, the presence of the ditches and berms upstream of the levee continues to restrict tidal exchange and natural meander, scouring processes of the alluvial fan that is present today. In lower Spring Branch Creek, where there is a wide floodplain, abandoned channels are present through meander scars, scarps, and pools from 75 years of channel movement (Figure 7). Sediment type in a given area is related to flow magnitude in that area (WWR 2010). Courser sediments are found in areas that experience higher discharge rates (CFS) (active channel), finer grained sediments are found in areas with lower discharge rates (Leopold et al. 1995). Vegetation composition is influenced by season depositional and erosional events and its position in the landscape, including occurrence in the active distributary channel, meander scares, lobes and flats, and impoundments. As sea level rises the boundary between tidal marsh and deltaic sediments of the alluvial fan will migrate up the spring branch creek gradient (Figure 8).

2.2. Landscape Context

Upstream land uses make hydrological reconnection of the entire Spring Branch Creek corridor infeasible within the scope of this project, due to the presence of impoundments upstream of the Solano Land Trust property. Although the Solano Land Trust owns the lower elevation reaches of Spring Branch Creek, Potrero Hills Landfill and a private rancher own the headwaters reach (Figure 5). In addition to the two impoundments, the Potrero Hills landfill has converted a portion of the headwaters reach with the creation of the landfill (EDAW 2007). A by-pass channel redirects the creek around the landfill (EDAW 2007). The headwaters remain intact, but plans to expand the landfill further upstream will permanently alter a portion of the headwaters (EDAW 2007). Full hydrological connection requires Solano Land Trust to coordinate with landowners. While it is infeasible to remove the landfill which permanently impacts a portion of the Spring Branch Creek headwaters reach, SLT can coordinate with landowners on a watershed approach to management. Specifically, SLT can coordinate with the adjacent private rancher to remove additional impoundments and coordinate with the landfill and the private rancher on weed control and California tiger salamander habitat enhancement.

Removal of berms and levees may initially impact the area directly downstream of Spring Branch Creek, with an increase in freshwater, sediment, and seed sources, but are unlikely to impact the area beyond Solano Land Trust property boundary (Matt Kondolf pers. comm. November 2011). The Conceptual Model (section 2.3) details potential impacts to hydrology, edaphic environment, and vegetation following removal of berms and levee.

2.3. Conceptual Model For Site Conditions Following Hydrological Reconnection

Topographic modifications (removal of berms and levee) directly and indirectly affects many aspects of Spring Branch Creek (Figure 9). Currently a levee trail that varies in height (NAVD 88) from .25 meters (at landward edge) to 1.75 meters (at the channel) partially blocks tidal flows from entering Spring Branch Creek (Figure 10). In addition, a 0.25 meter berm is present adjacent to a small borrow ditch. Elevations within lower Spring Branch Creek range from 5 meters (NAVD 88) adjacent to Grizzly Island Road to 1.25 meters (NAVD 88) at the channel bottom adjacent to the Road levee. Removal of the berm and levee allows full tidal reconnection but may impact other aspects of the site in positive and negative ways (Figure 9).

Hydrology

Tidal, seasonal freshwater and ground water hydrology are directly related to topographic modifications in Spring Branch Creek (pathway 1) (Figure 9). Historical topographic maps and the presence of remnant wetland vegetation indicate that tidal flows historically reached almost all the way to Grizzly Island Road (SFEI 1998) (Figure 6). Today tidal influence extends just beyond the L-shaped berm (Figure 7).

The Spring Branch Creek watershed is seasonally inundated. Q2, Q10, Q25 events have been calculated as 340, 520, 610 CFS respectively within the 1990 Rush Ranch Management Plan using rational method (Rantz 1971). The rational method relates the peak discharge (m3/sec) to the drainage area (ha), the rainfall intensity (mm/hr), and the runoff coefficient (Rantz 1971). Rain events cause the impoundment in upper Spring Branch Creek to overtop 1-2 times per year, with an event defined as rainfall for more than one consecutive day (Olson 2011). The Potrero Hills Landfill Environmental Impact Report indicates that landfill expansion will cause significant damage to discharged water quality and found that impacts to surface water quality will be significant. The landfill's proposed truck-wash facility may generate contaminants that could pollute downstream into Solano Land Trust's portion of Spring Branch Creek (EDAW 2007). However, a series of detainment ponds were added to the design below the areas of impact in order to mitigate the impact (EDAW 2007). If these detainment ponds over-top during storm events there may be water quality impacts to Spring Branch Creek and Suisun Marsh more broadly. Coordination with the Potrero Hills Landfill may be necessary to document such impacts.

Phil Williams & Associates reports that groundwater elevations are 1.5 meters below ground elevations within lower Spring Branch Creek (approx. 1 meter NAVD 88) and between 1.2-2.1 meters below ground level (approx. 1.6-2.3 meters NAVD 88) in upper Spring Branch Creek in monthly observations October –February (WRA 1990). Water column salinity (pathway 2) in First Mallard Slough ranges from .01-10.3 PPT (NERR 2008-2012).

Freshwater entering the marsh increases following removal of the upstream impoundment. In addition, the presence of the levees may be causing the ground water to artificially build up behind the levee, thus following removal of the levee the groundwater may drop (Phillip Williams pers. com, November 2011).

Tidal flows are likely to expand further up Spring Branch Creek following reconnection (Section 3.4, Figure 18). However, tidal ranges may not reach their historical range as the tidal range is dampened within greater Suisun Marsh due to the disking and diking of wetlands throughout Suisun Marsh. As the site evolves, and sea level rise accelerates, there is a possibility that tidal flows may return to historical ranges. However, planned restoration of 5,000-7,000 acres of tidal marsh within Suisun Marsh may further dampen the local tidal range, and lessen the impact of sea level rise, as levees are removed and areas are reintroduced to tidal flooding (USFWS 2011). Monitoring water elevation as the site evolves (section 4.3 below) can help land managers detect changes in water elevation from sea level rise and/or regional land use changes. Regardless of the outcome, removal of barriers to wetland expansion or retraction allows the site to adapt to sea level rise an/or regional land use changes.

Edaphic Environment

The edaphic environment (pathway 3A) indirectly relates to changes in topography. Within the seasonal wetlands/alluvial fans, Solano loam is the dominant soil type, whereas upslope on the older alluvial fans, Antioch San Ysidro Complex prevails. Whitcraft and Grewell characterize soil texture and nutrients within the Spring Branch Creek corridor (Whitcraft, Grewell unpublished data). Results indicate that pore water salinity within the (dry) active channel are an average 5 ppt and range between 4-10 ppt (Whitcraft unpublished data). Within the alluvial fan, salinity averages 3.2 ppt and ranges between 2-5ppt (Whitcraft unpublished data). Following hydrological reconnection, soil salinity may change with an increase in mixing of fresh and tidal water (pathway 3A). The change in soil salinity and inundation may in turn impact vegetation (pathway 5A). The degree of change (if any) in water salinity is unknown because the site may experience changes in both freshwater and salt water. While changes in water salinity are immediately measureable, soil salinity changes are likely gradual. Likewise, vegetation communities shift slowly in the areas where water salinity changes significantly. Pre and post restoration water and soil salinity measurements are taken across the site in order to evaluate changes (see section 4.3). Salinity data determines where and if significant changes in water salinity occur and whether revegetation plant palettes are appropriate for those conditions.

Sedimentation is evident within the channel in lower Spring Branch Creek with a .5-meter difference above and below the culverts within the channel. Sedimentation occurs in the upper Spring Branch Creek impoundment, as observed by the author. Pre restoration measurements of sediment, and morphology of the upstream impoundment occur prior to the final restoration design (see section 4.3). Following removal of levees and berms a pulse of sediment may migrate downstream over time. To minimize the potential impact of sediment moving downstream, sediment may be removed prior to levee and berm removal. However, sediment is a natural component of a fluvial-estuarine system where it facilitates channel deposition and scour processes associated with alluvial fans and the progradation of deltaic alluvium over tidal marsh sediments.

Vegetation

Vegetation indirectly relates to topographic modifications through salinity, hydrology, and the edaphic environment (pathways 3B, 4A, and 5A). Within the Spring Branch Creek corridor, eight vegetation types are present based on vegetation mapping efforts conducted by Solano Land Trust and the California Department of Fish and Game in 2009 (Figure 11A). Vegetation associations found in Spring Branch Creek include Bromus (*diandrus*, and *hordeaceus*)-*Brachypodium distachyson*, (2) *Centaurea (solstitallis, melitensis*) Semi Natural Herbaceous Stand, *Distichlis spicata*-annual grasses association, *Elocharis macrostachya, Frankenia salina - Distichlis spicata* association, *Frankenia salina* Alliance, *Leymus triticoides* association, *Lolium perenne*, *Lepidium latifolium*, and *Juncus-Leymus-Distichlis*. While all of these vegetation associations are present, not all associations are visible in aerial photographs for mapping purposes (Olson and Anacker 2011). The vegetation types are grouped in the following classifications: (1) *Bromus (diandrus*, and *hordeaceus*)-*Brachypodium distachyson*, and *Centaurea (solstitallis, melitensis*) Semi Natural Herbaceous Stand called *Bromus-Brachypodium* on the map (2) *Distichlis spicata*-annual grasses association, *Elocharis macrostachya, Frankenia salina - Distichlis spicata* association, *Frankenia salina* Alliance, and *Lolium perenne* called *Frankenia-Distichlis* on the map (3) *Leymus triticodes*, (called *Leymus –Carduus* on Figure 11A), (4) *Lepidium* (5) *Typha* (6) *Distichlis-Juncus-Triglochin-Glaux* and (7) *Cordylanthus* which is actually part of *Distichlis-Juncus-Triglochin-Glaux* association but is separate for emphasis. Following reconnection, wetland plant associations (#4, 5, 6, and/or 7) are likely to expand in the new areas that will receive tidal inundation (Figure 11B).

Invasive Weeds

In addition to perennial pepperweed (*Lepidium latifolium*), there are five other invasive plant species present within the project area that have an indirect relationship to modifications in topography (pathway 3C, 4B). Weeds include medusahead (*Taeniatherum caput-medusae*), harding grass (*Phalaris aquatica*), sicklegrass (*Hainardia cylindrica*), rabbitsfoot grass (*Polypogon monspeliensis*), and celery *(Apium graveolens*). Response of native and non-native vegetation following reconnection is largely unknown and needs to be carefully monitored as the site evolves (see section 4.3). Previous studies suggest that increased rates of inundation result in less sicklegrass and rabbitsfoot grass (Grewell 2005). An increase freshwater and tidal water exchange and potential changes in salinity and ground water following removal of the upstream and lower Spring Branch Creek impoundment (pathway 3C and 4B) may make Spring Branch Creek more or less favorable for invasive species (Figure 11B). The adaptive restoration framework (section 4.2) and site monitoring (section 4.3) allow managers to monitor and respond to variety of changes across time and space.

Table 2.1 Rare, Threatened, Or Endangered Species Known To Occur On Site

Species	Description
Soft bird's-beak (*Chloropyron molle* ssp. *molle*, syn., *Cordylanthus mollis* ssp. *mollis*)	A federally listed species that was reintroduced to the site in 2000, is now a population of over 100,000 individuals (Grewell 2003).
Black rails (*Laterallus jamaicensis*)	Threatened by the state of California and federally listed species of special concern, this species is known to occur within the tule vegetation in Spring Branch Creek (Grewell pers. comm).

The federally listed plant soft bird's-beak (*Chloropyron molle* ssp. *molle*, syn., *Cordylanthus mollis* ssp. *mollis*) is the only special status plant species that currently occurs within the Spring Branch Creek species corridor (Figure 11A). Because this plant species requires a specific hydrological inundation frequency, depth and duration, (Grewell et al. 2003) changes in hydrology following reconnection (by removing the berms at Spring Branch Creek) may impact the existing range for this species. For this reason, the site analysis (section 3) develops a conceptual model and tidal hydrological analysis specifically for soft bird's beak.

Wildlife

Hydrological reconnection may temporarily impact rare, threatened, or endangered wildlife species. In particular, black rails *(Laterallus jamaicensis)* nest in the cattails and tule vegetation in Spring Branch Creek since 1999 (Brenda Grewell pers comm, December 2011). Restoration efforts may temporarily impact this species. In order to minimize impact, restoration actions do not occur during the breeding season (February- August). However, this species may also be present year round.

There are also many other rare, threatened or endangered plant and animal species (pathways 6, 7A, 7B, 8) that have potential to reside within Lower Spring Branch Creek following reconnection (Table 2.2).

Infrastructure

Existing infrastructure (pathway 10) directly relates to removing levees and berms within lower Spring Branch Creek. Existing infrastructure consists of a berm, ditch and a levee road, which is currently used by a rancher, SLT staff, researchers, and for public horse-drawn carriage rides (Figure 12). Two four-foot culverts occur within the levee, installed in the 1990s. In addition, there is a boardwalk in disrepair across Spring Branch Creek just east of Grizzly Island Road. A water pipe is buried within lower Spring Branch Creek, which allows water to be pumped from the well within the headquarters to the south pasture for use by cattle. Two off-channel impoundments are present within lower Spring Branch Creek. These hold water seasonally, and may provide habitat for California tiger salamander (CTS) and/or California red legged frog (CRLF) though they have not been surveyed. Where Grizzly Island Road crosses Spring Branch Creek, two 4-foot culverts allow water to pass through during storm events, although the road occasionally floods during large storm events. Following reconnection, vehicle access to the south pasture is accessible via Grizzly Island Road. The pipe currently buried in tidal wetlands could be attached to a new boardwalk/footbridge. Two off-channel impoundments remain as potential habitat for CTS and CRLF.

Table 2.2 Rare, Threatened, Or Endangered Species With Potential To Occur On Site

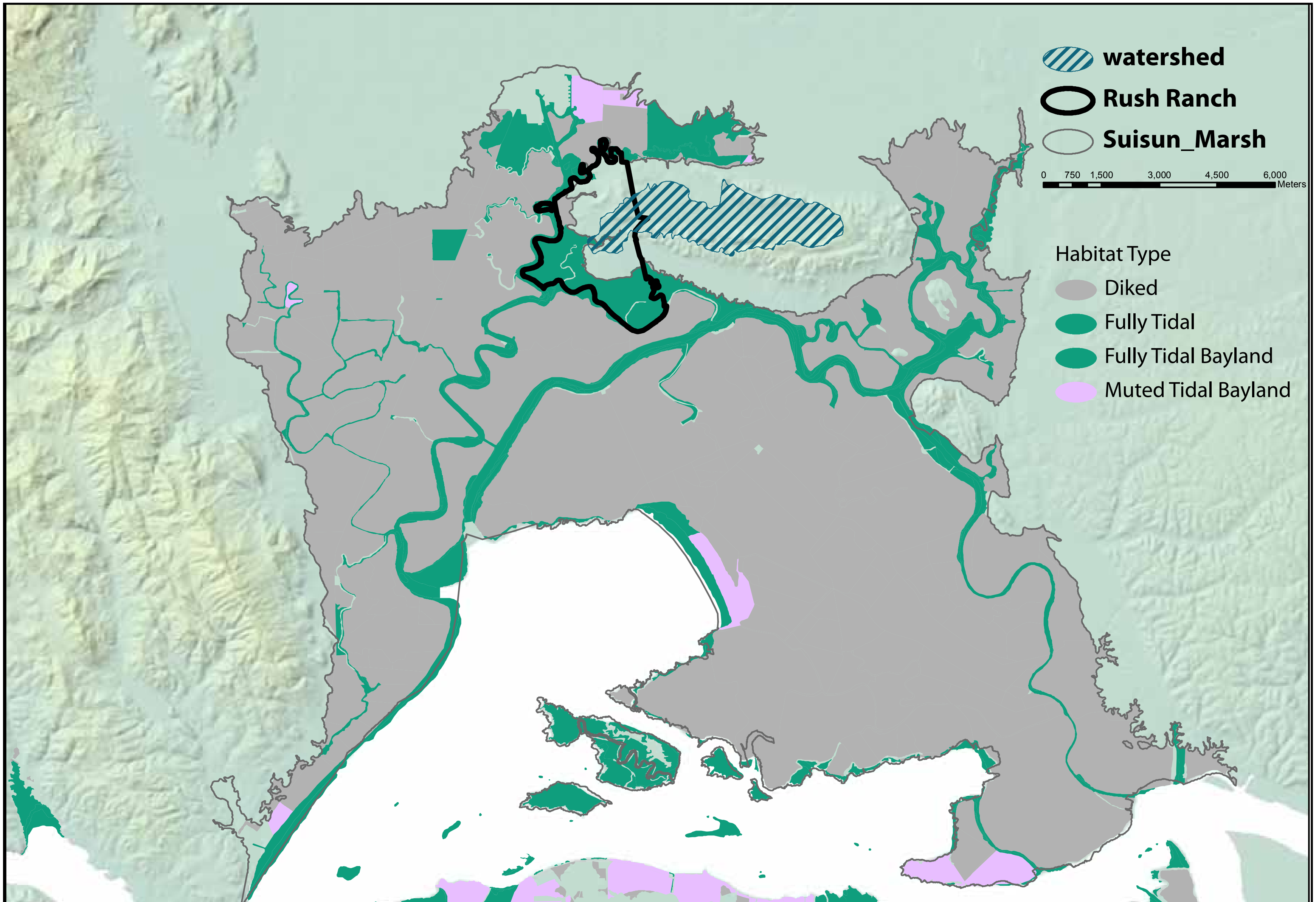
Species	Description
Suisun thistle (*Cirsium hydrophilum var. hydrophilum*)	A federally listed species that does not currently exist within the Spring Branch Creek corridor. However, following reconnection, it has potential to occur along the newly formed channel.
Salt marsh harvest mouse (*Reithrodontomys raviventris*)	A federally listed species that has not been found within Spring Branch corridor in trapping efforts conducted by the Department of Fish and Game (DFG). Following reconnection, the species has potential to occur within tidally influenced areas year-round and within 100 meters into upland habitats during high tides and flood events (USFWS 2010).
Suisun Shrew (*Sorex ornatus sinuosus*)	A species of special concern, this species also has not been found in the Spring Branch Creek cooridor, but it also has potential to occur within the site and into the upland grasslands within 100 meters (Hays and Lidicker Jr).
Delta smelt (*Hypomesus transpacificus*), Longfin smelt (*Spirinchus thaleichthys*), Sacramento splittail (*Pogonichthys macrolepidotus*), Chinook salmon (*Oncorhync hus tshawytscha*), Steelhead *(Oncorhynchus mykiss*)	First Mallard Slough has the highest counts of fish in Suisun Marsh (Teejay and Moyle 2008). Currently, there is a possibility that these listed fish can make their way through the culverts at Spring Branch Creek during high tides, but this is not documented. Following hydrological reconnection, fish may extend their range of habitat to include Spring Branch Creek.
California clapper rails (*Rallus longirostris obsoletus*)	According to DFG surveys, this Federally listed species has been found in nearby Goat Island marsh. There is potential for this species to occur on site now and in the future.
Yellow rails (*Coturnicops noveboracensis*)	A species of special concern, yellow rails are found adjacent to Spring Branch Creek and have potential to occur on site now and in the future (Spragens and Woo 2009).
Aquatic Insects	Several rare, and previously undescribed aquatic insects are found in Rush Ranch's Suisun Hill Hollow (WWR 2010). Spring Branch Creek, although very different hydrological system, may also be a location for rare insects pre and post hydrological connection (WWR 2010). Complete aquatic invertebrate surveys within Spring Branch Creek occur prior to removal of berms and levees (see section 4.3).

Public Access

Public access directly relates to topographic modification (pathway 11). Visitors to Rush Ranch access the levee trail that partially blocks tidal flows into Spring Branch Creek (Figure 12). Removal of this levee trail has potential to impact public access. According to the Solano Land Trust's Public Use context chapter in the underway Rush Ranch Management Plan, current public uses on site include carriage rides, hiking, research and grazing lease access (via vehicle). Following hydrological reconnection a new boardwalk needs to accommodate existing uses. The conceptual restoration design includes a new boardwalk (see section 4.2). As mentioned above, vehicle access is accommodated via Grizzly Island Road in the future.

Herbivores

Non-native herbivores (pigs and cattle) (pathway 12) indirectly relate to topographic modifications. An occasional escapee cow causes erosion/compaction and disturbs vegetation. Cattle grazing appears to inhibit growth of creeping wild rye (Figure 13). Wild pigs occasionally make their way to Spring Branch Creek and root around, cause erosion and disturb vegetation. These types of disturbances are likely to continue following hydrological reconnection unless fences are better maintained to keep out cattle and Suisun-Marsh wide pig control takes place. In order to accommodate ranch-wide grazing a cattle crossing location across lower Spring Branch Creek (see section 4.2).

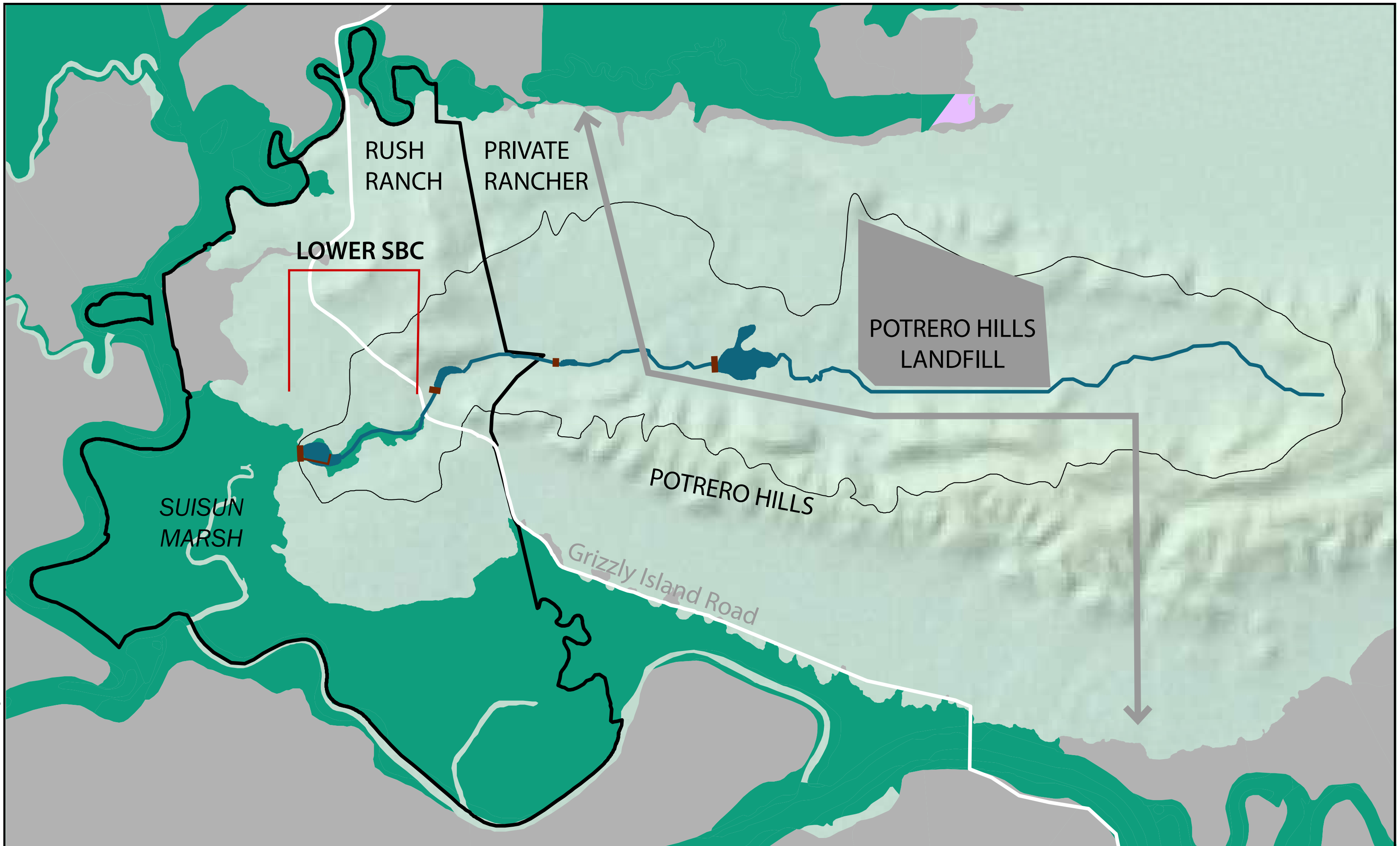


REGIONAL LOCATION

Notes: Map created by Jessie Olson using ESRI and Adobe Illustrator software. Data source Ecoatlas, SFEI over laid on CalATLAS hill-shade. Spring Branch Creek Watershed boundary digitized from 1-foot contours developed from 2007 DWR LIDAR.

May 2012

Figure 4

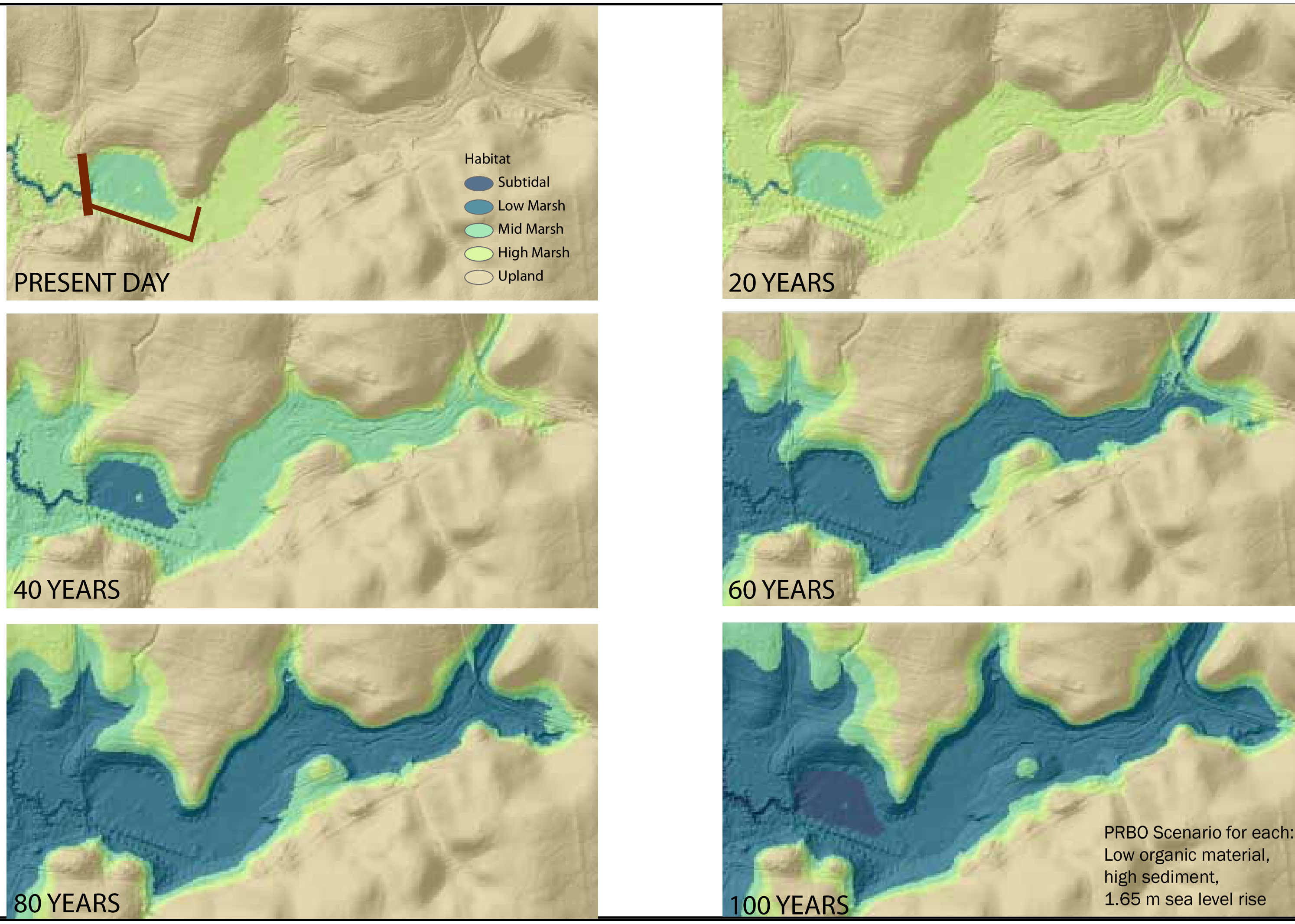


SPRING BRANCH CREEK WATERSHED

Notes: Map created by Jessie Olson using ESRI and Adobe Illustrator software. Data source Ecoatlas, SFEI over laid on CalATLAS hillshade.

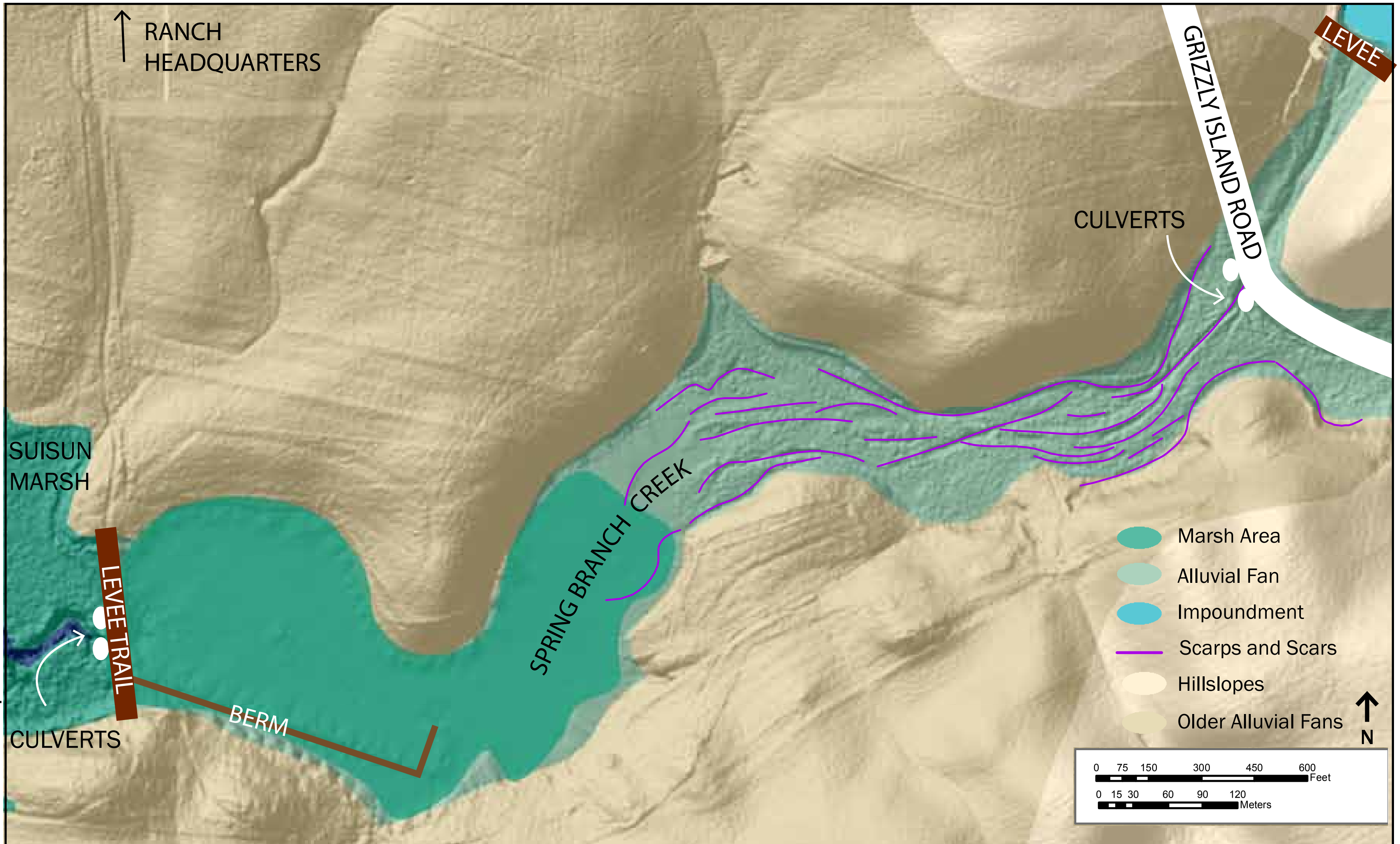
May 2012

Figure 5



HABITAT TRANSGRESSION SCENARIOS FOR LOWER SPRING BRANCH CREEK

Notes: Projections developed using PRBO python scrip with updated Digital Elevation Model (DEM) derived from DWR LiDAR and RTK ground sureys. PRBO python scrip run by Reza Ghezelbash, DEM and cartography by Jessie Olson. Variation between above projections and on-line PRBO scenarios may be due to elevation differences. On-line PRBO model used LiDAR elevation which may be capturing vegetation rather than actual ground surface. RTK ground survey elevations were lower in elevation than DEM used in on-line PRBO model.	May 2012	**Figure 6**

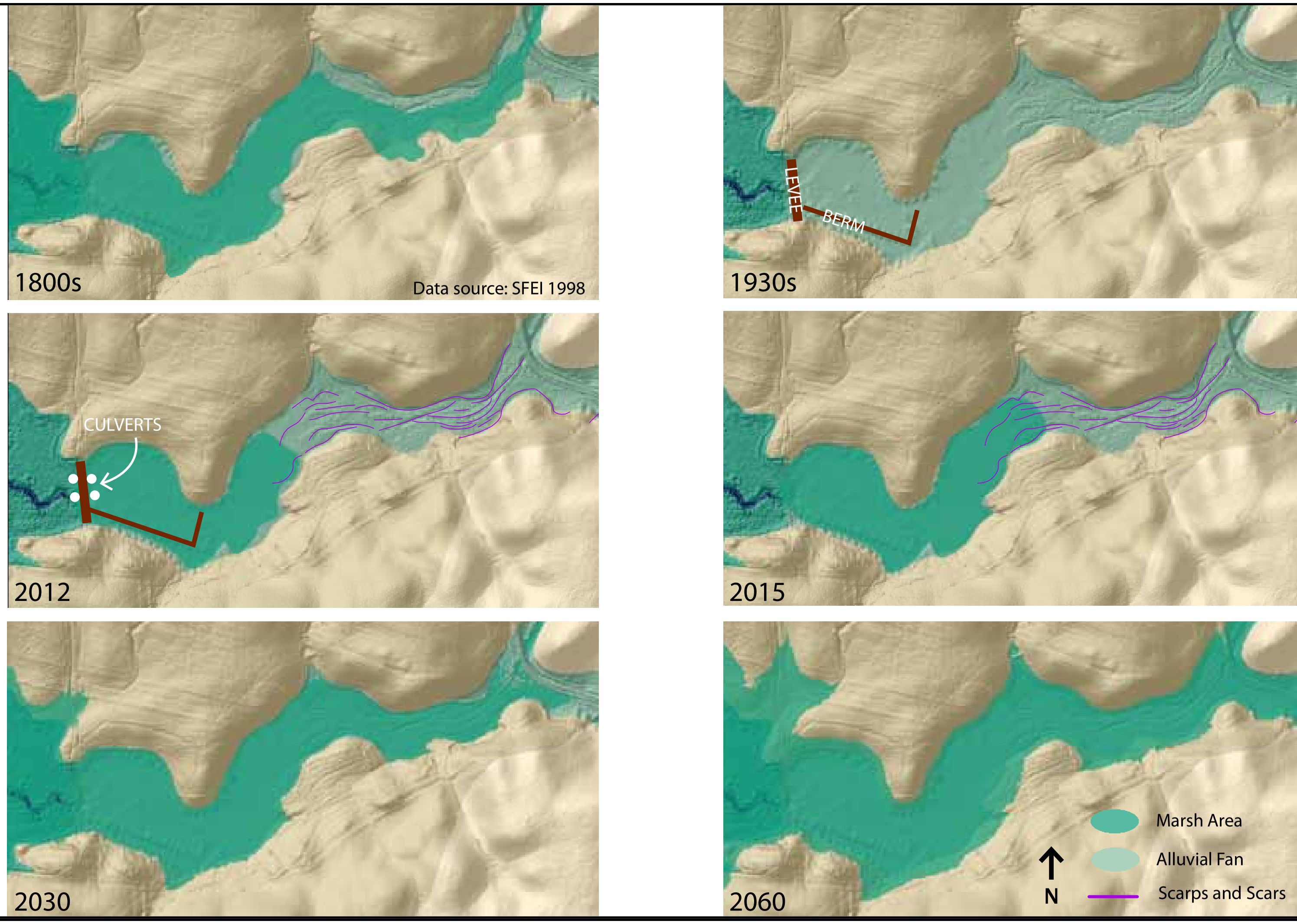


LOWER SPRING BRANCH CREEK PRESENT DAY ECOGEOMORPHIC FEATURES

Notes: Map created using ESRI and Adobe Illustrator software by Jessie Olson. Tidal range shown in Spring Branch Creek reflects existing conditions. (See Figure 18). Ecogeomorphic unit classification (alluvial fan, older alluvial fan, hillslopes) originally defined by Wetlands and Water Resources. Modified by Jessie Olson based on observed tidal elevation (see Figure 18). Hillshade derived from 2007 DWR LiDAR. All other data produced by Jessie Olson.

May 2012

Figure 7

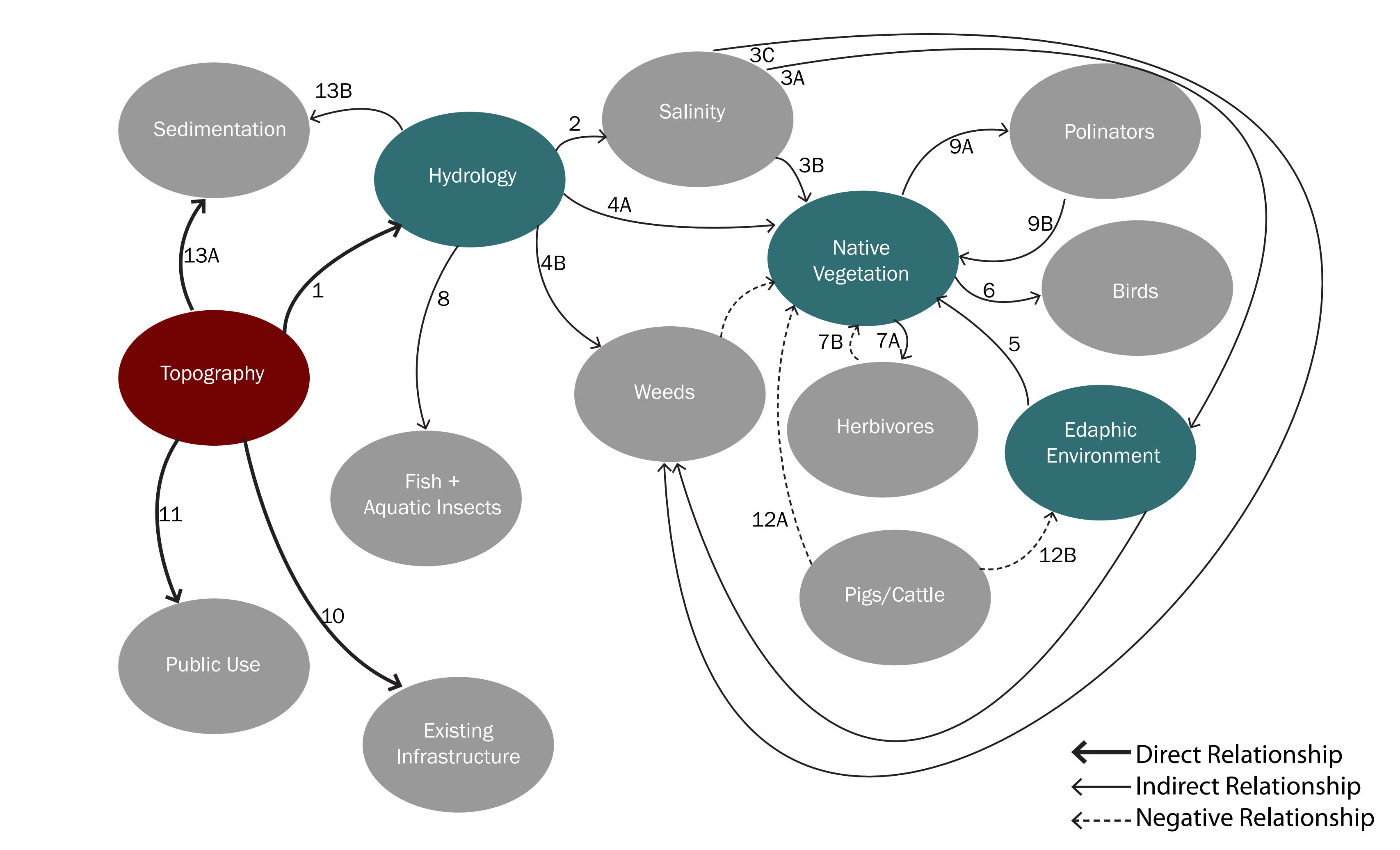


SHIFTING BASELINES: ECOGEOMORPHIC UNITS

Notes: Historical (1800s) marsh area estimates based on SFEI EcoAtlas (1998). 1930s ecogeomporphic units based on historical aerial photos. Present day ecogeomorphic units originally defined by Wetlands and Water Resources and modified by Jessie Olson based on observed tidal water elevation (see Figure 18). 2015 projection based on below culvert tidal elevations (see Figure 18). Future projections based on PRBO model (see Figure 6).

May 2012

Figure 8

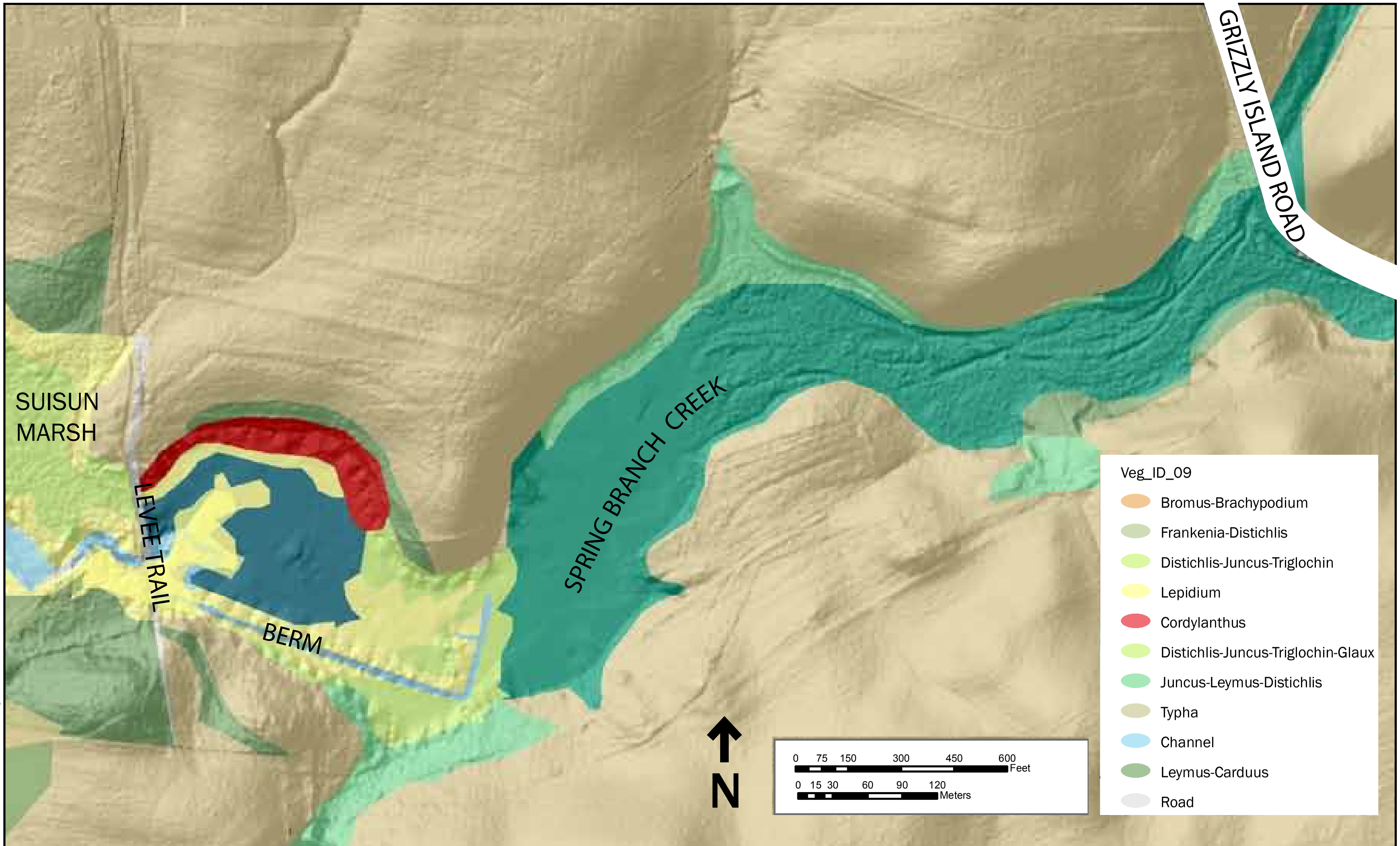


CONCEPTUAL MODEL FOR SPRING BRANCH CREEK FOLLOWING HYDROLOGICAL RECONNECTION

Notes: Figure created by Jessie Olson based on existing literature. Conceptual model shows direct and indirect relationships of reconnecting Spring Branch Creek to Suisun Marsh by removing levee and berms. Main ecological drivers in Spring Branch Creek are shown in red and green: hydrology, vegetation, and the edaphic environment.	May 2012	Figure 9

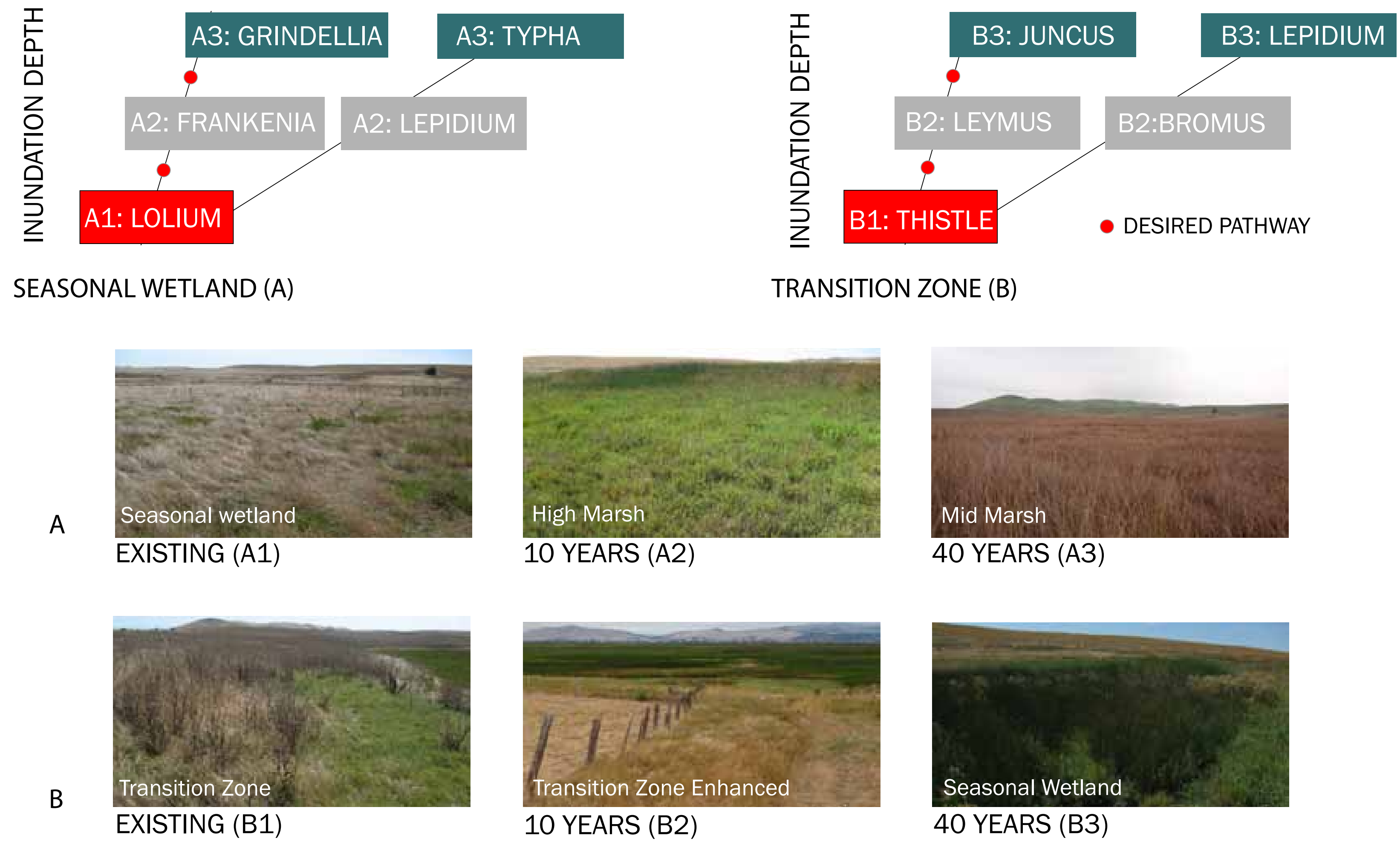
SITE PHOTO OF LOWER SPRING BRANCH CREEK LEVEE

Notes: Looking north at lower Spring Branch Creek levee. Photo taken by Jessie Olson in November 2011.	May 2012	Figure 10



LOWER SPRING BRANCH CREEK VEGETATION COMMUNITIES

Notes: Map produced using ESRI and Adobe Illustrator software by Jessie Olson. Vegetation data from Solano Land Trust and Department of Fish and Game. Hillshade derived from LiDAR and RTK survey DEM. Vegetation sub-associations as classified by Department of Fish and Game were grouped to broader associations for display purposes.	May 2012	Figure 11A

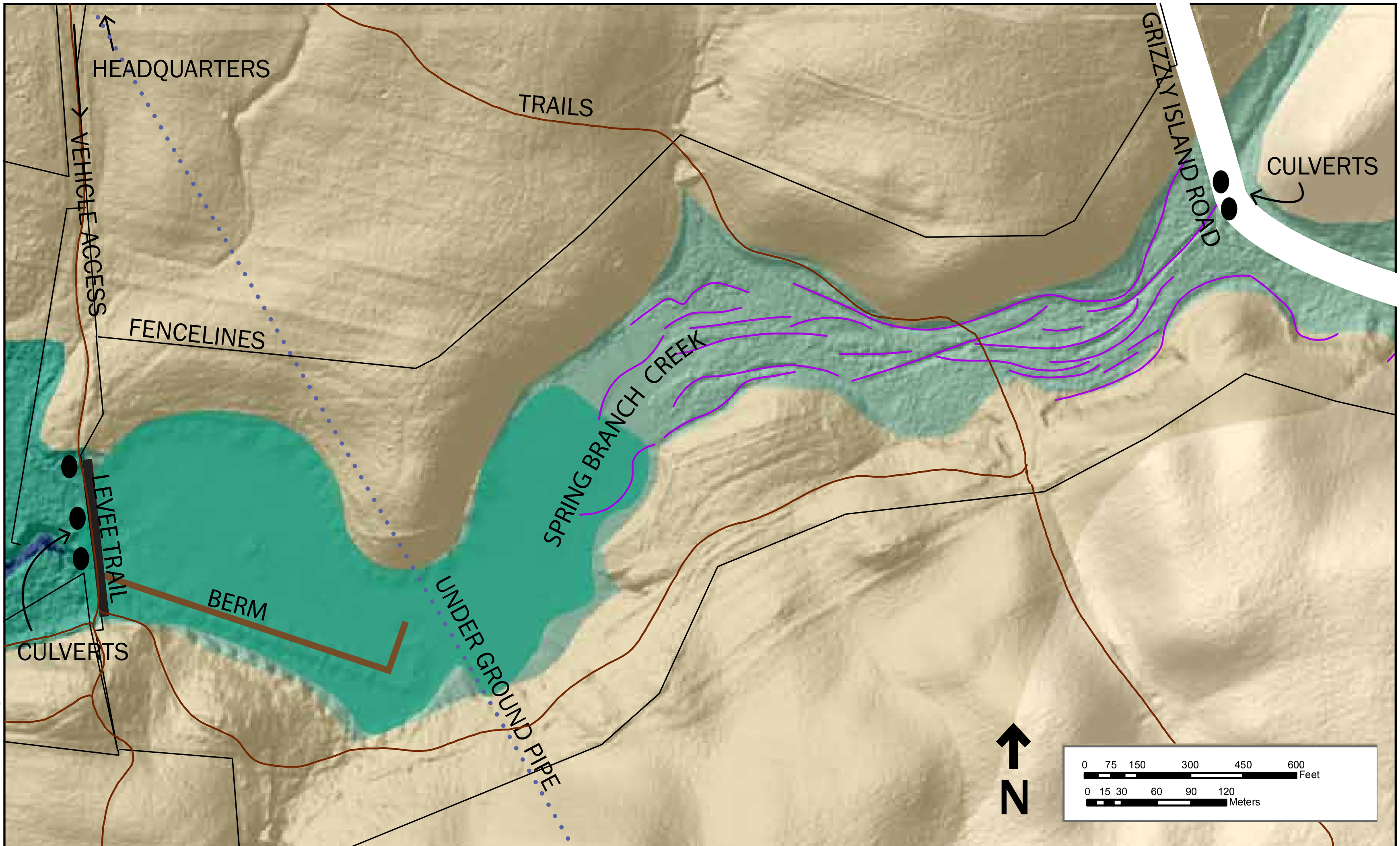


POTENTIAL STATE TRANSITIONS

Notes: Potential state transitions for Spring Branch Creek across time. While all possible trajectories are not illustrated, transition between states could be gradual, threshold driven, or two stable states could persist within the same environmental conditions (see figure 2 for details.) Photos show desired trajectory. Developed by Jessie Olson based on state-transition models presented in Suding and Hobbs 2009 paper.

May 2012

Figure 11B



EXISTING INFRASTRUCTURE & SITE ACCESS

Notes: Map created using ESRI and Adobe Illustrator software by Jessie Olson. Infrastructure data from Solano Land Trust. Hillshade derived from 2007 DWR LiDAR. All other data produced by Jessie Olson. Infrastructure overlaid on ecogeomorphic units.

May 2012

Figure 12

CATTLE GRAZING IMPACT TO CREEPING WILD RYE

Notes: Photo taken by Jessie Olson in September 2011. Photo shows impact of grazing on creeping wild rye grass. The ungrazed side has dense stands of the native rhizomatously-spreading grass, while the grazed side is dominated by invasive annual grasses.

May 2012

Figure 13

3. SPRING BRANCH CREEK SITE ANALYSIS

With the opportunity to reconnect Spring Branch Creek to Suisun Marsh there are potential constraints. Specifically, changes in hydrological inundation may impact a population of the federally listed plant soft bird's-beak (*Chloropyron molle* ssp. *molle,* syn., *Cordylanthus mollis* ssp. *mollis*), which was reintroduced to the upstream side of the hydrological impediments in 2000, and now is a population of over 100,000 individuals (Grewell 2005).

3.1 Previous Studies and Purpose of This Study

Brenda Grewell (2003, 2005, 2008) documented soft bird's beak ecological requirements across 5 sites in the San Francisco Bay, including the Spring Branch Creek population. While Grewell (2003) documented the variation of hydrological innundation depth, duration, and frequency related to soft bird's beak across five sites, the innundation depths were not tied to water elevation, which is required for spatial assessment of soft bird's beak hydrological requirements. Further, water elevation projections for soft bird's beak following reconnection of Spring Branch Creek were not documented. Using innundation depth alone does not account for topographic differences between sites. For instance, while the channel may be deeper and water depth may greater below the culverts when compared to the area above the culverts, water elevation above and below the culverts could be similar. The purpose of the site analysis is to (1) understand the tidal inundation elevation, frequency, and duration associated with the Spring Branch Creek soft bird's beak population and (2) to determine how changes in tidal water elevations following topographic modifications (for restoration) may impact the plant and it's associated vegetation communities. Based on Grewell's work, I first summarize the ecological requirements for soft bird's beak. Second, I document existing water elevations above and below the culverts at Spring Branch Creek in order to spatially assess soft bird's beak's current and future innundation elevation, duration, and frequency.

3.2. Soft Bird's Beak Distribution

Soft bird's beak is a California endemic, restricted to the high marsh zone in Napa, Solano, and Contra Costa Counties. Historically, soft bird's beaks range extended to all the counties bordering the Sacramento-San Joaquin river-delta and Suisun and San Pablo Bays, and the Marin and Sonoma counties' coast, including Marin, Sacramento, San Joaquin, and Sonoma Counties (CNDDB 2011).

3.3. Soft Bird's Beak Ecological Requirements

Soft bird's beak is a hemiparasite, and is dependent on its host community, the edaphic environment, tidal and seasonal flooding, and bee pollinators (Figure 14). Threats to its resiliency include invasive species, alteration in hydrology and herbivores. Brenda Grewell (2003, 2005, 2008) has thoroughly documented the ecological conditions of soft bird's beak through comparative field studies at five populations of soft bird's beak, including the Spring Branch Creek population, Potrero, Benicia, and Napa populations. Based on Grewell's work, each direct and indirect relationship between dependencies and threats to soft bird's beak is described below.

While the edaphic environment (pathway 1) has a direct relationship to soft bird's beaks survival, this species can survive under variable soil conditions at Spring Branch Creek (Grewell et al. 2003). In the First Mallard Slough (within Suisun Marsh) water column salinity, (pathway 1A) which is dependent on seasonal flood variation, ranges between .01-10.3 Parts Per Thousand (PPT) (NERR 2008-2012). Water column salinity has an indirect relationship to soft bird's beak by influencing the pore water salinity present in the edaphic environment. Grewell (2008) reports that soil salinity (pore water salinity) can vary between 2.0-10.0 PPT in Spring Branch Creek, with higher soil salinity in bare areas (areas lacking plant cover) and lower soil salinity in areas with natural plant cover. Salinity was even further reduced when soft bird's beak was present (Grewell 2008).

Restricted to the high marsh, soft bird's beak relies on a mixed halophyte vegetation host community (pathway 2) with intermediate canopy height and gaps at Spring Branch Creek (Grewell 2005). Canopy gaps allow the soft bird's beak to photosynthesize on its own, while it receives the other nutrients it requires from the roots of its host community. Soft bird's beak host community is not specific, but at Spring Branch Creek it is frequently found with salt marsh dodder (*Cuscuta salina*), salt grass (*Distichlis spicata*), fat hen (*Atriplex triangularis*), sea lavender (*Limonium californicum*), pickleweed (*Salicornia virginica*) and Mexican plantain (*Plantago subnuda)* (Grewell 2005). Diversity of the host community tends to be higher with the presence of soft bird's beak, whereas pickleweed tends to out compete rarer species (such as *Atriplex prostrate* and *Triglochin maritima*) following decline or removal of soft bird's beak (Grewell 2008).

There is a combined positive relationship between soft bird's beak and invasive winter annual grasses (pathway 3). Sickle grass (*Hainardia cylindrica*) and rabbitsfoot grass (*Polypogon monspeliensis*) have been linked with seedling mortality at Spring Branch Creek (Grewell 2005). Similarly, invasion by perennial pepperweed (*Lepidium latifolium*) in the high marsh zone is another direct threat. Removal of the hydrological barriers to tidal influence (berms and levee) may improve the soft bird's beak population by creating an unsuitable environment for the invasive annual winter grasses (and potentially perennial pepperweed), thus reducing soft bird's beak seedling mortality at a critical life stage (Grewell 2005). However, this hypothesis will need to be tested in order to determine its validity and is a recommended pre-project study included in the Adaptive Management and Monitoring section below.

There is also a direct relationship between soft bird's beak and seasonal and tidal flooding (pathway 4). Previous studies have characterized the inundation depth, duration, and frequency between soft bird's beak sites including Spring Branch Creek, Hill Slough, and Benicia (Grewell et al. 2003), and within site variation. Grewell (2003) found that within the Spring Branch Creek soft bird's beak reintroduction site, areas that experienced low seedling mortality and high plant density were correlated with areas that have greater flooding depth and duration. In addition, when comparing between sites, Grewell found that Benicia site had the greatest flooding depth, duration, and frequency when compared to other sites (Grewell 2003), which may be a contributing factor in greater survivorship and population growth at Benicia when compared to the Spring Branch Creek population (Grewell 2005) (Appendix F). Despite extensive hydrological surveys across five sites, inundation rates were not tied to specific water elevations that allow for spatial assessment. As mentioned in section 3.2, water elevation above and below the culverts is required in order to spacially display differences between water elevation before and after reconnection. Measuring water elevation at Spring Branch Creek is a main focus of this study in order to determine how changes in tidal water elevations following topographic modifications (for restoration) may impact soft bird's beak.

Phil Williams & Associates reports ground water elevations as 1.5 meters below ground elevations above the Spring Branch Creek culvert (approx. 1 meters NAVD 88) in the 1990 plan (WRA 1990). Topography (pathway 4A) indirectly relates to soft bird's beak, by providing a slope, gradient and elevation sufficient for tidal or seasonal inundation (Grewell 2005).

There is direct negative and positive relationship between soft bird's beak and herbivores (pathway 5A and 5B). The endangered salt marsh harvest mouse (*Reithrodontomys raviventris*)for example, eats soft bird's beak seeds (Grewell 2005), impacting soft bird's beak germination while providing a food source for salt marsh harvest mouse. Lastly, there are two direct positive relationships between bee pollinators and soft bird's beak (pathway 6A and 6B). Soft bird's beak requires the bees for pollination and the bees benefit from soft bird's beak as a food source (Grewell 2005).

3.4. Methods

I conducted fieldwork and data analysis to better describe tidal hydrology component of the conceptual model (pathway 4). I used three methods to characterize the existing tidal hydrology of the area above and below the Spring Branch Creek culverts; I analyzed (1) water elevation, (2) vegetation data, and (3) hypsometric diagrams. Using GIS I modeled future water elevations and predicted vegetation response above the Spring Branch Creek culverts following the removal of berms. Lastly, I conducted field observations at the Spring Branch Creek population and a second population at Rush Ranch and Benicia to determine how inundation rates differ between the two sites. Methods and results for the site comparison are included in Appendix E.

Water Elevation

I collected water level data above and below the culverts at Spring Branch Creek to determine the hydrological conditions under which soft bird's beak is currently thriving. I collected water level data over a spring and neap tidal cycle at 12-minute intervals using a troll level 500-pressure transducer, from April to September 2011. Spring tidal cycles correspond to tides that occur during new and full moon, where the gravitational pull of the moon and sun to earth is stronger (because the sun, earth, and moon are all in a line), resulting in higher high tides and lower low tides. The neap tides occur when sun and moon are at 45-degree angle to each other, which diminishes the gravitational pull and produces lower high tides and higher low tides. I installed the pressure transducers, housed in a stilling well, using Wetlands and Water Resources specifications (Appendix A). In addition, I attached an L-bracket to the stilling well and surveyed it using an RTK GPS, and tied points to a secondary control benchmark, located on top of Indian Grinding Rock hill, recorded in NAVD 1988 Datum (meters), to tie water level data to actual water elevation.

Every month, I collected calibration readings by direct observation of the water depth in comparison to the reading of the pressure transducer. In addition, I recorded the vertical distance between the stilling well elevation benchmark and the water level to calibrate the relationship between pressure transducer readings and water elevation (Appendix B). I converted water depth readings to water elevation using the relationship established from field measurements between the pressure transducer readings and water elevation (by adding .453 meters to each pressure transducer reading for the station below the culverts and adding 1.043 meters to each pressure transducer reading for the station above the culverts) (Appendix B). For each tidal day (24 hours and 50 minutes), I determined the two peak high tide elevations (higher high water [HHW] and low high water [LHW]), and the two low tide elevations (lower low water [LLW] and high low water [HLW]) (Appendix C & D). I used the highest and lowest elevation value for each tide cycle to define the range of water elevations possible for each tidal cycle. I then calculated the average (mean) water elevation per tidal cycle (Table 3). In addition I calculated the frequency of each tidal event including events above the mean for the highest high tide of the day.

To translate this data for spatial assessment, I developed a water elevation surface model in GIS using a topographic surface model and the high and low values for each of the four tidal water elevations. To do this, I created a ground surface digital elevation model (DEM) of the Spring Branch Creek Watershed, using 2007 DWR LiDAR and RTK GPS ground surveys conducted in 2009 and 3D interpolation of mean tidal stages (Appendix E).

Vegetation & Hypsometric Diagrams

To determine which vegetation types correspond with tidal elevations, I overlaid the Department of Fish and Game and Solano Land Trust vegetation polygon data on the tidal elevation data. Using digital elevation models, one for the area above and another for the area below the Spring Branch Creek culverts, I developed two hypsometric diagrams using R package hydroTSM version 0.3-3. The area used to develop these diagrams were similar is spatial extent and range of elevations above and below the culverts (Figure 16). Hypsometric diagrams are used to illustrate the proportional area of a given elevation at a site. On top of the hypsometric curve, I overlaid the elevation locations of each tidal height stage, site features and vegetation community. This shows the current relationship between % area and each factor: ground elevation, water elevation and vegetation.

Modeling Future Conditions

To see how water elevations would change following hydrological connection, I reclassified the water surface model above the culverts using the water elevations below the culverts. I assumed that following reconnection (and removal of the berms and levee), tidal inundation conditions would be similar to the area below the culverts. In addition I compared the hypsometric diagram between the area above and below the culverts to help predict how vegetation communities may shift following hydrological reconnection. While salinity and ground water are also related factors to future vegetation patterns, these data were not collected. However, I assumed that water column salinities would be similar to the area below the culverts following hydrological reconnection.

3.5. Results

Existing Tidal Hydrology Conditions

There is minimal difference between the ranges of high tide elevations seen above and below the culverts: 1.65-2.39 meters for the HHW range below the culverts compared to 1.60-2.33 meters above the culverts (Table 3.1 and Figure 15). Meanwhile, there is a significant difference between the low water elevations seen above and below the culverts: 0.62-0.84 meters for the LLW range below the culverts compared to 1.17-1.29 meters above the culverts.

The range of spring tide HHW elevations (tidal events during the new and full moon) above the culverts (events between mean HHW [MHHW]*, or 1.99 meters, and the most extreme spring tide HHW event of 2.3 meters) corresponds almost exactly to the elevation of highest and lowest elevation range occupied by soft bird's beak (Figure 16A and 16B). The range of spring tide HHW elevations below the culverts (2.0-2.4 meters) corresponds to marsh plain vegetation of saltgrass-rush- arrowhead grass-milkwort (*Distichlis-Juncus-Triglochin-Glaux*) assemblage. In terms of inundation frequency, soft bird's beak was inundated 55% of tidal days for the period of record (80 of 149 tidal days), or .5 times per tidal day, and an average of 2.37 hours per tidal day. The salt grass-rush- arrowhead grass-milkwort assemblage was inundated 63% (93 of 149 tidal days), for 2.86 hours per tidal day on average (Table 3.2). Spring tide HHW events tend to occur in 2-7 consecutive days in a row followed with 2-12 consecutive days without spring tide events. Below the culverts, the greatest percent area is within this tidal range, whereas narrow band exists above the culvert (Figure 17A and 17B).

Table 3.1 Tidal Water Elevation Ranges

Tidal Cycle		Minimum	Maximum	Mean	St. Dev.	Date of Maximum
Below Culvert						
	HHW	1.65	2.39	2.03	0.15	5/17/11
	LHW	1.42	2.00	1.74	0.14	5/16/11
	LLW	0.62	0.84	0.68	0.04	4/30/11
	HLW	0.62	1.19	0.85	0.15	4/29/11
Above Culvert						
	HHW	1.60	2.33	1.99	0.14	5/17/11
	LHW	1.37	1.96	1.69	0.15	5/16/11
	LLW	1.17	1.29	1.21	0.03	8/17/11, 8/18/11, 8/23/11
	HLW	1.17	1.31	1.23	0.04	8/18/11, 8/22/11

Notes: All measurements relative to NAVD 88 Datum, reported in meters.

The elevations between MHHW and MLHW above the culverts (1.7-1.99 meters) and below the culverts (1.74-2.00 meters) correspond to vegetation dominated by cattails (*Typha angustifolia*) and perennial pepperweed (*Lepidium latifolium*) (Figure 16A and 16B). These areas are inundated on average once per tidal day (144 of 149 tidal days), for an average of 5.78 (above culverts) and 5.98 (below culverts) days (Table 3.2). The greatest percent area above the culvert is within this tidal range, whereas a very narrow range is present below the culverts (Figure 17A and 17B). This indicates that the partially muted tidal marsh above the culverts is about .5 meters below elevation of downstream natural tidal marsh plain. This could be from the excavation that occurred in the attempt to create a stockpond, where previous landowners dug a borrow pit upstream of the levee in order to create the levee. Though historical aerial photographs indicate

*MHHW is the average of the Higher High Water tides observed for the period of record, relative to NAVD 88 Datum and is not the equivent datum of the National Tidal Datum Epoch.

that the digging likely occurred in a small area relative to the larger DEM area used to create the hypsometric diagram. Another possibility is that the area has subsided, where soil has settled downward following the 1930s installation of berms and levees, creating a marsh plain that is lower in elevation than the adjacent natural marsh.

The elevations between MLHW and MHLW above and below the culverts occupy a very narrow range within the tidal channel and channel edge (1.23-1.7 m and 0.85-1.74 m respectively). This area is primarily within the tidal channel and no vegetation is present, however there are some areas where vegetation corresponds to tule (*Schoenoplectus acutus*). These areas are inundated on average twice per tidal day, for 19.56 (above culverts) and 19.37 (below culverts) hours on average per tidal day. The elevations between MHLW and MLLW are within the tidal channel above (1.16- 1.21 m) and below (0.62-0.84 m) the culverts, and no vegetation is present. Water elevations below the MLLW are not present either above or below the culverts because water elevation is lower than existing channel ground surface. The area drains completely and the water level is zero at the MLLW elevations.

Table 3.2 Tidal Duration and Frequency

Tidal Stage Range	Duration (no. hours per tidal day)	St. Dev.	Frequency (no. days)	Frequency (no. times per day)	Associated Vegetation
Below Culvert					
Above MHHW	2:52	1:10	93	0.6 (60%)	salt grass-rush-arrowhead-milkwort
Above MLHW	5:59	2:06	144	1 (100%)	Cattails and perennial pepperweed
Above MHLW	19:22	1:26	149	2 (200%)	Tule
Above Culvert					
Above MHHW	2:22	1:11	80	.5 (50%)	Soft bird's beak and host community
Above MLHW	5:47	1:59	144	1 (100%)	Cattails and perennial pepperweed
Above MHLW	19:34	1:11	149	2 (200%)	Tule

Future Tidal Hydrology Conditions

Assuming tidal inundation depth, frequency and duration will be similar to the area below the culverts following removal of berms and levees, the range between MHHW to spring tide HHW will likely experience a slight (5 cm) increase in water elevations, and a slight increase in frequency of inundation (13 more tidal days of inundation) (table 3.3). This result indicates that hydrological reconnection may have a positive or neutral impact to soft bird's beaks livelihood because inundation depth, frequency and duration will not significantly change following reconnection. An increase in inundation frequency may have a positive overall affect on the soft bird's beak population by creating an unsuitable environment for the invasive annual winter grasses (and potentially perennial pepperweed), thus reducing soft bird's beak seedling mortality at a critical life stage (Grewell 2005). In addition, reference site populations at Benicia appear to be thriving under greater inundation frequency than observed at Spring Branch Creek (Grewell 2005, Appendix F). Upstream of the soft bird's beak population along the low-gradient slope of Spring Branch Creek, the MHHW-spring tide HHW range is predicted to experience a more dramatic change following reconnection, occupying over 9,000 m^2 more space (Figure 18) (Table 3.3). Vegetation is expected to transition to salt grass-rush-arrowhead-milkwort in this area. This area may also be potential suitable habitat for the soft bird's beak.

Table 3.3 Summary of Expected Changes in Tidal Hydrology

Tidal Stage Range	Depth (cm)	Duration (no. hours per tidal day)	Frequency (no. days)	Frequency (no. times per day)	Area (M^2)
Above Culvert					
Above MHHW	+ 5	+ 0:30	+ 13	+ 10%	+9,670
Above MLHW	+5	+ 0:12	No change	No change	No change
Above MHLW	------------------------TBD: Based on channel design --------------------------				

3.6. Discussion

Tidal hydrological analysis indicates that soft bird's beak has a hopeful future considering planned hydrological reconnection. However, in considering whether hydrological reconnection will impact the soft bird's beak, there is limited value in reviewing only tidal hydrological changes. Because tidal water elevation data were only collected for a six-month period, inter-annual variability and freshwater inputs and ground water were not adequately captured. However, existing data suggests how topographic modifications may impact seasonal fresh water flows, water column salinity, or pore water (soil) salinity, and ground water. Water column salinity is not expected to change in Spring Branch Creek following hydrological reconnection, aside from the area that will experience new tidal flows (Figure 18) because of the minimal difference between high water elevations above and below the culverts. However removal of the upstream impoundment may increase freshwater flows to the area negating the affect of increase brackish water. Following reconnection, the upstream area between MHHW to MLHW may experience better drainage and the water table may drop (Phil Williams pers. comm, November 2011) but the dominate vegetation of cattails are likely to persist because the area is lower in elevation than the area downstream, and may receive greater inundation frequency. Further, unless a channel is graded at lower elevations or a very large storm event creates a lower elevation channel, there will likely be little to no change in the MLHW to MHLW elevation ranges following reconnection. Future studies that examine the relationship between soft bird's beak and the inter-annual variation of rainfall and seasonal (freshwater) inputs, ground water and salinity would strengthen this study. These monitoring actions are included in the adaptive management and monitoring section below.

Grewell (2005) details other threats that directly impact soft bird's beak. In fact, the soft bird's beak population in Spring Branch Creek has experienced decline in recent years (Grewell 2005). Soft bird's beak appears to be most vulnerable at the emergent seedling stage when unsuitable hosts, exotic winter annual grasses, are present (Grewell 2005), causing seedling mortality. The decline may also be associated with an inadequate host population that may not be able support the growing hemiparasite population (Grewell 2005). In fact, host community die back has been observed in areas with the highest bird's beak establishment (Grewell 2005).

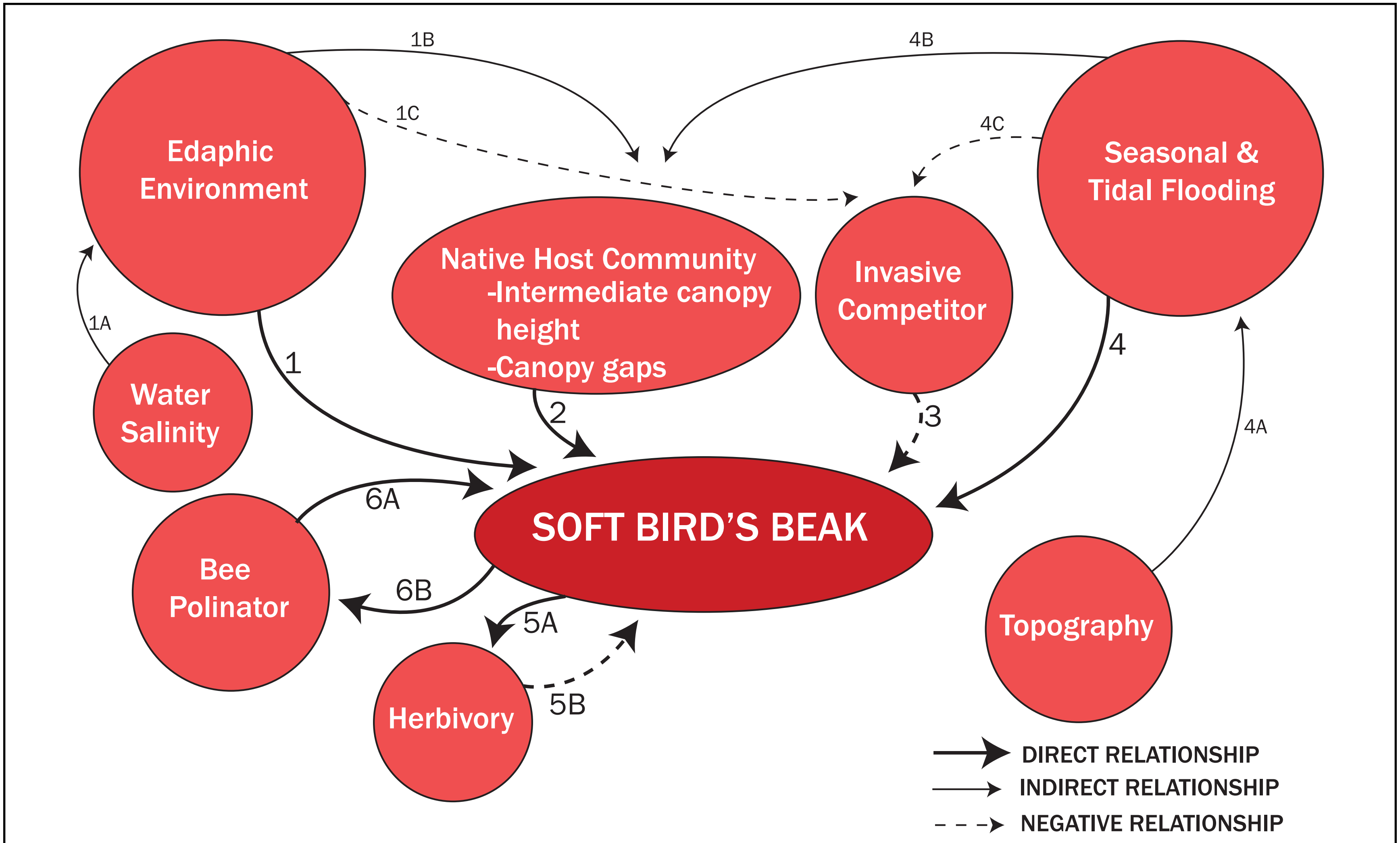
Management actions ensure the sustainability of the population of soft bird's beak in

Spring Branch Creek. Previous studies suggest that removal of the hydrological barriers may improve the soft bird's beak population by creating an unsuitable environment for the invasive annual winter grasses and by reducing soft bird's beak seedling mortality at critical life stage (Grewell 2005). However, this may not be the case because it appears the inundation rates for winter annual grasses elevations will not shift significantly. If hydrological reconnection does not cause a reduction in winter annual grasses, control of these weeds may be necessary. Control efforts are likely to be most effective in the late winter, when soft bird's beak and other native perennial marsh plants are dormant but winter annual grasses are growing (Grewell 2005). Additional weed species celery (*Apium graveolens*) and perennial pepperweed, which tends to co-invade, may further threaten soft bird's beak and a combined control strategy is likely to be most successful.

Sea level rise and estuarine transgression, however, may further threaten the species. The species may need to adapt by shifting up slope and up the Spring Branch Creek gradient. However, Spring Branch Creek, with active alluvial fans and gentle slopes, is particularly well suited to accommodate estuarine transgression (WWR 2010). In addition, non profit group PRBO Conservation Science web tool (http://data.prbo.org/apps/sfbslr/) shows projected changes in elevation under 0.52 and 1.65-meter sea level rise scenarios (Stralberg et al. 2011). The website offers an interactive feature where one can see projections with low and high sediment availability and low and high accumulation of organic material. A commonality among all sediment and organic matter accumulation scenarios is that high marsh elevations (which would be potential soft bird beak habitat) become less prevalent in lower Spring Branch Creek and more prevalent in upper Spring Branch Creek (Figure 6). Since sea level rise is likely to cause soft bird's beak to shift up the Spring Branch Creek gradient, management and restoration actions should ensure all physical impediments are removed that may prevent migration from occurring. Long term monitoring helps determine whether assisted migration is necessary or whether the species can migrate on it's own (see section 4.3).

3.7. Conclusion

Reconnection of Spring Branch Creek to full tidal influence from Suisun Marsh is unlikely to significantly change the hydrological conditions that soft bird's beak is currently thriving under. In fact, the predicted slight increase in inundation depth and frequency may improve environmental conditions for soft bird's beak and lead to a reduction in seedling mortality and an increase in population size. Nonetheless, management actions are necessary to ensure the long-term survival of the species as threats from other plants ensue. Sea level rise and estuarine transgression may further threaten the species if the soft bird's beak is unable to migrate landward and up the Spring Branch Creek gradient on its own. With careful monitoring, land managers may be able to detect whether the species is able to migrate on its own or if assisted migration up slope or up the Spring Branch Creek gradient is necessary.

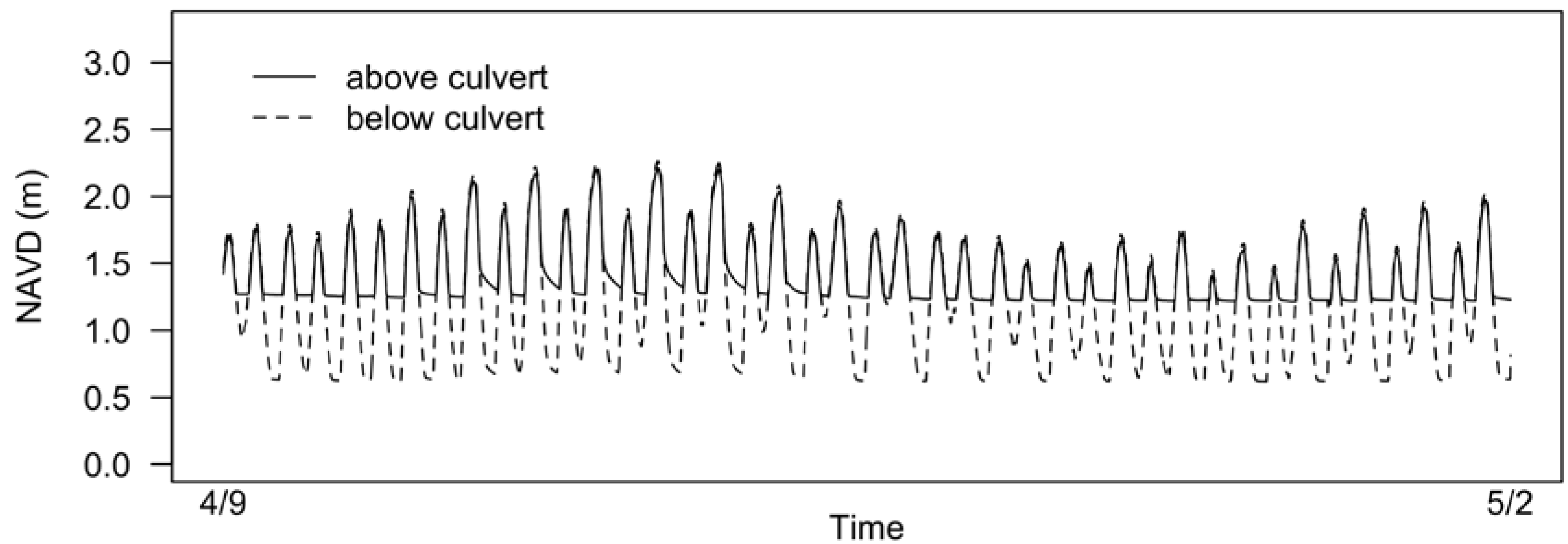


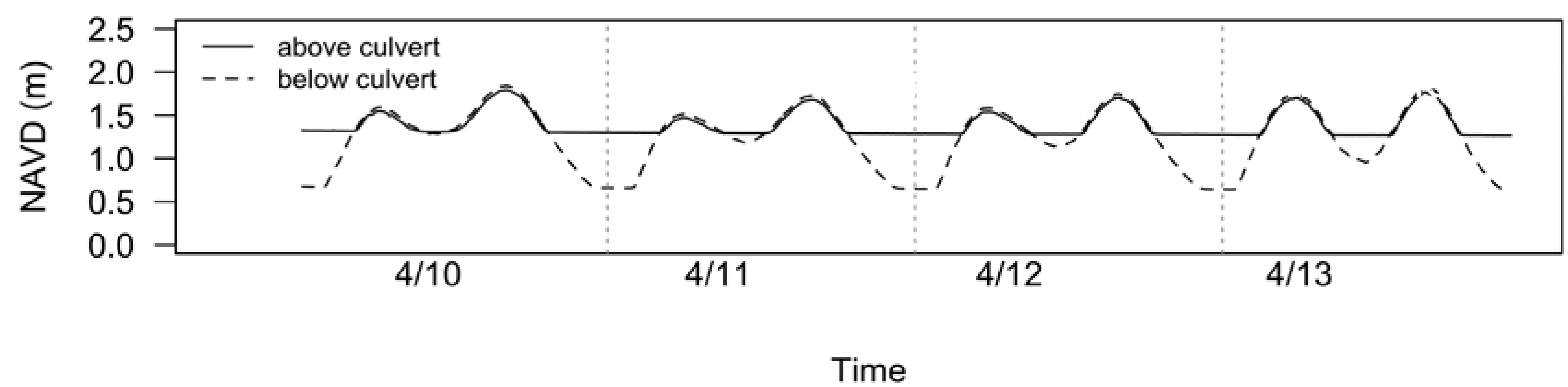
CONCEPTUAL MODEL FOR SOFT BIRD'S BEAK ECOLOGICAL REQUIREMENTS

Notes: Created by Jessie Olson based on the following data sources: (1) Grewell, B., M. DaPratro, P. Hyde, and E. Rejmankova. 2003. "Reintroduction of Endangered Soft Bird's Beak (Cordylanthus mollis ssp. mollis) to Restored Habitat in Suisun Marsh." Final Report for CALFED Ecosystem Restoration Project. (2) Grewell, B.J. 2005. "Population census and status of the endagnered soft bird's-beak (Cordylanthus mollis ssp. mollis) at Benicia State Recreation Area and Rush Ranch in Solano County, California." Report for Solano County Water Agency, Solano County Endangerred Species Conservation Program (3) Grewell, B.J. 2008. "Hemiparasites generate environmental heterogeneity and enhance species coexistence in salt marshes." Ecological Applications 18 (5): 1297–1306.

May 2012

Figure 14



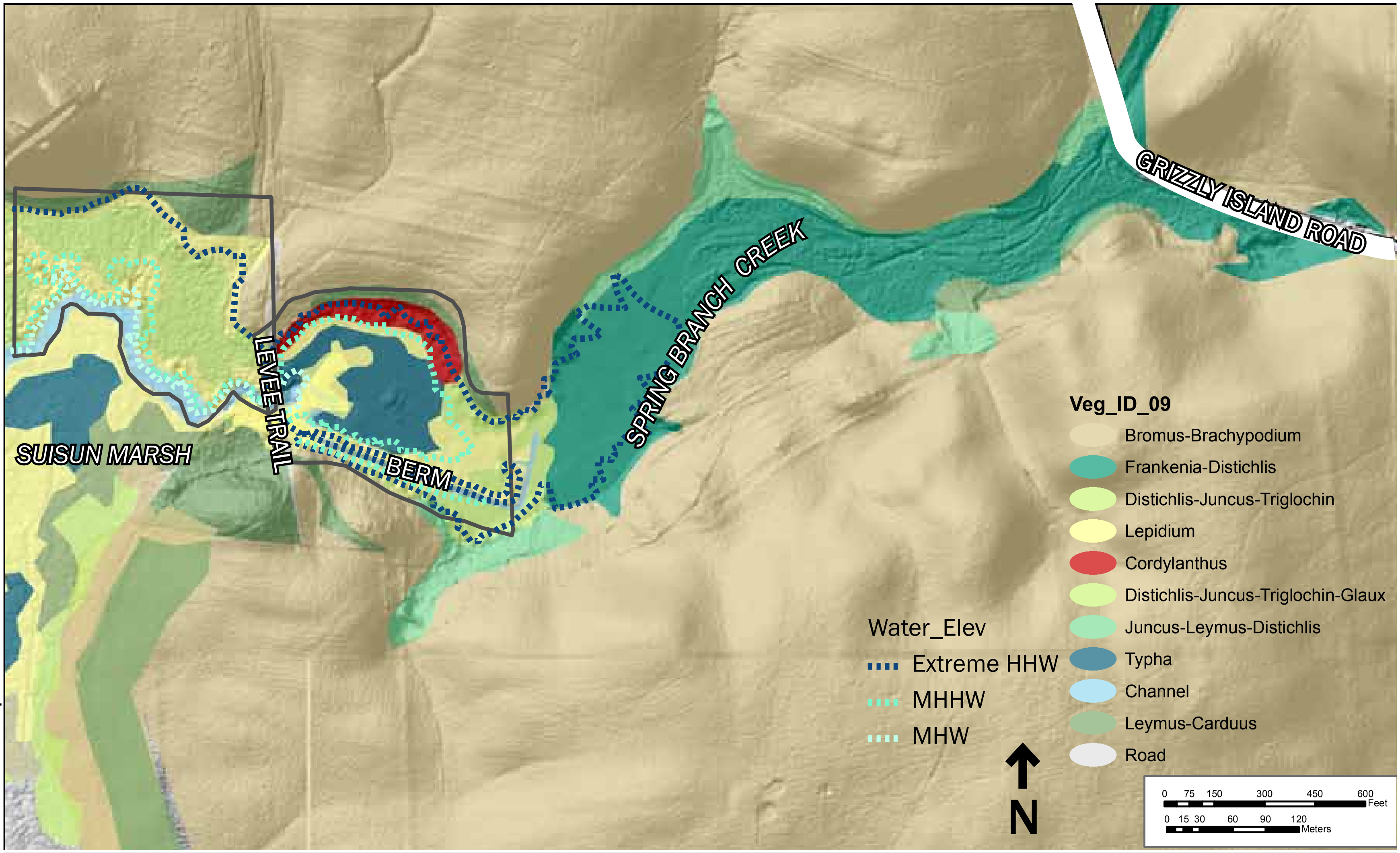


WATER ELEVATIONS ABOVE AND BELOW CULVERTS AT SPRING BRANCH CREEK

Notes: Figure generated by Jessie Olson using R package hydroTSM version 0.3-3. Figure does not included data for entire period of record for display purposes. Tidal day indicated by grey dashed line on lower figure.

May 2012

Figure 15

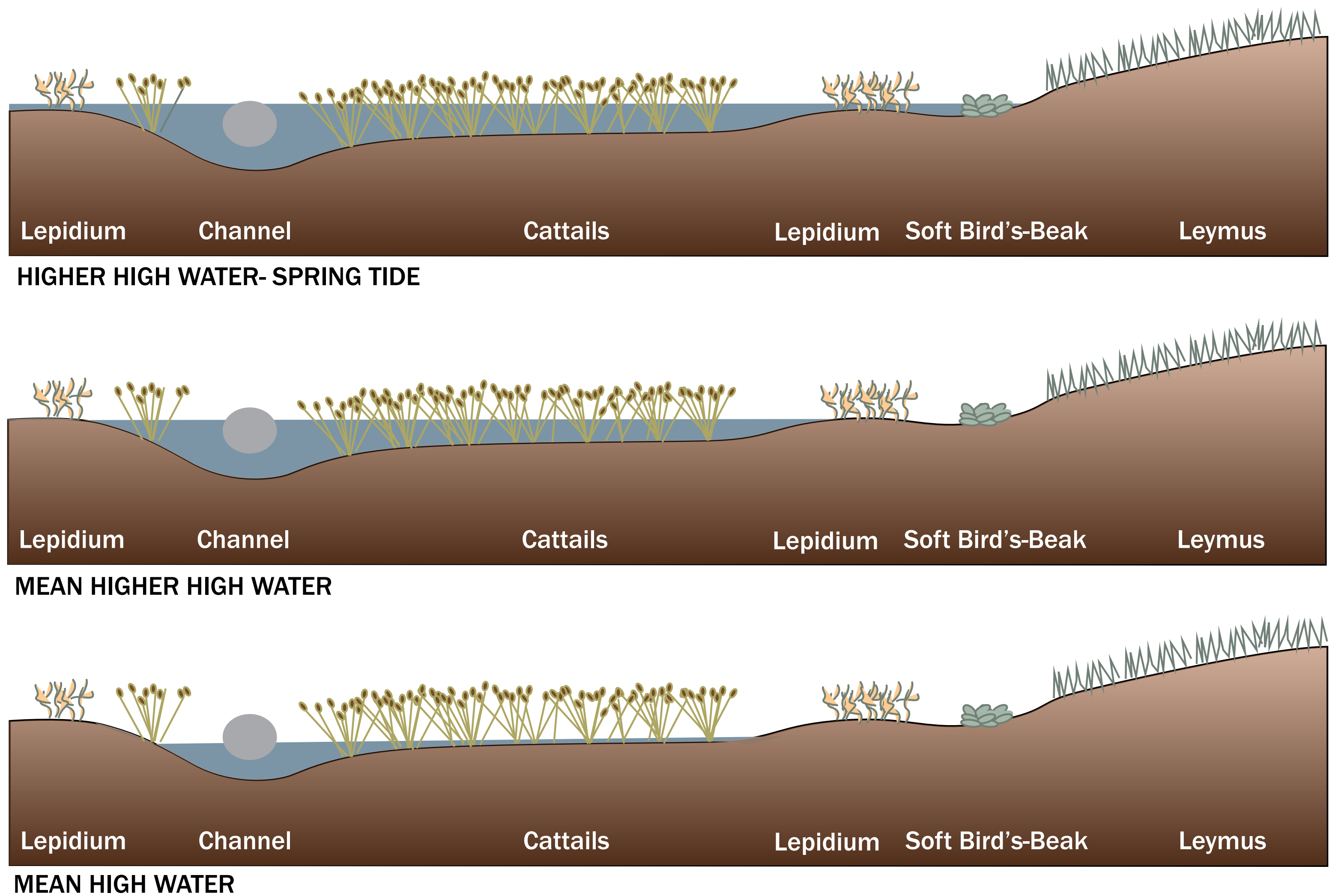


WATER ELEVATION AND VEGETATION: EXISTING CONDITIONS

Notes: Map produced using ESRI and Adobe Illustrator software by Jessie Olson. Vegetation data from Solano Land Trust and Department of Fish and Game. Vegetation sub-associations as classified by Department of Fish and Game were grouped to broader associations for display purposes. Water elevation current conditions created by reclassifying a Digital Elevation Model (DEM) derived from DWR LiDAR and RTK ground surveys.

May 2012

Figure 16A

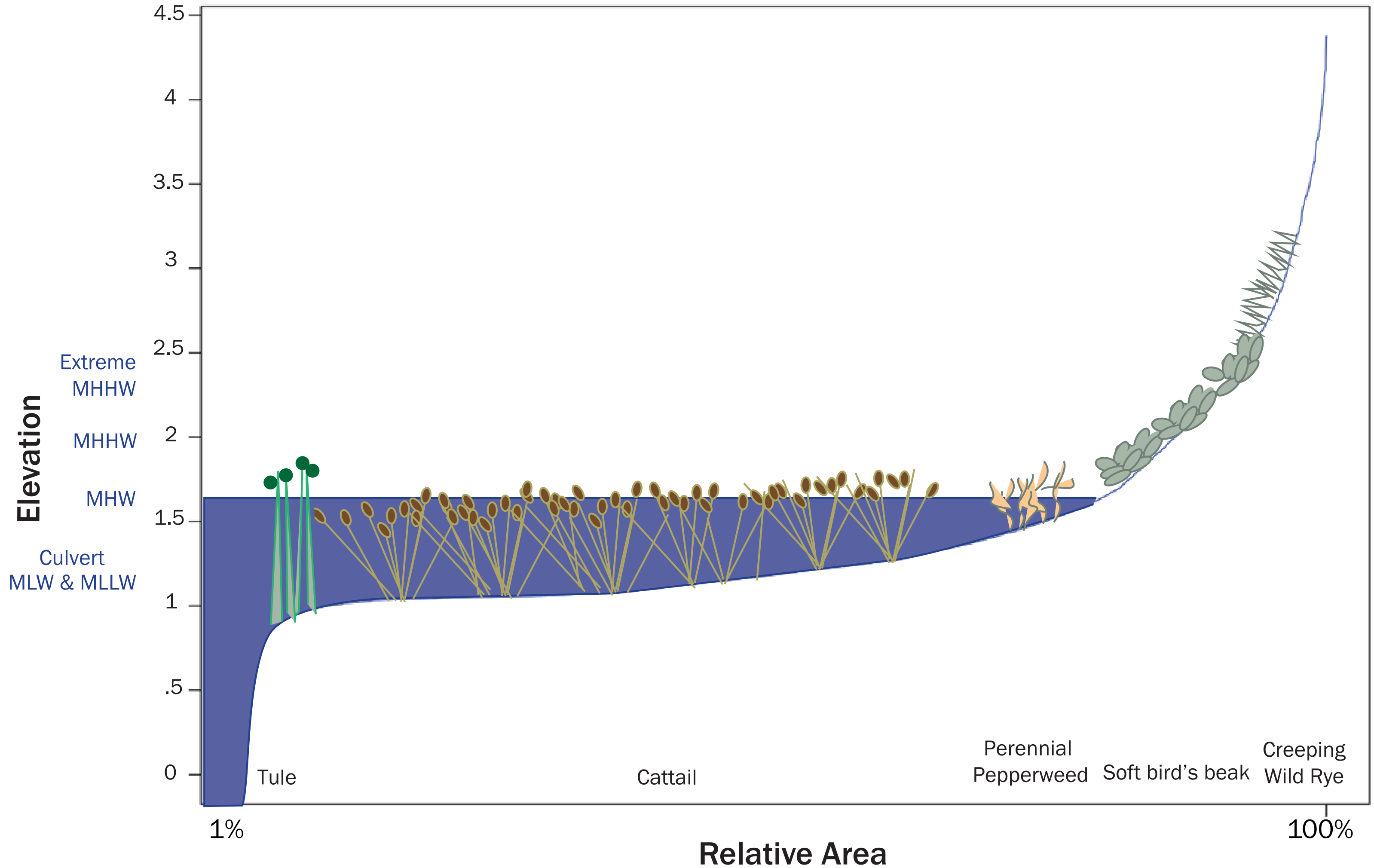


WATER ELEVATION AND VEGETATION: EXISTING CONDITIONS

Notes: Figure created by Jessie Olson using Adobe Illustrator software. Conceptual cross section of lower Spring Branch Creek looking down stream at culverts.

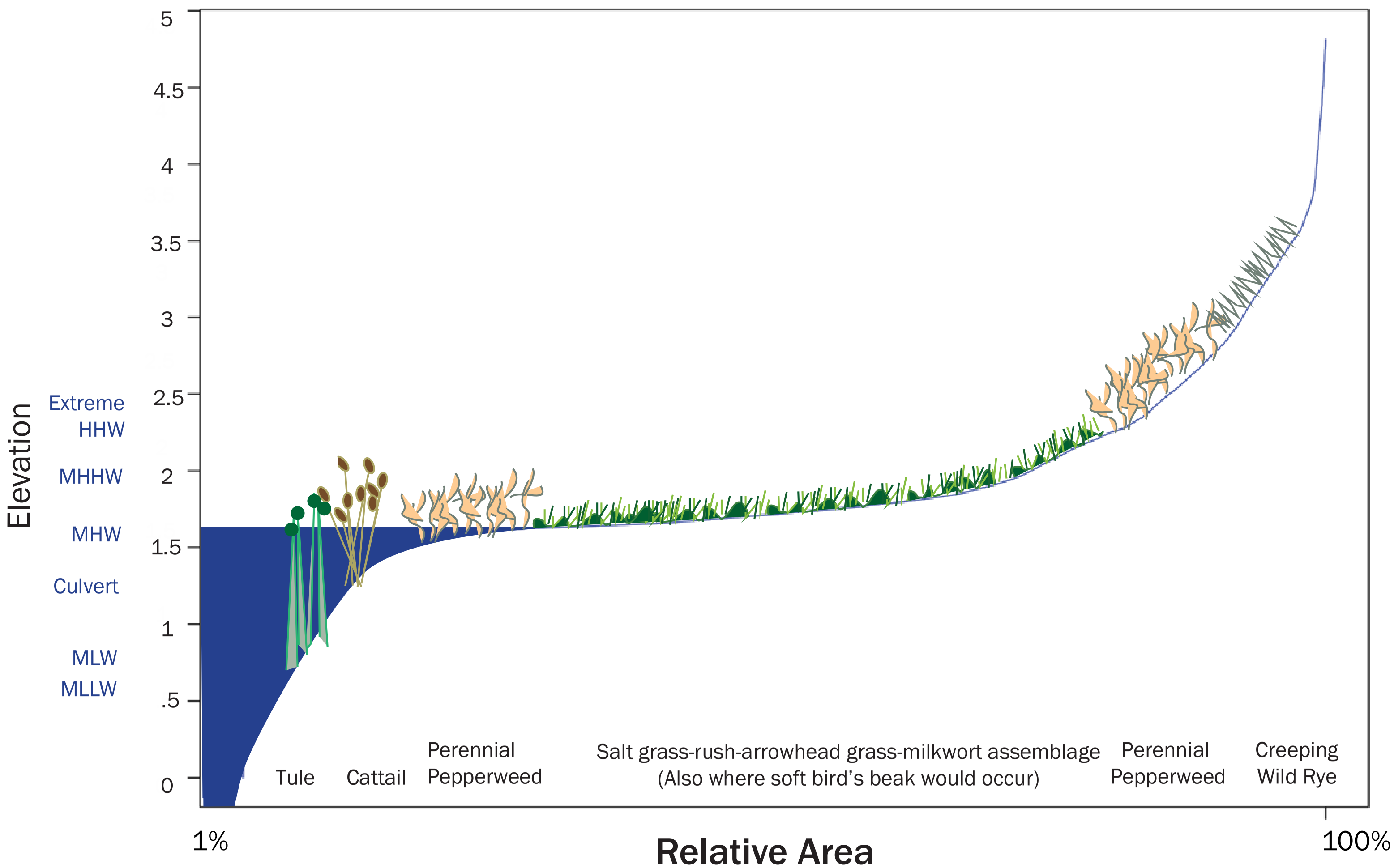
May 2012

Figure 16B



HYPSOMETRIC DIAGRAM OF AREA ABOVE CULVERTS

Notes: Hypsometric diagrams developed by Jessie Olson using R package hydroTSM version 0.3-3. The DEM boundary was defined to only use RTK survey data (LiDAR data was found to be up to .5 meters higher than actual ground surface) and to have similar spatial extent (square meters) and range of elevations (Appendix B) between the two locations. Vegetation and water elevation information was acquired from figure 16A.	May 2012	Figure 17A

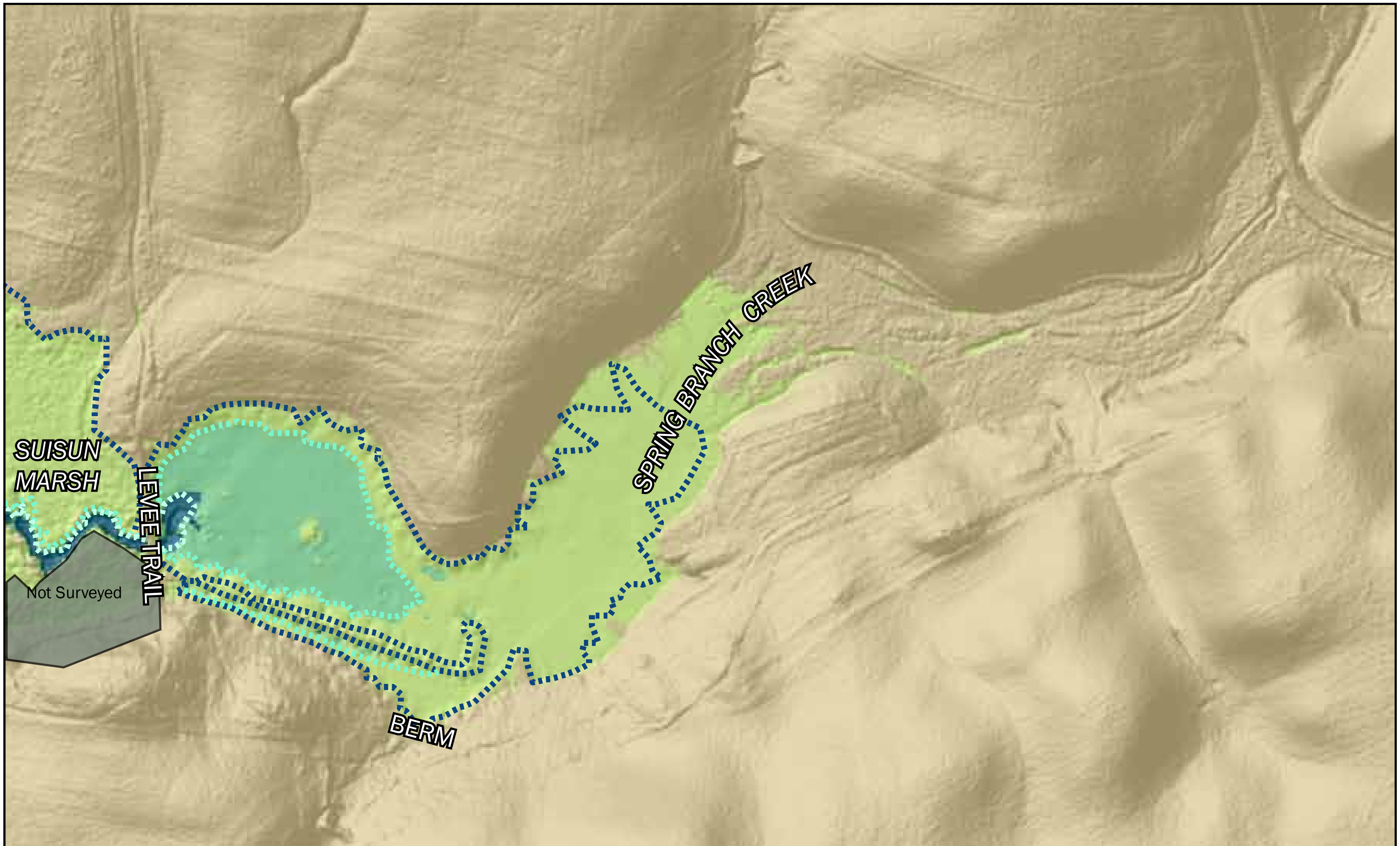


HYPSOMETRIC DIAGRAM OF AREA BELOW CULVERTS

Notes: Hypsometric diagrams developed by Jessie Olson using R package hydroTSM version 0.3-3. The DEM boundary was defined to only use RTK survey data (LiDAR data was found to be up to .5 meters higher than actual ground surface) and to have similar spatial extent (square meters) and range of elevations (Appendix B) between the two locations. Vegetation and water elevation information was acquired from figure 16A.

May 2012

Figure 17B



CURRENT AND POST RESTORATION TIDAL WATER ELEVATIONS FOR LOWER SPRING BRANCH CREEK

Notes: Map created using ESRI and Adobe Illustrator software by Jessie Olson. Water elevation projections created by reclassifying a Digital Elevation Model (DEM) derived from DWR LiDAR and RTK ground surveys. In marsh habitats DEM accuracy is limited to the areas where ground survey was conducted. Marsh areas that were not surveyed are indicated on the figure. Hillshade derived from LiDAR and RTK survey DEM.	May 2012	Figure 18

4. CONCEPTUAL RESTORATION DESIGN

The conceptual restoration design builds from the adaptive management planning framework set up in section one and the site conceptual model (section two) and the site analysis related to soft bird's beak (section three). The conceptual restoration design includes restoration objectives, restoration and management strategies, restoration, monitoring, and phasing.

The conceptual restoration design at Spring Branch Creek is based on eight primary restoration objectives (Table 4.1). Restoration objectives one-four were defined by Wetlands and Water Resources in the Management, Enhancement and Restoration Recommendations (2011).

Table 4.1 Restoration Objectives

	Restoration Objectives	Related Goal (no.)
1	Increase hydrologic and hydraulic connectivity between upland, fluvial, and estuarine habitats along the creek gradient by: · Eliminating lags and buffering of flood peaks or maximum energy of storm discharge events due to impoundments. · Eliminating sediment storage behind impoundments (berm). · Eliminating channel position stabilization and incision points below the culvert. · Restoring braided channel or sheetflow patterns and corresponding sediment deposition patterns. · Eliminating barriers (road berm and culvert) to storm tide-driven transport of debris rafts, large woody debris, and plant propagules, as well as barriers to the full storm surge flood elevation range. · Facilitating (1) the gradual progradation of tidal and seasonal marsh over lower floodplain habitats as sea level rises, and (2) the episodic progradation of deltaic/alluvial fans over tidal marsh sediments during extreme storm runoff events.	1, 4, 5
2	Reconnect the creek to its floodplain, and facilitate the establishment of natural fluvial processes such as scour and deposition across the floodplain.	1
3	Reduce the abundance of invasive, non-native plant species and increase the relative cover of native and special status plants in tidal marsh, and seasonal wetlands	3
4	Re establish (1) a perennial sedge rush meadow in loams or clay alluvium (primarily in floodplains bordering hillslopes), and (2) populations of alkali wet grassland/forbs in subsaline mineral soil flats and pools (i.e. in sandstone derived soils, primarily bordering old alluvial fans at low elevations).	2
5	Maintain and enhance habitat for special status species that currently use the site or have potential to use the site.	2
6	Enhance or maintain existing invertebrate populations.	2
7	Maintain and enhance existing public and educational use.	7 & 8
8	Accommodate cattle rotation between pastures.	6

Notes: Related goals listed in table 1.1 in section one.

4.1. Restoration Strategies

Restoration and management strategies are the guiding "best management practices" for restoration actions in the Spring Branch Creek Restoration Plan. Strategies apply to all target habitats (tidal wetland, seasonal wetland, seasonal pond, and transition zone) and describe a management strategy to help achieve specific restoration goals and objectives. Wetland and Water Resources contributed to management strategies in their Management Enhancement and Restoration Recommendations (WWR 2010).

Table 4.2 Restoration Strategies

	Strategy	Related Goal (no.)
1	Prioritize weed control within transitional habitats and areas where the greatest change in inundation is expected, preparing the site to experience inundation and making room for native plant establishment.	3 & 4
2	Prioritize weed control where native vegetation is within or adjacent to weeds.	1 & 3
3	Actively revegetate areas adjacent to existing native plant populations.	1 & 3
4	Plan for responsible weed control and use of herbicides where: chemical control is undertaken at pilot scale prior to ranch-wide control, weed control is integrated into property-wide control efforts.	3 & 4
5	Anticipate multiple outcomes across time and space by testing out revegetation plant pallets across sites	4
6	Monitor the sites evolution and adapt to changes iteratively.	4 & 5
7	Establish short-term and long term targets/benchmarks so managers can evaluate when to expect what and when management actions should be changed.	4 & 5
8	Establish and enhance desirable functional groups by increasing forb diversity for pollinators.	2
9	Use uncommon, inconspicuous species and species that recruit poorly in revegetation plant pallets.	2
10	Ensure adequate time and resources are allocated to: hire staff or consultants with appropriate level knowledge to carry out the plan, work with science and technical advisory team in undertaking restoration actions, pilot studies and making management decisions.	10
11	Promote and support research that aims to improve our understanding of coupled fluvial tidal restoration processes and the identification of optimal adaptive management strategies.	9

4.2. Restoration Actions

Restoration and monitoring actions are set up in an adaptive management framework where restoration actions work to meet specific measurable targets (or performance measures), and monitoring actions are set up to evaluate whether the measurable targets are met. The result of monitoring and subsequent analysis provides a basis for managers to make decisions to change management actions. Six categories summarize restorations actions: tidal marsh restoration, seasonal wetland restoration, transition zone enhancement, seasonal pond enhancement, and public and agricultural use, and adaptive restoration projects (Figures 19 and 20, Tables 4.2-4.7).

Action descriptions relate to objectives (Table 4.1) and phases. Completion of a final restoration design and acquisition of funding initiates the start of the restoration project. Phase I consists of the years 1-3 (starting from project initiation), phase II consists of years 4-6, and phase III includes years 7-10 (see section 4.4). Solano Land Trust and SF Bay NERR staff identify qualified staff and/or hiring contractors to carry out each project component. Following a description of the adaptive management strategy and restoration actions, section 4.3 describes monitoring actions and performance measures.

Table 4.3 Summary of Expected Changes Following Restoration

	Action	Pre (HA)	Post (HA)	Difference
1	Tidal Marsh	5.25	6.2	+.95
2	Seasonal Wetland	7.75	6.8	-.95
3	Seasonal Pond	0.2	0.2	0
4	Upland to Marsh Transition Zone Enhancement (Priority 1)	5.9	5.9	0
5	Upland to Marsh Transition Zone Enhancement (Priority 2)	5.4	5.4	0
6	Upland to Marsh Transition Zone Enhancement (Priority 3)	6.2	6.2	0

Adaptive Restoration

Revegetation and weed control actions within the tidal wetland, seasonal wetland, and transition zone are set up in an experimental, adaptive restoration context where cause-effect relationships are evaluated. The purpose is to determine: (A) which revegetation plant palettes are most successful across a range site conditions following hydrological reconnection (B) where weed species are colonizing or dissipating across this range, and what methods are successful across these ranges (C) where active and passive restoration is appropriate across the site. There are several benefits to this approach. This approach is cost effective (significant initial investment in revegetation is not necessary). In addition, this approach increases the likelihood of achieving restoration success across the site as the approach adapts restoration methods iteratively as the site evolves and the study yields more information. This approach is particularly helpful for successful establishment of rare or uncommon species.

Phase I establishes permanent plots within the tidal wetland, seasonal wetland and transition zone to evaluate pre restoration conditions. A stratefied-random plot placement approach targets specific conditions found within tidal wetlands, seasonal wetlands, and transition zones (tables 4.5, 4.9, 4.14) and randomly places the plot within that condition. The approach establishes a sufficient number of plots for each treatment type for each condition (e.g. weed control method 1 + active revegetation; weed control method 1 + passive revegetation; weed control method 2 + active revegetation; weed control method 2 + passive revegetation, etc). Measurements within each plot include vegetation, soil quality, and invertebrates (see section 4.3). While measurements are not explicitly taken at plot level, seasonal and tidal hydrology, geomorphology, ground water measurements can be scaled to the plot level (see section 4.3). A qualified ecologist determines the number of replicated treatment and control blocks necessary to be statistically significant. A qualified ecologist also finalizes the experimental design in concert with final restoration designs (outside the scope of this conceptual design).

Tidal Wetland Restoration

Tidal wetland restoration actions occur within all phases (I-III). Phase II consists of the main restoration actions including: berm and levee removal, site grading, and active revegetation (Table 4.4). Actions result in .95 HA gain in tidal marsh habitat, and enhancement of the entire 6.2 HA site. Actions increase native vegetation cover through weed removal and revegetation, increase habitat complexity with a newly constructed channel, and an increase in tidal prism following berm and levee removal and channel construction. Further, actions remove barriers to estuarine transgression, preparing the site for accelerated sea level rise.

Phase I coordinates site preparation and monitoring necessary to implement primary restoration actions. Revegetation (table 4.6) and weed control efforts (4.7) are set up in adaptive restoration framework in order to evaluate restoration success across a variety of site conditions (Table 4.5, Figure 19). Specifically, the purpose of the project is to determine (1) which revegetation plant palettes are most successful across a range site conditions, (2)where weed species are colonizing or dissipating across range of inundation depths or frequencies, (3) what weed control methods are successful across these ranges, (4) where passive versus active restoration is needed. A high priority weed control area for phase I is the area that transitions from seasonal wetland to tidal wetland following removal of berm and levee. A second weed control project removes winter annual grasses within soft bird's beak population. Phase I also coordinates the implementation of pre restoration measurements.

Phase II coordinates the removal of a 810m^3 berm and a 1940m^3 levee road. If beneficial reuse (filling of a borrow ditch) or suitable locations within upland grasslands are not identified, fill materials are transported off site. Grading occurs within the levee and berm removal area and dynamite creates a 1.5 m deep and 5 m channel. Active revegetation covers bare areas immediately following grading to avoid further colonization by cattails and/or other invasive species. As the site evolves, tidal marsh vegetation is expected to recolonize the area of new tidal influence. In order to take advantage of natural recruitment of desirable native vegetation, revegetation is set up in an adaptive restoration context in order to determine where revegetation is necessary (and where natural recruitment is sufficient) and which revegetation plant palettes are most successful across a range of conditions (see weed control and revegetation section below). Phase III continues post restoration measurements and initiates the soft bird's beak expansion project.

Table 4.4 Summary of Tidal Wetland Restoration Actions

	Action	Phase	Related objective (no.)
1	Eliminate the 810 m^3 L-shaped berm in the lower creek, fill its accompanying borrow ditch.	II	1
2	Create 1.5 m deep and 5 m wide channel using dynamite or grading, and facilitate the movement of winter-spring surface flows through the flats to the Lower Spring Branch Creek tidal marsh.	II	1
3	Remove the approximately 1940 m^3 levee road and two four-foot culverts and place in upland areas.	II	1
4	Actively revegetate all re-graded areas	II	2

5	Begin weed control efforts of perennial pepperweed and wild celery, and winter annual grass removal	I	3
6	Trail construction, materials and exact placement TBD in final design	II	2
7	Monitoring of pre-restoration site conditions: vegetation, salinity, groundwater, freshwater inundation, invertebrates, geomorphology, and more.	I	All

Table 4.5 Tidal Wetland Weed Control and Revegetation Areas

	Condition Description	Weed Control Target	Revegetation	
			Active	Passive
1	Between MHHW-Spring HHW, within the area that is expected to transition from seasonal wetland to tidal wetland. Vegetation dominated by invasive annual grasses.	Invasive annual grasses, perennial pepperweed, wild celery,	X	X
2	Between MHHW-Spring HHW, area that is dominated by distichlis-juncus-triglochin-glaux and soft bird's beak	Invasive annual grasses	X	X
3	Between MHHW-and MLHW, area that is dominated by perennial pepperweed and wild celery.	Perennial pepperweed, wild celery	X	X
4	Between MHHW-and MLHW, area that is dominated by cattails and tules	None	X	X
5	Downstream of culverts, area that is dominated by perennial pepperweed and wild celery	Perennial pepperweed, wild celery		

Notes: Within condition one, a secondary purpose is to evaluate potential soft bird's beak expansion areas. Within condition two, a secondary purpose of this project is determine whether (1) targeted removal of invasive annual winter grasses improves the condition (% cover, and stature) of the soft birds beak population, and (2) whether hydrological changes following reconnection reduce invasive annual winter grasses independent of removal efforts.

Table 4.6 Potential Weed Control Methods

Common name	Strategy	Method(s)	Condition
Perennial pepperweed, wild celery	Target small, incipient founder colonies of pepperweed and wild celery within and downstream of the project site.	Herbicide, mowing + herbicide, hand pulling	1, 3, 5
Invasive annual grasses	Target invasive annual grasses occurring within condition 1 and 2.	Herbicide, mowing + herbicide, hand pulling	1, 2, 5

Notes: The Rush Ranch Stewardship program, with coordination from an advisory team, conducts literature review and identifies specific weed control methods (including herbicides, rates, etc) for each weed present within each condition.

Table 4.7 Tidal Marsh Revegetation Plant Palette

	Species	Common Name	Condition
1	*Arthrocnemum subterminale*	Parishes Pickleweed	1-3
2	*Sarcocornia pacifica*	Pickleweed	1-3
3	*Cressa truxillensis*	Spreading Alkaliweed	1-3
4	*Distichlis spicata*	Salt Grass	1-3
6	*Frankenia salina*	Alkali Heath	1-3
7	*Grindelia stricta*	Gumweed	All
8	*Potentilla anserina* spp. *pacifica*	Silverweed	All
9	*Triglochin striata*	Arrowgrass	All
10	*Ranunculus canus*	Great Valley Buttercup	All
12	*Juncus arcticus*	Baltic Rush	All
13	*Jaumea carnosa*	Marsh Jaumea	All

Notes: List reflects a preliminary list of species to be used in revegetation efforts. List is updated within final restoration design and following vegetation surveys.

Soft Bird's Beak Expansion Project

This project expands the Federally listed plant soft bird's beak population to additional suitable locations within Spring Branch Creek. Site monitoring, within the first five years of the project, determines potential suitable locations (based primarily on hydrology, soils, and a host community). The invasive annual grass removal monitoring within tidal marsh informs this project. Reintroduction methods are based on findings from Grewell (2003, 2005). In addition, a technical advisory team consults SLT and NERR on implementation and monitoring methods.

Seasonal Wetland Restoration

Seasonal wetland actions occur within all phases. The primary actions include revegetation and weed control. Actions result in a reduction of .95 HA of seasonal wetland habitat due to the expansion of tidal marsh habitat. However, actions also result in 6.8 HA of seasonal wetland enhancement. Actions increase native vegetation through revegetation and weed removal, and increase freshwater flows through upstream berm removal. Revegetation (table 4.10) and weed control efforts (4.11) are set up in adaptive restoration framework in order to evaluate restoration success across a variety of site conditions (Table 4.9, Figure 19). Specifically, the purpose of the project is to determine (1) which revegetation plant palettes are most successful across a range site conditions, (2)where weed species are colonizing or dissipating across range of inundation depths or frequencies, (3) what weed control methods are successful across these ranges, (4) where passive versus active restoration is needed.

Table 4.8 Summary of Seasonal Wetland Restoration Actions

	Restoration Action	Phase	Related objectives (no.)
1	Weed control within and around existing native populations of *Frankenia-Distichlis* or *Juncus-carex* and transplanting and revegetating following weed control.	I-III	2, 3, 4
2	Weed treatments of pepperweed, medusa head and invasive annual grasses and revegetation (transitioning areas to *Frankenia-Distichlis* or *Juncus-carex* associations).	I-III	2, 3, 4
3	Reintroduce brackish/alkali-tolerant native annuals (and Parish's pickleweed) via heavy seeding in alkali flats (harsh/unproductive eroded)	I-III	2, 3, 4

Table 4.9 Seasonal Wetland Adaptive Restoration Areas

	Condition Description	Weed Control Target	Revegetation	
			Active	Passive
1	Sparsely vegetated, harsh, unproductive alkali flats.	Invasive annual grasses	X	X
2	Thick, loamy, alluvium, adjacent to hillslopes and existing native vegetation including sedge-rush-spikerush or frankenia-disticilis association	Invasive annual grasses, medusahead, perennial pepperweed	X	X
3	Thick, loamy, alluvium, with isolated patches of perennial pepperweed, wild celery, and medusa head	Medusahead, perennial pepperweed, wild celery	X	X

Table 4.10 Seasonal Wetland Weed Control Methods

Common name	Strategy	Method(s)	Condition
Perennial pepperweed, wild celery	Target small, incipient founder colonies of pepperweed and wild celery within and downstream of the project site.	Herbicide, mowing + herbicide, hand pulling	2, 3
Medusahead	Target small, incipient founder colonies	Herbicide, mowing	2
Invasive annual grasses	Target invasive annual grasses occurring adjacent to desirable native vegetation	Herbicide, mowing + herbicide, hand pulling	1, 2, 3

Notes: The Rush Ranch Stewardship program, with coordination from an advisory team, conducts a literature review and identifies specific weed control methods (including herbicides, rates, etc) for each weed within each condition.

Table 4.11 Seasonal Wetland Revegetation Plant Palette

	Species	Common Name	Condition
1	*Lepidium nitidum*	Small Fruited Peppercress	All
3	*Lasthenia* sp.	Goldfields	1
4	*Arthrocnemum subterminale*	Parishes pickleweed	1, 3
5	*Sarcocornia pacifica*	Pickleweed	1, 3
6	*Cressa truxillensis*	Spreading Alkaliweed	All
7	*Distichlis spicata*	Salt Grass	All
8	*Frankenia salina*	Alkali Heath	All
9	*Juncus* sp.	Rush	1-2
10	*Carex* sp.	Sedge	1-2
11	*Leymus triticoides*	Creeping Wild Rye	1-2

Notes: List reflects a preliminary list of species to be used in revegetation efforts. List is updated within final restoration design and following vegetation surveys.

Seasonal Pond Enhancement

Implementation of seasonal pond enhancement actions are dependent on a ranch-wide survey and evaluation to determine whether California Tiger Salamander (CTS) and California Red Legged Frog (CRLF) occurs or has potential to occur on site (phase I). If CTS and/or CRLF occur or have potential to occur on site, phase II expands the network of seasonal wetland pools and/or enhances the existing pools.

Table 4.12 Summary of Seasonal Pond Enhancement

	Action	Phase	Related Objectives (no.)
1	Conduct population study to determine whether it is possible for CTS and CRLF to occur on site. Consider reintroduction if Rush Ranch can sustain population.	I	5
2	Consider expanding network of seasonal wetland pools in backwater slough areas if population grows to require more and if pools do not form on their own.	II	5
3	Avoid spraying herbicide adjacent to pond (or within the area that water + herbicide could run off) as it could impact the species.	I-III	5
4	Maintain sunny shallow areas suitable for larvae and deep escape areas for juveniles and adults within the pond in order to provide habitat at multiple life-stages.	II	5

Transition Zone Enhancement

Transition zone enhancement actions occur within phases II and III. Primary actions include weed removal and revegetation. Transition zone enhancement actions priorities are based on distance from tidal and seasonal wetlands (closer to channel higher the priority) and proximity to existing native vegetation (closer to native vegetation, higher the priority). Actions result in 17.2 HA of transition zone habitat enhancement. Actions increase native vegetation through revegetation and weed removal. Revegetation (table 4.15) and weed control efforts (4.16) are set up in adaptive restoration framework in order to evaluate restoration success across a variety of site conditions (Table 4.9, Figure 19). Specifically, the purpose of the project is to determine (1) which revegetation plant palettes are most successful across a range site conditions, (2)where weed species are colonizing or dissipating across range of inundation depths or frequencies, (3) what weed control methods are successful across these ranges, (4) where passive versus active restoration is needed.

Table 4.13 Summary of Transition Zone Enhancement

	Action	Phase	Related Objectives (no.)
1	Enhance clonally-spreading sedges, rushes and grasses in upland-marsh ecotone areas by control thistles within and adjacent to existing populations and actively revegetating weed control areas with clonally-spreading sedges, rushes, and grasses (in priority 1 areas).	II	3
2	As resources allow, continue expanding clonally-spreading sedges rushes and grasses up slope into priority 2 and 3 areas.	III	3
3	Reintroduce native grassland forbs on a pilot study bases.	III	3

Table 4.14 Transition Zone Adaptive Restoration Areas

	Condition Description	Weed Control Target	Revegetation	
			Active	Passive
1	Areas dominated by creeping wild rye mixed with or adjacent to Italian thistle	Italian thistle	X	X
2	Areas adjacent to large stands of creeping wild rye.	Medusahead, invasive annual grasses.	X	X
3	Small incipient founder colonies of invasive weeds in transition zone.	Medusahead, harding grass, Italian thistle.	X	X

Table 4.15 Transition Zone Weed Control Methods

Common name	Strategy	Method(s)	Condition
Italian thistle	Target populations within and adjacent to creeping wild rye.	Herbicide, hand pulling	2, 3
Medusahead	Target small, incipient founder colonies and colonies adjacent to desirable native vegetation	Herbicide, mowing	2, 3
Harding grass	Target small, incipient founder colonies and colonies adjacent to desirable native vegetation	Herbicide, mowing	3
Invasive annual grasses	Target invasive annual grasses occurring adjacent to desirable native vegetation	Herbicide, mowing + herbicide, hand pulling	1, 2, 3

Notes: The Rush Ranch Stewardship program, with coordination from an advisory team, conducts a literature review and identifies specific weed control methods (including herbicides, rates, etc) for each weed within each condition.

Table 4.16 Transition zone Revegetation Plant Palette

	Species	Common Name	Condition
1	*Leymus triticoides*	Creeping wild rye	All
2	*Hemizonia* sp.	Native tarweed	2 & 3
3	Many	Native grassland forbs (TBD)	2 & 3

Notes: List reflects a preliminary list of species to be used in revegetation efforts. List is updated within final restoration design and following vegetation surveys. Purpose of wildflower mix is to attract pollinators and provide upland nest habitat.

Agriculture and Public Use Enhancement

Public use actions occur within phase II while agriculture use actions occur within phase I. Actions result in enhanced public and agriculture use features. Primary public use actions consist of installation an of a new public trail, platform and interpretative signs. The final design (outside the scope of this report) specify the trail materials, size and exact trail alignment. Phase I designates a cattle crossing location which allows cattle to rotate between pastures. In addition, phase I identifies and replaces fencing in need of repair/replacement.

Table 4.17 Agriculture And Public Use Enhancement

	Action	Phase	Related Objectives (no.)
1	Realign trails to better protect sensitive areas.	II	19
2	Design and install a pedestrian footbridge or boardwalk crossing over Spring Branch Creek.	II	19
3	Design and install interpretative signs and educational platforms	II	19
4	Designate a cattle crossing location to allow cattle to rotate between pastures	I	20
5	Remove old fencelines, and realign fencelines to better manage vegetation	I	20

4.3. Site Monitoring & Performance Measures

Performance measures (Table 4.19) describe the restoration targets this project aims to achieve. New information from baseline studies, literature reviews and the final restoration design may initiate an update of performance measures. Monitoring actions (1-13 below) measure whether the specific restoration targets/performance measures are met. Monitoring actions descriptions are general and in line with level of detail in the conceptual restoration design. The final restoration design specifies monitoring protocols necessary to evaluate performance measures.

To be successful, SLT and NERR applies for restoration funds in concert with monitoring research funds. Partnering with a principal investigator that focuses on wetland restoration ecology from local university (UC Berkeley, San Francisco State, UC Davis, University of San Francisco) is a key component to a successful project.

Monitoring Actions

1. Tidal and Seasonal Hydrology (Performance Measure 1, 2, 4)

Pressure transducers assess seasonal and tidal hydrology across the site conditions before and after hydrological reconnnection. SLT or NERR deploy pressure transducers in the locations necessary to capture the variation of tidal and seasonal water depth, duration, and frequency found across the primary site conditions within tidal and seasonal marsh (Tables 4.5 and 4.9).

2. Geomorphology (Performance Measure 3)

Geomorphic monitoring assesses the relationship between restoration actions and stream bed and bank scour and deposition before and after hydrological reconnection. Permanent cross sections and long profiles measure geomorphic changes every year, and are strategically positioned to capture changes within newly created channel and specific site conditions within tidal marsh, seasonal marsh, and transition zone (Tables 4.5, 4.9, and 4.14). Short-term channel dimension performance measures are based on marsh area-channel geometry relationships while long-term channel dimension performance measures are based on tidal prism-channel geometry relationships (Williams 2002, Simenstad 2006). In addition, sediment elevation tables (SETs) are installed within restoration conditions to capture changes in sediment deposition and erosion within the marsh plain.

3. Vegetation (Performance Measure 5-11)

Vegetation monitoring detects vegetation trends and response to restoration actions including hydrological reconnection, exotic plant management, and revegetation. A stratefied-random plot or transect placement approach targets specific conditions found within tidal wetlands, seasonal wetlands, and transition zones (tables 4.5, 4.9, 4.14) and randomly places the plot or transect within that condition. The approach establishes a sufficient number of plots or transects for each treatment type for each condition (e.g. weed control method 1 + active revegetation; weed control method 1 + passive revegetation; weed control method 2 + active revegetation; weed control method 2 + passive revegetation, etc). Monitoring detects general trends in the plant community (new weed observations or increases/decreases in species presence), and whether actions achieve the plant community structure and species composition objectives. Vegetation surveys occur on an annual basis during peak flowering time. While current performance measures for vegetation are general (increase, decrease) Rush Ranch Stewardship program defines performance measures for each weed species.

4. Soil Quality (Performance Measure TBD After Pre Restoration Measurements)
Soil quality monitoring assesses soil characteristics (organic matter, P, %C, %N, C:N, water content and soil pore water salinity) across site conditions (Table 4.5, 4.9, and 4.14) before and after restoration. SLT/NERR assesses conditions of soil within same plots established for vegetation monitoring above in order to evaluate the relationship between vegetation, restoration actions, and soil conditions.

5. Water Column Salinity (Performance Measure TBD After Pre Restoration Measurements)
Water column salinity measurements provide information on relationship between seasonal inundation, salinity, and vegetation community distribution. Measurements occur multiple times of year in order to capture the seasonal variation.

6. Ground Water (Performance Measure TBD After Pre Restoration Measurements)
Permanent piezometers, installed prior to restoration, measure ground water elevation across the range of site conditions within the tidal marsh and seasonal marsh (Table 4.5, 4.9) before and after restoration. Measurements occur multiple times a year to capture the seasonal variation.

7. Small Mammals (Performance Measure 17)
Project Managers coordinate with Department of Fish and Game to collect occurrence information for the salt marsh harvest mouse and the Suisun shrew within the tidal marsh, seasonal marsh, and transition zone. If DFG is unable to perform surveys, a qualified biologist with appropriate permits is contracted instead.

8. Birds (Performance Measure 17)
Project Managers coordinate with PRBO or another qualified specialist to conduct special status bird species surveys before and after restoration within the tidal marsh and seasonal marsh. In order to avoid impact to birds from restoration activities, site surveys occur prior to and during all restoration activities.

9. Invertebrates (Performance Measure 12)
A qualified invertebrate taxonomist surveys invertebrates prior to restoration within the tidal marsh and seasonal marsh. If taxonomist observes rare or unusual invertebrates, site grading avoids important invertebrate areas. Invertebrate surveys occur on an annual basis thereafter.

10. Soft Bird's Beak (Performance Measure 16)
Soft bird's beak population demographic monitoring occurs on an annual basis within the tidal marsh and seasonal marsh. A qualified botanist uses protocols developed by Brenda Grewell (2005) or another qualified expert to survey the population.

11. Public Use (Performance Measure 13)
SLT quantifies public use features including length of trail, and number of features (signs, etc) pre

and post restoration. Public use surveys evaluate public opinion of access features pre and post restoration in order to determine whether public objectives are met.

12. Rangeland Infrastructure (Performance Measure 14)
On an annual basis, SLT visually inspects fencelines to ensure that cattle access is restricted. Fenceline repairs occur on an as-needed basis.

13. Weed Control Efficacy (5-9)
Efficacy monitoring evaluates the effectiveness of particular weed treatment methodologies. For each weed control activity, project manager:

- Records spray locations and amount and type of chemical used each day of treatment, and total person hours required to implement action.
- Records percent cover and size (square meters) of weed patch before treatment and on an annual basis thereafter.
- Establishes photomonitoring locations at representative treatment areas. Revisit on annual basis.

4.4. Restoration Timeline

Table 4.18 Restoration Timeline

Phase I	Year Initiated	Year Complete
Weed Control & Revegetation Projects	1	10
Pre Restoration Measurements	1	10
Phase II		
Remove Berm & Levee & Site Grading	3	3
Revegetate Bare Areas	3	3
Trail Construction	3	3
Seasonal Wetland Enhancement	3	10
Transition Zone Enhancement	3	10
Phase III		
Remove Upstream Berm	5	5
Soft Bird's Beak Expansion Project	5	10

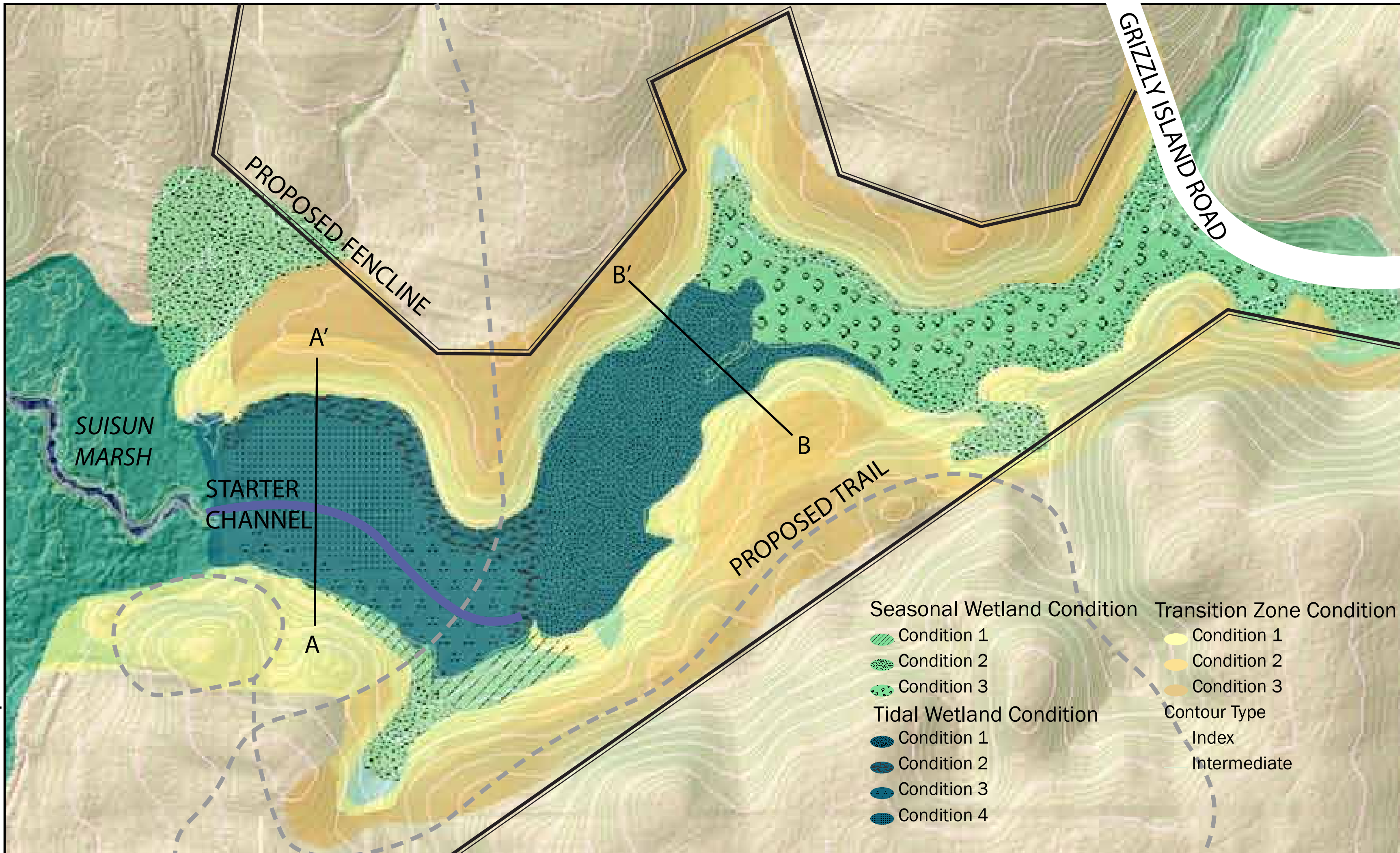
4.5. Next Steps

Construction-level drawings and detail (final designs) are a necessary next step to build this restoration project. SLT and NERR should pursue funding at the earliest opportunity. To be a successful adaptive restoration project, funding for restoration should be applied for in concert with funding for monitoring/research. A principal investigator focused on wetland restoration ecology at a local university (UC Berkeley, San Francisco State, UC Davis, University of San Francisco) that is interested in working with NERR or SLT should be identified at the earliest opportunity.

While funding an adaptive restoration approach may be difficult, there are many reasons why this approach is likely to lead to greater restoration success when compared to alternative approaches such as removing the levee and walking away. First, restoration in a dynamic, changing environment requires a dynamic approach. The proposed approach adapts restoration methods iteratively as the site evolves and the study yields more information. Specifically, monitoring allows site managers to understand how the site responds to restoration actions in a changing climate, and provides a basis for changing actions. An adaptive approach is particularly helpful for ecologically significant sites like Rush Ranch, where loss of rare, threatened, or endangered species would be detrimental to the region. An adaptive restoration approach allows managers to quickly detect and respond to the threats to rare species. Without monitoring, managers have very little information to base management decision making on. Lastly, this approach is cost effective as a significant initial investment in revegetation is not necessary and is particularly helpful for successful establishment of rare or uncommon species such as soft bird's beak.

Table 4.19. Performance Indicators

	Performance Indicator	Related Objective	Key Habitat or Species	Metric	Target 5-year	Target 10-year	Monitoring Tool
1	Area of connected functional tidal wetland below MHLW	1,5	Tidal Wetland	Depth, duration, frequency and extent of tidal inundation	6.2 HA	6.2 HA	Pressure transducers, GIS
2	Area of connected functional seasonal wetland	1,5	Seasonal Wetland	Depth, duration, frequency and extent of seasonal inundation	Levee Removal	6.8 HA inundated, TBD	Pressure transducers, GIS
3	Extent of functioning dendritic, tidal drainage system	1,5	Tidal Wetland	Width, depth, area of channel	1.4 M Depth 5 M Width	2.3 M Depth 15.9 M Width	Cross sections, long profile, SETs
4	Floodplain connectivity during 2-year flood	2	Seasonal wetland/Alluvial fan	Depth, duration, frequency and extent of seasonal inundation	Levee Removal	TBD	Pressure transducers, GIS
5	Reduction in perennial pepperweed	3	Tidal and seasonal wetland	Percent cover & extent (HA)	Decrease	Decrease	Vegetation + Weed control efficacy
6	Reduction of invasive annual grasses	3,5	Tidal and seasonal wetland	Percent cover & extent (HA)	Decrease	Decrease	Vegetation + Weed control efficacy
7	Reduction of celery	3	Tidal and seasonal wetland	Percent cover & extent (HA)	Decrease	Decrease	Vegetation + Weed control efficacy
8	Reduction of Italian thistle	3	Transition zone	Percent cover & frequency of occurance	Decrease	Decrease	Vegetation + Weed control efficacy
9	Reduction of medusahead	3	Seasonal wetlands/Transition zone	Percent cover & frequency of occurrence	Decrease	Decrease	Vegetation + Weed control efficacy
10	Regeneration of marsh plain vegetation	4	Tidal Wetlands	Acres, % cover natives vs. exotics	Improve baseline value	Improve baseline value	Vegetation + Weed control efficacy
11	Regeneration of seasonal wetland vegetation[2]	4	Seasonal wetlands/Transition zone	Acres, % cover natives vs. exotics	Improve baseline value	Improve baseline value	Vegetation + Weed control efficacy
12	Invertebrate species gained or maintained	6	Tidal wetlands & Seasonal wetlands	Species # by functional group	Maintain or improve baseline value	Maintain or improve baseline value	Invert surveys; contracted to specialist
13	Public and educational features gained or maintained	7	All	# Education features; Length of trail (ft.); visitor opinion	3; TBD in final design	3; TBD in final design	Visual inspection; Visitor/user surveys
14	Length of fenceline and cattle crossing gained and/or maintained	8	All	# Crossings; length of fenceline maintained (ft.)	1; TBD in final design	1; TBD in final design	Visual inspection
15	Maintanence or expansion of California black rail habitat	5	Tidal wetlands	# Occurences	Maintain or improve baseline value	Maintain or improve baseline value	PRBO-protocol surveys; contracted to PRBO
16	Maintenance or expansion of soft bird's beak habitat	5	Tidal wetlands	# Individuals	100,000 individuals or more	100,000 individuals or more	Grewell 2005 methods, contracted to Grewell, or other expert.
17	Expansion of habitat for special status species with potential to use the site	5	All	# Occurences	Maintain or improve baseline value	Maintain or improve baseline value	UC Davis Fish counts, DFG SMHM trapping, PRBO bird surveys.



LOWER SPRING BRANCH CREEK RESTORATION AREAS AND INFRASTRUCTURE: PROPOSED

Notes: Map created using ESRI and Adobe Illustrator software by Jessie Olson. Tidal wetland restoration areas delinated by water elevation projections following removal of the berm (Figure 18). Seasonal wetland restoration areas delinated based on presence of wetland vegetation (Figure 11A). Transition zone priority 1 areas delinated based on presence of native plant creeping wild rye within the areas. Priority 2 and 3 areas delinated based on distance from desirable native vegetation. Boundaries of wetland habitats are subject to fluxuation due to interannual variation.

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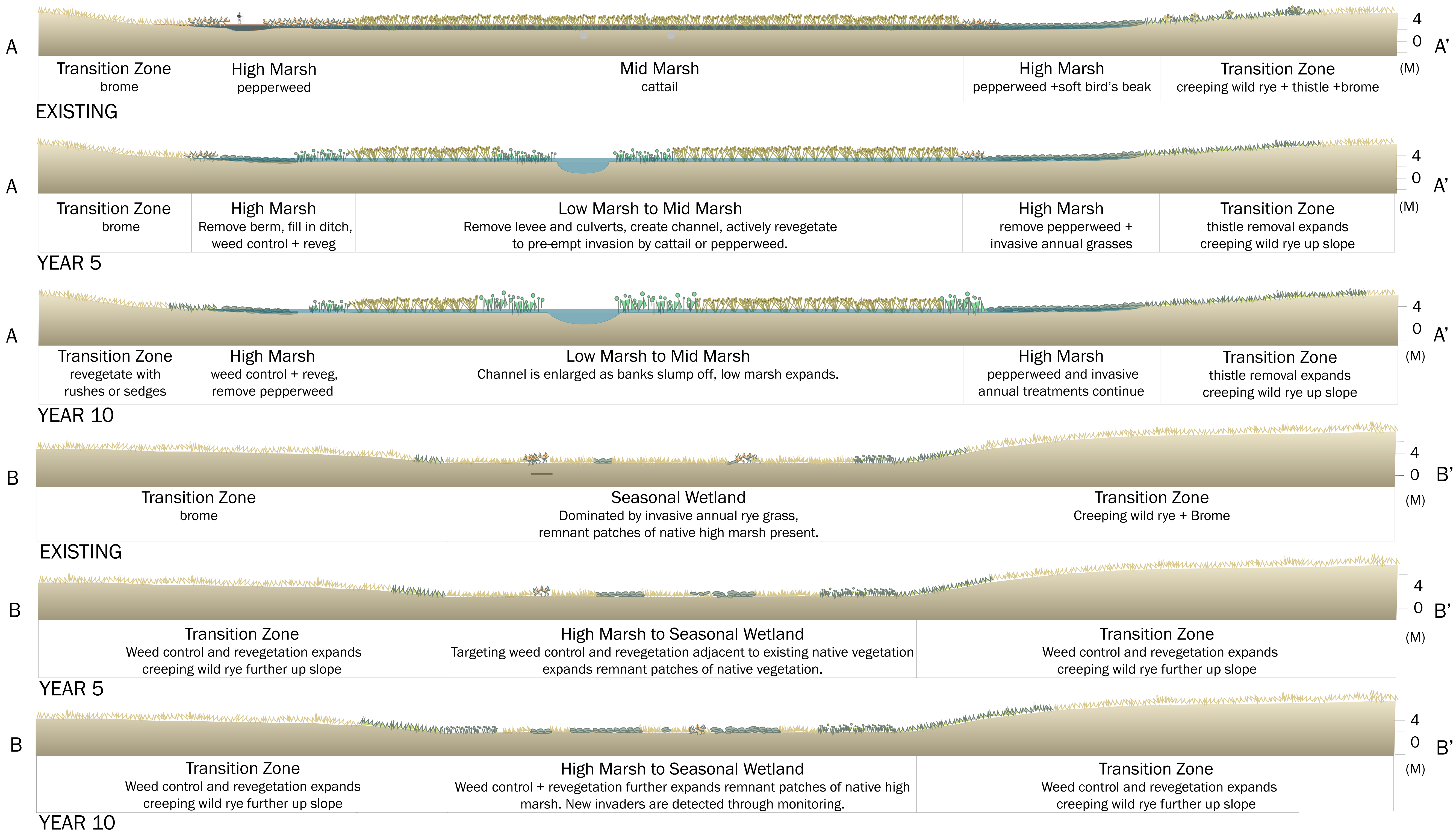
Figure 19



CROSS SECTIONAL DIAGRAMS

Notes: Cross sectional diagrams created by Jessie Olson in AutoCAD using .25 meter contours and illustrate in Adobe Illustrator. Countours derrived ground surveys and LiDAR. Short-term channel dimension performance measures are based on marsh area-channel geometry relationships while long-term channel dimension performance measures are based on tidal prism-channel geometry relationships (Williams 2002, Simenstad 2006).

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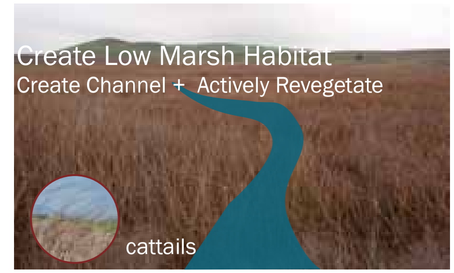
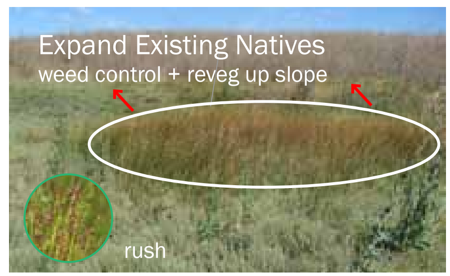
FUTURE HIGH MARSH

HIGH MARSH



MID MARSH

SEASONAL WETLAND



SEASONAL WETLAND

TRANSITION ZONE

SITE PHOTOS AND RESTORATION STRATEGIES

Notes: All photos taken by Jessie Olson. Photos illustrate how strategies listed on table. 4.2 are applied within specific conditions (Figure19).

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Figure 21

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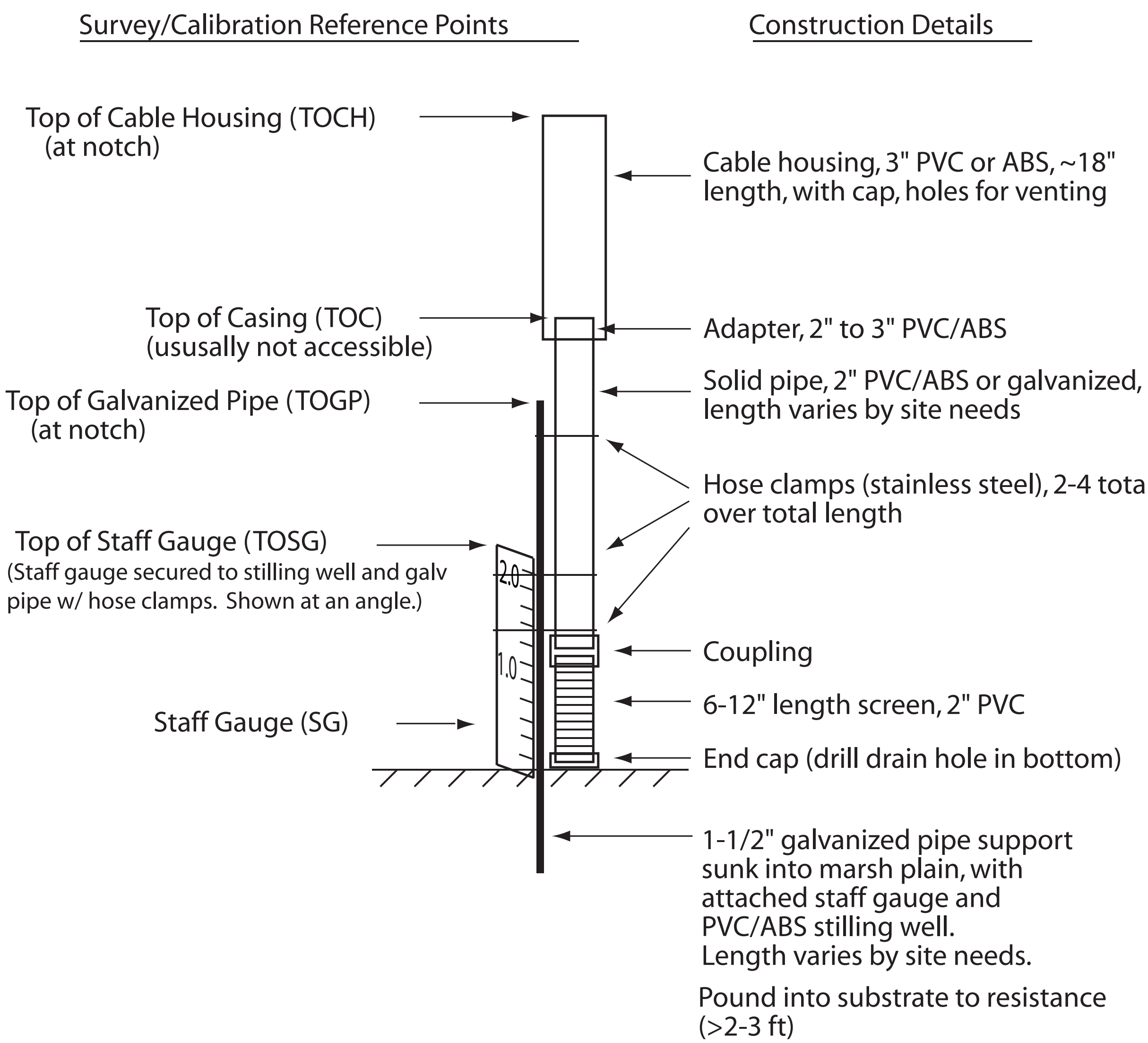
APPENDIX A: STILLING WELL DESIGN SPECIFICATION



Design Provided by Wetlands and Water Resources

RUSH RANCH
Notes: Looking downstream at stilling well below culverts

RUSH RANCH
Notes: Looking upstream at stilling well above culverts.

APPENDIX B: WATER LEVEL TO WATER ELEVATION OFF-SET CALIBRATION

APPENDIX B: WATER LEVEL TO WATER ELEVATION OFF SET CALCULATIONS

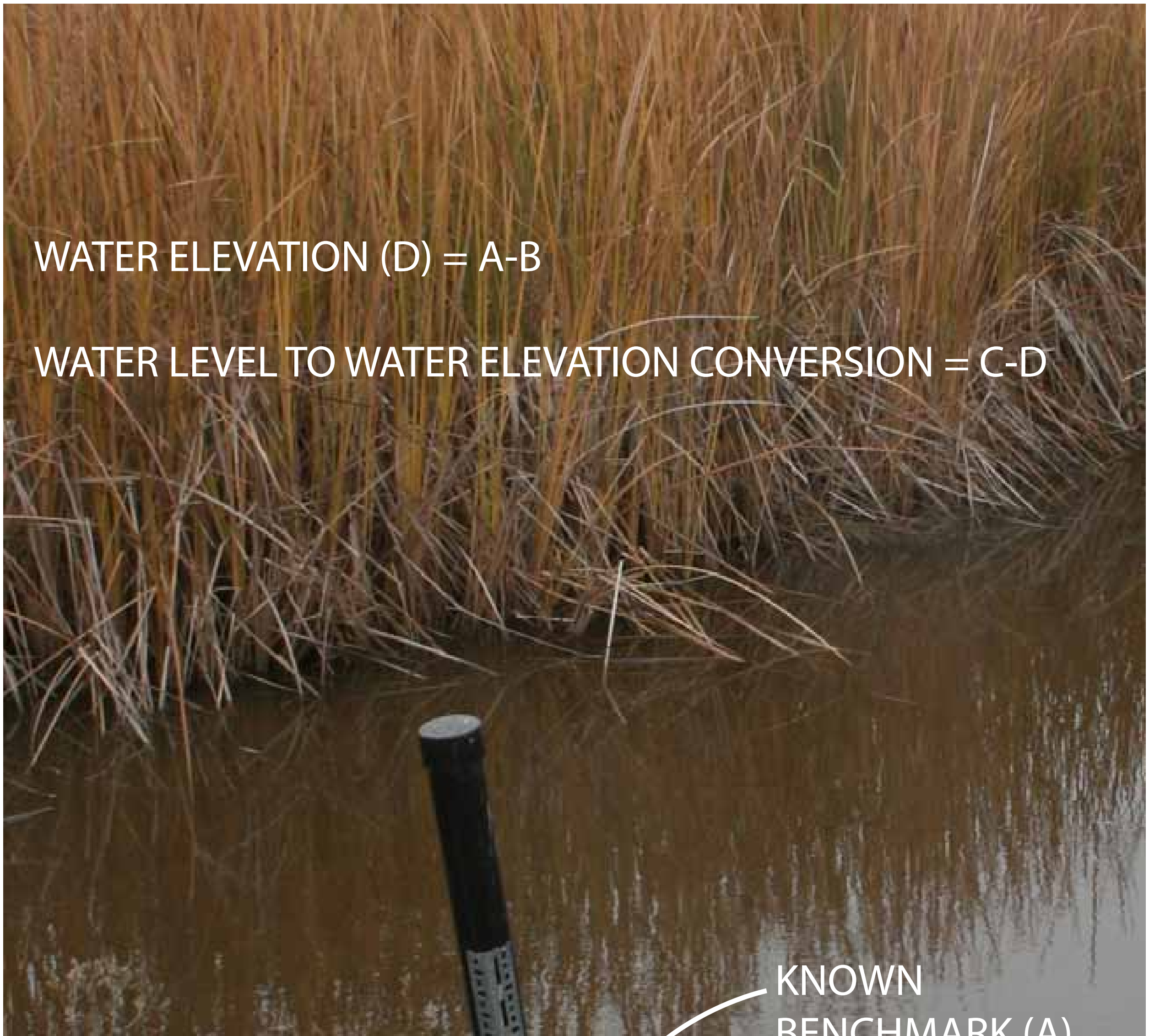
BELOW CULVERT						
		A	B	C (A-B)	D	E (C-D)
Date	Time	Bench Mark Elevation (m)	Water Level to Bench Mark-measured (m)	Water Level Elevation (m)	Pressure Transducer	Delta (m)
4/7/11	10:37	2.177	1.279	0.885	0.433	0.452
4/7/11	10:38	2.177	1.279	0.898	0.445	0.453
4/7/11	10:39	2.177	1.279	0.910	0.448	0.462
5/3/11	10:30	2.177	1.600	0.577	0.135	0.442
5/3/11	10:31	2.177	1.600	0.577	0.135	0.442
5/3/11	10:32	2.177	1.600	0.577	0.134	0.443
5/18/11	12:32	2.177	1.460	0.717	0.253	0.464
5/18/11	12:33	2.177	1.460	0.717	0.253	0.464
5/18/11	12:34	2.177	1.460	0.717	0.253	0.464
6/15/11	8:47	2.177	1.460	0.717	0.271	0.446
6/15/11	8:49	2.177	1.460	0.727	0.270	0.456
6/15/11	8:50	2.177	1.460	0.721	0.269	0.453
7/13/11	17:27	2.177	0.818	1.360	0.916	0.444
7/13/11	17:30	2.177	0.818	1.363	0.900	0.462
7/13/11	17:31	2.177	0.818	1.356	0.898	0.457
8/24/11	9:32	2.177	1.132	1.018	0.576	0.442
8/24/11	9:35	2.177	1.132	1.058	0.594	0.464
8/24/11	9:37	2.177	1.132	1.045	0.601	0.443
AVERAGE (OFFSET)						0.453

Notes: Elevations have not been corrected for atmospheric pressure.

APPENDIX B: WATER LEVEL TO WATER ELEVATION OFF SET CALCULATIONS

ABOVE CULVERT						
		A	B	C (A-B)	D	E (C-D)
Date	Time	Bench Mark Elevation (m)	Water Level to Bench Mark-measured (m)	Water Level Elevation (m)	Pressure Transducer water level (m)	Delta (m)
4/9/11	1:43	2.081	0.762	1.319	0.269	1.051
4/9/11	1:44	2.081	0.762	1.319	0.269	1.050
4/9/11	1:45	2.081	0.762	1.319	0.269	1.050
5/3/11	10:40	2.081	0.850	1.231	0.175	1.056
5/3/11	10:41	2.081	0.850	1.231	0.205	1.026
5/3/11	10:42	2.081	0.850	1.231	0.174	1.056
5/18/11	12:36	2.081	0.710	1.371	0.357	1.014
5/18/11	12:37	2.081	0.710	1.371	0.327	1.044
5/18/11	12:38	2.081	0.710	1.371	0.327	1.044
6/15/11	8:55	2.081	0.717	1.364	0.322	1.044
6/15/11	8:57	2.081	0.717	1.364	0.321	1.043
6/15/11	8:58	2.081	0.717	1.364	0.320	1.044
7/13/11	17:36	2.081	0.770	1.311	0.282	1.043
7/13/11	17:39	2.081	0.770	1.311	0.265	1.035
7/13/11	17:40	2.081	0.770	1.311	0.264	1.043
8/24/11	9:45	2.081	0.911	1.170	0.124	1.046
8/24/11	9:46	2.081	0.911	1.170	0.123	1.036
8/24/11	9:47	2.081	0.911	1.170	0.123	1.057
AVERAGE (OFFSET)						**1.043**

Notes: Elevations have not been corrected for atmospheric pressure.


WATER ELEVATION (D) = A-B
WATER LEVEL TO WATER ELEVATION CONVERSION = C-D
KNOWN BENCHMARK (A)
MEASUREMENT (B)
PRESSURE TRANSDUCER WATER LEVEL (C)

APPENDIX C: DAILY PEAKS BELOW CULVERTS

BELOW CULVERT PEAKS

	LW	HW	LW	HW	date
1	0.6587072	1.5158048	1.1844872	1.7248976	4/10/11 14:30
2	0.6489536	1.5837752	1.1372432	1.7480624	4/11/11 15:18
3	0.640724	1.7498912	0.9540584	1.8099368	4/12/11 16:18
4	0.6343232	1.791344	0.6715088	1.730384	4/13/11 17:06
5	0.6273128	1.9032056	0.628532	1.8303584	4/14/11 17:54
6	0.6221312	2.042804	0.6373712	1.9059488	4/15/11 18:42
7	0.627008	2.160152	0.6782144	1.954412	4/16/11 19:30
8	0.66206	2.2208072	0.6855296	1.9434392	4/17/11 20:18
9	0.759596	2.253116	0.68492	1.9068632	4/18/11 21:18
10	0.8827352	2.2643936	0.6885776	1.9251512	4/19/11 22:06
11	1.0409264	2.250068	0.6815672	1.8010976	4/20/11 22:54
12	0.9949016	2.080904	0.6495632	1.7733608	4/21/11 23:42
13	1.1064584	1.9684328	0.6257888	1.770008	4/23/11 0:30
14	1.1930216	1.8708968	0.6221312	1.7590352	4/24/11 1:18
15	1.0546424	1.724288	0.6227408	1.718192	4/25/11 2:18
16	0.8949272	1.541408	0.6221312	1.6718624	4/26/11 3:06
17	0.788552	1.5115376	0.622436	1.7163632	4/27/11 3:54
18	0.6446864	1.5618296	0.6629744	1.7678744	4/28/11 4:42
19	0.6230456	1.4508824	0.622436	1.648088	4/29/11 5:30
20	0.6203024	1.4816672	0.6449912	1.824872	4/30/11 6:18
21	0.6221312	1.567316	0.7562432	1.9120448	5/1/11 7:18
22	0.6242648	1.6258376	0.8284808	1.9617272	5/2/11 8:06
23	0.6294464	1.6639376	0.9007184	2.0217728	5/3/11 8:54
24	0.6364568	1.6971608	1.0040456	2.0278688	5/4/11 9:42
25	0.645296	1.7099624	1.0671392	2.038232	5/5/11 10:30
26	0.6462104	1.7477576	1.1549216	2.0470712	5/6/11 11:18
27	0.649868	1.7815904	1.1753432	2.039756	5/7/11 12:18
28	0.6477344	1.777628	1.1704664	1.838588	5/8/11 13:06
29	0.6382856	1.7255072	1.075064	1.742576	5/9/11 13:54
30	0.6395048	1.8026216	0.9632024	1.738004	5/10/11 14:42
31	0.6434672	1.9001576	0.7208864	1.6941128	5/11/11 15:30
32	0.6459056	1.9553264	0.6489536	1.7005136	5/12/11 16:18
33	0.6446864	2.1040688	0.6855296	1.8260912	5/13/11 17:18
34	0.6739472	2.236352	0.7239344	1.9089968	5/14/11 18:06
35	0.7766648	2.236352	0.7172288	1.8955856	5/15/11 18:54
36	0.8711528	2.3457752	0.7434416	2.0004368	5/16/11 19:42
37	1.0345256	2.3914952	0.7562432	1.9379528	5/17/11 20:30
38	0.9994736	2.2765856	0.7211912	1.8977192	5/18/11 21:18
39	0.9991688	2.1747824	0.6907112	1.853828	5/19/11 22:18
40	1.0534232	2.080904	0.668156	1.8587048	5/20/11 23:06
41	1.0869512	1.9538024	0.6431624	1.8550472	5/21/11 23:54
42	1.094876	1.7788472	0.6416384	1.7575112	5/23/11 0:42
43	0.9476576	1.5484184	0.6373712	1.7590352	5/24/11 1:30

	LW	HW	LW	HW	date
44	0.8470736	1.497212	0.6748616	1.7742752	5/25/11 2:18
45	0.6571832	1.41644	0.681872	1.8257864	5/26/11 3:18
46	0.64682	1.4725232	0.7912952	1.8931472	5/27/11 4:06
47	0.6459056	1.5447608	0.8751152	1.9794056	5/28/11 4:54
48	0.645296	1.5804224	0.9123008	1.9845872	5/29/11 5:42
49	0.6459056	1.6304096	0.9525344	2.0492048	5/30/11 6:30
50	0.6516968	1.6965512	0.9976448	2.090048	5/31/11 7:18
51	0.6821768	1.738004	0.9888056	2.087	6/1/11 8:18
52	0.6751664	1.6904552	0.979052	2.0754176	6/2/11 9:06
53	0.6745568	1.7355656	1.0326968	2.0745032	6/3/11 9:54
54	0.6968072	1.8318824	1.0723208	2.068712	6/4/11 10:42
55	0.680348	1.8145088	1.061348	2.0318312	6/5/11 11:30
56	0.6672416	1.8215192	0.9619832	1.8620576	6/6/11 12:18
57	0.648344	1.914788	0.934856	1.7687888	6/7/11 13:18
58	0.645296	1.9717856	0.7760552	1.6718624	6/8/11 14:06
59	0.6462104	2.0254304	0.6593168	1.6322384	6/9/11 14:54
60	0.6602312	2.0964488	0.6965024	1.6721672	6/10/11 15:42
61	0.8214704	2.1854504	0.7190576	1.7514152	6/11/11 16:30
62	0.9223592	2.2293416	0.7254584	1.779152	6/12/11 17:18
63	0.95924	2.2448864	0.7221056	1.7931728	6/13/11 18:18
64	0.9659456	2.265308	0.7266776	1.8489512	6/14/11 19:06
65	1.03544	2.28512	0.7370408	1.9272848	6/15/11 19:54
66	1.0677488	2.2747568	0.7330784	1.9699568	6/16/11 20:42
67	1.0845128	2.1973376	0.7114376	1.9580696	6/17/11 21:30
68	1.0805504	2.1095552	0.6855296	1.9138736	6/18/11 22:18
69	1.04306	1.958984	0.6553544	1.9233224	6/19/11 23:18
70	1.0805504	1.7986592	0.6532208	1.933076	6/21/11 0:06
71	1.0845128	1.6712528	0.6934544	1.9541072	6/22/11 0:54
72	0.9406472	1.5222056	0.817508	1.9157024	6/23/11 1:42
73	0.7678256	1.4231456	0.8854784	1.937648	6/24/11 2:30
74	0.6657176	1.4615504	1.0351352	1.9836728	6/25/11 3:18
75	0.6623648	1.5267776	1.0921328	2.0111048	6/26/11 4:18
76	0.6648032	1.6407728	1.1719904	2.1001064	6/27/11 5:06
77	0.6931496	1.7413568	1.1768672	2.1574088	6/28/11 5:54
78	0.7114376	1.7407472	1.1216984	2.1485696	6/29/11 6:42
79	0.7068656	1.7514152	1.072016	2.1552752	6/30/11 7:30
80	0.7059512	1.792868	1.0540328	2.1881936	7/1/11 8:18
81	0.7114376	1.87364	1.0497656	2.181488	7/2/11 9:18
82	0.70778	1.9175312	0.9997784	2.11748	7/3/11 10:06
83	0.70016	1.9495352	0.9507056	2.0437184	7/4/11 10:54
84	0.6791288	1.9912928	0.857132	1.9263704	7/5/11 11:42
85	0.6654128	2.0446328	0.7882472	1.7907344	7/6/11 12:30
86	0.6687656	2.0897432	0.7172288	1.6871024	7/7/11 13:18
87	0.7806272	2.1564944	0.7251536	1.6959416	7/8/11 14:18

	LW	HW	LW	HW	date
88	0.922664	2.1979472	0.7342976	1.7084384	7/9/11 15:06
89	1.0174568	2.2369616	0.7434416	1.7370896	7/10/11 15:54
90	1.0467176	2.2451912	0.7452704	1.791344	7/11/11 16:42
91	1.0589096	2.2643936	0.7562432	1.84316	7/12/11 17:30
92	1.0083128	2.2476296	0.7501472	1.8407216	7/13/11 18:18
93	0.98972	2.207396	0.73064	1.8474272	7/14/11 19:18
94	0.899804	2.1522272	0.7193624	1.8648008	7/15/11 20:06
95	0.8687144	2.083952	0.698636	1.8733352	7/16/11 20:54
96	0.8583512	1.9882448	0.6699848	1.8965	7/17/11 21:42
97	0.8187272	1.8498656	0.6660224	1.8611432	7/18/11 22:30
98	0.8080592	1.6791776	0.6644984	1.8754688	7/19/11 23:18
99	0.8287856	1.56122	0.687968	1.9324664	7/21/11 0:18
100	0.835796	1.5267776	0.9007184	1.9519736	7/22/11 1:06
101	0.7154	1.4633792	1.0073984	1.9806248	7/23/11 1:54
102	0.6745568	1.4746568	1.0790264	1.9906832	7/24/11 2:42
103	0.674252	1.5234248	1.1079824	2.0324408	7/25/11 3:30
104	0.675776	1.6133408	1.0686632	2.0857808	7/26/11 4:18
105	0.6968072	1.6874072	1.094876	2.14034	7/27/11 5:18
106	0.7141808	1.763912	1.0561664	2.2013	7/28/11 6:06
107	0.7227152	1.8245672	0.9772232	2.2168448	7/29/11 6:54
108	0.7266776	1.8608384	0.8781632	2.1881936	7/30/11 7:42
109	0.724544	1.901072	0.8101928	2.1269288	7/31/11 8:30
110	0.713876	1.9166168	0.7172288	2.0446328	8/1/11 9:18
111	0.6904064	1.9656896	0.6928448	1.9568504	8/2/11 10:18
112	0.6745568	2.0239064	0.6891872	1.8358448	8/3/11 11:06
113	0.6748616	2.0333552	0.6861392	1.6529648	8/4/11 11:54
114	0.6754712	2.0495096	0.6992456	1.5974912	8/5/11 12:42
115	0.7592912	2.0738936	0.712352	1.581032	8/6/11 13:30
116	0.8949272	2.0726744	0.7141808	1.59932	8/7/11 14:18
117	0.947048	2.082428	0.719972	1.663328	8/8/11 15:18
118	0.9625928	2.1141272	0.7339928	1.7437952	8/9/11 16:06
119	0.9878912	2.1421688	0.742832	1.7812856	8/10/11 16:54
120	0.9010232	2.1183944	0.733688	1.791344	8/11/11 17:42
121	0.8138504	2.0888288	0.7239344	1.823348	8/12/11 18:30
122	0.79922	2.0482904	0.7035128	1.8367592	8/13/11 19:18
123	0.724544	1.9809296	0.6840056	1.84316	8/14/11 20:18
124	0.724544	1.8876608	0.6766904	1.8526088	8/15/11 21:06
125	0.6998552	1.7861624	0.6769952	1.8526088	8/16/11 21:54
126	0.6837008	1.6682048	0.6806528	1.8876608	8/17/11 22:42
127	0.6840056	1.5898712	0.7583768	1.920884	8/18/11 23:30
128	0.6876632	1.5069656	0.8629232	1.9260656	8/20/11 0:18
129	0.686444	1.4261936	0.9976448	1.8715064	8/21/11 1:18
130	0.6858344	1.422536	1.1003624	1.8693728	8/22/11 2:06
131	0.6855296	1.4871536	1.0799408	1.9510592	8/23/11 2:54

	LW	HW	LW	HW	date
132	0.6852248	1.5920048	1.0583 2.0135432	8/24/11 3:42	
133	0.691016	1.6813112	0.950096	2.0598728	8/25/11 4:30
134	0.7013792	1.7407472	0.8406728	2.0876096	8/26/11 5:18
135	0.7221056	1.7925632	0.724544	2.0818184	8/27/11 6:18
136	0.7160096	1.8513896	0.6958928	2.0754176	8/28/11 7:06
137	0.7172288	1.9394768	0.6977216	2.0345744	8/29/11 7:54
138	0.7044272	2.0053136	0.7010744	1.9736144	8/30/11 8:42
139	0.6974168	2.077856	0.727592	1.9129592	8/31/11 9:30
140	0.7010744	2.0940104	0.7312496	1.7843336	9/1/11 10:18
141	0.7056464	2.1025448	0.7324688	1.738004	9/2/11 11:18
142	0.8290904	2.1116888	0.73826	1.6718624	9/3/11 12:06
143	0.9369896	2.0735888	0.7288112	1.6499168	9/4/11 12:54
144	0.9991688	2.0239064	0.7050368	1.6352864	9/5/11 13:42
145	0.9403424	1.9800152	0.6995504	1.663328	9/6/11 14:30
146	0.8345768	1.9684328	0.6995504	1.7276408	9/7/11 15:18
147	0.8153744	2.0037896	0.7022936	1.8093272	9/8/11 16:18
148	0.7830656	2.0193344	0.7074752	1.9083872	9/9/11 17:06
149	0.7955624	2.0043992	0.70778	1.899548	9/10/11 17:54

APPENDIX D: DAILY PEAKS ABOVE CULVERTS

ABOVE CULVERT PEAKS

	LW	HW	LW	HW	date
1	1.29613	1.47444	1.29095	1.67957	4/10/11 14:30
2	1.28302	1.53967	1.27967	1.70395	4/11/11 15:18
3	1.27297	1.70426	1.26961	1.76461	4/12/11 16:18
4	1.26413	1.74602	1.26230	1.68597	4/13/11 17:06
5	1.25376	1.85788	1.25407	1.78594	4/14/11 17:54
6	1.24431	1.99839	1.26626	1.86306	4/15/11 18:42
7	1.24736	2.11391	1.30924	1.91366	4/16/11 19:30
8	1.25834	2.17091	1.32600	1.90055	4/17/11 20:18
9	1.26596	2.20230	1.32966	1.86519	4/18/11 21:18
10	1.26961	2.21327	1.33515	1.88409	4/19/11 22:06
11	1.27510	2.20108	1.32753	1.75973	4/20/11 22:54
12	1.27175	2.03588	1.27845	1.73139	4/21/11 23:42
13	1.25681	1.92585	1.24431	1.72773	4/23/11 0:30
14	1.23913	1.82923	1.23121	1.71736	4/24/11 1:18
15	1.22999	1.68231	1.22420	1.67469	4/25/11 2:18
16	1.22328	1.49852	1.22237	1.62897	4/26/11 3:06
17	1.22206	1.46804	1.21993	1.67347	4/27/11 3:54
18	1.22145	1.51742	1.21871	1.72437	4/28/11 4:42
19	1.22298	1.40738	1.21871	1.60306	4/29/11 5:30
20	1.21963	1.44000	1.21566	1.78015	4/30/11 6:18
21	1.17726	1.52534	1.21871	1.86641	5/1/11 7:18
22	1.22328	1.58630	1.22024	1.91792	5/2/11 8:06
23	1.22359	1.61830	1.21993	1.97309	5/3/11 8:54
24	1.22664	1.65427	1.22206	1.98254	5/4/11 9:42
25	1.22938	1.66951	1.22420	1.99473	5/5/11 10:30
26	1.22999	1.70792	1.22664	2.00327	5/6/11 11:18
27	1.23426	1.73870	1.23212	1.99534	5/7/11 12:18
28	1.23426	1.73596	1.23090	1.79387	5/8/11 13:06
29	1.22481	1.68140	1.22511	1.69725	5/9/11 13:54
30	1.22206	1.75851	1.22633	1.69542	5/10/11 14:42
31	1.22145	1.85696	1.22725	1.64726	5/11/11 15:30
32	1.22206	1.91061	1.23151	1.65762	5/12/11 16:18
33	1.22481	2.05783	1.28302	1.78015	5/13/11 17:18
34	1.24371	2.18401	1.34490	1.86428	5/14/11 18:06
35	1.25955	2.18310	1.33850	1.85087	5/15/11 18:54
36	1.29491	2.28612	1.37294	1.95511	5/16/11 19:42
37	1.29430	2.33093	1.38513	1.88744	5/17/11 20:30
38	1.29186	2.21846	1.35221	1.85239	5/18/11 21:18
39	1.27479	2.12366	1.31686	1.81002	5/19/11 22:18
40	1.26413	2.03375	1.28211	1.81551	5/20/11 23:06
41	1.25773	1.90939	1.24218	1.81246	5/21/11 23:54
42	1.24127	1.73382	1.23487	1.71615	5/23/11 0:42
43	1.23487	1.50461	1.23060	1.71615	5/24/11 1:30

	LW	HW	LW	HW	date
44	1.23365	1.45493	1.23182	1.72986	5/25/11 2:18
45	1.23456	1.37142	1.23029	1.78320	5/26/11 3:18
46	1.23517	1.42902	1.22907	1.84904	5/27/11 4:06
47	1.23609	1.50096	1.23212	1.93408	5/28/11 4:54
48	1.23944	1.53967	1.23365	1.94078	5/29/11 5:42
49	1.23913	1.58691	1.23517	2.00540	5/30/11 6:30
50	1.25133	1.65153	1.24431	2.04381	5/31/11 7:18
51	1.28821	1.69115	1.25955	2.04167	6/1/11 8:18
52	1.27754	1.64848	1.25834	2.02978	6/2/11 9:06
53	1.28089	1.69115	1.26443	2.02857	6/3/11 9:54
54	1.30406	1.78686	1.27144	2.02247	6/4/11 10:42
55	1.29247	1.77101	1.27358	1.98650	6/5/11 11:30
56	1.27053	1.77680	1.26016	1.81703	6/6/11 12:18
57	1.24157	1.87220	1.24614	1.72620	6/7/11 13:18
58	1.23456	1.93072	1.24523	1.62958	6/8/11 14:06
59	1.23243	1.98345	1.25620	1.59026	6/9/11 14:54
60	1.23548	2.05295	1.27114	1.62928	6/10/11 15:42
61	1.21048	2.13738	1.31259	1.70822	6/11/11 16:30
62	1.21963	2.18005	1.32173	1.73657	6/12/11 17:18
63	1.22145	2.19499	1.31991	1.75242	6/13/11 18:18
64	1.22237	2.21602	1.33027	1.80880	6/14/11 19:06
65	1.22968	2.23491	1.34124	1.88622	6/15/11 19:54
66	1.23974	2.22455	1.33667	1.92890	6/16/11 20:42
67	1.24005	2.15109	1.30253	1.91762	6/17/11 21:30
68	1.23029	2.06545	1.25955	1.87556	6/18/11 22:18
69	1.21688	1.91884	1.19799	1.88561	6/19/11 23:18
70	1.20286	1.75882	1.19189	1.89659	6/21/11 0:06
71	1.19738	1.63233	1.18976	1.91640	6/22/11 0:54
72	1.19768	1.48236	1.19280	1.87647	6/23/11 1:42
73	1.19646	1.38452	1.18793	1.89720	6/24/11 2:30
74	1.19311	1.42079	1.18945	1.94139	6/25/11 3:18
75	1.19768	1.48419	1.19158	1.96852	6/26/11 4:18
76	1.19951	1.59819	1.19402	2.05661	6/27/11 5:06
77	1.24005	1.69877	1.24005	2.11117	6/28/11 5:54
78	1.26474	1.69877	1.21871	2.10385	6/29/11 6:42
79	1.25529	1.71096	1.21048	2.11178	6/30/11 7:30
80	1.25407	1.75425	1.20896	2.14317	7/1/11 8:18
81	1.26413	1.83532	1.21292	2.13768	7/2/11 9:18
82	1.26199	1.88074	1.21566	2.07581	7/3/11 10:06
83	1.24828	1.91152	1.21201	2.00357	7/4/11 10:54
84	1.21353	1.95480	1.20804	1.88622	7/5/11 11:42
85	1.18854	2.00601	1.22999	1.74967	7/6/11 12:30
86	1.19250	2.04990	1.26382	1.64574	7/7/11 13:18
87	1.19859	2.11421	1.29369	1.65336	7/8/11 14:18

	LW	HW	LW	HW	date
88	1.21201	2.15292	1.30954	1.66677	7/9/11 15:06
89	1.21414	2.18950	1.32265	1.69420	7/10/11 15:54
90	1.21871	2.19803	1.33027	1.75028	7/11/11 16:42
91	1.22237	2.21754	1.34185	1.80240	7/12/11 17:30
92	1.23334	2.20139	1.33606	1.80118	7/13/11 18:18
93	1.22907	2.16237	1.31107	1.80911	7/14/11 19:18
94	1.22359	2.10842	1.29156	1.82618	7/15/11 20:06
95	1.21871	2.04228	1.25620	1.83532	7/16/11 20:54
96	1.21079	1.94779	1.19616	1.85971	7/17/11 21:42
97	1.19219	1.81033	1.18427	1.82587	7/18/11 22:30
98	1.18671	1.63934	1.17787	1.84020	7/19/11 23:18
99	1.18549	1.52229	1.17391	1.89628	7/21/11 0:18
100	1.18671	1.48785	1.17634	1.91335	7/22/11 1:06
101	1.18488	1.42262	1.17299	1.94109	7/23/11 1:54
102	1.17939	1.43390	1.17269	1.95023	7/24/11 2:42
103	1.17756	1.48236	1.17726	1.99077	7/25/11 3:30
104	1.18854	1.57289	1.17391	2.04411	7/26/11 4:18
105	1.22755	1.64787	1.17726	2.09775	7/27/11 5:18
106	1.25041	1.72407	1.20408	2.15750	7/28/11 6:06
107	1.26535	1.78747	1.20621	2.17213	7/29/11 6:54
108	1.26961	1.82100	1.20225	2.14347	7/30/11 7:42
109	1.26596	1.86153	1.20317	2.08465	7/31/11 8:30
110	1.24950	1.87769	1.19433	2.00296	8/1/11 9:18
111	1.20743	1.92768	1.17909	1.91487	8/2/11 10:18
112	1.17177	1.98528	1.19067	1.79539	8/3/11 11:06
113	1.17177	1.99504	1.20561	1.61282	8/4/11 11:54
114	1.17238	2.01028	1.23029	1.55552	8/5/11 12:42
115	1.17543	2.03314	1.24950	1.53936	8/6/11 13:30
116	1.17939	2.03070	1.25133	1.55856	8/7/11 14:18
117	1.17756	2.03954	1.25834	1.62440	8/8/11 15:18
118	1.17665	2.07246	1.28089	1.70517	8/9/11 16:06
119	1.18366	2.10019	1.29552	1.73992	8/10/11 16:54
120	1.19158	2.07581	1.28424	1.75120	8/11/11 17:42
121	1.19097	2.04716	1.26565	1.78686	8/12/11 18:30
122	1.18305	2.00784	1.22999	1.79966	8/13/11 19:18
123	1.17665	1.94139	1.17452	1.80271	8/14/11 20:18
124	1.16964	1.84690	1.17086	1.81368	8/15/11 21:06
125	1.16872	1.74510	1.16933	1.81368	8/16/11 21:54
126	1.16842	1.62806	1.16751	1.84843	8/17/11 22:42
127	1.16811	1.54668	1.16751	1.88165	8/18/11 23:30
128	1.16872	1.46499	1.16842	1.88592	8/20/11 0:18
129	1.16872	1.38544	1.16781	1.82923	8/21/11 1:18
130	1.16811	1.38117	1.16811	1.82557	8/22/11 2:06
131	1.16751	1.44579	1.16872	1.90878	8/23/11 2:54

	LW	HW	LW	HW	date
132	1.16903	1.55795	1.16994	1.97766	8/24/11 3:42
133	1.17939	1.64574	1.17452	2.02308	8/25/11 4:30
134	1.19677	1.70426	1.17482	2.04990	8/26/11 5:18
135	1.22938	1.75821	1.18396	2.04350	8/27/11 6:18
136	1.23182	1.81490	1.18488	2.03771	8/28/11 7:06
137	1.23273	1.90421	1.18793	1.99473	8/29/11 7:54
138	1.20042	1.96943	1.19158	1.93499	8/30/11 8:42
139	1.17909	2.04076	1.25529	1.87403	8/31/11 9:30
140	1.19463	2.05508	1.26199	1.74632	9/1/11 10:18
141	1.18518	2.06453	1.26230	1.70334	9/2/11 11:18
142	1.19037	2.07368	1.27083	1.63446	9/3/11 12:06
143	1.19219	2.03466	1.24919	1.61129	9/4/11 12:54
144	1.18610	1.98285	1.20103	1.60215	9/5/11 13:42
145	1.17543	1.94017	1.17970	1.62653	9/6/11 14:30
146	1.17391	1.93377	1.17726	1.69146	9/7/11 15:18
147	1.17360	1.96943	1.18305	1.77345	9/8/11 16:18
148	1.17452	1.98224	1.19219	1.87525	9/9/11 17:06
149	1.17756	1.97218	1.18854	1.86794	9/10/11 17:54

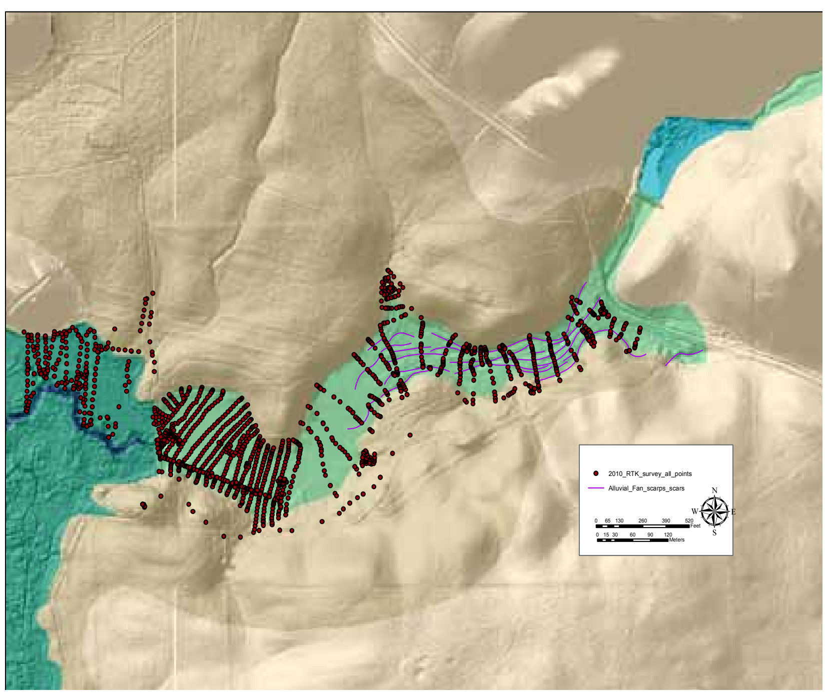
APPENDIX E: WATER SURFACE ELEVATION MODEL METHODS

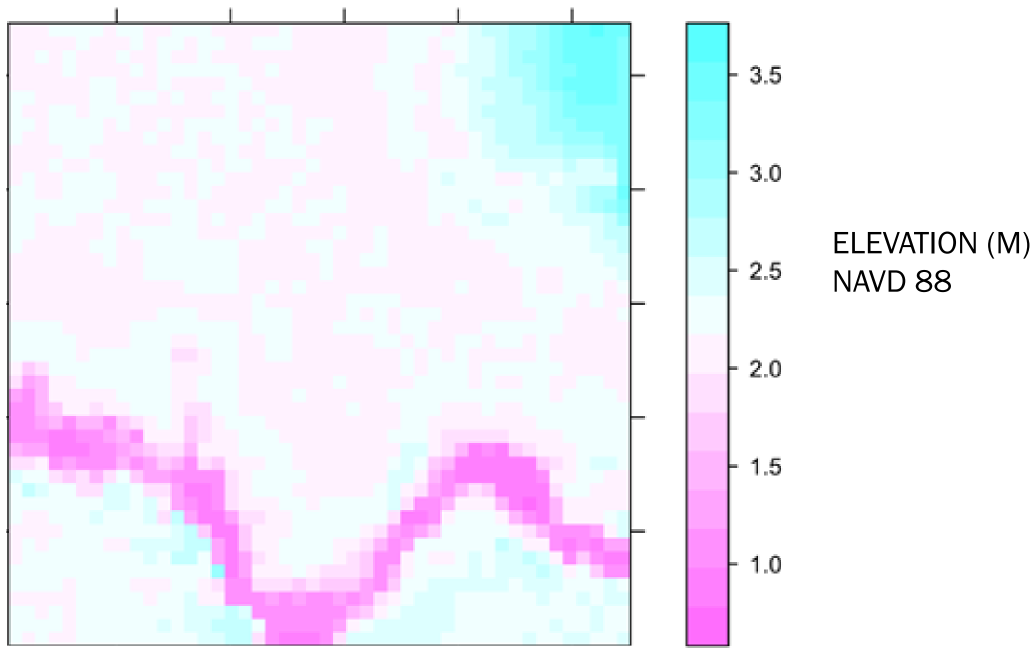
WATER SURFACE ELEVATION MODEL METHODS

I developed a water elevation surface model in GIS using a topographic surface model and the high and low values for each of the four tidal water elevations. To do this, I created a ground surface digital elevation model (DEM) of lower Spring Branch Creek Watershed, using 2007 DWR LiDAR bear earth xyz files and RTK GPS ground surveys conducted in 2009. There were several steps necessary to create this surface model.

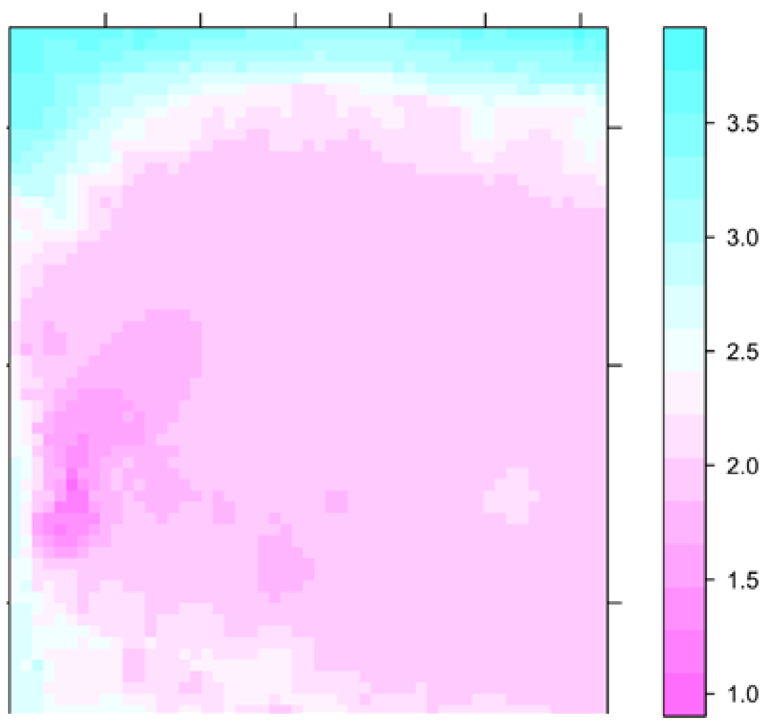
First, I tested the LiDAR accuracy. I brought the two XYZ file sources (point files that have three dimensional coordinates) into ArcScene in order to see whether the ground survey XYZ and LiDAR XYZ differed from one another. I found up to a half a meter difference in elevations between ground survey and LiDAR in areas within the marsh and lower Spring Branch Creek. Of particular error were areas with taller vegetation such as cattails and bull rush indicating that the LiDAR bare earth model may actually be a model of vegetation surface (not ground). In the upland habitats (grasslands) LiDAR appears to be hitting the actual ground surface, as there was no detectable difference between the two. Because of the inaccuracy of LiDAR observed within the marsh, I only used RTK data locations to assess differences in water elevations above and below the culverts Marsh areas that were not part of RTK ground survey are indicated on Figure 7. In addition, in order to ensure accuracy of the hypsometric diagram, I created two new DEMs derived only from ground survey xyz points (DEMs shown below).

To produce a DEM for the entire lower Spring Branch Creek cooridor, I digitized two clipping boundaries (1) of the Spring Branch Creek watershed and (2) boundary shapefile for the ground survey location. Then, I appended the two boundary files, selected only the Spring Branch Creek boundary and exported that as a new shapefile. This new shapefile had a "donut hole" where the ground survey data exists. Next, I clipped the ground survey XYZ points to ground survey boundary, and the LiDAR XYZ data to the Spring Branch Creek donut hole boundary. After appending the two xyz files, I created an Inverse Distance Weight (IDW) interpolated surface model using 3D analyst tools. Lastly, I reclassified the IDW raster to display the range of high and low tidal elevations.





DIGITAL ELEVATION MODEL USED IN HYPSOMETRIC DIAGRAM : BELOW CULVERTS



DIGITAL ELEVATION MODEL USED IN HYPSOMETRIC DIAGRAM : ABOVE CULVERTS

APPENDIX F: REFERENCE SITE COMPARISON

REFERENCE SITE COMPARISON: BENICIA

On November 25th, 2011 I visited the Spring Branch Creek Restoration project site and Benicia State Recreation Area to (1) investigate whether the projected high tide inundated the soft bird's beak populations at the two sites (2) to ground-truth the accuracy of the correlation between water inundation and vegetation shown in the hypsometric diagrams and water elevation model. I timed my visit to the two sites to occur as close as possible to the high tides, although travel time between the two site prevented me from visiting Benicia at peak high tide. I also collected site photos, and noted the general stature and elevation range occupied by the populations.

I visited the Rush Ranch site first, arriving at 1:00. The high tide for Rush Ranch was 1.88 meters (MLLW) at 1:14 according to the closest station, Joice Island Station (ID no. 9415379). The high tide reached just below the population, not inundating the population. Since the tide was projected to be within a lower range than the water elevations that correspond to soft bird's beak (1.99-2.3 m), this corresponds with my model results.

I arrived at Benicia at 2:30, 1.5 hours after high tide. The observed high tide for Benicia State Recreation area was 2.089 meters (NAVD 88) at 12:54 PM for Benicia according to the closest station, Port Chicago Station (ID no. 9415144). At 2:30 PM the tide was recorded at 1.87 meters (NAVD 88). The tide was inundating the soft bird's beak populations. In addition, the Benicia population was far more extensive, occupying a broader range within the marsh plain than the population at Rush Ranch. Further, it was much larger in stature (Appendix F).

The finding that during the same tide cycle, the Benicia population was inundated, while Rush Ranch population was not, indicates that soft bird's beak may be able to persist at higher rates of inundation than currently experienced at Rush Ranch. Supporting this observation, Grewell's 2003 hydrological assessment found the Benicia site to have greater inundation frequency compared to Rush Ranch (Grewell et al. 2003). The observation that the Benicia population appears more robust than the Rush Ranch population indicates that the environmental conditions (perhaps including hydrological conditions) at Benicia may be more suitable for the bird's beak. Previous studies and observation indicating greater population health and stature of the Benecia population compared to Rush Ranch population also suggest that the Benicia population is in better condition than the Rush Ranch population because of the increased frequency of inundation (Brenda Grewell pers. comm, December 2011.).

However, this comparison can only have limited value since this observation did not occur while I was actively collecting data at Spring Branch Creek, I cannot adequately test the water surface model projections.

REFERENCE SITE COMPARISON: RUSH RANCH

I compared the water elevation (inundation) range observed for a naturally occurring population of soft bird's beak at Rush Ranch's Second Mallard Slough drainage area to water elevations observed for the introduced Spring Branch Creek population. Ground elevation and water elevation ranges for the natural population were acquired from UC Berkeley PhD candidate Lisa Schile. Schile documented the location and ground elevation of soft bird's beak using an RTK GPS, tied to the secondary benchmark at Indian Grinding Rock Hill (NAVD 88 meters). Schile provided the maximum and mean water elevations for HHW and LHW for the same period of record as the Spring Branch Creek/First Mallard Slough data. The water elevation station was located within Second Mallard Slough, approximately a half mile from the population.

Results indicate that the introduced Spring Branch Creek population persists with less inundation frequency than the natural population in the southern portion of the Rush Ranch property. The natural population occurs between MHHW and MLHW (1.69-2 meters), and is inundated every tidal day compared to the population within Spring Branch Creek that occurs between spring tide HHW and MHHW (2-2.4 m), and is inundated 50% of tidal days. Soft bird's beaks presence at lower water elevation areas indicates that the soft birds beak has potential to occur under more frequent rates of inundation. However, the natural population is located in a marsh area that is surrounded by mosquito ditches, which may actually increase in drainage and dampen the tidal range at this location. Because the water elevation data was not collected within a proximity necessary to capture changes in hydrology due to mosquito ditching, this comparison has limited value.

BENICIA STATE RECREATION AREA
Notes: Soft bird's beak occurs in a much wider band when compared to the Spring Branch Creek population.

RUSH RANCH
Notes: Soft bird's beak at Spring Branch Creek occupies a much narrower range than the Benicia population.

BENICIA STATE RECREATION AREA

Notes: Soft bird's beak at Benicia appears to be a more robust population, larger in stature when compared to the Spring Branch Creek population. Photo taken by Jessie Olson on November 25th.

RUSH RANCH

Notes: Soft bird's beak at Spring Branch Creek is less robust and smaller in stature than the Benicia population. Photo taken by Jessie Olson on November 25th.