Lower Jacoby Creek Estuary Enhancement Conceptual Design Alternatives

For the City of Arcata Baylands Project

Prepared for:

City of Arcata, and

California Department of Fish and Game

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Prepared under the supervision of:

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1. Introduction

1.1. Background

The City of Arcata is proposing to restore and enhance tidal wetland function to Lower Jacoby Creek and its adjacent northerly pasture, an area that historically sustained extensive estuarine and salt marsh habitat. Currently the Lower Jacoby Creek system has limited function due to: (1) in-channel flood flow loss upstream and downstream of Old Arcata Road; (2) channel constriction (aggradation and levees) through the coastal plain reach; (3) hydrologic disconnection of the channel from the adjacent floodplain (pasturelands); and (4) a rapid transition between the freshwater and saltwater zone (i.e. stream-estuary ecotone).

This project consists of developing conceptual design alternatives for enhancing estuarine and intertidal habitats by reconnecting pasturelands to Gannon Slough and Jacoby Creek. It is anticipated that the restored tidal exchange will enhance mudflat, slough channel and tidal wetland habitats.

As part of a California Department of Fish & Game Grant (Grant No. P0410312), the City of Arcata retained Jeff Anderson & Associates (JAA) to help prepare conceptual design alternatives.

1.2. Project Location

The Jacoby Creek watershed drains the easterly forested mountains surrounding Humboldt Bay, California. The 15.6 square mile watershed flows east to west ultimately draining into North Bay. Approximately 3 miles upstream from North Bay, Jacoby Creek flows across pasturelands of the Eureka Plain through an aggraded and leveed channel. Within this 3 mile reach Jacoby Creek flows under three bridges, one at Old Arcata Road and two at Highway 101.

This conceptual design phase focuses on the lower 800 feet of Jacoby Creek upstream of Highway 101 and the adjacent northerly pasture (project area) shown in Figure 1-1. Also shown on this figure are the common names of adjacent pastures, roads, creeks and sloughs used in this report.

1.3. Project Limitations

This work focused on developing conceptual design alternatives for the project area based on the existing available data and information. Since the extent of tidal inundation of the project area was the major identified constraint, the major effort of this work focused on analyzing the increased tidal prism of each conceptual alternative, and understanding the extent, elevation and duration of tidal flooding within the project area under a range of tidal and streamflow conditions. The analysis of each alternative also focused on understanding the increased flooding potential, if any, by allowing a larger tidal prism into the project area.

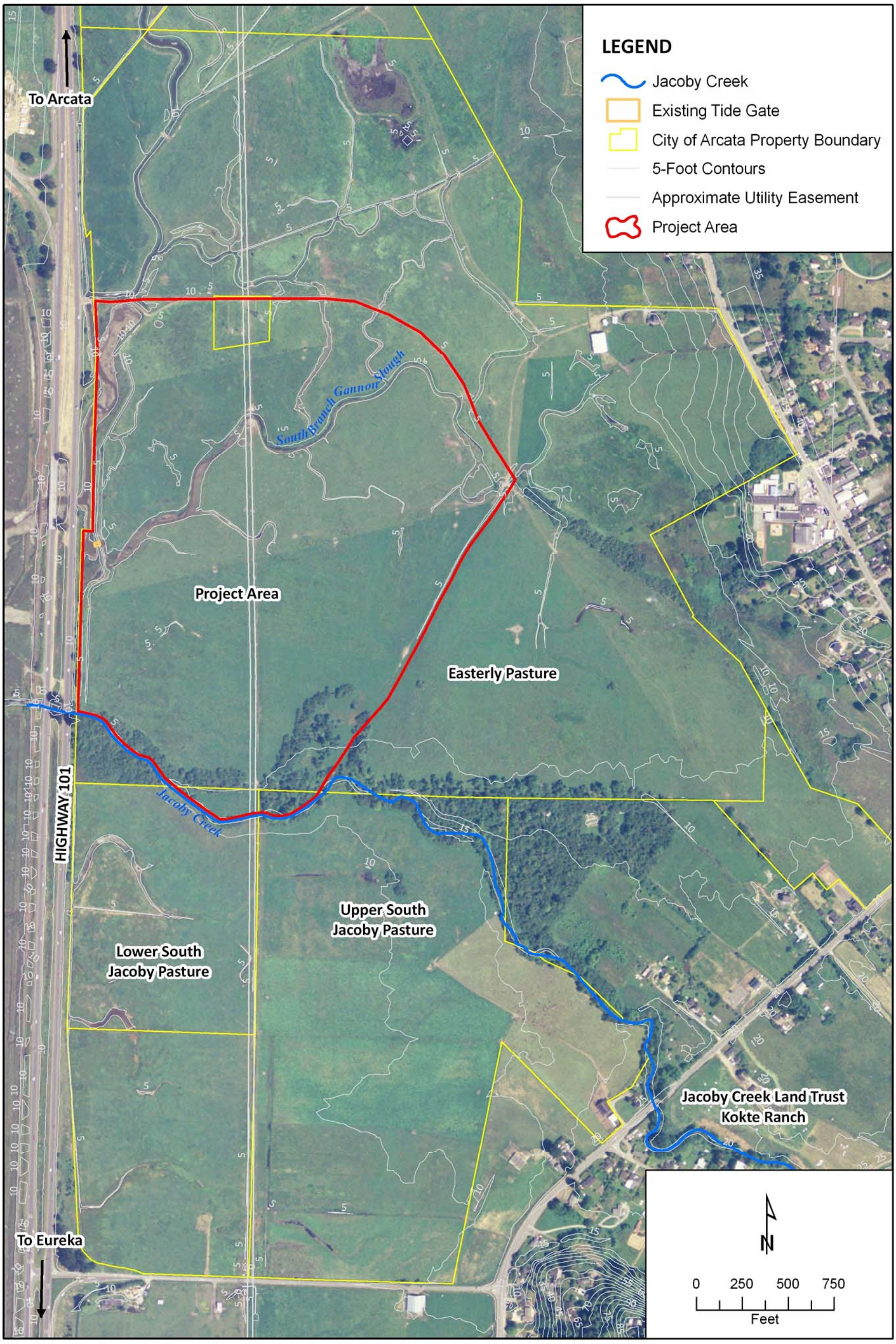

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Figure 1-1 Location and general vicinity map.

2. Historic Changes and Conceptual Models of Lower Jacoby Creek

2.1. Historic Changes to Lower Jacoby Creek

A review of historic maps and photos (Figure 2-1) indicates that Lower Jacoby Creek and estuary were part of a larger tidal wetland complex with multiple and sometimes interconnected slough channels that drained to Humboldt Bay. Higher flow events that overtopped the banks along Lower Jacoby Creek likely flowed laterally north towards Gannon Slough and south towards Brainard Slough. Between 1870 and 1916 a levee was constructed along a parcel line that borders the northern bank (right bank) of Jacoby Creek, disconnecting the stream channel from the north bank floodplain and tidal wetland system.

The following provides a brief history of the conditions and changes that have occurred to Lower Jacoby Creek and estuary over time (Figure 2-1).

2.1.1. 1870 U. S. Coast Survey Map

The 1870 U. S. Coast Survey Map of Humboldt Bay illustrates the Jacoby Creek estuary prior to development:

- Pre-railways, levees or bay front roads,
- Extent of historic salt marsh habitat and the density of slough channels,
- Dendritic channel formation typical of tidal systems,
- Narrow single thread channel of Jacoby Creek at the approximate location it occupies today,
- Small branch slough channels on Lower Part of Jacoby Creek,
- During overbank events Jacoby Creek could spread across tidal wetland towards slough channels to north and south.

2.1.2. 1916 U.S. Army Map

The 1916 U.S. Army Map shows the Jacoby Creek estuary post-railway development:

- Roads, railroads and/or levees ran north-south and bisected Jacoby Creek and adjacent slough channels,
- Jacoby Creek appears to be draining into the slough channel south of what is considered the main channel today (could be a mapping error),
- South Branch Gannon Slough is not mapped,
- It's likely that tidal wetlands adjacent to Jacoby Creek were converted for agricultural uses.

2.1.3. 1931 Aerial Photograph

The 1931 aerial photograph shows the highway has been built (2 lanes) and a number of the slough channels have been blocked from tidal inundation:

- Jacoby Creek is flowing through a single-thread, leveed channel,
- Slough channels are visible, north of the creek,
- A large levee extends along the north edge of Jacoby Creek west towards North Bay, then extends north-east towards Gannon Slough, this is the right bank levee that exists along Lower Jacoby Creek today,
- Riparian channel is intact within the lower channel perhaps indicating a limited estuary (tide water – fresh water ecotone).

2.1.4. 1958 Aerial Photograph

The 1958 aerial photograph shows Jacoby Creek estuary after Highway 101 is changed from a 2-lane to a 4-lane highway (north-bound lanes have been added):

- Jacoby Creek flows straight into North Bay, an oxbow was created upstream of Highway 101, which could have occurred during expansion of the highway,
- The oxbow is still visible,
- It appears that the Jacoby Creek delta/tidal marsh is expanding into North Bay,
- Slough channels are becoming less pronounced.

2.1.5. 1988 Aerial Photograph

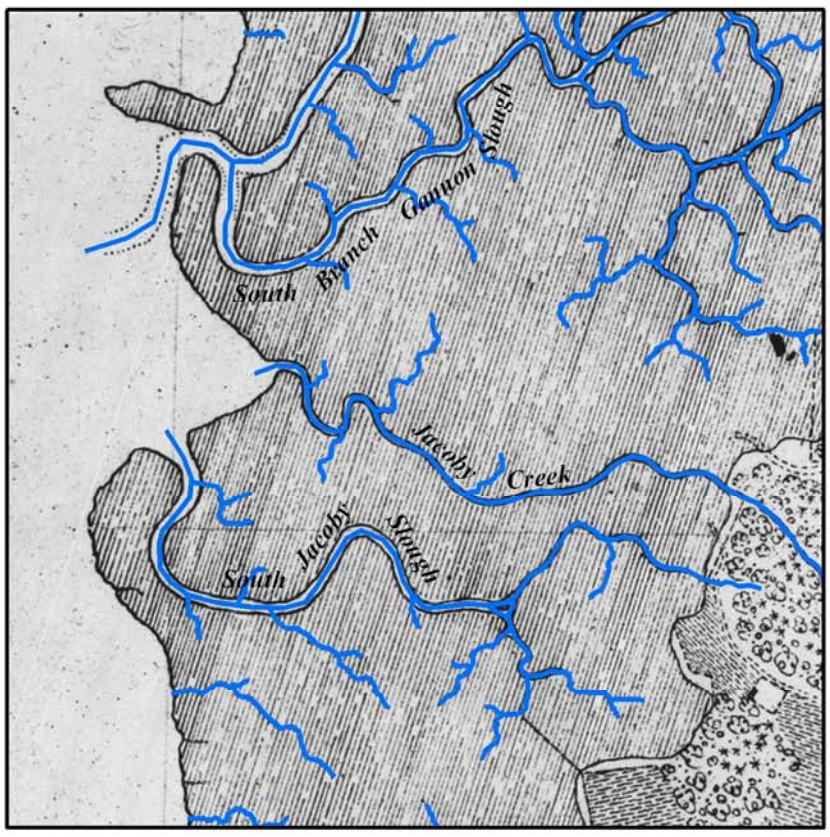
The 1988 aerial photograph shows Lower Jacoby Creek and estuary in its current alignment:

- The oxbow is not visible and has overgrown with vegetation,
- The Jacoby Creek delta/tidal marsh continues to form bay ward into North Bay,
- The mouth of Jacoby Creek runs straight west in North Bay and appears to have abandoned its historic north-west flowing slough channel, perhaps an effect of rapid delta formation, and/or being captured by another slough channel.

2.1.6. 2005 Aerial Photograph

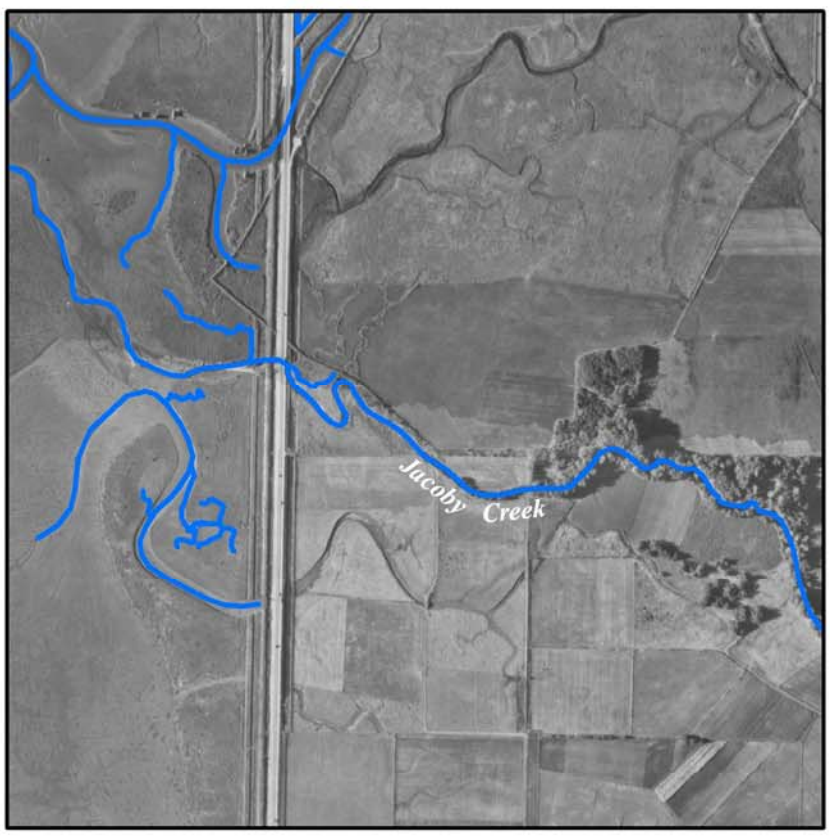
The 2005 aerial photograph shows Lower Jacoby Creek and estuary in its current alignment:

- The Jacoby Creek delta/tidal marsh continue to form into North Bay, increasing the complexity of the channels, bay ward of the highway,
- Slough channels north of Jacoby Creek appear to have filled in.

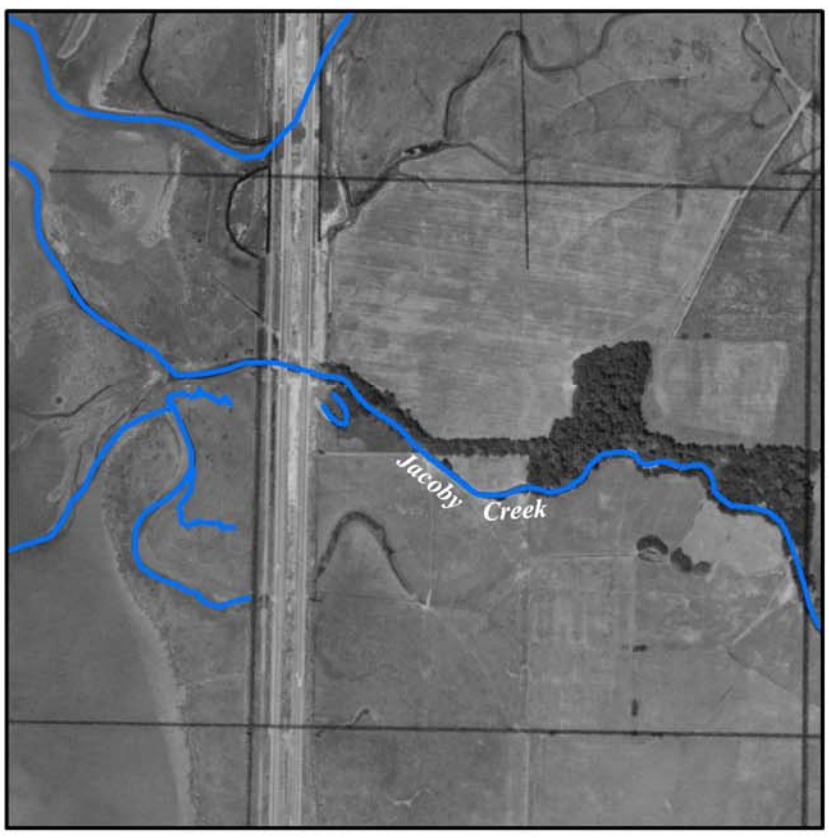


1870 U.S. Coast Survey Map

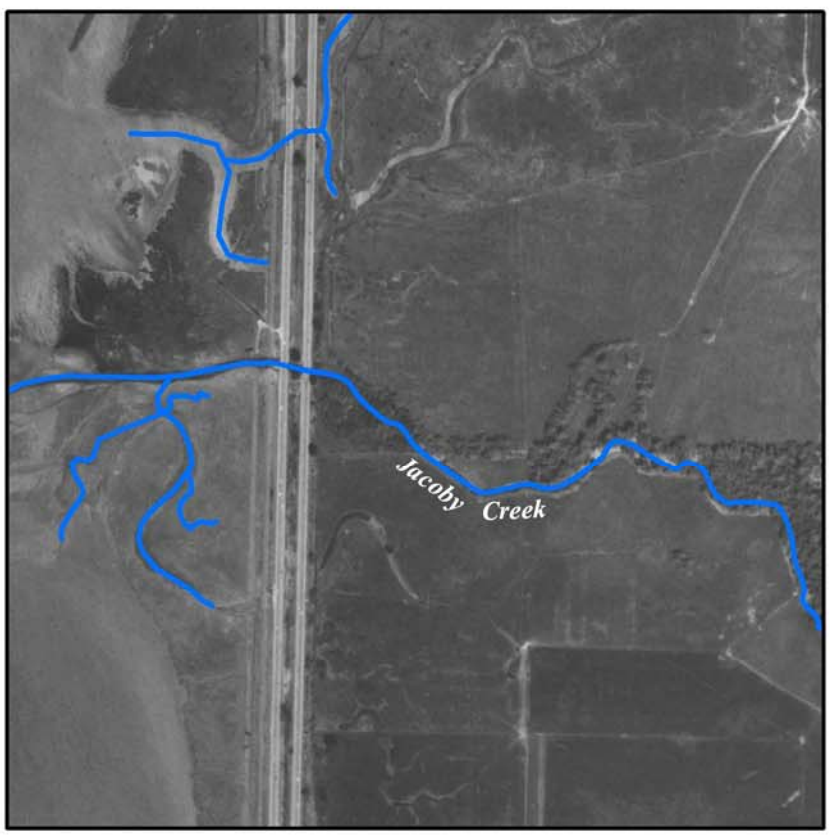
1916 U.S. Army Map



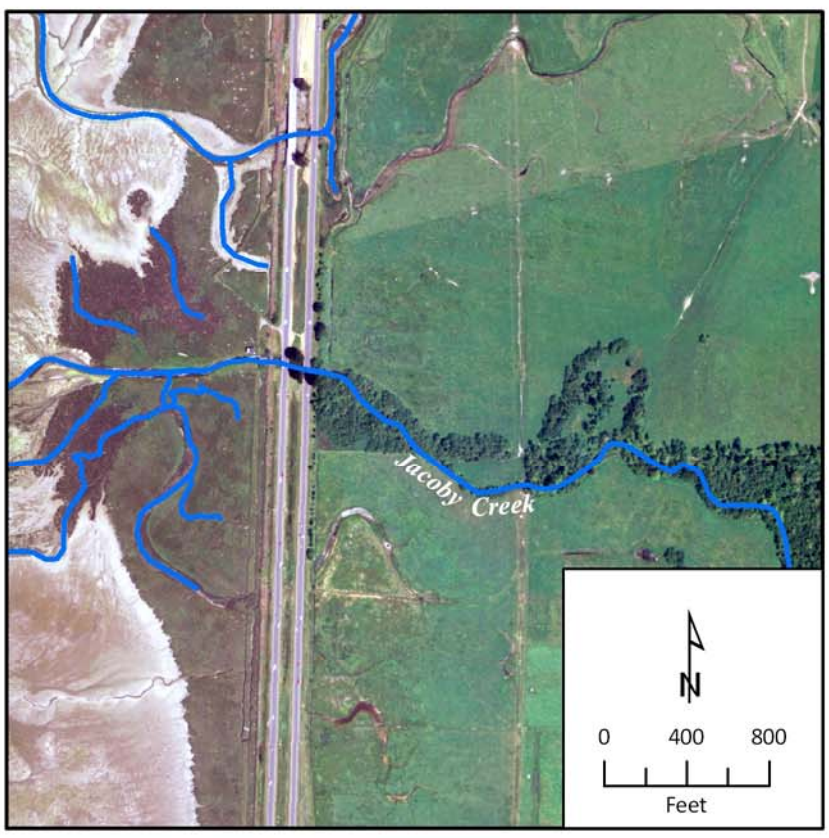
1931 Aerial Photograph



1958 Aerial Photograph



1988 Aerial Photograph



2005 Aerial Photograph

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Figure 2-1 Historical Evolution of the Jacoby Creek Estuary.

2.2. Conceptual Model of the Geomorphic Evolution of Jacoby Creek Proposed by Phillip Williams & Associates

In 2000 the Coastal Conservancy requested Philip Williams and Associates (PWA) to outline preliminary concepts for the lower part of Jacoby Creek. As part of that work, PWA developed a conceptual model of the geomorphic evolution of Jacoby Creek, which is repeated below (PWA, 2000, page 5):

> "While some geomorphic studies have been carried out on Jacoby creek (e.g. Lisle, Turtle) they do not appear to describe the floodplain and wetland landscape in the lower 1.5 miles. In the absence of a geomorphic analysis or of detailed topography, the following describes a conceptual model based only on a generalized understanding of floodplain/estuarine transitions, and a review of USGS 7.5 minute topography, aerial photos and a site visit. This conceptual model underlies the rationale for elements of the restoration concept described in succeeding sections.
>
> In its natural state sediments deposited by overbank flows created low natural levees and a floodplain that sloped away from the channel near the mouth of Jacoby Creek. The riparian corridor would have been wooded with large trees that were progressively undermined by channel migration and bank erosion creating a complex structure of fallen trees, scour holes, bars and pools. The floodplain may also have been wooded or was wet meadow sustained by high water tables just above the area of tidal influence. Here the floodplain intersected with a flat vegetated marshplain formed of estuarine sediments and peat accumulation at about the Mean Higher High water level. In the lower part of Jacoby Creek backwater from high tides would cause floodflows to spill out of the channel forming a natural riparian leveed corridor extending into the tidal marsh. During major flood events overflow onto the floodplain would tend to be concentrated by fallen trees into pools or parallel channels that might drain back into the main channel further downstream. Closer to the mouth flood overflows would be captured by tidal sloughs that fed tidal water onto the marshplain.
>
> Over the last 150 years this river system was substantially altered by clearing of the floodplain woodland and leveling of floodplain fields, thereby eliminating back channels and pools and reducing the complexity of floodplain habitat. Clearing and grazing also greatly reduced the amount of woody debris in the river channel allowing it to create a more simple form and significantly reducing the amount of pools and overhanging structure. Logging in the watershed greatly increased sediment delivery probably causing significant creekbed aggradation and filling of pools. The construction of roads and bridges 'pinched' the ability of the creek channel to migrate laterally as well as possibly increasing flood elevations upstream. Diking and draining of the tidal wetlands caused them to subside. Channel straightening and levee construction isolated the stream from the former wetlands and speeded up floodflows simplifying habitat structure.
>
> Over the next 100 year with no action taken to protect and restore the riparian corridor, the creek channel will continue to migrate and erode banks making it likely that individual landowners will attempt to harden or artificially control erosion, thereby degrading riparian habitat; in addition continued grazing will prevent recruitment of new riparian woodland leading to further degradation; sediment delivery may decline causing long term channel incision; and sea level will rise causing water-logging of low-lying areas and increased maintenance costs for dikes and drains."

2.3. Revised Conceptual Model and Vision of Lower Jacoby Creek Proposed by Jeff Anderson (Jeff Anderson & Associates) and Darren Mierau (McBain & Trush)

Recently Darren Mierau (McBain & Trush) and Jeff Anderson (JAA) have expanded on the PWA conceptual model based on ongoing work and field observations within Lower Jacoby Creek. As part of a recent California Department of Fish and Game grant proposal submitted by the Jacoby Creek Land Trust, they developed the following summary of their expanded conceptual model and vision for Lower Jacoby Creek, portions of which are repeated below:

Background Information

Jacoby Creek has limited functioning estuary. Other, more productive tributaries to Humboldt Bay (e.g. Freshwater Creek, Rocky Gulch) descend from the watershed and have two significant mainstem reaches, the "stream-estuary ecotone" defined as the tidally influenced freshwater reach, and a slough channel with a gradual transition from freshwater to brackish to marine salinities. Both these reaches occur below approximately 10 ft elevation (NAVD88). In Freshwater Creek the 10 ft contour crosses at approximately Howard Heights Bridge. In contrast, Jacoby Creek's profile is much steeper nearly all the way to Humboldt Bay, crossing the 10 ft contour 2,470 ft from Hwy 101, thus compressing the estuary and stream-estuary ecotone along the mainstem. We'll discuss juvenile salmonid use of these estuarine reaches below.

Jacoby Creek is an aggrading coastal plain that has been confined by levees for many decades in one valley-bottom location. Its high sediment load has promoted the formation of natural levee deposits (an alluvial delta) that have perched the mainstem at or near the valley floor elevation along much of the project reach. For example, the thalweg elevation in Jacoby Creek just upstream of the Old Arcata Road Bridge is approximately 19.5 ft, but 1,200 ft to the north, the floodplain elevation is approximately at the 20 ft elevation. The significant feature here is that for nearly the entire length of the reach from Brookwood Bridge to Humboldt Bay (3.3 miles of mainstem), Jacoby Creek has essentially no connectivity to its floodplain. Floodwaters that leave the mainstem channel do not return to the mainstem, but instead sheet-flow across wetland pastures and coalesces in a dysfunctional system of drainage ditches. We speculate that salmonids entrained in floodwaters and swept out of channel encounter nearly 100% mortality.

What We Know About Salmonid Use of Estuaries

A broad generalization of ecological and fisheries literature is that tidal marshes support high secondary production and contribute significantly to the early life history of many fish species (Simenstad et al. 2000), including juvenile salmonids. Healey (1982) proposed the concept of "estuarine dependence" in which tidal marshes are considered a requisite rearing habitat for juvenile salmonids. Several recent studies have shown that estuaries may even enable juvenile salmonids to recruit disproportionately to the adult population compared to fish that rear in upstream habitats, because larger fish have higher ocean survival rates (Beck et al. 2001, Ricker 2003, Miller and Sadro 2003, Bond 2006). Factors hypothesized to contribute to the disproportionate success of estuarine reared fish include higher growth rates resulting from abundant invertebrate food and

favorable water temperatures, suppressed predation resulting from high turbidity and deeper channels, and a favorable transition area for smoltification.

We define this highly productive rearing zone to include the "stream-estuary ecotone", the area extending from the upper limit of tidal influence downstream to where channels becomes surrounded by mudflats, and the downstream-most freshwater reach. This definition of the ecotone, borrowed from Merrell and Koski (1978) and Miller and Sadro (2003) includes all tidal channels and fringing marsh habitats that are accessible to fish for at least some portion of the tidal cycle. Additionally, we include the stream reach from the head of the valley to the head of the tide, because it is potentially equally productive if hydraulic and habitat conditions are optimal. Our goal is to attribute survival of returning adult salmonids to juvenile rearing within the stream-estuary ecotone. As Bond (2006) concluded, "In light of population declines, it is necessary to make the link between individuals that recruit to the reproductive population, and the factors that may have lead to their survival." Higher ocean survival of salmonids reared in the ecotone would be an important justification for continued and increased focus on estuary and tidal marsh restoration in Humboldt Bay and elsewhere in the Pacific Northwest.

We view salmonid populations in a manner similar to Mobrand et al (1997) who describe salmonid ecology in terms of three elements: habitat capacity and productivity, and life history diversity. Capacity encompasses density-dependent processes or habitat quantity, productivity encompasses density-independent processes or habitat quality, and life history diversity focuses on the multiple pathways or "tactics" individual organisms or cohorts utilize in completing their life cycle. Some basic management goals are thus to (1) increase capacity by restoring access to available or critical habitats (e.g., estuarine rearing), increase carrying capacity by increasing pool frequency, large woody debris, etc., (2) increase growth rates, condition factor, off-channel habitat with more favorable energetics, etc., all of which translate into higher productivity and a larger size-class distribution of rearing juveniles, and subsequent increased survival through the next life stage, and (3) increased life history diversity by providing alternative pathways (e.g., juvenile rearing in tributary, mainstem, or estuarine habitats), which renders salmonid populations more resilient to external disturbance and threat of extinction.

Our conceptual model is not new. Quinn and Peterson (1996) note that coho salmon populations may be limited by the amount of freshwater rearing habitat available, and that the carrying capacity may be set during the summer low-flow period by the amount of pool space. Their study found a strong correlation between the size of fish in early October and subsequent winter survival. Ricker (2003) back calculated steelhead smolt lengths at ocean entry from scale samples collected from adult steelhead returning to Freshwater Creek to spawn, and a regression relationship between scale radius and fish length. This analysis indicated the average size at ocean entry of returning adults was 194 mm whereas the average smolt length at the HFAC trap was 156 mm. Ricker speculated that steelhead spend time growing in the estuary before entering the ocean. Mike Wallace of CDFG has been sampling salmonids in the stream-estuary ecotone of several Humboldt Bay tributaries for several years, and has identified at least three different coho salmon life stages utilizing tidal zones (M. Wallace, personal communication): (1) extended summer rearing of age-0 coho in freshwater zones with suitable water temperatures, (2) extended winter rearing, potentially by an entirely

different cohort of age-1 coho, during which increased stream runoff expands the boundaries of the freshwater-dominated zone, and (3) brief rearing of spring age-1 in brackish zones for smolting.

Our Vision for a Functioning Stream-Estuary Ecotone

The key to understanding the potential for restoration of the stream-estuary ecotone on Jacoby Creek is to understand the pathway of floodwaters. Currently, water that exits Jacoby Creek via overbank flow cannot reenter Jacoby Creek anywhere downstream.

Jacoby Creek likely never had a "typical" estuary characterized by a long, low-gradient meandering channel with gradual transition from fresh to saline water. Instead, Jacoby Creek's estuary lies in the adjacent former tidelands to the north and south, lands wholly owned by the City of Arcata. On the north side, several small tributaries drain into Gannon Slough from the surrounding hillsides, including Campbell, Fickle Hill, and Beith Creeks. Hydrologic connectivity occurs between Gannon Slough and its tributaries, and Jacoby Creek, only briefly during large storm events, or at the very bottom of the system to the west of Hwy 101. This area, however, "receives" a large portion of the overbank flows from upstream reaches of Jacoby Creek, all of which are confined to drain through Gannon Slough into the bay. To the south of Jacoby Creek, remnant slough channels and pasture drainage ditches flow to a small, perched tide gate. The only hydrologic connection between this landscape and Jacoby Creek is one-way: overbank flows leave Jacoby Creek and flow down the pasture and into the tide gate, or across Bayside Cutoff into Brainard Slough.

The third zone of "hydrologic dysfunction and disconnection" is the broad valley upstream of Old Arcata Road. This area was partially described in a project completed in December 2006 for the Jacoby Creek Land Trust by Jeff Anderson and Associates (JAA). According to the JAA final memorandum (JAA 2006), the bankfull discharge for Jacoby Creek upstream of JCLT property is approximately 1150 cfs. Overbank flows on the Kokte Ranch property and downstream properties were observed by JAA staff on 13 December 2006. Using gaged streamflows for Jacoby Creek at the Brookwood Bridge (Randy Klein, personal communication), the observed discharge that overtopped the banks in the vicinity of Old Arcata Road was approximately 300 cfs and occurred both upstream and downstream of the Old Arcata Road bridge. Attachment 4 [see JAA, 2006] shows the general flow paths of overbank flow within the project area and adjoining properties observed by JAA staff on 13 December 2006. Conclusions for the JAA (2006) work include:

1. Lower Jacoby Creek is confined by levees along much of its length.
2. Overbank events occur at lower discharges than expected from a flood frequency analysis. This is likely a combination of channel aggradation and levee confinement.
3. Overbank flows have no return pathways to the stream channel and are intercepted by the existing storm drain system.
4. Overbank flows overwhelm the storm drain system resulting in flooding of the road and adjacent properties.

5. The frequency of flooding events will increase if lower Jacoby Creek is undergoing similar aggradational changes as those measured upstream.
6. Lower Jacoby Creek does not provide much low-velocity habitat or refugia due to the levees, existing flow paths, and nature of the existing floodplains.
7. Overbank flows have limited opportunities to directly return to the creek as flows recede. This also increases the potential of salmonid and other aquatic species stranding.

To summarize, overbank flows from Jacoby Creek upstream of Old Arcata Road occur frequently, and at a fraction of the bankfull discharge. Flood flows drain away from the channel into undersized and poorly-maintained ditches, across cattle pastures, and coalesce in either drainage ditches or relict slough channels before exiting under Hwy 101 into Humboldt Bay. Floodwaters do not reconnect to Jacoby Creek. Tidal marshes at the bottom of this "system" occupy less than 5% of the former tideland area.

Our vision for a functioning stream-estuary ecotone is to reconnect lower Jacoby Creek with restored tidal and freshwater marshes and a network of reconnected adjacent slough channels, and purposefully route upper Jacoby Creek's floodwaters into these habitats. This vision entails a mosaic of habitats, broad-gradient transitions between distinct zones, and multiple species including juvenile salmonids, tidewater goby, estuarine-dependent fish, and likely open space for cattle and goose grazing.

3. Existing Conditions

This chapter describes the existing conditions of the Lower Jacoby Creek area, with an emphasis towards the project area.

3.1. Project Area

The project area consists of an approximate 114 acre pasture immediately north of Lower Jacoby Creek (Figure 3-1). It is bounded by Jacoby Creek to the south, Highway 101 and Gannon Slough to the west, the historic railroad berm to the north and north-east, and a slightly elevated pasture road and drainage ditch to the east. South Branch Gannon Slough (also known as North Fork Jacoby Creek) bisects the project area and discharges into Gannon Slough via a tide gate structure.

3.2. Available Topography and Bathymetry

One foot photogrammetric topography of the project area and surrounding areas were conducted by the City of Arcata in 2003. The photogrammetry covered the overbank/pasture areas, but in-channel bathymetry of Jacoby Creek and slough channels was limited due to vegetation and surface water.

In 2006 McBain & Trush (M&T) conducted a limited thalweg and channel cross section survey of the project area, which included:

- 2,000 foot longitudinal profile, and three cross sections over an 800 foot reach of Lower Jacoby Creek directly upstream of Highway 101,
- 800-foot longitudinal profile, and one cross section in the drainage/borrow ditch north of Jacoby Creek and parallel to Highway 101, and
- 3,325-foot longitudinal profile, and two cross sections of South Branch Gannon Slough (or North Jacoby Creek).

Upstream of Old Arcata Road, six channel cross sections and a longitudinal profile was surveyed in Jacoby Creek by Jeff Anderson & Associates (JAA) and M&T in December 2006. Within this reach the survey showed that Jacoby Creek has simple channel geometry and a featureless floodplain that lacks high flow channels.

All vertical elevations reported in this report are referenced to NAVD88, unless otherwise noted.

3.3. Setting

Historically the project area was a part of a larger tidal wetland complex. The construction of levees, Highway 101, and the installation of tide gates has allowed the conversion of these tidal wetlands into pasture.

A large remnant slough channel known as South Branch Gannon Slough bisects the project area. This slough channel is tide gated at its downstream end just prior to discharging into Gannon Slough. Over the years this slough channel has filled with

sediment due to the loss of tidal flushing, and ranges from approximately 2 to 6 feet in elevation. The existing tide gate leaks, which has allowed enough saltwater to flow into South Branch Gannon Slough to sustain a small intertidal zone within the lower portions of this slough channel. However, the saltwater flow is entirely contained to the slough channel and the tidal prism (volume of tidal water) is not enough to establish substantial tidal wetlands within the pasture areas. Based on visual observations it appears that the upper extent of the existing intertidal zone is approximately elevation 3 to 4 feet.

The project area is completely surrounded by levees along the south, west and north to north-east side's (Figure 3-1). Jacoby Creek is separated from the project area by a large right bank levee along the lower end of the channel, and higher overbank sediment deposits on the upper end, with elevations ranging from 9 to 13 feet. The westerly edge of the project area is defined by a continuous levee with elevations ranging from 9 to 12 feet that parallels Highway 101. The historic railroad grade also functions as a levee along the north and north-east sides of the project area. The elevation of the railroad grade is approximately 8 to 10 feet. A breach exists in the railroad grade that allows flood waters to flow in and out of the project area from adjacent pastures.

Along the east project area boundary ground elevations rise to approximately elevation 7 to 8 feet. The ground in the easterly pasture continues to increase in elevation towards old Arcata Road. Historically the upper end of South Branch Gannon Slough continued east into the easterly pasture and north towards Beith Creek. Currently South Branch Gannon Slough terminates at the north-east corner of the project area at an old farm road and perhaps collapsed crossing. The easterly pasture drainage, which slopes in a north-west direction towards the upper end of South Branch Gannon Slough, backs up at the farm road during flood events and eventually overtops the road flowing into South Branch Gannon Slough.

Pasture elevations within the project area range from 5 to 8 ft, with the majority of the area at an approximate 6 foot elevation. Ground elevations are highest towards Jacoby Creek and slope in a north to north-east direction towards the historic railroad grade. The north and north-east portions of the project area are approximately one foot lower in elevation than the southerly portions, perhaps due to a lack of tidal sediment deposition and/or subsidence. Any overbank flows from Jacoby Creek within the project area would naturally flow towards South Branch Gannon Slough and exit out the existing tide gate.

The project area has no continual freshwater inflows except precipitation, overbank flows from Jacoby Creek, and perhaps some spring seeps along the easterly edge. Drainage from the entire project area is through a single 4 foot wide by 5 foot tall tide gate into Gannon Slough. The tide gate is top hinged and has an invert elevation of 0.46 feet.

During wet-weather periods overbank flows from Jacoby Creek, both upstream and downstream of Old Arcata Road, flood into this area causing standing water over a large portion of the pasture until drained through the single existing tide gate structure. Following high flood conditions water levels in the project area can sometimes take a number of days to drain completely.

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Figure 3-1 Jacoby Creek Estuary: Existing Ground Contours.

3.4. Tidal Hydrology

3.4.1. Measured Tidal Data

The nearest active tidal station to the project area is the North Spit tide gage (NOAA Station 9418767) near the Humboldt Bay entrance. Since tide levels in North Arcata Bay are generally higher and lag other areas of Humboldt Bay (e.g. entrance and South Bay). NOAA briefly monitored tide elevations in Mad River Slough (NOAA Station 9418865) for a four month period (December 1978 to March 1979), and has updated tidal data for this station to the current epoch.

As part of reference tidal wetland work, JAA measured tide elevations in the north-east corner of North Bay near a reference wetland. This tide gage was active for an approximate 12 month period (August 2006 to July 2007), and preliminary tidal data from this gage was used for this project. It should be noted that the JAA North Bay tide gage was above a downstream control (sill) that effected or controlled low tide elevations.

Table 3-1 summarizes tidal data for the North Spit, Mad River Slough, and JAA North Bay tide gages. Based on the Mad River Slough tidal data, the diurnal tide range is approximately 7.63 ft between mean higher high water (MHHW) and mean lower low water (MLLW). Also listed in Table 3-1 for the JAA North Bay tide gage is the mean monthly maximum water, which is the average of the maximum measured tide levels each month. This is not a typical tidal datum such as MHHW or an indicator of average spring tides, but was used as an indicator of the anticipated highest average monthly tide elevation.

Table 3-1 Tidal Data for North Spit and Mad River Slough Tide Gages (Tidal Epoch 1983-2001) and JAA North Bay Tide Gage (POR: August 2006 to July 2007) referenced to NAVD88.

Tidal Data	North Spit (NOAA Sta. 9418767) (feet, NAVD88)	Mad River Slough (NOAA Sta. 9418865) (feet, NAVD88)	JAA North Bay Tide Gage (feet, NAVD88)
Highest Observed Water Level (1/26/1983)	9.39		
Mean Monthly Maximum Water	7.74		7.84
Mean Higher High Water (MHHW)	6.53	6.63	6.87
Mean High Water (MHW)	5.82	5.91	6.14
Mean Sea Level (MSL)	3.37	3.25	
Mean Tidal Level (MTL)	3.37	3.13	
Mean Low Water (MLW)	0.93	0.35	
Mean Lower Low Water (MLLW)	-0.33	-1.00	
Lowest Observed Water Level (1/19/1988)	-3.23		

McBain & Trush monitored tide elevations in Lower Jacoby Creek immediately upstream of the Highway 101 Bridge for an approximate 7 month period (December 2005 to July 2006). Figure 3-2 shows the tidal curve for Lower Jacoby Creek and the North Spit Gage for the period from 3 to 16 July 2007. This measured tidal curve from the MT Jacoby

Creek tide gage was used in the hydraulic analysis for this project. It is apparent that Lower Jacoby Creek tide elevations are higher and lag North Spit tide levels. Due to the aggraded nature of Jacoby Creek a downstream low flow control is apparent at an approximate elevation of 4.2 feet. In fact, at the beginning of the tidal curve some of the North Spit lower high tides do not propagate into Lower Jacoby Creek.

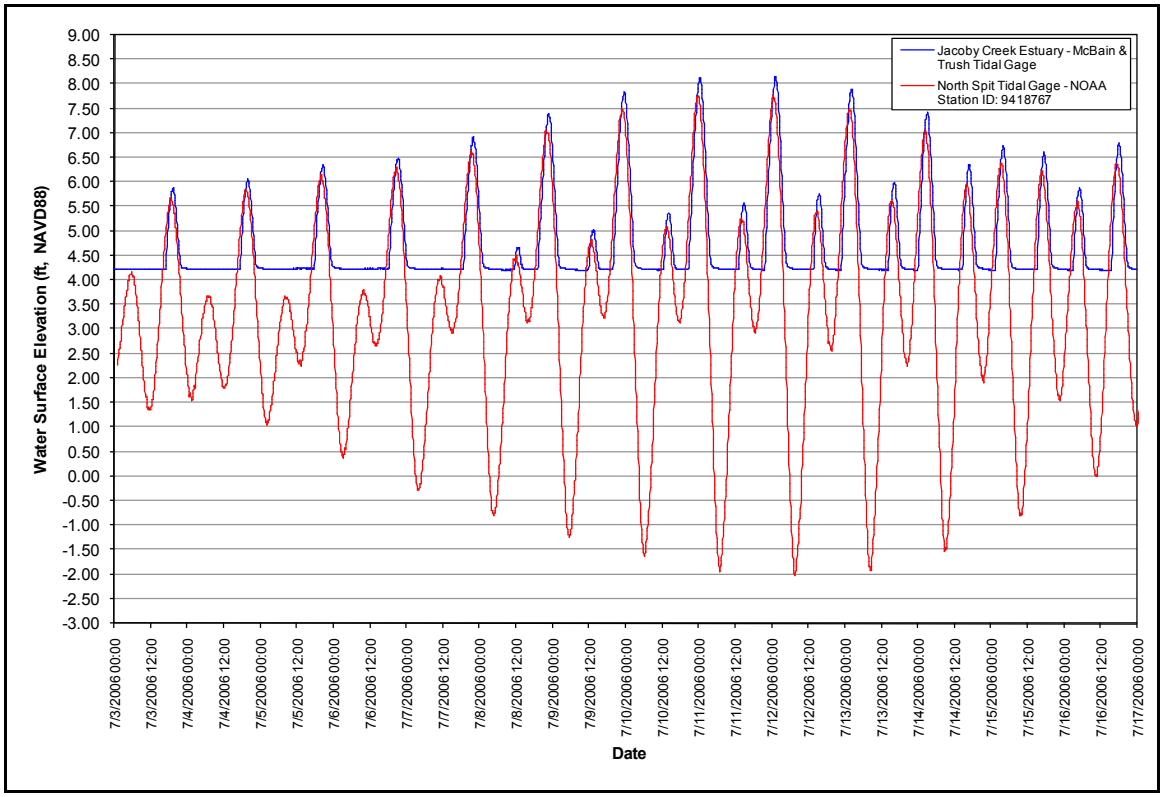

Figure 3-2 Measured tidal curve for Lower Jacoby Creek from 3 to 16 July 2006 (MT Jacoby Creek Tide Gage) and North Spit Gage (NOAA Station 9418767).

3.4.2. Synthetic Tidal Curve

To provide additional tidal data for project analysis a synthetic tidal curve was generated for Lower Jacoby Creek at its exit discharge point into North Bay. The synthetic tidal curve matches mean water levels (MHHW to MLLW), and can be used to simulate long-term average water levels and project intertidal habitat changes within the project area.

The synthetic tidal curve for Jacoby Creek was generated using a two-dimensional hydrodynamic model (2d model) of Humboldt Bay created by JAA (modeling work in progress) for producing tidal elevation boundary conditions for restoration projects in Humboldt Bay. The downstream boundary condition for the 2d model was a MHHW to MLLW synthetic tidal curve for the North Spit tide gage (Table 3-1) described as:

$$\mathbf{Ht\ (t) = a \cos (360t/T) + Z}$$

where Ht (t) = astronomical tide at time t, a = tidal amplitude, t = time, T = tidal period, and Z = vertical offset or datum adjustment. For this curve the tidal amplitude varied between 3.82 ft (MHHW to MLLW) with a tidal period of 12.42 hours (half of 21.84 hour tidal day).

Figure 3-3 shows the MHHW to MLLW synthetic tidal curve generated for Lower Jacoby Creek from the 2d model, along with the North Spit synthetic tidal curve boundary condition. As with the measured Lower Jacoby Creek tidal curve (Figure 3-2) the modeled synthetic tide curve shows a similar tidal propagation and lag compared to North Spit. The modeled Lower Jacoby Creek tide levels also show the effects of the higher mudflat and slough channel elevations that generally exist in North Bay.

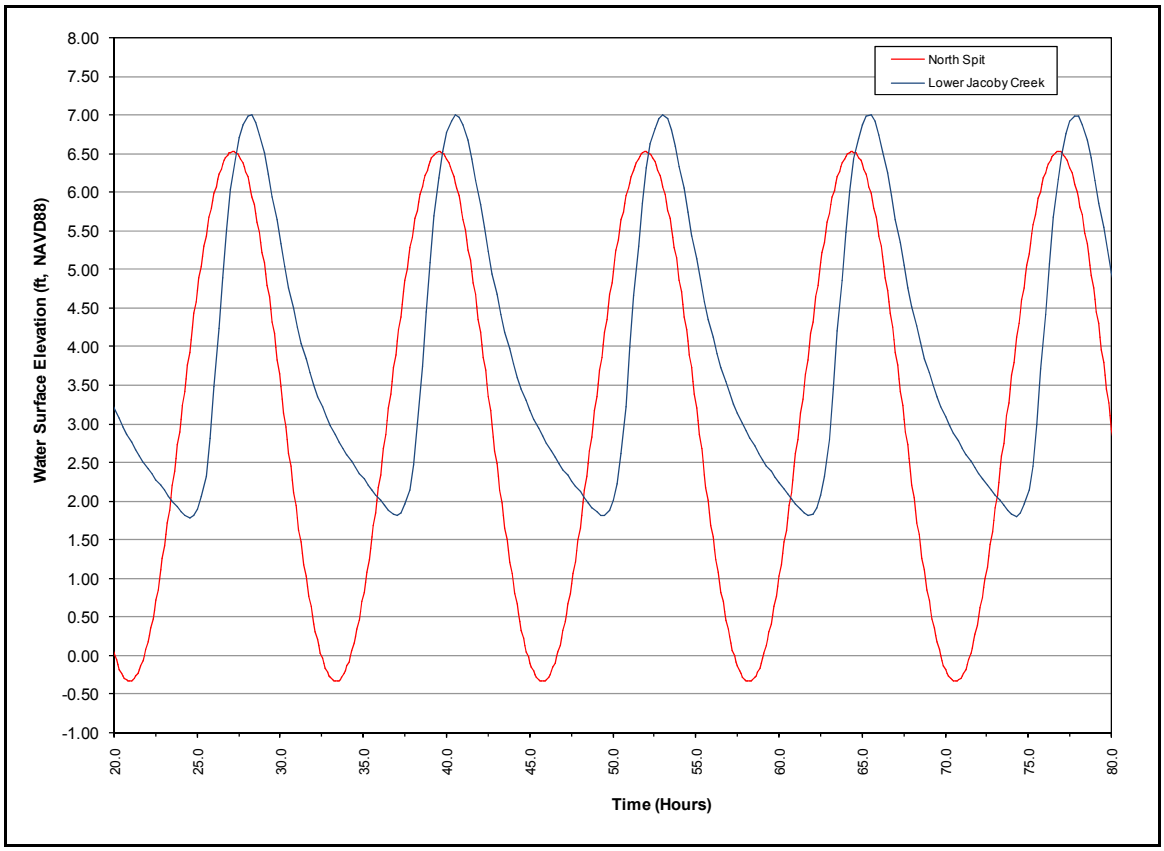

Figure 3-3 North Spit and Lower Jacoby Creek Synthetic MHHW to MLLW tidal curve.

3.5. Surface Water Hydrology

Currently Jacoby Creek is gaged at the Brookwood Bridge by Randy Klein (unfunded, volunteer basis). Based on gaged streamflows (Randy Klein, personal communication) a low flow estimate for Jacoby Creek in the months of May and June of 2006 was approximately 10 cfs. Bankfull discharge is the amount of flow a stream channel is capable of conveying before overtopping its banks. The typical annual recurrence interval for a bankfull event is 1.5-2 years (Leopold et al, 1964). Based on existing flow records, the bankfull discharge for Jacoby Creek near the Brookwood Bridge is approximately 1150 cfs (Lisle, 1986).

3.6. Existing Condition Hydraulic Model Results

To provide insight into existing hydraulic conditions within the project area, the hydraulic model developed for this project (described in Chapter 4) was run for two of the three analyzed conditions. Figure 3-4 shows modeled results for the Jacoby Creek

MHHW to MLLW synthetic tidal curve (Figure 3-3) and the low Jacoby Creek base flow of 10 cfs. The modeled high tide levels in Jacoby Creek are consistent with the downstream boundary condition. An assumption of the existing condition hydraulic model is that the tide gate does not leak, which is evident by the lack of tidal water in the storage areas.

To demonstrate flooding within the project area for existing conditions the hydraulic model was run for the MHHW to MLLW synthetic tidal curve boundary condition and the 1,200 cfs triangular flood hydrograph (Figure 3-5). Model results indicate that a large portion of the flood flow exits the Jacoby Creek channel and flows into the storage areas (overbank areas). Note that the stage in the storage areas are approximately elevation 10 feet, while the stage in Jacoby Creek is at 7.6 feet, only about 0.6 feet above MHHW. Previous flood work and observations on Jacoby Creek have shown that overbank flows occur on Jacoby Creek upstream and downstream of Old Arcata Road at approximately 300 cfs (Jeff Anderson & Associates, December 2006), and once flows go overbank there is no opportunity for flows to re-enter Jacoby Creek. In fact, results from the hydraulic model indicate that a little over 300 cfs remains in Jacoby Creek downstream of Old Arcata Road, indicating that a majority of flood flows overtop the existing channel levees and flow onto the floodplains. Model results also indicate that it takes over two days for the accumulated flood waters to drain from the project area (storage areas) through the single existing tide gate structure.

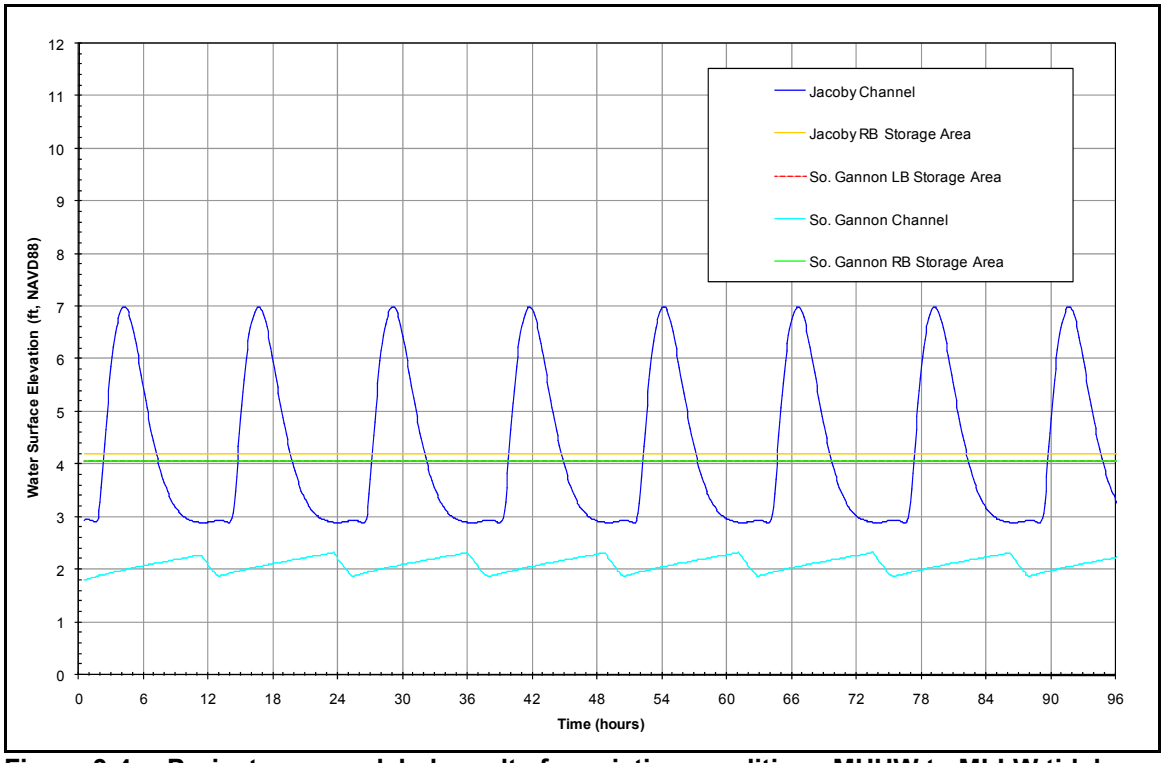

Figure 3-4 Project area modeled results for existing conditions MHHW to MLLW tidal conditions and low Jacoby Creek base flow.

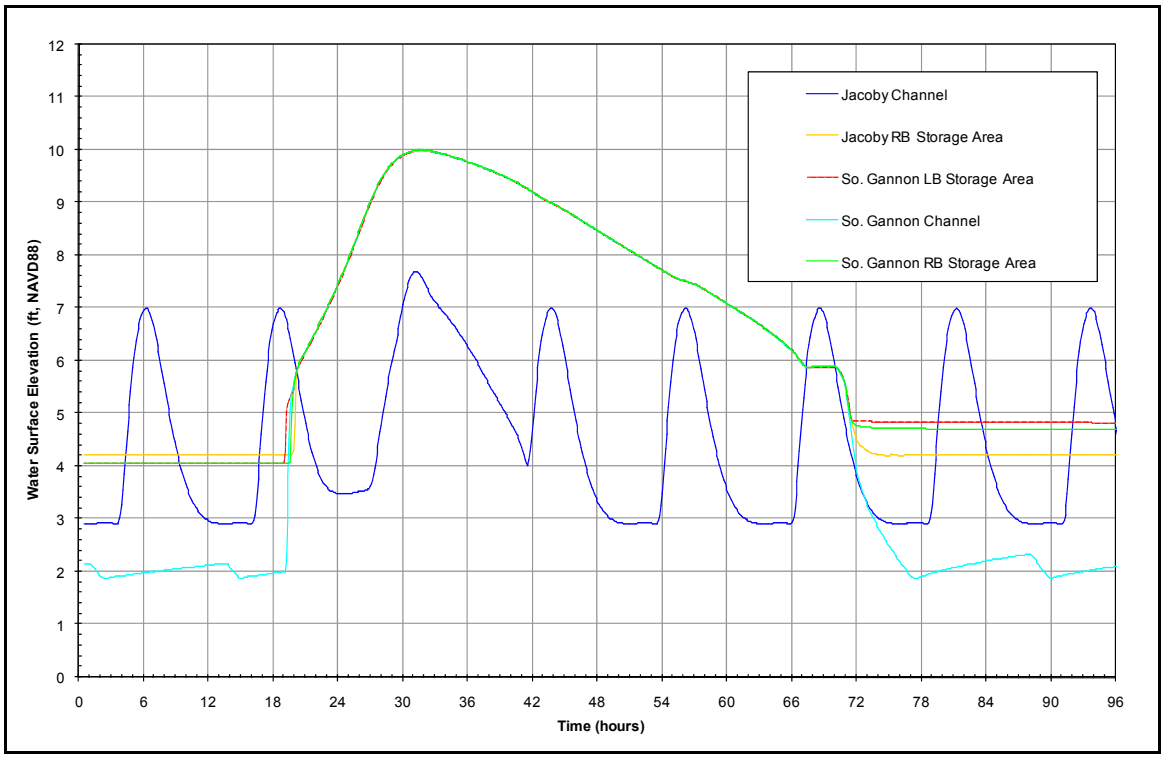

Figure 3-5 Project area modeled results for existing conditions MHHW to MLLW tidal conditions and a Jacoby Creek bankfull flood event.

4. Hydraulic Modeling

An important component of this work was to analyze the potential extent of tidal inundation under varying tidal and creek conditions for each of the different design alternatives. The tidal inundation shows the potential extent of land conversion from pasture/grazing to tidal and fresh water wetland, and the effects on utility infrastructure within the project area. To accomplish this analysis, a planning level hydraulic model was developed based on existing data and information. The hydraulic model was used to analyze existing conditions and each design alternative.

4.1. One-Dimensional Hydraulic Model

A one-dimensional hydraulic model (hydraulic model) was developed for this project using the U.S. Army Corps of Engineers HEC-RAS modeling system (USACE, HEC 2002). The HEC-RAS model calculates one-dimensional water surface profiles and average channel velocities for both steady gradually varied flow, and unsteady flow through a network of channels. For this analysis unsteady modeling was used to predict tidal and flood levels within the project area for a range of tidal conditions and creek flows. Reference can be made to the HEC-RAS manual for information specific to unsteady modeling. The hydraulic analysis addressed the effects of average tidal conditions (i.e. MHHW to MLLW) and extreme higher tides (i.e. mean monthly maximum tides.

4.1.1. Study Area and Model Extent

The general modeling area extends from North Bay to approximately 2,300 feet east of Old Arcata Road, and includes the large overbank areas to the north, and the South Jacoby Pasture to the south (Figure 4-1). Previous hydraulic modeling efforts for Jacoby Creek north of Old Arcata (Jeff Anderson & Associates, December 2006) and the South Jacoby Pasture Road (Jeff Anderson & Associates, March 2006) were incorporated into this modeling effort. The hydraulic model consists of a network of channels defined by cross sections for Jacoby Creek, the South Branch Gannon Slough channel within the project area, the Gannon Slough channel west into North Bay, and the westerly slough channel flowing into North Bay within the South Jacoby Pasture area. These cross section bed elevations were systematically lowered below MLLW elevation at the downstream cross sections (within North Bay) so that low tidal boundary conditions were not problematic in computations.

The existing large pasture/overbank areas within the study area were incorporated into the hydraulic model as a series of interconnected hydrologic storage areas. These storage areas were linked to adjacent storage areas, and to the primary channel network along channel banks and channel links. The hydrologic storage areas also defined the restored wetland areas, and the stage-volume relationships included the volume effects of the slough channels.

Tide gates and other hydraulic structures were incorporated into the model as required.

The existing conditions model for the study area was modified to represent the project elements for each conceptual alternative. The various project elements consisted of the addition of new tide gate structures, levee breaches or removal, construction of new slough channels, the construction of setback levees, and the reconfiguration of the hydrologic

storage areas with the project area to define restored wetlands, depending on the conceptual alternative.

4.1.2. Topographic, Bathymetric and Flow Structure Data

Where available, cross sections were based on topographic channel field surveys for Jacoby Creek and South Gannon Slough channel. For Jacoby Creek three channel cross sections were available for an approximate 800 foot reach of channel immediately upstream of HWY 101 (McBain & Trush 2006 field surveys). Upstream of Old Arcata Road six cross sections were surveyed along a 2,300 foot reach of Jacoby Creek by JAA and M&T in December, 2006. Due to large unsurveyed reaches of Jacoby Creek, it was necessary to interpolate a number of cross sections for the hydraulic model.

Two surveyed cross sections (M&T 2006 field surveys) were available for the South Gannon Slough channel. As with the Jacoby Creek channel, it was necessary to interpolate a number of cross sections to better define the South Gannon Slough channel within the hydraulic model.

The South Jacoby Pasture Slough and Gannon Slough channel cross sections were obtained from the 1-ft topographic map and Humboldt Bay Lidar data (provided by City of Arcata), field observations, and aerial photo interpolation.

The hydrologic storage areas were defined by stage-volume relationships extracted from the 1-ft topographic map. The stage-volume relationships included the volume of the existing remnant slough channels that exist in many of the storage areas.

Tide gates and hydraulic structures geometry and elevations were obtained from field surveys and measurements.

4.1.3. Channel Parameters

Manning' roughness coefficients (*n*) were estimated based on prior modeling efforts in Humboldt Bay, professional experience, and field comparison of channel conditions with published color photos, descriptive data, and computed *n* values for stream channels found in Barnes (1967), French (1985) and Hicks and Mason (1991). Slough channel *n* values ranged from 0.03 to 0.06 depending on location and vegetation, and an *n* value of 0.07 was used for Jacoby Creek.

The HEC-RAS default culvert and tide gate entrance and exit losses were used in the hydraulic analysis.

4.1.4. Boundary Conditions

For unsteady modeling, upstream and downstream temporal boundary conditions are necessary for the hydraulic model.

Upstream Boundary Conditions (Streamflow)

Upstream boundary conditions consisted of streamflows for Jacoby Creek. A low-flow continuous streamflow of 10 cfs was used to demonstrate the effects of tidal inundation within the project area for each conceptual design. To demonstrate the effects on flooding within the project area an approximate bankfull synthetic flood hydrograph was developed that was superimposed onto the 10 cfs baseflow. The bankfull event consisted of a 24 hour

triangular flood hydrograph that peaked at 1,200 cfs within the first 8 hours, with the flow recession lasting 16 hours.

Downstream Boundary Conditions (Tidal Stage)

The downstream boundary conditions will consist of tidal stages at the downstream ends of Jacoby Creek, Gannon Slough, and the South Jacoby Pasture slough. For this analysis two tidal stage series were used. To help analyze the average extent of tidal wetland restoration within the project area for each alternative, the synthetic MHHW to MLLW tidal curve generated for North Bay near Jacoby Creek, as discussed in Chapter 3, was used. This same tidal curve was also used with the synthetic 2-year flood hydrograph (upstream boundary condition) to demonstrate the effects of flooding within the project area for each conceptual alternative.

To provide insight on the extent of tidal inundation during tidal events higher than MHHW, the hydraulic model was run for a measured tidal period that included tidal levels above and below the mean monthly maximum water. For this area of North Bay the mean monthly maximum water is approximately 7.9 feet, as discussed in Chapter 3. Using the measured Jacoby Creek tidal data collected by McBain & Trush in 2006, a period of summer tidal levels was selected that covered a 14 day period from 3 to 16 July 2006 (Figure 3-2). This 14 day tidal series was used for downstream boundary conditions at Jacoby Creek, Gannon Slough, and the South Jacoby Pasture slough, for the high tidal event analysis.

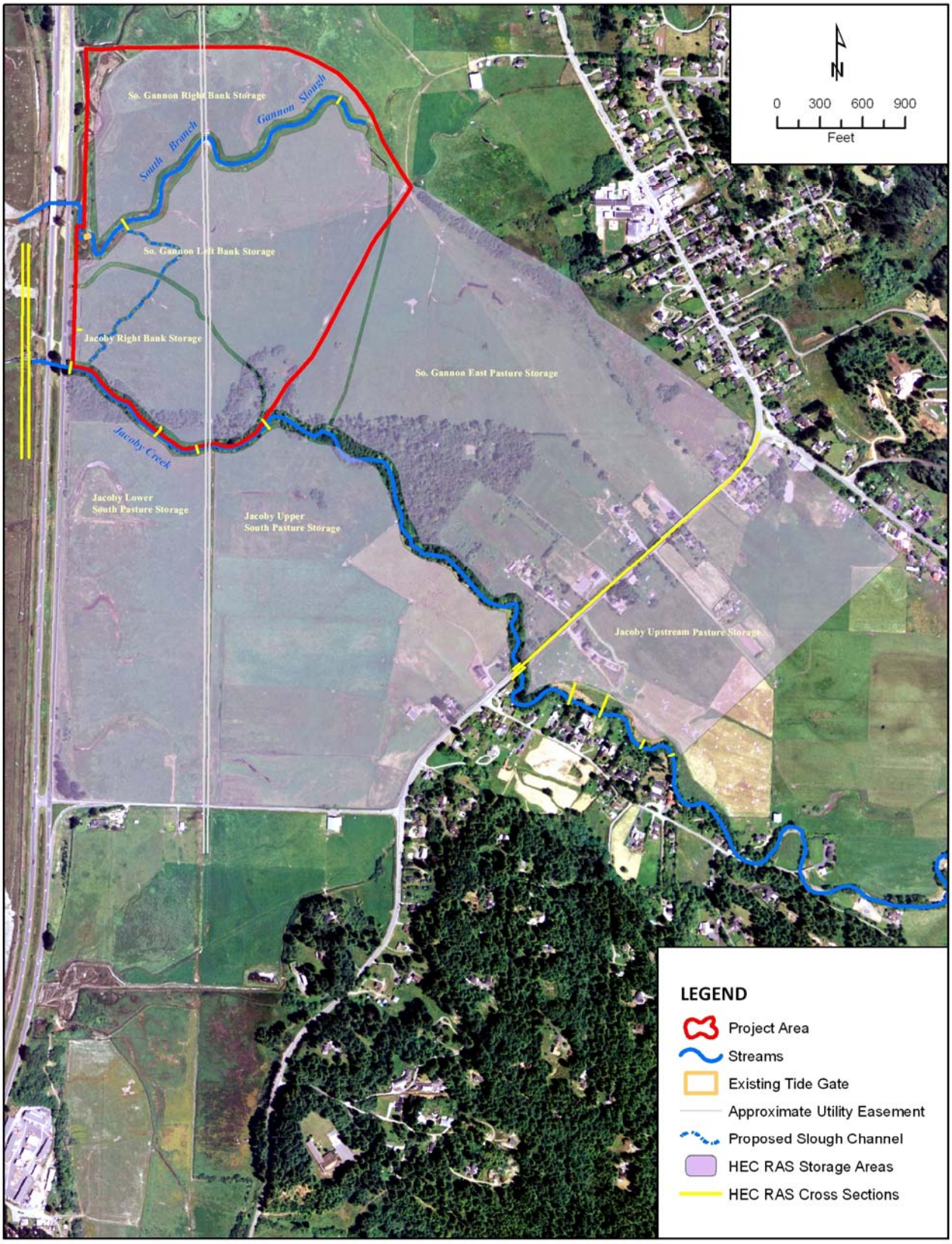

Figure 4-1 Extent of developed hydraulic model of Lower Jacoby Creek.

5. Conceptual Design Alternatives

Five conceptual design alternatives were developed for the project area that spans a range of enhancement opportunities, land and resource commitments. The following sections list the project objectives and constraints, the conditions for which the alternatives were analyzed and compared, and a description and comparison of each design alternative.

5.1. Project Objectives (Goals) and Constraints

The primary objectives (goals) of this work are to develop conceptual design alternatives for the project area that restores and enhances estuarine and intertidal habitats.

As part of the City of Arcata Mitigated Negative Declaration for the Baylands Enhancement/Restoration Project the following restoration/enhancement goals were identified for the Jacoby Creek/Gannon Slough project area (City of Arcata Mitigated Negative Declaration, May 2006).

> (a.) Restore 65 acres in the Jacoby Creek/Gannon Slough Project Area: (1) Restore 30.0 acres of estuarine channels associated with Jacoby Creek via tide gate modification/removal, (2) restore 15.0 acres of estuarine channels associated with Gannon Slough via tide gate modification/removal, and (3) restore 20.0 acres of Jacoby Creek floodplain and riparian forest along 3,767 lineal feet of Jacoby Creek by removing 4,291.5 feet of levees, fencing out livestock (7,534 feet of fencing) and revegetating the riparian corridor with Sitka spruce, Red alder and native willow.

The City of Arcata has identified the following two constraints for the project area:

- Limit the full conversion of pasture land to tidal wetland and/or intertidal habitats within the project area, and
- Limit tidal inundation of utility easements within the project area.

This conceptual design report specifically addresses goals (1) and (2), which is to enhance/restore 45 acres of estuarine habitat within the Jacoby Creek/Gannon Slough project area.

Due to project site topography and the aggraded nature of Jacoby Creek it was difficult to develop an alternative that meets the stated project objectives within the identified constraints. Instead of identifying a preferred design, we developed a number of design alternatives that provide the City of Arcata a range of tidal inundation and habitat enhancement options within the project area. It will be necessary for the City of Arcata to select the alternative that satisfies these constraints.

On a final note, any of the selected or pursued alternatives can be expanded upon in the future. Therefore, none of the alternatives limit or constrain enhancement actions into the future.

5.2. Conditions Hydraulically Analyzed for Each Alternatives

Each design alternative was analyzed for three hydrologic conditions:

1. Synthetic MHHW to MLLW Lower Jacoby Creek tidal curve (Figure 3-3) with a low creek streamflow of 10 cfs. This analysis provides long-term average water levels and potential intertidal habitat changes within the project area for each alternative.
2. Measured Lower Jacoby Creek tidal curve (Figure 3-2) with a low creek streamflow of 10 cfs. Results are provided for the peak highest tide in this series (approximately 8.1 feet), which is above the estimated mean monthly maximum tide level (7.9 feet) for this area of North Bay. This analysis provides a picture of the average maximum monthly extent of tidal inundation within the project area for each alternative.
3. Synthetic MHHW to MLLW Lower Jacoby Creek tidal curve (Figure 3-3) with the synthetic bankfull 24-hour triangular flood hydrograph peaking at 1,200 cfs. This analysis demonstrates the project area flood effects for each alternative.

5.3. Preliminary Cost Estimates

A preliminary cost analysis was performed for each conceptual alternative for comparative purposes. These cost estimates focused on construction costs only, and are based on estimated material volumes for each alternative. Unit costs, equipment mobilization and clearing and grubbing costs (as a percentage of total construction costs) were provided by the City of Arcata, and are based on actual construction costs for similar projects recently completed. A 15% contingency was included in the cost estimates.

Pre- and post-construction costs, such as flagging and staking, flow diversion, as-built surveys, revegetation, exclusion fencing, and erosion control, are not included in these costs. Indirect costs, such as permitting, additional engineering, design and analysis needs, final design plans and specifications, construction management, engineering oversight, compliance and performance monitoring, are also not included in these costs. Once an alternative is chosen, these items, along with updated contingency funds, and revised construction costs should be calculated into the total project cost.

5.4. Conceptual Alternatives Description and Analysis

5.4.1. Design Alternative 1: Full Restoration

Alternative 1 represents an approximate full restoration of the project area; reestablishing unimpeded tidal conditions to the project site and converting approximately 85 acres of pasture to intertidal channels and salt and brackish wetlands. Alternative 1 design

elements are listed in Table 5-1 and shown graphically on Figure 5-1. The design elements focus on removing existing obstructions from Jacoby Creek and South Branch Gannon Slough, filling historic drainage ditches, and creating marsh plain surfaces by restoring a large unimpeded tidal prism to the project area.

Table 5-2 summarizes the restored and created habitat areas, and Table 5-3 lists the estimated construction costs for Alternative 1. In Table 5-2 a range of potential restored or created habitat areas was provided that includes a lower limit at the MHHW level to an upper limit at the mean monthly maximum tide level.

Results of the hydraulic analysis for Alternative 1 indicate that a restored MHHW tide elevation of 6.8 feet can be expected within the project area (Figure 5-1), and an average maximum monthly tidal inundation of 7.9 feet (Figure 5-2). Figure 5-3 shows the tidal response for the MHHW to MLLW tidal series for different locations within the project area. High tide levels are essentially the same across the project area and Jacoby Creek, indicating essentially fully restored tidal function. Figure 5-4 shows that Alternative 1 greatly improves flood routing through the project area compared to existing conditions (Figure 3-5). The maximum water elevation within the project area is approximately 7.2 feet, which is almost 3 feet lower than the existing conditions peak stage of 10 feet. Also, for Alternative 1 the flood peak drains from the project area in approximately one low tide (6 hours) compared to the 2 days required for existing conditions.

For this alternative it will be necessary to construct a levee along the east boundary of the project area to contain tidal water from inundating the easterly pasture, and pastures to the north. It will also be necessary to install a tide gate(s) along the north east boundary to drain the easterly pasture during floods.

Design Alternative 1 Advantages and Disadvantages:

- Potential to capture Jacoby Creek during high flow events and re-route flow out of South Branch Gannon Slough. Further analysis of this alternative would address this issue and provide elevations for any necessary channel invert control.
- The highest potential for habitat diversity for salmonids, fish and other aquatic species.
- The greatest commitment of land to restoration.
- Open tidal marsh area allows for even marsh plain accretion from available suspended sediments throughout site.
- Open tidal marsh area along Jacoby Creek and Gannon Slough allows for better water quality exchange within the project area. This alternative creates the greatest opportunity for both salt and brackish marsh creation.
- A levee and tide gate structure will be necessary along the east project area boundary to prevent tidal inundation of the easterly pasture.

Table 5-1 Alternative 1 Design Elements

	Design Element	Cut (cy)	Fill (cy)
1.	Remove levee along 800 ft of the north bank of lower Jacoby Creek	1,030	
2.	Construct a slough channel in the floodplain north of lower Jacoby Creek	2,720	
3.	Breach levee at mouth of South Branch Gannon Slough	925	
4.	Fill spoils in borrow ditch along the highway levee		350
5.	Fill spoils in drainage ditch along the interior access road		900
6.	Fill breach in northern levee		50
7.	Build up northern levee to elevation 10 feet		1,700
8.*	Build up road (levee) along east project boundary to contain tidal water		1,075
9.*	Install two 48-in tide gates at the upstream extent of S. Branch Gannon Slough (north-east corner of project area) to drain Easterly Pasture	-	-
	TOTAL	**4,675**	**4,075**

* Prescriptive solution at this location will be tailored to chosen alternative.

Table 5-2 Alternative 1 Proposed Habitat Benefits

	Restored or Created Habitat	Length (ft)	MHHW Area (acres)	Peak Event Area (acres)
1.	Convert pasturelands within project area to tidal wetland		85	100
2.	Restore tidal regime and flood flow drainage to South Branch Gannon Slough	3,600		
3.	Restore hydrologic connectivity between lower Jacoby Creek and South Branch Gannon Slough by constructing a slough channel across floodplain	1,600		

Table 5-3 Alternative 1 Construction Costs Estimate

Item	Description	Unit	Unit Price	Quantity	Item Price
1	Equipment mobilization/demobilization (1% of construction costs)	LS	1%	$101,556	$1,016
2	Clearing and grubbing (2% of construction costs)	LS	2%	$101,556	$2,031
3	Breach South Branch Gannon Slough	CY	$3.63	925	$3,358
4	Remove levee north of Jacoby Creek, breach and spoil	CY	$3.63	1,030	$3,739
5	Cut slough channel north of Jacoby Creek and spoil	CY	$3.63	2,720	$9,874
6	Build road/levee along eastern project boundary	CY	$5.33	1,075	$5,730
7	Eastern boundary prescription to connect project to upstream pasture	LS	$78,856	1	$78,856
	Rounded Subtotal				$105,000
	Contingencies	%	15%	$105,000	$15,750
	Total Construction Costs				$120,750

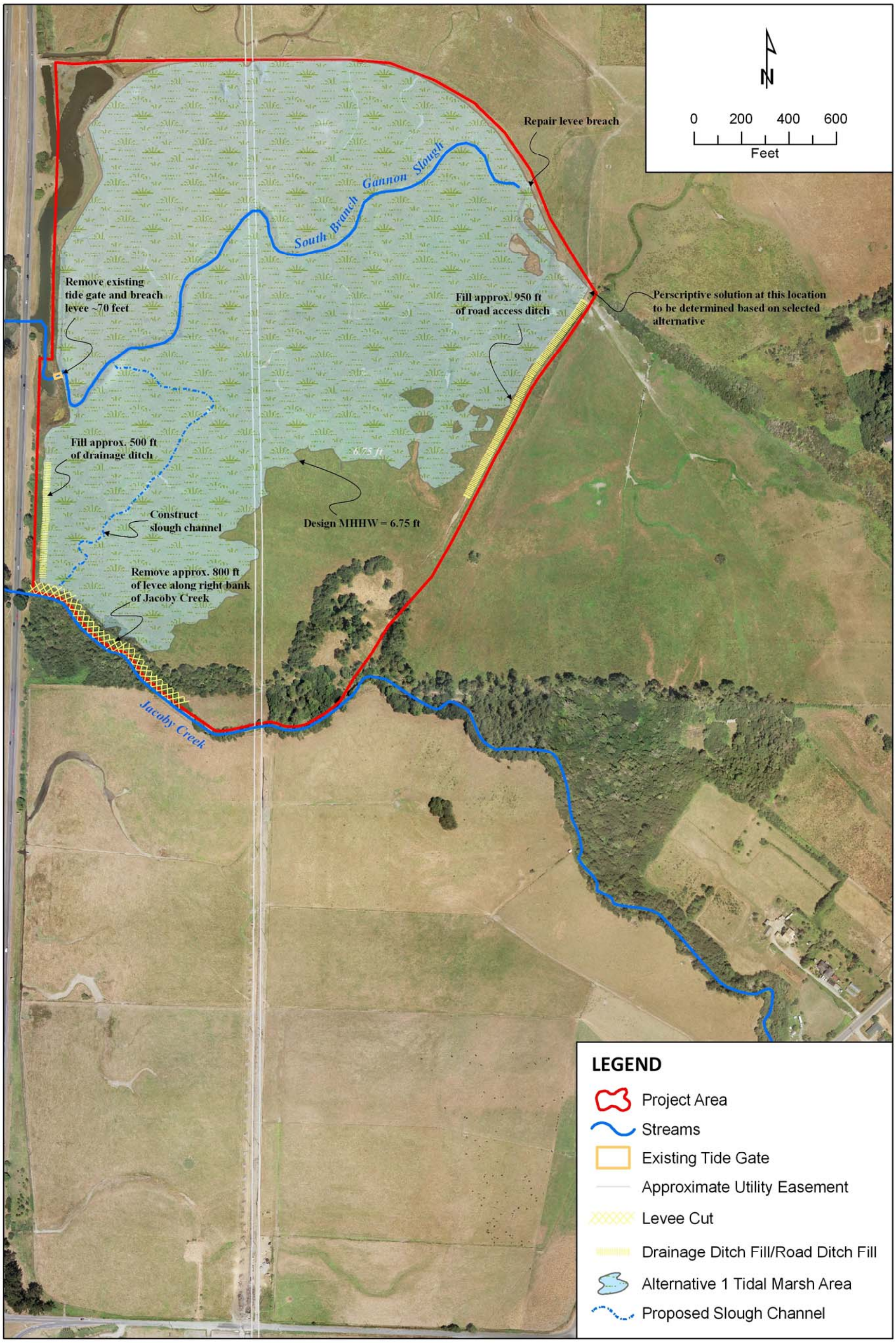

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Figure 5-1 Design Alternative 1: Full Restoration at MHHW.

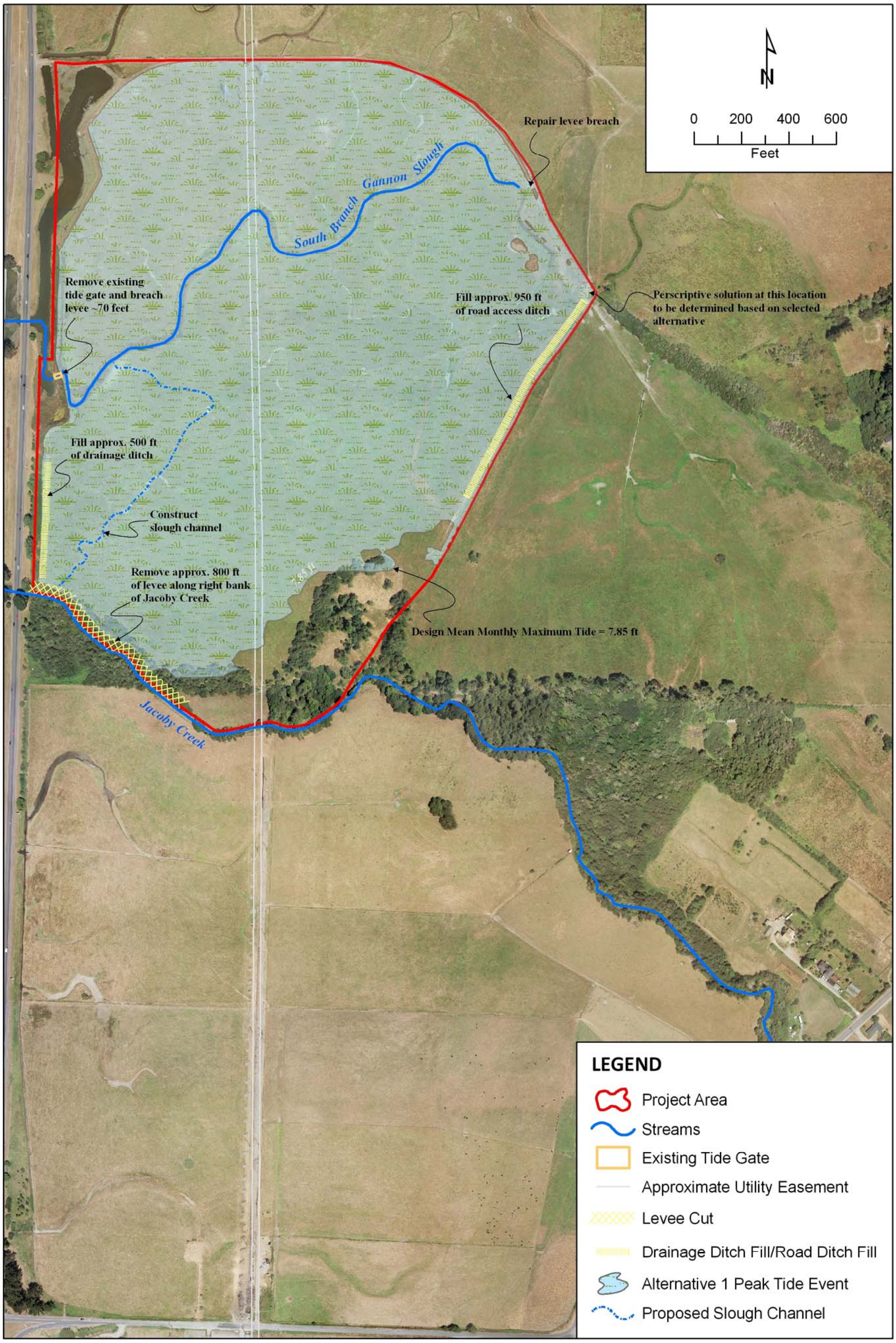

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Figure 5-2 Design Alternative 1: Full Restoration at Peak Tide.

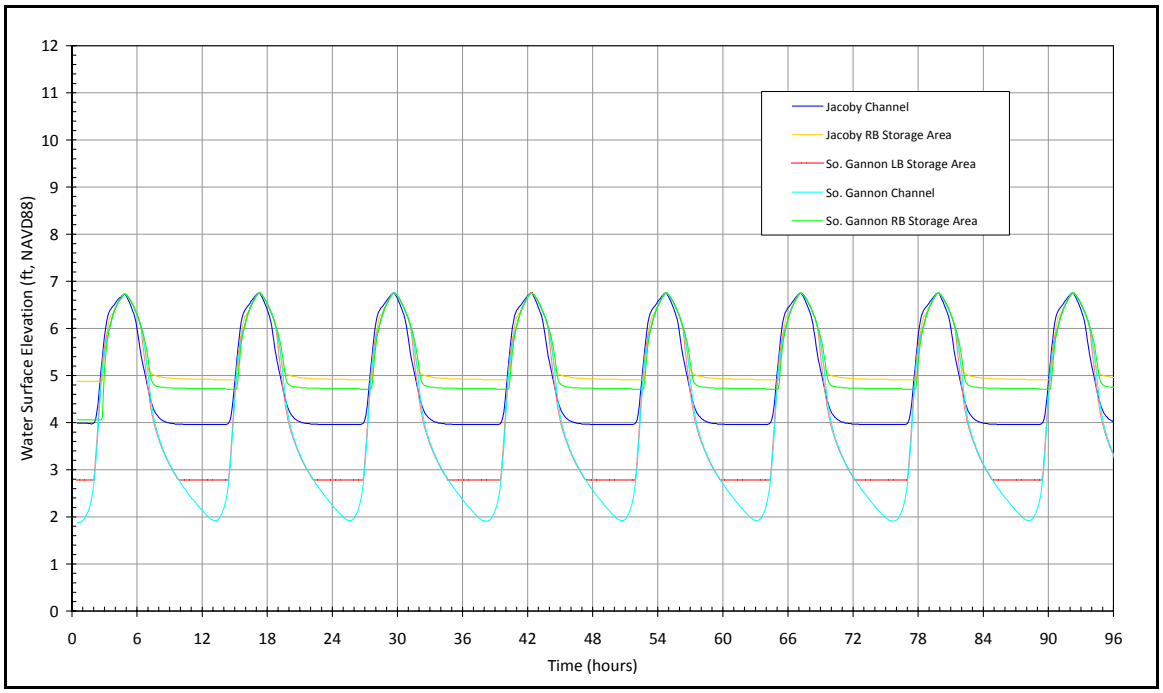

Figure 5-3 Modeled project area MHHW to MLLW tidal levels within the project area for Alternative 1 at low Jacoby Creek streamflow (10 cfs).

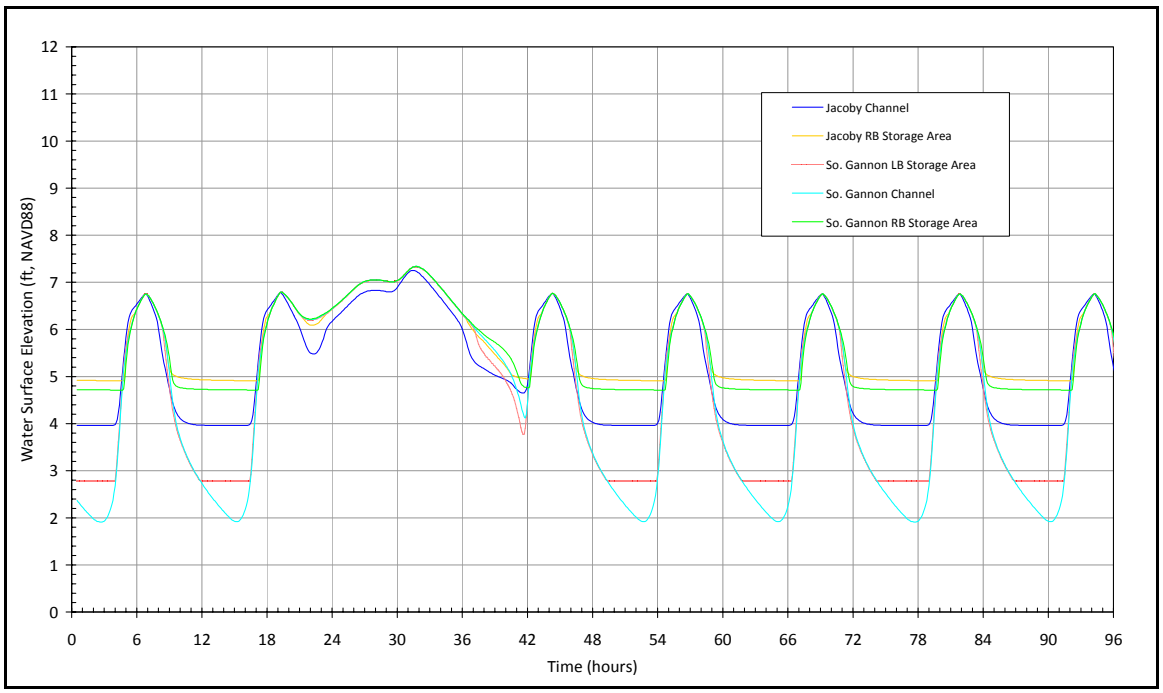

Figure 5-4 Modeled project area tide/water levels within the project area for Alternative 1 for the bankfull flood (1200 cfs) and the MHHW to MLLW tidal series.

5.4.2. Design Alternative 2: Remove Levee, Install Tide Gates

Alternative 2 represents a reduced version of full tidal inundation of the project area by reestablishing unimpeded tidal conditions from Jacoby Creek and a muted tidal prism from new tide gates at the mouth of South Branch Gannon Slough. This alternative proposes to convert approximately 52 acres of pasture within the project area to salt, brackish and fresh water wetland. Alternative 2 design elements are listed in Table 5-4 and shown graphically on Figure 5-5. The design elements focus on removing the existing right bank levee along Jacoby Creek, installing new tide gates on South Branch Gannon Slough that allow an adjustable muted tidal prism, filling historic drainage ditches, and creating marsh plain surfaces by restoring a muted tidal prism to the project area.

Table 5-5 summarizes the restored and created habitat areas, and Table 5-6 lists the estimated construction costs for Alternative 2. In Table 5-5 a range of potential restored or created habitat areas was provided that includes a lower limit at the MHHW level to an upper limit at the mean monthly maximum tide level.

Results of the hydraulic analysis for Alternative 2 indicate that a restored MHHW tide elevation of 6.1 feet in the northerly portions of the project area, and 6.3 feet near Jacoby Creek can be expected (Figure 5-5). An average maximum monthly tidal inundation of 6.8 feet can be expected across the project area (Figure 5-6). Figure 5-7 shows the tidal response for the MHHW to MLLW tidal series for different locations within the project area. Due to the muting effect from the proposed South Branch Gannon Slough tide gates, tide levels are higher in and near Jacoby Creek than in other portions of the project area. Figure 5-8 shows that Alternative 2 also improves flood routing through the project area compared to existing conditions (Figure 3-5). The maximum water elevation within the project area is approximately 8.2 feet, which is approximately 2 feet lower than the existing conditions peak stage of 10 feet. Also, for Alternative 2 the flood peak drains from the project area in approximately 12 hours compared to the 2 days required for existing conditions.

For this alternative it will be necessary to construct a levee along the east boundary of the project area to contain tidal water from inundating the easterly pasture, and pastures to the north. It will also be necessary to install a tide gate(s) along the north east boundary to drain the easterly pasture during floods.

Design Alternative 2 Advantages and Disadvantages:

- Potential to capture Jacoby Creek during high flow events and re-route flow out of South Branch Gannon Slough. Further analysis of this alternative would address this issue and provide elevations for any necessary channel invert control.
- High potential for habitat diversity for salmonids, fish and other aquatic species.
- A commitment of at least 52 acres of land to tidal wetland restoration.
- Open tidal marsh area along Jacoby Creek allows for more even marsh plain accretion, but the muted tide gate could slow accretion rates.

- Open tidal marsh area along Jacoby Creek allows for better water quality exchange with Jacoby Creek, but the muted tide gate would limit water quality exchange from Gannon Slough and North Bay. This alternative creates the greatest opportunity for brackish marsh creation.

- A levee and tide gate structure will be necessary along the east project area boundary to prevent tidal inundation of the easterly pasture.

Table 5-4 Alternative 2 Design Elements

	Design Element	Cut (cy)	Fill (cy)
1.	Remove levee along 800 feet of the north bank of lower Jacoby Creek	1,030	
2.	Construct a slough channel in the floodplain north of lower Jacoby Creek	2,720	
3.	Install two 48-in tide gates at the mouth of South Branch Gannon Slough	150	100
4.	Fill spoils in borrow ditch along the highway levee		350
5.	Fill spoils in drainage ditch along the interior access road		900
6.	Fill breach in northern levee		50
7.	Build up northern levee to elevation 10 feet		1,700
8.*	Build up road (levee) along east project boundary to contain tidal water		1,075
9.*	Install two 48-in tide gates at the upstream extent of South Branch Gannon Slough (north-east corner of project area) to drain Easterly Pasture	-	-
	TOTAL	**3,900**	**4,075**

* Prescriptive solution at this location will be tailored to chosen alternative.

Table 5-5 Alternative 2 Proposed Habitat Benefits

	Restored or Created Habitat	Length (ft)	MHHW Area (acres)	Peak Event Area (acres)
1.	Convert pasturelands within project area to tidal wetland		52	85
2.	Restore tidal regime and flood flow drainage to South Branch Gannon Slough	3,600		
3.	Restore hydrologic connectivity between lower Jacoby Creek and South Branch Gannon Slough by constructing a slough channel across floodplain	1,600		

Table 5-6 Alternative 2 Construction Costs Estimate

Item	Description	Unit	Unit Price	Quantity	Item Price
1	Equipment mobilization/demobilization (1% of construction costs)	LS	1%	$159,577	$1,596
2	Clearing and grubbing (2% of construction costs)	LS	2%	$159,577	$3,192
3	Install two 48-inch tide gates at mouth of South Branch Gannon Slough	LS	$91,500	1	$91,500
4	Remove levee north of Jacoby Creek, breach and spoil	CY	$3.63	1030	$3,739
5	Cut slough channel north of Jacoby Creek and spoil	CY	$3.63	2720	$9,874
6	Build road/levee along eastern project boundary	CY	$5.33	1075	$5,730
7	Eastern boundary connection of project to upstream pasture	LS	$48,100	1	$48,100
8	Import fill from adjacent City of Arcata lands	CY	$3.63	175	$635
	Rounded Subtotal				$165,000
	Contingencies	%	15%	$165,000	$24,750
	Total Construction Costs				$189,750

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Figure 5-5 Design Alternative 2: Levee Removal and Tide Gate Installation at MHHW.

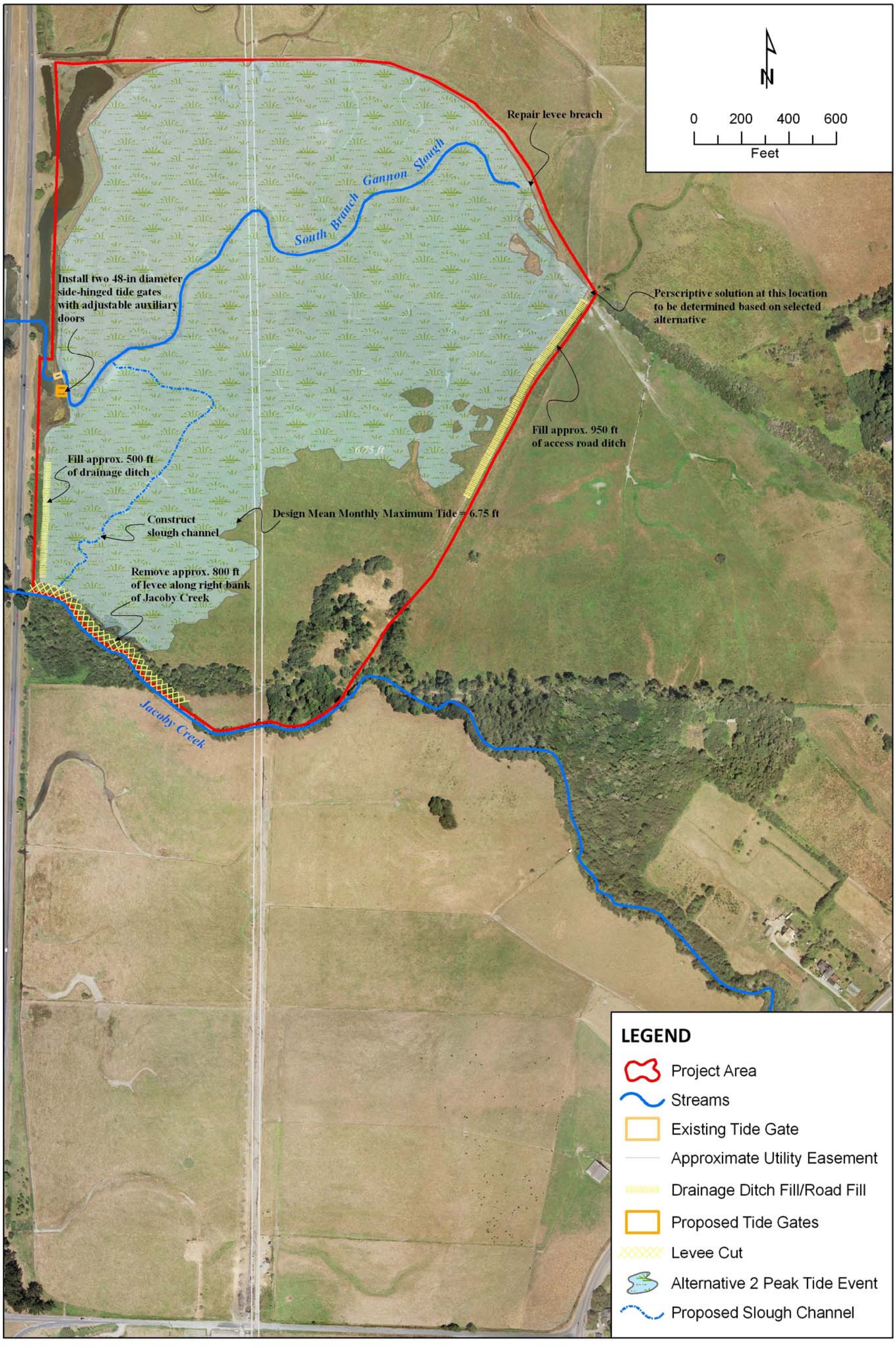

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Figure 5-6 Design Alternative 2: Levee Removal and Tide Gate Installation at Peak Tide.

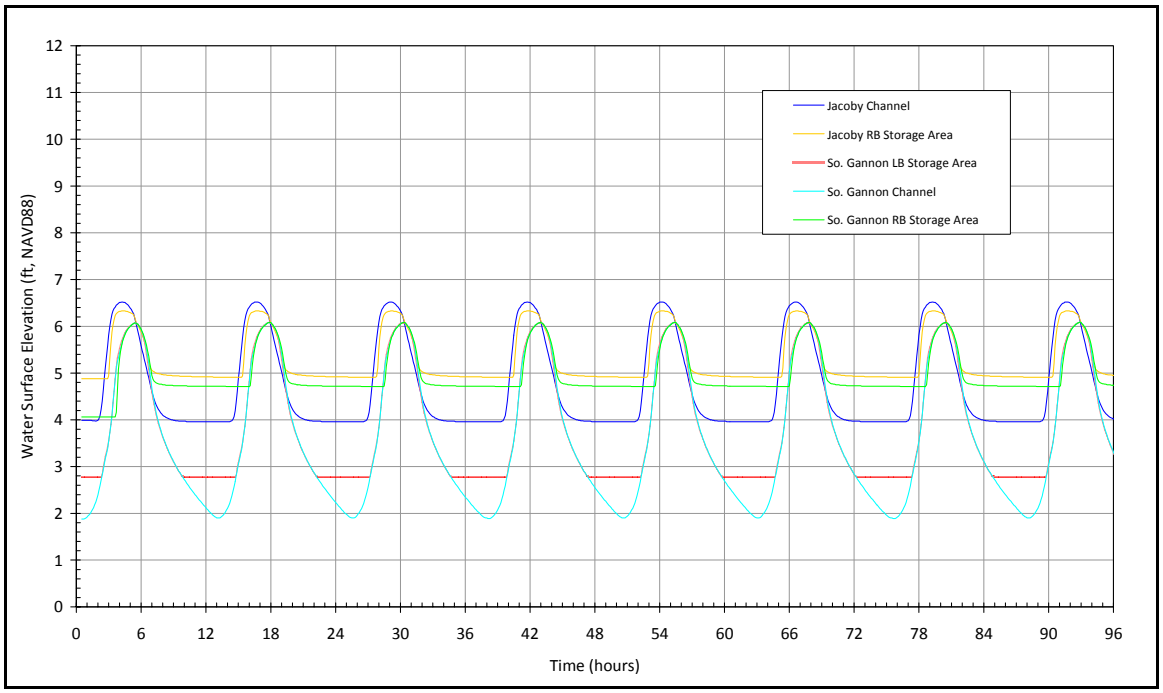

Figure 5-7 Modeled project area MHHW to MLLW tidal levels within the project area for Alternative 2 at low Jacoby Creek streamflow (10 cfs).

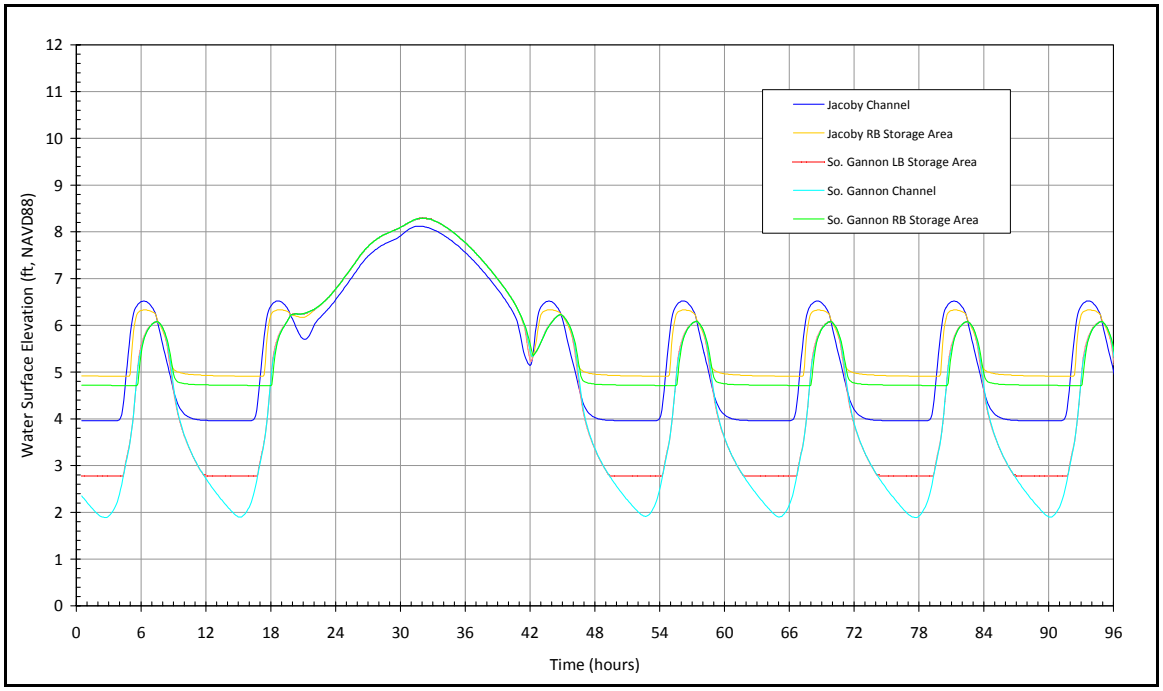

Figure 5-8 Modeled project area tide/water levels within the project area for Alternative 2 for the bankfull flood (1200 cfs) and the MHHW to MLLW tidal series.

5.4.3. Design Alternative 3: Breach Levee, Install Tide Gates

Alternative 3 represents a muted version of full tidal inundation of the project area by establishing muted tidal conditions from a small breach in the north levee of Jacoby Creek and a muted tidal prism from new tide gates at the mouth of South Branch Gannon Slough. This alternative proposes to convert approximately 38 acres of pasture within the project area to salt, brackish and fresh water wetland. Alternative 3 design elements are listed in Table 5-7 and shown graphically on Figure 5-9. The design elements focus on creating a small breach within the north levee along Lower Jacoby Creek that allows a muted tidal prism, install new tide gates on South Branch Gannon Slough that allow an adjustable muted tidal prism, construct a slough channel between Jacoby Creek and Gannon Slough, filling historic drainage ditches, and creating marsh plain surfaces by restoring a muted tidal prism to the project area.

Table 5-8 summarizes the restored and created habitat areas, and Table 5-9 lists the estimated construction costs for Alternative 3. In Table 5-8 a range of potential restored or created habitat areas was provided that includes a lower limit at the MHHW level to an upper limit at the mean monthly maximum tide level.

Results of the hydraulic analysis for Alternative 3 indicate that a restored MHHW tide elevation of 6.0 feet in the northerly portions of the project area, and 6.3 feet near Jacoby Creek can be expected (Figure 5-5). An average maximum monthly tidal inundation of 6.4 feet can be expected across the project area (Figure 5-10). Figure 5-11 shows the tidal response for the MHHW to MLLW tidal series for different locations within the project area. Due to the muting effect from the proposed Jacoby Creek levee and the South Branch Gannon Slough tide gates, tide levels are higher in and near Jacoby Creek than in other portions of the project area. Figure 5-12 shows that Alternative 3 also improves flood routing through the project area compared to existing conditions (Figure 3-5). The maximum water elevation within the project area is approximately 8.6 feet, which is approximately 1.4 feet lower than the existing conditions peak stage of 10 feet. For Alternative 3 the flood peak drains from the project area in approximately 18 hours (two tide cycles) compared to the 2 days required for existing conditions.

For this alternative it will not be necessary to construct a levee along the east boundary of the project area to contain tidal water, but some minor improvements of this area may be required. It may be necessary to install or improve the north east boundary flow conditions to better drain the easterly pasture during floods.

Design Alternative 3 Advantages and Disadvantages:

- Potential to capture Jacoby Creek during high flow events and re-route flow out of South Branch Gannon Slough. Further analysis of this alternative would address this issue and provide elevations for any necessary channel invert control.
- High potential for habitat diversity for salmonids, fish and other aquatic species.
- A commitment of at least 38 acres of land to tidal wetland restoration.
- Muted tidal conditions could limit or slow marsh plain accretions rates.

- Muted tidal conditions will limit water quality exchange from Jacoby Creek and Gannon Slough.

- Some improvements to the project area east boundary may be required.

Table 5-7 Alternative 3 Design Elements

	Design Element	Cut (cy)	Fill (cy)
1.	Cut a small breach in the levee of the north bank of Jacoby Creek at the mouth of constructed slough channel	120	
2.	Construct a slough channel in the floodplain north of lower Jacoby Creek	2,720	
3.	Install two 48-IN tide gates at the mouth of South Branch Gannon Slough	150	100
4.	Fill spoils in borrow ditch along the highway levee		350
5.	Fill spoils in drainage ditch along the interior access road		900
6.	Fill breach in northern levee		50
7.	Build up northern levee to elevation 10 feet		1,700
8.*	Install one 48-in tide gates at the upstream extent of South Branch Gannon Slough (north-east corner of project area) to drain Easterly Pasture	-	-
	TOTAL	**2,990**	**3,100**

* Prescriptive solution at this location will be tailored to chosen alternative.

Table 5-8 Alternative 3 Proposed Habitat Benefits

	Restored or Created Habitat	Length (ft)	MHHW Area (acres)	Peak Event Area (acres)
1.	Convert pasturelands connecting Jacoby Creek and Gannon Slough Estuary to tidal wetland		38	71
2.	Restore tidal regime and flood flow drainage to South Branch Gannon Slough	3,600		
3.	Restore hydrologic connectivity between lower Jacoby Creek and South Branch Gannon Slough by constructing a slough channel across the floodplain	1,600		

Table 5-9 Alternative 3 Construction Costs Estimate

Item	Description	Unit	Unit Price	Quantity	Item Price
1	Equipment mobilization/demobilization (1% of construction costs)	LS	1%	$158,108	$1,581
2	Clearing and grubbing (2% of construction costs)	LS	2%	$158,108	$3,162
3	Install two 48-inch tide gates at mouth of S. Branch Gannon Slough	LS	$91,500	1	$91,500
4	Breach levee north of Jacoby Creek	CY	$3.63	120	$436
5	Riprap levee breach	TON	$60	130	$7,800
6	Cut slough channel north of Jacoby Creek and spoil	CY	$3.63	2,720	$9,874
7	Eastern boundary prescription to connect project to upstream pasture	LS	$48,100	1	$48,100
8	Import fill from adjacent City of Arcata lands	CY	$3.63	100	$399
	Rounded Subtotal				$163,000
	Contingencies	%	15%	$163,000	$24,450
	Total Construction Costs				$187,450

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Figure 5-9 Design Alternative 3: Levee Breach and Tide Gate Installation at MHHW.

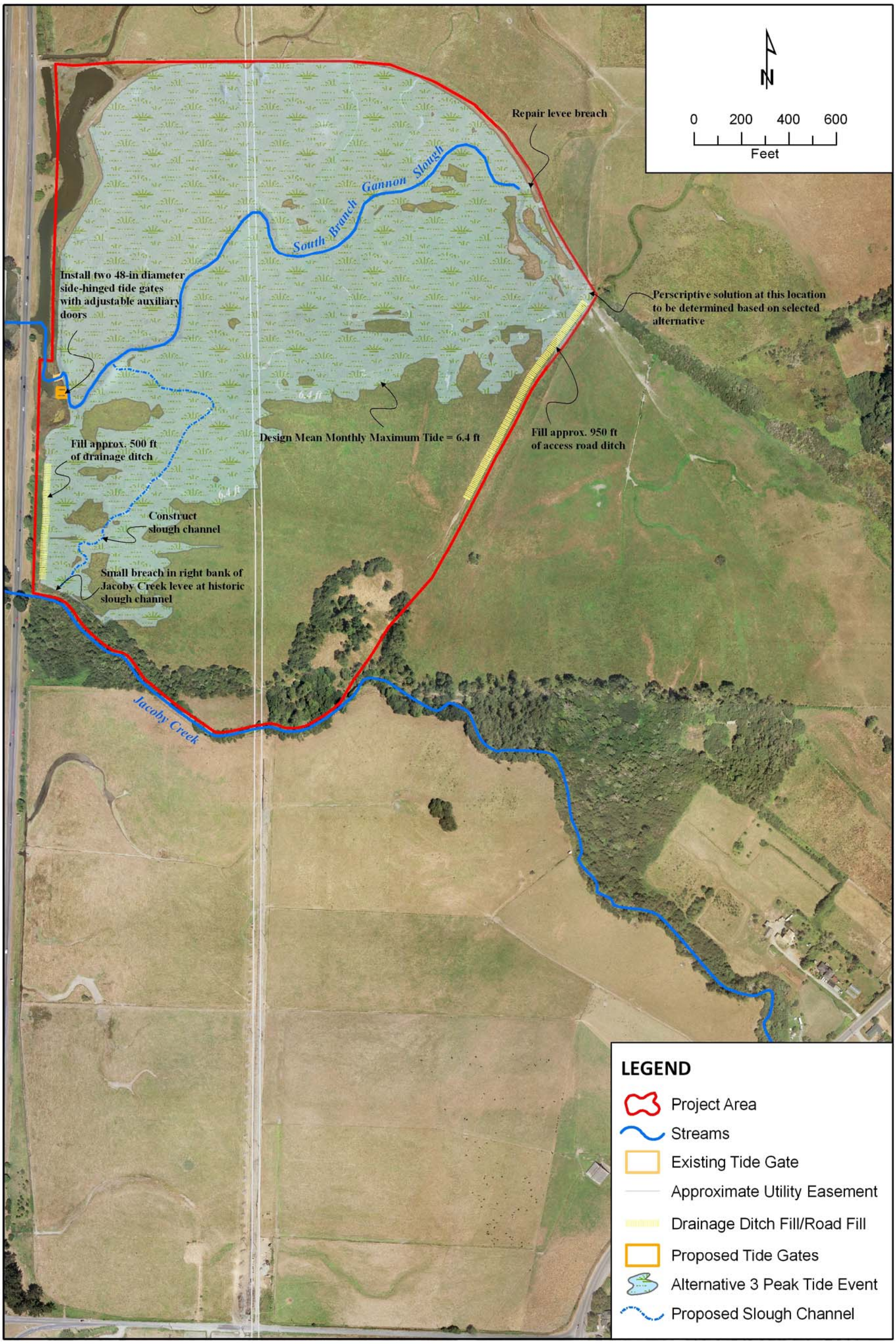

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Figure 5-10 Design Alternative 3: Levee Breach and Tide Gate Installation at Peak Tide.

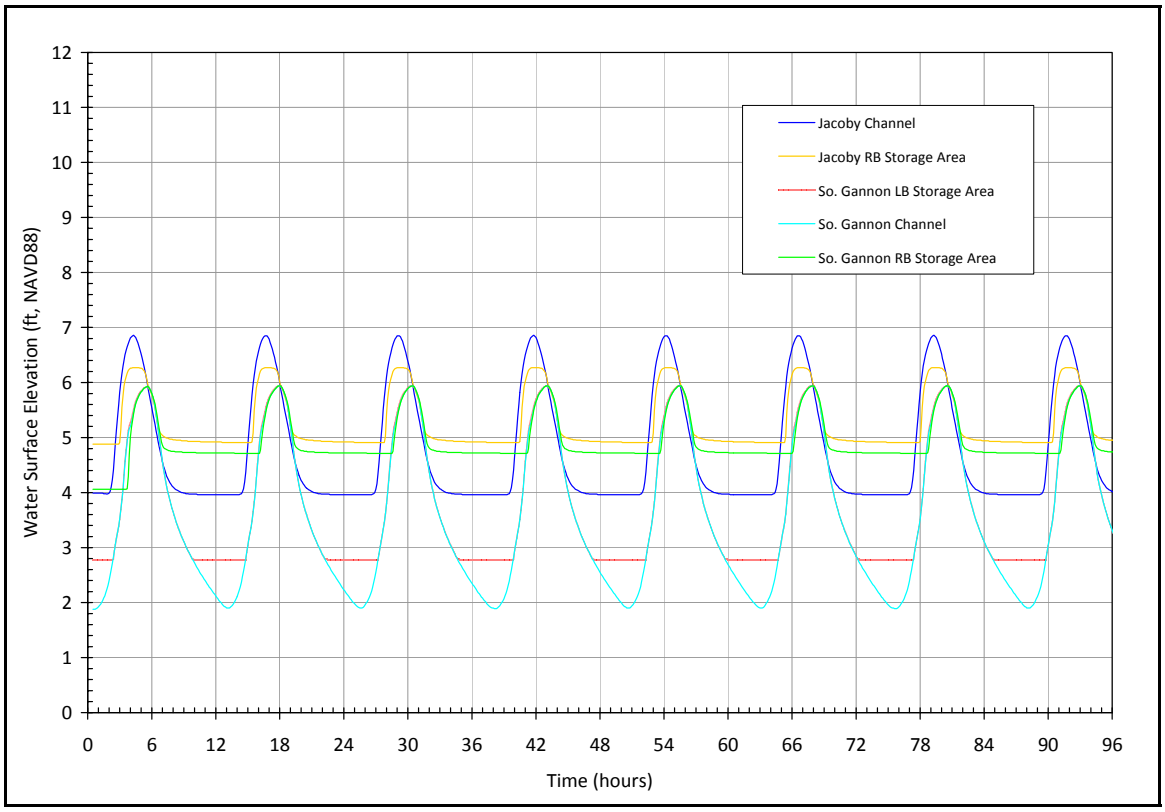

Figure 5-11 Modeled project area MHHW to MLLW tidal levels within the project area for Alternative 3 at low Jacoby Creek streamflow (10 cfs).

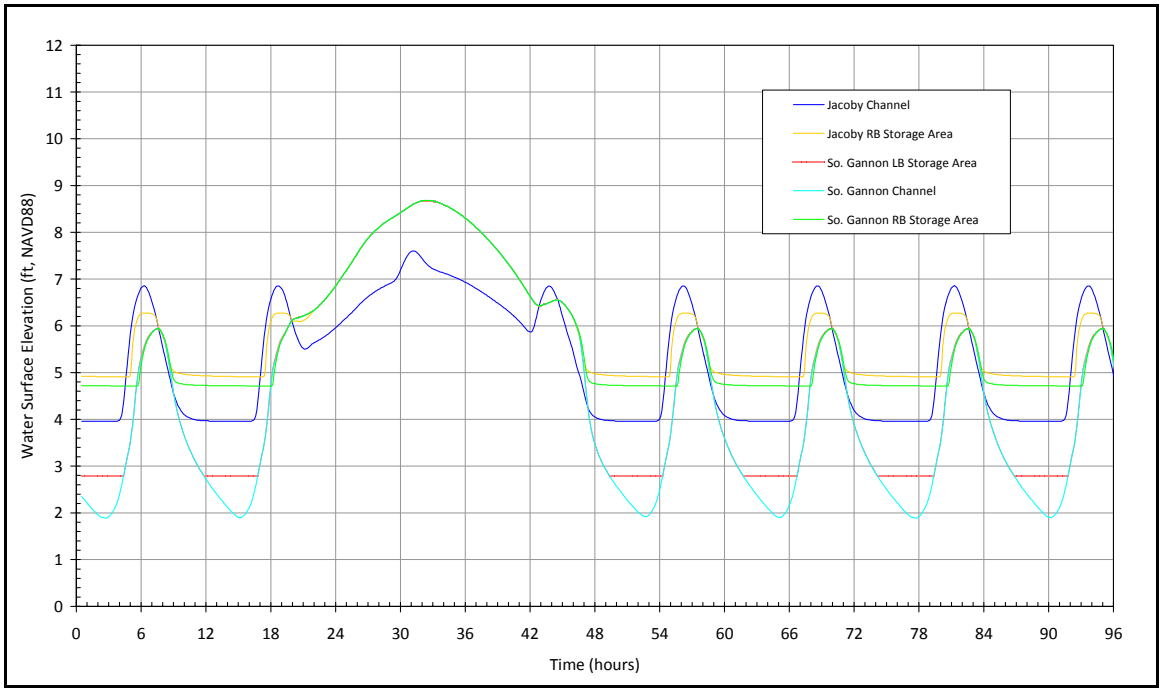

Figure 5-12 Modeled project area tide/water levels within the project area for Alternative 3 for the bankfull flood (1200 cfs) and the MHHW to MLLW tidal series.

5.4.4. Design Alternative 4: Remove Levee, Construct Setback Berm, Install Tide Gates

Alternative 4 allows unimpeded tidal inundation from Jacoby Creek onto 15 acres at the southern end of the project site, contained by an setback levee constructed to an elevation of 7.5 feet. Muted tidal inundation onto the northern end of the project site is through the proposed tide gates at the mouth of South Branch Gannon Slough. This alternative proposes to convert approximately 21 acres of pasture within the project area to salt, brackish and fresh water wetland. Alternative 4 design elements are listed in Table 5-10 and shown graphically on Figure 5-14. The design elements focused removing the north levee along Jacoby Creek, construct a offset berm to elevation 7.5 feet, install a tide gate through the offset berm that allows fish to move from South Branch Gannon Slough back into Jacoby Creek, install new tide gates on South Branch Gannon Slough that allow an adjustable muted tidal prism, filling historic drainage ditches, and creating marsh plain surfaces by restoring a muted tidal prism to the project area.

Table 5-11 summarizes the restored and created habitat areas, and Table 5-12 lists the estimated construction costs for Alternative 4. In Table 5-11 a range of potential restored or created habitat areas was provided that includes a lower limit at the MHHW level to an upper limit at the mean monthly maximum tide level.

Results of the hydraulic analysis for Alternative 4 indicate that a restored MHHW tide elevation of 7.0 feet in the created Jacoby Creek estuary (contained by offset berm), and 5.0 feet in the northerly portions of the project area (Figure 5-13). An average maximum monthly tidal inundation of 6.3 feet can be expected in the northerly portion of the project area as higher tides spill over the offset levee, and 7.7 feet in the created Jacoby Creek estuary (Figure 5-14). Figure 5-15 shows the tidal response for the MHHW to MLLW tidal series for different locations within the project area. Due to the muting effect from the South Branch Gannon Slough tide gates and the offset berm the tide levels in the northerly portion of the project area are muted well below Jacoby Creek and the created Jacoby Creek estuary. However, the created Jacoby Creek estuary is in sync with the Jacoby Creek channel. Figure 5-16 shows that Alternative 4 also improves flood routing through the project area compared to existing conditions (Figure 3-5). The maximum water elevation within the project area is approximately 8.2 feet, which is approximately 1.8 feet lower than the existing conditions peak stage of 10 feet. For Alternative 4 the flood peak drains from the project area in approximately 18 hours (two tide cycles) compared to the 2 days required for existing conditions.

For this alternative it will not be necessary to construct a levee along the east boundary of the project area to contain tidal water, but some minor improvements of this area may be required. It may be necessary to install or improve the north east boundary flow conditions to better drain the easterly pasture during floods.

Design Alternative 4 Advantages and Disadvantages:

- Containment of the open tidal regime from Jacoby Creek up to elevation 7.5 feet by the offset berm.
- Reduced potential for habitat diversity for salmonids, fish and other aquatic species.

- Movement of fish species between Sough Branch Gannon Slough and Jacoby Creek requires fish to pass over offset berm during high flows, or swim through small tide gated culvert in offset berm.
- A commitment of at least 21 acres of land to tidal wetland restoration.
- Potential for increased accretion rates in created Jacoby Creek estuary from Jacoby Creek due to offset berm.
- Muted tidal conditions could limit or slow marsh plain accretions rates.
- Muted tidal conditions will limit water quality exchange from Jacoby Creek and Gannon Slough.
- Some improvements to the project area east boundary may be required.

Table 5-10 Alternative 4 Design Elements

	Design Element	Cut (cy)	Fill (cy)
1.	Remove levee along 800 feet of the north bank of lower Jacoby Creek	1,030	
2.	Construct a slough channel in the floodplain north of lower Jacoby Creek	2,720	
3.	Construct a berm parallel to the creek channel to elevation 7.5 feet (~1.5 feet above the floodplain), impeding peak tidal inundation north of the berm	0	450
4.	Install one 24-in tide gate where the setback berm crosses the constructed slough channel to drain flood flows from South Branch Gannon Slough into Jacoby Creek and to allow for fish passage	0	0
5.	Install two 48-in tide gates at the mouth of South Branch Gannon Slough	150	100
6.	Fill spoils in borrow ditch along the highway levee	0	350
7.	Fill spoils in drainage ditch along the interior access road	0	900
8.	Fill breach in northern levee	0	50
9.	Build up northern levee to elevation 10 feet		1,700
10.*	Install one 48-in tide gate at the upstream (eastern) extent of South Branch Gannon Slough within the project area	-	-
	TOTAL	**3,900**	**3,550**

* Prescriptive solution at this location will be tailored to chosen alternative.

Table 5-11 Alternative 4 Proposed Habitat Benefits

	Restored or Created Habitat	Length (ft)	MHHW Area (acres)	Peak Event Area (acres)
1.	Convert pasturelands connecting Jacoby Creek and Gannon Slough Estuary to tidal wetland		21	76
2.	Restore tidal regime and flood flow drainage to South Branch Gannon Slough	3,600		
3.	Restore hydrologic connectivity between lower Jacoby Creek and South Branch Gannon Slough by constructing a slough channel across the floodplain	1,600		

Table 5-12 Alternative 4 Construction Costs Estimate

Item	Description	Unit	Unit Price	Quantity	Item Price
1	Equipment mobilization/demobilization (1% of construction costs)	LS	1%	$168,172	$1,682
2	Clearing and grubbing (2% of construction costs)	LS	2%	$168,172	$3,363
3	Install two 48-inch tide gates at mouth of South Branch Gannon Slough	LS	$91,500	1	$91,500
4	Remove levee north of Jacoby Creek, breach and spoil	CY	$3.63	1,030	$3,739
5	Cut slough channel north of Jacoby Creek and spoil	CY	$3.63	2,720	$9,874
6	Build setback berm	CY	$5.33	450	$2,399
7	Install one 24-inch culvert and tide gates in setback berm	LS	$12,560	1	$12,560
8	Eastern boundary prescription to connect project to upstream pasture	LS	$48,100	1	$48,100
	Rounded Subtotal				$174,000
	Contingencies	%	15%	$174,000	$26,100
	Total Construction Costs				$200,100

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Figure 5-13 Design Alternative 4: Levee Removal, Setback Berm & Tide Gate Installation at MHHW.

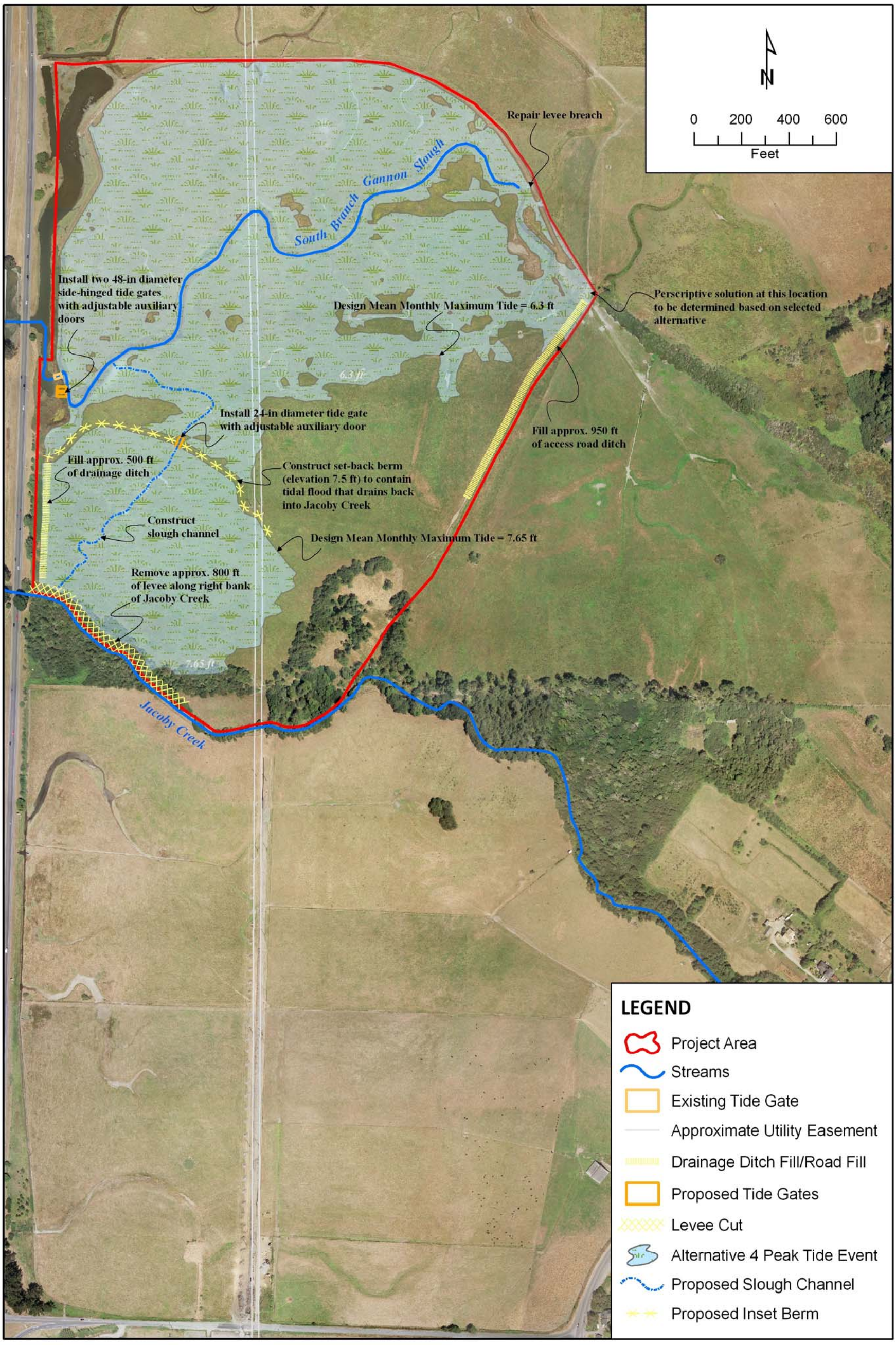

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Figure 5-14 Alternative 4: Levee Removal, Setback Berm and Tide Gate Installation at Peak Tide.

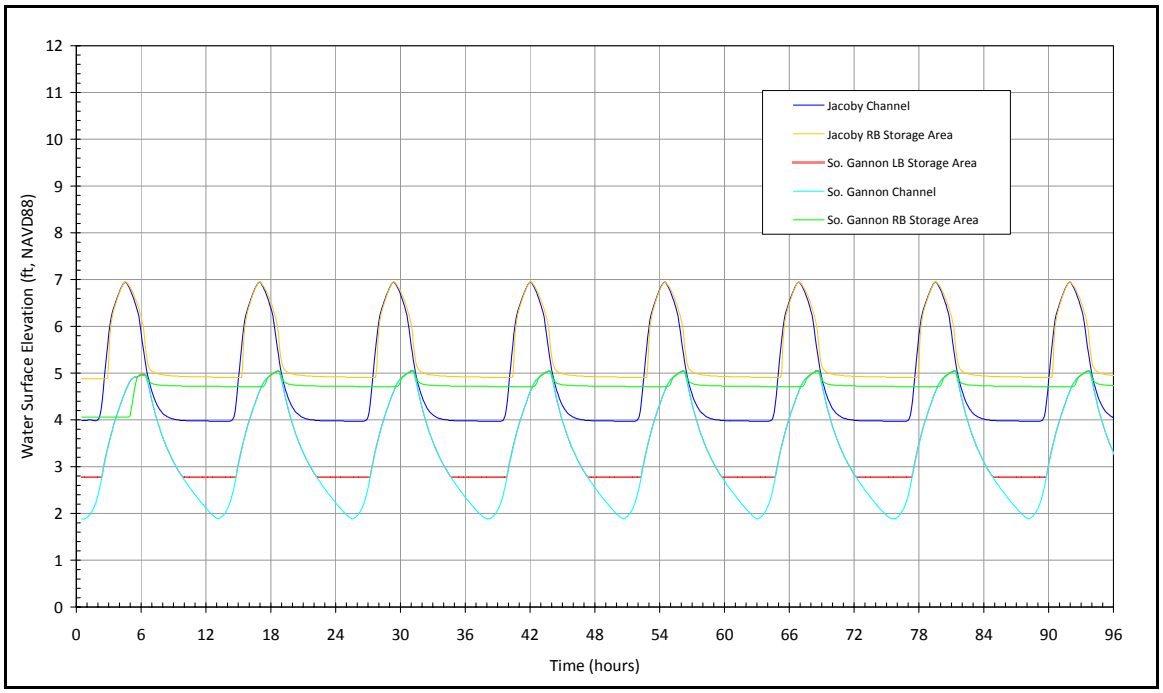

Figure 5-15 Modeled project area MHHW to MLLW tidal levels within the project area for Alternative 4 at low Jacoby Creek streamflow (10 cfs).

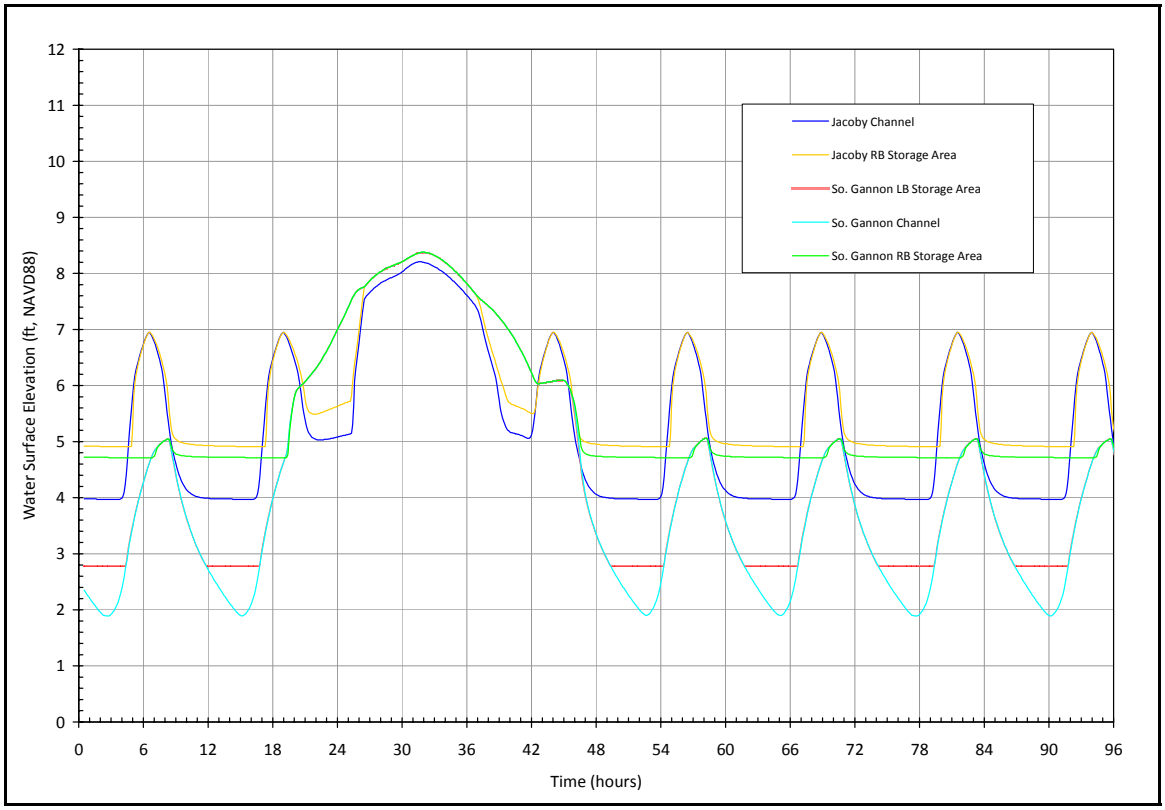

Figure 5-16 Modeled project area tide/water levels within the project area for Alternative 4 for the bankfull flood (1200 cfs) and the MHHW to MLLW tidal series.

5.4.5. Figure Design Alternative 5: Remove Levee, Construct Setback Levee, Install Tide Gates

Alternative 5 allows unimpeded tidal inundation onto 15 acres at the southern end of the project site from Jacoby Creek, contained by a setback levee constructed to an elevation of 10 feet. Muted tidal inundation onto the northern end of the project site is through the proposed tide gates at the mouth of South Branch Gannon Slough. This alternative proposes to convert approximately 21 acres of pasture within the project area to salt, brackish and fresh water wetland. Alternative 5 design elements are listed in Table 5-13 and shown graphically on Figure 5-17. The design elements focus on removing the north levee along Jacoby Creek, constructing an offset berm to elevation 10 feet to fully contain tidal flow from Jacoby Creek to the created 15 acre marsh, installing a tide gate through the offset berm that allows fish to move from South Branch Gannon Slough back into Jacoby Creek, installing new tide gates on South Branch Gannon Slough that allow an adjustable muted tidal prism, filling historic drainage ditches, and creating marsh plain surfaces by restoring a muted tidal prism to the project area.

Table 5-14 summarizes the restored and created habitat areas, and Table 5-15 lists the estimated construction costs for Alternative 5. In Table 5-14 a range of potential restored or created habitat areas was provided that includes a lower limit at the MHHW level to an upper limit at the mean monthly maximum tide level.

Results of the hydraulic analysis for Alternative 5 indicate that a restored MHHW tide elevation of 7.0 feet in the created Jacoby Creek estuary (contained by setback levee), and 5.0 feet in the northerly portions of the project area (Figure 5-17). An average maximum monthly tidal inundation of 5.6 feet can be expected in the northerly portion of the project area, and 8.1 feet in the created Jacoby Creek estuary (Figure 5-18). Figure 5-19 shows the tidal response for the MHHW to MLLW tidal series for different locations within the project area. Due to the muting effect from the South Branch Gannon Slough tide gates and the setback levee the tide levels in the northerly portion of the project area are muted well below Jacoby Creek and the created Jacoby Creek estuary. However, the created Jacoby Creek estuary is in sync with the Jacoby Creek channel. Figure 5-20 shows that Alternative 5 also improves flood routing through the project area compared to existing conditions (Figure 3-5). The maximum water elevation within the project area is approximately 9.3 feet, which is approximately 0.7 feet lower than the existing conditions peak stage of 10 feet. For Alternative 5 the flood peak drains from the project area in approximately 18 hours (two tide cycles) compared to the 2 days required for existing conditions.

For this alternative it will not be necessary to construct a levee along the east boundary of the project area to contain tidal water, but some minor improvements of this area may be required. It may be necessary to install or improve the north east boundary flow conditions to better drain the easterly pasture during floods.

Design Alternative 5 Advantages and Disadvantages:

- Complete containment of the open tidal regime from Jacoby Creek up to elevation 7.5 feet by the setback levee.

- Reduced potential for habitat diversity for salmonids, fish and other aquatic species.
- Movement of fish species between Sough Branch Gannon Slough and Jacoby Creek requires fish to swim through a small tide gated culvert in the setback levee.
- A commitment of at least 21 acres of land to tidal wetland restoration.
- Fill may be required to be imported to the site for the construction of the setback levee.
- Potential for increased accretion rates in created Jacoby Creek estuary from Jacoby Creek due to the setback levee.
- Muted tidal conditions could limit or slow marsh plain accretions rates.
- Muted tidal conditions will limit water quality exchange from Jacoby Creek and Gannon Slough.
- Some improvements to the project area east boundary may be required.

Table 5-13 Alternative 5 Design Elements

	Design Element	Cut (cy)	Fill (cy)
1.	Remove levee along 800 feet of the north bank of lower Jacoby Creek	1,030	
2.	Construct a slough channel in the floodplain north of lower Jacoby Creek	2,720	
3.	Construct a levee parallel to the creek channel to elevation 10 feet (~4 feet above the floodplain), restricting peak tidal inundation north of the levee	0	3,800
4.	Install one 24-in tide gate where the setback levee crosses the constructed slough channel to drain flood flows from South Branch Gannon Slough into Jacoby Creek and to allow for fish passage	0	0
5.	Install two 48-in tide gates at the mouth of South Branch Gannon Slough	150	100
6.	Fill spoils in borrow ditch along the highway levee	0	350
7.	Fill spoils in drainage ditch along the interior access road	0	900
8.	Fill breach in northern levee	0	50
9.*	Install one 48-in tide gate at the upstream (eastern) extent of South Branch Gannon Slough within the project area	-	-
	TOTAL	**3,900**	**5,200**

* Prescriptive solution at this location will be tailored to chosen alternative.

Table 5-14 Alternative 5 Proposed Habitat Benefits

	Restored or Created Habitat	Length (ft)	MHHW Area (acres)	Peak Event Area (acres)
1.	Convert pasturelands connecting Jacoby Creek and Gannon Slough Estuary to tidal wetland		21	34
2.	Restore tidal regime and flood flow drainage to South Branch Gannon Slough	3,600		
3.	Restore hydrologic connectivity between lower Jacoby Creek and South Branch Gannon Slough by constructing a slough channel across the floodplain	1,600		

Table 5-15 Alternative 5 Construction Costs Estimate

Item	Description	Unit	Unit Price	Quantity	Item Price
1	Equipment mobilization/demobilization (1% of construction costs)	LS	1%	$190,692	$1,907
2	Clearing and grubbing (2% of construction costs)	LS	2%	$191,692	$3,814
3	Install two 48-inch tide gates at mouth of South Branch Gannon Slough	LS	$91,500	1	$91,500
4	Remove levee north of Jacoby Creek, breach and spoil	CY	$3.63	1,030	$3,739
5	Cut slough channel north of Jacoby Creek and spoil	CY	$3.63	2,720	$9,874
6	Build setback levee	CY	$5.33	3,790	$20,201
7	Install one 24-inch culvert and tide gates in setback berm	LS	$12,560	1	$12,560
8	Eastern boundary prescription to connect project to upstream pasture	LS	$48,100	1	$48,100
9	Import fill from adjacent City of Arcata lands	CY	$3.63	1,300	$4,719
	Rounded Subtotal				$197,000
	Contingencies	%	15%	$197,000	$29,550
	Total Construction Costs				$226,550

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Figure 5-17 Alternative 5: Levee Removal, Setback Levee & Tide Gate Installation at MHHW.

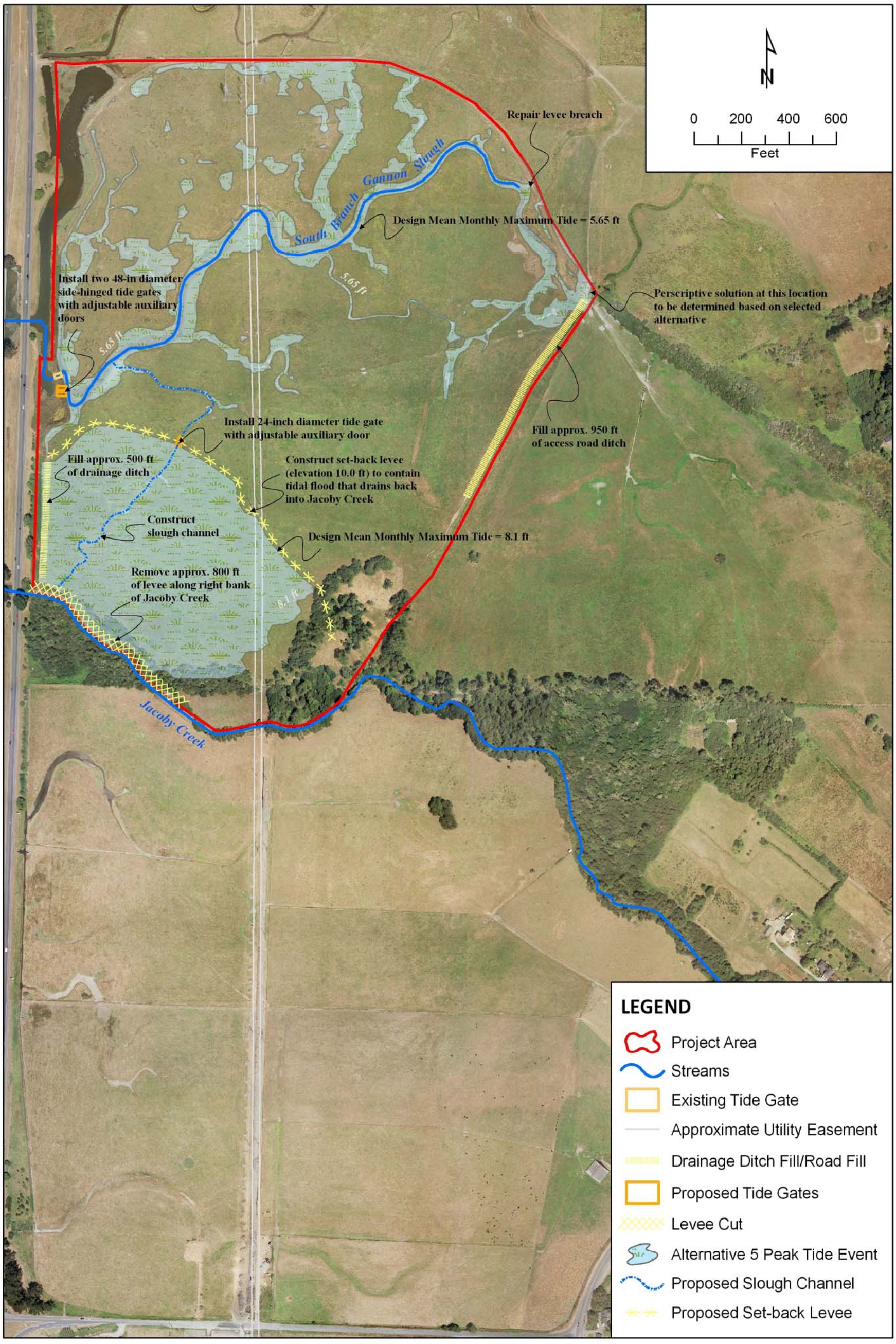

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Figure 5-18 Design Alternative 5: Levee Removal, Setback Levee and Tide Gate Installation at Peak Tide.

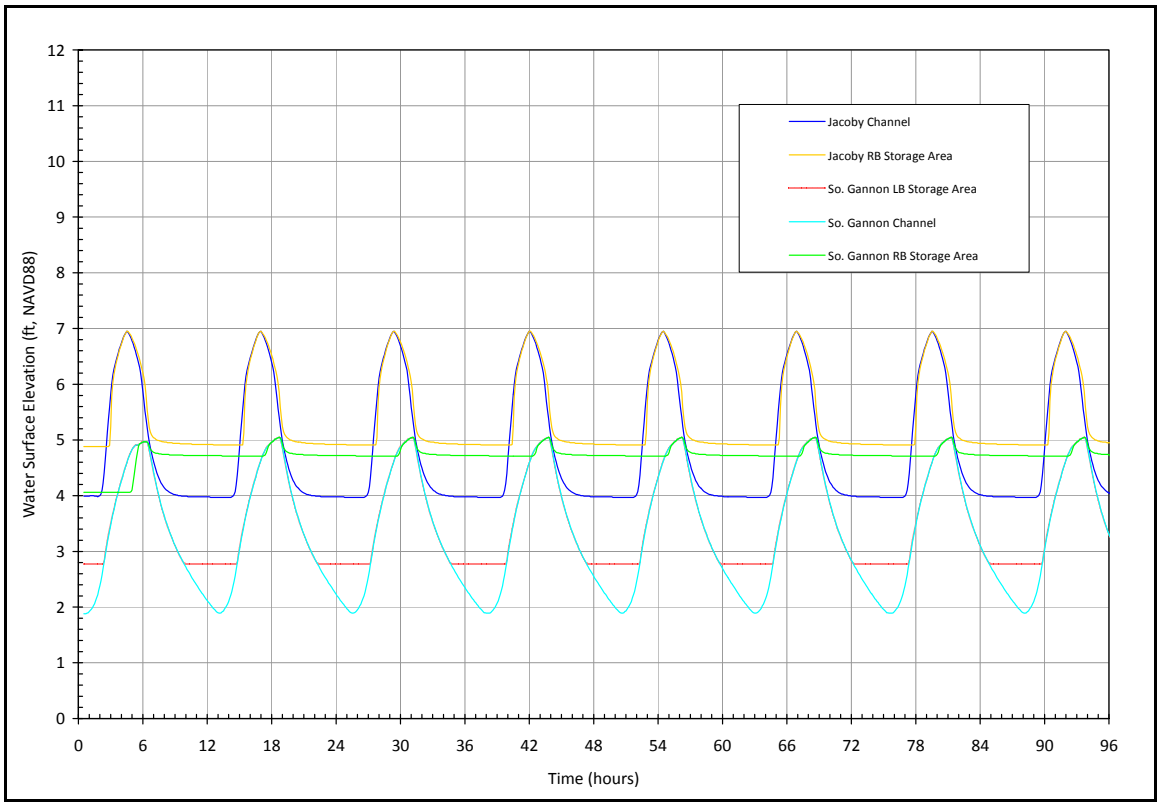

Figure 5-19 Modeled project area MHHW to MLLW tidal levels within the project area for Alternative 5 at low Jacoby Creek streamflow (10 cfs).

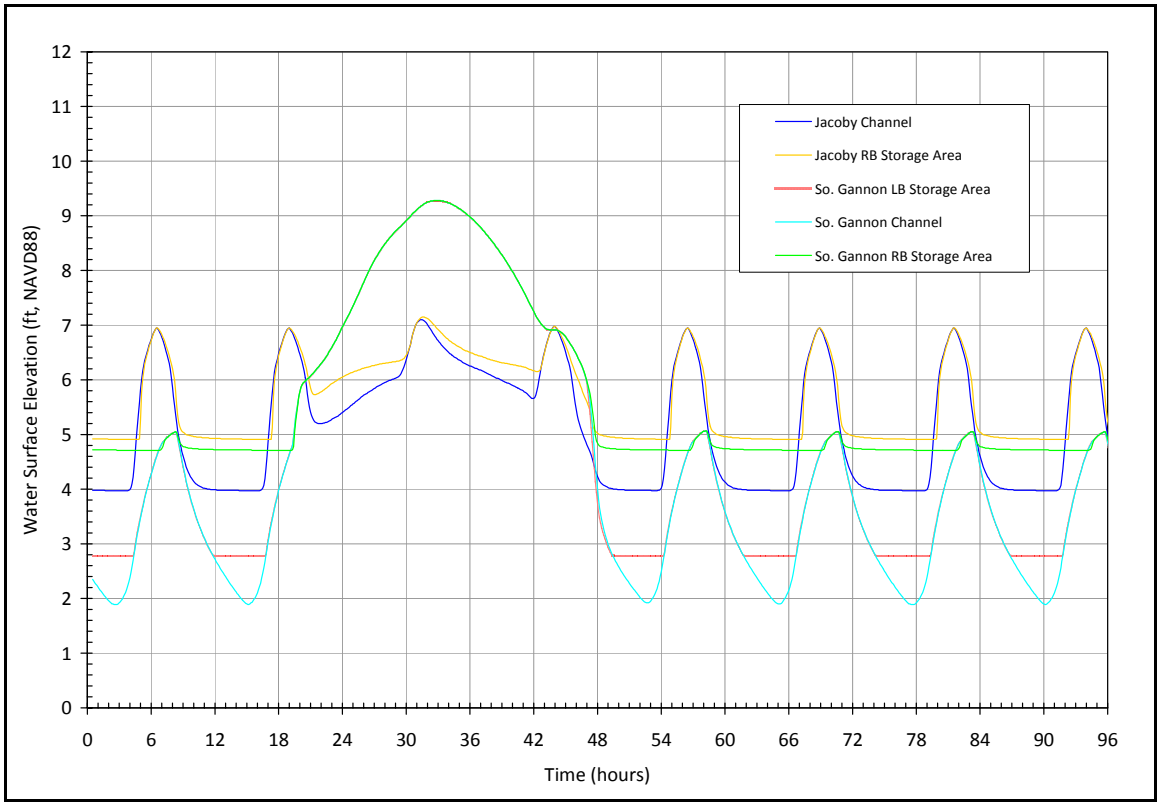

Figure 5-20 Modeled project area tide/water levels within the project area for Alternative 5 for the bankfull flood (1200 cfs) and the MHHW to MLLW tidal series.

5.5. Required Steps for Implementation

Alternatives developed and analyzed in this report are conceptual in nature. They are not engineered designs and additional technical and quantitative work will be required prior to implementing any one of the developed conceptual design alternatives.

Following is a list of additional work items that may be required prior to implementing one of the conceptual design alternatives, and will likely be determined by permitting, engineering and construction needs:

- Collect additional Jacoby Creek channel bathymetry data from North Bay to Old Arcata Road to better assess and understand the potential for creating backwater habitats, setback levees, levee removal, or levee breaching.
- Collect bathymetry in Gannon Slough to assess the invert of the proposed tide gate(s).
- Identify, locate and measure elevations of the infrastructure that needs to be protected in relation to the project.
- Collect water quality data in Lower Jacoby Creek and Gannon Slough to better understand existing conditions.
- Evaluate expected water quality conditions of restored habitats.
- Assess if ESA species are present within the project area.
- Evaluate impacts, both positive and negative, to ESA species from proposed action.
- Design proposed tide gate(s), and other water control structures. Assess erosion potential of these structures.
- Conduct detailed hydraulic analysis of the preferred alternative design that includes additional topography/bathymetry data and specified design details, and determine circulation patterns within restored habitats. This type of analysis may require two-dimensional modeling.
- Assess the potential sedimentation of restored habitats from Jacoby Creek.
- Conduct necessary engineering analysis, such as geotechnical studies; assess impacts to existing infrastructure (e.g. Gannon Slough bridge), and assess construction season groundwater levels.
- Work with Caltrans to address plans for the Highway 101 expansion project and opportunities to remove instream obstructions.
- Based on the selected design alternative, assess, design and engineer the east project area boundary tie-in to the easterly pasture.
- Develop construction plans and specifications for the selected design alternative, refine cut/fill volumes, design habitat structures, incorporate revegetation designs, and post-project monitoring studies.

6. Additional Enhancement Concepts Outside of Project Area

Another requirement of this work was to develop additional enhancement concepts for Jacoby Creek outside of the project area. Three specific areas were identified, (1) Lower South Jacoby Pasture, (2) Upper South Jacoby Pasture, and (3) the Easterly Pasture. All of the proposed enhancement concepts are preliminary. Additional data and analysis will be required to better assess the validity of each proposed enhancement concept.

Figure 6-1 shows a schematic of the proposed enhancement concepts along with projected MHHW elevations for Alternative 3 within the project area.

6.1. Lower South Jacoby Pasture

Potential enhancement concepts for the Lower South Jacoby Pasture include retrofitting the existing tide gate that drains this area under Highway 101 with a tide gate that allows a muted tidal prism, and either breaching or removing the levee along the left bank of Lower Jacoby Creek. Also, reconnecting Lower Jacoby Creek with the historic oxbow upstream of Highway 101 (Figure 2-1) could be explored. Reconnection of the historic oxbow along with an east-west trending setback levee constructed along the south boundary of the oxbow area could be evaluated as a stand-alone project, or could supplement the estuary enhancement to the north. The setback levee would allow reconnection and enhancement of the oxbow area without affecting the existing Lower South Jacoby Pasture area agricultural activities.

Jeff Anderson & Associates (March 2006) has already assessed some potential tide gate options for this area. Based on this work, it was estimated that a muted tidal prism from the modified tide gate and connection with Jacoby Creek could produce a MHHW elevation of approximately 6.5 feet in this area.

To pursue this concept further the hydraulic model developed in this study could be modified to include the modified tide gate and connection with Jacoby Creek. This would be a straight forward process as the South Jacoby Pasture area has already been included into the hydraulic model.

6.2. Upper South Jacoby Pasture

Potential enhancement concepts for the Upper South Jacoby Pasture include left bank levee removal along Jacoby Creek, the creation/enhancement of high flow channels, and the installation of tide gated culverts to improve flood flow drainage of this area into the Lower South Jacoby Pasture.

To pursue this concept further it will be necessary, at a minimum, to survey the thalweg elevation of Jacoby Creek from North Bay to Old Arcata Road, and better understand salmonid rearing habitat and high-flow refugia use within this reach of Jacoby Creek. For example, it has been observed that Jacoby Creek is perched such that thalweg elevations are higher than adjacent floodplain elevations. Creating a levee breach or backwater channel could inadvertently daylight Jacoby Creek and aquatic species onto its floodplain.

6.3. Easterly Pasture from Project Area

Potential enhancement concepts for the Easterly Pasture east of the current project area include reconnecting historic high flow channels with South Branch Gannon Slough. These restored high flow channels could better intercept overbank flood flows and the entrained aquatic species (e.g. salmonids) from Jacoby Creek and redirect them back into the project area and South Branch Gannon Slough.

This concept would require assessing the existing high flow channels and interconnectivity with drainage features under Old Arcata Road. Also, it would require assessing and designing a compatible connection at the north-east corner of the project area. For example, this connection could consist of a set of tide gated culverts depending on the extent of the restored tidal prism within the project area. It is likely that any improved connection between the Easterly Pasture and the project area would improve survival conditions for salmonids and also improve flood routing within this area.

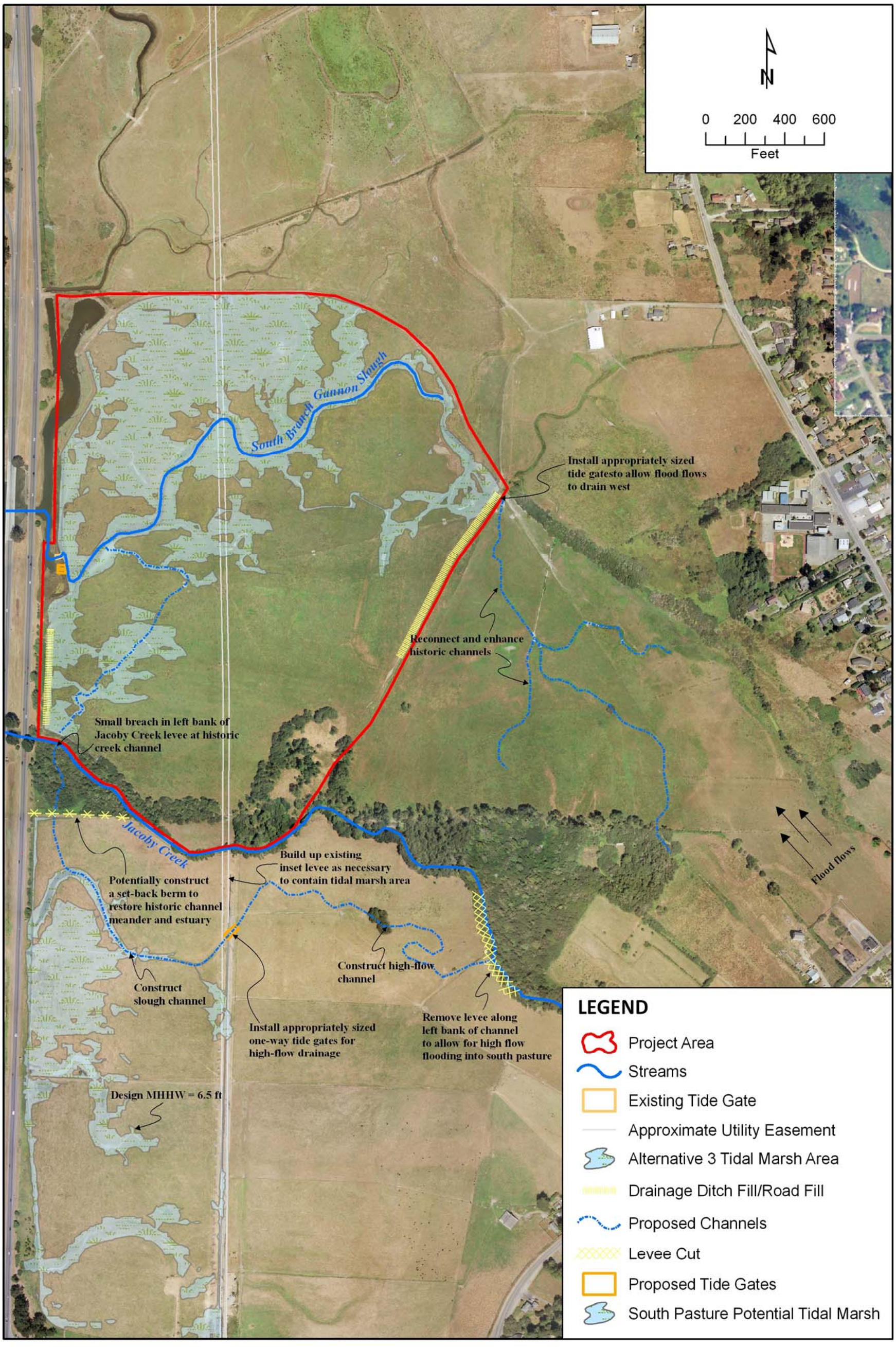

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Figure 6-1 Additional Conceptual Design Elements Shown in Combination with Design Alternative 3.

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