

Final Report
**Jacoby Creek Water Sustainability and Anadromous
Fish Habitat Enhancement Feasibility Study**

Bayside, California

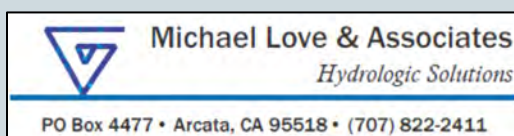


August 2024

Prepared for:



Prepared by:



Final Report

Jacoby Creek Water Sustainability and Anadromous Fish Habitat Enhancement Feasibility Study

Bayside, California

Prepared for:

Jacoby Creek Land Trust

County of Humboldt Department of Public Works

California Coastal Conservancy

City of Arcata

Prepared by:

Michael Love P.E.

Principal Engineer

License No. C71681

Michael Love & Associates, Inc.

mlove@h2odesigns.com • (707) 826-2411 x 1

Jeremy Svehla P.E.

Project Manager

License No. C72169

GHD, Inc.

jeremy.svehla@ghd.com • (707) 443-8326

August 2024

Cover photo: Flooding along Old Arcata Road, February 16, 2019

Table of Contents

1	Introduction	2
1.1	Purpose of Report.....	2
1.2	Project Location and Ownership.....	2
1.3	Project Need	2
1.4	Study Goals and Desired Outcomes	5
1.5	Overview of Study Activities.....	6
1.6	Project Team, Technical Working Group, and Stakeholders	6
1.7	Stream Corridor Management Plan.....	6
1.8	2021-2022 Landowner Survey Results	7
2	Project Setting.....	10
2.1	Topography.....	10
2.1.1	Field Surveys and Basemap Preparation.....	10
2.1.2	Topographic Basemap.....	12
2.2	Existing Land Use, Jurisdictional Boundaries, and Utilities	12
2.2.1	Land Uses.....	12
2.2.2	City of Arcata Baylands Wildlife Area	12
2.2.3	JCLT Aquatic Habitat Restoration Projects	19
2.2.4	Jurisdictional Boundaries	19
2.2.5	Utilities.....	19
2.3	Existing Watercourse Crossings, Drainage Structures, and Levees.....	19
2.3.1	Jacoby Creek Bridges.....	19
2.3.2	Arcata Baylands North.....	20
2.3.3	Arcata Baylands South	22
2.3.4	Old Arcata Road Drainage	22
3	Historical Maps and Imagery.....	23
3.1	1870 US Coastal Survey Map	23
3.2	The “Old Channel” - Jacoby Creek upstream of OAR (1854-1921).....	24
3.3	1931 and 1941 Fairchild Aerial Images.....	26
3.4	1948-1965 Images	27

3.5	Jacoby Creek Delta: 1970 - Present.....	27
3.6	2011 Google Earth Image – Historical Channel Traces	28
4	Field Mapping and Data Collection	33
4.1	Mapping Floodplain Inundation Patterns	33
4.2	Valley Cross Section	34
4.3	Jacoby Creek Streamflow and Bedload Sampling at Brookwood Bridge	37
4.3.1	Jacoby Creek at Brookwood Bridge.....	37
4.3.2	Bedload Transport Samples at Brookwood Bridge	37
4.4	Characterizing Streambed Material Size.....	38
4.5	Water Level Gaging	38
4.5.1	Water Levels in Arcata Baylands North	39
4.5.2	Jacoby Creek Water Levels.....	39
4.6	Water Quality Measurements	39
4.7	Stream Habitat Mapping and Fisheries Observations	41
4.7.1	Stream Habitat Mapping.....	41
4.7.2	Mapping Instream Wood and Debris Jams	41
4.7.3	Overbank Fish Sampling and Observations of Fish Stranding	44
5	Project Hydrology and Sea Level Rise Projections	45
5.1	Return Period Flow.....	45
5.2	Jacoby Creek Daily Average Flow Duration	45
5.3	Existing Tidal Water Levels and Stillwater Return Periods	45
5.4	Projected Sea Level Rise.....	46
6	Existing Hydraulic & Sediment Transport Analysis	48
6.1	Model Development.....	48
6.1.1	2D Model Extents, Terrain, Boundaries and Mesh.....	48
6.1.2	Drainage Structures in Model	48
6.1.3	Scaled JBW Streamflows to Model Inflows	50
6.1.4	Model Scenarios	50
6.1.5	Model Calibration	50
6.1.6	Model Validation.....	52

6.2	Channel Flow Losses.....	52
6.3	Channel Capacity and Spillage Locations During Small Flow Events.....	54
6.4	Inundation and Drain-Off Patterns from 2021 Holiday Storm Event.....	54
6.5	Inundation Extents During the 2019 Peak Flow Event.....	57
6.6	Sediment Transport Assessment.....	57
6.6.1	Methods.....	57
6.6.2	Results.....	59
6.7	SLR Vulnerability Analysis.....	61
6.7.1	Existing Levee Top Elevations Relative to Tidal Overtopping.....	61
6.7.2	Inboard Inundation with Existing 2-Year Peak Tide of 9.4 feet.....	61
6.7.3	Inboard Inundation with Existing 10-Year Peak Tide of 10.0 feet.....	61
6.7.4	Inboard Inundation with Existing 100-Year Peak Tide of 10.7 feet.....	62
6.7.5	Summary.....	62
7	Channel & Floodplain Geomorphic Characteristics	68
7.1	Elevations Relative to Valley Bottom	68
7.2	Channel Profiles	70
7.3	Jacoby Creek Baselevel Change and Channel Aggradation	70
7.4	Jacoby Creek Geomorphic Trajectory	73
7.5	Arcata Baylands Trajectory with SLR	74
8	Synthesis of Existing Condition Findings.....	76
8.1	Historical Changes to Jacoby Creek.....	76
8.2	Woody Vegetation, Debris, and Sedimentation	76
8.3	Flooding Patterns, Flow Losses, and Sediment Transport.....	77
8.4	Aquatic Habitat.....	77
9	Scoping of Alternatives	78
9.1	Goals and Objectives.....	78
9.2	Scoping of Project Approaches.....	78
9.2.1	Arcata Baylands 1 - Tidal Reintroduction	78
9.2.2	Arcata Baylands 2 - Capture Channel and Freshwater Wetland	79
9.2.3	Enhanced Riparian Corridor.....	80

9.2.4	Upstream of Baylands 1 – Improve OAR Drainage Infrastructure	80
9.2.5	Upstream of Baylands 2– Channel Realignment at Bridge & Upstream Meander	82
9.2.6	Upstream of Baylands 3– Floodplain Capture Swales and Flood Flow Routing.....	83
9.2.7	Upstream of Baylands 4– Deepen and Enlarge Lower Graham Road Reach.....	84
9.2.8	Upstream of Baylands 5– Realign Lower Graham Road Reach to the North	84
9.3	Compatibility of Approaches	85
10	Conceptual Alternatives	87
10.1	Alternative 1: OAR Drainage Improvements & Limited Channel Realignment.....	87
10.1.1	Description	87
10.1.2	Considerations.....	89
10.2	Alternative 2: Floodplain Swales & Freshwater Wetland Complex.....	89
10.2.1	Description	89
10.2.2	Considerations.....	91
10.3	Alternative 3: Tide Reintroduction & Channel Deepening from US 101 through lower Graham Road Reach.....	91
10.3.1	Description	91
10.3.2	Considerations.....	96
10.4	Probable Construction Cost	98
10.5	Additional Habitat Enhancement Opportunities on JCLT Properties	98
11	Environmental Constraints Analyses	99
11.1	Environmental Review	99
11.1.1	California Environmental Quality Act.....	99
11.1.2	National Environmental Policy Act.....	100
11.2	Wetlands and Waters	100
11.2.1	Wetlands “No Net Loss” Policy.....	100
11.2.2	Clean Water Act.....	101
11.2.3	Porter-Cologne Act	101
11.2.4	Lake and Streambed Alteration Agreement.....	101
11.3	California Coastal Act.....	101
11.3.1	Section 30233: Wetland Fill.....	102

11.3.2	Section 30240: Environmentally Sensitive Habitat Areas.....	102
11.3.3	Section 30241: Prime Agricultural Land.....	103
11.3.4	Section 30242: Agricultural Land	103
11.3.5	Section 30253: Minimize Development in Hazardous Areas.....	103
11.3.6	Section 30270: Sea Level Rise Considerations.....	103
11.4	Endangered Species	103
11.4.1	Endangered Species Act	103
11.4.2	California Endangered Species Act.....	104
11.5	Wildlife.....	104
11.5.1	Migratory Bird Treaty Act of 1918.....	104
11.5.2	California Fish and Game Code – Birds of Prey and Native Nesting Birds.....	104
11.6	Local Permits	105
11.6.1	Humboldt County Encroachment, Grading and Conditional Use Permits.....	105
11.6.2	City of Arcata Minor Use Permit.....	105
11.7	Anticipated Special Studies	105
11.8	Anticipated Regulatory Approvals.....	105
12	Strategies to Advance Next Steps	107
13	References	109

Appendices

Appendix A - Landowner Survey Results

Appendix B - Historical Maps and Aerial Images

Appendix C - Historical Floodplain Inundation Images (1948 – 2022)

Appendix D - Gradation of Streambed Material

Appendix E - Water Quality Measurements

Appendix F - Jacoby Creek Aquatic Habitat Assessment Technical Memorandum

Appendix G - TGAEC Field Memo – Overbank Fish Stranding

Appendix H - Return Period Flows from USGS StreamStats

Appendix I - Old Arcata Road Interim Drainage Improvements Memorandum

Appendix J - Appendix - Next Steps Workplan

1 INTRODUCTION

1.1 Purpose of Report

This Jacoby Creek Water Sustainability and Anadromous Fish Habitat Enhancement Feasibility Study Report (Report) was prepared as an initial phase in developing a community-supported, multi-benefit project to enhance aquatic habitat quality and reduce flooding impacts in the lower Jacoby Creek valley adjacent to Humboldt Bay (Project). This feasibility study provides an evaluation and characterization of existing conditions, identifies potential solutions to meet project objectives, and proposes multiple alternatives for consideration and analysis as part of a subsequent planning phase of the overall Project.

1.2 Project Location and Ownership

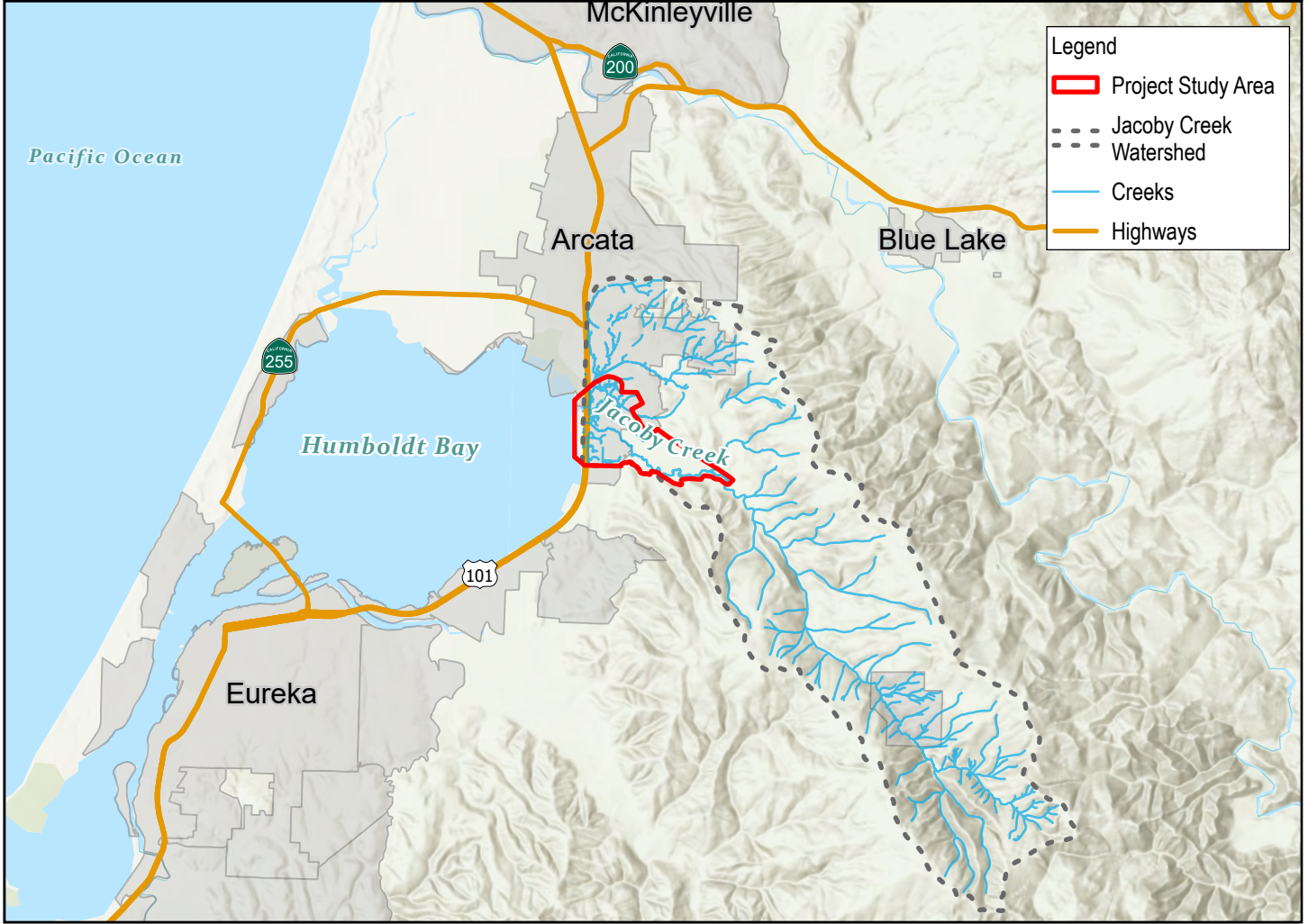
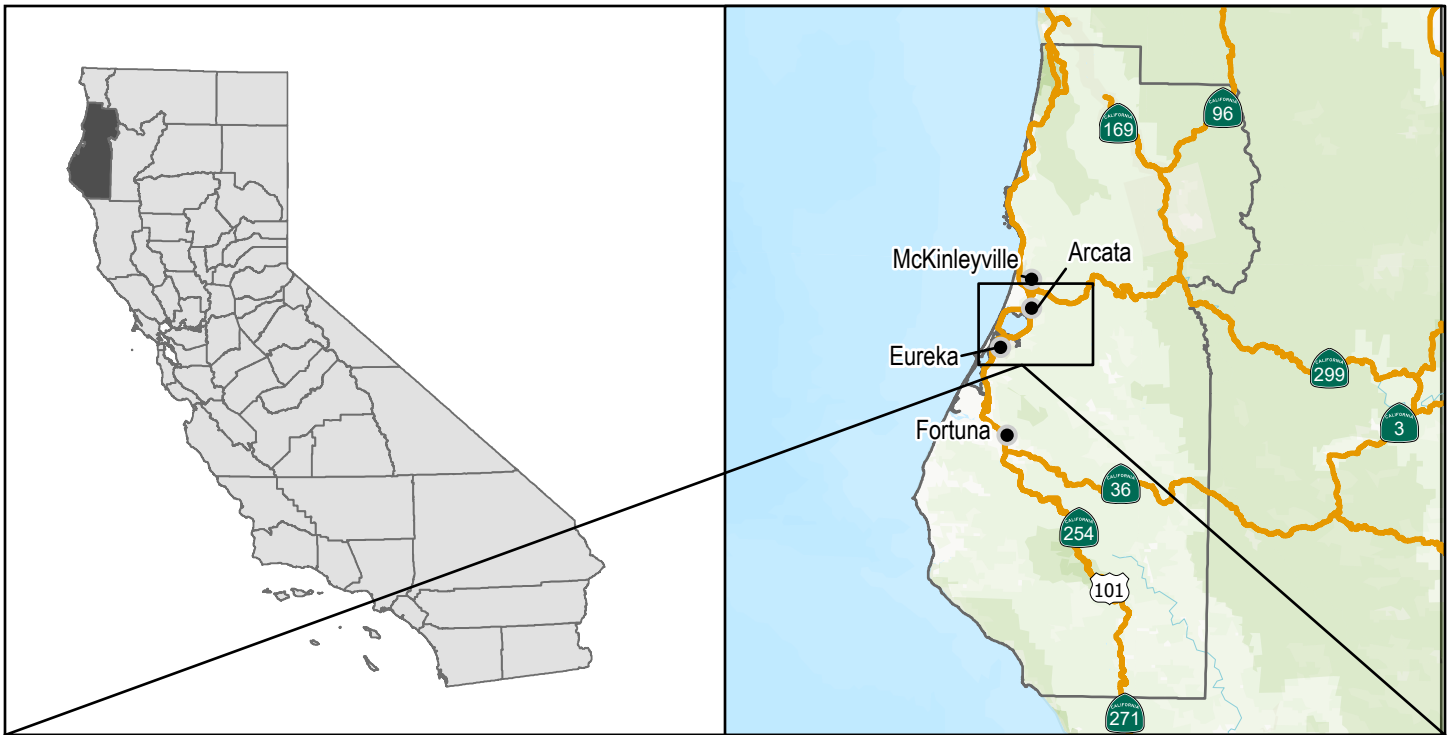
The project is in Humboldt County, California in both unincorporated areas and within the City of Arcata (Figure 1-1). The project study area includes the lower portions of Jacoby Creek and its floodplain, extending from US 101 along Humboldt Bay to the Brookwood Drive bridge crossing (Figure 1-1). The lower-elevation portions of the study area are part of the Jacoby Creek/Gannon Slough Wildlife Area owned and managed by the City of Arcata and referred to here as the Arcata Baylands. Inland from the Arcata Baylands the study area is primarily composed of private residences, private agricultural lands, and fee/title parcels and conservation easements held by the Jacoby Creek Land Trust. In total, the study area is approximately 900 acres and encompasses 128 individual parcels (Figure 1-2).

1.3 Project Need

Jacoby Creek is a major tributary to Humboldt Bay and flows through the community of Bayside along the southern city limits of Arcata. Jacoby Creek provides habitat for Coho Salmon, Chinook Salmon and Steelhead Trout, all listed as threatened species under the Federal Endangered Species Act (ESA); with Coho Salmon additionally listed as endangered under the California ESA. The stream also supports native Coastal Cutthroat Trout, Pacific and Brook Lamprey, and freshwater mussels, among many other native aquatic organisms. Watershed disturbances and development have altered physical and ecological processes and degraded aquatic habitat within the project area, which encompasses the lower and middle reaches of Jacoby Creek and its tributaries from Humboldt Bay to Brookwood Bridge.

Sedimentation has raised the streambed, reduced channel capacity, and caused the channel to be perched higher than the adjacent floodplain. The banks of Jacoby Creek are lined with natural and constructed berms and breaches, with frequent overtopping events. Flows from overbank flooding route across the floodplain through residential areas and over public roads rather than re-entering the channel, causing potential fish stranding and creating significant safety hazards and property damage.

Downstream of Old Arcata Road (OAR), a regional arterial road, the occurrence of overbank flooding is increasing and threatens to cause major channel avulsions. Although overflow and channel avulsions are natural processes, current land management and development and drainage infrastructure are incompatible with their occurrence. Large volumes of floodwaters collect into low-lying areas that drain through tide gates directly to Humboldt Bay, with little or no connectivity back to Jacoby Creek, thus preventing fish that are swept out of channel from returning to Jacoby Creek.



Paper Size ANSIA
 0 1 2
 Miles
 Map Projection: Mercator Auxiliary Sphere
 Horizontal Datum: WGS 1984
 Grid: WGS 1984 Web Mercator Auxiliary Sphere

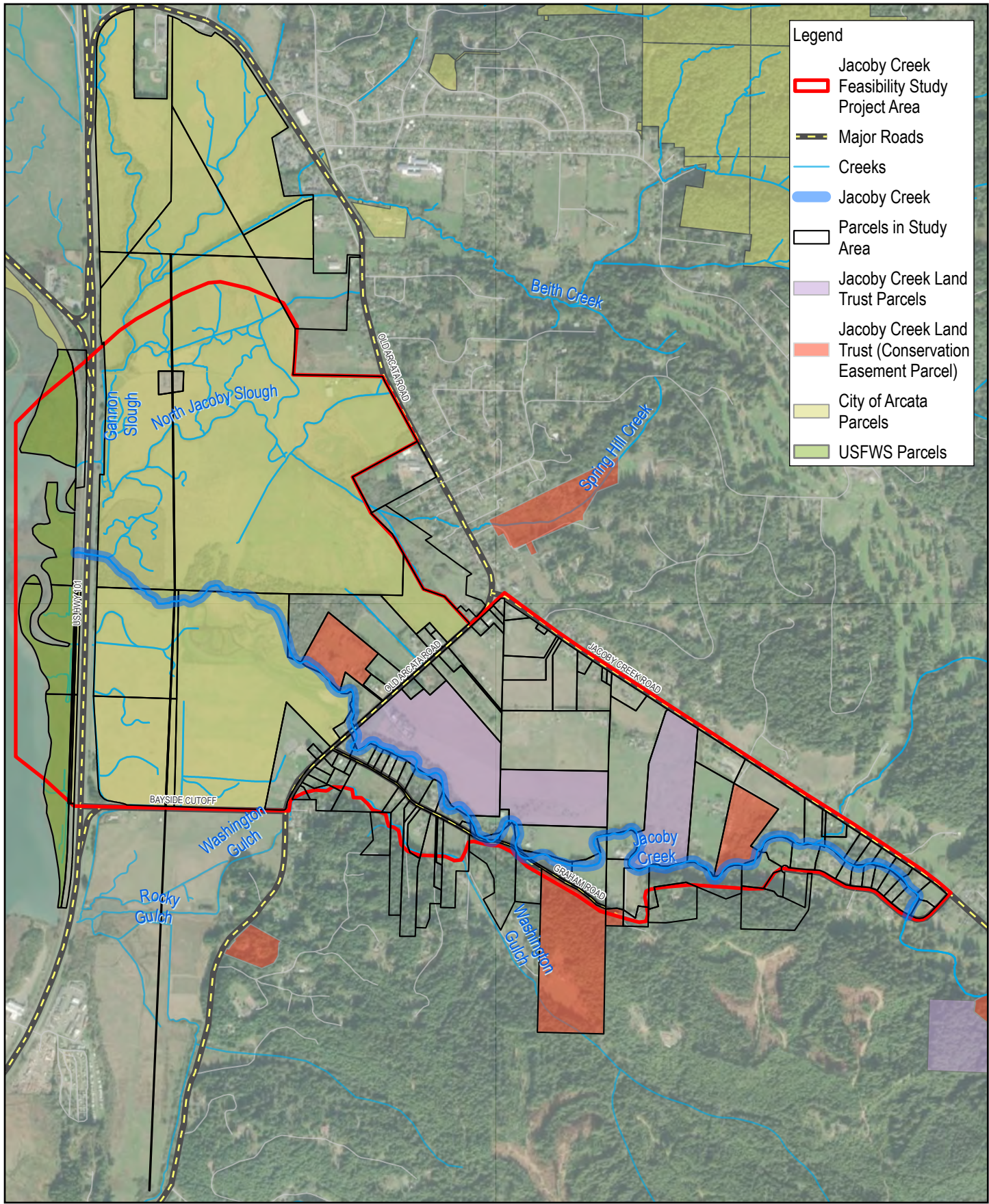


Jacoby Creek Land Trust
 Water Sustainability & Anadromous Fish
 Habitat Enhancement Feasibility Study

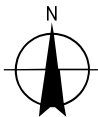
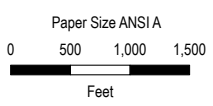
Project No. 11229552
 Revision No. -
 Date Dec 2023

Vicinity Map

FIGURE 1.1



- Legend**
- Jacoby Creek Feasibility Study Project Area
 - Major Roads
 - Creeks
 - Jacoby Creek
 - Parcels in Study Area
 - Jacoby Creek Land Trust Parcels
 - Trust (Conservation Easement Parcel)
 - City of Arcata Parcels
 - USFWS Parcels



**Jacoby Creek Land Trust
Water Sustainability & Anadromous Fish
Habitat Enhancement Feasibility Study**

Project No. 11229552
Revision No. -
Date Nov 2023

Map Projection: Lambert Conformal Conic
Horizontal Datum: North American 1983
Grid: NAD 1983 StatePlane California I FIPS 0401 Feet

Study Area

FIGURE 1-2

The lack of an organizing framework for stream corridor management and communication gaps between landowners and permitting agencies have resulted in haphazard individual actions affecting instream woody debris and riparian corridors that unintentionally impacts aquatic habitat. Due to the repetitive occurrences of severe flooding, some landowners have implemented localized flood protection measures (building berms and removing in-stream wood and bank vegetation) without fully accounting for ecological impacts or impacts on properties situated downstream or on the opposite bank.

Degradation of the aquatic habitat within the project area includes loss of floodplain connectivity, channel structure, floodplain aquatic habitat, and riparian corridor width. Backwater, side-channel, and floodplain habitats have been altered and disconnected from the main channel. Fish stranding occurs during overbank flooding. Multiple plans and studies have identified the lack of rearing habitat as a limiting factor for salmon productivity in Jacoby Creek (RCAA, 2005). The City of Arcata and Jacoby Creek Land Trust (JCLT) have implemented restoration projects over the past decade to improve off-channel habitat, but additional work is needed and at a larger scale. Some of these projects prompted objections related to concerns about potential adverse flooding impacts. Community engagement and support is needed to advance from a parcel-based restoration approach to an integrated, landscape-scale approach. To effectively plan and design larger-scale projects, knowledge gaps must be filled regarding alluvial processes, the floodplain drainage network, aquatic habitat function, and impacts of sea level rise.

1.4 Study Goals and Desired Outcomes

The project is a feasibility study to support planning for community-supported, multi-benefit projects to enhance aquatic habitat quality and reduce flooding. Desired outcomes from this current project phase include:

1. Develop a community-based approach for planning and implementing water resource projects at the landscape scale that integrate multiple benefits (e.g., habitat enhancement, flood impact alleviation, floodplain and flood flow connectivity, maintaining working landscapes), multiple ownerships (public, land trust, private), multiple locations (upstream/downstream, left bank/right bank), and multiple scientific disciplines (e.g., hydraulics, geomorphology, ecology).
2. Improve the understanding of the geomorphic context of Lower Jacoby Creek, channel-floodplain connectivity, ecological function and value of aquatic habitat elements, and the sensitivity of Jacoby Creek to human-caused disturbance and sea level rise, to support effective and sustainable restoration measures.
3. Establish measurable goals and objectives for aquatic and wetland habitat and flood management. Identify and screen project design concepts.
4. Develop three feasible alternatives at conceptual design level; ready for detailed analysis and comparison, selection, design, permitting, and construction in future phases.
5. Build relationships and an organizing framework for advancing collaborative efforts among public and private landowners to support stewardship of the Jacoby Creek stream corridor. Build capacity for project implementation and ongoing monitoring, coordination, community engagement, and adaptive management.

1.5 Overview of Study Activities

The current Study included the following activities:

1. Stakeholder engagement (landowner survey, three public meetings, and numerous individual landowner meetings) and technical consultation (four technical working group meetings).
2. Collecting necessary data and information to characterize existing conditions and understand the geomorphic context of the project area.
3. Developing a hydraulic model to support analysis of existing conditions and for use in future analysis of alternatives.
4. Developing schematic drawings for conceptual designs and identifying three project alternatives that rank highest for feasibility and achieving project goals and objectives.
5. Preparing a Stream Corridor Management Plan to guide stewardship of in-channel woody debris and riparian areas.

1.6 Project Team, Technical Working Group, and Stakeholders

The Project is being led by the Jacoby Creek Land Trust (JCLT), with funding from the California State Coastal Conservancy (SCC). Key project partners include the Humboldt County Department of Public Works and the City of Arcata. JCLT retained the services of a team of specialists, led by GHD Inc (GHD) to conduct the studies and develop Project concepts and alternatives. GHD team members include Michael Love & Associates, Inc. (MLA), Thomas Gast and Associates Environmental Consultants (TGAEC), and Baldwin, Blomstrom, Wilkinson & Associates, Inc. (BBWA). Team members are an interdisciplinary group of engineers, geomorphologists, hydrologists, biologists, land-use specialists, and environmental planners.

The Project established a Technical Working Group (TWG) to guide development of study work-plans, provide critical review of study findings, and provide guidance in identifying Project concepts and alternatives. Members of the TWG included staff from the County, City of Arcata, State Coastal Conservancy, Jacoby Creek Land Trust, Cal Poly Humboldt, California Department of Fish and Wildlife (CDFW), National Marine Fisheries Service (NMFS), US Fish and Wildlife Service (USFWS), and Blue Lake Rancheria. The TWG met on four occasions during the Study to provide input and comments.

1.7 Stream Corridor Management Plan

A component of the current planning effort includes developing an interim stream corridor management plan. The Jacoby Creek Stream Corridor Management Plan provides a framework to assist the Jacoby Creek corridor landowners with stream management actions that can be taken within and adjacent to Jacoby Creek to reduce flooding while maintaining beneficial aquatic habitat for Endangered Species Act-listed threatened fish. The Plan complements the long-term creek restoration planning efforts covered in this report and is intended to provide landowners with an interim strategy to manage channel vegetation and debris jams until long-term restoration is completed.

Specifically, the Plan provides an annual monitoring strategy of debris jams and provides a standardized approach to assess the biological value and structural complexity of each debris jam, a quantitative scoring methodology, and matrix to further rank each debris jam for future maintenance actions. The Plan provides guidance on recommended maintenance actions based on debris jam

ranking. It also identifies the required permits needed to be obtained prior to conducting the maintenance actions. The Plan is intended to create a streamlined pathway to implement a suite of maintenance actions that could be covered under programmatic permits on a five-to-ten-year period, rather than acquiring annual site-specific permits.

1.8 2021-2022 Landowner Survey Results

A property owner survey was mailed to the 125 landowners within the study area in November 2021, of which 55 surveys were returned in total (44%). Questions on the landowner survey were developed to solicit direct, first-hand knowledge from affected community members related to flooding in the project area alongside opinions related to other concerns and community values. The survey included ten survey questions, largely focused on flood-related issues and community values:

1. How long have you owned and/or resided on this property?
2. What is the frequency at which your property experiences flooding?
3. If you have experienced flooding on your property, describe the location on your property in which this flooding occurs.
4. Has your property ever experienced damage due to flooding?
5. From your perspective, what has been the cause of flooding on your property?
6. What is the most concerning to you when Jacoby Creek floods?
7. Do you know if your property is located in a FEMA Mapped Flood Hazard Zone?
8. What do you value most about where you live?
9. Would you support a community-based approach to monitor and manage the health of Jacoby Creek?
10. If you have specific interests or skills, please list them here.

To provide a level of anonymity, the survey results were compiled and aggregated together (Appendix A) and summarized below.

Question 1 – How long have you lived on the property?

Question 1 asked property owners how long they had lived on their property. The majority of landowners (61% of respondents) have lived on their property for more than 20 years. An additional 22% of respondents have lived on their property between 10 and 20 years. A total of 16% of respondents have lived on their property for less than 10 years. These responses indicate participating property owners have lived in the watershed for many years and thus have had the opportunity to observe numerous flood events and changes in flood patterns over time.

Question 2 – What is the frequency at which your property experiences flooding?

Question 2 asked property owners how often their property experienced flooding. Half (50%) of respondents indicated flooding occurs during major rainfall events. A total of 7% noted flooding occurs even during minor rainfall events. An additional 26% of respondents indicated flooding occurs most years. The minority of respondents (13%) never experience flooding. Response variability could be attributed to the property owner's location within the watershed and general proximity to flood prone reaches of Jacoby Creek.

Question 3 – If you have experienced flooding on your property, describe the location on your property in which this flooding occurs.

Question 3 requested information on specific flood attributes, for those who experience flooding. Flooding impacted vegetated yards and/or pastures (34%) most commonly, followed by driveways and parking lots (19%), around the perimeter of houses (17%), out-structures such as barns and sheds (12%), septic systems (7%), and inside of houses (2%). In addition, 8% of respondents indicated other types of flood-related damage, including flood water under houses, drainage ditch flooding and standing water, flooded basements, damage and destruction of outdoor trees, damaged parking lot pavement, destroyed electrical panel of a water pump, damaged insulation under a house, damaged fencing and decking, and damaged carpeting.

Question 4 – Has your property experienced damage due to flooding?

Question 4 assessed if property owners experienced damage due to flooding. A total of 53% had not experienced damage, while 47% had experienced damage.

Question 5 – From your perspective, what has been the cause of flooding on your property?

Question 5 sought landowner opinions on the cause of flooding on their properties. No single leading cause was identified. Debris in stream was reported by 25% of respondents, followed by dense vegetation in streams (19%), limited stream capacity (18%), reduction in stream capacity related to the bridge (10%), and plugged or undersized culverts (9%). In addition, 21% of respondents indicated other causes of flooding, which included a lack of maintenance in the creek, land use practices related to development and urbanization, current and historic watershed management, increased sedimentation, poor drainage, precipitation, concurrent fluvial and tidal flooding, and natural processes.

Question 6 – What is the most concerning to you when Jacoby Creek floods?

Question 6 allowed respondents to rank their concerns related to flood impacts. Choices included public safety on Graham and Old Arcata roads, impacts to sensitive fish and wildlife species, damage to private property, impaired access to residences, impacts to water quality, and other.

Damage to private property was the most frequent highest-ranked concern followed by public safety on Graham and Old Arcata roads. Impacts to sensitive fish and wildlife species and impaired access to residences generally ranked similarly to one another. Impacts to water quality was the most frequent lowest ranked concern. Other concerns reported by individual respondents included safety along Jacoby Creek Road, flood events intensified by sea level rise, runoff into City of Arcata wetlands in the coastal zone, and constraints related to cutting fallen trees in Jacoby Creek.

Question 7 – Do you know if your property is located in a FEMA mapped flood hazard zone?

Question 7 asked property owners if they know if their property is located in a FEMA mapped flood hazard zone. Many but not all parcels in the project area overlap the FEMA mapped flood hazard zones, which include the 500-year flood zone, 100-year flood zone, and floodway. A total of 55% of respondents said yes and 45% said no, thus do not fully understand their flood risk.

Question 8 – What do you value most about where you live?

Question 8 allowed respondents to rank what they value most about where they live. Choices included safety, environment, community, and other.

The environment was the highest ranked value, followed by safety and community. Other was the lowest ranked value and included school districts, proximity to Eureka and Arcata, wildlife, aesthetics, quiet, and soil quality.

Question 9 – Would you support a community-based approach to monitor and manage the health of Jacoby Creek?

Question 9 asked if property owners would support a community-based approach to monitor and manage the health of Jacoby Creek. A total of 35% of respondents indicated yes and 13% indicated no. The remaining 52% of respondents indicated they would like to learn more information before deciding.

Question 10 – Specific interests or skills

Question 10 queried property owners about specific interests or skills they might be able to share. Respondents provided a varied list, noting scientific expertise, invasive plant removal, native plant restoration, hands-on restoration work, salmonid monitoring, engineering, and manual labor. Other respondents noted expertise in environmental education, organizational skills, communication, and community organizing. Respondents also offered photos of past flooding events and access to Jacoby Creek.

In summary, while the survey results varied, participants documented frequent flooding is affecting their private properties, at times resulting in damage to land and infrastructure. Participating property owners noted concerns related to damage to private property, public safety on roadways, and other factors. They also valued the environment, safety, and community. Many landowners were not aware they lived in a FEMA mapped flood hazard zone. The survey results, in addition to individual landowner meetings conducted during the study, were used to help inform alternative development.

2 PROJECT SETTING

This section summarizes the surveys, assessments, and analysis conducted to characterize historical and present-day hydrogeomorphic processes and flooding patterns within the study area. Findings from these efforts were used to identify specific approaches to address the underlying issues exacerbating flooding impacts and degrading aquatic habitat. An overview map of the study area is provided in Figure 2-1.

2.1 Topography

2.1.1 Field Surveys and Basemap Preparation

Topography data was obtained from several sources and combined into a single representative existing-ground digital elevation model (DEM). The DEM served as the basemap for the geomorphic assessment, hydraulic model development, and development of project concepts. Topographic data sources included:

- 2019 Eureka/Arcata LiDAR DEM (obtained from the City of Eureka)
- As-built DEM for the South Jacoby Wetlands Project provided by USFWS
- 2021 field-run topographic surveys conducted by MLA

The 2019 Eureka/Arcata LiDAR was collected on September 24th, 2019 through a contract with the City of Eureka. The LiDAR DEM was provided at 1-foot resolution. The City of Eureka supplied the LiDAR point cloud, DEM and imagery data to the Office for Coastal Management (OCM), and they were added to the NOAA Data Access Viewer (DAV), available for public download.

The 2021 field-run surveys focused on the Jacoby Creek channel below top of bank, hydraulic structures, and at reference points for installed water level loggers. This survey was completed with a combination of real-time kinematic global navigation satellite system (RTK-GNSS) base-station and rover (Figure 2-2) and a robotic total station. The survey was primarily conducted in January of 2021, when the leaves were off the riparian vegetation, allowing for better visibility and use of RTK. The in-channel survey extended from west of US 101 to 11,900 feet upstream. It consisted of surveying 157 channel cross sections that captured the channel thalweg, active channel margins, and top of bank, where accessible.

Survey data were post-processed using an RTK base station position correction from the National Geodetic Survey (NGS) Online Positioning User Service (OPUS) and aligned to North American Datum 1983 (NAD83) California State Plane, Zone 1, in feet, and North American Vertical Datum of 1988 (NAVD 88) in feet. The channel survey points were used in AutoCAD Civil 3D to create a DEM of the bankfull channel corridor. The channel DEM was then merged with the 2019 LiDAR DEM, with the South Jacoby Wetlands Project DEM. Combined, the DEM formed the topographic basemap for the project. All elevations provided in this report are in feet, NAVD 88.

Dense vegetation resulted in poor LiDAR resolution and inaccurate elevations in some of the riparian overbank areas along Jacoby Creek, reporting higher ground than actual. Other areas with poor topographic coverage due to vegetation include along the Spring Hill Creek corridor as it flows onto Arcata Baylands North and portions along the City of Arcata Gannon Slough levee that are covered in brush. Elevations shown in these areas should be recognized as inaccurate.



Legend

- Creek
- Slough
- - - Ditch
- Stationing (ft)
- Roads
- ▲ Monitoring Stations
- ◆ Pebble Counts/Bulk Samples
- - - Humboldt Bay Trail
- Culvert
- ◇ Culvert w/ Gate
- Tide Gate
- Coastal Zone
- - - Arcata City Limits
- ▨ Bridge
- - - Utility Corridor
- - - Historical Railroad Alignment

Datums:
Horizontal: NAD83 State Plane CA Zone 1

Source: 2018 Bing Aerial Imagery



0 1,000 2,000 ft



Michael Love & Associates
Hydrologic Solutions

Thomas Gast & Associates
Environmental Consultants

Jacoby Creek Water Sustainability and Anadromous Fish Habitat Enhancement Feasibility Study

Figure 2-1. Project aerial basemap.

Nov, 2023



Figure 2-2. RTK rover in Jacoby Creek tidal channel west of US 101

2.1.2 Topographic Basemap

Hillshade relief basemaps of the project study area from Humboldt Bay to upstream of the channel survey extents are provided in Figure 2-3. The topography from the project DEM is shown with colors and contours at 5-foot intervals. Note that much of the Arcata Baylands is at inter-tidal elevations (8 feet and lower) but lies behind existing levees and tide gates that prevent tidal inundation.

2.2 Existing Land Use, Jurisdictional Boundaries, and Utilities

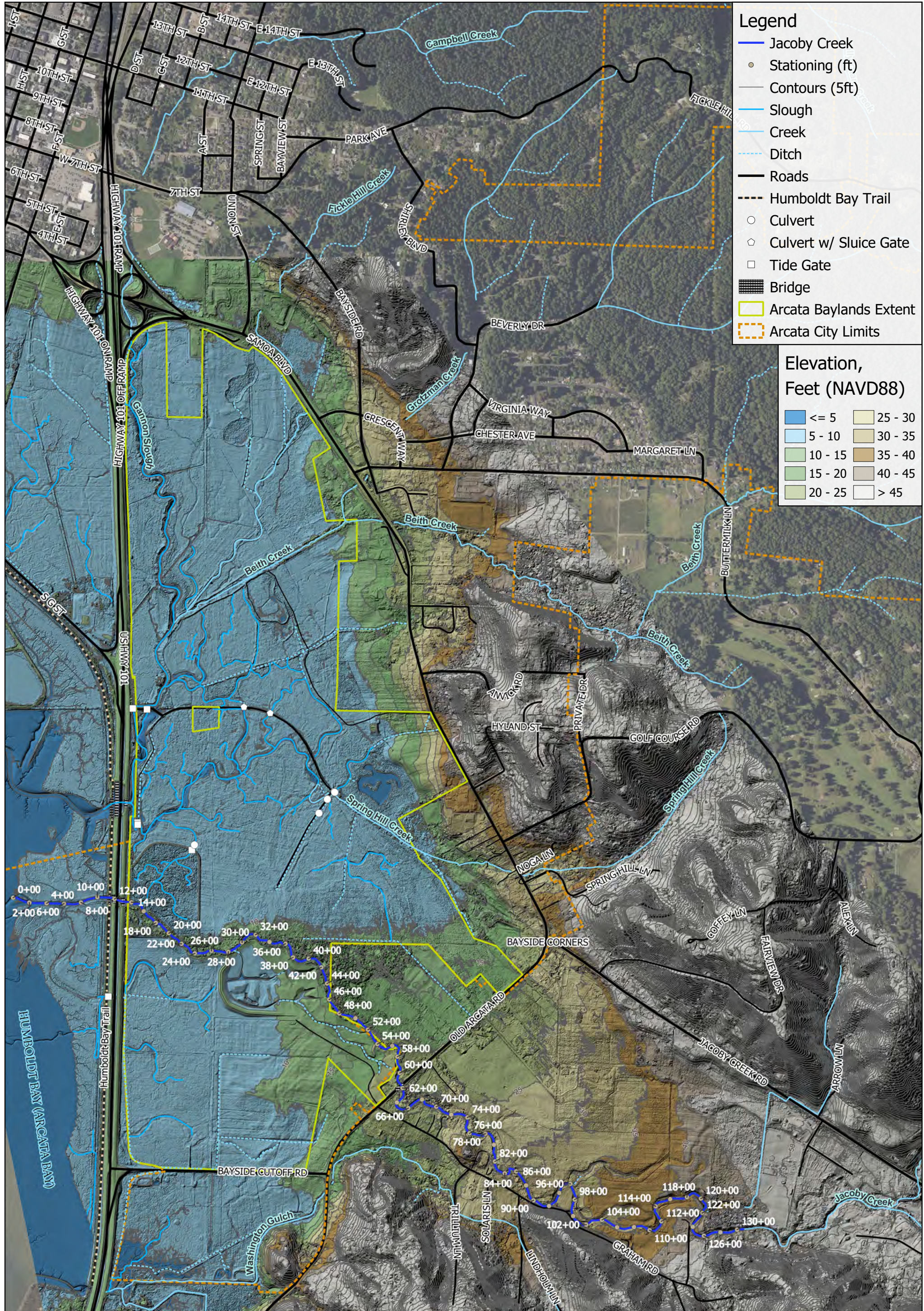
The study area is comprised of multiple land uses, ownerships, and crosses jurisdictional boundaries, as shown on Figure 1-1 and Figure 2-1.

2.2.1 Land Uses

The majority of the study area is used as pasture for livestock, while areas along OAR Road, Jacoby Creek Road and Graham Road areas are both rural and medium density residential. The JCLT Kokte Ranch property and the City of Arcata’s Baylands are leased for cattle grazing. There is some vegetable farming in the study area too, including on the JCLT Kokte Ranch property and at the upstream end of the study area at the Redwood Roots Farm Cooperative.

2.2.2 City of Arcata Baylands Wildlife Area

The Jacoby Creek Gannon Slough Wildlife Area, now owned by the City of Arcata, was established over an 11-year period between 2002 and 2013. This permanently protected public land area is also known as the Arcata Baylands Project. The 586-acre City owned wildlife area was dedicated on November 9, 2007, and with the City’s Arcata Marsh and Wildlife Sanctuary, the federally owned Humboldt Bay National Wildlife Area, and the state-owned Mad River Sough Wildlife Area constitute a contiguous 1,500-acre area of protected wildlife lands around northern Humboldt Bay/Arcata Bay. Ownership of this large municipal wildlife area is consistent with the City’s overall economic strategy to enhance ecotourism, provide for sea level rise “retreat” and protect, and improve natural resources within the City.



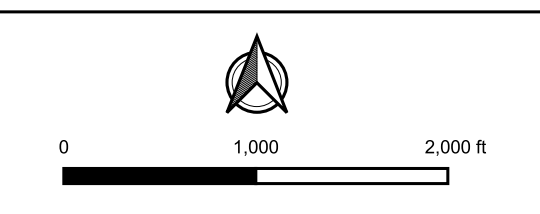
- Legend**
- Jacoby Creek
 - Stationing (ft)
 - Contours (5ft)
 - Slough
 - Creek
 - - - Ditch
 - Roads
 - - - Humboldt Bay Trail
 - Culvert
 - ◇ Culvert w/ Sluice Gate
 - Tide Gate
 - ▒ Bridge
 - ▭ Arcata Baylands Extent
 - ▭ Arcata City Limits

Elevation, Feet (NAVD88)

≤ 5	25 - 30
5 - 10	30 - 35
10 - 15	35 - 40
15 - 20	40 - 45
20 - 25	> 45

Datums:
 Horizontal: NAD83 State Plane CA Zone 1
 Vertical: NAVD88

Sources:
 Elevation: 2019 Eureka Coastal Lidar DEM
 Aerial Image: 2018 Bing Aerial Imagery



Jacoby Creek Water Sustainability and Anadromous Fish Habitat Enhancement Feasibility Study

Figure 2-3. Topographic basemap of the study area.

The Baylands project area involved five separate property transactions with four willing sellers (Figure 2-4). The acquisitions prevented future subdivision development, conversion to non-resource uses, water diversions and management that is contrary to protection, and management of critical wildlife habitats. The entire area is located outside the City's Urban Services Area and 90% of the wildlife area is within the Coastal Commission Permit and Appeal Jurisdictions.

The Jacoby Creek/Gannon Slough properties are adjacent to the U.S. Fish and Wildlife Services Humboldt Bay Wildlife Refuge and the southeast boundary of the City of Arcata Marsh and Wildlife Sanctuary. Most of the lower Jacoby Creek area was originally part of Humboldt Bay's extensive intertidal salt marsh prior to the construction of the Northwestern Railroad line adjacent to the bay and later US 101.

To help facilitate the property acquisitions, in 1999 the City and funding partners mapped the 642-acre Jacoby Creek/Gannon Slough Enhancement Area or Land Acquisition Evaluation (LAE). These properties contain 41,411 feet of stream corridor. Later in 2000, the LAE was expanded to a Conceptual Area Protection Plan or (CAPP). A CAPP is a document that must be prepared to make properties eligible to be funded by the Wildlife Conservation Board. A CAPP is used for multiple properties that contain similar habitat and/or species targeted for protection. It covers multiple ownerships and addresses ecological resources and threats, and prioritizes land acquisitions. Soon thereafter the CAPP was expanded to a much larger watershed wide scale.

To protect the integrity of the Jacoby Creek/Gannon Slough Wildlife area, the City completed several upland forest land acquisitions and worked with the JCLT to complete several more property (fee and conservation easement) acquisitions as part of the Jacoby Creek CAPP. The result of these additional land acquisitions is a seven mile long protected riparian corridor from the headwaters to the bay.

The Arcata Baylands project is the result of over 19 years of work and participation in over 17 grant cycles with funding from the Wildlife Conservation Board, California Department of Fish and Wildlife, U.S. Fish and Wildlife Service Partners for Fish and Wildlife, California Coastal Conservancy, California Department of Water Resources, Pacific States Marine Fisheries Commission, National Fish and Wildlife Foundation, the Natural Resource Conservation Service, Redwood Region Audubon Society, and the Arcata Co-op Foundation. To complete the work on this property the City partnered with the California Department of Fish and Wildlife, U.S. Fish and Wildlife Service, Redwood Community Action Agency, Jacoby Creek Land Trust, Humboldt Bay National Wildlife Refuge, Humboldt Fish Action Council, Jacoby Creek School, and community volunteers.

The City of Arcata has prioritized process-based restoration and enhancement actions within the wildlife area that lead to self-sustaining low-cost operation and maintenance. Some of the key restoration projects are shown on Figure 2-5.




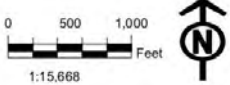
 <p>City of Arcata Environmental Services 736 F Street Arcata, California 95521 T 707 822-8184 F 707 825-2116 Email: eservices@cityofarcata.org Web: https://www.cityofarcata.org</p>	 <p>0 500 1,000 Feet 1:15,668</p> <p>Map Projection: Lambert Conformal Conic Horizontal Datum: North American 1983 Grid: NAD 1983 StatePlane California I FIPs 0401 Feet</p>	<p>Jacoby Creek/Gannon Slough Wildlife Area Acquisition Dates</p>	<p>Sheet 1 of 1</p> <hr/> <p>Date: 9/30/2020</p>
--	---	--	--

Figure 2-4. Formerly acquired parcels that currently comprise the City of Arcata Baylands.

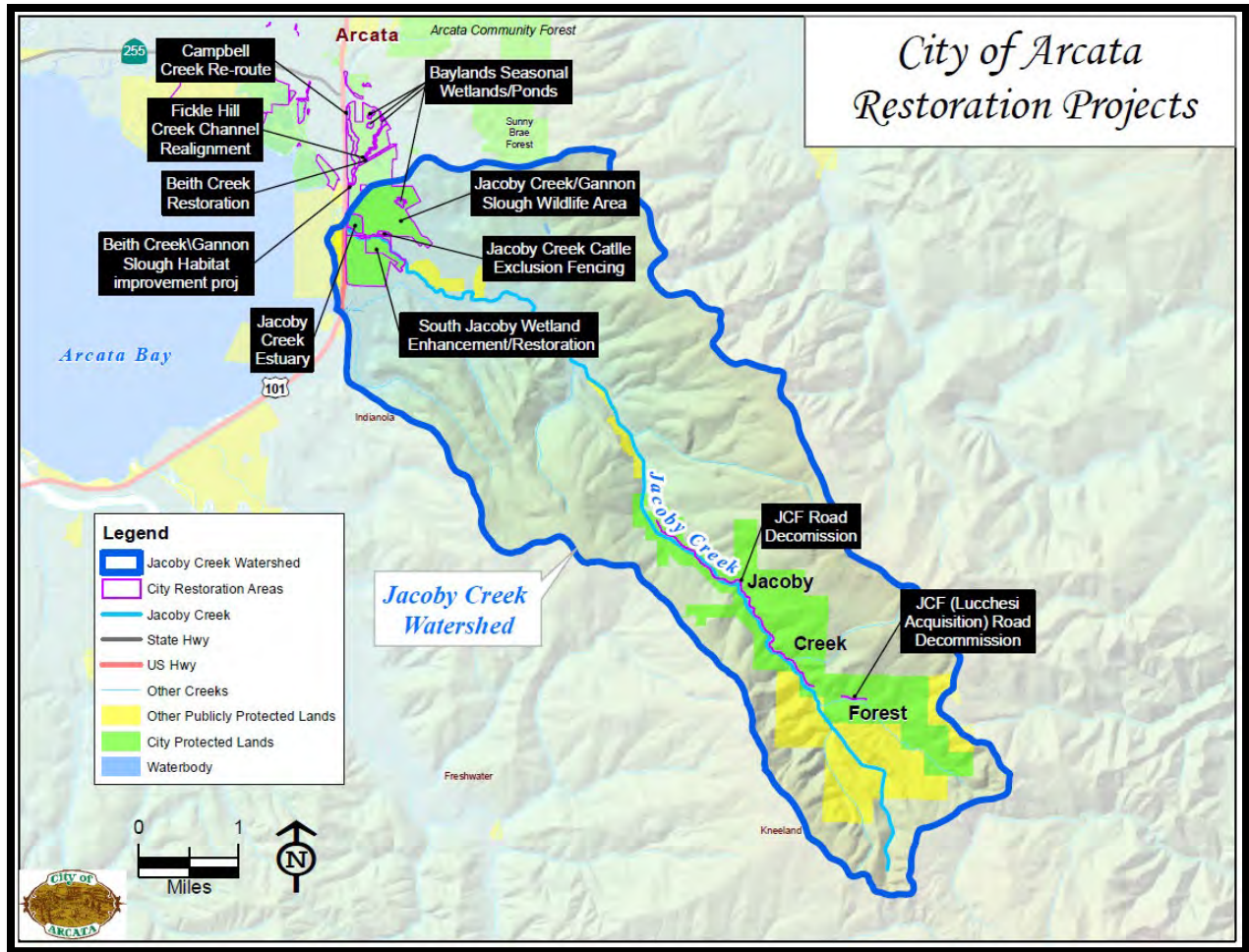


Figure 2-5. City of Arcata Restoration Projects within the Jacoby Creek Watershed.

Since the City acquired the lands, there have been numerous enhancements to the property that include billboard removal, removal and replacement of culverts with some replaced with bridges for ranch maintenance vehicles and livestock; construction of 8.7 acres of shallow wetland ponds; riparian planting and cattle exclusion fencing along 2 miles of Gannon Slough watercourses; recontouring (naturalizing) of 0.9 miles of channelized stream segments on Beith, Grotzman and Cambell creeks; and installing fish habitat structures. Boulder fish “jump pools” were installed on upped Campbell Creek to facilitate fish passage at the Community Park segment north of Samoa Blvd. Two large fish friendly tide gates were installed on Gannon Slough that increased drainage capacity in the Jacoby Creek/Gannon slough basin. In 2006, the City relinquished a 140-acre-ft/yr. water right on the mainstream of Jacoby Creek to reserve the water for instream flow for public trust resources.

In 2011 the North Jacoby Tidal Marsh project created a 13.6-acre estuary on the north side of Jacoby Creek that greatly expanded the very limited estuarine habitat in Jacoby Creek. In 2018, the South Jacoby Wetlands Project restored connectivity between Jacoby Creek and its floodplain, reducing fish stranding potential and creating an 11-acre freshwater marsh and channel wetland complex over an approximately 30-acre project area. Grazing has been used to maintain and

enhance waterfowl use including Aleutian cackling geese which have significantly increased in numbers since the establishment of the wildlife area.

The Baylands project area cannot be used for CEQA mitigation, be transferred, used for debt security, converted or managed for incompatible uses that are stipulated in the recorded deed, grant agreements, and Notices of Unrecorded Grant agreements.

A common thread of the grants awarded to the City for land acquisition include the following purpose statement:

“The primary purpose of this proposed grant is to protect and allow for the protection of the Jacoby Creek corridor and the various other small creeks that flow into Jacoby Creek. Jacoby Creek is part of the larger Humboldt Bay ecosystem that provides wetland habitat for fish, waterfowl, wading birds, shorebirds, passerines, raptors and other water associated wildlife.”

The property has deed constraints for managing the property for specific purposes. For example, from the USFWS and California Waterfowl Association grant agreement:

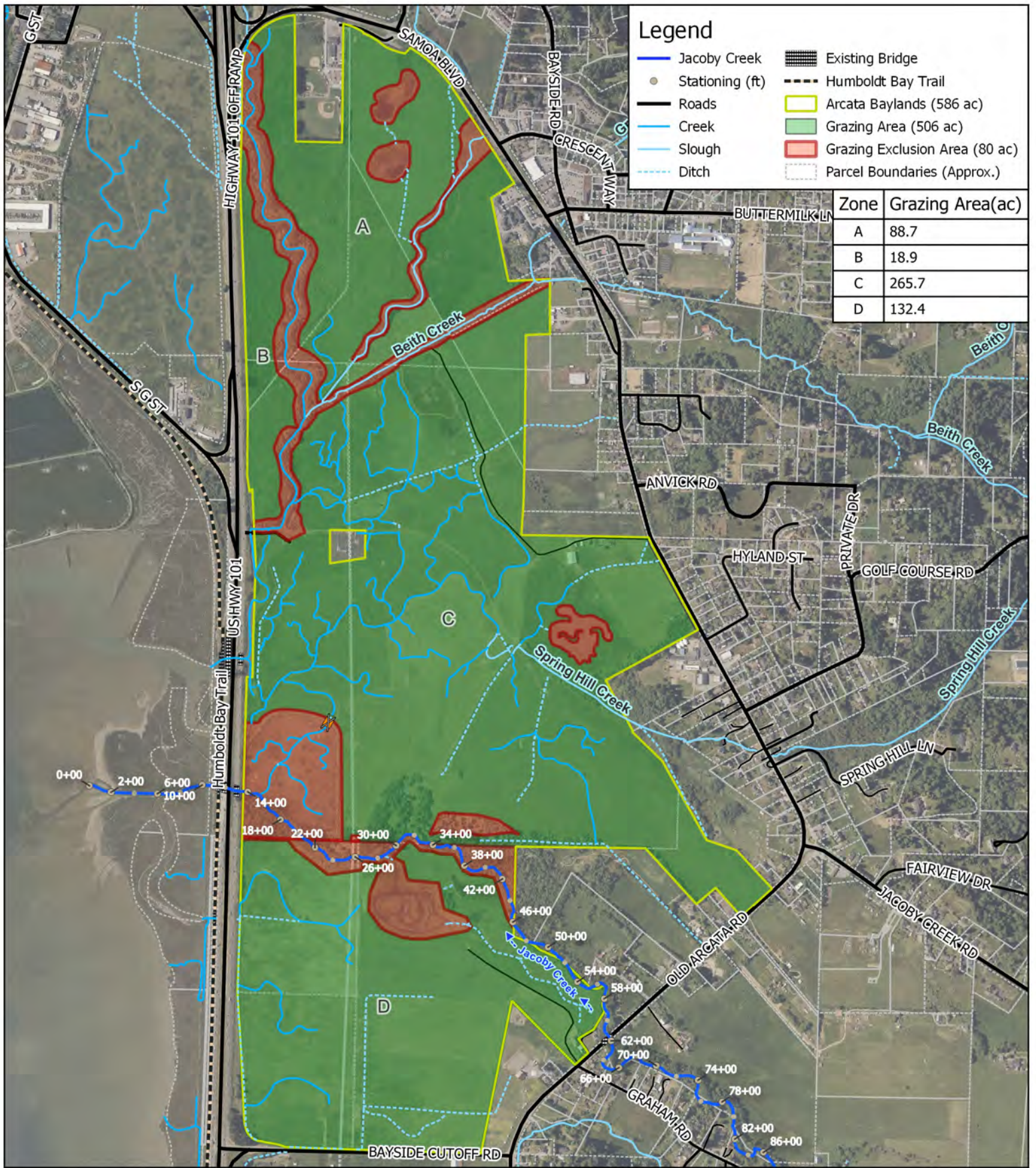
“The purpose of this project is to continue the acquisition, restoration and enhancement of critical wetland habitats within the coastal lowlands of northwestern California. The purchase of Bayview Ranch (322 acres) consisting of freshwater and riparian wetlands immediately adjacent to Humboldt Bay will allow protection and management for waterfowl, shorebirds and other water associated birds. Three endangered species Act (ESA) listed salmonid species spawn in Jacoby Creek which run along the south side of the property. Enhancement activities that include increasing habitat values for fish and migratory birds will adhered to. The wetland values of this tract will be significantly increased through the management of the new titleholders, the City of Arcata. Grant funds will be used to purchase Bayview Ranch to provide protection in perpetuity for fish and wildlife”.

The following Coastal Conservancy requirement (2004-44399_SCC) is also recorded on title:

“The City of Arcata shall permanently dedicate the property for resource enhancement, public access, open space and scenic protection, and agricultural preservation, in a manner acceptable to the Executive Officer and consistent with Public Resources Code Section 31116(b);”.

There are two rental houses, a barn, and ranch outbuildings on the wildlife area north of Jacoby Creek and one 4,000 square foot barn on the south side of Jacoby Creek. The City leases Baylands for livestock grazing, resulting in approximately 506 acres of pasture actively grazed (Figure 2-6). Revenue from the rentals and the livestock leases are used by the City for funding the management of the wildlife area, leveraging other grants, and for other drainage and open space projects in the City.

The City Environmental Services Department is in the process of developing a management plan for the wildlife area. The Management Plan will describe the baseline conditions, opportunities for limited public access and opportunities that may include use of the houses as visitor serving facilities such as a hostel. Public access to date has been primarily creating wildlife viewing portals on the perimeter of the property, limited docent lead walks, education, and research. Public use within the interior of the property requires a Nature Area Use Permit and must be compatible with livestock grazing and minimize disturbance to wildlife.



Datums:
Horizontal: NAD83 State Plane CA Zone 1

Sources:
Aerial Image: 2018 Bing Aerial Imagery

0 1,000 2,000 ft



Michael Love & Associates
Hydrologic Solutions

Thomas Gast & Associates
Environmental Consultants



Coastal
Conservancy



Jacoby Creek Water Sustainability and Anadromous
Fish Habitat Enhancement Feasibility Study

Figure 2-6.
Current grazing leases on City of Arcata Baylands.

2.2.3 JCLT Aquatic Habitat Restoration Projects

The Jacoby Creek Land Trust owns 168 acres of fee lands in the Jacoby Creek watershed and holds conservation Easements on an additional 68 acres. Besides the restoration activities on the City of Arcata's Baylands, the JCLT has implemented restoration projects to improve aquatic habitat. This includes riparian planning along the north bank of Jacoby Creek upstream of OAR, and construction/reconnection of off-channel ponds for use by salmonids.

In 2015 the JCLT, in partnership with Pacific Coast Fish, Wildlife, and Wetlands Association and with funding from CDFW Fisheries Restoration Grant Program, connected an existing isolated pond, formed by a remnant channel on the floodplain, to Jacoby Creek to provide fish access to the pond for rearing. This pond is on the JCLT Kokte Ranch property and is referred to as the Lower Pond. As part of the same project, a second pond was constructed on a JCLT fee parcel upstream of the Kokte Ranch. Referred to as the Upper Pond, it also created off-channel habitat connected to Jacoby Creek for winter use by rearing juvenile salmonids.

2.2.4 Jurisdictional Boundaries

The area downstream of OAR is within the Arcata City Limits (Figure 2-1) while the upstream study area is unincorporated. The State Coastal Boundary is located along the eastern side of OAR, with the Jacoby Creek corridor downstream of OAR and most of the Arcata Baylands within State jurisdiction, and the remainder in Local Jurisdiction. West of US 101 the salt marsh is owned by the US Fish and Wildlife Service and part of the Humboldt Bay National Wildlife Refuge (Figure 1-1).

2.2.5 Utilities

There are numerous utilities within the study area. This includes underground and overhead utilities along OAR and Graham Road. A municipal water line is suspended on the downstream face of the OAR Jacoby Creek bridge deck.

The main buried PG&E north-south gas transmission line runs through the study area on the east side of the US 101 corridor. Most notable, within the Arcata Baylands is a regional utility corridor that runs north-south approximately 1,000 feet east of the US 101 northbound lanes (Figure 2-1). This corridor is an easement held by the City of Eureka and includes the City's two parallel municipal water delivery lines. The two buried lines provide redundancy for the City's water supply. Within this corridor PG&E maintains two sets of high voltage transmission lines on towers. For Baylands North, access to the utility corridor is through a gated access road of US 101 at the Gannon Slough tide gates. For Baylands South access is via a gated road off of Bayside Cutoff.

2.3 Existing Watercourse Crossings, Drainage Structures, and Levees

2.3.1 Jacoby Creek Bridges

There are multiple bridges over Jacoby Creek within the study area (Figure 2-1). From downstream to upstream, they are:

1. Abandoned NWP Railroad Bridge (Station 11+20)
2. Humboldt Bay Trail pedestrian bridge (Station 11+40)
3. US 101 Southbound (Station 11+90)
4. US 101 Northbound (Station 12+90)

5. Old Arcata Road (Station 61+70)
6. 2437 Graham Road (Private) (Station 90+00) (Rael Bridge)
7. 2559 Graham Road (Private) (Station 99+30) (Cody Bridge)
8. Brookwood Drive (JBW)

The 55-foot span wooden NWP railroad bridge is in a dilapidated state with wooden piers in the channel. The Humboldt Bay Trail prefabricated bridge was recently installed, and the US 101 bridges were replaced by Caltrans within the past 3 years. These bridges are within the tidal reaches of Jacoby Creek and all three appear to fully span the channel.

The Old Arcata Road bridge at Jacoby Creek has approximately a 90-foot span bridge supported on piles. A series of concrete bents are in the center of the channel, creating two 42.5-foot bays. Based on record drawings, the pile tips for the bents are minimum 40 feet below the crown of the bridge deck. The southern bay is filled with sediment and effectively provides no flow conveyance (Figure 2-7).



Figure 2-7. Under the northern bay of the Old Arcata Road bridge at Jacoby Creek in (a) March 2006 and (b) September 2021 showing the center bent (left on photos) buried in sediment.

The bridges at 2437 and 2559 Graham Road are located on driveways to single private residences. These bridges include multiple spans and piers, with the primary span extending across the channel and the additional span(s) providing additional floodplain conveyance. There are no bridge piers located in the channel.

The Brookwood Drive Bridge was designated as the upstream end of the project study area because it serves as the location of a long-term streamflow and sediment gaging station (JBW) operated by volunteers (see Section 4.3.1). The bridge is a covered bridge that houses the gaging instrumentation and is used to do high-flow discharge measurements and bedload sampling.

2.3.2 Arcata Baylands North

The Arcata Baylands north of Jacoby Creek (Figure 2-1) is predominately at intertidal elevations (Figure 2-3) and protected from tidal inundation through a series of levees (a.k.a. dikes). The primary levee runs along a slough channel east of US 101 and around the 10-acre North Jacoby Tidal Marsh. Baylands North is divided into two drainage basins separated by a historical railroad embankment,

built in 1882 by Flanigan, Brosnan & Co. (Rhodes, 2020). There are two 24-inch culverts with slide gates through the railroad embankment. When open, they allow limited exchange of ponded waters between the two basins. During larger flood events ponded waters in the southern basin can rise sufficiently to overtop low points along the railroad embankment and flow into the Gannon Slough basin to the north.

The area to the south of the railroad embankment collects Jacoby Creek overflow waters, freshwater inflow from Spring Hill Creek, and local rainfall. The waters collecting on these lands drain out North Jacoby Slough, through the levees, and into Humboldt Bay via two tide gates. One is an approximately 5-foot tall by 4-foot wide concrete box culvert and the other is a 4-foot diameter HDPE pipe. Both contain side-hinged tide gates on the bay side of the structures installed by Nehalem Marine in 2010.

The area to the north of the historical railroad embankment is located within the Gannon Slough basin. The basin has freshwater inflows from Beith Creek, Grotzman Creek, and Campbell Creek. Waters drain through a series of tide gates at the downstream end of Gannon Slough adjacent to US 101 and into Humboldt Bay.

The Gannon Slough tide gates include a 4-foot diameter circular side-hinged gate maintained by the City of Arcata installed, which contains a “pet door” within the gate that is cracked open to allow a limited amount of tidal inflow. Caltrans maintains an additional set of tide gates consisting of a triple bay box culvert, with each bay opening of 5-foot x 5-foot. These gates were replaced in 2020 and consist of one top-hinged flap gate and two side-hinged gates (Cal Poly Humboldt and MLA, 2022). The top-hinged gate has a small auxiliary door left slightly open to allow limited tidal inflow. One of the side-hinged gates has a muted tide gate regulator (MTR) with a float on the interior side of the levee used to hold the gate open on incoming tides until interior water levels reach a set elevation (Figure 2-8). Together these gates create muted tidal conditions in Gannon Slough and its tributary sloughs, with high tides contained within the banks of the slough channels.



Figure 2-8. The Caltrans maintained Gannon Slough (a) tide gates and (b) MTR float.

2.3.3 Arcata Baylands South

South of Jacoby Creek the Arcata Baylands ground elevations are largely below high tide, and the land is protected from tidal inundation by the elevated roadway associated with US 101 (Figure 2-3).

A levee along Washington Gulch to the south also provides some protection. Water ponding in these low areas is predominately from rainfall, with some input from Jacoby Creek overbank flooding. These waters drain out South Jacoby Slough, through a concrete box culvert under US 101, and into Humboldt Bay. The 5-foot by 5-foot culvert has a tide gate that was replaced in 2020. It consists of a side-hinged aluminum gate with a “mitigator” that allows a limited amount of tidal inflow before closing each tide cycle.

2.3.4 Old Arcata Road Drainage

OAR is frequently inundated by overbank flows from Jacoby Creek. Roadway drainage structures along OAR as it crosses the floodplain north of Jacoby Creek bridge were installed in 1991. The drainage consists of 10 drop inlets with grated tops along the eastern shoulder of the roadway. Spaced 95 to 200 feet apart, each drop inlet is combined with a flared end section that projects through the east side of the road embankment to collect drainage from the adjacent fields. Inflows from all the inlets are routed into a 24-inch lateral collection line discharging into a single ditch on the west side of the road (Figure 2-1). This ditch drains along a property line before discharging onto the fields in the Arcata North Baylands. The collection system and ditch are frequently overwhelmed during Jacoby Creek overbank flood events. On Arcata North Baylands these waters are route to a location where several different inflows join, locally referred to as “malfunction junction.”

3 HISTORICAL MAPS AND IMAGERY

An understanding of the historical and current-day geomorphic setting and processes informs the project development, highlighting both geomorphic constraints and opportunities for restoration. Historical maps and aerial photographs available in *The Historic Atlas of Humboldt Bay and Eel River Delta* (Laird et al., 2008) as well as images from the UC Santa Barara collection, Google Earth, NAIP Imagery, and photographs provided in local historical compilations were evaluated. Excerpts of historical maps and images are provided in Appendix A.

3.1 1870 US Coastal Survey Map

The first detailed map of the tidal marsh and channels around the fringes of Humboldt Bay is provided in the 1870 US Coastal Survey (USCS) Map (Figure 3-1). Present-day streets and waterways are shown on the map for reference.

This is the only detailed map showing the tidal marsh prior to diking and provides the most insight into the geomorphic processes and landforms present prior to European settlement. At the time of mapping, OAR was established as a wagon route following its present-day alignment, including crossing Jacoby Creek in its current location. Prior to European settlement this route served as a trail connecting native Wiyot villages along the fringes of Arcata Bay (Rohde, 2020; Schafran, 1984).

Though there is some spatial drift, the similarity of mapped and remnant slough channels shows a high level of map resolution and accuracy. The diagonal hatching represents salt marsh, while the shorter dash hatches represent agricultural fields.

Though there is some spatial drift, the map shows a high level of accuracy and detail when compared to the remnant slough channels in the Arcata Baylands. Upstream of the salt marsh within the Jacoby Creek floodplain, the lands on the map not indicated as open or of agricultural use on the map are mapped as a mixture of deciduous (popcorn hatch) and conifer vegetation (star hatch). The vegetation hatching matches the description given by Schafran (1984) of the Jacoby Creek valley at Bayside in the 1850's as "...covered by a dense growth of underbrush; tall spruce trees of giant dimensions, alder, ash, willow, maple and pepperwood." Generally, the USCS maps did not depict streams within the conifer areas.

Jacoby Creek is shown generally following its present-day alignment downstream of OAR. There is a tight meander where the channel flows into the bay, which was straightened as part of constructing present-day US 101. The deltaic mouth of Jacoby Creek as it entered the bay was notably different than present day, changes that occurred following the 1964 flood (see Section 3.5). The historical salt marsh ran along both banks of Jacoby Creek up to approximately Station 38+50. Except at the very downstream end of Jacoby Creek, there were no tidal channels connected to the stream, and its channel is depicted as being substantially narrower than the major slough channels to the south and north. The small size of the channel and lack of lateral tidal inflows suggests the historical Jacoby Creek channel geometry was dominated by fluvial processes rather than tidal. The high marsh flanking the margins of the channel functioned as 'natural levees', only becoming inundated during spring tides and combined fluvial-tidal events (Albernas et al., 2020).

To the south of Jacoby Creek is a larger slough channel, commonly referred to as South Jacoby Slough or Old Jacoby Slough (HSU-MLA, 2002). At present-day, the channel persists within the fields of Arcata Baylands South and drains through a Caltrans tide gate. Of note in the 1870 map is the northern finger of this channel extending inland of the salt marsh, suggesting that streamflows

spilled out of Jacoby Creek around Station 46+00 and into this overflow channel. The mapped historical channel matches channel patterns shown in later aerial images.

South of Jacoby Creek, there are no tributaries, including Washington Gulch, shown entering the bay. A rail line that follows a portion of the present-day flow path of Washington Gulch marks the tramline that was used to haul logs to the Brainard Slough log dump (Rhode, 2020). A finger of Brainard Slough is shown as a straightened channel that extends to the terminus of the rail line.

North of Jacoby Creek, the 1870 map shows a series of large sloughs with a tributary channel network that drained a vast salt marsh complex. The mapped channels align with the remnant channel network still present in Baylands North. The southern arterial channel, now referred to as North Jacoby Slough, drained the salt marsh immediately north of Jacoby Creek. It would have received Jacoby Creek floodwaters that overtopped its salt marsh vegetated banks and flowed north. This drainage network extended inland to within 600 feet of OAR.

Spring Hill Creek is shown along the eastern edge of the mapping as a squiggly line flowing down to OAR, disappearing between OAR and the salt marsh, and then flowing into the historical salt marsh. Another channel is shown extending inland beyond the southeastern extent of the salt marsh towards “Bayside Corners,” presumably capturing floodplain flows originating from further inland.

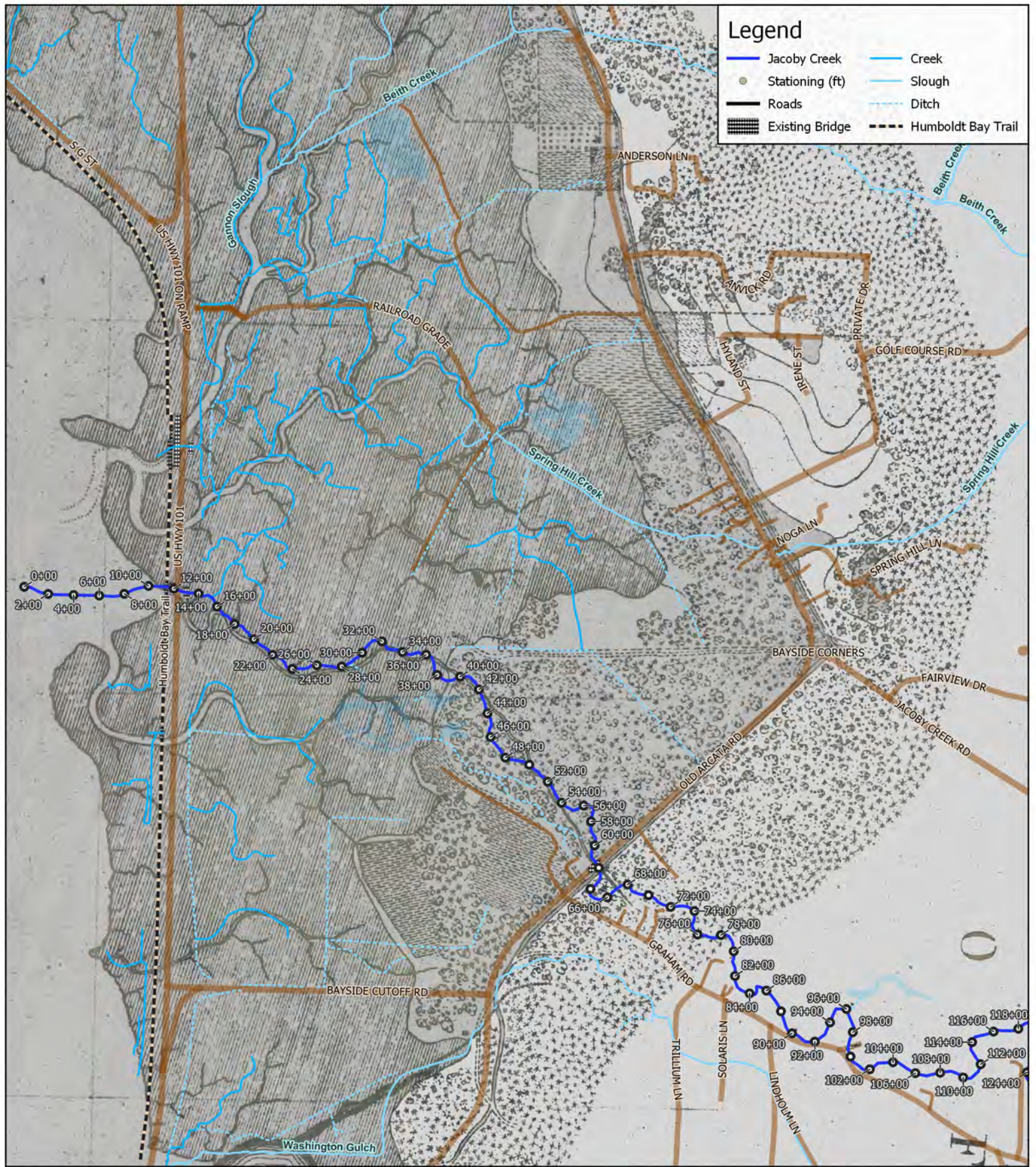
The large channel oriented north-south is Gannon Slough, historically referred to as Big Slough or Embarcadero Slough (Van Kirk, 2015). Gannon Slough historically extended north to present-day Samoa Boulevard/OAR at US 101 and included fingers that captured inflows from Beith Creek, Grotzman Creek, Fickle Hill Creek, and Campbell Creek.

3.2 The “Old Channel” - Jacoby Creek upstream of OAR (1854-1921)

The earliest map in the atlas is the 1854 US Survey General’s Township Plat Map, which shows the historical salt marsh extents and Jacoby Creek (Appendix B). The map’s resolution is relatively poor and details are sparse, but it generally shows Jacoby Creek (referred to as Jacoby’s Creek) was in its current location west of the present-day Lower JCLT Pond near Station 97+50 (Figure 2-1).

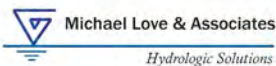
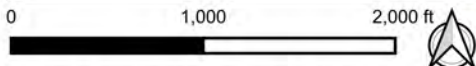
Upstream of this location the historical channel followed what is now an existing remnant channel feature that in-part forms the Lower JCLT Pond. The historical channel also runs close to the present location of the Upper JCLT Pond (Station 122+00, Figure 2-1). The map also shows the location of Washington Gulch as it flows south out of the hills but does not show its flow path downstream of approximately Lindholm Road.

The 1890 Surveyor General’s map (Appendix B) is an updated version of the 1854 map. It shows the historical Jacoby Creek channel continuing to flow north of its current location upstream of Station 97+50. However, between OAR and Station 97+50 it shows the stream channel flowing south of Graham Road. The map indicates Washington Gulch flowed into Jacoby Creek between present-day Solaris Lane and McMahan Road. It is uncertain if this is an accurate depiction of the Washington Gulch and Jacoby Creek alignments. A map published by Schafran (2020) depicting the Bayside area circa 1900 shows the two channels separated and Jacoby Creek flowing north of Graham Road, similar to present-day (Figure 3-2). Like the 1854 and 1890 Surveyors General’s maps, the channel on the Schafran map is shown flowing to the north of the present channel, through the remnant channel that is now the Lower JCLT Pond. A long-time resident adjacent to the remnant channel from the Theuerkauf family had called this alignment the “Old Channel” (personal communications, Thomas Gast, 2022).



Datums:
 Horizontal: NAD83 State Plane CA Zone 1
 Vertical: NAVD88

Sources: 2008 Historical Atlas of Humboldt Bay
 and Eel River Delta



**Jacoby Creek Water Sustainability and Anadromous
 Fish Habitat Enhancement Feasibility Study**

**Figure 3-1. 1870 US Coastal Survey Map with
 present-day streets and waterways
 shown for reference.**

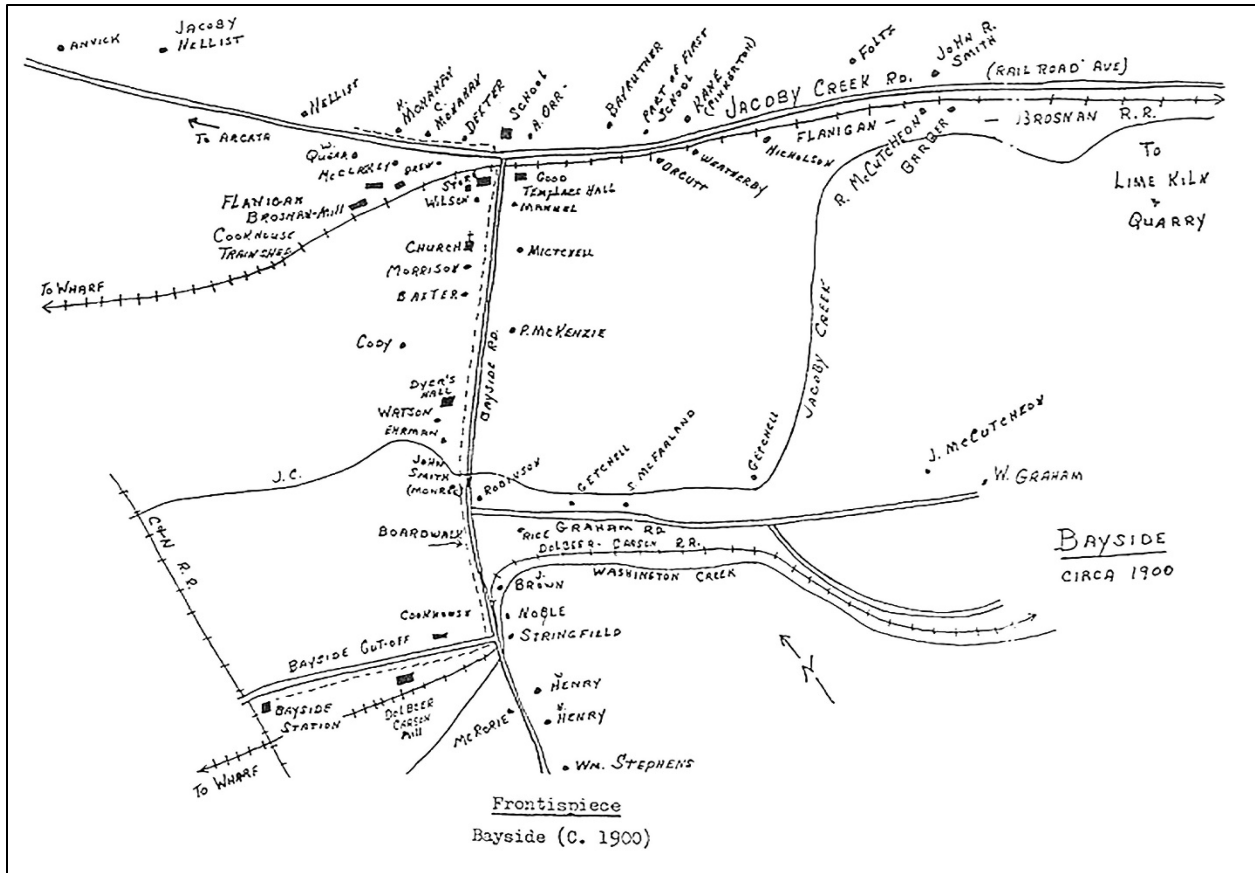


Figure 3-2. Map of Bayside circa 1900 showing Jacoby Creek flowing north-south upstream of Lindholm Lane. Washington Gluch is shown flowing close to its current alignment (published by Schafran, 1984).

The 1916 USACE Tactical Map (Appendix B) also shows the historical alignment of Jacoby Creek following this approximate “Old Channel” flow path upstream of the Lower JCLT Pond. It also shows Jacoby Creek on the Arcata Baylands routed into South Jacoby Slough rather than following its historical and present-day alignment to the north.

The 1921 USDA soils map (Appendix B), which has relatively low accuracy regarding waterways, shows the historical channel moved up against the southern hillslope and no longer following the “Old Channel” alignment to the north. It also shows Washington Gulch flowing into Jacoby Creek next to Lindholm Lane. The soil mapping along the Washington Gulch alignment is the same soil mapped for other floodplain soils.

3.3 1931 and 1941 Fairchild Aerial Images

The 1931 and 1941 aerial images from UCSB collection are the earliest of the project area and provide insights into the extents of diking and overbank flooding patterns. They are high resolution and excellent quality (Figure 3-3 and Appendix B).

By this time, the alignment of Jacoby Creek was similar to its current alignment. The historical salt marsh areas east of US 101 had been diked and drained, and levees ran up both banks of Jacoby Creek to keep the tide from inundating the adjacent pasture. It appears that the levees extended

from the highway inland to at least Station 26+00. Agricultural fields were present along both sides of the channel west to US 101.

Notable is the remnant channel network draining towards the head of South Jacoby Slough, which suggests that Jacoby Creek had flowed into this slough channel, as shown in the 1916 map. It appears that out-of-bank flows had scoured an overflow channel near Station 45+00. The 1931 photo also shows an excavated connection to Jacoby Creek near Station 29+00, the same location the channel is shown diverted in the 1916 map.

In the 1931 image Eureka-Arcata highway had been constructed parallel to the railroad line. The delta west of US 101 and the railroad was much smaller than present-day; still similar in extents as shown in the 1870 map (Figure 3-1).

The 1941 image shows that Washington Gulch is not flowing into Jacoby Creek, but is routed in straight-line ditches to the southwest. It also shows the Lower JCLT Pond near Station 96+00 as dry, rather than ponded up in later images. The location of the Upper JCLT Pond near Station 122+00 appears to be a recently scoured cutoff channel created by Jacoby Creek.

3.4 1948-1965 Images

In the 1948 image (Appendix B) the fields adjacent to Jacoby Creek, extending to US 101, are under extensive agricultural production. The Lower JCLT Pond (Station 96+00) appears to be wetted-up, similar to present-day conditions, but the 1955 image shows it dry.

The 1965 image (Figure 3-4) follows the December 1964 flood of record for the region. It shows traces of floodplain flow paths from the high flow event spanning the valley upstream of OAR. Many of the flow paths appear associated with tributaries entering the valley from the north. The Jacoby Creek channel corridor upstream of approximately Station 92+00, appears to have limited riparian vegetation, and large exposed gravel deposits are visible within the channel bed. Downstream of OAR the riparian corridor was also thinned, with exposed gravel bars revealed downstream of Station 44+00. Evidence of overbank flooding along the north side of Jacoby Creek both upstream and downstream of OAR is also evident, similar to present-day locations that flow spills out of bank. A distinctive meander trace can be seen on the floodplain behind the Bayside Community Church northwest of OAR.

3.5 Jacoby Creek Delta: 1970 - Present

The size and configuration of the Jacoby Creek salt marsh delta west of present-day US 101 remained relatively stable from the earliest detailed mapping of 1870 (Figure 3-1) through the 1965 image (Figure 3-4). Figure 3-5 shows a progression of the delta evolution from 1970 through 2018. The 1970 image shows the delta having a very similar extent and configuration as 1965, with the primary Jacoby Creek channel flowing northwest through the mudflats and into the larger Gannon Slough outflow channel. The 1981 image shows an extensive increase in the size and change in configuration of the delta. Subsequent images from 1988 and 2018 show the salt marsh establishing on the enlarged delta and changes in the Jacoby Creek outflow channel west of the salt marsh, with it becoming disconnected from the Gannon Slough outflow channel.

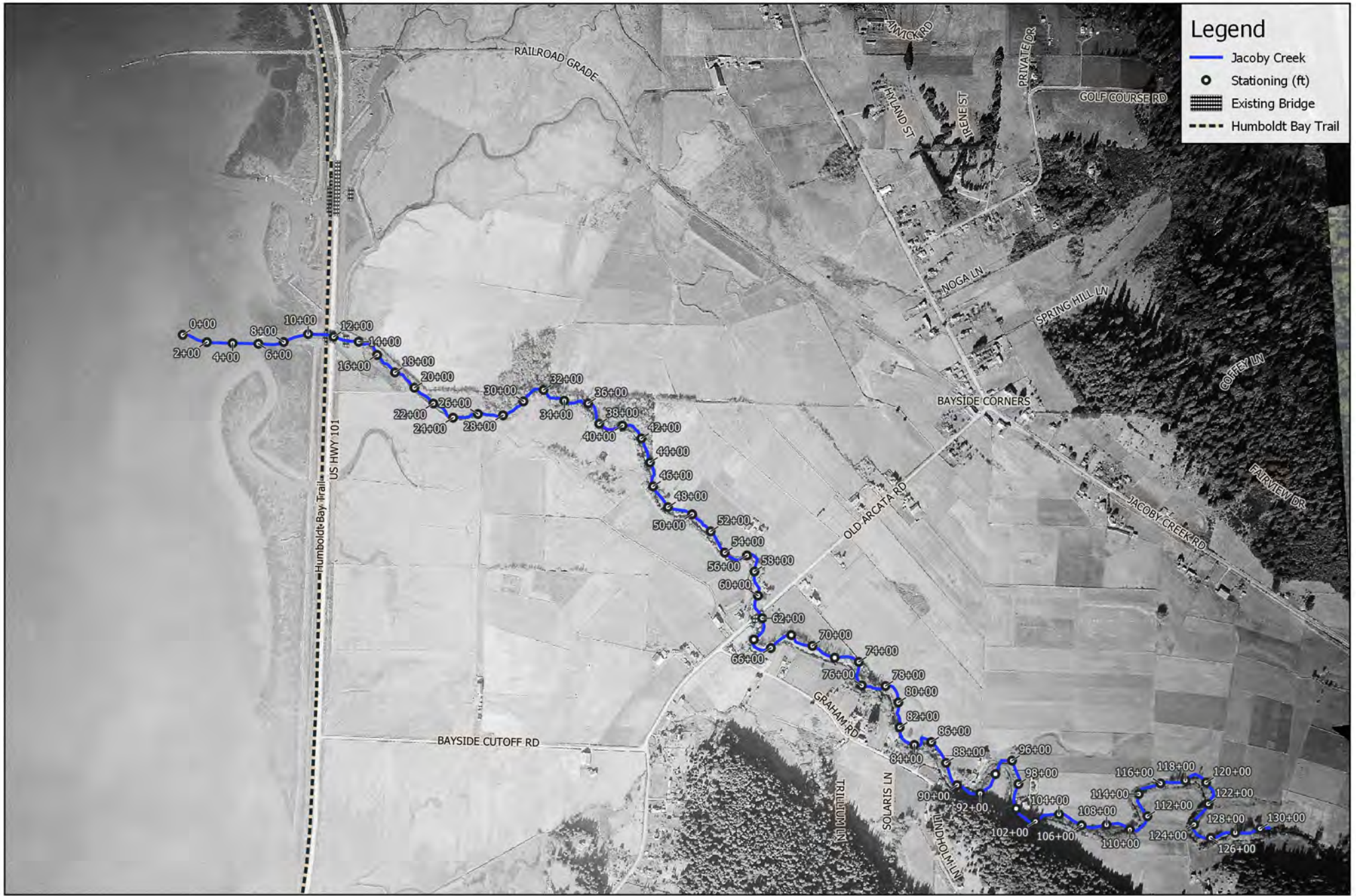
Prior to historical diking, sediment carried by Jacoby Creek would have flowed out onto the adjacent salt marsh several thousand feet upstream of present-day US 101. Since the early 1900's, diking along Jacoby Creek and subsequent aggradation along the streambanks downstream of OAR forced flows and sediment to remain in-channel until west of US 101, where it could spread laterally. This is

evident by the changes in the salt marsh delta at its intersection with the mudflats of Humboldt Bay between 1970 and 1981 aerials. The extensive growth of the delta during this period is likely associated with this confinement of the channel east of US 101 combined with extensive sediment delivery to Jacoby Creek and its tributaries during the 1964 flood of record and the preceding timber harvest practices that exacerbated conditions. Much of this in-channel sediment was likely routed out towards Humboldt Bay during larger flood events between 1970 and 1981, unable to spread out laterally east of US 101, like it would have prior to diking.

3.6 2011 Google Earth Image – Historical Channel Traces

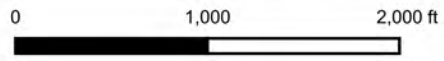
A review of the satellite images available from Google Earth revealed evidence of historical channel traces across the Jacoby Creek valley (Figure 3-6). These are most prominent during the September 16, 2011 image (Figure 3-6) and other images taken during early fall, when there are regions of both green and brown grasses. Coarser streambed material often deposited within the channel bed is better draining, resulting in delayed greening during the early fall rains. Some of the channel traces matched traces observed in the 1965 post-flood image (Figure 3-4).

The 2011 image shows a multi-channel network of historical channel traces upstream of OAR that span the full width of the valley. Some of the channel traces are likely associated with small tributaries rather than Jacoby Creek. The direction of these traces suggests some of the flow was routed down the valley bottom and into the large tidal slough network that are shown in the 1870 map in present-day Arcata Baylands North. This multi-channel network is consistent with the historical descriptions given in newspaper clippings from the 1850's and 60's (Van Kirk, 2015) and in Schafran (1984). This suggests the historical Jacoby Creek delta consisted of a diversity of interconnected low-gradient aquatic habitats that transitioned from tidal marine and brackish to freshwater fluvial over an extended distance.



Datums:
Horizontal: NAD83 State Plane CA Zone 1

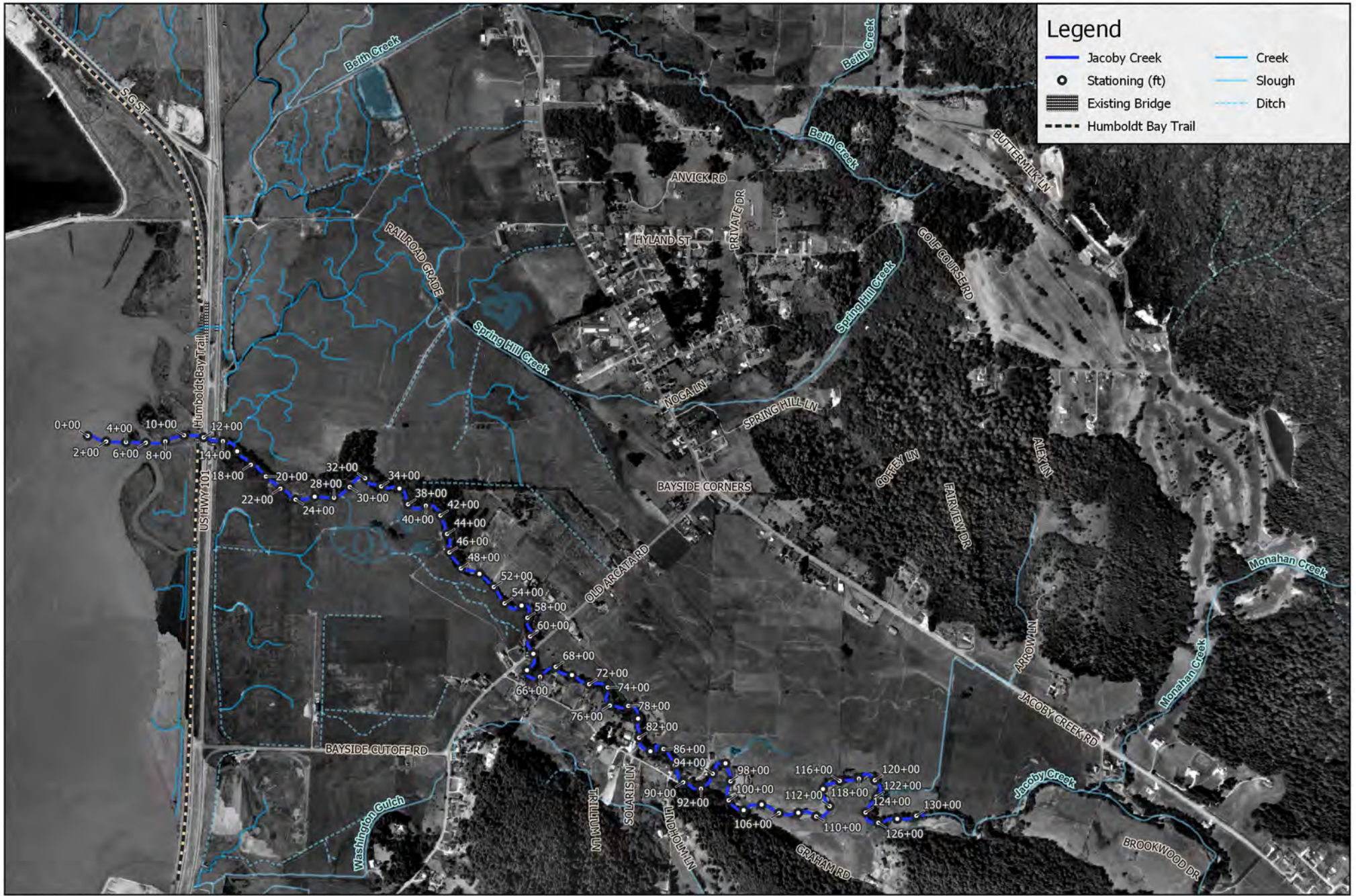
Sources: 2018 Bing Aerial Imagery,
UC Santa Barbara Library



Jacoby Creek Water Sustainability and Anadromous Fish Habitat Enhancement Feasibility Study

Figure 3-3.
1941 Fairchild Aerial Survey (from UCSB).

Nov. 2023



Datums:
Horizontal: NAD83 State Plane CA Zone 1

Source: 2008 Historical Atlas of Humboldt Bay and Eel River Delta

0 1,300 2,600 ft



Jacoby Creek Water Sustainability and Anadromous Fish Habitat Enhancement Feasibility Study

Figure 3-4.
1965 Aerial Mosaic. Existing waterways and road labels overlaid for reference.

Nov. 2023

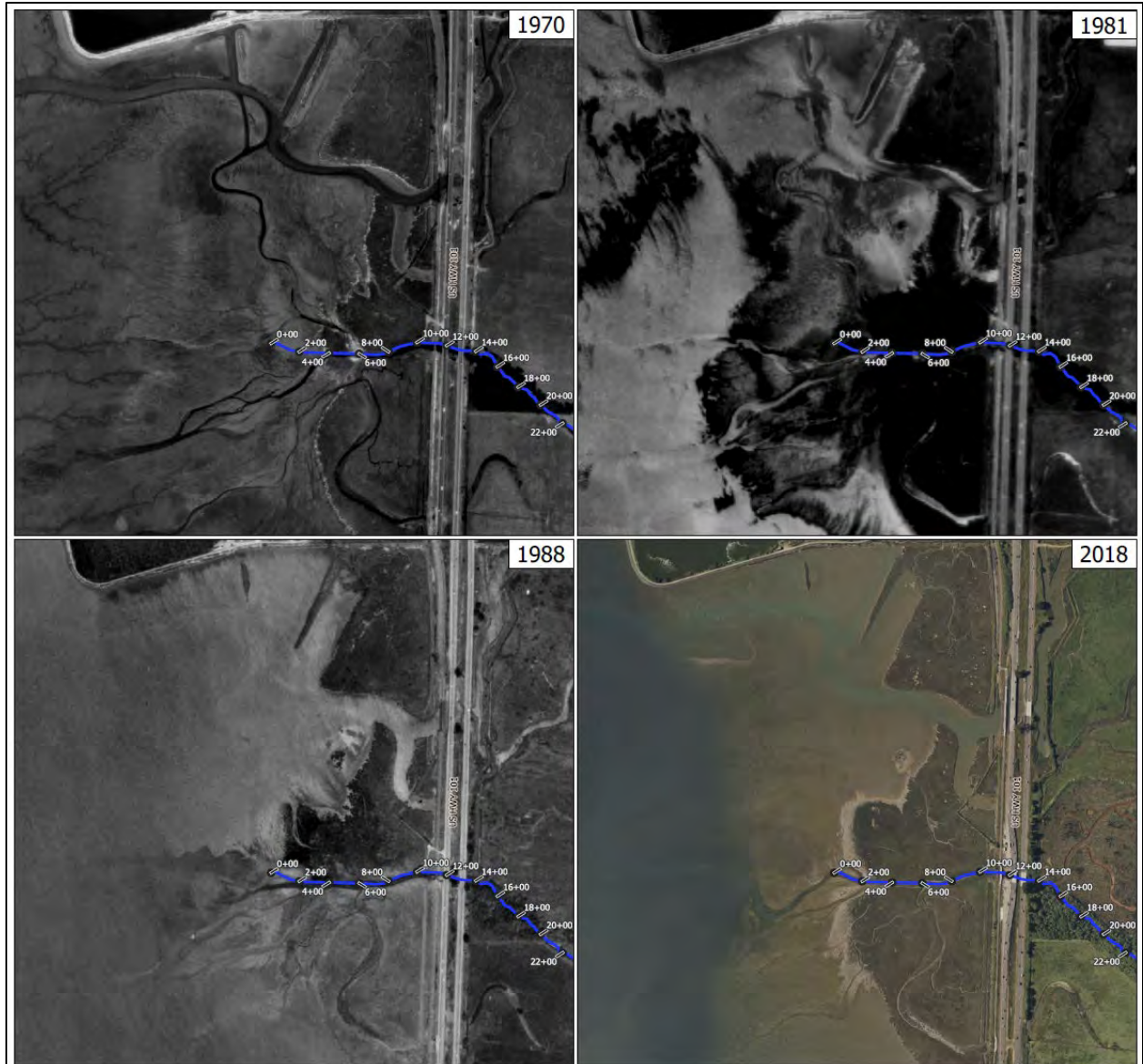


Figure 3-5. Images showing the expansion of the Jacoby Creek salt marsh delta west of US 101 between 1970 and 1981, with the extents remaining relatively stable in subsequent images (images from 2008 Historical Atlas of Humboldt Bay and Eel River Delta, and 2018 Bing Aerial)



Figure 3-6. September 2011 Google Earth image highlighting channel traces within the grass fields, likely associated with coarser material deposited within historical channels across the valley bottom.

4 FIELD MAPPING AND DATA COLLECTION

4.1 Mapping Floodplain Inundation Patterns

To better characterize existing flooding patterns, the locations that overbank flows spill out of Jacoby Creek, the route they travel across the valley and into the Baylands, and locations that ponding occurs were mapped using a combination of:

- Aerial images from the Cal Poly Humboldt Shuster Collection from 1947 and 1948.
- Fixed wing aircraft aerial images from 1974, 1975, and 2004 provided by Humboldt County Department of Public Works,
- Ground-based photographs provided by JCLT and MLA,
- Images from fixed wing aircraft by Brad Finney during the JBW event of record on December 2, 2012, and
- Images and videos from unmanned aerial vehicles (UAVs) from 2017 – 2022.

Select flood images are provided in Appendix C. Additional information regarding flooding patterns was obtained from multiple interviews of residents along Graham Road and OAR.

The resulting map of floodplain flow and ponding patterns is provided in Figure 4-1 for upstream of the Arcata Baylands, and Appendix C includes the Arcata Baylands. Flow patterns were separated into two categories: frequent flooding (occurring multiple times per year) and larger flood events. Based on both images and interviews with residents, it is evident that the locations and frequency of floodwaters overtopping Jacoby Creek banks changes yearly in response to formation and growth of vegetative debris jams, followed by subsequent removal of jams by residents. The buildup of vegetated debris jams upstream of OAR have tended to move flooding impacts further upstream along Graham Road. An extensive clearing of the channel in this reach in summer of 2019 increased local channel capacity but anecdotally increased downstream flooding frequency. Although the location and frequency of flows spilling out of bank may change with time, the general route that waters take across the floodplain remains consistent from year to year.

Upstream of OAR, flows leave Jacoby Creek along both banks. Floodwaters spill along the south bank downstream of a high topographic knob near Station 75+00, flowing through residential properties and across Graham Road. Prior to clearing of vegetated debris jams in summer of 2019, flows would also frequently spill out of the bank upstream of Solaris Road. Floodwaters spilling from the south side of Jacoby Creek flow into the low area along Washington Gulch, where it slowly drains. Washington Gulch appears to be deeply entrenched downstream of this low area, with sufficient capacity to convey the additional inflow without impacting adjacent residences.

Along the north bank of Jacoby Creek, floodwaters frequently spill out of bank within the first 1,000 feet of channel upstream of OAR. These floodwaters flow down and across the road closest to the Jacoby Creek bridge.

Further upstream on Jacoby Creek, floodwaters spill out along low areas within private and JCLT pastures (Stations 78+00 to 104+00). These waters flow northwest, where they pond upstream of the OAR roadway embankment. The ponded area upstream of the OAR roadway embankment receives flows from Jacoby Creek from as far upstream as Station 106+00. Floodwaters overtop OAR as the roadway drainage system becomes overwhelmed. The inundation of the roadway creates

hazardous driving conditions. Vehicles crossing through the floodwaters also create wakes that wash into downstream residences, exacerbating flooding impacts. All of the floodwaters crossing OAR flow through rural residential properties, eventually reaching Arcata Baylands North, where the water ponds behind existing levees and drains out the City of Arcata tide gates. Stranded adult salmon have been observed in these flows.

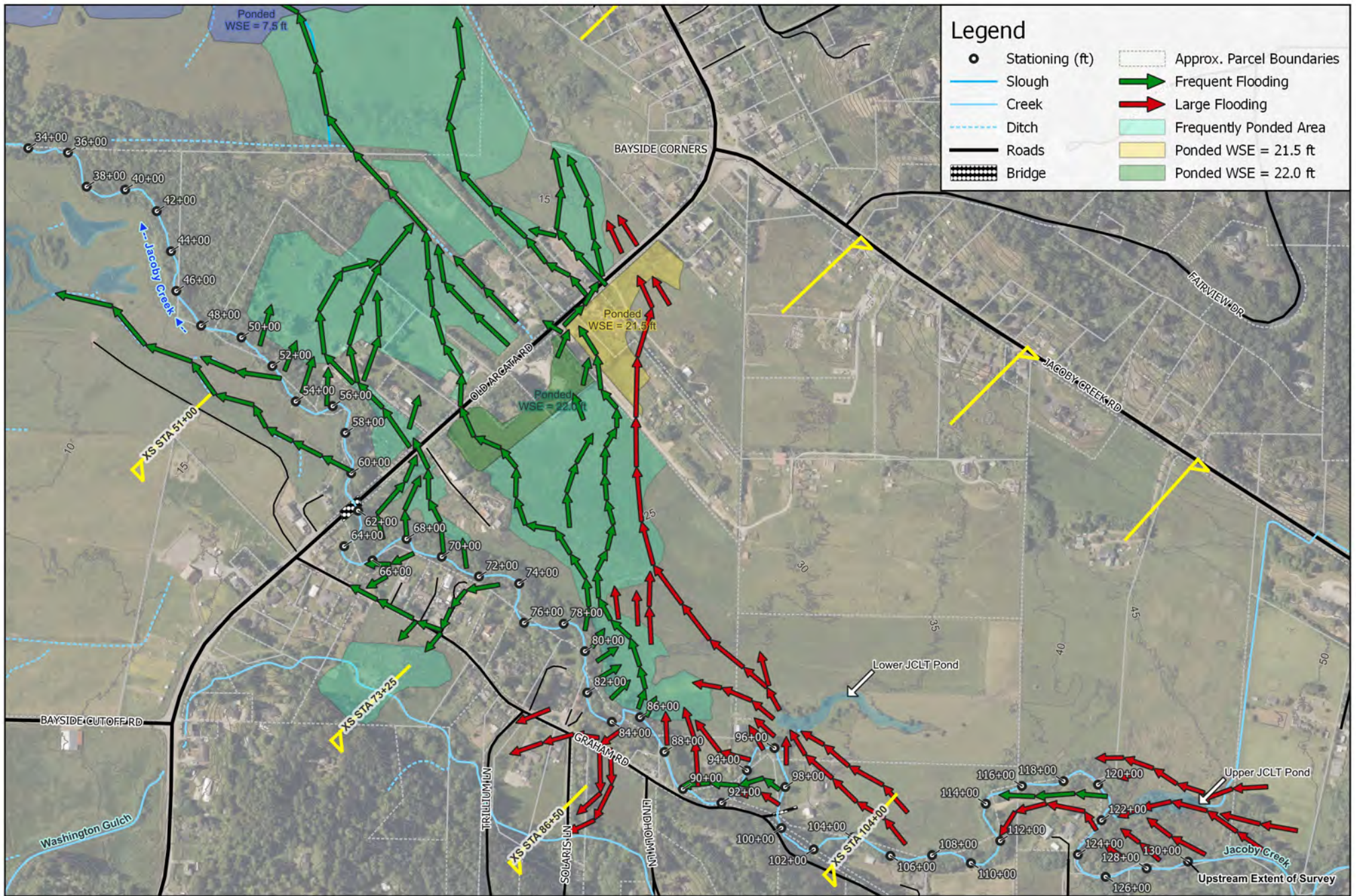
There is also localized overbank flooding from upstream of the project area to about Station 112+00. The overbank flows drain back into the channel as the flood recedes.

For approximately 1,000 feet downstream of OAR, floodwaters frequently spill out of both banks of Jacoby Creek. Along the north bank, flows spill onto private properties, causing widespread inundation, before draining into the Arcata Baylands North. There is a distinct breach in the north bank at Station 51+00, with a large scoured channel that directs flows towards the north. This breach, best described geographically as a crevasse, has persisted for several years and is one of the first locations where water spills out of Jacoby Creek, occurring for multiple weeks per year. Along the south bank of Jacoby Creek, waters spill into recently constructed capture channels on the Arcata Baylands South, flowing into the South Jacoby Wetland Complex and draining back into Jacoby Creek near the head of tide. Water spills into these capture channels for multiple weeks per year. There does not appear to be any flows spilling out of bank downstream of Station 50+00 due to all of the upstream flow losses from the channel.

In the Arcata Baylands North, floodplain flows are routed to “malfunction junction,” overtopping the existing cattle lane and ponding. The ponded water is contained to the north by the historical railroad embankment and the outer levee to the west, with a small amount of flow going through two small culverts within the railroad embankment and into the Gannon Slough basin. The ponded water discharges through the two City of Arcata gates at North Jacoby Slough and into Humboldt Bay, draining over multiple tide cycles. A limited amount of water also drains through a tide gate and into the North Jacoby Tidal Marsh. During larger flood events portions of the railroad embankment are overtopped and a portion of Jacoby Creek flows spill into the Gannon Slough basin.

4.2 Valley Cross Section

Four valley wide cross sections are cut at the locations indicated in Figure 7-1 and are shown in Figure 4-2. They illustrate that moving down-valley the channel banks become perched above the valley bottom. Station 51+00 also shows the levees that have historically been built along the top of bank.



Datums:
 Horizontal: NAD83 State Plane CA Zone 1
 Vertical: NAVD88

Sources:
 Elevation: 2019 Eureka Coastal Lidar DEM
 Aerial Image: 2018 Bing Aerial Imagery

0 600 1,200 ft



Jacoby Creek Water Sustainability and Anadromous Fish Habitat Enhancement Feasibility Study

Figure 4-1.
 Mapped flow paths across floodplain during frequent and larger flood events.

Nov. 2023

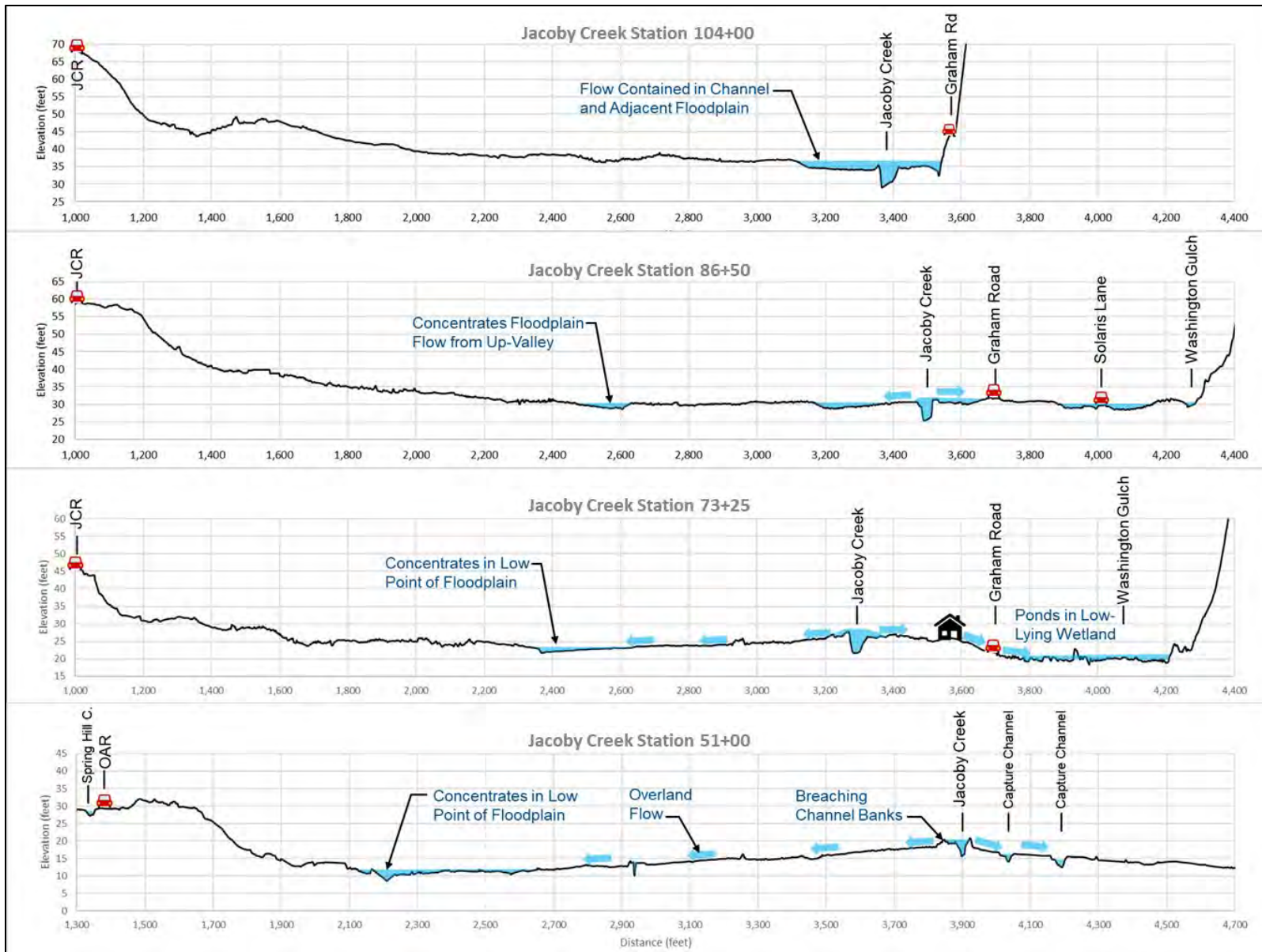


Figure 4-2. Valley cross sections showing elevational differences and floodplain inundation patterns.

4.3 Jacoby Creek Streamflow and Bedload Sampling at Brookwood Bridge

4.3.1 Jacoby Creek at Brookwood Bridge

Randy Klein, hydrologist, has been operating a streamflow gaging station on Jacoby Creek at the Brookwood Drive bridge crossing (gaging station JBW) since November 2003 to current. The contributing drainage area at JBW is 13.7 square miles. For much of the period of record the station also monitored turbidity and suspended sediment concentrations. The stage-discharge rating curve was regularly updated to account for rating shifts. The highest measured discharge during the period of record was 1,567 cfs on January 17, 2016. As part of the current study, additional discharge measurements were taken by TGAEC and added to the stage-discharge rating curve for JBW.

The water year (WY) 2022 streamflow, turbidity, and cumulative precipitation are plotted in Figure 4-3. Annual rainfall was only 62% of average and the peak discharge of 381 cfs has an approximate return period of less than 1.01 years. Despite the lack of any substantial large flow events, substantial overbank flooding occurred within the study area.

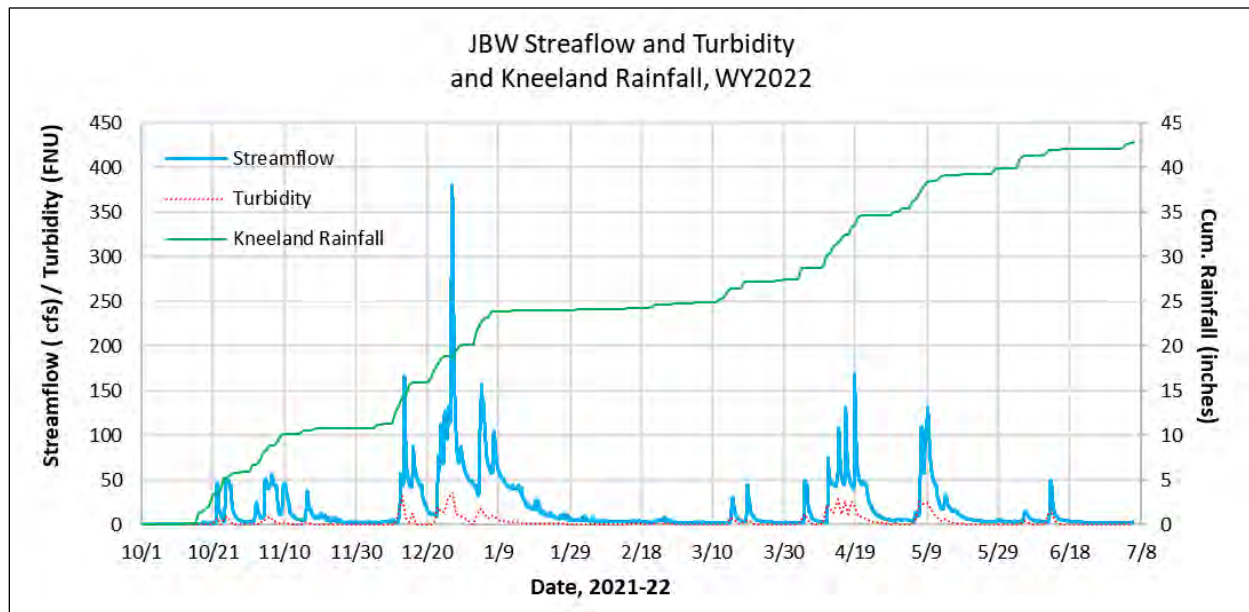


Figure 4-3. Water year (WY) 2022 instantaneous streamflow and turbidity at the JBW gaging station and cumulative precipitation at Kneeland. Maximum instantaneous streamflow of 381 cfs.

4.3.2 Bedload Transport Samples at Brookwood Bridge

High flow bedload samples were taken from the bridge at JBW during different periods. In water year (WY) 1978 and 1979 bedload samples and associated stream discharge measurements were taken at the Brookwood Bridge by the US Forest Service Redwood Science Lab as part of a research project. Subsequently, Randy Klein and Wes Smith collected bedload samples in WY 2004, 2005, 2007, 2008, and 2019. As part of the current study, each of the 13 samples taken in WY 2019 were sieved to determine the cumulative particle size distribution of the material in transport. Measurements of bedload discharge versus streamflow are plotted in Figure 4-4.

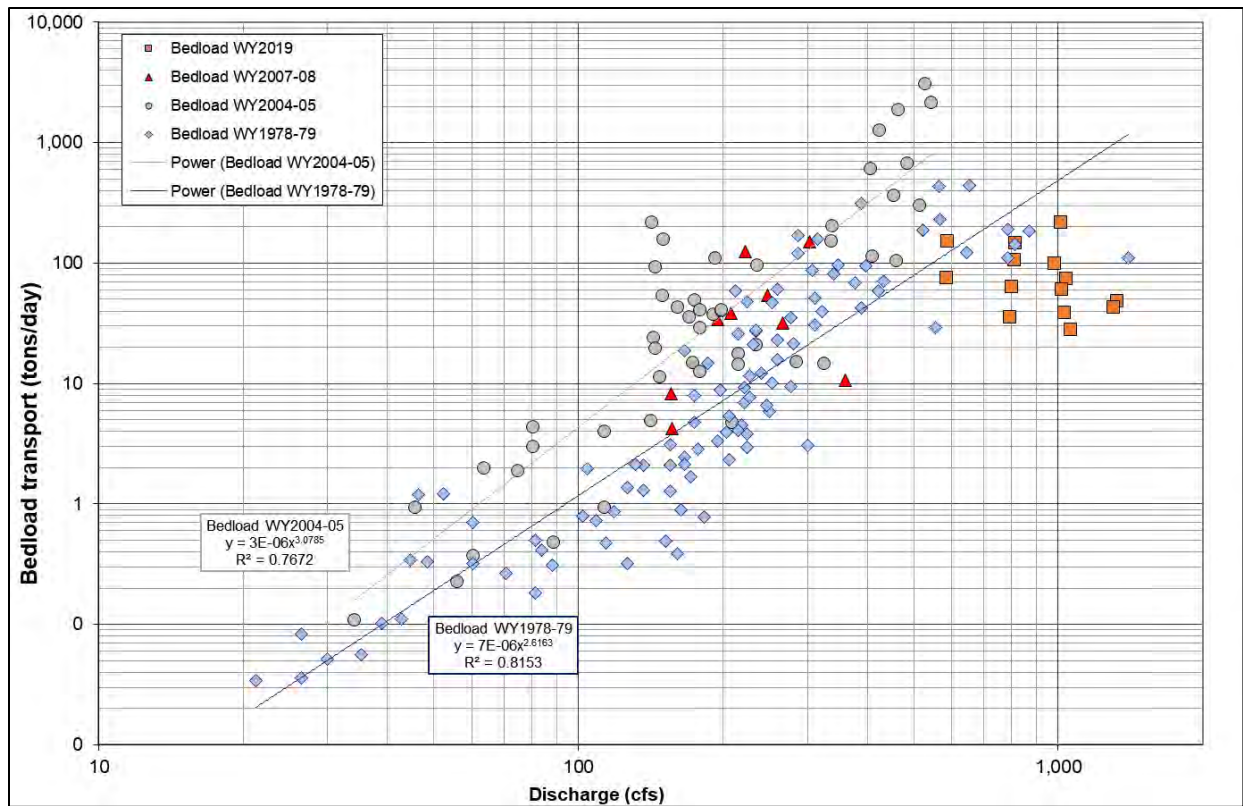


Figure 4-4. Jacoby Creek at Brookwood Bridge (JBW) bedload discharge rating.

4.4 Characterizing Streambed Material Size

The gradation (size distribution) of the alluvium in Jacoby Creek on the surface of the streambed was characterized using Wollman pebble counts at 10 locations spaced out from the downstream of OAR to the Brookwood Bridge JBW gaging station (Figure 2-1). Subsurface bulk samples were also collected at four of these locations and processed by SHN down to very fine sand (#200 sieve) following ASTM C-136. Resulting gradations are provided in Appendix D.

From the pebble counts, the D_{84} (84th percentile) particle size ranged from 11 to 86 mm (medium gravel to fine cobble). The D_{84} for the four subsurface bulk samples ranged from 11.5 mm to 66.5 mm (medium to very coarse gravel).

The resulting D_{84} sizes showed a general coarsening of the bed from downstream to upstream. The coarsest material was PC/BS10 at the JBW gaging station, which generally does not have out of bank flows. Samples PC7, PC/BS8, and PC9 were also coarse, and are in a reach that has a limited floodplain with flows remaining contained within the channel corridor. Downstream of PC7, where the streambed material begins to fine, the debris jams become more abundant and flows leave the channel and do not return, suggesting less sediment transport competence.

4.5 Water Level Gaging

A total of 9 water level gaging stations were installed as part of the study. Stations JC1A and JC1B and JC2 were placed in historical slough channels within the Arcata Baylands North. The remaining 6 stations were located in Jacoby Creek. Locations of each gaging station are shown in Figure 2-1.

The stations recorded water levels in NAVD 88 from November 3, 2021 to July 8, 2022. The data was used to calibrate and validate the project’s existing conditions hydraulic model and characterize tidal influence at select locations in Arcata Baylands North and at the lower end of Jacoby Creek. Water levels for each station are plotted for the water year in Figure 4-5a.

4.5.1 Water Levels in Arcata Baylands North

JC1A and JC1B are located on the upstream and downstream side of a culverted crossing under an existing cattle lane at “malfunction junction.” JC2 is located in the lower portion of North Jacoby Slough. It shows muted tidal influence associated with the downstream leaky tide gates. The muted tide within the slough ranged from 0.5 feet to 4.3 feet at JC2.

During periods when Jacoby Creek is spilling onto the northern floodplain, water levels pond up in the Arcata Baylands North (see Section 4). At JC2, water levels peaked at 6.7 feet on December 27, 2022, but rapidly drained down as the tide ebbed (Figure 4-5b). At JC1A the water level did not recede as rapidly, but slowly fell over multiple days. The difference in rate of drainage is associated with the routing of floodplain flows from near the head of the ponding to the tide gates.

4.5.2 Jacoby Creek Water Levels

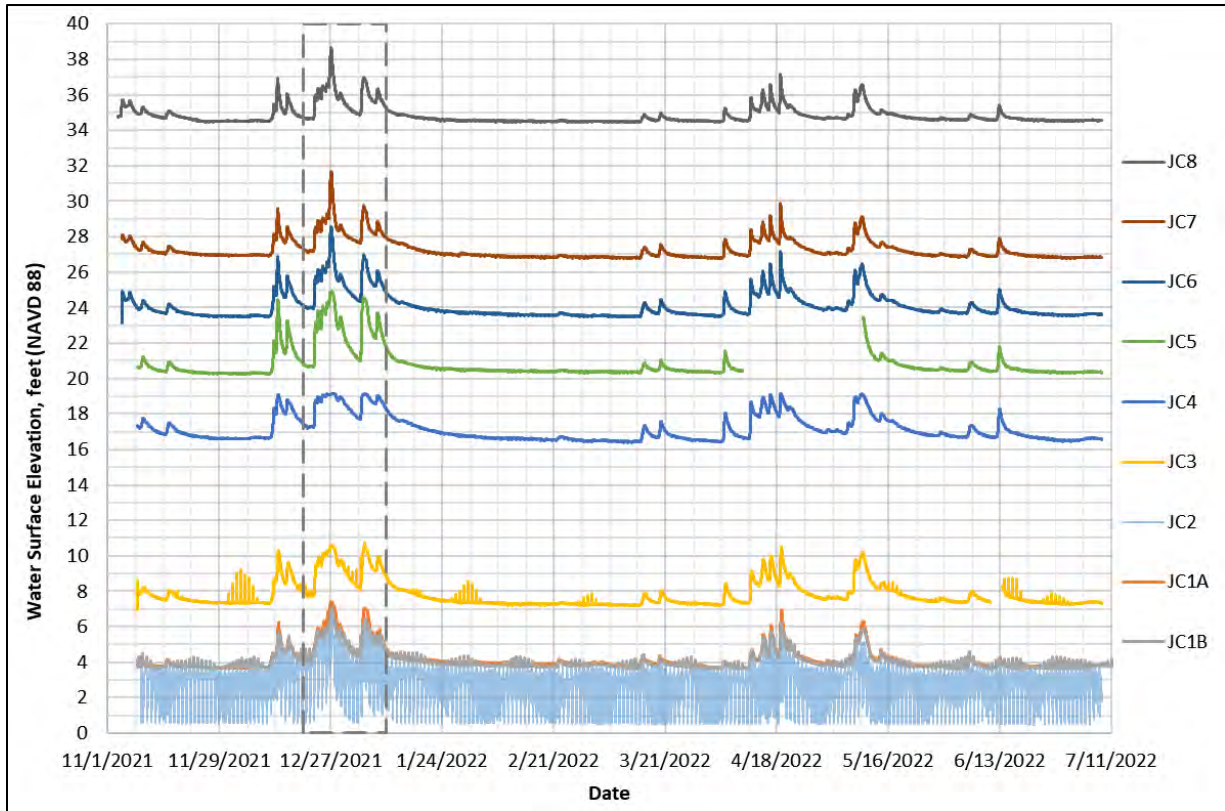
The downstream-most station in Jacoby Creek (JC3) was located near the head of tide, where the utility corridor crosses the channel. Water surface elevations at JC3 remained above 7.3 feet due to a downstream riffle control. During monthly spring tides and baseflow conditions, the station recorded tidal backwater influence.

When reviewing the shape of the stage plots associated with each high flow event (Figure 4-5a), the peaks become flattened downstream of JC5, which is at the OAR bridge. During the largest flow event of the year on December 27th, the peak stage is also flattened at JC5 (Figure 4-5a). The flattening of the peaks is associated with the extensive flow losses from the channel beginning downstream of JC6. Station JC4 is located immediately below the downstream-most location where flow spill out of the channel. At this station the water level only fluctuates 2.5 feet from summer baseflow to the peak flow event of the year, and each high flow event results in the water level reaching the same peak stage of 19.0 feet. The stage plot for JC4 suggests that regardless of the upstream flow magnitude, streamflow in this reach of Jacoby Creek is restricted due to upstream out-of-bank losses.

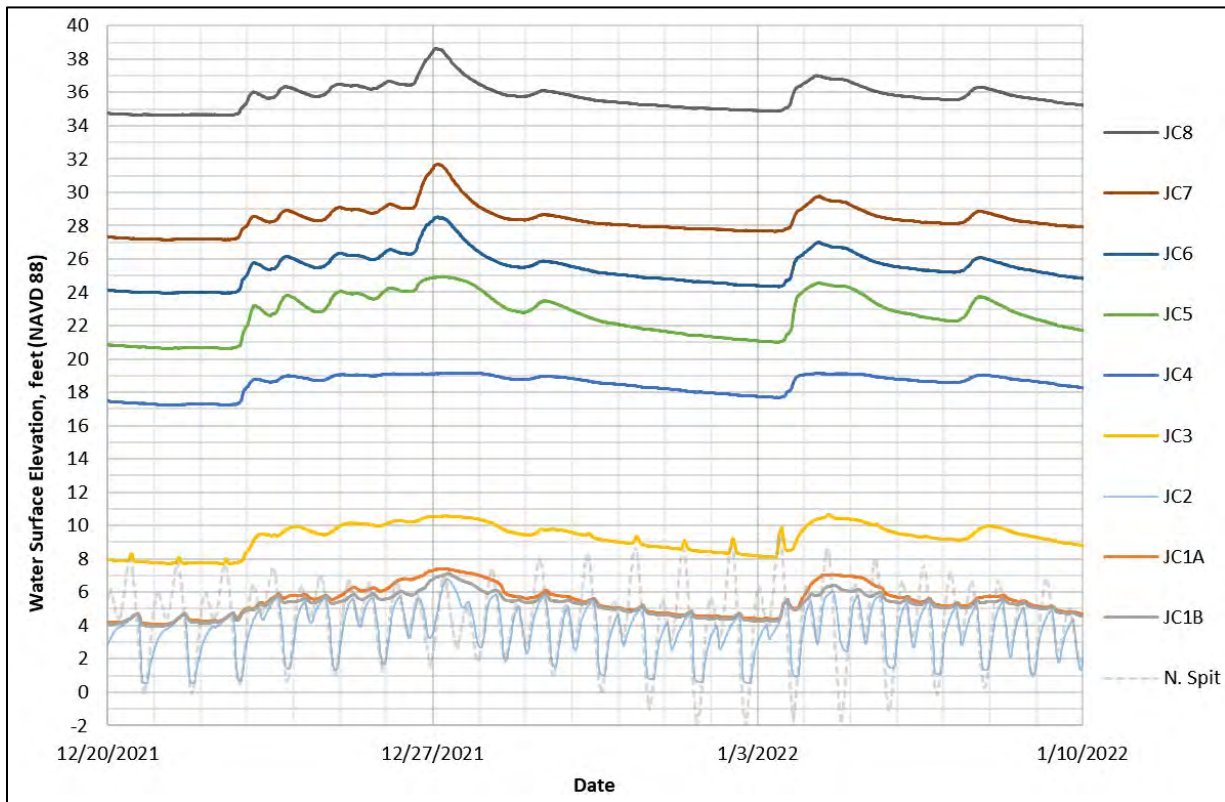
4.6 Water Quality Measurements

TGAEC took water quality spot measurements in the Arcata Baylands North on April 26, 2022 and May 13, 2022. Both days followed high flow events that resulted in overbank flows being routed into the area. Parameters measured were dissolved oxygen (DO), water temperature, salinity and conductivity, and pH. Summary of the measurements are provided in Appendix E.

The spot measurements found DO to be consistently above 4.5 mg/l, a common lower limit for rearing juvenile salmonids (Whitmore et al., 1960). During the sampling period the more tidally influenced channels had water temperatures as high as 20° C and salinity as high as 9 ppt. Areas around where Spring Hill Creek enter the Arcata Baylands and at Malfunction Junction had no salinity, temperatures generally at or below 15° C and DO greater than 6 mg/l. In the Spring Hill Creek channel adjacent to the wetlands DO was measured as high as 9.8 mg/l.



(a)



(b)

Figure 4-5. Recorded water levels at JC1 – JC8 (a) in WY 2022 and (b) during the peak flow event of the water year on December 27, 2021. North Spit (Sta. 9418767) tidal levels added for reference.

Installed salinity loggers at JC2 and JC3 provided continuous salinity measurements. The loggers were placed at the bottom of the water column. At the downstream end of the North Jacoby Slough channel (JC2) salinity fluctuated with the tide daily, frequently ranging from nearly zero to above 25 ppt. During floodplain inundation events, when freshwater was ponding in the Arcata Baylands North, the salinity still fluctuated with the tide but peak salinities decreased to less than 3 ppt. At JC3 located in Jacoby Creek near the head of tide, the only periods when salinity was greater than zero were during four consecutive days in December when large spring tides occurred during low flows, and one day during the 8.4-foot January king tide. The December salinity concentrations reached 27 ppt, while the January event, which was during a period of higher rainfall and flows, had a peak salinity concentration of only 3 ppt.

4.7 Stream Habitat Mapping and Fisheries Observations

4.7.1 Stream Habitat Mapping

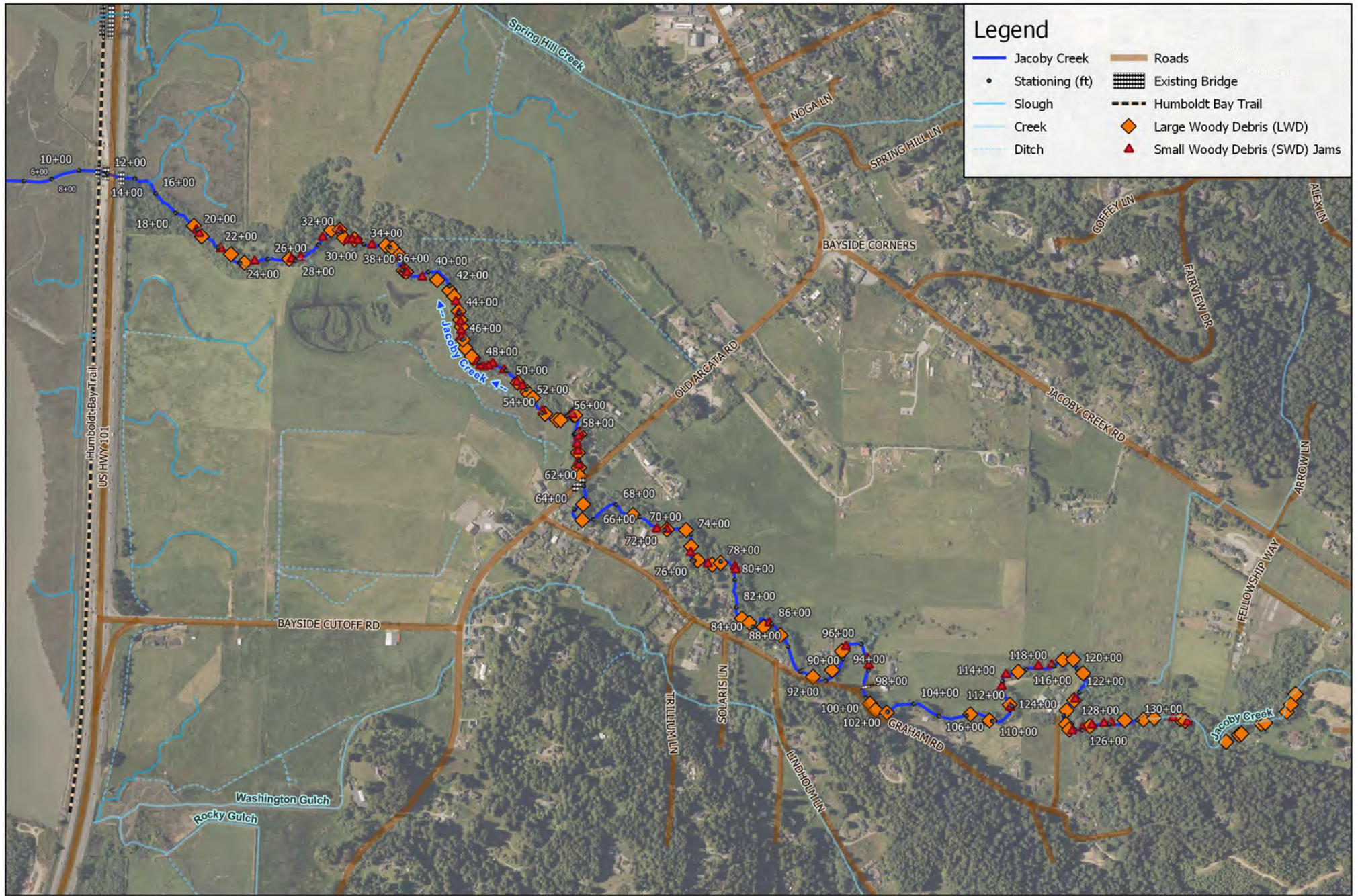
In January and February of 2022 TGAEC conducted detailed stream habitat mapping upstream US 101 to approximately 13,000 feet upstream. The stream habitat assessment provides a baseline for monitoring future changes to channel condition, including supporting the interim Stream Corridor Management Plan (see Section 1.7). The mapping followed the Habitat Inventory Level 3 protocol described by Flosi et al. (2010). The protocol was supplemented with the collection of information on large and small woody debris jams, salmonid redds and carcasses, and western freshwater pearlshell mussel (*Margaritifera falcata*) presence. The field data was recorded and spatially referenced using QGIS QField software on an android tablet with a sub-meter grade GPS unit. Photographs were also tagged with GIS coordinates. A GIS database was created with attribute tables containing the collected data and photos. Results from the habitat mapping were summarized in a technical memorandum provided in Appendix F.

The data was analyzed based on comparing reaches downstream versus upstream of OAR. In general, Jacoby Creek downstream of OAR was dominated by flat-water habitats, sandy substrates, small woody debris jams, and had the greatest abundance of freshwater mussels. Upstream of OAR, the stream was dominated by gravel and cobble occurrence increasing with distance upstream. There were also a greater number of redds observed upstream of OAR than downstream.

4.7.2 Mapping Instream Wood and Debris Jams

Mapping of woody debris was conducted to identify their role in hydraulic constrictions and controls within the channel, their composition, process of formation, and types of habitat they create and support. Large woody debris (LWD) was defined as any piece of wood with a minimum diameter of 12 inches and at least 6 feet long. Pieces with lengths exceeding 20 feet were counted separately. Small woody debris (SWD) had a diameter of less than 12 inches. Information was collected to describe each jam and whether it was comprised of anthropogenic materials. The GPS location of each mapped LWD and SWD jam are plotted on Figure 4-6.

SWD jams, especially downstream of OAR, often had anthropogenic materials incorporated into the jam (Figure 4-7). It was common to find pieces of lumber in these jams, such as two-by-fours, as well as other wood that did not originate from the stream (i.e., pallet board, wooden planter box). It was also very common to find cut rounds of trees, which were visibly cut by chainsaw, that became trapped in the SWD jams. Aside from wood materials, the SWD jams also collected brush debris, which may or may not have naturally found their way into the stream. Propane tanks, plastic bottles, and metal cans were also found in the SWD jams, particularly near OAR bridge.



Legend

- Jacoby Creek
- Stationing (ft)
- Slough
- Creek
- - - Ditch
- Roads
- Existing Bridge
- - - Humboldt Bay Trail
- ◆ Large Woody Debris (LWD)
- ▲ Small Woody Debris (SWD) Jams

Datums:
Horizontal: NAD83 State Plane CA Zone 1

Source:
Aerial Image: 2018 Bing Aerial Imagery

0 900 1,800 ft



Jacoby Creek Water Sustainability and Anadromous Fish Habitat Enhancement Feasibility Study

Figure 4-6.
Locations of large woody debris (LWD) and small woody debris (SWD) jams, mapped by TGAEC in January/February 2022.

Nov. 2023



Figure 4-7. Examples of small woody debris jams (a&b) formed by in-channel vegetation and cut lumber and initiated by (c) a fallen alder. Some channel obstructions are completely formed of (d) live willow. Upstream of OAR much of the debris and in-channel vegetation had been cleared in (e) 2019 and (f) 2021.

The riparian corridor composition is primarily alder and willow. Many of the woody debris jams in Jacoby Creek were initiated by live woody vegetation, primarily willow, growing from the northern bank across the channel bed with vertical branches that created “strainers” trapping any floating material of size. Other jams were initiated with the leaning and falling of willows and alders into the channel from the adjacent bank. The presence of these riparian trees in the channel and their contributing to wood jams appears to be in part due to them leaning across the channel towards sunlight due to a lack of an overstory canopy.

During the time of survey, there was a higher occurrence of SWD jams downstream of OAR than upstream of OAR. Upstream of OAR, there was evidence of jams and spanning-trees being cut out of the stream by landowners, which influenced the low occurrence of SWD jams observed in that section of the stream. From discussions with landowners along Graham Road, it appeared that the majority of the jams upstream of OAR were removed in summer of 2019, with additional ones removed in 2020 and 2021.

Cut willow branches and trunks were also observed along the streambanks in the lowest reach of Jacoby Creek, downstream of Station 43+00. These cut willows were located near the toe of the streambank and appeared to have been cut a number of years prior. Based on discussions with USFWS staff (Conor Shea, personal communication), these willow cuts were observed as far back as 2014, during a channel survey as part of designing the South Jacoby Creek Wetland Complex.

4.7.3 Overbank Fish Sampling and Observations of Fish Stranding

TGAEC conducted fisheries sampling in flooded pastures and documented adult Coho Salmon stranding during overbank flooding in December 2021 and January 2022. They prepared a field memo, which is provided in Appendix G. The memo documents the observation of three adult Coho Salmon stranded around a residence on the north side of Jacoby Creek downstream of OAR. This included an unspawned female coho carcass recovered on the floodplain in brushy vegetation on December 30, 2021 and a Coho Salmon captured by CDFW biologist near a barn and released back to Jacoby Creek. The memo also documents the capture of a juvenile Coho Salmon on the inundated floodplain on this same property.



Figure 4-8. Adult unspawned female coho salmon carcass (left) on floodplain and stranded coho salmon rescued from driveway (right). Photos from TGAEC and Carol Anderson.

5 PROJECT HYDROLOGY AND SEA LEVEL RISE PROJECTIONS

5.1 Return Period Flow

Peak flows for given return periods were estimated for multiple locations within the study area using the USGS StreamStats online application (USGS, 2019). The application calculates contributing drainage area, mean annual precipitation, and return period peak flows using regional regression equations developed by Gotvald et al. (2012). Resulting drainage areas and flows for select locations are provided in Table 5-1 and StreamStats reports are provided in Appendix H.

Table 5-1. Peak flow values by return period for Jacoby Creek and tributaries to Study Area.

Location	Drainage Area (mi ²)	Peak Flow (cfs) for Return Period					
		2-year	5-year	10-year	25-year	50-year	100-year
Jacoby Creek at JBW	13.6	1,140	2,020	3,440	4,050	4,050	4,670
Jacoby Creek downstream of Monaham Creek	15.2	1,230	2,200	2,870	3,750	4,410	5,080
Monaham Creek	1.4	120	231	311	417	498	583
No Name Trib. to Upper JCLT Pond	0.1	9.8	20.2	28.0	38.5	46.7	55.5
Spring Hill Creek	0.3	25.7	52.5	72.3	98.9	120	142
Bieth Creek	1.3	105	206	279	375	450	528
Grotzman Creek	0.7	60.7	120	163	220	264	311
Campbell Creek	1.1	83.3	166	227	308	370	436

5.2 Jacoby Creek Daily Average Flow Duration

Daily average flows calculated using the 10-minute flow data from JBW for ten water years from WY2006 through WY2023 were provided by Randy Klein. Other water years during the period of JBW operations were not used due to data gaps during low-flow periods in the dry season. The daily flows were used to calculate the percentage of time flows equaled or exceeded annually at the JBW gage. These exceedance flows were then scaled to the drainage area of Jacoby Creek downstream of Monaham Creek, as given in Table 5-1. Figure 5-1 includes the flow duration curves for each year and the entire 10 years of daily flows combined.

5.3 Existing Tidal Water Levels and Stillwater Return Periods

Existing tidal datums and extreme high-water level probability estimates for Arcata Bay at the Arcata Marsh & Wildlife Sanctuary were calculated by Northern Hydrology & Engineering (NHE, 2018) and are provided in Table 5-2. These values are assumed to be applicable to the study area given the proximity. These values were used to assess tidal backwater influences in Jacoby Creek, evaluate the current vulnerability of existing tidal levees, and assess risks associated with sea level rise (SLR).

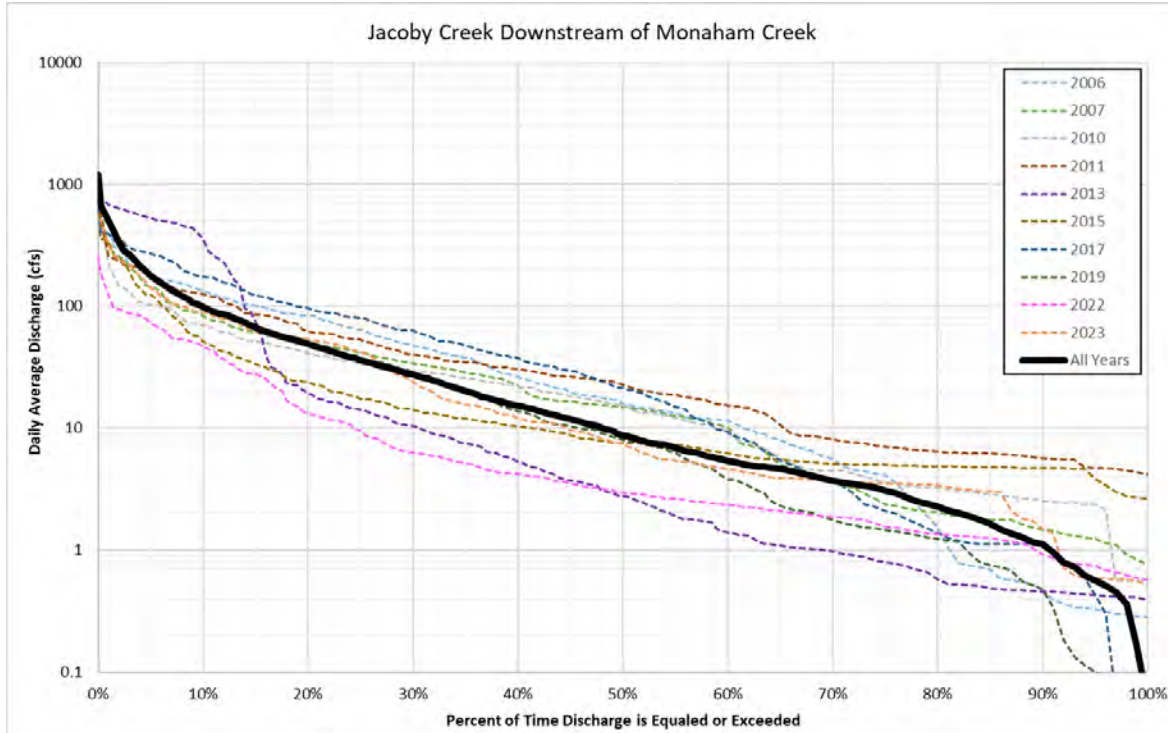


Figure 5-1. Annual flow duration curves (FDCs) for Jacoby Creek downstream of Monaham Creek, calculated using JBW daily average flows scaled by difference in drainage areas. Plots include each FDCs for each water year and from all water years combined.

Table 5-2. Tidal water levels and still water return periods for the study area (from NHE, 2018)

Return Interval	Elevation, feet (NAVD 88)
Mean Higher High Water (MHHW)	7.1
Mean Monthly Maximum Water (MMMW)	8.4
Mean Annual Maximum Water (MAMW)	9.4
1.01-year	8.7
2-year	9.4
10-year	10.0
100-year	10.7

5.4 Projected Sea Level Rise

SLR is the primary issue of concern when considering how impacts from a changing climate could affect infrastructure and lands along Humboldt Bay. SLR is unique among other natural processes and episodic events because it will develop over the span of decades. Initially, SLR may be difficult to distinguish among the variable water levels of Humboldt Bay, but even small amounts of SLR may increase the risk of coastal flooding during extreme events, posing a threat to a variety of coastal resources.

Global mean sea level is rising, with acceleration in recent decades due to increasing rates of ice loss from the Greenland and Antarctic ice sheets, as well as continued glacier mass loss and ocean thermal expansion (IPCC, 2019). The rate of global SLR for 2006-2016 of 3.6 mm/year is unprecedented over the last century and was 2.5 times higher than the rate for 1901-1990 of 1.4 mm/year (IPCC, 2019).

SLR projections along the west coast of California are provided in the 2018 State of California Sea Level Rise Guidance document (OPC, 2018) for 12 active tide gauges. The California Coastal Commission (CCC) Sea Level Rise Policy Guidance, updated in 2018 to reflect the latest projections, refers to these as the “best available science” on SLR projections in California. SLR projections for Humboldt Bay North Spit on (Station ID: 9418767), the nearest tide gauge to Eureka, are appropriate for the study area. These projections are shown in Figure 5-2 for a range of probabilistic scenarios and time horizons through 2070. Future updates to the OPC and CCC guidance are expected to utilize SLR projections reported in the National Oceanic and Atmospheric Administration’s February 2022 Global and Regional Sea Level Rise Scenarios for the United States.

SLR projections may be added to existing tidal datums and extreme high-water level probability estimates in Table 5-2. The increased probability of higher water levels in the future with SLR (Table 5-3) are modeled to indicate the extent of overtopping of shoreline infrastructure and coastal flooding.

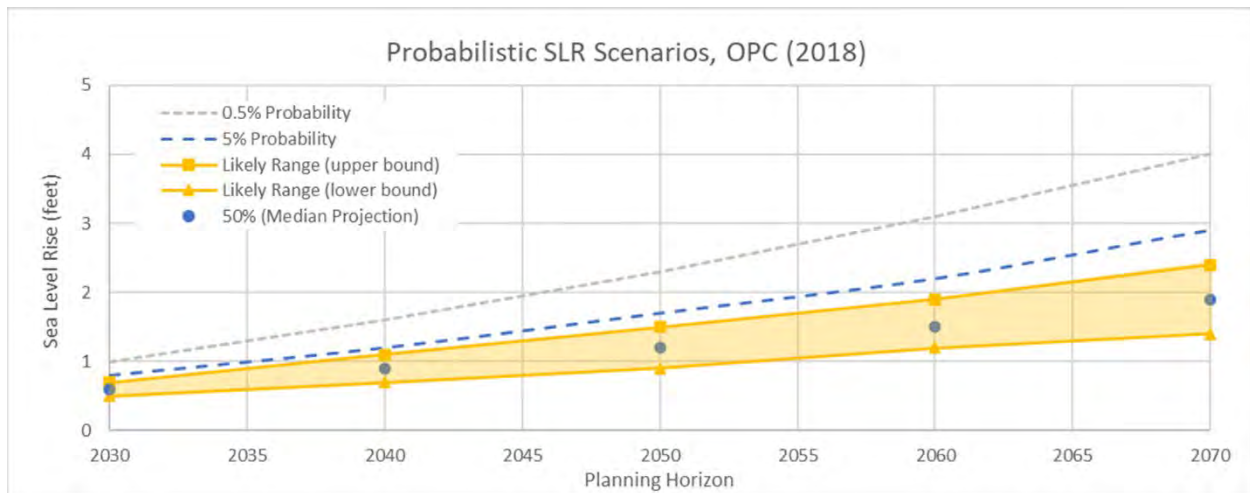


Figure 5-2. Sea level rise projections at North Spit, with baseline level from 2000 (OPC, 2018)

Table 5-3. Return period of given tidal water levels with varying degrees of SLR.

SLR	Water Level (NAVD 88) and Resulting Return Period with SLR			
	9.4 feet	10.0 feet	10.7 feet	11.7 feet
0 feet	2-year	10-year	100- year	-
~1 feet	MMMW	1.01-year	10- year	100- year
~2 feet	MHHW	MMMW	1.01- year	10- year
~3 feet	-	MHHW	MMMW	1.01- year

6 EXISTING HYDRAULIC & SEDIMENT TRANSPORT ANALYSIS

As part of the current planning effort, a detailed numerical hydraulic model was developed for Jacoby Creek and adjoining floodplain. The model was used to quantify in-channel hydraulic capacity and flow resistance associated with vegetation and debris, sediment transport competency and capacity, floodplain routing, inundation extents, and drain-off conditions. The model provided insights that helped develop an understanding of ongoing fluvial geomorphic processes, flooding impacts, and identify potential alternatives. It will also function as a tool for analyzing alternatives as part of the next phase of project development.

6.1 Model Development

The project hydraulic model was developed in the US Army Corps of Engineers HEC-RAS, 1D and 2D, version 6.2.

6.1.1 2D Model Extents, Terrain, Boundaries and Mesh

The HEC-RAS 2D model was used for all hydraulic modeling except the sediment transport assessment (Section 6.6). The modeled topography (terrain) was based on the project DEM (see Section 2.1.1). The model domain, shown in Figure 6-1, extends from Humboldt Bay to 13,000 feet upstream, and from Bayside Cutoff north to the intersection of US 101 and Samoa Boulevard/OAR.

The base mesh element size was 25 feet by 25 feet. Breaklines and refinement regions were added to better represent the existing Jacoby Creek channel, top of bank, and levees throughout the project area. A refinement region was used for the South Jacoby Wetland Complex. Use of break lines and refinements areas decreased the mesh density to as small as 3 feet by 3 feet.

The model contains seven stage/flow boundaries. The Jacoby Creek upstream boundary was a flow input located at Station 130+00, spanning the channel and adjacent top of banks. For the magnitude of flow events analyzed, streamflows are confined within the channel at this location. Other inflow boundaries were provided at the edge of the model domain for Campbell Creek, Grotzman Creek, Beith Creek, and Spring Hill Creek. For flows spilling out of Jacoby Creek and into the Washington Gulch basin, a normal depth outflow boundary was used at the stream's OAR crossing.

The downstream (western) stage boundary in Arcata Bay that controls water levels through the Jacoby Creek and Gannon Slough bridge crossings under US 101. The stage boundary was based on 15-minute interval Gannon Slough water levels collected as part of the Caltrans tide gate monitoring project (HSU and MLA, 2022).

6.1.2 Drainage Structures in Model

The model included multiple drainage structures. In Jacoby Creek the highway, trail, and railroad bridges were not included, as the bottom of the decks are above the highest water levels analyzed. The OAR bridge was included in the model based on surveyed dimensions. The upstream Rael and Cody bridges were not included in the model, as the low portion of the bridge decks were above the water surface for the analyzed flow events and no bridge piers in the channel.

Three small culverts were included through embankments and Malfunction Junction. Two small culverts were included through the railroad embankment that connects North Jacoby Slough basin to Gannon Slough basin.

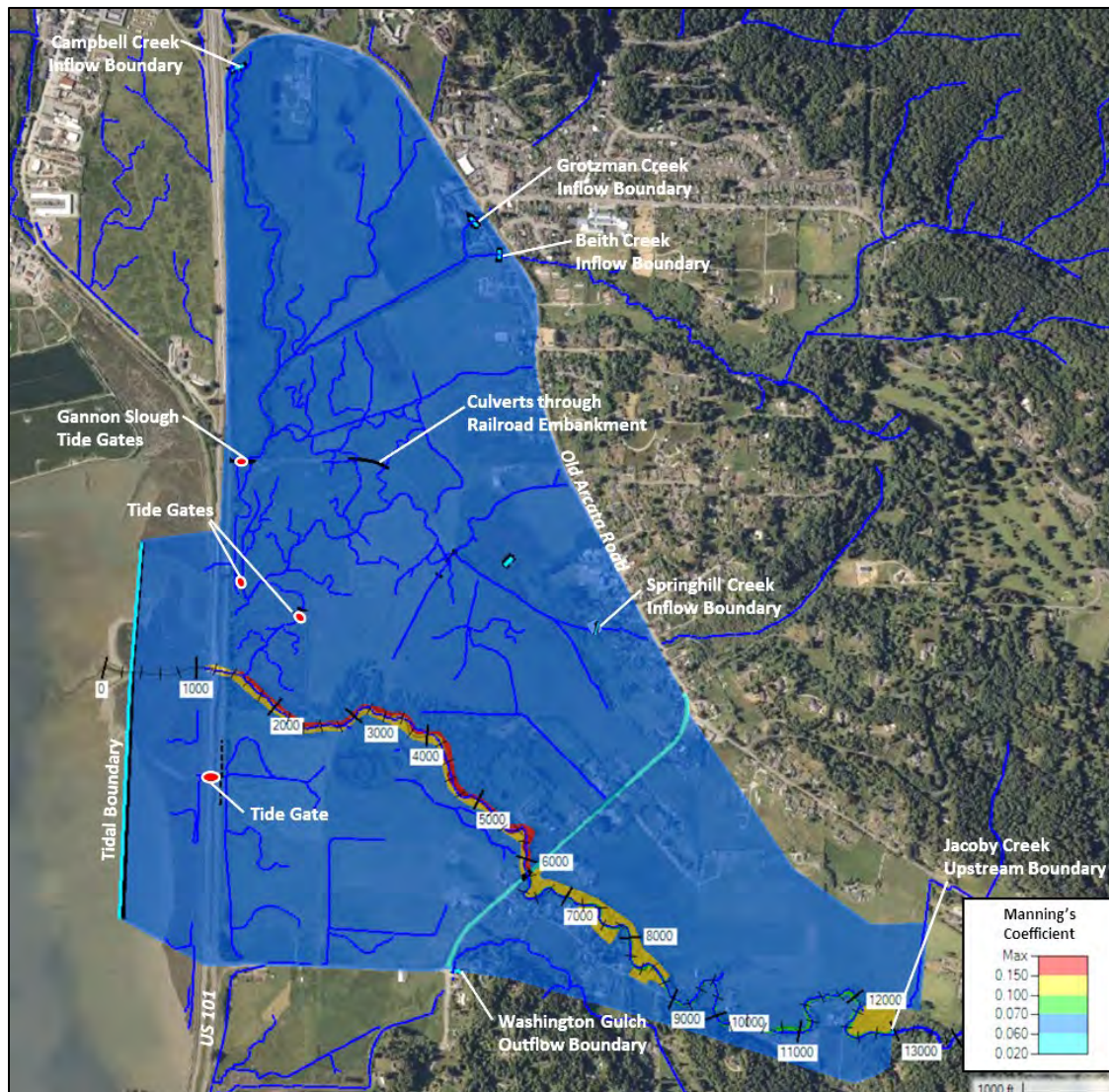


Figure 6-1. Bing satellite image with project HEC-RAS 2-D model domain, Jacoby Creek stationing, model inflow and outflow boundaries, drainage structures, and Mannings coefficient regions and values.

The model included eight tide gate structures modeled based on surveyed dimensions and dimensions provided by HSU and MLA (2022). All were modeled with a simple one-way flap gate to prevent tidal inflow. Gate features that create muted tidal conditions on the interior side of the levees, which include the muted tide gate regulator, the mitigator, and auxiliary door, were not included in the model (see Section 2.3).

The roadway drainage system for OAR north of Jacoby Creek, consisting of drop inlets and flared end section connected to a single lateral line was not included due to model limitations. Three small culverts were included through embankments and Malfunction Junction. Two small culverts were included through the railroad embankment that connects North Jacoby Slough basin to Gannon Slough basin.

6.1.3 Scaled JBW Streamflows to Model Inflows

There are several tributaries to Jacoby Creek downstream of JBW that contribute flows to the creek. The drainage area at JBW is 13.7 mi² while the contributing drainage area at the upstream limit of the hydraulic model is 15.7 mi², an increase in area of 115%. However, two flow measurements by TGAEC at the Rael bridge (145 cfs and 278 cfs), located at Station 90+00, were compared to flows recorded at the JBW gage and found to be approximately 120% greater. Therefore, the JBW recorded streamflows was increased by 120% for use as the Jacoby Creek model inflow boundary.

Where inflows were modeled at other locations, JBW flows scaled by drainage area were used.

6.1.4 Model Scenarios

Table 6-1 lists each of the scenarios analyzed with the existing conditions 2-D model and the flow and stage inputs. All scenarios except No. 4 were modeled using HEC-RAS 2D. Scenario 4 was modeled using HEC-RAS 1D.

All scenarios were run using the diffusion wave equations rather than full momentum to achieve model stability and run-time efficiency.

6.1.5 Model Calibration

The first modeling scenario evaluated a range of selected flows to calibrate the 2D model to match recorded water levels along the channel length. This was performed by adjusting the hydraulic roughness coefficient values. At select locations, the model terrain was modified along the top of bank to remove artificial high elevations originating from LiDAR returns on riparian vegetation.

The hydraulic roughness, a measure of flow resistance, was simulated in the model using a Manning's roughness coefficient. The model domain was divided into numerous roughness regions based on the topography, bed material, and vegetation. The floodplain was assigned a base Manning's roughness coefficient of 0.060, representing the short grass pasture found throughout much of the model domain (Arcement and Schneider, 1989; Chow, 1988). Riparian vegetation along the channel banks was dense in specific locations, and sparse in others. Downstream of OAR the riparian vegetation was generally denser along the north bank, and was assigned a coefficient value of 0.15, while the south bank was assigned 0.10. Denser locations upstream of OAR were assigned a coefficient of 0.10, with areas of sparse or thin riparian vegetation assigned the same as the floodplain (0.060).

A total of 9 flows were used to calibrate the model. Manning's roughness coefficients for the channel were adjusted until they best matched recorded water levels at the six water level gaging locations in the stream (JC3 – JC8). For flows that represented a peak of an event recorded at JBW, the related peak water level measured at the gaging locations were used for calibration to address the delay associated with streamflow routing.

Based on field observations of vegetation and debris in the channel and initial model results, Jacoby Creek was divided into four reaches for calibration. Resulting reaches and corresponding calibrated roughness coefficients are provided in Table 6-2. Roughness coefficient values were extremely high compared to typical channels (USGS, 1967), but not unexpected given the flow restrictions created by numerous dense vegetated debris jams, especially downstream of OAR (see Section 4.7.2). Upstream of OAR, the observed channel was more open, with less obstructions within the active flow area, resulting in a substantially lower roughness coefficient.

Table 6-1. HEC-RAS 2-D model scenarios performed for both existing and proposed conditions.

No.	Scenario	Boundary Conditions	Purpose
1	Steady State Calibration and Channel Capacity	<p><u>Jacoby Creek Inflow</u>: Peak flows of JBW hydrographs from multiple WY2022 events, scaled by 120% to account for downstream tributaries.</p> <p><i>Modeled Flows for Calibration (Steady state):</i> 36 cfs, 59 cfs, 66 cfs, 145* cfs, 158 cfs, 188 cfs, 202 cfs, 278* cfs, 457 cfs</p> <p><i>Modeled Flows for Channel Capacity (Steady state):</i> 278* cfs, 371 cfs, 457 cfs, 661 cfs, 900 cfs, 1165 cfs</p> <p>* Measured at Rael Bridge (no scaling)</p> <p><u>Tributary Inflows</u>: No tributary inflows</p> <p><u>Downstream Boundary</u>: Steady WSE of 6.0 ft.</p>	<p>Calibrate Manning’s roughness coefficients for each channel reach.</p> <p>Evaluate amount of flow remaining in channel from upstream to downstream</p>
2	Jacoby Creek 2021 Holiday Storm Event	<p><u>Jacoby Creek Inflow</u>: Recorded 10-min flows from JBW station, scaled by 120% to account for downstream tributaries. Peak Flow of 457 cfs (Unsteady state)</p> <p><u>Precipitation</u>: 5-minute rainfall totals across domain from Bayside Personal Station KCABAYS17. No infiltration</p> <p><u>Tributary Inflows</u>: JBW flows scaled by drainage area.</p> <p><u>Downstream Boundary</u>: Recorded 15-min water level in Gannon Slough downstream of tide gates.</p> <p><u>Duration of Simulation</u>: 10 days (Dec. 22-31, 2021)</p>	<p>Validate model to observed WSEs.</p> <p>Evaluate overbank flow patterns, water depths and velocities, extent of inundation and drain-off patterns.</p>
3	Jacoby Creek February 2019 (~2-year Peak Event)	<p><u>Jacoby Creek Inflow</u>: Recorded 10-min flows from JBW station, scaled by 120% to account for downstream tributaries. Peak Flow of 1,595 cfs (Unsteady state)</p> <p><u>Tributary Inflows</u>: JBW flows scaled by drainage area.</p> <p><u>Downstream Boundary</u>: Recorded 15-min water level in Gannon Slough downstream of tide gates.</p> <p><u>Duration of Simulation</u>: 10 days (Feb. 23 – Mar. 5, 2019)</p>	<p>Evaluate flow patterns, velocities, and drain-off during 2-year return period event.</p>
4	Jacoby Creek Sediment Transport Assessment	<p><u>Jacoby Creek Inflow</u>: Steady inflow at selected flowrate based on sampled grain size in transport. <i>Modeled Flows</i>: 661 cfs and 1,667 cfs (Steady state)</p> <p><u>Tributary Inflows</u>: No tributary inflows</p> <p><u>Downstream Boundary</u>: Normal Depth</p>	<p>Evaluate sediment transport competence and capacity in study reach of Jacoby Creek vs. size and rate delivered from upstream at JBW.</p>
5	SLR Vulnerability Assessment	<p><u>Jacoby Creek and Tributaries Inflow</u>: No inflow</p> <p><u>Downstream Boundary</u>: 6-day synthetic tide series. Three scenarios: High tide peaks at 9.4 ft, 10.0 ft, and 10.7 ft</p>	<p>Analyze levee vulnerability with SLR for overtopping depth duration, and inboard inundation.</p>

Table 6-2. Jacoby Creek channel Manning’s calibrated roughness coefficients by reach.

Reach	Calibrated Manning’s Roughness Coefficient
0+00 to 11+00 (US 101)	0.060
11+00 (US 101) to 43+00	0.100
43+00 to 61+00 (OAR Bridge)	0.150
61+00 (OAR Bridge) to 130+00	0.070

6.1.6 Model Validation

Scenario 2 was used in part to validate the calibrated hydraulic model by simulating the largest flow event in WY2022, which peaked on December 27, 2021 and is referred to here to as the “Holiday Storm.” The model included precipitation falling uniformly across the domain based on recorded rainfall. The ground was assumed saturated and set to 100% impervious in the model.

The model water surface elevations at each water level gaging station (shown in) were compared to recorded water levels and plotted in Figure 6-2. The resulting model-simulated water surface elevations generally matched, or were slightly lower, than observed. At JC1, located at Malfunction Junction, the model accurately simulated water levels associated with inundation from floodplain flows. At the JC2 North Jacoby Slough location inside of the tide gates, the modeled water surface generally followed the same pattern as observed, but failed to drain as low during ebb tides. This may be due to a lack of sufficient bathometric resolution in the DEM for this section of the slough channel. The modeled water level at JC2 was consistently lower than the observed and may be the results of a localized debris jam downstream elevating the observed water level. In general, the model appeared to be sufficiently calibrated and accurately simulating both in-channel and overbank flow patterns.

6.2 Channel Flow Losses

Using results from model Scenario 1, six flows between 278 cfs (exceeded approximately 10 days per year) and 1,165 cfs (approximate 2-year return period) were modeled. For each model run, the flow remaining in the channel was plotted against the corresponding channel station (Figure 6-3). Results show that for all analyzed streamflows, flow spills out and leaves the stream corridor due to a lack of channel capacity. Regardless of the streamflow at the upstream end, the flow remaining in the channel downstream of Station 46+00 (the downstream-most location where water spills out of the channel) is only approximately 61 cfs. Flows routed into the South Jacoby Wetland project return to Jacoby Creek at Station 28+00, causing the in-channel flows to increase.

Figure 6-3 shows larger flows spilling out of bank further upstream than smaller flows. At 278 cfs, flows begin leaving the channel approximately 1,000 feet upstream of OAR. At 661 cfs, flows leave the channel downstream of the Rael bridge and do not return. During a 2-year event of 1,165 cfs, flows leave the channel upstream of the Cody bridge and do not return. These substantial flow losses have implications on both overbank flooding as well as the ability of the channel to continue transporting sediment delivered from upstream.

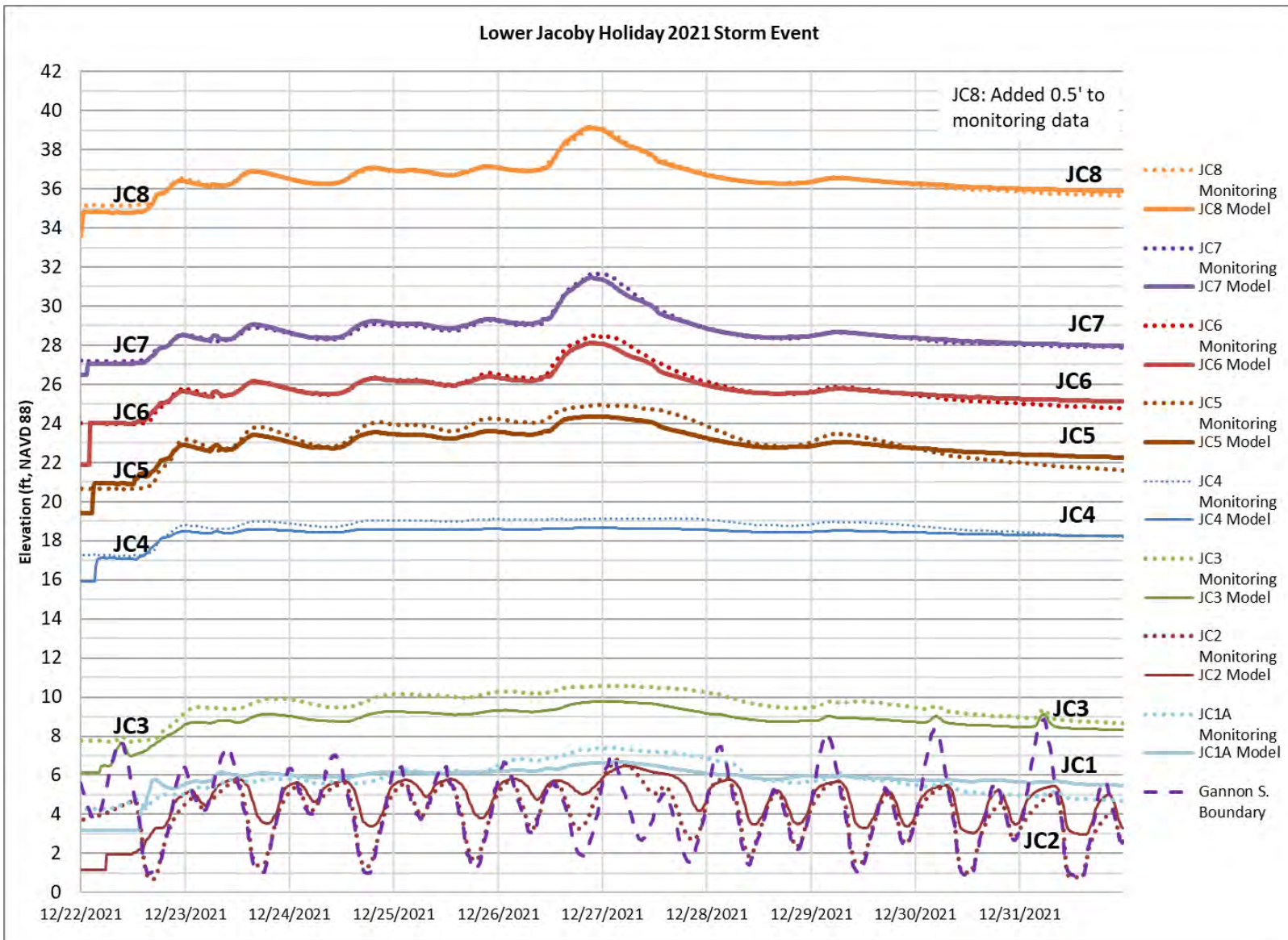


Figure 6-2. Modeled versus measured water surface elevations at water level monitoring locations for WY2022 peak flow event.

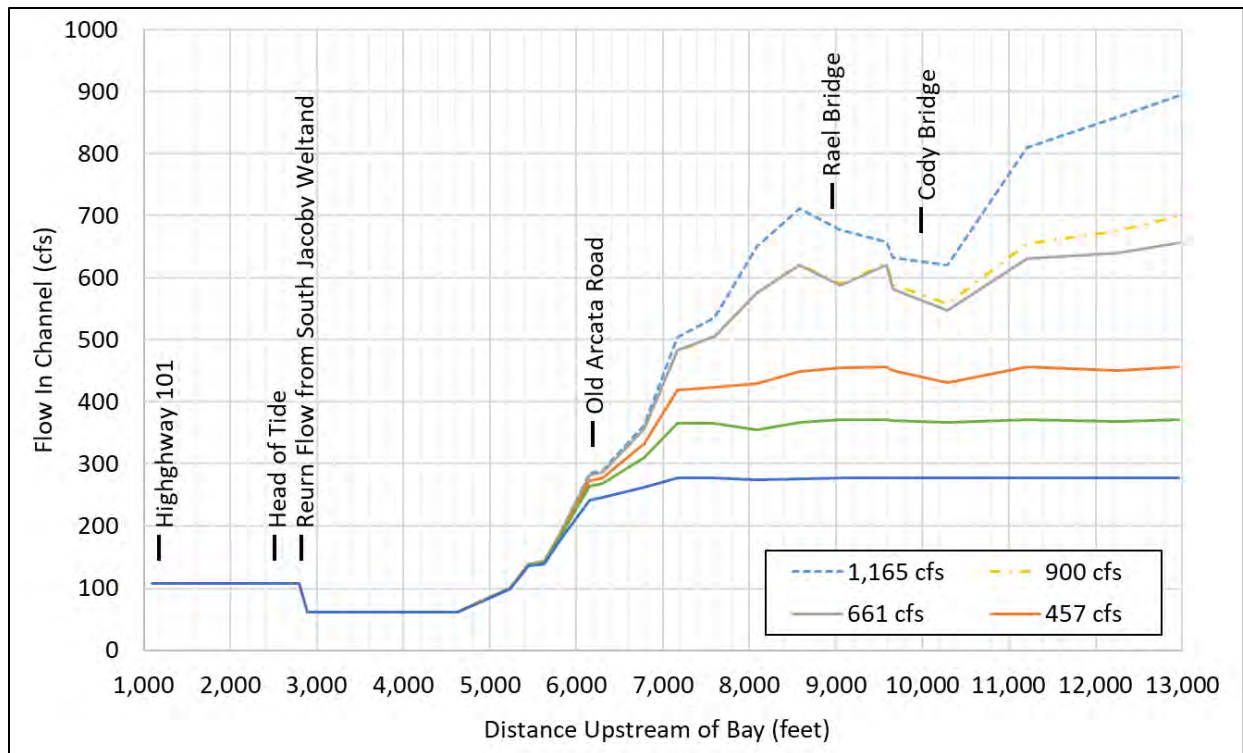


Figure 6-3. Flow remaining in channel at given Jacoby Creek station.

6.3 Channel Capacity and Spillage Locations During Small Flow Events

The reach of Jacoby Creek downstream of OAR has the lowest channel capacity. Based on channel conditions in 2021-2022, water begins spilling out of bank at streamflows above approximately 30 cfs, which occurs over 200 days per year on average (Figure 6-4). Waters simultaneously begin to spill along both banks, flowing to the south into the capture channel constructed as part of the South Jacoby Wetland Complex and to the north approximately 1,100 feet downstream of the OAR bridge. The amount spilling increases at a flow of 66 cfs, but continues to be in the same location. At 158 cfs (flow exceeded 118 days per year) flows also begin to spill out of the north bank immediately downstream of OAR bridge at multiple locations, inundating multiple private residences. Out of bank flows are confined to the constructed capture channel along the south bank. At 278 cfs (flow exceeded 3 weeks per year), in addition to the spilling downstream, waters begin to spill out of both banks upstream of the OAR bridge, flowing down and across OAR as well as across Graham Road to the south and into the Washington Gulch basin.

As flows increase, the flooding extents increase further upstream, as discussed in later sections.

6.4 Inundation and Drain-Off Patterns from 2021 Holiday Storm Event

The peak flow event for WY2022 occurred on December 27, 2021 (Figure 4-3). It was minor event with a return period of less than 1.01-years based on the 20 years of record from the JBW gage. The event was simulated using the project model and Scenario 2 (Table 6-1), to evaluate inundation and drain-off patterns. Figure 6-5 shows the Jacoby Creek inflow hydrograph for the event and five snapshots in time of the inundation depth and flooding extents from the model simulation.

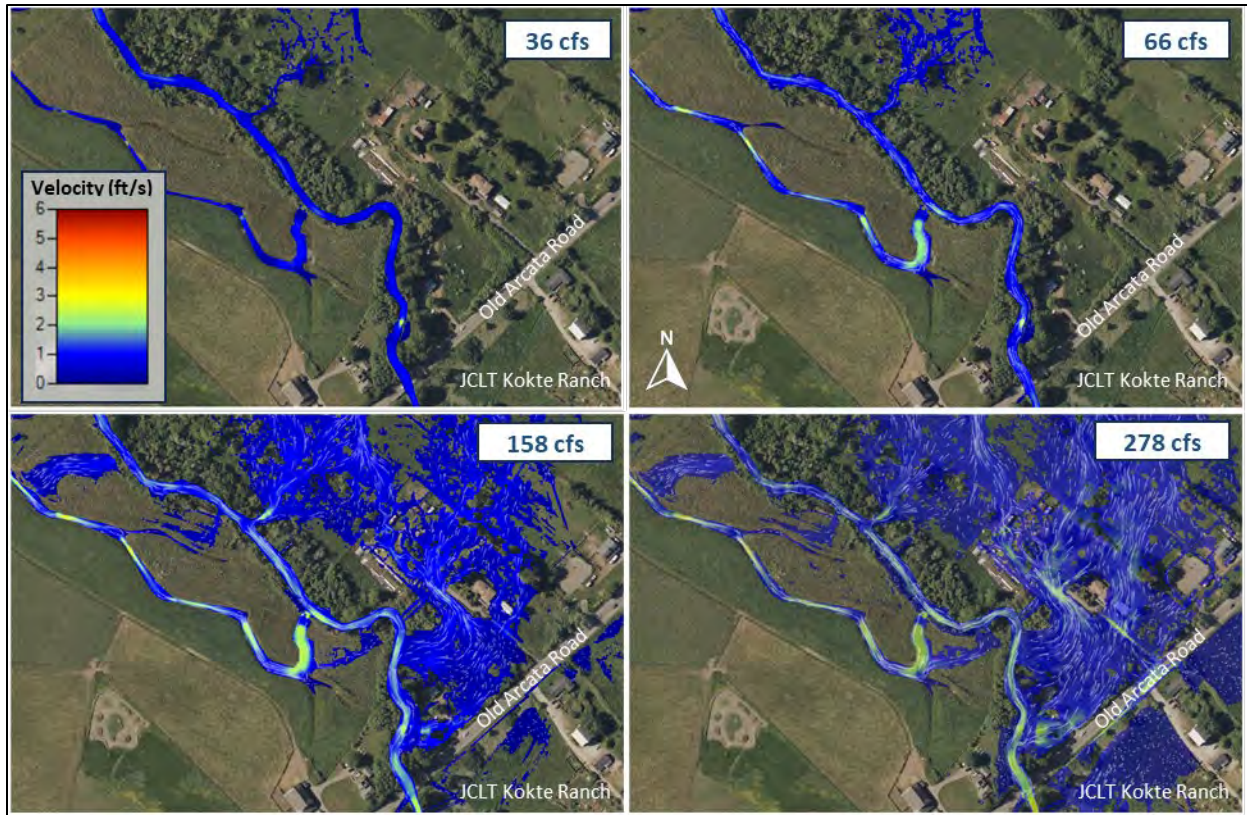


Figure 6-4. Model simulations showing locations flow spills out of Jacoby Creek channel banks downstream of OAR at 36 cfs, 66 cfs, 158 cfs, and 278 cfs.

Frame 1 shows water spilling out of Jacoby Creek downstream of OAR at a relatively low flow, but ponding had not begun in the Arcata Baylands North. Frame 2 is after several days of elevated streamflows. Water spills out of Jacoby Creek at multiple locations downstream of OAR and ponds in the upper portions of Arcata Baylands North. Flows from Gannon Slough tributaries also cause ponding north of the railroad embankment.

The inundation extent at the peak of the hydrograph is shown in Frame 3. Flows spill out of both banks in multiple locations upstream of OAR, with waters flowing to the south and into the Washington Gulch basin as well as to the north and across OAR. There is widespread inundation of residential properties along Graham Road and OAR, and extensive ponding in the Arcata Baylands North.

Frame 4 shows the peak of ponding in the Arcata Baylands North. By the time this occurs, the amount of flow spilling out of bank upstream of OAR has decreased, with most flows spilling limited to 800 feet upstream and 1,000 feet downstream of OAR.

Frame 5 is from 2 days after the peak of the event, with in-channel flows returning to 100 cfs. Water continues to spill out of select locations along both banks downstream of OAR, but widespread inundation has ceased and the ponded waters in the Arcata Baylands North have mostly drained out to the bay.

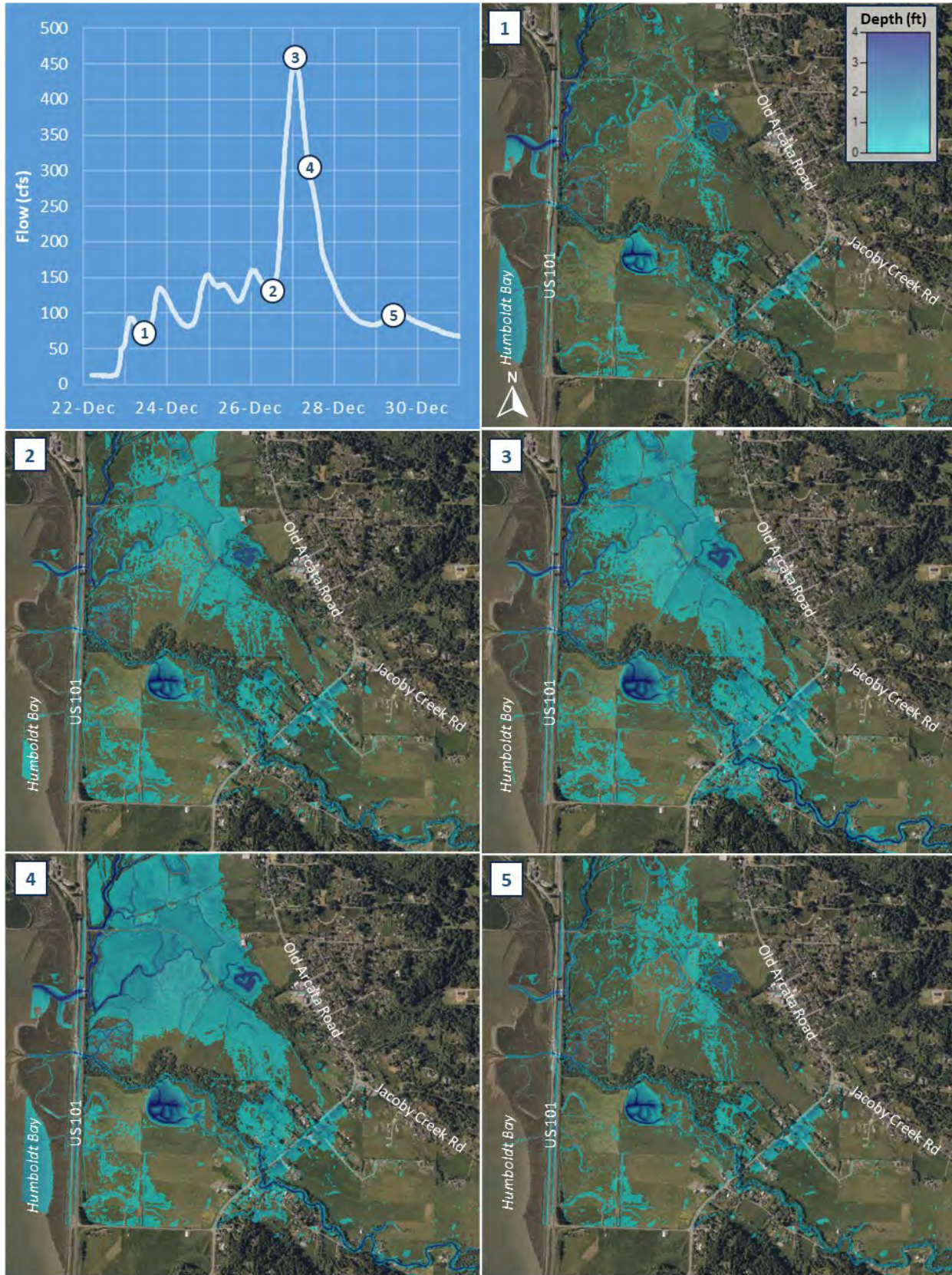


Figure 6-5. Flow at model inflow and snapshots of inundation from 2021 Holiday Event simulation.

6.5 Inundation Extents During the 2019 Peak Flow Event

The WY2019 annual peak event was simulated with the model as described under Scenario 3 (Table 6-1). This event had a peak flow of 1,595 cfs at the upstream extents of the model, which has an approximate return period slightly greater than 2 years. This event occurred prior to clearing LWD and SWD jams upstream of OAR by residents. Therefore, the additional flow resistance created by them was not accounted for in the model simulation.

Figure 6-6 shows the model-predicted floodplain inundation extents, water velocities, and flow patterns at the point of peak inundation during the 2019 event. Peak overbank flows across indicated sections are listed in the table. The figure shows flow patterns that match those described by residences along OAR and Graham Road.

Along the north bank of Jacoby Creek upstream of OAR, flows begin leaving the stream corridor as far upstream as Station 115+00. Most of the flow travels northwest, around the eastern side of the JCLT Kokte Barn and other buildings, before flowing through residential properties and crossing OAR. Along the south bank, flows leave as far upstream as Station 89+00, with floodwaters crossing over Graham Road as far east as Solaris Lane. Residents along lower Graham Road experienced extensive inundation as floodwaters crossed their property before flowing into the Washington Gulch basin.

Downstream of OAR, flow spilling out of the south bank are contained by the capture channels of the South Jacoby Wetland Complex, while the north bank has multiple spill locations. The downstream-most spillage point is at the breach (crevasse) in the north channel bank near Station 50+00. Downstream of this point the peak flow remaining in the channel ranges from 53 to 65 cfs.

6.6 Sediment Transport Assessment

6.6.1 Methods

A sediment transport analysis was undertaken for Jacoby Creek to assess the channel's ability to transport the sediment load delivered from upstream given the flow losses occurring within the study reach. The analysis focused on estimating the grain size mobilized (competence) and total sediment load (capacity) carried along the length of Jacoby Creek at two bedload transporting flows. The two flows were selected to correspond with bed load sediment transport samples from Brookwood Bridge (JBW). These flows included the highest flow when bedload sediment transport sampling was performed, which occurred during a flow of 1,398 cfs at JBW (1,667 cfs at model inflow, 1979 Sample #13). This flow is close to a 2-year event on Jacoby Creek. Flows were also evaluated for a sampling event performed during a more moderate flow of 554 cfs at JBW (661 cfs at model inflow, 1979 Sample #78).

Sediment transport competence (grain size mobilized by applied shear stress) was assessed using model predicted shear stresses and Shields Equation. A dimensionless Shields number of 0.05 (Julien, 2010) was selected based on the gradation of the sediment samples. Scenario 4 (Table 6-1) and the calibrated HEC RAS 2D model was used for this analysis.

Sediment transport capacity (volume or weight of sediment the channel is capable of transport at a given flow) was estimated using the Meyer-Peter-Muller sediment transport equations. Gradations of the two bedload samples were used as model input. An equilibrium load boundary condition was used at the upstream limits of the model.

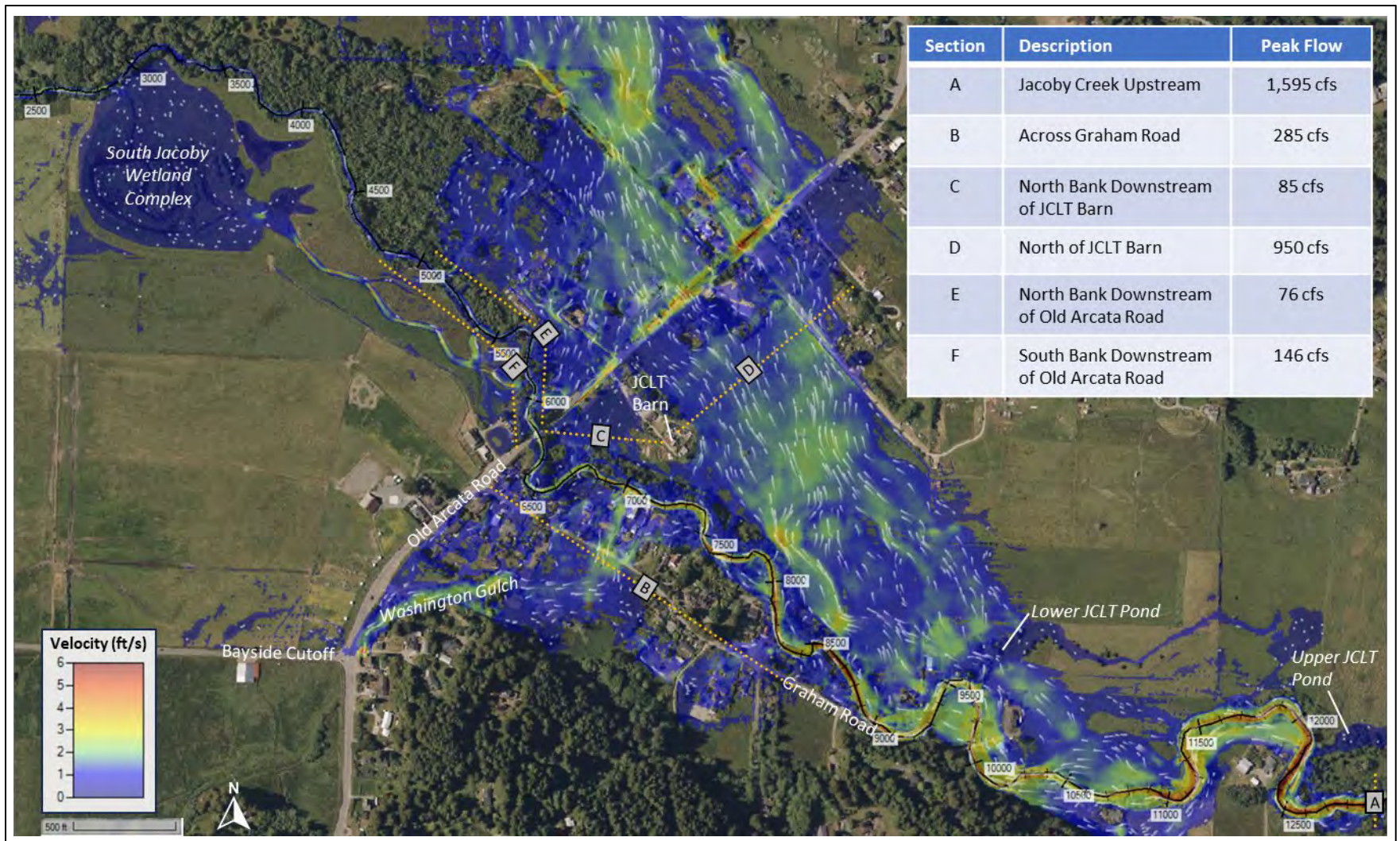


Figure 6-6. Simulation of February 2019 flow event with approximate 2-year return period, showing peak inundation extents, floodplain flow patterns, and water velocities. Table lists peak flowrates across indicated section lines.

The 1D version of HEC-RAS 6.2 was used for the sediment transport capacity analyses. The model was performed for the channel only. Model cross sections consisted of the surveyed cross sections used to develop the channel portion of the project DEM (Section 2.1.1), spaced on average 75 feet apart. Channel Manning's roughness coefficients from the calibration modeling were used. Locations and values of water spilling out of the channel were modeled as flow losses using "uniform lateral flow" boundary conditions. The model was run in quasi-unsteady flow with a normal depth boundary condition of 0.27% derived from the channel thalweg profile.

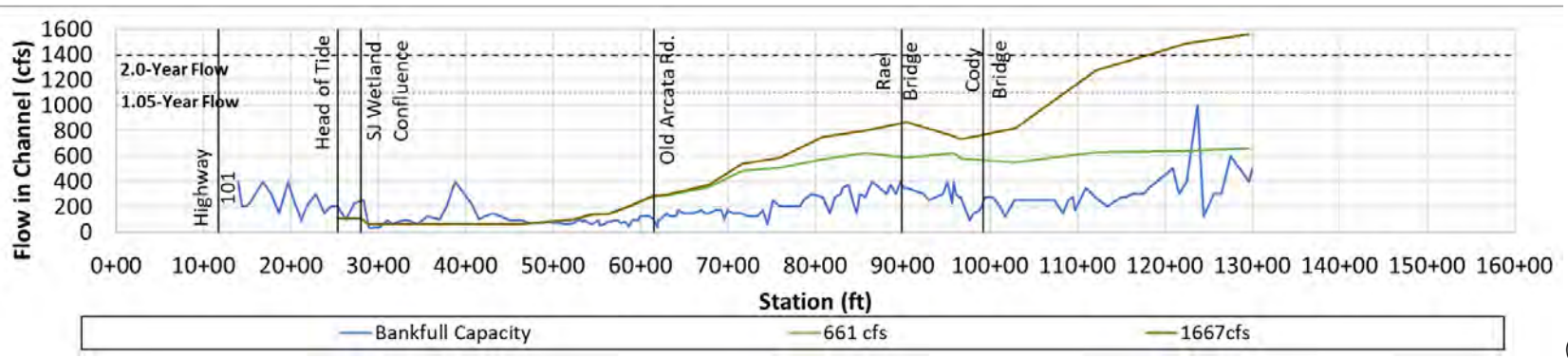
6.6.2 Results

Figure 6-2a shows the amount of flow remaining in the channel along its length. Figure 6-2b shows the channel sediment transport competence, which is the largest particle size the channel could theoretically move. Figure 6-2b compares the results with the median (D_{50}) and 84th percentile (D_{84}) of surface pebble counts, subsurface bulk samples, and bedload samples taken at corresponding flows. Results from only one bedload sample are shown because both bedload sample gradations were similar.

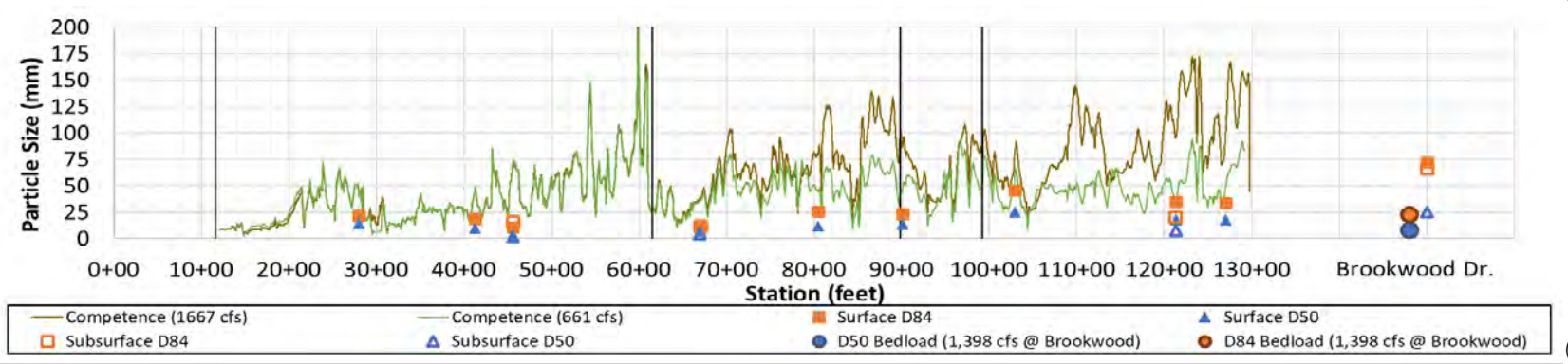
As shown on Figure 6-2b, bed grain size and grain sizes that Jacoby Creek can transport decrease from upstream to downstream as in-channel flows decrease. The sub-surface bulk sample gradation typically reflects the gradation of sediment in transport because it is not skewed by armoring (Parker and Klingeman, 1982). The model-predicted grain size that can be transported is larger than the actual sub-surface grain size of the bulk samples, suggesting that the stream has the competence to transport the size of bed material present. However, this does not address the issue of bedload transport capacity – the ability of the channel to transport the load delivered from upstream.

To evaluate whether Jacoby Creek can transport the sediment load (weight or volume) of sediment delivered from upstream, a sediment transport capacity assessment was performed. Figure 6-2c plots the predicted transport capacity along the length of the modeled reach, showing a dramatic decline in transport capacity in the downstream direction. The loss in transport capacity is caused by the decrease in in-channel flows and channel confinement. As flows reach OAR and downstream, the channel has little transport capacity, evidenced by the sand and silt deposition in the channel and overbanks.

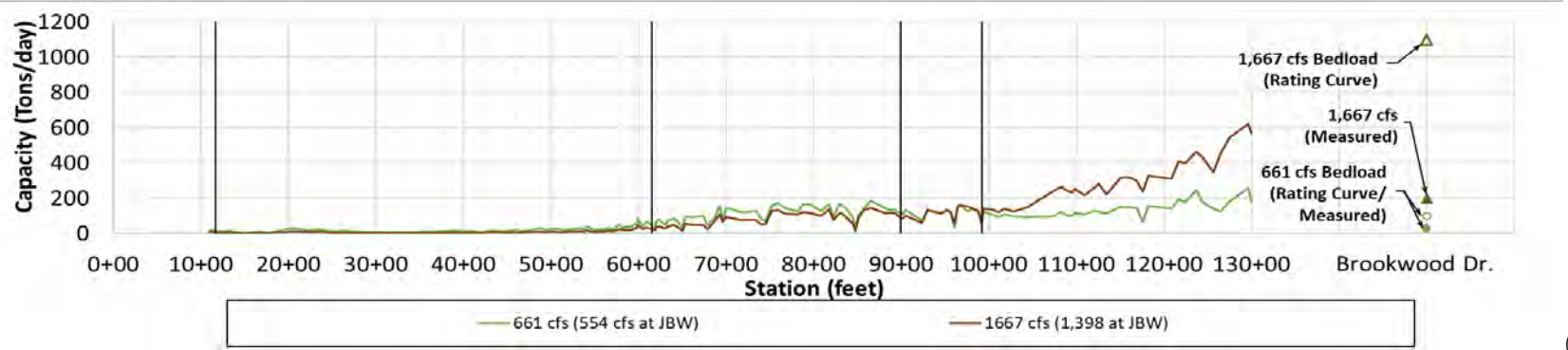
The results of the sediment transport modeling suggest that the stream can transport the sediment sizes delivered from upstream, but does not have the capacity to transport the load delivered. This results in the sediment deposition areas observed along the stream length. The lack of transport capacity compared to the load delivered from upstream often causes a feedback loop. As more sediment is deposited in the channel, the bed aggrades, further reducing channel capacity. Without intervention, the channel will likely avulse (rapid abandonment of a stream channel and the formation of a new stream channel).



(a)



(b)



(c)

Figure 6-7. Jacoby Creek streamflow (a) remaining in channel, (b) maximum sediment size mobilized compared to pebble counts, bulk samples, and bedload sample, and (c) sediment transport capacity for two flows, with measured and rating curve-predicted transport rates.

6.7 SLR Vulnerability Analysis

Scenario 5 involved assessing the risk of tidal overtopping of existing tidal levees and US 101 along the western edge of the Arcata Baylands and resulting inundation on the Arcata Baylands. Three tidal water levels were modeled to evaluate the extent of overtopping and flooding for present-day lower probability/low frequency events that will become more frequent with rising sea levels. The existing 2-year (9.4 feet), 10-year (10.0 feet) and 100-year (10.7 feet) recurrence water levels were selected for modeling (Table 5-2).

Increased water levels with SLR will result in a higher frequency of occurrence for each peak tidal event, as shown in Table 5-3, such that with approximately 2 feet of SLR, the present-day 100-year tidal flood event will become an annual event.

6.7.1 Existing Levee Top Elevations Relative to Tidal Overtopping

South of Jacoby Creek the road prism associated with US 101 prevents tidal flooding of Arcata Baylands South. Roadway elevations of northbound US 101 are above elevation 10.7 feet, which is the present-day 100-year tidal (Figure 6-8). The levees protecting Arcata Baylands North, north of Jacoby Creek, have top elevations ranging from below 9.4 feet up to 10.7 feet (Figure 6-9), suggesting that portions of the levee are overtopped more frequently than every other year.

While overtopping of levees causes inboard tidal flooding and can lead to levee failure, the extent of flooding and likelihood of failure is highly dependent on the depth and duration of overtopping, among other site-specific factors. An overtopping depth of more than 1 foot for more than two hours results in a higher probability failure of a non-reinforced earthen levee (USBR-USACE, 2019). This combination of depth and duration, given typical levee elevations at or above elevation 9 feet is rare in the project area. At a peak 100-year tide of 10.7 feet, even the lowest point along the levee would not be inundated by more than 1 foot of depth for more than two hours due to the tidal elevation rate of change. Surficial erosion of the levee would be expected during these overtopping events and would contribute to long-term degradation and higher likelihood of future failure should the levees go unrepaired.

6.7.2 Inboard Inundation with Existing 2-Year Peak Tide of 9.4 feet

A high tide of 9.4 feet results in limited overtopping of the lowest elevation levees. Tidal flooding is primarily limited to the lowest elevations east of the highway, extending to the old railroad grade (Figure 6-10). The peak inboard water level associated with tidal flooding would be 6.2 feet (Figure 6-11). This results in less than one foot of flood depth on the pasture on multiple days during the higher high tide (Figure 6-10)

6.7.3 Inboard Inundation with Existing 10-Year Peak Tide of 10.0 feet

A high tide of 10.0 feet would result in widespread overtopping of the lowest elevation levees (Figure 6-9). Similar to the flooding associated with a 9.4-foot tide, tidal flooding would primarily be limited to the lowest area immediately adjacent to the highway, extending to south and east of the old railroad grade (Figure 6-12). The peak inboard water level associated with tidal flooding is 6.8 feet (Figure 6-13) and overtopping results in approximately one foot of flood depth over the levee tops on multiple days during the higher high tide.

6.7.4 Inboard Inundation with Existing 100-Year Peak Tide of 10.7 feet

A high tide of 10.7 feet would result in widespread overtopping of the levees (Figure 6-9) and extensive flooding of the North and South Baylands (Figure 6-14). The peak inboard water level associated with tidal flooding is 7.1 feet (Figure 6-15), 0.3 feet higher than the 10.0-foot tidal event, but would result in a significantly larger area of flooding. The greater extent of tidal flooding is likely due to the inability of the interior lands to fully drain between tidal cycles and the extent of lands showing only slightly higher elevations, between 6.8 and 7.1 feet.

6.7.5 Summary

The hydraulic modeling results suggest the existing earthen levees paralleling the east side of US 101 are currently vulnerable to tidal water overtopping and the frequency of overtopping will increase with sea level rise. The short-term (mid-century) impacts from overtopping and increased inundation are anticipated to result in continued levee erosion, decline in agricultural pasture productivity from saltwater inundation, and prolonged delays in accessing the utility corridors. The City of Arcata is embarking on a sea level rise vulnerability and adaptation planning process in 2024 that will provide additional information related to coastal and fluvial flood hazards within the study area. Impacts on groundwater levels from sea level rise will also be assessed qualitatively. The results from the planning process will inform adaptation strategies throughout the City, including the study area, for mid and late-century.



Datums:
 Horizontal: NAD83 State Plane CA Zone 1
 Vertical: NAVD88

Sources:
 Elevation: 2019 Eureka Lidar DEM
 Aerial Image: Google Satellite

0 300 600 ft

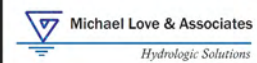
**Levee Top Elevations
 Elevation - ft (NAVD 88)**

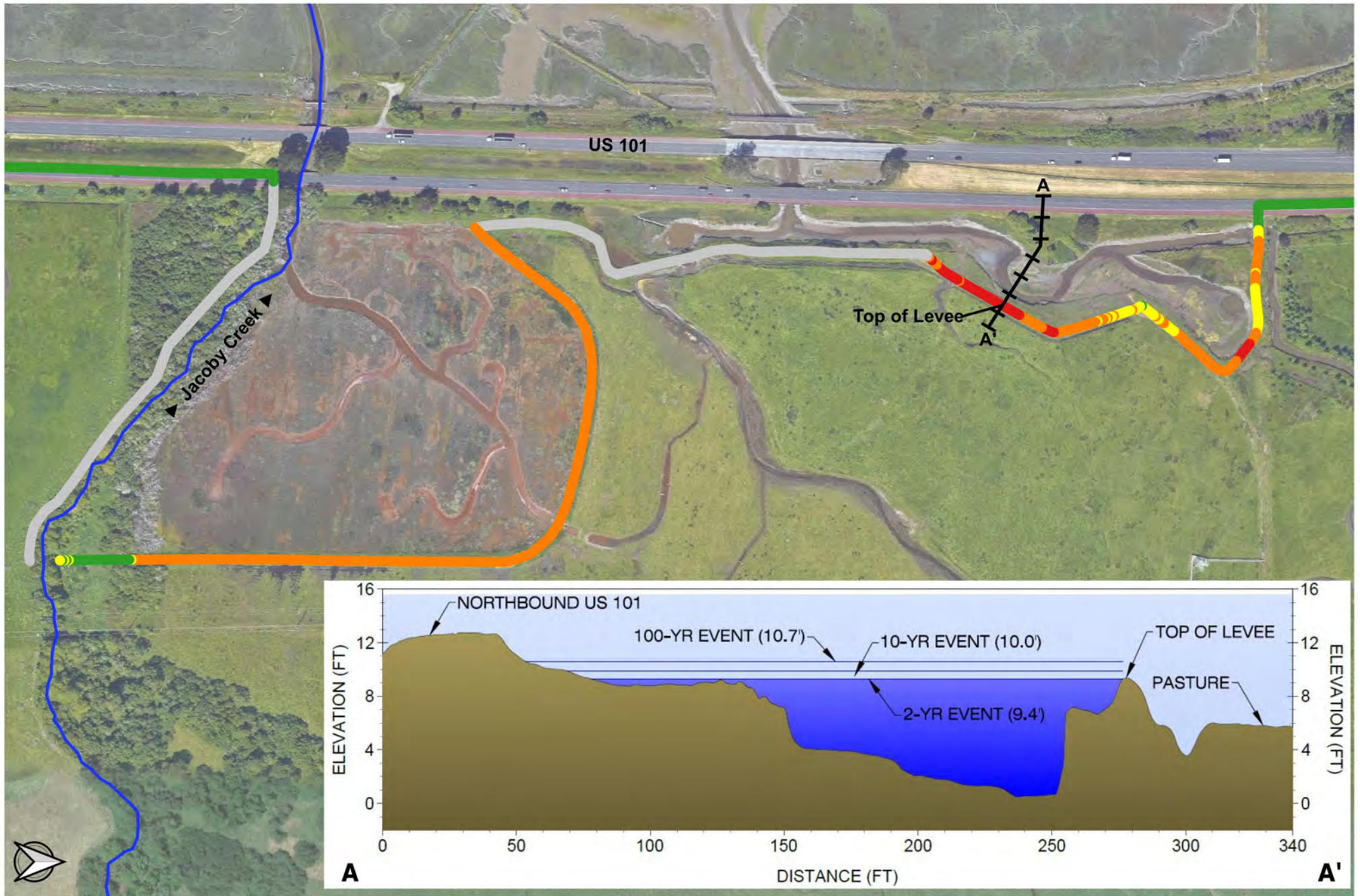
- Undefined
- >10.0 - 10.7
- ≤ 9.4
- >10.7
- >9.4 - 10.0

**Present-Day Return Periods
 of Tidal Levels**

- 2 Year - 9.4'
- 10 Year - 10.0'
- 100 Year - 10.7'

Figure 6-8. Height of north bound US 101 relative to tidal water levels.





Datums:
 Horizontal: NAD83 State Plane CA Zone 1
 Vertical: NAVD88

Sources:
 Elevation: 2019 Eureka Lidar DEM
 Aerial Image: Google Satellite

0 300 600 ft

Levee Top Elevations
 Elevation - ft (NAVD 88)

- Undefined
- >10.0 - 10.7
- ≤ 9.4
- >10.7
- >9.4 - 10.0

Present-Day Return Periods of Tidal Levels

- 2 Year - 9.4'
- 10 Year - 10.0'
- 100 Year - 10.7'

Figure 6-9. Levee top elevations protecting Arcata Baylands North relative to tidal water levels.



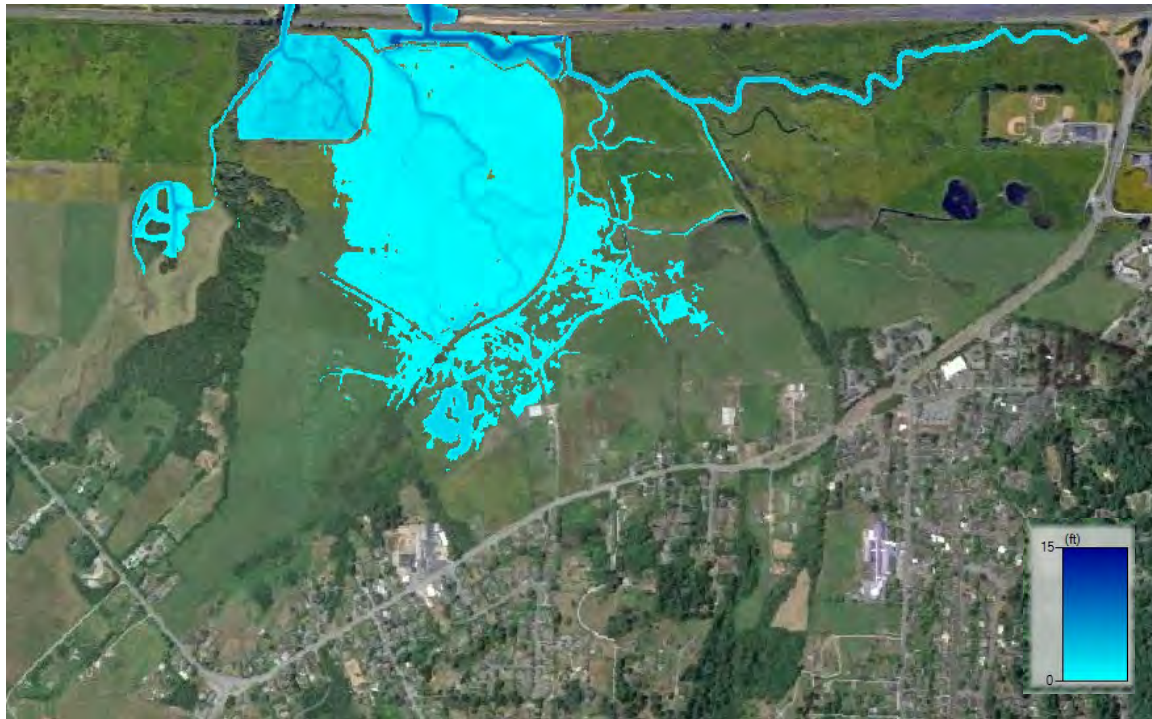


Figure 6-10. Modeled extent of tidal flooding for a peak tide of 9.4 feet in Humboldt Bay.

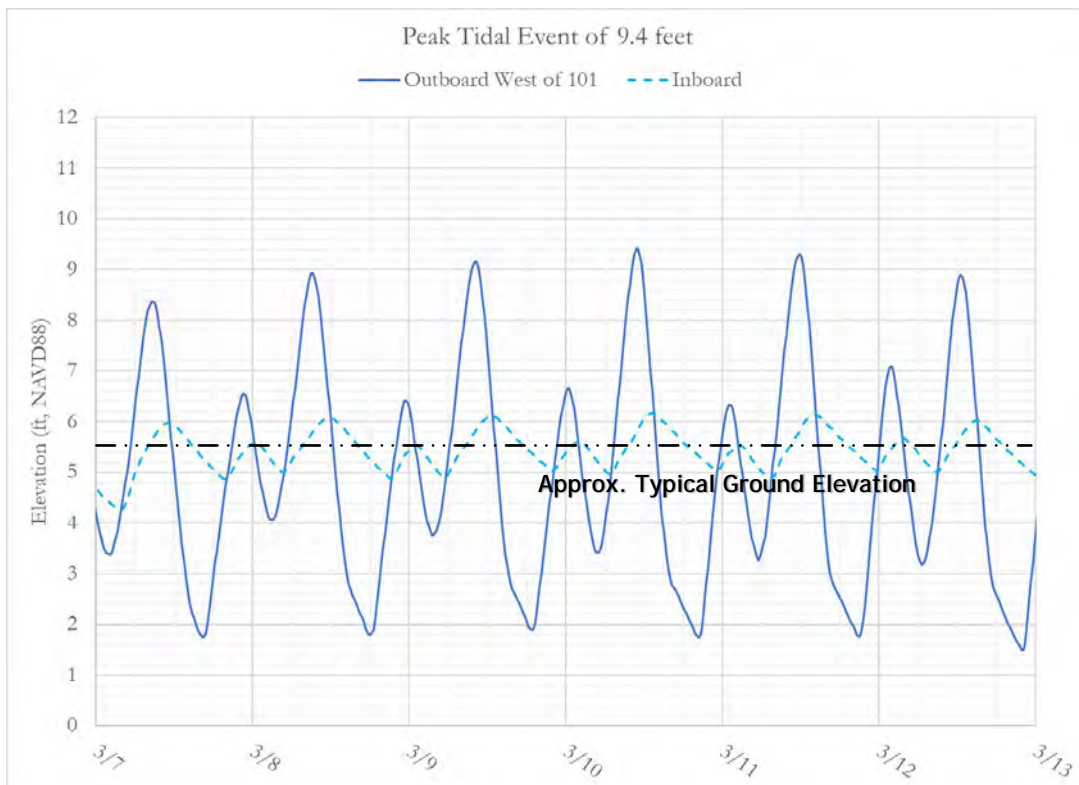


Figure 6-11. Modeled tidal water levels in Humboldt Bay with peak tide of 9.4 feet and resulting peak water levels of 6.2 feet inboard of the levees.

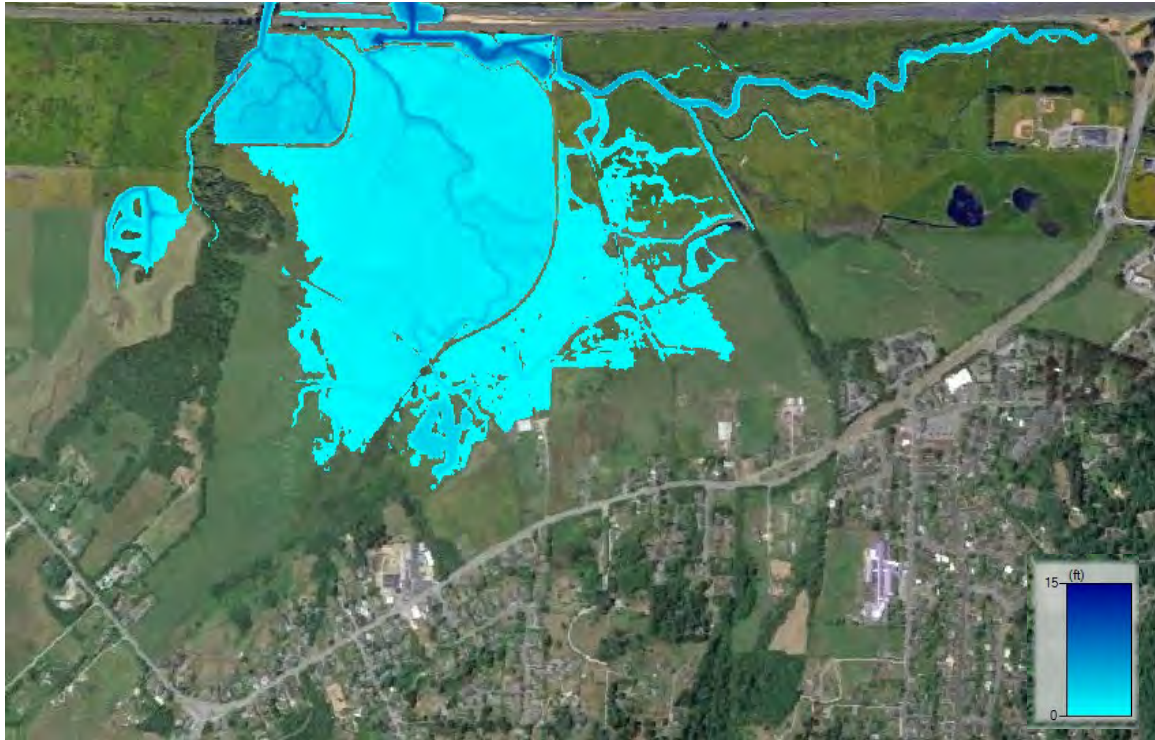


Figure 6-12. Modeled extent of tidal flooding for a peak tide of 10.0 feet in Humboldt Bay.

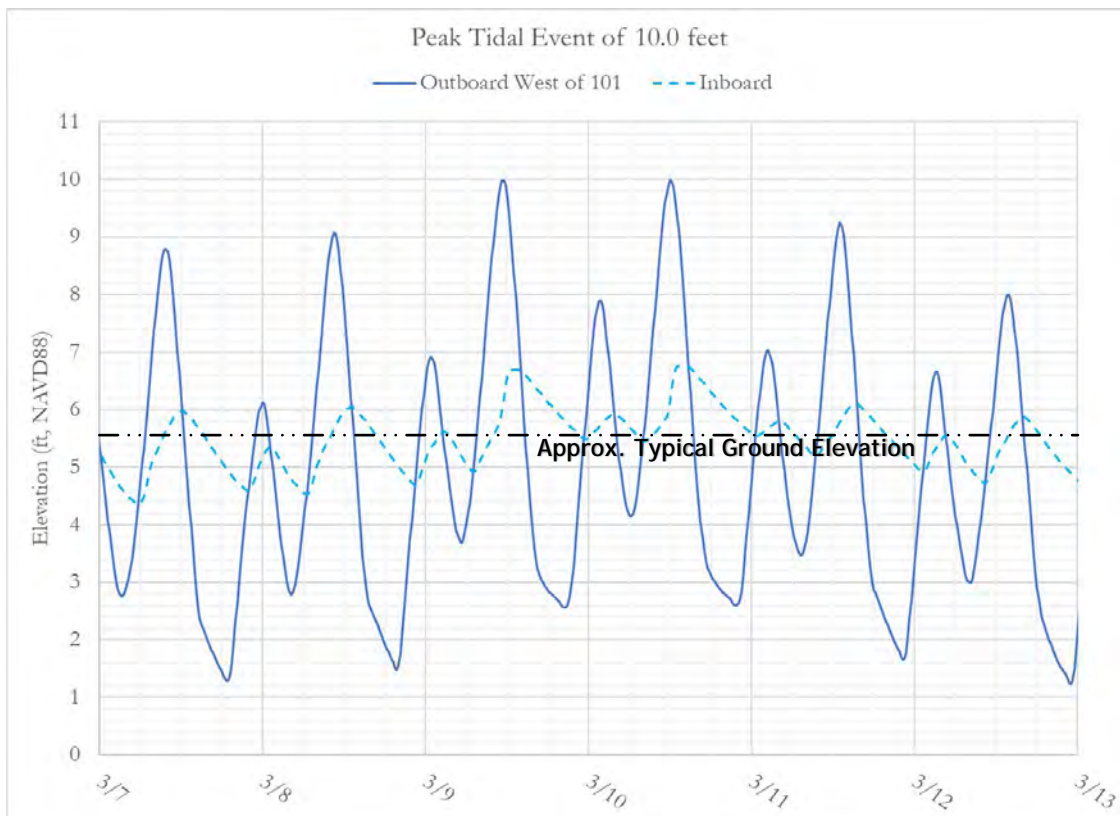


Figure 6-13. Modeled tidal water levels in Humboldt Bay with peak tide of 10.0 feet and resulting peak water levels of 6.8 feet inboard of the levees.

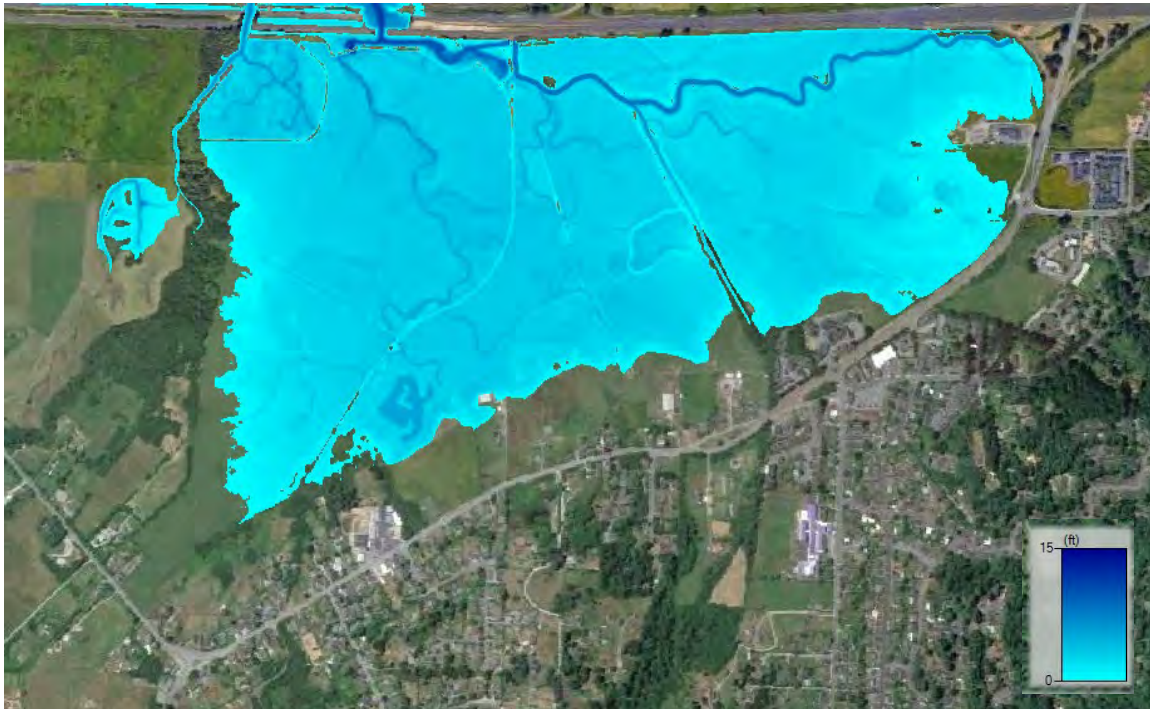


Figure 6-14. Modeled extent of tidal flooding for a peak tide of 10.7 feet in Humboldt Bay.

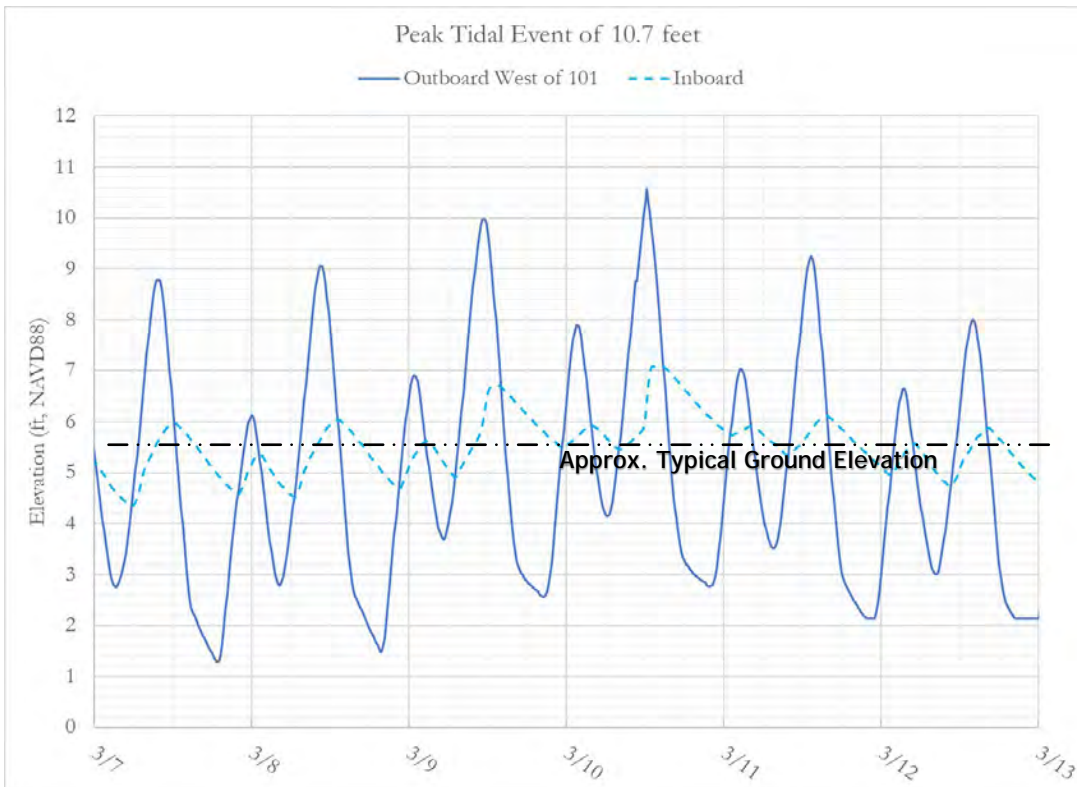


Figure 6-15. Modeled tidal water levels in Humboldt Bay with peak tide of 10.7 feet and resulting peak water levels of 7.1 feet inboard of the levees.

7 CHANNEL & FLOODPLAIN GEOMORPHIC CHARACTERISTICS

The following sections describe the current geomorphic conditions of Jacoby Creek and adjoining floodplain, an understanding of ongoing processes that have led to these conditions and discussion of potential future conditions if no actions are taken.

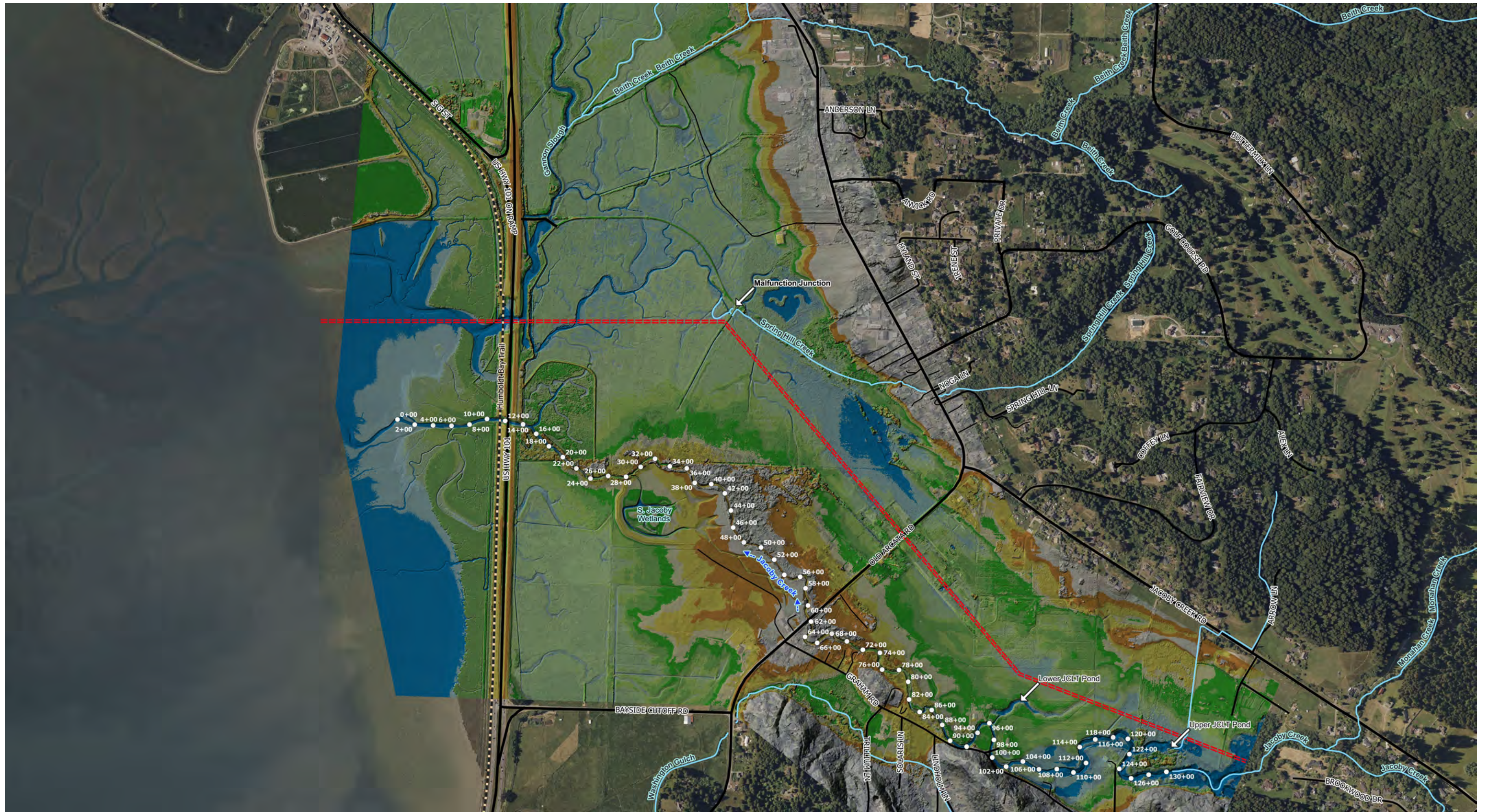
7.1 Elevations Relative to Valley Bottom

A relative elevation model (REM) was created for the study area (Figure 7-1) using the project digital elevation model (DEM) (Section 2.1). The REM created for the study area normalizes elevations, providing height of ground above/below the low point in the valley along its length. The low point of the valley is along the north side of Jacoby Creek. Ground that is lower than the adjacent valley floor appears as shades of blue and ground above appear as greens through browns. The REM helps visualize fluvial landforms that may otherwise be hard to discern from aerial images and the DEM.

The project REM highlights the remnant historical channel alignments of Jacoby Creek and its tributaries across the floodplain upstream of Station 96+00 and the slough channels throughout the historical tidal marsh in the Arcata Baylands. It also highlights the degree to which Jacoby Creek is “perched” above the valley floor from approximately Station 100+00 to US 101. From approximately 1,000 feet upstream to 3,000 feet downstream of the OAR the banks of Jacoby Creek are at least 6 to 8 feet above the adjacent valley floor on both sides of the stream corridor. The result is that any water spilling out of bank along the north or south side of Jacoby Creek flows away from the channel to the low point in the valley and generally does not return to Jacoby Creek. This is made evident by the frequent flooding patterns experienced in the Jacoby Creek valley (see Section 4.1).

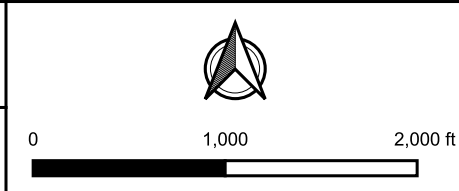
The REM also shows multiple lobes of higher ground associated with sediment deposition to the south of Jacoby Creek at and downstream of OAR. This appears to be an alluvial fan associated with historical alignments of Jacoby Creek. When forming these lobes, the stream would have flowed into the slough channels of Arcata Baylands South and possibly also into slough channels south of Bayside Cutoff that drain to Brainard Slough. In the 1870 map (Figure 3-1) this area of sediment deposition was shown as being upland and farmed, suggesting the formation of these alluvial fan lobes predates European settlement.

The REM also reveals the low area (green) that Washington Gulch flows through paralleling Graham Road. This area, that serves as a “floodbasin” for Jacoby Creek, may be substantially lower than other areas adjacent to the channel due in part to the high knob located along the south bank of the stream between Station 73+00 and 81+00. This knob blocks overbank flows and sediment from flowing south. Note Washington Gulch floodbasin is confined at its downstream end by higher ground, presumably associated with a depositional lobe from Jacoby Creek, pinching the outlet.



Datums:
 Horizontal: NAD83 State Plane CA Zone 1
 Vertical: NAVD88

Sources:
 Elevation: 2019 Eureka Coastal Lidar DEM
 Aerial Image: 2018 Bing Aerial Imagery



Legend

- Jacoby Creek Station (ft)
- Valley Bottom Baseline
- Roads
- Creek

Relative Elevation Model (ft)

Blue	<= -2	Light Green	0.5 to 1	Yellow	3 to 4
Light Blue	-1.2 to -0.5	Medium Green	1 to 2	Orange	4 to 6
Green	-0.5 to 0.5	Dark Green	2 to 3	Brown	6 to 8

Michael Love & Associates
 Hydrologic Solutions

Thomas Gasi & Associates
 Environmental Consultants

GHD

Coastal Conservancy

JACOBY CREEK LAND TRUST

Jacoby Creek Water Sustainability and Anadromous Fish Habitat Enhancement Feasibility Study

Figure 7-1.
 Relative Elevation Model - Full Scale.

Nov, 2023

7.2 Channel Profiles

The surveyed thalweg and top of bank profiles are plotted in Figure 7-2, along with the valley bottom profile used to create the REM (Figure 7-1). The thalweg points downstream of Station 10+50 are from the LiDAR DEM. It shows a tidal sill located in the delta west of US 101, with a crest at elevation 4.0 feet. This is consistent with field observations, such that tides in the Jacoby Creek channel at US 101 do not drop below 4.0 feet. Upstream of US 101 the channel has a relatively constant slope of 0.28% (Slope A) based on channel controls (i.e. riffle crests). However, there is an abrupt vertical offset of approximately 2.5 feet in the channel thalweg at Station 45+00. This is associated with a large vegetated debris jam and previous clearing of low debris jams in the reach downstream. From Station 45+00 to 103+00 the channel appears to be elevated above the overall profile (Slope B) and has a slightly lower slope (0.26%). The elevated channel bed in this reach is the result of localized aggradation caused in part by in-channel vegetation and debris jams, including the reach that had recently been cleared of such jams.

Comparing the channel top of bank and valley bottom profiles reveals the valley bottom becomes lower than the top of bank downstream of approximately 100+00, near the Cody Bridge. Downstream from this location overbank flows begin to flow away from the channel towards the low point in the valley. Around Station 41+00 the top of bank is approximately 10 feet above the valley bottom, which is comprised of the drained historical saltmarsh at elevation 6 feet.

7.3 Jacoby Creek Baselevel Change and Channel Aggradation

The channel aggradation in Jacoby Creek is primarily driven by historical changes in tidal base level, with in-channel vegetation and debris jams causing additional localized aggradation. The existing thalweg profile (Figure 7-2) shows the MHHW tide of 7.1 feet only extending to approximately Station 27+20. A review of the 1870 USCS map (Figure 3-1) shows that tidal salt marsh flanked both banks of the channel up to Station 39+00. The channel banks within the saltmarsh areas would have been natural levees along the channel corridor formed at a high tidal marsh elevation (Albernaz, et al., 2000). Given that global sea level has risen between 8 and 9 inches since 1880 (NOAAClimate.gov) and likely more in Humboldt Bay due to interseismic subsidence (Patton et al., 2023; 2017), the elevation of these high tidal marsh banks would have likely been between elevation 7.0 and 8.0 feet. The channel thalweg at Station 39+00 would have been at least several feet below the adjacent marsh elevation, likely at or below elevation 4.0 feet. Currently at Station 39+00 the thalweg elevation is 10.7 feet and the left and right top of bank is 13.7 feet and 15.2 feet, respectively. This suggests the channel bed and banks have aggraded 6 to 7 feet at Station 39+00 since the 1870 mapping.

Figure 7-3 shows an approximation of the historical channel profile of Jacoby Creek. Linework shows the existing channel thalweg profile and the approximate elevation of the 1870 salt marsh along the channel banks extending upstream to Station 39+00 (A). The inferred channel bed (red) in 1870 is plotted from the Bay to Station 39+00 based on the assumption that the bed was 3 to 4 feet below the banks at the upstream end of the mapped salt marsh (B), similar to the current channel bed and adjacent tidal marsh elevations west of US 101. The profile then extends upstream, at a similar slope at the present-day slope of the channel (C), transitioning to the overall slope of the valley bottom (D & E). The inferred profile ends at the Lower JCLT Pond, where early maps showed the channel deviating from its current upstream alignment. Under this scenario, the channel bed at the present-day Old Arcata Road crossing of Jacoby Creek would be approximately 9 feet lower than present-day.

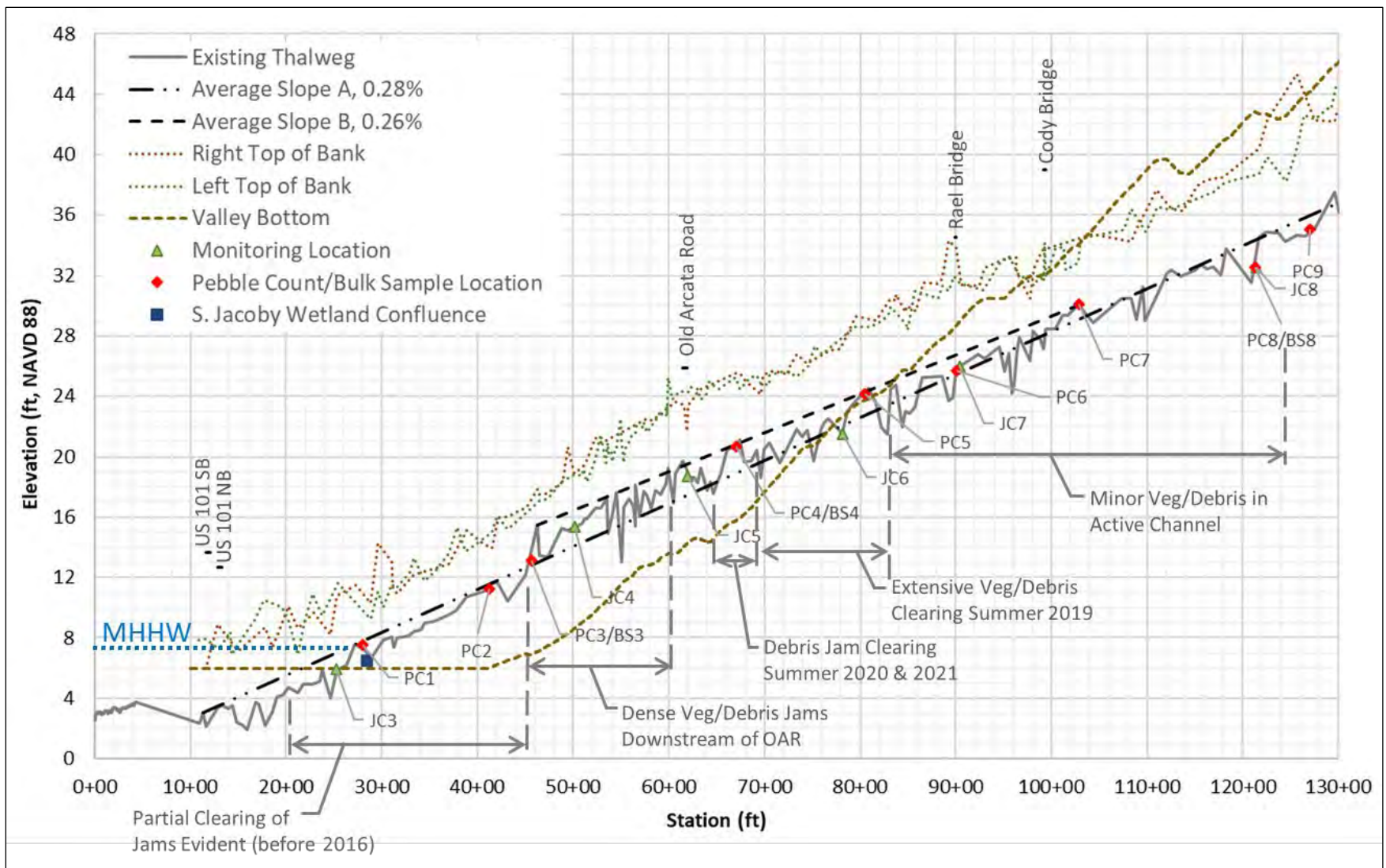


Figure 7-2. Jacoby Creek thalweg and top of bank profile from 2021 with locations of water level gages and sites of pebble counts (PC) and bulk samples (BS) of streambed material. The average overall channel slope (A) of 0.28% and locally aggraded slope (B) are plotted on the profile along with noted in-channel vegetation conditions and debris accumulations are noted.

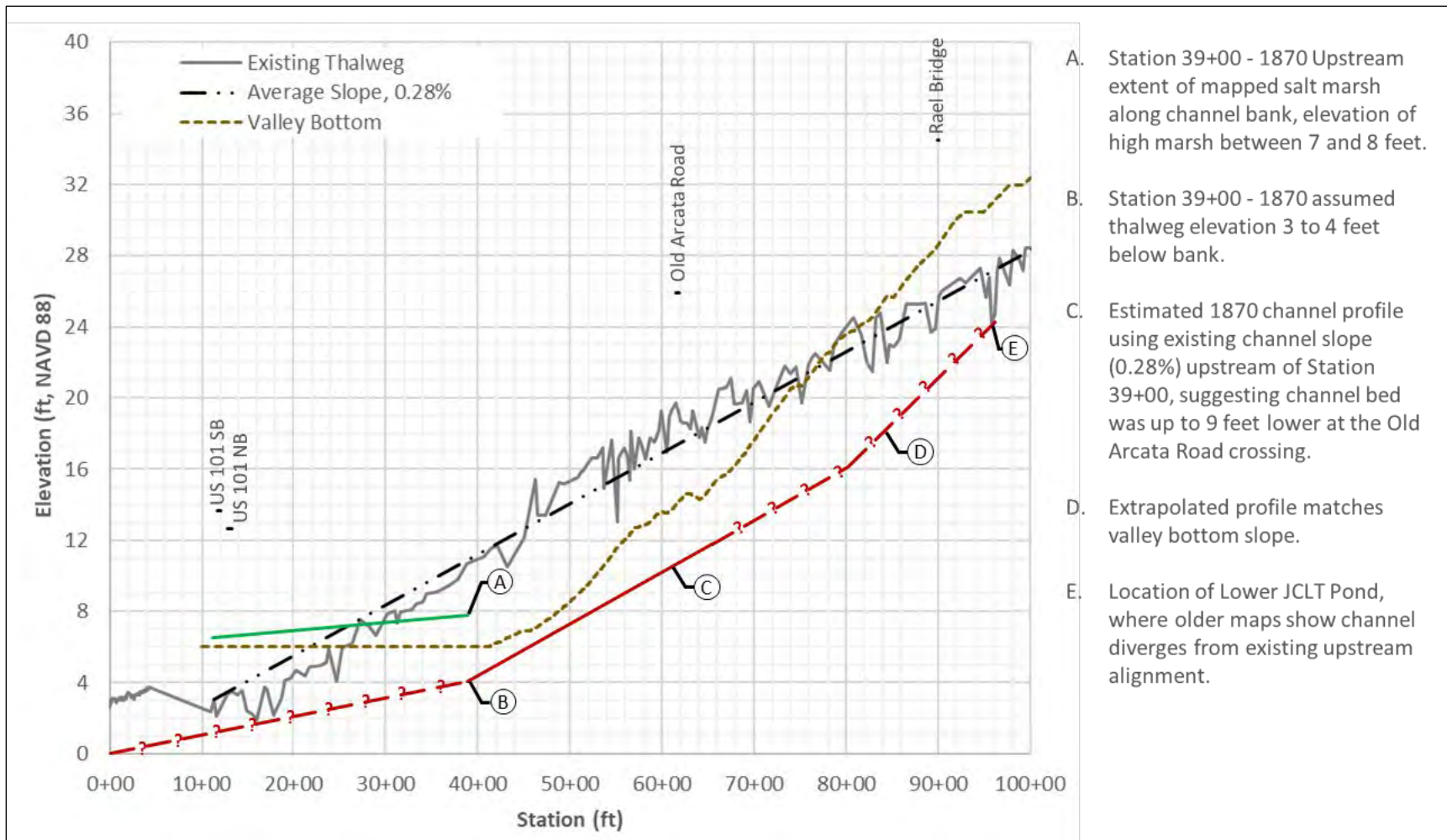


Figure 7-3. Estimated historical channel profile prior to diking along Jacoby Creek, based on 1870 USCS map and slope of present-day channel and valley.

The cause for the extensive aggradation in lower Jacoby Creek appears to be driven by the diking and draining of the tidal wetlands located along both banks of the stream 2,800 feet upstream of present-day southbound US 101. Before diking, flows in Jacoby Creek expanded laterally once water levels crested onto adjoining tidal marsh, preventing water surface elevations in the stream from becoming much higher than the adjoining marsh. The diking effectively lengthened the fluvial channel of Jacoby Creek an additional 2,800 feet by preventing its flows from expanding outward into the tidal waters until west of the highway and railroad embankments.

As described by Lane (1954), stable natural channels are in balance with streamflow, channel gradient, and sediment load and size. Lengthening a channel initiates a geomorphic response that results in aggradation (sedimentation) of the channel bed as the channel adjusts its overall slope to account for the increased length.

For Jacoby Creek, the channel profile appears to have aggraded in response to shifting the Jacoby Creek tidal baselevel 2,800 feet west. This process of aggradation likely accelerated with the increased sediment loads from the 1964 flood and historical timber harvest activities in the upper watershed (see Sections 3.4 and 3.5). The 6 to 7 feet of aggradation that appears to have occurred at Station 39+00 would naturally propagate upstream. The aggradation would decrease channel capacity and increase overbank flooding. Sediment-laden floodwaters typically deposit their coarser suspended sediment, such as fine sands and silts, on the floodplain close to the channel banks. This would accelerate the building of natural levees along lower Jacoby Creek (Albernaz et al., 2020), further perching the streambanks above the elevation of the adjacent valley bottom.

7.4 Jacoby Creek Geomorphic Trajectory

Historical interventions in channel geomorphic processes along Jacoby Creek have included removal of vegetation and debris from the channel and reportedly historical dredging of the channel bed. However, under current regulatory constraints, these activities are generally not allowed on a piecemeal basis and typically need to be part of a larger restoration plan.

Without intervening, the geomorphic processes occurring in lower Jacoby Creek will continue to evolve. The sediment transport capacity of the channel appears to be substantially lower than the load delivered from upstream (see Section 6.6) such that the channel cannot transport all the delivered coarse bedload. The continued accumulation of sediment in the lower reaches would propagate further upstream, leading to additional channel breaches and scour of opening (crevasses) through the natural levees that form the channel banks. Secondary “daughter channels” would form at these openings, similar to the one present along the north bank at Station 51+00. Eventually one or more of these daughter channels would capture the entire streamflow, resulting in abandonment of Jacoby Creek’s primary channel. The newly formed channel(s) would likely follow current floodplain flow patterns, such as crossing diagonally across the valley towards the northwest.

Given current land use, including residential structures, it is unlikely that these geomorphic processes will be allowed to progress uninterrupted. However, traditional means of managing sediment and debris may not be practical or cost-effective under current conditions. Instead, projects that focus on resetting geomorphic processes should be considered. This includes considering reintroduction of tidal processes similar to historical conditions, thus resetting baselevel for the channel.

7.5 Arcata Baylands Trajectory with SLR

Interviews with residents and land managers living and working within the study area revealed that overbank sediment deposition decreases in the downstream direction. Residents along upper portions of Graham Road reported substantial silt deposits on their property following large floods. Once downstream of OAR, residence report that little to no slit deposits, and in the Arcata Baylands North the rancher reported that he has not seen any deposits or buildup of sediment, even when the area is ponded with overbank floodwaters for multiple days. This has a direct influence on the long-term trajectory of the Arcata Baylands.

The Arcata Baylands is comprised of diked and drained historical salt marsh and tidal slough channels. Since diking these lands have ceased to receive tidal derived sediments, which would have been delivered daily with each tidal cycle. Although these lands receive overbank floodwaters from Jacoby Creek, the amount of sediment deposited during these events appears to be minimal, if any. Instead, the sediments appear to be depositing closer to the stream banks where the flows leave the channel. The elimination of tidally derived sedimentation since diking, combined with sea level rise and ground subsidence from organic decomposition and vertical land motion caused by tectonic subsidence (Curtis et al., 2022) has resulted in much of the Arcata Baylands being 1.0 to 1.5 feet lower in elevation than present-day tidal salt marsh west of US 101 (Figure 7-4).

Historic and current accretion rates have been assessed within the Jacoby Creek marsh west of US 101. Historic accretions rates were estimated using chronological and carbon dating techniques conducted by UCLA from sediment cores. The results show historic accretion rates ranging from approximately 2.9 mm/year to 8.4 mm/year, which exceeds the eustatic sea level rise rates of 1 to 2 mm/year (Gerwein, 2019 and Brown, 2019). More recent accretion rates were measured by USGS (Curtis 2019) between 2015 and 2017 at Jacoby Creek marsh. Accretion rates were measured using surface elevation tables (SETs) and feldspar marker horizon (MH) and correlated with suspended sediment concentrations (SSC) from continuous water quality sampling. Elevation change measured by the SETs averaged 0.89 mm/year and accretion measured by the MHs measured 0.71 mm/year (Curtis 2019). SET measurements reflect the combined elevation changes created by plant growth, sediment deposition, and tectonic land movement. The MH measurement reflects only the accretion due to deposition of sediment and organics on the surface. These accretion rates are lower relative to net sea level rise rates (combination of sea level rise and local tectonic subsidence) of 5 mm/year and would suggest Jacoby Creek marsh are not keeping pace with relative sea level rise. However, the rate is based on a limited three-year data set and additional data is needed to confirm this hypothesis. Based on climate change modeling, an increase in fine-sediment delivery to Humboldt Bay from future increased precipitation intensity is predicted. The increase in sediment delivery is anticipated to partially or wholly meet the future sediment demand of mudflats and marshes caused by subsidence, sea level rise, and tidal prism expansion within Humboldt Bay (Curtis 2021). The study applied a Bay-wide mass-balance approach to compare future sediment supply and demand, however sediment distribution patterns within Humboldt Bay are complex given the spatial and temporal varying erosional and depositional characteristics. The current depositional patterns of Jacoby Creek will continue to limit sediment delivery to the Arcata Baylands and Humboldt Bay marshes where the sediment could otherwise provide ecosystem services and benefits related to salt marsh resiliency.

There are also feedback mechanisms between salt marshes and sea level rise which promote marsh accretion to an equilibrium elevation relative to sea level that maintains the marshes. Marshes that are flooded by increasing sea level can recover equilibrium marsh elevation through increased

organic production and increased accretion (Cahoon et al. 2021). Rates of sediment deposition increase because the extended duration of flooding allows more sediment to settle out of the water column. These feedbacks support marsh accretion and return to an equilibrium elevation, but only if the rate of sea level rise is not rapid enough to suppress primary plant production. If primary production is suppressed, then the marsh vegetation will die off and the marsh will drown.

Based on Eicher (1987) native salt marsh vegetation can become established at elevations as low as approximately 1 foot below MHHW. MHHW in the study area is 7.1 feet (NAVD 88). Based on Eicher (1987), this suggests the current elevation in much of the Arcata Baylands is suitable for establishing low marsh vegetation (primarily native *Sarracenia virginica* and invasive *Spartina densiflora*). If these lowlands remain behind dikes and without tidally derived sediment inputs, they will likely not accrete sediment nor increase in elevation through time. With ongoing and projected SLR, the lands will soon become too low to support tidal marsh vegetation. If a coastal shoreline retreat strategy is taken after another 6 to 12 inches of SLR, these lands will almost entirely become mudflat and unable to support tidal marsh vegetation.

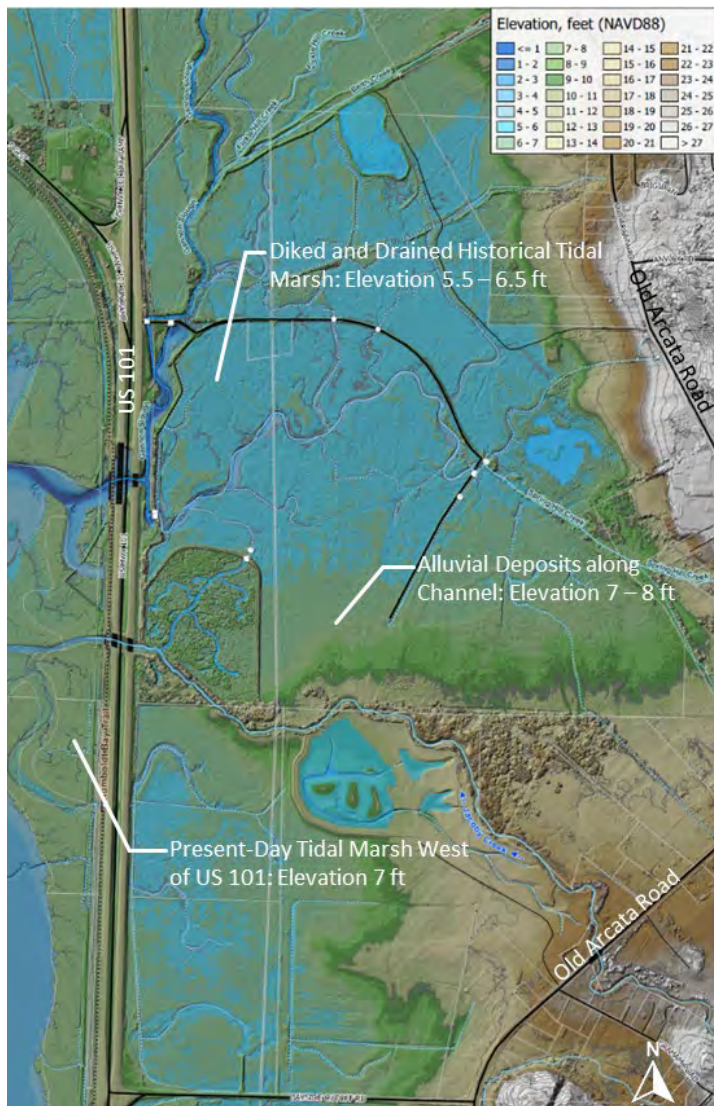


Figure 7-4. Elevations of present-day tidal marsh west of US 101 and diked and drained lands in the City of Arcata Baylands east of US 101.

8 SYNTHESIS OF EXISTING CONDITION FINDINGS

This section of the report briefly summarizes the findings discussed in Sections 2-7.

8.1 Historical Changes to Jacoby Creek

The earliest accounts of OAR crossing Jacoby Creek valley and the Wiyot trail that preceded it, describe the area as marshy, with multiple areas of standing water, making it impassible during the wet season. Channel traces observed in historical and present-day aerial images show a multi-channel system spanning the entire width of the valley in this area, with the primary channel of Jacoby Creek generally in its current location at OAR (Section 3.6).

Jacoby Creek has migrated across the width of its valley, with remnant channels still present. Upstream of OAR early maps show the channel following a different course that appears to align with the abandoned channel feature forming the Lower JCLT Pond (Section 3.2). Additionally, Washington Gulch is shown on several early maps, including the 1890 Surveyor General's map, as flowing directly into Jacoby Creek rather than flowing west through the geomorphic "floodbasin" and out to Brainard Slough as it currently does.

The 1870 USCS map (Figure 3-1) shows that tidal marsh extended along the banks of Jacoby Creek 2,800 feet upstream of present day. It also shows lobes of sediment deposition south of the channel at, and downstream of, OAR associated with alluvial deposits along various alignments of the channel. Based on the 1870 map, these appear to predate European settlement.

Diking along Jacoby Creek and draining the adjacent tidal marsh for agriculture effectively increased stream length, extending it by 2,800 feet west. The channel response to this lengthening was sediment aggradation (Section 7.3). The diking also forced sediment to flow further out into Humboldt Bay. In the 1970's following the flood of record and associated large sediment loads delivered to Jacoby Creek, a large delta formed west of US 101 as a result (Section 3.5).

As the channel aggraded the stream capacity decreased and overbank flooding increased. Floodwaters deposited their coarser sediments on the floodplain close to the channel. As a result, sediment deposition along channel bed and banks created an extremely 'perched' stream channel above its floodplain, with the channel banks being as much as 8 feet above the valley bottom. As a result, overbank flows spill out and away from the channel, and do not return. It is expected that this cycle of aggradation and flooding will increase in the future if not addressed.

8.2 Woody Vegetation, Debris, and Sedimentation

Mapping of small and large woody debris (SWD and LWD) jams found them to be numerous throughout the study area, but most prevalent downstream of OAR (Section 4.7.2). The jams appear to frequently be initiated by channels spanning woody vegetation, primary willows in a narrow riparian area, with vertical live branches forming pickets that capture flowing debris. Within the SWD and LWD jams were numerous items of anthropogenic origins, including trash and cut wood. Upstream of OAR many of the debris jams and associated vegetation had been recently removed by residents. The locations and size of debris jams are constantly changing, with residents removing them occasionally followed by new ones forming in different locations. As a result, the locations and rate water spills out of bank and flood patterns constantly shift along Jacoby Creek (Section 4.1).

Hydraulic analysis of the channel flow conveyance and water level monitoring found that downstream of OAR the dense in-channel vegetation and debris jams causes resistance to flow (as

measured by the Manning's roughness coefficient) more than double that of the cleared reaches further upstream (Section 6.1.5). A review of the channel thalweg profile suggests that the debris jams and in-channel vegetation is causing local channel bed aggradation of up to 2 feet (Section 7.2). This locally aggraded reach extends from approximately 1,600 feet downstream to 4,000 feet upstream of OAR.

Interviews with residents and ranchers living and working within the study area revealed that overbank sediment deposition decreases in the downstream direction. Residents along upper portions of Graham Road reported substantial silt deposits on their property following large floods. Once downstream of OAR, residents report that little to no silt deposits. In the Arcata Baylands North, the rancher reported that he has not seen any deposits or buildup of sediment, even when the area is ponded with overbank floodwaters for multiple days.

8.3 Flooding Patterns, Flow Losses, and Sediment Transport

Jacoby Creek spills nearly all its flow out of bank due to lack of channel capacity and because the channel is perched above the valley bottom. Regardless of the flow conveyed into the study area, only approximately 61 cfs remains in the channel downstream of Station 51+00 (Section 6.2)

Downstream of OAR streamflows greater than 30 cfs were found to spill out of bank as much as 200 days per year. Water spilling out along the south bank is intersected by capture channels constructed to guide flows into the South Jacoby Wetland Complex on the City's Baylands South. Along the north bank flows spill into a breach in the channel bank near Station 51+00. At slightly higher flows, water spills along multiple locations downstream and immediately upstream of OAR crossing. The road drainage system is frequently overwhelmed by these out of bank flows, causing frequent roadway inundation.

Flood mapping (Section 4.1) and hydraulic modeling (Section 6) of floodplain flow patterns found that as flows increase, the extent of flooding increases in the upstream direction. During storms smaller than a 1-year event, floodwaters spill out and away from the channel between 1,100 feet downstream to 5,000 feet upstream of OAR. Flows spilling along the north bank travel across the entire valley, through multiple residential properties, and cross over OAR before ponding in the Arcata Baylands North. These ponded waters are forced to drain through tide gates that discharge directly into the bay rather than returning the flow back to Jacoby Creek. Flows spilling along Graham Road generally flow through residential properties, over the road, and into the floodbasin to the south that drains out Washington Gulch.

The sediment transport analysis (Section 6.6) found the channel lacks the ability to transport the delivered sediment load due to inadequate channel capacity and flow losses. This results in deposition of coarse bed material and continued aggradation of the channel. As this process continues, channel capacity further decreases in the upstream direction.

8.4 Aquatic Habitat

Water quality sampling found that the wetlands created by Spring Hill Creek appear promising for creating off-channel salmonid habitat within the study area (Section 4.6). Beith Creek also provides perennial freshwater inflows to Gannon Slough. However, these waterbodies are currently disconnected from Jacoby Creek and fish are unable to move between habitats. Additionally, fish swept downstream in overbank flows to Arcata Baylands North are unable to return to Jacoby Creek and are forced to leave directly to the bay through tide gates. Before they smolt, salmonids are incapable of surviving the saline waters in the bay.

9 SCOPING OF ALTERNATIVES

9.1 Goals and Objectives

Findings from the characterizations of historical and existing conditions within the study area guided development of goals and objectives for the project. The following were developed by the project team and reviewed by the TWG:

The Project goal is to restore tidal and fluvial processes within the Jacoby Creek corridor that promote recovery of habitat for native fish, invertebrates, wildlife, and plant species while reducing flood impacts. To achieve this goal, the following objectives have been established by the project partners:

1. Increase Jacoby Creek channel and floodplain capacity and sediment routing through restoration of natural processes.
2. Reduce flood hazards on public roads.
3. Reduce flood impacts to private property.
4. Improve aquatic organism access to restored habitats.
5. Diversify and expand native plant communities and control invasive non-native species.
6. Increase resiliency to climate change and sea level rise.

9.2 Scoping of Project Approaches

Numerous approaches for achieving the project goal and objectives were identified through a scoping process that relied on insights gained from the work-to-date and discussions with the TWG, the JCLT board, City of Arcata and Eureka staff, landowners, and Arcata Baylands North and JCLT Kokte Ranch lessees. The scoping process focused on landscape scale enhancements to the Jacoby Creek corridor and floodplain. Though numerous discrete habitat enhancement opportunities present in the study area are not specifically identified in these approaches, they would likely get incorporated into selected the project.

The identified approaches were presented to the various groups and expanded upon based on feedback received. The approaches are divided into two spatial regions: City of Arcata Baylands and Upstream of Baylands. These approaches are not stand-alone and one or more will need to be implemented in each region to be successful, as discussed in Section 9.3.

9.2.1 Arcata Baylands 1 - Tidal Reintroduction

The first approach for the Arcata Baylands reach, as shown in Figure 9-1, involve reintroduction of the tide to portions of Arcata Baylands along lower Jacoby Creek. The approach focuses on shifting the tidal baselevel of Jacoby Creek inland towards its historical location, allowing the floodwaters of Jacoby Creek to spread out into the adjoining tidal marsh further upstream than presently (see Section 7.3), thus lowering the water level in the channel. This action is intended to reset the stream's profile and reverse the ongoing channel aggradation processes. The further inland the tide is extended, the greater extent the channel will be reset towards its pre-diking conditions, which is illustrated in Figure 7-3. The channel bed could be allowed to naturally degrade (lower) in response

to this approach or could be excavated to reset the bed elevation to the new stable profile of the channel.

The main channel of Jacoby Creek could be rerouted to the north, flowing out through Gannon Slough, or kept in its current alignment. The aggraded channel banks along portions of lower Jacoby Creek would be lowered to increase tidal exchange between the stream channel and the adjacent tidal marsh. This approach also allows the sediments transported by the stream channel to be delivered to the restored tidal marsh, promoting accretion of the marsh surface that provides resiliency to SLR.

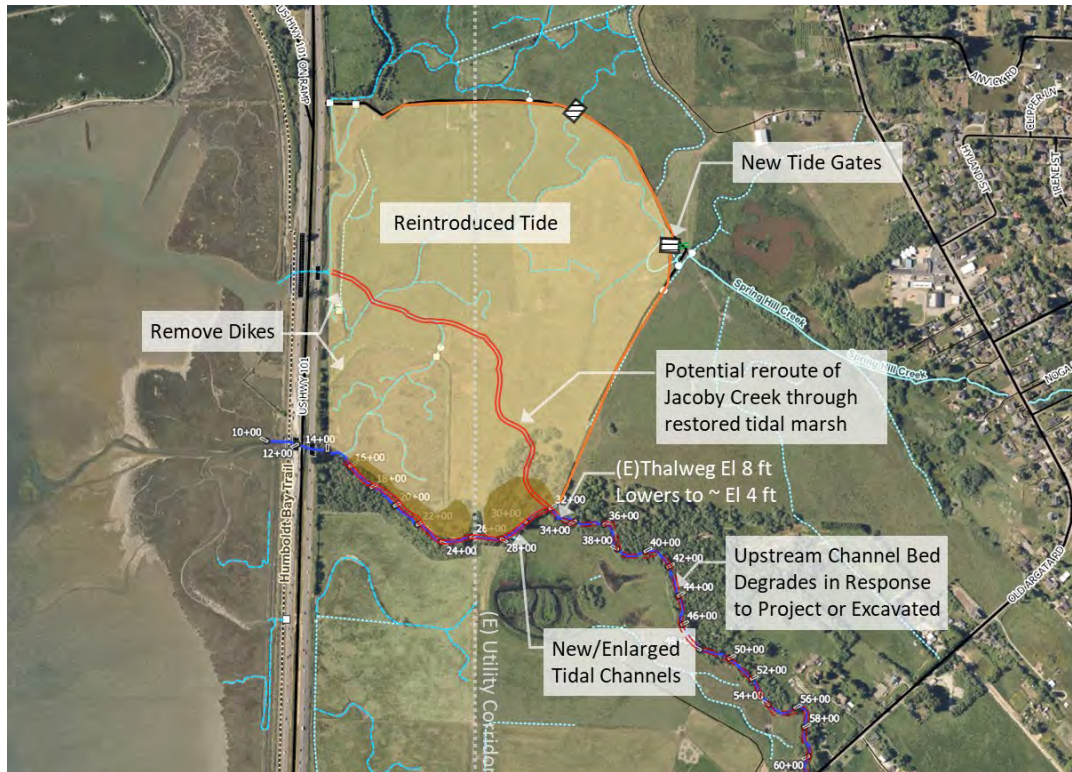


Figure 9-1. Baylands Approach 1 – Tidal reintroduction.

9.2.2 Arcata Baylands 2 - Capture Channel and Freshwater Wetland

An alternative approach for the Arcata Baylands is to construct a floodwater capture channel and receiving freshwater wetland on the north side of Jacoby Creek downstream of OAR (Figure 9-2), mimicking the existing South Jacoby Wetland Complex. The channel would capture all of the floodplain flows originating from up-valley and route them into an extensive wetland. The wetland would be connected with a return channel to Jacoby Creek near the present-day head of tide.

Rerouting flows back to Jacoby Creek would substantially increase the amount of flow conveyed downstream of the return channel. To accommodate the additional flow, the downstream Jacoby Creek channel would be enlarged. This approach helps route fish swept out onto the floodplain into a high quality, low velocity habitat that connects back to the Jacoby Creek channel rather than being discharged through tide gates into Humboldt Bay.

This approach does not address the ongoing aggradational processes and lack of channel capacity in Jacoby Creek.



Figure 9-2. Baylands Approach 2 - Capture channel and freshwater wetland.

9.2.3 Enhanced Riparian Corridor

A component of any alternative should focus on both expanding the width of the riparian corridor along Jacoby Creek upstream of tidal reaches, and also diversifying the riparian species to include a mixed canopy. The riparian corridor throughout much of the study area is relatively narrow and dominated by alders and willows. This is especially the case along the south bank of the channel. As a result, trees along the north bank tend to grow towards the sunlight, leaning over and frequently falling into the channel. Trunks of fallen willow then span the channel, growing vertical branches that restrict flow and initiate debris jams.

Historical maps (see Section 3.1) and accounts describe the riparian forest along Jacoby Creek valley as being a mixture of Sitka spruce, redwood, and deciduous trees. The larger conifers help cast shade over the channel, reducing the density of willow and alders growing along the banks. They also promote a diverse vegetated understory. This type of riparian corridor, once established, would contribute to reducing frequency and density of debris jams and vegetated constrictions within the bankfull channel.

9.2.4 Upstream of Baylands 1 – Improve OAR Drainage Infrastructure

Increasing the capacity of the roadway drainage along OAR north of the Jacoby Creek bridge would substantially reduce the duration that the roadway is inundated as well as neighboring properties.

The current roadway drainage system north of Jacoby Creek was installed in 1991. Observations have shown it to be undersized for conveying floodplain flows for all but the smallest flood events. This is due to both the capacity of the culverts and the capacity of the receiving ditch that conveys the flow towards the north. OAR is most frequently inundated by overbank flooding spilling within 400 feet upstream of the Jacoby Creek bridge crossing. Increasing roadway drainage capacity for these flows would substantially reduce the frequency of roadway inundation.

The proposed approach (Figure 9-3) would place new culverts under OAR and create multiple pathways for floodwaters to be conveyed under the roadway, rather than routing all flow into a single undersized collection system, as is currently done. These new cross-drain culverts would be located between the Jacoby Creek bridge and the JCLT Kokte Ranch driveway to the northeast, a roadway length of approximately 350 feet. The outlets would discharge into new channels that would route the flows back into Jacoby Creek within 400 feet downstream of the bridge. The return channels could flow into constructed alcoves along the bank of Jacoby Creek, creating slow-water habitat for native fish. Downstream of where the water would be returned to the channel, Jacoby Creek would need to be widened to accommodate the additional flow to avoid further exacerbating downstream out of bank flooding.

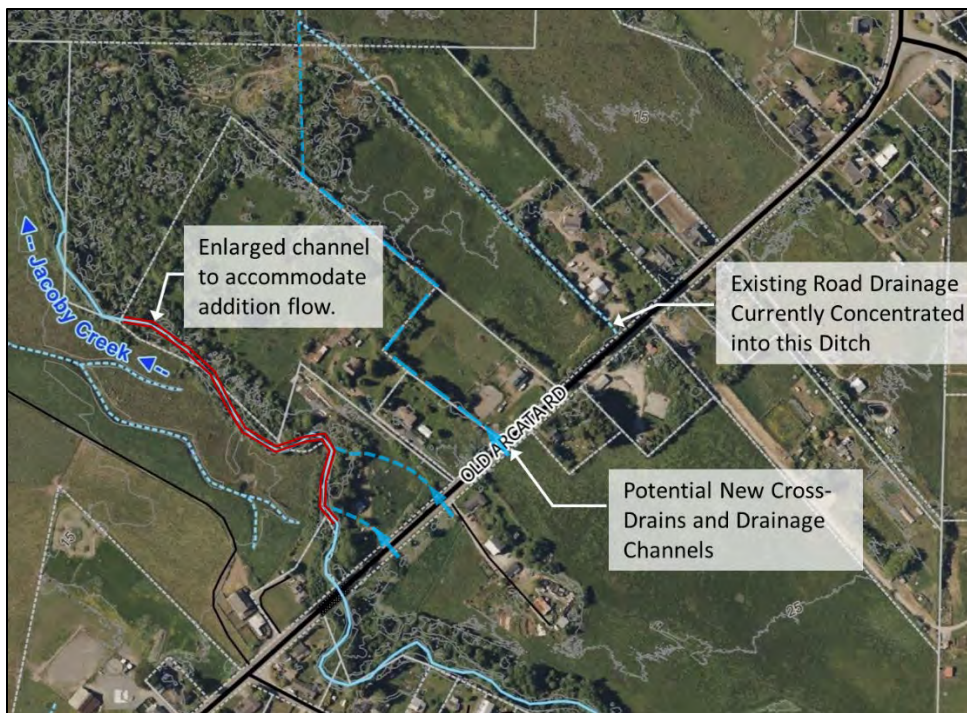


Figure 9-3. Upstream of Baylands 1 – Improved OAR drainage infrastructure.

Landowners have also suggested another cross-drain under OAR approximately 600 feet northwest of the Jacoby Creek bridge combined with a new receiving drainage ditch to route this flow towards the Arcata Baylands North property. This location would help drain ponded waters on the north side of the Koke Ranch, but would require coordination with multiple landowners for the new drainage ditch.

9.2.5 Upstream of Baylands 2– Channel Realignment at Bridge & Upstream Meander

Field observations and hydraulic model results highlighted two sections of Jacoby Creek that have problematic planform geometry that exacerbates routing flood flows. One area involves the channel alignment upstream and downstream of the OAR bridge. The other addresses an abrupt turn in the channel due to historical armoring of the south streambank near Station 85+00. Addressing these two locations is the focus of this approach (Figure 9-5).

Improving the channel alignment through the OAR bridge crossing would help increase channel capacity in this flood-prone reach of Jacoby Creek. A tight meander upstream of the bridge causes the channel to approach the bridge at a skewed angle, forcing flows into the north bay of the bridge, placing the south bay on the inside of the meander and causing the channel to fill it with sediment. With one bay filled, hydraulic capacity under the bridge is halved. The downstream channel includes a tight meander and substantial debris jams. Realigning and enlarging approximately 1,200 feet of channel (400 feet upstream and 800 feet downstream of OAR) to decrease the tightness of the bends, would likely cause a noticeable increase in flow conveyance and decrease frequency of out of bank flooding in this reach.



Figure 9-4. Upstream of Baylands 2 -Channel realignment at bridge and upstream meander.

At approximately Station 85+00, the streambank was armored with concrete rubble by the previous owner of the Kokte Ranch. This appears to have been an attempt to prevent lateral migration of a meander in Jacoby Creek. The result is an abrupt 90-degree turn in the channel that forces flows against several residential properties, including a house located on the top of bank. Removing this rubble and realigning the channel will move the channel away from the house, improve flow conveyance, and provide for a large riparian corridor along the south channel bank.

9.2.6 Upstream of Baylands 3– Floodplain Capture Swales and Flood Flow Routing

The Jacoby Creek valley within the study area has always been an active floodplain. An approach to reducing the impacts of floodplain flows on lands north of Jacoby Creek is to capture and guide the water through a designated corridor (Figure 9-5). Given mapped and modeled overbank flooding patterns, this could be accomplished through construction of shallow floodplain swales across the existing JCLT pasture on the Kokte Ranch and on an adjoining pasture. These swales would be located in existing low areas and have gentle slopes to allow for continued grazing and mowing. The swales would guide flows to the north where they would concentrate flow into a deeper and narrower floodplain channel. This channel would be routed under the two existing driveways and then under OAR before being routed onto the Arcata Baylands North. This system of floodplain swales and channel could greatly reduce flooding of residents along OAR and roadway flooding.

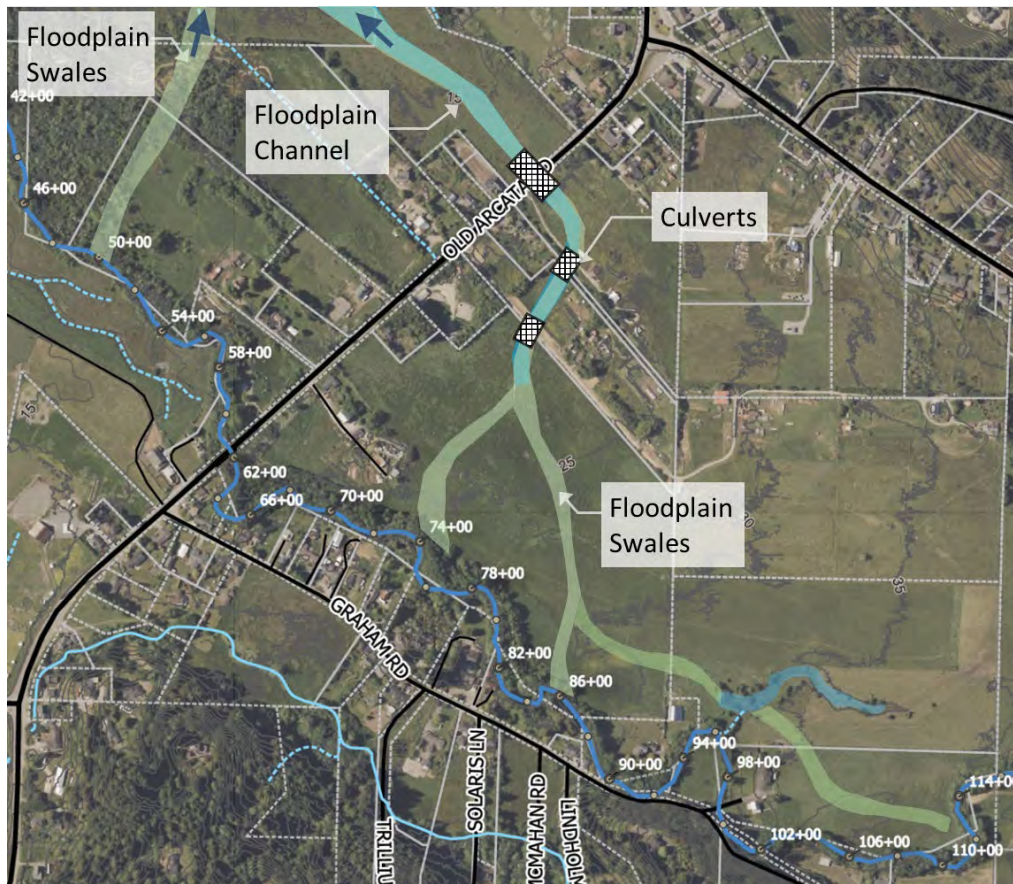


Figure 9-5. Upstream of Baylands 3 – Floodplain capture swales and flood flow routing.

9.2.7 Upstream of Baylands 4– Deepen and Enlarge Lower Graham Road Reach

This approach focuses on increasing channel capacity and reversing channel aggradation processes to reduce out of bank flooding (Figure 9-6). Given the low height of the streambanks in the reaches upstream of the Arcata Baylands, widening the channel alone is not a practical approach to restoring channel capacity. Instead, it must be deepened. However, this can only be accomplished in conjunction with approaches that also deepen the channel reach on the downstream Arcata Baylands, such as using the tidal reintroduction approach to shift tidal baselevel inland, as discussed in Section 9.2.1. As part of deepening the channel, it would need to be widened to a limited degree. It could also be shifted away from structures along Graham Road.

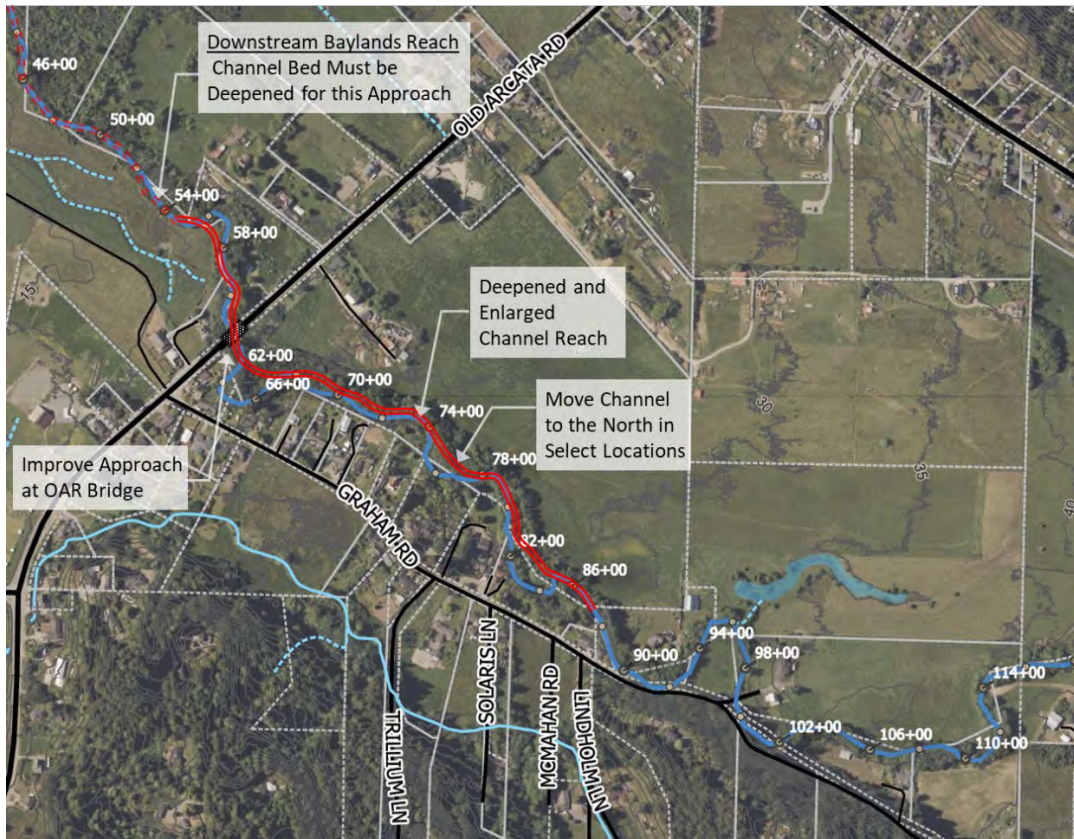


Figure 9-6. Upstream of Baylands 4 - Conceptual approach for deepening and enlarging lower Graham Road reach.

9.2.8 Upstream of Baylands 5– Realign Lower Graham Road Reach to the North

The last approach developed as part of the scoping processes involved realigning the channel upstream of OAR, shifting it to the north, and providing increased channel depth and width while still crossing under OAR at the existing bridge (Figure 9-7). Given the topography, with the highest ground running along the existing channel banks, shifting the channel north would cause floodwaters to spill along the north bank preferentially, substantially reducing flooding of properties along lower Graham Road. However, given that the existing land is lower in elevation to the north, the channel profile would need to be substantially lower than the existing channel to provide adequate capacity to convey high flows and the delivered sediment from upstream. Like the previous approach, this can only be accomplished in conjunction with approaches that also deepen the channel reach downstream on Arcata Baylands.

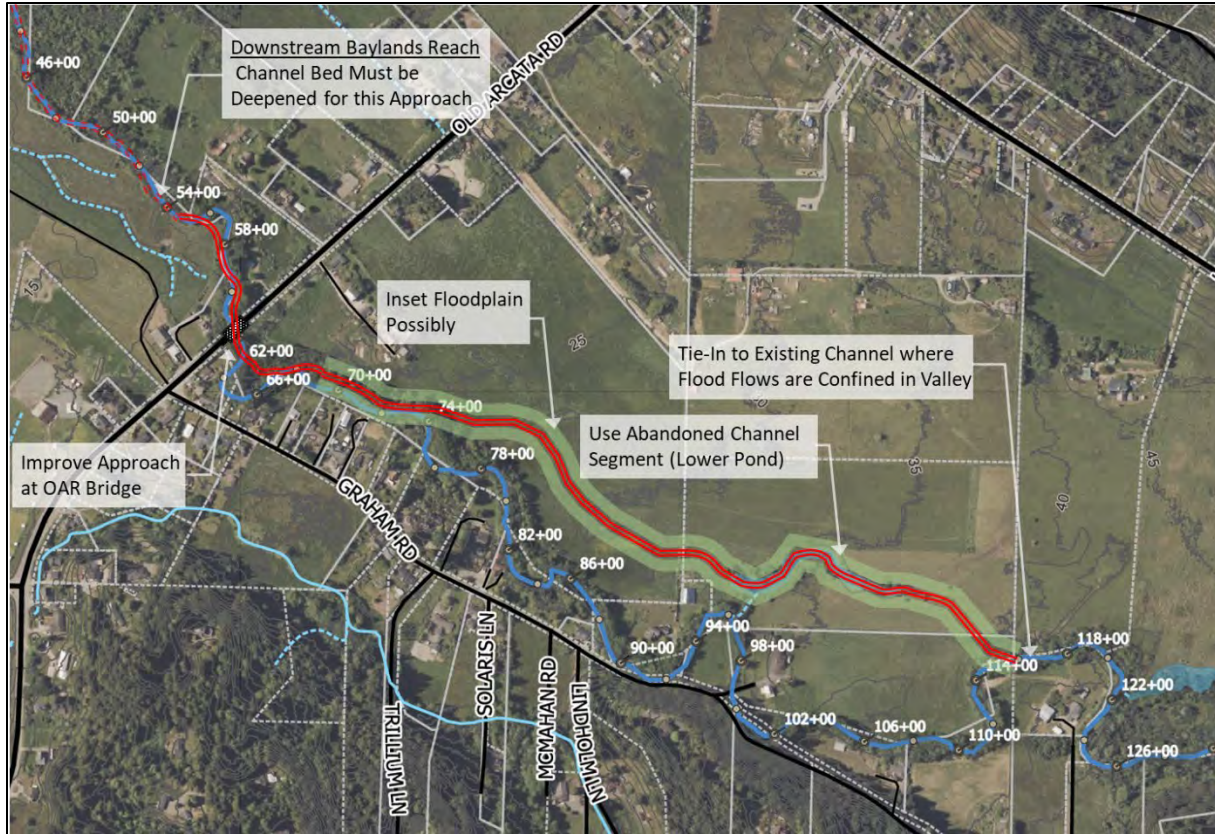


Figure 9-7. Upstream of Baylands 5 - Conceptual approach for realigning lower Graham Road reach to the north.

9.3 Compatibility of Approaches

Many of the approaches can be combined together to create a comprehensive and effective project. However, the upstream of Arcata Baylands approaches that involve deepening the channel reach can only be implemented in conjunction with the deepening of the downstream channel, thus not all approaches can be combined. Table 9-1 provides a matrix showing which approaches are compatible with others. This was used as part of developing conceptual alternatives for the entire study area.

Table 9-1. Compatibility of various restoration approaches with one another.

Compatibility of Combining Approaches	<u>Baylands 1</u> Tidal Reintroduction	<u>Baylands 2</u> Capture Channel & Freshwater Wetland	<u>Upstream of Baylands 1</u> Improve OAR Drainage Infrastructure	<u>Upstream of Baylands 2</u> Channel Realignment at Bridge & Upstream Meander	<u>Upstream of Baylands 3</u> Floodplain Capture Swales and Flood Flow Routing	<u>Upstream of Baylands 4</u> Deepen and Enlarge Graham Road Reach	<u>Upstream of Baylands 5</u> Realign Lower Graham Rd Reach to the North
<u>Upstream of Baylands 1</u> Improve OAR Drainage Infrastructure	✓	✓	NA	✓	✓	✓	✓
<u>Upstream of Baylands 2</u> Channel Realignment at Bridge & Upstream Meander	✓	✓	✓	NA	✓	✓	✓
<u>Upstream of Baylands 3</u> Floodplain Capture Swales and Flood Flow Routing	✓	✓	✓	✓	NA	✓	✓
<u>Upstream of Baylands 4</u> Deepen and Enlarge Lower Graham Road Channel Reach	✓		✓	✓	✓	NA	
<u>Upstream of Baylands 5</u> Realign Lower Graham Road Reach to the North	✓		✓	✓	✓		NA

10 CONCEPTUAL ALTERNATIVES

The study developed numerous approaches for achieving the stated project objectives (see Section 9). Through combining these approaches, and incorporating comments and recommendations from landowners and the technical working group, the study has prepared the following three conceptual alternatives for consideration. Alternatives 1 – 3 have progressively increasing project footprint, complexity, cost, and effectiveness. Alternative 3 includes three different options, referred to as A, B and C. These alternatives are intended to be further developed, analyzed, and evaluated as part of the next phase of the project. Outcomes from the alternative analysis will support the selection of a preferred alternative to be forwarded for final planning and implementation.

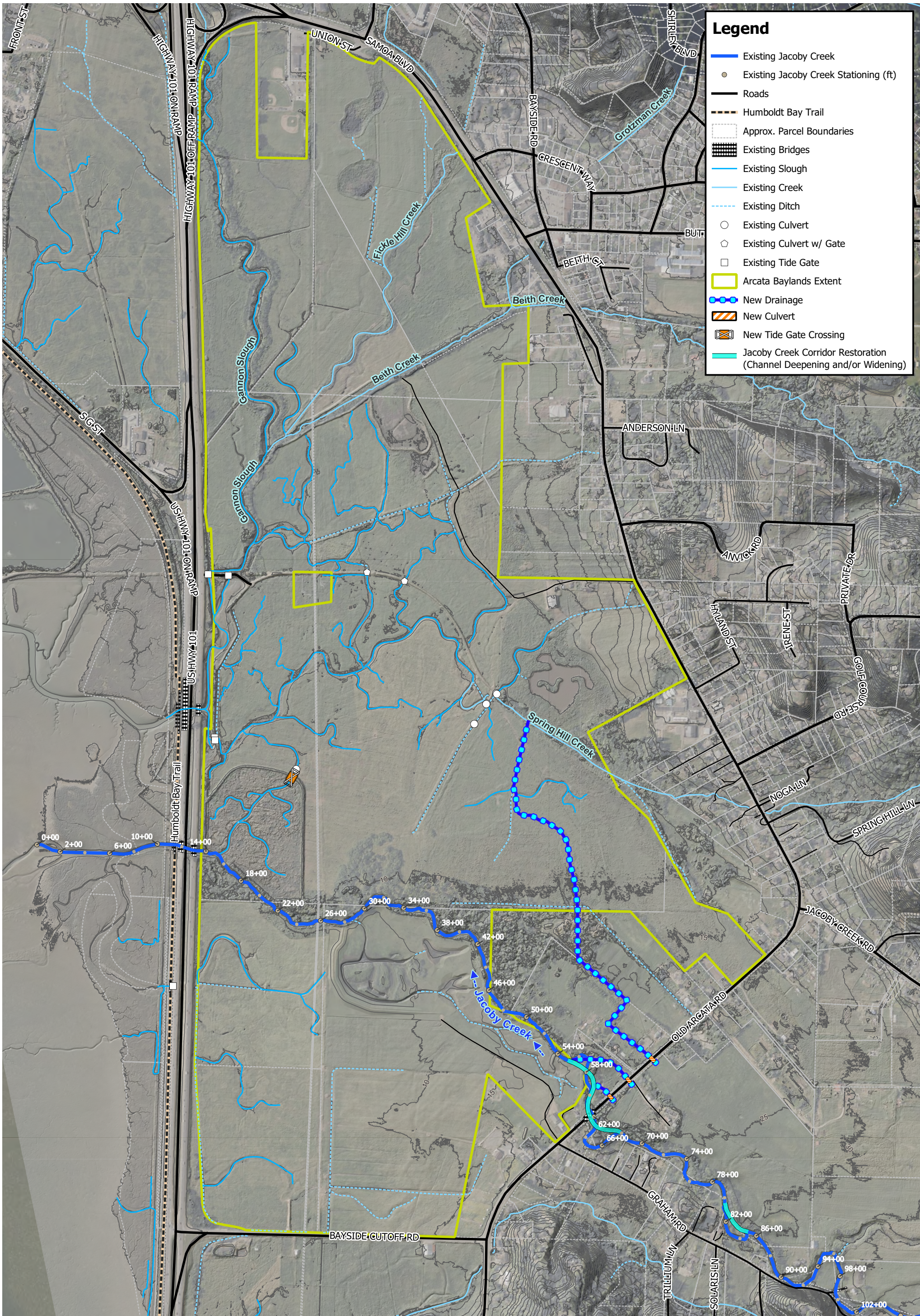
10.1 Alternative 1: OAR Drainage Improvements & Limited Channel Realignment

10.1.1 Description

Alternative 1 focuses on OAR roadway drainage improvements and addressing two sections of problematic channel alignments upstream of the Arcata Baylands (Figure 10-1). These areas were discussed in the approaches described in Section 9.2.4 and Section 9.2.5. This alternative also includes replacement of a tide gate that drains into the North Jacoby Tidal Marsh from the Arcata Baylands North.

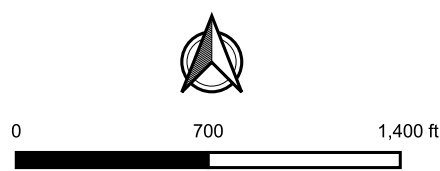
Components of Alternative 1 include:

1. Increase conveyance of floodplain flows under OAR:
 - Add at least two additional floodplain culverts under OAR close to the Jacoby Creek bridge crossing to convey floodplain flows under road and back into downstream channel.
 - Add an additional outlet for existing road drainage system approximately 650 feet northeast of Jacoby Creek bridge, discharging into a new 3,450-foot long drainage ditch flowing onto the Arcata Baylands North and into Spring Hill Creek.
2. Strategic improvements of Jacoby Creek channel conveyance:
 - Reroute approximately 650 feet of Jacoby Creek through OAR Bridge to improve alignment with bridge and reduce sedimentation in south bridge cell, increasing effective bridge opening for conveying streamflow.
 - Enlarge the Jacoby Creek channel, extending to approximately 700 feet downstream of OAR to improve flow conveyance through the reach and reduce backwatering and sedimentation at OAR Bridge.
 - Remove existing concrete rubble armoring north channel bank, which currently directs flow towards residences, and realign approximately 500 feet of Jacoby Creek towards north and away from residential structures along Graham Road.
3. Replacement of the Jacoby Tidal Marsh tide gate with a fish-friendly tide gate that allows for muted bi-directional flow to increase fish access between Jacoby Creek and the Arcata Baylands North waterways.



Datums:
 Horizontal: NAD83 State Plane CA Zone 1
 Vertical: NAVD88

Sources:
 Elevation: 2019 Eureka Coastal Lidar DEM
 Aerial Image: 2018 Bing Aerial Imagery



Jacoby Creek Water Sustainability and Anadromous Fish Habitat Enhancement Feasibility Study

Figure 10-1.
 Alternative 1 - Old Arcata Road (OAR) Drainage Improvements and Channel Realignment in Strategic Locations.

GHD analyzed various conceptual configurations of drainage improvements for OAR as an interim measure to reduce roadway flooding. The concepts analyzed were limited to increasing capacity of the existing drainage system and adding an additional drainage culvert and ditch that routes flow from the east side of OAR to the north and onto the Arcata Baylands North. The findings were summarized in a memorandum that is provided in Appendix I. While the concepts developed will reduce the frequency of flooding on OAR and are compatible with this Alternative and the following alternatives, the interim drainage improvements will require obtaining permissions from private landowners to implement.

10.1.2 Considerations

This alternative would substantially reduce the frequency of roadway inundation on OAR, thus providing a public safety benefit. It would also result in some reduction in flooding of properties immediately downstream of the OAR bridge. Reduced flood frequency and duration would also be expected for lower-elevation Graham Road and adjoining properties. The upstream realignment section will also help protect private properties, including a house currently located on the top of the south channel bank. Overall flood reduction provided by this alternative will be relatively limited given that it does not address overall channel capacity and ongoing in-channel sedimentation. Quantifying the degree of flood reduction requires hydraulic analysis that would be part of the next phase of the project.

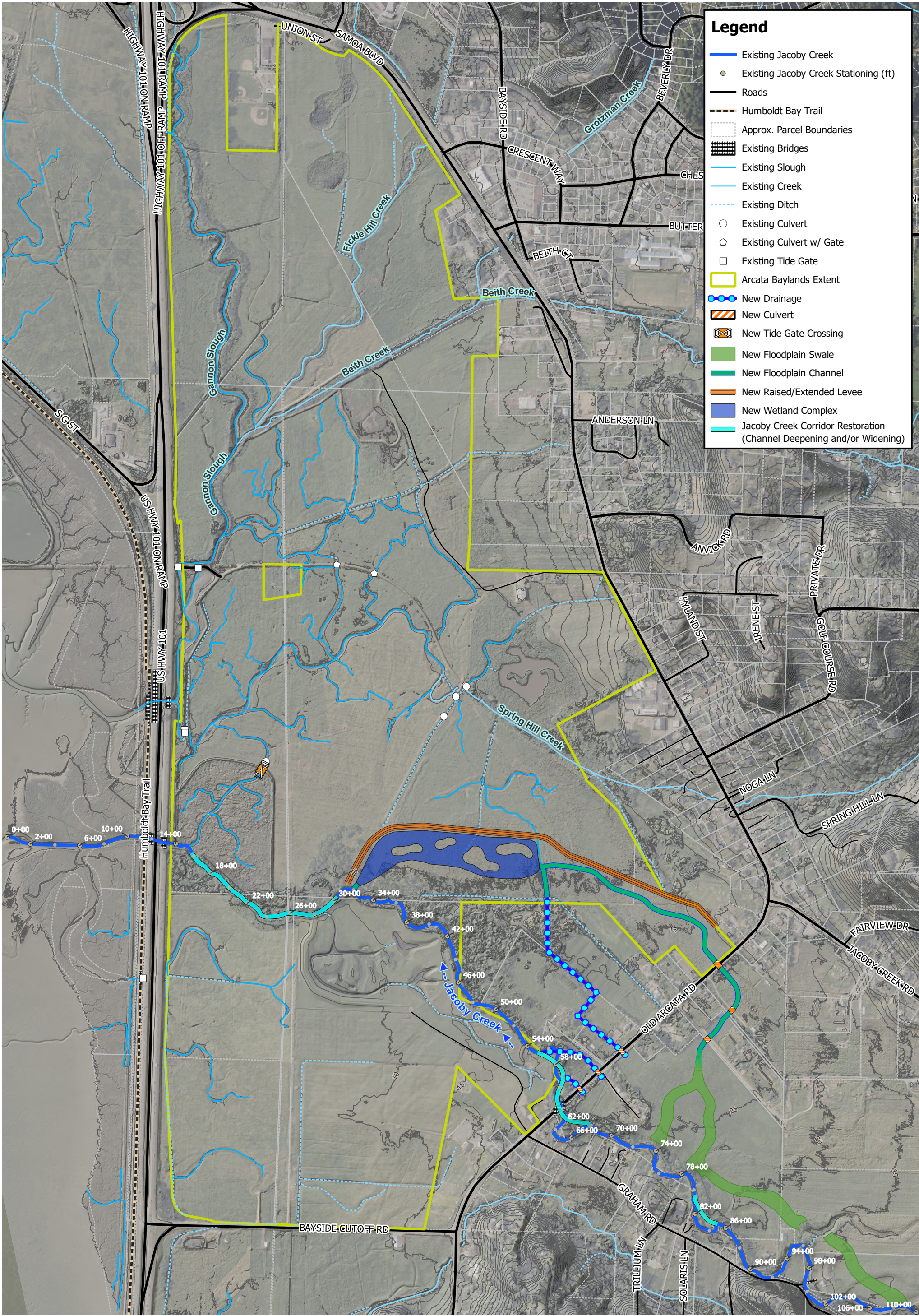
Habitat enhancements accomplished by constructing alcoves along the bank where waters are returned to the channel would be beneficial for rearing salmonids in Jacoby Creek. Extending the new ditch onto the Arcata Baylands North and connecting to Spring Hill Creek near Malfunction Junction will help reduce stranding of fish that are swept out of Jacoby Creek and into these drainage features on the floodplain. The replacement tide gate at the North Jacoby Tidal Marsh would provide fish swept into the Arcata Baylands North a more reliable pathway to return to Jacoby Creek rather than discharging through tide gates into the more marine environment of Humboldt Bay.

10.2 Alternative 2: Floodplain Swales & Freshwater Wetland Complex

10.2.1 Description

Alternative 2 (Figure 10-2) includes all components of Alternative 1. It also includes floodplain swales and a floodplain capture channel based on the approach described in Section 9.2.6. These additional components include:

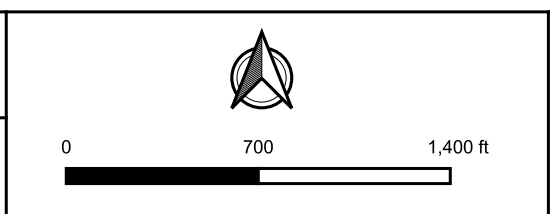
1. Broad and gently sloping capture swales through the JCLT pasture and an adjacent private pasture upstream of OAR (approximately 5 acres) to route northern floodplain flows into a confined floodplain channel approximately 3,000 feet in length that drains under two driveways and OAR, before flowing onto the Arcata North Baylands property.
2. The floodplain channel would flow into a constructed wetland complex (approximately 10 acres) on Arcata North Baylands that reconnects to Jacoby Creek, returning floodplain flows the stream channel near the head of tide. A 3,400-foot long low-profile berm would be constructed along the north side of the wetland complex to help contain floodwaters.
3. Jacoby Creek channel downstream of the connection to the new wetland complex (approximately 2,600 feet) would be enlarged to accommodate the additional inflow.



- ### Legend
- Existing Jacoby Creek
 - Existing Jacoby Creek Stationing (ft)
 - Roads
 - - - Humboldt Bay Trail
 - Approx. Parcel Boundaries
 - Existing Bridges
 - Existing Slough
 - Existing Creek
 - - - Existing Ditch
 - Existing Culvert
 - Existing Culvert w/ Gate
 - Existing Tide Gate
 - Arcata Baylands Extent
 - New Drainage
 - New Culvert
 - New Tide Gate Crossing
 - New Floodplain Swale
 - New Floodplain Channel
 - New Raised/Extended Levee
 - New Wetland Complex
 - Jacoby Creek Corridor Restoration (Channel Deepening and/or Widening)

Datums:
 Horizontal: NAD83 State Plane CA Zone 1
 Vertical: NAVD88

Sources:
 Elevation: 2019 Eureka Coastal Lidar DEM
 Aerial Image: 2018 Bing Aerial Imagery



Jacoby Creek Water Sustainability and Anadromous Fish Habitat Enhancement Feasibility Study

Figure 10-2.
Alternative 2 - Broad Swales to Capture and Direct Floodplain Flows Into a Freshwater Wetland Complex Connected to Jacoby Creek.

10.2.2 Considerations

The addition of the floodplain swales, combined with the roadway drainage improvements and select channel changes, is anticipated to cause a large reduction in flooding of OAR and the adjacent properties. The drainage structures under the two driveways and OAR will need to be relatively large culverts or short-span bridges given the flow magnitude that spills out of bank and to the northeast of the Kokte Ranch buildings (see Section 6.5). This alternative will not provide additional reductions in flooding along Graham Road when compared to Alternative 1. Also, like Alternative 1, it does not address overall channel capacity and ongoing in-channel sedimentation. Quantifying the degree of flood reduction requires hydraulic analysis that would be part of the next phase of the project.

The routing of floodplain flows into a wetland connected to the stream channel will greatly reduce stranding of fish and create diverse slow-water deep habitat for rearing salmonids as well as amphibians, waterfowl, and other aquatic-dependent species. It could remove approximately 20.8 acres from cattle grazing, as shown in Figure 10-6, but greatly reduce flooding of existing pastures to the west and north of the wetland complex.

10.3 Alternative 3: Tide Reintroduction & Channel Deepening from US 101 through lower Graham Road Reach.

10.3.1 Description

Alternative 3 includes all components from Alternative 1 and the floodplain swales from Alternative 2. Additionally, it utilizes the tidal reintroduction and channel deepening and widening approaches described in Section 9.2.1 and Section 9.2.7, respectively. These additional components are shown in Figure 10-3, Figure 10-4 and Figure 10-5, and include:

1. Deepen and enlarge Jacoby Creek channel through excavation, extending from US 101 through the lower Graham Road reach (approximately 6,300 feet of length). Deepened channel supported by extending tidal influence further inland, resulting in increased flow conveyance and sediment transport capacity.
2. Reintroduce tide to one or more cells (Alternative A, B, or C) within the Arcata Baylands and lower the aggraded streambanks along Jacoby Creek to restore tidal conditions 2,400 to 3,100 feet upstream of US 101.

This alternative has three different potential configurations with respect to the areas receiving tidal reintroduction on the Arcata Baylands, as described below.

Alternative 3A Tidal Cell

The tidal cell in Alternative 3A (Figure 10-3) would reintroduce the tide to approximately 94 acres in Arcata Baylands North, remove 3,500 feet of existing tidal levees, and raise the existing railroad embankment and north-south cattle lane (totally 4,400 feet) to serve as new tidal levee surrounding the north and east sides of this cell. . A new raised utility corridor is included, consisting of a berm with maintenance road running along the top and the Eureka municipal water lines buried within the berm. There would be two bridge crossings along the utility corridor at slough channels to allow for tidal exchange within the tidal cell. The water lines could be suspended from the bridges or directionally drilled under the slough channels.

The tidal cell would exchange flows with Jacoby Creek up to Station 36+00 by lowering approximately 10 acres of existing high ground and berms along the north bank of Jacoby Creek down to intertidal elevations to hydrologically connect the channel with the adjacent restored tidal marsh. This alternative also includes excavating approximately 27,000 feet of historical tidal channels in the new tidal cell and to the north to promote tidal exchange and route flows between the Gannon Slough basin and the new tidal cell. Excavated materials would be placed on the new marsh plain surface to create a diversity of salt marsh elevations.

The floodplain channel originating from up-valley of OAR will be routed into Spring Hill Creek. These waters, along with other freshwater inflows to the Gannon Slough basin, which is a muted tidal basin, would be interconnected with this new tidal cell using up to four new fish-friendly tide gates that allow for bi-directional flow using muted tide regulators. The exchange of flow between the freshwater tributaries of Gannon Slough, freshwater inflows from Jacoby Creek would produce multiple locations of freshwater to brackish water transitional habitat.

Alternative 3B Tidal Cell

The Alternative 3B tidal cell (Figure 10-4) would not include eastern tidal levee shown in Alternative 3A and would remove the existing elevated cattle lane, allowing the reintroduced tide to extend inland unimpeded, running up onto existing higher ground in the Arcata Baylands North. The northern tidal levee may extend eastward, intersecting the higher ground and ending at approximately elevation 14 feet. This would result in approximately 115 acres of new tidal marsh along with a transition zone between high marsh and freshwater pasture.

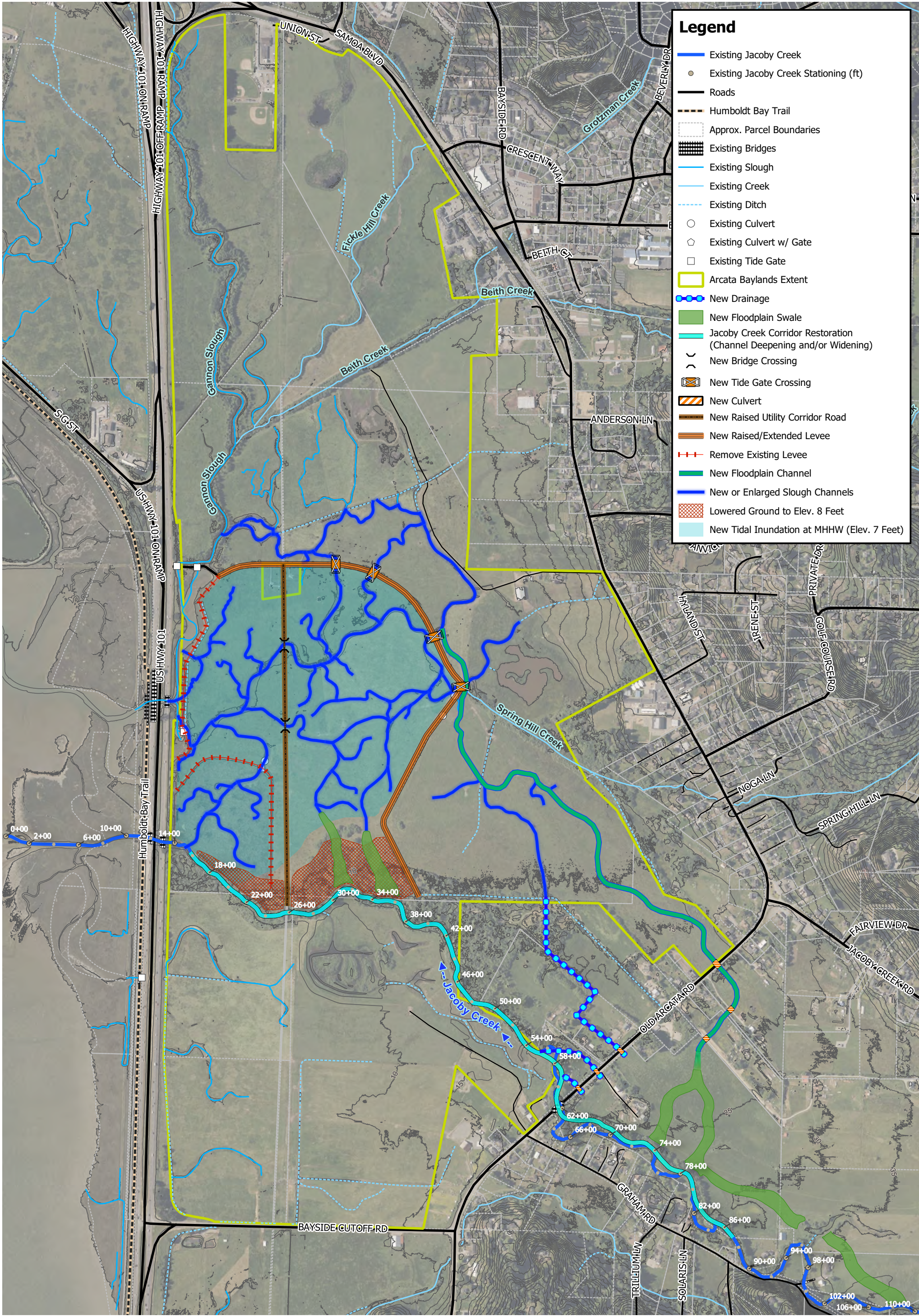
Approximately 19 acres of the existing high ground and berms along the Jacoby Creek banks would be lowered, extending tidal influence along Jacoby Creek to approximately Station 41+00.

Approximately 29,000 feet of historical tidal slough channels would be excavated within the new tidal basin and to the north towards Gannon Slough. Excavated materials would be placed on the restored marsh plain to create a diversity of marsh elevations. The floodplain channel would be routed into the head of the tidal slough channels, similar to conditions shown in the USCS 1970 map (Figure 3-1).

Like Alternative 3A, Spring Hill Creek would continue to be routed into the Gannon Slough basin and would be interconnected with this new tidal cell via new fish-friendly tide gates. The exchange of flow between the freshwater tributaries of Gannon Slough, freshwater inflows from Jacoby Creek would produce multiple locations of freshwater to brackish water transitional habitat.

Alternative 3C Tidal Cells

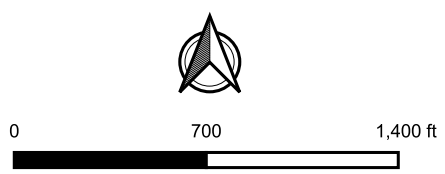
Alternative 3C includes all components of Alternative 3B, with an additional tidal cell in the Arcata Baylands South (Figure 10-5). This southern cell would extend south of Jacoby Creek to Bayside Cutoff, creating approximately 46 acres of tidal marsh south of Jacoby Creek. Approximately 6,700 feet of historical and new slough channels would be excavated and enlarged with the south cell, with the material used to construct new tidal levees. Portions of the high ground and existing berms along Jacoby Creek south bank (approximately 5 acres) would be lowered to increase tidal exchange.



- ### Legend
- Existing Jacoby Creek
 - Existing Jacoby Creek Stationing (ft)
 - Roads
 - - - Humboldt Bay Trail
 - Approx. Parcel Boundaries
 - Existing Bridges
 - Existing Slough
 - Existing Creek
 - - - Existing Ditch
 - Existing Culvert
 - Existing Culvert w/ Gate
 - Existing Tide Gate
 - Arcata Baylands Extent
 - New Drainage
 - New Floodplain Swale
 - Jacoby Creek Corridor Restoration (Channel Deepening and/or Widening)
 -) (New Bridge Crossing
 - New Tide Gate Crossing
 - New Culvert
 - New Raised Utility Corridor Road
 - New Raised/Extended Levee
 - - - Remove Existing Levee
 - New Floodplain Channel
 - New or Enlarged Slough Channels
 - Lowered Ground to Elev. 8 Feet
 - New Tidal Inundation at MHHW (Elev. 7 Feet)

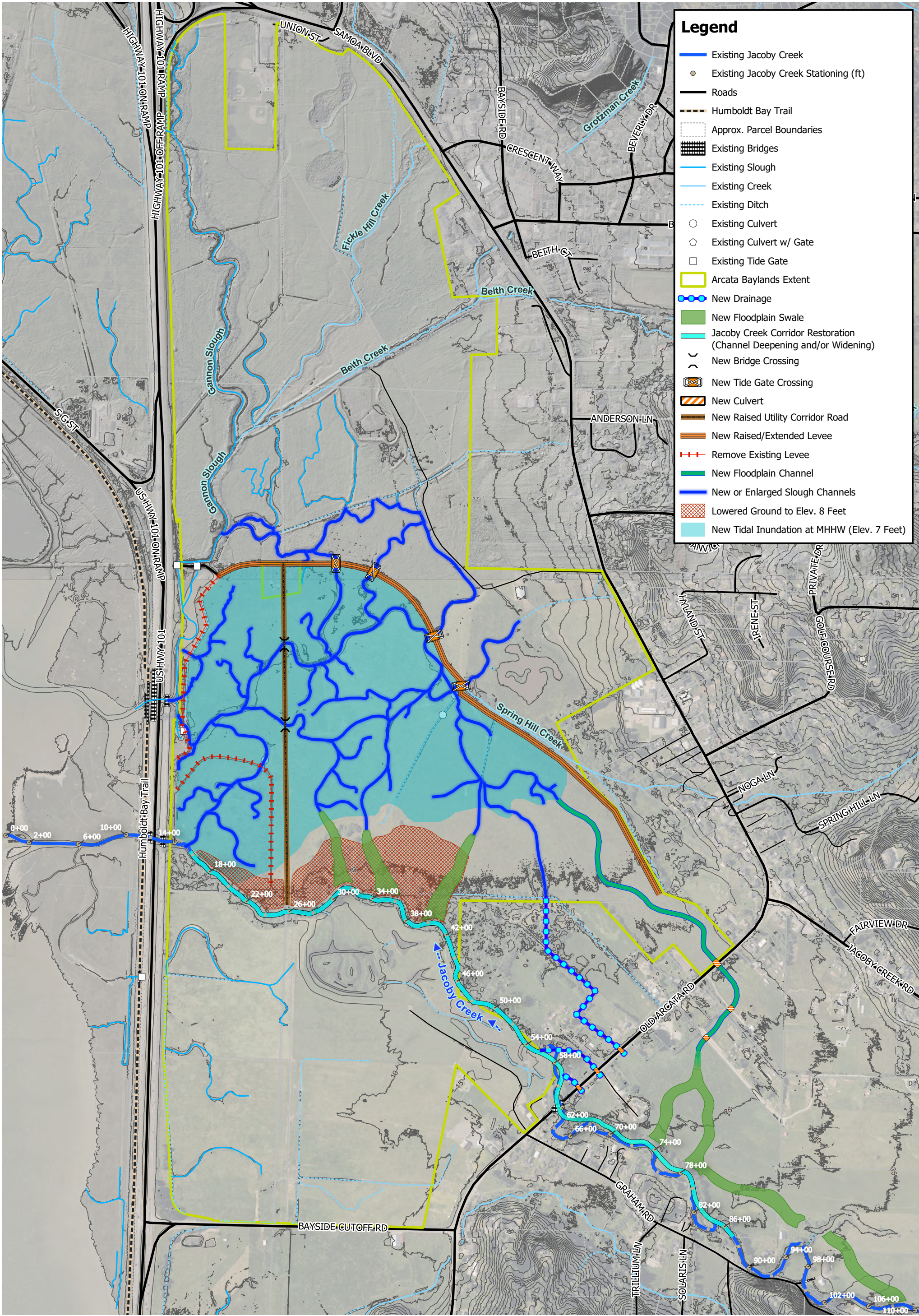
Datums:
 Horizontal: NAD83 State Plane CA Zone 1
 Vertical: NAVD88

Sources:
 Elevation: 2019 Eureka Coastal Lidar DEM
 Aerial Image: 2018 Bing Aerial Imagery



Jacoby Creek Water Sustainability and Anadromous Fish Habitat Enhancement Feasibility Study

Figure 10-3.
 Alternative 3A - (Area A) Tide Reintroduction Along Jacoby Creek to Support a Deeper and Wider Channel from US 101 Through Lower Graham Road Reach.

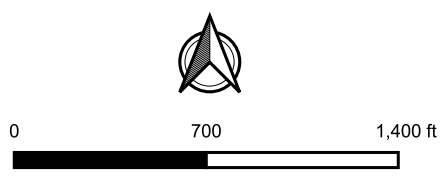


Legend

- Existing Jacoby Creek
- Existing Jacoby Creek Stationing (ft)
- Roads
- - - Humboldt Bay Trail
- Approx. Parcel Boundaries
- Existing Bridges
- Existing Slough
- Existing Creek
- - - Existing Ditch
- Existing Culvert
- Existing Culvert w/ Gate
- Existing Tide Gate
- Arcata Baylands Extent
- New Drainage
- New Floodplain Swale
- Jacoby Creek Corridor Restoration (Channel Deepening and/or Widening)
-) (New Bridge Crossing
- New Tide Gate Crossing
- New Culvert
- New Raised Utility Corridor Road
- New Raised/Extended Levee
- - - Remove Existing Levee
- New Floodplain Channel
- New or Enlarged Slough Channels
- Lowered Ground to Elev. 8 Feet
- New Tidal Inundation at MHHW (Elev. 7 Feet)

Datums:
 Horizontal: NAD83 State Plane CA Zone 1
 Vertical: NAVD88

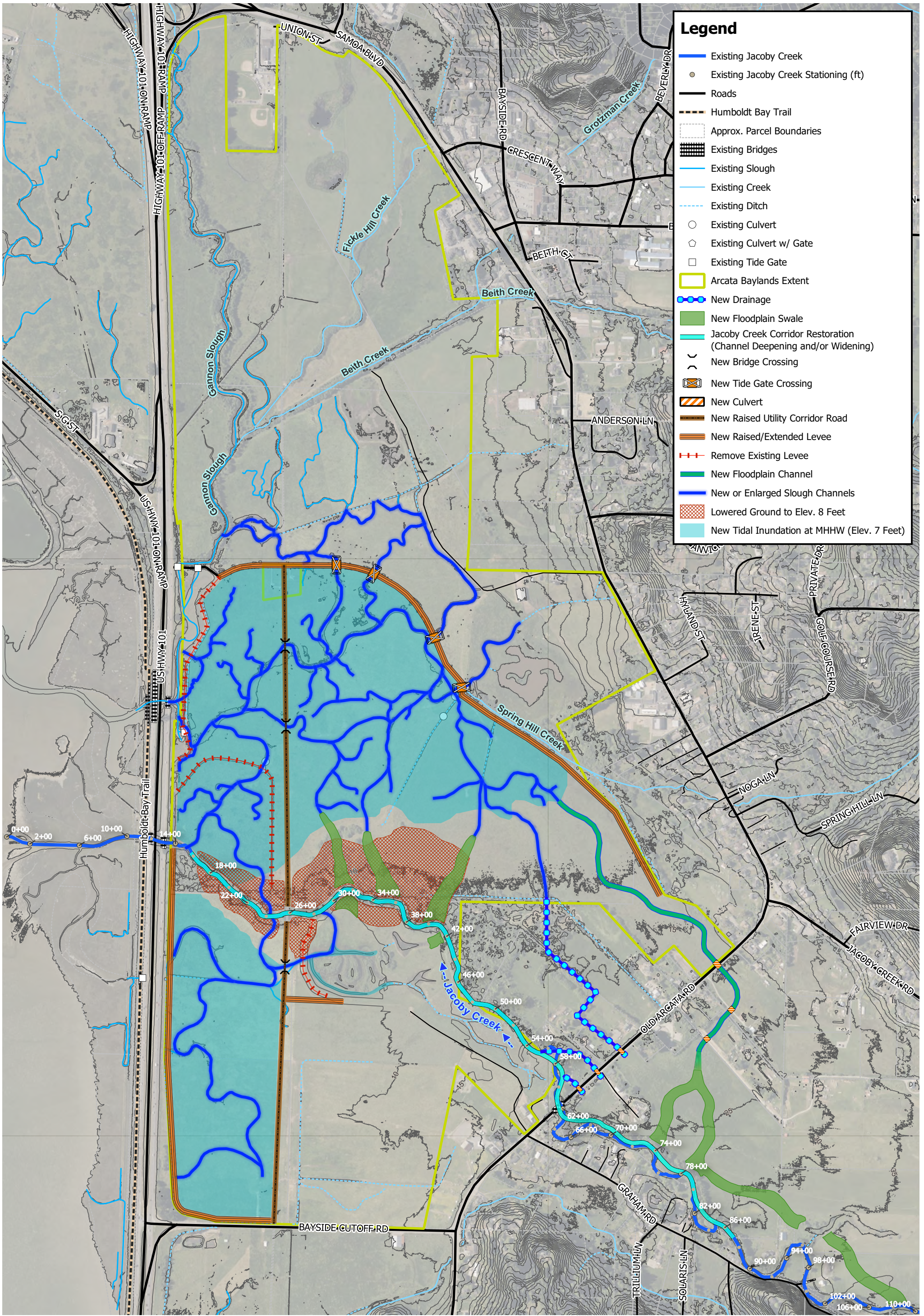
Sources:
 Elevation: 2019 Eureka Coastal Lidar DEM
 Aerial Image: 2018 Bing Aerial Imagery



Michael Love & Associates
 Hydrologic Solutions

Jacoby Creek Water Sustainability and Anadromous Fish Habitat Enhancement Feasibility Study

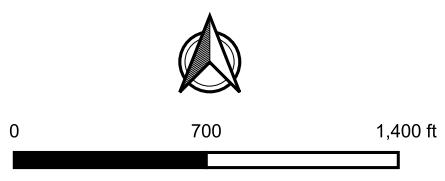
Figure 10-4.
 Alternative 3B - (Area B) Tide Reintroduction Along Jacoby Creek to Support a Deeper and Wider Channel from US 101 Through Lower Graham Road Reach.



- ### Legend
- Existing Jacoby Creek
 - Existing Jacoby Creek Stationing (ft)
 - Roads
 - - - Humboldt Bay Trail
 - Approx. Parcel Boundaries
 - Existing Bridges
 - Existing Slough
 - Existing Creek
 - - - Existing Ditch
 - Existing Culvert
 - Existing Culvert w/ Gate
 - Existing Tide Gate
 - Arcata Baylands Extent
 - New Drainage
 - New Floodplain Swale
 - Jacoby Creek Corridor Restoration (Channel Deepening and/or Widening)
 -) (New Bridge Crossing
 - New Tide Gate Crossing
 - New Culvert
 - New Raised Utility Corridor Road
 - New Raised/Extended Levee
 - - - Remove Existing Levee
 - New Floodplain Channel
 - New or Enlarged Slough Channels
 - Lowered Ground to Elev. 8 Feet
 - New Tidal Inundation at MHHW (Elev. 7 Feet)

Datums:
 Horizontal: NAD83 State Plane CA Zone 1
 Vertical: NAVD88

Sources:
 Elevation: 2019 Eureka Coastal Lidar DEM
 Aerial Image: 2018 Bing Aerial Imagery



Jacoby Creek Water Sustainability and Anadromous Fish Habitat Enhancement Feasibility Study

Figure 10-5.
Alternative 3C - (Area B and C) Tide Reintroduction Along Jacoby Creek to Support a Deeper and Wider Channel from US 101 Through Lower Graham Road Reach.

New tidal levees would parallel US 101 to avoid tidal inundation of the highway embankment. The western portion of the Bayside Cutoff Road surface falls below high tide elevations, requiring an east-west levee segment. Alternatively, flooding on this road could be addressed by raising the roadway to match the elevation of US 101, having it also serve as a tidal levee. A new inland north-south levee would also serve as the elevated utility corridor.

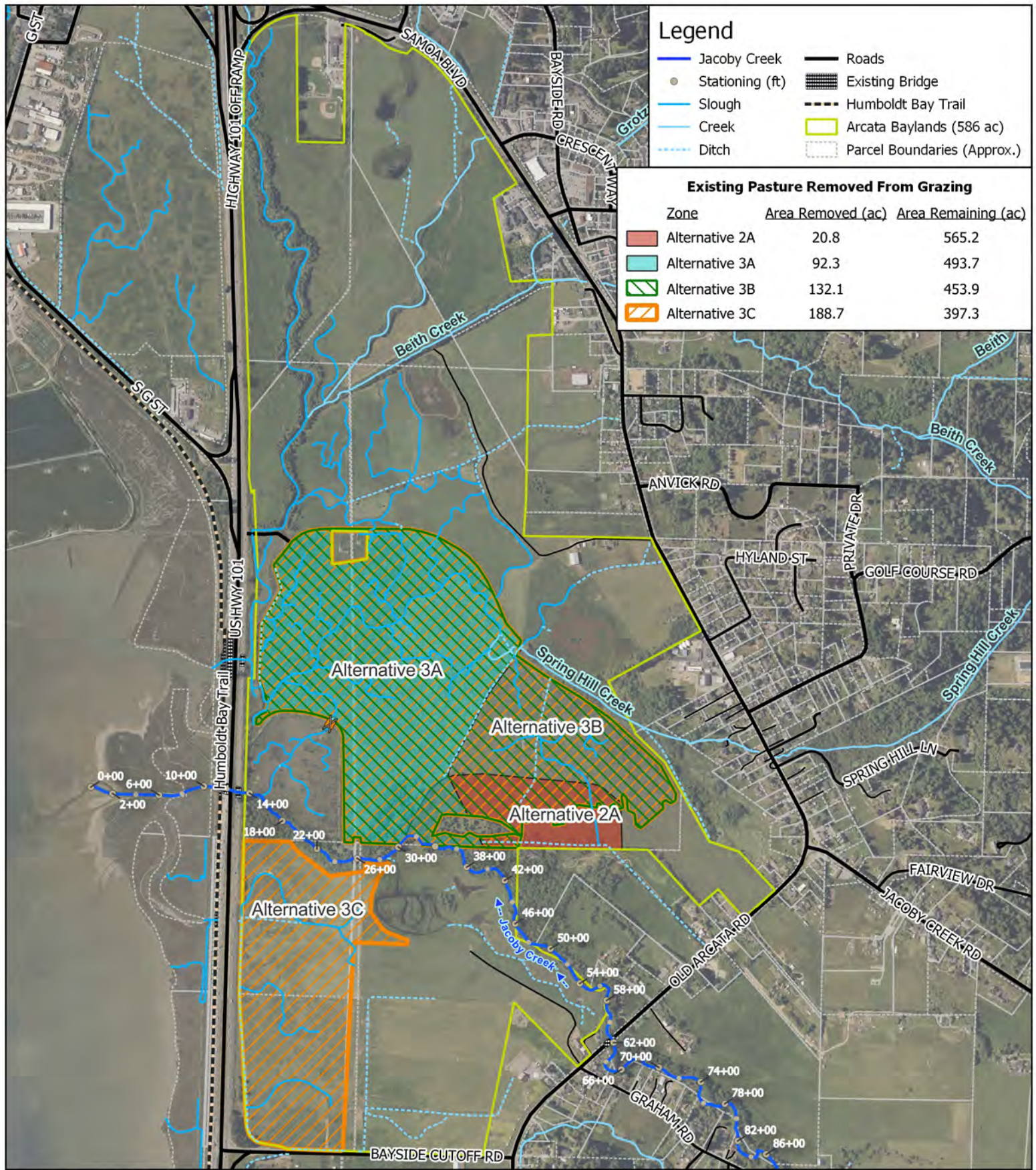
Given the lower elevation of the existing South Jacoby Wetland Complex, it would convert into a tidal wetland. A bridge crossing would be included along the utility corridor to accommodate a new slough channel connecting to the wetland complex. In total, 6,500 feet of new tidal levees, including the elevated utility corridor, are shown encompassing the south cell.

10.3.2 Considerations

Alternative 3 uses tidal reintroduction to effectively shorten the length of Jacoby Creek, resetting the channel profile, and increasing channel capacity extending upstream of OAR through the lower Graham Road reach. The deepening and enlargement of the channel will increase sediment transport capacity, conveying sediment downstream to the tidal reaches. The enlarge channel will also greatly lower the frequency of floodplain inundation along both sides of the channel. Floodplain flows along the north side of Jacoby Creek will be guided through swales and the floodplain channel, further reducing the inundation frequency of OAR and adjoining properties. Quantifying the degree of flood reduction would be part of the analysis conducted during the next phase of the project.

The interconnection between Jacoby Creek and the new tidal cell(s) would allow both coarse and fine sediment delivered from upstream to be deposited onto the new tidal marshes. This increase in delivery of fluvial sediment combined with reintroduction of tidally derived sediments from the bay would accelerate accretion rates on the marsh to keep pace with SLR. The configuration of the northern tidal cell in 3B and 3C also provides habitat resilience to SLR by allowing the tidal marsh to expand inland unimpeded by tidal levees along its eastern edge. This is also provided along a portion of the southern cell in 3C. Alternative 3A configuration, if constructed, could be expended to the 3B configuration as part of a phased approach, if desired, as part of a phased retreat strategy for increasing SLR. Also, any of these tidal cells could be expanded in phases as part of such strategy.

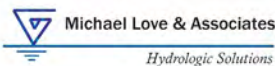
Currently the City of Arcata leases approximately 586 acres of the Baylands for grazing. The reduction in leased grazing areas on City property associated with Alternative 3 A, B, and C of 92.3 acres, 132.1 acres, and 188.7 acres respectively is shown in Figure 10-6. Although grazing would be lost within the areas converted to tidal marsh, other areas within the footprint of the project could continue to be managed as short grass habitat with cattle grazing. The areas retained for grazing may also exhibit improved drainage and productivity associated with implementation of the Alternative, potentially benefiting continued grazing operations and foraging of Aleutian geese. The northern tidal cell in Alternative 3 also provides the opportunity for public access to the City's wildlife areas, consistent with one of the intended uses for the property (see Section 2.2.2). The tidal levees and utility corridor berm could serve as walking paths.



Datums:
Horizontal: NAD83 State Plane CA Zone 1

Sources:
Aerial Image: 2018 Bing Aerial Imagery

0 1,000 2,000 ft



Jacoby Creek Water Sustainability and Anadromous Fish Habitat Enhancement Feasibility Study

Figure 10-6
Approximate reduction in City of Arcata grazing areas associated with each alternative.

10.4 Probable Construction Cost

A Rough Order of Magnitude (ROM) opinion of probable construction cost range was developed for each alternative and shown in Table 10-1. The opinion of costs developed are considered a Class 5 Estimate with an expected accuracy range of +70% to -50%. The opinion of costs include a 30% estimating contingency and are intended to allow for cost comparison of alternatives based on preliminary concepts. These estimates will be refined and revised as the designs are further developed.

Please note that in providing estimates of likely construction costs, the Project Team has no control over the actual costs at the time of construction. The actual cost of construction may be impacted by the availability of construction equipment and crews and fluctuation of supply prices at the time the work is bid. The Project Team makes no warranty, expressed or implied, as to the accuracy of such estimates as compared to bids or actual costs.

Table 10-1. Rough Order of Magnitude (ROM) Opinion of Probable Construction Cost range.

Alternative	\$ Millions (-50% to +70%)
1	\$2-7
2	\$8-26
3A	\$19-63
3B	\$20-64
3C	\$24-80

10.5 Additional Habitat Enhancement Opportunities on JCLT Properties

In outreach with landowners and during field characterization of the Study Area and alternatives scoping process additional opportunities for wetland, riparian, and stream habitat enhancements were noted. Of particular focus was opportunities on the JCLT fee parcel upstream of the Kokte Ranch that borders Jacoby Creek. The 23 acre parcel is sloping downward to the south towards Jacoby Creek, transitioning from upland to low lying wetland pasture, with riparian forest along the Jacoby Creek corridor. On the southern end of the parcel is the Upper JCLT Pond (Figure 2-1) constructed for winter use by rearing juvenile salmonids. It is directly connected to Jacoby Creek and receives inflows from a ditch at the head of the pond. The ditch drains a small watershed north of Jacoby Creek Road, sometimes referred to as Arrow Creek.

The JCLT and adjoining neighbor are interested in moving this drainage out of the straight ditch and into a natural sinuous channel with connected wetlands and riparian forest on the JCLT property. This would create habitat for numerous aquatic, avian, and terrestrial organisms, further enhancing the overall lower Jacoby Creek restoration project. As restoration planning advances, this concept can be integrated into any of the alternatives previously described.

11 ENVIRONMENTAL CONSTRAINTS ANALYSES

Advancing the project alternatives from the current feasibility study to alternative selection and implementation will require engaging with state and federal agencies to coordinate with existing policies and obtain permits to demonstrate adherence to state and federal regulations. The following state and federal environmental regulations will need to be considered as the project alternatives advance. It is recommended that these pathways be confirmed with the respective agencies as part of the next planning phase.

11.1 Environmental Review

11.1.1 California Environmental Quality Act

The California Environmental Quality Act (CEQA) ensures that projects have been adequately assessed for environmental impacts, and that project alternatives have been explored and thoroughly considered prior to a project being adopted or permitted. The CEQA process is led by a Lead Agency but involves review by many state agencies, the public, and potentially federal agencies. Lead Agencies can be local or state agencies with jurisdictional authority, land use control, and/or funding contributions related to the Project. The Lead Agency has not been determined for this project.

Possible lead agencies could include:

- Humboldt County (public road right-of-way owner)
- City of Arcata (property owner)
- State funders (State Coastal Conservancy, Wildlife Conservation Board, etc.)
- Other Public Agency or Special District (Humboldt County Resource Conservation District)

The CEQA pathway determined will be based on the alternative selected and the discretion of the Lead Agency. Two new CEQA pathways have been recently approved for restoration projects and are described below.

In 2022 the SWRCB issued the State Restoration General Order (SRGO) which provides Clean Water Act Section 401 water quality certification coverage (for projects that require a Clean Water Act Section 404 permit), and Waste Discharge Requirement coverage for projects that do not require a Section 404 permit. The order includes certification of a Programmatic Environmental Impact Report (PEIR) and approves the associated Mitigation, Monitoring and Reporting Program (MMRP). Projects that qualify for use of the SRGO include the following (the qualifying project activities that are proposed in the project alternatives are in bold):

1. Improvements to Stream Crossings and Fish Passage
2. Removal of Small Dams, Tide Gates, Flood Gates, and Legacy Structures (included in proposed project alternatives)
3. Bioengineered Bank Stabilization
4. Restoration and Enhancement of Off-Channel and Side-Channel Habitat (included in proposed project alternatives)
5. Water Conservation Projects
6. Floodplain Restoration

7. Removal or Remediation of Pilings and Other In-Water Structures
8. Removal of Nonnative Terrestrial and Aquatic Invasive Species and Revegetation with Native Plants
9. Establishment, Restoration, and Enhancement of Tidal, Subtidal and Freshwater Wetlands (included in proposed project alternatives)
10. Establishment, Restoration, and Enhancement of Stream and Riparian Habitat and Upslope Watershed Sites

All project alternatives contain restoration elements and therefore it is anticipated that the portions of the selected project that include restoration elements will be permitted through the SRGO process, and portions of the selected project that include flood reduction activities would be permitted via a Supplemental Project-level EIR. Special studies, such as biological and cultural resources, would need to be conducted throughout the entire project area regardless of whether it is in the PEIR or Supplemental Project-level EIR areas for CEQA and permitting purposes.

An additional CEQA streamlined pathway is the Statutory Exemption for Restoration Projects (SERP) which adds Section 21080.56 to the California Public Resources Code and provides a CEQA statutory exemption until January 1, 2030 for fish and wildlife restoration projects that meet certain requirements. CDFW's Cutting the Green Tape program coordinates with lead agencies seeking to utilize the SERP pathway. Similarly to SRGO, project alternatives that include restoration components will meet the SERP statutory exemption however may require a Supplemental Project-level EIR document for components that are found to not be incidental to restoration.

11.1.2 National Environmental Policy Act

The National Environmental Policy Act (NEPA) is a federal law that requires a process for reviewing and weighing environmental quality equally with other considerations when permitting a project or policy that is either funded or otherwise influenced by a federal agency. It establishes a formal planning framework, review process, and means for public input. For this project, the USACE would complete NEPA as part of their Clean Water Act Section 404 review. If federal funding is used on this project, then NEPA would be required to be completed by the funding lead agency (which could tier off of the USACE NEPA documentation).

11.2 Wetlands and Waters

11.2.1 Wetlands “No Net Loss” Policy

An important feature of much environmental permitting is the implementation of a “no net loss” policy related to the filling and mitigation of wetlands. Initiated as a federal goal in 1977, this policy is also fundamental to many state environmental regulations. Multiple agencies, including the U.S. Army Corps of Engineers (USACE), Regional Water Quality Control Board (RWQCB), and the California Coastal Commission (CCC) will have criteria and review process for ensuring that wetlands impacted by a project will be adequately replaced or mitigated.

Regardless of which project alternative is selected, actions that result in fill or excavation of one- or three-parameter wetlands would be accompanied by creation of wetlands or other waters (i.e. drainage channels) to achieve a no net loss. An overall loss of either three- or one-parameter wetlands is not anticipated for any of the current alternatives, however this would be assessed as part of the next planning phase.

11.2.2 Clean Water Act

Construction activities frequently trigger review for compliance with Sections 404 and 401 of the Clean Water Act. Section 404 governs the dredging and filling of Waters of the United States and is regulated through the USACE. Section 401 pertains to water quality standards and is regulated through the United States Environmental Protection Agency (EPA), which delegates authority to the State Water Resources Control Board (SWRCB), which in turn delegates authority to its regional offices, or RWQCBs. Due to the dredging and filling of Waters of the U.S. anticipated to occur under either project alternative, a Section 404 permit and Section 401 Water Quality Certification are anticipated to be necessary. Due to the project size, a Section 404 Individual Permit from the USACE is anticipated.

11.2.3 Porter-Cologne Act

The Porter-Cologne Act is also the California Water Code Division 7, which established the SWRCB and RWQCBs. It applies federal National Pollutant Discharge Elimination System (NPDES) permits and mandates water quality control plans for Waters of the State. For Waters of the U.S., Section 401 Water Quality Certification through the RWQCB also provides coverage of the Porter-Cologne Act (as described above).

However for dredging or filling of Waters of the State, that are not considered Waters of the U.S., a Waste Discharge Requirement would be required. Recent supreme court case *Sackett v. EPA* resulted in a revised definition of Waters of the U.S., and an increase in wetlands and waters that are no longer considered Waters of the U.S. but are considered Waters of the State and thus regulated under the Porter-Cologne Act through a Waste Discharge Requirement permit.

11.2.4 Lake and Streambed Alteration Agreement

A Lake and Streambed Alteration Agreement (LSAA) is required for any activity that diverts, obstructs, changes the channel, bed, or banks of any river, stream, or lake, or otherwise uses or disposes of material from any river, stream or lake. An LSAA will be required for all project alternatives due to the earthwork in and along the banks of Jacoby Creek.

11.3 California Coastal Act

The California Coastal Commission, in partnership with coastal cities and counties, implements the Coastal Act, established in 1976. The Coastal Act sets forth standards for public access and protection of coastal resources. As a part of its responsibility to administer the Coastal Act, the Coastal Commission also issues guidance and resources for local governments on climate change adaptation and coastal resilience. It issues Coastal Development Permits (CDP) for development projects in areas of its CDP jurisdiction, and delegates CDP issuance responsibilities to local jurisdictions with Local Coastal Programs (LCP) that have been certified by the Commission, such as cities or County. For this project, the Coastal Zone is located westward of Bayside Road/Old Arcata Road, and the Coastal Commission has jurisdiction within the project alternative footprints. Therefore, the project will need to acquire a CDP from the Coastal Commission.

In some cases, the Coastal Commission also performs Federal Consistency Determinations to ensure that federal projects within the Coastal Zone or which may have spillover effects on the Coastal Zone adhere to federal Coastal Zone Management Act policies. It is possible, though unlikely, that the Coastal Commission may exercise their Federal Consistency Determination and issue a CDP for the entire project (including the area outside of the Coastal Zone).

The following sections of the Coastal Act are important to note due to their implications for special studies to determine whether said resources are present, such as a Wetland Delineation Report (or Upland Delineation Report, due to the large amount of wetlands within the project footprints), and Biological Resources Report to inventory the potential presence of rare plants, sensitive habitat, and determine likelihood for special status species. One-parameter wetlands (i.e. wetlands that contain either hydric vegetation, soils or hydrology) are regulated by the Coastal Commission, and therefore one-parameter wetlands should be mapped during the delineation effort.

11.3.1 Section 30233: Wetland Fill

Allowable diking, dredging, and filling of open coastal waters, wetlands, estuaries, and lakes under Section 30233 of the Coastal Act is permitted only for seven specific types of projects, and in those cases only if there is no feasible less environmentally damaging activity and if feasible mitigation measures are provided to minimize adverse environmental effects. These project types include:

1. New or expanded port, energy, and coastal-dependent industrial facilities
2. Maintaining existing or previously dredged navigation channels, turning basins, and similar boating areas
3. New or expanded boating facilities (disallowed in wetlands)
4. Incidental public services, such as burying cables and pipes
5. Mineral extraction
6. Restoration purposes
7. Nature study, aquaculture, and similar resource dependent activities

The project alternatives are anticipated to be considered restoration and incidental public services projects, because each alternative includes components of restoration and storm- and creek-derived water management to reduce flooding for property owners along Old Arcata Road and Graham Road, and automobilists along Old Arcata Road. The project will not result in a net loss of wetlands, however is anticipated to result in a change in type of wetland (e.g. seasonal freshwater wetlands may become tidal wetlands). Beneficial fill placement on seasonal agricultural wetlands is anticipated to be implemented, however the placement would not exceed a thickness to result in a conversion of wetlands to uplands, or would be mitigated for onsite by creating wetlands from existing uplands to results in a net loss of wetlands.

In evaluating potential allowability for wetland dike, dredge, and fill under Section 30233, the Commission requires an analysis to demonstrate the proposed project is the least environmentally damaging feasible activity in the context of wetland impacts.

11.3.2 Section 30240: Environmentally Sensitive Habitat Areas

- a) Environmentally sensitive habitat areas shall be protected against any significant disruption of habitat values, and only uses dependent on those resources shall be allowed within those areas.
- b) Development in areas adjacent to environmentally sensitive habitat areas and parks and recreation areas shall be sited and designed to prevent impacts which would significantly degrade those areas, and shall be compatible with the continuance of those habitat and recreation areas.

11.3.3 Section 30241: Prime Agricultural Land

The maximum amount of prime agricultural land shall be maintained in agricultural production to assure the protection of the areas' agricultural economy, and conflicts shall be minimized between agricultural and urban land uses through all of the following (...)

The listed reasons do not apply to this project and are therefore not included in this analysis. An agricultural analysis should be conducted during the next phase to determine whether prime agricultural land exists within the footprint of the project alternatives.

11.3.4 Section 30242: Agricultural Land

All other lands suitable for agricultural use shall not be converted to nonagricultural uses unless (1) continued or renewed agricultural use is not feasible, or (2) such conversion would preserve prime agricultural land or concentrate development consistent with Section 30250. Any such permitted conversion shall be compatible with continued agricultural use on surrounding lands.

An agricultural productivity analysis should be conducted to provide justification that proposed placement of fill, such as to create set-back berms, on agricultural lands would preserve and potentially enhance agricultural productivity, and to determine whether prime agricultural land exists within or adjacent to the project footprints.

11.3.5 Section 30253: Minimize Development in Hazardous Areas

Section 30253 requires the minimization of development, and therefore risks to life and property, in areas of high geologic, flood, and fire hazards. The policy also requires that new development "assure stability and structural integrity," and therefore not require "construction of protective devices that would substantially alter natural landforms along bluffs and cliffs." The project alternatives do not include new development that would put life or property at risk and is designed to enhance habitat while reducing flooding, thereby protecting property and infrastructure from coastal flooding hazards.

11.3.6 Section 30270: Sea Level Rise Considerations

Section 30270 requires the Commission to consider the effects of sea level rise in project evaluation in order to avoid and mitigate potential effects, to the extent feasible. Sea level rise is a threat to coastal infrastructure, predominantly agricultural land located west of Highway 101 and the City of Eureka's water transmission lines. project alternatives will improve coastal resilience via relocating critical infrastructure and retreating from degraded shoreline protective structures.

11.4 Endangered Species

11.4.1 Endangered Species Act

Under the Endangered Species Act (ESA), the "taking" of ESA-listed, candidate or proposed species and their habitats is regulated through a review and mitigation process under the supervision of the United States Fish and Wildlife Service (USFWS) and/or National Oceanic and Atmospheric Agency (NOAA) Fisheries Service. Under Section 7 of the ESA, federal agencies are required to consult with either USFWS and/or NOAA Fisheries for any actions that they authorize, fund, or otherwise implement. Formal consultation under the ESA includes preparation of a Biological Assessment to USFWS and/or NOAA Fisheries and issuance of a Biological Opinion including the allowable take of the species or habitat, and conservation measures to reduce take. Due to the

presence of ESA-listed species in Jacoby Creek (i.e. Coho Salmon, Steelhead, Tidewater Goby) and actions to occur within the Jacoby Creek channel and lower tidal floodplain, formal consultation under the ESA is anticipated to occur between the USACE and NOAA Fisheries. Depending upon the alternatives, the project may be eligible for NOAA Fisheries updated Programmatic Biological Opinion which provides a streamlined pathway for ESA consultation. Should this route be taken, the portions of the project that are not considered for restoration purposes would need to complete ESA consultation separately.

11.4.2 California Endangered Species Act

Similar to the federal ESA, the California Endangered Species Act (CESA) regulates the take of CESA-listed, candidate or proposed species. The California Department of Fish and Wildlife (CDFW) may provide a Consistency Determination with a Biological Opinion when it contains findings that adequately address CESA, with no additional CESA permits required. Other means of complying with CESA include attainment of an Incidental Take Permit, or Safe Harbor Agreement. An Incidental Take Permit allows a permittee to take a CESA-listed species if such taking is incidental to and otherwise lawful activity, and a Safe Harbor Agreement allows for incidental take of a listed species when the larger project provides net benefits to a species. The anticipated pathway of CESA compliance for whichever project alternative is selected is a Consistency Determination.

11.5 Wildlife

11.5.1 Migratory Bird Treaty Act of 1918

This international treaty established federal responsibilities for the protection of nearly all species of birds, their eggs, and nests. A migratory bird is defined as any species or family of birds that live, or migrate within or across international borders at some point during their annual life cycle. The MBTA prohibits the take, possession, buying, selling, purchasing, or bartering of any migratory bird including feathers or other parts, nests, eggs, or products. To comply with the Migratory Bird Treaty Act, surveys for nesting birds occur during the nesting season (March 15 through August 15) within the vicinity of project disturbance, and no-work buffers are implemented around nests. The size of the buffers are based upon the species that is nesting. It is recommended that all vegetation planned for removal be removed outside of the nesting bird season, to avoid more labor-intensive (and expensive) nesting bird surveys and associated potential no-work buffers.

11.5.2 California Fish and Game Code – Birds of Prey and Native Nesting Birds

Section 3503 of the California Fish and Game Code prohibits the take, possession, or needless destruction of the nest or eggs of any bird. Subsection 3503.5 specifically prohibits the take, possession, or destruction of any birds in the orders *Falconiformes* (hawks and eagles) or *Strigiformes* (owls) and their eggs or nests. These provisions, along with the federal Migratory Bird Treaty Act, essentially serve to protect nesting native birds. Similar to the Migratory Bird Treaty Act, non-native species, including the European Starling, Rock Dove, and House Sparrow, are not afforded protection under Fish and Game Code. The implementation of pre-construction surveys for nesting birds and (if necessary) no-work buffers satisfies this Fish and Game Code requirement.

11.6 Local Permits

11.6.1 Humboldt County Encroachment, Grading and Conditional Use Permits

Construction activities within the County ROW will require an encroachment permit. Additionally, a Conditional Use Permit (CUP) and grading permit issued by Humboldt County would likely be required for any of the alternatives.

11.6.2 City of Arcata Minor Use Permit

A Minor Use Permit is issued for projects that include a change in land use in a particular zoning district. These are conditional permits meaning certain requirements need to be met to make the permit valid.

11.7 Anticipated Special Studies

The following special studies are anticipated to be necessary to successfully comply with the various regulatory requirements described above. These studies are recommended to be completed during the next planning phase.

- **Wetland Delineation and Report** – an inventory of both one- and three-parameter wetlands using USACE survey protocols should be conducted throughout the project area. Alternatively, due to the large amount of wetland, an upland delineation survey and report may be the preferred route.
- **Biological Resources Assessment and Report** – would include the findings of up to two seasonally-appropriate rare plant surveys, vegetation mapping of Sensitive Natural Communities/Environmentally Sensitive Habitat Areas, inventory of suitable wildlife habitat within the project area, a review of special status species databases to determine the potential likelihood for special status species to occur in the project area footprint, and avoidance measures to reduce potential impacts to biological resources from implementation of the project.
- **Cultural Resources Assessment** – would include a pedestrian archaeological survey, communication with local tribes about the project, and a database review of known archaeological resources in the Project's Area of Potential Effect. The findings of this report will satisfy Section 106 of the National Historic Preservation Act which will be necessary for the USACE who will be completing NEPA.
- **Agricultural Impact Analysis** – this analysis would include an assessment of existing versus proposed conditions on all agriculturally zoned lands within the project area, an investigation of potential Williamson Act contracts, and impact analysis for potential changes to agricultural lands (i.e. conversion out of agricultural production).

11.8 Anticipated Regulatory Approvals

The following regulatory approvals and permits are anticipated to be required by the project applicant for any of the selected project alternatives:

- Section 404 (USACE)
- Section 401 (RWQCB)

- Restoration components of the project to be permitted via the SRGO, and non-restoration components to be permitted via the traditional 401 certification pathway.
- LSAA Section 1600 (CDFW)
- Section 7 ESA consultation for Coho Salmon, Steelhead (NMFS) and Tidewater Goby (USFWS)
 - Potential consultation with USFWS for other unknown species, such as rare plants
- CESA Consistency Determination (CDFW)
- Coastal Development Permit (CA Coastal Commission)
- Conditional Use Permit, Grading Permit and Encroachment Permit (Humboldt County)
- NEPA (funding dependent)
- CEQA (described above)

12 STRATEGIES TO ADVANCE NEXT STEPS

As described in this report, the alternatives developed provide a broad range in scale, complexity and ability to achieve the overarching goals and objectives. To better define the flood reduction and ecological benefits of each alternative, an alternatives analyses is recommended during the next planning phase. The alternatives analyses would include a quantitative assessment to compare and contrast the alternatives and to support an informed selection process. The alternatives analyses will also help determine if a phased implementation approach is necessary given potential constraints related to available funding, right-of-way, permitting, utility relocation and other factors that will be better defined upon completion of the alternatives analyses. Steps to advance the project to completion are described below and correspond with a workplan included in Appendix J. Including steps 1-4 described below in the next planning phase is recommended.

1. **Implement Interim Stream Corridor Management Plan (SCMP).** Advancing an alternative developed in this study to implementation could take minimum of 2-3 years and therefore this step includes implementing the SCMP which will include developing the workplan and obtaining the necessary permitting and CEQA approvals. Implementation of the SCMP will also require obtaining permissions from private property owners adjacent to the creek for ingress/egress and completing any necessary actions. Obtaining these approvals will be required early in the planning process for successful implementation of the SCMP and as an initial step, a determination of an agency lead will be necessary.
2. **Perform Special Studies to Support Alternatives Analysis and CEQA.** This step includes conducting baseline studies including upland delineations, vegetation mapping, biological resources report, cultural resources assessment and agricultural conversion analyses to support evaluation of alternatives and support CEQA.
3. **Alternatives Analyses, Selection and 30% Design.** During this step, additional geomorphic analyses, hydraulic modeling and engineering design will be applied to advance the alternatives; and the baseline studies completed in the above step will be used to compare and contrast the alternatives. This step will also include development of more detailed construction costs for each alternative and engagement with regulatory agencies and stakeholders. Upon completion of this step, the project proponent(s) would select the apparent best alternative, or a combination of alternatives that could be implemented through a phased approach overtime. During this step, a funding strategy would need to be developed to determine the targeted Local, State and/or Federal funding programs and timing necessary to implement and monitor the project.
4. **California Environmental Quality Act (CEQA).** Prior to the start of this step, a lead agency will need to be determined. Potential lead agencies were identified in previous sections of this report. Depending upon the alternative selected, various CEQA pathways could be considered. For Alternatives 2 and 3 the following options may be appropriate whereas for Alternative 1 an Initial Study-Mitigated Negative declaration (IS/MND) would be anticipated.
 - Option A: Programmatic EIR Coverage (PEIR) with Supplemental Project-level EIR
 - o The downstream portion of the project may be covered under State Restoration General Order (SRGO) PEIR due to restoration components of project (assumes

SWRCB okay with flood reduction being a mutual benefit of the project, and would allow downstream project to be considered under SRGO umbrella)

- Supplemental Project-level EIR would be completed for
 - Downstream portion of project for site-specific items (cultural resources, botanical, etc.) that are not included in SRGO PEIR.
 - Upstream portion of project (assuming upstream project is at 30% design)
 - Option B: CDFW Statutory Exemption for Restoration Projects (SERP)
 - Given the project includes flood reduction components that are incidental to the broader restoration approach, this option should be explored with CDFW and could greatly simplify the CEQA process.
 - Option C: Project-level EIR
 - Complete an EIR for entire Project (both upstream and downstream components)
5. **Engineering Design, ROW and Permits.** Under this task, the design of the selected alternative will be advanced, and regulatory permits will be developed and submitted to the regulatory agencies. Any Right-of-Way needed to implement and maintain the project would be defined and obtained during this step. A monitoring and management plan would also be developed during this step that would define the recommended biological and physical monitoring and potential management actions needed to keep the project aligned with meeting its goals and objectives long-term.
 6. **Construction Award, Administration and Management.** This step includes awarding the construction contract, and administering and managing the construction contract during project construction.
 7. **Post-Construction Monitoring.** The step includes post-construction monitoring and reporting to document the performance of the project in meeting the stated goals and objectives. The reporting requirements are commonly defined during the permitting process.

13 REFERENCES

- Alvernaz, M.B, L. Roelofs, H.J. Pierik, and M.G. Kleinhans. 2000. Natural levee evolution in vegetated fluvial-tidal environments. *Earth Surf. Process. Landforms* 45, 3824-3841.
- Arcement, George and Schneider, Verne. 1989. Guide for selecting Manning's roughness coefficients for natural channels and floodplains. USGS Water-Supply Paper 2339.
- Cahoon, D. R., K. L. McKee, and J. T. Morris. 2021. How Plants Influence Resilience of Salt Marsh and Mangrove Wetlands to Sea-Level Rise, *Estuaries and Coasts*, 44:883-898, <https://doi.org/10.1007/s12237-020-00834-w>.
- California Coastal Commission. 2018. California Coastal Commission Sea Level Rise Policy Guidance: Interpretive Guidelines for Addressing Sea Level Rise in Local Coastal Programs and Coastal Development Permits" State & Federal Reports and Publications. 4. https://digitalcommons.humboldt.edu/hsuslri_state/4
- Chow, V.T, D. R. Maidment, and L.W. Mays. 1988. *Applied Hydrology*. McGraw-Hill, Inc. New York.
- Curtis, J.A., K.M. Thoren, C.M. Freeman, K.J. Buffinton, and J.Z. Drexler. A Summary of Water-Quality and Salt Marsh Monitoring, Humboldt Bay, California. U.S. Geologic Survey, Open-File Report 2022-1076.
- Curtis, J. A., C. Freeman, and K. Thorne. 2019 Early results-salt marsh response to changing fine-sediment supply conditions, Humboldt Bay, CA.
- Curtis, J. et al. 2021 DRAFT. Amplified impacts of climate change on fine-sediment delivery from fluvial sources and implications for building ecosystem-based resiliency to sea-level rise, Humboldt Bay, California
- Eicher, A. 1987. Salt Marsh Vascular Plant Distribution in Relation to Tidal Elevation, Humboldt Bay, California. M.A. Thesis, Humboldt State University.
- Gotvald, A. J., Barth, N. A., Veilleux, A. G., & Parrett, C. 2012. Methods for Determining Magnitude and Frequency of Floods in California, Based on Data through Water Year 2006. Tech. rep., U.S. Geologic Survey.
- Humboldt State University (HSU) and Michael Love & Associates (MLA). 2022. Eureka-Arcata corridor tide gate replacement project: post-project monitoring. Prepared for Caltrans District 1.
- IPPC. 2019. Refinement to the 2006 IPCC Guidelines for National Greenhouse Gas Inventories. The Intergovernmental Panel on Climate Change.
- Julien. P. 2010. *Erosion and Sedimentation*, Second Edition. Cambridge University Press. 371 pp.
- Laird, A., Powell, B., Robinson, J., & Schubert, K. 2008. Historical Atlas of Humboldt Bay and Eel River Delta. Digital database of historical photos, imagery, and maps.
- Lane, E.W. 1954. The Importance of Fluvial Morphology in Hydraulic Engineering. Hydraulic Laboratory Report No. 372. United States Department of the Interior, Bureau of Reclamation. Denver, CO.

- Northern Hydrology & Engineering (NHE). 2018. Sea-Level Rise in the Humboldt Bay Region. Prepared for City of Arcata. March 2018
- National Marine Fisheries Service (NMFS). 2014. Recovery Plan for Southern Oregon/Northern California Coast Coho Salmon (*Oncorhynchus kisutch*). National Marine Fisheries Service. Arcata, CA.
- Ocean Protection Council (OPC). 2018. State of California Sea-Level Rise Guidance 2018 Update. California Natural Resources Agency.
- Parker, G. and Klingeman, P. 1982. On Why Gravel Beds are Paved. *Water Resources Research*, Vol 18, No. 5: 1409-1423
- Patton, J, T. Williams, J. Anderson, M. Hemphill-Haley, R.J. Burgette, R. Weldon II, R.C. McPherson, and T. Leroy. 2023. 20th to 21st Century Relative Sea and Land Level Changes in Northern California: Tectonic Land Level Changes and their Contribution to Sea-Level Rise, Humboldt Bay Region, Northern California. *Tektonicka*. Vol 1.1, 16 pages.
- Patton, J, T. Williams, J. Anderson, and T. Leroy. 2017. Tectonic land level changes and their contribution to sea-level rise, Humboldt Bay regions, Northern California. Final Report. Prepared for U.S. Fish and Wildlife Service Coastal Program. Cascadia GeoSciences, McKinleyville, CA
- Redwood Community Action Agency (RCAA). 2005. Humboldt Bay Watershed Salmon and Steelhead Conservation Plan.
- Rohde, Jerry. 2020. Humboldt Bay Shoreline, North Eureka to South Arcata: A History of Cultural Influences. June 2020. 162 pages.
- Schafran, Walter. 1984. Bayside through the years. Humboldt Bay Maritime Museum.
- U.S. Bureau of Reclamation (USBR) and U.S. Army Corps of Engineers (USACE). 2019. Best Practices in Dam and Levee Safety Risk Analysis. Version 4.1. July 2019.
- U.S. Geological Survey. 2019. The StreamStats program, online at <https://streamstats.usgs.gov/ss/> .
- U.S. Geological Survey. 1967. `Roughness characteristics of natural channels. Water-supply paper 1849.
- Van Kirk, Susie. 2015. Research Nots on Bayside and Jacoby Creek. Susie Van Kri Papers. 10. <https://digitalcommons.humboldt.edu/svk/10>
- Van Kirk, Susie. 2015. Arcata marsh history: Union Wharf, Mad River Canal, Reclamation, Lumber Mills, city designs. Susie Van Kirk Papers. 1. <https://digitalcommons.humboldt.edu/svk/1>
- Whitmore, C.M., C.E. Warren, and P. Doudoroff. 1960. Avoidance reactions of salmonid and centrarchid fishes to low oxygen concentrations. *Transactions of the American Fisheries Society*. 89:17-26.