US Army Corps
of Engineers ®
Portland District

Tillamook Bay and Estuary, Oregon
General Investigation Feasibility Report

February 2005

ABBREVIATIONS AND ACRONYMS

Corps	U.S. Army Corps of Engineers
cfs	cubic feet per second
ESA	Endangered Species Act
FEMA	Federal Emergency Management Agency
GI	General Investigation
LWD `	large woody debris
NEP	National Estuary Project
NRCS	Natural Resources Conservation Service
ODFW	Oregon Department of Fish and Wildlife
OWRD	Oregon Water Resources Department
PWA	Philip Williams and Associates, Ltd.
RM	river mile(s)
TBHEID	Tillamook Bay Habitat and Estuary Improvement District
TCSWCD	Tillamook County Soil and Water Conservation District
USEPA	U.S. Environmental Protection Agency
USGS	U.S. Geological Survey
USFWS	U.S. Fish and Wildlife Service

Executive Summary

The Tillamook Bay and Estuary, Oregon, General Investigation study was authorized by a U.S. Senate Committee Resolution on June 5, 1997. The purpose of the study is to evaluate flood damage reduction and ecosystem restoration in the Tillamook Bay watershed in Tillamook County in northwestern Oregon. The feasibility report describes the progression of the study and the activities that have been completed to date. It provides a status of the potential alternatives evaluated, including initial modeling results and preliminary cost estimates. The feasibility report is the final response to the study authority.

A Feasibility Cost Sharing Agreement was executed in July 1999 with Tillamook County Soil and Water Conservation District. Tillamook County requested to become the formal sponsor, which the District agreed to on February 17, 2000. A Feasibility Study Advisory Council was established to provide local public oversight for the study.

Five major rivers enter into Tillamook Bay and estuary. The lower valleys of three of these rivers (Wilson, Trask and Tillamook) merge to form a broad alluvial plain to the east and south of the bay on which the City of Tillamook is located. Declared a federal disaster area because of the February 1996 flood, Tillamook County suffered over $53 million in damage, which is the equivalent of 148% of the county's annual budget. The lower portions of the rivers overflow frequently because channel capacity is inadequate to handle heavy flows during severe rainstorms when combined with high tides. The resulting flooding cut off access to U.S. Highway 101, the major north-south arterial along the Pacific Coast, and inundated residential, commercial, and pasture areas. No vehicular access was possible between the north and south portions of the county.

Designated as a significant tidal estuary in the National Estuary Program and a component of the Oregon Coastal Salmon Restoration Initiative (*Oregon Plan*), Tillamook Bay and its watershed are economically and ecologically valuable to the State of Oregon. An extensive analysis of the watershed was conducted under the National Estuary Program, which resulted in the identification of four goals that were consistent with the Corps' study authority. These goals included: (1) restoration of critical habitat for salmonid species; (2) reduction of sedimentation for salmonid spawning and rearing habitat; (3) reduction of bacterial contamination; and (4) reduction of magnitude, frequency, and impact of flood events.

Fifty-nine potential alternative measures were initially considered. During the process to prioritize and narrow the measures, the sponsor decided to support only those alternatives providing both ecosystem restoration and flood damage reduction benefits, as well as having overall public support. This reduced the number of alternative measures to 33. Further evaluation with an area of focus in and around the City of Tillamook, and based on engineering and biological evaluation, further reduced this number to 14 potential alternatives.

A one-dimensional, hydrodynamic model of the five rivers was developed as the primary evaluation tool for screening the 14 potential alternatives. Preliminary model runs were performed to increase the understanding of the system and to aid in the process of prioritization and narrowing of alternatives. From the modeling results, it appeared that some of the potential alternatives would not provide many benefits for flood damage reduction. The sponsor decided that these alternatives would no longer be considered for further evaluation. The Wetland Acquisition/Swale and Hall Slough alternatives were evaluated further because they had the greatest potential to provide both ecosystem restoration and flood reduction benefits.

The Hall Slough alternative consists of reconnection of tidal flows in the historic slough, high flow flushing from the Wilson River, and setback levees with riparian plantings. It is a high priority ecosystem restoration action and would eliminate flooding in the Highway 101 business district up to approximately the 2-year flood event. Because the sponsor indicated that they do not have adequate funds for implementation at this time, the alternative was not developed further.

The Wetland Acquisition/Swale alternative would restore tidal marsh/wetlands with actions to offset flood increases. It is a high priority ecosystem restoration action and would reduce flooding for lower flood events. However, the sponsor requested that remaining study funds focus on developing the Modified Wetland Acquisition alternative endorsed by the Tillamook Bay Habitat and Estuary Improvement District. The Modified Wetland Acquisition alternative meets ecosystem restoration requirements without causing an increase in flood elevations, meets the requirements of the sponsor, and is acceptable to the community. After initial evaluation and modeling, the sponsor requested that the Modified Wetland Acquisition alternative be transferred to either the Continuing Authorities Program or to Section 536 of the Water Resources Development Act of 2000 (Public Law 106-541) for further evaluation and implementation.

Tillamook Bay and Estuary, Oregon
General Investigation Feasibility Report

Table of Contents

Table of Contents (continued)

LIST OF TABLES

LIST OF FIGURES

APPENDICES

Appendix A
Overview of Hydrologic Study and Model Development, prepared by the U.S. Army Corps of Engineers, Portland District.

Appendix B
Hydraulic Modeling for the Tillamook Bay and Estuary Study, prepared by WEST Consultants, Inc.

Appendix C
MIKE11 to HEC-RAS Conversion, prepared by WEST Consultants, Inc.

Appendix D
Fluvial Geomorphic Analysis of the Tillamook Bay Basin Rivers, prepared by Monte Pearson, BOHICA Ent.

Appendix E
Modeling 2-Dimensional Unsteady Flow at the Confluence of Riverine and Estuarine Regimes, prepared by Hans R. Moritz[1], Arun Chawla[2], Michael T. Knuston[1], Jessica R. Hays[1], U.S. Army Corps of Engineers, Portland District[1] and OGI School of Science and Engineering, Oregon Health and Science University[2]; and *Numerical Simulation of Flow Fields in the Tillamook Bay*, prepared by OGI School of Science and Engineering, Oregon Health and Science University.

Appendix F
Coordination

1. INTRODUCTION

1.1. PURPOSE AND NEED

The purpose of the Tillamook Bay and Estuary, Oregon, General Investigation (GI) study is to evaluate flood damage reduction and ecosystem restoration in the Tillamook Bay watershed in Tillamook County in northwestern Oregon (Figure 1, located at the end of this chapter). Five major rivers enter into Tillamook Bay and estuary. The lower valleys of three of these rivers (Wilson, Trask and Tillamook) merge to form a broad alluvial plain to the east and south of the bay on which the City of Tillamook is located. The lower portions of the rivers overflow frequently because channel capacity is inadequate to handle heavy flows during severe rainstorms when combined with high tides. Designated as a significant tidal estuary in the National Estuary Program (NEP) and a component of the *Oregon Coastal Salmon Restoration Initiative* (*Oregon Plan*), Tillamook Bay and its watershed are ecologically and economically valuable to the State of Oregon. Tillamook County is the local sponsor for the study.

The feasibility report describes the progression of the study and the activities that have been completed to date. It provides a status of the potential alternatives evaluated, including initial modeling results and preliminary cost estimates. The feasibility report is the final response to the study authority.

1.2. STUDY AUTHORITY

The Tillamook Bay and Estuary, Oregon, GI study was authorized by a U.S. Senate Committee Resolution on June 5, 1997:

> *RESOLVED BY THE COMMITTEE ON ENVIRONMENT AND PUBLIC WORKS OF THE UNITED STATES SENATE, that the Secretary of the Army is requested to review the report of the Chief of Engineers on Tillamook Bay and Bar, Oregon, published as House Document Numbered 349, Sixty-second Congress, and other pertinent reports, to determine the feasibility of modifications and improvements for the purposes of flood control, ecosystem restoration, erosion and other water resource needs in the Tillamook Bay estuary and watershed, Oregon.*

1.3. STUDY AREA

Tillamook Bay is located in Tillamook County in northwestern Oregon. Tillamook Bay is 50 miles south of the Columbia River and 60 miles west of Portland, Oregon. The watershed surrounding Tillamook Bay is dominated by broad valleys along the coastal plain that abruptly rise to steep mountains. Elevations vary from near sea level in the coastal lowlands to above 3,500 feet in the Coast Range Mountains. The majority of area of each watershed contributing to the bay is located within the Coast Range Mountains. Dense forest covers much of the terrain, which overlies impermeable strata in the mountainous watershed. The majority of human settlement has taken place in the broad river valleys. The valley forests were stripped, wetlands were filled, and dikes were placed in the valleys for agricultural purposes about 150 years ago.

The Wilson and Trask Rivers are the two largest rivers in the area and contribute to the majority of sedimentation and flooding in the region. The Miami and Kilchis Rivers have similar watersheds and characteristics as the Wilson and Trask, but they are smaller and are located in sparsely populated areas. The Tillamook River has a low gradient relative to the other rivers and a watershed located along the coastal foothills. The Tillamook River contributes the least to flooding and erosion problems in the region. Four of these rivers flow into the southern end of Tillamook Bay except for the Miami River, which flows into the bay at its northern end.

The majority of settlement in the area occurred in and around the City of Tillamook. The City was founded in 1891 along a low-ridge separating the Trask and Wilson Rivers. The surrounding floodplains of the Tillamook, Trask and Wilson Rivers were developed for agriculture. As the area is rich in rainfall, grasses are plentiful and the Tillamook area has long been an excellent location for dairy farming. Beyond the City lie numerous dairies throughout each of the five major river valleys.

For purposes of agriculture, the floodplains of the rivers have been diked, sloughs have been filled, and structures have restricted the historic movement of the river channels. In essence, the ties of floodplain to river channel have been separated in the river valleys. A few major sloughs remain connected to their rivers including Dougherty Slough to the Wilson River and Squeedunk Slough to the Kilchis River. Other sloughs in the area have generally lost their upstream tie to rivers and now are either stagnant or tidal sloughs.

1.4. Scope of Study

The existing conditions in the study area have been captured in numerous reports (see Section 1.5 of this chapter). An extensive analysis of the Tillamook Bay and watershed was conducted under the Tillamook Bay NEP, which resulted in the identification of four goals that were consistent with the study authority. These goals include: (1) restoration of critical habitat for salmonid species; (2) reduction of sedimentation for salmonid spawning and rearing habitat; (3) reduction of bacterial contamination; and (4) reduction of magnitude, frequency, and impact of flood events. In the Oregon Plan, the Tillamook Bay system has been identified as having poor habitat for native coastal salmon. Modeling shows that some salmon populations may experience a higher risk of extinction because of this condition. Anadromous salmonid species known to occur in the Tillamook Bay watershed include chinook salmon (*Oncorhynchus tshawytscha*), coho salmon (*O. kisutch*), chum salmon (*O. keta*), steelhead trout (*O. mykiss*), and coastal cutthroat trout (*O. clarki clarki*). In August 1998, coastal coho salmon were listed as a threatened species under the Endangered Species Act (ESA). Coastal cutthroat and steelhead are candidate species for listing.

Declared a Federal disaster area because of the February 1996 flood, Tillamook County suffered over $53 million in damage, which is the equivalent of 148% of the county's annual budget. The county suffered significant losses because of the disruption caused to U.S. Highway 101, the major north-south arterial along the Pacific Coast. The lower portions of the rivers overflow frequently because channel capacity is inadequate to handle heavy flows during severe rainstorms when combined with high tides. The resulting flooding cut off access to Highway 101 and inundated residential, commercial, and pasture areas. No vehicular access was possible between the north and south portions of the county; emergency and service vehicles could not go north and ambulances could not get to the hospital on the southwest side of the city. During the 1998-1999 flood season, damages due to flooding were $5 million in the study area.

The reconnaissance phase of the study was completed in August 1999. Key areas addressed in the reconnaissance report (*Section 905(b) Analysis, Tillamook Bay and Estuary, Oregon*, December 1998) included opportunities to modify existing floodplain features, stream channels, and the estuary in order to restore natural wetlands, high value estuarine habitats, and coastal salmonid habitats while reducing flood damages. Some of the measures included reconnecting wetland and floodplain areas with the rivers to absorb greater flood flows, channel modifications to restore flood capacity, restoring structural complexity in stream channels and the estuary, and riparian habitat development.

A Feasibility Cost Sharing Agreement was executed in July 1999 with Tillamook County Soil and Water Conservation District (TCSWCD). Tillamook County requested to become the formal sponsor, which the TCSWCD agreed to on February 17, 2000. A Feasibility Study Advisory Council was established to provide local public oversight for the study. Seven focus groups also were established at the request of the sponsor to develop a plan for ecosystem restoration and flood damage reduction. As the study progressed, the focus groups were combined into a larger Biological Focus Group and a Flood Damage Reduction Focus Group. Chapter 5 of this report discusses the public involvement undertaken for the study.

Fifty-nine potential alternative measures were initially considered. During the process to prioritize and narrow the measures, the sponsor decided to support only those alternatives providing both ecosystem restoration and flood damage reduction benefits, as well as having overall public support. This reduced the number of alternative measures to 33. Further evaluation with an area of focus in and around the City of Tillamook, and based on engineering and biological evaluation, further reduced this number to 14 potential alternatives.

A one-dimensional, hydrodynamic model (MIKE11) of the five rivers was developed as the primary evaluation tool for screening the 14 potential alternatives. Preliminary model runs were performed to increase the understanding of the system and to aid in the process of prioritization and narrowing of alternatives. A discussion of the potential alternative measures and modeling is found in Chapter 2 of this report. Chapter 3 provides a description of the MIKE11 model.

Initial model results were presented to the Feasibility Advisory Council and interested citizens on March 27, 2002. From these preliminary results, discussions ensued as to which alternatives were to remain for further evaluation and cost analysis. From the modeling results, it appeared that some alternative areas would not provide many benefits for flood damage reduction to the Tillamook area. Tillamook County decided that these alternatives would no longer be studied. Through a long process and much discussion, the Hall Slough and Wetland Acquisition/Swale alternatives were selected for further evaluation because they had the greatest potential to provide ecosystem restoration and flood reduction benefits.

The Hall Slough alternative consists of reconnection of tidal flows in the historic slough, high flow flushing from the Wilson River, and setback levees with riparian plantings. It is a high priority ecosystem restoration action and would eliminate flooding in the Highway 101 business district up to approximately the 2-year flood event. Because the sponsor indicated that they do not have adequate funds for implementation at this time, the alternative was not developed further.

The Wetland Acquisition/Swale alternative would restore tidal marsh/wetlands with actions to offset flood increases. It is a high priority ecosystem restoration action and would reduce flooding for lower flood events. However, the sponsor requested that remaining study funds focus on developing the Modified Wetland Acquisition alternative endorsed by the Tillamook Bay Habitat and Estuary Improvement District (TBHEID). This modified alternative meets ecosystem restoration requirements without causing an increase in flood elevations, meets the requirements of the sponsor, and is acceptable to the community. After initial evaluation and modeling, the sponsor requested that the Modified Wetland Acquisition alternative be transferred to either the Continuing Authorities Program (CAP) or to Section 536 of the Water Resources Development Act of 2000 (Public Law 106-541) for further evaluation and implementation.

With the decision to transition from the GI feasibility study process, a decision also was made to convert the existing MIKE11 model to the U.S. Army Corps of Engineers (Corps) HEC-RAS model. At the time the MIKE11 model was selected for use in the study, it had a solid reputation, whereas not enough information was available for the HEC-RAS model. Since then, a newer version of the HEC-RAS model has been developed, which is more sophisticated than MIKE11 and more capable of addressing the complex nature of flooding in the Tillamook area. The HEC-RAS is currently the most common river analysis model used. Chapter 3 provides a description of the HEC-RAS model.

1.4.1. Timeline of Study Events

Study Event	Date
Senate Resolution	June 5, 1997
Reconnaissance phase completed	August 1999
Feasibility Cost Sharing Agreement completed	July 1999
Initiated Feasibility Study	August 1999
Change of sponsor from TCSWCD to Tillamook County	February 17, 2000
Advisory Council established	May 2000
Notice of Intent in *Federal Register*	May 30, 2000
Public scoping meetings	July 25, 2000
MIKE 11 model completed	December 2001
Presentation of preliminary analysis using MIKE 11 model	March 2002
Updated plan for narrowing alternatives	April 2002
Public meeting presenting benefits of Hall Slough, Dougherty Slough and Wetland Acquisitions/Swale Alternatives	July 2002
Preliminary design and cost estimate for Hall Slough, Wetland Acquisition, and Modified Wetland Acquisition/Swale alternatives	August 2002
Decision to convert Modified Wetland Acquisition/Swale alternative to Continuing Authorities Program/Section 536	June 18, 2003
Model conversion to HEC-RAS completed	December 2003

1.4.2. Tillamook Area Flood Conditions

The flooding problems in the Tillamook region were evaluated by the Corps in order to develop alternatives that could alleviate flooding in the area. In order to understand flooding in and around the City of Tillamook, the topography of the lower Wilson, Trask and Tillamook Rivers was evaluated. The rivers of Tillamook are perched above their floodplains. The high sediment loads of the rivers spill out of each river during flood events and are deposited near their banks. The floodplains are lower and are reconnected to the river system through a network of sloughs. However, for agricultural use the floodplains were diked along their rivers and sloughs and do not allow tidal inundation. Therefore, floodwater from the Wilson, Trask, Kilchis and Tillamook Rivers is trapped in the floodplains behind the natural levees and constructed tidal dikes. ‘Flood cells’ were delineated for the study based on their independence of one another in flooding condition. Each flood cell acts independently because it is diked from its neighboring flood cell, slough, or river.

Both natural and constructed dikes have separated the rivers and sloughs in the Tillamook area from their floodplains. The complex nature of flooding in the Tillamook area had not been analyzed in a floodplain development context, including the placement of tidal dikes. The result is a system of channels that are disconnected and create increased flood problems including standing water when floods recede and increased flood stages within channels. Areas which did not flood historically may currently flood because of upstream or downstream actions of landowners in the Tillamook region.

Although the rivers have been forced to evacuate all floodwater, they will never have the capacity to do so. In analyzing the peak flows from gauges in the Tillamook area for the November 1999 flood event, it was apparent that the lower rivers do not have the capacity to carry their floodwater and depend largely on the floodplain to carry the floodwater to Tillamook Bay. Additional discussion on flooding in the Tillamook region is found in Chapter 3 of this report.

1.5. Prior Studies, Reports, and Existing Water Projects

1.5.1. Prior Studies and Reports

Development of an Integrated River Management Strategy, September 21, 2002. Prepared by Philip Williams & Associates, Ltd., Clearwater BioStudies, Inc., Michael P. Williams Consulting, Urban Regional Research, and Green Point Consulting. Prepared for the U.S. Fish and Wildlife Service, U.S. Environmental Protection Agency, and U.S. Army Corps of Engineers.

This project put forward an integrated river management strategy that combined flood damage reduction with salmon recovery. The strategy was developed by an interdisciplinary team using Tillamook Bay Basin as a pilot study area. Analyses of the fluvial, biological, and institutional elements composing the Tillamook Bay river system were conducted at a number of spatial scales. The results were used to identify opportunities and constraints, and to develop a planning level Integrated River Management Strategy for Tillamook.

Tillamook Bay Wetlands: Management Plan for the Wilson, Fuhrman, and Farris Wetland Acquisition Properties, November 2001. Compiled and written by Derek Sowers and Mark Trenholm, staff of the Tillamook County Performance Partnership, for Wetlands Management Plan Development Team.

The purpose of this management plan is to describe how the properties proposed for acquisition and restoration by the Tillamook County Performance Partnership will be managed to meet the goals and objectives stated in the grant agreements with the Oregon Watershed Enhancement Board and the U.S. Fish and Wildlife Service (USFWS), and as agreed upon by the relevant local stakeholders. The management plan is designed to provide assurance to the grant funding agencies, all potentially affected parties, as well as the general public, that the acquisition and management of the land parcels will be implemented in a carefully planned manner and to address any existing or potential concerns. The management plan contains discussions of all of the major elements in need of consideration prior to making the substantial commitment of resources necessary to implement and maintain the project. The elements include goals and objectives, site descriptions and background information, restoration and enhancement activities, identification of responsible participants, public access plan, monitoring and evaluation, and costs and funding.

Wilson River Watershed Assessment, February 2001. Prepared by E&S Environmental Chemistry, Corvallis OR.

The assessment was prepared to inventory and characterize the current conditions of the Wilson River watershed, and to provide recommendations that address the issues of water quality, fisheries and fish habitat, and watershed hydrology. The assessment creates a framework for identifying restoration activities to improve water quality and aquatic habitat in the watershed.

Comprehensive Conservation and Management Plan for Tillamook Bay, Oregon, December 1999. Prepared by the Tillamook Bay National Estuary Project, Garibaldi OR.

The Tillamook Bay NEP was funded by the U.S. Environmental Protection Agency (USEPA) to evaluate the condition of the bay and estuary, especially concerning water quality issues. Coordination with and comments from representatives from public groups and local citizens supplemented extensive input from agencies at federal, state and local levels. The *Comprehensive Conservation Management Plan* presents the proposed actions and policies to achieve targets for solution of the problems identified since 1994. The four priority problems include: (1) critical habitat loss, (2) sedimentation, (3) bacterial contamination, and (4) flooding. The plan also includes characterization of the bay, an analysis of the current policies which impact the priority problems, a financing plan, and a monitoring plan. The technical analysis and extensive review process of the NEP provided a significant resource for the foundation of this GI study. Many of the agencies and groups that developed the policies, actions and targets in the comprehensive management plan were interested in participating in the GI study.

Tillamook Bay Environmental Characterization: A Scientific and Technical Summary, July 1998. Prepared by the Tillamook Bay National Estuary Project, Garibaldi OR.

This document summarizes the relevant facts and figures to describe the natural features of the Tillamook Bay watershed. The report provides an overview of the coastal landscape, discusses human uses, and focuses on the priority problems identified by the NEP: biological resources, water quality, sedimentation, and flooding.

Tillamook County Performance Partnership, June 1998.

This document is an action plan to achieve mutually agreed-upon, results-based outcomes, which addresses specific problems in Tillamook County. Agencies at various levels, along with public and private organizations, have agreed to partner with Tillamook County to attain the four goals of improved water quality, enhanced fish habitat, reduced flood damages, and improved economic conditions. Two of these goals specifically relate to ecosystem restoration and flood damage reduction, while the other two are closely associated. The Performance Partnership provides a framework for how the many active groups in Tillamook County work together and minimizes duplication of work in the pursuit of the common goals.

The Oregon Plan for Salmon and Watersheds (Oregon Plan), Executive Order EO99-01, January 8, 1999. State of Oregon.

The purpose of the *Oregon Plan* is to restore Oregon's wild salmon and trout populations and fisheries to sustainable and productive levels that will provide substantial environmental, cultural, and economic benefits and to improve water quality. The *Oregon Plan* is a long-term, ongoing effort that began as a focused set of actions by state, local, tribal and private organizations and individuals in October of 1995. The *Oregon Plan* first addressed coho salmon on the Oregon Coast, was then broadened to include steelhead trout on the coast and in the Lower Columbia River, and then expanded to all at-risk wild salmonids throughout the state. The *Oregon Plan* is described in two principal documents, the *Oregon Plan* dated March 1997, and the *Oregon Plan for Salmon and Watersheds, Supplement I - Steelhead*, dated January 1998.

Tillamook County Flood Hazard Mitigation Plan, November 1996. Prepared by Tillamook County.

This plan addresses the events and impacts associated with the February 1996 flooding in Tillamook County. While flooding was common throughout Oregon and the Northwest, Tillamook County sustained damages well beyond other watersheds, when compared to the local economy. Damages totaled $53 million. In addition to descriptions of historic flood damage reduction solutions within the county, the plan includes proposed policies and general actions to deal with flooding in the future. Non-structural flood reduction measures are a major component of the program. This document serves as Tillamook County's strategy for reducing future flood damages.

Tillamook Bay NEP Studies

Numerous studies have been undertaken for the Tillamook Bay NEP, as listed below.

- July 2000 - Ecological interactions among eelgrass, oysters, and burrowing shrimp in Tillamook Bay, Oregon, year 2 (1999) report. Prepared by K. Griffin.
- July 2000 - Identifying sources of fecal coliforms delivered to Tillamook Bay. Prepared by J. Moore and R. Bower.
- October 1999 - Tillamook Bay fish use of the estuary. Prepared by R.H. Ellis.
- October 1998 - Three Graces Intertidal program: A report on visitor use patterns at Three Graces Intertidal. Prepared by B. White, Camp Magruder.
- August 1998 - Sediment sources and accumulation rates in Tillamook Bay, Oregon. Prepared by J. Mcmanus, P.D. Komar, G. Bostrom, D. Colbert, and J.J. Marra.
- August 1998 - Reconnaissance survey of tide gates in Tillamook Bay vicinity. Prepared by J. Charland.
- March 1998 - A biological inventory of benthic invertebrates in Tillamook Bay. Prepared by J.T. Golden, D.M. Gillingham, V.H. Krutzikowsky, D. Fox, J.A. Johnson, R. Sardiña, and S. Hammond, Oregon Department of Fish and Wildlife.
- March 1998 - Forest roads, drainage, and sediment delivery in the Kilchis River watershed. Prepared by K. Mills, Oregon Department of Forestry.
- March 1998 - Bathymetric analysis of Tillamook Bay, comparison among bathymetric databases collected in 1867, 1957 and 1995. Prepared by J.A. Bernert and T.J. Sullivan.
- September 1997 - Invertebrate fauna of Tillamook Bay. Prepared by B. Houck, S. Kolmes, L. Fergusson-Kolmes, and T. Lang, University of Portland.
- July 1997 - Eelgrass ecology and commercial oyster cultivation in Tillamook Bay, Oregon. Prepared by K. Griffin.
- September 1996 - Determining abundance and distribution of eelgrass (*Zostera* spp.) in the Tillamook Bay estuary, Oregon using multispectral airborne imagery. Prepared by J.R. Strittholt and P.A. Frost, Earth Design Consultants.
- June 1996 - An environmental history of the Tillamook Bay estuary and watershed. Prepared by K. Coulton and P.B. Williams, Philip Williams and Associates, Ltd., with P.A. Benner, Oregon State University and assistance from the Tillamook Pioneer Museum.
- 1996 - Spatial analysis of the bridges of Tillamook County. Prepared by S. Kujack as a cooperative effort with Tillamook Bay Community College and Tillamook Bay NEP.
- November 1995 - Landscape change in the Tillamook Bay watershed. Prepared by J.R. Strittholt and P.A. Frost, Earth Design Consultants.
- July 1995 - Tillamook Bay watershed analysis framework. Prepared by W. Nehlsen, and T.C. Dewberry, The Pacific Rivers Council.
- July 1995 - Identification and distribution of subtidal and intertidal shellfish populations in Tillamook Bay, Oregon. Prepared by K.F. Griffin.
- June 1995 - Inventory of the management framework for Tillamook Bay National Estuary Project priority problems: Phase I of the base programs analysis. Prepared by G. Plummer.
- February 1995 - Fish and wildlife issues in Tillamook Bay and watershed: Summary of a Tillamook Bay NEP Scientific/Technical Advisory Committee forum. Prepared by J. Miller and R.J. Garono.

- January 1995 - Impacts of erosion and sedimentation in Tillamook Bay and watershed: Summary of a Tillamook Bay NEP Scientific/Technical Advisory Committee forum. Prepared by J. Miller and R.J. Garono.
- December 1994 - Biochemical water quality issues in Tillamook Bay and watershed: Summary of a Tillamook Bay NEP Scientific/Technical Advisory Committee forum. Prepared by J. Miller and R.J. Garono.

1.5.2. Existing Federal Water Projects

Previous federal water projects in the Tillamook region were primarily built for navigational purposes. Although the entrance channel and navigation structures are still maintained to serve the small boat harbors at the north end of Tillamook Bay, the amount of dredging for navigation purposes within the bay has been greatly reduced over the years. All five of the major rivers in the Tillamook watershed are unregulated rivers. No major impoundments exist on any of the rivers except for a small dam on the upper Trask River, which influences less than 5% of the Trask River watershed. Existing flood control facilities consist of private dikes, which protect lands near the City of Tillamook. Beyond the one federally constructed levee (the Stillwell Levee), the majority of dikes in the area are tidal dikes locally constructed to control tide waters from inundating agricultural lands. Dikes in the area provide little flood protection and in some instances likely may make flood problems worse by storing floodwaters when rivers recede.

<u>Tillamook Bay and Bar</u>. This project provides for a north and south jetty along with an entrance channel and inner channel in the estuary. This project was initially authorized in 1912 and has since been modified several times, with the last increment being the south jetty extension in 1974. The north and south jetties are 5,700 and 8,000 feet in length, respectively. The entrance and inner channels are maintained to a depth of 18 feet. The entrance channel has no specified width, while the inner channel is 200 feet wide up to Miami Cove. Local interests maintain a small boat basin at Garibaldi. The project also provides for construction of a dike to stabilize the peninsula, where the south jetty is connected.

<u>Stillwell Levee, Section 205 Flood Damage Reduction Project</u>. This project upgraded a levee system initially constructed by local interests circa 1919. The Stillwell Drainage District operates and maintains this project, which is the only levee in the study area that offers major flood damage reduction. The levee was originally built to a sufficient height to protect against combinations of flood and tide such as could be expected to occur on an annual basis. The levee was upgraded in 1957 to provide protection for the 50-year recurrence frequency flood with 2 feet of freeboard. The levee is over 22,000 feet in length and circles approximately 450 acres of agricultural land. The drainage district is bounded on the north and east by the north branch of Trask River, on the south side by the south branch of Trask River and on the west by Tillamook River.

<u>Section 14, Emergency Bank Protection</u>. Emergency bank protection projects were undertaken at four locations in the study area using riprap to protect segments of county roads along the Miami, Wilson, and Trask Rivers. The work protected riverbanks from damage by erosion but provided no flood protection. Tillamook County, the Natural Resources Conservation Service (NRCS), and local diking districts have constructed riprap erosion protection at various locations in the study area in order to protect roads, dikes, and private property.

Figure 1. Location Map, Tillamook Bay and Estuary

Figure 2. Tillamook Bay River System

2. ALTERNATIVE ANALYSIS

2.1. INTRODUCTION

Fifty-nine potential alternative measures were identified for the feasibility study though a number of forums. Formulation of alternatives was based on the four main study objectives: reduced flooding, improved salmonid and wildlife habitat, reduced sedimentation, and improved water quality. One list was generated from local interests through a number of local groups including public meetings. The NOAA Fisheries, Oregon Department of Fish and Wildlife (ODFW), USFWS, NRCS, and the Corps, in conjunction with biologists from Tillamook County and the Performance Partnership, developed another list of potential ecosystem restoration projects for the study area. The Biological Focus Group played a significant role in this process. The Corps study team generated a list of potential ecosystem restoration and flood damage reduction measures. Provided below is a listing of the 59 potential alternative measures (Figure 3, located at the end of this chapter).

Tillamook River
- Tomlinson Slough connection.
- Peterson setback levee.
- Norwood setback levee.
- Fagan Creek setback levee, tide gate modification.
- Lendl-Shriver setback levee, slough and riparian restoration.
- Halthaway Marina restoration, enhancement, fencing.
- Horse property purchase, restoration.
- Setback levee.
- Hoffman land purchase, restoration.
- Anderson Creek restoration.
- Beaver Creek restoration, tide gate evaluation/modification.
- Setback levee along entire river, where possible.

Wilson River
- Wetland Acquisition area (includes Nolan Slough).
- Hall Slough restoration.
- Restoration of approximately 0.5-0.75 miles of channel off Hall Slough northeast of the main channel, below Highway 101.
- Bud Gienger riparian restoration/tide gate modification.
- Makenster setback levee.
- Reconnect old slough to Dougherty Slough.
- Lower Dougherty Slough riparian restoration.
- Yankee Branch Creek fish passage evaluation/enhancement.
- Beaver Creek restoration/passage evaluation.
- Hoquarten Slough/wetland restoration.

Trask River
- Rudee's Slough restoration/tide gate evaluation/restoration.
- Setback/breach dike, restoration.
- Holden Creek tide gate modification.
- Unknown creek enhancement, restoration, fencing.

Trask River (continued)
- Mill Creek restoration.
- Riparian restoration across from fish hatchery.

Miami River
- Riparian restoration along entire corridor including tributaries.
- Estuarine/wetland restoration to Ellingsworth Creek.
- Breach dike and restore.
- Punch hole in old channel of Miami River upstream of Highway 101.
- Remove tile system upstream of Highway 101.
- Identify and replace all priority culverts, especially in tributaries.
- Reestablish meanders in Minich Creek.
- Reestablish meanders in tributary to Moss Creek.
- Reconnect forest and wetland.
- Placement of large woody debris.
- Enhance, restore, and reconnect channels and backwater areas in historic channel.
- Riparian planting and fencing.

Kilchis River
- Squeedunk Slough reconnection, restoration, passage modification; lower river, large area between Squeedunk Slough and Kilchis; potential levee modifications on east side of Squeedunk and northeast to Kilchis.
- Gienger dike restoration; approximately 0.2-mile section on lower river in wooded section.
- Vaughn Creek restoration, enhancement, passage modification; fish passage improvement, potential dike breach or setback levee.
- Stasek/Neilson Slough restoration, passage modification.
- Dooher setback levee, riparian enhancement; approximately 0.5-mile area west of Stasek Slough on the east side of Kilchis River.
- Coal Creek and Clear Creek channel restoration, enhancement; habitat improvements just above confluence of creeks and Kilchis River.
- Murphy Creek restoration, channel relocation.
- Oxbow reconnection, enhancement.
- Mapes Creek restoration, passage evaluation.
- Kilchis River off-channel rearing.
- Mrytle Creek fish riparian and passage enhancement.

During the process to narrow alternatives, the sponsor, Tillamook County, decided to only support ecosystem restoration alternatives that also provided flood damage reduction benefits, and that were of sufficient size to justify the steps required to receive Congressional authorization for project implementation. Another goal of the sponsor was to achieve general public commitment to the process and the alternatives developed. In addition, the sponsor made written contact with all landowners in the area of the initial 59 measures, and 9 landowners stated that they were not willing to participate in the study. Based on these sponsor requirements, the initial list of 59 measures was reduced to 33 measures that had the potential to provide dual benefits (flood damage reduction and ecosystem restoration).

The remaining 33 alternatives were evaluated based on engineering and biological evaluation as to their ability to provide dual benefits. Because Tillamook County determined that the area of focus should be in and around the City of Tillamook, the alternatives on the Miami and Kilchis Rivers were dropped from further consideration, with the exception of evaluating the lower Kilchis River. This left 14 alternatives for modeling with the MIKE11 model. Additional information about the development of the MIKE11 model can be found in Chapter 3 of this report.

The alternatives were modeled under several configurations and combined with other alternative measures to evaluate the response to flooding. Of these alternatives, it was determined that only nine areas provided flood reduction on a scale satisfactory to the sponsor. These alternatives were further evaluated (see Section 2.2). Each alternative was discussed with the sponsor, local citizens, and resource agencies. From these discussions, three alternatives remained to develop preliminary design and to determine preliminary costs and benefits (see Section 2.3). The other alternatives were dropped from consideration based on environmental concerns, low flood reduction benefits, high costs, or lack of local support.

2.2. INITIAL MIKE11 MODELING OF ALTERNATIVES

Preliminary modeling of alternatives took place to evaluate each area's effectiveness on reducing flood impacts on Tillamook County. Preliminary alternatives were minimally designed to show greatest possible benefits for evaluation. The alternatives were modeled with MIKE11 for the November 1999 flood. Model results were compared to base condition results for the November 1999 flood. After running several scenarios in each alternative area, results were summarized and discussed with the Feasibility Advisory Council.

The following alternatives were evaluated with the MIKE11 model for their effectiveness in reducing flood stages in the Tillamook area. Alternatives were initially modeled with trapezoidal channel cuts and large channel changes. This was done to analyze the alternative's effectiveness in providing flood benefits. If it appeared that flood benefits did exist, then the alternative was kept in the process and further refined. If flood benefits were minimal or did not exist, then the alternative was dropped from further study. The following summary describes each of the alternatives initially modeled and its flood reduction potential (additional information is found in Appendix A).

2.2.1. Wetland Acquisition Area/Nolan Slough

The Wetland Acquisition area was purchased by the Tillamook County Performance Partnership in conjunction with Tillamook County and is slated for ecosystem restoration. The area is located between the mouths of the Wilson and Trask Rivers and Tillamook Bay. This area is critical in terms of flooding in the Tillamook area. This area was modeled with MIKE11 by Philip Williams and Associates, Ltd. (PWA) for Tillamook County. The area is currently cut-off from the rivers and bay by dikes that surround the property. The measures modeled with MIKE11 included dike removal or setback. Environmental restoration benefits include fish and wildlife habitat, fish passage, tidal wetland, ecosystem function, floodplain function, and water quality.

Initial modeling results showed that dike removal or setback in this area resulted in slightly increased peak flood stages at the Highway 101 business district. As this area recently had 10 tidegate culverts installed in the dike bordering Tillamook Bay, it was determined that the area currently helps alleviate flooding by storing floodwaters during flood tide and releasing floodwaters during ebb tide. It was determined that this area could be included in other alternatives and possibly more favorable results would occur with some modifications (see discussion of Wetland Acquisition/Swale in Section 2.3.3)

2.2.2. Hall Slough

Hall Slough is a side channel of the Wilson River. The slough's origins are upstream of Highway 101 near the Wilson River Loop Road, and its downstream end comes back into the Wilson River about 2 miles downstream (near the mouth of the Wilson River). Hall Slough was connected to the Wilson River at its upstream end before 1950. At that time, a bridge was in place that crossed Hall Slough on the Wilson River Loop Road. Since then the slough has been filled at its upstream end, the bridge removed, and a small culvert placed through the Wilson River Loop Road to drain the area behind it. This area currently represents the area of the Wilson River that overtops first during a flood event. Floodwaters flow over along the left bank of the river near the historic Hall Slough entrance and flow down the Wilson River Loop Road to Highway 101, where they flow south along the highway and eventually cross and flood the highway. These nuisance floods occur frequently and may be controlled by reestablishing the historic slough connection to the Wilson River. The measures modeled with MIKE11 included connecting the slough to the Wilson River at the upstream end, setting back dikes, establishing new levees along the slough, and deepening the slough. Environmental restoration benefits include fish and wildlife habitat, fish passage, tidal wetland, ecosystem function, floodplain function, and water quality.

Initial modeling results using the November 1999 flood event showed that the slough would carry approximately 1,000 cubic feet per second (cfs) of floodwater that would have previously flooded Highway 101. This alternative also lowered the duration of flooding on Highway 101 by approximately 4 hours. Although this alternative would not control flooding for all floods in excess of the nuisance floods, it would help to control the common flooding in the Highway 101 area.

2.2.3. Lower Trask River

This alternative is located along the Trask River between river mile (RM) 2 and the downstream confluence with the Tillamook River. This area represents a constriction in the Trask River because the lower river was rerouted and channelized. The current river channel has a much lower capacity in this reach than both reaches upstream and downstream from it. Furthermore, this reach of the river lacks riparian habitat and channel complexity. This reach is essentially a tidal flume devoid of riparian vegetation other than grazed, trapezoidal banks. The measures modeled with MIKE11 for this reach included setting back dikes and widening and deepening the channel. Environmental restoration benefits include ecosystem function, floodplain function, and water quality.

Initial modeling results showed that modifying the channel had the most profound effects on flood stages, whereas dike modification provided minimal flood reduction. Channel modifications were initially modeled as large cuts on the extreme side of what would be realistic to perform. However, this was done to determine the largest flood reduction benefit and to determine if further development of the alternative was warranted. For the November 1999 flood, water surface elevations were significantly reduced in the reach, as well as upstream of the reach. Stages in the Tillamook-Trask Drainage District, an upstream area frequently flooded, were reduced by about 1.3 feet. At the same time, the Trask River was carrying approximately 6,000 cfs more flow through this reach of river. From a flooding standpoint, this alternative increased flow through the reach and decreased flood stages. Although the channel modification was modeled on the extreme side in terms of channel geometry, the possibilities for minor flood reduction benefits in this area were shown.

2.2.4. Old Trask River

The Old Trask River is a branch of the Trask River, possibly representing the former mouth of the Trask River. This reach flows between the Trask River and the Tillamook River near Trask RM 1.8, and helps alleviate flooding on the Trask River. The reach currently has levees/dikes along both sides. The Stillwell Drainage District is on the north side of the channel and the Tillamook-Trask Drainage District is on the south side. The Stillwell levee provides approximately 50-year protection while the Tillamook-Trask dike only protects for tidal flows. Therefore, the area to the south is often flooded. The measures modeled with MIKE11 included modifying the channel by widening and deepening, as well as setting back the levees/dikes along the channel. Environmental restoration benefits include ecosystem function, floodplain function, and water quality.

Initial modeling results showed that this alternative had similar results as the Lower Trask River alternative, but on a smaller scale. Setting back only the levees/dikes showed minimal benefits, whereas setting back both the levees/dikes and modifying the channel provided the greatest flood reduction benefits. Channel stages were only slightly reduced; however, an increase in channel capacity of about 2,400 cfs was obtained from the combined measures when modeled using the November 1999 flood event.

2.2.5. Dougherty and Hoquarten Sloughs

Dougherty and Hoquarten Sloughs below Highway 101 represent a critical area in terms of both flood problems in the Highway 101 business district and environmental concerns. Several alternatives were evaluated with the MIKE11 model to assess possible solutions to flood problems in this area. The measures modeled included removal and/or setback of dikes, channel modifications, and a combination of alternatives in downstream reaches. Channel modifications included benching one side of Dougherty and Hoquarten Sloughs from the bridge at Highway 101 to the Trask River, lowering cross dikes along Hoquarten Slough, and setting back the Trask River dike in the Wetland Acquisition area. Also, an alternative was modeled with the channel modifications in the Trask River alternative. Environmental restoration benefits include spawning habitat, tidal wetland, ecosystem function, floodplain function, and water quality.

Initial modeling results showed that if modifications were only performed within Dougherty and Hoquarten Sloughs, very little effect would occur to flood levels at Highway 101. However, if the alternative incorporated dike setbacks and channel modifications, then significant flood reductions could be achieved at Highway 101.

2.2.6. Lower Wilson River Channel Modification

The objective for this alternative was to increase flood conveyance to Tillamook Bay in the lower reach of the Wilson River. The lower reach is between the railroad bridge over the lower Wilson River and Tillamook Bay on the Wilson River mainstem. The channel was modified throughout this reach to increase channel conveyance by a combination of deepening and widening. Environmental restoration benefits include ecosystem function, floodplain function, and water quality.

The channel was initially modified as a trapezoidal channel with a bottom width of 80 feet and 2:1 side slopes. This modification was only performed for narrow areas as some areas of the reach were already this large. The bottom was deepened such that a positive slope occurred throughout the reach. Most of the deepening was located where sedimentation has occurred below the ‘Big Cut’ branch between the Wilson and Kilchis Rivers to Tillamook Bay. Model results showed that flows could be increased by approximately 2,000 cfs in this reach and channel stages could be reduced by 0.3 foot at the railroad bridge to 1.3 feet near the bay. Flood cells adjacent to this reach also had reduced water surface stages and flood durations. This channel modification showed some flood benefits to the lower Tillamook region.

2.2.7. Lower Wilson River Dredging

The Wilson River branches into three reaches before its terminus into Tillamook Bay. Bathymetric data and historic accounts show that this area has been aggrading for some time. Sediment and woody debris deposits have been left in the area. This reach represents a very dynamic area in terms of sedimentation and planform morphology. At the tidal interface, sediments are deposited as the Wilson River slows. Historically, the river would have aggraded and changed course as a delta was formed. However, development created a condition where the river was not allowed to change course. To determine the extent of impact on flood conditions from sedimentation, the area was dredged and the three channels deepened in the MIKE11 model to determine if sedimentation was causing flooding problems upstream, and if dredging would alleviate the problems.

Using a trapezoidal channel, the ‘Little Cut’ and the ‘Big Cut’ branches between the Wilson and Kilchis Rivers were dredged with an 80-foot bottom width and the mainstem of the Wilson was dredged with a 100-foot bottom width. Side slopes were 2:1. Dredging depths ranged from zero to 5.5 feet to achieve a positive slope to the bay. Dredging was performed from RM 0.25 to the mouths of the three branches. Initial modeling results showed that there was stage reduction in the Wilson River at the dredge location and in nearby flood cells of up to 1 foot. Upstream, however, the stage reduction was reduced until it was null at Highway 101 across the Wilson River. This appears to be caused by the existing channel constraints between Highway 101 and the mouth of the Wilson River. These constrictions in the channel control the water surface slope during flood conditions.

2.2.8. Lower Wilson River Channel Modification/Dredging

This alternative combined the channel modification from the railroad bridge at RM 2 to the mouth and included full dredging of the Wilson and the ‘Big Cut’ and the ‘Little Cut’ branches as described for the dredging alternative. Modeling results using the November 1999 flood event showed that no further stage reduction was realized at Highway 101 during flood conditions. Some minor stage reduction did occur near the dredged area. These results show that water surface stages at or above Highway 101 during high water conditions are controlled by the capacity of the Wilson River channel, not by tidal conditions or sedimentation at the mouth of the river.

2.2.9. Lower Trask and Tillamook Rivers Dredging

Similar to the Wilson River, the Lower Trask and Tillamook Rivers have been aggrading at their tidal interface with Tillamook Bay. This alternative analyzed dredging the sediments in the Lower Trask and Tillamook Rivers to view the effects on flooding at upstream locations in the Tillamook region. The Tillamook River was dredged from RM 0.86 to the bay and the Trask River was dredged from RM 1.14 to the bay. The Tillamook River was dredged with a bottom width of 215 feet and depths varying from 0.6 to 5.2 feet. The Trask River was dredged with a bottom width of 80 feet and depths varying from zero to 3.0 feet.

Initial modeling showed results that were similar to those of the Lower Wilson River Channel Modification/Dredging alternative. Water surface stages during flooding were reduced in and near the dredged area. This included stage reductions of up to 1.6 feet on the Tillamook River near the Netarts Highway bridge and up to 0.8 feet on the Trask River near its mouth. Adjacent flood cells had a reduction in flood stage from 0.3-0.5 feet. Also, the Trask River had an approximate 1,200 cfs increase in flow at it peak. However, at locations upstream including Highway 101 at Hoquarten Slough, impacts from dredging were minimal. From these results, it appeared that a project on the Trask River may be beneficial to flood stages if it included either the Lower Trask River or Dougherty/Hoquarten Sloughs alternatives, or some combination of the alternatives.

2.3. REFINED ALTERNATIVE ANALYSIS

The initial MIKE11 model results described above showed that the greatest flood damage reduction benefits could be achieved by increasing the capacity of the existing channels or by providing additional channels. The most effective way to increase the capacity of the channels would be to increase the width of the channel. Increasing the depth of the channel did have an effect and may be effective in conjunction with increased channel width based on the specific river under consideration. However, increasing channel depth had a much less significant impact on flood levels and is more localized in nature. The key for both ecosystem restoration and flood damage reduction benefits appeared to be associated with increasing channel width or providing additional channels.

Initial modeling results were presented to the Feasibility Advisory Council and interested citizens on March 27, 2002. From these preliminary results, discussions ensued as to which alternatives were to remain for further evaluation and cost analysis. From the modeling results, it appeared that some alternatives likely would not provide many flood damage reduction benefits to the Tillamook area. Therefore, Tillamook County decided that these alternatives would no longer be studied. Through a long process and much discussion, three alternatives remained for detailed evaluation because they had the greatest potential to provide dual ecosystem restoration and flood reduction benefits. The alternatives considered for further study included Dougherty Slough, Hall Slough, and the Wetland Acquisition/Swale area.

2.3.1. Dougherty Slough

The Dougherty Slough alternative would reconnect the slough to its floodplain from Highway 101 downstream to the Trask River. Dikes would be removed and the top 2 feet of soil would be scraped from the banks to reconnect the slough to the floodplain. Riparian vegetation and fencing would be placed adjacent to the slough channel, and some large wood would be placed in the slough for habitat complexity. To achieve more than incidental flood reduction, it would be necessary to increase channel capacity, a measure which would be unlikely to be economically justified. Because this alternative was the sponsor's lowest priority of the three alternatives being considered for further study, this alternative was not developed further, although it remains a viable ecosystem restoration alternative.

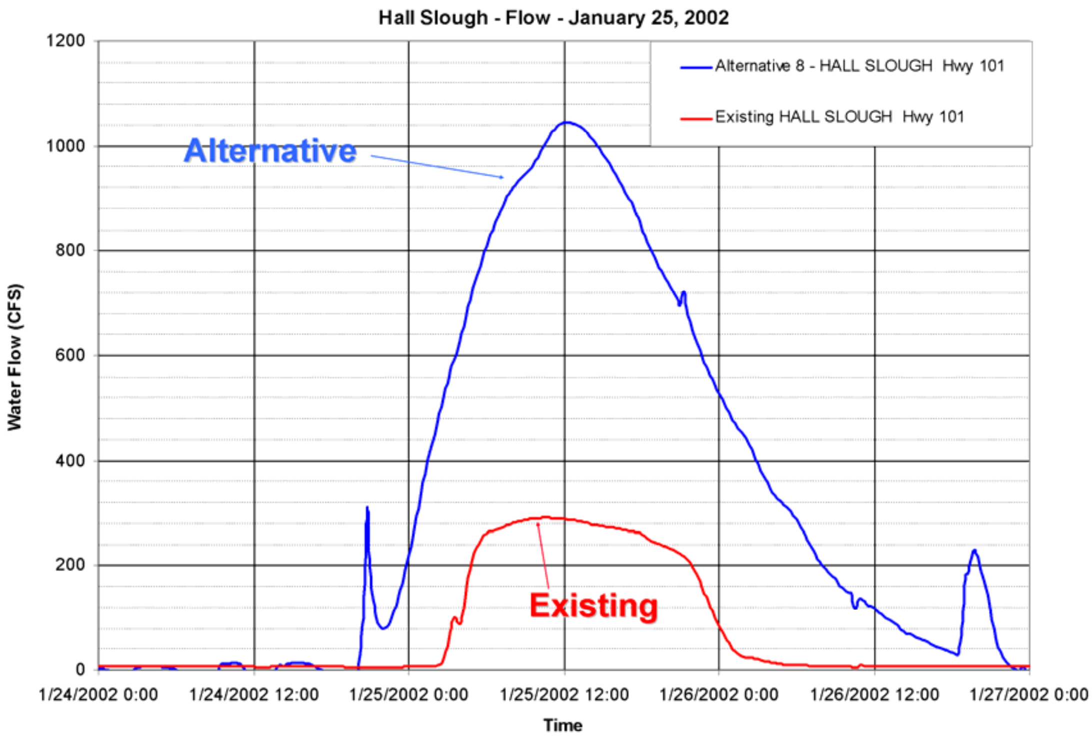
2.3.2. Hall Slough

The goals for the Hall Slough alternative were to restore upper Hall Slough to conditions that would be ecologically beneficial, especially to salmonids, as well as collecting overflow from the Wilson River into a channel for passage to Tillamook Bay. Hall Slough was disconnected from the Wilson River at its upper end and floodwater has since filled much of the historic upper channel with sediment. As floodwater overflows the Wilson River, it flows out towards the historic upper slough connection, but ends up flowing down roads and fields including down and across Highway 101. Hall Slough is not large enough to contain all the floodwater, but it could contain flows of up to about 1,000 cfs, which is approximately the amount of overflow that occurs with an annual flood. These nuisance floods disrupt Highway 101 could be completely controlled. Also, another goal was to take excess floodwater (above 1,000 cfs) from this area and direct it around Highway 101 to the greatest extent possible.

In the MIKE11 model, the slough was deepened throughout to maintain a positive slope to the bay and to be tidally active throughout its length (Figure 4, located at the end of this chapter). A conceptual overflow structure also was placed at the slough's upper end to allow flows from the Wilson River to enter Hall Slough when the river reached an elevation of 15.4 feet NAVD88 (North

American Vertical Datum of 1988). Wilson River flows would then be allowed in Hall Slough via a weir structure. In order for increased flows in Hall Slough to remain within the slough, the slough was widened and deepened from its upstream end down to the Goodspeed Road bridge. Also, small levees were needed in a few low spots along the slough. The Hall Slough bridge at Highway 101 was lined with vertical concrete walls and deepened to pass flows of 1,000 cfs. Hall Slough downstream of Goodspeed Road was unchanged other than the dike on the right bank was setback for riparian plantings.

Modeling was performed using the January 25, 2002 flood which represents an annual event on the Wilson River. Modeling results showed that overflows from the January 2002 flood that had flowed across Highway 101 and into the fields behind Fred Meyer were contained in Hall Slough. The following graph shows the change in flow in Hall Slough with and without the modeled changes.



In summary, the Hall Slough alternative consists of reconnection of tidal flows in the historic slough, high flow flushing from the Wilson River, and setback levees with riparian plantings. It is a high priority ecosystem restoration action and would eliminate flooding in the Highway 101 business district up to approximately the 2-year flood event. A preliminary cost estimate for this alternative is approximately $7.5 million. To meet the 35% cost-share requirement, the sponsor would need approximately $1.5 million in cash plus donated land (approximately $1 million) for implementing the alternative. Because the sponsor indicated that they do not have adequate funds for implementation at this time, the alternative was not developed further.

2.3.3. Wetland Acquisition/Swale

The wetland acquisition/swale alternative represents a unique area in the Tillamook Bay watershed. Not only is it at the tidal interface of the two largest rivers in the area (Wilson and Trask Rivers), it sits at the downstream end of the area's greatest flood prone properties, the Highway 101 business district. It appeared to be an area with a good likelihood of providing both flood reduction and ecosystem restoration benefits.

During initial MIKE11 modeling, it was shown that opening up the diked area to tidal conditions would increase flooding conditions at Highway 101. Since this would not be acceptable, other alternatives were considered. One of these alternatives showed some positive results for allowing the wetland acquisition area to be reconnected to tidal conditions of Tillamook Bay by setting back the existing dikes, while also reducing flooding at Highway 101 (Figure 5, located at the end of this chapter). This alternative included a large swale that would begin upstream of Highway 101 and continue downstream to the edge of the wetland acquisition area. The swale concept was simple in that it would be a large depression that would remain dry for most of the year. However, during flood conditions, overflows from Dougherty and Hall Sloughs would end up in the swale and be swiftly evacuated to Tillamook Bay during ebb tide. The current situation allows for these overflows to find their way to the bay through businesses, farm fields, and dikes. The swale was located in fields used for grazing of dairy cattle, and it was assumed this use could continue with the swale.

The initial swale design consisted of a long, shallow depression that would have a minimal slope and invert elevation of 5 feet NAVD88. The depression has a bottom width of 50 feet and a top width of 150 feet with varying side slopes of 10- to 25-feet horizontal to 1-foot vertical. The intention of the swale would be to collect overflows from Hall and Dougherty Sloughs in a central location and to evacuate those overflows in the most expedient manner possible. The swale included a bank of ten 6-feet in diameter tide-gated culverts at its downstream end in the levee for the wetland acquisition area. It also included culverts under Highway 101. Initial modeling results for this concept showed that during the November 1999 flood, maximum flood elevations at the swale just upstream of Highway 101 would have been 0.3 feet lower and the duration of flooding would have been 5 hours less with the swale in place.

A geotechnical investigation was undertaken by the Corps along the proposed alignment of the swale. Hand auger borings were made at each end of the swale and at six intermediate points. The borings were taken to a depth of 4 feet. Materials recovered in all borings were generally plastic silts and clays, except for peat that was found at approximately elevation 3.4 feet NAVD88 at the western end of the swale alignment. The soils were brown, with no signs of mottling which indicates that they were generally above the water table. In general, the soil in all borings had a medium consistency between the surface and a depth of 2 feet, but below about 2 feet the strength of the soil declined dramatically and the consistency dropped to very soft. This rapid change in soil strength is probably the result of cyclic saturation and drying which tends to cause plastic soils to develop high negative pore pressures that consolidate the soil. Compaction of the upper surface of the soil also is a function of it use by farm equipment and grazing animals.

The lack of soil strength below a depth of 2 feet will impact construction. It also will take some time for the soil to gain sufficient strength to support livestock once construction is complete. As would be expected, the soil moisture content increased with depth. Water was encountered in the last four borings at the western end of the swale, and depth to water was estimated in the remaining borings. Groundwater was estimated to be at about elevation 6.5 feet NAVD88 on the east side of Highway 101, and varied between about elevation 6 feet NAVD88 just west of the highway and elevation 4.5 feet NAVD88 at the west end of the swale. Groundwater in the western half of the swale alignment appears to be controlled by drainage ditches. It could not be determined if any agricultural drainage tile had been installed in any of the areas. If so, it is probable that it is helping control the groundwater elevation.

Therefore, with the swale at elevation +5 feet NAVD88, it is possible to keep the groundwater sufficiently low enough to allow beneficial use of the swale if a drainage ditch is incorporated into the swale design. The ditch would need to be tied to a local drainage system, which has a tide gate to control water levels to about elevation 3.5 to 4 feet NAVD88. Also, the soil below a depth of 2 feet has insufficient strength to support conventional construction equipment. Special considerations will be needed when planning the construction period and sequence. It is recommended that construction be scheduled for late summer, and that low soil pressure construction equipment will be necessary.

In summary, the Wetland Acquisition/Swale alternative restores tidal marsh/wetlands with actions to offset flood increases. It is a high priority ecosystem restoration action and would reduce flooding for lower flood events. However, the sponsor requested that remaining study funds focus on developing the Modified Wetland Acquisition alternative endorsed by the TBHEID. This modified alternative meets ecosystem restoration requirements without causing an increase in flood elevations, meets the requirements of the sponsor, and is acceptable to the community. After initial evaluation and modeling, the sponsor requested that the Modified Wetland Acquisition alternative be transferred to either the Continuing Authorities Program (CAP) or to Section 536 of the Water Resources Development Act of 2000 (Public Law 106-541) for further evaluation and implementation. The Modified Wetland Acquisition alternative is discussed in the next section.

2.3.4. Modified Wetland Acquisition Alternative

The TBHEID provided Tillamook County with four documents suggesting numerous concepts to modify the Wetland Acquisition/Swale alternative. The goals for the alternative are to form a large area of fully tidal saltwater marsh including two major slough systems, a large area of enhanced regulated tidal wetland for juvenile salmon habitat, and enhancement of an area for Aleutian Canada Goose habitat, as well as providing flood damage reduction benefits. The concepts were incorporated into the Wetland Acquisition/Swale alternative by the study team to develop the Modified Wetland Acquisition alternative. A preliminary cost estimate for the Modified Wetland Acquisition alternative is approximately $4.5 million. The Modified Wetland Acquisition alternative was modeled and analyzed with the HEC-RAS model (see Appendix C).

The dominant new feature includes a new levee dividing the area in half, east to west, separating a fully tidal area to the north with a flood storage area to the south (Figure 6, located at the end of this chapter). Agreement was reached that while flood storage area could be used for ecosystem restoration, it could not be fully tidal and it must be reserved for flood storage and conveyance during flood events. A muted tide concept was discussed. The muted tide gate would allow the flood tide to rise to a specified elevation, for example 5 feet NAVD88, but the tide gate would shut at the specified elevation. The muted tide would allow partial saltwater intrusion on the wetland acquisition property and prevent seawater from reaching the landowners beyond the project boundaries.

The full-time saltwater marsh to the north would be reconnected to the Wilson River by removing the plug in Blind Slough, removing the levee at several historic sloughs, and creating an overflow from the left bank of Hall Slough. Beyond the wetland acquisition property a swale would be required from the project boundary to Averil's property boundary but would not be required to extent upstream of Highway 101. Without the swale, the project caused a rise in 100-year flood elevations at several locations. The swale was included to ensure that the project did not increase flood elevations. An additional ecosystem restoration feature of the flood storage area could be an excavation of the existing drainage ditch and additional excavation to create saltwater marsh that would be inundated with the muted tide.

Figure 3. Ecological Restoration Areas

Figure 4. Hall Slough Alternative

Figure 5. Wetland Acquisition/Swale Alternative

Figure 6. Modified Wetland Acquisition Alternative

3. ENGINEERING ANALYSIS

3.1. TILLAMOOK AREA HYDROLOGY

The Tillamook area is hydrologically active. Located on the northwest coast of the United States, Tillamook lies in the direct path of the north pacific jet stream. Storms come off the Pacific Ocean and encounter the Coast Range Mountains immediately east of the coast. As they rise over the coastal mountains, these storms release significant amounts of precipitation. In fact, with locations at the top of the Coast Range receiving over 200 inches of precipitation per year, this is one of the wettest locations in North America. Most of the precipitation falls as rain and most falls between the months of October and March. Locations in the lowland valleys receive significant rainfall as well, averaging approximately 100 inches per year. With all the rainfall comes a large amount of runoff. It is common for the Wilson River to rise 10,000 cfs in a matter of hours during winter storm events.

The Tillamook region has very few long-term precipitation gauges. One gauge is located at the local radio station, and another gauge is located in the upland area at the South Fork of the Wilson River. Other precipitation gauges have been in operation throughout the coastal areas on a sporadic basis. Stream gauges have been operated on a sporadic basis as well.

3.1.1. Discharge-Frequency Relationships

3.1.1.1. Wilson River

The Wilson River has a drainage area of 161 square miles at its gauged location with an additional 30 square miles of area that joins the Wilson River on its way to Tillamook Bay. Therefore, approximately 84% of the drainage area is gauged. The North Fork of the Wilson River enters the Wilson at RM 8.61 and represents approximately 66% of the remaining 30 square miles of ungauged tributary area. Using the Corps' HEC-FFA program (flood flow frequency model), a discharge-frequency relationship was computed for the Wilson River (see Appendix A). The frequency curve contains 71 years of peak flood values ranging from a peak value of 36,000 cfs in 1972 to 3,665 cfs in 2001. Utilizing current Corps regulations, values used for this study rely on the expected probability of occurrence.

Historic computations of discharge-frequency on the Wilson River include a 1993 U.S. Geological Survey (USGS) report documenting statistical summaries of gauges in Oregon. Other historic computations include the 1978 Federal Emergency Management Agency (FEMA) Flood Insurance Study for Tillamook County that was updated in 1999 for the lower Wilson River. Table 1 summarizes peak discharge values from the two historic studies in comparison with this study.

Table 1. Wilson River near Tillamook, Annual Peak Discharge-frequency Values

Study/Date	Discharge for Indicated Annual Percent Chance of Exceedance (cfs)				
	50%	10%	2%	1%	0.2%
Corps 2002 Record 1932-2002	17,700	27,800	36,100	39,400	47,200
USGS 1993 Record 1915-1987	17,200	26,300	33,100	35,800	NA
FEMA 1978 Record 1932-1976	NA	25,000	33,000	36,300	43,500

3.1.1.2. Trask River

The Trask River has a drainage area of 145 square miles at its gauged location, with an additional 14 square miles of area that joins the Trask River on its way to Tillamook Bay. Therefore, approximately 91% of the drainage area is gauged. Only minor tributaries enter the Trask River below the gauge. Using HEC-FFA, a discharge-frequency relationship was computed for the Trask River (see Appendix A). The frequency curve contains 48 years of peak flood values ranging from a peak value of 25,800 cfs in 1996 (estimated) to 2,520 cfs in 2001.

Historic computations of discharge-frequency on the Trask River include the 1993 USGS report documenting statistical summaries of gauges in Oregon. Other historic computations include the 1978 FEMA Flood Insurance Study. Table 2 summarizes peak discharge values from the two historic studies in comparison with this study.

Table 2. Trask River near Tillamook, Annual Peak Discharge-frequency Values

Study/Date	Discharge for Indicated Annual Percent Chance of Exceedance (cfs)				
	50%	10%	2%	1%	0.2%
Corps 2002 Record 1932-1972, 1996-2002	12,600	19,400	26,000	29,100	37,200
USGS 1993 Record 1922-1972	12,600	19,300	25,800	28,800	NA
FEMA 1978 Record 1932-1972	NA	19,000	24,700	27,400	33,100

3.1.1.3. Tillamook River

The Tillamook River has a drainage area of approximately 60 square miles at its downstream terminus into Tillamook Bay. The watershed of the Tillamook River differs from the other four major rivers because its origins arise in the lowland coastal foothills and valleys paralleling the coast rather than from the Coast Range Mountains. Therefore, orographic effects on the watershed are less pronounced as compared to the other four rivers, which results in a lower flood peak-to-drainage area ratio. Also, there is less historic hydrologic data for this watershed than for the other watersheds in the region. The river has had a few periods of gauging including 1973-1977, 1995-1998, and February 2001 to present. All gauging has been performed by the Oregon Water Resources Department (OWRD). With only 8 years of broken record, it was difficult to produce a discharge-frequency curve for this river. Table 3 shows the Tillamook River discharge-frequency values from the 1978 FEMA Flood Insurance Study. These values are based on the USGS regional flood frequency method. Further analysis was not performed for this river during this feasibility study.

Table 3. Tillamook River at Old Trask Confluence, Annual Peak Discharge-frequency Values

Study/Date	Discharge for Indicated Annual Percent Chance of Exceedance (cfs)				
	50%	10%	2%	1%	0.2%
FEMA 1978	NA	7,170	9,730	10,800	13,400

Note: Values based on USGS regional methods.

3.1.1.4. Kilchis River

The Kilchis River has a drainage area of approximately 67.3 square miles at its terminus in Tillamook Bay. The watershed of the Kilchis River is similar to that of the Wilson River in that it is dominated by the Coast Range, which is steep, forested terrain with shallow soils over impermeable strata. Orographic characteristics of the watershed lead to steep hydrographs with relatively large peak flows during winter rain events. Little gauging has been performed on this river. The OWRD began gauging the river in 1995 and continued this gauge until 1998. This study funded the OWRD to continue gauging the river from spring 2001 to spring 2003. The intention of additional gauging was to capture large storm events, to analyze the watershed's response to those events, and to use the information as a boundary condition in the hydrodynamic model.

With only 4 years of gauging data, it was difficult to develop statistical relationships for the Kilchis River beyond the 10% to 50% chance of exceedance. The flood of 1996 approximately represented a 2% chance of exceedance event on the Wilson River, and the peak flow on the Kilchis River for this event was approximately 15,971 cfs. From the inherent locations and geology of the two watersheds, they appear to behave similarly. Also, the discharge-frequency from the 1978 FEMA Flood Insurance Study shows that the estimate of 13,895 cfs for the 50-year event on the Kilchis River is approximately 14% less than the peak in 1996, while from their estimate the Wilson peak (35,000 cfs versus 33,000 cfs) also was underestimated. It is assumed that 16,000 cfs approximately represents the 2% chance of exceedance for the Kilchis River. From this preliminary analysis, it was assumed that the expected probabilities for the Wilson and Kilchis Rivers are linearly related. Table 4 shows the peak discharge-frequency values from the 1978 FEMA Flood Insurance Study as compared to this feasibility study.

Table 4. Kilchis River near Tillamook, Annual Peak Discharge-frequency Values

Study/Date	Discharge for Indicated Annual Percent Chance of Exceedance (cfs)				
	50%	10%	2%	1%	0.2%
Corps 2002 (based on 0.457*Wilson peak)	8,100	12,700	16,500	18,000	21,600
FEMA 1978 1978-estimated	NA	10,240	13,895	15,360	18,965

3.1.1.5. Miami River

The Miami River has a drainage area of 36.4 square miles at its terminus with Tillamook Bay. Like the Kilchis, Wilson and Trask Rivers to the south, the Miami has its origins in the Coast Range. Therefore, the Miami River responds quickly to intense precipitation, often producing steep hydrographs with significant peak flows relative to the size of its watershed. The Miami River has been gauged near Moss Creek by the OWRD intermittently since 1975. Although a significant amount of gauge data exists, the Corps was able to obtain gauge data only for the years 1995-1998 and 1999-2002, and a continuous record for the past 7 years was compiled. However, with only 7 years of data, it was difficult to develop sufficient discharge-frequency relationships beyond the 10-year event. In the period 1995-2002, the largest event occurred on February 7, 1996 with a recorded flow of approximately 9,900 cfs. However, this reading is suspect because the gauge was washed out during the flood. Other large floods during the period included the November 1999 flood where the gauge recorded a peak flow of approximately 5,600 cfs. Another large flow of 6,200 cfs occurred in

November 1995. Discharge-frequency curves were not developed for this gauge. Table 5 shows the peak discharge-frequency values from the 1978 FEMA Flood Insurance Study.

Table 5. Miami River at Mouth of Miami Cove, Annual Peak Discharge-frequency Values

Study/Date	**Discharge for Indicated Annual Percent Chance of Exceedance (cfs)**				
	50%	**10%**	**2%**	**1%**	**0.2%**
FEMA 1978	NA	5,650	7,220	7,900	9,400

Note: Values based on USGS regional methods.

3.2. FLOODING ANALYSIS FOR THE TILLAMOOK REGION

The flooding problems in the Tillamook area were evaluated by the Corps in order to define alternatives that would possibly alleviate flooding in the area (see Appendix A). In order to understand flooding in and around the City of Tillamook, the topography of the lower Wilson, Trask and Tillamook Rivers was evaluated. The rivers of Tillamook are perched above their floodplains. The high sediment loads of the rivers spill out of each river during flood events and are deposited near their banks. The floodplains are lower and are reconnected to the river system through a network of sloughs. For agricultural use, the floodplains were diked along their rivers and sloughs to not allow tidal inundation. Therefore, when floodwater exits the Wilson, Trask, Kilchis and Tillamook Rivers, it is trapped in the floodplains behind the natural and constructed dikes. 'Flood cells' were delineated for the study based on their independence of one another in flooding condition. Each flood cell acts independently because it is diked from its neighboring flood cell, slough, or river.

Both natural and constructed dikes have separated the rivers and sloughs in the Tillamook area from their floodplains. The complex nature of flooding in the Tillamook area had not been analyzed in a floodplain development context, including the placement of tidal dikes. The result is a system of channels that are disconnected and create increased flood problems including standing water when floods recede and increased flood stages within channels. Man-made features such as levees, dikes and roads, along with land use practices have caused flooding in areas that did not historically flood. Although the rivers have been forced to evacuate all floodwater, they will never have the capacity to do so. In analyzing the peak flows from gauges in the Tillamook area for the November 1999 flood event, it was apparent that the lower rivers do not have the capacity to carry their floodwater and depend largely on the floodplain to carry the floodwater to Tillamook Bay.

The lower Wilson and Trask Rivers do not have the capacity to move their floodwaters to Tillamook Bay. The Wilson River has approximately 12,000 cfs of capacity and the Trask combined with the 'Old Trask' has approximately 11,900 cfs capacity. It is natural for rivers to not have the capacity to take flood flows within their banks. Their bankfull discharge (or channel forming discharge) is that discharge that the river can move before it overflows its banks. The bankfull discharge of a river is typically on the order of an annual or bi-annual event. For the Wilson River, 12,000 cfs capacity represents approximately the 90% chance of exceedance flow; for the Trask River, 11,900 cfs capacity represents approximately the 60% chance of exceedance flow for any given year. However, the Tillamook River is an anomaly among the three rivers; its lower reach is broad in comparison to its flow and it has more capacity than the river typically flows. The reason for this is that the Trask River flows towards and into the Tillamook River through floodplains and the Old Trask River adding large amounts of floodwater to the Tillamook River near its mouth.

Much of the impetus for this feasibility study lies in the regular flooding that occurs in the valleys of the Tillamook region, with the most severe flooding occurring in and around the City of Tillamook. The flood of February 1996 was region-wide and was especially devastating in the Tillamook area. The City of Tillamook lies along a ridge that separates the Wilson and the Trask Rivers. Just downstream of the City is Tillamook Bay. The Wilson and Trask Rivers are the two largest Rivers that flow into Tillamook Bay and produce the largest floods. The Wilson River has reached flood stage (approximately 14,100 cfs) numerous times over the past 32 years; it has exceeded flood stage approximately 60 times, averaging almost two floods per year in the recent past.

The City itself largely remains flood free; however, newly developed areas to the north and south of the City experience catastrophic flooding on a regular basis. The worst flooding occurs north of the City along the Highway 101 business area. This recently developed area lies in the direct path of floodwaters from the Wilson River. Floodwaters come from all sides in this area, from the Wilson, Trask, and the Tillamook Rivers and from high tides and storm surges in Tillamook Bay. Other areas in Tillamook along the Trask, Tillamook and Kilchis Rivers also have historically flooded. The majority of lands in the area are operated as dairy farms and many of the historic dairies are located on high points throughout the area. Although many dikes have been built around the area, only the Stillwell levee actually protects a large tract of land from flooding. The levee protects a large farmed area that lies at the mouth of the Trask and Tillamook Rivers. The levee forces waters to flow around it through two narrow channels, the Trask and Tillamook Rivers. As a result, floodwater regularly overtops their banks upstream of the Stillwell levee and floods the area between the Trask and Tillamook Rivers.

3.3. MIKE11 MODEL

The MIKE11 model is a one-dimensional, unsteady flow model developed by the Danish Hydraulic Institute. The hydrodynamic model solves the Saint Venant equations for fluid momentum and continuity by a finite difference scheme utilizing an alternating grid. At each point in the model grid, the model solves for either stage (H) or flow (Q) on an alternating basis. The model also is able to solve general hydraulic equations for hydraulic structures as internal boundary conditions such as weirs and culverts. Basic input to the model includes river cross-sections, structural geometries and geographical networks. The model utilizes branches for rivers and floodplains that consist of nodes (points along the branch) with corresponding cross-sectional dimensions. Like all unsteady flow models, the MIKE11 model requires a boundary condition at all upstream branches and downstream branches of a model network. In the case of Tillamook, flow gauges were utilized at all upstream ends of the five rivers and the downstream boundary consisted of tidal conditions in Tillamook Bay.

Geometric data collection done by the Corps included river cross sections; floodplain mapping; river structures (cross sections of bridges, culverts, dikes, levees, and tidegates); boundary condition data (hydrologic data for each point within the model that is either an end to a reach, a beginning of a reach or a source or sink of water within a reach); crest stage gauge data; highwater mark surveys; and tributary inflows.

Interior drainage in the Tillamook region is provided by hundreds of tide-gated culverts throughout the lower river system. As there are so many private culverts, it was impossible for this study to survey them all. However, the Tillamook County Watershed Council in cooperation with the Tillamook Bay NEP completed a cursory inventory of all culverts in the area. This data was used to develop the initial models. Some culvert lengths and most elevations of culverts were estimated from floodplain mapping. For 20 culverts, a local contractor, Nehalem Marine, was hired to survey culvert properties. Other data was gathered from Nehalem Marine's records of recent culvert replacement and installations.

Prior to the MIKE11 model study, the most recent hydraulic modeling study of the Tillamook area was performed in late 1960s and early 1970s by the Corps and CH2M Hill in development of the 1978 FEMA Flood Insurance Report for Tillamook County. This modeling utilized 2-foot topographic data and cross-sectional data gathered in 1965. The study evaluated the rivers with the one-dimensional, steady-state model HEC-2. As all the rivers of Tillamook Bay are tidally influenced, it was readily apparent that the only way to develop a good understanding of flood behavior in the Tillamook area was to develop an unsteady flow model of the rivers.

Initial scoping efforts for the MIKE11 model study included the development of the Corps' one-dimensional, unsteady-flow model, UNET. However, during the scoping phase for the study, the Danish Hydraulic Institute was in the region promoting their unsteady flow model MIKE11. At the time, their model boasted the ability to create flood area maps and slide shows. Also, their model was integrated in a system that allowed the user to incorporate multiple modeling modules such as sedimentation, water quality, and hydrologic models. The sponsor, Tillamook County, supported the use of the MIKE11 model for the feasibility study.

3.3.1. MIKE11 Model Development

WEST Consultants Inc., under contract by the Corps, developed the MIKE11 one-dimensional, unsteady-flow model of the combined Tillamook, Trask, and Wilson River systems for the study (see Appendix B). Surveyed cross-section information was provided for the Tillamook, Trask, Wilson and Old Trask Rivers; Hall, Dougherty, and Hoquarten Sloughs; and the 'Little Cut' and 'Big Cut' branches between the Wilson and Kilchis Rivers.

A geographic information system (GIS) triangular irregular network (TIN) was used to define overbank features including floodplain geometry and dike/levee heights for the model, and to delineate flooding extents and depths. Aerial mapping for two-foot contour accuracy of the TIN was conducted by the Corps in September 1999 and May 2000. Bathymetric data for Tillamook Bay was collected by the Corps in 1995 and 2000.

Wilson and Trask River hourly stage and flow data, gauges #14301500 and #14302480, respectively, were obtained from the USGS. Tillamook River flows, gauge #14302700, were collected by the OWRD. Fifteen-minute tidal information at Garibaldi (located near the north end of Tillamook Bay), as well as 15-minute hourly stage data at Kilchis Cove and Dick Point (both in Tillamook Bay), Gienger Farm (on the Wilson River), and Carnahan Park (on the Trask River) were recorded at Corps gauges.

Bridge information was supplied from Corps surveys, Oregon Department of Transportation bridge scour reports and bridge plans, and the 1999 FEMA Flood Insurance Restudy. Culverts included in the model typically connect the overbank areas to the rivers or sloughs. Culvert data were collected and supplied by Tillamook County. Upstream and downstream invert elevations were estimated from the TIN when survey data were not available.

Orthophotos (color photos dated 2000, black and white photos dated 1995) were supplied by the Corps. A photo album by the Best Impressions Picture Company in Rockaway, Oregon and an aerial video of the November 1999 flood event also were provided. Highwater marks for the November 1999, May 2001, and November 2001 flood events were provided by the Corps and Tillamook County. The stage data at Dick Point, Gienger Farm, and Carnahan Park, as well as the imagery of the November 1999 event, also were used in calibrating the hydraulic model.

The MIKE11 model was calibrated to an in-bank event (May 2001) and out-of-bank event (November 1999). In both cases, the simulated versus observed peak values compared relatively well, differing by ±0.4 and ±0.8 feet, respectively, for the two events. The verification run (November 2001) using the November 1999 Manning's 'n' values and geometry varied by ±2.1 feet. However, the November 2001 discharge values were between those in the November 1999 and May 2001 simulations, and different Manning's 'n' values were used when calibrating these two latter events. Therefore, the Manning's 'n' values should likely be modified as well to better calibrate this 'in-between' flow. A verification run of magnitudes similar to those of the November 1999 and May 2001 events would better verify the MIKE11 model parameters.

Areas of potential improvements to the model include making modifications and additions to the culverts and dikes/levees. Only the significant culverts were added to the model, and many of the invert elevations of these were estimated from the TIN. Additional culverts and surveyed invert elevations may be necessary to perform more detailed modeling in any specific location. Dike/levee ('link channel') elevations were also estimated from the TIN. Surveying the dike/levee elevations and modifying the MIKE11 model accordingly may yield more accurate results.

3.4. Conversion to HEC-RAS Model

With the decision to transition from the GI feasibility study process, a decision also was made to convert the existing MIKE11 model to the Corps' HEC-RAS model. At the time the MIKE11 model was selected for use in the study, it had a solid reputation, whereas not enough information was available for the HEC-RAS model. Since then, a newer version of the HEC-RAS model has been developed, which is more sophisticated than MIKE11 and more capable of addressing the complex nature of flooding in the Tillamook area. The HEC-RAS is currently the most common river analysis model used. The HEC-RAS model will be able to serve the Tillamook project in an easier and less expensive manner. WEST Consultants Inc., under contract by the Corps, performed the conversion of the MIKE11 model to HEC-RAS (see Appendix C).

3.5. Fluvial Geomorphic Analysis

A fluvial geomorphic analysis of the five major rivers in the Tillamook area was performed by Monte Pearson under contract to the Corps and Tillamook County (see Appendix D). The purpose of the analysis was to inventory and characterize the Miami, Kilchis, Wilson, Trask and Tillamook River watersheds in the study area, and to provide a foundation for undertaking a geomorphic analysis. The resulting report provides a discussion of the sediment problem, regional geologic setting, geographic and physiographic setting, geomorphic sedimentation and transport, landforms and geomorphic processes, fluvial and geomorphic analysis, and future geomorphic landscapes. Provided below is a summary of the erosion-sediment problem found in the Tillamook region.

- Channels in the bay are impassable to most shipping because of sediment.
- Sediment carried down the rivers and into the bay has built up at rapid rates, filling former channels south of Garibaldi.
- The drastic erosion-sediment problem has been traced in part to the devastating forest fires in the region from 1933 and 1945. These fires have exposed over 228,000 acres of highly erodible material to severe winter storms.
- As the channels became larger, more soil particles and debris were carried down the slope and accelerated erosion problems.
- The lower river channels were choked with sediment; as a result of reduced channel capacity, flooding was often aggravated during storms.

- Commercial activities such as farming, logging, road construction, and uncontrolled cattle movement across stream banks increased the erosion-sediment problem.
- The general problem is obvious: too much sediment.
- The problems are complicated and oversimplification is a hazard.

The analysis concluded that positional landscapes prevail in the Tillamook region. Erosion is the dominant geomorphic process occurring in the upland/mountain regions. Historical fires in the Tillamook Basin have caused erosion and sediment yield which, when combined with the region's hydrology, supports and aids the mass movement process.

Given the scale of the rivers in the study area, with the floodplain and the long relaxation time involved in fluvial processes, it appears unlikely that the river-floodplain and river-bay transition zones are in equilibrium. Erosion and sedimentation events and location adjust on different time-scales and to a different frequency distribution. It appears that the major forest fire events were the most significant sediment producers from the upland/mountainous regions. The fire events and burn patterns appear to have produced pseudo-cycles in which periods of high quantities of sediment were generated and then delivered to the channel networks. During initial sediment generation from the uplands, areas the floodplain and river/bay zones could have been in a stable geomorphic state or equilibrium.

Due to changing sediment supply and transport location, the geometry of the channel system and related floodplain has quite different effects on the bay or river-bay transition zone. The partial uncoupling of the river-floodplain and river-bay zones has been greatly increased by human actions. These include deliberately increasing flood deposits on some floodplain locations, reducing flood deposits by construction of dikes and some dredging, the prevention of avulsion and migration by dikes and revetments, and filling or blocking secondary channels and sloughs.

The recommendations for controlling or reducing the flooding impact can be presented with two perspectives: the geologic and the geomorphic. The geologic perspective is strictly based on geologic processes and events of geologic time. The channel system in the Tillamook Bay area is attempting to return to an equilibrium state by way of tectonics, climatic conditions, and basin geology. Left alone, the alluvial plain will reestablish connectivity with the sloughs in order to regain the fluvial geomorphic pyramid. Bank and bed erosion is direct evidence that this process is evolving. Sediment wedge development at the rivers' mouths is the first phase to increasing sinuosity and channel freedom. The lower half of the alluvial plain could become a more complex alluvial fan and delta environment resulting from sedimentation processes. Failure to remove or modify a large percentage of structures that reduce channel freedom would preclude the natural process from occurring. Nevertheless, the channel system will evolve to one of equilibrium and continuing human intervention will attempt to manage this evolution. Flooding is a process nature uses to maintain balance and advance the return to an equilibrium state.

The geomorphic perspective is a mix of geologic, geomorphic, and human intervention. Human actions, including engineering elements, will attempt to manage the Tillamook river systems to enhance geomorphic and geologic processes. The reestablishment of hydrologic conductivity between the upper alluvial plain to Tillamook Bay is needed. This could be completed by the reconnection of the sloughs and the mainstem channel systems. This would allow some fluvial pyramid development to proceed, as well as increase the degree of channel freedom in the deltaic area. However, the total removal of dikes and other structural elements retarding channel freedom would not be an acceptable solution. Allowing some set back of these structures would allow natural channel processes to develop. The increase in channel cross-sectional area would reduce high flow or flood events. There must be a combination of restoring natural channel processes, while at the same time controlling the degree of freedom of the channels with some engineering elements. The mix and location becomes a political situation; however, without some combination, there would be no reduction of flood events in the Tillamook area.

3.6. Numerical Simulation of Flow Fields in Tillamook Bay

A two-dimensional, finite element model ADvanced CIRCulation (ADCIRC) was used to evaluate several alternatives for decreasing the stage of multiple rivers that discharge into the Tillamook Bay estuary (see Appendix E). Tillamook Bay is a shallow estuary with complex system of tidal channels and broad inter-tidal mudflats. The estuary receives riverine input from five rivers, all with headwaters in the Coast Range. A number of narrow channels provide confined pathways for riverine flows entering the estuary from upland sources and the tidal flows entering and leaving the estuary from the ocean. During times of significant upland precipitation and runoff, the hydraulic conditions within the backbay area of the estuary become dominated by riverine flow. The situation becomes a battle of two flow regimes: riverine versus estuarine.

The objective of the ADCIRC modeling was to determine if an estuarine-based channel modification could reduce the water elevation in the backbay area of the estuary during high riverine flow events. Conventional wisdom could lead to the conclusion that increasing the conveyance of estuary would reduce stage at the river mouths during a high riverine flow event. However, based on the modeling results, estuary-based alternatives were not effective for reducing the stage at the river mouths during high riverine flow events. The best method for reducing river stage and alleviate coastal flooding around Tillamook is to (partially) restore the floodway for each of the major coastal rivers discharging into the bay.

Based on the model results, inland flooding near the City of Tillamook was found not to be related to conveyance issues within Tillamook Bay. The only feasible way to reduce inland riverine flooding from the bay would be to change to hydraulic characteristics of the rivers and associated floodways.

4. ENVIRONMENTAL ANALYSIS

A Biological Focus Group was formed for the feasibility study and consisted of representatives from county, state, federal agencies, non-profit organizations, and citizens including:

U.S. Fish and Wildlife Service
NOAA Fisheries
Natural Resources Conservation Service
Oregon Department of Fish and Wildlife
Oregon Department of Land Conservation and Development
Oregon State University Sea Grant Extension
Tillamook County Planning
Tillamook County Performance Partnership
Tillamook County Watershed Council
Tillamook County Soil and Water Conservation District

The Biological Focus Group developed an Ecosystem Matrix to evaluate environmental outputs based on several existing rating methods utilized by other Corps' GI studies (the Bellingham Bay Demonstration Project, the Green-Duwamish and Stillaguamish Ecosystem Restoration Project, and the Chehalis River Study, all in the Corps' Seattle District). These studies utilized a rating system for the ecosystem restoration projects in riverine and estuarine areas based on several criteria and/or limiting factors to fish and wildlife. These parameters included: hydrologic processes, habitat connectivity, critical and rare habitats, fish passage, channel diversity, floodplain function, water quality, sediment transport and recruitment, and habitat availability and complexity.

The Biological Focus Group devised a similar method for this feasibility study that rated existing conditions and potential alternatives based on both watershed-level processes and local habitat features, for both fish and wildlife species. Initially, several watershed processes and habitat parameters were listed and defined and the group went through several iterations to include all of the factors deemed important within the study area. The rating system and parameters were defined so that no additional data collection other than observation would be necessary. The Biological Focus Group then agreed on the methodology and definitions, and developed a tidal and non-tidal matrix (Tables 6 and 7) for scoring each alternative utilizing the expertise within the group to come to consensus. A matrix score sheet showing its use for the Hall Slough, Dougherty Slough, and Wetland Acquisition alternatives is shown in Table 8.

Table 6. Tidal Ecosystem Matrix

Parameter	Rating	Definitions
Spawning Habitat for Anadromous Salmonids (chum salmon)	5	Excellent cover, depth, velocity, and gravel composition.
	4	Very good cover, depth, velocity, and gravel composition.
	3	Good habitat is present but limited conditions.
	2	Fair to marginal conditions.
	1	Poor conditions, little or no habitat.
Fish Passage	5	Localized habitat fully accessible to fish species for all life histories at all times of the year, as appropriate to geomorphic setting.
	4	
	3	Localized habitat accessible to fish species for all life histories during most of the year, but may be inaccessible seasonally or periodically to fish species due to constraints.
	2	
	1	Localized habitat is not accessible to fish species.
Tidal Wetland/Salt Marsh	5	Wetlands/salt marsh present as expected for geomorphic setting. Community structure dominated by native species. Wetlands fully connected to hydrologic sources and unconstrained in providing expected functions (includes as appropriate, flood storage, sediment detention, groundwater recharge/discharge, nutrient detention, habitat for fish and wildlife species, native plant richness, primary production/organic export). 100% tidal connection - no structures (i.e., culverts with tide gates) to impede hydrology.
	4	
	3	Wetlands/salt marsh present as expected for geomorphic setting. Community structure dominated by native and non-native species. Wetlands losing hydrologic connections and often isolated from providing expected functions. Partial tidal connection/structures (i.e., culverts with tide gates) may impede hydrology.
	2	
	1	Wetlands not present due to filling, draining, etc. No tidal connection.
Ecosystem Function	5	Aquatic and terrestrial habitats highly diverse, complex, and support native species. Off-channel habitat areas, if present, are accessible during normal tidal cycles. Large woody debris (LWD) abundant. Riparian and floodplain habitats function properly and provide a diverse mix of habitat types. Local habitat is connected to upstream and downstream areas.
	4	
	3	Aquatic and terrestrial habitats of moderate to low diversity and support native and non-native species. Off-channel habitat areas, if present, have partial tidal connection. LWD present but infrequent. Riparian and floodplain habitats still function, but are disturbed and/or fragmented. Local habitat partially fragmented from upstream and downstream by land use practices or structures (i.e., pasture/hayland, dikes/levees, roads, bridges).
	2	
	1	Aquatic and terrestrial habitats not diverse and dominated by non-native species. Off-channel habitat areas not present. Tidal flow rarely occurs (except extreme high tides). LWD not present. Riparian and floodplain habitats not functioning, limited, and disturbed/fragmented. Local habitat disconnected from upstream and downstream areas.

Table 6. Tidal Ecosystem Matrix (continued)

Parameter	Rating	Definitions
Floodplain Function	5	Over bank flows occur during higher tides and occupy the floodplain. River freely migrates in its floodplain, channel armoring rare, off-channel habitats abundant as appropriate to geomorphic setting. Natural floodplain plant communities common. LWD present and captures/retain sediments.
	4	
	3	Over bank flows occur during extreme tides and occupy a fragmented floodplain due to land use practices. Natural floodplain plant communities present but competing with exotic species. LWD present but not abundant. Channel armoring occurs in some areas. Off-channel habitat approximately 50% disconnected.
	2	
	1	Over bank flows do not occur during extreme tides, channel not connected to floodplain. River is confined. Channel armoring occurs. Erosion common and channel is incised. Off-channel habitats rare or absent.
Water Quality/Hydrologic Connection	5	Functioning properly, no impairment, has hydrologic connection.
	4	
	3	Functioning with partial impairment, losing hydrologic connections and often isolated.
	2	
	1	Not functioning properly, impaired, current land use negatively influencing water quality, poor or no hydrologic connection.

Table 7. Non-tidal Ecosystem Matrix

Parameter	Rating	Definitions
Spawning Habitat for Anadromous Salmonids	5	Excellent cover, depth, velocity, and gravel composition.
	4	Very good cover, depth, velocity, and gravel composition.
	3	Good habitat is present but limited conditions.
	2	Fair to marginal conditions.
	1	Poor conditions, little or no habitat.
Fish Passage	5	Localized habitat fully accessible to fish species for all life histories at all times of the year, as appropriate to geomorphic setting.
	4	
	3	Localized habitat accessible to fish species for all life histories during most of the year, but may be inaccessible seasonally or periodically to fish species due to constraints.
	2	
	1	Localized habitat not accessible to fish species.
Wetlands	5	Wetlands present as expected for geomorphic setting. Community structure dominated by native species. Wetlands fully connected to hydrologic sources and unconstrained in providing expected functions (includes flood storage, sediment detention, groundwater recharge/discharge, nutrient detention, habitat for fish and wildlife species, native plant richness, primary production/organic export).
	4	
	3	Wetlands present as expected for geomorphic setting. Community structure dominated by native and non-native species. Wetlands losing or lost hydrologic connections and often isolated from providing expected functions.
	2	
	1	Wetlands not present due to past/current land use practices (i.e., filling, draining).
Ecosystem Function	5	Aquatic and terrestrial habitat highly diverse. Off-channel habitat areas, if present, are accessible at most or all flows. LWD abundant. Riparian and floodplain areas provide a diverse mix of habitat types and local habitat is well connected to upstream and downstream areas.
	4	
	3	Aquatic and terrestrial habitats of moderate to low diversity. LWD present, but infrequent. Off-channel habitat areas, if present at site, have low flow or other passage difficulties. Riparian and floodplain habitats still function, but are disturbed and/or fragmented. Local habitat partially fragmented from adjacent upstream and downstream habitats by roads/bridges or other land use practices
	2	
	1	Aquatic and terrestrial habitats not diverse. One aquatic habitat type dominant. LWD and off-channel habitats absent. Riparian vegetation limited and dominated by non-native species. Overbank flows rarely occur (flows~100 yr.). Local habitat does not provide a migratory link between upstream and downstream habitats.

Table 7. Non-tidal Ecosystem Matrix (continued)

Parameter	Rating	Definitions
Floodplain Function	5	Over bank flows occur at 2-yr. flow event and occupy the floodplain. River freely migrates in its floodplain, channel armoring rare, off-channel habitats abundant as appropriate to geomorphic setting. Natural floodplain plant communities common. LWD present and captures/retain sediments.
	4	
	3	Over bank flows occur at >5- to 10-yr. flow events. Channel armoring occurs in some areas. Natural floodplain plant communities present but competing with exotic species. LWD present but not abundant. River is disconnected from 50% of its former off-channel areas. Channel migration significantly reduced.
	2	
	1	Over bank flows restricted to ~100-yr. flow event. Channel not connected to floodplain. Off-channel habitats rare or absent. River is confined, does not meander. Channel armoring occurs. Erosion common and channel is incised.
Water Quality/Hydrologic Connection	5	Functioning properly, no impairment, has hydrologic connection.
	4	
	3	Functioning with partial impairment, losing hydrologic connections and often isolated.
	2	
	1	Not functioning properly, impaired, current land use negatively influencing water quality, poor or no hydrologic connection.

Table 8. Matrix Score Sheet

Parameter	Hall Slough		Dougherty Slough		Modified Wetland Acquisition	
	Existing Score	Post-project Score	Existing Score	Post-project Score	Existing Score	Post-project Score
Fish Passage	2	4	5	5	2	5
Tidal Wetland/ Salt Marsh	2	4	2	4	2	4
Ecosystem Function	2	3	2	4	2.5	5
Floodplain Function	1	3	1	4	1	4
Water Quality/ Hydrologic Connection	1	4	1	3	1	4
Total Score	8	18	11	20	8.5	22

5. ECONOMIC ANALYSIS

Only limited economic screening was done during the feasibility study. Several iterations of alternatives were considered with the sponsor and the Feasibility Study Advisory Council. In the spring of 2002, preliminary discussions focused on the need to screen potential alternatives. One of the considerations important to the sponsor was the potential for flood reduction benefits in each of the alternative areas.

Previous Corps' flood reduction studies in the Tillamook area did not result in economically justified federal projects. While the local area recognizes that there are serious flood problems in Tillamook, it is more difficult to realize that there are difficulties in implementing alternatives that significantly reduce flood damages from the types of flooding experienced. There has been continued development in flood prone areas, as well as a general policy of no net loss of agricultural land for cattle grazing. In some cases, a potential solution in one area causes flooding in another area. In other cases, an alternative may reduce flooding from nuisance flood events, but then larger flood events overcome its potential to make much difference and flooding problems continue. To some degree, land availability was a constraint on workable alternatives, as well as the potential operation and maintenance costs that the sponsor would be responsible for in the event that long-term sedimentation was an issue.

Given the difficulty in finding a flood reduction alternative that could be economically justified, it was determined in the project study plan to look at ecosystem restoration as the initial benefit, because it would likely be necessary to economically justify alternatives based on ecosystem restoration, with incidental flood reduction benefits. After this initial evaluation, the potential to add an additional increment for flood reduction could be evaluated to determine if it showed a positive benefit-to-cost ratio, based on Corps' National Economic Development criteria.

During the initial screening process, the study team looked at the alternative areas that appeared to have the highest potential for flood reduction benefits, as requested by the sponsor. Discussions focused on the lower Trask River, lower Trask and the Old Trask Rivers, Hall Slough, the lower Wilson River, and Dougherty Slough. A preliminary assessment of areas that may benefit from reduced flooding was made, so that an initial number of properties (residences, commercial properties, farms/barns/homes, and farm land acreage) could be estimated.

The initial MIKE11 modeling effort showed an approximate frequency up to which potential flood reduction measures could make a difference in damages. Based on the preliminary estimates of numbers of properties, average inundation depths, frequencies, average values, and associated types of damage functions, estimates of the potential for flood reduction benefits were made by the study team.

In conjunction with the preliminary assessment of flood reduction benefits, an initial assessment was made of the potential for realizing environmental outputs given the general magnitude of associated costs. The study team discussed the potential outputs and developed a spreadsheet for review with the sponsor, which showed the likelihood of alternatives that supported both ecosystem restoration and incidental flood reduction benefits. In April 2002, the following list of priority alternatives was provided to the sponsor. One list focused on the potential for flood damage reduction while the other list focused on ecosystem restoration.

Ecosystem Restoration	Flood Damage Reduction
Tomlinson Slough	Dougherty Slough (high)
Dougherty Slough	Hall Slough (high)
Boquist Creek	Trask River Alternatives (high)
Juno Creek	Wilson River (medium)
Hall Slough	
Nolan Slough	
Wilson River (depending on alternative specifics)	

In general, Hall Slough and Dougherty Slough were considered to have good opportunity to be justified based on ecosystem restoration, with incidental flood reduction benefits. Hall Slough was expected to reduce durations and reduce nuisance flooding north of Hall Slough to the Wilson River around Highway 101. Dougherty Slough was expected to reduce flooding near Highway 101 for nuisance floods. While both alternatives would have been evaluated based on ecosystem restoration, they also were expected to yield some incidental flood reduction benefit. To achieve more than incidental flood reduction for Dougherty Slough, it likely is necessary to increase channel capacity, which is unlikely to be economically justified.

6. REAL ESTATE ANALYSIS

The Real Estate Division provided general and technical input and support on real estate matters for the GI study. General study support included participation in site visits, study team and public meetings, coordination with local sponsor representatives, coordination with other team members to identify real property requirements for the alternatives, and evaluation of alternatives developed during the study.

Technical input and support included acquisition of real estate in-grants (rights-of-way) required for study purposes, and research and development of information related to real property ownership, zoning, and value for the study area. In coordination with the local sponsor, more than 30 'rights-of-entry for survey and exploration' were obtained from landowners in the study area to allow access to their property for field investigations, soil sampling and survey work. A permit was obtained from the U.S. Coast Guard to install, operate, and maintain a meteorological gauging station at the Coast Guard Station in Garibaldi. The gauging station permit allows for use of the site to gather tidal stage and wind data for study purposes. The temporary permit covered the period from July 1, 2000 through June 30, 2005. A lease agreement also was obtained from a private landowner (Gienger Farms, Inc.) to install, operate and maintain tide gauging equipment on the Wilson River to record river stage data for study purposes. The lease covered the period from January 1, 2001 through September 30, 2005.

As part of the study, real property ownership and valuation information was obtained from the Tillamook County Assessor's office for properties which would be affected by implementation of the alternatives identified for further study. Based on an assessment of the features and right-of-way requirements needed for implementation, a preliminary real estate cost/value estimate was prepared for each alternative.

7. PUBLIC INVOLVEMENT

In order to provide local public oversight for the feasibility study, a Feasibility Study Advisory Council was established and held its first meeting on May 17, 2000. Members of the public make up the Advisory Council, supported by public agency staff, all of whom were formally appointed by the Tillamook County Board of Commissioners. Formal meetings were held once a month for the purpose of analyzing and formulating policy recommendations and alternative proposals. Advisory Council members also functioned in focus groups dealing with the following aspects of the feasibility study.

- Public Involvement/Website
- Model Development/Oversight
- Historical Conditions
- Water Quality and Land Use Impacts
- Alternative Project Formulation
- Fish and Wildlife Habitat
- Budget/Fiscal Management

However, as the study progressed, these focus groups were combined into a larger Biological Focus Group, chaired by the Corps, and a Flood Damage Reduction Focus Group, chaired by the sponsor.

Numerous presentations were given by the Corps study team to the Advisory Council.

- November 20, 2001 – MIKE11 model presentation.
- March 27, 2002 – Geomorphologic analysis presentation.
- March 27, 2002 – Preliminary modeling results presentation.
- April 30, 2003 – Study status/modeling results presentation.
- September 24, 2003 – Continuing authorities program presentation.

A *Notice of Intent to prepare a Draft Environmental Impact Statement for the Tillamook Bay and Estuary Flood Damage Reduction and Ecosystem Restoration Project* appeared in the *Federal Register* on May 30, 2000 [65(104):34452-34453]. Two initial public scoping meetings were held on July 25, 2000 at the Tillamook County Courthouse. The Corps and Tillamook County discussed the work plan for the feasibility study, model development, and elements of the Environmental Impact Statement. The public was encouraged to provide comments on the scope of the Environmental Impact Statement.

Two public meetings also were held on July 25, 2002 at the Tillamook County Courthouse to discuss the status of the feasibility study, including development of the hydrodynamic model and potential alternatives being considered. At the public meetings held for the study, local citizens voiced concerns on several issues. The most significant issues are discussed below.

Issue: Dredging at the River Mouths

<u>Response</u>: The model analysis shows that dredging to increase the depth of the rivers has a less significant reduction on flood levels than increasing the width of the channels. It also is more localized in its effects. Also, dredging to increase channel depths is not expected to provide ecosystem benefits, unless it results in opening up an old slough or channel that has become disconnected from a river. Therefore, the project would have to be economically justified from a

flood damage reduction standpoint, which is not likely. In addition, even if it were economically justified, the sponsor would be required to provide funding for channel maintenance over the life of the project. Because of these reasons, dredging to deepen the channels was not considered a viable option in the feasibility study.

Issue: Increasing the Width of River Channels

Response: This would require willing landowners to provide some land that would cease to be available for current uses. There are local issues concerning the loss of grazing lands that could affect the amount of land available for a potential project. However, obtaining land for additional width is a key issue for providing both flood damage reduction and ecosystem restoration benefits.

Issue: Eliminating the Kilchis River from Further Consideration

Response: Modeling analysis showed that changes to the Kilchis River to reduce flows in Squeedunk Slough would not affect flood levels at the Highway 101 business district. In addition, the flood reduction benefits would be localized in the immediate area of the project. Because of these reasons, all potential measures on the Kilchis River were eliminated from further consideration in the feasibility study.

8. CONCLUSIONS AND RECOMMENDATION

8.1. Summary and Conclusions

- The Tillamook Bay and Estuary, Oregon, General Investigations study was authorized by a U.S. Senate Committee Resolution on June 5, 1997. The purpose of the study is to evaluate flood damage reduction and ecosystem restoration in the Tillamook Bay watershed in Tillamook County in northwestern Oregon.

- A Feasibility Cost Sharing Agreement was executed in July 1999 with Tillamook County Soil and Water Conservation District. Tillamook County requested to become the formal sponsor, which the District agreed to on February 17, 2000. A Feasibility Study Advisory Council was established to provide local public oversight for the study.

- Five major rivers enter into Tillamook Bay and the lower valleys of these rivers merge to form a broad alluvial plain to the east and south of the bay on which the City of Tillamook is located. Declared a federal disaster area because of the February 1996 flood, Tillamook County suffered over $53 million in damage, which is the equivalent of 148% of the county's annual budget. The county suffered significant losses because of the disruption caused to U.S. Highway 101, the major north-south arterial along the Pacific Coast. The lower portions of the rivers overflow frequently because channel capacity is inadequate to handle heavy flows during severe rainstorms when combined with high tides.

- Designated as a significant tidal estuary in the National Estuary Program and a component of the Oregon Coastal Salmon Restoration Initiative (*Oregon Plan*), Tillamook Bay and its watershed are ecologically and economically valuable to the State of Oregon. An extensive analysis of the watershed was conducted under the National Estuary Program, which resulted in the identification of four goals that are consistent with the Corps' study authority. These goals include: (1) restoration of critical habitat for salmonid species; (2) reduction of sedimentation for salmonid spawning and rearing habitat; (3) reduction of bacterial contamination; and (4) reduction of magnitude, frequency, and impact of flood events.

- Fifty-nine potential alternative measures were initially considered. During the process to prioritize and narrow the measures, the sponsor decided to support only those alternatives providing both ecosystem restoration and flood damage reduction benefits, as well as having overall public support. This reduced the number of alternative measures to 33. Further evaluation with an area of focus in and around the City of Tillamook, and based on engineering and biological evaluation, further reduced this number to 14 potential alternatives.

- A one-dimensional hydrodynamic model (MIKE11) of the five rivers in the study area was developed as the primary evaluation tool for screening the 14 potential alternatives. Preliminary model runs were performed to increase the understanding of the system and to aid in the process of prioritization and narrowing of alternatives.

- From the modeling results, it appeared that some of the potential alternatives would not provide many benefits for flood damage reduction. The sponsor decided that these alternatives would no longer be considered in the feasibility study. The Wetland Acquisition/Swale and Hall Slough alternatives remained for further evaluation because they had the greatest potential to provide both ecosystem restoration and flood reduction benefits.

- The Hall Slough alternative consists of reconnection of tidal flows in the historic slough, high flow flushing from the Wilson River, and setback levees with riparian plantings. It is a high priority ecosystem restoration action and would eliminate flooding in the Highway 101 business district up to approximately the 2-year flood event. Because the sponsor indicated that they do not have adequate funds for implementation at this time, the alternative was not developed further.

- The Wetland Acquisition/Swale alternative would restore tidal marsh/wetlands with actions to offset flood increases. It is a high priority ecosystem restoration action and would reduce flooding for lower flood events. However, the sponsor requested that remaining study funds focus on developing the Modified Wetland Acquisition alternative endorsed by the Tillamook Bay Habitat and Estuary Improvement District. The Modified Wetland Acquisition alternative meets ecosystem restoration requirements without causing an increase in flood elevations, meets the requirements of the sponsor, and is acceptable to the community. After initial evaluation and modeling, the sponsor requested that the Modified Wetland Acquisition alternative be transferred to either the Continuing Authorities Program or to Section 536 of the Water Resources Development Act of 2000 (Public Law 106-541) for further evaluation and implementation.

- This feasibility report describes the progression of the feasibility study and the activities completed to date. It provides a status of the potential alternatives evaluated, including initial modeling results and preliminary cost estimates. The feasibility report is the final response to the study authority.

8.2. RECOMMENDATION

I have given consideration to all significant aspects of this study in the overall public interest, including the environmental, social, and economic, and engineering aspects, and the requirements of the sponsor, Tillamook County.

I recommend that the Modified Wetland Acquisition alternative be transferred to either the Continuing Authorities Program or to Section 536 of the Water Resources Development Act of 2000 (Public Law 106-541) for further evaluation and implementation. This proposed alternative meets ecosystem restoration requirements without causing an increase in flood elevations, meets the requirements of the sponsor, and is supported by the community.

The recommendations contained herein reflect the information available at this time and current Departmental policies governing formulation of individual projects. They do not reflect program and budgeting priorities inherent in the formulation of national Civil Works construction program nor the perspective of higher review levels within the Executive Branch.

Date: ___________________

RICHARD W. HOBERNICHT
Colonel, EN
Commanding