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8. An Integrated River Management Strategy (IRMS) for the Tillamook Bay Watershed

8.1 Introduction

This section describes the approach used to develop a planning-level IRMS for the Tillamook Bay river system and the major provisions of the strategy. The IRMS is based upon a holistic approach that considers physical processes at the watershed and local scales, land use and ecological resources of the watershed. The plan is intended as a template that can be refined as additional data and more knowledge on the linkages between physical process and the ecology become available. Adaptive management principles can be used to refine the implementation stages. Planning-level means the strategy is displayed graphically on maps and is based on scientific and technical facts, but more refined analyses would be required prior to implementation of individual elements. The map information shows general areas of the river system where actions may be taken, but the ultimate decisions on specific locations and prioritization of these actions remain with the local jurisdictions and the community.

This section begins with a description of an alternative future vision to the one described at the end of the previous section. This vision is intended to articulate potential opportunities with mutual benefits to both the natural and human environments. Realization of these opportunities will be dependent on an integrated management of the river system. A conceptual framework for the IRMS is then described with its foundation built on the goal of restoring and enhancing salmon habitat while reducing flood risk to the human inhabitants in the river system. Key principles of the framework are described including those concepts related to flood risk reduction, salmon recovery, and landscape ecology.

Guided by the key principles, and the findings from the opportunities and constraints evaluation, specific strategies and actions of an IRMS are then developed. For the purpose of this work, strategies are defined as the application of the key principles to the unique conditions of the river system landscape. Actions are defined as activities that can be taken to support one or more strategies and may involve physical manipulation of the river system (structural action) or policy changes (non-structural action) to achieve project objectives. Strategies and actions are described in context with the landscape zones developed in the previous section, including uplands, lowlands and estuary.

The section ends with a description of a potential IRMS for the Tillamook Bay river system. A map is used to describe how a set of actions may be applied at the different spatial scales of the Tillamook Bay system to achieve strategies for reducing flood risk and restoring salmon habitat and recovering fish populations. The IRMS includes provisions for management and maintenance of the river system and addresses the need for changing our institutional system so that permitting and other regulatory actions better serve the intent of an integrated approach to managing river systems.

8.2 A Vision for the Integrated Management of the Tillamook Bay Watershed

This section provides a vision for how the Tillamook Bay river system might look and function in the future, under an integrated river management strategy that is driven by the mutual goals of reducing flood hazards to humans and protecting and restoring habitat for fish and wildlife. This vision is presented as a general narrative that addresses how key issues in the Tillamook Bay system, that have been identified through a characterization of the river system, an assessment of historic disturbances and the current state and future trends in the river system, might be resolved. The narrative is intended to instill an understanding for the scope and elements of an integrated river management strategy for the Tillamook Bay system and set the stage for the development of actions to fulfill the strategy.

The Strategy

It is several years in the future, and the people of Tillamook have just experienced another severe winter flood event. After years of being besieged by floods, the people of Tillamook have adopted a strategy to coexist with their dynamic landscape dominated by rivers and the tides. The strategy involves managing the river system in a way that allows the rivers to overflow and the tides to ebb and flood in a more natural manner, for the primary purposes of reducing flood risk to the human population and restoring habitat for fish and wildlife species. The strategy is integrated, that is, it is based on considerations for how one action in the river system will affect another. Over time, natural forces and processes have shaped the landscape of Tillamook Bay region that an increasing number of people now call home. This integrated river management strategy is therefore an attempt to work with, rather than against, the forces of nature to increase the safety of the residents and sustain the other species that have evolved within the river system.

A river system represents the primary mechanism for the movement of water, sediment and organic matter within a drainage basin. Coastal drainage basins, such as the Tillamook Bay Basin, consist of three main landscapes-the uplands, lowlands, and estuary. Across these landscapes, the hydrologic cycle-the continual movement of water, from rain, to runoff, to evaporation-operates unceasingly and imparts water and life into the river system. The integrated management of the river system begins where a majority of water enters the river system--in the uplands.

The Uplands

The steep, forested slopes of the uplands historically presented a first line of natural mechanisms to moderate the effects of rain and snow falling on the land. Live and fallen needles and leaves of trees and other vegetation provided surfaces to intercept, trap, store and evaporate water before it coursed down the steep inclines in the upper reaches of the river system. The forested uplands provided, and continue to provide, a valuable natural resource in wood products to the region. Forestry practices in the uplands have changed to selective cutting based on natural drainage patterns and runoff and sedimentation processes, and not rigid boundaries. A primary consideration is to manage more closely the harvest of trees in regions of the uplands where precipitation-rain and snow--is more intense and where evaporation rates are higher. The strategy of using vegetation to intercept and evaporate, or transpire, precipitation where it lands helps to return the balance of water in the river system to more natural levels and represents the first line of natural flood defense in the managed river system. The altered harvesting procedures have restored the frequency of debris flows and landslides to a less frequent and more natural periodicity. This has reduced the sediment loading in the downstream reaches where flooding is most damaging.

The precipitation that collects and runs off the forested uplands courses down steep tributaries of the river system. In these headwater reaches, even small quantities of water have tremendous amounts of energy to scour and transport sediment and debris. In selected locations of the river system, the natural accumulations of wood debris, or wood jams, have been restored to reduce the energy of flowing water and trap sediment within the river system. Wood jams were historically prevalent throughout the river system and offered a natural mechanism of moderating floods. Based on observations of natural wood jams and using innovative *engineering, log jams have been designed and constructed using large wood to attenuate flood flows, capture sediment and provide habitat for fish and wildlife. GIS mapping techniques are used to locate reaches in the river system where wood jams would tend to occur naturally and be most beneficial The construction of the jams is governed by hydraulic and structural engineering principles to reduce the risk of failure and downstream impacts. The engineered log jams also serve to collect debris that could accumulate at downstream lowland valley structures, causing blockages, flooding and possible failure of structures.*

The culverted road and railroad crossings, once numerous throughout the uplands, have been removed or enlarged to allow a more natural movement of water and sediment. These upland actions have significantly lessened the unraveling of the natural slopes and erosion of constructed fill embankments. The upstream management of precipitation and the sources of runoff now helps to extend the life of many of the existing culverts by keeping the quantities of water and sediment closer to the design values used to originally build the structures. Where fish passage is required, culverts have in many places been replaced by larger openings that allow an unconstrained flow of water and sediment and offer the fish a seemingly natural corridor for movement.

The Lowlands

The river system experiences an abrupt steep to flat transition from the uplands to the lowlands. This transition leads to a significant reduction in the slope of the river channels and results in river reaches where sediment is deposited and transported in a dynamic fashion. These are the reaches that exhibit the most significant natural changes in the last 50 years. Water is spread across the heads of the lowland valleys and sediment is transported across the floodplains. Fine sediments are deposited in restored riparian and wetland areas, thus improving the wetland productivity and reducing fine sediment deposition further downstream across pasturelands.

Since the lowlands are the most highly developed and inhabited portion of the river system, the complex patterns of water and sediment flow that occur here are extremely important to understand to protect land uses, but difficult to predict and manage. Land managers now use a dynamic computer model of the lowland floodplains to help guide the complex decisions necessary to reduce flood risk to humans and increase habitat for fish and wildlife. The model is dynamic because it can simulate the complex interaction of river flow and tidal action over time, predict the rate of sediment deposition in critical areas and determine critical thresholds to identify when maintenance activities are necessary. The model also shows how one action in a river system may affect another portion of the system.

Even with the actions taken in the uplands to reduce the variability and amount of water, sediment and other materials transported downstream, significant quantities continue to reach the lowlands. In the vicinity of the upland-lowland boundary, efforts have been taken to manage the active flow of water and sediment. The natural erosion and deposition patterns of the rivers have been observed and harnessed to guide the accumulation of river gravel and cobbles in accessible off-channel areas for harvesting in a sustainable manner. Continual monitoring and measurement of sediment quantities removed ensures the harvest of these materials takes place at a rate that does not exceed the natural upstream supply. In this way, impacts such as accelerated streambank erosion and channel incision to downstream channel reaches, that could become "starved" from the lack of sediment, are reduced.

Within this active floodplain zone, rows of native trees and shrubs, similar to hedgerows, have been planted to slow and detain overbank flows. Much like snow fences, *the hedgerows filter flood flows while encouraging the deposition of sediments and flood debris in locations that would be accessible for maintenance and removal following a flood event. These floodplain hedgerows also help guide floodwaters towards flood relief routes and overflow routes that divert excessive flood flows away from livestock refuge areas, high value agricultural zones and urban development. The restored floodplain areas also provide flood storage thus reducing the volume of water that has to be passed through the lower reaches - particularly at high tide conditions.*

Continuing downstream along the lowland rivers, plantings of native trees and shrubs have been re-established along selected reaches of river and slough channels to provide complexity for fish and wildlife habitat, shade for cooler water temperatures and a source of detritus, and other organic matter for natural food supplies to the river system. The location of the plantings, or shelterbelts, have been strategically decided with respect to the seasonal angle of the sun and direction of the winds, so as to maximize the benefits of these natural features. The width, or landward extent, of the shelterbelts are not imposed as a fixed width along a reach of river, but rather they are designed to fit the lay of the land and accommodate long term natural processes of river channel change and human land uses. Once again the floodplain computer model has been used to guide decisions concerning the location and benefits of shelterbelts to improving habitat for fish and wildlife and reducing flood impacts to humans.

The planting and ensuing growth of floodplain vegetation along the margins of pasturelands has reduced flood impacts by trapping and filtering out flood debris and sediments close to the river banks while managing the extent and depth of these flood deposits across high-value agricultural lands. This is important in very low-lying areas to ensure that the pasture elevations increase at a rate that equals or exceeds that of sea-level rise. This strategy will help maintain the area of viable pasture and reduce the duration of waterlogged soils or standing water. The growth of vegetation along the edges of existing or recently setback dikes and levees has lessened the erosive energy of river currents and has helped to reduce maintenance costs and extend the life of these flood control structures.

Selected river reaches formerly constrained by levees and dikes have been re-connected to their floodplains and marshplains by selectively setting back levees and dikes, excavating terraces along the channels and establishing overbank flood relief routes. These actions have allowed sediment-laden flood waters to overflow and deposit fine silt and sands outside of the river channel. The resulting cleaner gravels in the rivers have led to better habitat for aquatic insects-the foundation of the aquatic foodchain--and have improved spawning habitat for the salmon. The reconnection of the floodplains has also increased the flood carrying capacity of river channels. By giving the rivers "elbow room" in these ways the erosive energy and depths of the floodwaters have been reduced and streambank erosion problems have become less severe and more manageable.

Where levees and dikes have been setback on pasturelands, the traditional abrupt prismatic shape of these flood control structures has been changed into a wider bermed structure with gradually sloped grassed surfaces that allows farm animals to graze on the structures themselves. The flatter slopes of the grassed berms are more resistant to erosion from overtopping flows and require less long term maintenance efforts and expenses. These new grassed berms also create refuge areas and egress routes for livestock during flood events. The crest elevations of the setback grassed berms have been kept at the same elevation as the original structures to provide the same level of flood protection, or in some cases raised or lowered to meet other river management objectives. The floodplain *model has been intensely used to explore the best alternatives for moving and shaping levees and dikes, changing the volume of fill material in the floodplain, and guiding the movement of floodwaters.*

One significant use of the model has been for the design of flood relief routes that carry floodwaters efficiently through the many floodplain encroachments in the developed portions of the lowlands. The routes have been aligned to follow the patterns of flooding and the natural drainage patterns of the land. In many cases where the lowland flood relief routes and river channels encounter bridges, the bridge and approaches to the bridge have been changed so that flood water and debris pass through more efficiently, while reducing the potential for scour of bridge foundations. These changes have involved modifications to the bridge abutments, piers, height of the bridge deck, and road approach fill embankments. For some bridges, the upstream edges of the bridge piers have been changed to reduce the potential to collect and hold woody flood debris. The changes have made the piers more streamlined to flows so that floating debris is separated and diverted around the otherwise blunt pier face, and carried downstream through the bridge and into the estuary. For bridges presenting a more significant floodplain obstruction, the earthen fill material for the road approaches has been removed and the land graded down to elevations blending into the natural floodplain contours. The new road approaches are elevated on pilings over the reconstructed floodplain, allowing floodwaters to flow more freely under the roadway, much like the turn-of-the-century railroad trestles that still cross some waterways in the Tillamook lowlands.

The Estuary

The series of dikes and levees in the tidal estuary of Tillamook Bay were first established to prevent the intrusion of saltwater onto tidal lands reclaimed for pasture. The structures have served this purpose, but have also served as a trap for freshwater river overflows trying to flow back into the bay as flooding recedes. Building upon earlier efforts in Tillamook started in the late 1990s, old tide gates have been enlarged and some have been removed to increase the speed and efficiency in draining the protected pasturelands. In some cases, special tide gates have been installed that allow interior tidal flooding up to an established elevation and then close if storm surges threaten higher water levels. These gates have been used where tidal sloughs have been restored for chum salmon habitat and where adjacent pasturelands can tolerate some tidal inundation. These new structures have also been sited in a manner to spped the drainage of flood relief routes so that far less land is now inundated for long periods of time after major flood events. Local property owners and farmers gather in the County offices after major floods and use computer model simulations to observe the success of the flood management strategy compared with the massive flood damages incurred during the 1980s and 90s during lesser events.

Just as river levees and dikes have been setback to lessen the force and depth of floodwaters, tidal levees and dikes have been selectively setback to reduce the damaging effects of high tides, waves and overtopping. The setbacks have been established to restore tidal inundation to the marsh fringe of the bay. The increase of inundated area increases the tidal prism associated with tidal channels tributary to the bay. The tidal prism is the average volume of water that flows in and out during a typical tide cycle. The increased tidal prism volume naturally maintains larger channel openings that help convey higher flows during river floods. The restoration of tide lands in this way has allowed the ebb and flood of the tide to restore and maintain natural shapes of tidal sloughs and marshes and has reduced the need for some maintenance dredging. Dredging increases channel volume at the dredged location in the short term, but if it occurs below a low tide level, it will *not increase the active tidal prism volume and will not contribute to a more natural way of sustaining channel openings.*

Water quality components of the computer model are used in a predictive mode to estimate bacteria and other contaminant loadings to the bay. This results in a greater understanding for when to schedule shellfish bed closures. In addition the model provides information that enables the duration of these closures to be shorter than before the integrated modeling/monitoring program was in place.

8.3 Fundamental Principles of the IRMS

The framework for an effective IRMS is built upon basic principles. The primary principles are associated with those activities that support the goal of the project to achieve flood risk reduction and salmon recovery. Since an IRMS involves a river system and its relationship to the landscape, principles of landscape ecology are also considered. The unique aspect of this project is that these principles are considered in an integrated manner, not as discrete sets of principles governing independent disciplines. The framework for an effective integrated river management strategy is already in place, developed from lessons learned by others in the respective disciplines of flood management, salmon recovery and landscape ecology.

For flood risk reduction, the Midwest Flood of 1993 resulted in a comprehensive assessment of problems and opportunities for river management. The findings of the investigations, referred to as the Galloway Report, articulated the basic principles and strategies for effectively managing the effects of floods. Other flood experiences in the United States since then-the Southwest floods of 1994, the Pacific Northwest floods of 1996, the Northern California floods in 1996-97 and the North Dakota Red River flood in 1997 - all verify the need for and the elements of an effective river management strategy. For salmon recovery, the proposed strategy needs to be consistent and complement other regional initiatives, including the Governor's Salmon Recovery Plan, OWEB, the Northwest Power Planning Council multi-species framework, the Independent Scientific Group (2000), and the National Research Council (1996).

8.3.1 Flood Risk Reduction Principles

The fundamental principle that forms the foundation for this project is the premise that requirements for effective flood risk reduction and salmon recovery are largely complementary. Restoring river systems and functions to accommodate flooding and improve the effectiveness of existing flood control works are both key components of a successful river management strategy. There is substantial consensus that successful integrated management of a river is best achieved with the restoration of the natural physical processes that form the habitat sustaining the ecosystem. In river systems, the dominant processes are floods, the movement of sediment and organic material, and the free interaction of flows between river channel and floodplain.

Based on our lessons learned from flooding, together with recent recommendations for successful habitat protection and restoration in the Pacific Northwest, several key principles for flood risk reduction should be considered (Box 8-2).

8.3.2 Salmon Recovery and Conservation Biology Principles

Principles for salmon recovery (Box 8-3) can be focused on protecting and sustaining the basic life cycle requirements necessary for the survival of the species. These basic requirements for habitat include: spawning, rearing, passage, as well as suitable food sources, refuge areas and management of potential predation or harvest. In a sense, this results in a trend toward ecosystem recovery rather than just species recovery.

Principle 1: Longitudinal connectivity. There is a natural longitudinal connectivity from hillslopes, along the stream network to the ocean. The condition of the stream channel is a direct reflection of the conditions of the uplands. Soil disturbance in upland areas has a direct effect on the quality of the stream network. Identification and protection of these networks throughout the hillslope areas, which allow for flood pulses and sediment transport processes, will enable more cost-effective management strategies to protect infrastructure and land uses. Among the most significant landscape impacts to hillslope processes is the density and condition of the road and culvert system. In the absence of the historic quantities of large wood mediating landscape processes, the stream network has enough energy now to deliver excess sediments to stream channels, which damages spawning gravels and can cause problems for infrastructure maintenance.

Principle 2: Lateral connectivity. Lateral connectivity is the linkage between the river channel, its floodplains and tidal marshes. Floodplains are formed by the processes of flooding, sediment transport, and deposition. In the estuary, tidal marshes form the link between channels and terrestrial ecosystems. This dynamic interaction is the physical basis of the fish and wildlife habitats associated with rivers and floodplains. Resource management philosophy is now shifting toward the reconnection of floodplains and tide marshes which have been disconnected from the adjacent stream channel. When this natural connection is restored, sustainable habitats can regenerate spontaneously, even if these processes may require years to decades to occur. Floodplain and tidal marsh hydrological and geomorphic functions can guide the basis of land use management. The boundaries of a designated flood, such as the 5-year flood, could provide the basis for minimum limits for protection of the stream corridor network. Local tide gages could provide data for minimum dike setbacks in diked tidal wetlands. The cycles of flooding, fires, channel migration and other natural disturbance are essential to the structure of maintenance of habitat (Bisson et al., 1997). Allowing natural channel meandering to occur within predetermined limits and reestablishing lateral connectivity are important physical processes that govern the ecological value of habitat.

Principle 3: Protection of plant communities. Plant communities that regenerate along the river corridor have evolved under a historic flood and tidal disturbance regime, and are therefore able to establish at the proper soil, moisture and salinity conditions that enable them to grow to maturity and reproduce. Riparian, floodplain, and tidal marsh plant communities can withstand flood flows, high velocities, sediment deposition and scour. However, it is important to verify through field monitoring or analysis that these plant communities can survive in channelized reaches with levees constricting the flows. With little management effort, these plant communities can provide the functions of flood attenuation, fish habitat, water quality improvements, increased summer base flows, increased channel and bank stability, fish and wildlife habitats, biodiversity conservation and a host of other functions which directly benefit human society. To achieve these desirable, multi-functional goals, the width of the floodplain corridor or area of tidal influence must allow adequate area for the growth of the riparian, floodplain and tidal marsh plant communities. Designation of this appropriate floodplain or dike setback width to reflect the ecological functions of streamside plant communities is a key component of environmentally sensitive river management for flood risk reduction. It is also important to note that the scour and erosion of some vegetation and subsequent re-colonization is an important process in a healthy riparian corridor, as it results in a diversity of vegetation types and ages.

Principle 4: Sustainable production, recruitment and retention of large wood. Large wood historically provided most of the physical structure of Pacific Northwest stream ecosystems, and much of the attenuation of sediment pulses delivered to the stream by hillslope processes such as landslides. Large wood structures are essential components of the habitats needed to sustain salmon populations at every level of the landscape, from the hillslope to valley floor, in-stream, in-estuary and even into the ocean (Maser & Sedell, 1994). Recovery of adequate volumes of instream large wood is a high priority for river corridor management where salmon populations are threatened. The use of large wood structures is potentially compatible with flood risk reduction, when adequate area is given for the floodplain to convey floodwaters. In addition, the strategic placement of large woody debris can function as a useful management tool in preventing accumulation of flood debris as critical locations such as road crossings. Protection of existing large wood in streams is a high priority at a policy level and for consistent implementation.

Principle 5: Protect the best, restore the rest. This principle is a general rule of thumb derived from the field of conservation biology that considers spatial scales. If stronghold populations exist, then these will generate more fish than can be sustained in the available habitat, and the population will spread gradually to neighboring watersheds. Stronghold populations also indicate that the physical conditions of the watershed are such that the population is unlikely to be decimated in a single, catastrophic event such as fire or flood. Protection of relatively intact ecosystems provides more certainty for success and is less expensive than efforts to restore degraded systems (Nehlsen, 1997). Federal, state, and local resource managers, affected landowners and the community should help in this type of prioritization.

8.3.3 Landscape Ecology Principles

The principles proposed in the IRMS are inter-disciplinary, and the strategy of increasing diversity throughout the river system and restoring natural process can be expressed in the terminology of the landscape ecologist (Box 8-4). The principles of landscape ecology indicate structurally complex landscapes are generally higher in biodiversity and are therefore more ecologically significant than simplified landscapes. The landscape of the Tillamook basin is complex, encompassing steep headwater streams to riparian corridors, wetland environments and an extensive estuarine system, all in a relatively small geographic area. Biodiversity in this basin is therefore, very high, and accounts for the high ecological significance of this basin within the Pacific Northwest Coastal Ecoregion. This biodiversity increases the resilience of the Tillamook Bay ecosystem to change, and should be preserved.

8.3.4 Sustainability Principles

Sustainability is difficult to define and difficult to measure (Bell and Morse, 1999). For the purposes of the IRMS it will be simply defined as ensuring that the value of efforts taken as part of the IRMS do not diminish through time. For the IRMS to be sustainable, several principles need to be considered (Box 8-5).

Commitment of the stake-holders. The IRMS must maintain the commitment of the stake-holders, politicians, public interest groups, land-owners and agencies. Local ordinances and legislation may help ensure this commitment and funding mechanisms.

Secured funding. Funding must be secured for implementation, regulation and maintenance of IRMS actions. In addition, actions like those related to logging or agriculture must be fiscally viable.

Resilient ecological and physical processes. The IRMS should be resilient to episodic and chronic changes to the system. Episodic events might include floods, fires and insect or disease outbreaks. Chronic issues cover processes such as the gradual sedimentation of tidal channels if there is insufficient tidal prism to maintain the current channel dimensions. As an example of a local indicator of sustainability, consider a tidal reach that is diked on both banks. At low flows, there may be insufficient scouring action of the channel bed by tidal action and the channel gradually fills with sediment. On the next significant flood, the deposited material may or may not be scoured and the level of flood protection varies accordingly. One solution may be dredging. However, the long term sustainability of this flood management action is contingent on a long term funding source.

A more sustainable alternative could be a combination of levee setbacks and tidal marsh restoration. The marsh restoration increases the volume of water exchanged on the ebb and flood of the tides and increases the scouring of the channel bed, thus maintaining a channel that is closer to an equilibrium condition. This condition requires less human intervention to maintain. This dynamic equilibrium condition represents the river condition that is adjusted to the current hydrology and tidal processes and represents the "minimum maintenance section". Monitoring and computer simulations can identify what these conditions are for each river system. This represents one potential example for how sustainable conditions might be achieved through an IRMS.

The IRMS is multi-faceted and will be implemented over a significant period of time - this also implies that sometimes one objective can be achieved in different ways. Due to the complexity of the ecology, hydrology, natural perturbations of the river system through flood or fire, and linkages with current land use practices, it is not possible to develop the definitive solution for the next few decades in the Tillamook Basin. However, it is possible to define common objectives and performance criteria to assess, on a regular basis, whether the stake-holder and funding commitments to the IRMS are sustainable, and whether the evolution of the river system is on a trajectory to achieve natural sustainability. Field monitoring can be used to ensure the level of flood risk expected by the community is maintained while other ecological and agricultural goals are achieved. This concept is discussed further in Section 8.6.

8.3.5 Cumulative Effects Principles

Cumulative effects have long been recognized in watershed management, and analyses for these effects are required in Environmental Impact Statements. General principles for the evaluating cumulative effects are listed in Box 8-6.

Cumulative effects may be negative impacts or benefits. Often physical parameters can be measured as an indicator of cumulative effects in the watershed. For example, water temperature is a function of hydraulic geometry (width-depth ratio), geomorphic diversity, groundwater levels, vegetative cover and streamflow. Water temperature is easily monitored, and the recording of trends in water temperature can provide an understanding for the effects of enhancement actions through the river system and over time and at specific locations.

8.4 Summary of Potential IRMS Strategies and Actions

8.4.1 Overview

Using the findings from the opportunities and constraints evaluation and guided by the fundamental principles just described, potential strategies and actions for a Tillamook IRMS were developed. For the purpose of this effort, strategies are defined as broad concepts for achieving the goals and objectives of an IRMS and actions are more specific activities that can be considered to implement the strategy. In this section, upland, lowland and estuary IRMS strategies are introduced together with a mix of structural and non-structural actions.

Strategies. Information derived from the characterization of the Tillamook Basin river system was evaluated to develop potential management strategies. These strategies support the fundamental principles of the IRMS and are applied with consideration for the landscape zones. In general, management strategies call for the attenuation of water and sediment flows in the active floodplain zone, and the conveyance of water and sediment through the floodplain and tidal zones. These attenuation and conveyance zones, respectively, are represented as overlays on the main lowland landscape zones (Figure 8-1).

Estuarine areas represent the most dynamic parts of the system, because tidelands experience the daily ebb and flood of the tide. Strategies for managing the estuary zone of the river system generally consider restoring the natural mixing of fresh and salt waters, and reducing the inland flood effects of backwater from the bay on the lowland river reaches. The natural resiliency of the estuary to recover landform and vegetation with the restoration of tidal flows was considered, together with the opportunities for salmon habitat recovery and the constraints imposed by existing human land use in the estuary zone.

Actions. Potential river management actions were identified to support and implement the strategies. For this planning-level investigation, a list of potential actions was initially developed based on structural and non-structural actions commonly employed in flood management. The list was also tailored to include potential actions that could be implemented in the unique physical setting of the Tillamook Bay Basin. Table 8-1 provides a summary of these actions with respect to their potential benefits to fish, wildlife and human populations.

Action areas within the tidal, floodplain, and active floodplain zones were identified. In the tidal zone, land slope and tidal elevations were used to determine the minimum dike or levee setback needed to restore tidal action within the zone. In the floodplain zone, topography and flood flow routing information from FEMA study and maps were used to identify potential flood flow conveyance routes. In the active floodplain, historic channel locations were overlaid to delineate the meander corridor through the active zones where energy dissipation might be accommodated. Table 8-2 provides a summary of the actions in Table 8-1 but relates them to the zones and action areas within the system where they might be implemented. The underlined actions shown on the two tables were selected as examples for further consideration in one potential IRMS for the Tillamook Bay lowland and estuary.

Lowland IRMS map. Strategies and actions were spatially located on a map of the south Tillamook Bay lowlands (Figure 8-1). The spatial features presented here represent one potential combination of strategies and actions that could comprise an IRMS for the Tillamook lowlands. The feasibility and appropriateness of these features needs to be further refined and evaluated using field investigations, hydrodynamic modeling and landowner consultations. Selected strategies and actions for this IRMS map are briefly described in the following sections. Upland management strategies are reviewed but not mapped.

8.4.2 Fundamental Upland Management Strategies

Upland areas represent the largest portion of the Tillamook Basin and serve as source areas for many of the system's physical and biological processes. The large expanse of the upland landscape collects precipitation and conveys water, sediment and organic materials through the river system to the lowlands. Since the upland and lowland portions of the river system are so strongly connected, successful management of the lowlands begins with proper management of the uplands. Fundamental strategies for managing the uplands to improve the success of a lowland IRMS include the following:

Manage the Runoff of Water Where it First Falls as Precipitation. Upland management strategies are most effective when applied at the source of inputs to the river system. Since precipitation typically first encounters vegetation as it falls, management of vegetation in the uplands is of primary importance. Vegetation serves to absorb, detain and transpire precipitated water. This process delays in time and reduces in volume the water reaching the river system. Precipitation that reaches the ground either runs off or is infiltrated. Infiltration, like vegetative transpiration, both delays and lessens precipitation entering the river system. However, since the upland soils are generally shallow, the potential for infiltration depends largely upon the underlying geology. Nonetheless, the combined reduction in water volume from transpiration and infiltration contributes to a reduced downstream flood risk and a more even distribution of water throughout the watershed. Management of these upland areas should receive higher scrutiny to protect and maintain the natural ability of the uplands to moderate the contribution of water to the river system.

Manage the Recruitment and Movement of Large Wood in Upland River Reaches. Montgomery and Buffington (1993) found that channel morphology at the reach scale is controlled by hydraulic discharge, sediment supply, and large woody debris (LWD). Stable wood in stream channels can have a significant hydraulic effect by increasing boundary roughness and forming flow obstructions. Large wood plays an important role in the formation and sustenance of aquatic habitats. The presence of flow obstructions is probably the single most effective means of increasing the diversity and range of physical habitat. Large wood can moderate the effects of flooding in lowland reaches of a river system by increasing energy losses in water flow and providing sediment storage. Management of land use in the uplands can ensure the recruitment of large wood to the river system, helping to attenuate downstream flood and sedimentation effects, thereby contributing dramatically to both upland habitat restoration and lowland flood risk reduction.

Manage Stream Impacts at Crossings. Road systems have been extended across the uplands for access to natural resources and for transportation connections to other points within and beyond the basin. Significant impacts may result where the fixed road system intersects the dynamic river system. Management efforts need to be focused at these locations to ensure the downstream movement of water, sediment and organic material is not excessively obstructed or cumulatively impacted. Where these system intersections occur along river reaches traveled by salmon, management efforts need to ensure the successful upstream passage of adult salmon and the safe downstream passage of juvenile salmon.

8.4.3 Combined Floodplain and Active Floodplain Zones

Strategy and Actions. Strategies for the floodplain and active floodplain zones of the lowland valley should be to attenuate flood flows and manage the overbank flow and distribution of floodwater, debris and sediment. The primary actions considered for common use in both the active floodplain zone and floodplain zone were floodplain shelterbelts, riparian plantings, alternative grazing practices, levee modifications, floodplain restoration and floodplain structure modifications. These common actions are described below with additional actions more specific to the active and general floodplain zones described in the following two subsections.

Floodplain Shelterbelts. Shelterbelts are plantings consisting primarily of tall trees, intended to benefit fish and wildlife and agricultural interests. They would be most beneficial for fish where they are planted along the northwest edges of streams, such that leaves, twigs and other organic matter are blown directly into the water and contribute to the food source for benthic invertebrates and, in turn, for fish. Shelterbelts placed along the southern edges of streams would shade surface waters to moderate water temperatures and improve water quality for fish and other aquatic organisms (Figure 8-2). Shelterbelts have been used for centuries as a method to protect agricultural crops and soils from wind damage and erosion. Shelterbelts along the northwest edges of existing or restored floodplain wetlands would reduce summer wind speeds and reduce evaporation rates from wetted areas. This would help moderate excessive changes in the seasonal water balance in agricultural areas.

Riparian plantings. Riparian plantings were considered for use throughout the lowlands. Plantings can be utilized anywhere in the lowlands, but would be favored on riverbanks and restored floodplains. Riparian plantings should be wider in the active floodplain zones because of the potential for channel meandering.

Natural Levees. As sediment-laden floodwaters overtop a riverbank and overflow onto the floodplain, suspended sediment is deposited. The portion of the floodplain immediately adjacent to the river channel is most effective in trapping fine suspended sediments and typically forms natural levees -- low mounds of earth that become vegetated and provide functions similar to those of constructed levees for lower-elevation, higher-frequency flood events. If land use activities encroach on the floodplain, the value of this floodplain function may be reduced and an increased amount of fine sediment may be deposited in the stream channel itself, leading to increased embeddedness of salmon spawning gravels and impacts on fish production. By setting back constructed levees, the floodplain may regain its function to serve as an effective sink for fine sediment, silt and clay sized particles suspended in flood flows. The development of a natural levee on the riverbank may be replicated by constructing low mounds of earth (Figure 8-3).

Vegetated Levees. Levee failures are often attributed to excessive changes in soil pore water pressures as the earthen structure experiences the rapid rise and fall of floodwaters. The root mass of riparian vegetation can moderate this soil condition and help keep the soil structure intact (Figure 8-4). The stems and leaves of plant materials can also reduce the surface erosion of levees by reducing floodwater velocities and wave action. The existing structural integrity and original design assumptions of any levee or other flood control structure should be reviewed before vegetation is introduced, however.

Floodplain Rotational Grazing. The flat terrain characteristic of lowland floodplains often provides easy river access for livestock watering. River bank disturbances and water quality degradation may result as livestock trample the fragile land-water boundary. River bank erosion during subsequent flood events may be initiated where riparian vegetation and soil has been disturbed. Fencing is used to control the movement of livestock to and from the river and provides a contained area for grazing. During flood events, fencing can create obstructions to flood flows and trap flood debris, causing local scour and erosion of pastureland (Figure 8-5). The impacts of grazing can be lessened if cattle are moved on and off land parcels on a rotational basis to improve the production of the land for farming and ecological purposes. Several farms in the Klamath Basin are experimenting with this approach (PWA, 1998).

Streamlined Floodplain Structures. The geometric configuration of infrastructure built on floodplain lands reflects traditional design considerations and the economical use of materials and land. These features may result in obstructions to flood flows. Innovative uses of floodplain vegetation and modifications to the traditional design of floodplain construction to streamline flood flows may reduce flood impacts (Figure 8-6). The streamlined movement of floodwaters around obstructions may lessen the potential for damages from floating debris and reduce localized erosion.

Levee Setbacks with Floodplain Terracing. To reduce flood elevations and increase the ability of a river reach to carry floodwaters, it is necessary to increase the flow area of the river channel. Levee setbacks together with terracing of the floodplain would accomplish this and also provide ecological benefits for fish and wildlife habitats (Figure 8-7). Reconnection of a seasonal flood pulse to floodplain lands would increase the direct deposition of organic materials to the river system and provide food for aquatic organisms. The grading of river banks may also provide better access to the river for recreational purposes.

8.4.4 Active Floodplain Zone

Strategy and Actions. The specific strategy for this zone (Figure 8-1) was to attenuate floodwaters and trap sediment and flood debris after floodwaters leave the uplands and prior to their discharge to the downstream floodplain zone. The primary actions considered were the use of floodplain hedgerows and gravel traps.

Floodplain Hedgerows. Hedgerows are strategically placed plantings consisting primarily of short shrubs and are intended to slow and detain overbank flows. Functioning much like snow fences, the hedgerows would be planted densely, but would be permeable enough to filter flood flows while encouraging the deposition of sediments and debris in locations that would be accessible for maintenance and removal following a flood event. The vegetation would be generally placed in rows perpendicular to observed overbank flood flow directions to best retard the movement of floodwaters. The alignment of the hedgerows would be optimized through the use of hydrodynamic modeling, but could be aligned predominantly in a north-south direction to minimize shading on agricultural fields and pasturelands. The composition and density of the rows of vegetation would vary. Thin and permeable rows could be designed to slightly detain floodwaters and filter flood debris. Thicker and denser rows, perhaps constructed with low walls similar to European hedgerows, would be designed where complete flow detention and debris entrapment is desired. Potential hedgerow alignments would be reviewed with landowners and easements would be negotiated to enable the vegetated structures to be laid out to counter anticipated natural flood patterns, as opposed to strictly following existing property boundaries.

Gravel Traps. The active floodplain zone represents a reach of the river system where sediment deposition is prevalent, as material from the uplands is transported to reaches of lower gradient and greater width. The natural erosion and deposition patterns of the rivers would be harnessed to guide the accumulation of river gravel and cobbles in accessible off-channel areas for harvesting in a sustainable manner. Continual monitoring and measurement of sediment quantities removed would ensure that the harvest of these materials takes place at a rate that does not exceed the natural upstream supply. In this way, impacts to downstream channel reaches, such as accelerated streambank erosion, channel incision, and sediment "starvation" would be reduced.

8.4.5 Floodplain Zone

Strategy and Actions. The specific strategy for this zone (Figure 8-1) was to effectively convey floodwaters and sediment though the various human encroachments in the floodplain towards the tidal zone. The primary actions considered were the use of flood relief routes and overflow routes, fill embankment and bridge encroachment modifications, and debris traps.

Flood Relief Routes and Overflow Routes. Land use and generalized hydraulic data were utilized to delineate flood relief routes and overflow routes. The routes were considered for use within the floodplain zone, downstream of the active floodplain zone and upstream of the tidal zone. Flood relief routes would be dedicated easements on floodplain lands, utilized to relieve flood hazards, such as flood elevations and flow velocities, within the same river system. Flood overflow routes would be utilized to relieve flood hazards by conveying flood flows to another lowland river system. The routes were initially laid out according to flood patterns associated with the 10-year flood, with consideration of natural topography and drainage patterns, to promote more natural drainage of floodwaters from floodplain lands. These initial routes were refined in alignment and width to avoid existing land uses such as buildings and public infrastructure. The routes were further refined to include and connect existing wetland communities, and to interconnect proposed riparian plantings to form lowland vegetation corridors for fish and wildlife. The widths of flood relief routes are intended to be defined as best as possible by the existing terrain. Where land elevations are not high enough to contain floodwaters or where existing properties need to be protected, bermed levees (Figure 8-8) would be used to contain floodwaters. The bermed levees would be constructed using land slopes that would allow animal grazing over their crest. Land use practices and infrastructure within the flood relief routes would be reviewed for opportunities to reduce or eliminate obstructions to flood flow.

Road and Railroad Fill Embankment Modifications. Many linear encroachments extend across the lowland floodplains. These built features create obstacles to flood flow and result in unnaturally excessive flow velocities and scour of riparian areas and riverbanks. Fill embankment modifications, using large culverts and other hydraulic openings, would be located where the flood relief routes and overflow routes intersect encroachments and would allow the flow of water, sediment and flood debris across the floodplains in a more natural manner. Flood elevations would be lower, reducing flood risks, and there would be less risk to riparian and channel habitat (Figure 8-9).

Bridge Approach Modifications and Guide Banks. Although bridges are usually designed to span active river channels, they typically constrict the flow of water on floodplains, such that all flow is forced to pass through the opening sized for the shape of the channel. Modifications to bridge approaches would involve the replacement of earth fill with an open viaduct or trestle construction that would allow flood flows to pass under the roadway with less constriction (Figure 8-10). Since the cost of this type of modification to existing infrastructure would be high, this action would be reserved for only the most restrictive bridge crossings. As an alternative, bridge openings would be modified to include the use of guide banks (Figure 8-11). These structures help to streamline the flow of floodwaters through the bridge opening and reduce the potential for erosion of bridge abutments.

Floating Debris Trap. Floating debris is a recurring flood problem that threatens the integrity of bridges in the Tillamook lowlands. Huge rafts of debris pile up on the upstream side of bridge openings and require significant time and resources for removal and disposal (Figure 8-12). Levee setbacks and floodplain terracing would be used in combination with riparian plantings to serve as an off-channel trap for floating debris. Engineered log jams would be located on opposite banks to deflect flood flows and debris into restored floodplain areas. They could also be located at other upstream locations to serve as designated places for debris accumulation.

8.4.6 Tidal Zone

Strategy and Actions. The general strategy for this zone would be to restore tidal flushing action and increase the conveyance of water and sediment from the floodplain zone to the bay. The primary action considered was tidal prism restoration.

Tidal Prism Restoration. Dike and levee setbacks would be considered on tidelands to restore full tidal action on marshlands, which in turn would restore tidal channels and habitat. Restoration of the natural tidal prism, or the volume of water exchanged during a typical tide cycle, would be done by removing and setting back dikes and levees. Since the vertical resolution of the 30 meter DEM used to create the zones is corse, assumptions were made to define a realistic setback distance. Setbacks would be prioritized seaward of the brackish-freshwater interface. A typical marshplain slope of 1:150 was assumed based on a tidal range of 7 feet between MHHW and MLLW. For these conditions, full tidal action would require the restoration of tidelands approximately 1000 feet from MLLW. Restoration would lead to the evolution of complex off-channel tidal slough channels with great habitat potential. Using data from Coats et al (1995), a minimum marsh area of 10 acres was estimated to support a third order tide channel system. For the 1000-foot setback, a 10-acre land parcel would be about 500 feet wide. This minimum parcel size was used for planning purposes.

8.5 IRMS Implementation Considerations

One of the common myths in river management is that flood control, ecological restoration and making the river "look natural" cannot occur simultaneously. From the practical point of view, looking at other successful river management plans, it is evident that the opposite is true. Why are communities looking at multi-objective projects rather than just flood protection? The answer is simple - multi-objective river management also implies multiple potential funding sources.

As an example, the plans for a Napa River Flood Control project for the City of Napa in California was rejected three times by the local community as it benefited only those living in the flood plain. It also called for dredging and massive bank stabilization that would have dramatically impacted the ecology of the river system. The 'Living River Strategy' developed by the local community with assistance from state and federal agencies was a multi-objective project backed by local business, private property owners, special interest groups, local government, and state and federal agencies. FEMA has used this project nationally as an example of a community-based multi-objective approach to flood management. As the project has grown from a project focused only on flood control of a few miles of channel, to a watershed wide initiative, there have been many other benefits and funding sources. Examples of spin-off projects funded from other sources include: the phased restoration of more than 20,000 acres of abandoned salt ponds and diked wetlands; the renaissance of downtown Napa; reduction in flood risks of other communities along the river; watershed wide ecological enhancement initiatives; cleanup of contaminated land; and a coordinated approach to TMDL issues.

Examples of this type of integrated planning are increasing in the United States. The success of future projects depends in large part on key considerations for their implementation based on the "lessons learned" from recent integrated river management strategies (Box 8-7).

Tillamook has an opportunity to be a similar nationally recognized project capable of attracting the diverse range of funds achieved by the Napa Community. Some of the similarities that make Tillamook a prime candidate as a model approach include:

1. Region of great natural beauty
2. Strong tourism economy
3. Severe existing flood problem
4. High quality aquatic environment
5. Watershed is small enough that inter-agency responsibilities can be coordinated more easily

The successful implementation of the IRMS will require several refinements of the concepts presented herein. These refinements include:

1. Support and adoption of the formal plan will be required from landowners, local government, state and federal agencies, and public interest groups. This will be achieved best through a series of workshops and individual meetings with stake-holders.
2. Adjustments to planning and zoning designations where appropriate, and new guidelines for the issuance of permits for activities that affect the aquatic resources and environmental quality of the Tillamook Bay watershed.
3. Computer modeling and related analyses will be required to confirm the expected performance of the actions discussed in Section 8.4, and to evaluate the spatial extent of these measures.

8.6 Monitoring Program and Adaptive Management Considerations

The development of an IRMS is immensely complex and includes ecological, economic, social, hydrological, and cultural issues. The interactions among these issues are difficult to predict, and unforeseen circumstances -- both positive and negative -- may arise as an IRMS is implemented and becomes established over time. Secondly, the conditions in the watershed are not static in time and are subject to the geomorphic evolution of the river system, episodic events such as fire and flood, and external factors such as conditions in the ocean, changes in legislation or funding opportunities.

A cornerstone of the proposed IRMS is the establishment of a clear set of performance criteria, and periodic monitoring standards to ensure that the IRMS is on a trajectory to achieve these performance criteria. The monitoring program will also build our knowledge and understanding of the response of the river system to changes in its watershed. With this knowledge, it is then possible to undertake adaptive management through a review panel of interested parties to alter priorities in management actions to ensure that the objectives of the IRMS are achieved in the most effective manner.

The primary objectives of a monitoring program for the IRMS are to:

1. Coordinate existing monitoring programs and supplement where necessary.
2. Establish a central database of key indicators, computer models and GIS coverages to be used in the assessment of the IRMS.
3. Document changes in flood risk and minimize flood damages for larger events.
4. Document changes in floodplain and marsh plain connectivity with tidal channels and rivers.
5. Document changes in quality and quantity of habitat for indicator species, e.g. Chum salmon, and others identified by the review panel.
6. Monitor changes in vegetation communities.
7. Document changes in access and connectivity to habitat for indicator species through channels during ecologically important times of the year.
8. Monitor costs and ensure that the expenses are sustainable over time.
9. Track changes in habitat, particularly related to indicator, threatened, endangered or “of concern” species.
10. Monitor changes in river and tide channel size and location to anticipate loss of property due to bank erosion or loss of channel flood conveyance (i.e increases in flood risk). Note: it is unnecessary to monitor a large number of sections. A few sections sited in critical positions will provide an indicator of where significant changes are occurring. If these changes are deemed to be significant to flood risk, ecological impacts or other objectives, a more thorough survey could be undertaken.

The computer model currently being developed for the Tillamook Bay by the Portland District, US Army Corps of Engineers will be a valuable decision-making tool if used to assess the effects of sedimentation, dredging, channel scour, salinity intrusion, temperature and water quality under different management strategies. It is also recommended that this model be integrated with a 2-dimensional model of Tillamook Bay so that a better understanding of the link between the hydrodynamics of the bay and lowland river systems can be developed. This modeling approach can then be used to determine water quality, extent of salinity intrusion, and sedimentation trends as a result of different management approaches.

Table 8.3 presents a skeletal monitoring approach with general considerations for all landscape zones of the Tillamook Bay river system. Refined monitoring plans would ultimately be adopted for each landscape zone described earlier. The plan sets out a series of broad objectives, with a column describing the relative importance. For example, flooding in the uplands might be less of a risk than flooding in the city of Tillamook. Associated with each objective is a metric, or parameter, that can be used to quantitatively assess whether the objective is achieved. Associated with each parameter are performance criteria that will determine whether the objective is achieved, or if additional actions are required. The table also gives an indication of how the metrics will be measured. These metrics should be based on existing monitoring data to the extent feasible. Establishing performance criteria and monitoring for adaptive management should be developed in more detail by the review panel, participating agencies and other interested parties.

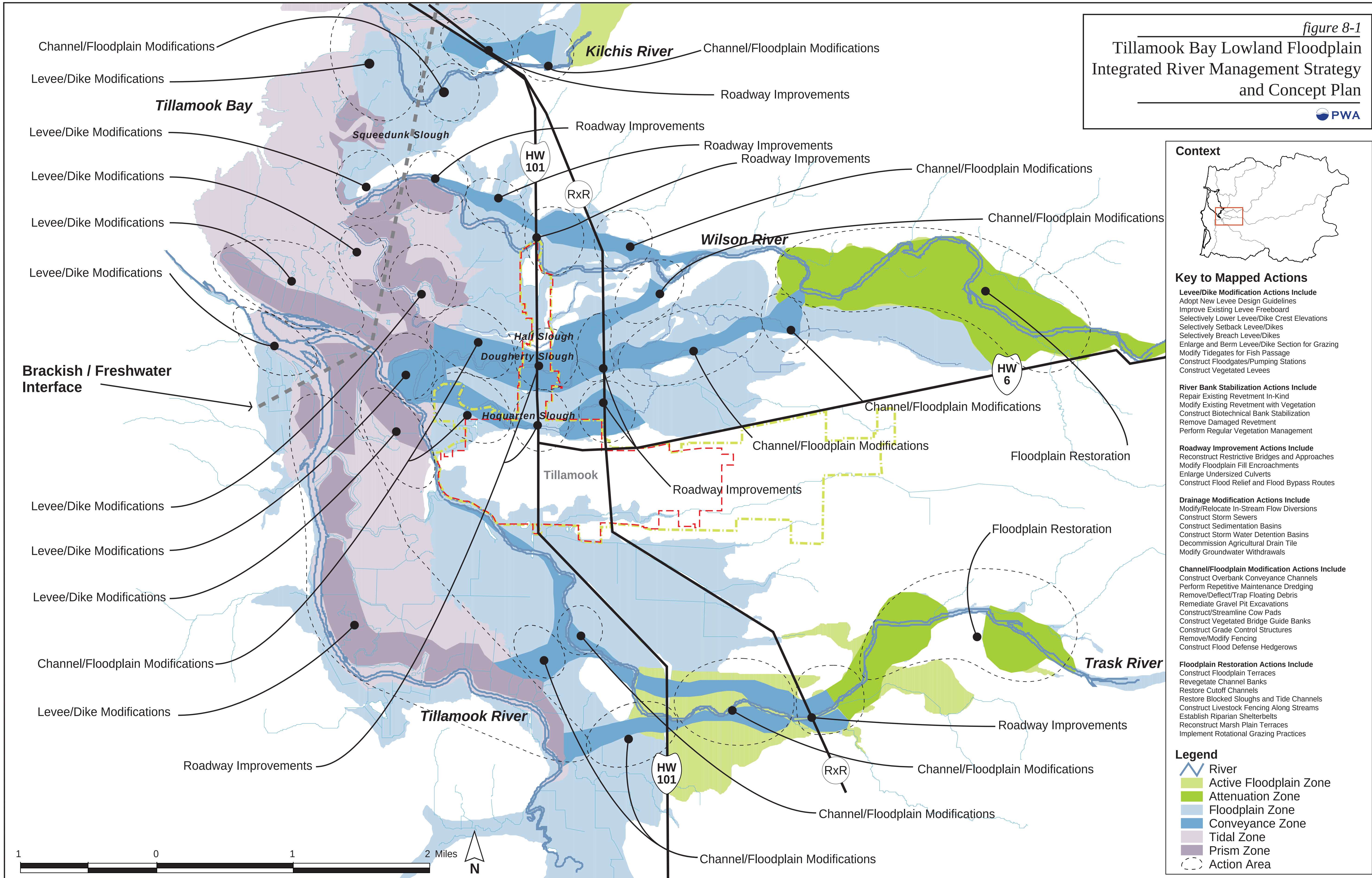

figure 8-1

Tillamook Bay Lowland Floodplain Integrated River Management Strategy and Concept Plan

Table 8.3 Skeletal Outline of Performance Criteria for IRMS

Landscape Zone: Upland, Lowland and Estuary				
Objective	**Metric**	**Performance Criteria**	**Methodology**	**Relative Significance**
Flood Management	1. Conveyance 2. Water surface elevations 3. Land use zoning and planning	1. Designated acceptable risk 2. Required maintenance 3. Duration of standing water 4. Flood damages 5. % key floodplain areas undeveloped	1. Periodic surveys of monitoring sections 2. Computer model 3. Flood elevation monitoring 4. GIS land use coverages	High/Medium/Low (depending on region)
Ecological Enhancement	1. Indicator species	1. Abundance 2. Harvest records 3. Redd counts	1. Snorkel counts, stream surveys, electro-shocking, angler reports and other techniques.	High/Medium/Low (depending on region)
	2. Channel response / geomorphic diversity	1. Slope/sinuosity 2. Width/depth ratio 3. Bankfull flow 4. Substrate suitability index	1. Periodic surveys of monitoring sections 2. Pebble counts/bed samples	
	3. Revegetation / bio-stabilization	1. Survival rate 2. Rate of bank retreat 3. % vegetation cover on banks	1. Vegetation transects 2. Cross-section surveys 3. Visual assessments from aerial imagery	
	4. Water quality	1. Number of days in year shellfish beds closed 2. Temperature criteria 3. Flows 4. Turbidity 5. Fine sediment 6. Nutrients 7. E-coli	1. Coordination of current water quality sampling programs 2. Supplemental sampling as found necessary from modeling or other interpretation of existing monitoring programs.	
Maintenance	1. Costs of maintenance 2. Extent of structural bank stabilization 3. Extent of biostabilization 4. Extent of dredging	1. Minimize costs 2. Reduce rip-rap and other structural measures where appropriate	1. Track annual maintenance costs 2. Establish inventory of channel conditions (updated periodically)	High/Medium/Low (depending on region)

Box 8-2
Principles of Flood Risk Reduction

1. Preserve and enhance natural floodplain functions;
2. Avoid and rehabilitate inappropriate uses of the floodplain;
3. Modify susceptibility to flood damage through both modified structural and non-structural management actions;
4. Mitigate flood damages as they occur;
5. Modify the impact of flooding on individuals and the community;
6. Modify flood patterns;
7. Improve the management of watershed land uses;
8. Streamline flood management policy and procedures, and;
9. Encourage the development of shared databases and new technologies to convert data into knowledge upon which decisions can be based.
10. Identify and protect existing habitat that support stronghold populations of species of concern

Box 8-3
Salmon Recovery and Conservation Biology Principles

1. Longitudinal connectivity
2. Lateral connectivity
3. Protection of the plant communities
4. Recruitment and retention of large wood
5. Protect the best, and restore the rest

Box 8-4
Landscape Ecology Principles

1. Landscapes differ structurally in the distribution of species, energy, and materials.
2. Landscapes differ functionally in the flow of species, energy, and materials.
3. Landscape diversity decreases interiors, increases edges, and enhances species richness.
4. Landscape diversity controls species distribution changes.
5. Landscape disturbances increase nutrient flows.
6. Landscape diversity increases flows of energy and biomass across boundaries.
7. Landscapes will develop either physical system stability, resilience, or resistance to disturbances.

Box 8-5
Sustainability Principles

1. Commitment of stake-holders
2. Secured funding
3. Resilient ecological and physical processes

Box 8-6
Cumulative Effects Principles

1. Include past, present and future actions
2. Use natural boundaries, not political or arbitrary ones in resource management
3. Address additive, countervailing and synergistic effects
4. Look beyond the lifespan and areal impact of any one action
5. Address the sustainability of resources, ecosystems, and human communities
6. Employ a whole-systems approach to resource management

Box 8-7
Key IRMS Implementation Considerations

The IRMS will initiate a longterm management strategy that maintains the quality of life for aquatic and terestrial species as well as the community of Tillamook County.

The IRMS does not represent a single project to be undertaken, but a common vision that the community will aspire to in the coming decades. Individual elements of the plan can be implemented as funding for easements, development opportunities, bridge replacement or willingness of individual landowners pose opportunities.

Condemnation of property is not considered an option, but rather voluntary participation to help reduce flood risks to neighbors and maintain or enhance the ecological resources of the watershed.