Tillamook Bay National Estuary Project
Watershed Information System

by

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TILLAMOOK BAY NATIONAL ESTUARY PROJECT
WATERSHED INFORMATION SYSTEM

1. INTRODUCTION

The National Estuary Program (NEP) recognizes that information and data generated through resource characterizations are critical for long term, environmental planning. Therefore, estuary projects admitted into the NEP must gather available information pertaining to environmental problems and develop a conceptual framework that can be used to identify data gaps and guide scientific research efforts (EPA 1992, Strittholt and Noss 1997). It is also important that scientific findings of a NEP be widely communicated, made available to resource managers, and form the basis for public education efforts (EPA 1992).

Tillamook Bay was included in the NEP in October, 1992. As part of this program, the Tillamook Bay National Estuary Project (TBNEP) seeks to develop innovative and efficient ways to manage natural resource information. The TBNEP is using Geographic Information System (GIS) to organize, analyze, and archive data collected and generated through scientific investigations to address the environmental priority problems of pathogen contamination, sedimentation, and habitat degradation. Since agencies and scientists are beginning to recognize that GIS data can be used to improve watershed management decisions, the TBNEP needs a way to compile their GIS data into a product that shares information and helps facilitate an interagency management approach. In addition, the TBNEP needs to increase public awareness about watershed resources, impacts, and management decisions.
While working for the TBNEP, I addressed some of these needs by developing a Watershed Information System to help agencies, scientists, and community members understand issues in the Tillamook Bay watershed and increase their awareness of basic GIS applications. To create the TBNEP Watershed Information System, I compiled data sets and background information on two individually customized CD-ROMs entitled (1) Tillamook Bay National Estuary Project Geographic Information System (version 2) and (2) Tillamook Bay National Estuary Project Watershed Characterization (Table 1). Information on these two CDs can be accessed by a wide variety of users, including natural resource managers, scientists, educators, and local Tillamook residents. Until now, groups involved in TBNEP projects did not have access to GIS data and watershed information in a user-friendly format.

This report is organized into four chapters that provide background on watershed topics, GIS applications, and methodology related to development of the TBNEP Watershed Information System. The need for this product is established in Chapter two. First, the role of ecosystem management and the Tillamook Bay watershed is presented before explaining how watersheds are used as a framework for analysis and assessment. The use of GIS in estuarine and watershed management, its role in public outreach, and concerns related to GIS development are also discussed in Chapter two. Chapter three describes the project objectives and methods used to develop the two CD-ROMs. Scientific, outreach, and management applications of the Watershed Information System are presented in Chapter four. This section also provides recommendations for implementation and future use of the CD-ROMs before concluding with remarks on the significance of the Watershed Information System.
<table>
<thead>
<tr>
<th>Description</th>
<th>Tillamook Bay National Estuary Project Geographic Information System (version 2)</th>
<th>Tillamook Bay National Estuary Project Watershed Characterization</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date</td>
<td>October 1997</td>
<td>January 1998</td>
</tr>
</tbody>
</table>
| Purpose     | • Prioritize existing TBNEP GIS data and gather new data to fill any targeted gaps  
• Provide information in a user-friendly format (HTML)  
• Increase access to resource managers and community members | • Document watershed topics related to the Tillamook Bay watershed  
• Create ArcView tutorials that increase awareness of watershed issues by using TBNEP data from CD-ROM version 2 |
| Contents    | • TBNEP background  
• Description of GIS, metadata, and ArcView  
• Metadata catalog  
• Inventory of prioritized TBNEP GIS coverages with metadata links  
• ARC/INFO export files (.e00 format)  
• ARC/INFO coverages  
• ArcExplorer software  
• Basic ArcView tutorials  
• TBNEP contact list  
• Reference list of sci-tech reports  
• Photographs of the Tillamook Watershed  
• HTML format | • Report with background on watershed topics  
• Basic ArcView tutorials  
• Advanced ArcView tutorials on watershed issues  
• Inventory of prioritized TBNEP GIS coverages with metadata links  
• HTML format |

Table 1. Tillamook Bay National Estuary Project Watershed Information System components
2. BACKGROUND

2.1 National Estuary Program

Estuaries provide habitat for a variety of organisms while attracting industrial, commercial, and residential development to their shorelines and watersheds. Thus, many coastal communities are confronted by difficult decisions about conserving estuarine resources and encouraging economic development (Colt 1994). In 1987, U.S. Congress acknowledged the growing concerns about the nation's estuaries by establishing the National Estuary Program (NEP) under Section 320 of the Clean Water Act (EPA 1992, Colt 1994). The mission of the NEP is to identify nationally significant estuaries and to establish and oversee a process for improving and protecting estuarine resources. The NEP seeks to identify priority problems, or the environmental problems facing the estuarine watershed, collect natural resource information, and involve the public by bringing together regional stakeholders (EPA 1992).

After an estuary has been nominated, the study area defined, and goals established, the EPA convenes a Management Conference comprised of local, state, and federal officials, environmental activists, scientists, and various stakeholders or user groups. When a Management Conference is formed, each NEP begins characterizing the estuary. A characterization describes valued estuarine resources and defines watershed problems and impacts (EPA 1992). During a characterization, a data inventory is compiled, needs for new data are identified, scientific/technical reports are written, and
public outreach efforts are begun. At this stage, GIS is an important tool used to describe watershed features and processes. After characterization is complete, the next step is to develop a Comprehensive Conservation Management Plan (CCMP) which identifies action strategies and management recommendations to address the environmental priority problems (EPA 1992). During this process, the data generated from the scientific/technical program can be shared and monitoring protocol established.

The traditional approach to environmental protection has been to consider specific issues or individual resources – often with little consideration of maintaining or improving conditions of a whole watershed (EPA 1992). However, the NEP focuses on identification, assessment, and action on a variety of environmental problems within a watershed context. The watershed approach to resource management looks at the entire system and examines the combined impact of laws, programs, and human behavior on an ecosystem.

2.2 Tillamook Bay National Estuary Program

The Tillamook Bay Estuary was included in the NEP in October, 1992 (State of Oregon 1992). Three environmental priority problems were identified by the Tillamook Bay National Estuary Project (TBNEP): (1) pathogen contamination affecting shellfish and water-contact uses; (2) excessive sedimentation in the bay and tributaries affecting fresh and saltwater flows and living resources; and (3) critical habitat degradation affecting salmon spawning, increasing stream temperatures, and contributing to bay sedimentation (State of Oregon 1992). These priority problems may be a result of
activities occurring throughout the entire watershed (Nehlsen and Dewberry 1995) and are complex issues that cannot be easily solved with simple solutions. For example, sedimentation and habitat degradation of the bay can be strongly affected by urbanization, silviculture activities in the upper watershed, and diking associated with agricultural activities. Thus, environmental concerns of the Tillamook region require an integrated management approach linking the economy and the environment throughout the watershed.

2.3 Ecosystem Management

Traditionally, natural resources have been managed for a single resource or species, often for commercial or recreational purposes (Knight and Bates 1995). However, an ecosystem management approach has recently emerged to better address the complex ecological needs of individual species, communities, and ecosystems. An ecosystem is defined as a "spatially explicit unit of the earth that includes all of the organisms, along with all components of the abiotic environment within its boundaries" (Boyce and Haney 1997). Although ecosystem management is often defined as managing ecosystems so as to assure their sustainability (Boyce and Haney 1997), many interpretations exist. Grumbine (1994) identified some dominant themes of ecosystem management: multiple scales, recognition of ecological boundaries, systematic research and data collection, monitoring, adaptive management, interagency cooperation, and humans as an ecosystem component.

Ecosystem management is based on concepts of adaptive management. As new knowledge and information continues to accumulate, managers must alter basic
assumptions and predictions and modify their decisions (Boyce and Haney 1997). They must realize that all management prescriptions are based on limited information with significant degrees of uncertainty. Recognizing this, ecosystem managers must design their activities so as to "contribute to the learning process - managing to learn and learning from management... Thus a systematic collection of information and its feedback into the decision making process is required" (Boyce and Haney 1997). Monitoring data and feedback is one way to measure the effectiveness of management decisions and can be used to adjust strategies and goals (Boyce and Haney 1997). Although it is often expensive and choices of what and where to monitor are difficult, monitoring should be made a part of an ecosystem approach.

Ecosystem management addresses a variety of spatial scales. Conceptually it is appropriate to view an aquarium, a watershed, a region, or the entire globe as an ecosystem (Boyce and Haney 1997). The selected scale is determined by the particular set of processes or species of concern. For example, strategies to conserve salmon in the Pacific Northwest involve scales ranging from stream reaches to landscapes and larger drainage basins. Resource assessments can be made at different scales (Table 2) depending on the type of data that are available and the questions being asked in a watershed context (State of Oregon 1997a). Before using a certain scale, it is important to identify the resolution needed to address a particular question. When data of different scales are combined, conclusions should only be drawn from the data with the least resolute scale. The range of scale is one of the greatest strengths of the ecosystem concept for it allows the scientist or resource manager to select a scale that is appropriate to a particular objective or interest (Boyce and Haney 1997).
Table 2. Watershed terminology and associated GIS scales for the Tillamook region

<table>
<thead>
<tr>
<th>Term</th>
<th>Example</th>
<th>Typical GIS Map Scale</th>
</tr>
</thead>
<tbody>
<tr>
<td>Region</td>
<td>Pacific Northwest</td>
<td>1:500,000</td>
</tr>
<tr>
<td>Subregion</td>
<td>North Coast Basin</td>
<td>1:250,000</td>
</tr>
<tr>
<td>River Basin</td>
<td>Tillamook Bay Basin</td>
<td>1:100,000</td>
</tr>
<tr>
<td>Subbasin</td>
<td>Kilchis River</td>
<td>1:24,000</td>
</tr>
<tr>
<td>Watershed</td>
<td>N. Fork Kilchis River</td>
<td>1:24,000</td>
</tr>
<tr>
<td>Subwatershed</td>
<td>Schroeder Creek</td>
<td>&lt;24,000</td>
</tr>
</tbody>
</table>

Ecosystem management requires large amounts of data from various sources. Thus, the use of GIS is increasing as resource managers recognize how this technology can store and organize diverse datasets and incorporate the variety of scales needed for an ecosystem approach. This technology provides a tool for resource managers and scientists to visualize data, perform spatial and statistical analysis, and integrate social and economic factors into the analysis of ecosystems. GIS is also well suited for purposes of adaptive management since it provides the ability to reach certain conclusions while helping to formulate new questions and directions for future study. For these reasons, GIS is becoming recognized as a valid scientific tool and is being increasingly used to enhance the broad, landscape-scale analysis required for ecosystem management (Boyce and Haney 1997).
2.4 The Tillamook Bay Watershed: Definition and Characteristics

A watershed defined as the area of land from which water drains to a single point or given place in a stream (Omernik and Griffith 1991). Topographic divides such as ridge tops or mountain ranges usually delineate the watershed boundary (Figure 1).

![Watershed divide and River mouth](image)

**Figure 1.** Watershed boundary delineation. Shown is an area of land from which the water drains to a single point or given place on a stream. Topographic divides delineate boundaries.

Geology, vegetation, and slope, among other drainage basin characteristics, influence hydrology, nutrient cycling, species distribution, and geomorphic processes in a watershed (EPA 1994). Basin characteristics are also influenced by the history of natural
and human disturbance in the region, which when combined, make every watershed unique (Washington Forest Practices Board 1995). For example, the Tillamook Bay watershed is characterized by a disturbance history of fires, spit breaching, logging, and conversion of lowlands to dairy farming through diking and draining (Appendix A).

The Tillamook Bay watershed is located on the northern coast of Oregon (Figure 2), between the crest of the Oregon Coast Range and the Pacific Ocean and encompasses a total area of 1476 km² (570 mi²) (TBNEP 1996). The watershed is a complex of five major river basins including the Miami, Kilchis, Wilson, Trask, and Tillamook subwatersheds which all drain into Tillamook Bay before entering the Pacific Ocean (Figure 3). The lower basin is characterized by gently rolling hills and floodplains while

![Figure 2. Location of the Tillamook Bay watershed, Oregon](image)
the upper basin is predominantly steeply sloped rocky uplands and deeply incised canyons (Nehlsen and Dewberry 1995). The climate of the Tillamook basin is strongly affected by the Pacific Ocean with wet winters, moderately dry summers, and relatively small annual temperature fluctuations (Nehlsen and Dewberry 1995).

Figure 3. Subwatersheds in the Tillamook Basin

2.4.1 Watersheds as a Framework for Analysis and Assessment

Watershed assessment and analysis are techniques used to determine how important watershed components operate (State of Oregon 1997a). The analysis and
assessment framework is based on scientific and social agendas that address regional concerns and issues (Figure 4); in the case of the Tillamook Bay watershed, the issues are identified as the three priority problems of sedimentation, pathogen contamination, and habitat degradation. The multi-step approach used in watershed assessment and analysis (Appendix B) involves gathering, inventorying, and organizing information about topographic, hydrologic, biologic features, and watershed functions (Doppelt et al. 1996, State of Oregon 1997a, TBNEP 1997a). This information is used to characterize a watershed based on such things as water flow, sediment transport, vegetation change,
wildlife habitat, and pollution sources (EPA 1994). The range of resource issues considered by estuarine managers is reflected by the wide range of data sources they use. Essential basemaps needed to characterize an estuarine watershed include basin boundaries, vegetation, ownership, hydrology, roads, soils, geology, land use bathymetry, floodplains, and wetlands (Zisman 1993).

Although the terms watershed "assessment" and "analysis" have often been used interchangeably, the two terms need to be distinguished (Table 3). A watershed

<table>
<thead>
<tr>
<th><strong>Descriptor</strong></th>
<th><strong>Assessment</strong></th>
<th><strong>Analysis</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Requires extensive technical training on the part of team members conducting the work.</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Describes the current condition of resources in the watershed.</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Is organized into modules that deal with a specific set of resources or ecological processes within the watershed.</td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Requires field investigations to (1) develop information for modules lacking current studies, (2) examine historic information, and (3) project trends based on the synthesis of the historic and current information.</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>May use models to make predictions about system behavior under different management regimes.</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>Relates human activities to their impacts and links the impacts to affected resources.</td>
<td>X</td>
<td>X</td>
</tr>
</tbody>
</table>

Table 3. Watershed Assessment and Analysis Distinctions

*assessment* describes features of a watershed and is therefore comparable to resource "characterization". An assessment is completed by local watershed councils, public
planners, and others who are familiar with watersheds, but may not be watershed specialists with technical experience (TBNEP 1997b). Assessment results are often used to identify areas for additional study or more intensive analysis. Although watershed analysis is also used to characterize resources, it has the additional step of synthesizing results to develop and prioritize protection, restoration, and management efforts. An analysis is completed by professionals and interdisciplinary teams with technical experience (Washington Forest Practices Board 1995). Watershed assessment and analysis should consider social and economic factors of land ownership, land use, and political boundaries. When natural, social, and economic factors are combined, a watershed can be described as a hydrologic unit and as an ecosystem with human influences (EPA 1994).

In the spring of 1997, the TBNEP began conducting a watershed analysis in the Kilchis subwatershed to identify processes, functions, and conditions of the Tillamook basin by using a procedure similar to the one documented in Appendix B. Analysis results will be used to develop potential management and restoration strategies that address the three environmental priority problems (Nehlsen and Dewberry 1995). One reason the Kilchis watershed was chosen for analysis was because its data inventory was more complete than for any other part of the Tillamook basin. Thus, GIS could be used as an integral part of the study. Once this analysis is complete, lessons learned will be passed along to projects in the other four subwatersheds so that less time and resource intensive studies can be conducted.
2.4.2 Trends in Watershed Management

Within a watershed, management actions are often taken by multiple agencies which have uncoordinated desires and goals.

"For example, the Oregon Department of Forestry (ODF) is required to develop basin plans which include management actions for timber harvest, forest fires, road maintenance, and riparian buffer strips. The Natural Resource Conservation Service (NRCS) develops strategies for manure management and individual farm plans for agricultural areas. Finally, the Oregon Department of Fish and Wildlife (ODFW) develop fisheries management plans for rivers, creeks and estuaries. Each of these agencies has its own data collection and reporting needs that are as separate as the landscape components they manage.

...Consider the point of view of a fisheries biologist; if a fisheries biologist is interested in maximizing the production of Chum Salmon, that biologist may manage lower parts of the watershed to increase the extent of wetlands since wetlands are known to be an important component in the life history of this salmonid species. In this case, the management of the salmon would call for an increase in the extent of wetlands. An increase in wetland extent would also be desired by resource managers who manage water quality since wetlands are known to have a positive effect on water quality. However, agricultural land is also a valued resource in some coastal and lowland areas. Any increase in wetland extent would remove that area from dairy production. So, from the point of view of the manager of a dairy farm, an increase in wetland extent may be undesirable. Unless activities of various resource managers are coordinated at the watershed scale and evaluated in common terms (i.e., dollars), management activities themselves can be conflicting and perhaps, rendered ineffective" (Garono and Strittholt 1997).

In the Pacific Northwest, many watershed resources have been used and managed independently (i.e., timber, fish, wildlife, and water). As a result, an inadequate understanding of their interrelations has often led to controversial resource management disputes. Wise use of natural resources in resolving such disputes requires research and information at watershed and landscape scales (Naiman 1992). GIS is a tool that can incorporate data on a variety of spatial scales and can facilitate interagency communication. Development of a watershed management strategy should involve close interaction between managers, planners, and analysts to ensure that (1) the analysis is
relevant to planning, (2) desired conditions are feasible, and (3) proposed management activities are consistent with attaining those conditions (Montgomery et al. 1995).

Watershed management requires the recognition of several basic facts:

1) consistent efforts must be made to identify, involve, and work constructively with stakeholders in phases of watershed assessment, planning, and implementation;

2) needs, priorities, and action plans should be based on clear methodology and scientific information;

3) increased tendencies to use technical solutions (i.e., hatcheries) must be complemented with increased habitat protection;

4) intra and inter-agency inconsistencies in environmental regulations must be corrected; and

5) interrelationships between the watershed, community, and economy must be considered to achieve sustainability (Naiman 1992, River Network undated).

Effective watershed management combines local actions with federal and state partnership and incentive programs (Appendix C). However, as watershed conservation is placed more in the hands of local people or they begin taking a more active role, governments must provide guidance by finding voluntary, cooperative, and incentive-based ways to encourage private landowners to take part in ecosystem management efforts (River Network undated).

2.5 The Public Role in Watershed Activities

Rather than state and federal programs creating top-down policy with minimal local input for watershed management, authorities and citizens are being given more opportunities to influence land management and policy decisions at a local level (EPA 1994, OSU Extension 1997). There are a number of state initiatives and programs that
aim to mitigate watershed health problems through the use of voluntary practices. Many of these programs rely on landowners to voluntarily make changes in their land management practices (OSU Extension 1997). Therefore, it is increasingly important that the public understands resource management decisions and represents themselves within phases of watershed assessment, restoration, and regulation (EPA 1994).

Watershed protection requires a long-term commitment to monitoring, adaptive management, and stewardship from all stakeholders (River Network undated). Watershed stakeholders include (1) individuals who live, work and recreate in the watershed, (2) conservation organizations with interests in the watershed, (3) public agencies with responsibilities in the watershed, and (3) individuals, businesses, or organizations with environmental economic, educational, or scientific interests that might be affected by the outcome of watershed management efforts (River Network undated). These groups need to establish partnerships and recognize that the most effective watershed efforts involve positive working relationships with a variety of interests, perspectives, and expertise (River Network undated).

Public participation and education are an integral component of the NEP approach to watershed management (EPA 1992, TBNEP 1995). The goal of public participation is to involve citizens in resource management decisions concerning their communities, waterways, and estuarine habitats of the watershed. The purpose of education is to teach people about their environment, the part they play in degrading it, and the role they have in restoring and protecting it. The TBNEP Management Conference has developed a public participation strategy with activities that include a mailing list, newsletters, a web...
site, and other informational resources such as pamphlets and posters. The Watershed Information System forms another component of this outreach strategy.

Although the public cannot directly change policies, they can influence decisions by being more demanding of political representatives and calling for greater public dialogue about key watershed issues. Thus, developing a public understanding of watershed issues is one key to better management. Well informed citizens can increase the value of watershed studies with the time and energy they provide and the implementation strategies they develop and support (EPA 1994). Through public participation and education programs, citizens of the estuarine watershed will become motivated to protect resources for future generations (EPA 1992).

Volunteer monitoring is an example where public education and involvement is used to help citizens gain a better understanding of an estuary's functions. Such activities can be used to enlist citizen support and increase awareness of estuarine problems (EPA 1992). Over the last three years, the TBNEP has worked to organize and promote volunteer programs including Baykeepers/Streamkeepers, a citizens action committee, a coalition of community college and high school students, and a watershed council. These groups are responsible for watershed monitoring, public education, and conservation support. It would be impossible for TBNEP staff to accomplish their goals without volunteer support. For example, studying water quality and riparian areas in the Tillamook Bay watershed is a challenging task. Therefore, the help of volunteer Baykeepers/Streamkeepers and watershed councils is essential for providing information needed for monitoring and restoration projects (TBNEP 1995).
2.6 The Use of GIS in Estuarine and Watershed Management

GIS is a valuable tool that provides an efficient, organized way to store, manage, and update large amounts of spatial data for interpretation and representation. GIS is used in coastal management to (1) provide a receptacle for data from diverse sources, (2) provide a mechanism to store and update information about the data, (3) map watershed characteristics, (4) improve the visualization of data, (5) support modeling and impact analysis, and (6) support management decisions (Ricketts 1992, Wold 1996). Since the vast majority of coastal resource data and issues are spatial in nature and increasing amounts of data are now in digital format, GIS has the potential to significantly enhance estuarine watershed management (Ricketts 1992). GIS is also a tool that can be used to identify problems and solutions in a visual, user-friendly manner to engage the public in scientific and technical issues (Barstow 1994).

2.6.1 Descriptive and Prescriptive GIS Mapping

GIS has been described as having both a descriptive and prescriptive function (Garono and Stritholt 1997). One step of a watershed analysis or assessment is to use descriptive mapping to identify the condition of biological, physical, and cultural characteristics of the watershed. Features such as vegetation, soils, wetlands, estuarine habitats, and land ownership are components of descriptive mapping. Examples of resource descriptions include land cover measurements (i.e., urban, agricultural, forest, rural, or wetlands) within each river or stream reach basin, stream and road mile measurements, oyster lease locations, and the extent of wetland and riparian areas (Garono and Stritholt 1997).
Prescriptive modeling and mapping are used to explain or predict how the watershed works and how management actions aimed at one specific resource may influence another. As descriptive data are collected, prescriptive mapping is used to develop models that explore alternative management actions (Garono and Strittholt 1997). Examples of prescriptive mapping include GIS-based models for hydrologic regimes, the effects of land use change on flooding, conservation area planning, and ecosystem classifications (Garono and Strittholt 1997, Strittholt and Noss 1997). Critical coastal management issues such as sensitivity analysis of different environments, habitat modeling, and pollution monitoring require the ability of resource managers to make rapid and appropriate decisions (Ricketts 1992). Thus with prescriptive mapping, different policies or management actions can be considered before actions are taken on the ground (Strittholt and Noss 1997).

Although there are differences between descriptive and prescriptive mapping, most GIS watershed projects contain aspects of both (Strittholt and Noss 1997). For example, the TBNEP began its characterization phase by assembling descriptive data for features and processes in the Tillamook Bay watershed. Currently, components of this descriptive database (i.e., vegetation, soils, hydrology, water quality, and precipitation) are being used to develop a hydrologic model for the basin.

2.6.2 The Use of GIS in Outreach Activities

One of the difficulties in gathering information to describe a watershed stems from the inability of people to develop an effective cognitive map of their environment (Lee 1992, Pacific Rivers Council 1996). GIS is revolutionizing the way we create, use,
and learn from maps - changing them from paper references to dynamic, interactive tools for exploration and discovery (Barstow 1994). GIS as an educational tool, encourages creative thinking and allows students to discover information at their own pace (Winn et al. 1996). While using GIS to develop data analysis and spatial reasoning skills that address the relationships and complexity of watershed resources, scientists and managers can ask questions and pursue answers to local and regional problems in their watershed (Pacific GIS 1995).

The introduction of GIS into natural resource management has created a need for managers, their technical staff, and scientists to become knowledgeable about this technology (Arnold et al. 1993, Barstow 1994). As GIS becomes more commonly used, computers are needed by these audiences to get detailed, up-to-date information about watershed characteristics in the form of digital maps. As individuals and organizations become more aware of GIS applications, they will better understand issues, make more informed decisions, and take greater responsibility for watershed protection.

2.6.3 Concerns of Developing a GIS

The time, money, and expertise required to assemble GIS data can seem overwhelming and may prove inefficient if a project has a short timeline (as is the case with NEP programs that dismantle after four or five years). These time burdens often discourage many resource managers from adopting GIS technologies. However, due to advances in computer technology and remote sensing techniques, data are becoming easier, more efficient, and less costly to access, accumulate, and analyze (Arnold et al. 1993, Benoit 1996). Also, many more datasets are readily available from the government
and private sector and are affordable to a growing number of users. For example, the State of Oregon's Service Center for GIS provides data access from their web site at no cost (State of Oregon 1997b). As spatial data becomes readily accessible, more project resources can go toward actual conservation planning rather than toward constructing GIS coverages (Strittholt and Noss 1997).

Difficulties of quality assessment can arise when GIS coverages exist in a variety of different locations, spatial scales, and formats. Often, many conflicting versions of databases can be found to circulate within and between organizations with various methods for collecting and compiling data. For example, different sampling techniques used for fish surveys may bias population and distribution estimates. These sampling discrepancies introduce varying degrees of uncertainty into the GIS database. This concern underlies the need for a skilled user who understands data limitations. In addition, map combinations and scale differences affect analysis and potential conclusions. These concerns highlight the need to monitor, edit, and update GIS data while developing an organized information system with metadata to document assumptions and procedures (Benoit 1996, Queen et al. 1996).

As GIS technology becomes more available and user-friendly, an “erroneous notion has developed that these changes mean that the technology can be mastered by almost anyone with minimal effort” (Marble 1998). This thinking has led to academic programs requiring only an introductory course in GIS. However, not only are there many new users to be trained, but the technology development process requires the involvement of many individuals with skill levels in both geography and computer science. The current level of GIS education should include more advanced and highly
technical courses. "Moving beyond basic skills of cartography, spatial thinking, and computing, curricula should seek to further develop spatial analysis, computer programming, database organization, and modeling skills" (Marble 1998).
3. DEVELOPING A WATERSHED INFORMATION SYSTEM FOR THE TILLAMOOK BAY NATIONAL ESTUARY PROJECT

3.1 Study Objectives

In August 1996, TBNEP GIS information was compiled on a CD-ROM entitled *An Interactive Metadata Catalog for the Tillamook Bay National Estuary Project (version 1)* (Table 4) and was distributed to local agencies for review (Benoit 1996). This first CD-ROM was primarily used by GIS analysts and TBNEP scientists. At this time, the GIS database did not have complete metadata and the coverages had not been prioritized or evaluated. Therefore in October 1997, I produced an updated CD entitled *Tillamook Bay National Estuary Project Geographic Information System (version 2)* (Table 4). The GIS (version 2) CD-ROM was distributed by the TBNEP among community groups and natural resource professionals to assist their efforts in protecting and restoring the Tillamook Bay watershed. Since GIS (version 2) is formatted in HTML, it provides a user-friendly tool that local citizens, watershed councils, conservation groups, and resource managers can access.

To address the need for a watershed educational tool, I created a third CD-ROM for the TBNEP in January, 1998 entitled *Tillamook Bay National Estuary Project Watershed Characterization* (Table 4). This CD instructs users to identify watershed concerns in a visual, user-friendly manner by using TBNEP GIS data coverages from the GIS (version 2) CD-ROM. Three training modules illustrate concerns of road density, land cover, riparian vegetation, large woody debris, and the location of coho habitat. These exercises help
<table>
<thead>
<tr>
<th>Description</th>
<th>An Interactive Metadata Catalog for the Tillamook Bay National Estuary Project (version 1)</th>
<th>Tillamook Bay National Estuary Project Geographic Information System (version 2)</th>
<th>Tillamook Bay National Estuary Project Watershed Characterization</th>
</tr>
</thead>
<tbody>
<tr>
<td>Date</td>
<td>August 1996</td>
<td>October 1997</td>
<td>January 1998</td>
</tr>
<tr>
<td>Purpose</td>
<td>- Provide an initial compilation of TBNEP GIS data and metadata</td>
<td>- Prioritize existing TBNEP GIS data from CD-ROM version 1 and gather new data to fill targeted gaps</td>
<td>- Document watershed topics related to the Tillamook Bay watershed</td>
</tr>
<tr>
<td></td>
<td>- Organize and archive spatial data to be used by scientists and GIS analysts</td>
<td>- Provide information in a user-friendly format (HTML) and increase access to resource managers and community members</td>
<td>- Create ArcView tutorials that increase awareness of watershed issues by using TBNEP data from CD-ROM version 2</td>
</tr>
<tr>
<td>Contents</td>
<td>- TBNEP background</td>
<td>- TBNEP background</td>
<td>- Report with background on watershed topics</td>
</tr>
<tr>
<td></td>
<td>- Description of GIS and metadata</td>
<td>- Description of GIS, metadata, and ArcView</td>
<td>- Basic ArcView tutorials</td>
</tr>
<tr>
<td></td>
<td>- Metadata catalog (incomplete)</td>
<td>- Metadata catalog (complete)</td>
<td>- Advanced ArcView tutorials on watershed issues</td>
</tr>
<tr>
<td></td>
<td>- ARC/INFO export (.e00) files</td>
<td>- Inventory of prioritized TBNEP GIS coverages with metadata links</td>
<td>- Inventory of prioritized TBNEP GIS coverages with metadata links</td>
</tr>
<tr>
<td></td>
<td>- ArcView version 1.0 software</td>
<td>- ARC/INFO export files (.e00 format)</td>
<td>- HTML format</td>
</tr>
<tr>
<td></td>
<td>- VivaText format</td>
<td>- ARC/INFO coverages</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>- ArcExplorer software</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Basic ArcView tutorials</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>- TBNEP contact list</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Reference list of sci-tech reports</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>- Photographs of the Tillamook Watershed</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>- HTML format</td>
<td></td>
</tr>
</tbody>
</table>

Table 4. Tillamook Bay National Estuary Project CD-ROM catalog
increase the awareness of characteristics and patterns of change in the Tillamook Bay watershed.

Although (version 1) of the TBNEP CD-ROM set has been archived, the two most recent CDs combined create the Tillamook Bay Watershed Information System. This information provides a mechanism for GIS to be used by resource managers and specialists for scientific/technical work and by the public to increase their awareness of watershed issues. By creating the GIS (version 2) and Watershed Characterization CD-ROMs, the TBNEP has found a way to (1) distribute information to researchers, agency staff, and the public; (2) provide a data time capsule to be used once the TBNEP dismantles; (3) link scientific information to community based conservation efforts; and (4) integrate spatial information into management decisions.

3.2 Methods

This section outlines the procedures involved in developing the TBNEP Watershed Information System CD-ROM products. Both the GIS (version 2) and Watershed Characterization CDs are compatible for PC systems with the Microsoft Windows© operating system and a web browser.

3.2.1 Tillamook Bay National Estuary Project Geographic Information System (version 2)

The first CD-ROM created for this project entitled, Tillamook Bay National Estuary Project Geographic Information System (version 2), was completed in October
1997 (Appendix D). The first step in creating this CD-ROM was to meet with TBNEP staff to discuss scientific and outreach applications of the GIS data. From these meetings, a prioritized list of TBNEP GIS coverages was created based on their utility in descriptive and prescriptive watershed characterization. At this time, decisions were made regarding which data to archive, keep, or target for acquisition. For example, 53 coverages considered to be outdated or inadequate for use in scientific or outreach applications were archived and removed from the distribution list while 112 coverages were kept active. At the same time, GIS coverages considered to be data gaps and not available during the first data inventory were targeted for acquisition including National Wetland Inventory data, detailed geologic maps, and culvert locations, among others. By archiving unnecessary coverages and acquiring new data to fill information gaps, the TBNEP was able to construct an organized, updated GIS catalog.

The cost of acquiring new GIS coverages varies depending on the source, type of data, and time involved in production. For example, coverages from the State of Oregon's Service Center for GIS are provided at no cost (State of Oregon 1997b) while private consultant contracts vary in cost (Table 5).

### 3.2.1.1 Inventory List of TBNEP GIS Coverages

After all GIS coverages were prioritized, an inventory list was created to identify and organize the TBNEP GIS holdings (Appendix D). The inventory list contains documentation describing the coverage, original source, scale, feature type, provider, and subject category. Each coverage is placed in one of seven subject categories including land use, bathymetry, demographic, land cover, hydrology, political, fish, and regulatory.
<table>
<thead>
<tr>
<th>Source</th>
<th>Task</th>
<th>Deliverable</th>
<th>Time</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Consultant A</td>
<td>Acquire data and process imagery</td>
<td>unclassified, mosaiced images</td>
<td>38 days</td>
<td>$15,000</td>
</tr>
<tr>
<td></td>
<td>Interpret image and generate maps</td>
<td>five 24 x 36° color maps and georeferenced classified image files</td>
<td>41 days</td>
<td>$9,000</td>
</tr>
<tr>
<td></td>
<td>Construct GIS coverages</td>
<td>exported ARC/INFO coverages that can be read by the TBNEP computer system</td>
<td>39 days</td>
<td>$5,000</td>
</tr>
<tr>
<td></td>
<td>Produce report</td>
<td>final report fully documenting procedures followed throughout the project and summarized results</td>
<td>30 days</td>
<td>$1,000</td>
</tr>
<tr>
<td>Consultant B</td>
<td>Construct a historic GIS layer by digitizing wetland boundary types</td>
<td>GIS layer of prehistoric wetlands in the Tillamook basin</td>
<td>four months</td>
<td>$1,100</td>
</tr>
<tr>
<td></td>
<td>Construct a wetland conversion GIS layer from current USGS quads</td>
<td>GIS layer of the converted wetlands in the Tillamook basin</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 5. Approximate production time and cost estimates for TBNEP GIS tasks from two sources (estimates obtained from TBNEP contract invoices)
In addition to these coverages, TBNEP satellite imagery, classified imagery, and grids are documented. From this inventory page, a user can click on the coverage name and link directly to its associated metadata.

3.2.1.2 Metadata

Creating metadata for a GIS coverage is a crucial step in data development (NOAA 1998). While archiving and acquiring TBNEP data, a complete, interactive, metadata catalog for each GIS coverage was created. Metadata organizes and provides descriptions for the content, quality, condition, and other characteristics of a data set (Benoit 1996, NOAA 1998). Metadata was compiled by researching TBNEP files or by contacting the data generator. Information such as the date, scale, accuracy, resolution, and provider was important to gather so that the user can access each dataset and have enough information to determine whether it pertains to their needs (Colt 1994, Benoit 1996). Metadata is especially important for the TBNEP GIS database since it is being distributed for public use.

Metadata information on CD-ROM GIS (version 2) is available to the user completely separate from the actual TBNEP GIS coverages. This format allows users to make informed decisions about data layer functionality without having to access the GIS coverage directly. A separate page of metadata for each TBNEP coverage is linked to an inventory list of coverages (Appendix D). Each metadata page has a pop-up window that displays an image of the theme. Thus, users can link to the pop-up view directly from the
metadata page and decide if it is a coverage they might be interested in before using it in ArcView®.

### 3.2.1.3 HTML Formatting

All documentation placed on the CD-ROM is written in Hyper Text Markup Language (HTML) to make an interactive and user-friendly product. HTML documents can be read on any platform as long as there is a browser that can read and understand HTML (i.e., Netscape® or Internet Explorer®). By writing text in this format, users can navigate through a series of documents. Rather than reading text in a rigid, linear structure, users can easily navigate between topics to get more information that interests them at the time. For example, while viewing the *Inventory list of TBNEP GIS Coverages* (Appendix D), a user would simply have to click on a theme name to view its metadata and image pop-up window. In addition to providing an interactive catalog of information, HTML formatting allows all documentation to be placed on a website of choice. The entire *Tillamook Bay National Estuary Project Geographic Information System (version 2)* CD-ROM was placed on the Tillamook Community College website in December, 1997. Since more users will have remote access to website information, HTML formatting allows the CD-ROM to be distributed to a wider audience.
3.2.1.4 **CD-ROM Production**

After GIS coverages were organized, the inventory list created, and the metadata documented, additional information was gathered to be placed on the CD-ROM including (1) background on the National Estuary Project, (2) descriptions of GIS, ArcView and metadata, (3) ArcExplorer® software for viewing the data, (4) TBNEP contact information, (5) a list of available scientific and technical reports, (6) photographs of the Tillamook Bay Watershed, and (7) basic ArcView (version 3.0) tutorials. Since users may not have the ArcView skills needed to display and query data, the following set of basic ArcView tutorials were written using TBNEP GIS data:

Lesson 1: Developing a Project  
Lesson 2: Text and Labeling  
Lesson 3: Legend Editor  
Lesson 4: Multiple Views  
Lesson 5: Creating a Layout  
Lesson 6: Focusing Queries to collect Information  
Lesson 7: Tillamook Bay Water Quality and Shellfish Management Areas

While completing these exercises, a user can either (1) toggle back and forth between the tutorials and the ArcView project or (2) print a hard copy of each tutorial to read while manipulating layers in ArcView.

When all of this information was compiled, a CD-ROM was created, reviewed, and tested by TBNEP staff. After minor revisions and staff approval, the *Tillamook Bay National Estuary Project Geographic Information System (version 2)* was sent to a CD-ROM company in Portland which produced liners, the CD imprint, and discs in bulk. In October 1997, the CDs were published in quantities of 150 and sent to the TBNEP for distribution (Table 6).
<table>
<thead>
<tr>
<th>Description</th>
<th>Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Estimate Artwork Fees</td>
<td>$601.00</td>
</tr>
<tr>
<td>Jewel Case Inserts (min 1000)</td>
<td>$524.00</td>
</tr>
<tr>
<td>Tooling Fee</td>
<td>$525.00</td>
</tr>
<tr>
<td>Setup Fee</td>
<td>$150.00</td>
</tr>
<tr>
<td>150 Color CD's at $1.00 each</td>
<td>$150.00</td>
</tr>
<tr>
<td>2 Extra Screens</td>
<td>$80.00</td>
</tr>
<tr>
<td>150 Jewel Case Assembly</td>
<td>$42.00</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>$2,072.00</strong></td>
</tr>
</tbody>
</table>

Table 6. Cost of GIS (version 2) CD-ROM Production

3.2.2 Tillamook Bay National Estuary Project Watershed Characterization CD-ROM

Although the GIS (version 2) CD provides users with a data catalog, it does not teach them how to perform queries that address natural resource concerns in the watershed. To target the need for a GIS-based watershed educational tool, the second component of the TBNEP Watershed Information System was created. In January, 1998 the Tillamook Bay National Estuary Project Watershed Characterization CD-ROM was produced (Appendix E). With this product, watershed concerns can be identified in a visual, user-friendly manner by using TBNEP GIS data from the GIS (version 2) CD-ROM.
Three training modules that use GIS data to address specific watershed issues are one component of the Watershed Characterization CD-ROM (Appendix E). Background information and procedures for these modules were obtained in meetings with the TBNEP GIS Coordinator and staff scientists who are using GIS data to conduct a watershed analysis. Module 1 examines watershed area, road density and the proportion of roads near streams (Appendix E). Module 2 investigates canopy cover throughout the watershed, and Module 3 assesses where the critical rearing habitat for coho salmon are located within the Kilchis subwatershed. After completing these three modules, citizens will become more aware of concerns in Tillamook Bay watershed management.

A second component of the Watershed Characterization CD is a report, entitled A Watershed Perspective (Appendix E) which provides citizens and watershed councils with basic information on watershed characteristics, processes, impacts, assessment, and analysis. Information in this document is based on a literature review of federal, state, and local watershed publications. In this text, scientific words and phrases are highlighted and linked to a glossary; the user simply has to click once on a word to list its definition. After reading A Watershed Perspective, users can proceed with the three watershed assessment training modules. The Watershed Characterization CD-ROM is formatted in HTML to provide an interactive, user-friendly format and was placed on the Tillamook Coastal Watershed Resource Center website in August, 1998.
3.2.3 Using the Watershed Information System as an Outreach Tool

The TBNEP has distributed both CD-ROM components of the *Watershed Information System* to a variety of audiences including (1) the Tillamook Bay Community College where GIS and environmental study courses are taught to college students and community members; (2) the Tillamook County Department of Community Development which has a large interest in spatial information and GIS capabilities; (3) state and federal agencies who use GIS data to make management decisions (Pacific GIS 1995); (4) Oregon State University's Hatfield Marine Science Center which is a marine resource library and data repository located on the mid-coast of Oregon; (5) Oregon Sea Grant Extension Agents who are developing a Watershed Information Services Program (OSU Extension 1997); and (6) the OSU Oceanography Department.

The Tillamook Coastal Watershed Resource Center is also using the *Watershed Information System*. The purpose of this newly developed center is to promote community awareness of watershed issues, teach watershed assessment classes, and become a data repository for state and local agencies. Staff at the watershed center will maintain and update incoming GIS layers and produce new layers as needed by local agencies. This location is an ideal information site for groups wanting to assess local conditions and make informed decisions about resources in the Tillamook Bay watershed.
4. CONCLUSIONS AND RECOMMENDATIONS

4.1 Scientific Applications

In the first years of the program, the TBNEP gathered data and funded scientific studies to characterize natural resources in the watershed. One study undertaken by TBNEP staff was a Kilchis Watershed analysis. This analysis was performed for three reasons: (1) to focus and synthesize the results of applied research on the condition, trends, and impacts on natural resources; (2) to synthesize research results and formulate action plans; and (3) to create a model for watershed assessments planned in the other four subwatersheds (TBNEP 1997a). Throughout the Kilchis analysis, TBNEP GIS coverages were used extensively to query and display spatial data. Appendix F is an example taken from the Kilchis Watershed Analysis which illustrates areas of wetlands that have been converted to other uses through diking, draining, vegetative clearing, or filling. This is an example of how GIS can be used to evaluate historic wetland loss. Resulting maps and analyses from studies such as this can assist resource managers in making educated decisions based on watershed conditions.

One objective of watershed assessment and analysis is to gather all existing information and data into one place where it can be accessed by watershed councils, local residents, and resource managers for future studies. The TBNEP Watershed Information System meets this objective by providing a time capsule of all existing GIS related watershed data (TBNEP 1997b). This tool will make it easier to continue watershed analysis in the future when more resources and data become available.
4.2 Outreach Applications

GIS is used to identify problems and solutions in a visual, user-friendly manner. The TBNEP Watershed Information System is an educational tool that can be used to (1) engage the public into looking at scientific, technical, and spatial information for watershed components (i.e., the relation of land use to water quality); (2) link scientific endeavors with community based conservation efforts; (3) integrate the best available science into decision making; and (4) gain an understanding of the estuary and its problems and thus foster a willingness to address these problems.

It is important that scientific findings be widely communicated and form the basis for public education efforts (EPA 1992).

"...we must clarify and present information in such a way that allows people to grasp and understand it to the degree they care to. We are visual learners, especially where information is complex and the territory unfamiliar. If we prepare information in a visual, attractive and even interactive manner we will engage those citizens that are willing and attract some that are initially not interested. If we do not communicate the facts and knowledge we gain from analyzing those facts, we make no progress in our learning and addressing the changes that are inescapable" (Pacific GIS 1995).

If the TBNEP is able to educate and capture the interest of various stakeholder groups by using the Watershed Information System, then there is a better chance to increase cooperation and involvement (TBNEP 1995).

The TBNEP Watershed Information System targets different audience types including citizens, agency professionals, TBNEP committees, and students. For example, there is an interest in the Tillamook School District to develop curricula based on environmental studies using TBNEP data (Pacific GIS 1995). Since the TBNEP
Watershed Characterization CD-ROM has several exercises that highlight GIS data to address management concerns (i.e., coho habitat, roads in riparian areas, etc.), teachers can construct ArcView projects and develop workbook materials based on this information. These exercises can be placed on the Internet so classrooms around the school district have remote access (Pacific GIS 1995). This is one example where the TBNEP Watershed Information System has the potential to increase awareness about GIS mapping capabilities, resources, and opportunities for a targeted audience.

4.3 Management Applications

Management planning for an estuary and its watershed should focus on spatial and temporal dimensions of the environmental priority problems and incorporate scientific analysis into policy development and implementation (Colt 1994). The knowledge needed for natural resource decision making might be improved if managers begin using information and GIS databases in watershed assessment and analysis. For example, the Watershed Information System is an appropriate tool for integrating scientific and technical information into the TBNEP Comprehensive Conservation Management Plan (CCMP). The CCMP identifies strategies and action plans to address priority problems while restoring and protecting the natural resources of the bay (EPA 1992). In addition, GIS is a practical tool for analyzing potential impacts of resource management strategies outlined in the CCMP. The development of a diverse GIS database requires cooperation between all organizations involved with data production and acquisition. Given the number and variety of potential data contributing organizations, cooperation and coordination is something that is not easy (Ricketts 1991).
However, resource managers must realize they need to work together to effectively manage an entire watershed; a GIS based watershed assessment provides a tool to facilitate data sharing and cooperation (Garono and Strittholt 1997). The TBNEP Watershed Information System is a tool that can improve communication among agencies involved in implementation and development of estuarine management and policy (Malouf et al. 1994).

4.4 Recommendations

(1) Lessons learned from the development of a Watershed Information System provide useful guidelines for future development of GIS for other estuarine watersheds. Data quality, collection and organization, user group diversity, and audience education are issues encountered through the development of the Watershed Information System. Lessons learned from this project can be applied to other regions so that a more efficient and effective support system for resource and environmental decision-making can be developed elsewhere by program managers (Queen et al. 1996).

(2) One of the first steps of the TBNEP data management strategy is to “assemble a GIS data library of existing relevant data for use in characterization” (TBNEP date unknown). However, project managers need to define the application, objective, and scope of GIS projects related to the environmental priority problems before gathering data (Ricketts 1991). Before any data acquisition begins, it is important to clearly define data input needs. If clear statements and goals of data acquisition are developed, problems concerning the anticipated use of GIS databases can be minimized. Without initial guidance on data needs, considerable effort can be wasted on the capture of
unnecessary information (Benoit 1996). Essential GIS coverages needed to characterize a watershed include basin boundaries, vegetation, ownership, hydrology, roads, soils, geology, land use, floodplains, and wetlands (Zisman 1993).

(3) Many TBNEP GIS coverages need to be updated as watershed characteristics have changed since the data was first collected in the early 1990s. For example, estuarine bathymetry has been modified by the 1996 spring flood. In order to update existing data and receive new GIS coverages, it is important to continue working with agencies that develop and maintain information related to the Tillamook Bay watershed.

(4) Training in GIS applications for watershed analysis or assessment is essential (Interrain Pacific 1998). Watershed Information System ArcView tutorials provide opportunities for self-driven training with exercises introducing users to GIS principles and examples of watershed assessment and management. These tools help local groups understand watershed assessment, assist development of monitoring programs, and organize data collection strategies. For example, the Watershed Information System is currently being used by the TBNEP outreach coordinator in a class studying the Trask subwatershed. In addition to training, it is important to offer technical support for organizations currently developing the capacity to use GIS software for management of information needs (Interrain Pacific 1998).

(5) A TBNEP forum or exhibit to engage public interest in the use of GIS ideas, actions, and information for the Tillamook Bay watershed would be a useful development (Pacific GIS 1995). If such an exhibit were designed, it could rotate through different parts of the watershed or be shown at different times of the year as new information is produced (Pacific GIS 1995). Potential sites for a display might include the Tillamook
Community College or Public Library, primary and secondary classrooms, or the
Tillamook Cheese Factory.

(6) One of the key indicators of TBNEP success will be the establishment of
organizations to implement the project’s management recommendations. In the spring of
1997, the Tillamook Coastal Watershed Resource Center (TCWRC) was developed as a
local community technology center by staff from the Tillamook Community College,
Economic Development Council, and the TBNEP. Since one goal of the TBNEP is to
provide a clearinghouse of GIS information for the region, the *Watershed Information
System* will prove to be a useful component of the TCWRC. The resource center is also
helping community groups acquire and synthesize GIS databases, develop new data,
design and conduct watershed assessments, and map local knowledge. Many public
works departments, educational centers, and local agencies will discover GIS applications
through the center's activities. For example, a class is currently be taught in watershed
assessment for the Trask subwatershed. The tutorials and database from the TBNEP
*Watershed Information System* need to be used as a component of this curricula.

4.5 Conclusion

The final products of the TBNEP *Watershed Information System* are available on
two CD-ROMs that have been distributed to public agencies, organizations, and other
interested community members and placed on the Tillamook Community College and
TCWRC websites. Based on tests with a variety of groups, the TBNEP *Watershed
Information System* provides a tool that orients people to the Tillamook Bay watershed
and gets community members involved in watershed management issues. These outcomes are essential as the TBNEP will cease to exist in December, 1998.

The use of a GIS by the TBNEP facilitates successful resource studies and management in Tillamook Bay. Spatial data can be efficiently retrieved, shared, analyzed, and presented in the form of a report or a visual presentation. GIS also aids the scientific/technical work of a project as visually-displayed patterns increase understanding about the cause and effects of TBNEP priority problems. In addition to GIS data, other information provided in a TBNEP *Watershed Information System* will help conservation organizations, researchers, policymakers, and citizens understand the dynamics of the Tillamook Bay watershed and make informed choices about natural resource management.

There is a need for a holistic way of thinking and acting that looks at whole systems, not isolated elements (Boyce and Haney 1997). The watershed may emerge as the reference in which environmental issues will be addressed in years to come. The TBNEP *Watershed Information System* is an enduring resource that will continue to (1) support characterization of the Tillamook basin, (2) create models of watershed processes, (3) support long term monitoring, (4) enhance educational efforts, and (5) generate project reports.
Literature Cited


River Network. *Starting up: a handbook for new river and watershed organizations.* Portland, OR, date unknown.


APPENDIX A

IMPACTS IN THE TILLAMOOK BAY WATERSHED
Alterations in sediments, heat, chemicals, nutrients, and hydrology are examples of impacts that occur in a watershed (EPA 1994). The combination of individual upstream impacts on downstream sites are defined as cumulative impacts (EPA 1994, State of Oregon 1997a). Recently, scientists and watershed managers have begun to investigate how cumulative impacts of land use activities on federal, state, and private lands affect hydrologic and ecological processes. Many of the current environmental problems such as declining salmon populations or forest fragmentation are evidence of the difficulty in dealing with cumulative effects (Grant et al. 1994). For example, dam construction, temperature increase, sediment input, loss of large woody debris, and overfishing contribute to salmonid population decline. These cumulative impacts on anadromous fish have a greater combined effect than they would have individually.

Human and natural disturbance may alter watershed functions such as the ability to provide habitat or maintain water quality. Human impacts include road construction, timber harvest, introduced species, urbanization, or agricultural practices. Natural impacts include fire, flood, drought, disease, or landslides. Because these impacts can have cumulative effects, it may take many years for a watershed to stabilize and re-establish prior functions.

Humans often perceive watershed resources as a commodity to be used for urbanization, forestry, recreation, agriculture, mineral extraction, and water utilization activities. For example, water is used for domestic, agricultural, industrial, and recreational purposes (EPA 1994). Settlement in the Tillamook basin began in 1851. The first settlers were farmers who cleared the land of large conifer trees to raise crops.
that support dairy herds in the lower portions and floodplains of the basin. Since this time, land uses with major impacts on the Tillamook Bay watershed have been dairy farming, timber production, and associated filling, diking, and dredging activities which have substantially altered the estuarine and lower river reaches of the Tillamook basin. (Nehlsen et al. 1995).

Agricultural Activities

Agricultural activities in the floodplain and lower Tillamook Bay watershed have affected estuarine and freshwater resources of the basin. Historically, removal of conifer, hardwood, and understory vegetation along stream banks was especially damaging. Removal of riparian vegetation reduces the amount of shade, resulting in increased water temperatures, loss of stream bank stability, loss of sediment filtration, and reduction in organic nutrients delivered to streams through leaf fall (Nehlsen et al. 1995).

Livestock often congregate in riparian zones where water, shade, cooler temperatures, and forage are available. Trampling from livestock increases soil compaction, reduces infiltration, increases sediment runoff, modifies the channel, and alters bank stability (Brooks et al. 1997, State of Oregon 1997a). Grazing in riparian areas reduces riparian shrubs, trees, and the input of large woody debris in stream channels. Streams in grazed areas tend to be wider, shallower, warmer, and have higher nutrient levels than streams in ungrazed areas. Where grazing is intense, the stream can become disconnected from the floodplain, resulting in a lower water table and a shift in bank vegetation (State of Oregon 1997a).
Forestry

Forest activities are associated with natural vegetation removal, soil compaction, road construction, and culvert installation. Tree harvest and road construction typically increase sediment delivery while removing plant biomass and nutrients from the system. Forest road-related landslides and/or fires can add massive quantities of sediment to streams and rivers which causes them to aggrade. Bed aggradation results in bank erosion and loss of riparian vegetation, channel widening, and higher stream temperatures (Brooks et al. 1997).

The removal of riparian vegetation directly impacts instream water temperatures. As the vegetative canopy is removed, greater solar radiation reaching the stream increases greater daily and seasonal fluctuations in temperature (State of Oregon 1997a). Without shade, instream water temperatures become warmer in the summer and cooler in the winter. Loss of riparian vegetation also decreases the amount of organic litter and large woody debris delivered to the channel and reduces complexity of stream habitats. Alterations associated with forestry practices may persist for decades until revegetation occurs in harvested areas (State of Oregon 1997a).

Beginning in the 1860s, early logging in the Tillamook Bay watershed was concentrated near low and mid-elevation streams, and logs were transported using splash dams and log drives. To facilitate navigation and log transportation, woody debris in the channel and conifer trees in riparian zones were often removed. Removal of wood from
streams continued into the late 1900s until its ecological importance became accepted through scientific studies (Nehlsen et al. 1995).

**Bacterial Contamination**

Bacterial contamination of the bay and rivers is another identified impact in the Tillamook Bay watershed and is a concern as it affects shellfish and other water contact uses. Dairy operation practices are identified as potential sources of fecal coliform bacteria. These practices primarily include manure storage and management in barnyards, disposal of manure on pastures, contamination from malfunctioning sewage treatment plants, and inadequate subsurface sewage disposal systems. In addition to nonpoint sources, fecal coliform can enter Tillamook Bay from point sources including the Tillamook Creamery Association, the Port of Tillamook, and the cities of Garibaldi, Bay City, and Tillamook. When functioning properly however, these locations are not significant sources of bacteria contamination (Nehlsen et al. 1995).

**Natural Impacts**

The Tillamook Bay watershed has burned repeatedly. During the 1930s, 1940s, and 1950s, a series of forest fires occurred. Several other fires occurred in the late 1800s and early 1900s as well. Some areas have burned as many as four times. Approximately 63 percent of the total basin has burned (Nehlsen et al. 1995). After fires, roots weaken, and cause an increased rate of sediment movement into stream channels.
Streams in the Tillamook basin are especially vulnerable to floods because of their geology, topography, and orientation relative to winter storm patterns. Forest management practices likely increase the occurrence of high peak flows. As a result of flooding, stream channels are simplified as alder stands colonize flood deposited terraces – making conifers rare and degrading the riparian area (Nehlsen et al. 1995).
APPENDIX B

WATERSHED ASSESSMENT AND ANALYSIS:
A MULTI-STEP APPROACH
1. Initially, the investigative team defines the watershed boundaries.

2. The next step is to define goals of the assessment or analysis. By establishing goals early in the process, data collection can be focused and questions can be asked accordingly. For example, goals may include improving water quality or implementing sustainable forestry practices.

3. The third step is to develop a general sense of the ecological processes, functions, and history of the watershed. In this stage, it is important to investigate physical, biological, ecological, ownership, historical trends, and the relevance of existing laws and policies within the watershed. Investigating available information provides a perspective on current watershed knowledge and helps identify data gaps needed to complete the assessment. Information should be gathered in the form of maps and surveys, local landowner knowledge, scientific reports, or historical journals.

4. Once a general overview of the watershed is developed, key issues should be identified and summarized in step four. Focusing on specific issues can help watershed councils and local agencies prioritize key problems in their watershed.

5. The fifth step is to compare current watershed conditions and functions to historical trends (i.e., land use patterns, ecological conditions, and natural and human disturbance). This step helps identify how the system has changed through time and establishes future trends (generally beyond the scope of assessment).

6. After historical reconstruction is complete, benchmarks should be established by the assessment team. Benchmarks are quantifiable estimates of watershed processes and elements expected in a functioning system. Benchmarks establish what the system looked like, how it functioned, and the condition of watershed processes and elements prior to detrimental human influence (generally beyond the scope of assessment).

7. Step seven identifies the mechanisms or problems that historically or currently are moving the watershed away from benchmark levels (generally beyond the scope of assessment).

8. After data collection, analyses, and syntheses are complete, the information must be shared with decision makers to determine management recommendations, planning, and implementation strategies. Prioritization of problems within a watershed helps managers, who often lack specific expertise. Examples of information for scientists to communicate might include: identification of species and their remaining critical habitat, identification of road density within riparian areas, analysis of water quality data, or evaluation of historical wetland change.

APPENDIX C

FEDERAL AND STATE PRACTICES THAT ADDRESS WATERSHED CONCERNS
Federal Watershed Management


(1) Under the National Environmental Policy Act (NEPA), federal agencies are required to prepare preliminary environmental assessments to determine whether proposed activities are actions that will significantly affect the quality of the environment. If so, then the agency must prepare a more comprehensive environmental impact statement (EIS) with a review of cumulative impacts and consideration of the environmental implications and alternatives (EPA 1994). Since cumulative impacts are a concern in watershed management, NEPA requirements are an important component.

(2) The Clean Water Act (CWA) is the primary statutory vehicle for protecting the quality of ground and surface waters in the United States. Control of NPS pollution was formally listed as a national goal in 1987 with amendments to the CWA. Section 319 calls for states to develop assessment reports and management programs to address non-point source pollution. In addition, the Watershed Protection Approach Framework Document reflects the EPA’s expanding commitment to addressing water quality problems in a comprehensive, holistic fashion (EPA 1994).

(3) The Endangered Species Act (ESA) has had significant impacts on watershed management. Because a primary purpose of the ESA is to preserve the habitats of species listed as threatened or endangered, designation of “critical habitats” under the ESA provides a potentially powerful legal mechanism for the protection of watersheds.

(4) Section 6217 of the 1990 amendments to the federal Coastal Zone Management Act (CZMA) created a Coastal Non-point Pollution Control program that could prove significant in maintaining and improving water quality in coastal watersheds. The leading sources of NPS pollution in estuary waters are urban runoff and agriculture. The CZMA guidelines for state coastal non-point source programs include management measures to control NPS from agriculture, silviculture, urban development, and marinas (EPA 1994).
State Watershed Management

The mandates of Section 319 of the Clean Water Act and the 1990 reauthorization of the Coastal Zone Management Act have increased interest in developing watershed-based water quality management programs at the state level (EPA 1994). Watershed management and NPS pollution control are land use issues under state jurisdiction. In Oregon, existing programs including the Forest Practices Act, state land use goals, the NPS pollution program, and the work of soil and water conservation districts are conducive to statewide watershed management. The Oregon Department of Environmental Quality (DEQ) initiated a pollution prevention program to emphasize the use of Best Management Practices that minimize critical water quality problems in a basin affected by a variety of non-point sources. One objective of the program includes assessing cumulative effects under section 303 of the Clean Water Act. In addition, the Oregon Land Conservation and Development Commission has established a comprehensive statewide program of land-use planning. Several of the land use goals include water management objectives. For example, Goal 5 mandates the inventory of fish and wildlife habitats and watershed and groundwater resources. Goal 6 mandates that future and existing development and land uses be coordinated to maintain water quality standards (EPA 1994).
APPENDIX D

TILLAMOOK BAY NATIONAL ESTUARY PROJECT
GEOGRAPHIC INFORMATION SYSTEM (VERSION 2) CD-ROM
COMPONENTS

CD contents can be obtained from the TBNEP or Marine Resource Management Program (OSU) offices or by visiting the TBNEP web site at http://www.orst.edu/dept/tbaynep/nephome.html
Example 1.
CD-ROM Cover

Tillamook Bay National Estuary Project
Geographic Information System

October 1997
Version 2
Example 2.

CD-ROM Introduction

To get started, please choose among the following:

- What is the TBNEP?
- What is GIS, ArcView and Metadata Management?
- Inventory List of GIS Layers and Metadata Links
- TBNEP Contact List
- ArcView Tutorials
- References
- ArcExplorer Information

TBNEP Web Page
Example 3.

Tillamook Bay National Estuary Project GIS Coverage
INVENTORY LIST

*(sample page)*

updated October 1997

Click each coverage name for links to metadata

**ALT/TAB to toggle between this list and metadata links while viewing coverages in ArcView**

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<tr>
<th>Coverage</th>
<th>Description</th>
<th>Original Source</th>
<th>Scale</th>
<th>Feature Type</th>
<th>Provider</th>
<th>Subject Category</th>
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<td>AutoCAD Inventory Information for upper Wilson watershed. Line image with no associated attribute data.</td>
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<td>N/A</td>
<td>arc/point</td>
<td>Interrain Pacific</td>
<td>Land use</td>
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<tr>
<td>Bathpts</td>
<td>Bathymetry Points</td>
<td>Interrain Pacific created from NOS cartographic code files containing all points gathered for latitude 45 to 46 degrees and longitude 122 to 125 degrees. Channel emphasis.</td>
<td>0.1 m to 120 m (ave. = 40 m)</td>
<td>point</td>
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<tr>
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<td>Bathymetry points from 1957 NOS data</td>
<td>Created at Interrain Pacific from NOS cartographic code files containing all points gathered for latitude 45 to 46° and longitude from 122 to 125°: sounding points vary from 0.1 m to 120 m; the average is » 40 m. The channels most heavily sampled.</td>
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<td>1867 bathymetric points from US Coast Survey Office</td>
<td>Xerox from Army Corps of Engineers, Steve Cheser (503) 326-6089.</td>
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<td>Bathymetry points from 1995 US COE survey</td>
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Example 4

Sample of a TBNEP Metadata Page

click image to see full screen version

DATA SET IDENTIFICATION:

Data File Name: Bla_geo
Description: One of six geologic maps of the Tillamook highlands, Northwest Oregon coast range. Identifies faults, deposition contacts, and geologic unit identities.
Provider: U.S. Geological Survey
Contact: Ray Wells
Address: 345 Middlefield Rd, MS 975, Menlo Park, CA 94025
Phone: (415) 329-4933
E-mail: rwells@usgs.gov
Date Acquired: 1993
APPENDIX E

TILLAMOOK BAY NATIONAL ESTUARY PROJECT
WATERSHED CHARACTERIZATION CD-ROM
COMPONENTS

CD contents can be obtained from the TBNEP or Marine Resource Management Program (OSU) offices or by visiting the Tillamook Watershed Resource Center website at http://www.tbcc.cc.or.us/~tcwrc/tutorials
Example 1.
CD-ROM Cover

Tillamook Bay National Estuary Project
Watershed Characterization
April, 1998
One objective of the Tillamook Bay National Estuary Project (TBNEP) is to develop innovative ways to manage natural resources. Toward this end, the TBNEP has developed a geographic information system (GIS) to organize, analyze, and archive spatial data. Synthesizing data and survey results with GIS allows users to assess and query information about a particular watershed. Such inquiries support the characterization and decision making process that occur throughout a watershed assessment. Basic information on watershed characteristics, processes, and assessment, is provided in *A Watershed Perspective*.

TBNEP watershed assessment modules demonstrate how ArcView is used to perform basic inquiries related to watershed assessment. The modules lead you through several exercises using TBNEP GIS layers. **Module 1** examines watershed area, road density, and proportion of roads near streams. **Module 2** looks at landcover in the watershed. **Module 3** identifies where coho rearing habitats are located within the Kilchis subwatershed and examines how factors
A Watershed Perspective

This document, entitled *A Watershed Perspective*, provides citizens and watershed councils with basic information on watershed characteristics, processes, and assessment. Information is based on a literature review of federal, state, and local watershed publications. Words highlighted in the text are linked to a glossary; click once on the word to list definitions. After reading this document, proceed with the three watershed assessment modules contained on this CD-ROM. After reviewing *A Watershed Perspective* and completing the assessment modules, citizens can begin to identify and address concerns in Tillamook Bay Watershed management.

Contents

- Watershed Processes
- Watershed Impacts
- Watershed Assessment and Analysis
- Oregon Manual
Example 4.

Introductory Page to Module 3

Module 3

Exercise 1: location of coho habitat
Exercise 2: blockage to fish passage
Exercise 3: assessing riparian conditions
  Exercise 4: riparian ownership
  Exercise 5: large woody debris
Exercise 6: synthesis and conclusions

Home
APPENDIX F

A SECTION OF THE KILCHIS WATER SHED ANALYSIS ILLUSTRATING THE USE OF TBNEP GIS COVERAGE

(source: TBNEP 1997a)
7.0 Wetlands

Introduction

The coastal plain portions of the Tillamook Basin were formerly dominated by a variety of wetland types. Since the arrival of Euro-american settlers there has been a concerted effort to convert these wetlands to other uses. The current uses are primarily agricultural, residential and roads.

This section covers:
- conversion of wetlands to other uses,
- national wetland inventory,
- and hydrologic isolation of wetlands.

Conversion of Wetlands to Other Uses

Prehistoric wetlands in the Kilchis Watershed and Tillamook Estuary were extensive and varied. The wetland types consisted of: brush or wooded swamp, grassy swamp, grassy tidal marsh, main valley floodplain bottomland, tidally-influenced forest, and upriver valley timbered floodplain (Benner 1995). Figure 7-1 shows the historic extent of these wetlands as recorded during the land surveys conducted in the 1850's and 1860's (Benner 1995).

Grassy tidal marsh covered all of the delta areas at the river outlets above the high tideline, and below the tideline were intertidal mudflats with eelgrass and algae. Tidally-influenced forest was a riparian type that formed a broad belt behind the tidal marsh in the upper tidally-influenced zone; it was forested with Sitka spruce, western hemlock, western redcedar, bigleaf maple and red alder. The main valley floodplain bottomland type was the most extensive in the Tillamook Basin and covered all of the lower valley bottomlands with the largest stands in the Wilson, Trask and Kilchis river valleys. The floodplain tree species were similar to the tidally-influenced forest with the addition of Douglas-fir, crabapple and an impenetrable understory of various berry species, salal, and vine maple. The upriver valley timbered floodplain was found along all rivers and streams and merged into the general forest with just a change in the proportion of the tree species making up the stands. The common upriver floodplain riparian trees were western redcedar, Sitka spruce, western hemlock, black cottonwood, red alder, Douglas-fir, and crabapple with an impenetrable understory of various berry species, salal, hazelnut, elderberry and vine maple. The brush or wooded swamp type was less extensive and was found on a relict channel of the Trask River and in areas ponded by beaver activity. These ponded areas in gentle terrain were covered with red alder and willow species and an understory of sedges, grasses and rushes. The grassy swamp type was found in several large patches along the Trask and Tillamook Rivers and consisted of sedges, grasses and rushes.
Extensive areas of wetlands have been converted to other uses through diking and draining, vegetative clearing and/or filling. Figure 7-2 shows the approximate extent of wetlands that have been converted to other uses within the Tillamook Basin based on interpretation of 1984 USGS topographic maps. The original extent of wetlands in the Basin was approximately 26,912 acres for all types. The current extent of wetlands consists of approximately 3400 acres in the original wetland communities and 221 acres of former agricultural land that is being allowed to revert to wetlands. This conversion rate is approximately 86% for all wetland types in the coastal plain portion of the Basin. The following paragraphs discuss each wetland type, where it has been converted and what the current use of the land is.

The type with the smallest acreage converted is the intertidal mud flats type between the grassy tidal marshes and the estuary. The method of conversion is filling and/or dredging and the places this has occurred are the Garibaldi wharf, the Bay City oyster facility, and the Highway 101 right-of-way at Larson Cove north of Bay City (see Figure 7-2). Grassy tidal marshes have been converted to agriculture through diking and draining. This has primarily occurred in the delta regions of the Kilchis, Wilson, Trask and Tillamook Rivers.

The tidally influenced forest has almost vanished in the Tillamook Basin due to its conversion to agricultural land. Following the establishment of a diking, drainage and tide gate system (as was used for the tidal marshes), these forests were cleared of trees and put into pasture. The soil was very productive due to annual flood inputs of rich soil and the high water table reduced the need for summer irrigation. The Kilchis formerly had a stand of tidally influenced riparian stretching from Vaughn Creek to the main channel (see Figure 7-1).

The riparian floodplain type covering the entire Kilchis valley floor nearly out to the present Highway 101 was converted to agricultural land through clearing of the riparian forest. The same situation occurred in the Wilson and Trask river valleys (compare Figure 7-1 to 7-2). The upland riparian was also cleared from most of the river terraces in the region between Mapes Creek and Clear Creek to convert the land to agriculture. These riparian types required no diking and draining and so were easier to convert to agricultural uses than the lower-lying tidally influenced forest.

From comparing Figures 7-1 to 7-2 it is readily apparent that the vast majority of wetlands in the lowland portions of the Kilchis watershed and Tillamook Basin in general have been converted to agricultural uses. These lands were annually enriched with fertile soil from overbank river flows and are now very productive farmlands. However, their original functions in the landscape such as flood amelioration, sediment traps, bank stabilization, and salmon and wildlife habitat have largely been lost due to their conversion to their present uses.
Historic Wetland Communities
1867

Vegetation Community
- Brush or Wooded Swamp
- Estimated Location of Unmeandered River
- Grassy Swamp
- Grassy Tidal Marsh
- Lake
- Main Valley Floodplain Bottom Land
- Meandered (surveyed) River Channel
- Mountainous Uplands
- Ocean
- Prairie Lands
- Tidally-Influenced Forest
- Timbered Valley Lands
- Upriver Valley Timbered Floodplain

Figure 7-1