GIS Based Riparian Area Management Plans: Recommendations to Local Governments of the Columbia River Estuary Study Taskforce

By

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A Research Paper

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Dr. Philip L. Jackson
This paper evaluates Oregon Statewide Planning Goal 5: Natural Resources and Goal 17 Coastal Shorelands, planning programs and makes recommendations for improvement to the Oregon members of the Columbia River Estuary Study Task Force (CREST). CREST is a Council of Governments formed in 1974 which includes the local counties, cities and port districts surrounding the Columbia River Estuary in both Oregon and Washington. The focus of this paper is the management of riparian areas, lands within 250 horizontal feet of streams, rivers, and estuaries. The impetus for this project is recent Federal Endangered Species Act (ESA) listings of Pacific salmon species. These ESA listings have prompted all local governments in areas of know use by listed species, such as Oregon CREST member governments, to reevaluate planning programs, including riparian area land use planning and management. The process used to reach the riparian recommendations included several tasks. First, riparian area and watershed land use planning principles and practices were reviewed. Second, one CREST member, the City of Seaside, was used as a demonstration area to perform a detailed geographic information systems (GIS) characterization of the watershed and study area riparian setting. Finally, the results of the City of Seaside study were used to make recommendations to the city and other Oregon CREST members.

A review of the principles and practices of riparian area management produced two products. First, a summary of the literature on sizing riparian management zones illustrated that no one size is recommended and the size required varies with the attributes of the riparian area landscape and the management goal. Second, a review of the planning processes applied to riparian area management produced a strategy for developing the riparian area management plan. This strategy integrated the natural setting of the study area, selection of a riparian area management goal, a detailed study of the riparian zone, and objectives and constraints of landowners into the planning process.

A geographic information system (GIS) was utilized to develop these recommendations. GIS has been used extensively in land use planning, including riparian area management. GIS riparian buffer delineation models have been developed to make determinations on buffer width for varying management goals including water detention and stream shading. The GIS riparian buffer delineation model for water detention was selected as most appropriate for the study area and used as a tool in making the riparian area recommendations.

Several recommendations were produced through the riparian area management planning process. First, the City of Seaside riparian area the topography, soils and vegetation when applied to riparian buffer width literature suggest a buffer of 75 to 100 feet is necessary. Second, it is recommended the impact of a 75 to 100 feet buffer on land development potential be mitigated through environmental site planning and land use planning techniques. Finally, the geographic setting of City of Seaside is generally similar to that of other Oregon CREST members. Therefore, recommendations made to the City of Seaside will likely be applicable to other Oregon CREST members.

These recommendations have the potential to substantially benefit the quality of the City of Seaside’s surface waters. These recommendation, however, are only one part of stream protection. Separate actions must be taken throughout the watershed, such as reducing impervious surface and the amount of pollutants introduced into the system through point source discharges in order to ensure proper water quality.
Acknowledgements

I have many individuals to thank for their role in this project and my education at Oregon State University. I have been extremely fortunate in the funding of this research and my education. Family, faculty, and fellow graduate students have been of invaluable assistance throughout my graduate student career.

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The staff of Columbia River Estuary Study Task Force (CREST) and the City of Seaside were instrumental in initiating and carrying out this research. Kathy Taylor and Matt Van Ess of CREST were tremendously helpful during this research project. I am grateful to Kathy Taylor for working with me to develop the project and obtain funding. My sincere thanks go to Matt Van Ess for taking time to advise me throughout the project and review earlier drafts of the research paper. I appreciate the willingness of Kevin Cupples, City of Seaside Planning Director, to work with me in developing the portion of this research project that focused on the City of Seaside.

Several graduate student colleagues have been a valuable resource in preparing this report and throughout graduate school. I sincerely appreciate the friendship and guidance provided by Nate Wood throughout my graduate career. Kyle Gomez provided assistance with geographic information systems technical issues and much need encouragement to take exercise breaks. I thank Aimee David for her friendship and taking time on numerous occasions to discuss the challenges of graduate school and coastal zone management with me.
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INTRODUCTION

This paper evaluates Oregon Statewide Planning Goal 5: Natural Resources and Goal 17 Coastal Shorelands land use planning programs and makes recommendations for improvement to the Oregon members of the Columbia River Estuary Study Task Force (CREST). CREST is a Council of Governments formed in 1974 which includes the local counties, cities and port districts surrounding the Columbia River Estuary in both Oregon and Washington. The focus of this paper is the management of riparian areas, lands within 250 horizontal feet of streams, rivers, and estuaries. The process used to reach the riparian recommendations included three broad tasks. First, riparian area and watershed land use planning principles and practices were reviewed. Second, one CREST member, the City of Seaside, was used as a demonstration area to perform a detailed geographic information systems (GIS) characterization of the watershed and riparian setting of the region. Third, the results of the study in Seaside were used to make recommendations to the city and other Oregon CREST members.

The impetus for this project is the recent Federal Endangered Species Act (ESA) listings of Pacific salmon species. In March of 1999, the United States National Marine Fisheries Service (NMFS) listed the Lower Columbia River Evolutionarily Significant Unit (ESU) of Chinook salmon (Oncorhynchus tshawytscha) and Columbia River ESU of Chum salmon (Oncorhynchus keta) as threatened under the ESA. As prescribed under Section 4(d) of the ESA, whenever any species is listed as a threatened species, the Secretary of Commerce shall issue such regulations as he deems necessary and advisable to provide for the conservation of such species. On July 10, 2000, NMFS published *Endangered and Threatened Species; Salmon and Steelhead; Final Rules*. The 4(d) rules and other NMFS publications indicate that many local, state, and other programs currently in place, such as clean water controls and land use programs, can be adjusted to conserve listed salmon species (Federal Register, 50 CFR Part 223, July 10, 2000). Furthermore, NMFS has expressed strong interest in working collaboratively with all affected governmental entities to recognize existing management programs and to strengthen other programs toward conservation of listed salmonids. Specifically, the 4(d) rules of July 10, 2000 state that municipal, residential, commercial, and industrial (MRCI) development regulatory programs are a method to protect listed salmonids and their habitat. The Oregon CREST member governments all have existing land use planning programs that seek to minimize the adverse impacts of MRCI development on
the landscape. The research and recommendations put forward in this report are meant to assist the Oregon CREST member community planners in collaborative efforts with NMFS to evaluate and where necessary strengthen land use planning programs to conserve threatened Pacific salmon.

This paper presents the results of the riparian area evaluation and the recommendations in six sections: 1) Riparian Area Planning Overview; 2) Study Area and Setting; 3) Selection of Riparian Area Management Goal; 4) Riparian Area Characterization Methodology; 5) Results of Riparian Area Characterization; 6) Riparian Management Recommendations.

Scope and Applicability

It is important to recognize several factors relating to the scope and applicability of this study. First, the recommendations for buffer width in this paper only speak to land use actions in the riparian area. While consideration was made to the watershed setting, the recommendations do not extend to actions throughout the watershed. Actions throughout the watershed can also adversely impact the streams and river in the city. Buffering as per the recommendations provided here is only one element of surface water quality protection. Impervious surface reduction, elimination of point source discharges, and other water quality protection efforts are also necessary to maintain water quality and fish habitat. Second, the topography, soils and vegetation data used in this study to characterize the riparian areas also have limitations. These limitations have the potential to affect the performance of recommendations put forward in this report and are discussed further in Section Four: Riparian Area Characterization Methodology.
SECTION ONE: RIPARIAN AREA PLANNING OVERVIEW

Why Protect Riparian Areas

Riparian zones are the interfaces between terrestrial and aquatic ecosystems. They encompass sharp gradients of environmental factors, ecological processes, and plant communities creating valuable wildlife habitat and buffering fragile stream systems. This ecological richness is evident in the Pacific Northwest where twice as many plant species are found in riparian zones in comparison to upland areas (Gregory et al., 1991). The buffering functions provided by riparian areas include flow moderation, erosion control, and pollutant absorption. Riparian areas also provide aesthetic and outdoor recreation value to society. Collectively, the ecological traits, buffering functions, and aesthetic value render riparian areas an important feature on the landscape.

Land Use Planning and Riparian Area Management

The present continental United States landscape is a mosaic of developed lands and natural areas. Expanding human development within the landscape can inflict a number of negative impacts upon stream and riparian resources (Castelle et al., 1992). In an effort to avoid adverse impacts, all levels of government implement land use plans to manage activities on the landscape in a manner that allows use of the land while maintaining stream and riparian resources.

The most common method land use planners use to protect stream and riparian resources is the establishment of a strip of land adjacent to the stream where development is not permitted. This strip of land is commonly referred to as a riparian buffer. Riparian buffers are widely recognized to provide the beneficial functions of sediment reduction, nutrient abatement, contribution of woody debris and organic litter, habitat protection, aesthetic improvement, and erosion control (Wenger, 1999; Desbonnet et al., 1995). Furthermore, Wenger (1999) and Desbonnet et al. (1994) point out the riparian buffer technique is commonly applied throughout the United States, and researches have investigated the issue of riparian buffer width sizing for approximately 40 years. While research efforts have provided insight into the recommended width of buffers, a consensus buffer width has not been established.
Riparian Buffer Width Research

Buffer width is a horizontal measure of the perpendicular distance between the high water mark (or vegetation line, if preferred) and the upland edge of the buffer. Several literature reviews addressing the sizing of riparian buffers have been undertaken in the past (Wenger, 1999; Desbonnet et al.; 1995, and Johnson and Ryba, 1992). The results of these literature reviews are summarized in Table 1. Investigations into the sizing of riparian buffers have been conducted in many different geographic locations under an array of site conditions. Therefore the literature reviews produce a range of recommended buffer widths (Figure 1). Furthermore, the majority of conclusions cited in Table 1 and summarized in Figure 1 are the result of observational studies. Therefore, the conclusions cannot be accepted as replicable in all riparian areas. Rather, these conclusions provide insight into the general range of riparian buffer width necessary to maintain water quality (Ramsey and Schafer, 1997). For example, the recommended range of an effective sediment reduction riparian buffer is from 30 to 197 feet. In this case a buffer less than 30 feet provides extremely low sediment reduction, and a buffer of greater than 197 feet provides minimal water quality enhancement for any additional increase in buffer size. This range as well as other ranges of recommended buffer widths are a result of varying physical landscape attributes and management objectives. Physical attributes include the riparian area slope, soil properties, and vegetation. Management objectives include water detention, stream shading, and wildlife habitat. The range is a starting point for a land use planner developing a riparian area management plan. The procedure suggested here is to apply this range to the physical landscape features and management objectives in an individual riparian planning process in order to obtain the necessary width for an individual study area. For further discussion of the riparian buffer width research see Appendix A.

Variables to Consider in Riparian Buffer Width Decision Making

Most riparian buffer width decisions are made by professional judgement using available data and information about the watershed and site characteristics and desired buffer functions (Todd, 2000). Both watershed and riparian area data are critical to developing a riparian area management plan. At the watershed level, data that describe the watershed land use and basin hydrology are valuable in developing a management plan. Useful riparian area data are slope
Table 1: Summary of Reported Riparian Buffer Widths and Functions

<table>
<thead>
<tr>
<th>Reported Riparian Area Width (ft)</th>
<th>Function</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>87% Sediment, 30% Phosphorus, 50% Nitrogen Reduction</td>
<td>Dillaha et al. (1988)</td>
</tr>
<tr>
<td>15</td>
<td>76% Sediment, 30% Phosphorus, 50% Nitrogen Reduction</td>
<td>Dillaha et al. (1988)</td>
</tr>
<tr>
<td>15</td>
<td>66% Sediment, 41% Phosphorus, 17% Nitrogen Reduction</td>
<td>Magette et al. (1989)</td>
</tr>
<tr>
<td>15</td>
<td>61% Phosphorus, 63% Nitrogen Reduction</td>
<td>Dillaha et al. (1989)</td>
</tr>
<tr>
<td>20</td>
<td>68% Sediment, 70% Phosphorus, 85% Nitrate Reduction</td>
<td>Daniels and Gilliam (1996)</td>
</tr>
<tr>
<td>20</td>
<td>55% Sediment, 45% Phosphorus, 75% Nitrate Reduction</td>
<td>Daniels and Gilliam (1996)</td>
</tr>
<tr>
<td>20</td>
<td>65% Sediment, 30% Phosphorus, 50% Nitrate Reduction</td>
<td>Daniels and Gilliam (1996)</td>
</tr>
<tr>
<td>23</td>
<td>Approximately 90% Nitrogen Reduction</td>
<td>Hubbard and Lowrance (1996)</td>
</tr>
<tr>
<td>25</td>
<td>6% Phosphorus, 15% Nitrogen Reduction</td>
<td>ScHELling and Clausen (1992)</td>
</tr>
<tr>
<td>25</td>
<td>18% Phosphorus, 16% Nitrogen Reduction</td>
<td>ScHELling and Clausen (1992)</td>
</tr>
<tr>
<td>30</td>
<td>99% Sediment Reduction</td>
<td>Coyne et al. (1995)</td>
</tr>
<tr>
<td>30</td>
<td>95% Sediment Reduction</td>
<td>Dillaha et al. (1988)</td>
</tr>
<tr>
<td>30</td>
<td>88% Sediment Reduction</td>
<td>Dillaha et al. (1988)</td>
</tr>
<tr>
<td>30</td>
<td>82% Sediment Reduction</td>
<td>Magette et al. (1989)</td>
</tr>
<tr>
<td>30</td>
<td>19% Phosphorus, 7% Nitrogen Reduction</td>
<td>Dillaha et al. (1988)</td>
</tr>
<tr>
<td>30</td>
<td>80% Phosphorus, 77% Nitrogen Reduction</td>
<td>Dillaha et al. (1988)</td>
</tr>
<tr>
<td>30</td>
<td>57% Phosphorus, 71% Nitrogen Reduction</td>
<td>Dillaha et al. (1988)</td>
</tr>
<tr>
<td>30</td>
<td>79% Phosphorus, 76% Nitrogen Reduction</td>
<td>Dillaha et al. (1989)</td>
</tr>
<tr>
<td>30</td>
<td>53% Phosphorus, 51% Nitrogen Reduction</td>
<td>Magette et al. (1989)</td>
</tr>
<tr>
<td>62</td>
<td>90% Sediment, 60% Nitrate Reduction</td>
<td>Peterjohn and Correll (1984)</td>
</tr>
<tr>
<td>66</td>
<td>8 to 100% Removal of herbicides</td>
<td>Arora et al. (1996)</td>
</tr>
<tr>
<td>75</td>
<td>33% Sediment Reduction</td>
<td>Schellinger and Clausen (1992)</td>
</tr>
<tr>
<td>80</td>
<td>Maximum Shading Capacity Reached</td>
<td>Brazier and Brown (1973)</td>
</tr>
<tr>
<td>85</td>
<td>89% Phosphorus, 92% Nitrogen Reduction</td>
<td>Schwer and Clausen (1989)</td>
</tr>
<tr>
<td>90</td>
<td>79% Sediment, 88% Phosphorus, 87% Nitrogen Reduction</td>
<td>Young et al. (1980)</td>
</tr>
<tr>
<td>90</td>
<td>67% Sediment, 84% Phosphorus, 81% Nitrogen Reduction</td>
<td>Young et al. (1980)</td>
</tr>
<tr>
<td>100</td>
<td>Chinook Salmon Habitat</td>
<td>Raleigh et al. (1986)</td>
</tr>
<tr>
<td>102</td>
<td>Recruitment of Large Wood</td>
<td>Bottom et al. (1983)</td>
</tr>
<tr>
<td>131</td>
<td>Red-Eyed Vireos Habitat</td>
<td>Stauffer and Best (1980)</td>
</tr>
<tr>
<td>35–100</td>
<td>Plant Species Habitat</td>
<td>Spackman and Hughes, 1995</td>
</tr>
<tr>
<td>164</td>
<td>98% Atrazine, 90% Alachlor Pesticide Removal</td>
<td>Lowrance et al. (1997)</td>
</tr>
<tr>
<td>197</td>
<td>94% Sediment Reduction</td>
<td>Peterjohn and Correll (1984)</td>
</tr>
<tr>
<td>330</td>
<td>8 Bird Species Habitat</td>
<td>Kilgo et al. (1998)</td>
</tr>
<tr>
<td>584</td>
<td>Red-eyed Vireo Habitat</td>
<td>Robbins et al. (1989)</td>
</tr>
<tr>
<td>246–575</td>
<td>Bird Habitat</td>
<td>Spackman and Hughes (1995)</td>
</tr>
<tr>
<td>1,435</td>
<td>Acadian Flycatcher Habitat</td>
<td>Robbins et al. (1989)</td>
</tr>
<tr>
<td>1640</td>
<td>6 Bird Species Habitat</td>
<td>Kilgo et al. (1998)</td>
</tr>
<tr>
<td>2339</td>
<td>Summer Tanager Habitat</td>
<td>Robbins et al. (1989)</td>
</tr>
<tr>
<td>4753</td>
<td>Pileated Woodpecker Habitat</td>
<td>Robbins et al. (1989)</td>
</tr>
</tbody>
</table>
steepness, soil hydrologic properties, and vegetation type. The availability of these datasets to land use planners is limited. Furthermore, available data may not be as accurate and precise as needed to make riparian management decisions.

It is also important to realize when making riparian width decisions that all riparian functions will not be protected equally. The role of the land use planner is to evaluate available data, select riparian functions to be managed for, and determine necessary buffer width. One of the most common functions managed for is detention. By detaining surface and ground water, sediments and pollutants (nutrients, pesticides) are physically or biologically removed before water enters the stream. Other management goals include stream shading for water temperature moderation and terrestrial wildlife habitat. Some of the watershed and riparian area characteristics important in developing a riparian area management plan are discussed below.
Physical Watershed Characteristics

A watershed is the area of a landscape that routes water through a stream and river system to a common discharge point. The size of streams within a watershed varies from headwater streams to rivers. As the size of a stream varies so does the biota of the stream. In headwater streams lacking sunlight, organic inputs from the riparian area are the dominant food source. A stream lower in the watershed typically receives a significant amount of both riparian organic inputs and sunlight. In the lower watershed, streams and rivers are dominated by photosynthetic primary production. Therefore, it is important to inventory the size and type of streams before creating a riparian management plan.

Human Watershed Activities

Human activities in the watershed are another important characteristic to consider. A study addressing lowland streams in the Pacific Northwest (May et al., 1997; May et al., 1997a) established two specific watershed measurements that can aid in riparian area management. First, preserving at least 50 percent of the total watershed in natural forest cover. Second, ensuring at least 70 percent of the riparian corridor has a minimum buffer width of 100 feet. With these two conditions met the assumption can be made that the watershed hydrology will remain relatively close to predevelopment conditions. These measurements are watershed wide and include areas outside of the riparian management plan boundary. Therefore they are recommended for use in determination of riparian area management objectives.

Site Specific Riparian Characteristics

The riparian zone slope, soil hydrologic properties, and vegetation affect the buffer performance and must be considered when making a buffer width determination (Phillips, 1989; Phillips, 1989a). Each of the above mentioned variables plays a role in the ability a certain riparian area has to physically moderate the flow of surface and groundwater.

**Slope:** Slope is the change in elevation over a given distance. The residence time of surface and groundwater passing through a riparian buffer is directly related to slope (Fennessy and Cronk, 1997). The steeper the slope gradient the faster water moves both above and below the soil.
surface. Under conditions of low slope, a narrow buffer will most likely maintain beneficial riparian functions. Conversely, in a riparian area with steep slope, a wide buffer will be necessary to maintain beneficial riparian functions because of the relatively large elevation change.

Soil Characteristics: For a riparian management program to be successful consideration should be given to the influence of underlying soils on the rate of water movement (Hubbard and Lowrance, 1996). Specifically, the soil properties of infiltration and permeability also play a role in the residence time of water passing through a vegetated buffer.

Infiltration is the process of water moving into soil. The infiltration capacity of the soil is the maximum rate at which the soil in a given condition can absorb water. At the point rainfall intensity exceeds infiltration capacity, rainfall collects on the soil surface and runs over the ground to streams (Dunne and Leopold, 1978). Rainfall running overland into streams carries with it sediments and nutrients that degrade water quality. Soils with high infiltration capacity permit a larger amount of water to enter the soil increasing the residence time of water in the buffer and requiring a smaller buffer. Soils slow in infiltration, however, require a larger buffer.

Permeability or saturated hydraulic conductivity is the quality of soil that describes the amount of water that would move through pores in the soil after infiltration has occurred (Soil Survey Division Staff, 1993). Permeability is another important factor in determining riparian buffer residence time (Fennessey and Cronk, 1997). As permeability of a soil increases, more water can flow into the soil and less will flow across the soil, meaning less runoff and erosion (Keefer, 2000). Therefore, as is the case with infiltration rate, a soil high in permeability will require a small buffer and a soil low in permeability will require a large buffer.

Vegetation Type: Riparian vegetation provides two important functions in riparian area water detention. First, vegetation creates a rough surface and slows the runoff of water. Second, the presence of vegetation also assimilates nutrients from surface runoff entering riparian soils (Herson-Jones et al., 1995; Haycock and Pinay, 1993). In riparian areas with minimal vegetation little water detention and nutrient assimilation occurs. Therefore, riparian areas lacking vegetation or comprised of grass vegetation will require a larger buffer than those with dense shrub and tree vegetation.
Making Riparian Buffer Width Determinations

The scientific literature clearly supports that there is no "ideal" buffer width for all management objectives in all geographic areas (Table 1). Data availability is limited and questions on data quality increase the uncertainty. Furthermore, buffer width decisions are complicated by the persistent problem in land use planning of balancing environmental protection and economic development (Desbonnet et al. 1995). While nearly all parties agree there is a need for some buffering of valuable aquatic resources from potential anthropogenic degradation, there is often little agreement regarding the degree of buffering necessary or how best to achieve that measure of protection (Castelle et al. 1994). Each of the above mentioned variables must be addressed in developing a riparian area management plan.

Figure 2 (modified from Todd, 2000) provides a riparian area management decision making framework and is used here as a guide to develop riparian area recommendations. This process attempts to include both science based and landowner criteria in developing recommendations for riparian area management.
SECTION TWO: STUDY AREA AND SETTING

Study Area

The City of Seaside is located in Clatsop County, Oregon (Figure 4). The city stretches in a somewhat linear shape north – south along the Pacific coast. In 2000, the population of Seaside was 6,220. This represents an approximately 15% increase from the 1990 population of 5,359 (Population Research Center, 2000). The City of Seaside Urban Growth Boundary (UGB) defines the area of anticipated development for the future. The UGB has an approximate area of 2,400 acres. Portions of the city limits, however, are outside of the UGB. Therefore the total area of the city is approximately 2,600 acres. All lands and waterways within the city limits and UGB have been included in this study and define the study area boundary (Figure 5).

Climate

The City of Seaside has a temperate marine climate. The average annual precipitation is approximately 78.51 inches. Approximately 61 inches occurs during the rainy season (October through March) with December being the month of highest precipitation averaging almost 12.5 inches. Snowfall is relatively rare, averaging only 2 inches per year (CREST, 2001). Due to these climate conditions the streams and rivers of Seaside experience high and relatively flashy flows during the winter months. Summer months, however, are the opposite, characterized by low steady flows (Figure 3).

Figure 3: South Fork Necanicum River Hydrograph (Water Year 1995)*

* (State of Oregon, 2001)
Figure 4: Location of Clatsop County, Necanicum Watershed and City of Seaside
Figure 5: Study Area in Detail

Study Area Boundary

0 1 Miles

Pacific Ocean
Topography

Average elevation in the city is 13 feet above sea level. Much of the area within the city limits generally lacks significant changes in topography (CREST, 2001). Exceptions to the lack of topography occur on the east side and in the southwest corner of the city. Within these areas the foothills of the Oregon coast range enter the study area.

Watershed, Streams, Rivers, and Estuary

Named streams and rivers within the study area include Necanicum River, Neawanna Creek and Thompson Creek (Figure 5). Additionally, many unnamed streams exist within the city. This study examines these streams and river as all members of the Necanicum watershed. The City of Seaside is located at the bottom of the Necanicum watershed (Figure 6). Due to their location in the watershed, the majority of streams within the study area are higher order (Strahler, 1952, stream order methodology). The Necanicum River receives the flow of all streams within the study area. At the north end of study area is a small estuary where the Necanicum river empties into the Pacific Ocean.

Fish Presence

There are numerous fish species that occur in the estuaries, rivers, and streams within the Seaside UGB. Salmonid species known to use aquatic areas in the City of Seaside are Coho salmon, Chum salmon, and steelhead (Figure 7). A complete list of fish species utilizing aquatic areas in the City of Seaside is found in Table 2.

Land Use Zoning in the Necanicum River Watershed and City of Seaside

Necanicum watershed land use zoning is largely commercial forestry. Other land use zones present in the watershed include agricultural, coastal, natural resource, park and recreation, rural residential, and urban (Figure 6).

The City of Seaside land use zoning, in contrast to the watershed, is largely urban. The majority of land is zoned residential, occupying approximately one half of the land area. Open space and resource lands cover approximately one quarter of the land area. The remaining quarter is largely commercial with limited industrial use (Cupples, personal communication, 2001).
Figure 6: Necanicum Watershed Zoning

- Agriculture
- Coastal
- Forestry
- Natural Resource
- Park and Recreation
- Rural Residential
- Urban
- Water

Seaside City Boundary
Necanicum Watershed Zoning

0 - 6 Miles
Figure 7: Fish Use in the City of Seaside

Winter Steelhead, Coho and Chum Salmon
Coho and Chum Salmon

0 1 Miles
Table 2: Fish Species Present in the Necanicum Watershed

<table>
<thead>
<tr>
<th>Common Name</th>
<th>Scientific Name</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chum salmon</td>
<td>Oncorhynchus keta</td>
</tr>
<tr>
<td>Chinook salmon</td>
<td>Oncorhynchus tschawytscha</td>
</tr>
<tr>
<td>Steelhead</td>
<td>Salmo gairdneri gairdneri</td>
</tr>
<tr>
<td>Cutthroat trout</td>
<td>Salmo clarki clarki</td>
</tr>
<tr>
<td>Shiner Perch</td>
<td>Cymatogaster aggregata</td>
</tr>
<tr>
<td>Striped perch</td>
<td>Embiotoca lateralis</td>
</tr>
<tr>
<td>Pile perch</td>
<td>Rhacochilus vacca</td>
</tr>
<tr>
<td>Walleye perch</td>
<td>Hyperprosopon argenteum</td>
</tr>
<tr>
<td>Redtail perch</td>
<td>Amphistichus rhodoterus</td>
</tr>
<tr>
<td>Starry flounder</td>
<td>Platichthys stellatus</td>
</tr>
<tr>
<td>Pacific staghorn sculpin</td>
<td>Leptocottus armatus</td>
</tr>
<tr>
<td>Surf smelt</td>
<td>Hypomesus pretiosus</td>
</tr>
<tr>
<td>Northern anchovy</td>
<td>Engraulis mordax</td>
</tr>
<tr>
<td>Pacific herring</td>
<td>Clupea herengus pallasi</td>
</tr>
<tr>
<td>Bay pipe fish</td>
<td>Syngnathus griseolineatus</td>
</tr>
<tr>
<td>Carp</td>
<td>Cyprinus carpio</td>
</tr>
<tr>
<td>Three spine stickleback</td>
<td>Gasterosteus aculeatus</td>
</tr>
<tr>
<td>Pacific lamprey</td>
<td>Entosphenus tridentatus</td>
</tr>
<tr>
<td>Sturgeon (green)</td>
<td>Acipenser medirostris</td>
</tr>
</tbody>
</table>

*(Maine, 1979)*

Land Use Planning in Oregon and the City of Seaside

The Oregon legislature in 1973 adopted Senate Bill 100, which enacted a statewide land use planning program. Oregon’s Department of Land Conservation and Development (DLCD) administers the program through a system of 19 planning goals and guidelines that mandate communities and counties to meet certain land use requirements. Local governments (counties and incorporated cities) implement statewide goals through locally developed, adopted and enforced comprehensive plans and implementing ordinances. Specifically, statewide planning Goal 5 addresses the protection of riparian resources and has led to the creation of riparian buffer strips around streams throughout Oregon. Furthermore, Goal 17 Coastal Shorelands addresses the lands next to estuaries and coastal lakes creating identical buffers to those implemented for riparian areas in streams.

The City of Seaside currently implements Goals 5 and 17 through their zoning ordinance. Specifically, Article 4 of the Seaside Zoning Ordinance addresses the development of land adjacent to aquatic areas (Cupples, personal communication, 2001). The current development
standards contained in Article 4 call for a minimum 15 feet and maximum 25 feet development setback from streams and estuaries (City of Seaside, 1996). The exact criteria for the establishment of these buffers is not known, but it is suspected the current setbacks were established without detailed scientific assessments (Cuppers, personal communication, 2001).
SECTION THREE: SELECTION OF RIPARIAN AREA MANAGEMENT GOAL

Potential riparian area management goals include stream shading, wildlife habitat and water detention. Taking into account the City of Seaside's location in the watershed and land use, a riparian management goal of water detention is recommended. The city is located at the lower end of the Necanicum watershed. The surface waters in the City are higher order streams (Strahler, 1952, stream order methodology) or estuary. Additionally, land use in the watershed is suited to a detention goal. Land use within the watershed is largely commercial forest use. As a result of this land use pattern the watershed is protected from a high percentage of impervious surface coverage. Furthermore, all forest operations that take place must conform to State of Oregon Forest Practices Act ensuring a 100 foot buffer will be left around streams. Stream shading was not selected as the management goal as higher order streams and estuaries receive large amounts of sunlight under natural conditions. Terrestrial wildlife habitat was not selected as the size requirements are considered over-burdensome on landowners to successfully implement.

The detention method proposed achieves water quality goals through maintaining a high residence time of water in the riparian buffer. Residence time, defined as the amount of time a unit of water stays in the system, is probably the single most important variable for water quality improvement. The longer the water stays in the system, the longer biological and physiochemical processes that assimilate the nutrients have time to act, and the greater the potential for water quality improvement (Fennessy and Cronk, 1997).

It is important to note that the proposed management goal is limited in its ability to buffer the stream systems. Hydrology or the water quantity of the entire watershed is not an element of this management goal. Hydrology of the watershed is largely dependent on the land use within the entire basin. As most of the basin is in forest use with strict riparian management rules it is assumed that hydrology is not a priority concern in the lower portion of the watershed. A final limitation is the detention goal does not protect streams from point sources of pollution such as drainage pipes directly entering waterways. Due to this fact a point source pollution reduction program implemented in conjunction with the riparian area management program is essential to maintain water quality.
SECTION FOUR: RIPARIAN AREA CHARACTERIZATION METHODOLOGY

To characterize the physical features of Seaside’s riparian areas, a geographic information system (GIS) was used to examine existing spatial and tabular attribute data. GIS has been used extensively in land use planning, including riparian area management. GIS riparian buffer delineation models have been developed to make determinations on buffer with for varying management goals including water detention and stream shading (Dick, 1991; Xiang, 1993; Xiang, 1996; Narumalani et al., 1997). While not replicated in its entirety, the water detention model of Xiang (1996) was used as guide for these methods. This model uses the riparian zone slope, soil properties, and vegetation to derive a recommended riparian buffer width.

Data layers used in this examination include United States Geological Survey (USGS) 10 meter Digital Elevation Models (DEM’s), U.S. Natural Resource Conservation Service (NRCS) (formerly Soil Conservation Service) Soil Survey of Clatsop County, Oregon (1988), and the Necanicum River Watershed Assessment riparian vegetation layer. The USGS DEM was used to determine the riparian area slope within the study area. NRCS soil survey data was used to examine water infiltration and permeability properties of riparian soils. The rate of overland flow through riparian areas was evaluated using the riparian vegetation GIS layer obtained from the Necanicum River Watershed Council (NRWC). An appropriate surface water detention classification was applied to each data layer in order to map the detention properties of riparian soils in the study area. Each layer was then converted to a 30-meter grid coverage. A histogram was generated for each grid coverage to illustrate the distribution of each cell type.

It is important to note several items relating to the spatial data used in these methods. The elevation, soils, and vegetation data layers used in this characterization have intrinsic limitations. The surface used to derive slope of the riparian areas was interpolated by the USGS from a set of elevation points. Due to the fact this data is interpolated it has limitations in how accurately it represents the actual topography. Soils data from the NRCS presented here is designed for many different uses. Great differences in soil properties can occur within short distances and may not be represented in this dataset. The vegetation data supplied by the Necanicum River Watershed Council and Oregon Watershed Enhancement Board is in draft format and has not passed quality
Due to these limitations it is recommended that these maps be used for planning purposes only.

Data Compilation and Manipulation

Spatial data used in this analysis were acquired from various sources (Table 3). The geographic referencing used for this project is described in Table 4. All data acquired not geographically referenced as described in Table 4 was reprojected to those parameters. Other actions performed on the data include clipping images and coverages to the project study area and to isolate the riparian areas within the study area, and adding tabular attribute data to existing coverages. Appendix B provides a complete description of the spatial data layers and actions performed on the layers.

<table>
<thead>
<tr>
<th>Coverage</th>
<th>Type</th>
<th>Scale</th>
<th>Source</th>
</tr>
</thead>
<tbody>
<tr>
<td>Digital Orthophotos</td>
<td>Grid</td>
<td>1:24,000</td>
<td>CREST</td>
</tr>
<tr>
<td>Digital Raster Graph</td>
<td>Grid</td>
<td>1:24,000</td>
<td>Regional Ecosystem Office</td>
</tr>
<tr>
<td>Zoning</td>
<td>Polygon</td>
<td>1:100,000</td>
<td>SSCGIS</td>
</tr>
<tr>
<td>Urban Growth Boundary</td>
<td>Line</td>
<td>1:24,000</td>
<td>SSCGIS</td>
</tr>
<tr>
<td>City Limits</td>
<td>Line</td>
<td>1:24,000</td>
<td>SSCGIS</td>
</tr>
<tr>
<td>Streams</td>
<td>Line</td>
<td>1:12,000</td>
<td>CREST</td>
</tr>
<tr>
<td>Rivers</td>
<td>Polygon</td>
<td>1:12,000</td>
<td>CREST</td>
</tr>
<tr>
<td>Necanicum Watershed Boundary</td>
<td>Line</td>
<td>1:12,000</td>
<td>CREST</td>
</tr>
<tr>
<td>Chum Use</td>
<td>Polyline</td>
<td>1:100,000</td>
<td>CREST</td>
</tr>
<tr>
<td>Coho Use</td>
<td>Polyline</td>
<td>1:100,000</td>
<td>CREST</td>
</tr>
<tr>
<td>Winter Steelhead Use</td>
<td>Polyline</td>
<td>1:100,000</td>
<td>CREST</td>
</tr>
<tr>
<td>Riparian Vegetation</td>
<td>Polygon</td>
<td>1:24,000</td>
<td>NRWC</td>
</tr>
<tr>
<td>Elevation</td>
<td>Grid</td>
<td>10 meter</td>
<td>Regional Ecosystem Office</td>
</tr>
<tr>
<td>Soils</td>
<td>Polygon</td>
<td>1:20,000</td>
<td>CREST</td>
</tr>
</tbody>
</table>

Table 4: Geographic Referencing Parameters Used for Spatial Data

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Input</th>
</tr>
</thead>
<tbody>
<tr>
<td>Projection</td>
<td>Oregon Stateplane Fipszone 3601</td>
</tr>
<tr>
<td>Horizontal Datum</td>
<td>HPGN (High Precision GPS Network)</td>
</tr>
<tr>
<td>Vertical Datum</td>
<td>Not Input</td>
</tr>
<tr>
<td>Units</td>
<td>International Feet (3.280839895)</td>
</tr>
</tbody>
</table>
SECTION FIVE: RESULTS OF RIPARIAN AREA CHARACTERIZATION

Riparian Area Slope

The classification presented in Table 5 provides a general assessment of slope as it relates to water detention, and was applied to the riparian areas within the City of Seaside. Figure 8 illustrates the dominate slope class in City of Seaside is minimal (0 to 5%). Three isolated areas in the city have slopes greater than 5 degrees (Figure 9). These areas are in the northeastern, southwestern and southern portions of the city. It is important to note that even in these areas the slope rarely exceeds 20 degrees. This suggests runoff rates at or below moderate occur in the City of Seaside riparian area (Table 5).

Table 5: Slope Classification

<table>
<thead>
<tr>
<th>Classification</th>
<th>Average Slope (%)</th>
<th>Average Slope (degrees)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minimal Runoff Rate</td>
<td>0 to 5</td>
<td>Less than 3</td>
</tr>
<tr>
<td>Low Runoff Rate</td>
<td>5 to 10</td>
<td>Between 3 and 6</td>
</tr>
<tr>
<td>Moderate Runoff Rate</td>
<td>10 to 20</td>
<td>Between 6 and 11</td>
</tr>
<tr>
<td>High Runoff Rate</td>
<td>20 to 25</td>
<td>Between 11 and 14</td>
</tr>
</tbody>
</table>

*(Herson-Jones et al., 1995; Van Starven et al., 1998)
Figure 9: Riparian Area Slope Map

- **Rivers and Lakes**
- **Streams**

**Slope (percent)**
- Minimal (0 to 5)
- Low (5 to 10)
- Moderate (10 to 20)
- Steep (20 to 25)

0 1 Miles
Riparian Area Soils

Infiltration

The rate of infiltration is classified here using the NRCS hydrologic group designation (Table 6). Figure 10 illustrates all infiltration classes are present in riparian soils of the City of Seaside, and the dominant infiltration class is slow (0 to .04 in/hr). The spatial distribution of soil infiltration classes reveals infiltration rates greater than .31 in/hr and below .15 in/hr are present in the city center, and soils showing an infiltration rate between .15 in/hr and .31 in/hr are present in northeastern and southwestern portions of the city (Figure 11). Soil types with minimum infiltration rates above 0.25 in/hr are generally adequate to provide reliable control of surface runoff for average storm events if other conditions are favorable (Herson-Jones, 1995). The majority of riparian soils in the City of Seaside do not possess an infiltration rate above 0.25 in/hr and therefore the potential for rapid or very rapid runoff exists in many areas of the city.

Table 6: Soil Infiltration Rate Classification*

<table>
<thead>
<tr>
<th>Hydrologic Group</th>
<th>Infiltration Class</th>
<th>Minimum Infiltration Rate (in/hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Very Rapid</td>
<td>.31 to .47</td>
</tr>
<tr>
<td>B</td>
<td>Rapid</td>
<td>.15 to .31</td>
</tr>
<tr>
<td>C</td>
<td>Moderate</td>
<td>.04 to .15</td>
</tr>
<tr>
<td>D</td>
<td>Slow</td>
<td>0 to .04</td>
</tr>
</tbody>
</table>

*(Dunne and Leopold, 1978)
Figure 11: Riparian Area Soil Infiltration Map

- **Rivers and Lakes**
- **Streams**

Infiltration Rates (in/hr)
- Very Rapid (.31 to .47)
- Rapid (.15 to .31)
- Moderate (.04 to .15)
- Slow (0 to .04)
- No Data
Permeability

Soil permeability class is related to flow through a saturated soil (Table 7) (Keefer, 2000). The dominant permeability classes in the City of Seaside riparian areas are moderate (0.2 to 6.0 in/hr) and slow (0 to 0.2 in/hr) (Figure 12). Soils with slow permeability (0 to 0.2 in/hr, however, are found in several regions of the city (Figure 13). In soils with slow permeability (0 to 0.2 in/hr) the water will accumulate near the surface quickly and produce surface runoff or shallow subsurface flow (Allan, 1995). As the City of Seaside is dominated by soils with permeabilities greater than 0.2 in/hr the potential for surface runoff is diminished.

Table 7: Soil Permeability Classification*

<table>
<thead>
<tr>
<th>Permeability Class</th>
<th>Rate of Flow (in/hr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Slow</td>
<td>0 to 0.2</td>
</tr>
<tr>
<td>Moderate</td>
<td>0.2 to 6.0</td>
</tr>
<tr>
<td>Rapid</td>
<td>6.0 to 20.0</td>
</tr>
<tr>
<td>Very rapid</td>
<td>More than 20</td>
</tr>
</tbody>
</table>

*(Keefer, 2000)
Figure 13: Riparian Area Soil Permeability Map
Riparian Area Vegetation

Vegetation is another parameter in the reduction of surface runoff, therefore enhancing water detention. As the density of vegetation increases, the resistance of surface water flow increases. This resistance is mathematically described by the Manning coefficient (Table 8). The classification in Table 8 was applied to the riparian vegetation within 50 feet of the surface waters of the City of Seaside. This data set is not complete in that the riparian vegetation is not described for the entire study area. In areas where data exists the vegetation cover is dominated by the grass and tree classes (Figure 14). The most developed region of the city is characterized largely by grass and brush vegetation with limited areas of no vegetation, and less developed areas in the city are characterized by grass, brush and tree buffers (Figure 15). These vegetation characteristics suggest that in areas where data exists surface runoff will be attenuated by vegetation.

Table 8: Vegetation Runoff Classification

<table>
<thead>
<tr>
<th>Vegetation Type</th>
<th>Manning Roughness Coefficient</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>&lt; 0.025</td>
</tr>
<tr>
<td>Grass</td>
<td>0.025 - 0.050</td>
</tr>
<tr>
<td>Brush</td>
<td>0.035 - 0.160</td>
</tr>
<tr>
<td>Trees</td>
<td>0.110 - 0.200</td>
</tr>
</tbody>
</table>

*(Dingman, 1993)*

Figure 14: Vegetation Grid Histogram
Figure 15: Riparian Area Vegetation Map

Riparian Vegetation

- None
- Grass
- Brush
- Tree
- Rivers and Lakes
- Streams

0 1 Miles
SECTION SIX: RIPARIAN MANAGEMENT RECOMMENDATIONS

Recommendations on Buffer Width

Combining the riparian characterization results with the assumption stated earlier regarding buffer ranges in Figure 1, a recommendation on riparian buffer width for Seaside was produced. Currently, the City of Seaside requires a minimum riparian setback of 15 feet. According to Figure 1, a buffer of 15 feet does not provide adequate protection for riparian zones. The City of Seaside riparian area characterization has shown gentle topography that would lead to low runoff rates, soil infiltration properties that would produce rapid runoff, soil permeability properties indicating a moderate capacity for receiving and holding water, and vegetation largely capable of attenuating surface water flows. Collectively, these properties indicate riparian areas in the City of Seaside are not the type to rapidly produce surface runoff. When comparing these riparian area characteristics, the watershed setting, and the selected riparian management goal of the City of Seaside with the literature on stream buffer width in Figure 1 a buffer of 75 to 100 feet appears necessary to maintain water quality through detention.

Recommendations to Accommodate Landowner Objectives and Constraints

As acknowledged in the proposed riparian buffer width decision process (Figure 2) it is essential to consider land owner objectives and constraints in riparian management decisions. Increasing buffer size has the potential to reduce the amount of buildable land. This reduction in buildable land may be unacceptable for some landowners. Under such conditions environmental site planning and land use planning techniques can be a valuable resource for land use planners. Table 9 presents a summary overview of techniques that may be applied to reduce the buffer size and prevent significant loss of buildable land. It is assumed these techniques will enable a buffer to maintain water quality under reduced buffer width conditions.

Potential Applicability to other CREST Member Communities

The City of Seaside shares many of its natural and built environment characteristics with the other Oregon CREST Members. Due to their location on the coastal plain, unincorporated areas in Clatsop County and the City of Warrenton likely share many of the landscape features (topography and soil properties) as the City of Seaside. Furthermore, these jurisdictions also have
Table 9: Overview of Buffer Width Reduction Mitigation Measures

<table>
<thead>
<tr>
<th>Mitigation Measure</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Environmental Site Planning Techniques</strong></td>
<td></td>
</tr>
<tr>
<td>1. Designing for sheet flow</td>
<td>Sheet flow is the flow of water uniformly across a surface as opposed to channelized. Maintaining sheet flow is critical to maintaining a properly functioning buffer. Two general ways to promote the occurrence sheet flow on a site are to (Herson-Jones et al, 1995): a) Install a level spreader along the upland edge of the buffer, or b) Create a flat grassy area about 30 feet wide on the upland side of the buffer where runoff can spread out; this grassy area can be incorporated in the buffer itself; it is unnecessary to set aside additional land to create this area.</td>
</tr>
<tr>
<td>2. Require porous pavement</td>
<td>Porous pavement has a high capability to remove both soluble and fine particulate pollutants in urban runoff, and also provides groundwater recharge, low flow augmentation, and streambank erosion control (Schueler, 1997).</td>
</tr>
<tr>
<td>3. Require grassed swales</td>
<td>Grassed swales are typically applied in single family residential areas as an alternative to curb and gutter drainage systems. Another application is parallel to the vegetated buffer upland edge to provide enhanced water flow reduction (Schueler, 1997).</td>
</tr>
<tr>
<td>4. Enhancing vegetative cover</td>
<td>Improve lawn like or areas bare of vegetation by planting native species of shrubs and trees (Herson-Jones et al, 1995).</td>
</tr>
<tr>
<td>5. Pesticide reduction</td>
<td>Restrict or eliminate the use of pesticides (Klessig, 1983).</td>
</tr>
<tr>
<td>6. Septic system maintenance</td>
<td>If a septic system is used on the lot require tank be pumped at least every three years (Klessig, 1983).</td>
</tr>
<tr>
<td><strong>Land Use Planning Techniques</strong></td>
<td></td>
</tr>
<tr>
<td>1. Transfer of development rights</td>
<td>The transfer of development rights (TDR) allows property owners within riparian areas to sell their development rights to owners of developable property (ANJEC, 1998).</td>
</tr>
<tr>
<td>2. Bonus/incentive zoning</td>
<td>Bonus zoning is similar to transferable development rights, except that the additional development rights are generated and used by the developer rather than purchased from another landowner (Palone and Todd, 1997).</td>
</tr>
</tbody>
</table>

a similar land use make-up to the City of Seaside (Figure 16). This suggests the recommendations put forward here of a water detention management goal, buffer width, and buffer width reduction mitigation measures will likely be applicable in unincorporated Clatsop County and the City of Warrenton. The City of Astoria is not a likely candidate for implementation of these recommendations due to the significant elevation changes and build out of the city.
SUMMARY AND CONCLUSION

Applying the best available scientific literature on riparian buffer width to the natural and human setting of the City of Seaside riparian areas several recommendations have been reached. First, a riparian management goal of detention is recommended over other goals such as shading and wildlife habitat. Second, the topography, soils and vegetation in riparian areas when applied to riparian buffer width literature suggest a buffer of 75 to 100 feet is necessary. Third, it is recommended the impact of a 75 to 100 foot development restriction buffer be mitigated through environmental site planning and land use planning techniques. Finally, due to the fact the City of Seaside shares many of its natural and built environment characteristics with the other Oregon CREST members it is postulated these recommendations are applicable in other CREST member communities.

Each of these recommendations has the potential to benefit the quality of the City of Seaside's surface waters. These recommendations, however, are only one part of stream protection. Other actions are required throughout the watershed, such as reducing impervious surface and the amount of pollutants introduced into the system through point source discharges in order to ensure proper water quality. The recommendations put forward here implemented together with other water quality protection measures represent a comprehensive local government water quality program.
REFERENCES


Columbia River Estuary Study Task Force (CREST), 2000. City of Seaside Local Wetland Inventory. Astoria, OR.


APPENDIX A: RIPARIAN BUFFER
WIDTH LITERATURE REVIEW
Introduction

Width is the most commonly used term in the design of buffer strips (Brazier and Brown 1973). Buffer width is a horizontal measure of the perpendicular distance between the high water mark (or vegetation line, if preferred) and the upland edge of the buffer. Generally, it is considered the most important determinant of pollutant removal effectiveness (Herson-Jones, 1995). Several literature reviews addressing the sizing of riparian buffers have been undertaken previously (Wenger, 1999; Desbonett et al., 1994; and Johnson and Ryba, 1992). This literature review was performed in order to gain the necessary background knowledge to make riparian width recommendations to the local government members of the Columbia River Estuary Study Task Force. The review was accomplished in two steps. First, each previous review was read and the conclusions were summarized. Second, the bibliography of each previous review was used as a source of peer-reviewed articles describing the buffer functions under various circumstances. Articles cited in the reviews were acquired, reviewed, and summarized. Summaries are provided in the text below. The review is organized by pollutant. Each pollutant is introduced, followed with a synopsis from previous literature reviews and selected individual investigations, and conclusions are provided. It is important to note the majority of conclusions cited in this appendix and the recommendations put forward in this appendix are the result of observation studies. Therefore, the conclusions and recommendations cannot be accepted as replicable in all riparian areas (Ramsey and Schafer, 1997). Rather these conclusions provide insight into the general range of riparian buffer necessary to maintain water quality.

Sediment

Sediment is particulate soil matter that can be created by surface water runoff or erosion within the stream channel itself. Climate, topography, geology, vegetation and hydrology control sediment delivery rates and composition. Land-use practices, through alteration of soil structure, vegetation and hydrology, can significantly increase the delivery of sediments to the stream (Spence et al., 1996). An increase in sediment negatively impacts the stream in numerous ways. For example, excess sediment reduces light transmittance, decreasing algal production and sediment deposited on streambeds reduces habitat for fish and invertebrates (Wenger, 1999). It has been shown that riparian buffers are effective at reducing sediment loads in surface water runoff (Daniels and Gilliam, 1996).

Page A-1
Conclusions of Previous Literature Reviews

Previous literature reviews concluded that an 82 to 98 feet buffer is the minimum size required to protect a stream from sedimentation. Wenger (1999) concluded a 98 feet buffer sufficiently traps sediments under most circumstances, but the buffer will likely need to increase to account for factors such as steep slopes and land uses that yield excessive erosion. Desbonnet et al., (1994) discussed sediment and total suspended solids (TSS) separately and stated an 82 feet buffer removes 80% of sediment and a 197 feet buffer removes 80% of TSS. Johnson and Ryba (1992) reviewed five references on sediment removal and recommended 82 feet as three out of five references suggested 82 feet.

Conclusions of Individual Investigations

Individual studies of sediment reduction by riparian buffers are largely focused on the performance of the buffer in agricultural and forestry settings. These studies measured buffer performance in a variety of locations with different physical settings.

Two forestry studies investigated the use of riparian buffers to mitigate the impacts of commercial logging (Table A-1). A study in Pennsylvania monitored the sediment load in commercially logged watershed. Twelve (12) best management practices (BMPs) were implemented during the timber harvest. One of the BMPs was a riparian buffer of 100 feet. Post cutting monitoring data showed only a minor increase in turbidity and no serious channel erosion was observed (Lynch et al., 1985). Moring (1982) examined the gravel permeability, which is often degraded by stream sedimentation causing depleted dissolved oxygen levels, and found permeability remained statistically normal in a stream left with a riparian buffer of 100 feet.

Eight agricultural studies investigating the performance of riparian buffers were reviewed (Table A-1). Specifically, five of these studies (Coyne et al., 1995; Dillaha et al., 1988; Magette et al., 1989; Schellinger and Clausen, 1992; Young et al., 1980) evaluated the performance of a grass buffer in reducing sediment from agricultural livestock fields. Both Coyne (1995) and Dillaha et al., (1988) tested a 30 feet buffer strip and found 99% and 70% to 98% of sediments trapped respectively. Megette et al., (1989) tested 15 and 30 feet buffers and found a 66% and 82% sediment reduction. Young et al., (1980) found cropped buffer strips on a 4% slope...
reduced runoff and total solids transported from a feedlot by 67% and 79%. Schellinger and Clausen (1992) tested a 75 feet grass buffer and 33% of the sediment was retained in the buffer over the period of a one year study. The poor removal percentage was attributed to excessive hydraulic loading rate resulting in an inadequate detention time for proper treatment.

Three studies (Daniels and Gilliam, 1996; Dillaha et al., 1989; Peterjohn and Correll, 1984) evaluated the potential of buffer strips to remove sediment from croplands. Daniels and Gilliam (1996) tested grass, shrub, and mixed hardwood forest buffer and found a grass buffer of 20 feet eliminated approximately 60% of sediment while a mixed hardwood buffer of 60 feet eliminated approximately 80% of sediment. Dillaha et al., (1989) found a 15 and 30 feet buffer eliminated approximately 80% and 90% of sediment respectively. Peterjohn and Correll (1984) tested the ability of a forest to remove sediment from surface runoff and concluded a 62.32 feet buffer removed 90% of sediment.

Conclusions Sediment

Buffer zones reduce sediment transport through infiltration within the buffer zone, reduction of surface flow velocities owning to the increased hydraulic roughness of the vegetation in the buffer, and the physical filtering effect of dense vegetation (Muscutt et al., 1993). The literature review has produced studies where 90% or greater of the sediment has been removed by a buffer range of 30 to 197 feet. The correct amount of buffering within this range is dependent on several factors including slope and soils in the riparian zone. Furthermore, the effectiveness of a buffer for sediment removal has been shown to decrease with channellized flow and the amount of time sediment accumulated in the buffer (Dillaha et al., 1989). Each of these factors must be considered when establishing a buffer width.

Nitrogen

Nitrogen is a biologically limiting nutrient in water and therefore very important to water quality. Nitrogen is usually dissolved and transported by surface and ground water flow as both inorganic forms: nitrogen gas (N₂), nitrate (NO₃⁻), nitrite (NO₂⁻), ammonia (NH₃) or
### Table A-1: Results of Sediment Reduction Investigations*

<table>
<thead>
<tr>
<th>Investigator(s)</th>
<th>Width (ft)</th>
<th>Slope %</th>
<th>Soils</th>
<th>Buffer Vegetation</th>
<th>% Sediment Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dillaha et al., (1988)</td>
<td>15</td>
<td>11</td>
<td>silt loam</td>
<td>grass</td>
<td>87</td>
</tr>
<tr>
<td>Dillaha et al., (1988)</td>
<td>15</td>
<td>16</td>
<td>silt loam</td>
<td>grass</td>
<td>76</td>
</tr>
<tr>
<td>Dillaha et al., (1989)</td>
<td>15</td>
<td>11</td>
<td>silt loam</td>
<td>grass</td>
<td>86</td>
</tr>
<tr>
<td>Dillaha et al., (1989)</td>
<td>15</td>
<td>16</td>
<td>silt loam</td>
<td>grass</td>
<td>53</td>
</tr>
<tr>
<td>Magette et al., (1989)</td>
<td>15</td>
<td>3.5</td>
<td>sandy loam</td>
<td>grass</td>
<td>66</td>
</tr>
<tr>
<td>Daniels and Gilliam (1996)</td>
<td>20</td>
<td>4.9</td>
<td>sand to clay loam</td>
<td>grass</td>
<td>68</td>
</tr>
<tr>
<td>Daniels and Gilliam (1996)</td>
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<td>2.1</td>
<td>sand to clay loam</td>
<td>shrub</td>
<td>55</td>
</tr>
<tr>
<td>Daniels and Gilliam (1996)</td>
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<td>sand to clay loam</td>
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<td>65</td>
</tr>
<tr>
<td>Coyne et al., (1995)</td>
<td>30</td>
<td>9</td>
<td>silt loam</td>
<td>grass</td>
<td>99</td>
</tr>
<tr>
<td>Dillaha et al., (1988)</td>
<td>30</td>
<td>11</td>
<td>silt loam</td>
<td>grass</td>
<td>95</td>
</tr>
<tr>
<td>Dillaha et al., (1988)</td>
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<td>16</td>
<td>silt loam</td>
<td>grass</td>
<td>88</td>
</tr>
<tr>
<td>Dillaha et al., (1989)</td>
<td>30</td>
<td>11</td>
<td>silt loam</td>
<td>grass</td>
<td>98</td>
</tr>
<tr>
<td>Dillaha et al., (1989)</td>
<td>30</td>
<td>16</td>
<td>silt loam</td>
<td>grass</td>
<td>70</td>
</tr>
<tr>
<td>Magette et al., (1989)</td>
<td>30</td>
<td>3.5</td>
<td>sandy loam</td>
<td>grass</td>
<td>82</td>
</tr>
<tr>
<td>Peterjohn and Correll (1984)</td>
<td>62</td>
<td>5</td>
<td>fine sandy loam</td>
<td>forest</td>
<td>90</td>
</tr>
<tr>
<td>Schellinger and Clausen (1992)</td>
<td>75</td>
<td>2</td>
<td>silt clay loam</td>
<td>grass</td>
<td>33</td>
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<tr>
<td>Young et al., (1980)</td>
<td>90</td>
<td>4</td>
<td>Unknown</td>
<td>grass</td>
<td>79</td>
</tr>
<tr>
<td>Young et al., (1980)</td>
<td>90</td>
<td>4</td>
<td>Unknown</td>
<td>grass</td>
<td>67</td>
</tr>
<tr>
<td>Peterjohn and Correll (1984)</td>
<td>197</td>
<td>5</td>
<td>fine sandy loam</td>
<td>forest</td>
<td>94</td>
</tr>
</tbody>
</table>

* Modified from Wenger, 1999.

ammonium ($\text{NH}_4^+$) and organic forms: (organic N) (Spence, 1996, Naiman et al., 1992). As a limiting nutrient nitrogen has the potential to contribute to the eutrophication of waters. Eutrophication causes adverse impacts to the stream such as algae blooms, depressed dissolved oxygen levels, and release of toxins (Schueler, 1997). Sources of nitrogen to a stream system include agricultural fields, septic drain fields, leaking sewer pipes, and fertilizers applied to lawns. Riparian buffers reduce nitrogen entering the stream in both surface water and groundwater. Two processes occur in riparian buffers: uptake by vegetation and denitrification to remove excess nitrogen (Muscott et al., 1993). Uptake of nitrogen occurs as aqueous nitrate flows in shallow groundwater and passes through the root zone of riparian vegetation. Denitrification is the conversion of nitrate into nitrogen gas by anaerobic bacteria (Wenger, 1999).

**Conclusions of Previous Literature Reviews**

Previous literature reviews have not reached a common conclusion on the size of buffer necessary to reduce excess nitrogen from reaching the stream. Wenger (1999) concluded a minimum buffer of 50 feet is probably necessary for most buffer to reduce nitrogen levels, but
recognizing that shallow groundwater is the dominant mode of nitrate transport a wider buffer of 100 feet or greater is encouraged to include areas of denitrification. Through a modeled relationship Desbonnet et al. (1994) found removal efficiency of nitrogen in a 30 feet vegetated buffer is expected to be about 60% and increases with increasing buffer width to about 80% removal at 197 feet of buffer width, after which point the rate of removal of nitrogen per unit increase in buffer width slows. Addressing all nutrients (nitrogen, phosphorus, etc.) Johnson and Ryba (1992) stated generally that nutrient reduction occurs in buffers of 33 to 131 feet, with four of six investigators recommending buffer widths of 50 to 100 feet.

Conclusions of Individual Investigations

There have been several investigations addressing the ability of riparian buffers to reduce nitrogen in agricultural settings (Table A-2). These studies have evaluated the performance of grass and forested buffers.

Dillaha et al. (1989, 1988); Schellinger and Clausen (1992); Magette et al. (1989); and Young (1980) used simulated rainfall to test a grass buffer. Dillaha et al. (1989) concluded a 30 feet grass filter strip with shallow uniform flow removed 73% of incoming nitrogen. Dillaha et al. (1988) sampled a range of nutrient reduction in a series of nine field plots, and found a buffer of 30 feet reduced nitrogen by as little as 7% and as much as 77%. Schellinger and Clausen (1992) found that due to excessive surface water flow generated during the experiment a grass buffer of 75 feet retained only 18% of nitrogen. Magette et al. (1989) tested buffers of 15 and 30 feet and found 17% and 51% reduction in nitrogen respectively. Young et al. (1980) found 84% of total nitrogen was removed from feedlot runoff by a 90 feet grass buffer.

Daniels and Gilliam (1996); Hubbard and Lowrance (1996); Peterjohn and Correll (1984); and Jacobs and Gilliam (1985) evaluated the ability of forested buffer in reducing nitrogen. Daniels and Gilliam (1996) over a two year study determined a mixed hardwood riparian buffer of 43 feet eliminated approximately 75%, and 25% of NO₃⁻ and NH₄ respectively. Hubbard and Lowrance (1996) concluded NO₃⁻ and N were virtually completely removed 23 feet into the riparian forest buffer. Peterjohn and Correll (1984) over the course of a one year study found dramatic changes in water borne nutrient loads occurred in the riparian forest. A forest buffer of 62 feet reduced the total nitrogen by 62% and the nitrate by 60%. Jacobs and
Gilliam (1985) did not specify a single buffer measure. Rather they concluded a buffer of less than 52 feet was effective for inducing significant losses of nitrate before drainage water reached the stream.

The ability of vegetated buffer strips to uptake nutrients from direct application of livestock wastewater was measured by Schwer and Clausen (1989). A vegetated strip of 85 feet reduced the nitrogen by 92%.

Other studies have evaluated grass versus forest buffers and denitrification of water at the surface or subsurface. Osborne and Kovacic (1993) concluded that riparian forests are more efficient at removing nitrate in shallow subsurface water than are grass buffer strips. Jacobs and Gilliam (1985) found drainage that cannot percolate into the soil and accumulates causes the sediments to fall out creating reducing conditions that in turn enhances denitrification in the water before it reaches the stream.

**Conclusions Nitrogen**

Generally, the scientific literature reveals nitrogen removal process appears to take place over quite a short distance in a riparian buffer. Buffers of 23 to 85 feet have been shown to remove 90% or greater of nitrogen. This range, however is questionable for several reasons. As is the case with sediment reduction, nitrogen load in surface runoff concentrated in drainageways changes very little as it moves through riparian systems (Daniels and Gilliam, 1996). Furthermore, differences among riparian forests clearly affect their nutrient retention properties (Jordan et al., 1993), and vegetation uptake of nitrogen is limited during the winter months (Jacobs and Gilliam 1985). Finally the residence time of groundwater in the riparian zone also determines the amount of nitrogen removed (Jordan et al., 1993).

**Phosphorus**

Phosphorus, like nitrogen, is a limiting nutrient in streams, and tends to be absorbed by sediment and transported in particulate form (Naiman et al., 1992). As a limiting nutrient phosphorus, again like nitrogen, contributes to the eutrophication adversely impacting the stream system. Phosphorus is naturally input into surface waters largely from mineral sources. Human
Table A-2: Summary of Riparian Nutrient Removal Effectiveness*

<table>
<thead>
<tr>
<th>Investigator(s)</th>
<th>Slope %</th>
<th>Soils</th>
<th>Buffer Vegetation</th>
<th>Width (ft)</th>
<th>% Removal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Daniels and Gilliam (1996)</td>
<td>4.9</td>
<td>sand to clay loam</td>
<td>grass</td>
<td>20</td>
<td>70</td>
</tr>
<tr>
<td>Daniels and Gilliam (1996)</td>
<td>2.1</td>
<td>sand to clay loam</td>
<td>shrub</td>
<td>20</td>
<td>45</td>
</tr>
<tr>
<td>Daniels and Gilliam (1996)</td>
<td>4.1</td>
<td>sand to clay loam</td>
<td>forest</td>
<td>20</td>
<td>30</td>
</tr>
<tr>
<td>Dillaha et al., (1988)</td>
<td>11</td>
<td>silt loam</td>
<td>grass</td>
<td>15</td>
<td>63</td>
</tr>
<tr>
<td>Dillaha et al., (1988)</td>
<td>16</td>
<td>silt loam</td>
<td>grass</td>
<td>15</td>
<td>52</td>
</tr>
<tr>
<td>Dillaha et al., (1988)</td>
<td>5</td>
<td>silt loam</td>
<td>grass</td>
<td>30</td>
<td>19</td>
</tr>
<tr>
<td>Dillaha et al., (1988)</td>
<td>11</td>
<td>silt loam</td>
<td>grass</td>
<td>30</td>
<td>80</td>
</tr>
<tr>
<td>Dillaha et al., (1988)</td>
<td>16</td>
<td>silt loam</td>
<td>grass</td>
<td>30</td>
<td>57</td>
</tr>
<tr>
<td>Dillaha et al., (1989)</td>
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<td>silt loam</td>
<td>grass</td>
<td>15</td>
<td>61</td>
</tr>
<tr>
<td>Dillaha et al., (1989)</td>
<td>16</td>
<td>silt loam</td>
<td>grass</td>
<td>30</td>
<td>79</td>
</tr>
<tr>
<td>Hubbard and Lowrance (1996)</td>
<td>n/r</td>
<td>fine loam</td>
<td>forest</td>
<td>23</td>
<td>90</td>
</tr>
<tr>
<td>Jacobs and Gillam (1985)</td>
<td>n/r</td>
<td>silty clay loam</td>
<td>forest</td>
<td>52</td>
<td>99</td>
</tr>
<tr>
<td>Magette et al., (1989)</td>
<td>n/r</td>
<td>sandy loam</td>
<td>grass</td>
<td>15</td>
<td>41</td>
</tr>
<tr>
<td>Magette et al., (1989)</td>
<td>n/r</td>
<td>sandy loam</td>
<td>grass</td>
<td>30</td>
<td>53</td>
</tr>
<tr>
<td>Peterjohn and Correll (1984)</td>
<td>4</td>
<td>sandy loam</td>
<td>corn</td>
<td>62</td>
<td>62</td>
</tr>
<tr>
<td>Schellinger and Clausen (1992)</td>
<td>2</td>
<td>silty clay loam</td>
<td>grass</td>
<td>25</td>
<td>6</td>
</tr>
<tr>
<td>Schellinger and Clausen (1992)</td>
<td>2</td>
<td>silty clay loam</td>
<td>grass</td>
<td>25</td>
<td>18</td>
</tr>
<tr>
<td>Schwer and Clausen (1989)</td>
<td>2</td>
<td>n/r</td>
<td>grass</td>
<td>85</td>
<td>89</td>
</tr>
<tr>
<td>Young et al., (1980)</td>
<td>4</td>
<td>Unknown</td>
<td>grass</td>
<td>90</td>
<td>88</td>
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<tr>
<td>Young et al., (1980)</td>
<td>4</td>
<td>Unknown</td>
<td>grass</td>
<td>90</td>
<td>84</td>
</tr>
</tbody>
</table>

a: Total Phosphorus  
b: Total Nitrogen  
c: Nitrate  
* adapted from Desbonnett et al., (1995)

induced sources of phosphorus include agricultural fields, septic drain fields, leaking sewer pipes, and fertilizers applied to lawns (Wenger, 1999). Phosphorus readily attaches itself to small sediment particles and is transported in surface water flow; therefore buffers effective at reducing sediment in surface water will also reduce phosphorus (Herson-Jones et al., 1995).

Width Conclusions of Previous Literature Reviews

Wenger (1999) concluded riparian zones of 50 to 100 feet (wide enough to provide sediment control) should provide short-term control of sediment bound phosphorus, and long term control of phosphorus by a riparian buffer can only be accomplished through reduction in the sources. Desbonnett et al., (1994) concluded a buffer of 39 feet removes approximately 60% of phosphorus and a buffer of 279 feet removes approximately 80% of phosphorus. As mentioned above, Johnson and Ryba (1992) stated generally that nutrient (nitrogen, phosphorus, etc.) reduction occurs in buffers of 33 to 131 feet, with four of six investigators recommending buffer widths of 50 to 100 feet.
Width Conclusions of Individual Investigations

Eight individual investigations into the removal of phosphorus by riparian buffers of a certain width and vegetation type were identified and reviewed.

Six studies (Dillaha et al., 1988, 89; Magette et al., 1989; Schellinger and Clausen, 1992; Schwer and Clausen, 1989; and Young et al., 1980) evaluated phosphorus removal by grass vegetated buffers (Table A-2). Of these six, four investigations used simulated rainfall to test the buffers (Dillaha et al., 1988, 89; Magette et al., 1989; Young et al., 1980). Dillaha et al., (1989) found a 30 and 15 feet buffer with shallow uniform flow removed an average of 79% and 61% of incoming phosphorus, respectively. In a similar study, Dillaha et al., (1988) found 30 and 15 feet buffers with shallow uniform flow removed an average of 69% and 51% of incoming phosphorus, respectively. Young et al., (1980) tested a buffer of 90 feet with feedlot runoff and found phosphorus was reduced by 83%. Magette et al., (1989) tested vegetated filter strips of 15 and 30 feet with chicken litter nutrient sources and found a 41% and 53% reduction in phosphorus, respectively. Schwer and Clausen (1989) and Schellinger and Clausen (1992) tested 85 and 25 feet buffers in a dairy barnyard runoff study. The buffer of 85 feet reduced phosphorous by 89% while the 25 feet buffer reduced approximately 15% of phosphorus. It was concluded that the poor performance of the 25 feet buffer was due to an excessive hydraulic loading rate resulting in an inadequate detention time for proper treatment (Schellinger and Clausen 1992).

Daniels and Gilliam (1996) tested both a forested and grass riparian buffer of 20 feet. The forested buffer removed only 30% while the grass buffer removed 70% of total phosphorus. Peterjohn and Correll (1984) found 66% of phosphorus was removed 62 feet into a riparian forest.

Conclusions Phosphorus

The studies reviewed above report a total phosphorus removal rate of 18 to 89 percent and a buffer range of 20 to 90 feet. It is important to note when making phosphorus buffer decisions that it is possible for a buffer to become saturated with phosphorus when all soil binding sites are filled. This can cause phosphorus export from the buffer at higher than inflow
due to the release of phosphorus previously trapped in the filters (Dillaha et al., 1989). Another factor to consider is forested and grassed buffers are equally effective at eliminating phosphorus (Wenger, 1999).

**Pesticides**

Pesticides (herbicides, insecticides, and fungicides) are chemicals used to kill undesirable plants, insects, and other forms of life. They are commonly applied to lawns, rooftops and other areas. Methods of pesticide movement to the stream are surface runoff, leaching into groundwater or volatilization and drift. Pesticides that reach surface waters can be toxic to aquatic life or may alter primary and secondary production, influencing the food chain of a stream (Spence et al., 1996). Riparian buffers reduce the amount of pesticides reaching a stream through trapping and providing more time for sunlight and microbes break down pesticides.

**Width Conclusions of Previous Literature Reviews**

Wenger (1999) concluded buffers of at least 20 feet and probably much wider are useful for reducing pesticides; width should be extended for steeper slopes that would reduce buffer contact time. Furthermore, pesticide reduction measures are required in order to maintain an effective buffer. Others (Desbonett et al., 1994; Johnson and Ryba, 1992) completing literature reviews of recommended riparian buffer widths did not include a discussion of pesticides.

**Width Conclusions of Individual Investigations**

Few investigations have tested the ability of riparian buffers to protect the stream system from pesticides. Arora et al., (1996) found that a riparian buffer of 66 feet with 3% slope retained 8 to 100% of herbicides over a two year natural rainfall study. The high range was a result of variable surface water runoff rates. Lowrance et al., (1997) tested two herbicides, atrazine and alachlor on a 164 feet buffer with forest, managed forest, and grass zones. The 164 feet buffer reduced atrazine and alachlor in surface water by 98% and 90% respectively. Both herbicides were at or below detection limits in ground water near the stream. Hatfield et al., (1995) used both simulated and natural rainfall to test the effectiveness of a 40 and 66 foot buffer strip at removing atrazine, cyanazine, and metolachlor. Results were a reduction of 10 to 40% in
each buffer with the soil concentration as the primary factor controlling the effectiveness of the buffer strip.

**Conclusions Pesticides**

Turf researchers and stream researchers typically show conflicting data on the issue of pesticides in streams. Turf researchers generally report very little runoff or leaching of pesticides during controlled experiments, while stream researchers frequently detect a relatively wide range of herbicides and insecticides in urban and suburban streams (Schueler, 1995). For the most part pesticides are fixed to sediment and behave similar to phosphorus. A lesser portion, anywhere from 2% to 25%, can drift away and land on impervious surfaces and are then picked up by surface water (Schueler, 1995). Therefore, a buffer that reduces sediments from reaching the stream will also reduce the amount of pesticides reaching the stream. Furthermore, the ability of pesticides to become absorbed by sediment dictates the amount of pesticide removed from surface water in the buffer. Strongly absorbed pesticides will be removed much more effectively than weakly absorbed pesticides that will likely be transported through as a solute (Arora et al., 1996). Specific elements that determine the riparian buffer system capacity to reduce pesticides in surface runoff are soil moisture storage and infiltration, vegetation condition, dilution, and the condition of the riparian buffer system (Lowrance et al., 1997). Pesticides in groundwater and volatized in the air are best addressed by encouraging proper or limited use of pesticides. While buffers help to reduce the amount of pesticides, total reduction—particularly in groundwater and from volatized in the air—will require reducing the amount introduced into the watershed.

**Water Temperature**

Stream water temperature is an important criterion for water quality and largely influenced by the rate of streamflow, elevation, and the amount of shade (Cohen et al., 1987). Changes in riparian vegetation along urban streams can alter the degree of shading provided to the stream, which in turn influences seasonal and diurnal temperature ranges (Spence et al., 1996). These temperature changes affect stream denizens in several ways. Stream organisms' metabolism is influenced, dictating the amount of food required for daily activities and reproductive products. Changes in stream water temperature create physical changes in the
water that affect the amount of energy required to swim (Naiman et al., 1992). Maintaining a
forested riparian buffer along the stream creates shade and regulates stream water temperature.

**Width Conclusions of Previous Literature Reviews**

Wenger (1999) concluded a forested and continuous riparian buffer of 33 feet is needed
along all stream channels to maintain proper stream temperatures. Johnson and Ryba (1992)
found a general indication that the greatest benefit to stream temperature occurred with forested
buffer of 100 feet. Desbonnet et al., (1994) made no recommendation on the size of riparian
buffer required to regulate stream water temperature.

**Width Conclusions of Individual Investigations**

Two examinations (Brazier and Brown 1973; Brown et al., 1971) of the required buffer
size to maintain stream water temperatures have occurred in the state of Oregon. One conclusion
was maximum shading capability of the average buffer strip is reached within a width of 80 feet
and 90% of that maximum is reached within 55 feet (Brazier and Brown, 1973). Brown et al.,
(1971), determined buffer strips 50 feet wide were nearly as effective as an uncut block of forest
in attenuating incoming solar radiation to the stream.

Studies in other regions have found a slightly smaller buffer is required. Barton et al.
(1985) specifically investigated the dimension of riparian buffer strips required to maintain trout
habitat in Southern Ontario streams. A 33 feet wide buffer strip maintained stream water
temperature although the authors admitted somewhat of an extrapolation beyond the data limits
in reaching this conclusion. Lynch et al. (1985) suggested a minimum buffer strip of 40 feet to
prevent excessive temperature increases in small streams. This width was not empirically tested
though; it was a general recommendation made from a watershed study.

**Conclusions Water Temperature**

This literature review has found a buffer range of 33 to 100 feet is needed to maintain
proper stream water temperature. It is important to note that the buffer of 33 feet was not
empirically tested and therefore a buffer of 50 to 100 feet is recommended. Other
recommendations relate to the stream size, native tree species, and geographic location. Small
streams have the greatest temperature problem. On larger streams buffer strips have minimal

Page A- 11
effect on the water temperature for several reasons including the volume of water in the stream (Brazier and Brown, 1973). Furthermore, minimum buffer width depends on the age and species composition of the riparian vegetation and its resulting height and foliage density (Barton et al., 1985).

**Organic Material and Large Wood**

A vegetated riparian buffer provides the stream systems with organic material and large wood. Organic material is small wood, conifer cones, and deciduous leaves input to the stream from the riparian zone. Large wood consists of large trees that have fallen into the stream (Spence et al., 1996). Organic material provides an important food source to aquatic comminutes, and large wood dissipates energy, traps moving materials and forms habitat in the stream (Naiman and Decamps, 1997). Ecologically healthy streams require a riparian forest as a source of organic material (Naiman et al., 1992). A lack of large wood inputs commonly results in a homogenous straight stream channel with little habitat complexity (Spence et al., 1996). An intact and mature riparian zone is the key to maintenance of instream large woody debris (May et al., 1997). Typically wood likely enters the stream from toppling or windthrown trees. An additional source of wood is mass wasting and debris torrents (Spence et al., 1996).

*Width Conclusions of Previous Literature Reviews*

One of the previous literature reviews made a recommendation on an appropriate buffer size for recruitment of large woody debris. Wenger (1999) suggested a minimum buffer of 50 feet appears necessary to provide woody debris inputs to the stream. Within this buffer no tree harvesting should occur within 25 feet of the stream (50 feet is preferable), and harvesting in the remainder of the buffer should leave some mature and senescent trees.

*Width Conclusions of Individual Investigations*

Several studies were identified addressing the appropriate buffer size required to maintain proper recruitment of large wood. Collier et al., (1995) (cited in Wenger, 1999) recommended a buffer width of at least one tree height to maintain inputs of LWD. Spence et al. (1996) reported that large wood is contributed from a distance of 98 and 180 feet from the stream. These lengths correspond with 75% to 100% of the native tree height potential. Furthermore, Bottom et al.,
(1983) (cited in Johnson and Ryba, 1992) reached the same conclusion reporting a buffer of 102 feet as necessary for recruitment of large woody debris.

**Conclusions Organic Material and Large Wood**

The overwhelming majority of studies reports maximum native tree height as the desired buffer width in order to maintain recruitment of large woody debris. Therefore the recommended buffer width is native tree height in the riparian management region.

**Wildlife Habitat**

Riparian areas are extremely important habitat for wildlife. Wildlife are attracted to riparian areas for several reasons including the presence of water and diverse plant assemblages (Spence et al., 1996). Additionally, riparian areas serve as a key landscape component maintaining habitat connections along extended and dynamic environmental gradients (Naiman and Decamps, 1997). Maintaining a riparian zone buffer retains a portion of this valuable wildlife habitat.

**Width Conclusions of Previous Literature Reviews**

Only two of the previous riparian buffer width literature reviews has addressed wildlife habitat. Wenger (1999) concluded a 300 feet buffer is required to protect diverse terrestrial riparian wildfire. Johnson and Ryba (1992) reviewed the literature related to buffer widths for wildlife protection and found recommended buffer widths to be highly variable, ranging from 33 to 656 feet.

**Width Conclusions of Individual Investigations**

The focus of most investigations into riparian buffer width requirements of wildlife has been directed toward avian species. Relatively few studies were identified addressing other animals.

Each of the investigations into the riparian buffer requirements of avians produced a large buffer width conclusion (Table A-3). Minimum corridor widths of 246 to 574 feet were needed to include 90% of the bird species (Spackman and Hughes, 1995). Kilgo et al., (1998) concluded
narrow riparian stands are extremely valuable avian habitat, but complete avian community characteristics of bottomland hardwoods in South Carolina can be maintained only in the few remaining riparian zones that are extremely wide (> 1650 ft.). Keller et al., (1993) surveyed 177 riparian corridors that ranged from 75 to 2,600 feet in width. Based on these surveys they recommend that riparian forest buffer be at least 330 feet wide to provide some nesting habitat for area-sensitive species.

Several investigations into buffer requirements of mammals, plants, and fish were identified (Table A-3). Cross (1985) concluded a streamside vegetative leave-strip appears to maintain riparian communities of small mammals at levels comparable to nearby undisturbed areas, but optimum or minimum size of streamside riparian buffers that can provide habitat for both resident and transient wildlife remains to be determined. Spackman and Hughes (1995) investigated the protection of riparian plants species. It was concluded that to include 90% of the streamside plant species, minimum corridor widths ranged from 33 to 100 feet above the high water mark, depending on the stream. The buffer needs for salmon seem to be much less than that required for avian species. In low to moderate gradient terrain, a buffer strip about 100 feet wide on each side of the stream, 80% of which is well vegetated, provides adequate erosion control and maintains undercut stream banks characteristic of good salmonid habitat (Raleigh et al., 1986).

Conclusions Wildlife Habitat

Considering the high number of plant and animal species using the riparian zone, reaching a single minimum width requirement is extremely difficult. Distribution of species along streams varied greatly by taxon, stream, and location of the high water mark (Spackman and Hughes, 1995). Furthermore, it has been reported that urban and suburban parks fail as avifaunal preserves because fragment sensitive species are replaced by generalized residents (Smith and Schaefer, 1992). The width recommendations found during literature review range from 35 to 2,339 feet. Establishing a buffer on the high end of this range is considered difficult to implement. Therefore minimum riparian buffer width should be based on water quality and aquatic habitat functions. Buffer systems established to protect water quality and quantity will likely provide some level of wildlife habitat.
Table A-3: Summary of Wildlife Riparian Buffer Requirements*

<table>
<thead>
<tr>
<th>Investigator(s)</th>
<th>Width (ft)</th>
<th>Target Species</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Robbins et al., (1989)</td>
<td>1,435</td>
<td>Acadian Flycatcher</td>
<td>50% probability of occurrence</td>
</tr>
<tr>
<td>Robbins et al., (1989)</td>
<td>584</td>
<td>Red-eyed Vireo</td>
<td>50% probability of occurrence</td>
</tr>
<tr>
<td>Robbins et al., (1989)</td>
<td>2,359</td>
<td>Summer Tanager</td>
<td>50% probability of occurrence</td>
</tr>
<tr>
<td>Robbins et al., (1989)</td>
<td>4753</td>
<td>Pileated Woodpecker</td>
<td>50% probability of occurrence</td>
</tr>
<tr>
<td>Stauffer and Best (1980)</td>
<td>131</td>
<td>Red-Eyed Vireos</td>
<td>minimum width found in agricultural area</td>
</tr>
<tr>
<td>Spackman and Hughes, 1995</td>
<td>35 - 100</td>
<td>plant species</td>
<td>retain 90% streamside plant species</td>
</tr>
<tr>
<td>Spackman and Hughes, 1995</td>
<td>246 - 575</td>
<td>bird species</td>
<td>retain 90% bird species</td>
</tr>
<tr>
<td>Kilgo et al., (1988)</td>
<td>330</td>
<td>8 bird species</td>
<td>50% probability of breeding occurrence</td>
</tr>
<tr>
<td>Kilgo et al., (1998)</td>
<td>1,640</td>
<td>6 bird species</td>
<td>50% probability of breeding occurrence</td>
</tr>
<tr>
<td>Raleigh et al., (1986)</td>
<td>100</td>
<td>Chinook salmon</td>
<td>in low to moderate gradient terrain</td>
</tr>
</tbody>
</table>

1. cited in Smith and Schaefer, 1992

Summary and Conclusions

The literature review has produce a range of recommended buffer widths (Tables A-1, A-2, A-3) for protecting stream and riparian resources. The range of recommended buffer widths varies with the physical attributes of the landscape and the management objective. These studies alone do not provide a definitive answer to the question of how large a riparian buffer strip is necessary. But, the range provides a starting point for a land use planner developing a riparian area management plan. It can generally be inferred from these studies that a buffer larger than the maximum reported will provide minimal water quality enhancement for any additional increase in buffer size. In contrast the minimum buffer reported is the smallest size buffer achieve water quality maintenance under optimal conditions.

Other general management recommendations discovered through this literature review are valuable to the land use planner. These include applicability of the studies, long-term buffer performance, and critical management functions. With respect to application of buffer studies, Dillaha et al. (1988) recognized that rates of pollutant removal observed in small scale experimental studies are unlikely to be representative of those which occur in typical catchments. Furthermore, the long term performance of buffer zones is also unclear. Where natural riparian zones have survived, pollutant removal has been observed; however, it has been suggested that riparian areas may achieve an equilibrium such that pollutant inputs from agricultural areas which are retained in riparian areas would subsequently be released (Muscutt et al., 1993). Finally, it can be said the most critical variable to water quality improvement in vegetated
buffers is residence time. The longer the water stays in the systems, the longer the biological and physiochemical processes that act on nutrient have time to act, and the greater the potential for water quality improvement. One of the most important factors determining residence time of surface flows is the ground slope. Second in importance is the infiltration and permeability of buffer soils (Fennessy and Cronk, 1997).

In conclusion, it is extremely important that any land manager working with riparian buffers realize their limits. Buffers are only one part of stream protection. Although they are a very important part, actions must be taken throughout the watershed such as reducing impervious surface and the amount of pollutants introduced into the system.
APPENDIX B: GEOGRAPHIC INFORMATION
SYSTEM DATA DICTIONARY
APPENDIX B: GEOGRAPHIC INFORMATION SYSTEM DATA DICTIONARY

Introduction

The GIS outlined here was designed to characterize the water detention properties of a riparian areas within the City of Seaside. The purpose of the characterization within the project is to provide technical information to aid in riparian buffer width decision making. The system has data layers from four different categories:

1. Background Imagery
2. Political Themes
3. Built Environment Themes
4. Natural Environment Themes

Data came from a multitude of local, county, state, and federal sources. All data was then projected into the following system:

- **Projection:** Oregon Stateplane, Fipszone 3601
- **Horizontal Datum:** High Precision GPS Network (HPGN)
- **Vertical Datum:** Not Input
- **Units:** International Feet (3.280839895)

Data Layers

**Background Imagery**

*Color Digital Orthophoto Quads*

*Geographic Scope:* Entire Study Area
*Form:* Image (.tif)
*Attributes:* None
*Source:* Columbia River Estuary Study Task Force (CREST)
*Contact:* 750 Commercial Street, Room 205, Astoria, OR 97103 (503-325-0435)
*Date Taken:* May, June, and July 1994
*Original:* unknown
*Pixel Size:* 1 meter
*Scale:* 1:12,000
*Comments:* Natural Color, high resolution film, quarter township centered flights, high resolution ZEISS6" cameras with integrated GPS survey system.
*Metadata:* spec sheet available from CREST

*Black and White Digital Orthophoto Quads* -- gearhart.tif, tillamookhead.tif

*Geographic Scope:* Entire Study Area
*Form:* Image (.tif)
*Attributes:* none
*Source:* Oregon Department of Land Conservation and Development
Contact: 635 Capitol St. NE, Suite 150, Salem, OR 97301 (503-373-0050)
Date Developed: 1994
Pixel Size: 1 meter
Scale: 1:24,000
Comments: USGS quadrangles (gearhart.tif, tillamookhead.tif) were mosaiced, reprojected and clipped to the study area.

Study Area Digital Raster Graph -- drg.tif
Geographic Scope: Entire Study Area
Form: image (.tif)
Attributes: none
Source: Regional Ecosystem Office (http://www.reo.gov/reo/data/data.htm) accessed 2/15/01
Contact: 333 SW 1st Ave, Portland, OR 97208 (503-808-2165)
Pixel Size: 2.4 meters
Date Developed: unknown
Scale: 7.5 minute quads, 1:24,000
Comments: USGS quadrangles (gearhart.tif and tillamookhead.tif) were mosaiced, reprojected, and clipped to the study area.

Political Themes

City of Seaside City Limits -- City limits.shp
Geographic Scope: Political Boundary of Seaside, Oregon
Form: polygon (.shp)
Attributes: shape, area, perimeter, citylim, citylim_id, name, desig, county, fips, latlong, mapname, Lat_deg, Lat_min, Lat_sec, Long_deg, Long_min, Long_sec
Source: Oregon Geospatial Data Clearinghouse (http://www.sscgis.state.or.us) accessed 1/10/01
Contact: 955 Center St. NE US 10, Salem, OR 97301-2558 (503-378-2166)
Date Developed: unknown
Scale: 1:24,000
Comments: Layer obtained from Oregon Geospatial Data Clearinghouse contained city limits for all incorporated cities in Oregon. The City of Seaside limits were selected and saved as a separate shapefile.
Metadata: available on-line at: http://www.sscgis.state.or.us/data/theme/politics.html

City of Seaside Urban Growth Boundary -- Ugb.shp
Geographic Scope: urban growth boundary for the city of seaside
Form: polyline (.shp)
Attributes: shape, Fnode, Tnode, Lpoly, Rpoly, Length, Ugbhpng, Ugbhpng_id, Mslink, Name, Cnty, Area, Perimeter, Acres
Source: Oregon Geospatial Data Clearinghouse (http://www.sscgis.state.or.us) accessed 1/10/01
Contact: 955 Center St. NE US 10, Salem, OR 97301-2558 (503-378-2166)
Date Developed: unknown
Scale: 1:24,000
Comments: Layer obtained from Oregon Geospatial Data Clearinghouse contained urban growth boundaries for all incorporated cities in Oregon. The City of Seaside urban growth boundary was selected and saved as a separate shapefile.
Metadata: available on-line at: http://www.sscgis.state.or.us/data/theme/politics.html

City of Seaside Riparian Planning Study Area -- Ripstudyarea.shp
Geographic Scope: All lands within the Urban Growth Boundary and City Limits of Seaside
Form: polyline (.shp)
Attributes: polyline, id
Source: created by Steve Tolzman
Contact:
Date Developed: unknown
Scale: 1:24,000
Comments: Layer produced by digitizing over Seaside Urban Growth Boundary and City Limits layers.
Metadata: none

Clatsop County Boundary -- Clatsop County.shp
Geographic Scope: Political Boundary of Clatsop County
Form: polygon
Attributes: shape, area, perimeter, Counties_, Counties_I, Fips, Name, Fips_st, Fips_cnty
Source: Oregon Geospatial Data Clearinghouse (http://www.sscgis.state.or.us) accessed 1/10/01
Contact: 955 Center St. NE U510, Salem, OR 97301-2558 (503-378-2166)
Date Developed: unknown
Scale: 1:500,000
Comments: Layer obtained from Oregon Geospatial Data Clearinghouse contained all counties in Oregon. The Clatsop County boundary was selected and saved as a shapefile.
Metadata: available on-line at: http://www.sscgis.state.or.us/data/theme/politics.html

Natural Environment Layers

Digital Elevation Model
Geographic Scope: Clatsop County
Form: grid
Attributes: elevation
Source: Regional Ecosystem Office (http://www.reo.gov/reo/data/data.htm) accessed 2/15/01
Contact: 333 SW 1st Ave, Portland, OR 97208 (503-808-2165)
Date Developed: unknown
Pixel Size: 10 meter
Scale: 7.5 minute quads, 1:24,000
Comments: Digital Elevation model of Clatsop County was produced by Kyle Gomez, OSU Geosciences Graduate Student by mosaicing USGS quadrangles from the Regional Ecosystem Office and clipping to the county boundary. This layer was further clipped to the study area and again to the riparian areas within the study area.
Elevation Slope for Riparian Study Area -- correctslope.shp

Geographic Scope: Riparian zones with study area
Form: polygon
Attributes: shape, id, gridcode
Source: Built by Steve Tolzman from 10m DEM data
Contact:
Date Developed: 4 March, 2001
Scale: 1:24,000
Comments: Digital elevation model of Clatsop County was clipped to the riparian area, 250 foot buffer of waterways in the city of Seaside. The slope was derived from the digital elevation model, reclassed into four bins by grid code (see below), and converted to shapefile. Gridcode classifications are:

<table>
<thead>
<tr>
<th>Gridcode</th>
<th>Slope in Degrees</th>
<th>Slope in Percent (rounded)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0 to 3.000</td>
<td>0 to 5</td>
</tr>
<tr>
<td>2</td>
<td>3.001 to 6.000</td>
<td>5 to 10</td>
</tr>
<tr>
<td>3</td>
<td>6.001 to 11.000</td>
<td>10 to 20</td>
</tr>
<tr>
<td>4</td>
<td>11.001 to 25.206</td>
<td>20 to 45</td>
</tr>
</tbody>
</table>

Metadata: none

Soils -- riparainsoils.shp

Geographic Scope: Riparian zones within study area.
Form: polygon (.shp)
Attributes: area, perimeter, Musym, Stssaid, Muid, Muname, symbol, hydrologic group (hydrologic), depth to high water table in feet ((ft)_high_), Drainage class (Drainage_c), Permeability (Permeability), Runoff class (Runoff), Hazard of erosion by water (Hazard_of), Depth to bedrock in inches ((in)_depth),
Classification: Soil layer included all of Clastop County. The relevant portion of this layer was clipped and saved as a shapefile
Source: Oregon Geospatial Data Clearinghouse (http://www.sscgis.state.or.us) accessed 1/10/01
Contact: 955 Center St. NE U510, Salem, OR 97301-2558 (503-378-2166)
Date Developed: Developed by Natural Resource Conservation Service in 1998
Scale: 1:20,000
Comments: Layer obtained from Oregon Geospatial Data Clearinghouse contained soils of Clatsop County. Soils within the study area riparian zone were clipped from the Clatsop County Soils Layer. Additionally, tabular data from the published soil survey was added to the .dbf file associated with the soils shapefile. Columns added include:

<table>
<thead>
<tr>
<th>Attribute Column Name</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrologic</td>
<td>USGS hydrologic group</td>
</tr>
<tr>
<td>(ft)<em>high</em></td>
<td>depth to high water table in feet</td>
</tr>
<tr>
<td>Drainage_c</td>
<td>drainage class</td>
</tr>
<tr>
<td>Permeability</td>
<td>soil permeability</td>
</tr>
<tr>
<td>Perm_class</td>
<td>reclass of soil permeability</td>
</tr>
<tr>
<td>Runoff</td>
<td>runoff class</td>
</tr>
<tr>
<td>Hazard_of</td>
<td>Hazard of erosion by water</td>
</tr>
<tr>
<td>(in)_depth</td>
<td>depth to bedrock in inches</td>
</tr>
</tbody>
</table>
The Permeability column was further simplified by reducing the 4 classes with moderate (moderate, moderate to moderately rapid, moderately rapid, moderately slow) to one class 'moderate.'

*Metadata:* available on-line at: http://www.sscgis.state.or.us/data/theme/natural.html

**Riparian Vegetation -- Riparianveg.shp**

*Geographic Scope:* Layer does not cover entire study area. Portions of Necanicum and Neawanna Rivers in the City of Seaside and several tributaries are included. Many of the tributaries, however are not in the dataset.

*Form:* polyline (.shp)

*Attributes:* shape, id, new_id, rip_veg

*Source:* Necanicum River Watershed Council and E & S Environmental

*Contact:* Need address for Watershed Council

*Date Developed:* 2001

*Scale:* 1:24,000

*Comments:* E & S Environmental interpreted the riparian area vegetation within 50 feet of waterways in the City of Seaside from 1:24,000 digital orthophotos. Layers prepared by E & S Environmental were in line form and separated into two files, right and left bank. Left and right bank vegetation data were contained as attributes in the line file with identical geographic coordinates. These layers were used to digitize the riparianveg.shp line file. New lines were digitized on the left and right side of each stream. Furthermore data was reclassed as follows.

<table>
<thead>
<tr>
<th>Original Vegetation Class</th>
<th>Reclassed Vegetation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mostly conifer trees (&gt;70%)</td>
<td>Trees</td>
</tr>
<tr>
<td>Mostly hardwood trees (&gt;70%)</td>
<td>Trees</td>
</tr>
<tr>
<td>Mixed conifer/hardwoods</td>
<td>Trees</td>
</tr>
<tr>
<td>Brush species</td>
<td>Brush</td>
</tr>
<tr>
<td>Grass/meadow</td>
<td>Grass</td>
</tr>
<tr>
<td>Wetlands</td>
<td>N/A (class not present in the city)</td>
</tr>
<tr>
<td>No riparian vegetation</td>
<td>None</td>
</tr>
</tbody>
</table>

*Metadata:* available from Necanicum River Watershed Council

**Rivers -- Nechdrdro.shp**

*Geographic Scope:* Entire Study Area

*Form:* polygons (.shp)

*Attributes:* shape, id

*Source:* Columbia River Estuary Study Task Force (CREST)

*Contact:* 750 Commercial Street, Room 205, Astoria, OR 97103 (503-325-0435)

*Date Developed:* 1996

*Scale:* 1:12,000

*Comments:* Spencer B. Gross Inc., photogrammetrically derived rivers from aerial photography in 1996. Layer contained river system of the Necanicum watershed. Layer was clipped to the project study area.

*Metadata:* available from CREST
Streams -- seaside streams.shp
Geographic Scope: Entire Study Area
Form: polygon (.shp)
Attributes: shape, id
Source: Columbia River Estuary Study Task Force (CREST)
Contact: 750 Commercial Street, Room 205, Astoria, OR 97103 (503-325-0435)
Date Developed: 1996
Scale: 1:12,000
Comments: Spencer B. Gross Inc., photogrametrically derived streams from aerial photography in 1996. Layer contained stream system of the Necanicum watershed. Layer was clipped to the project study area.
Metadata: available from CREST

Necanicum Watershed Boundary -- Necanbound.shp
Geographic Scope: Necanicum Watershed Boundary
Form: polygon (.shp)
Attributes: shape, entity, handle, layer, elevation, thickness, color, linetype, linewidth, style, text, watershed, area
Source: Columbia River Estuary Study Task Force (CREST)
Contact: 750 Commercial Street, Room 205, Astoria, OR 97103 (503-325-0435)
Date Developed: 1999
Scale: 1:12,000
Comments: CREST developed watershed boundaries in 1999 from Spencer B. Gross streams data.
Metadata: available from CREST

Winter steelhead use in the City of Seaside -- Wintersteel.shp
Geographic Scope: Entire Study Area
Form: polyline (.shp)
Attributes: shape, entity, layer, elevation, thickness, color
Source: Columbia River Estuary Study Task Force (CREST)
Contact: 750 Commercial Street, Room 205, Astoria, OR 97103 (503-325-0435)
Date Developed: 1999
Scale: 1:100,000
Comments: This information is based on the best professional judgement of Oregon Department of Fish and Wildlife staff biologists and in some cases, that of staff from other natural resource agencies within Oregon. Areas mapped are considered suitable habitat currently believed to be utilized by wild, natural, and/or hatchery fish populations. Layer contained winter steelhead use areas throughout the Necanicum watershed. Layer was clipped to the project study area.
Metadata: available on-line at: http://rainbow.dfw.state.or.us/data.html

Coho salmon use in the City of Seaside -- Coho.shp
Geographic Scope: Entire Study Area
Form: polyline (.shp)
Attributes: shape, entity, layer, elevation, thickness, color
Source: Columbia River Estuary Study Task Force (CREST)
Contact: 750 Commercial Street, Room 205, Astoria, OR 97103 (503-325-0435)
Date Developed: 1999
Scale: 1:100,000
Comments: This information is based on the best professional judgement of Oregon Department of Fish and Wildlife staff biologists and in some cases, that of staff from other natural resource agencies within Oregon. Areas mapped are considered suitable habitat currently believed to be utilized by wild, natural, and/or hatchery fish populations. Layer contained winter steelhead use areas throughout the Necanicum watershed. Layer was clipped to the project study area.
Metadata: available on-line at: http://rainbow.dfw.state.or.us/data.html

Chum salmon use in the City of Seaside -- Chum.shp
Geographic Scope: Entire Study Area
Form: polyline (.shp)
Attributes: shape, entity, layer, elevation, thickness, color
Source: Columbia River Estuary Study Task Force (CREST)
Contact: 750 Commercial Street, Room 205, Astoria, OR 97103 (503-325-0435)
Date Developed: 1999
Scale: 1:100,000
Comments: This information is based on the best professional judgement of Oregon Department of Fish and Wildlife staff biologists and in some cases, that of staff from other natural resource agencies within Oregon. Areas mapped are considered suitable habitat currently believed to be utilized by wild, natural, and/or hatchery fish populations. Layer contained winter steelhead use areas throughout the Necanicum watershed. Layer was clipped to the project study area.
Metadata: available on-line at: http://rainbow.dfw.state.or.us/data.html

Human Environment

Zoning -- Necanicum Watershed Zoning.shp
Geographic Scope: topographic watershed break for Necanicum River
Form: polygon
Attributes: shape, area, perimeter, zoning, zoning_id, county, zoning_lab, general_zoning, land use, description, symbol, edited
Source: Oregon Geospatial Data Clearinghouse (http://www.sscgis.state.or.us) accessed 1/10/01
Contact: 955 Center St. NE U510, Salem, OR 97301-2558 (503-378-2166)
Date Developed: unknown
Scale: 1:100,000
Comments: Layer obtained from Oregon Geospatial Data Clearinghouse contained zoning for the state of Oregon. The Necanicum river watershed was clipped from the statewide layer and saved as shapefile.
Metadata: available on-line at: http://www.sscgis.state.or.us/data/themes.html