NRDC
THE EARTH'S BEST DEFENSE

NATURAL RESOURCES DEFENSE COUNCIL

13 March 2003

Zoning Commissioners
441 4th Street, N.W. – Suite 200
Washington D.C. 20001

Re: Case No. 02-42 (Text Amendment –Waterfront Open Space (W-O) Zone District)

Dear Zoning Commissioners:

The following comments discuss the proposed District of Columbia zoning text amendment, which would create a new Waterfront Open Space ("W-O") Zone District. The proposed zoning classification would not be applied to any particular parcels at this time. Instead, according to Part VIII of the October 18, 2002 memo to the D.C. Zoning Commission from Andrew Altman, the W-O Zone District is intended to govern the development of federally owned and National Park Service lands along the Anacostia and Potomac Rivers that are sold, traded, or leased so that they could contain private enterprises. A properly-drafted zoning amendment could help ensure that the use and development of these waterfront lands does not degrade water quality.

The draft proposal is a significant improvement over the existing D.C. zoning classifications that might be applied to such parcels. The Office of Planning should be applauded for taking a more proactive approach toward guiding development on the District's Waterfront.

There are, however, several ways in which NRDC suggests improvements to this proposal. The W-O zone text amendment, for example, includes a long list of uses subject to special exception—*i.e.*, uses that could be permitted by the D.C. Board of Zoning Adjustment ("BZA") after review of a specific development proposal "where, in the judgment of the Board, the special exceptions will be in harmony with the general purpose and intent of the Zoning Regulations and Zoning Maps and will not tend to affect adversely, the use of neighboring property in accordance with the Zoning Regulations and Zoning Map," and subject to special conditions required by the zoning ordinance. 11 D.C.M.R. § 3104.1.

Given the many special exceptions in the proposed text amendment, it cannot be assumed that only "as-of-right" uses will be constructed in areas zoned W-O. Therefore, the specific site plan standards contained in the proposed zoning amendment are critical. The W-O zone amendment includes some size, lot occupancy, and impervious coverage restrictions on development within the Zone, but NRDC recommends additional requirements—which would apply to both as-of-right and special exception uses, unless a variance is granted—to prevent the special exceptions from swallowing up the rule.

www.nrdc.org
1200 New York Avenue, NW, Suite 400
Washington, DC 20005
TEL 202 289-6868 FAX 202 289-1060
NEW YORK · LOS ANGELES · SAN FRANCISCO

100% Postconsumer Recycled Paper

ZONING COMMISSION
District of Columbia
Case 02-42
Exhibit 29

ZONING COMMISSION
District of Columbia
CASE NO.02-42
EXHIBIT NO.29

NRDC realizes that no amount of regulatory language will ensure all waterfront development is compatible with environmental goals; a City determined to allow a particular development has fairly broad discretion to grant rezonings and waive specific site plan requirements. Including clear, environmentally-sound site plan standards in the W-O Zone definition, however, should encourage more appropriate development practices. Below we list some site plan principles and standards that NRDC recommends the Zoning Commission consider. Additionally, to facilitate consideration of *low impact development* (LID) techniques and water quality impacts in the development review process we also identify additional information that developers seeking special exceptions should be required to submit as part of their applications.

1. Site Plan Standards

Even with the adoption of the W-O Zone, there will be waterfront development, so it is critically important that waterfront development be consistent with water quality goals. This section discusses two possible changes to the W-O Zone: (a) an increased riparian buffer setback; and (b) an express requirement that LID practices be integrated into the design of any buildings, structures, and uses.

a. Riparian Buffer Setback

Based on materials we have reviewed from other urban jurisdictions, the critical issue appears to be the riparian buffer setback. Perhaps because of concerns that a complete bar on development would trigger regulatory takings claims, some development is typically allowed. Portland, Oregon, for example, uses an overlay zone for stream corridors that restricts the area disturbed by development to some fraction of the amount allowed in the underlying zone classification,[1] but Portland does not impose an absolute prohibition on development on such parcels. Other urban areas use similar approaches to balance development with environmental goals and to avoid regulatory takings challenges.

If every parcel along the D.C. waterfront were developed as a W-O Zone Special Exception use, up to the maximum allowed size, the "Waterfront Open Space" area would not look very much like open space; but so long as the development is properly designed and does not encroach on an appropriate riparian buffer area, it should be possible to protect water quality.

The proposed text amendment's 20-foot buffer, however, seems inadequate. We are attaching a copy of *Streamside Science and an Inventory of Significant Riparian and Wetland Resources*, an October 2001 publication from the Healthy Portland Streams Project of the City of Portland, Oregon. Attachment A. The report surveys the literature on riparian buffers (at 24-30) and concludes (at 40-41) that while site-specific analyses of buffer distances is preferable,

---

[1] *E.g.*, for parcels with a Storefront Commercial zoning classification within the overlay zone, the disturbed area for development might be limited to half the area that would otherwise be allowed under that zoning classification

> [b]ased on the literature reviewed in this report, we conclude that a buffer of 100 to 300 feet is advisable, where feasible, to support fish conservation efforts along the small streams in the City of Portland.

We do not know if the 20-foot buffer proposed in the W-O zone text amendment is supported by site-level environmental research on the Anacostia and Potomac waterfronts; but that seems unlikely since the proposed setback is a fixed number, independent of slope or soil type. The table that appears at the end of this section recommends a 100- to 250-foot buffer, depending on slope and soils conditions, based on the D.C. Department of Health's recommendations pertaining to the *Urban Forest Preservation Act of 2002* (the "Tree Bill") and the literature reviewed in *Streamside Science*.

There are some potential downsides to increasing the size of the riparian buffer. First, to the extent that the District hopes developers will voluntarily seek rezoning to the W-O zone classification, increasing the required riparian buffer to 100-feet could discourage that from happening. If those developers instead build under their existing zoning with no riparian buffer at all, the limited environmental benefits of the 20-foot buffer could be lost.

Second, depending on the dimensions and configuration of the parcels that might be eligible for W-O zoning, a 100-foot riparian buffer requirement might effectively preclude any development on some properties, potentially triggering legal claims. While this concern could be reduced by carefully monitoring subdivisions and drafting provisions to relax the buffer for problem parcels (so long as LID and engineered systems for addressing stormwater impacts are used), a 100- to 250-foot riparian buffer could be in some instances more difficult to implement.

At this point, we do not know if either of these problems would be significant. It makes sense to seek a riparian buffer setback that will provide real environmental benefits. NRDC supports a wider setback than that which is put forth in the proposal.

b. Requiring the Use of LID (low impact development)

The proposed W-O zone text amendment already includes a requirement that "[b]uildings, structures, and uses shall be located and designed to minimize adverse impacts on the river and the riverbank areas." This general requirement should be expanded to direct developers to use the LID techniques recommended in the Department of Health's *Storm Water Management Guidebook* to the extent practicable.

Table 1. Recommended Changes to Proposed Text Amendment Site Plan Standards

Proposed Text Amendment	***Recommended Changes***
Buildings and structures shall not occupy more than 25% of the lot.	No change.
Impervious materials shall not cover more than 35% of the lot.	No change.
A setback from the normal high water mark	"Slope" shall be defined as vertical rise in feet

Proposed Text Amendment	*Recommended Changes*
shall be provided of not less than 20 feet to any building or structure, with the exception of a wharf, pier, or houseboat.	divided by horizontal run in feet in the steepest 100 foot segment multiplied by 100%. For parcels with adjacent Slopes of less than 15%, within 200 feet of the stream/river bank, a setback from the normal high water mark shall be provided of not less than 100 feet to any building, structure, or impervious paved area, with the exception of a wharf, pier, or houseboat. A Slope shall be considered moderately steep if it meets or exceeds 15% but less than 25% slope within 200 feet of the stream/river bank. Under these conditions, a setback from the normal high water mark shall be provided of not less than 125 feet to any building, structure, or impervious paved area, with the exception of a wharf, pier, or houseboat. A Slope shall be considered steep if it meets or exceeds 25% slope within 200 feet of the stream/river bank. Under these conditions, a setback from the normal high water mark shall be provided of not less than 150 feet to any building, structure, or impervious paved area, with the exception of a wharf, pier, or houseboat. Erodible soils are those soils classified as having a severe hazard of erosion in the soil profile descriptions of the Soil Survey of District of Columbia (July, 1976), published by the Natural Resources Conservation Service (formerly the Soil Conservation Service). Setbacks from streams, rivers, and wetlands adjacent to erodible soils will be expanded to include the area of the erodible soils up to a 100 foot maximum. (Above Recommendations from District of Columbia, Department of Health, Environmental Health Administration, Watershed Protection Division.)
Riverbanks shall be left in or returned to a natural state, with natural grades and the use of appropriate native plant species.	No change.

Proposed Text Amendment	*Recommended Changes*
Buildings, structures, and uses shall be located and designed to minimize adverse impacts on the river and the riverbank areas.	Expand to include a requirement that to the extent practicable, buildings, structures, and uses shall be designed and constructed using the Low Impact Development techniques recommended by the District of Columbia Department of Health's Storm Water Management Guidebook.
Height and floor area ratio limits.	No change.

2. Information Requirements

To facilitate effective review of site plans submitted under the Waterfront Open Space Zone, additional information should be provided by applicants seeking a special exception:

1. The boundaries of the 100-year floodplain.
2. Existing streams, wetlands, other water bodies, and general drainage patterns, using an arrow to indicate the direction of major drainage flow.
3. An outline showing the distribution of existing vegetation, including trees, shrubs and ground cover, with a list of most abundant species.
4. The outline of any existing disturbed area, including existing utility locations, paved areas, streets, utilities, culverts, stormwater management systems, and bridges.
5. A map showing the outline of the proposed permanent disturbed area, including utility locations, paved areas, streets, utilities, culverts, stormwater management systems, and bridges.
6. A grading plan showing proposed alteration of the ground at two foot vertical contours in areas of slopes less than ten percent and at five foot vertical contours in areas of slopes ten percent or greater.
7. A detailed description and site plan of stormwater management systems to be used on the site, including retention, infiltration, detention, discharges, and outfalls.
8. If the project is located entirely or partially within any identified floodplain, provide all the necessary information in sufficient details and clarity to enable government officials to determine if the project complies with DC Flood Hazard Rules outlined in Title 20, DCMR, Chapter 31.

In conclusion, NRDC would like to emphasize that zoning regulations are valuable tools for watershed management to mitigate the District's stormwater runoff problems and the severely impaired water quality of surrounding water bodies. NRDC believes this proposed

Waterfront Open Space Zone District is an important step for restoring the Anacostia River and managing waterfront development with environmental protection in the District of Columbia.

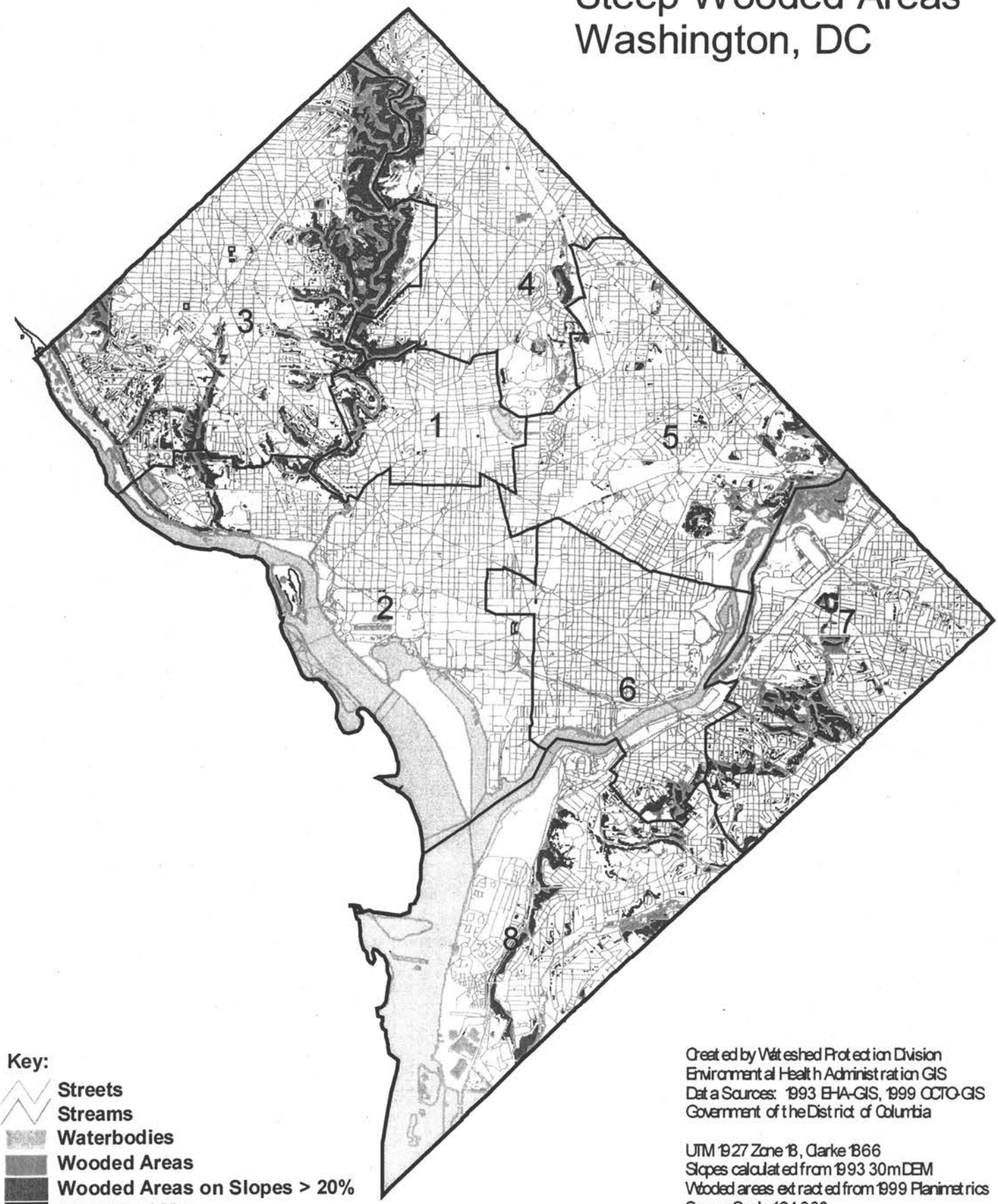
Thank you for the opportunity to comment on this important issue before the Zoning Commission. Please feel free to contact me if you have any questions or comments.

Sincerely,

James W. Woodworth, Jr.
Urban Water Specialist
NRDC

Attachments

Steep Wooded Areas
Washington, DC



Key:

- Streets
- Streams
- Waterbodies
- Wooded Areas
- Wooded Areas on Slopes > 20%
- 1990 Ward Map

Created by Watershed Protection Division
Environmental Health Administration GIS
Data Sources: 1993 EHA-GIS, 1999 OCTO-GIS
Government of the District of Columbia

UTM 1927 Zone 18, Clarke 1866
Slopes calculated from 1993 30m DEM
Wooded areas extracted from 1999 Planimetrics
Source Scale 1:24,000

2 0 2 4 6 Miles

Draft

Setting a New Goal for Riparian Forest Buffers

As Presented to the Nutrient Sub Committee
January 22, 2003

I. Process
II. Summary of Stakeholder Sessions
III. Technical Analysis
IV. Urban Ecosystem Restoration
V. Economic Analysis
VI. Proposed Goals
VII. Policy Recommendations
VIII. Next Steps

At the request of the Nutrient Sub Committee, the Forestry Workgroup (FWG) of the Chesapeake Bay Program has taken the lead in the *Chesapeake 2000* commitment to, "By 2003, establish a new goal to expand buffer mileage." The following summary includes 1) the proposed process to determine a new goal, 2) the results of the first series of Stakeholder sessions, and 3) the technical analysis that has been completed to date. It represents work done by a committee over an eight-month period.

I. PROCESS FOR SETTING THE NEW GOAL

Instead of using a formal "Panel," as was the case in adoption of the initial goal, the FWG is relying on a technical analysis, feedback from two series of stakeholder sessions, and a review of the policies recommended in the Riparian Buffer Panel Report, in order to set the new goal. The report explores the potential for goal setting in two additional areas of concern that were raised early in the process: 1) the need for additional focus on conservation and maintenance of existing and restored buffers, and 2) the need to include a target for urban areas.

Currently, a three-part proposal is being developed:

1. A revised numeric restoration goal for 2010 - This would include a range of mileage options, while holding constant the deadline of 2010.
2. Context and Recommendations – The context includes findings from the policy review and Stakeholder sessions. Recommendations are made regarding program efficiency, targeting, funding needs, capacity to deliver, and renewed emphasis on areas such as conservation of existing and restored buffers, and maintenance and protection of restored buffers. These could take the form of new or updated Policy Recommendations or new goals.
3. Possible new goals (Section IV).

The Forest Service is compiling information for a "5 Year Status Report" on the Chesapeake Bay Program's Riparian Initiative. This status report will serve as a reference document for the new goal setting process.

II. SUMMARY OF INITIAL STAKEHOLDER SESSIONS

In conjunction with state forestry agencies, five stakeholder sessions were held to expose initial concerns and opportunities for a new goal for Riparian Forest Buffers (RFB) in the Chesapeake Bay watershed.

Riparian Forest Buffer Stakeholder Sessions, 2002:

- June 6, Pennsylvania Chesapeake Bay Advisory Council, Harrisburg, Pa
- June 24, Annapolis, Md
- June 27, Charlottesville, Va
- July 9, Hagerstown, Md
- July 15, Easton, Md

Attendees included the Pennsylvania Chesapeake Advisory Council (a diverse group of resource professionals, developers, and agency personnel) NRCS, Chesapeake Bay Foundation, FSA, state agency personnel, county forestry boards, city representatives, private consultants, VaDOT, and extension agents.

This summary is organized according to the questions posed at the Stakeholder Sessions. The top responses to each of the questions are summarized.

1. What benefits do you receive personally, or through your agency or organization, by the establishment of Riparian Forest Buffers?

Benefits of RFB were felt on many levels: environmentally, economically, and socially. Here are the most often heard benefits:

- Water quality and wildlife habitats are improved.
- Incentive payments benefit landowners.
- There is economic benefit in the potential for timber harvest over time.
- The public is more aware of the ecological importance of riparian forest buffers, and there is greater community involvement in restoration.

2. What impediments or opportunities do you see to converting riparian areas to forest buffers?

Impediments:

- RFBs compete with established crops for available land.
- RFBs preclude or compete with development potential; trees obstruct views and prohibit recreation.
- Landowners often lack resources to maintain the RFB. This lack of maintenance seems to be due to any one of a number of factors: lack of money, will, or manpower; not knowing what to do; absence of maintenance training or programs; necessary thinning of planted trees is not encouraged; and additional trees may not be available. Newly planted trees require time-consuming and costly maintenance. The time and expense of maintenance varies greatly according to the site, seedlings, and weather. Much of the cost of maintenance is defrayed in the percentage of money provided to the landowner through programs like CREP specifically for maintenance.

Opportunities:

- CREP, the vehicle by which riparian areas on agricultural land becomes an RFB, is relatively new (about five years old in Maryland and 2 years old in Pennsylvania and Virginia). There are improvements that could be made in CREP that would make it more effective.
- RFB's have helped increase and open a dialogue between citizens, developers and local officials and Bay advocates where previously none existed.
- The tax incentives for RFB plantings and conservation efforts have helped make the CREP program very successful. An increase in incentives may boost restoration efforts.

3. Since the Riparian Forest Buffer initiative began, less than 1% of the Bay's riparian buffers have been restored. Do you think that we could increase the rate we restore riparian forests, or do you think we should maintain the current rate of restoration (assuming current level of services)?

The responses to this question ranged from increasing to decreasing the rate of restoration. Primarily what we heard were:

- There is concern that the rate of implementation may slow because those landowners who are most interested/active have already been reached (low-hanging fruit argument).
- With the appropriate level (increased) of funding and technical assistance, the rate of restoration could increase.
- Instead of increasing the rate, focus efforts, instead, on quality, conservation and maintenance of existing buffers.

4 and 5. What new services would be necessary to increase the rate that riparian areas are restored and help you or your organization be more involved?

Three types of resources were commonly mentioned:

- The need for more education/outreach programs targeted at landowners. Outreach materials directed at landowners and local governments (including purpose of RFBs, progress, success stories, how they can become involved, etc.) are especially needed. Planners and implementers need to be part of the process/dialogue (Board of Supervisors, local planners and politicians).
- Additional funds and technical assistance for maintaining forest buffers.
- Improved tracking of accomplishments and better reporting mechanisms.
- Information about where buffers currently exist and which watersheds are most in need.

6. Do you think that there needs to be more emphasis on the conservation and maintenance of existing buffers?

There was solid agreement on the need to emphasize greater conservation and maintenance. The focus of the new RFB goal could be on net gain of RFBs. Some felt that a focus on conservation and maintenance should reduce the numeric goal to be set, while others felt that enough separate groups and programs are involved and that the numeric goal should not be less with a conservation and maintenance emphasis. Innovative programs could be developed that encourage landowners to keep land forested (i.e., tax incentives). RFB easements, already a goal in Maryland and Virginia, should be extended to Pennsylvania. The states or their private land trust partners would hold these easements.

7. Do you think that a targeting approach should be used in restoring buffers? If so, what criteria should be used?

Most everyone agreed that targeting should be done, and if the mechanisms can be developed, it should be done at the local level. Also, targeting low-order, headwater and intermittent streams would provide the greatest water quality benefits. Some felt that targeting would take energy away from a higher restoration goal. If one area is targeted, there should be assurance that environmental programs are adequately addressed in other areas.

III. Technical Analysis-- Goal Setting Options

To derive a new mileage goal by 2010, three options are currently being evaluated: maximum contribution to water quality, the current rate of restoration, and an environmental analysis. These options can be taken wholly, in part, or combined. The range of mileage goals and the accompanying policy recommendations will be selected after conducting an economic analysis on each, and a policy analysis, to determine feasibility.

A. Maximum Contribution to Water Quality

This option uses the model results for total riparian forest buffers projected as needed to de-list the Bay by 2010 under the new Chesapeake Bay Water Quality Standards Use Attainability Analysis. Anticipation is that this will be guided by Tier 3 of the analysis, which is the highest feasible level of restoration. (Current estimates place this somewhere in the neighborhood of 30-35,000 miles.).

B. Current Rate of Restoration

This option assumes that the current level of effort would be held static until 2010. A detailed analysis of this approach was conducted that included various iterations of the status and trend of progress thus far. Based on the average annual accomplishment (as an average of the last 3 years) or the 2002 accomplishment rate, a static rate of restoration would yield between 7,700 to 10,400 miles by 2010.

An analysis of the continued trend (if the current rate of restoration is allowed to continue accelerating, as opposed to keeping it static) would yield 14,000 miles by 2010.

C. Targeting High Priority Areas - Environmental Mapping Analysis

The 1996 Riparian Buffer Panel Report stated that the restored miles of forest buffer would be targeted where they will be of greatest value to water quality and living resources. However, it is difficult for targeting exercises to match actual delivery of buffer restoration on-the-ground as most programs are offered on a willing landowner basis. The approach however does provide two clear benefits. First, it provides a check on the numbers generated using other analysis methods. Second, it could influence a more customized implementation of Farm Bill and other incentive programs. Ideally, targeting is practiced locally.

Watersheds (11-digit HUC) that are highest in priority to receive riparian forest buffers have been determined by compiling available data on 1) water quality, 2) aquatic habitat, and 3) terrestrial habitat. In each case the assumption is that a number would be generated that represents the restoration of unbuffered miles in the priority areas.

<u>Water Quality Restoration Theme</u>

High priority watersheds to restore based on water quality are determined by:

1. Current high nutrient or sediment loading based on Bay Program or Sparrow Model.
2. Watersheds that do not have a high degree of impervious surface (ability for buffers to succeed in improving water quality).
3. Hydro geomorphic regions with greatest potential for buffer effectiveness.

Aquatic Habitat Restoration Theme

Criteria for high priority aquatic habitat includes streams that:

1. Drain into near-shore areas that are identified as priorities for SAV and oyster restoration
2. Are used by anadromous fish and spawning (dams removed or planned to remove).
3. Are source of or needed for rare aquatic species

Terrestrial Habitat Restoration Theme

This theme depicts where forest buffers are most needed to protect or restore important terrestrial wildlife habitat corridors and biodiversity. This work has been done for Maryland through the Greenprint Mapping Project. The Bay Program Resource Lands Assessment identifies important hubs and corridors for the other States. This restoration theme combines the following issues:

1. Create continuous corridors.
2. Link priority forest patches (hubs) using buffers.
3. Provide habitat for rare species.
4. Restore buffers in areas with high public use (greenways, water trails)

To determine representative number of miles that would restore high priority watersheds based on the environmental analysis, the riparian forest buffer inventory will be overlaid with the theme layer.

IV. Urban Ecosystems—Placing trees on the landscape where they are most needed

Why a separate goal?:

On farmland, trees in the riparian area are well positioned to capture the flow of water entering a stream. By contrast, urban riparian forests do not filter as much runoff that is often delivered directly to stormwater systems instead. There is a greater need and a greater opportunity to use the filtering capacity of trees throughout an urban landscape to improve the health of the Bay watershed. For the purposes of this document, urban is broadly interpreted as any land that is not rural.

Urban forests provide benefits to both the local community and the environment. Forests, even individual trees, reduce greenhouse gases, decrease summer air temperatures, while they mitigate stormwater issues and improve water quality. Trees also increase property values, and provide an aesthetic draw to commercial areas. Carbon and ozone sequestration, the ability of trees to clear pollutants from the air, may soon earn local governments credits, a potential added source of revenue.

While nearly sixty percent of the Chesapeake watershed is forested, urban areas both start with less forest cover, and lose more forested area to development.

Studies show that impervious surfaces have increased by 20% over the past two decades in urban areas. These are the very areas that would benefit most by tree retention. With its emphasis on sound land use and promise to enhance funding for locally-based programs that pursue restoration and protection projects, *Chesapeake 2000* supports using trees throughout the urban setting, not only in buffers, as a meaningful goal for municipalities. All local governments, municipal or county, are encouraged to adopt a goal of tree cover.

Stormwater

Trees, rain gardens, and other vegetated areas reduce stormwater. Constructed stormwater facilities are created to compensate for tree loss. These facilities are expensive to build and maintain, and they often fail to protect the Bay from pollutants.

The Stormwater Directive of the Chesapeake Bay Program encourages the establishment of innovative demonstration projects that includes using vegetative solutions to stormwater management problems.

Air Quality

Burning fossil fuels pumps pollutants into the atmosphere, and only a few urban areas meet national clean air standards. Trees sequester many pollutants from the atmosphere, including nitrogen dioxide (NO2), sulfur dioxide (SO2), ozone (O3), carbon monoxide (CO), and small particulate matter (<10 microns).

The USDA Forest Service developed a methodology to assess the air pollution removal capacity of urban forests. Dave Nowak, Ph.D, researched the amount of pollution being deposited in a given city and estimates the removal rate based on the area of tree and/or forest canopy coverage in the area.

Air Quality benefits are reported both in pounds removed per year, as well as annual dollar savings. For instance in Washington DC, 878,000 lbs of pollutants are removed annually by trees; worth $2.1 million with respect to air pollution.

Energy Conservation

Well-placed trees cool urban neighborhoods in the summer, saving money on energy costs and related water usage and air pollution. The energy conservation benefits from direct shading on residences can be calculated. A city such as Washington DC, saves in excess of $1 million annually because of tree shading.

In addition, many Chesapeake Bay towns and cities are TreeCityUSA cities (www.TreeCityUSA.org). To receive this designation, there must be an official tree Board or Department, 2) a tree care ordinance, 3) a community forestry program with an annual budget of at least $2 per capita, and 4) observe Arbor Day.

STRATEGY

Local Governments

An important strategy for urban areas is to educate county and city government officials in designing zoning ordinances for undeveloped areas within their jurisdiction. This was recommended in the 1996 Riparian Buffer Initiative, and still holds true now.

Urban Tree Planting

While the ultimate goal is to have mature tree cover, a continuous crop of newly planted trees will help attain that. Planting trees is ideal for sustained, active citizen involvement. By having urban volunteers restore trees, multiple *Chesapeake 2000* commitments can be met (e.g., personal involvement, minority and multi-cultural education; and the commitments under Community Engagement in addition to habitat restoration). If well maintained, an average newly planted hardwood would yield a tree cover of xx sq ft within xx years. Currently the average life of an urban tree is considered to be 7 years, but this can be changed with proper planning and maintenance.

A Goal of Tree Cover

The canopy is the overhead, "umbrella" portion of a tree or forest, and what is referred to when speaking of tree cover. Canopy tree cover is desirable for the physical and biological environment because it intercepts precipitation, aids water infiltration, provides cooling shade, improves air quality, and is visually appealing. Larger, mature trees form the best canopies and contribute the most cover. A canopy goal can be sustained by conserving existing trees and planting new trees over time.

In the Bay watershed, Maryland has adopted a 40 percent tree cover goal for its urban areas. This establishes a benchmark for more locally targeted urban goals within or outside of Maryland. More rural areas should adopt tree cover goals between 50-70%, or a specified additional amount (e.g., 10%) to what currently exists. Local urban/community forestry programs can assess the existing forest cover.

Steps to A Healthy Urban Watershed

1. Establish a tree board and a tree recognition program for the local jurisdiction.
2. Involve neighborhoods. Educate them about their watershed.
3. Plan to inventory existing tree cover. GIS and satellite technology is available for tree cover inventories. This will help in maintenance and replanting efforts as well as identifying priority tree planting sites. Look for opportunities to plant trees.
4. Develop zoning and regulations to conserve existing trees and forests. Plan to protect trees and forests in newly acquired parcels of land.
5. Plant more trees. Support tree planting programs with maintenance plans to ensure survival and growth of the tree.
6. Establish reliable sources of funding for urban forest programs.
7. Develop forest management plans for identifiable tracts of land such as schools and corporations.
8. Adopt a tree canopy cover goal.

V. Economic Analysis (Not Completed)

The cost of establishing and planting riparian forest buffers to date has been high. The cost of the tree seedling ($0.50-1.00/ea) and even the tree shelter ($5.00/ea) is small compared to the cost of staff time spent in technical assistance and administration of programs, especially the Conservation Reserve Enhancement Program (CREP). In CREP, the landowner also receives rental payments. In one analysis, Maryland spent…

VI. Proposed New Goals

1. Restore xxxxx miles of riparian forest buffers along streams and shorelines in the Chesapeake Bay watershed by 2010. A range of alternatives from 7,700 to 33,000 miles is currently being considered.

2. Maintain newly established buffers to assure a well-stocked stand (planted or naturally regenerated) after 3 years.

3. Long term Goal for RFB
   Maintain a minimum of sixty-five percent (per Schuler) of the Chesapeake Bay streamside and shoreline in forest buffers. (Sixty-five percent of 199,000 streamside/shoreline miles is 129,350 miles.)

4. Forest Buffer Conservation Goals
   a) Permanently protect twenty-five percent of all riparian forest buffers established since 1997 through conservation easements or other mechanisms.
   b) Ensure that the restoration and conservation of riparian forests are a high priority within State and Federal forest, farmland, and open space programs.

5. Urban Goals
   a) Plant trees
   - By 2010, successfully establish 1,000,000 new trees in urban areas to maximize the tree canopy cover (a 40% or more tree cover goal).
   - Catalogue existing opportunities of places to plant trees, and create other opportunities.

   b) Adopt locally-set tree canopy cover goals for 30 jurisdictions
   By 2007, work with at least 10 local jurisdictions and communities in each state to complete an assessment of urban forests, adopt a tree canopy goal and plan to attain it, and implement measures necessary to maximize tree canopy cover (an increase of at least 10% or a 40% goal).
   - In selecting jurisdictions, look for innovative approaches to funding and executing the three phases of this goal (assessment, plan, and implementation).
   - Choose jurisdictions with the potential for knowledge transfer (program staff exchange) and demonstration capability.

c) Establish tree programs within jurisdictions

Increase by 30% the number of towns and cities that are enrolled in tree recognition programs, similar to TreeCityUSA, that do at least the following things:

- Implement a Community Forestry Program with an annual budget
- Establish a Tree Board or Department
- Adopt a tree protection and care ordinance.

d) Integrate vegetative solutions (e.g., trees, rain gardens, green roofs, other Low Impact Design innovations) into state and local stormwater management programs.

VII. Policy Recommendations

Five policy recommendations were adopted by the Executive Council as part of the 1996 Riparian Buffer Panel Report. Since then steps taken by states, federal, and local government as well as newly enacted laws and programs have enabled the accomplishment of many of those recommendations. The most notable example is the Conservation Reserve Enhancement Program (CREP).

Since the 1996, all five policy recommendations were acted upon by each state, to various degrees. An evaluation of those recommendations is being conducted. Despite significant advancement in riparian forest buffer policy, most of the recommendations that were asserted in the 1996 Panel Report are still valid and require continued attention by the jurisdictions.

1. Enhance Program Coordination and Accountability (this includes the need for more support to the states for outreach and technology assistance)
2. Promote Private Sector Involvement
3. Enhance Incentives
4. Support Research, Monitoring, and Technology Transfer
5. Promote Education and Information

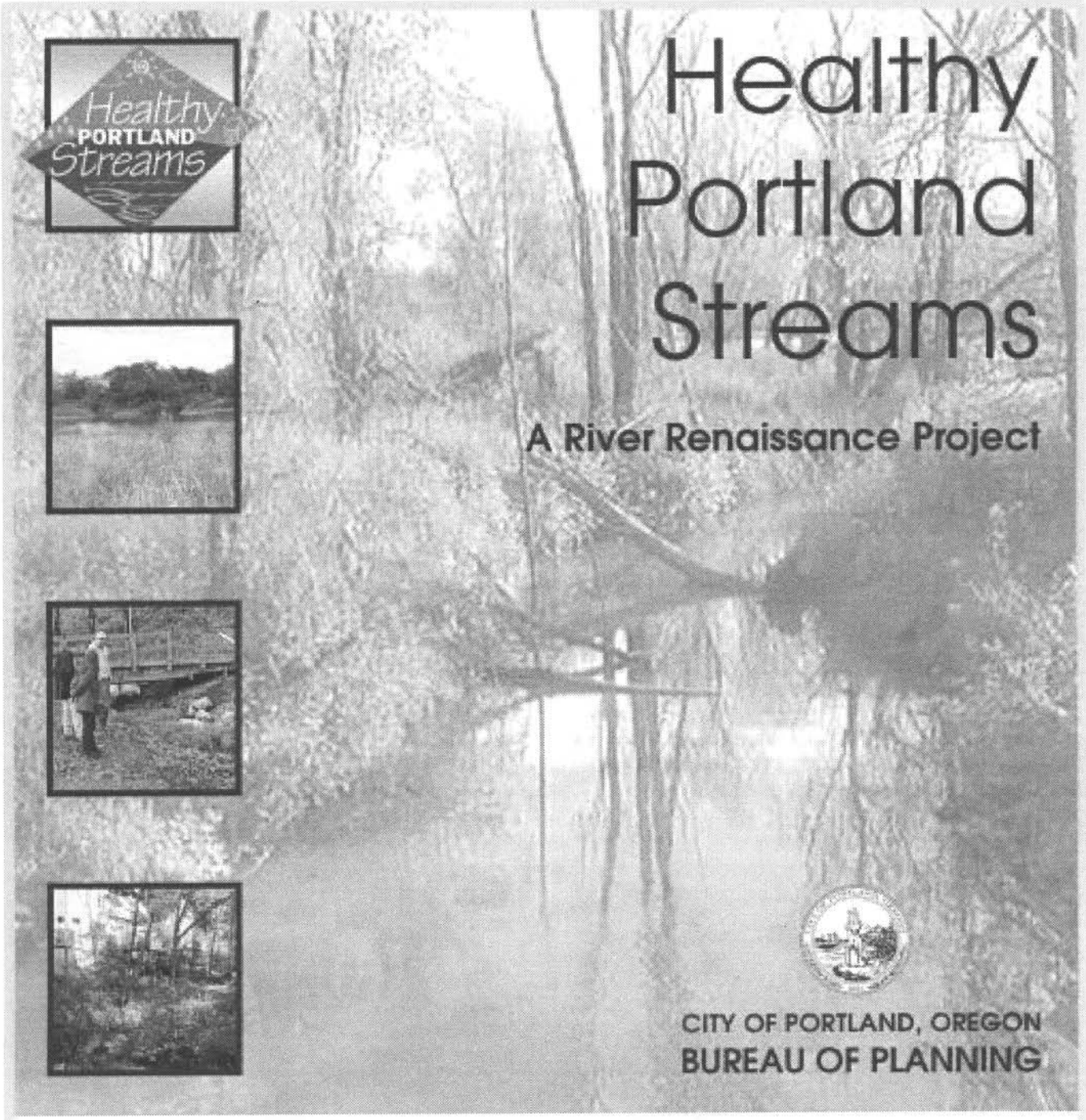
New policies such as the following two are also being recommended:

- Create New Incentive Programs. States work through State Technical teams and with USDA to update and streamline CREP and other programs.
    a. Higher incentives to use trees instead of grass in buffers.
    b. Higher incentives for trees <100' to streams rather than >100' from streams.
    c. Higher incentives for forest buffers on headwater streams over other streams.
    d. Customize incentives to be greater in priority watersheds while still maintaining wide availability.
    e. Emphasize the importance of maintenance by providing more up-front technical assistance and education, including information on how to minimize spread of invasive plants.

- Strengthen Conservation Commitments
    a. Expand benefits to landowner to retain riparian areas in forests. Promote working land easements for riparian forest buffers. Explore options such as long-term lease, up-front money for lease, etc.
    b. Support permanent sources of state funding to establish easements on riparian forest buffers.
    c. Promote role of land trusts in riparian forest buffer easements by developing closer working relationships with them.
    d. Educate existing RFB landowners using demonstration sites.
    e. Encourage land preservation through preferential tax assessments along stream corridor. Work with groups such as Rural Legacy, state land trust organizations, etc.

VIII. Next Steps

- Refine process, proposed goals and policy by incorporating comments on proposal from NSC, CBP
- Complete environmental mapping analysis
- Complete economic analysis
- Finalize Recommendations
- Plan, execute, and incorporate feedback from the second series of Stakeholder feedback sessions in Spring 2003
- Pending approval by NSC, meet with IC and PSC to review progress/recommendations
- If the EC meeting is in June, 2003, instead of Fall, decide whether we should accelerate our timeline to have a proposal ready by that date and look at alternatives for not doing so



Healthy Portland Streams

A River Renaissance Project

CITY OF PORTLAND, OREGON
BUREAU OF PLANNING

Discussion Draft

Streamside Science and an Inventory of Significant Riparian and Wetland Resources

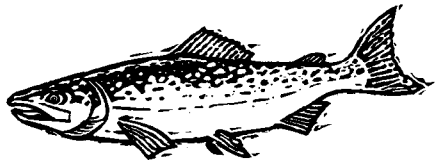
October 2001

Portland City Council

Vera Katz, Mayor and Commissioner-in-Charge
Jim Francesconi, Commissioner
Charlie Hales, Commissioner
Dan Saltzman, Commissioner
Erik Sten, Commissioner

Portland Planning Commission

Richard Michaelson, President
Steve Abel, Vice President
Ethan Seltzer, Vice President
Ernie Bonner
Richard Fernandez
Amanda Fritz
Rick Holt
Marcy McInelly
Ingrid Stevens



Endangered Species Act Program

RIVER RENAISSANCE

The Bureau of Planning is committed to providing equal access to information and hearings. If you need special accommodation, please call 503-823-7700 (TTY 503-823-6868).

Acknowledgements

Portland Bureau of Planning
Gil Kelley, Director
Deborah Stein, Principal Planner
Sallie Edmunds, Environmental Planning Manager

Project Staff
Tom McGuire, Senior Planner, Project Leader
Eric Engstrom, Environmental Specialist (through 6/01)
Barb Grover, Environmental Specialist
Tom Carter, City Planner (through 3/01)
Chris Scarzello, City Planner
Shannon Buono, City Planner
Gary Odenthal, GIS Coordinator
Kevin Martin, GIS Analyst

Additional Assistance
Jim Middaugh, Portland ESA Program Manager
Donah Baribeau, Clerical Specialist
Barbara Hart, Public Involvement Coordinator
Melanie Mills, Graphic illustrations
Lutz Vollmer, GIS Assistance
Lee Rahr, Community Service Aid
Paul Ketcham, Metro

Consultants
Kim Jones and Alexis Vaivoda, Aquatic Habitat Inventory Project, Oregon Department of Fish and Wildlife
Nancy Jerrick, Counterpoint Consulting

printed on recycled paper

Special thanks to three teams that provided invaluable technical guidance:

City of Portland Planning, Permitting and Enforcement Team

Chris Prescott and Michael Reed, Portland ESA Program
Kermit Robinson, Office of Planning and Development Review
Mary Stephens and Dawn Hottenroth, Bureau of Environmental Services
Rebecca Geisen, Rick Lapp, and Roberta Jortner, Bureau of Water Works
Elizabeth Papadopolous and Doug MacCourt, Office of Transportation
Cadence Moylan and John Southgate, Portland Development Commission
Deborah Lev and Rob Crouch, Portland Parks and Recreation

Citizen Review Committee

Linda Bauer, Mike Houck, Jeff Keeney, Jason Miner, Jay Mower, Hank Ashforth, Gail Day, Corbin Shays, Christe White, Tom Wright, Amanda Black, Judy Henderson, Steve Johnson, David Lomas, Randy Hite, Jim Labbe, Ann Gardner, Dave Warrington, Richard Allan, Geraldine Moyle, Margot Barnett

Independent Science Review Panel

Dr. Boone Kauffman, Associate Professor, Department of Fisheries and Wildlife, Oregon State University
Dr. William Liss, Professor of Fisheries, Department of Fisheries and Wildlife, Oregon State University
Dr. Richard Horner, Research Associate Professor, Departments of Civil Engineering and Landscape Architecture and Adjunct Professor, Center for Urban Horticulture, University of Washington
Steve Ralph, Regional Salmon Ecologist, U.S. Environmental Protection Agency, Office of Ecosystems and Communities, Region 10
Keith Kurko, Fisheries Biologist and ESA Watershed Coordinator for the Cedar River/Lake Washington Basin, City of Seattle

TABLE OF CONTENTS

HEALTHY PORTLAND STREAMS — INTRODUCTION 1

ORGANIZATION OF THIS REPORT 2

PROJECT STEPS 2

CHAPTER 1

PURPOSE OF THE LITERATURE REVIEW 7

BIOLOGICAL NEEDS OF SALMON AND TROUT 8

WHAT IS THE RIPARIAN AREA? 11

RIPARIAN FUNCTIONS 12

RIPARIAN BUFFERS 21

- CHARACTERISTICS AFFECTING BUFFER WIDTH 22
- BUFFER WIDTHS AS RECOMMENDED IN THE LITERATURE 24
- GENERAL RECOMMENDATIONS 27
- BUFFER DESIGN 30

RIPARIAN MANAGEMENT ISSUES IN AN URBAN AREA 30

- APPLICATION OF SCIENCE TO AN URBAN SETTING 31

SCIENCE SUMMARY AND CONCLUSIONS 36

- FISH BIOLOGY 36
- RIPARIAN AREAS 36
- RIPARIAN BUFFERS 38
- THE URBAN ENVIRONMENT 41
- RESTORATION IN AN URBANIZED AREA 42

LITERATURE CITED 43

CHAPTER 2

PURPOSE OF THE INVENTORY 52

- RIPARIAN AREAS AND WETLANDS 52

ORGANIZATION OF THE INVENTORY 53

CRITERIA USED TO IDENTIFY AND MAP SIGNIFICANT RESOURCES 55

- MATRIX OF SIGNIFICANCE FACTORS 55
- "AREAS OF INFLUENCE" 56

RELATIONSHIP OF INVENTORY TO ENVIRONMENTAL ZONES AND STATE PLANNING GOALS 64

INVENTORY PROCESS **65**

REVIEW OF EXISTING INFORMATION 66
COLLECTION AND REVIEW OF NEW INFORMATION 66
DETERMINE THE ADEQUACY OF INFORMATION 68
PUBLIC INVOLVEMENT 70

SITE-SPECIFIC INVENTORY INFORMATION **71**

RESOURCE SITES – FORMAT OF INFORMATION 71
MAPS OF SIGNIFICANT RESOURCES 72
HOW TO READ THE INVENTORY MAPS 73

Healthy Portland Streams — Introduction

Portland embraces its natural environment—the rivers and streams that run through our neighborhoods, the parks and open spaces where we meet for fun or relaxation, and the fish and wildlife that live in our midst. It's all part of what makes our city special.

But as the region grows and develops, we cannot take our natural heritage for granted. If we treasure our clean water, clear air, forests and wildlife, we must protect them. Our community—Portland and the region—is responding to the challenge.

The Healthy Portland Streams project is just one piece of the comprehensive *River Renaissance*, but it's an important one. Under Healthy Portland Streams, we will work to protect and restore our important urban waterways, such as Johnson Creek, Tryon Creek, Fanno Creek, Balch Creek, and the Columbia Slough. That means not only a hard look at the water in the streambeds, but also at the stream banks, the streamside vegetation, and the areas around the stream that occasionally flood.

Through Healthy Portland Streams, we are evaluating and recommending solutions—regulations and voluntary efforts—to help protect and restore our streams and their surroundings, to ensure clean water, prevent erosion, manage floods and the natural spaces, for wildlife, fish and people to enjoy. We want to spur discussion of the issues, and the solutions.

Healthy Portland Streams aims to develop solutions that are:

- Up-to-date and based on the latest science;
- Flexible, allowing a variety of possible solutions;
- Fair to all involved;
- Understandable, feasible, and enforceable; and
- Effective in protecting and restoring our streams.

Environmental overlay zoning is an effective conservation tool that has been in place in the City since 1989. Part of the Portland Zoning Code, the environmental overlay zones help protect and conserve the quality of the environment near streams, rivers, and other natural resources by managing urban development and re-development in these areas. The Healthy Portland Streams project will update environmental overlay zoning to ensure that zoning reflects current conditions and needs. While it is important to make sure regulations are up-to-date, non-regulatory approaches must also be explored. A variety of City programs contribute toward the protection and restoration of streamside areas, but additional public and private efforts are needed. The Healthy Portland Streams report is the beginning of a larger public discussion about how we should manage streams within Portland.

Your Participation is Encouraged

This project is a work-in-progress. There area many difficult issues to be discussed and resolved. At this time, only draft recommendations have been developed to facilitate public discussion. While some recommendations are provided in these reports, there may be other approaches to consider. The City of Portland is searching for the best possible solutions. We encourage you to participate in these discussions.

Organization of the Healthy Portland Streams Discussion Draft

The Healthy Portland Streams Discussion Draft is organized into two sections: analysis and strategies. Within each section there are several reports, each under separate cover. The chart on the following page is a listing of the reports included in each section.

Analysis

The analysis section, along with a number of related appendices, presents background information and a decision-making framework. These sections include:

- A discussion of the supporting science related to streamside resources;
- An inventory of significant areas that contribute to stream health;
- A description of the kind of land uses found within the City of Portland; and
- A description of the economic, social, environmental, and energy issues that inform this decision-making process.

Strategies

The strategies sections of the report describe the possible actions that the City could take to improve environmental conditions along Portland streams. There are several types of strategies presented in these sections, including adoption of new policies, new environmental zoning provisions, and new non-regulatory approaches. These strategies are presented to spur public discussion. Not all of the strategies will be implemented. Based on public discussion, project staff will recommend that the City pursue some of the strategies.

- Comprehensive Plan Goals, Policies, and Objectives provide a coordinated set of guidelines for decision making to guide the future growth and development of the City. The comprehensive Plan guides how and where major public investments are made, how City agencies plan for the future, and how land is used in the future.

- The Portland Zoning Code is one tool that implements the Comprehensive Plan. This report includes suggested changes to the Portland Zoning Map and Zoning Code.

- The goals of this project are broad, and cannot be achieved through a strategy that focuses only on the Zoning Code. Other tools must also be explored. This report presents several non-regulatory actions. Several actions are presented for public discussion, including public acquisition of land, revised tax policies to encourage conservation of resource lands, and education programs. Some of these tools may be pursued if there is sufficient public support. This discussion draft provides the basis for a broader public discussion of these actions.



Analysis:

Streamside Science and Inventory of Significant Riparian and Wetland Resources

you are here

- Scientific Framework and Literature Review
- Applying the Science - Inventory Maps
- Watershed Information
- Site-Specific Resource Information

Economic, Social, Environmental, and Energy (ESEE) Factors

- Identification and Description of Urban Land Uses
- Analysis of Land Use Impacts on Identified Resources
- General Economic, Social, Environmental, and Energy (ESEE) Analysis
- Site-Specific ESEE Analysis

Strategies:

Comprehensive Plan Amendments

- Amendments to City Goals, Policies, and Objectives

Voluntary Conservation Actions

- Land Acquisition
- Tax Policies
- Incentives
- Stewardship and Education
- Resources

Zoning Code Amendments

- Amendments to the text of the Portland Zoning Code
- Commentary pages providing background and issue clarification

Zoning Map Amendments

- Quarter-section maps showing suggested amendments to the environmental overlay zoning boundaries

Appendices

- Background and Process
- Vegetated Riparian Corridors – Visual Survey of Existing Conditions
- Information on Special Status Species
- Wildlife Habitat Assessment (WHA) Methodology
- Oregon Department of Fish and Wildlife (ODFW) Surveys
- Independent Science Review Panel (ISRP) Discussion
- Citizen Review Committee (CRC) Discussion
- Economic Factors
- Policy and Regulatory Framework
- Glossary

PROJECT STEPS

The Healthy Portland Streams project is using a four-step process to develop ways to protect and restore our important urban waterways. Steps one and two are complete and this discussion draft represents the beginning of step three.

Step One: Develop an inventory of resources and analyze conflicts between protection and development of those resources.

The first step involved identification of the location, quantity, and quality of streamside natural resources. This step started with a review of the existing inventory that was done to meet State Land Use Planning Goal 5 and proceeded to identification of additional resources that are important for healthy riparian areas. Step one involved the use of a scientific framework for evaluating the significance of the identified resources based on their functional values (the benefits they provide). An independent panel of scientists reviewed the methodology that the city used for resource evaluation, and a citizen review committee reviewed both the methodology and the inventory of streamside resources. In addition, six open houses provided an opportunity for the public to learn about and comment on the inventory. The comments contributed to the accuracy and completeness of the draft inventory. The result of this inventory is proposed amendments to the city's existing Goal 5 resource inventory.

After the inventory was complete, an analysis of the economic, social, environmental, and energy impacts of protecting or developing the resource was conducted. The analysis included identification of land uses that conflict with the natural function of resources and an examination of the impacts of limiting, prohibiting, or allowing the use. The analysis was conducted on a general citywide level and on a resource-by-resource basis.

Step Two: Develop regulatory and voluntary actions to protect and restore resources.

The second step identified the various actions that can be employed to limit conflicting uses and achieve streamside protection goals. Step two identified programs and activities already in place to protect natural resources, and identified other actions that could achieve resource protection. The actions explored include both regulatory and voluntary efforts. The result of step two is proposed amendments to the City's environmental zoning code and zoning maps, and a list of voluntary approaches to streamside restoration and conservation.

Step Three: Present the results of step one and two to the public for evaluation.

Release of the Healthy Portland Streams Discussion Draft represents the beginning of the third step. The reports that make up the discussion draft contain all of the information regarding the results of steps one and two: the inventory of resources, analysis of conflicting uses, and development of voluntary and regulatory actions. The bulk of step three will involve public discussion and evaluation of the proposed



actions. The result of step three will be a refined proposal that can proceed to step four.

Step Four: Make recommendations of Planning Commission and City Council.

Based on the results of steps one, two, and three, the Planning Bureau will make recommendations to the Portland Planning Commission and City Council. The recommendations will include changes to the City's environmental zone mapping and environmental zone regulations and will improve streamside health. The recommendations will also include improving or adding voluntary actions that can result in streamside restoration or conservation. The Planning Commission and City Council will hold public hearings on the recommendations and the City Council will make the final decision.

Chapter 1
Streamside Science – A Literature Review

- The biological needs of salmon and trout
- The riparian area - definitions
- Riparian functions
- Bibliography

Purpose of the Literature Review

This chapter summarizes recent scientific literature and studies relevant to management of streamside land. In particular this chapter describes the relationship between salmon conservation, habitat requirements, and land use along small urban streams.

This chapter is also closely related to state, regional, and federal requirements:

State of Oregon Land Use Goals

One purpose of this review is to provide the scientific basis to update the City's state-acknowledged "Inventory of Significant Natural Resources" ——to incorporate resources that are significant for salmon conservation and protection of other wildlife habitat along streams. Oregon land use laws require the City of Portland to identify the significant natural resources within its jurisdictional boundaries (State *Goal 5* and related *administrative rules* - OAR 660-023). This chapter presents scientific information necessary to identify the significant natural resources. Particular attention is paid to those resources that have not already been protected under existing programs (the environmental overlay zoning program, for example).

Metro

At the regional level, Metro has identified regional requirements to protect water quality resource areas along streams (*Metro Title 3*), and is in the process of completing a regional inventory and analysis of riparian (streamside) natural resources for the purpose of fish and wildlife protection. Much of the scientific information presented in this chapter has also been cited by Metro as they develop a regional strategy to protect riparian corridors. This chapter serves to present and analyze information cited by Metro in a context more specific to Portland streams and the existing environmental zoning program. Readers particularly interested in the scientific basis for riparian protection may wish to read Metro's report as well.

Federal Endangered Species Act (ESA)

For purposes of meeting Federal ESA requirements, the City must have an accurate assessment of baseline habitat conditions. Understanding the existing condition of natural resources is critical if the City is to evaluate its salmon conservation efforts. Federal resource agency policies and court interpretations of the Endangered Species Act also emphasize the importance of documenting existing conditions. Specific details on fish presence and habitat conditions are found in the inventory section of this report. This chapter includes general information that forms the scientific foundation necessary to understand the habitat requirements of salmon and trout.

As a permitting agency, the City is responsible under the ESA for ensuring that its permitting decisions do not harm listed species. The ESA definition of "harm" includes adverse modification of habitat. In order to make informed permitting decisions in the future, the City must have a clear understanding of existing (baseline) habitat conditions and the supporting science that describes the function of that habitat.

Biological Needs of Salmon and Trout

Salmon and trout species require specific environmental conditions to survive. Because salmon are *anadromous* (they migrate between the ocean and freshwater environments), the timing of these environmental conditions is also important. Some species include several sub-populations that migrate and spawn at different times of the year. An excellent source of basic information on the listed salmon species is a series of species profiles published by the U.S. Fish and Wildlife Service (cited below). Those profiles summarize the biological needs of each species, and constitute the primary source material for this section. Readers interested in more detailed citations (original studies) documenting these parameters should refer to sources cited in the USFWS profiles.

Stream Conditions that Affect Salmon and Trout Survival

- *Water temperature*
- *Type of material in the stream bed (substrate)*
- *Amount of dissolved oxygen in the water*
- *Water flow characteristics*
- *Amount of suspended sediment in the water*
- *Amount of clean water*
- *Amount of shelter and cover available in the stream channel*
- *Availability of preferred food sources*

Temperature

Salmon and trout species generally require cold water. In general, high temperatures lead to increased disease and mortality, changes in metabolic rates, increased presence of warm water species that compete with or prey upon salmon and trout, and decreased spawning (Johnson and Ryba 1992). Temperatures above 73° to 79° F (23° to 26° C) are lethal for many species (Pauley et al. 1986; Pauley et al. 1988; Pauley et al. 1989; Beauchamp et al. 1983; Hickman and Raleigh 1982; Laufle et al. 1986). Cutthroat trout appear to tolerate the highest temperatures. According to Pauley et al. (1989), cutthroat can withstand short periods in temperatures as high as 79° F (26° C) provided there is significant nighttime cooling. Preferred salmon and trout spawning, incubation, and rearing temperatures generally range between 39° and 63° F (4°C and 17°C) (Pauley et al. 1986; Pauley et al. 1988; Pauley et al. 1989; Beauchamp et al. 1983; Hickman and Raleigh 1986; Laufle et al. 1986).

Temperatures can be influenced by a number of factors, including air temperature, the presence of cold water springs, groundwater interaction, stormwater runoff, canopy cover, solar heating, and channel width-to-depth ratios. The extent to which direct sunlight affects stream temperatures is related to the presence or absence of streamside vegetation and is discussed in more detail later in this report.

Substrate

Salmon and trout species spawn by excavating nests (*redds*) into the bottom of a stream, depositing their eggs into the gravel and cobbles. The availability and size of materials at the bottom of the stream can impact viability of salmon and trout populations. Although the preferred size varies between species, salmon and trout generally prefer gravel between 0.5 to 4 inches (1.3 and 10.2 cm) in diameter for

spawning (Pauley et al. 1988; Pauley et al, 1989; Beauchamp et al. 1983; Raleigh et al. 1986; Laufle et al. 1986). Gravel size also affects invertebrate organisms living in the stream, which affects food supply available to fish. According to Pauley et al. (1986), invertebrate food supplies are optimal if substrate is a mix of gravel and rubble sized materials.

Dissolved Oxygen

The concentration of *dissolved oxygen* in the water is also important. Low concentrations of dissolved oxygen can adversely impact salmon and trout populations by affecting the ability to swim, and causing distress during rearing. Dissolved oxygen levels in the spaces between spawning gravel is particularly important as eggs develop (Pauley et al. 1986). Salmon and trout generally avoid areas where dissolved oxygen is below 4.5 mg/l (Pauley et al. 1989; Beauchamp et al. 1983). Some level of impairment has been noted among steelhead when levels are below 6.0 mg/l (Pauley et al. 1986). Supersaturation (too much oxygen) can also be a problem (Pauley et al. 1986), although this generally occurs only below dams and man-made structures.

Low levels of dissolved oxygen can result when bacteria and/or nitrogen levels in a stream reach are elevated. Warmer temperatures compound oxygen depletion because the warmer temperatures create an environment favorable to bacteria growth. Excess bacteria often result from warm stream temperatures, aquatic plants, and agricultural or urban runoff associated with fertilizers. All of these conditions lead to increased nitrogen levels in the stream reach that creates algal blooms resulting in reduced dissolved oxygen levels. In addition, low oxygen levels can also be the result of higher temperatures. Dissolved oxygen levels decrease as water temperatures increase.

Sediment

Salmon and trout species prefer clear water, with low concentrations of suspended sediments. Several authors note that fish prefer sediment concentrations of less than 25 mg/l. Levels above 4000 mg/l may stop upstream migration (Pauley et al. 1986; Pauley et al. 1988; Pauley et al. 1989; Buechamp et al. 1983; Laufle et al. 1986). Excessive silt and sand deposits will also interfere with emergence of fry from spawning gravels (Pauley et al. 1986) and abrade and clog the gills of fish.

High levels of sediment can cause reduced feeding, destruction of food supplies, decreased growth rates. Cutthroat trout adults stopped feeding at turbidities above 35 ppm (Pauley et al. 1989). In continuous clay turbidities of 50 *nephelometric turbidity units (NTUs)* salmon and trout grow less well than those in clear water (Pauley et al. 1986, citing Sigler et al. 1984).

Water Velocity and Flow

Salmon and trout require streams with a variety of flow conditions. Flow volumes and velocities vary in natural stream channels. Salmon and trout streams often have a series of deep pools, mixed with areas of faster or shallower water. These flow and velocity conditions create habitat used during different life history stages. Different salmon and trout species also use slightly different niches, and are often found in different parts of a stream.

Excessive flow velocities may prevent upstream migration or "flush" fish species from a stream system. The maximum velocity that still allows for upstream migration of adult steelhead is 7.8 ft/s (Pauley et al. 1986). Excessive flow velocities also have been documented to scour *redds*, creating channel bed instability, filling pools and displacing large wood jams. (Orsborn and Ralph 1994). On the other hand, streams with extremely low water velocity may not have suitable spawning gravel. According to Pauley et al. 1986 (citing Reisner and Bjornn 1979), minimum flow velocity is a significant factor affecting embryo development within spawning gravel because velocity impacts the amount of oxygen available and the rate at which metabolic waste products are removed.

Insufficient water depth can block upstream migration. Depth also impacts food availability by affecting the growth of aquatic invertebrate organisms that fish eat (Pauley et al. 1986). According to Pauley (citing Hooper 1973) the best depth for invertebrate food production is between 6-36 inches (15 and 91 cm) deep. Several reports refer to optimal spawning depths between 12-47 inches (30 and 120 cm) (Pauley et al. 1989; Pauley et al. 1988; Laufle et al. 1986). Cutthroat can spawn in as little as 4-6 inches (10 to 15 cm) of water (Pauley et al. 1989). Pauley et al. 1986 cites 7 inches (18 cm) as the minimum depth needed for upstream steelhead migration. Water depth must also be sufficient to keep eggs submerged. Reisner and Bjornn (1979) identified optimal stream flow characteristics for salmon production as:

- a water depth of 1.5-2 ft over riffles
- riffle/pool ratio of near 1:1
- depth so that 60 percent of the riffle area is covered with water
- riffles with velocities of 12 to 18 in/s
- pools with velocity of 3.5-9 in/s
- availability of in-stream and over-story cover (Pauley et al. 1986)

Shelter and Cover

Salmon and trout depend on specific physical features of the stream channel to rest, feed, spawn, and find cover from predators. Morgan and Hinojosa (1999) discuss winter habitat requirements of salmon species. When over-wintering in fresh water, fish may use different habitat types found in the watershed that provides a diversity of hydraulic and vegetative conditions. Different species and age classes within the same species seek these different conditions in order to find refuge from flow and temperature changes, more favorable habitat and avoid competition for resources. Important stream features that provide cover include:

- Structural shelter (overhanging vegetation and banks, large wood, root wads, debris jams, and large and small rocks);
- Variations in water flow and velocity (deep pools, surface turbulence, slack water areas, and beaver ponds); and
- Off-channel habitat (ponds, channel braids, backwaters, side channels, near-to-channel wetlands, smaller slow-water tributaries, distributary sloughs).(Morgan and Hinojosa 1999; Sedell et al. 1988; Sedell et al. 1990; Beechie and Sibley 1997; Spence et al. 1996; Reisner and Bjornn 1979; Raleigh et al. 1986; Hickman and Raleigh 1982).

Food Supplies

Salmon and trout are primarily carnivorous, relying on invertebrates such as insects and crustaceans for sustenance as juveniles and adding small fish to their diet as they mature. During the life stages spent instream salmon consume a wide variety of organisms but insects are their primary prey (Hunter 1991; Beauchamp et al. 1983; Pauley et al. 1986). Both aquatic and terrestrial invertebrates can be part of their diet. During the summer, an estimated 40-50 percent of the juvenile salmon diet is composed of terrestrial invertebrates. However, when terrestrial invertebrates are unavailable fish rely on aquatic species (Johnson and Ryba 1992). In headwater steams and other areas where rearing habitat occurs, riparian areas often provide habitat and organic materials that support invertebrate populations (Pollock and Kennard 1998; Gregory et al. 1991; Hachmoller et al. 1991) and increase invertebrate diversity (Erman et al. 1977; Hachmoller et al. 1991). A more in depth discussion follows in the section on riparian functions.

What is the Riparian Area?

In general terms, the term "riparian" refers to the environment adjacent to streams and rivers. Functionally, riparian areas are described as "three-dimensional zones of direct interaction between terrestrial and aquatic ecosystems (Gregory et al. 1991)." The riparian area includes the stream channel between low and high water and extends outward from high water to the limits of flooding (and influenced by elevated water tables) and upward into the canopy of streamside vegetation (Kauffman et al. 2001;Naiman and Décamps 1997) (see Figure 1). The aquatic-terrestrial interactions in riparian areas include biological, chemical, and physical processes (Beschta and Kauffman 2000). Gregory et al.(1991) defines this area to include:

Riparian Areas

... are the environment adjacent to streams and rivers.

...include the stream channel between low and high water

...extend outward from high water to the limits of flooding (and influenced by elevated water tables)

...extend upward into the canopy of streamside vegetation

- The area along a stream subject to flooding, where there is direct contact between water and the surrounding landscape and where the physical landscape and geology is shaped by the processes of streamflow;
- The zone of vegetation (including the tree canopy) surrounding the stream that is influenced or supported by stream hydrology and the geology; and
- The zone of influence for key ecological interactions between uplands and aquatic ecosystems (the extent of the zone of influence may vary according to the specific interactions – a topic discussed in greater detail in the remainder of this report).

Riparian Functions

The term "*function*" is used throughout this report. This term is generally used to refer to ecological functions and is defined as the ecological values or benefits provided by the resource. Benefits can be physical, biological, chemical, or a combination of these. Most natural resources have many *functional values*.

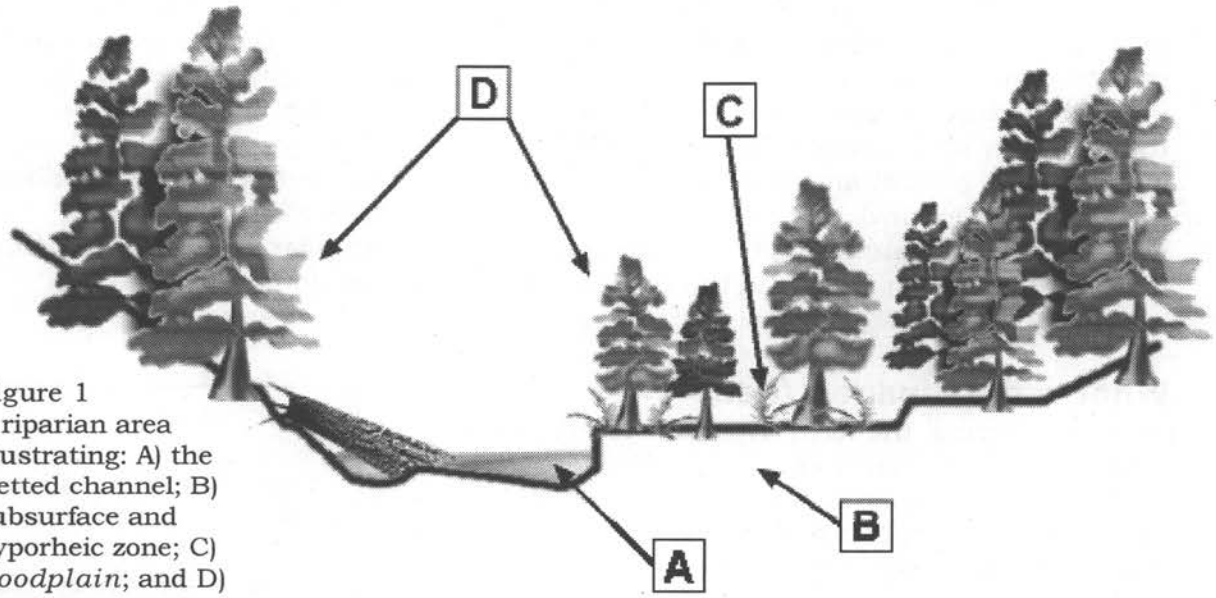


Figure 1
A riparian area illustrating: A) the wetted channel; B) subsurface and hyporheic zone; C) *floodplain*; and D) riparian vegetation.

Riparian areas provide a range of functions; they are areas of diverse composition, size, and structure. That diversity is a result of interactions between four natural ecosystem characteristics: 1) soils/geomorphology, 2) hydrology, 3) biota, and 4) climate-*microclimate* (Kauffman et al. 2001). Human activities are also an influence in many riparian environments.

The interactions of the above characteristics influence the type and extent of function provided by the riparian zone. Though this report uses separate categories to describe riparian functions, it is important to remember that all of these functions are connected, each influencing the other. Riparian functions, as organized for this report, are as follows: organic inputs (food web), channel dynamics and *morphology*, water quality, water quantity, micro-climate, and wildlife habitat.

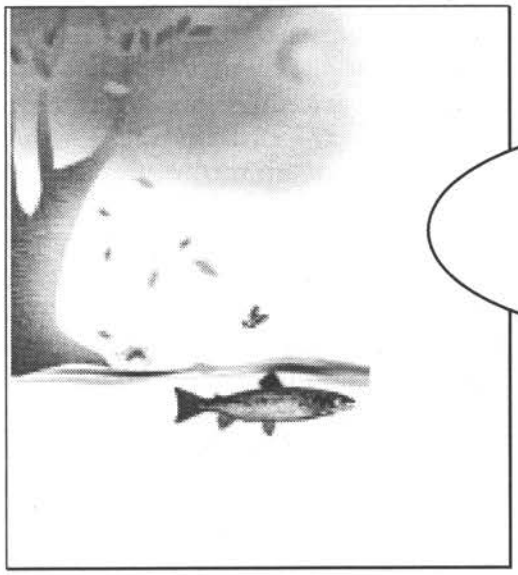
Riparian Functions

As organized for this report, riparian functions include:

- *Organic inputs (food web)*
- *Channel dynamics and morphology*
- *Water quality*
- *Water quantity*
- *Microclimate*
- *Wildlife habitat*

Organic Inputs-the Food Web

Riparian vegetation influences adjacent aquatic systems by providing important components of the food web (Hachmoller et al. 1991; FEMAT 1993). The food web begins as solar energy is converted to food by plants. A variety of organisms consume living and dead plant material produced from that energy, and these organisms are in turn consumed by larger and larger organisms. At each stage of the food web a transfer of energy from one organism to the next occurs.



RIPARIAN AREAS PROVIDE NATURAL ORGANIC INPUTS TO THE STREAM ECOSYSTEM

Riparian vegetation contributes up to an estimated 99 percent of the energy in aquatic food webs (Cummins 1974, citing Fisher and Likens 1973). Natural organic material from riparian plants, known as litterfall, also provides food resources for aquatic organisms (Gregory et al. 1991), and plays a significant role in the structure of aquatic communities. Litterfall, such as leaves, twigs, bark, and needles, can fall to the ground or directly into the stream providing an important food source for insects and other invertebrates (Cummins 1974; Gregory et al. 1991). In turn, aquatic and terrestrial insects are an important food source for fish, including juvenile salmon. Terrestrial insects are known to comprise up to 50 percent of juvenile salmon diets in summer months (Johnson and Ryba 1992 citing Hynes 1970).

Riparian communities are strongly influenced by disturbance. Upland disturbances such as fire and windthrow (FEMAT 1993) and river processes such as flooding affect the riparian zone, creating structurally and compositionally diverse stands of vegetation (Gregory et al. 1991). The diversity created from natural disturbance provides more opportunities for food, nutrients, cover, and nesting for fish and

wildlife (Gregory et al. 1991). These disturbance processes are often events that provide large wood to the riparian area, contributing to a fully functioning riparian ecosystem.

Vegetative structure and composition also influence riparian functions. The age, extent, and type of trees in the riparian area influence canopy cover shading. Thicker, mature canopies provide more shade, and conifers create shade throughout the year. In contrast, a thin stand of young deciduous trees would provide less shade. It is important that a variety of vegetation communities of different ages are present in a riparian ecosystem to create microhabitats and refugia as well as a diversity of plant species. This diversity also provides a variety of nutrient inputs at different times of the year.

Channel Dynamics and Morphology

Many stream channels are dynamic. Water velocities and levels fluctuate over time, submerging and exposing the riparian areas and the *floodplain* (Swanson et al. 1982). In unconstrained valley bottoms, meanders can shift slowly downstream or across the floodplain as erosion wears at stream banks, or can suddenly migrate when a flood cuts a new channel that captures the bulk of a stream's flow. This stream and floodplain connection is important for maintaining a healthy watershed (FEMAT 1993). Such processes help create a variety of habitats in the floodplain and maintain channel complexity. Flooding allows for the interchange of organic material and nutrients in the form of wood, leaf litter, and invertebrates. Seasonal flooding is one influence on the establishment (Spence et al. 1996) and composition of riparian vegetation (Swanson et al. 1982; Dykaar and Wigington 1998) and can control the biotic communities inhabiting the floodplain. Many species found in the riparian area are specifically adapted to the water level fluctuations. In turn, the composition of riparian vegetation affects the structure and complexity of the stream channel. Floodplain vegetation reduces velocities, redirects flow, and in some cases facilitates the creation of side-channels (Junk et al. 1989). Flooding allows for the creation of off-channel habitat that increases the diversity of hydraulic and vegetative conditions for juvenile salmon and other aquatic life. If meandering is prevented by channelization or other development, the benefits of flooding to habitat creation, maintenance of channel complexity, and similar functions are greatly diminished or lost.

The area within which a stream can travel is called a *meander corridor*, and its natural limits are set by geological controls and flow characteristics of the river. Geologic controls include bedrock outcrops, valley walls, alluvial terraces, or similar features that tend to resist channel migration. Where a stream flows unconstrained by valley walls or bedrock patterns, the meander corridor may reasonably be defined by the limits of identifiable historic meanders, by the location of alluvial terraces, or by the outlines of the 100-year floodplain (Skidmore et al. 1999). In an urbanizing area, human development – such as bridges, buildings, dams or dikes – can dramatically alter the meander corridor.

Off-channel habitat, or side channels, differ from main-channel habitat in that they can be isolated from the main channel during periods of low flow (Brown and Hartman 1988). Many researchers have documented the use of off-channel winter

habitats by juvenile salmon (Peterson 1980 [for coho]; Cederholm and Scarlett 1982; Peterson and Reid 1984 [for coho]; Scarlett and Cederholm 1984 [for coho]). Juvenile salmon and trout may use *off channel habitat* as a refuge from adverse conditions, such as high flow events and large volumes of suspended sediment. Such habitats may also provide juvenile salmon with alternatives to rearing in the main channel. The availability of these habitats can reduce the effects of single catastrophic events such as debris torrents, or conditions such as high water temperatures and the presence of pollutants by ensuring that at least a proportion of the juvenile population survives.

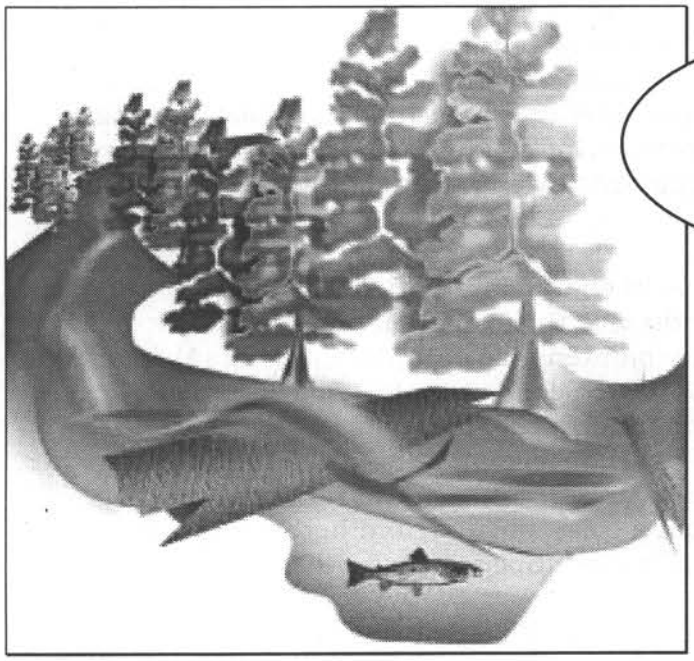
Riparian vegetation plays a strong role in channel migration and morphology. The root systems of riparian vegetation influence the formation of stream banks and gravel bars, and the development and maintenance of undercut banks that provide fish habitat (FEMAT 1993; May et al. 1997; Sedell et al. 1988). Vegetation immediately adjacent to the stream channel is considered most important in maintaining bank integrity. Roots of riparian vegetation bind soil particles together, making streams less susceptible to erosion. Because of the variations in root morphology between conifers, deciduous trees, shrubs, and herbs, vegetative diversity results in optimal bank stabilization (Spence et al. 1996).

Large wood entering the stream channel from adjacent riparian areas also influences channel dynamics by diverting flow, creating channel roughness, and stabilizing banks (FEMAT 1993; May et al. 1997; Gregory et al. 1991; Sedell et al. 1988). Large wood is defined as logs measuring greater than 4 inches (10 cm) in diameter (Beechie and Sibley 1997; Van Sickel and Gregory 1990; Ralph et al. 1994) and greater than 5 feet (1.5m) in length (Van Sickel and Gregory 1990). The riparian forest is the source of most instream wood (Van Sickle and Gregory 1990), which enters stream channels through a variety of means (Spence et al. 1996). Though small wood, such as branches and twigs, plays a role in creating and maintaining pool habitats, large wood including logs, rootwads, and debris jams, is considered a key component for maintaining salmon and trout habitat (May et al. 1997; Spence et al. 1996) and habitat diversity (May et al. 1997; Hicks et al. 1991).

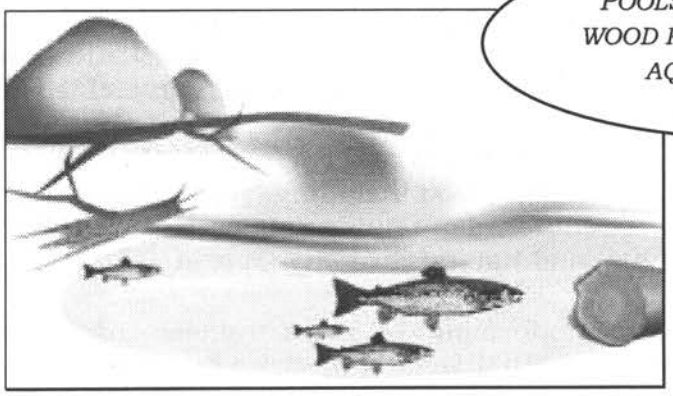
Large trees play a key role in forming the structural elements of streams and serving to retain small debris that would otherwise be transported downstream during high flow events. Large wood is correlated with the formation and maintenance of side channels, pools and low velocity areas (May et al. 1997; Bilby and Ward 1989; Beechie and Sibley 1997; Sedell et al. 1988). Pools formed by large wood provide habitat for fish and act as depositories for sediment and particulate organic material

(Sedell et al. 1988). Accumulation of large wood can change channel position resulting in new channels that are cut as water circumvents debris (Swanson et al. 1982). After disturbance events such as floods, fires, and landslides, large wood also accelerates stream channel restabilization and helps maintain aquatic habitat (Sedell et al. 1988). Pools, riffles, and side channels are important in maintaining fish and wildlife and provide a "suite of habitats...that we consider to be refugia" (Sedell et al. 1990). Refugia are locations that support organisms with reduced or

limited habitat range (FEMAT 1993). Refugia contribute to species diversity and can encourage recolonization following disturbance (Spence et al. 1990).



LARGE WOOD PLAYS AN IMPORTANT ROLE, AFFECTING CHANNEL MORPHOLOGY.

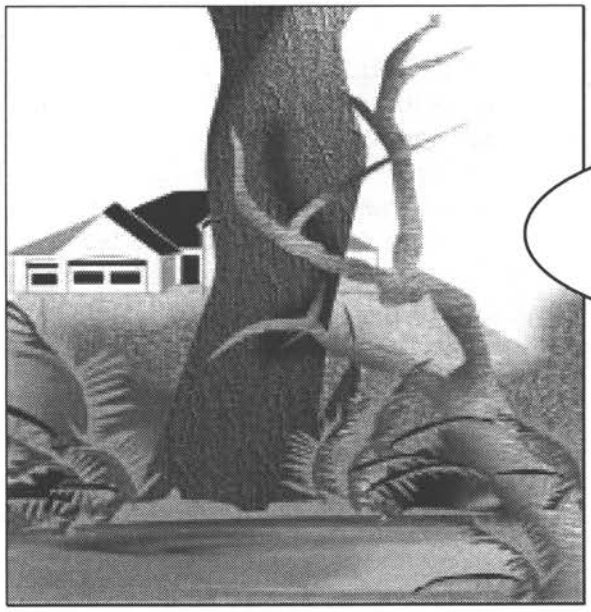


POOLS FORMED BY LARGE WOOD PROVIDE HABITAT FOR AQUATIC ANIMALS.

Water Quality

The roots, wood, and soils in the riparian area contribute to maintaining water quality (FEMAT 1993). Roots and wood help prevent sediments from entering the stream by moderating the erosive power of floodwaters and holding soils in place (Budd et al.1987). The degree to which a riparian system can perform this function varies depending on vegetation species composition, the degree to which a stream is channelized or decoupled from the floodplain, and other site characteristics (Spence et al. 1996). Riparian vegetation acts as a barrier that reduces sediment and debris transport (Swanson et al. 1982: Gregory et al. 1991), slows surface flows, and encourages infiltration (Budd et al. 1987; Knutson and Naef 1997). Riparian areas also serve to filter (from groundwater and surface flows) sediments (FEMAT 1993), pollutants (Knutson and Naef 1997), metals, and excess nutrients (Castelle et al. 1994). Riparian vegetation absorbs and stores nutrients and other dissolved

materials as they are transported through the riparian zone (Spence et al. 1996). In addition, water quality is influenced by the chemical transformation of nutrients in the stream due to interactions with gravels (Ferald et al. 2000) and in the riparian area.



RIPARIAN AREAS HELP MAINTAIN WATER QUALITY.

Water Quantity: Stream flow, sources, and storage

Water is a finite resource; only a limited amount exists and no new water can be created. It is in constant motion around the planet, moving from the atmosphere to the earth and oceans and back into the atmosphere in a process known as the water cycle (or hydrologic cycle). This complex water circulation system influences the amount, and timing, of water reaching a stream.

In a watershed, a variety of characteristics, such as climate, topography, geology, geomorphology, and vegetation, all interact to determine the amount of water flowing in a stream (Spence et al 1996). In riparian areas, and throughout a watershed, water can be stored and transported in the atmosphere, vegetation, stream channel, floodplain, soil, and in shallow or deep groundwater aquifers. Riparian areas are "the most sensitive zones of most watersheds, and require particular attention; they also produce the greatest return in terms of healthy watershed conditions for each management expenditure (Black 1990, 286)." This section focuses on the some of the riparian features and functions that are a critical part of this storage and transport system.

Riparian plants intercept, store, and transpire water. Water stored in the atmosphere can be intercepted by vegetation, or other structures. The leaves, needles, and branches in the canopy and on the ground, can block precipitation and prevent it from reaching the ground, or slow its progress reducing the impact of rainfall (Black 1990). Although this captured moisture may not contribute to the soil moisture or the groundwater table, it can reduce the amount of moisture taken out of the soil by a plant by reducing transpiration rates.

Some riparian plants can collect atmospheric moisture with their leaves and needles. In areas where advective moist air is common, a process known as fog drip provides a water source. Under the right conditions fog drip can add several inches a year to the soil moisture (Black 1990). Fog drip not only serves as a water source, but it also reduces the amount of water lost to transpiration.

The quantity and type of riparian vegetation influences the amount of interception, storage, and collection. Dense coniferous forests have greater interception and storage capacity than sparse coniferous forests, deciduous forests, shrublands, or grasslands (Spence et al. 1996). Old growth coniferous forests can add substantial moisture through fog drip compared to sparsely vegetated areas (Black 1990). Under dense forest canopy evaporation from wetted soil occurs slowly because of low temperature, shading, high humidity, and low wind speeds (Spence et al. 1996). Interception can also decrease the amount of water reaching the soil and ultimately the stream. In areas with dense overlapping canopies and thick litter up to 1" of rain may need to fall before any moisture reaches the soil (Black 1990).

The two primary factors influencing a flow regime are the percent of impervious area and the rate at which water is transmitted across the land and into the stream (Leopold 1968). Quantity, quality, and timing of surface and subsurface flow are influenced by runoff (Naiman et al. 1992). Volume of runoff is related to soil type, slope, and vegetative cover (Leopold 1968).The roots, stems, and fallen leaves and branches of riparian vegetation act to slow runoff, and in some cases prevent runoff from reaching the stream by encouraging infiltration.

Soil type influences permeability which also influences the amount of runoff. The pore space in the soil serves as a reservoir. The larger the pore spaces the greater the soil's ability to hold water and the lower the amount of runoff. Soil texture, the size of the soil particles, also influences the rate at which water moves downward through the soil. This downward movement is known as percolation. Soils with higher percolation rates also have less surface runoff. Organic materials in the soil serve to maintain permeability and porosity (Black 1990). Riparian areas that have soil high in organic matter will have low surface runoff and high storage capacity .

Soils can store water in a variety of ways. Puddles on the surface of the soil are a form of storage, known as depression storage. Detention storage is the water stored in the pores of the soil not under tension. This water drains from the soils relatively rapidly and usually flows out of the soil within 24 hours (Black 1990). Storage of water in soil pores that is under tension is known at retention storage. This water is the water used by plants for transpiration and growth. Relative humidity influences transpiration rates, (Black 1990) therefore the higher relative humidity present in riparian areas indicates that transpiration rates, and the amount of water uptake occurring in vegetation would be lower, thereby allowing water to be held in storage in the soil for longer than in an area with lower humidity.

Water flowing from detention storage is known as subsurface runoff. If it flows to a stream or river via groundwater reservoir it is known as base flow. Water stored in shallow aquifers is a source of streamflow. Winter precipitation that recharges local

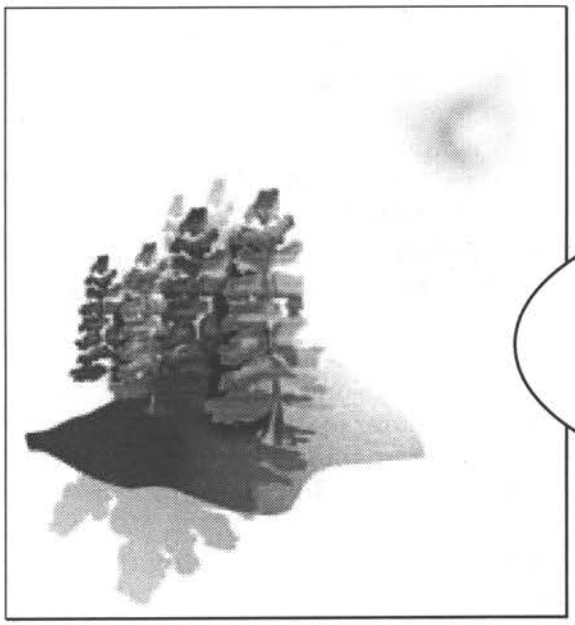
groundwater aquifers is important element of streamflow levels (Naiman et al. 1992). Floodplains provide groundwater recharge, storage, and discharge that, in turn, provide benefits to the riparian and aquatic ecosystems by enhancing base flows, and improving water quality through filtration (Metro 1997) Streams are often classified in relationship to their streamflow characteristics. Streams that flow throughout the year in response to both base flow and stormflow are classified as perennial or permanent. In contrast, ephemeral streams flow only in response to storm flow. Intermittent streams flow in response to groundwater flow, rising as the water table rises

Water can also be stored in the river channel and during high flow levels in the floodplain. Overbank flooding provides recharge of groundwater and wetlands (Naiman et al. 1992). In natural river systems floodplains provide for temporary storage of floodwater, resulting in decreases in downstream flood peaks (Leopold 1968).
Floodplains function to provide flood storage, thus reducing flood velocities, flood peaks, and wind and wave impacts (Metro 1997).

Microclimate
Diverse vegetation structure and composition in the riparian zone can create diverse *microclimates*, different heights in tree canopy, and off-channel areas that provide fish and wildlife habitat.

Riparian vegetation influences the microclimate of both the riparian area and stream environment. Depending on the cover, riparian zones will vary in impacting soil moisture and temperature, air temperature, water temperature, wind speed, and relative humidity (FEMAT 1993). In headwater streams, Olson et al (2000) found distinct microclimate differences in the near-stream environment compared with conditions in the upstream environment. Riparian areas have greater relative humidity and cooler near-stream temperatures (Olson et al. 2000). The extent of influence of riparian vegetation on these microclimate elements varies depending upon the age, composition, and density of vegetation (Gregory et al. 1991; FEMAT 1993; orientation to the summer sun, and topography (Barton et al. 1985).

Riparian vegetation influences the amount of heat and light that enters the riparian area by absorbing, reflecting, and filtering solar radiation (Gregory et al. 1991). The resulting shade helps maintain stream water temperatures (Castelle et al. 1994; Budd et al. 1987;). Canopy removal increases air temperatures and the amount of direct sunlight reaching the stream, which results in increases in stream temperature (Brown and Krygier 1970). Increased stream temperature can negatively alter the productivity and activity of aquatic organisms and increase disease and mortality in some fish species (Pauley et al. 1986).



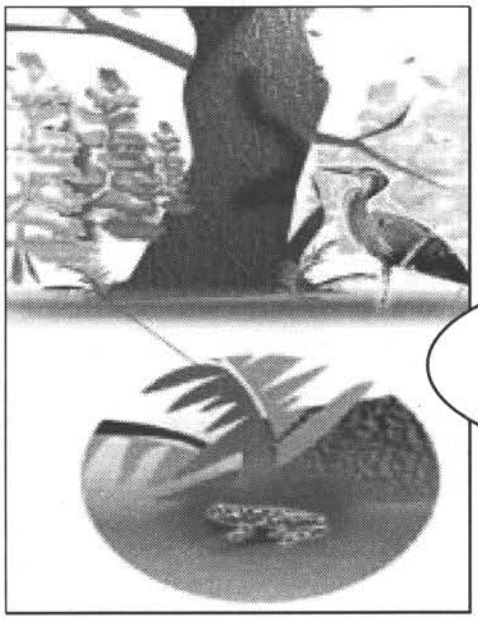
RIPARIAN AREAS CREATE DIVERSE MICROCLIMATES, INFLUENCING TEMPERATURE, HUMIDITY, AND WIND.

Wildlife Habitat

Riparian areas provide connectivity to habitat across the landscape that is beneficial for both fish and wildlife. Kauffman et al. (2001) states that riparian areas are important to fish and wildlife for a number of reasons. Intact riparian areas:

- have a high diversity of vegetation species and structure;
- often have unique vegetation assemblages relative to the upland area;
- exhibit high edge to area ratios because of their linear nature;
- influence the environment-microclimate, chemistry, structure;
- provide corridors and migration routes; and
- provide habitat features necessary for the survival of many species-, water, forage, nesting and breeding habitat, resting areas, and cover (Kauffman et al. 2001).

FEMAT (1993) reports that most vertebrates regularly use the riparian zone for some part of their activity and that the zone also provides wet micro-sites, seeps, and springs that are important for maintaining arthropods, mollusks, bryophytes, vascular plants and riparian-associated amphibians. Riparian vegetation is also known to influence *benthic* communities (Erman et al. 1977), birds and mammals (Castelle et al. 1994; Kauffman et al. 2001), and herpetofauna (Kauffman et al 2001). Budd et al. (1987) claims that "there is no other habitat type upon which wildlife is more dependent" (Budd et al. 1987, 590). This statement is supported by Kauffman et al. (2001) who report that although riparian zones only cover an estimated one to two percent of the landscape, fifty-three percent (319 out of 593) of wildlife species that occur in Oregon and Washington use these areas.



RIPARIAN AREAS ARE IMPORTANT TO VARIETY OF WILDLIFE.

Riparian areas play an important role in linking intact channel-adjacent, upstream, and upslope habitat that promote species movement, recolonization and quality habitat (Frissell et al. 1992). Wildlife corridors serve two primary functions; first they allow periodic movement between habitat types and second they offer permanent immigration and emigration pathways. As a result, corridors will help provide gene flow between individuals and increase recolonization (Meffe et al. 1997). However, corridors also allow for the movement of disease and exotic species.

Riparian Management

Riparian Buffers

The term "*buffer*" has a variety of meanings in relation to natural resources. Used generally, a buffer is an area adjacent to a resource that preserves or protects the resource and its environmental functions. In the context of land use management, buffers are often used to describe:

"Buffer" Defined:
When used in this report, the term "buffer" refers to an area where human activities are regulated (either minimized or prohibited) to protect specific environmental functions and values of a resource.

- Setbacks that are used to prohibit new development or resource exploitation within a set distance of the stream; and
- Regulated areas along the stream, where special standards or review processes are used to affect development design and resource exploitation.

The term "vegetated corridor" is also used in some literature, referring to the goal of maintaining and restoring a corridor or natural vegetation along streams. In urban areas *buffer* management must include consideration of human impact on the resource. Therefore, when used in this report, the term "buffer" refers to an area

where human activities are regulated (either minimized or prohibited) to protect specific environmental functions and values of a resource.

Characteristics Affecting Buffer Width

The most common criteria for determining the buffer size include: the value provided by the protected resource, intensity of adjacent land use, specific functions proposed for protection, general management goals, and riparian and watershed characteristics (Castelle et al. 1994; Spence et al. 1996; Johnson and Ryba 1992; Todd 2000). The riparian and watershed characteristics that influence the buffer's effectiveness in providing desired functions need to be considered in determining buffer size and include width, *floodplain* connectivity, corridor connectivity, and vegetation composition. These characteristics are discussed in more detail below.

Site Potential Tree Height

One standard commonly used to measure the direct influence of riparian vegetation on the stream corridor is the potential height of the dominant tree species at a site, also known as *"site potential tree height" (SPTH).* This standard was developed in the context of forest land management. In that context, it serves to communicate a generalized riparian standard in terms familiar to foresters (i.e. tree height). In an urban context, the term "site potential tree height" may be confusing, particularly in areas where there are few large trees. Keep in mind that this term is meant to communicate a general ecological standard that allows for multiple functions, not just those directly attributed to trees. Many of the fundamental ecological principles that guide the interaction between land and water are still at work in an urban setting (nutrient flows, geologic processes, food chains, the hydrologic cycle, etc.). It is these principles that form the basis of any generalized riparian buffer recommendation.

Site Potential Tree Height
In an urban context, the term "site potential tree height" may be confusing, particularly in areas where there are few large trees. Keep in mind that this term is meant to communicate a general ecological standard that allows for multiple functions, not just those directly attributed to trees.

Tree height is an important indicator of the potential contribution of wood and the extent of shading in riparian areas (NMFS 1999a; FEMAT 1993). Large wood is not only a key element in maintaining habitat diversity (May et al. 1997; Swanson et al. 1982), but riparian areas considered large enough to protect large wood are likely to protect other riparian functions (Ruckleshaus et al. 1999). According to the National Research Council (NRC), "the direct influence of riparian vegetation on streams declines with increasing distance from the channel and with the height of the dominant tree species" (NRC 1996). Since tall trees potentially contribute organic material (large wood, small wood, and litterfall) and provide shade at greater distances from the stream than small trees (NRC 1996), using site potential tree height as a measure of appropriate riparian buffer width considers the significant contributions of large wood to all functions and the linkages to the aquatic biota. The correlation between



tree height, distance from the stream, input of organic matter, and shading makes reference to site potential tree height preferable to arbitrary distances for determining riparian buffer widths (FEMAT 1993; Kauffman 2001).

Site-potential tree height is generally defined as the average maximum height of the tallest dominant trees at maturity (FEMAT 1993). Site-potential tree height is ideally based on forest-specific analysis (FEMAT 1993), however, several studies generalize SPTH for northwest forests. Some of these studies are summarized below (Table 1). The range of recommendations likely reflects differences in site conditions, dominant vegetation, and management objectives. The reader should also note that Table 1 is included primarily to demonstrates the broad range of SPTH interpretation. This table reflects SPTH based on forest values, and not necessarily urban areas. For the Portland area, SPTH would be based on Douglas Fir (*Psuedotsuga menziesii*), black cottonwood (*Populus trichocarpa*), big-leaf maple (*Acer macrophyllum*), and red alder (*Alnus rubra*) (Kauffman 2000) and should be based on research relating to those tree species.

Table 1. Selected literature references generalizing SPTH in Western Oregon

Source	SPTH	Geographic Context
FEMAT 1993	170 feet	Forests west of Cascades (excepting Siuslaw National Forest)
Spence et al. 1996	100-170 feet	Western Oregon Forests
NMFS 1999a	175 feet	Metro region
Pollock and Kennard 1998	105-250 feet	Forests west of Cascades

Riparian Habitat Connectivity

The linear distance and spatial area of a riparian area should be considered in determining appropriate buffer width (Johnson and Ryba 1992; Fischer et al. 2000). The loss of habitat connectivity or fragmentation into smaller isolated "islands" surrounded by development has been shown to significantly impact the diversity of plants and wildlife (Sauer 1998; Malanson 1993; Perry 1994). Fragmentation affects wildlife by preventing or decreasing species movement and recolonization (Meffe et al. 1997). Continuous intact riparian areas provide better habitat and seasonal migration routes for fish and wildlife (Fischer et al. 2000; FEMAT 1993), and are more effective at moderating stream temperatures and reducing non-point source pollution (Fischer et al. 2000). Fragmentation affects plant distribution by affecting the spread of seeds, and by increasing the impact of the "edge effect." The edge effect refers to the different environmental conditions that occur at the edge of a forest (for example, additional light reaches the forest floor at the edge). Castelle et al. (1994) state, "edge effect theory proposes that species numbers of both plants and animals increase at edges, due to overlap in adjacent habitats and the creation of unique edge-habitat niches."

In natural environments, isolated or very narrow edge habitat riparian areas will not support the same plants and animals that would occur in a larger more contiguous riparian forest. Moyle and Yoshiyama (1994) warn that species that are successful in edge habitats are usually good invaders also known as *invasive species*. Moyle and Yoshiyama (1994) recommend that in order to minimize the problems associated with edge effect, wide terrestrial buffer zones should be left (or

created if necessary) around aquatic reserves that will help generate a natural flow regime. Restored riparian habitat connectivity, is important not only to salmon trout survival, but also to maintaining the viability of other wildlife populations that are dependent on a healthy riparian environment.

Floodplain Connectivity

Another natural characteristic used to delineate riparian buffers is the *floodplain.* References to flooding and stream hydrology are commonly included in definitions of "riparian". Flooding directly or indirectly influences many if not all riparian functions. Modifications to stream channels will change the ecological character of both the river and its floodplain (Heiler et al. 1995). Seasonal flooding is important for regulating the exchange of materials, energy, and organisms between the aquatic and riparian *ecosystems.* It is also critical to the productivity of the organisms in those ecosystems (Sparks et al. 1990). In order to maintain the ecological integrity of riparian ecosystems, it is important to include the active channel migration area and the annual floodplain as a part of the riparian buffer (May and Horner 2000).

Vegetation Composition

The quality of the riparian area is as important as buffer width in protecting riparian functions. The vegetation type, species diversity, physical condition, and age should reflect conditions found in the regions' natural ecosystem and "should be factored into any riparian management or buffer width design" (May and Horner 2000). Under natural conditions, riparian areas contain a variety of plant assemblages in different stages of ecological succession (Spence et al. 1996.) This diversity provides a variety of feeding, nesting and roosting opportunities for many species of wildlife (Kauffman et al. 2001). Diverse stands of vegetation (mixed herbaceous and woody plants) are more effective in maintaining bank stability (Spence et al. 1996) and improving water quality (Todd 2000) than assemblages dominated by one species. The leaves of many riparian plant species breakdown more quickly than upland species providing nutrients to the aquatic ecosystem (Kauffman et al. 2001).

Buffer widths as recommended in the literature

A broad range of recommended buffer widths, some of which are based on, or expressed in terms of, site-potential tree height and floodplains, can be found in the literature. This range reflects a diversity of management goals, social values, land ownership, site conditions, and study methodologies. This section summarizes frequently cited riparian studies and the width recommended to maintain specific riparian functions (see Table 2). The relevance of these studies to urban settings will be addressed in a separate section.

Organic Inputs and Food Web

The dominant contribution of riparian vegetation to the food web is *allocthonous* inputs (predominately fine litterfall-leaves, needles, bark, cones, and fine wood) that fall directly into the stream. *Allocthonous* inputs (inputs not in their place of origin) can be significant even in incised reaches (Kauffman 2000). The literature reviewed generally agreed that the first 100-feet adjacent to a stream plays an important role in maintaining food web functions. Spence et al. (1996)

recommended buffers extending a distance equal one site potential tree height from the stream to maintain food web functions, with one site potential tree being equal to 170-foot in western Oregon forests. Maintaining 100-foot to 170-foot buffers is considered the minimum width required to help maintain particulate organic debris contributions that in turn help support healthy and diverse *benthic* communities.

Channel Dynamics

To maintain channel dynamics, buffer areas ranging 65 to 250 feet wide, or the 100-year floodplain are recommended in unconstrained reaches. Spence et al. (1996) recommends buffers equivalent to one site potential tree height (approximately 170 feet) to protect the riparian elements that stabilize streambanks, but also recommends that potential recruitment of wood from outside the riparian zone be considered. To maintain a supply of large and small wood (necessary to retain channel complexity), Pollock and Kennard (1998) also recommend basing riparian buffers on the site potential tree height, which they define as 105 to 250 feet in Western Oregon forests. To protect the channel migration zone they recommend a buffer equal to the 100-year floodplain.

Water Quality

To protect the water quality functions of riparian areas, a range of buffer widths, extending 10 to 860 feet on either side of the stream have been suggested in the literature. Recommended riparian buffer widths varied depending on the material being sampled or regulated, the topography of the area, and the character of the vegetation. Riparian buffers are considered most effective in controlling sediments in sheet flow (Spence et al. 1996). The literature proposing the widest corridors recommends buffers 860-feet from the stream for the removal of excess nutrients and solids produced by feedlots (Castelle et al. 1994). A distance of ten feet is considered appropriate to filter sand particles (Johnson and Ryba 1992 citing Wilson 1967). The quality, composition, and structure of vegetation also has an important influence on water quality (Todd 2000; Fischer et al. 2000).

Spence et al. (1996) states, "Because of the high degree of variability in the effectiveness of buffers, we cannot draw any conclusions regarding buffer widths required for sediment" and nutrient control (Spence et al. 1996, 219). However, he also concludes that buffers designed to protect other riparian functions should be able to control sediments. The sediment and nutrient filtering functions attributed to riparian areas assumes that the runoff source, riparian area, and aquatic system are all connected. In urban environments, riparian areas can be decoupled from the runoff source; an in-depth discussion of this issue is found later in this chapter under "Riparian management issues in an urban environment."

Water Quantity

Although the literature acknowledges the importance of riparian vegetation to maintaining streamflows, little is stated about the buffer size needed to protect water quantity. However, the literature does include references relative to riparian condition and water quantity. Johnson and Ryba (1992) and Castelle et al. (1994) discuss the importance of vegetated buffers for increasing infiltration and the importance of forest vegetation and litter adjacent to the stream to reduce

floodflows. The proximity and hydrologic connectivity of the floodplain and the channel is important for floodplain functions such as flood flow reduction and recharge of aquifers and wetlands (Stanford 1998; Heggenberger et al. 1998;). It should be acknowledged that conditions of the entire watershed and not just the riparian area are critical for maintaining hydrologic conditions such as streamflow and groundwater storage (Naiman et al. 1992; Bledsoe and Watson 2001; Stanford 1998; Tabacchi et al. 1998)

Microclimate

To maintain *microclimate* functions sources in the literature recommend maintaining buffers 33 to 525 feet wide. The width recommended depends on which microclimate features are of concern. On the low end of the scale Barton et al. (1985) considered 33-feet adequate for providing shade to maintain water temperature in streams in Southern Ontario, Canada. FEMAT states that microclimate is probably influenced by the width of the stream channel, topography, and the riparian area, but recommended buffers extending one to three site potential tree heights from the stream to maintain air temperature, wind speed, and humidity (FEMAT 1993). Based on their review of literature, Knutson and Naef (1997) recommend 200-525 feet to maintain localized microclimate conditions in the riparian area. Microclimate condition can also extend to side and *off channel habitat* if the riparian area is unconstrained and flood conditions are allowed to occur.

Wildlife Habitat

Riparian habitat is valuable to a broad range of wildlife species. To protect wildlife that use the riparian environment, buffers extending 10-984 feet are recommended depending on the species being protected. Most wildlife (87 percent) found in western Oregon and Washington use the riparian zone or *wetlands* during some part of their lifecycle (FEMAT 1993, citing Brown 1985: Kauffman 2001)). Most wildlife species depend on the riparian areas as a source of water, cover, food, plant communities, optimum microclimate conditions, high edge–to-area ratios, and as migration routes (FEMAT 1993, citing Carlson 1991; Kauffman et al. 2001).

At a minimum, Castelle et al. (1994) considered ten-feet adequate for some wildlife species. In contrast, bald eagle nesting and roosting sites require 600-foot buffers (FEMAT 1993). Most wildlife species that rely on riparian habitats can be accommodated with a buffer width of one site potential tree (150 feet) or more. For example, amphibians require cool, moist conditions to maintain their respiratory functions. They also are dependent upon migratory pathways along streams. In order to meet these needs, FEMAT recommends a buffer area equal to two site potential tree (300 feet) for the protection of most riparian-dependent amphibians.

Many avian species also rely on riparian areas (Kauffman et al. 2001). Bird use, particularly nesting for songbirds, is an important function of larger riparian areas. Waterfowl spend the winter in lowland ponds, bays and rivers. Protecting over-wintering habitat is critical to their well being. FEMAT citing Roderick and Miller (1991) recommends riparian buffers between 165 to 330 feet, depending on the waterfowl species. Knutson and Naef (1997) (citing Bowman and Siderius 1984, Kelsall 1989, and Vos et al. 1985) suggest 984-foot buffers to protect heron

rookeries. Riparian buffers adjacent to intense land uses may need to be even larger (Castelle et al. 1994) to adequately protect the above mentioned wildlife. Friesen et al. (1995) discusses the decrease in neotropical bird diversity associated with urban sprawl. Study results indicate a clear association between the increase in homes or development with the decrease in neotropical bird diversity (Friesen et al. 1995).

By definition riparian corridors connect terrestrial and aquatic habitat, but they also connect summer and winter habitats providing seasonal migration routes for fish and wildlife. Castelle et al. (1994) states that buffers need to be larger, 10-350 feet, depending on resource needs of the species for birds, mammals, reptiles and amphibians, when adjacent to intense land uses (such as urban development). Because habitat fragmentation that results from human disturbances is a major contributor to the loss of biodiversity, restored riparian habitat which can lead to connectivity, will be an important tool not only to salmon and trout survival, but to the viability of other wildlife that are dependent on a healthy riparian environment.

General Recommendations

Many of the authors discussed specific functions, and the *buffers* necessary to protect them, but they also included general recommendations (see Table 3). The range of general recommendations is from 50 feet to 326 feet on each side of the stream. Although 100-foot buffers are frequently cited as appropriate in other literature reviews (Johnson and Ryba 1992; Castelle et al. 1994; Metro 1997; Schueler 1995), recent work by Pollock and Kennard (1998) suggests that if buffers are designed to protect all of the functional values of a stream, they should be approximately 250 feet wide. Knutson and Naef (1997) suggest buffer widths aimed at retaining fully functioning riparian habitat be based on the seasonality, width of the stream, and erosion potential. For perennial streams less than 5 feet wide, the literature suggests 150-foot buffers for each side of the stream, and for streams wider than 5 feet, 200-foot wide buffers are preferred. In seasonal streams with high erosion potential, buffers up to 225 feet are recommended, with 150 foot-wide buffers considered adequate for seasonal streams with low erosion potential (Knutson and Naef 1997). FEMAT (1993) recommended a range of 150 to 300 feet for each side of the stream to accommodate the sustainability of key riparian functions.

Management constraints can result in the need to generalize buffer widths. A number of buffer width studies consider this need (see Table 3), and provide generalized recommendations. Generic buffer widths provide regulatory predictability and ease of enforcement (Castelle et al. 1994). However, generic buffers can be criticized because they do not consider site-specific conditions and constraints (May et al. 1997; Johnson and Ryba 1992) or the specific habitat requirements of individual species (Spence et al. 1996).

Buffer width should be based on site-specific considerations, and not a generalized width; scientific evidence of a 'one-size-fits-all' solution is scarce.

In cases where generic buffer widths are applied, buffers may be too small, putting resources at risk (May et al. 1997) and being more difficult to maintain over time (Todd 2000). Buffers that are larger than necessary can restrict land use, potentially impinging upon private property rights (May et al.

1997; Castelle et al. 1994; Todd 2000). Budd et al. (1987) concluded that "a generic corridor width which would satisfy habitat maintenance while satisfying human demands does not exist." In some cases, generalized buffers have been imposed as interim protection pending completion of site-specific watershed or project analysis (NMFS 1999). The literature reviewed for this report indicates that, though commonly used, "scientific evidence of a 'one-size-fits-all' solution is scarce" (May 1997,148), and buffer width should be based on site-specific considerations, and not a single generalized "best width" (Pollock and Kennard 1998; NMFS 1999; FEMAT 1993; Spence et al. 1996; Hicks et al. 1991; Pollock and Kennard 1998; Todd 2000; Fischer et al. 2000).

Table 2. Summary of literature: minimum riparian buffer width recommendation

	RIPARIAN FUNCTION	STUDY	MINIMUM WIDTH[1]
Organic Inputs-food web	Organic material	FEMAT 1993	100 ft or .5 SPTH[2]
	Organic litter	Spence et al. 1996	170 ft
	Benthic communities	Erman et al. 1977	100 ft
	Benthic communities	FEMAT 1993*	100 ft
	Range of width for function		*100-170 ft*
Channel Dynamics and Morphology	Large wood [3]	Budd et al. 1987 (Citing Bottom et al. 1983)	100 ft
	Large wood	Pollock and Kennard 1998*	1 SPTH or 105-250 ft
	Large wood	Van Sickle and Gregory 1990	164 ft
	Large wood	Spence et al. 1996	170 ft
	Bank stability	Spence et al. 1996	170 ft
	Channel morphology	Johnson and Ryba 1992	65-100 ft
	Channel migration zone	Pollock and Kennard 1998*	100-year floodplain
	Range of width for function		*65-200 ft / 100-yr floodplain*
Water Quality	Water quality	Budd et al. 1987	100 ft
	Water quality	FEMAT 1993	12-860 ft
	Water quality	Metro 1997*	50-200 ft
	Nutrient regulation	Spence et al. 1996	170 ft
	Nutrient removal	Todd 2000*	33-98 ft
	Filter metals and nutrients	Castelle et al. 1994 *	100 ft
	Filter sediment	FEMAT 1993	200 ft
	Filter sediments	Johnson and Ryba 1992 citing Wilson 1967*	10-400 ft
	Filter sediments	Budd et al. 1987 (Citing Bottom et al. 1983)	100 ft
	Range of width for function		*10-860 ft*
Microclimate	Shade	Johnson and Ryba 1992(based, in part, on Steinblums et al 1994)	.75 SPTH or 100 ft
	Shade	Castelle et al. 1994*	50-100 ft
	Shade	FEMAT 1993	100 ft
	Shade	Spence 1996	100 ft
	Shade-Water temperature	Castelle et al. 1994*	76 ft
	Shade-Water temperature	Todd 2000*	15-33 ft
	Shade-Water temperature	Barton et al. 1985	33 ft
	Microclimate	Knutson and Naef 1997*	200-525 ft
	Microclimate	FEMAT	.5-3 SPTH
	Microclimate	Pollock and Kennard 1998*	250 ft
	Range of width for function		*33-525 ft*
Wildlife Habitat	Wildlife habitat	FEMAT 1993 (citing Roderick and Milner 1991)	100-600 ft
	Wildlife habitat	Knutson and Naef 1997 (citing others)	25-984 ft
	Wildlife habitat	Castelle et al. 1994*	10-350 ft
	Wildlife habitat	Todd 2000*	100-325 ft
	Wildlife habitat and migration corridors	Fischer et al. 2000*	325 ft
	Biodiversity	Pollock and Kennard 1998*	200 ft
	Range of width for function		*10-984 ft*

[1] Refers to the width on each side of the stream.

[2] See page 19 for definition of SPTH.

* Based on author's review of literature

[3] Large wood also contributes organic material and nutrients to riparian systems

Table 3. General riparian buffer recommendations.

	Study	Minimum width[4]
General	Johnson and Ryba 1992	50-100 ft
General	Castelle et al. 1994	50-100 ft
General	Erman et al. 1977	100 ft
General	Fischer et al. 2000	50-325 ft
General	Spence et al. 1996	100-170 ft
General	May et al. 1997	100-326 ft
Perennial streams	Pollock and Kennard 1998	250 ft
Perennial streams	Knutson and Naef 1997	150-200 ft
Seasonal streams	Pollock and Kennard 1998	120 ft
Seasonal streams	Knutson and Naef 1997	150-225 ft
General	Metro 1997	50-200 ft
Headwater/ mid-section streams	Metro 1999	150 ft
General	Schueler 1995	100 ft
General	Oregon Division of State Lands, 1998	20-120 ft
General	FEMAT 1993	150-300ft
	Range of width	*50-326 ft*

Buffer Design

As discussed earlier this report defines the term "buffer" as an area where human activity is regulated to protect the environmental functions and values of a resource. This section discusses the degree of development that is appropriate in buffer areas. Preservation of some riparian functions may demand that "no-build" setbacks be established within some portion of the buffer. It may be possible to preserve other functions through more targeted development regulations while still allowing some level of development within the buffer. At least one author (Schueler 1995) suggests a multi-tiered buffer architecture, where the strongest protection is focused in areas closest to the stream. The City's existing environmental zoning regulations parallel that suggestion by providing three levels of protection:

- The environmental protection zone and minimum setback standards establish an inner "no-build" zone;
- The environmental conservation zone is often applied in areas immediately beyond the protection zone, serving to conserve specific functional values while still allowing some development to occur; and
- The transition area provides limited number of standards to help shield the resource from urban impacts.

Riparian management issues in an urban area

Recent literature describing the function of riparian corridors for salmon conservation was described. This section discusses several important dynamics affecting application of these principles in an urban context.

[4] Refers to buffer size on each side of the stream.

Application of science to an urban setting

Much of the scientific literature discussing riparian ecosystems and their protection does have application to urban streams (May et al. 1997) because of similarities in ecological values, diversity, hydrology, fish species, and climate (Kauffman 2000). Riparian zones are universally areas of high wildlife diversity. The physical properties and functions of water are applicable in urban areas. All animals need clean water, food, and shelter. Riparian vegetation, though varying from species to species, share the same basic needs for light, water, and nutrients whether in the city, the desert, or the mountains.

Urban areas and forestry science
Much of the scientific literature discussing riparian ecosystems and their protection does have application to urban streams because of similarities in ecological values, diversity, hydrology, fish species, and climate.

In addition, many forms of human disturbance described in rural landscapes are also found in urban areas (May et al. 1997). Road construction, road crossings, vegetation removal, fragmentation, and soil compaction are disturbances associated with both timber-harvest and urban development. However, in urban areas human disturbance can be more intense and widespread (Spence et al. 1996). While the impacts of timber-harvest can be intensive and long-term, the potential for permanent alteration of the ecosystem structure is higher in urban areas. Impacts resulting from urban activities such as road paving, channelization or piping streams, landscape maintenance, non-point source pollution can be more intense and pervasive, altering hydrologic regimes and the composition of vegetative communities and ecosystems.

Urban Stormwater Management

Urban stormwater drainage patterns have substantial impacts on riparian functions. Urban development increases the extent of hard (impervious) surfaces within a watershed (paving, rooftops, etc.). Water drains more quickly from paved surfaces and through piped drainage systems than it does from an undeveloped forest (Booth 1991; Schueler 1995). As a result, development eliminates infiltration, which increases both stormwater volume and velocity. Urbanization significantly changes the volume, rate, and timing of water flowing through stream systems, which can impact the physical dimensions of the stream channel (Booth 1991, Schueler 1995, May et al. 1997). As the stream channel changes in response to urbanization, the riparian ecosystem will be influenced (Booth 1991; Schueler 1995).

Urbanization significantly changes the volume, rate, and timing of water flowing through stream systems, which can impact the physical dimensions of the stream channel.

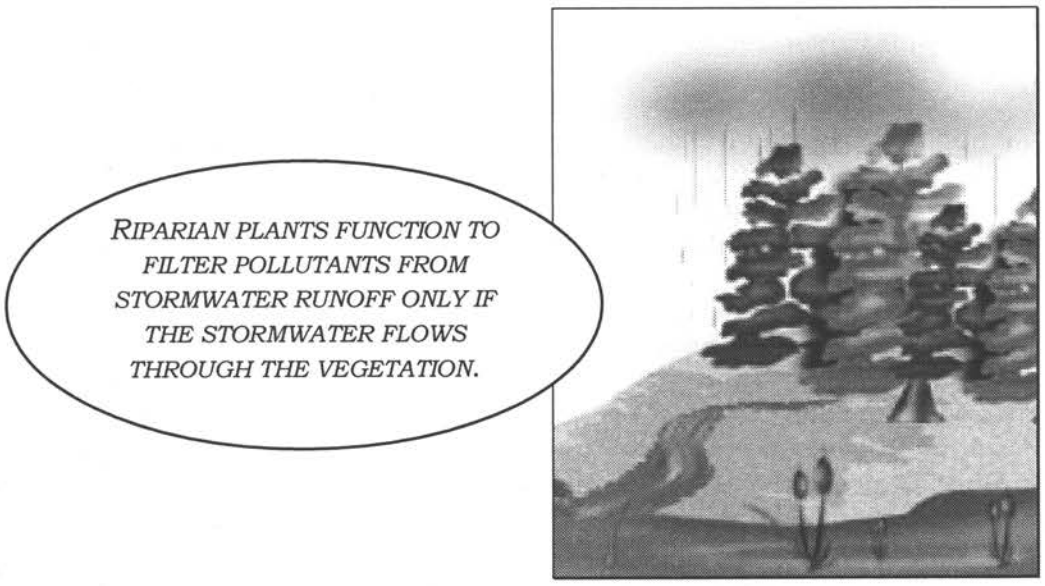
One rationale for avoiding development in the riparian area is to facilitate processes for the creation of natural channel diversity. That necessary stream channel complexity is expressed in features such as stream meanders, oxbows, backwater areas, and connections to off-channel wetlands and floodplains. However, even when the riparian corridor is protected from direct development pressure, natural features of the stream channel can be altered or lost as the channel responds to different flow conditions associated with development (Imhoff et al. 1991; Booth

1991). Channelization of streams in urban areas may also exacerbate the affects of stormwater because of the stream's inability to adjust its shape and accommodate changing stormwater volumes delivered to the stream.

Based on a study of two watersheds near Seattle Washington, Scott et al. (1986) observed that the diversity of fish species appears to be inversely related to the extent of *impervious surface* within a watershed. The diversity of aquatic life is in part related to the diversity of physical habitats within and near the stream channel (Sedell et al. 1988; Beechie and Sibley 1997). Urban hydrology has often lead to simplified stream channel habitats, reducing the diversity of aquatic life. These factors ultimately affect the food web on which salmon and trout and other fish and wildlife species rely.

Riparian vegetation stabilizes streambanks and prevents erosion. Changes in stormwater flow brought about by urbanization, however, can cause downward erosion (incision) within the streambed (Booth 1991) regardless of riparian vegetation. Incision of the streambed often leads to larger embankments along the margins of the stream, which are a result of erosion that undercut stream banks. Incision will decouple the linkages between the aquatic biota and the floodplain (riparian zone). Large embankments resulting from undercut banks prevent important stream/floodplain interactions. This process can eliminate or damage riparian vegetation that might otherwise have provided natural soil stabilization. Native riparian plant communities evolved under different hydrological conditions, and will be affected by hydrological changes brought about by urbanization (Booth 1991). Although riparian vegetation is often cited as a solution to stream bank erosion, the effectiveness of natural vegetation may be limited if hydrology and channel incision (channel morphology-the shape and height of the streambank) is not also addressed.

Vegetation adjacent to the stream improves water quality by filtering pollutants or sediments from runoff (FEMAT 1993) and providing shade that moderates stream temperatures. Urban stormwater systems, however, bypass the natural stormwater filtering function of the riparian area by collecting runoff into storm sewers and discharging stormwater directly into stream channel. These systems reduce overland flow and increase concentrated flows of stormwater. Riparian plants function to filter pollutants, nutrients, and sediment from stormwater only if the stormwater flows in a dispersed manner through the vegetation (Schueler 1995). However, riparian vegetation may play a significant role in controlling runoff from construction and development near the stream corridor.



Wood Dynamics in Urban Streams

As discussed previously, streamside vegetation is an important source of large wood, which plays a critical role in shaping the stream channel and maintaining habitat complexity (Bilby 1984; FEMAT; Gregory et al. 1991; Pollock and Kennard 1998; May et al. 1997; Spence et al. 1996; Sedell et al. 1988). It is also clear that the supply of large wood will be reduced in urbanized areas due to the lack of significant riparian vegetation, particularly trees (Booth 1991). One example is Johnson Creek, within the City of Portland, were many of the reaches lack large wood (ODFW 1999c). However, even where a mature tree canopy is present along the stream, urban development, stream management practices, and landscaping traditions have reduced the amount of large wood in the stream. This loss of large wood is often purposeful in urban streams where it is removed because of its perceived negative effects. The current state of many urban streams reflects many years of active wood management.

In a natural system some large wood naturally migrates downstream with flood events, becoming lodged into the streambed or banks (Sedell et al. 1988). This debris creates pools, meanders, rapids, and other habitat features in the stream. The downstream migration of wood supplies material to wider streams and to areas where there is no significant riparian tree canopy. This process creates large debris "structures" in coastal estuaries and larger rivers (Sedell et al. 1988). Urban streams, however, are conveyed under streets at frequent intervals. Many stream crossings are built over small diameter culverts that were not designed to accommodate large wood. As a result, debris accumulates on the upstream side of road crossings until maintenance crews remove it. Because large wood can damage existing urban infrastructure such as culverts and bridges, some agencies actively remove it from stream channels (May et al. 1997; Sedell et al. 1988). Flood control and navigation concerns have led government agencies to remove debris in order to

allow for more "efficient" drainage (Sedell et al. 1988). Recreational use of urban waterways may also create pressure to remove wood for safety reasons.

Urban landscaping practices also interrupt the natural accumulation of large and small wood. In an urban area landscape maintenance firms and landowners often remove dying trees before they fall. When trees are allowed to fall naturally, the wood may be used as firewood or simply removed in order to maintain a more managed landscape aesthetic that many urban residents prefer (May et al. 1997).

In order to maintain large wood in urban streams, active management will be required. Specific large wood management policies and operating procedures may need to be developed to ensure that debris placement does not exacerbate flooding, create an unreasonable safety hazard, or damage urban infrastructure while at the same time providing beneficial ecological functions. To the extent that natural landscapes are maintained in the riparian area, some problems may be avoided. Bridge and road culvert design will also be a critical management issue.

Elimination of the Dynamic Change from Urban Stream Systems

Salmon species evolved to cope with dynamic and diverse stream channels. A stream channel simplified and permanently constrained in one location by retaining walls or other structures will not provide the necessary structural/morphological diversity to support some fish species.

Even when the stream is allowed in a natural area, where additional stream features can develop or are maintained over time (sinuosity, backwaters, and connections to an adjacent floodplain), there may still be pressure to hold the channel in place and prevent water from escaping the banks. Such pressures include:

- Natural stream channel movement or natural flooding events are perceived as a threat to adjacent development, and action is often taken to prevent it even if it is well within a designated open space;

- Urban infrastructure such as sewer lines and roads must cross the riparian area, which places constraints on realistic levels of channel meandering and floodplain interaction that can be accommodated without large expense; and

- Urban hydrology is not in equilibrium with historical stream channel morphology, resulting in down cutting, channel widening, or bank erosion (May et al. 1997; Schueler 1995). Programs to treat these symptoms often include placing rock in the channel and along the banks, with the possible effect of locking the channel in place over time, preventing growth of riparian vegetation, and blocking floodplain connections.

Urban Landscape Issues Affecting the Health of Riparian Vegetation

The extent of vegetation in the riparian area can impact nutrient loads, water quality, food supplies and habitats available to organisms that fish consume (such as insects), channel morphology, and ultimately affect fish distribution and diversity (Shaw and Bible 1996; Hachmoller et al. 1991; Scott et al. 1986; Meehan

1996; Gregory et al. 1987). Vegetation in the riparian corridor also shades the stream and helps maintain suitable water temperatures.

Riparian tree canopies can be degraded by a number of factors in the urban environment, including:

- new and existing development (buildings, parking lots, lawns, etc.),
- historical and current land use (compaction, fill, dumpsites, agricultural use, logging activities, etc.),
- constant disturbance (roadside maintenance, recreational use of the streambank, vegetation thinning for visibility and safety, etc.),
- the prevalence of non-native (invasive) plant communities (ivy, blackberries),
- poor soil management (grading, fill, and removal of topsoil),
- streambank management (riprap, removal of wood),
- altered hydrology (scour due to flashy high flashy flows in the urban environment, and
- the loss of sites suitable for seedling establishment (alters vegetation communities and structure).

Invasive exotic plant species play a significant role in the urban forest and may impact the stability of the riparian *ecosystem* (Perry 1994). In Portland, reed canary grass, English ivy, Himalayan blackberry, Scot's broom, and clematis are some of the significant invaders and are particularly problematic in fragmented, narrow, and highly disturbed riparian corridors. In many cases exotic species have become the dominant undergrowth in the urban forest. Himalayan blackberry and English ivy are prevalent throughout the City of Portland. Even in Forest Park, one of the largest urban wilderness parks in the nation, English ivy is noted as a significant threat to native plant and wildlife communities (City of Portland 1995). Norway Maple has also had a significant impact in some Pacific Northwest forests. These species often colonize recently disturbed sites, growing in dense thickets that choke out and retard the development of native trees and shrubs.

Increases in exotic non-native *invasive species* are often accompanied by declines in plant and animal diversity. Human disturbance and fragmentation of habitat generally increases the rate of exotic species invasion. Through the creation of disturbed habitats, exotics travel rapidly, establish and dominate (Meffe et al. 1997).

Fragmentation, the loss and isolation of natural habitats, is one of the greatest threats to regional and global biodiversity. The loss of connectivity of habitat prevents normal dispersal of genetics and migration that is critical to population viability for many species (Meffe et al. 1997).

Land and water use activities within the urban landscape affects the health of habitat in many ways including effects on the health of soils. According to Perry

(1994), "the importance of soil to forest productivity cannot be overstated." Plants and soil are tightly linked. Plant growth is dramatically affected by soil conditions, and soil development is dependent on vegetation (Allaby 1996). Restoring soil conditions may be a key component of restoring degraded environments (Perry and Amaranthus 1990). The uppermost layer of soil (topsoil) is particularly important for plant growth. Urban development often involves extensive grading and alteration of topography to achieve level building sites and to establish road grades. In many cases topsoil is removed and lost as development occurs. In other cases structural fill material may be brought in to a site without topsoil. After development is complete, landscaping is frequently installed without proper soil preparation, which can retard plant growth, provide opportunities for exotic (invasive) plants, increase the rate of stormwater runoff, and increase the need for fertilizers in the future (affecting water quality and nutrient loads in urban streams) (WORC 1999).

Science Summary and Conclusions

Steelhead trout, chinook salmon, and chum salmon (although chum are not found in Portland's small streams) are listed as *threatened* under the Endangered Species Act (ESA) in the Portland metropolitan area. Although some steelhead and salmon populations still use Portland's streams and rivers, the urban environment has greatly reduced the quantity and quality of their habitat. Since the ESA listings City of Portland staff has initiated studies to better understand the habitat required by salmon and steelhead. This report is part of an analysis of riparian areas along Portland's smaller tributary streams and the regulations that protect them.

Although there are many factors that have led to the listing of salmon and steelhead in this region, degraded water quality and the lack of quality habitat within the City of Portland have contributed to this decline. This chapter reviews the recent scientific literature describing habitat requirements for fish and other aquatic and riparian dependent species, and the problems that urban development imposes on those requirements.

Fish Biology

Salmon and steelhead evolved in response to the natural environmental conditions of the Pacific Northwest. They require those conditions for survival and productivity. Salmon and trout generally require cold between 39°-63° F (4° to 17° C)), clean water in streams with a variety of flow, velocity, and water depth. Areas that provide shelter and cover, such as undercut banks, large rocks and wood, deep pools, and side channels also contribute to survival and health by providing resting, hiding, and feeding habitat. Gravel streambeds relatively free of sediment are necessary for spawning. A wide variety of aquatic and terrestrial food sources also need to be available, ranging from insect and crustaceans to small fish. The stream conditions that provide these biological necessities and the elements they require are often referred to as *properly functioning conditions (PFC).*

Riparian Areas

Riparian areas are the environments adjacent to streams and rivers, a zone of direct interaction between terrestrial and aquatic ecosystems. An intact riparian area

serves a multitude of functions vital to aquatic ecosystem health. More specifically, a healthy riparian and aquatic ecosystem embodies the following functions:

Organic Inputs.
Organic material contributes to the aquatic food web and influences channel morphology. Riparian vegetation can contribute up to an estimated 99 percent of the energy in aquatic food webs (Budd et al. 1987). Riparian vegetation influences adjacent aquatic systems by providing important components of the food web (Hachmoller et al. 1991; FEMAT 1993), and plays a significant role in the structure of aquatic communities. Litterfall, such as leaves, twigs, bark, and needles, can fall to the ground or directly into the stream providing an important food source for insects and invertebrates (Cummins 1974; Gregory et al. 1991). In turn, aquatic and terrestrial insects are an important food source for fish, including juvenile salmon.

Channel Dynamics.
Many stream channels are dynamic systems. Water velocities and levels fluctuate, submerging and exposing the riparian zone and floodplain (Swanson et al. 1982) through time. Meanders can shift slowly downstream or across the floodplain as erosion wears at stream banks, or can suddenly migrate when a flood cuts a new channel that captures the bulk of a stream's flow. Wood entering the stream channel from the riparian area influences channel dynamics by diverting flow, creating channel roughness, and stabilizing banks (FEMAT 1993; May et al. 1997; Gregory et al. 1991; Sedell et al. 1988). Such processes help create a variety of habitats in the floodplain and maintain channel complexity. Annual flooding allows for the interchange of organic material and nutrients (in the form of wood, leaf litter, and invertebrates) between the riparian and aquatic environments.

Water Quality.
The roots, wood, and soils in the riparian area contribute to maintaining water quality (FEMAT 1993). Roots and wood help prevent sediments from entering the stream by moderating the erosive power of floodwaters and holding soils in place (Budd et al. 1987). The degree to which a riparian system can perform this function varies depending on its species composition, the degree to which a stream is channelized or decoupled from the floodplain, and other site characteristics (Spence et al. 1996). Riparian vegetation acts as a barrier that reduces sediment and debris transport (Swanson et al. 1982: Gregory et al. 1991), slows surface flows, and encourages infiltration (Budd et al. 1987; Knutson and Naef 1997). Riparian areas also serve to filter (from groundwater and surface flows) sediments (FEMAT 1993), pollutants (Knutson and Naef 1997), metals, and excess nutrients (Castelle et al. 1994). Riparian vegetation absorbs and stores nutrients and other dissolved materials as they are transported through the riparian zone (Spence et al. 1996). In addition, water quality is influenced by the chemical transformation of nutrients in the stream due to interactions with gravels (Ferald et al. 2000) and in the riparian area.

Water Quantity

Microclimate.
The diverse structure and composition of the riparian zone create *microclimates*, multi-layered canopies, and off-channel areas that provide fish and wildlife habitat. Riparian vegetation creates a microclimate that influences both the riparian area and stream environment by impacting soil moisture and temperature, air temperature, water temperature, wind speed, and relative humidity (FEMAT 1993). Juvenile salmon trout use the calmer off-channel habitat as a refuge from adverse conditions, such as high flow events and large volumes of suspended sediment. Such habitats also provide juvenile salmon with an alternative to rearing in the main channel.

Wildlife Habitat
Budd et al. (1987) claims that "there is no other habitat type upon which wildlife is more dependent". This statement is supported by Kauffman et al. (2001) who report that although riparian zones only cover an estimated one to two percent of the landscape, fifty-three percent (319 out of 593) of wildlife species that occur in Oregon and Washington use these areas. FEMAT (1993) reports that most vertebrates regularly use the riparian zone for some part of their activity and that the zone also provides wet micro-sites, seeps, and springs that are important for maintaining arthropods, mollusks, bryophytes, vascular plants and riparian associated amphibians. Riparian vegetation is also known to influence *benthic* communities (Erman et al. 1977), birds and mammals (Castelle et al. 1994; Kauffman et al. 2001), and herpetofauna (Kauffman et al 2001).

Intact riparian areas are important to fish and wildlife because they:

- have a high diversity of vegetation species and structure,
- often have unique vegetation assemblages relative to the upland area,
- exhibit high edge to area ratios because of their linear nature,
- influence the environment-microclimate, chemistry, structure,
- provide corridors and migration routes, and
- provide habitat features necessary for the survival of many species-, water, forage, nesting and breeding habitat, resting areas, and cover (Kauffman et al. 2001)

Riparian Buffers
Stream *buffers* are often used to protect riparian structure and functions. The most common criteria for determining the buffer size include: the value provided by the protected resource, intensity of adjacent land use, specific functions proposed for protection, general management goals, and riparian and watershed characteristics (Castelle et al. 1994; Spence et al. 1996; Johnson and Ryba 1992; Todd 2000). The riparian and watershed characteristics that influence the buffer's effectiveness in providing desired functions need to be considered in determining buffer size and include width, floodplain connectivity, corridor connectivity, and vegetation composition.

Site Potential Tree Height
One standard commonly used to measure the direct influence of riparian vegetation on the stream corridor is the potential height of the dominant tree species at a site,

also known as "site-potential tree height" (SPTH). Tree height is an important indicator of the potential contribution of wood and the extent of shading in riparian areas (NMFS 1999a; FEMAT 1993). Large wood is not only a key element in maintaining habitat diversity (May et al. 1997; Swanson et al. 1982), but riparian areas considered large enough to protect large wood are likely to protect other riparian functions (Ruckleshaus et al. 1999).

This standard was developed in the context of forest land management. In that context, it serves to communicate a generalized riparian standard in terms familiar to foresters (i.e. tree height). The term "site potential tree height" may be confusing in an urban context, particularly in areas where there are few large trees in the riparian area. Readers should keep in mind that this term is meant to communicate a general riparian standard that allows for the operation of multiple ecological functions, not just the functions directly attributed to trees. Many of the fundamental ecological principles that guide the interaction between land and water are still at work in an urban setting (nutrient flows, geologic processes, food chains, the hydrologic cycle, etc.). It is these principles that form the basis of any generalized riparian buffer recommendation.

Site-potential tree height is generally defined as the average maximum height of the tallest dominant trees at maturity (FEMAT 1993). Site-potential tree height is ideally based on forest-specific analysis (FEMAT 1993). References to site potential tree height are often preferable to arbitrary distances for determining riparian buffer widths because of the correlation between tree height, distance from the stream, input of organic matter, and shading makes(FEMAT 1993; Kauffman 2001). For the Portland area, SPTH would be based on Douglas Fir (*Psuedotsuga menziesii*), black cottonwood (*Populus trichocarpa*), big-leaf maple (*Acer macrophyllum*), and red alder (*Alnus rubra*) (Kauffman 2000) and should be based on research relating to those tree species.

Habitat Connectivity

The linear distance and spatial area of a riparian area should be considered in determining appropriate buffer width (Johnson and Ryba 1992; Fischer et al. 2000). The loss of habitat connectivity or fragmentation into smaller isolated "islands" surrounded by development has been shown to significantly impact the diversity of plants and wildlife (Sauer 1998; Malanson 1993; Perry 1994). Continuous intact riparian areas provide better habitat and seasonal migration routes for fish and wildlife (Fischer et al. 2000; FEMAT 1993), and are more effective at moderating stream temperatures and reducing non-point source pollution (Fischer et al. 2000). In natural environments fragmented or very narrow riparian habitat areas will not support the same plants and animals that would occur in a larger more contiguous riparian forest. Moyle and Yoshiyama (1994) recommend that in order to minimize the problems associated with edge effect, wide terrestrial buffer zones should be left (or created if necessary) around aquatic reserves that will help generate a natural flow regime. Restored riparian habitat connectivity is important not only to salmon and trout survival, but also to maintaining the viability of other wildlife populations that are dependent on a healthy riparian environment.

Floodplain Connectivity

Another natural characteristic used to delineate riparian buffers is the floodplain. References to flooding and stream hydrology are commonly included in definitions of "riparian". Flooding directly or indirectly influences many if not all riparian functions. Modifications to stream channels will change the ecological character of both the river and its floodplain (Heiler et al. 1995). Annual flooding is important for regulating the exchange of materials, energy, and organisms between the aquatic and riparian ecosystems. It is also critical to the productivity of the organisms in those ecosystems (Sparks et al. 1990). In order to maintain the ecological integrity of riparian ecosystems, it is important to include the active channel migration area and the annual floodplain as a part of the riparian buffer (May and Horner 2000).

Vegetation Composition

The quality of the riparian area is as important as width in protecting riparian functions. The vegetation type, species diversity, physical condition, and age should reflect conditions found in the regions' s natural ecosystem and "should be factored into any riparian management or buffer width design" (May and Horner 2000). Under natural conditions, riparian areas contain a variety of plant assemblages in different stages of ecological succession (Spence et al. 1996.) This diversity provides a variety of feeding, nesting and roosting opportunities for many species of wildlife (Kauffman et al. 2001). Diverse stands of vegetation (mixed herbaceous and woody plants) are more effective in maintaining bank stability (Spence et al. 1996) and improving water quality (Todd 2000) than assemblages dominated by one species. The leaves of many riparian plant species breakdown more quickly than upland species providing nutrients to the aquatic ecosystem (Kauffman et al. 2001).

Buffer Size

The literature supports site-specific analysis of buffer distances where possible, but recognizes that generalized buffer requirements may be more practical in cases where time and money prevent a detailed site-specific analysis. Many of the studies that focus on urban areas also recommend that riparian protection be accompanied by adequate stormwater management, watershed-wide planning, and erosion control standards. Based on the literature reviewed in this report, we conclude that site specific analysis of buffer distances is the best method for buffer width determination.

When site-specific analyses are not possible, general riparian buffer widths can be applied. The range of general riparian buffer width recommendations identified in this report ranges from 50 feet to 326 feet although100-foot buffers are frequently cited as appropriate in other literature reviews (Johnson and Ryba 1992; Castelle et al. 1994; Metro 1997; Schueler 1995). Recent work by Pollock and Kennard (1998) suggests that buffers should be designed to protect all of the *functional values* of a stream, and should be approximately 250 feet wide. FEMAT (1993) recommended a range of 150 to 300 feet. As stated above, a buffer of 100-feet is frequently noted as the minimum necessary to maintain critical fisheries related functions. Based on the literature reviewed in this report, we conclude that a buffer of 100 to 300 feet is advisable, wherever feasible, to support fish conservation efforts along the small streams in the City of Portland. Buffers of this size also

provide a wealth of other benefits associated with increased aesthetics, wildlife diversity, and improved water quality.

Where a floodplain is still present and connected to the river, it is also advisable to include the annual floodplain within the buffer area. This allows for river-floodplain interactions that are critical to the interchange of organic and inorganic material between the riparian and aquatic ecosystems. The river-floodplain interface allows for the formation of off-channel habitat that creates the hydraulic and vegetation diversity important to juvenile salmon, trout, and other aquatic organisms.

The Urban Environment

Development and human activities in and near riparian areas can and has significantly impacted the stream conditions important to salmon, steelhead, and other aquatic and riparian dependent species. Areas of limited or no human activity help preserve riparian values.

The urban environment reduces, and in some cases eliminates, many riparian functions. Impacts resulting from urban activities such as road paving, storm sewers, channelization or piping of streams, landscape maintenance, and non-point source pollution can be intense and pervasive, altering the hydrologic system and the composition of vegetative communities and *ecosystems*. The following human activities are the primary ways in which urban development is impacting habitat and water quality in which steelhead and salmon depend.

Stormwater Management.

The extent of impervious area and the use of storm sewers in urban areas affect hydrology. In many cases stormwater is channeled into conveyance systems completely bypassing riparian areas and changing the volume, rate, and timing of water delivery to streams. Peak flows are increased and are shorter in duration. This reduces or eliminates the water quality function performed by riparian areas. Stormwater runoff and its impacts are further exacerbated in an urban environment because channelized streams cannot meander or overflow into the floodplain to accommodate changing stormwater volumes. Changes in hydrology impact the composition and establishment of streamside vegetation resulting in increased erosion and channel incision.

Wood.

Large wood has been actively removed from stream channels because of its potential to damage existing urban infrastructure such as culverts and bridges (May et al. 1997; Sedell et al. 1988). Navigation, flood control, and recreational use of urban waterways also create pressure to remove wood. Property owners and managers often prune or remove trees reducing the amount of wood available to the stream system. The removal of wood negatively impacts microhabitat, reducing food inputs, and contributing to the loss of channel complexity.

Channel Dynamics and Morphology.

Retaining walls, dikes, levees, and other instream structures established to keep floodwaters or erosion from damaging property can permanently constrain many

stream channels and banks thereby preventing the riparian area from fully performing its functions.

Habitat Connectivity.
Urban development can result in habitat fragmentation leading to significantly reduced plant and wildlife diversity. Degradation and reduction in the size of riparian zones as well as fragmentation also creates more favorable environments for invasive species. The loss of habitat connectivity prevents genetic dispersal, and plant and animal migration.

Restoration in an Urbanized Area
The City of Portland's ability to contribute to the survival of salmon and trout will depend largely on its ability to rehabilitate or recover the channel complexity, healthy riparian zones, intact linkages between the stream channel and the riparian zone. Restoration efforts can enhance many riparian functions. Protection and restoration of riparian vegetation can affect microclimate, organic inputs, fish and wildlife values, and to some extent, channel dynamics, even in already developed areas. However, it is unrealistic to imagine fully restoring the water quality, channel shaping functions, and reconnect the floodplains of the many urban riparian areas in Portland. Various hardened bank structures (riprap, gabion, etc.) prevent flooding and channel migration. The extent and nature of urban stormwater drainage systems alters the quantity and seasonality of flow, increasing the volume and shortening the duration of peak flows. These urban practices have decoupled the stream from its banks, preventing the river and floodplain interaction. Improving water quality and stabilizing channel dynamics in developed areas is more directly related to the state of the watershed than the state of the riparian area. Although some ecological functions can be restored, *ecosystem* rehabilitation or enhancement is a more appropriate goal for urban areas.

As noted in the previous section, the suite of riparian functions is reduced in highly modified riparian zones within urban environments. This report argues that the most realistic riparian strategy in small and medium sized streams includes protection and restoration of natural resources and features that play a direct functional role in the urban environment. These functions rely heavily on the presence of vegetation in the riparian area.

Literature Cited

Allaby, Michael. 1996. Basics of Environmental Science. Routledge Publishing, New York.

Bayley, Peter B. 1991. The Flood Pulse Advantage and the Restoration of River-Floodplain Systems. *Regulated Rivers: Research and Management*, 6:75-86.

Beauchamp, D.A., M.F. Shepard, and G.B Pauley. 1983. Species Profiles: Life Histories and Environmental Requirements of Coastal Fishes and Invertebrates (Pacific Northwest) – Chinook Salmon. *U.S. Fish and Wildlife Service Biological Report 82(11.6).* U.S. Army Corps of Engineers, TR EL-82-4. 21pp. Available online from the USGS National Wetlands Research Center at: http://www.nwrc.gov/publications/specintro.html.

Beechie, Timothy J. and Thomas H. Sibley. 1997. Relationship Between Channel Characteristics, Woody Debris, and Fish Habitat in Northwestern Washington Streams. *Transactions of the American Fisheries Society* 126:217-229.

Beschta, R. L. and J. Boone Kauffman. 2000. Restoration of Riparian Systems-Taking a Broader View. Pages 323-328 in P. J. Wigington and R. L. Beschta, eds. *Riparian Ecology and Management in Multi-Land Use Watersheds*. American Water Resources Association, Middleburg, Virginia.

Bilby, Robert E. and James W. Ward. 1989. Changes in Characteristics and Function of Woody Debris with Increasing Size of Streams in Western Washington. *Transactions of the American Fisheries Society* 118: 368-78.

Black, Peter E. *Watershed Hydrology*. Prentice Hall: Englewood Cliffs, New Jersey.

Bledsoe, B. P., and Watson, C. C. 2001. Effects of Urbanization on Channel Instability. *Journal of the American Water Resources Association* 37 (2): 255.

Booth, Derek B. 1991. "Urbanization and the natural drainage system – impacts, solutions, and progress." *Northwest Environmental Journal* 7 (1): 93-118.

Brown T.G. and Hartman, G.F. 1988. Contribution of Seasonally Flooded Lands and Minor Tributaries to the Production of Coho Salmon in Carnation Creek, British Columbia. Department of Fisheries and Oceans, Fisheries Research Branch, Pacific Biological Station Nanaimo, British Columbia V9R 5K6, Canada.

Brown, G. W. and Krygier, J. T. 1970. Effects of Clear-cutting on Stream Temperature. *Water Resources Research* 6 (4):1133-1139.

Budd, William W., Paul L. Cohen, Paul R. Saunders, and Frederick R. Steiner. 1987. Stream Corridor Management in the Pacific Northwest: I. Determination of Stream Corridor Widths. *Environmental Management* 11(5): 587-97.

Castelle, A.J., A.W. Johnson, and C. Conolly. 1994. Wetland and Stream Buffer Size Requirements-A Review. *Journal of Environmental Quality* 23:878-82.

Cederholm, C.J. and Scarlett, W.J. 1982. Seasonal Immigrations of Juvenile Salmonids into Four Small Tributaries of the Clearwater River, Washington, 1977-1981. Pages 98-110 in E.L. Brannon and E. O. Salo, eds. *Proceedings of the Salmon and Trout Migratory Behavior Symposium.* University of Washington, School of Fisheries, Seattle, Washington.

City of Portland, Portland Parks and Recreation, and the Bureau of Planning. 1995. *Forest Park Natural Resources Management Plan.*. Portland, Oregon.

Cummins, Kenneth C. 1974. Structure and function of stream ecosystems. *BioScience* 24: 631-641.

Dykaar, Bruce B, and Wigington, P. J. Jr. 2000. Floodplain Formation and Riparian Ecosystem Development on the Willamette River, Oregon, USA. *Environmental Management* 25 (1):82-104.

Erman, Don C., J. Denis Newbold, and Kenneth B. Roby. 1977. *Evaluation of Streamside Bufferstrips for Protecting Aquatic Organisms.* California Water Resources Center: Davis, California.

FEMAT. 1993. Forest Ecosystem Management: An Ecological, Economic, and Social Assessment. Interagency SEIS Team: Portland, Oregon.

Ferald, Alexander, Dixon Landers, and P.J. Wigington. 2000. Water Quality effects of hyporheic processing in a large river. Pages 167-172 in P. J. Wigington and R. L. Beschta, eds. *Riparian Ecology and Management in Multi-Land Use Watersheds.* American Water Resources Association, Middleburg, Virginia.

Fischer, R. A., C. O. Martin, and J. C. Fischenich. 2000. Improving Riparian Buffer Strips and Corridors for Water Quality and Wildlife. Pages 457-462 in P. J. Wigington and R. L. Beschta, eds. *Riparian Ecology and Management in Multi-Land Use Watersheds.* American Water Resources Association, Middleburg, Virginia.

Frissell, Christopher A., W. J. Liss, R. K. Nawa and J. L. Ebersole. 1992. *Cumulative Effects of Land use on Salmon Habitat in Southwest Oregon Coastal Streams.* Ph.D. Thesis, Oregon State University.

Gillilan, David M. and Brown Thomas C. 1997. *Instream Flow Protection: Seeking a Balance in Western Water Use.* Island Press: Washington, DC.

Gregory, Stanley V. and Frederick J. Swanson, W. Arthur McKee, and Kenneth W. Cummins. 1991. An Ecosystem Perspective of Riparian Zones: Focus on Links Between Land and Water. *BioScience* 41(8): 540-551.

Hachmoller, Bernard, R. A. Matthews and D. F. Brakke. 1991. Effects of Riparian Community Structure, Sediment Size, and Water Quality on the Macroinvertabrate Communities in a Small, Suburban Stream. *Northwest Science* 65(3): 125-132.

Heiler, G., Hein, T., Schiemer, F. and Bornette, G. 1995. Hydrological Connectivity and Pulses as the Central Aspects for the Integrity of a River-floodplain System. *Regulated Rivers* 11(3/4):351-361.

Hickman, Terry, and Robert F. Raleigh. 1982. *Habitat Suitability Index Models: Cutthroat Trout.* Habitat Evaluation Procedures Group. Western Energy and Land Use Team. U.S. Fish and Wildlife Service. FWS/OBS-82/10.5. U.S. Department of Interior.

Hicks, B.J., J.D. Hall, P.A. Bisson, and J. R. Sedell. 1991. Responses of Salmonids to Habitat Changes. In Influences of Forest and Rangeland Management on Salmonid Fishes and Their Habitats. *American Fisheries Society Special Publication* 19:483-518.

Huggenberger, P., Hoehn, E., Beschta, R, and Woessner, W. 1998. Abiotic Aspects of Channels and Floodplains in Riparian Ecology. *Freshwater Biology* 40: 407.

Hunter, Christopher J. 1991. Better Trout Habitat: A Guide to Stream Restoration and Management. Washington DC: Island Press.

Imhof, J. G., R.J. Plank, F.M. Johnson, and L.C. Halyk. 1991. Watershed Urbanization and Managing Stream Habitat for Fish. *Transactions of the 56th Annual Wildlife & Natural Resources Conference.* March 17-22, 1991, Edmonton, Alberta. Published by the Wildlife Management Institute, Washington D.C.

Johnson, Alan W. and Diane M. Ryba. 1992. *A Literature Review of Recommended Buffer Widths to Maintain Various Functions of Stream Riparian Areas.* King County Surface Water Management Division: Washington.

Junk, W.J., Bayley, P.B., Sparks, R.E. 1989. The Flood Pulse Concept in river-Floodplain Systems. *Canadian Special Publications in Fisheries and Aquatic Sciences* 106:110-127.

Kauffman, J. B. 2000. Comments on the City of Portland, Environmental Zoning Analysis, Technical Background Report.

Kauffman, J. B., M Mahrt, L. A. Mahrt, and W. D. Edge. 2001. Riparian Wildlife Communities and Habitats. In *Wildlife Habitats and Species Associations within Oregon and Washington: Building a Common Understanding for Management.* Oregon State University Press, Corvallis, OR. (In press).

Knutson, K. L. and V. L. Naef. 1997. *Management Recommendations for Washington's Priority Habitats: Riparian.* Washington Department of Fish and Wildlife. Olympia, Washington: 181.

Laufle, J.C.; G.B. Pauley; and M.F. Shepard. 1986. Species Profiles: Life Histories and Environmental Requirements of Coastal Fishes and Invertebrates (Pacific Northwest) – Coho Salmon. Prepared by U.S. Fish and Wildlife Service Biological report 82(11.48). U.S. Army Corps of Engineers, TR EL-82-4. 18pp. Available online from the USGS National Wetlands Research Center at: http://www.nwrc.gov/publications/specintro.html.

Leopold, Luna. 1968. *Hydrology for Urban Land Planning: A Guidebook on the Hydrologic Effects of Urban Land Use Planning.* US Department of the Interior, US Geological Survey, Geological Survey Circular 554, Washington, DC.

Malanson, G.P. 1993. *Riparian Landscapes: Cambridge Studies in Ecology.* Cambridge University Press, Cambridge.

May, C. W., E.B. Welch, R. R. Horner, J. R. Karr, and B.W. Mar. 1997. Quality Indices for Urbanization Effects in Puget Sound Lowland Streams. Washington Department of Ecology: Olympia, Washington.

May, C. W., and R. R. Horner. 2000. The Cumulative Impacts of Watershed Urbanization on Stream-Riparian Ecosystems. Pages 281-286 in P. J. Wigington and R. L. Beschta, eds. *Riparian Ecology and Management in Multi-Land Use Watersheds.* American Water Resources Association, Middleburg, Virginia.

Meffe, Gary K., C.R. Carroll, and Contributors. 1997. *Principles of Conservation Biology,* Second Edition. Sinauer Associates, Inc. Sunderland, MA.

Metro. 1997. Policy Analysis and Scientific Literature Review for Title 3 of the Urban Growth Management Functional Plan: Water Quality and floodplain Management Conservation. Metro: Portland, Oregon.

Metro. 1999. Development of Measures to Conserve, Protect, and Restore Riparian Corridors in the Metro Region: Streamside CPR, Preliminary Draft. Metro Growth Management Services: Portland, Oregon.

Morgan, Amy and Frank Hinojosa. 1999. *Winter Habitat Utilization by Juvenile Salmonids: a Literature Review.* Online publication, available at <http://bulltrout.nwifc.wa.gov/TFW/reports/report5.htm>. Northwest Indian Fisheries Commission, and Grays Harbor College.

Moyle, Peter B. and Ronald M. Yoshiyama. 1994. Protection of Aquatic Biodiversity in California: A Five-tiered Approach. *Fisheries,* 19(2):6-18.

Naiman, R. J., Beechie, T. J., Benda, L. E., Berg, D. R., Bisson, P. A., MacDonald, L.H., O'Conner, M. D., Olson, P. L., and Steel, E. A. 1992. Fundamental Elements of Ecologically Healthy Watersheds in the Pacific Northwest coastal Ecoregion. In R. J. Naiman Eds, *Watershed Management: Balancing Sustainability and Environmental Change.* Springer-Verlang: New York

Naiman, R. J. and H. Décamps. 1997. The Ecology of Interfaces: Riparian Zones. Annual. Rev. Ecol. Syst. 28:621-658.

National Marine Fisheries Service, Pacific NW Region. 1999. *Factors Responsible for the Decline in Salmon Abundance and Distribution in the Pacific Northwest.* A table based on studies of rivers in Western Oregon and Northern California. Adapted with permission by Pacific States Marine Fisheries Commission from Status and Future of Salmon of Western Oregon and Northern California: Overview of Findings and Options by Botkin, Cummins, Dunne, Regier, Simpson, Sobel, and Talbot. For a copy send $17 to The Center for the Study of the Environment, P.O. Box 6945, Santa Barbara, California.

National Marine Fisheries Service, Pacific NW Region. 1999a. *Endangered Species Act Status of West Coast Salmonids.* Online publication: http://shoveler.wrc.noaa.gov/sites/nwnmfs/1salmon/salmesa/index.htm, updated on September 9, 1999.

National Research Council (NRC) Committee on Protection and Management of Pacific Northwest Anadromous Salmonids. 1996. *Upstream: Salmon and Society in the Pacific Northwest.* Washington, D. C.: National Academy Press

Oregon Department of Fish and Wildlife (ODFW). 1999c. *Aquatic inventories Project Physical Habitat Surveys: Johnson Creek and Tributaries.* ODFW and City of Portland Bureau of Environmental Services; Portland, OR.

Oregon Division of State Lands. 1998. Urban Riparian Inventory and Assessment Guide: A Tool for Oregon Land Use Planning. Salem, Oregon.

Orsborn, J.F. and S.C. Ralph. 1994 An Aquatic Resource Assessment of the Dungeness River System: Phase II - Physical Channel Analysis, Hydrology and Hydraulics and Phase III - Fisheries Habitat Survey. Prepared for Jaemstown S'Klallam Tribe. Sequim, Washington.

Pauley, G.B., B.M. Bortz, and M.F. Shepard. 1986. Species Profiles: Life Histories and Environmental Requirements of Coastal Fishes and Invertebrates (Pacific Northwest) – Steelhead Trout. U.S. Fish and Wildlife Service. Biological Report 82(11.62). U.S. Army Corps of Engineers, TR EL-82-4. 24pp. Available online from the USGS National Wetlands Research Center at: http://www.nwrc.gov/publications/specintro.html.

Pauley, G.B., K.L Bowers, and G.L Thomas. 1988. Species Profiles: Life Histories and Environmental Requirements of Coastal Fishes and Invertebrates (Pacific Northwest) – Chum Salmon. U.S. Fish and Wildlife Service Biological report 82(11.81) U.S. Army Corps of Engineers, TR EL-82-4. 17pp. Available online from the USGS National Wetlands Research Center at: http://www.nwrc.gov/publications/specintro.html.

Pauley, G.B., K. Oshima, K.L. Bowers, and G.L. Thomas. 1989. Species Profiles: Life Histories and Environmental Requirements of Coastal Fishes and Invertebrates (Pacific Northwest) – Sea-Run Cutthroat Trout. U.S. Fish and Wildlife Service Biological Report 82(11.86). U.S. Army Corps of Engineers, TR EL-82-4. 21pp. Available online from the USGS National Wetlands Research Center at: http://www.nwrc.gov/publications/specintro.html.

Pauley, G.B., R. Risher, and G.L Thomas. 1989a. Species Profiles: Life Histories and Environmental Requirements of Coastal Fishes and Invertebrates (Pacific Northwest) – Sockeye Salmon. U.S. Fish and Wildlife Service Biological report 82(11.116). U.S. Army Corps of Engineers, TR EL-82-4. 22pp. Available online from the USGS National Wetlands Research Center at: http://www.nwrc.gov/publications/specintro.html.

Perry, David, and Michael P. Amaranthus. 1990. "The Plant-Soil Bootstrap: Microorganisms and Degraded Ecosystems." In, John J. Berger, ed. *Environmental Restoration: Science and Strategies for Restoring the Earth.* Washington, D. C.: Island Press.

Perry, David. 1994. *Forest Ecosystems.* Department of Forest Science and Cascade Center for Ecosystem Management. Oregon State University, Johns Hopkins University Press.

Peterson, N. P. 1980. The Role of Spring Ponds in the Winter Ecology and Natural Production of Coho Salmon (Oncorhynchus kisutch) on the Olympic Peninsula, Washington. Master's thesis. University of Washington, Seattle.

Peterson, N. P. and Reid, L.M. 1984. Wall-base Channels: Their Evolution, Distribution, and Use by Juvenile Coho Salmon in the Clearwater River, Washington. Pages 215-225 in J.M. Walton and D.B. Houston, eds. *Proceedings of the Olympic Wild Fish Conference.* Peninsula College, Fisheries Technology Program, Port Angeles, Washington.

Pollock, Michael M. and Paul M. Kennard. 1998. A Low-risk Strategy for Preserving Riparian Buffers Needed to Protect and Restore Salmonid Habitat in Forested Watersheds of Washington State: Version 1.1. 10,000 Years Institute: Bainbridge Island, Washington.

Raleigh, Robert F, William J. Miller, and Patrick C. Nelson. 1986. *Habitat Suitability Index Models and In-stream Flow Suitability Curve: Chinook Salmon.* National Ecology Center, Division of Wildlife and Contaminant Research, Fish and Wildlife Service, U.S. Department of Interior. Washington D.C. Biological Report 82(10.122).

Ralph, S. C, G.C. Poole, L.C. Conquest, and R.J. Naiman. 1994. Stream Channel Morphology and Woody Debris in Logged and Unlogged Basins of Western Washington. *Canadian Journal of Fisheries and Aquatic Science* 51:37-51.

Reisner, D. W. and T.C. Bjornn. 1979. Habitat Requirements of Anadromous Salmonids. Pages 1-54 in W. R. Meehan, ed. *Influence of Forest and Range Management on Anadromous Fish Habitat in Western North America.* U. S. Forest Service Gen. Tech. Report PNW-96. Pacific Northwest Forest and Range Experiment Station, Portland, Oregon.

Sauer, Leslie Jones, and Andropogon Associates. 1998. The Once and Future Forest: A Guide to Forest Restoration Strategies. Island Press.

Scarlett, W.J. and Cederholm, C.J. 1984. Juvenile Coho Salmon Fall-Winter Utilization of Two Small Tributaries of the Clearwater River, Jefferson County, Washington. Pages 227-242 in J.M. Walton and D.B. Houston, eds. *Proceedings of the Olympic Wild Fish Conference.* Peninsula college, Fisheries Technology Program, Port Angeles, Washington.

Schueler, Tom. 1995. *Site Planning for Urban Stream Protection.* Washington D. C., Metropolitan Washington Council of Governments and the Center for Watershed Protection.

Scott, J.B, C.R. Steward, and Q.J. Stober. 1986. "Effects of urban development on fish population dynamics in Kelsey Creek, Washington." Fisheries Research Institute, University of Washington. Seattle, Washington. *Transactions of the American Fisheries Society* 115:555-567.

Sedell, James R., Gordon H. Reeves, F. Richard Hauer, Jack A. Stanford, and Charles P. Hawkins. 1990. Role of Refugia in Recovery from Disturbances: Modern Fragmented and Disconnected River Systems. *Environmental Management* 14(5):711-724.

Sedell, James R., P. A. Bisson, F. J. Swanson, and S. V. Gregory. 1988. What We Know About Large Trees That Fall Into Streams and Rivers. In *From the Forest to the Sea: A Story of Falled Trees.* USDA Forest Service and U. S. Department of Interior, BLM. General technical Report PNW-GTR-229: 47-112. Portland, OR.

Shaw, David C. and Ken Bible. 1996. An Overview of Forest Canopy Ecosystem Functions with Reference to Urban and Riparian Systems. *Northwest Science,* 70. Special Issue, 1996.

Skidmore, Peter, Paula Cooper, and Karin Boyd. 1999. Methodology for Determining Meander Corridor Limits. Pages 421-424 in Watershed Management to Protect Declining Species, Proceedings of the 1999 Annual Water Resources Conference of the American Water Resources Association. Seattle, Washington.

Sparks, Richard E, Peter B. Bayley, Steven L. Kohler, and Lewis L. Osborne. 1990. Disturbance and Recovery of Large Floodplain Rivers. *Environmental Management,* 14(5):699-709.

Spence, B. C., G.A. Lomnicky, R.M. Hughes, and R.P. Novitzki. 1996. *An Ecosystem Approach to Salmonid Conservation.* TR-4501-96-6057. ManTech Environmental Research Services Corp., Corvallis, Oregon.

Stanford, J. A. 1998. Rivers in the Landscape: Introduction to the Special Issues on Riparian and Groundwater Ecology. *Freshwater Biology* 40: 402.

Swanson, F. J., S.V. Gregory, J. R. Sedell, and A.G. Campbell.1982. Land-Water Interactions: The Riparian Zone. In Robert L. Edmunds, ed. *Analysis of Coniferous Forest Ecosystems in the Western United States.*

Tabacchi, E., Correl, D. L., Hauer, R., Pinay, G., Planty-Tabacchi, A., Wissmar, R.C. 1998. Development, Maintenance and Role of Riparian Vegetation in the River Landscape. *Freshwater Biology* 40:497.

Todd, Albert J. 2000. Making decisions about riparian buffer width. Pages 445-450 in P. J. Wigington and R. L. Beschta, eds. *Riparian Ecology and Management in Multi-Land Use Watersheds.* American Water Resources Association, Middleburg, Virginia.

Van Sickle, J. and Gregory, S. V. 1990. Modeling Inputs of Large Woody Debris to Streams from Falling Trees. Can. J. For. Res. 20; 1593-1601.

WORC. 1999. *Soils for Salmon: The Urban Environment.* A conference sponsored by the Washington Organic Recycling Council, Pacific Lutheran University, October 6, 1999. Abstract Prepared by J. Marx, A. Bary, S. Jackson, D. McDonald, H. Wescott.

Chapter 2
Application of the Science – An Inventory of Significant Riparian and Wetland Resources

- The biological needs of salmon and trout
- The riparian area
- Riparian functions
- Bibliography

Purpose of the Inventory

The inventory section of this report identifies significant environmental resources located near small streams, sloughs, and wetlands within the City of Portland. Inventories provide the information necessary to locate and evaluate natural resources, and develop programs to conserve and protect them — using both regulatory and non-regulatory approaches. Inventories provide an informational resource to help communities manage their natural resources. Inventories also provide a record of current conditions — the starting point as we discuss plans for the future.

Inventories provide the information necessary to locate and evaluate natural resources, and develop programs to protect them.

One purpose of the inventory map is to identify specific areas surrounding Portland streams and wetlands that require special attention.

The result of this inventory is a map of significant resources. One purpose of the inventory map is to identify specific areas surrounding Portland streams and wetlands that require special attention. A specific effort was made to identify those areas not already protected by the City of Portland's environmental overlay zoning regulations. Upland habitat areas with no direct connection to stream corridors or wetlands were not evaluated. Resource areas located directly along the Willamette and Columbia Rivers are identified in separate inventories.

Riparian Areas and Wetlands

As discussed in the literature review (Chapter 1), the riparian area is the area adjacent to a river, lake, or stream. It is the area where water and land meet. It is a more precise technical term for "streamside areas." The riparian area includes:

- The area along a stream subject to flooding, where there is direct contact between water and the surrounding landscape, and where the physical landscape and geology is shaped by the processes of flowing water;
- The area of vegetation (including the tree canopy) surrounding the stream that is influenced or supported by stream hydrology and geology;
- The "zone of influence" for key ecological interactions between uplands and aquatic ecosystems; and
- "Any vegetation adjacent to water bodies, that if removed, could result in a measurable change in the physical, chemical, or biological properties of the water body." (Pollock and Kennard, 1998)

Wetlands are defined by the Portland City Code and many other regulatory authorities as:

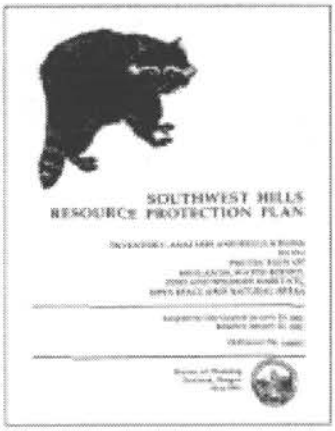
> "An area that is inundated or saturated by surface or ground water at a frequency and duration sufficient to support, and that under normal circumstances does support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands include swamps, marshes, bogs, and similar areas." (Portland City Code, Section 33.910, Definitions)

In addition to identifying riparian resources, this inventory identifies wetlands regulated by Metro's Title 3 that are not already regulated by the City of Portland's environmental overlay zoning regulations, including:

- Wetlands fed by surface flows, sheet flows, or precipitation, that have evidence of flooding during the growing season, have 60 percent or greater vegetative cover, and are larger than ½ acre in area;
- Wetlands that qualify as having "intact water quality function" under the 1996 Oregon Freshwater Assessment Methodology;
- Wetlands that are in a Flood Management Area, have evidence of flooding during the growing season, are larger than 5 acres, and have a restricted outlet or no outlet;
- Wetlands that qualify as having "intact hydrologic control function" under the 1996 Oregon Freshwater Assessment Methodology; and
- Wetlands, or portions of wetlands that are within ¼ of a mile from a water body which meet the Oregon Department of Environmental Quality definition of a "water quality limited water body" in Oregon Administrative Rules (OAR) Chapter 340, Division 41 (1996).

Organization of the Inventory

The City of Portland's existing natural resource inventories are included within a series of eight adopted plans. The resource summaries included with this report are organized based on these existing study areas:



- The *Johnson Creek Basin Protection Plan* (including the *Boring Lava Domes Supplement*)
- The *Columbia Corridor Industrial/Environmental Mapping Project*
- The *Balch Creek Watershed Protection Plan*
- The *Northwest Hills Natural Areas Protection Plan*
- The *Southwest Hills Resource Protection Plan*
- The *East Buttes, Terraces and Wetlands Conservation Plan*
- The *Fanno Creek and Tributaries Conservation Plan*
- The *Skyline West Conservation Plan*

Figure 2 shows the areas covered by each plan. Each of these areas is further divided into resource sites, based generally on watershed sub-basin boundaries, or other prominent physical features such as forests, buttes or bluffs. Readers interested in reviewing the inventory information relevant to a specific neighborhood or individual property may request the portions of the report most relevant to them.

Figure 2: Environmental overlay zoning study areas

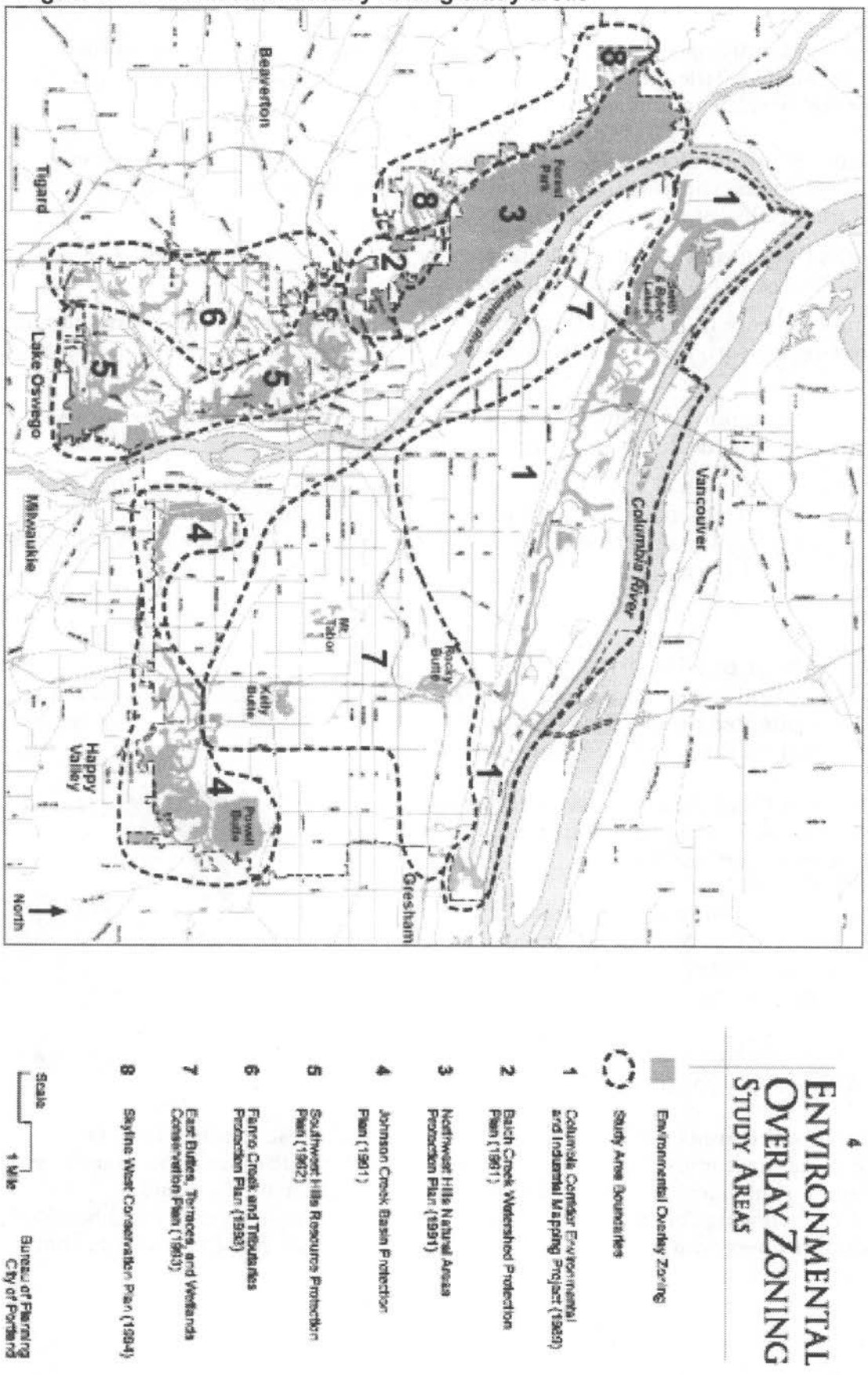
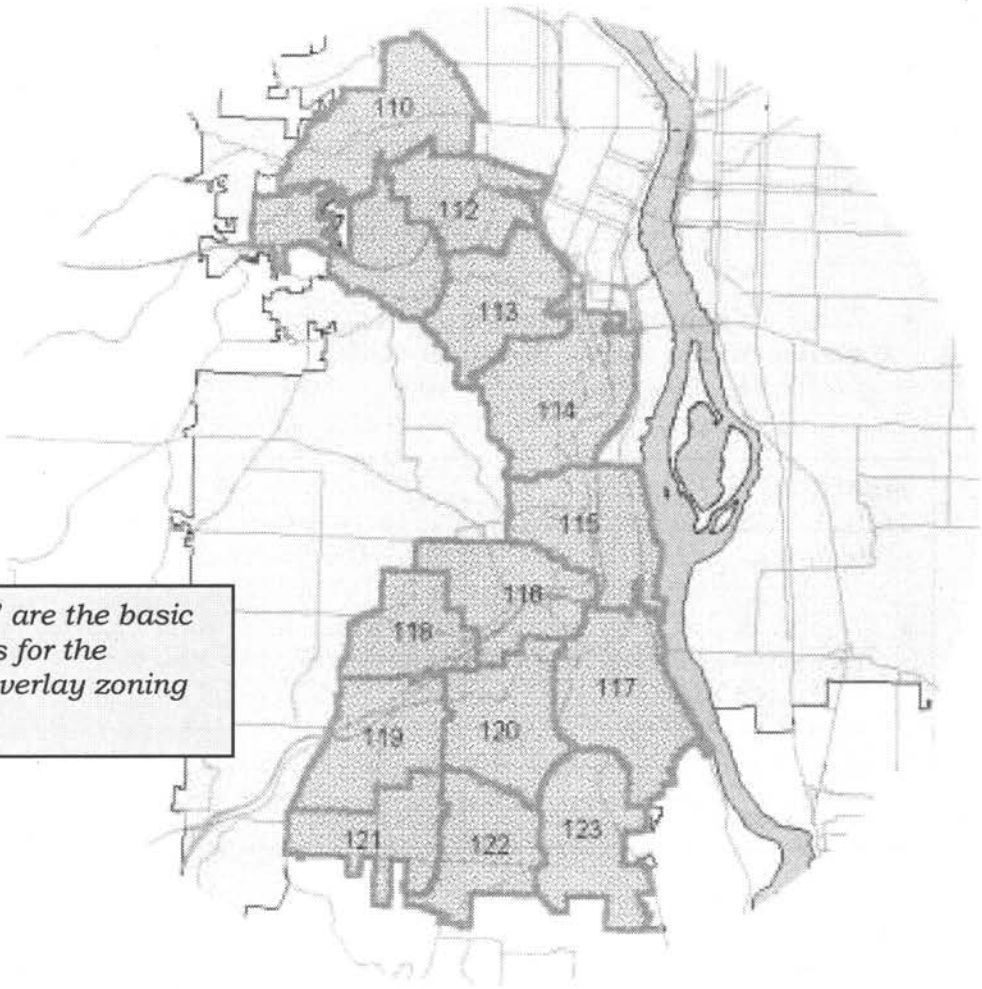


Figure 3: Resource Sites

This map shows resource sites within the Southwest Hills Resource Protection Plan area (Study Area 5 on the previous map). Other plan areas are also divided into resource sites.



"Resource sites" are the basic units of analysis for the environmental overlay zoning program.

Criteria Used to Identify and Map Significant Resources

Matrix of Significance Factors

Table 4 is an adaptation of a tool the City of Portland has used in the past to identify and evaluate the relative "significance" of natural areas and open spaces, based on the benfits they provide. This table serves to describe the specific land features that provide those benefits (or functional values). Table 4 provides a set of consistent criteria to identify and map significant areas. Previous inventory efforts have been based on similar criterion. The table developed for this project is designed to capture the benefits provided by riparian areas and wetlands. It is designed to incorporate the scientific principles discussed in Chapter 1 of this report. Federal and state resource agencies have developed similar tools to

"Functional values" are the benefits provided by resources.

Table 4 is designed to capture the benefits provided by riparian areas and wetlands.

use as a basis for resource evaluation (for example, the National Marine Fisheries Service publishes a similar "matrix" summarizing the needs of salmon and trout based on specific habitat characteristics).

Table 4 is organized as follows:

- The left column lists the resource benefits (or "functional value") of riparian areas and wetlands;
- The middle column identifies general land features that are associated with that functional value; and
- The right column provides a set of criteria (*significance factors*) to help map significant resources. Significance factors are described either as *decision factors* or *contributing factors.*

Significance Factors
The concept of significance factors is used to establish the relative functional importance of an individual land feature. Significance Factors are divided into two groups:

- *Decision factors are those factors which, on their own, are important and establish the resource as significant.*
- *Contributing factors are factors that have limited or moderate importance on their own, but when considered in combination with other decision or contributing factors for the same resource, that resource is deemed significant.*

"Areas of Influence"

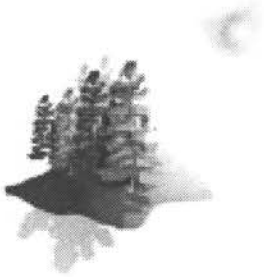
The riparian area is often defined as the area within which certain land-to-water ecological interactions occur. The riparian area might also be described as an *area of influence* surrounding a body of water. Any program designed to protect streams and wetlands must consider not only the location of existing resource areas, but also the geographic extent of land-to-water ecological interactions.

Within what areas can urban development disrupt the ecological benefits provided by riparian areas?

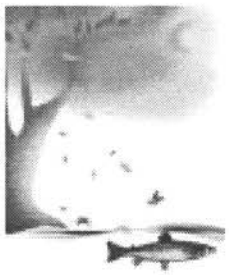
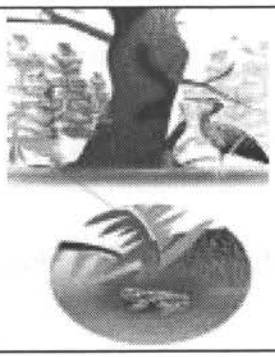
Chapter 1 of this report provides a review of current scientific literature that addresses this question.

Given the riparian functions identified in Table 4, within what areas can urban development disrupt the ecological benefits provided by riparian areas? Special land use regulations may be appropriate in these areas. These areas could also potentially become priority areas for incentive programs, environmental education, or land acquisition programs. To determine the appropriate area of influence it is necessary to describe ecological interactions that occur between streams and the surrounding land area. These interactions are discussed in detail in the first chapter of this report.



	Riparian Benefit/Functional Value	Land Features that Provide Benefit
	Water Quality (including sediment filtering, nutrient/pollutant filtering, erosion control, and stream bank stability)	Vegetation and streambank areas. Vegetation growing from the streambank can help prevent erosion. Roots and fallen tree trunks may also stabilize stream channel banks. Artificial channelization of stream reaches can lead to additional erosion in other downstream reaches. Vegetation growing in the riparian area also filters sediment, excess nutrients, and chemical pollutants from stormwater runnoff. This functional value occurs where stormwater is allowed to flow through riparian vegetation before entering the stream channel. Healthy soil. Maintaining un-compacted topsoil that is rich in organic materials allows stormwater to infiltrate into the ground rather than flow over the surface (reduced surface erosion). Wetlands and floodplains. Passing water through a wetland or vegetated floodplain also helps remove sediment, excess nutrients, and chemical pollutants.
	Riparian Microclimate	Stands of trees and shrubs. Stands of trees and other vegetated areas can impact air temperature and humidity within the riparian area of an individual stream reach. The local humidity and air temperature can impact water temperature in small streams and impact localized habitat conditions. Topographic features. Localized topography can also impact air temperature and humidity (for example, a riparian area in a deep gorge may be cooler).
	Water Quantity: Stream Flow, Sources, and Storage	Springs, seeps, and wetlands. These land features supply water to streams (cold water sources are particularly important in an urban area). Forests. Headwaters and riparian forests act as a sponge to hold water, slow stormwater runoff, and maintain stable flow in streams (baseflow). Wetlands and floodplains. These areas store floodwaters and reduce "flashy" stream hydrology. Healthy soil. Un-compacted topsoil rich in organic materials can hold water and slow stormwater runoff.

Significance Factors (Decision Factors and Contributing Factors)
The land feature is significant if it is: • within 50 feet of a perennial, seasonal, or ephemeral stream; or • within 200 feet of a perennial, seasonal, or ephemeral stream if the slope is greater than 25 percent; or • a wetland within ¼ mile of a stream that has intact "water quality function" according to the 1996 Oregon freshwater Wetland Assessment Methodology; or • within 50 feet of a hydrologically-connected wetland or within an area subject to frequent flooding (approximated by 1996 flood inundation area surrounding tributaries). When considered with other resource functions, this functional value may be a contributing factor if the land feature is: • located on a hillside with a slope steeper than 25 percent, if that slope begins within 50 feet of a perennial, seasonal, or ephemeral stream.
The land feature is significant if it is: • within 50 feet of a perennial, seasonal, or ephemeral stream; or • within 50 feet of a hydrologically-connected wetland or within an area subject to frequent flooding (approximated by 1996 flood inundation area surrounding tributaries). When considered with other resource functions, this functional value may be a contributing factor if the land feature is: • within 50 to 250 feet of a perennial, seasonal, or ephemeral stream.
The land feature is significant if it is: • hydrologically-connected to the stream channel; or • a wetland within ¼ mile of a stream that has intact "hydrologic control function" according to the 1996 Oregon freshwater Wetland Assessment Methodology. When considered with other resource functions, this functional value may be a contributing factor if the land feature is: • contiguous to the riparian area (for example, stands of trees that are contiguous with the stream, but extend farther than 200 feet from the channel).

	Riparian Benefit/Functional Value	Land Features that Provide Benefit
	Organic Materials	Vegetation. Trees and other overhanging vegetation are a source of leaf-litter, fallen branches, logs, and other organic matter. This material is an important food source for the organisms that fish eat (aquatic and terrestrial invertebrates). Floodplains. Organic material can enter the aquatic environment by falling into the stream, or when the stream floods and carries away organic material from a vegetated area.
	Channel Dynamics	Large trees. Stream channels that have complex "structure" support a larger diversity of wildlife (for example, a variety of features, such as pools, areas of white water, meanders). Large wood that falls into the stream channel can create pools and other complex channel habitat features. Side-channels, oxbows, and off-channel wetlands. These areas provide refuge for fish during flooding, when the current in the main channel may be too fast. The Meander Zone. Low gradient streams tend "snake" across their floodplain in a series of "S"-curves. This is a natural hydrologic process. Altering this natural flow pattern in one location can cause significant change in another location as the stream seeks a new equilibrium. Human structures built in the meander zone can interfere with natural stream hydrology, and lead to decreased in-stream habitat complexity. Streambank Areas. The landscape in close proximity to a stream is a dynamic place. Pools, small backwaters, meanders, and other important stream channel features will not form if the channel is confined to a narrow space.
	Riparian Wildlife Habitat and Connectivity	Corridors of native vegetation. Wildlife species require access to water, food, and cover/shelter. Wildlife cannot survive in isolated patches of habitat if water, food, or cover is absent. Some wildlife species also require an area of suitable habitat of a certain minimum size. Corridors of natural vegetation along streams provide pathways for wildlife movement between larger natural areas. Maintaining such pathways helps to reduce the impact of habitat fragmentation.

Significance Factors (Decision Factors and Contributing Factors)
The land feature is significant if it is: • within 100 feet of a perennial, seasonal, or ephemeral stream; or • within 50 feet of a hydrologically-connected wetland or within an area subject to frequent flooding (approximated by 1996 flood inundation area surrounding tributaries). When considered with other resource functions, this functional value may be a contributing factor if the land feature is: • within 100 to 200 feet of a perennial, seasonal, or ephemeral stream; or • within the vegetated portion of the 100-year floodplain.
The land feature is significant if it is: • within 100 feet of a perennial, seasonal, or ephemeral stream accessible to an ESA-listed fish species (or a reach that could realistically be accessible in the near future); or • within 50 feet of a hydrologically-connected wetland, side channel, old oxbow, or within an area subject to frequent flooding (approximated by 1996 flood inundation area surrounding tributaries); or • located on a hillside abutting the outside curve of a stream meander, where there is a slope of more than 25 percent; or • located within an "S" - curve in a stream channel (for example, land surrounded by an oxbow). When considered with other resource functions, this functional value may be a contributing factor if the land feature is: • within 50 feet of a perennial, seasonal, or ephemeral stream; or • within 100 to 200 feet of a perennial, seasonal, or ephemeral stream accessible to an ESA-listed fish species (or a reach that could realistically be accessible in the near future); or • within the 100-year floodplain more than 200 feet from a stream.
The land feature is significant if it is: • within 100 feet of a perennial, seasonal, or ephemeral stream; or • within 50 feet of a hydrologically-connected wetland or within an area subject to frequent flooding (approximated by 1996 flood inundation area surrounding tributaries). When considered with other resource functions, this functional value may be a contributing factor if the land feature is: • within 100 to 300 feet of a perennial, seasonal, or ephemeral stream.

Table 5 Applicability of Resource Functions in the Columbia Slough

Function	Applicable?
Water Quality (including sediment filtering, nutrient/pollutant filtering, erosion control, stream bank stability)	Yes – Vegetation within the levee cross-sections may play an important role in improving water quality. The watershed is relatively flat, but it is no longer allowed to flood. Water flow is based on a complex system of pipes, ditches, and pumping stations. Significance factors must be modified to account for these realities.
Riparian Microclimate	Yes – Slough water quality is limited by temperature problems. Forested areas can provide cooling and prevent direct heating of stagnant water from the sun.
Sources of Stream Flow, and Flood Storage	Yes – Where springs and seeps still exist, these areas provide important sources of cool water. Floodplain resources are limited in this watershed as most areas are managed by a drainage district (the FEMA floodplain is a function of pumping capacity rather than topography).
Organic Materials	Yes – To the extent that the slough is surrounded by vegetation, levels of leaf litter and organic debris would be effected. This could have an effect on aquatic organisms. Floodplain resources are limited in this watershed as most areas are managed by a drainage district (the FEMA floodplain is a function of pumping capacity rather than topography).
Channel Dynamics	Very Limited – Because much of the watershed is managed by a drainage district (pump stations, levees, etc.), there is very little opportunity to facilitate dynamic changes to the channel. Much of this watershed is highly managed, and contains very little variation of in-stream habitat (many channels are trapezoidal, for example). The Drainage District mimics "meander" features within the levee cross-section in some locations, as a part of regular channel maintenance activities. There is no natural pathway for large wood to travel through the system. However, large wood may have localized importance for some species (for example, turtle habitat along the edge of ponds and connected sloughs). ESA-listed fish are not present in the upper watershed due to pump stations and levees.
Riparian Wildlife Habitat and Connectivity	Yes – To the extent that there are vegetated areas large enough to support the species in question (much of the slough is very fragmented). The largest "core" habitat areas are the Smith and Bybee Lakes, West Hayden Island, and areas in the eastern portion of the Columbia South Shore Plan District.

The scientific literature summarized earlier in this report generally supports site-specific analysis where possible. Based on the literature reviewed, project staff concluded that it was advisable to evaluate all areas within 300 feet of streams and other water bodies. Where land is subject to flooding, the floodplain area was also evaluated. This inventory uses the general recommendations of Chapter 1 as a starting point to arrive at a more site-specific identification of significant riparian and wetland resources (which are illustrated with the inventory maps).

The mapped streamside (riparian) area is affected by a variety of site–specific factors, such as:

- Topography (including the specific location of major changes in slope);
- Geology (such as a localized slope failure or slump);
- Vegetation patterns;
- Existing infrastructure that affects drainage and stormwater flowpaths (for example, roads running parallel to the stream, stormwater pipes, etc.);
- Intensity of surrounding land uses.

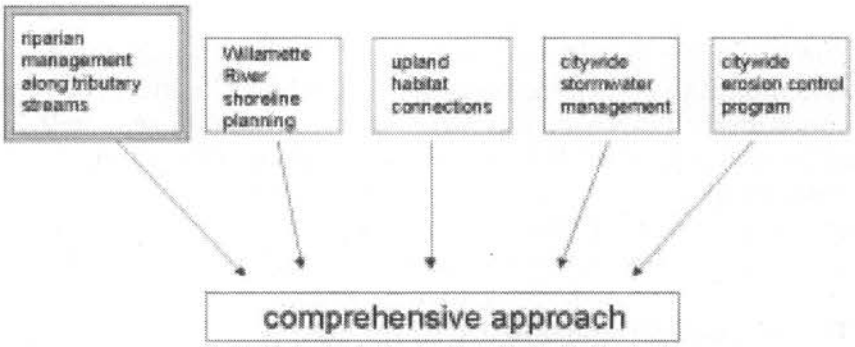
Streamside Protection in the Context of Watershed Management

Many of the scientific studies that focus on urban streams recommend that riparian protection be accompanied by adequate stormwater management, watershed planning, and erosion control standards. Based on those watershed-wide interactions, why doesn't the scope of this inventory include the entire watershed?

A watershed is any area of land from which water, sediment, woody debris and dissolved materials drain to a common point – a river, stream, pond or lake. Mountain ridges form watershed boundaries and control the geographic patterns of drainage.

The present inventory focuses on those ecological interactions that are specific to the streamside (riparian) and wetland environment, recognizing there are a number of other significant impacts that result from land use patterns throughout a watershed. This project is one part in a larger and more comprehensive effort to protect water quality, revitalize streams and rivers, and address Endangered Species Act listings. Figure 4 outlines how this inventory fits into the City of Portland's larger strategy.

Figure 4: Watershed Context of Riparian Management



Relationship of Inventory to Environmental Zones and State Planning Goals

One goal of the Urban Streamside Project is to update the City of Portland's environmental overlay zoning program. Because the environmental overlay zone is a State-acknowledged implementation of Oregon land use law, significant changes to the program must be carried out in compliance with the relevant Oregon Administrative Rules (OARs). The Administrative Rule that governs the Portland's environmental overlay zones outlines specific procedures for adopting and updating a citywide inventory of significant natural resources, and establishes a legal foundation for the City's decision-making process when land use regulations are proposed to protect inventoried natural resources.

Statewide Planning Goal 5 requires local governments to follow a four-phase natural resource planning process. This chapter addresses the first phase in that process – an inventory. The four phases are:

Phase 1. Inventory Resources
This involves determining the location, quantity, and quality of natural areas and open spaces in Portland. At the conclusion of this process, all sites deemed "significant" must be included in an adopted inventory and are subject to the remaining steps in the process. This chapter describes the methodology and results of that inventory process.

This chapter describes the methodology and results of the inventory process (Phase 1 of the State Goal 5 Process).

Phase 2. Identify Potential Development Conflicts
This step involves examining the land uses allowed by the City's Zoning Code in the areas where significant resources are identified. Land uses that might conflict with resource protection are identified. Impact areas are also determined during this phase. The impact area is the area surrounding a significant resource where allowed land uses could have an adverse affect on that resource (much like the "areas of influence" described earlier).

Phase 3. ESEE Analysis
Where conflicting uses are identified, the economic, social, environmental, and energy (ESEE) consequences of resource protection must be evaluated. This analysis is done by asking, "What are the ESEE consequences of allowing the



conflicting use?" and "What are the ESEE consequences of fully protecting the resource?" The ESEE Analysis is available under separate cover.

Phase 4. Adopt (or Update) the Protection Plan
The final step is adoption of a program or plan to protect significant resources. Based on the inventory and ESEE analysis, cities have three choices (OAR 660-023):

1. The conflicting use can be allowed without restriction, with no protection for the resource;
2. The conflicting uses can be limited — to provide a balance of protection and development; or
3. The conflicting uses can be prohibited, and the resource fully protected.

Local governments must then adopt a program to carry out these decisions. In the past the City of Portland has relied on the environmental overlay zoning designations to satisfy the requirements of State Planning Goal 5. The "strategies" section of this report includes suggested updates to Portland's existing regulatory program. This report also identifies possible non-regulatory approaches to protecting natural resources.

Inventory Process

The inventory phase consists of four steps:

1. Collect information about resource sites;
2. Determine the adequacy of that information;
3. Determine the significance of resource sites; and
4. Adopt a list or map of significant resource sites.

The inventory step described in the Oregon Administrative Rules requires the City to identify "significant" resource sites. In this context, when the City makes a determination that a resource is significant, that determination places that resource on the City's list of significant resource sites. This determination by itself does not have any regulatory impact on the site. The term "significant" in this context should not be confused with the meaning of the same term in statistical sampling. A determination of significance simply means that the resource site is important enough to warrant consideration of protective regulations (pending further analysis). Zoning protections are not applied until that (ESEE) analysis process is complete.

A determination of significance simply means that the resource site is important enough to warrant consideration of protective regulations (pending further analysis). Zoning protections are not applied until the ESEE analysis process is complete.

Review of Existing Information

The inventory process begins with the collection of existing and available information, including inventories, surveys, and other applicable data about potential resource sites.

The present inventory effort serves to amend the City of Portland's existing (State-Acknowledged) inventory. These amendments are limited in scope to:

- Changes based on the recent listing of salmon and trout species as threatened under the Endangered Species Act; and
- Changes based on recent research regarding the significance of riparian and wetland resources for water quality and wildlife habitat purposes.

This report does not replace the City's previously acknowledged Goal 5 inventory – rather it is a supplement to that previous work.

The existing environmental zones are based on a series of eight adopted natural resource plans (listed earlier in this chapter). Detailed information regarding resource location, quality, and quantity was collected during previous inventory efforts, and is presented in those plans, available from the Bureau of Planning.

Relevant state and federal agencies were consulted during the preparation of the above listed plans. During the development of these plans, the City of Portland also carried out extensive field surveys using the Wildlife Habitat Assessment (WHA) Protocol (see Appendix). The result of that survey work is that all identified Goal 5 resource sites within the City have been rated according to relative wildlife habitat value. The current inventory effort does not seek to replicate those wildlife habitat assessments, but is intended to provide a supplement of those assessments based on new information.

Collection and Review of New Information

In addition to the existing inventory reports, this report relies on several specific sources of new information:

- Since the listing of steelhead trout and chinook salmon as threatened under the Endangered Species Act, the City has been working with the National Marine Fisheries Service (NMFS) and other natural resource agencies to better understand the needs of these species. Toward that end, federal and state agencies have provided extensive information, which has been integrated into the science presented in Chapter 1 of this report. A complete bibliography is included with that framework.
- The City has worked with adjacent jurisdictions and the Oregon Department of Fish and Wildlife (ODFW) to obtain more detailed surveys of the habitat features within urban stream channels. Information collected includes the location of stream features such as pools, riffles, large wood, the type of channel substrate, stream bank conditions, etc. This work was carried out using an aquatic habitat inventory methodology being used throughout the state to characterize streams



for salmon habitat restoration purposes (ODFW's Aquatic Inventories Project). See the Appendices for more detailed information.

- The Bureau of Environmental Services has completed additional assessments in the Fanno and Tryon Creek watersheds (the *Fanno Creek Resource Management Plan*, 1998; and *the Upper Tryon Creek Corridor Assessment*, 1997). Information available in these reports includes fish habitat quality assessments, stream channel erosion assessments, and wildlife habitat surveys.
- In cooperation with ODFW, the City has completed an inventory of culverts under City jurisdiction, and a preliminary assessment of fish passage. This information is particularly relevant to riparian restoration objectives and related resource values because as additional reaches are made accessible to fish through culvert replacements or improvements, there is a need to ensure that riparian areas adjacent to these reaches are protected.
- Using 1998 and 1999 air photos, the Bureau of Planning prepared a citywide inventory of existing vegetated riparian corridors using a visual assessment methodology. This information was used to assess the relative quantity of riparian vegetation throughout the City. See *Vegetated Riparian Corridors-Visual Survey of Existing Conditions* in the Appendices for more information.
- The Bureau of Environmental Services is developing proposals to address flooding in the Johnson Creek Basin (The Johnson Creek Restoration Plan). As part of that effort, BES has collected and prepared information on flood frequency, stream flows, and has prepared detailed models of basin hydrology. The Bureau of Planing reviewed and considered this information. As part of this effort the Bureau of Environmental Services completed additional wetland assessments in the Johnson Creek Basin, which are described in a report published in September, 2000 (*Wildlife Habitat Assessments, Wetland Delineations, and Functional Value Assessments - Johnson Creek Predesign Sites: Tideman Johnson, Errol Heights, Lents, and Lower Powell Butte Target Areas).*
- To better understand how salmon and trout use Portland's smaller watersheds, the City is developing a long-term fish-presence monitoring effort. While there have been fish population surveys in some Portland streams (some are cited in this inventory), there have not been any that have been repeated to evaluate changes over time or to update old information. This monitoring effort will build on fish surveys that have been conducted in the past as well as complementing a number of ongoing and proposed habitat surveys and integrated assessments. Sample sites have been selected in several watersheds (including Johnson Creek, Tryon Creek, Fanno Creek, Balch Creek and the Columbia Slough). All information collected as a result of this monitoring effort will be compiled in an annual report. The City has obtained a Scientific Take Permit from the Oregon Department of Fish and Wildlife.

In addition to the new information described above, there is an extensive collection of relevant natural resource information available on the World Wide Web. For example:

- The U.S. Geological Survey (USGS) and the City of Portland's Bureau of Environmental Services are cooperating to enhance the surface-water and ground water monitoring of the Johnson Creek Basin. Current temperature and flow data for Johnson Creek collected from several field stations is available on the World Wide Web at: http://wwworegon.wr.usgs.gov/jcrk/jcrk_175.html. Some of this information is updated every half-hour.
- The Bureau of Environmental Services, working in partnership with Portland State University, completed an assessment of Johnson Creek habitat during the summer of 1998. The Johnson Creek Assessment was an attempt to create a baseline data set of the stream and riparian habitat conditions. The data collected, using the EPA's Rapid Bio Assessment Protocol, was compiled and linked to maps.
- The City of Portland Auditor's Office has prepared a report describing relevant data that is being collected (or should be collected) to monitor the City's progress toward restoring viable salmon populations. The benchmark report is currently available at:
  http://www.p-m-benchmarks.org/tblcnts.html
- Additional information concerning salmon and trout ecology is available from the National Marine Fisheries Service on the World Wide Web at:
  http://www.nwr.noaa.gov/1salmon/salmesa/pubs.htm.
- Information regarding ODFW's Aquatic Inventory Program is currently available on the World Wide Web at:
  http://osu.orst.edu/Dept/ODFW/freshwater/inventory/invent.html.

As required by OAR 660-023 (Oregon Administrative Rules, Procedures and Requirements for Complying with Goal 5), the Bureau of Planning also consulted the following sources:

- Oregon Department of Forestry stream classification maps;
- United States Geological Service (USGS) 7.5 minute quadrangle maps;
- National Wetlands Inventory maps;
- Oregon Department of Fish and Wildlife (ODFW) maps indicating fish habitat; and
- Current Federal Emergency Management Agency (FEMA) flood maps, including recently revised maps for Johnson Creek.

Determine the Adequacy of Information

Information about a particular resource site is deemed adequate if it provides the location, quality and quantity of the resource.

- Information about location must include a description or map of the resource area for each site. The information must be sufficient to determine whether a resource exists on a particular site.

- Information on quality must indicate a resource site's value relative to other known examples of the same resource.
- Information on quantity must include an estimate of the relative abundance or scarcity of the resource.

As noted above, the City's existing inventory of significant resource sites is described in a series of natural resource plans (for example, the Johnson Creek Basin Protection Plan, Fanno Creek and Tributaries Conservation Plan, etc.). The present inventory relies on those previously adopted and acknowledged inventory maps to establish baseline resource location, quality, and quantity. As the existing resource plans were prepared, each plan area was divided into specific resource sites. Each of the existing resource plans includes maps showing the location of significant resource sites. This report includes revised resource site maps identifying any significant resource areas not previously mapped.

It has been more than 12 years since the first resource inventories were done to establish the City's existing environmental zoning maps. The resource information collected as part of this report emphasizes many of the specific riparian and water-resource functions relevant to salmon and trout conservation, and water quality. It serves to supplement and improve upon previously collected data – in particular to highlight specific functionally important resource functions and land features not previously evaluated.

The present inventory relied on 1998 and 1999 air photos, and other information available from the City's Geographic Information system to re-map significant resource sites based on new resource information. These air photos allow the City to confirm the location of specific land features known to have functional value (forested areas, streams, wetlands, etc.).

The existing inventory reports contain detailed written descriptions of each significant resource site. Those descriptions include lists of the *functional values* attributed to each site, summaries of the significant land features noted within each site, and information on the relative quality of resources. The City has used the concept of functional value to evaluate the relative significance of resource sites and specific land features within those resource sites.

Many of the functional values discussed in this report relate to the habitat needs of threatened salmon and trout. It is important to note that the resource being inventoried with this effort is the riparian area, wetlands, and the resource functions that occur in that area, not the threatened salmon and trout themselves. As discussed in the Technical Background Report, recovery of salmon and trout populations is closely related to the ecological health of whole watersheds. Salmon and trout exhibit a complex life history, migrating from small streams to the ocean and back again. Many of these species cannot survive in isolated refuges disconnected from the sea. As a result, salmon recovery must focus on improving general habitat features related to overall watershed and stream health. Although the City is taking steps to monitor the specific location and quantity of salmon and trout in Portland's small streams, resource significance is not based only on the

current presence or absence of fish in a particular stream reach (though documented presence is certainly considered). One of the reasons that salmon and trout are threatened is that the environmental conditions in too many of our streams are not suitable.

Public Involvement

This document is the first public draft of this inventory and proposed regulatory program. The intent of this draft is specifically to allow for public input prior to formal presentation of this inventory to the Planning Commission. It is important to emphasis that this report is preliminary in nature – public comments are strongly encouraged.

The Bureau of Planning has involved the public in the preparation of this draft report:

- The Bureau of Planning convened a Citizen Review Committee (CRC) for this project in the Spring of 2000. The concepts and proposals included within this report are based on input from that committee. The CRC was re-convened (during September and October 2000) to review more specific proposals. Members of the CRC where appointed by the Mayor, with input from Neighborhood Coalitions. The committee included several landowners with affected property. Copies of the CRC reports are available as an Appendix to this report.
- During the month of October 2000 the Bureau of Planning organized three Open Houses to allow the general public a preview of the proposed inventory maps. Open House visitors where asked to comment on the inventory process and invited to provide additional information about local resource areas.
- During October and November (2000) Bureau of Planning also met with a number of more focused interest groups, including the Columbia Corridor Association Representatives (regarding the Columbia Slough), and Citizens involved in the Lents Urban Renewal District process (regarding Johnson Creek). Preliminary inventory maps were shared with both groups.



Site-specific Inventory Information

Resource Sites – Format of Information

The inventory portion of this report is presented in a series of supplemental resource site summaries. For each resource site, a map is also included showing the specific location of the significant resources identified within that site. Resource sites are organized according to natural resource plan area. Sites 1 through 30 correspond to resource areas in the Johnson Creek Watershed. Sites 36 through 68 are found in the Columbia Corridor. The Northwest Hills and Skyline areas are mapped as sites 73 through 109, and 143 through 145. Southwest Portland resources are described in sites 110 to 131. The following pages provide locator maps for all resource sites described in this inventory.

The following information is summarized for each resource site:

Natural Resource Plan Area: The applicable resource plan describing the site. For example, the *Southwest Hills Resource Protection Plan.* These plans are the reports that established the existing environmental zones. Refer to these existing plans for more detailed information about each site.

Location: A geographic description of the resource site location, such as a major street intersection in the vicinity.

Watershed: The drainage basin within the City of Portland. For example, Tryon Creek, Fanno Creek, Johnson Creek, Balch Creek, etc.

Neighborhood: The recognized Neighborhood Associations in the vicinity of the resource site.

Maps: The relevant USGS quadrangle maps, state section maps, and City of Portland Quarter-Section maps.

Zoning Designations: The current zoning designation for the site (City of Portland base zone).

Description: A brief summary of the type of resources present within the site, including general vegetation characteristics and any other notable landscape features.

Wildlife Habitat Assessment (field survey): The numerical resource quality rating given to the site based on previous field surveys using the Wildlife Habitat Assessment Protocol (a description of that methodology is available in the appendices of this report). This rating system describes the relative value of the site to wildlife based on a variety of factors.

ODFW Aquatic Inventory: A reference to the Oregon Department of Fish and Wildlife's Aquatic Inventories Project report for the site, if available. The Aquatic Inventory Project is designed to provide quantitative information on habitat

conditions for streams throughout Oregon. This information is used to provide basic information for biologists and land managers, to establish monitoring programs, and to direct or focus habitat restoration efforts. Cited reports are filed at the Bureau of Planning, and may also be available from ODFW (see the appendices for more information).

Previously Identified Resources and Functional Values: The existing environmental zones are based on functional values, or specific resource types known to have functional value. For each resource site, previously adopted plans identify the applicable functional values and resource types.

Additional Functional Values Identified: These are additional (or more specific) functional values identified with this project. The additional riparian-related functional values that are the focus of this inventory were discussed earlier in this report. These functional values are the basis for determining if significant resources exist within the resource site outside of the existing environmental zones. These functional values are also discussed in more detail in the first chapter of this report.

Special Status Species: Plant and animal species designated by state or federal resource agencies under the Endangered Species Act or related state programs (see the Appendices for details).

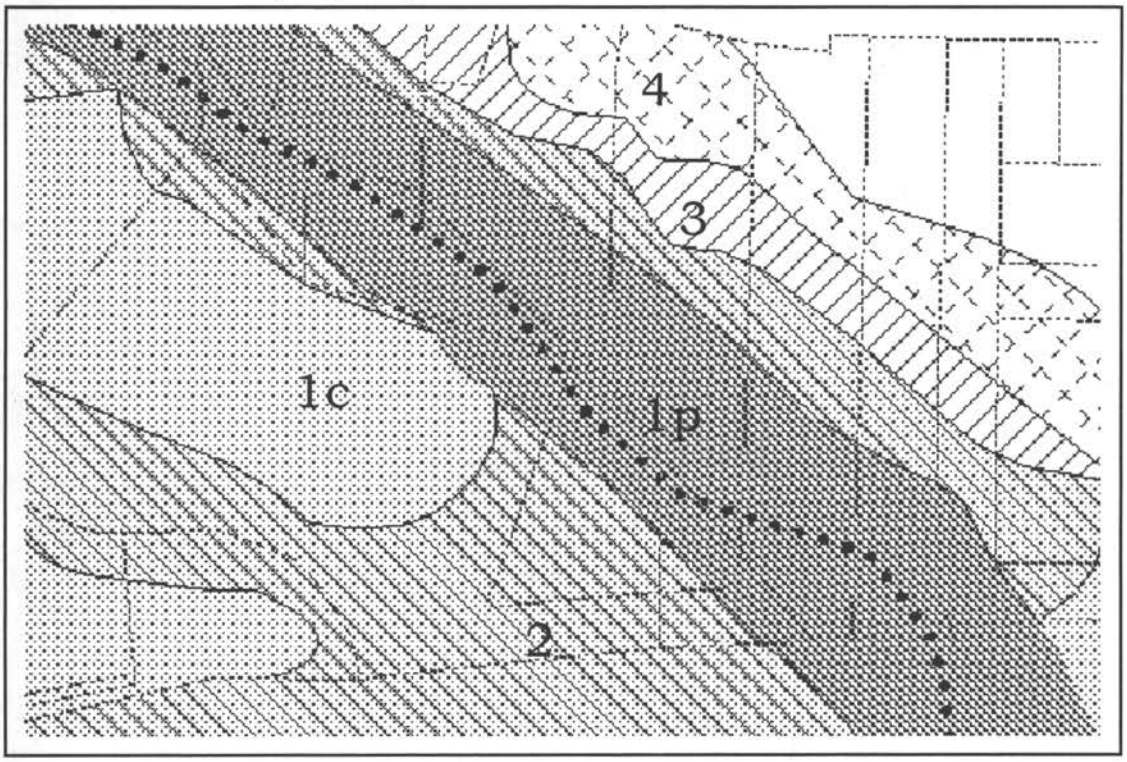
Maps of Significant Resources

A map of each resource site is included with the site summary information. The inventory map shows three different areas:

- The existing environmental zones. There are two existing environmental overlay zones: the "protection zone" and the "conservation zone". Some of the existing conservation zones have been identified for re-evaluation, to determine if a higher level of protection is appropriate.
- Additional significant riparian resource areas have been identified that are not currently within the environmental overlay zone. These areas have been mapped based on the functional values discussed earlier (the matrix of significance factors).
- Other riparian areas have been mapped where few existing resource functions are present, but where land use practices may have significant influence on riparian functions. As discussed above, these "areas of influence" are mapped based on the science presented earlier in this report.

How to Read the Inventory Maps

Figure 4: Inventory Map Key



The inventory maps designate land areas into one of five categories, listed below.

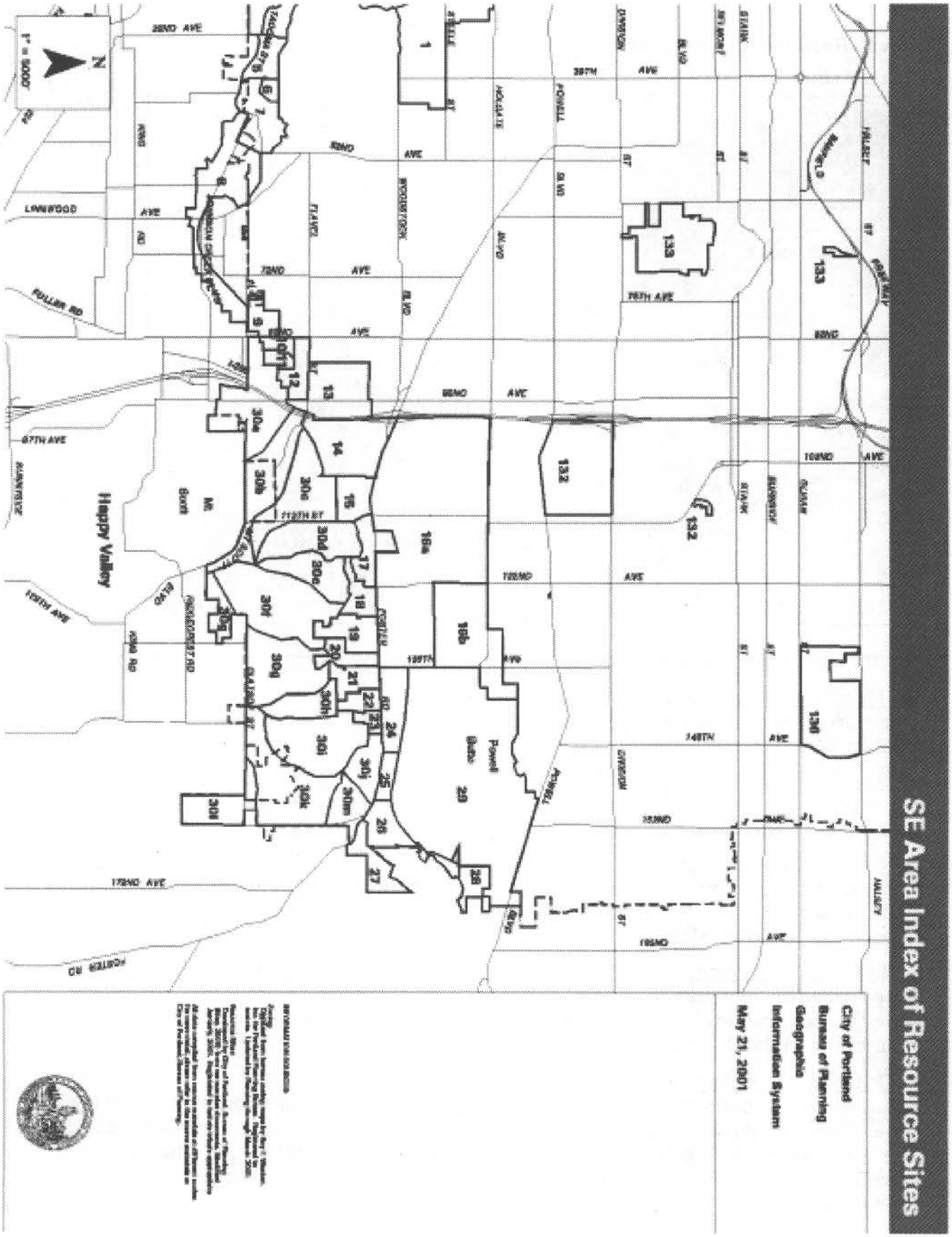
1c. Existing Conservation Zone
These areas are already mapped as significant resources and are within the existing environmental conservation ("c") overlay zone.

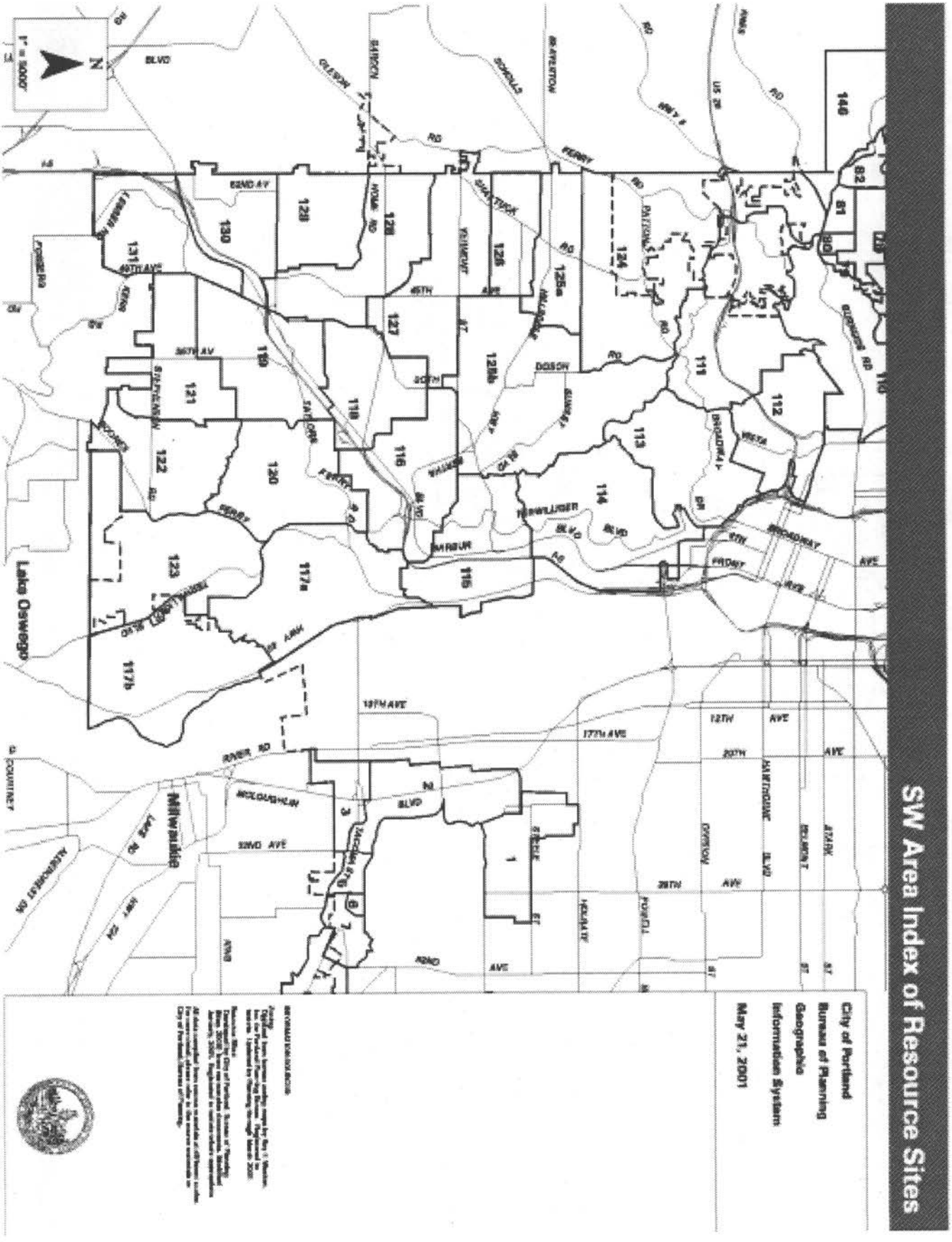
1p. Existing Protection Zone
These areas are already mapped as highly significant resources and are within the existing environmental protection ("p") overlay zone.

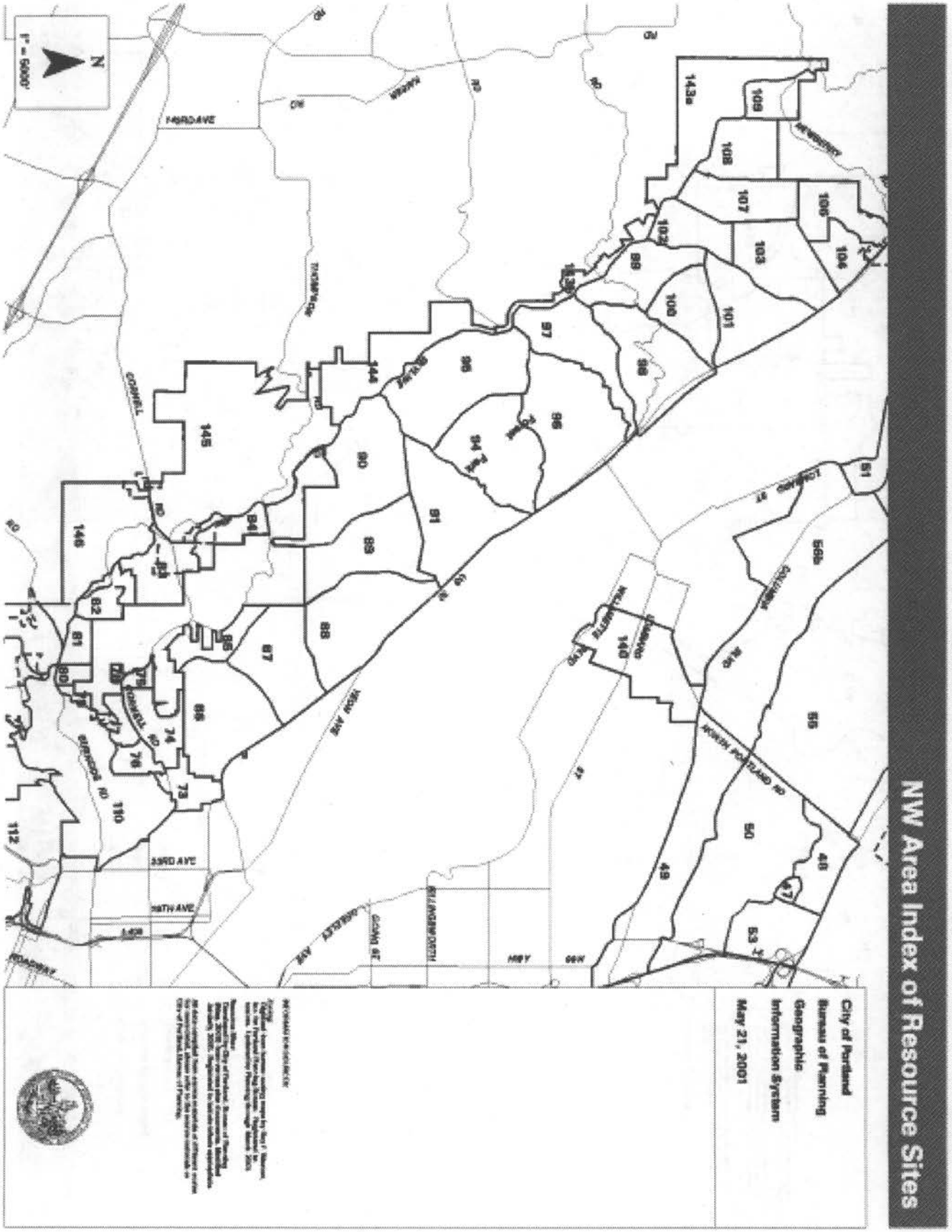
2. Existing Conservation Zone, Elevated Significance
These areas are within the resource area of the existing environmental conservation ("c") overlay zones. These areas are identified for further evaluation. Multiple riparian or wetland-related ecological functions are present in these areas.

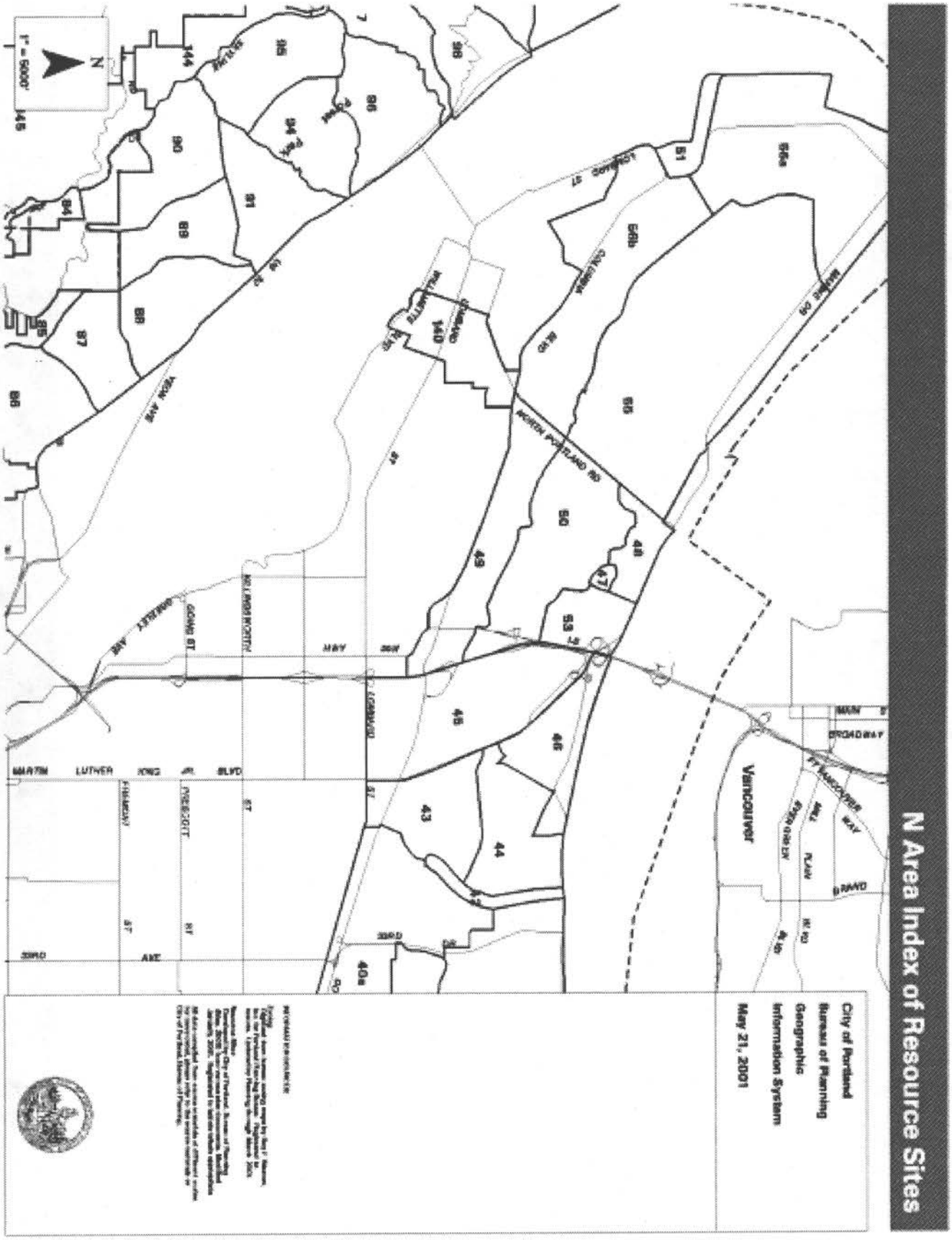
3. Significant Resource Areas Not Already Within the Environmental Overlay Zone.
These areas are not currently within the resource area of the environmental overlay zone. These areas are identified as significant because resources here provide riparian or wetland - related ecological benefits.

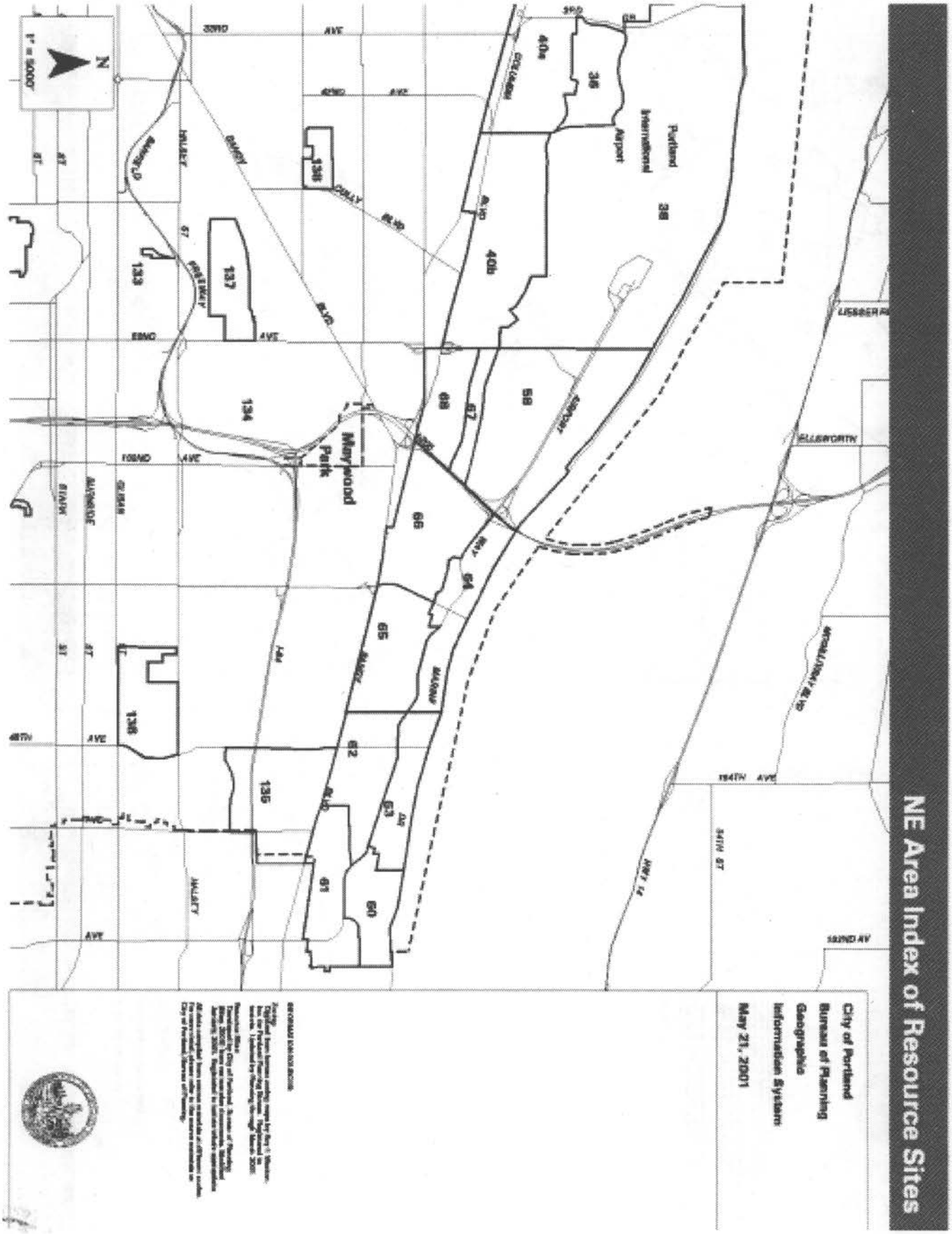
4. Other Areas of Riparian Influence
These areas are not currently within the resource area of the environmental overlay zone. These areas do not currently contain significant environmental resources. The conditions in these areas, however, can impact stream and wetland health. Environmental restoration within these areas would help us maintain or increase the benefits we receive from streams and wetlands.


SE Area Index of Resource Sites
City of Portland
Bureau of Planning
Geographic
Information System
May 21, 2001
Happy Valley
Mt. Scott
Powell Butte
1" = 8000'
N


SW Area Index of Resource Sites
City of Portland
Bureau of Planning
Geographic
Information System
May 21, 2001
Lake Oswego
Milwaukie


NW Area Index of Resource Sites
City of Portland
Bureau of Planning
Geographic
Information System
May 21, 2001
1" = 5000'
N
NW 53RD AVE
CORNELL
THURMAN
NW 25TH AVE
NW 23RD AVE
NW 19TH AVE
NW 18TH AVE
NW 17TH AVE
NW 14TH AVE
NW 13TH AVE
NW 12TH AVE
NW 11TH AVE
NW 10TH AVE
NW 9TH AVE
NW 8TH AVE
NW 7TH AVE
NW 6TH AVE
NW 5TH AVE
NW 4TH AVE
NW 3RD AVE
NW 2ND AVE
NW 1ST AVE
NW 1ST PL
NW 1ST CT
NW 1ST TER
NW 1ST DR
NW 1ST LOOP
NW 1ST WAY
NW 1ST CIR
NW 1ST PKWY
NW 1ST BLVD
NW 1ST ALLEY
NW 1ST PATH
NW 1ST TRAIL
NW 1ST ROAD
NW 1ST STREET
NW 1ST AVENUE
NW 1ST PLACE
NW 1ST COURT
NW 1ST TERRACE
NW 1ST DRIVE
NW 1ST LOOP
NW 1ST WAY
NW 1ST CIRCLE
NW 1ST PARKWAY
NW 1ST BOULEVARD
NW 1ST ALLEY
NW 1ST PATH
NW 1ST TRAIL
NW 1ST ROAD
NW 1ST STREET
NW 1ST AVENUE
NW 1ST PLACE
NW 1ST COURT
NW 1ST TERRACE
NW 1ST DRIVE


N Area Index of Resource Sites
City of Portland
Bureau of Planning
Geographic
Information System
May 21, 2001
Vancouver
MARTIN LUTHER KING JR. BLVD
PRESCOTT ST
FREMONT ST
33RD AVE
GOING ST
COLUMBIA BLVD
NORTH PORTLAND RD
CHARLESTON
PHILLIPPI
CANYON
BARNES DR
SW HOOD
SW 185TH
SW CORNELL RD
SW BARNES RD
SW CANYON CT
SW MACADAM AVE
SW GIBBS ST
SW 1ST AVE
SW 4TH AVE
SW 6TH AVE
SW 10TH AVE
SW 12TH AVE
SW 13TH AVE
SW 18TH AVE
SW 20TH AVE
SW 21ST AVE
SW 26TH AVE
SW 30TH AVE
SW 31ST AVE
SW 33RD AVE
SW 34TH AVE
SW 35TH AVE
SW 37TH AVE
SW 39TH AVE
SW 40TH AVE
SW 41ST AVE
SW 42ND AVE
SW 43RD AVE
SW 44TH AVE
SW 45TH AVE
SW 46TH AVE
SW 47TH AVE
SW 48TH AVE
SW 49TH AVE
SW 50TH AVE
SW 51ST AVE
SW 52ND AVE
SW 53RD AVE
SW 54TH AVE
SW 55TH AVE
SW 56TH AVE
SW 57TH AVE
SW 58TH AVE
SW 59TH AVE
SW 60TH AVE
SW 61ST AVE
SW 62ND AVE
SW 63RD AVE
SW 64TH AVE
SW 65TH AVE
SW 66TH AVE
SW 67TH AVE
SW 68TH AVE
SW 69TH AVE
SW 70TH AVE
SW 71ST AVE
SW 72ND AVE
SW 73RD AVE
SW 74TH AVE
SW 75TH AVE
SW 76TH AVE
SW 77TH AVE
SW 78TH AVE
SW 79TH AVE
SW 80TH AVE
SW 81ST AVE
SW 82ND AVE
SW 83RD AVE
SW 84TH AVE
SW 85TH AVE
SW 86TH AVE
SW 87TH AVE
SW 88TH AVE
SW 89TH AVE
SW 90TH AVE
SW 91ST AVE
SW 92ND AVE
SW 93RD AVE
SW 94TH AVE
SW 95TH AVE
SW 96TH AVE
SW 97TH AVE
SW 98TH AVE
SW 99TH AVE
SW 100TH AVE
SW 101ST AVE
SW 102ND AVE
SW 103RD AVE
SW 104TH AVE
SW 105TH AVE
SW 106TH AVE
SW 107TH AVE
SW 108TH AVE
SW 109TH AVE
SW 110TH AVE
SW 111TH AVE
SW 112TH AVE
SW 113TH AVE
SW 114TH AVE
SW 115TH AVE
SW 116TH AVE
SW 117TH AVE
SW 118TH AVE
SW 119TH AVE
SW 120TH AVE
SW 121ST AVE
SW 122ND AVE
SW 123RD AVE
SW 124TH AVE
SW 125TH AVE
SW 126TH AVE
SW 127TH AVE
SW 128TH AVE
SW 129TH AVE
SW 130TH AVE
SW 131ST AVE
SW 132ND AVE
SW 133RD AVE
SW 134TH AVE
SW 135TH AVE
SW 136TH AVE
SW 137TH AVE
SW 138TH AVE
SW 139TH AVE
SW 140TH AVE
SW 141ST AVE
SW 142ND AVE
SW 143RD AVE
SW 144TH AVE
SW 145TH AVE
SW 146TH AVE
SW 147TH AVE
SW 148TH AVE
SW 149TH AVE
SW 150TH AVE
SW 151ST AVE
SW 152ND AVE
SW 153RD AVE
SW 154TH AVE
SW 155TH AVE
SW 156TH AVE
SW 157TH AVE
SW 158TH AVE
SW 159TH AVE
SW 160TH AVE
SW 161ST AVE
SW 162ND AVE
SW 163RD AVE
SW 164TH AVE
SW 165TH AVE
SW 166TH AVE
SW 167TH AVE
SW 168TH AVE
SW 169TH AVE
SW 170TH AVE
SW 171ST AVE
SW 172ND AVE
SW 173RD AVE
SW 174TH AVE
SW 175TH AVE
SW 176TH AVE
SW 177TH AVE
SW 178TH AVE
SW 179TH AVE
SW 180TH AVE
SW 181ST AVE
SW 182ND AVE
SW 183RD AVE
SW 184TH AVE
SW 185TH AVE
SW 186TH AVE
SW 187TH AVE
SW 188TH AVE
SW 189TH AVE
SW 190TH AVE
SW 191ST AVE
SW 192ND AVE
SW 193RD AVE
SW 194TH AVE
SW 195TH AVE
SW 196TH AVE
SW 197TH AVE
SW 198TH AVE
SW 199TH AVE
SW 200TH AVE
SW 201ST AVE
SW 202ND AVE
SW 203RD AVE
SW 204TH AVE
SW 205TH AVE
SW 206TH AVE
SW 207TH AVE
SW 208TH AVE
SW 209TH AVE
SW 210TH AVE
SW 211TH AVE
SW 212TH AVE
SW 213TH AVE
SW 214TH AVE
SW 215TH AVE
SW 216TH AVE
SW 217TH AVE
SW 218TH AVE
SW 219TH AVE
SW 220TH AVE
SW 221ST AVE
SW 222ND AVE
SW 223RD AVE
SW 224TH AVE
SW 225TH AVE
SW 226TH AVE
SW 227TH AVE
SW 228TH AVE
SW 229TH AVE
SW 230TH AVE
SW 231ST AVE
SW 232ND AVE
SW 233RD AVE
SW 234TH AVE
SW 235TH AVE
SW 236TH AVE
SW 237TH AVE
SW 238TH AVE
SW 239TH AVE
SW 240TH AVE
SW 241ST AVE
SW 242ND AVE
SW 243RD AVE
SW 244TH AVE
SW 245TH AVE
SW 246TH AVE
SW 247TH AVE
SW 248TH AVE
SW 249TH AVE
SW 250TH AVE
SW 251ST AVE
SW 252ND AVE
SW 253RD AVE
SW 254TH AVE
SW 255TH AVE
SW 256TH AVE
SW 257TH AVE
SW 258TH AVE
SW 259TH AVE
SW 260TH AVE
SW 261ST AVE
SW 262ND AVE
SW 263RD AVE
SW 264TH AVE
SW 265TH AVE
SW 266TH AVE
SW 267TH AVE
SW 268TH AVE
SW 269TH AVE
SW 270TH AVE
SW 271ST AVE
SW 272ND AVE
SW 273RD AVE
SW 274TH AVE
SW 275TH AVE
SW 276TH AVE
SW 277TH AVE
SW 278TH AVE
SW 279TH AVE
SW 280TH AVE
SW 281ST AVE
SW 282ND AVE
SW 283RD AVE
SW 284TH AVE
SW 285TH AVE
SW 286TH AVE
SW 287TH AVE
SW 288TH AVE
SW 289TH AVE
SW 290TH AVE
SW 291ST AVE
SW 292ND AVE
SW 293RD AVE
SW 294TH AVE
SW 295TH AVE
SW 296TH AVE
SW 297TH AVE
SW 298TH AVE
SW 299TH AVE
SW 300TH AVE
SW 301ST AVE
SW 302ND AVE
SW 303RD AVE
SW 304TH AVE
SW 305TH AVE
SW 306TH AVE
SW 307TH AVE
SW 308TH AVE
SW 309TH AVE
SW 310TH AVE
SW 311TH AVE
SW 312TH AVE
SW 313TH AVE
SW 314TH AVE
SW 315TH AVE
SW 316TH AVE
SW 317TH AVE
SW 318TH AVE
SW 319TH AVE
SW 320TH AVE
SW 321ST AVE
SW 322ND AVE
SW 323RD AVE
SW 324TH AVE
SW 325TH AVE
SW 326TH AVE
SW 327TH AVE
SW 328TH AVE
SW 329TH AVE
SW 330TH AVE
SW 331ST AVE
SW 332ND AVE
SW 333RD AVE
SW 334TH AVE
SW 335TH AVE
SW 336TH AVE
SW 337TH AVE
SW 338TH AVE
SW 339TH AVE
SW 340TH AVE
SW 341ST AVE
SW 342ND AVE
SW 343RD AVE
SW 344TH AVE
SW 345TH AVE
SW 346TH AVE
SW 347TH AVE
SW 348TH AVE
SW 349TH AVE
SW 350TH AVE
SW 351ST AVE
SW 352ND AVE
SW 353RD AVE
SW 354TH AVE
SW 355TH AVE
SW 356TH AVE
SW 357TH AVE
SW 358TH AVE
SW 359TH AVE
SW 360TH AVE
SW 361ST AVE
SW 362ND AVE
SW 363RD AVE
SW 364TH AVE
SW 365TH AVE
SW 366TH AVE
SW 367TH AVE
SW 368TH AVE
SW 369TH AVE
SW 370TH AVE
SW 371ST AVE
SW 372ND AVE
SW 373RD AVE
SW 374TH AVE
SW 375TH AVE
SW 376TH AVE
SW 377TH AVE
SW 378TH AVE
SW 379TH AVE
SW 380TH AVE
SW 381ST AVE
SW 382ND AVE
SW 383RD AVE
SW 384TH AVE
SW 385TH AVE
SW 386TH AVE
SW 387TH AVE
SW 388TH AVE
SW 389TH AVE
SW 390TH AVE
SW 391ST AVE
SW 392ND AVE
SW 393RD AVE
SW 394TH AVE
SW 395TH AVE
SW 396TH AVE
SW 397TH AVE
SW 398TH AVE
SW 399TH AVE
SW 400TH AVE
SW 401ST AVE
SW 402ND AVE
SW 403RD AVE
SW 404TH AVE
SW 405TH AVE
SW 406TH AVE
SW 407TH AVE
SW 408TH AVE
SW 409TH AVE
SW 410TH AVE
SW 411TH AVE
SW 412TH AVE
SW 413TH AVE
SW 414TH AVE
SW 415TH AVE
SW 416TH AVE
SW 417TH AVE
SW 418TH AVE
SW 419TH AVE
SW 420TH AVE
SW 421ST AVE
SW 422ND AVE
SW 423RD AVE
SW 424TH AVE
SW 425TH AVE
SW 426TH AVE
SW 427TH AVE
SW 428TH AVE
SW 429TH AVE
SW 430TH AVE
SW 431ST AVE
SW 432ND AVE
SW 433RD AVE
SW 434TH AVE
SW 435TH AVE
SW 436TH AVE
SW 437TH AVE
SW 438TH AVE
SW 439TH AVE
SW 440TH AVE
SW 441ST AVE
SW 442ND AVE
SW 443RD AVE
SW 444TH AVE
SW 445TH AVE
SW 446TH AVE
SW 447TH AVE
SW 448TH AVE
SW 449TH AVE
SW 450TH AVE
SW 451ST AVE
SW 452ND AVE
SW 453RD AVE
SW 454TH AVE
SW 455TH AVE
SW 456TH AVE
SW 457TH AVE
SW 458TH AVE
SW 459TH AVE
SW 460TH AVE
SW 461ST AVE
SW 462ND AVE
SW 463RD AVE
SW 464TH AVE
SW 465TH AVE
SW 466TH AVE
SW 467TH AVE
SW 468TH AVE
SW 469TH AVE
SW 470TH AVE
SW 471ST AVE
SW 472ND AVE
SW 473RD AVE
SW 474TH AVE
SW 475TH AVE
SW 476TH AVE
SW 477TH AVE
SW 478TH AVE
SW 479TH AVE
SW 480TH AVE
SW 481ST AVE
SW 482ND AVE
SW 483RD AVE
SW 484TH AVE
SW 485TH AVE
SW 486TH AVE
SW 487TH AVE
SW 488TH AVE
SW 489TH AVE
SW 490TH AVE
SW 491ST AVE
SW 492ND AVE
SW 493RD AVE
SW 494TH AVE
SW 495TH AVE
SW 496TH AVE
SW 497TH AVE
SW 498TH AVE
SW 499TH AVE
SW 500TH AVE
SW 501ST AVE
SW 502ND AVE
SW 503RD AVE
SW 504TH AVE
SW 505TH AVE
SW 506TH AVE
SW 507TH AVE
SW 508TH AVE
SW 509TH AVE
SW 510TH AVE
SW 511TH AVE
SW 512TH AVE
SW 513TH AVE
SW 514TH AVE
SW 515TH AVE
SW 516TH AVE
SW 517TH AVE
SW 518TH AVE
SW 519TH AVE
SW 520TH AVE
SW 521ST AVE
SW 522ND AVE
SW 523RD AVE
SW 524TH AVE
SW 525TH AVE
SW 526TH AVE
SW 527TH AVE
SW 528TH AVE
SW 529TH AVE
SW 530TH AVE
SW 531ST AVE
SW 532ND AVE
SW 533RD AVE
SW 534TH AVE
SW 535TH AVE
SW 536TH AVE
SW 537TH AVE
SW 538TH AVE
SW 539TH AVE
SW 540TH AVE
SW 541ST AVE
SW 542ND AVE
SW 543RD AVE
SW 544TH AVE
SW 545TH AVE
SW 546TH AVE
SW 547TH AVE
SW 548TH AVE
SW 549TH AVE
SW 550TH AVE
SW 551ST AVE
SW 552ND AVE
SW 553RD AVE
SW 554TH AVE
SW 555TH AVE
SW 556TH AVE
SW 557TH AVE
SW 558TH AVE
SW 559TH AVE
SW 560TH AVE
SW 561ST AVE
SW 562ND AVE
SW 563RD AVE
SW 564TH AVE
SW 565TH AVE
SW 566TH AVE
SW 567TH AVE
SW 568TH AVE
SW 569TH AVE
SW 570TH AVE
SW 571ST AVE
SW 572ND AVE
SW 573RD AVE
SW 574TH AVE
SW 575TH AVE
SW 576TH AVE
SW 577TH AVE
SW 578TH AVE
SW 579TH AVE
SW 580TH AVE
SW 581ST AVE
SW 582ND AVE
SW 583RD AVE
SW 584TH AVE
SW 585TH AVE
SW 586TH AVE
SW 587TH AVE
SW 588TH AVE
SW 589TH AVE
SW 590TH AVE
SW 591ST AVE
SW 592ND AVE
SW 593RD AVE
SW 594TH AVE
SW 595TH AVE
SW 596TH AVE
SW 597TH AVE
SW 598TH AVE
SW 599TH AVE
SW 600TH AVE
SW 601ST AVE
SW 602ND AVE
SW 603RD AVE
SW 604TH AVE
SW 605TH AVE
SW 606TH AVE
SW 607TH AVE
SW 608TH AVE
SW 609TH AVE
SW 610TH AVE
SW 611TH AVE
SW 612TH AVE
SW 613TH AVE
SW 614TH AVE
SW 615TH AVE
SW 616TH AVE
SW 617TH AVE
SW 618TH AVE
SW 619TH AVE
SW 620TH AVE
SW 621ST AVE
SW 622ND AVE
SW 623RD AVE
SW 624TH AVE
SW 625TH AVE
SW 626TH AVE
SW 627TH AVE
SW 628TH AVE
SW 629TH AVE
SW 630TH AVE
SW 631ST AVE
SW 632ND AVE
SW 633RD AVE
SW 634TH AVE
SW 635TH AVE
SW 636TH AVE
SW 637TH AVE
SW 638TH AVE
SW 639TH AVE
SW 640TH AVE
SW 641ST AVE
SW 642ND AVE
SW 643RD AVE
SW 644TH AVE
SW 645TH AVE
SW 646TH AVE
SW 647TH AVE
SW 648TH AVE
SW 649TH AVE
SW 650TH AVE
SW 651ST AVE
SW 652ND AVE
SW 653RD AVE
SW 654TH AVE
SW 655TH AVE
SW 656TH AVE
SW 657TH AVE
SW 658TH AVE
SW 659TH AVE
SW 660TH AVE
SW 661ST AVE
SW 662ND AVE
SW 663RD AVE
SW 664TH AVE
SW 665TH AVE
SW 666TH AVE
SW 667TH AVE
SW 668TH AVE
SW 669TH AVE
SW 670TH AVE
SW 671ST AVE
SW 672ND AVE
SW 673RD AVE
SW 674TH AVE
SW 675TH AVE
SW 676TH AVE
SW 677TH AVE
SW 678TH AVE
SW 679TH AVE
SW 680TH AVE
SW 681ST AVE
SW 682ND AVE
SW 683RD AVE
SW 684TH AVE
SW 685TH AVE
SW 686TH AVE
SW 687TH AVE
SW 688TH AVE
SW 689TH AVE
SW 690TH AVE
SW 691ST AVE
SW 692ND AVE
SW 693RD AVE
SW 694TH AVE
SW 695TH AVE
SW 696TH AVE
SW 697TH AVE
SW 698TH AVE
SW 699TH AVE
SW 700TH AVE
SW 701ST AVE
SW 702ND AVE
SW 703RD AVE
SW 704TH AVE
SW 705TH AVE
SW 706TH AVE
SW 707TH AVE
SW 708TH AVE
SW 709TH AVE
SW 710TH AVE
SW 711TH AVE
SW 712TH AVE
SW 713TH AVE
SW 714TH AVE
SW 715TH AVE
SW 716TH AVE
SW 717TH AVE
SW 718TH AVE
SW 719TH AVE
SW 720TH AVE
SW 721ST AVE
SW 722ND AVE
SW 723RD AVE
SW 724TH AVE
SW 725TH AVE
SW 726TH AVE
SW 727TH AVE
SW 728TH AVE
SW 729TH AVE
SW 730TH AVE
SW 731ST AVE
SW 732ND AVE
SW 733RD AVE
SW 734TH AVE
SW 735TH AVE
SW 736TH AVE
SW 737TH AVE
SW 738TH AVE
SW 739TH AVE
SW 740TH AVE
SW 741ST AVE
SW 742ND AVE
SW 743RD AVE
SW 744TH AVE
SW 745TH AVE
SW 746TH AVE
SW 747TH AVE
SW 748TH AVE
SW 749TH AVE
SW 750TH AVE
SW 751ST AVE
SW 752ND AVE
SW 753RD AVE
SW 754TH AVE
SW 755TH AVE
SW 756TH AVE
SW 757TH AVE
SW 758TH AVE
SW 759TH AVE
SW 760TH AVE
SW 761ST AVE
SW 762ND AVE
SW 763RD AVE
SW 764TH AVE
SW 765TH AVE
SW 766TH AVE
SW 767TH AVE
SW 768TH AVE
SW 769TH AVE
SW 770TH AVE
SW 771ST AVE
SW 772ND AVE
SW 773RD AVE
SW 774TH AVE
SW 775TH AVE
SW 776TH AVE
SW 777TH AVE
SW 778TH AVE
SW 779TH AVE
SW 780TH AVE
SW 781ST AVE
SW 782ND AVE
SW 783RD AVE
SW 784TH AVE
SW 785TH AVE
SW 786TH AVE
SW 787TH AVE
SW 788TH AVE
SW 789TH AVE
SW 790TH AVE
SW 791ST AVE
SW 792ND AVE
SW 793RD AVE
SW 794TH AVE
SW 795TH AVE
SW 796TH AVE
SW 797TH AVE
SW 798TH AVE
SW 799TH AVE
SW 800TH AVE
SW 801ST AVE
SW 802ND AVE
SW 803RD AVE
SW 804TH AVE
SW 805TH AVE
SW 806TH AVE
SW 807TH AVE
SW 808TH AVE
SW 809TH AVE
SW 810TH AVE
SW 811TH AVE
SW 812TH AVE
SW 813TH AVE
SW 814TH AVE
SW 815TH AVE
SW 816TH AVE
SW 817TH AVE
SW 818TH AVE
SW 819TH AVE
SW 820TH AVE
SW 821ST AVE
SW 822ND AVE
SW 823RD AVE
SW 824TH AVE
SW 825TH AVE
SW 826TH AVE
SW 827TH AVE
SW 828TH AVE
SW 829TH AVE
SW 830TH AVE
SW 831ST AVE
SW 832ND AVE
SW 833RD AVE
SW 834TH AVE
SW 835TH AVE
SW 836TH AVE
SW 837TH AVE
SW 838TH AVE
SW 839TH AVE
SW 840TH AVE
SW 841ST AVE
SW 842ND AVE
SW 843RD AVE
SW 844TH AVE
SW 845TH AVE
SW 846TH AVE
SW 847TH AVE
SW 848TH AVE
SW 849TH AVE
SW 850TH AVE
SW 851ST AVE
SW 852ND AVE
SW 853RD AVE
SW 854TH AVE
SW 855TH AVE
SW 856TH AVE
SW 857TH AVE
SW 858TH AVE
SW 859TH AVE
SW 860TH AVE
SW 861ST AVE
SW 862ND AVE
SW 863RD AVE
SW 864TH AVE
SW 865TH AVE
SW 866TH AVE
SW 867TH AVE
SW 868TH AVE
SW 869TH AVE
SW 870TH AVE
SW 871ST AVE
SW 872ND AVE
SW 873RD AVE
SW 874TH AVE
SW 875TH AVE
SW 876TH AVE
SW 877TH AVE
SW 878TH AVE
SW 879TH AVE
SW 880TH AVE
SW 881ST AVE
SW 882ND AVE
SW 883RD AVE
SW 884TH AVE
SW 885TH AVE
SW 886TH AVE
SW 887TH AVE
SW 888TH AVE
SW 889TH AVE
SW 890TH AVE
SW 891ST AVE
SW 892ND AVE
SW 893RD AVE
SW 894TH AVE
SW 895TH AVE
SW 896TH AVE
SW 897TH AVE
SW 898TH AVE
SW 899TH AVE
SW 900TH AVE
SW 901ST AVE
SW 902ND AVE
SW 903RD AVE
SW 904TH AVE
SW 905TH AVE
SW 906TH AVE
SW 907TH AVE
SW 908TH AVE
SW 909TH AVE
SW 910TH AVE
SW 911TH AVE
SW 912TH AVE
SW 913TH AVE
SW 914TH AVE
SW 915TH AVE
SW 916TH AVE
SW 917TH AVE
SW 918TH AVE
SW 919TH AVE
SW 920TH AVE
SW 921ST AVE
SW 922ND AVE
SW 923RD AVE
SW 924TH AVE
SW 925TH AVE
SW 926TH AVE
SW 927TH AVE
SW 928TH AVE
SW 929TH AVE
SW 930TH AVE
SW 931ST AVE
SW 932ND AVE
SW 933RD AVE
SW 934TH AVE
SW 935TH AVE
SW 936TH AVE
SW 937TH AVE
SW 938TH AVE
SW 939TH AVE
SW 940TH AVE
SW 941ST AVE
SW 942ND AVE
SW 943RD AVE
SW 944TH AVE
SW 945TH AVE
SW 946TH AVE
SW 947TH AVE
SW 948TH AVE
SW 949TH AVE
SW 950TH AVE
SW 951ST AVE
SW 952ND AVE
SW 953RD AVE
SW 954TH AVE
SW 955TH AVE
SW 956TH AVE
SW 957TH AVE
SW 958TH AVE
SW 959TH AVE
SW 960TH AVE
SW 961ST AVE
SW 962ND AVE
SW 963RD AVE
SW 964TH AVE
SW 965TH AVE
SW 966TH AVE
SW 967TH AVE
SW 968TH AVE
SW 969TH AVE
SW 970TH AVE
SW 971ST AVE
SW 972ND AVE
SW 973RD AVE
SW 974TH AVE
SW 975TH AVE
SW 976TH AVE
SW 977TH AVE
SW 978TH AVE
SW 979TH AVE
SW 980TH AVE
SW 981ST AVE
SW 982ND AVE
SW 983RD AVE
SW 984TH AVE
SW 985TH AVE
SW 986TH AVE
SW 987TH AVE
SW 988TH AVE
SW 989TH AVE
SW 990TH AVE
SW 991ST AVE
SW 992ND AVE
SW 993RD AVE
SW 994TH AVE
SW 995TH AVE
SW 996TH AVE
SW 997TH AVE
SW 998TH AVE
SW 999TH AVE
SW 1000TH AVE


NE Area Index of Resource Sites
City of Portland
Bureau of Planning
Geographic
Information System
May 21, 2001
Portland International Airport
Maywood Park
1" = 5000'
N