Watershed Characterization and Analysis of Clark County

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

Introduction

Background

In spring 2006, the Washington State Legislature provided funding to the Department of Ecology to develop, in conjunction with Clark County, a comprehensive wetlands mitigation program for the rapidly urbanizing watersheds in the county. The primary objectives of this watershed-based mitigation program are to:

- provide better long-term protection of wetland functions and
- reduce permitting time and mitigation costs through increased specificity on type and location of required mitigation.

This effort will build on the County's existing Wetland Inventory and Identification of Mitigation Opportunity Areas (Clark County, 2004), and will result in a plan for the rural and urban areas in the western half of the county (see Figure 1).

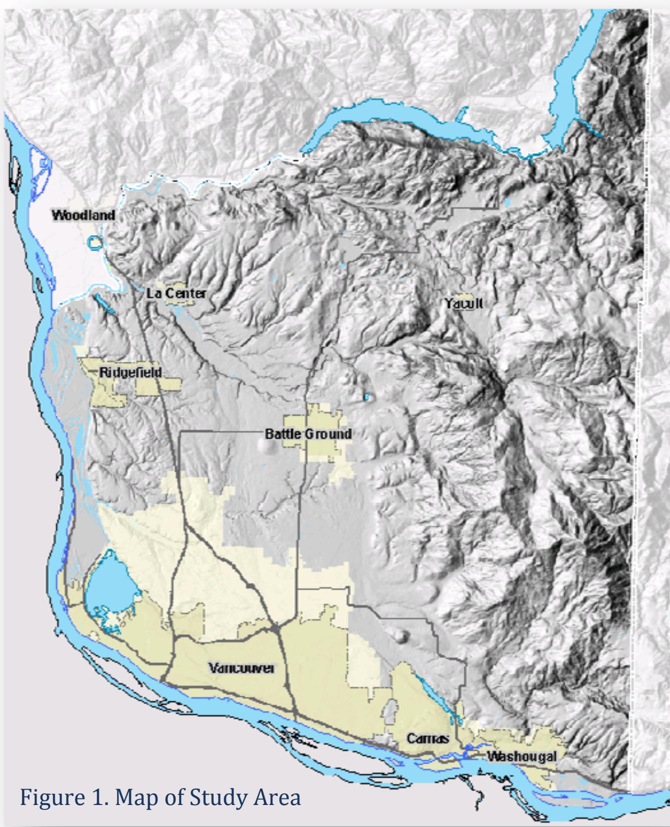

Figure 1. Map of Study Area

Approach

Characterizing watershed processes within the study area is central to developing a successful watershed-based mitigation plan. It provides local jurisdictions with information on the best areas for mitigation, protection of watershed processes, and development.

For example, watershed characterization and analysis helps to identify areas that are important for maintaining watershed processes (Figures C-1 and C- 4). It also determines how much these areas have been impaired (Figures C-2 and C-5).

The matrix shown in Figure 2 synthesizes the analyses for each sub-unit into a final map of areas most suitable for protection and restoration (Figures 4 and 5).

The central assumption in this characterization approach is that the health of aquatic resources depends on intact, up-gradient watershed processes. Research has shown that we must consider the watershed processes that occur outside of aquatic ecosystems if we are to protect and restore our lakes, rivers, wetlands, and estuaries (National Research Council 2001; Dale et al. 2000; Bedford and Preston 1988; Roni et al. 2002; Poiani et al. 1996; Gersib 2001; Gove et al. 2001).

> ***Watershed Processes:*** In this document, *watershed processes* refers to the dynamic physical and chemical interactions that form and maintain the landscape at the geographic scales of watersheds to basins (from hundreds to thousands of square miles).
>
> These processes include the movement of water, sediment, nutrients, pathogens, toxins, and wood as they enter, move through, and eventually leave the watershed.

Our management and regulation of these aquatic ecosystems have typically focused on the biological, physical, and chemical character of the individual lake, wetland, stream reach, or estuary, and not on the larger watershed that controls these characteristics.

Scientific studies show that watershed processes interact with landscape features, climate, and each other to produce the structure and functions of aquatic ecosystems that society wants to protect (Beechie and Bolton 1999). For example, a flood can create off-channel habitat that is important for fish. Much of the research concludes that protection, management, and regulatory activities could be more successful if they included consideration of watershed processes.

Potential Uses

The final characterization map showing priorities for protection and restoration could be used by a county to develop an initial suite of potential mitigation sites. These mitigation sites can include aquatic resources such as wetlands and riparian areas, as well as upland areas that are important to maintaining processes for these aquatic resources.

County planners and managers can also use this information in updating Shoreline Master Program and Comprehensive Growth Management Plans. For example, Shoreline Master Program Guidelines[1] require local governments to prepare a characterization of ecosystem-wide processes and ecological functions and to identify measures to protect and restore them. See Appendix B, Framework for Planning, for examples of applying characterization to local planning processes.

The characterization can also be used to develop comprehensive mitigation programs for Critical Areas Ordinance updates (for example, off-site mitigation, in-lieu fees, transfer of development rights). This includes using characterization results to establish service areas for mitigation banks. This approach should help sustain aquatic ecosystems by replacing and restoring functions within a common set of watersheds.

[1] WAC 173-26-201(3)(d)(i)(A)

Results of Characterization

The following section presents the results of the characterization for Clark County, including the most suitable areas for protection, restoration, and development. The characterization includes analysis of processes for the delivery, movement and loss of water and nitrogen. From these results a watershed management plan framework is presented for the study area.

Identify Areas of Protection and Restoration

Land use planning should occur within a framework that focuses first on maintaining or restoring watershed processes (Hidding and Teunissen 2002; Dale et al. 2000; Gove et al. 2001). To assist land use planning efforts in Clark County, Figures 4 and 5 present an initial framework for watershed protection, restoration, and development. This framework is based on the synthesis of the information displayed in the maps of the relative index for the important areas and the relative index of impairments. The watershed management matrix synthesizes these two categories of information (Figures 2 and C-8). Detailed maps in Appendix C identify

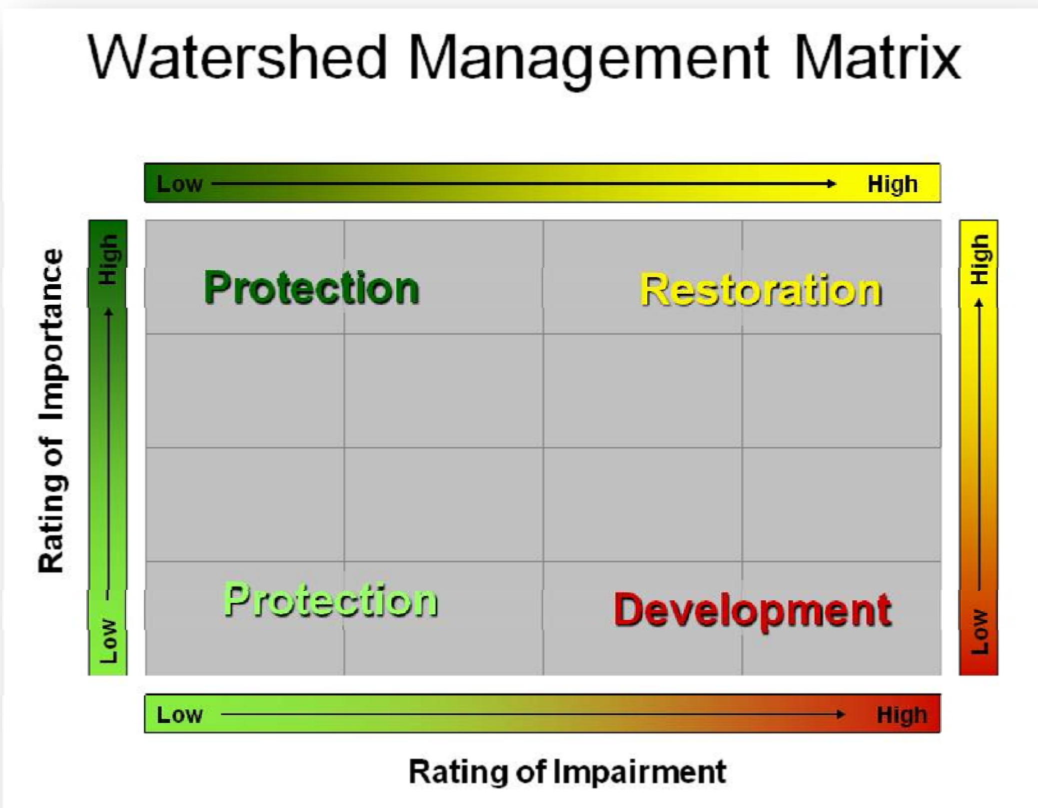

Figure 2. Watershed Management Matrix. The ranking of importance is on the vertical axes, and ranking for impairment is along the horizontal axes. Together, the two rankings indicate suitability of the sub-unit for protection, restoration, or development.

areas important for the processes associated with the delivery, movement and loss of water (hydrologic process) and nitrogen (denitrification process) and their relative degree of impairment.

The watershed management matrix presents a range of planning and management options. These options are displayed on maps as follows:

- **Green** areas have higher levels of importance for watershed processes and limited impairment and should be considered for **protection**. Development may be suitable in these areas but extra care should be taken, especially in dark green areas, to establish land use patterns (i.e. land use types, activities, development policies, standards and regulations) that protect and maintain watershed processes in these areas. Lighter green areas may have a lower level of importance but may play an important role in sustaining down-gradient aquatic resources.

- **Yellow** areas have higher levels of importance for watershed processes and a higher level of impairment and should be considered for **restoration** unless watershed processes are permanently impaired by urban development. Restoration in "dark yellow" areas will have the most significant benefit, relative to other rated sub-units, in restoring watershed processes and aiding in sustaining down-gradient aquatic resources. Again, care should be taken to establish land use patterns that protect and maintain areas important for watershed processes.

- **Orange to red** areas have lower levels of importance for watershed processes and higher levels of impairment and should be considered as more suitable for **development**. Because orange areas represent a transition from restoration areas, planning measures employing both restoration and appropriately sited development should be considered.

Definitions of watershed protection and restoration and further examples of how they can be interpreted are presented below.

Protection: Any activity that ensures that **the watershed process remains relatively unimpaired**. This can include traditional efforts of protecting land from human activities (such as, open space or conservation easements), but it can also mean designing development in a way that allows the watershed process to continue with minimal impairment. For instance, with new development an area important for recharge could be set aside and low impact development standards applied to ensure recharge of the additional surface runoff generated by the new buildings and impervious surfaces.

Restoration: Any activity that ensures that **the watershed process is re-established or re-habilitated**. This can involve restoring the natural condition of an important area but it can also include activities that restore the capacity of the important area to support the process. For instance, an area important for recharge that is covered with impervious surfaces could be modified to accommodate recharge or could be restored to natural conditions.

The specific design of any of these activities requires further site-level analysis.

Characterization Results for the Delivery, Movement and Loss of Water

This characterization uses a landscape classification approach based on the "hydrologic-landscapes" described by Winter (2001) and the hydrogeologic work of Bedford (1999 & 1988). It uses precipitation type, landform, geology, and surface water/groundwater patterns to group the landscape into similar units. The analysis area for Clark County has four landscape groups (Figure 3), which are described in more detail in Appendix A. This includes the Rain-on-Snow, Snow Dominated Mountainous Unit, Rain Dominated Mountainous Unit, Rain Dominated Terrace Unit, and the Columbia River Unit.

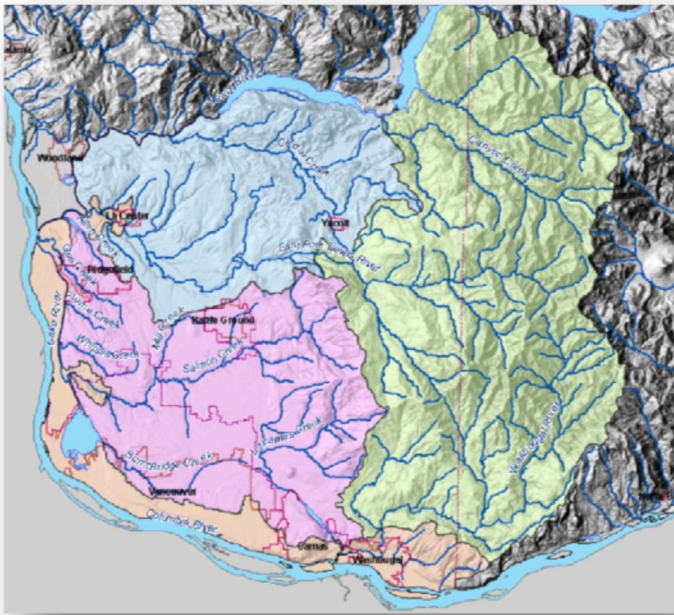

Figure 3. Landscape Groups. Green is the Rain-on Snow and Snow-Dominated Mountainous unit; blue is the Rain-dominated Mountainous unit (East Fork and Mainstem of the Lewis); pink is the Terrace unit; and orange identifies the Columbia River unit.

Figure 4 and Table 1 present the results of the characterization for delivery, movement and loss of water within each of these landscape groups. The results indicate that much of the upper watersheds for the mountainous landscape groups have both high importance and relatively low impairment. These areas would be more suitable for lower intensity development activities that protect the hydrologic processes.

Areas having a high suitability for restoration (high importance and high impairment) are concentrated in the southeastern and northern portion of the terrace unit; the lowland floodplain of the East Fork of the Lewis (rain-dominated mountainous unit) and its upper watershed; northern and southwestern portions of the rain-on-snow and snow dominated mountainous unit; and northwestern portion of the Columbia River unit.

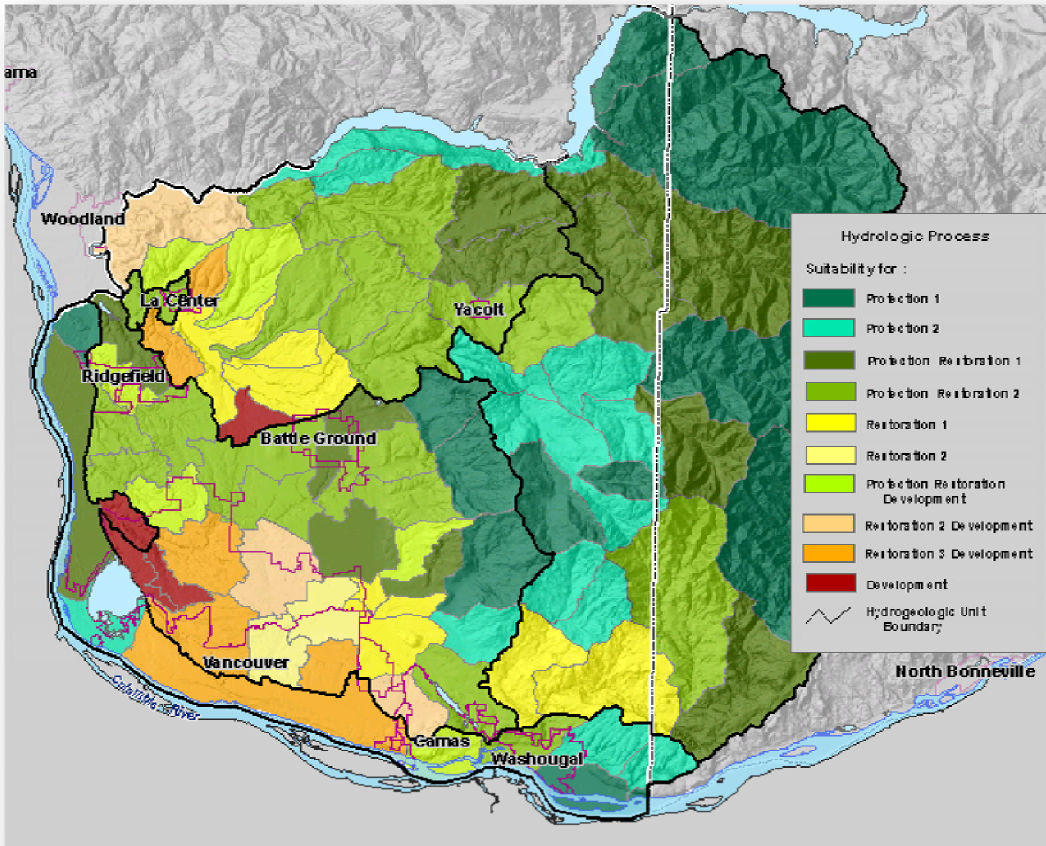

Figure 4. Synthesis Map for Hydrologic Process. Priority areas for protection and restoration of hydrologic processes. Areas bound by black lines represent landscape groups (H_RANK). This map combines Figures C-1, C-2, and the analysis matrix shown in Figures 2 and C-8. The results of the variables used to develop Figures C-1 and C-2 are presented in Figures C-9 through C-21.

Areas more suitable for urban development (low importance and high impairment) in conjunction with restoration and protection measures are concentrated south and northeast of the City of La Center, northwest of the City of Battleground and within the Cities of Ridgefield, Vancouver and Camus.

Characterization Results for the Delivery, Movement and Loss (Denitrification) of Nitrogen

Figure 5 shows the areas for protection and restoration for the delivery, movement and loss of nitrogen. This map was developed using Figures C-4 and C-5 and the analysis matrix (Figure C-8).

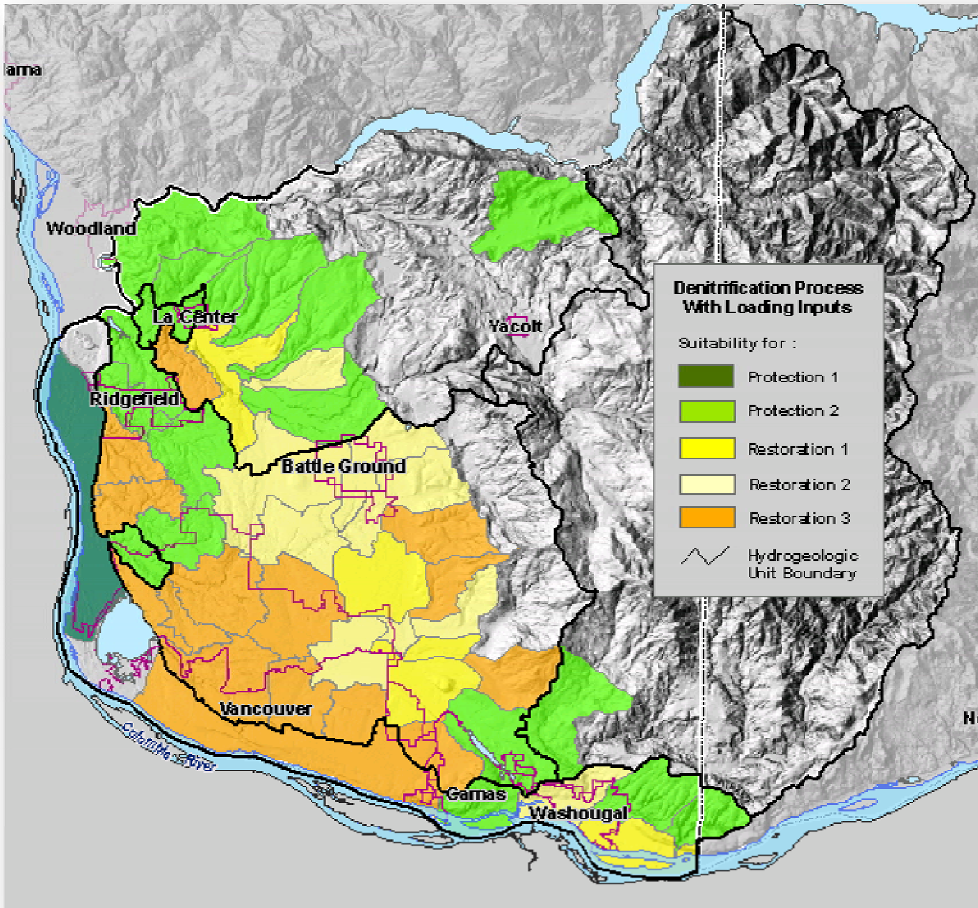

Figure 5. Synthesis Map for Nitrogen Process (Denitrification). Priority areas for protection are shown in darker green and priority areas for restoration shown in dark yellow (N_RANK).

The characterization assumes that depressional and riparian wetlands, especially those located downstream of nitrogen sources, are important areas for removing nitrogen through denitrification.

Areas suitable for priority protection (higher importance to denitrification and a low level of impairment) include the westernmost portion of the Columbia River Floodplain unit. Other protection areas include tributaries to the East Fork of the Lewis River near the town of La Center, and Allen Canyon Creek, Upper and Lower Gee Creek, Upper Whipple Creek, and Lower Salmon Creek watersheds. In the southern portion of the study area, protection areas include the Lacamas Lake, eastern portion of the City of Camus, Lower Little Washougal, and Gibbons and Lawton Creek watersheds.

The important areas suitable for restoration (high importance and impairment) of the denitrification process are concentrated in the terrace unit, particularly in the eastern portion (sub-units for Salmon Creek, Mill Creek, Woodin Creek, China Ditch, Fifth Plain Creek, Burnt Bridge Creek and Lacamas Creek). Priority restoration areas are also present in the rain-dominated mountainous unit for the lower reaches of the East Fork of the Lewis River (including some tributaries such as Dean Creek). For the Columbia River unit, priority restoration is within and adjacent to the town of Washougal.

Most of these restoration areas have a high percentage of depressional and riverine wetlands and sources of nitrogen within or upstream of them. Restoration measures should focus specifically on restoring hydrologic processes (such as, removing ditches and drains and restoring hydrology inputs) to depressional and riverine wetlands and restoring recharge processes that support riparian ecosystems (for example, the Columbia River Floodplain unit).

Developing a Watershed Management Plan for Clark County

This section takes the results of the synthesis maps (Figures 4 & 5) and demonstrates how to use this information to develop a watershed management plan for Clark County. For each landscape group (terrace, snow-dominated mountainous, rain-dominated mountainous, and Columbia River), we show management zones based on synthesis results (Also see Table 1).

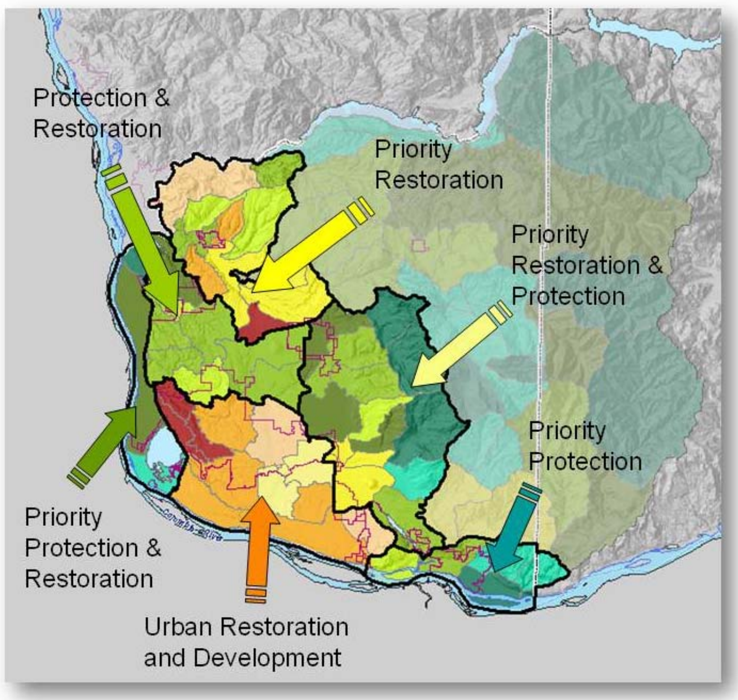

Figure 6. Development Management Zones for Terrace, East Fork of Lewis River & Columbia River Units. The six zones, (black lines) are: Priority Restoration & Protection (Battleground area); Priority Protection & Restoration (Refuge and Ridgefield area); Urban Restoration & Development (Vancouver); Priority Protection (Washougal & Camas); and Priority Restoration (East Fork Lewis River). Urban growth boundaries for Ridgefield, Battle Ground and Vancouver are shown in red lines.

Terrace Unit

Moving from the eastern flank of this unit toward the west and southwest, this characterization (Figure 6) generally identifies the:

- upper watershed (eastern portion) as a priority area for protection and restoration;
- northwestern portion of the terrace suitable for protection and restoration; and
- southern portion of the terrace as suitable for a combination of urban development and protection/restoration of stream corridors.

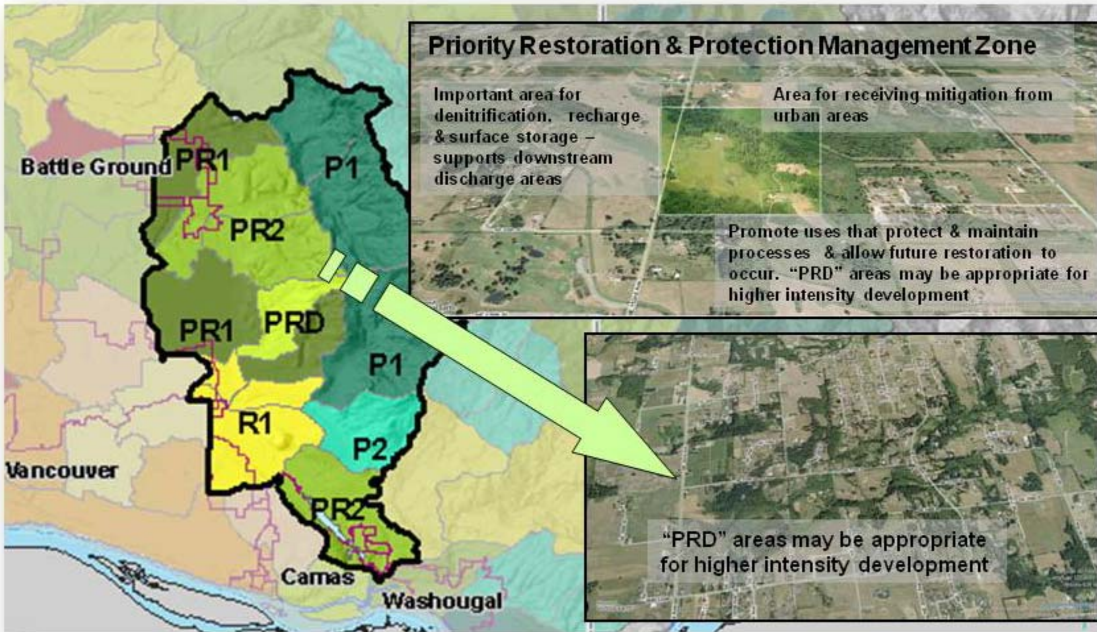

Figure 7. Eastern Terrace Results. Priority Restoration and Protection Zone recommended. Protection priorities indicated by P1 and P2. R1 indicates that the China Ditch subunit is a key area for restoration. Both Protection and restoration priorities are represented by PR1 and PR2. PRD is a lower priority area that may be more suitable for high intensity development.

The eastern terrace is an important recharge, surface storage, and denitrification area. Restoration and protection of these important areas should be the focus of this management zone (Figure 7) given its role in supporting groundwater discharge to streams in the western terrace (Figure 8 and Appendix A, Geology). The USGS determined that aquifers in portions of the eastern terrace were more susceptible to contamination relative to the western terrace (Figure 8 and Appendix A, Figure A-4). Uses that allow for continued functioning of these processes, such as agriculture and forestry, are appropriate. Limited residential uses could occur if clustering and other low impact development measures are taken. More intense development may be appropriate in the "PRD" hydrologic units (protection, restoration and development). The "R1, PR1 or PR2" units could support mitigation for impacts within the City of Battleground and other areas more suitable for development (e.g. PRD units - protection, restoration and development subunits, Figure 4 and 7).

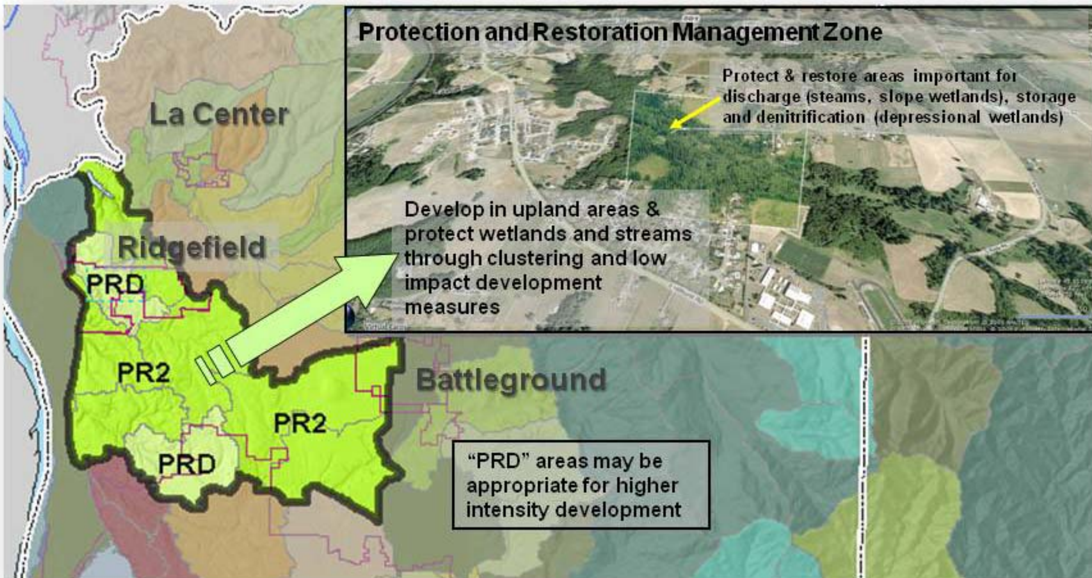

Figure 8. Western Terrace Results. Protection and Restoration Zone recommended.

For the western terrace area, care should be taken to protect existing wetland resources and stream areas (Figure 8). These resources are important for surface storage, groundwater discharge and denitrification and should be protected and restored where possible. For example, in the Ridgefield area, the characterization showed that groundwater discharge is very important to maintaining stream surface flows (Figures A-3 and A-4), Gee and Allen Canyon Creeks) and denitrification (Figure 5).

Higher density development should be concentrated in subunits designated "PRD" (Protection, Restoration and Development) where the relative level of importance is lower than surrounding subunits. Low-impact development measures, including clustering, should be used for all development in order to protect stream corridors from high flows.

Suggested management measures include:

- Protect stream discharge areas by preventing filling, channelization, diversions, and ditching within the stream floodplain or adjacent areas that contribute to surface flows, such as slope seeps and springs.
- Maintain stream structure by maintaining normal range of surface flows through use of low-impact development measures (infiltration, pervious pavement, use of native vegetation zones to encourage subsurface flow).

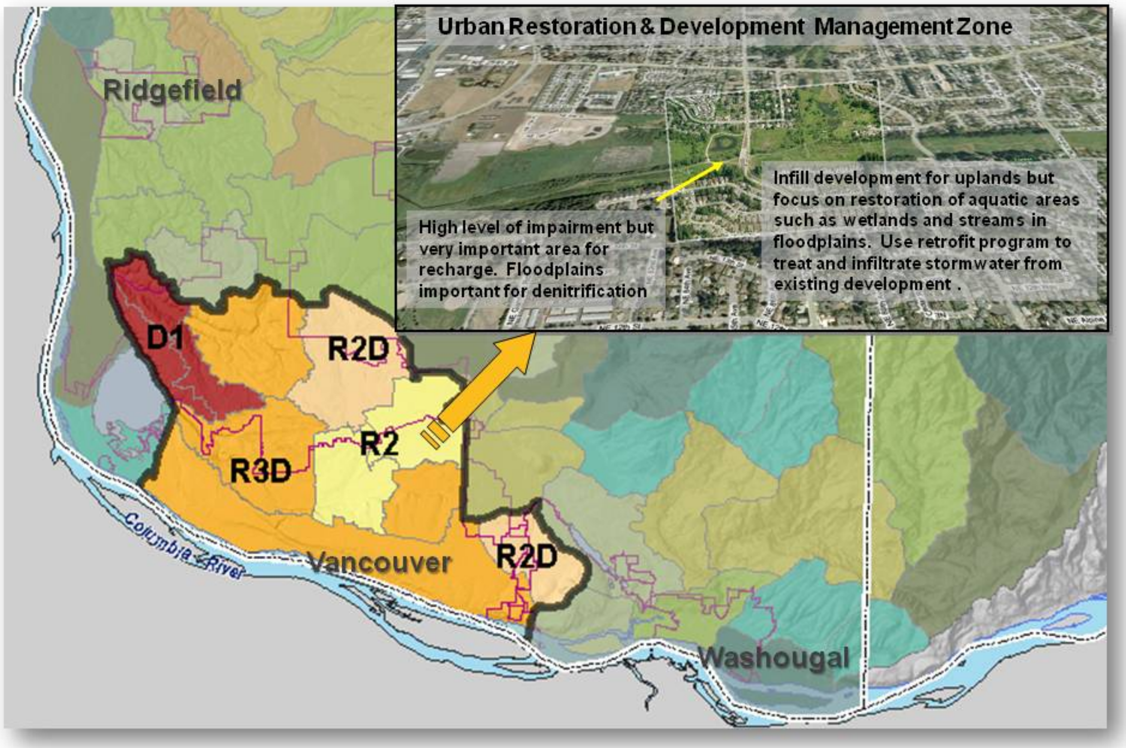

Figure 9. Vancouver Area Results. Urban Restoration and Development Zone recommended.

The City of Vancouver unit is identified as an Urban Restoration and Development Management Zone (Figure 9), due to a low to moderate importance for processes and a high level of impairment. Extensive permeable deposits support significant groundwater flows to the Columbia River and adjacent wetlands and streams, such as Burnt Bridge Creek. Urban development, however, has impaired much of the upland infiltration and recharge areas. Given the area's importance to groundwater processes and denitrification, protection and restoration of the remaining aquatic resources, including the floodplain of Burnt Bridge and Curtin Creek, is recommended.

Figure 10. Columbia River West Results. Priority Protection and Restoration Management Zone recommended.

The western portion of the Columbia River unit (Figure 10) is recommended for a priority protection and restoration zone. This area is important for water process and is still relatively un-impaired due to the presence of the Ridgefield National Wildlife Refuge. Both surface and groundwater flows of the upslope management zones (Figure 7 and 8, East and West Terrace) directly affect this unit. Upstream development patterns and measures that negatively affect these processes will affect ecosystem structure and function in this management zone. To maintain this ecosystem and the high success potential of future restoration projects, recommendations for the upstream management zones must be properly implemented.

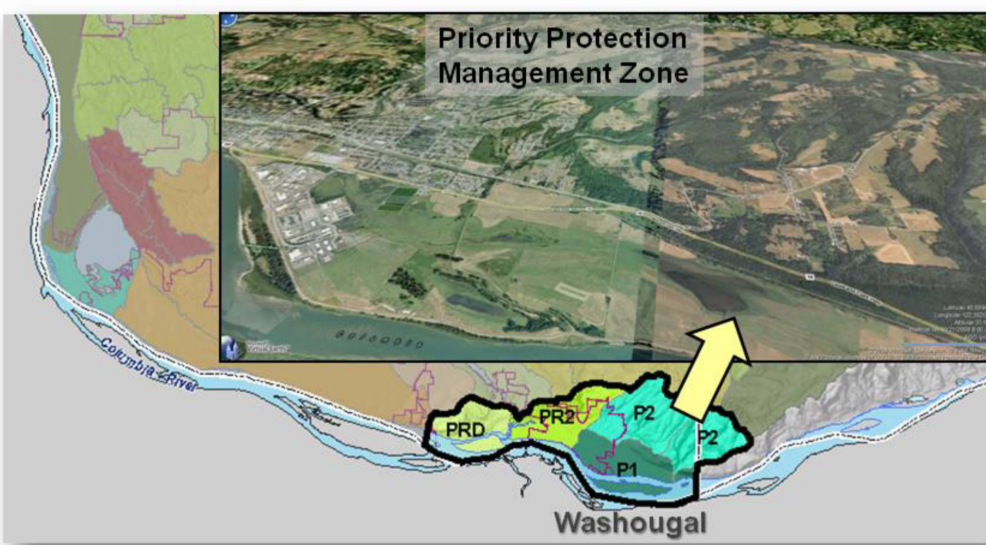

Figure 11. Columbia River East Results. Priority Protection Management Zone for the area east of Washougal and Camus.

For the eastern portion of the Columbia River Unit, a priority protection zone is recommended (Figure 11). The eastern half of the zone supports forested uplands and large areas of lowland wetlands (WDFW wildlife reserve) and is important for groundwater recharge/discharge and denitrification. Processes are basically intact, except for overbank flooding from Columbia River. Therefore future management should focus on protection of forested cover in upland basins and minimizing impervious surfaces.

Urban development increases towards the western portion of the zone, which has impacted processes. The Washougal area is important for hydrologic processes. The lower watershed is urbanized, and the upper watershed consists of large-lot rural residential and agricultural uses. New development in the upper watershed should be sited and designed to restore hydrologic processes (promoting infiltration and recharge) and to protect or restore existing riparian corridors and wetlands. The City of Camas has processes of lower importance and is therefore an appropriate area to increase development density while protecting existing wetlands and riparian areas.

Snow-Dominated and Rain-on-Snow Mountainous Unit

Figure 12 depicts the three management zones for this unit. This unit plays a significant role in supporting surface and groundwater flow processes for the Main and East Fork of the Lewis River. Extensive areas of high precipitation, as snow, support spring river flows and late season base flows. Rain-on-snow areas also support flooding processes downstream (rain zone mountainous unit) which help form and maintain riverine wetlands and riparian habitats. Because processes have not been permanently impaired in this management unit, restoration has a high probability of success. Restoration may include: reducing the density of logging roads and the number of stream crossings, decommissioning roads in high hazard areas (erosion, landslides), increasing forested cover through replanting and reducing the area of individual logging cuts.

In the central portion of the unit, areas with limited alteration were placed in the Protection Management Zone. Sub-units with a greater degree of alteration but high importance were designated as Protection and Restoration Management Zone. Both of zones are less suited for intensive logging practices given their importance to water flow processes.

To the south, the Restoration Management Zone includes some of the highest priority restoration areas in this mountainous unit. Processes have been significantly, though not permanently, impaired by forest clearing for large-lot rural residential and agricultural development. Management policies may include protecting and restoring forest cover areas with high permeability soils, restoring drained wetlands, and replanting riparian corridors.

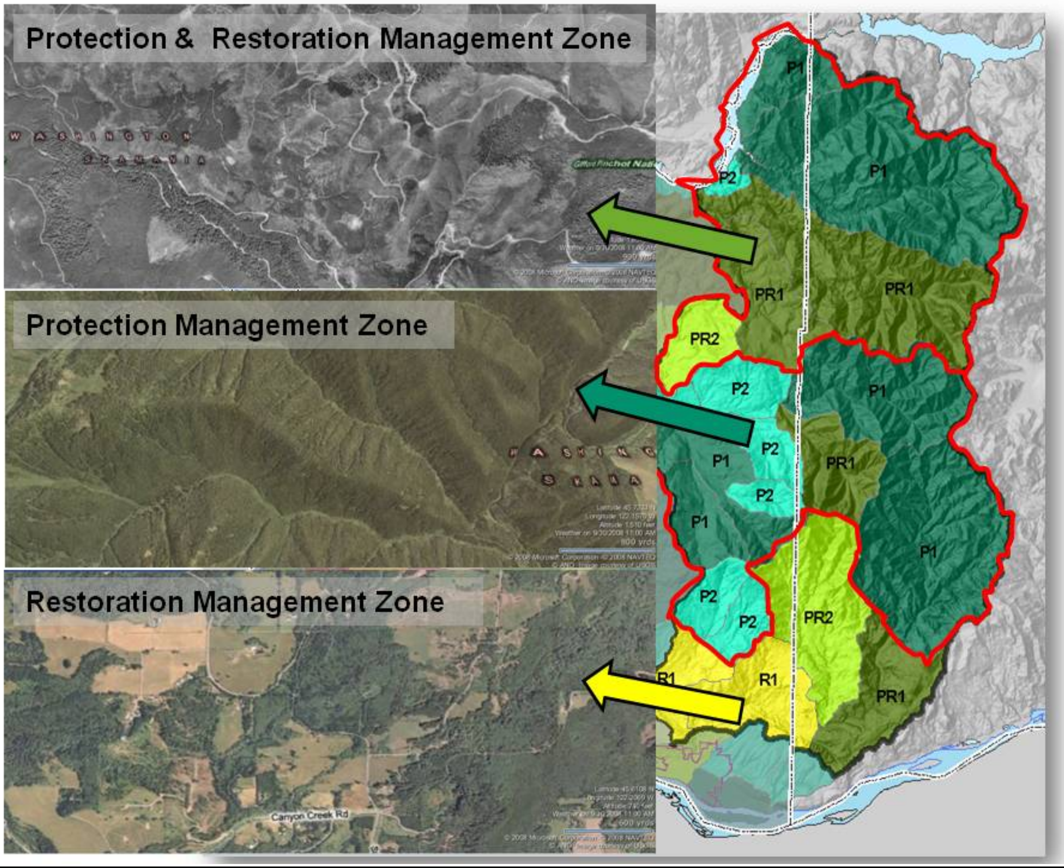

Figure 12. Snow-Dominated and Rain-on-Snow Mountainous Unit. Three management zones recommended: Protection (blue-green); protection/restoration (green); and restoration (yellow).

Rain-Zone Mountainous Unit for East Fork and Mainstem of Lewis River

Figures 13 and 14 present the recommended management zones for the rain-dominated portion of the Lewis River. The upper and mid-reaches of the mainstem of the Lewis and portion of the East Fork of the Lewis watersheds fall within the highest categories of protection and restoration (PR1 and PR2) and a protection and restoration management zone is recommended. This suggests protecting watershed processes by maintaining forest cover in sub-units with high importance and undertaking restoration measures such as: reducing the density of logging roads and the number of stream crossings, decommissioning roads in high hazard areas (erosion, landslides), increasing forested cover through replanting and reducing the area of individual logging cuts.

Hydrologic and denitrification processes have high importance in the lower gradient floodplain areas of both the main stem of the Lewis River and its East Fork. Restoration opportunities are identified in the middle reaches of the East Fork and the mouth of the Main Fork of the Lewis River (R1 and PR2 in Figure 13 and R2D in Figure 14). Lower intensity development which does not permanently alter these processes and promotes restoration is suggested for these areas.

The areas north, east and south of the City of La Center are suitable for restoration and higher intensity development. Processes have lower relative importance and higher impairment in these areas and include drainages for McCormick, Lockwood, Riley, Jenny, and Brezee Creeks, and the East Fork of Mill Creek (Figure 14, R3D, PRD).

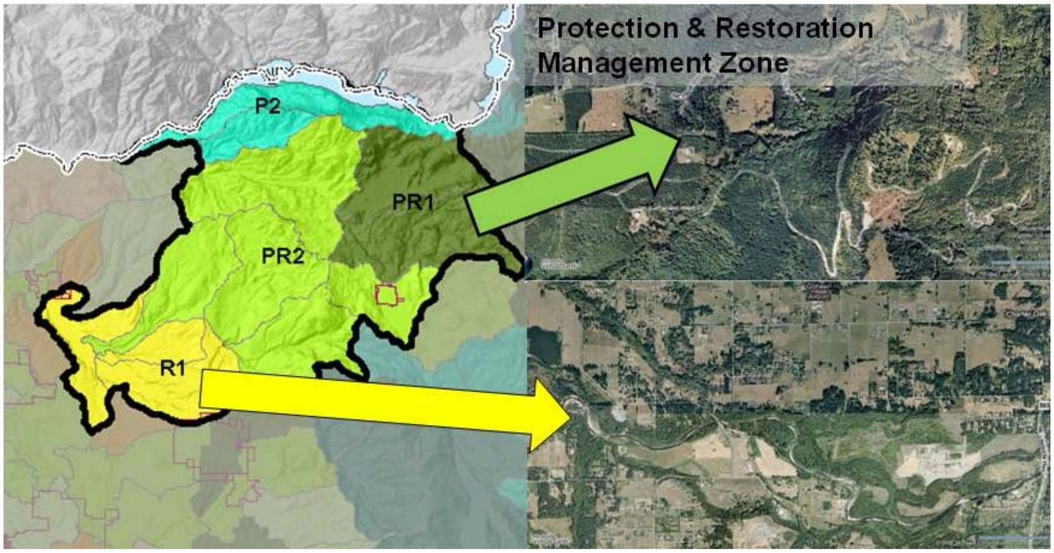

Figure 13. Rain-dominated Mountainous Unit – East Lewis River. Protection and Restoration (green), and Restoration Management (yellow) Zones recommended.

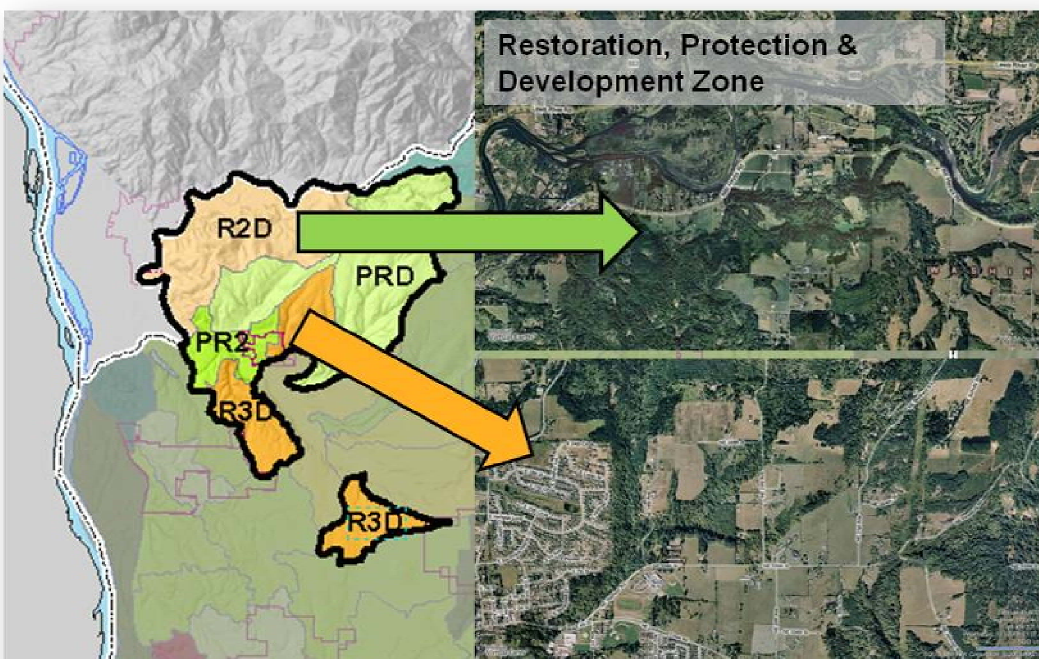

Figure 14. Rain-Dominated Mountainous Unit – West Lewis River. Restoration, Protection, and Development Management Zones recommended.

Figure 15. Sub-units for Analysis and their associated names.

Table 1 – Summary of Characterization Results for Water Flow Process

Sub_Unit for Analysis	Landscape group	Importance Score 0-1	Importance Ranking H,M,L	Impairment Score 0-1	Impairment Ranking H,M,L	Protection, Restoration, Development Ranking
Camas	Columbia	0.00	L	0.42	M	PRD
Cathlapotle	Columbia	0.57	MH	0.14	L	P1
Columbia Slope	Columbia	0.30	M	1.00	H	R3D
East Fork Lewis (r.m. 00.00)	Columbia	0.39	M	0.39	M	PR2
Gibbons Creek	Columbia	0.16	L	0.17	L	P2
Lake River	Columbia	1.00	H	0.30	M	PR1
Lawton Creek	Columbia	0.11	L	0.00	L	P2
Salmon Creek (r.m. 00.60)	Columbia	0.14	L	0.77	H	D1
Steigerwald Lake	Columbia	0.84	H	0.24	L	P1
Vancouver Lake	Columbia	0.34	M	0.00	L	P2
Washougal (Lower)	Columbia	0.43	M	0.50	M	PR2
Big Creek	Headwater Snow Dom	0.40	M	0.34	M	PR2
Boulder Creek	Headwater Snow Dom	0.25	L	0.17	L	P2
Canyon Creek	Headwater Snow Dom	0.60	MH	0.32	M	PR1
Cold & Cedar Creek (East Fork)	Headwater Snow Dom	0.60	MH	0.07	L	P1
Copper Creek	Headwater Snow Dom	0.65	MH	0.27	M	PR1
Coyote Creek	Headwater Snow Dom	0.56	MH	0.12	L	P1
East Fork Lewis	Headwater Snow Dom	0.69	MH	0.19	L	P1
East Fork Lewis (r.m. 21.50)	Headwater Snow Dom	0.00	L	0.23	L	P2
East Fork Lewis (r.m. 26.85)	Headwater Snow Dom	0.21	L	0.07	L	P2
Jackson Creek	Headwater Snow Dom	0.40	M	0.30	M	PR2
King Creek	Headwater Snow Dom	0.29	M	0.14	L	P2
Little Fly Creek	Headwater Snow Dom	1.00	H	0.41	M	PR1
Little Washougal (Lower)	Headwater Snow Dom	0.81	H	1.00	H	R1
Little Washougal (Upper)	Headwater Snow Dom	0.22	L	0.12	L	P2
Rock Creek (South)	Headwater Snow Dom	0.47	M	0.14	L	P2
Siouxon Creek	Headwater Snow Dom	0.66	MH	0.15	L	P1
Upper Washougal	Headwater Snow Dom	0.72	MH	0.16	L	P1
Washougal	Headwater Snow Dom	0.60	MH	0.47	M	PR1
Washougal (Middle)	Headwater Snow Dom	0.81	H	0.61	MH	R1

Table 1 Continued – Summary of Characterization Results for Water Flow Process						
Sub_Unit for Analysis	**Landscape group**	**Importance Score 0-1**	**Importance Ranking H,M,L**	**Impairment Score 0-1**	**Impairment Ranking H,M,L**	**Protection, Restoration, Development Ranking**
Yale Dam	Headwater Snow Dom	0.38	M	0.07	L	P2
Yale Lake	Headwater Snow Dom	0.81	H	0.00	L	P1
Brezee Creek	Lewis Rain Dom	0.06	L	0.51	MH	R3D
Cedar Creek (Lower)	Lewis Rain Dom	0.26	M	0.28	M	PR2
Cedar Creek (Middle)	Lewis Rain Dom	0.26	M	0.27	M	PR2
Cedar Creek (Upper)	Lewis Rain Dom	0.91	H	0.29	M	PR1
Chelatchie	Lewis Rain Dom	0.53	MH	0.36	M	PR1
Dean Creek	Lewis Rain Dom	1.00	H	0.62	MH	R1
East Fork Lewis (r.m. 03.19)	Lewis Rain Dom	1.00	H	0.73	MH	R1
East Fork Lewis (r.m. 07.25)	Lewis Rain Dom	0.84	H	0.91	H	R1
East Fork Lewis (r.m. 15.75)	Lewis Rain Dom	0.38	M	0.43	M	PR2
Jenny Creek	Lewis Rain Dom	0.00	L	0.42	M	PRD
Lake Merwin	Lewis Rain Dom	0.44	M	0.00	L	P2
Lockwood & Riley Creek	Lewis Rain Dom	0.10	L	0.33	M	PRD
Mason Creek	Lewis Rain Dom	0.46	M	0.45	M	PR2
McCormick Creek	Lewis Rain Dom	0.31	M	0.79	H	R3D
Mill Creek (East Fork)	Lewis Rain Dom	0.24	L	1.00	H	D1
North Fork Lewis River (Lower)	Lewis Rain Dom	0.44	M	0.51	MH	R2D
Pup Creek	Lewis Rain Dom	0.15	L	0.06	L	P2
Rock Creek (North)	Lewis Rain Dom	0.38	M	0.36	M	PR2
Yacolt Creek	Lewis Rain Dom	0.40	M	0.48	M	PR2
Allen Canyon Creek	Terrace	0.51	MH	0.34	M	PR1
Burnt Bridge Creek Lower	Terrace	0.36	M	0.98	H	R3D
Burnt Bridge Creek Upland	Terrace	0.54	MH	0.87	H	R2
Burton Channel	Terrace	0.71	MH	1.00	H	R2
Burton Sink	Terrace	0.43	M	0.87	H	R3D
China Ditch	Terrace	0.74	MH	0.47	M	PR1
Cougar Creek	Terrace	0.13	L	0.91	H	D1
Curtin Creek	Terrace	0.29	M	0.72	MH	R2D
Dwyer Creek	Terrace	0.44	M	0.55	MH	R2D

Table 1 Continued – Summary of Characterization Results for Water Flow Process						
Sub_Unit for Analysis	**Landscape group**	**Importance Score 0-1**	**Importance Ranking H,M,L**	**Impairment Score 0-1**	**Impairment Ranking H,M,L**	**Protection, Restoration, Development Ranking**
Flume Creek	Terrace	0.29	M	0.32	M	PR2
Gee Creek (Lower)	Terrace	0.16	L	0.33	M	PRD
Gee Creek (Upper)	Terrace	0.36	M	0.39	M	PR2
Lacamas Lake	Terrace	0.27	M	0.28	M	PR2
Lakeshore	Terrace	0.00	L	0.82	H	D1
Lower Fifth Plain Creek	Terrace	0.89	H	0.70	MH	R1
Lower Lacamas Creek	Terrace	0.99	H	0.57	MH	R1
Matney Creek	Terrace	0.31	M	0.18	L	P2
Middle Lacamas Creek	Terrace	0.87	H	0.51	MH	R1
Mill Creek	Terrace	0.31	M	0.47	M	PR2
Morgan Creek	Terrace	0.27	M	0.33	M	PR2
Rock Creek	Terrace	0.60	MH	0.25	L	P1
Salmon Creek (r.m. 03.83)	Terrace	0.29	M	0.83	H	R3D
Salmon Creek (r.m. 08.96)	Terrace	0.29	M	0.45	M	PR2
Salmon Creek (r.m. 14.66)	Terrace	0.49	M	0.36	M	PR2
Salmon Creek (r.m. 22.20)	Terrace	0.61	MH	0.13	L	P1
Shanghai Creek	Terrace	0.56	MH	0.37	M	PR1
Upper Fifth Plain Creek	Terrace	0.24	L	0.31	M	PRD
Upper Lacamas Creek	Terrace	1.00	H	0.00	L	P1
Whipple Creek (Lower)	Terrace	0.43	M	0.37	M	PR2
Whipple Creek (Upper)	Terrace	0.13	L	0.46	M	PRD
Woodin Creek	Terrace	0.60	MH	0.47	M	PR1

Table 2 – Summary of Characterization Results for Nitrogen Process								
Sub_Unit for Analysis	**Landscape group**	**Importance Score 0-1**	**Importance Ranking H,M,L**	**Impairment Score 0-1**	**Impairment Ranking H,M,L**	**Loading Score 0-1**	**Loading Ranking H,M,L**	**Protection, Restoration, Development Ranking "X"= no ranking**
Camas	Columbia	0.31	M	0.36	M	0.837	M	P2
Cathlapotle	Columbia	0.93	H	0.31	L	0.680	M	X
Columbia Slope	Columbia	0.08	L	0.58	M	1.384	MH	R3
East Fork Lewis (r.m. 00.00)	Columbia	0.19	L	0.62	M	0.766	M	P2
Gibbons Creek	Columbia	0.03	L	0.52	M	0.801	M	P2
Lake River	Columbia	0.92	H	0.59	M	0.795	M	P1
Lawton Creek	Columbia	0.01	L	0.53	M	0.685	M	P2
Salmon Creek (r.m. 00.60)	Columbia	0.25	L	0.69	H	0.906	M	P2
Steigerwald Lake	Columbia	0.79	H	0.42	M	1.077	MH	R1
Vancouver Lake	Columbia	1.00	H	0.33	L	0.775	M	X
Washougal (Lower)	Columbia	0.41	M	0.54	M	1.125	MH	R2
Big Creek	Headwater Snow Dom	0.00	L	0.09	L	0.343	L	X
Boulder Creek	Headwater Snow Dom	0.00	L	0.06	L	0.283	L	X
Canyon Creek	Headwater Snow Dom	0.00	L	0.05	L	0.338	L	X
Cold & Cedar Creek (East Fork)	Headwater Snow Dom	0.01	L	0.01	L	0.222	L	X
Copper Creek	Headwater Snow Dom	0.00	L	0.06	L	0.182	L	X
Coyote Creek	Headwater Snow Dom	0.00	L	0.00	L	0.182	L	X
East Fork Lewis	Headwater Snow Dom	0.00	L	0.03	L	0.192	L	X
East Fork Lewis (r.m. 21.50)	Headwater Snow Dom	0.00	L	0.04	L	0.293	L	X
East Fork Lewis (r.m. 26.85)	Headwater Snow Dom	0.00	L	0.01	L	0.182	L	X
Jackson Creek	Headwater Snow Dom	0.00	L	0.06	L	0.313	L	X
King Creek	Headwater Snow Dom	0.00	L	0.01	L	0.273	L	X
Little Fly Creek	Headwater Snow Dom	0.01	L	0.11	L	0.303	L	X
Little Washougal (Lower)	Headwater Snow Dom	0.04	L	0.40	M	0.741	M	P2
Little Washougal (Upper)	Headwater Snow Dom	0.00	L	0.02	L	0.273	L	X
Rock Creek (South)	Headwater Snow Dom	0.01	L	0.04	L	0.283	L	X
Siouxon Creek	Headwater Snow Dom	0.00	L	0.03	L	0.227	L	X

Table 2 Continued – Summary of Characterization Results for Nitrogen Process								
Sub_Unit for Analysis	**Landscape group**	**Importance Score 0-1**	**Importance Ranking H,M,L**	**Impairment Score 0-1**	**Impairment Ratnkng H,M,L**	**Loading Score 0-1**	**Loading Ranking H,M,L**	**Protection, Restoration, Development Ranking "X"= no ranking**
Upper Washougal	Headwater Snow Dom	0.00	L	0.02	L	0.317	L	X
Washougal	Headwater Snow Dom	0.03	L	0.11	L	0.525	M	X
Washougal (Middle)	Headwater Snow Dom	0.04	L	0.30	L	0.651	M	X
Yale Dam	Headwater Snow Dom	0.29	M	0.01	L	0.273	L	X
Yale Lake	Headwater Snow Dom	0.24	L	0.01	L	0.222	L	X
Brezee Creek	Lewis Rain Dom	0.01	L	0.56	M	0.861	M	P2
Cedar Creek (Lower)	Lewis Rain Dom	0.03	L	0.31	L	0.805	M	X
Cedar Creek (Middle)	Lewis Rain Dom	0.01	L	0.23	L	0.393	L	X
Cedar Creek (Upper)	Lewis Rain Dom	0.01	L	0.12	L	0.333	L	X
Chelatchie	Lewis Rain Dom	0.17	L	0.36	M	0.713	M	P2
Dean Creek	Lewis Rain Dom	0.41	M	0.68	H	1.122	MH	R2
East Fork Lewis (r.m. 03.19)	Lewis Rain Dom	0.52	MH	0.74	H	1.022	MH	R1
East Fork Lewis (r.m. 07.25)	Lewis Rain Dom	0.36	M	0.55	M	0.957	M	P2
East Fork Lewis (r.m. 15.75)	Lewis Rain Dom	0.08	L	0.25	L	0.941	M	X
Jenny Creek	Lewis Rain Dom	0.00	L	0.57	M	0.718	M	P2
Lake Merwin	Lewis Rain Dom	0.37	M	0.05	L	0.358	L	X
Lockwood & Riley Creek	Lewis Rain Dom	0.01	L	0.49	M	0.941	M	P2
Mason Creek	Lewis Rain Dom	0.12	L	0.57	M	0.971	M	P2
McCormick Creek	Lewis Rain Dom	0.15	L	0.93	H	1.245	MH	R3
Mill Creek (East Fork)	Lewis Rain Dom	0.29	M	0.71	H	1.086	MH	R2
North Fork Lewis River (Lower)	Lewis Rain Dom	0.16	L	0.38	M	0.857	M	P2
Pup Creek	Lewis Rain Dom	0.00	L	0.08	L	0.563	M	X
Rock Creek (North)	Lewis Rain Dom	0.13	L	0.32	L	0.989	M	X
Yacolt Creek	Lewis Rain Dom	0.09	L	0.28	L	0.518	M	X
Allen Canyon Creek	Terrace	0.27	M	0.75	H	0.925	M	P2
Burnt Bridge Creek Lower	Terrace	0.16	L	0.69	H	1.930	H	R3
Burnt Bridge Creek Upland	Terrace	0.29	M	0.79	H	1.648	H	R2
Burton Channel	Terrace	0.21	L	0.67	H	1.909	H	R3
Burton Sink	Terrace	0.00	L	0.67	H	1.688	H	R3

Table 2 Continued – Summary of Characterization Results for Nitrogen Process								
Sub_Unit for Analysis	**Landscape group**	**Importance Score 0-1**	**Importance Ranking H,M,L**	**Impairment Score 0-1**	**Impairment Ranking H,M,L**	**Loading Score 0-1**	**Loading Ranking H,M,L**	**Protection, Restoration, Development Ranking "X"= no ranking**
China Ditch	Terrace	0.73	MH	1.00	H	1.433	MH	R1
Cougar Creek	Terrace	0.17	L	0.68	H	1.385	MH	R3
Curtin Creek	Terrace	0.24	L	0.85	H	1.659	H	R3
Dwyer Creek	Terrace	0.24	L	0.72	H	1.460	MH	R3
Flume Creek	Terrace	0.09	L	0.79	H	1.126	MH	R3
Gee Creek (Lower)	Terrace	0.09	L	0.72	H	0.955	M	P2
Gee Creek (Upper)	Terrace	0.15	L	0.89	H	0.984	M	P2
Lacamas Lake	Terrace	0.23	L	0.59	M	0.926	M	P2
Lakeshore	Terrace	0.08	L	0.63	M	1.136	MH	R3
Lower Fifth Plain Creek	Terrace	0.31	M	0.91	H	1.524	H	R2
Lower Lacamas Creek	Terrace	0.56	MH	0.79	H	1.494	MH	R1
Matney Creek	Terrace	0.05	L	0.34	M	1.040	MH	R3
Middle Lacamas Creek	Terrace	0.52	MH	0.81	H	1.347	MH	R1
Mill Creek	Terrace	0.37	M	0.93	H	1.387	MH	R2
Morgan Creek	Terrace	0.17	L	0.63	M	1.165	MH	R3
Rock Creek	Terrace	0.08	L	0.23	L	1.111	MH	X
Salmon Creek (r.m. 03.83)	Terrace	0.16	L	0.66	M	1.376	MH	R3
Salmon Creek (r.m. 08.96)	Terrace	0.40	M	0.91	H	1.326	MH	R2
Salmon Creek (r.m. 14.66)	Terrace	0.27	M	0.64	M	1.267	MH	R2
Salmon Creek (r.m. 22.20)	Terrace	0.00	L	0.12	L	0.398	L	X
Shanghai Creek	Terrace	0.28	M	0.53	M	1.276	MH	R2
Upper Fifth Plain Creek	Terrace	0.13	L	0.48	M	1.216	MH	R3
Upper Lacamas Creek	Terrace	0.04	L	0.05	L	0.449	L	X
Whipple Creek (Lower)	Terrace	0.16	L	0.85	H	1.036	MH	R3
Whipple Creek (Upper)	Terrace	0.08	L	0.70	H	0.984	M	P2
Woodin Creek	Terrace	0.43	M	0.60	M	1.619	H	R2

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Appendix A - Characterization Methods

Methods

The approach used for this project is described in Ecology publication #05-06-027, "Protecting Aquatic Ecosystems by Understanding Watershed Processes: A Guide for Planners." This document provides guidance on how to conduct a coarse-scale characterization for multiple watershed processes. Appendices B and C of this publication also present the models used to score hydrologic and denitrification processes: http://www.ecy.wa.gov/programs/sea/pubs/0506027/review.html .

The appendices in publication #05-06-027 provide tables describing the parts of each process, as well as human activities that impair the process. For the water, nitrogen, and pathogen processes, there are numeric models that identify the areas in a watershed more important to maintaining that process, and the areas where that process is most impaired. The equations in these models use variables (environmental characteristics described in the tables) to establish the relative level of importance and impairment.

Variables are assigned values of 1, 2, or 3, representing low, medium, or high. A high total score can reflect either that a sub-unit has a greater importance for supporting a watershed process, or, has a higher degree of process impairment.

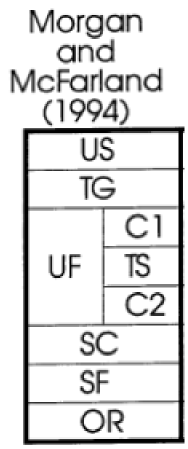
In general, scoring is normalized to conditions in a watershed or basin. However, indicators of importance or impairment are based on peer-reviewed research suggesting regional thresholds for certain process components (such as, minimum wetland area and relationship to surface water flows). Thus, the models provide a *comparison* of the *relative level of importance and impairment* of process components (see Steps 3 and 4 of Ecology publication #05-06-027). The scores do not represent an absolute rate (e.g., rate of removal of sediment or nitrogen) or specific level of process impairment, and cannot be compared to scores outside of the analysis area. We do not have enough information to calibrate models to conditions statewide nor establish relative importance of processes and impairments among different watersheds.

The maps in Appendix B show model results for Clark County. See the appendices in Ecology publication #05-06-027 for descriptions of the scoring methods (http://www.ecy.wa.gov/programs/sea/pubs/0506027/review.html).

Landscape groups

This characterization uses a landscape classification approach based on the "hydrologic-landscapes" described by Winter (2001) and the hydrogeologic work of Bedford (1999 & 1988), and uses precipitation type, landform, geology, and surface water/groundwater patterns to develop landscape groups.

Clark County established landscape groups based on both the EPA eco-regional classification (Ecoregion 3) and local geologic and water-bearing characteristics (Swanson 1993; Morgan and McFarland 1996). The units consist of:



(1) unconsolidated sedimentary aquifer (US)
(2) Troutdale gravel aquifer (TG)
(3) confining unit 1 (C1)
(4) Troutdale sandstone aquifer (TS)
(5) confining unit 2 (C2)
(6) sand and gravel aquifer, upper coarse-grained sub-unit (SC)
(7) sand and gravel aquifer, lower fine grained sub-unit (SF)
(8) older rocks (OR).

In order to maintain the relationship between processes and the aquatic ecosystems that they influence, this characterization modified the existing classification scheme by adding precipitation type and surface/groundwater patterns to geology and landform.

These modified landscape groups were then divided so that watersheds with significantly different patterns of precipitation and geomorphology were not compared to one another during the scoring process. For example, the Lewis River unit watersheds have higher precipitation patterns, including rain-on-snow and snow-dominated zones relative to the lower precipitation levels in the rain-dominated Terrace units. Comparing both of these units together will artificially reduce the scores of the lower precipitation Terrace units. The Terrace units, however, support important aquatic ecosystems and should be characterized separately from the Lewis River watersheds.

There are four landscape groups (see Figure A-1) used in the Clark County characterization. The easternmost unit (upper Lewis and Washougal River watersheds) is characterized by rain-on-snow and snow-dominated precipitation, generally shallow groundwater flow, consolidated bedrock, and steep topography. This is called the Rain-on-Snow and Snow-Dominated Mountainous Unit.

The second landscape group is called the Rain-Dominated Mountainous Unit and is a transition unit between the Terrace and Rain-on-Snow units. It is located on the mid-reaches of the Lewis River and the lower reaches of the East Fork of the Lewis River. It is characterized by rain-dominated precipitation, shallow and deep patterns of groundwater flow, glacial till over consolidated formations as well as more permeable sedimentary formations (e.g. river alluvium and Troutdale formation), and moderate to steep topography. In particular, this unit represents a northward shift in Terrace groundwater flow patterns towards the East Fork and away from a westward flow towards the Columbia River. It is also influenced by surface waters draining out of the Rain-on-Snow unit to the east into the lower reaches of the East Fork of the Lewis River.

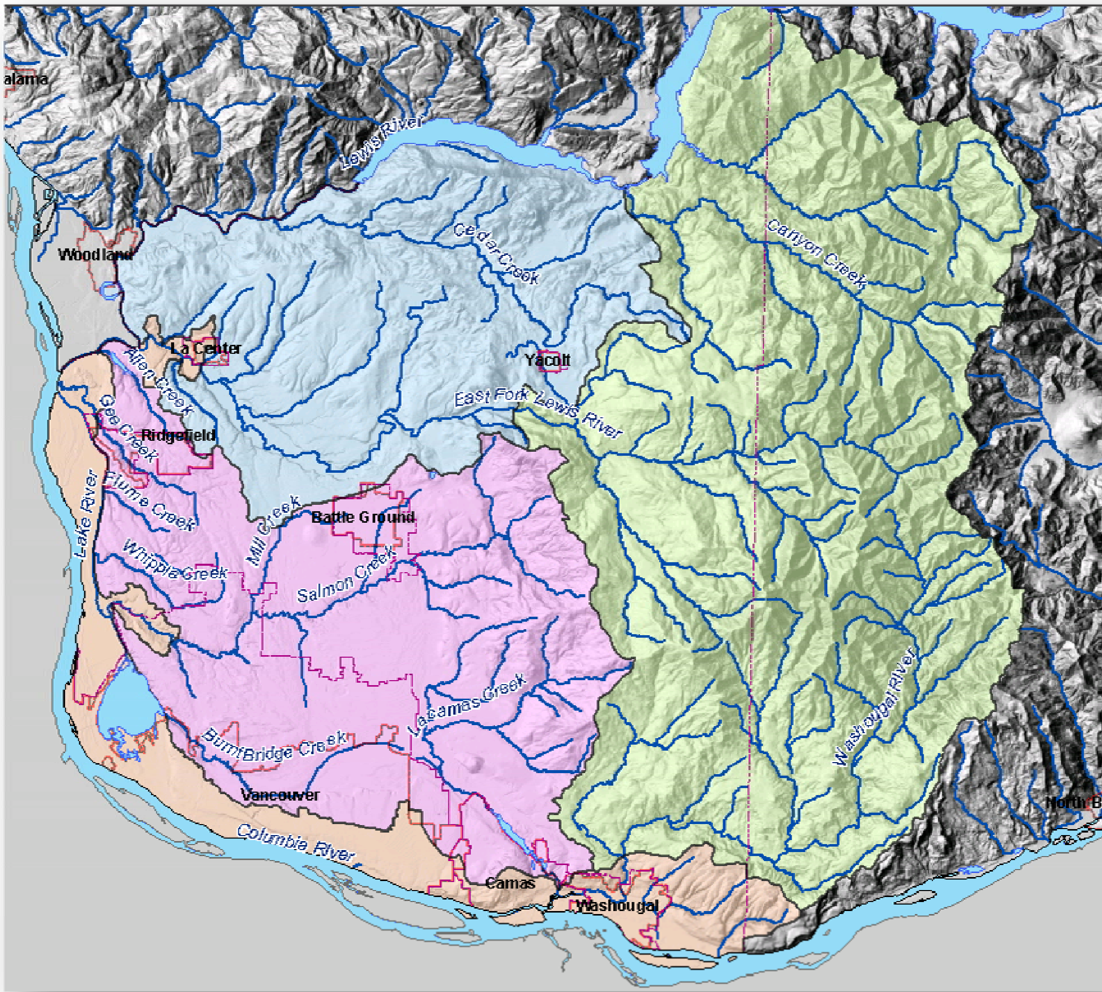


Figure A-1. Landscape Groups. Green is the Rain-on-Snow and Snow-Dominated Mountainous unit; blue is the Rain-dominated Mountainous unit (East Fork and Mainstem of the Lewis); pink is the Terrace unit; and orange identifies the Columbia River unit.

The third landscape group, called the Terrace Unit, includes the large Terrace plains (Figure A-2) with associated up-gradient foothills and down-gradient slopes above the Columbia River. This unit is dominated by rain and has a westward to southwestern trending groundwater flow pattern; a large delta (now a terrace) formed by glacial floods consisting of gravels, sand, silts and clay; and a relatively level to moderately steep topography in the foothills and slopes above the Columbia River. The groundwater flow patterns on the north end of this unit that trend north and northeast separate it from the Lewis River Rain Zone Unit.

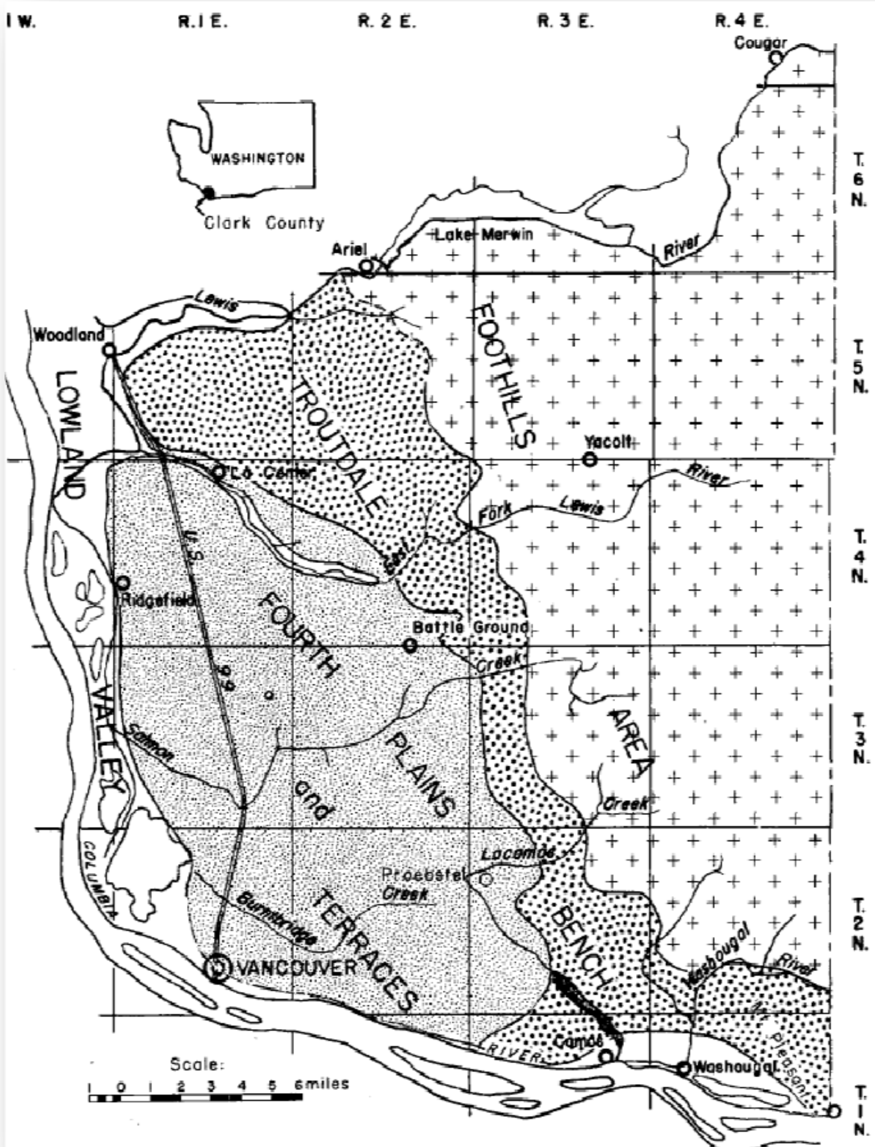


Figure A-2. Map of Landforms in Western Clark County. (Mundorff, 1964)

The fourth landscape group is the Columbia River Unit, the Columbia floodplain area dominated by the Columbia River. It is located in a rain zone, has sub-surface water flow patterns (influenced by groundwater discharge from the adjacent upland units) and recharge from the river surface waters, geologic deposits consisting primarily of relatively recent river alluvium (sand and silt), and a riverine floodplain and valley walls formed by fluvial action of the river.

The geology, landform, and groundwater flow patterns of these units are discussed in further detail below.

Geology

Information on Clark County geology is based on work by Mundorff (1964), Water Resources Bulletin 9, Swanson et al. (1993), McFarland and Morgan (1996), Morgan and McFarland (1994) and Snyder et al. (1996). These works describe the aquifer system within the Portland Basin, including western Clark County. It is divided into three major subsystems: upper sedimentary rocks, lower sedimentary rocks, and older rocks. The following description of Clark County geology is within the context of these subsystems, the individual landscape groups described by Morgan and McFarland (1994), and the modified landscape groups used in this characterization (Figure A-1).

Clark County lies on the western flank of the Cascade Mountains. The upper elevations in the eastern part of the county consist of steep mountainous terrain underlain by andesite, basalt, and sedimentary formations (Morgan and McFarland 1994). These formations are generally consolidated and have low permeability. Surface water infiltrates primarily into fractures of these consolidated deposits. This area is identified as the Rain-on-snow Mountainous Unit for this characterization.

The western portion of the county is dominated by the upper and lower sedimentary subsystems. The upper sedimentary system is comprised of unconsolidated sedimentary deposits (UC in Morgan and McFarland 1994) and the Troutdale gravel aquifer and volcanic deposits (TG in Morgan and McFarland 1994). These deposits are located within a series of nearly flat plains and benches which rise step like from the Columbia River, a few feet above sea level to approximately 800 feet above sea level (Figure A-2 and A-3). The majority of the deposits closest to the surface were the result of several Pleistocene glacial outburst floods from the release of impounded waters at Lake Missoula (US in Morgan and McFarland 1994). The unconsolidated deposits in the Columbia River are the result of more recent alluvial deposits from Columbia River flooding.

The Troutdale gravel aquifer (also known as the upper Troutdale formation) is an important source of public and industrial water. This aquifer has been exposed by erosion from the Columbia River and tributaries immediately above the Columbia, resulting in groundwater discharge to riverine and associated wetland ecosystems. The Troutdale gravel aquifer is also exposed at the ground surface in the Troutdale bench area. Due to long-term weathering in this area, the deposit is reduced close to its base elevation in most of this bench area, resulting in significantly reduced capacity to infiltrate, recharge, or store significant quantities of precipitation. The Rain-dominated Terrace unit for this report includes the UC and TG deposits. The Columbia River Unit includes the recent UC deposits.

The lower sedimentary system overlies older rocks and is comprised of confining deposits and consolidated silt, sand and clay, and sandstone basaltic conglomerate (C1 and C2, TS, SC, SF, and OR in Morgan and McFarland 1994). The silt, sand, and clay deposits are also known as the Lower Troutdale formation and attain a thickness of 660 feet. It is a low permeability deposit and is, therefore, not the principal aquifer for the county. These deposits primarily underlie the Terrace, Columbia River, and western portion of the Rain-dominated Mountainous Units.

North and northeast of Battle Ground are glacial deposits from the advance and recession of the Mount St. Helens glacier. This includes till, glaciofluvial, outwash, and lake/pond deposits. The outwash deposits are the most permeable and underlie the Chelatchi Prairie and Yacolt Basins and are included in the unconsolidated sedimentary subsystem, located in the Rain-dominated Mountainous unit. Otherwise, the glacial deposits in this area are of low permeability.

Groundwater Flow Patterns

Figures A-3 and A-4 present the generalized geology and subsurface water flow patterns for the western portion of Clark County. The dominant sub-surface flow pattern for the watersheds south of the cities of Ridgefield and Battleground is towards the west and southwest. North of these cities the sub-surface water flow patterns trend towards the northwest and north. These water flow patterns were used to create the landscape groups for the Rain-dominated Terrace unit (southwest corner of the county) and the Rain-dominated Mountainous unit (East Fork and Mainstem of the Lewis River).

Groundwater flow patterns were not available for the eastern portion of the county and, therefore, precipitation type and geology/landform were primarily used to establish landscape groups.

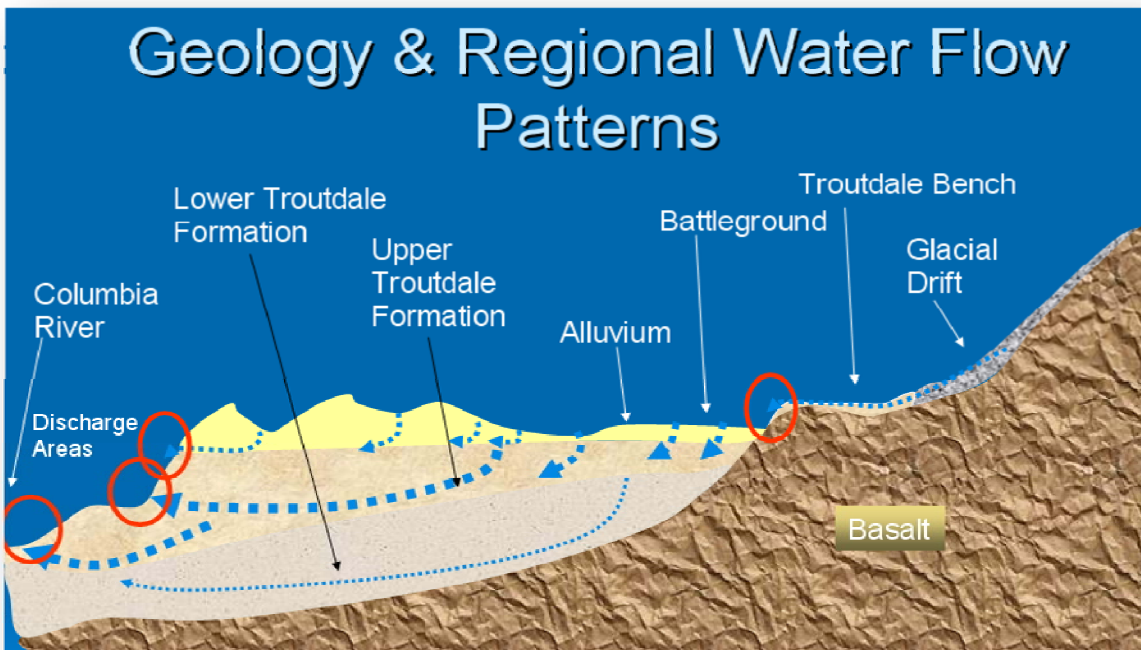


Figure A-3. Generalized Geology and Regional Sub-surface Water Flow Patterns for Western Clark County. View is north along a broad cross section running east-west from mountains east of the City of Battleground through the Fourth Plains and Terraces to the Columbia River. Source: Mundorff 1960.

Figure A-4 depicts the results of USGS modeling for the Troutdale gravel aquifer. The USGS conducted the modeling to determine water flow patterns, important areas for recharge, and those areas most sensitive to groundwater contamination. It shows that the area including and

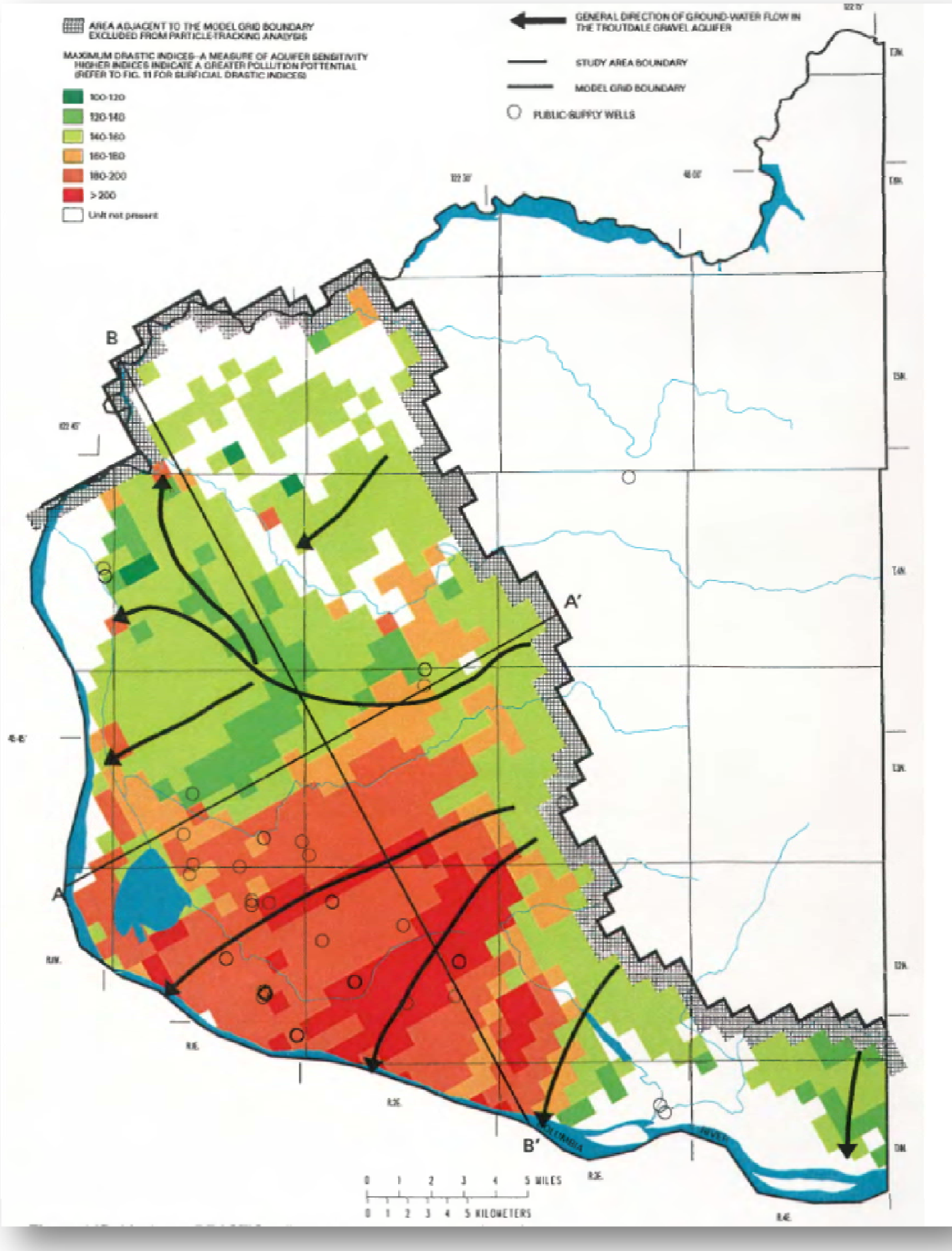


Figure A-4. Generalized Groundwater Flow Patterns for Troutdale Gravel Aquifer. This figure also depicts measurement of aquifer sensitivity to contamination using DRASTIC methodology (Figure 14B in USGS Open File Report 96-328).

south of Salmon Creek as the most sensitive to groundwater contamination. North of Salmon Creek towards Ridgefield, the USGS modeling shows the Terrace unit as having a lower sensitivity to contamination of the Troutdale gravel aquifer.

Appendix B - Planning Framework

Framework

Successful watershed planning uses larger scale information (i.e. the characterization) to help identify planning solutions at smaller scales. To accomplish this, a watershed based planning framework, as presented below (see Figure B-1), should be applied. A more detailed discussion of this planning framework is presented in Guidance for Protecting and Managing Wetlands in Western Washington, Volume 2, Chapters 4 and 5 (Granger et al. 2005).

The methods described in this document for mapping important areas and relative impairments to watershed processes address the first box of the diagram, “Characterize Watershed Processes” shown in Figure B-1. Planners can then use this information to develop preliminary solutions (box 2, “Prescribe Solutions”) including alternative scenarios for development/ management. Examples include:

- Selecting the appropriate types and intensity of development for different locations
- Changing zoning to better protect the ecological services provided by the environment
- Identifying the best locations for mitigation
- Identifying the types of mitigation needed in different areas
- Locating the best areas for cost-effective restoration.

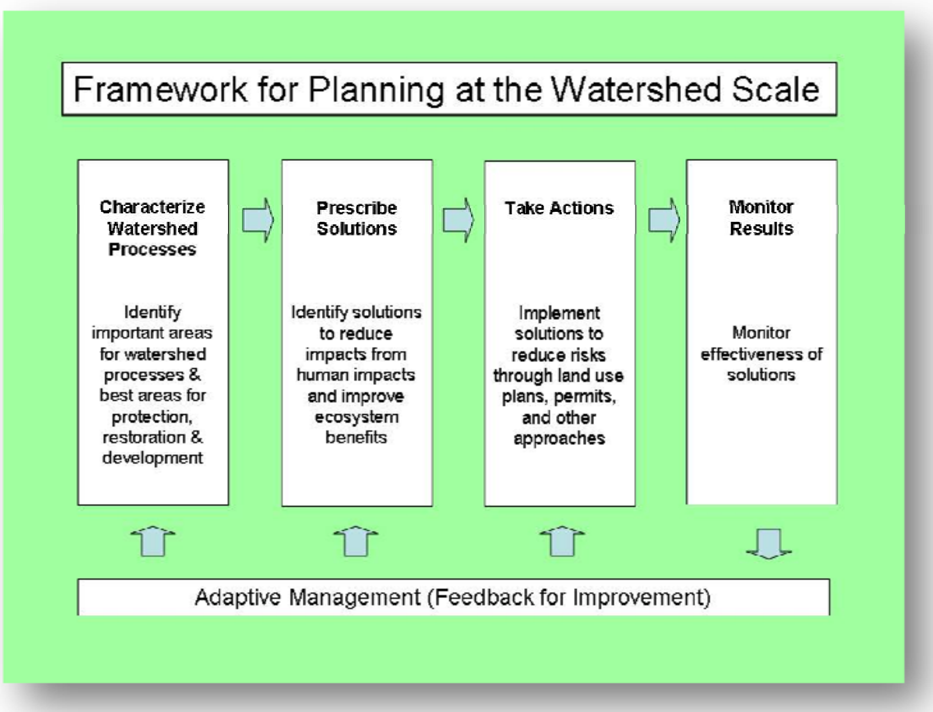


Figure B-1 – Framework for Watershed Scale Planning. The four main steps for developing a watershed based plan.

When scenarios for future development and management are analyzed, locally reviewed, and accepted, the solutions can be incorporated in Shoreline Master Program and/or Comprehensive Plan updates and implemented through the regulatory process. The final, and most important step in the framework, is monitoring the results of the adopted plan. This determines if the provisions of the plan are effectively protecting and/or restoring aquatic ecosystems. Feedback from this monitoring effort can be used to modify or "adapt" the plan to correct those aspects that are not meeting the objectives of protection and restoration.

Examples of Jurisdictions Using the Framework

Whatcom, King, and Jefferson counties are presently using a framework for planning at the watershed scale as part of their Shoreline Master Programs (SMP) updates. These jurisdictions are using earlier versions of the characterization models outlined in Ecology Publication 05-06-027 The Whatcom County Council adopted their draft SMP on February 27, 2007. The draft SMP characterization and restoration reports (Appendix C, Volumes I and II) are available at the following site:

http://www.co.whatcom.wa.us/pds/shorelines_critical_areas/workproducts.jsp

Whatcom County's characterization work provided information necessary to: 1) select appropriate environment designations and development standards for shoreline areas and 2) develop watershed-based restoration and protection recommendations for shoreline resources. Figure B-2 displays the important areas identified for the hydrology process in Whatcom County at the watershed scale. Using this information, as well as a characterization of the level of impairment, the county developed tables providing recommendations at a reach scale for protection and restoration measures and environment designations (Figure B-3).

A draft watershed management plan was developed by Whatcom County in 2007 for the Birch Bay watershed. Using a watershed based characterization of ecosystem processes and wildlife, protection, restoration and development management zones were identified (Figure B-4). Additionally, specific measures for restoration of processes were proposed for each sub-unit within the study area. The County is in the process of preparing regulatory and non-regulatory measures to implement the management plan. The draft management plan is available at the following site:

http://www.co.whatcom.wa.us/pds/shorelines_critical_areas/pdf/CompleteBBCharacter_PublicDraft.pdf

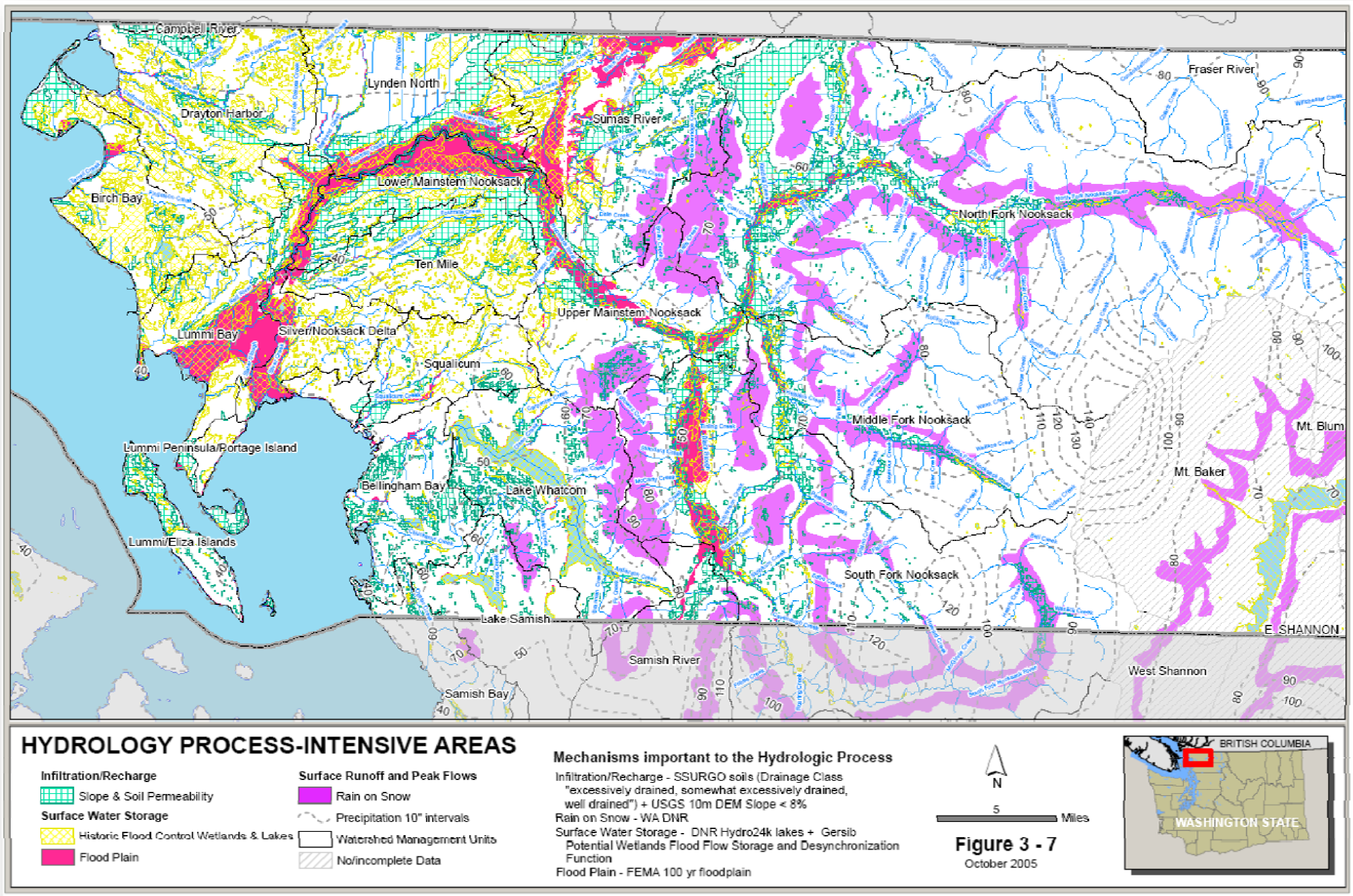


Figure B-2. Example of Characterization Map for Water Process. (Whatcom County). This map was developed using methods described in the Department of Ecology publication # 05-06-027 (Protecting Aquatic Ecosystems). This map, along with maps for four other watershed processes, was used to develop SMP protection and restoration measures (Figure B-3).

ble 7-1. Summary of Process Intensity and Alterations by Drainage Area, Upper Mainstem Nooksack WMU

Process		Hydrology								Sediment						Water Quality				LWD		Heat/Light		
		Process Intensity[a]																						
Mechanism		Infiltration & Recharge		Surface Water Storage		Snowmelt and Runoff		Ground-water		Mass Wasting		Surface Erosion		Storage		Inputs		Storage		LWDRP		Canopy Cover		
Intensity		Process	Alteration	Process	Alteration	Process	Alteration	Process	Alteration	Process	Alteration	Process	Alteration	Process	Alteration	Process	Alteration	Process	Alteration	Process	Alteration	Process	Alteration	Potential for Restoration and Protection
1	Lower Nooksack Floodplain	↑	↓	↑	↓	↓	↓	↑	↔	↓	↓	↓	↔	↑	↓	↓	↔	↑	↓	↔	↑	↓	↑	This portion of the Nooksack Mainstem has significant, intact riparian wetlands, but armoring and levees likely limit surface, hyporheic, and groundwater interactions between the river and its floodplain. Strategic levee setbacks accompanied by riparian restoration may help restore natural stream morphology and improve habitat.
2	Smith Creek	↓	↓	↓	↓	↑	↓	↓	↓	↓	↔	↓	↓	↓	↓	↓	↓	↓	↓	↑	↓	↑	↑	Upper Smith Creek is relatively unimpaired by forest practices. Lower Smith Creek lies on the Nooksack floodplain, and has a hydrologic connection to the larger river system. Restoring /preserving connectivity in the lower drainage may improve functions in both the Nooksack and the creek.
3	Lower Anderson Creek	↔	↓	↔	↑	↓	↓	↔	↔	↓	↓	↓	↓	↔	↑	↓	↔	↔	↑	↑	↔	↑	↔	Restoring lost wetlands and riparian areas in lower Anderson Creek has the potential to improve water quality, water quantity, and habitat complexity.
4	Upper Anderson Creek	↓	↓	↓	↓	↑	↑	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↑	↓	↑	↔	The upper Anderson Creek is relatively unimpaired by forest practices. Protection of rain-on-snow zones and landslide hazard areas is recommended to prevent increased disturbance regime.
5	Upper Nooksack Floodplain	↑	↔	↑	↔	↓	↓	↑	↔	↓	↓	↓	↔	↑	↔	↓	↔	↑	↔	↔	↑	↓	↑	Riparian restoration is the key component for re-establishing natural geomorphology. Such restoration will likely succeed only in the context of reduced sediment supply from upstream sources. The area in the vicinity of Smith Creek is highly altered and may provide significant opportunities for restoration projects.
6	Other Tributaries	↓	↓	↓	↓	↔	↔	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↑	↓	↑	↔	These are typically short, steep tributaries upstream of the major tributaries. Opportunities for restoration may be more limited.

Red: High restoration potential: Moderate to high process intensity with high degree of alteration
Blue: Moderate restoration potential: -- Moderate to high process intensity with moderate degree of alteration; OR low process intensity with high degree of alteration
White: Low restoration potential: Low process intensity with low to moderate degree of alteration
Gold: High protection potential: Moderate to high process intensity with low degree of alteration

[a] Function responses to alteration of these processes tend to be less dependent on the level of process-intensity, which is historically low in Whatcom County. Therefore, the assessment of restoration potential is based primarily on the degree of alteration

Reach	Existing SEDs	Recommended SEDs		Comment
		Left Bank	Right Bank	
Reach 16	Conservancy	Resource/ Conservancy	Conservancy	Rural near downstream end of Reach 16 near Eversor, otherwise Conservancy designation will protect existing process-intensive areas
Reaches 17-19	Conservancy/ Tribal	Conservancy/ Tribal	Conservancy/Tri bal	

Recommended SMP environment designations for upper mainstem Nooksack Water Management Unit based on characterization results. Includes the upper and lower Nooksack floodplains listed in table 7-1 above. The characterization suggested important areas for several watershed processes including removal of nitrogen (water quality), surface water and sediment storage and recharge

Figure B-3. Protection and Restoration Measures. The upper table was used by Whatcom County to summarize watershed characterization results for the upper mainstem Nooksack Water Management Unit. Components for each process are evaluated based on intensity/importance of the processes, the degree of impairment, and the potential for protection and restoration. This table was then used to help determine appropriate land-use designation (lower table) for shoreline reaches and specific restoration measures in a separate restoration plan.

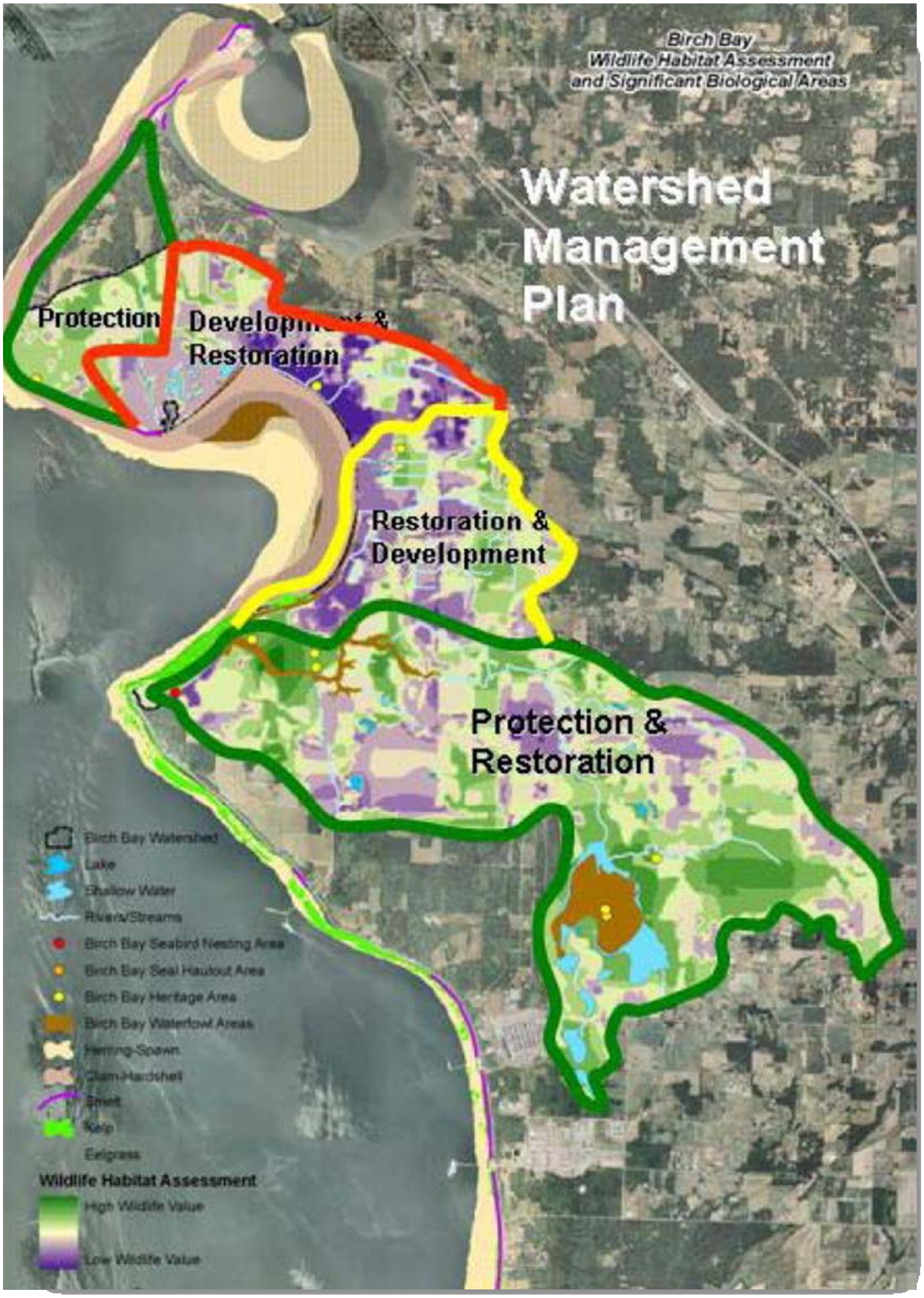


Figure B-4. Draft Management Plan for Birch Bay, Whatcom County.

Appendix C - Detailed Characterization Results

Areas of Importance for the Hydrologic Process

Figures C-1 and C-9 present the important areas for the hydrologic process. Important areas are a combination of physical conditions (i.e. precipitation level, presence of wetlands and floodplains, permeability of geologic deposits) that are key to the delivery, movement and loss of water. The important areas for each geomorphic unit are discussed below. See Figure 15 for names of individual watersheds within the study area.

Snow-Dominated and Rain-on-Snow Unit

This unit has the greatest area of “high importance” for delivery of precipitation within Clark County. Figure C-1 depicts the majority of the upper basins of the main fork of the Lewis River and Washougal River as “high importance” to the water flow processes. This is due to both the predominance of high levels of precipitation and rain-on-snow and snow-dominated zones (C-10 and C-23) in the upper watershed. Together, these areas play a significant role in the delivery of precipitation to the entire watershed. As a result this unit scores high for importance for the delivery component (C-10). Compared to the other landscape groups, this unit has relatively low permeability (Figure C-14) and limited surface storage in depressional wetlands (Figure C-12). Some surface storage, however, is provided in the confined and moderately confined floodplains of the dense stream network (C-11, C-28).

Rain-Zone Unit for Mainstem and East Fork of the Lewis River

The portion of this unit draining to the mainstem of the Lewis River has high importance due to higher precipitation levels (Figure C-10, C-23), and presence of moderate level of surface storage from stream floodplains (Figures C-11, C-28). The watersheds draining to the East Fork of the Lewis, while experiencing lower rainfall levels, have significant areas of importance due to higher permeability deposits (Figure C-14), extensive areas of wetlands (Figure C-12 and C-27), and large areas of floodplain storage (Figure C-11, C-28). The lower watershed tributary sub-units (draining to La Center) in this unit score lower in importance due to lower precipitation levels, lower permeability deposits, and limited area of wetlands.

Terrace Unit

The terrace unit, despite lower relative levels of precipitation, has large areas of moderate to high importance (Figure C-9). This is due to the presence of the largest area of higher permeability deposits (Figure C-14, C-25) and wetlands (Figure C-12, C-27) within Clark County. Moderately confined floodplains also play a role for surface storage (C-28). The areas for highest to moderate permeability are located at the southern end of the unit (Burnt Bridge Creek watershed), northeast corner (Woodin Creek watershed), and middle and lower reaches of the Salmon Creek watershed. Though the lower reaches of these watersheds score lower in importance, overall, they contain important discharge areas (i.e. streams) directly linked to the higher scoring upgradient areas of the unit (higher precipitation and recharge). Therefore, aquatic resources located in these downstream areas of the basin are dependent on the processes located in the upper basin.

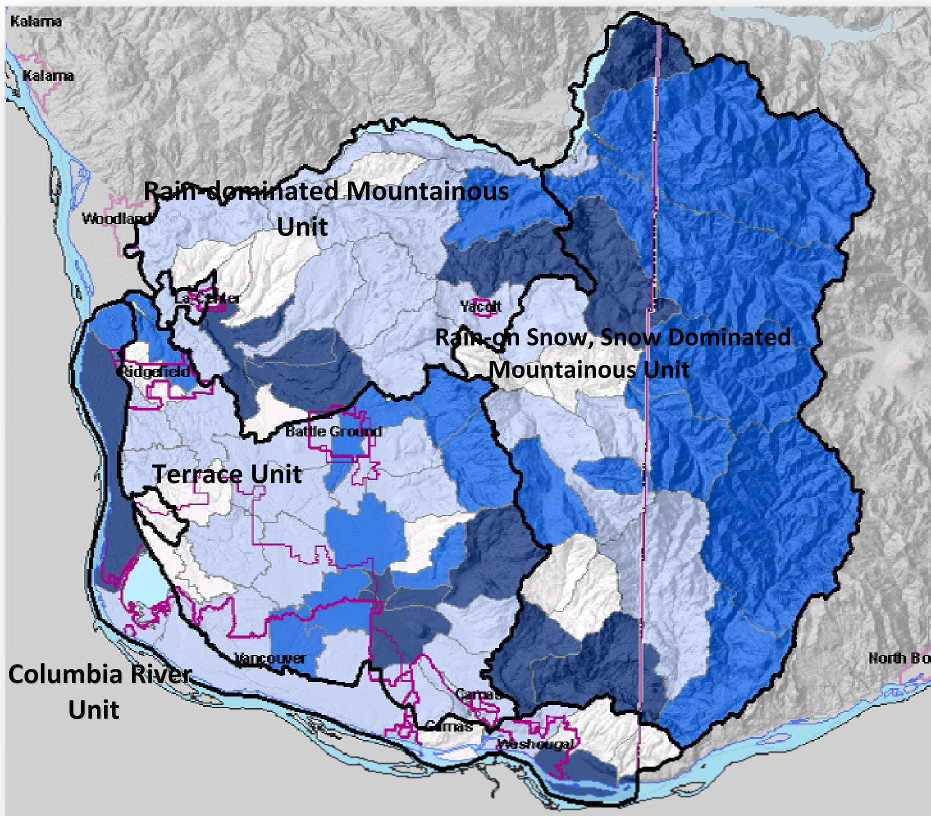


Figure C-1. Ranking of Importance to the Hydrologic Process. Final Score. Darkest = highest importance and lightest = lowest importance. (HU_M1)

Columbia River Floodplain Unit

Overall, the hydrology of the Columbia River floodplain unit is dominated by the influence of the Columbia River (i.e. hyporheic exchange and overbank flooding). However, within this unit riparian areas adjacent to the terrace slopes receive considerable subsurface and surface discharges from adjoining upland units. Figure C-1 shows large areas in the Columbia floodplain unit as scoring high in importance. The importance of these areas is determined by extensive areas of wetlands (Figure C-12, C-27), areas of high permeability (Figure C-14, C-25), large areas of unconfined floodplains (Figure C-11, C-28) and large areas of groundwater discharge and recharge (C-13) linked to upland areas in the Terrace Unit.

Areas of Impairment to the Hydrologic Process

Figures C-2 and C-15 depict the final score for areas of high, medium, and low impairment for the hydrologic process. The impairment score includes analysis of the extent of forest clearing and impervious surfaces and ranking of wetland and stream impacts. The relative degree of impairment for each landscape group is discussed below.

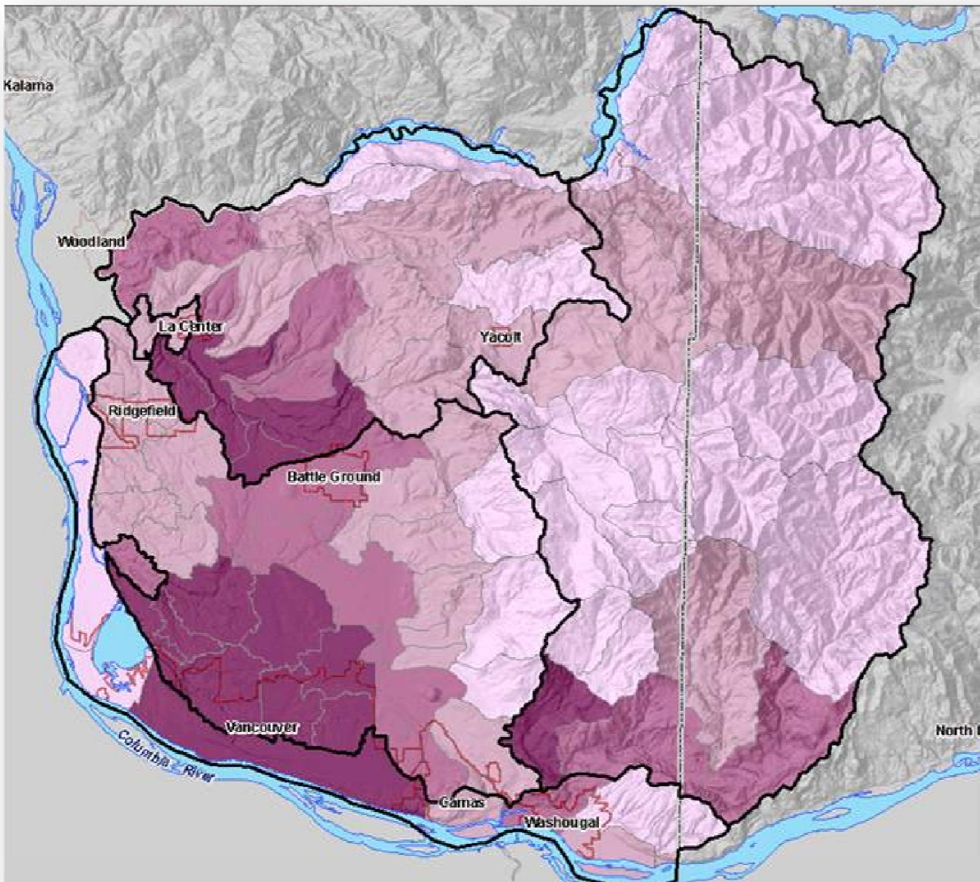


Figure C-2. Ranking of Impairment to the Hydrologic Process. Final Score. Darkest = highest impairment, lightest = lower levels of impairment. (HI_M2)

Snow-dominated and Rain-on-Snow Unit

Figure C-2 depicts the majority of the upper sub-units of the mainstem of the Lewis River and Washougal River as having relatively low impairment to the water flow processes. The most significant sources of impairment are forest loss (C-16) and road impacts. Both of these factors are reflected in the overall impairment to groundwater (Figure C-18), since they affect recharge and shallow sub-surface water movement. The most significantly affected sub-units are Big Creek, Little Fly Creek, Canyon Creek, Jackson Creek, the Little Washougal (lower) and Middle Washougal Rivers. Impairment was slightly lower for the surface water component (Figure C-17 wetlands, floodplains) with the lower fork of the Little Washougal River and middle fork of the Washougal watershed having the most impairment.

The Lower Columbia Salmon Recovery and Fish & Wildlife Sub-unit Plan (2004), identified sub-units within the upper watershed of this unit as either functional or moderately impaired, and the majority of the sub-units in the lower watershed as impaired (Figure C-3). The Lower Columbia Salmon Recovery Plan relies on thresholds for non-forest cover, percent impervious surfaces, and road density to calculate the categories of functional, moderately impaired, and impaired. This characterization uses equivalent indicators of impairment. Though not exact, the level of impairment identified by this characterization is similar to the results of the Lower

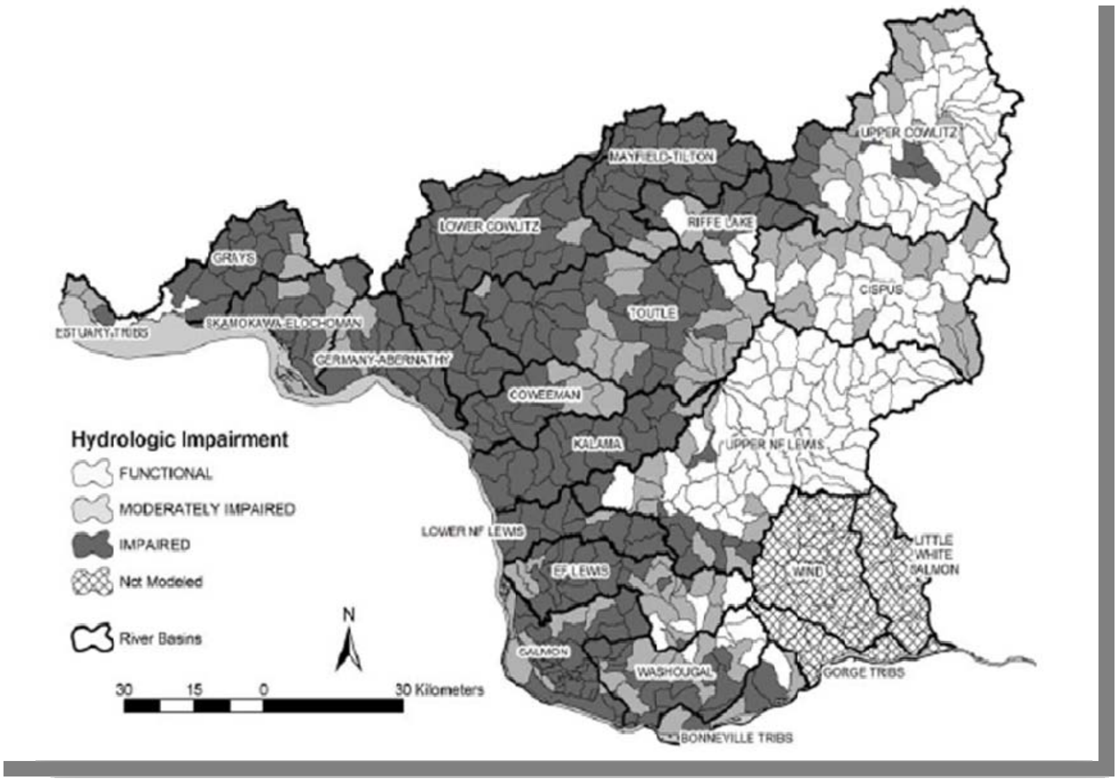


Figure C-3. Hydrologic Impairment for Watersheds in the Lower Columbia Region (Lower Columbia Salmon and Fish & Wildlife Recovery Plan 2004). The Integrated Watershed Assessment was used by this study to calculate degree of hydrologic impairment (Chapter 3, Limiting Factors and Threats, Figure 2).

Columbia Salmon Recovery and Fish & Wildlife Sub-unit Plan. The individual maps indicating impairment for this characterization, such as forest cover, road density and impervious cover, can be viewed in Figure C-16 through C-21.

Rain-Zone Unit for Mainstem and East Fork of Lewis River

Figure C-2 depicts the majority of the upper and middle sub-units as having a low to moderate level of impairment for this unit. The middle to lower basin of the East Fork of the Lewis have a moderate to high level of impairment due to forest clearing, loss of surface storage, and impervious surfaces and road impacts (Figures C-16, C-17, C-19, C-20 and C-21).

The Lower Columbia Salmon and Fish & Wildlife Recovery Plan also found that most sub-units in the East Fork and mainstem of the Lewis were impaired (Figure C-3).

Terrace Unit

The Terrace unit is the most extensively impaired unit within the characterization study area (Figure C-2 and C-15). The Lower Columbia Salmon Recovery Plan (2004, shown in Figure C-3) also shows the majority of this area as impaired. The southern portion of this unit scores high for impairment due to road impacts and large areas of impervious surfaces in the Cities of Vancouver and Camas, forest clearing, lost of surface storage (channelizing streams, draining wetlands) and loss of forest (Figures C-16, C-17, and C-18). This includes the middle reaches of the Salmon Creek and Lacamas Creek watersheds and most of the Burnt Bridge watershed.

A moderate to high level of impairment is present for the mid and lower portions of the Salmon Creek watershed. The watersheds for Whipple, Flume, Gee and Allen Creeks have low to moderate impairment. This is due to primarily surface storage loss (i.e. streams and wetlands) and loss of forest from agricultural and urban activities (Figures C-17 and C-20).

Columbia River Floodplain Unit

The Columbia River Floodplain Unit shows a low level of impairment for the areas adjacent to the west slope of the Terrace unit. Forest clearing (Figure C-16 and C-19) and roads are the primary impairment for this unit. The Lower Columbia River Salmon Recovery Plan (2004) also identified these areas as having a moderate level of impairment. This area includes Port of Vancouver holdings as well as the Ridgefield National Wildlife Refuge operated by the US Department of Fish and Wildlife. These areas contain large areas of wetlands that are subject to the hydrologic influence of the Columbia River, as well as surface and subsurface flows from the adjoining Terrace unit.

The southern portion of the unit adjacent to the City of Vancouver has been significantly impaired through loss of forest, loss of storage (river channel), road construction and impervious surfaces in the contributing slopes (C-16, C-17, C-20 and 21). The areas east of the City of Washougal have a lower level of impairment.

Areas of Importance for the Denitrification Process

Figure C-4 presents the important areas for the denitrification process. This includes depressional wetlands, riparian areas and lakes.

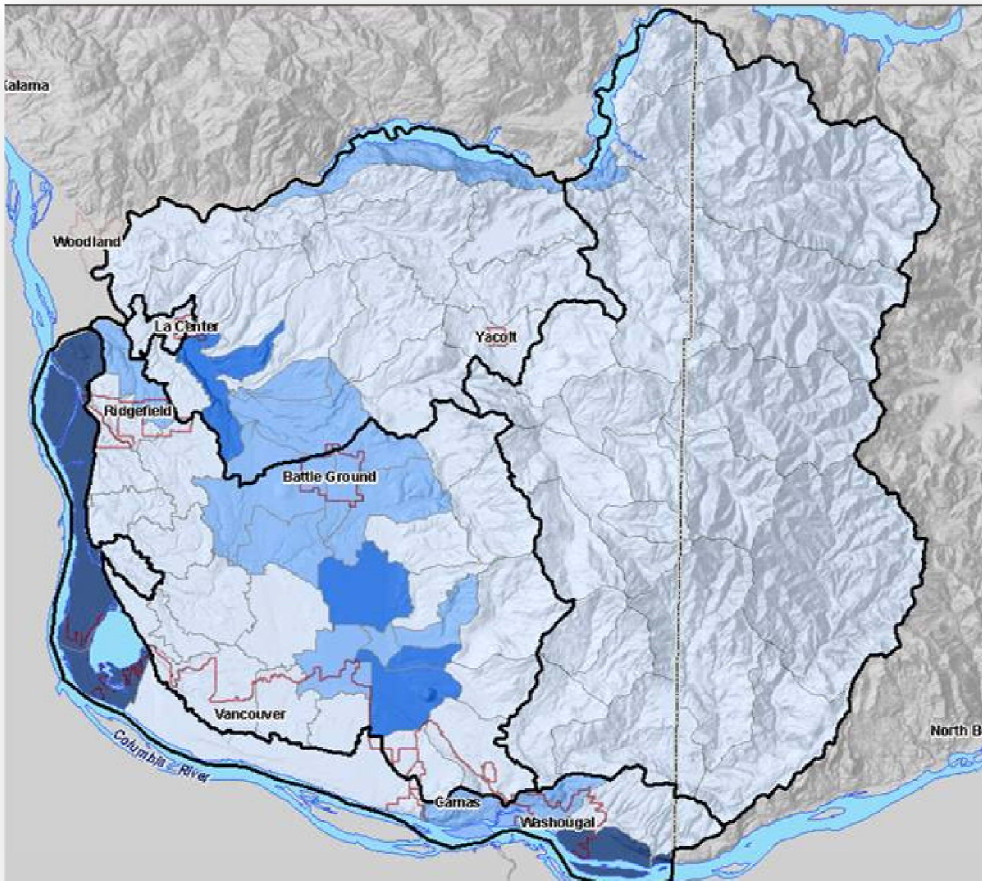


Figure C-4. Ranking of Importance to the Denitrification Process, includes influence of nitrogen sources. Darkest = highest importance, medium= medium importance, and lightest = lowest importance. (NU_M1)

<u>Snow-Dominated and Rain-on-Snow Unit</u>

Figure C-4 depicts almost the entire area of this landscape group as having relatively low importance for the denitrification process. This is due to the limited area of wetlands and broad lowland riparian areas (C-12, C-27 and C-28) within this geomorphic unit. One area that does score higher for denitrification includes the large lake area (Lake Yale) created on the mainstem of the Lewis River.

<u>Rain Zone Unit for Mainstem and East Fork of the Lewis River</u>

The lower watershed sub-units of the East Fork of the Lewis River have a high level of importance for the denitrification process. This is due to the high percentage of depressional wetlands (C-12 and C-27) and unconfined riparian areas (C-28). A large portion of the mainstem of the Lewis River scores moderately high for importance due to the presence of Lake Merwin.

Terrace Unit

The Terrace unit provides the largest area important for the denitrification process. This is due to depressional wetlands (Figure C-12, C-27) concentrated in the central and northern portion of the unit adjacent and within the City of Battleground and in the mid reaches of Lacamas Creek. This includes the watersheds for the Mill Creek and Woodin Creek, mid-reaches of Salmon Creek, China Ditch, Shanghai Creek, upper Burnt Bridge Creek and Lacamas Lake.

Columbia River Floodplain Unit

Due to the presence of extensive riparian wetlands (Figure C-12 and C-27) most of this unit has high importance for the removal of nitrogen. The southern portion of this unit below the City of Vancouver, however, had lower importance for the removal of nitrogen due to the limited number of wetlands relative to the rest of the unit.

Areas of Impairment to the Denitrification Process

Figure C-5 depicts the areas of high, medium, and low impairment. Important areas represent the severity of human impairment to unimpaired or natural conditions that were modeled and depicted in Figure C-4. Variables for impairment include loss of wetlands and loss of recharge to areas discharging in riparian zones.

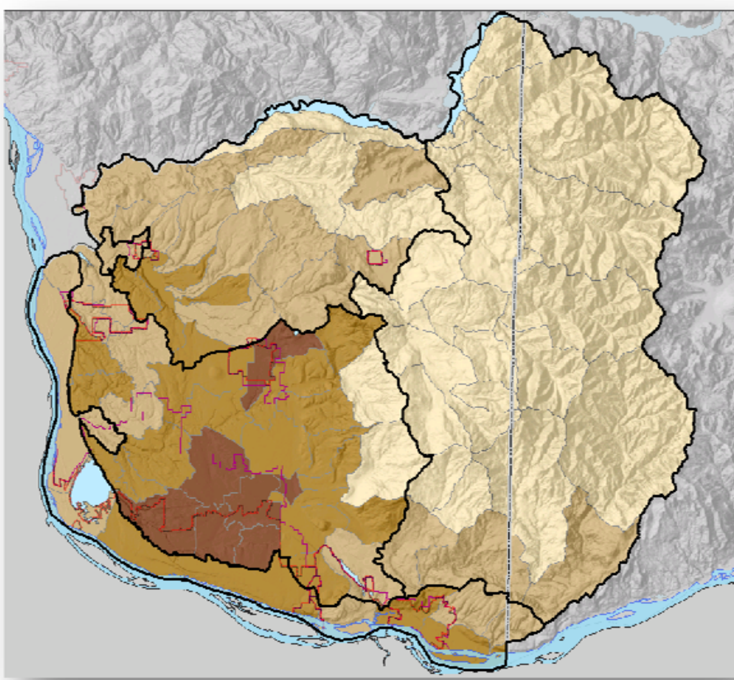


Figure C-5. Ranking of Impairment to the Denitrification Process. Darkest = highest levels of impairment, lightest = lowest levels of impairment. (NI_M3). Figure C-22 presents the raw scores used to develop this map.

The highest degree of impairment is within the Terrace unit, including the middle reaches of Salmon Creek and the tributaries of Woodin Creek; Curtain Creek, upper and middle Burnt Bridge Creek watershed; and Burton Channel and Burton Sink watershed. Impairment in these areas is due to loss of wetlands and loss of recharge due to forest clearing and impervious surfaces.

Important Areas for Protection, Restoration and Development for Denitrification Process/Loading Not Included

Using the synthesis matrix shown in Figure C-8, the results of the important areas analysis and impaired areas analysis are synthesized into a map showing the preliminary areas of protection, restoration and development. This map does not consider the potential inputs of nitrogen, which were used to develop the final protection, restoration and development map presented in the main section of this characterization (Figure 5).

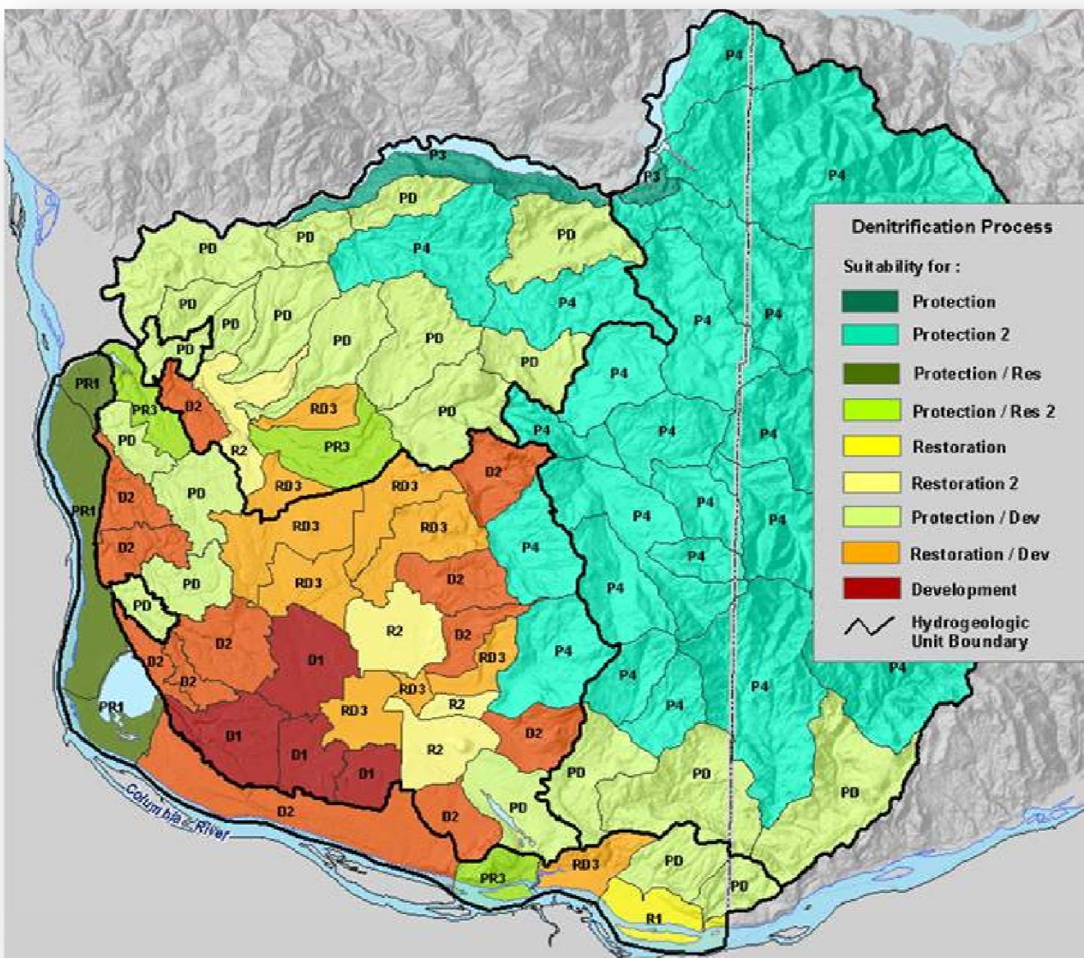


Figure C-6. Preliminary Protection, Restoration, and Development Map for Denitrification. Nitrogen sources or loading is not considered in this map. (N_RP4)

Sources of Nitrogen Loading

To develop the final protection, restoration and development map for denitrification (Figure 5), the potential sources for nitrogen must be considered. This is necessary since wetlands, lakes and riparian will remove nitrogen at a greater rate when significant nitrogen sources are present. As a result, the importance of wetlands, lakes, and lowland riparian areas for denitrification increases when they are down gradient of high nitrogen loads such as those generated by agricultural and urban land uses. Therefore, sub-units that may have a low total percentage of wetlands and riparian areas relative to other sub-units, may score higher due to the presence of nitrogen sources.

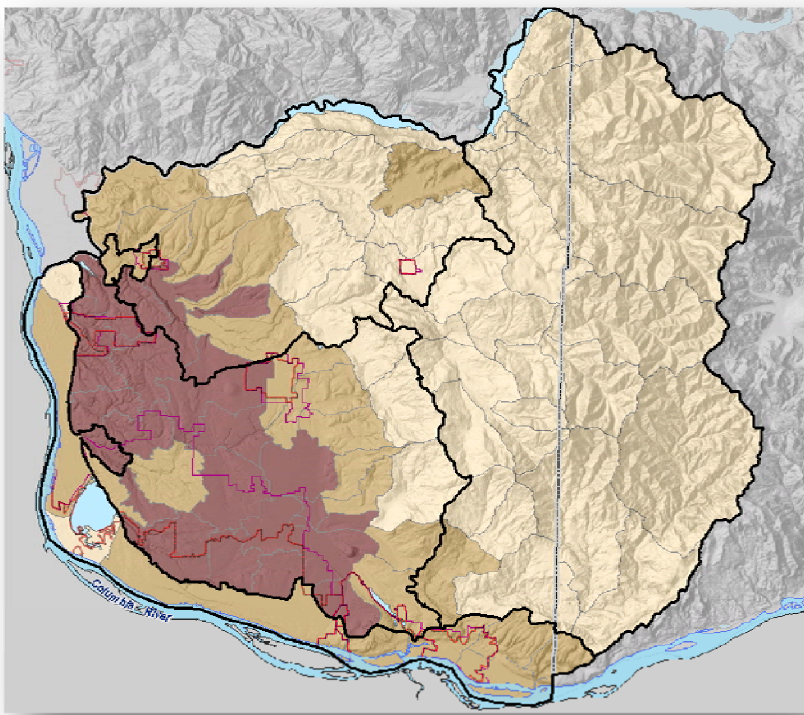


Figure C-7. Ranking for Nitrogen Loading. Areas with a "high" potential for nitrogen loading are "dark brown" and areas with a "low" are shown as "light tan." (NI_M2, LOADING)

Figure C-7 shows the ranking of urban and agricultural areas for nitrogen loading. By combining this map with the preliminary map for protection, restoration and development (Figure C-6) the final protection, restoration map was created (Figure 5). Table C-1 was used to combine the results of the two maps.

If a low level of loading is predicted for a watershed then important areas shown in Figure C-6 are not shown in the final denitrification map (Figure 5). For example, the areas important for protection in the Rain-on-Snow Dominated Mountainous Unit (Figure C-6) have no significant sources of loading (Figure C-7) and are, therefore, not shown in the final denitrification map (Figure 5). Similarly, areas in the Terrace Unit which have lower importance for restoration in the preliminary map (Figure C-6, **RD3**) that are also located within an area of greater loading are increased in restoration potential in the final map.

Table C-1 Loading and Synthesis Map Matrix		
Synthesis Map Result Figure C-6	Loading Map Level Figure C-7	Final Nitrogen Ranking Figure 4
R1, R2	H or M	R1
RD3	H or M	**R2**
P1, P2,PR1,PR2	H or M	P1
P3,P4,PR3,PD,	H or M	P2
D1,D2,	H or M	R3
Any result	L	Don't Map

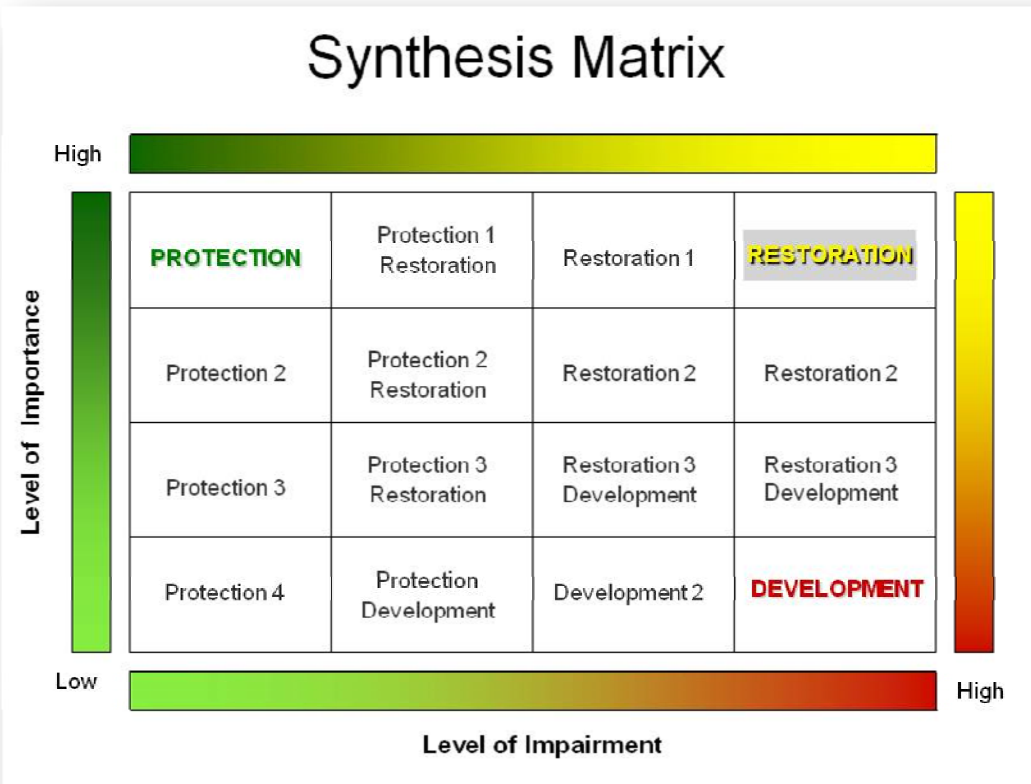


Figure C-8. Detailed Analysis Matrix for Final Restoration and Protection Map for the hydrologic and denitrificatiton processes. (Based on Figure 2)

Figure C-8 depicts the detailed matrix for synthesizing the results of the importance and impairment maps for the hydrologic and denitrification processes (Figures C-1, C-2, C-4, C-5 and C-7). The matrix is based on watershed-based research indicating that areas with low levels of impairment to watershed processes should be protected and areas with higher levels of impairment to processes with a higher level of importance should be restored (Stanley et al.

2005). Restoration in urban areas of important areas may be limited to functions providing important ecosystem services such as water quality improvement, since full restoration of processes is not possible.

Detailed Maps of Analysis Results

Figures C-9 through C-22 show the results of the individual analyses included in this characterization. Figures C-23 through C-28 show the main data sets used in the analyses. Direct comparison of rankings between landscape groups should not be made since ranking scores are normalized within each landscape group.

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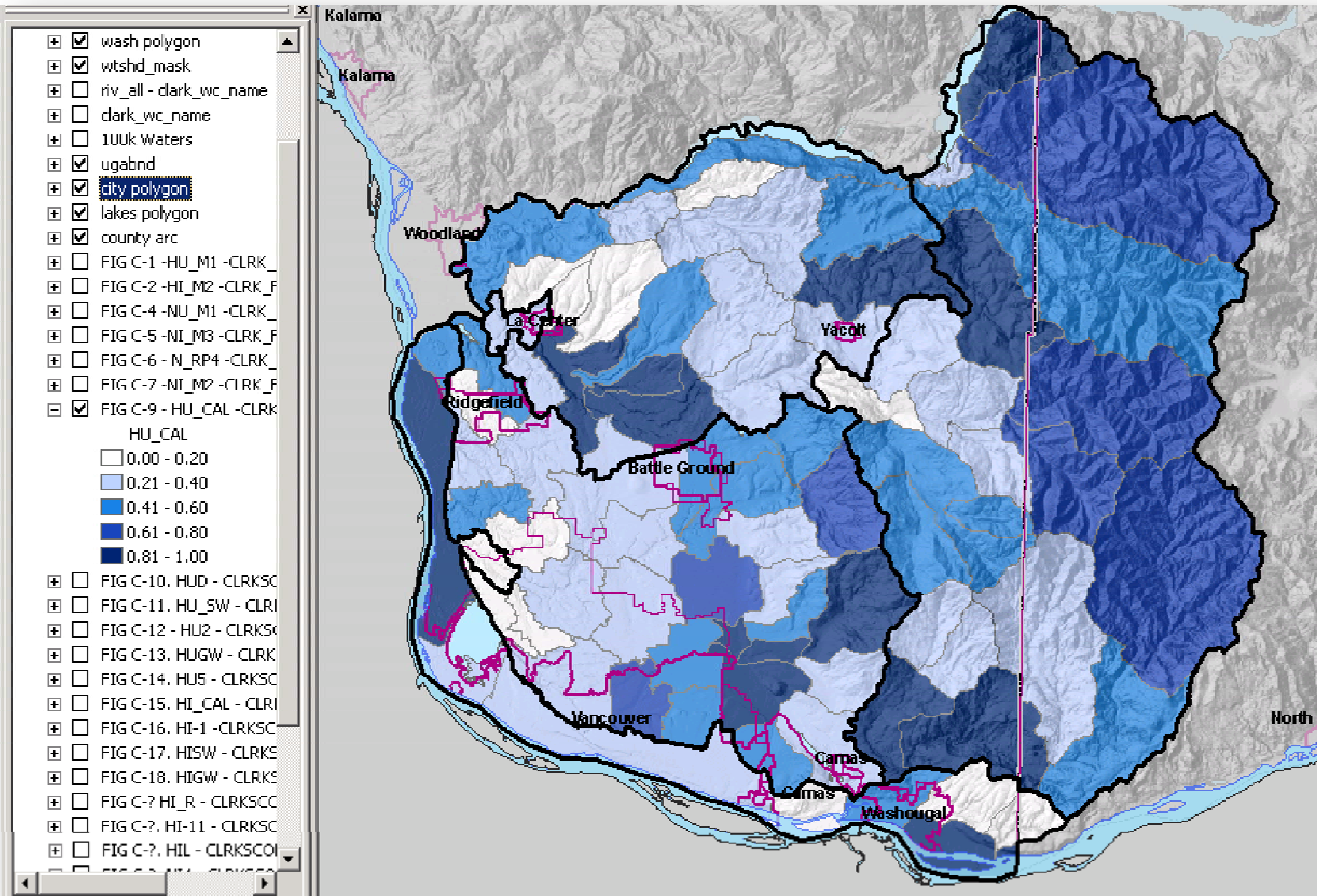

Figure C-9. Total Raw Score for Ranking of Important Areas for Hydrologic Process. Dark blue the highest importance and light blue = lowest. (HU_CAL) Direct comparison of rankings between landscape groups should not be made since ranking scores are normalized within each landscape group.

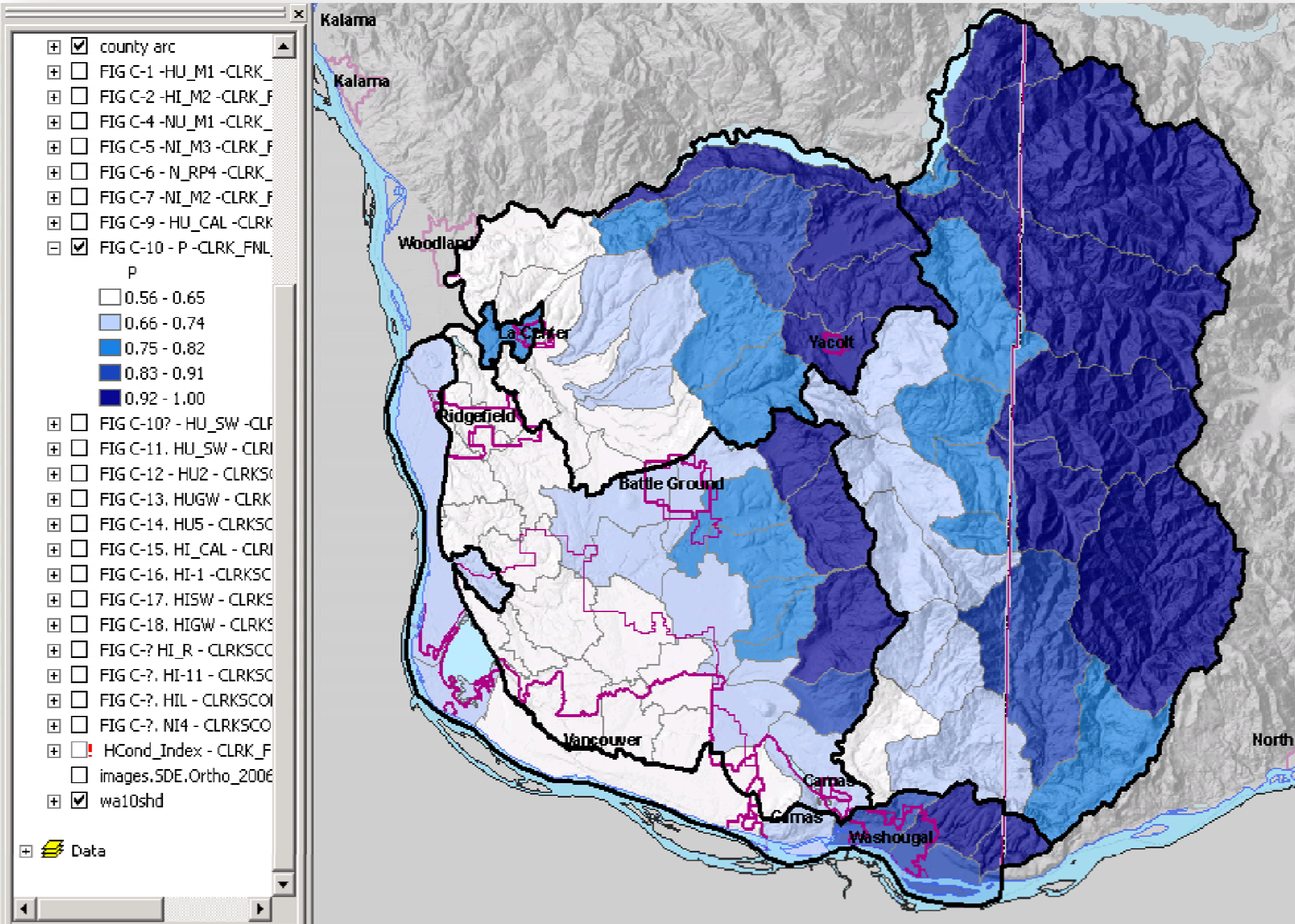

Figure C-10. Ranking of Importance for Delivery Component (precipitation variable only). Darkest = the highest importance and lightest = lowest. (P) Direct comparison of rankings between landscape groups should not be made since ranking scores are normalized within each landscape group.

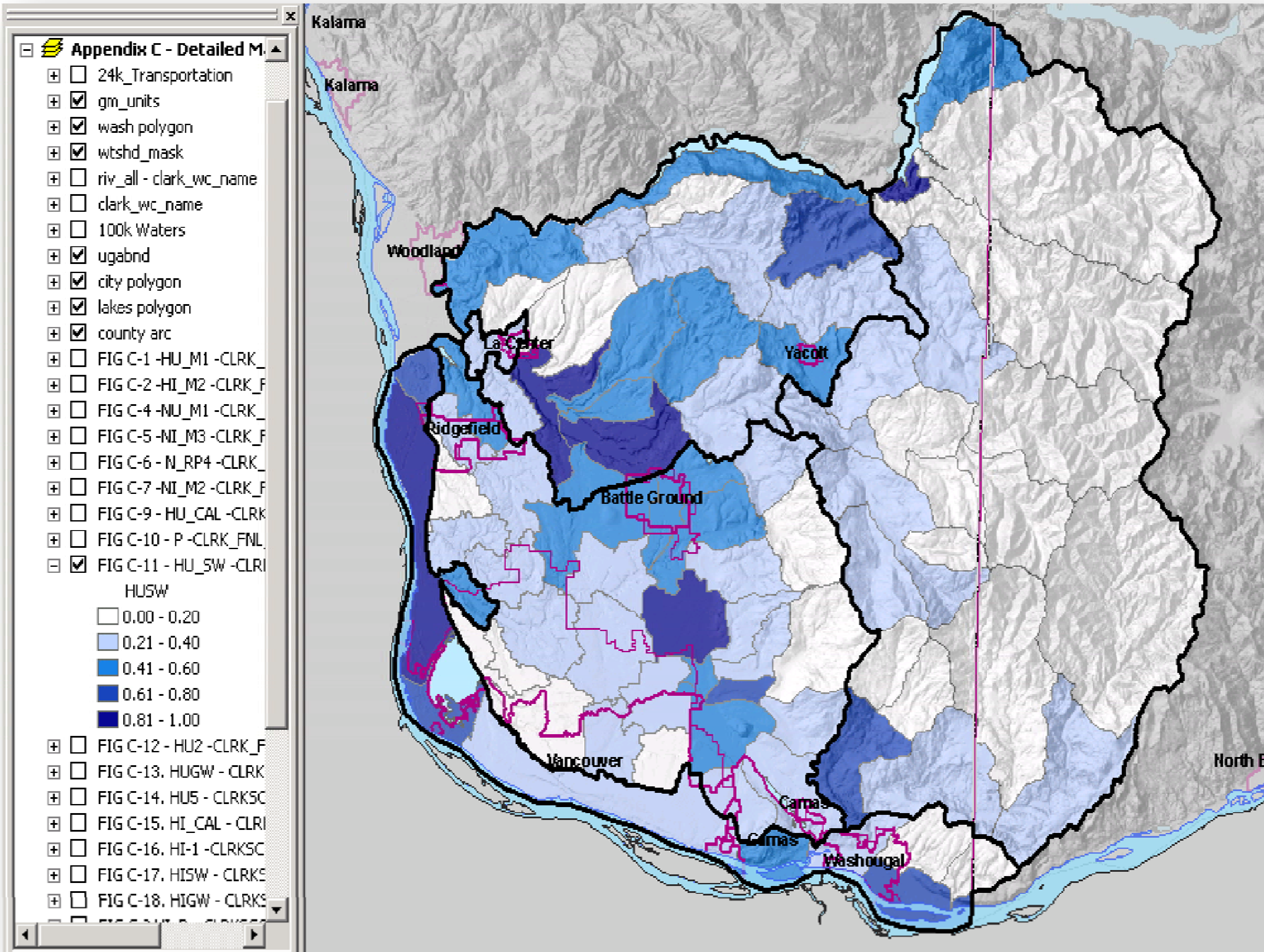

Figure C-11. Ranking of Importance for Surface Water Component. (storage in wetlands and streams) Darkest = the highest importance and lightest = lowest. (HUSW). Direct comparison of rankings between landscape groups should not be made since ranking scores are normalized within each landscape group.

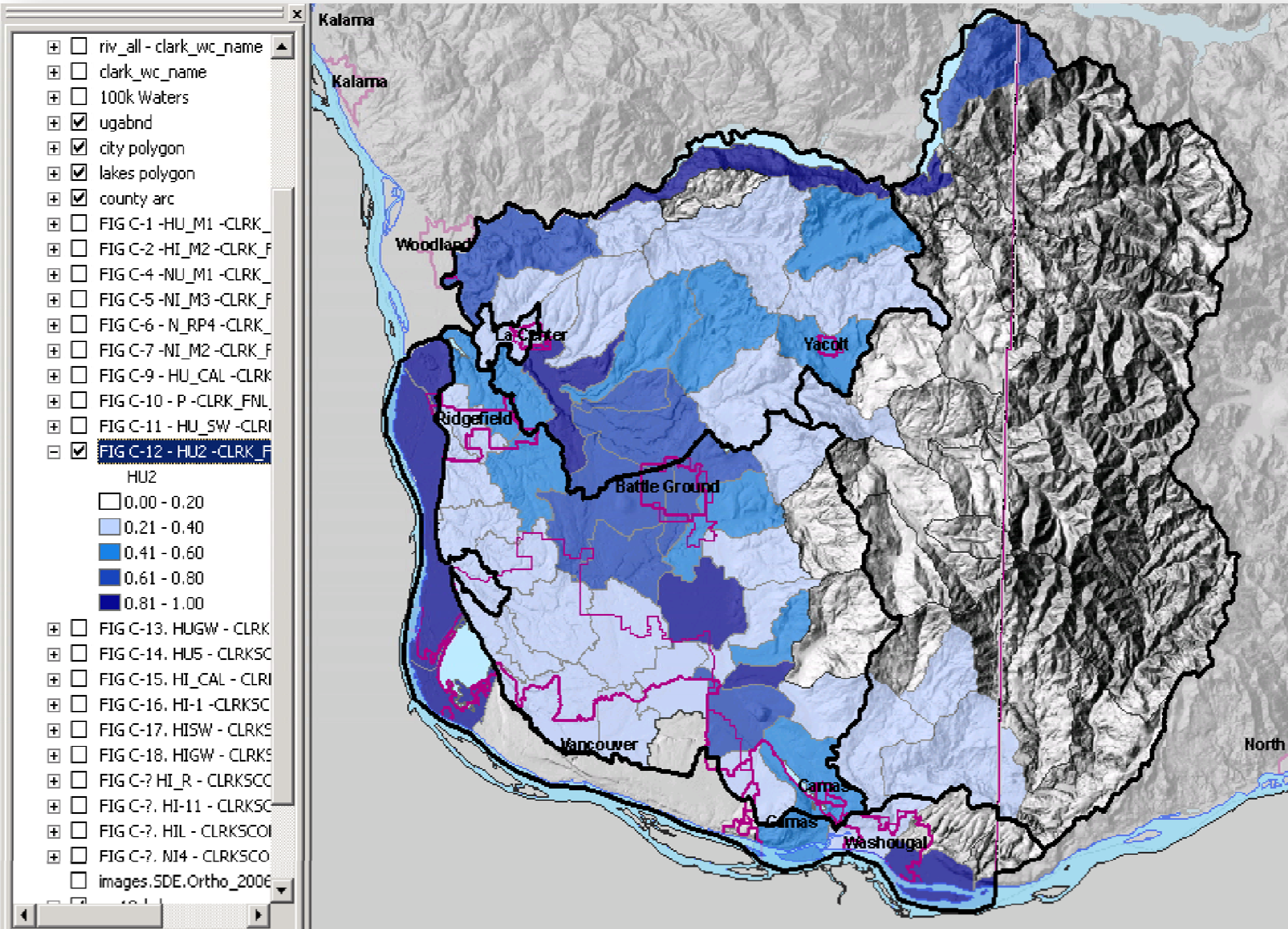

Figure C-12. Ranking of Importance for Wetlands. (surface storage). Darkest = the highest importance and lightest = lowest. Areas not colored have less than 5% wetlands for the sub-unit analysis unit. (HU2) Direct comparison of rankings between landscape groups should not be made since ranking scores are normalized within each landscape group.

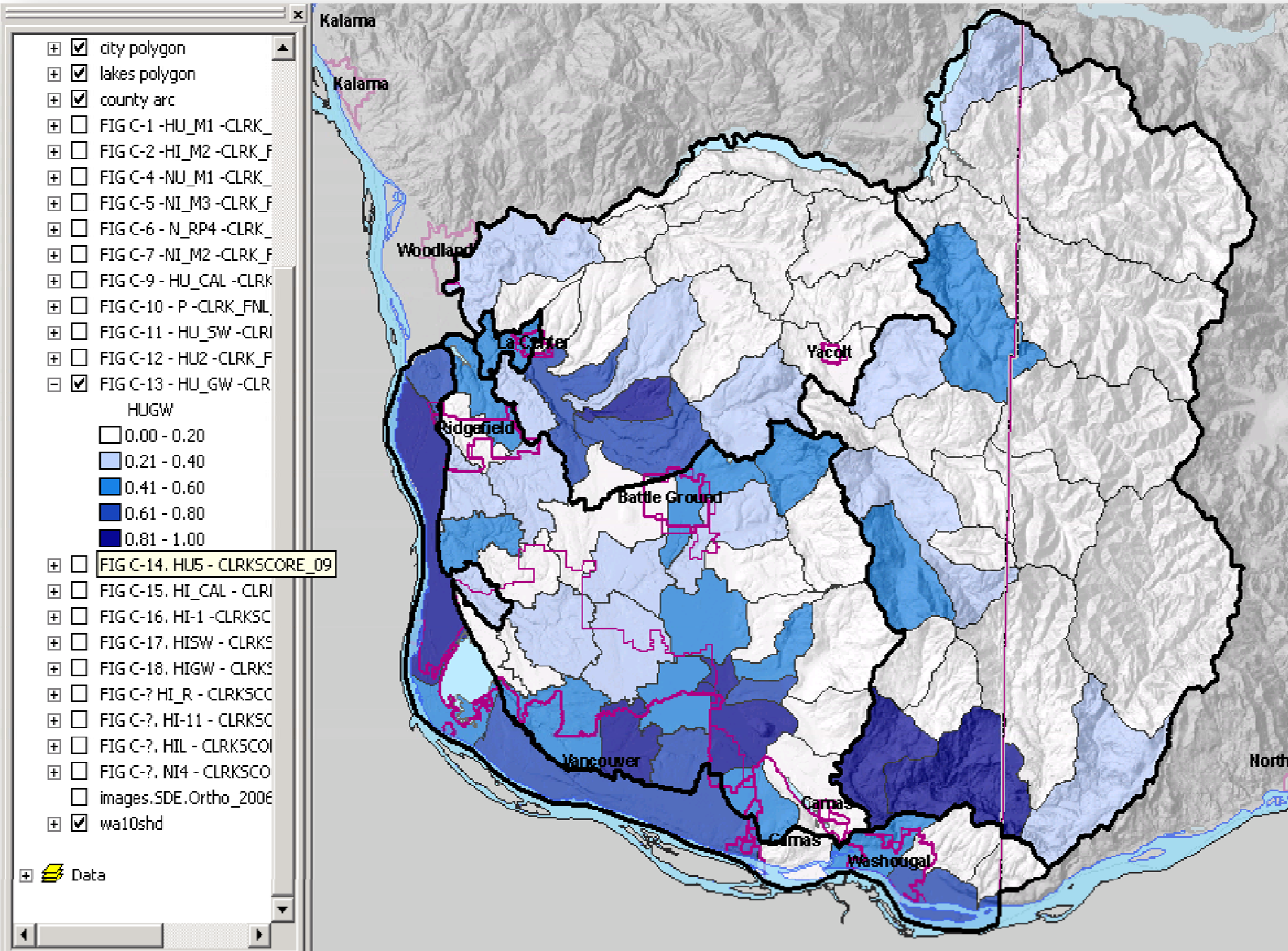

Figure C-13. Ranking of Importance for Groundwater Component (higher precipitation, infiltration, percolation, and recharge). Darkest = the highest importance and lightest = lowest (HUGW) Direct comparison of rankings between landscape groups should not be made since ranking scores are normalized within each landscape group.

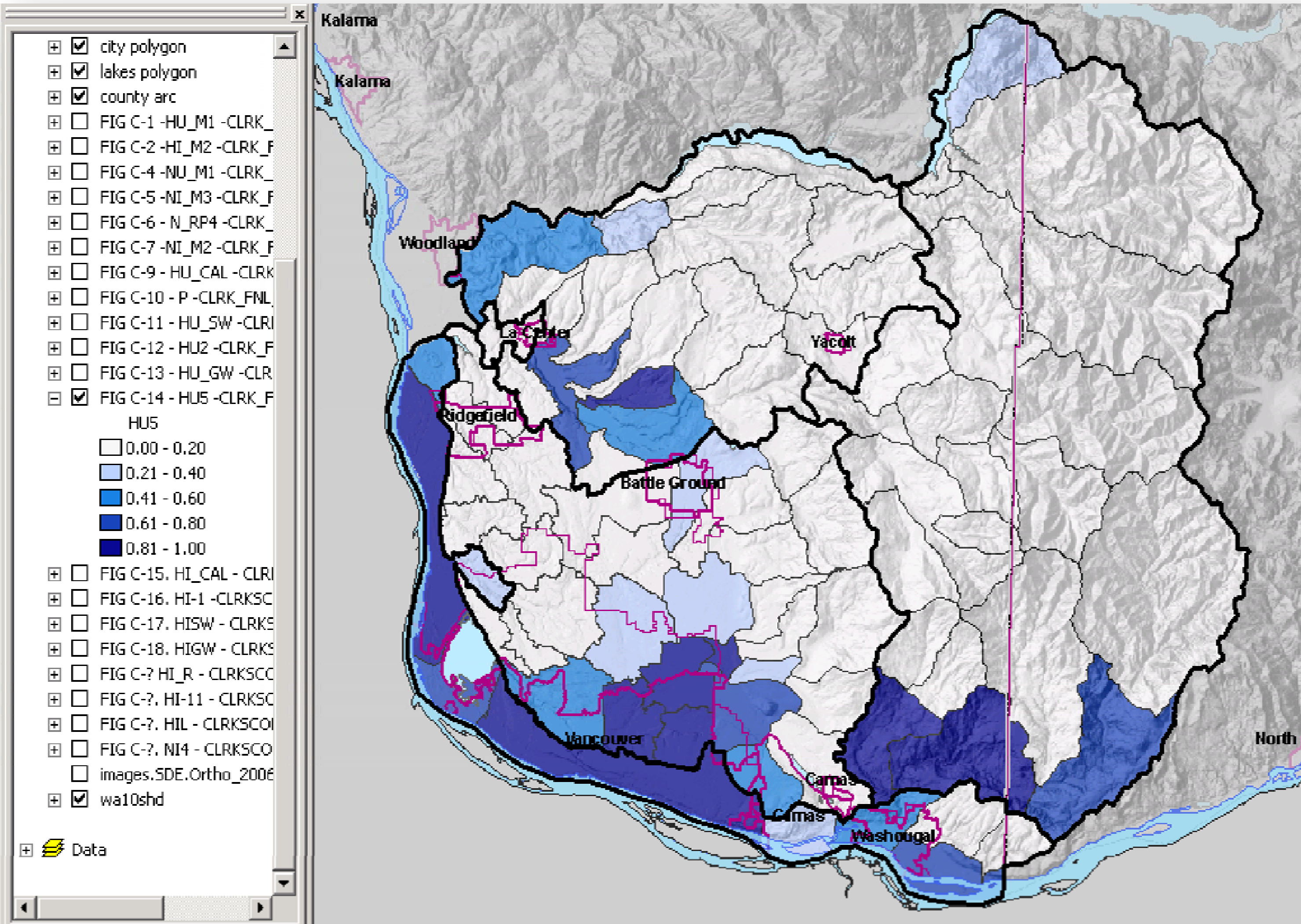

Figure C-14. Ranking of Importance for Moderate to High Permeability (groundwater variable in groundwater component). Darkest = the highest importance and lightest = lowest. (HU5) Direct comparison of rankings between landscape groups should not be made since ranking scores are normalized within each landscape group.

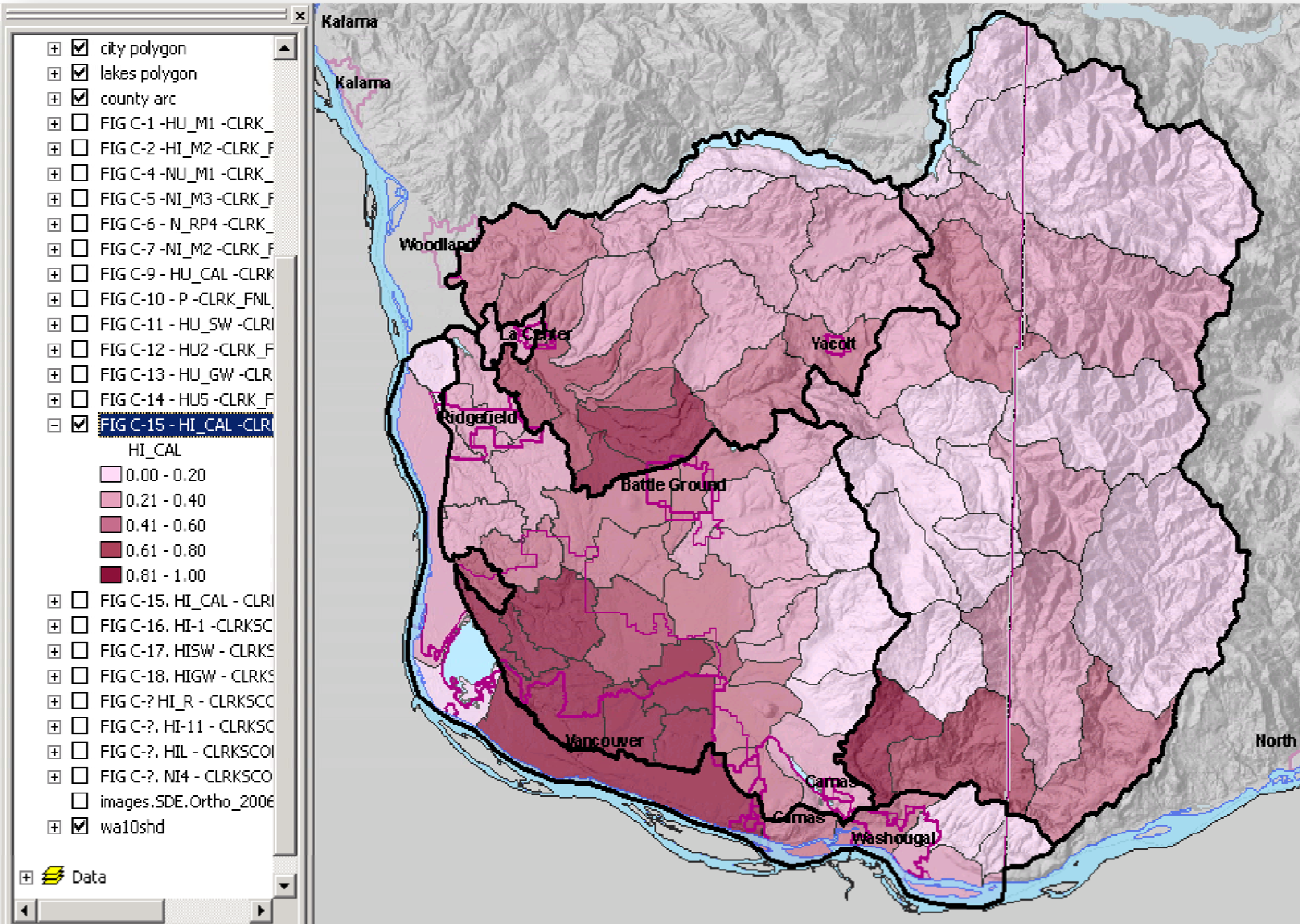

Figure C-15. Ranking of Overall Hydrologic Impairment. Darkest = the highest impairment and lightest = lowest. (HI_CAL). Direct comparison of rankings between landscape groups should not be made since ranking scores are normalized within each landscape group.

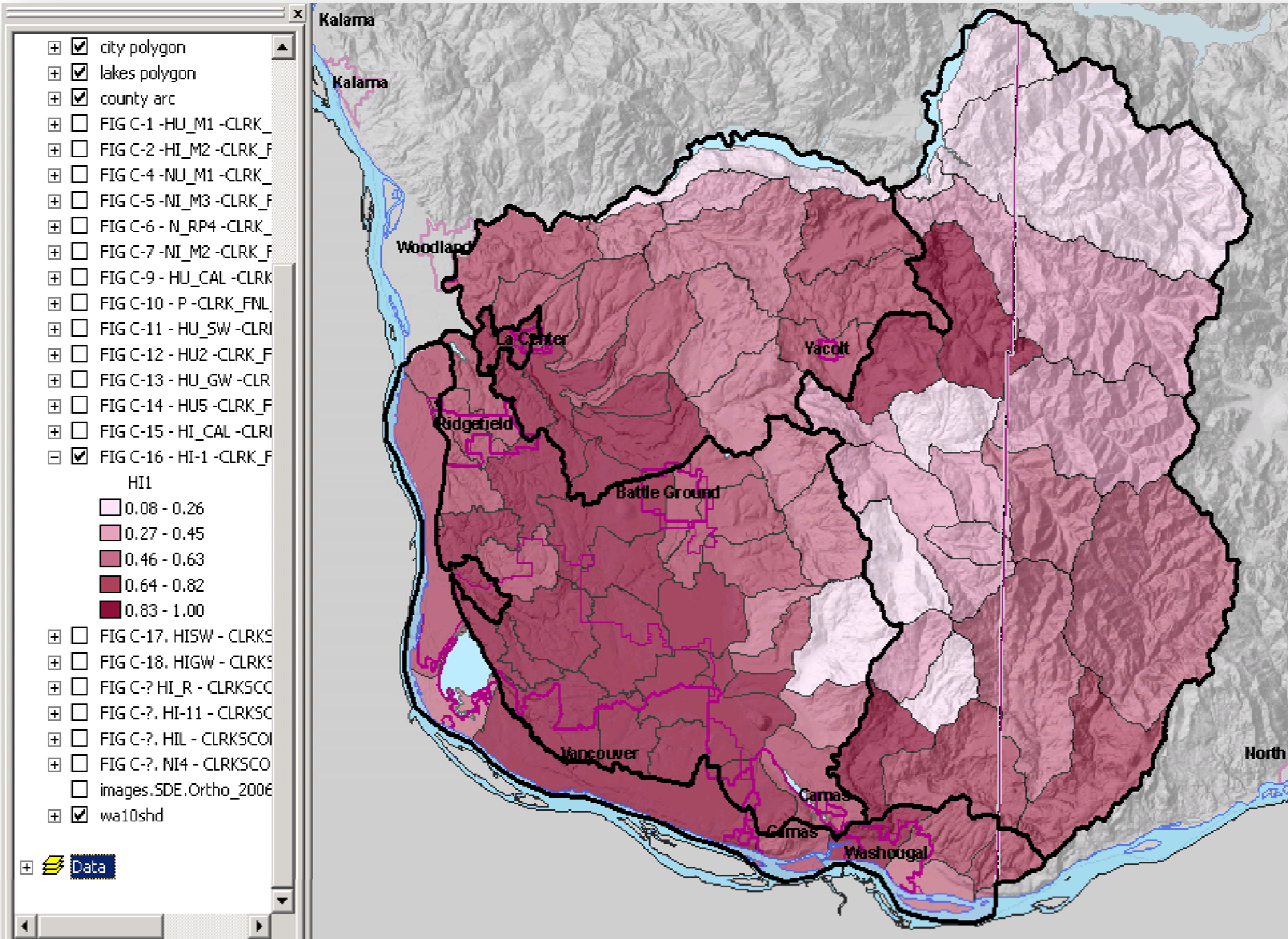

Figure C-16. Ranking of Impairment to Water Delivery Component. (forest loss) Darkest = the highest impairment and lightest = the lowest. Ranking the relative loss of forest for each sub-unit. Direct comparison of rankings between landscape groups should not be made since ranking scores are normalized within each landscape group. (HI1)

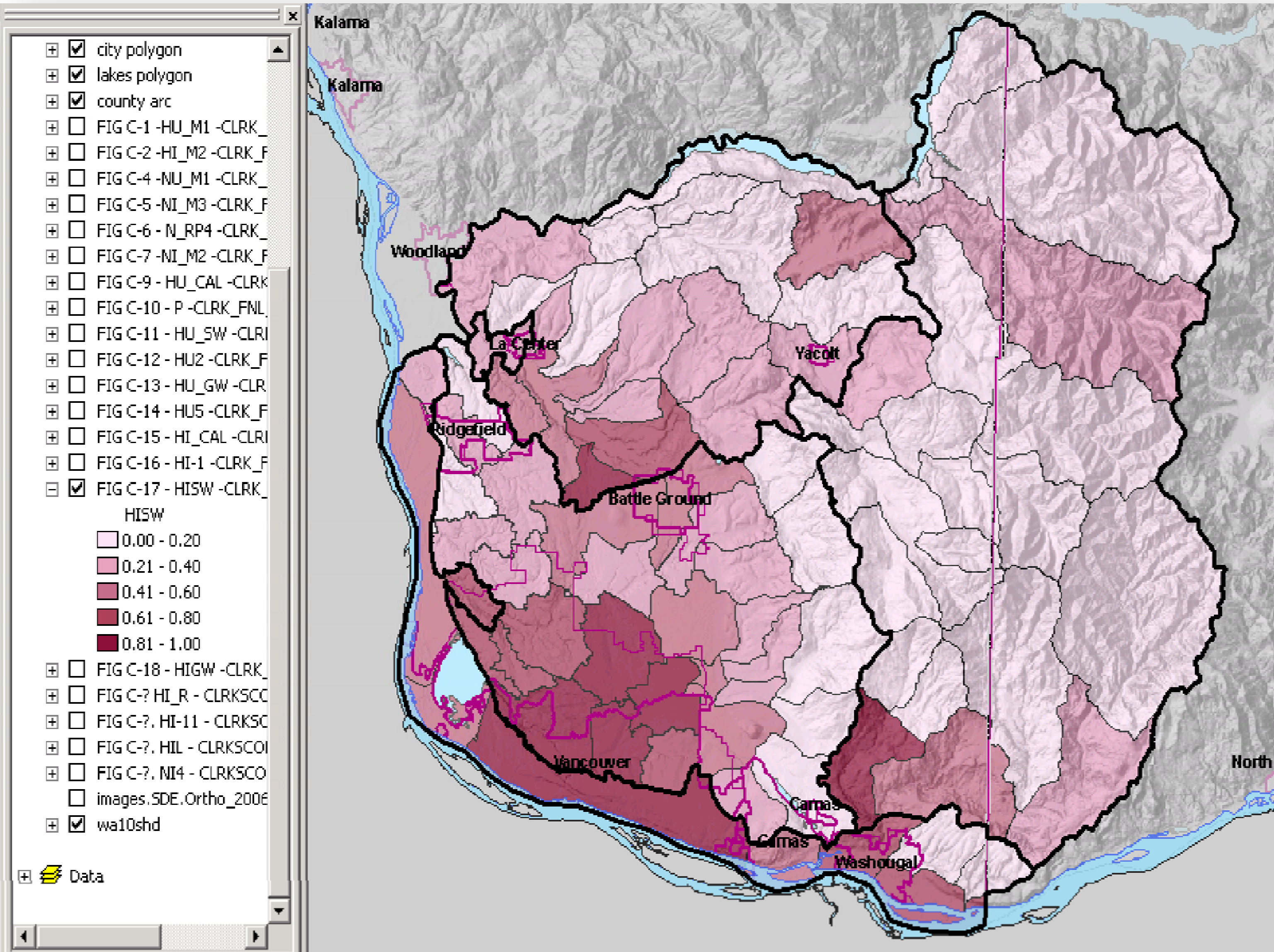

Figure C-17. Ranking of Impairment to Surface Water Component. Darkest = the highest impairment and lightest = lowest. (HISW). Ranking of the relative loss of surface storage provided by wetlands & floodplains and the relative increase of overland flow caused by impervious surfaces. Direct comparison of rankings between landscape groups should not be made since ranking scores are normalized within each landscape group.

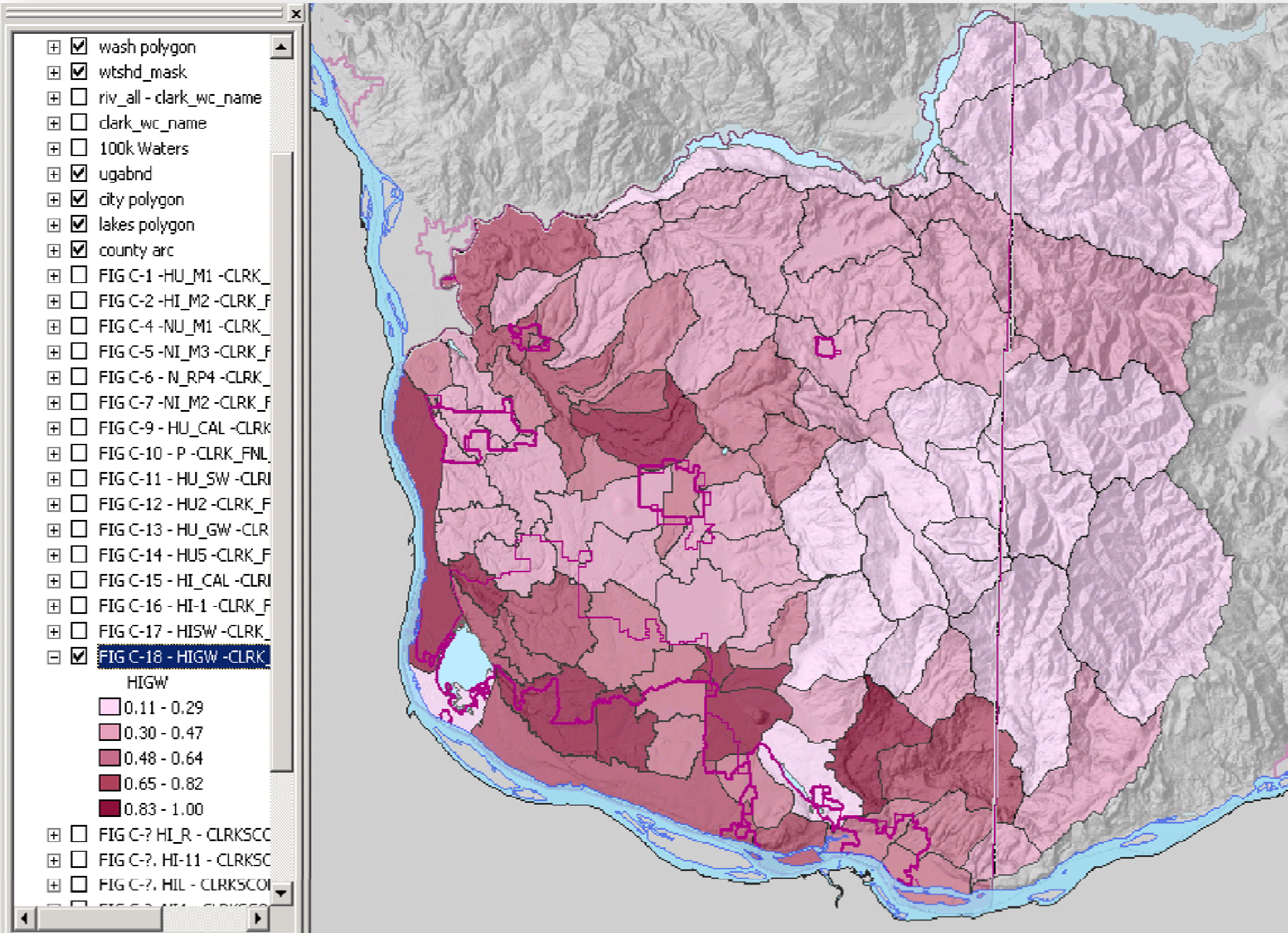

Figure C-18. Ranking of Impairment to Groundwater Component (recharge+discharge). Darkest = the highest impairment and lightest = lowest. (HIGW). Greatest stressors include forest clearing on high permeability deposits, channelization of streams in unconfined floodplains with high permeability deposits, road density, and percent imperviousness (loss of evapotranspiration). Direct comparison of rankings between landscape groups should not be made since ranking scores are normalized within each landscape group.

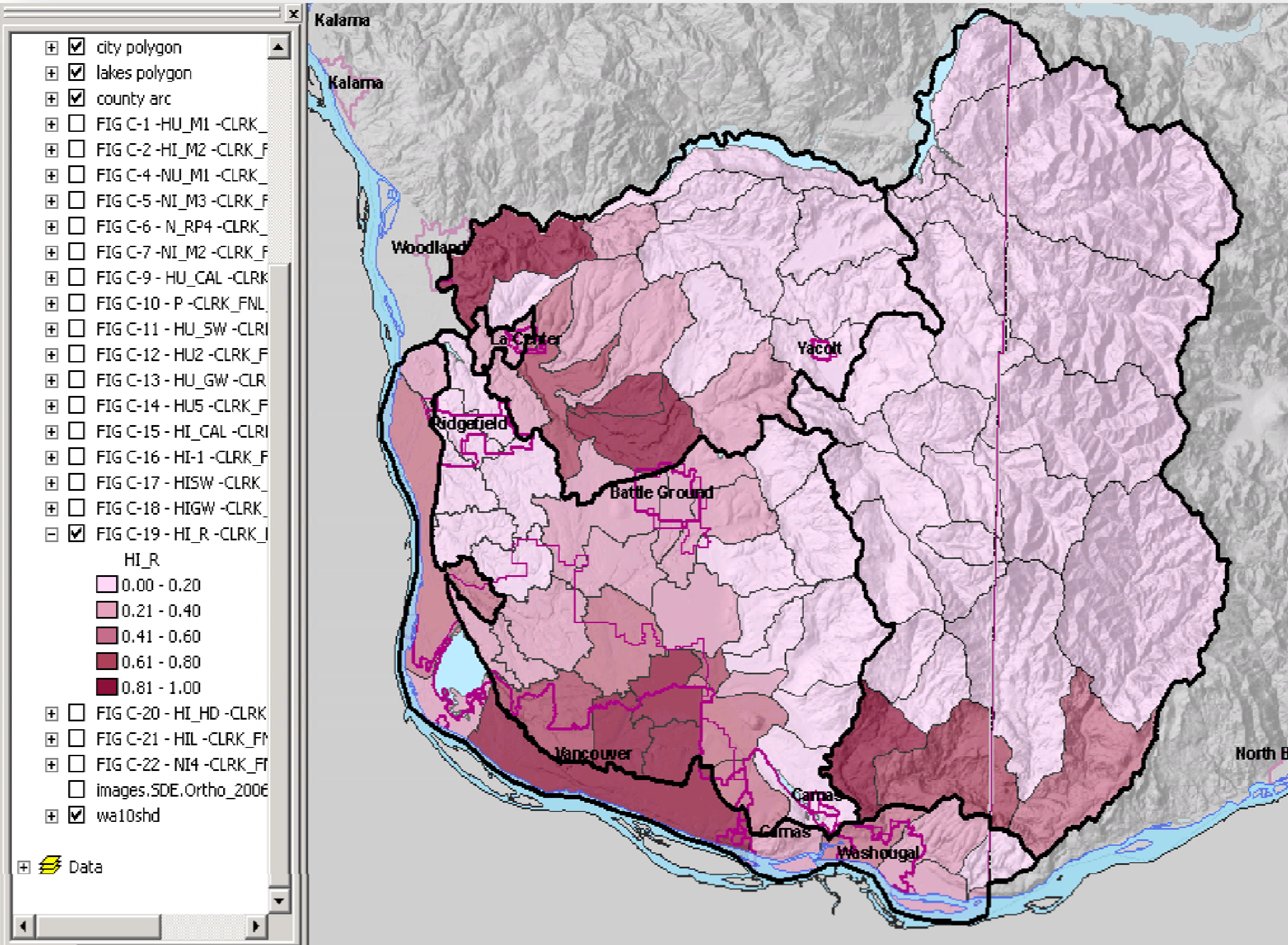

Figure C-19. Ranking of Impairment to Recharge. Darkest = the highest impairment and lightest = the lowest. Loss of forest on high permeability deposits (HI_R). Direct comparison of rankings between landscape groups should not be made since ranking scores are normalized within each landscape group.

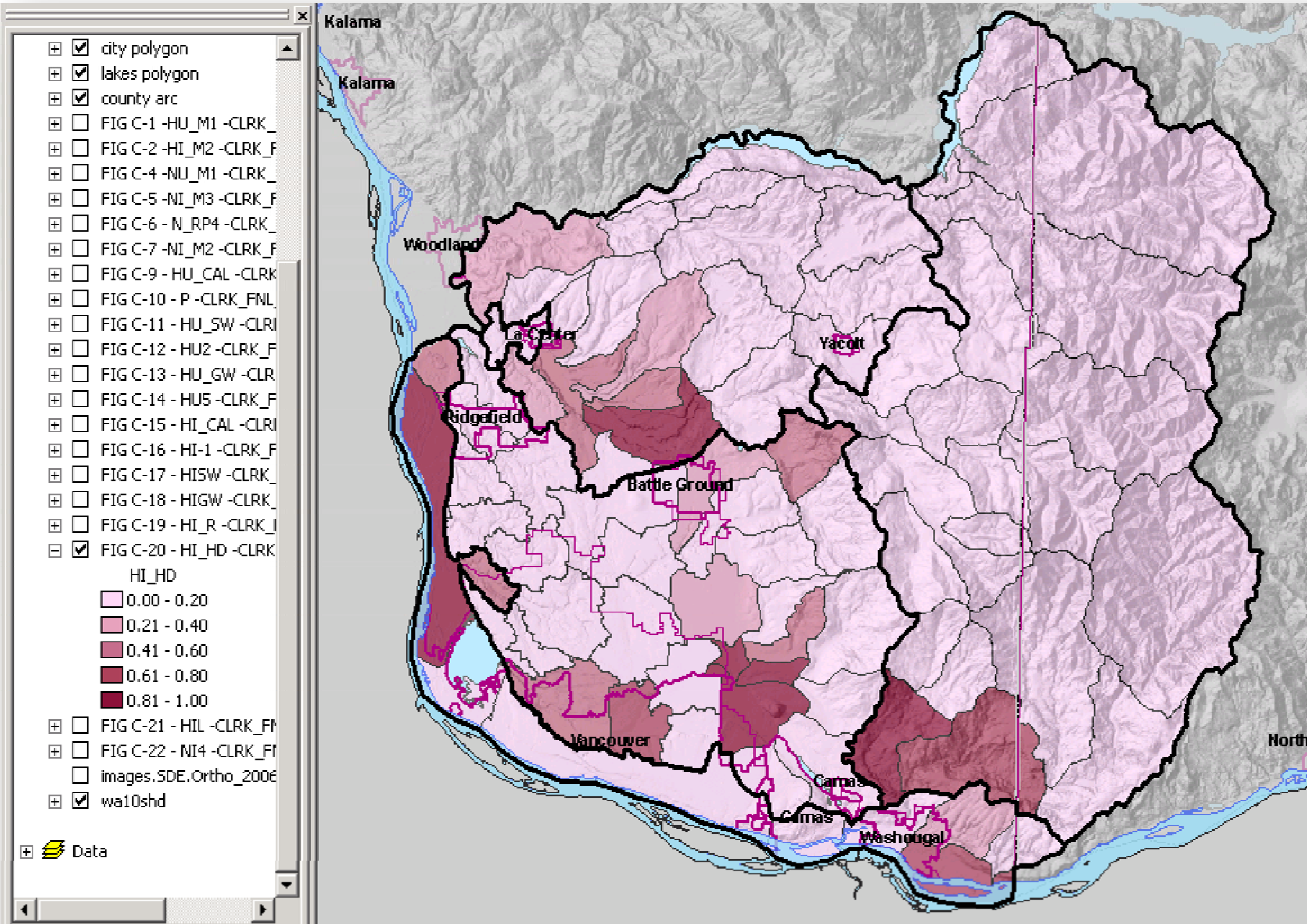

Figure C-20. Ranking of Impairment to Discharge. Darkest = highest impairment; lightest = lowest impairment. (HI_HD) Direct comparison of rankings between landscape groups should not be made since ranking scores are normalized within each landscape group.

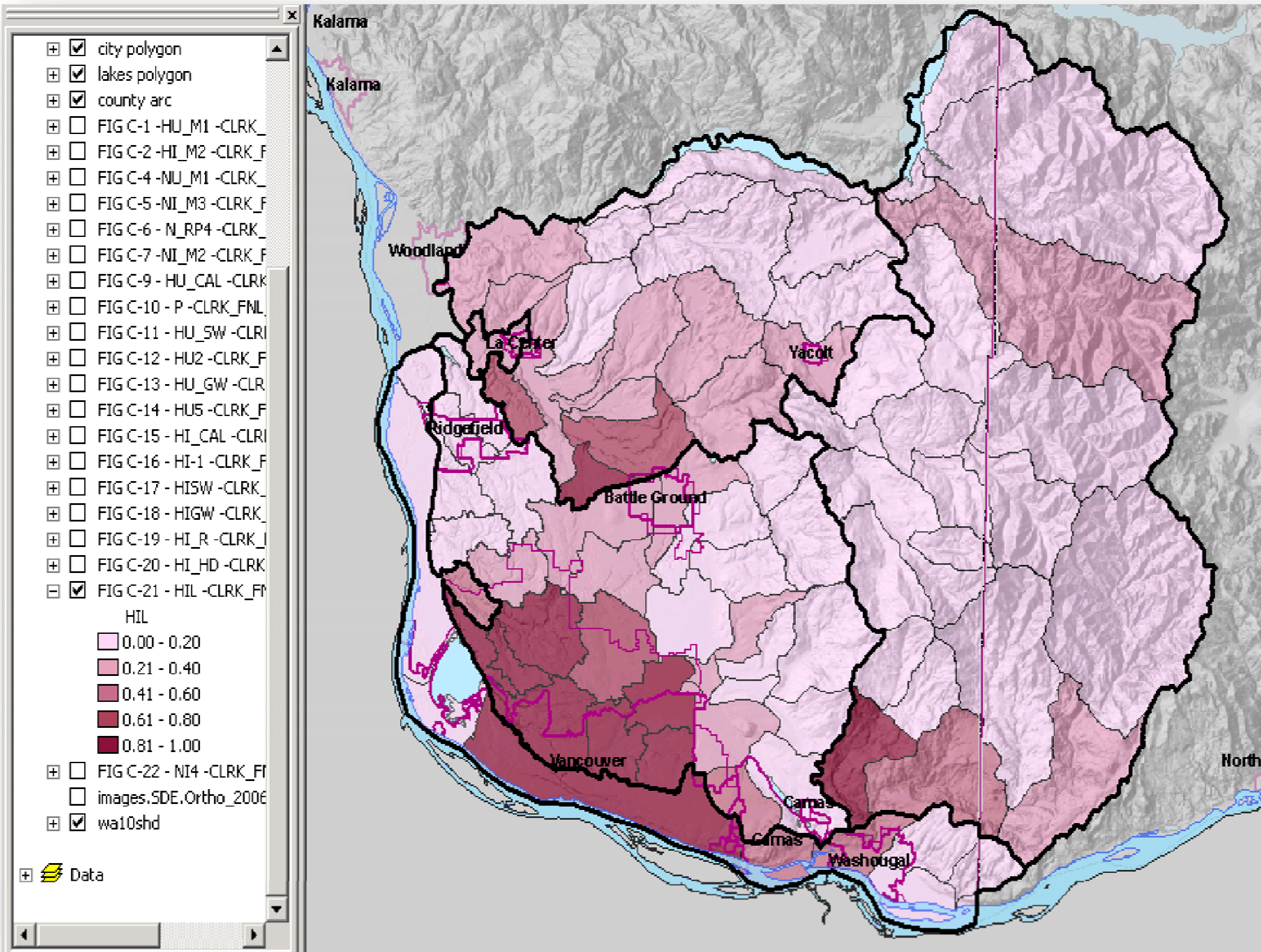

Figure C-21. Ranking of Loss of Evapotranspiration.
Ranking of the relative loss of evapotranspiration based on the percent of impervious cover. The final loss is relative for each landscape group and does not represent actual percentages of impervious surfaces. (HIL)

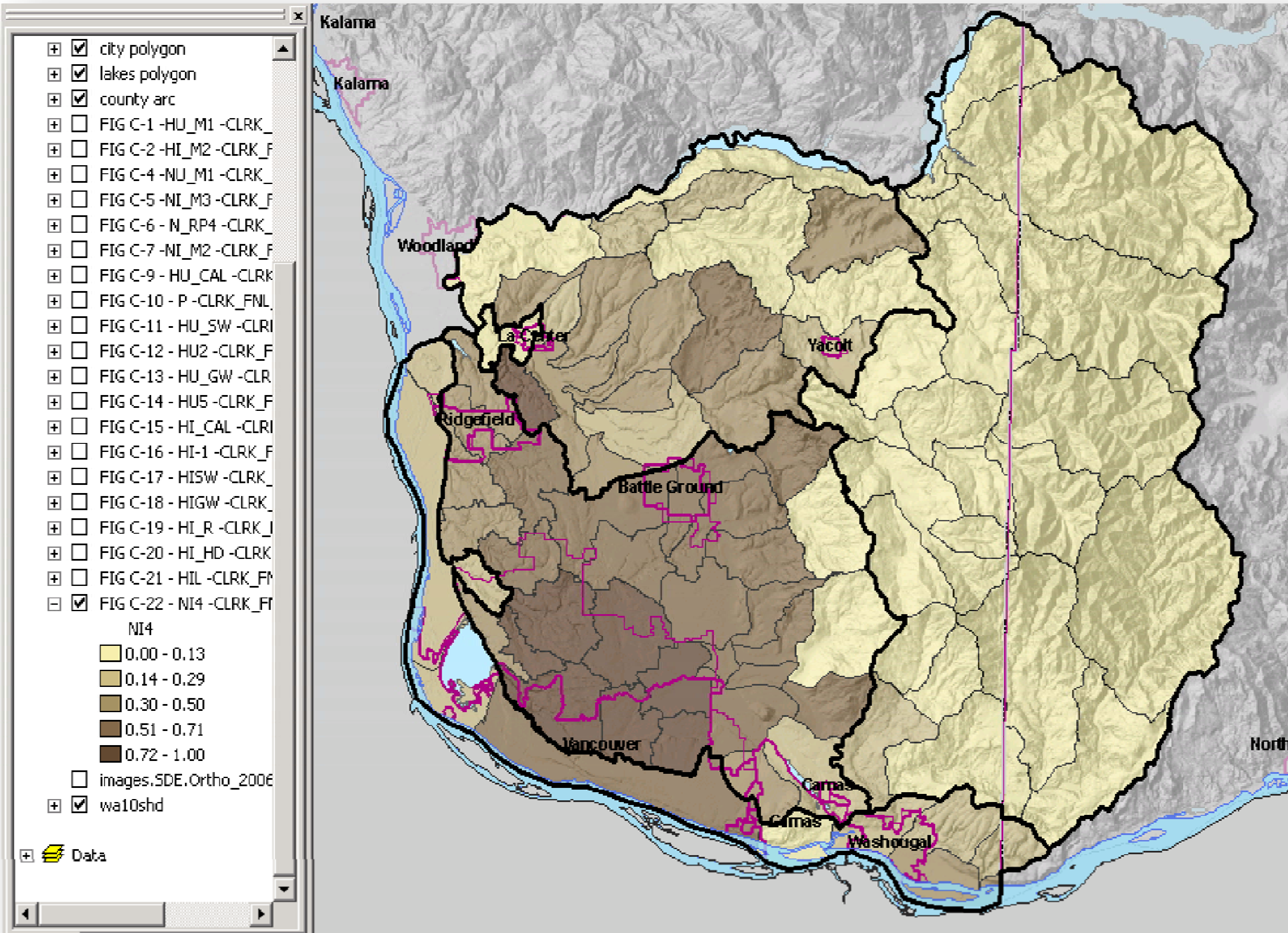

Figure C-22. Ranking of Impairment to Wetlands and Denitrification. Darkest = most impairment to wetlands, lightest = least impairment to wetlands. (NI4). Direct comparison of rankings between landscape groups should not be made since ranking scores are normalized within each landscape group.

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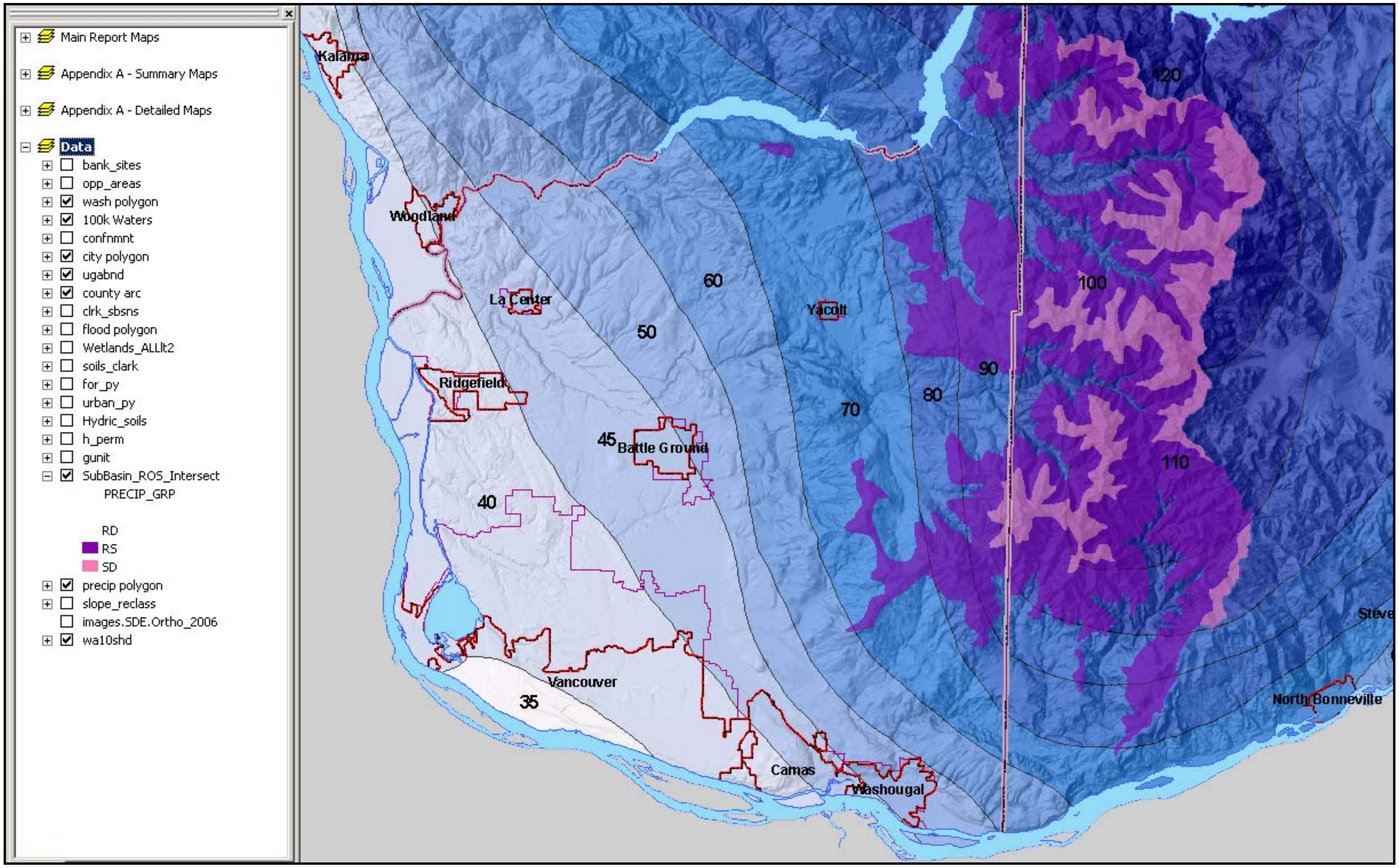

Figure C-23. Precipitation Levels, Rain-on-Snow, and Snow-Dominated Areas. Precipitation is shown in blue bands, labeled in inches; rain-on-snow areas shown purple; and snow-dominated in pink.

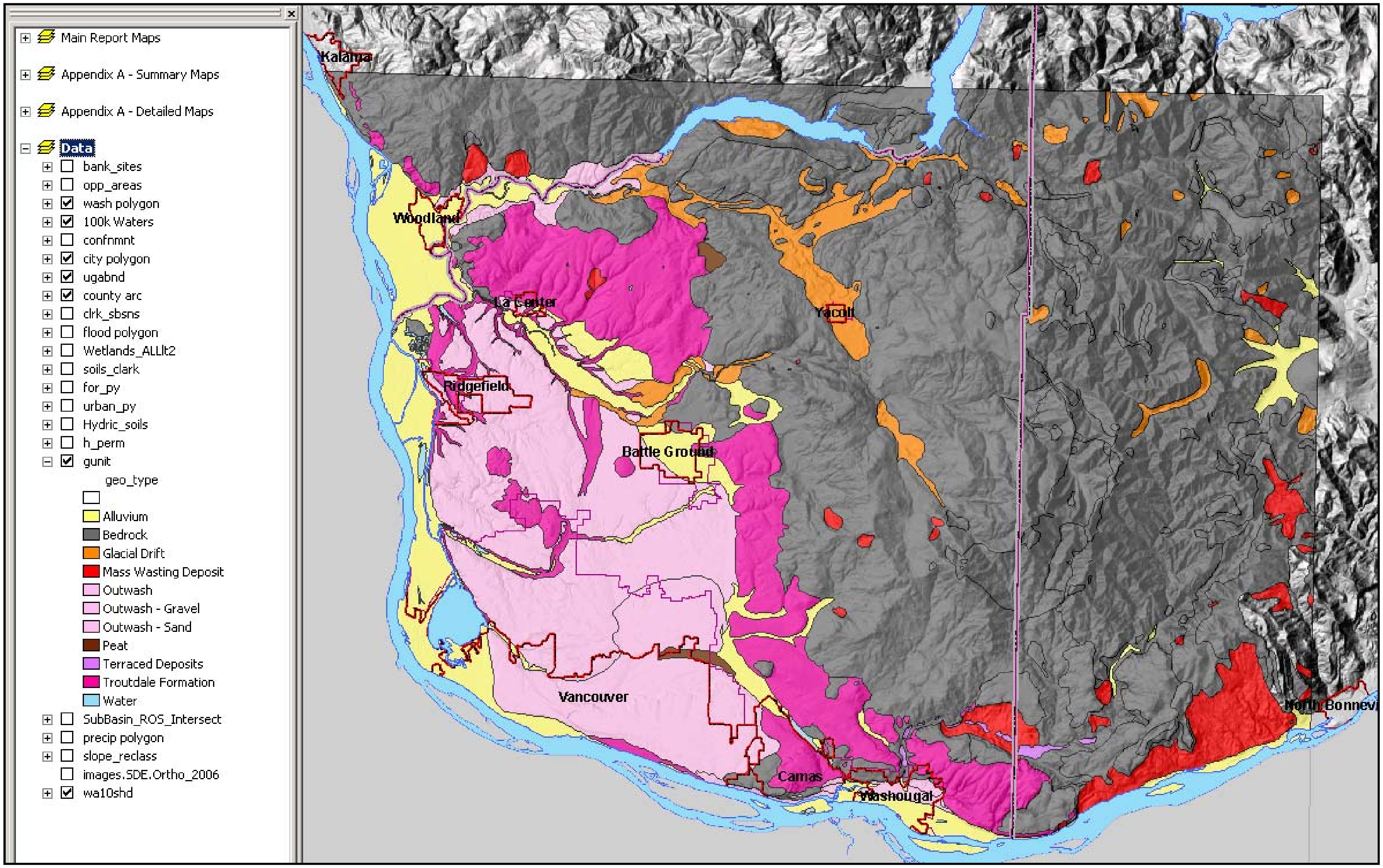

Figure C-24. Surficial Geology.

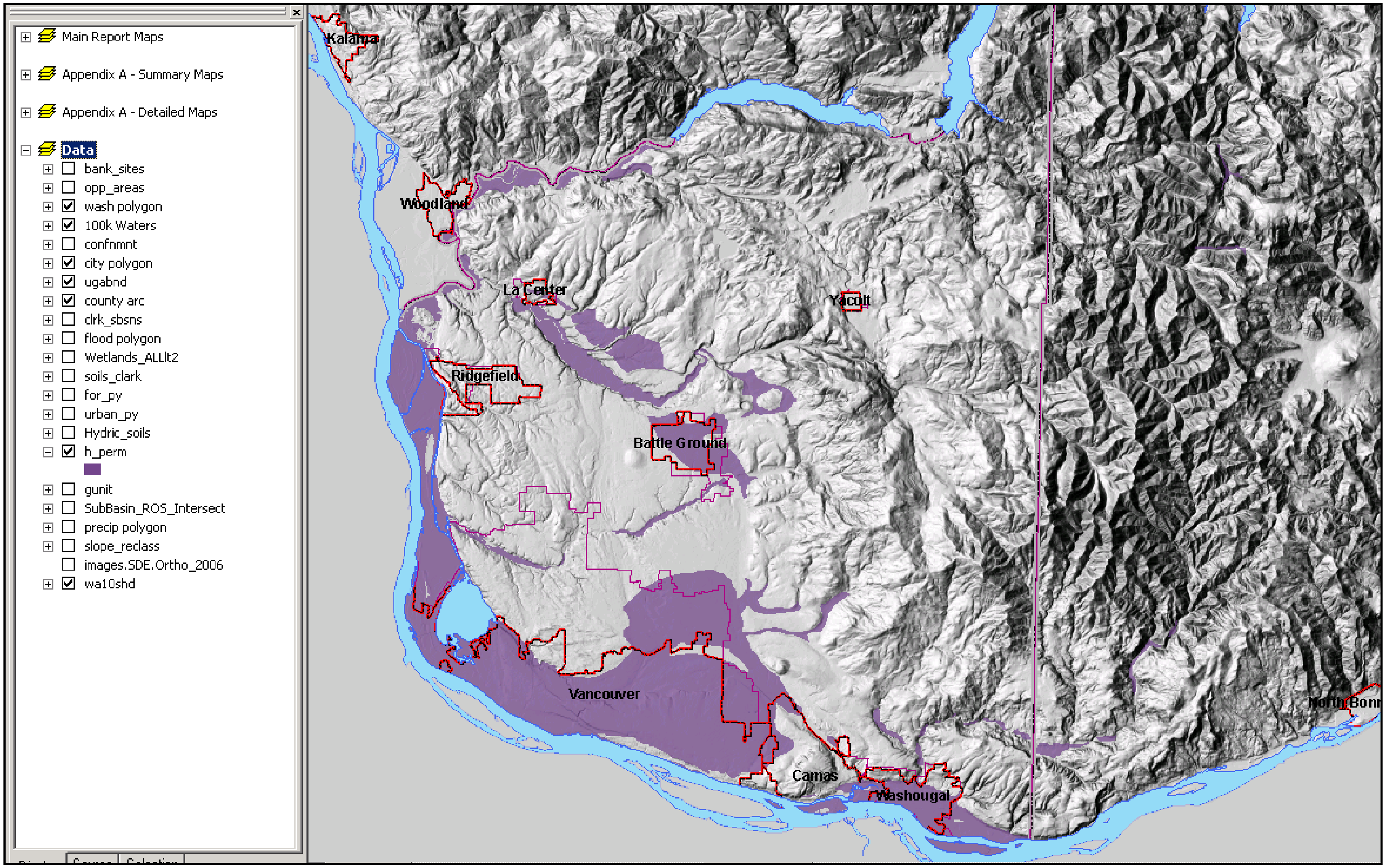

Figure C-25. Permeable Deposits. Areas with higher permeability are shown in purple.

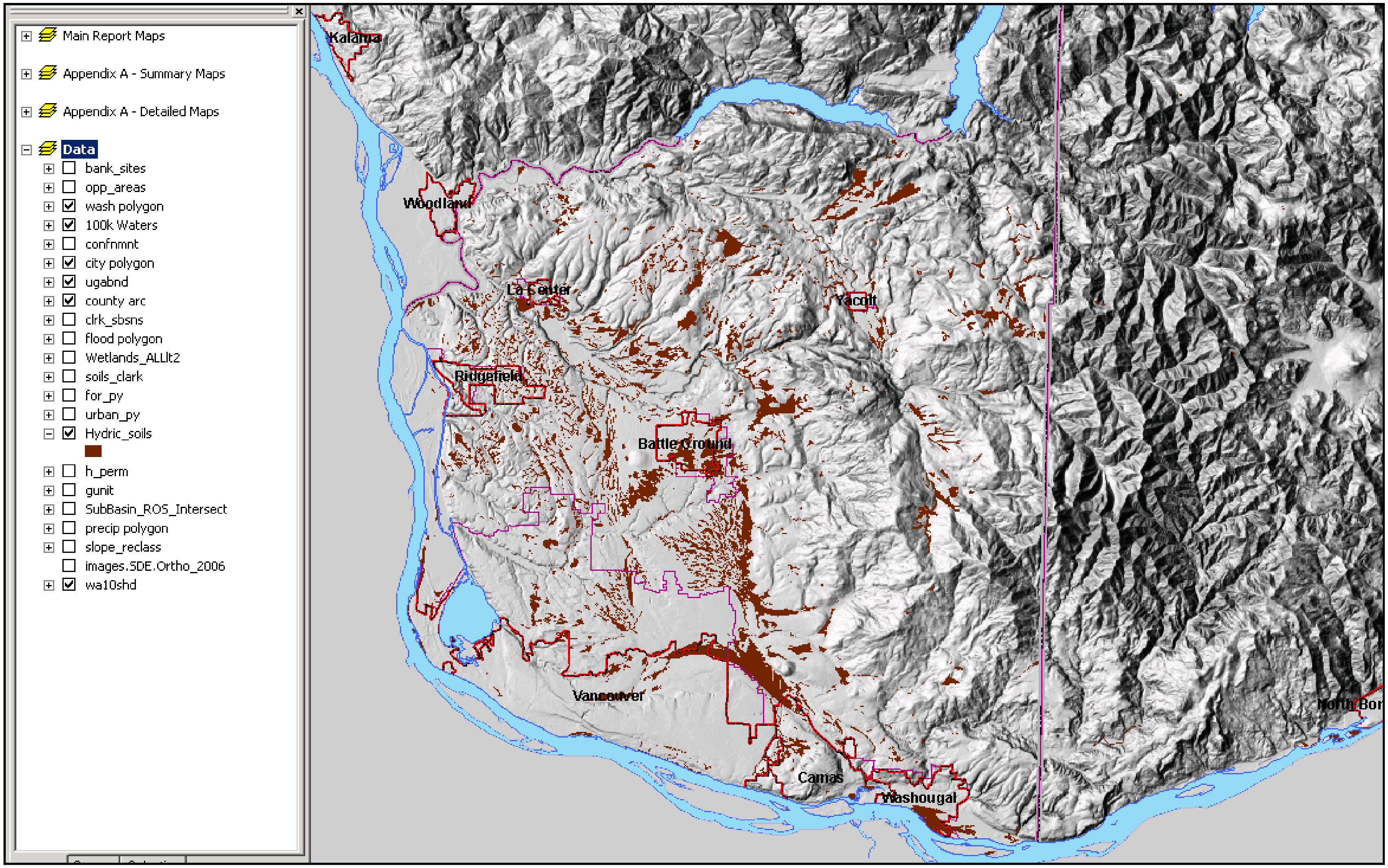

Figure C-26. Hydric Soils. Areas with hydric soils are shown in brown.

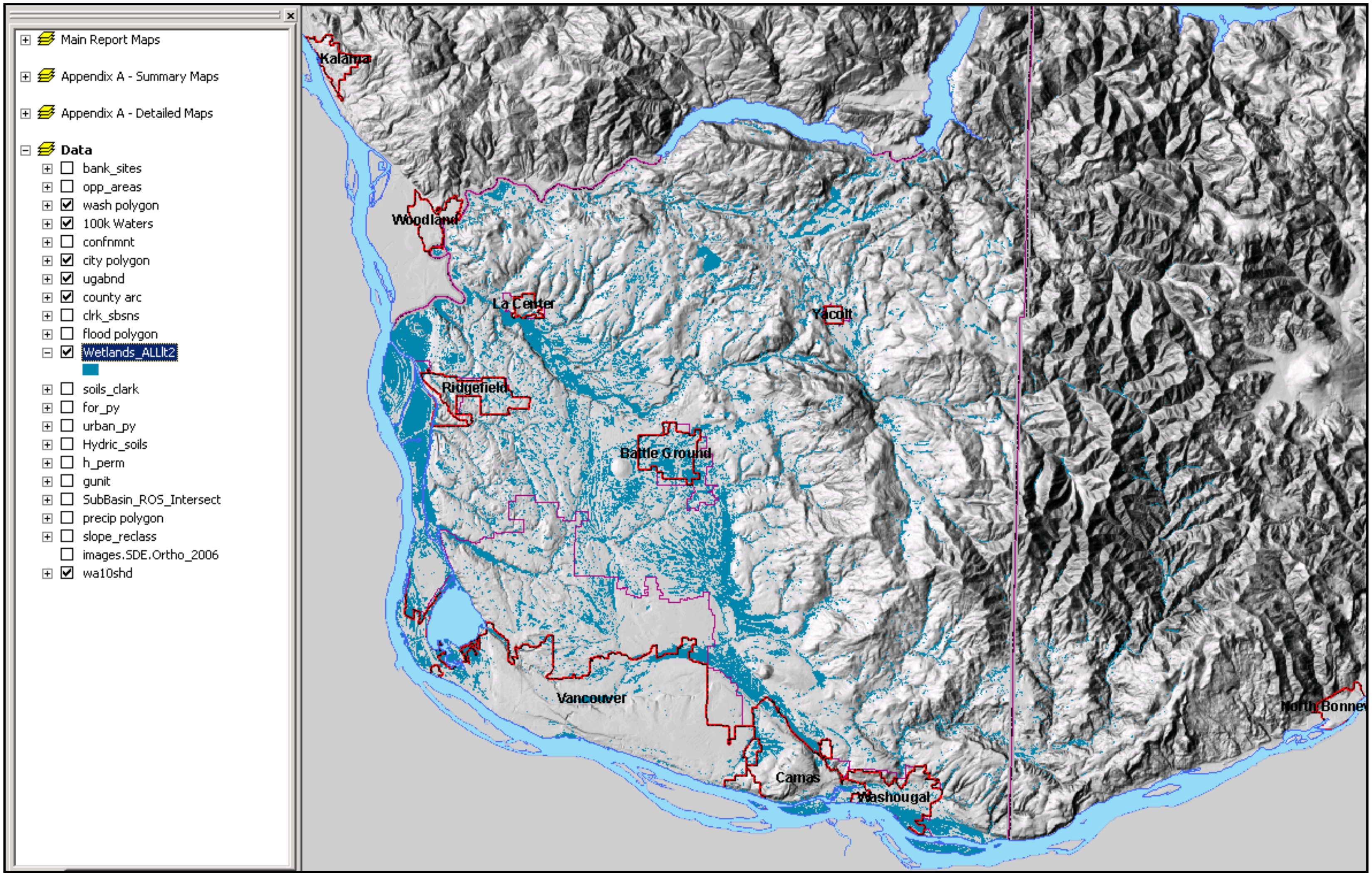

Figure C-27. Depressional Wetlands. Includes both existing and potential depressional wetlands. Areas of depressional wetlands were developed by intersecting hydric soils with areas of slope that are 2% or less. Potential wetlands include areas of mapped hydric soils that have been altered by development activity.

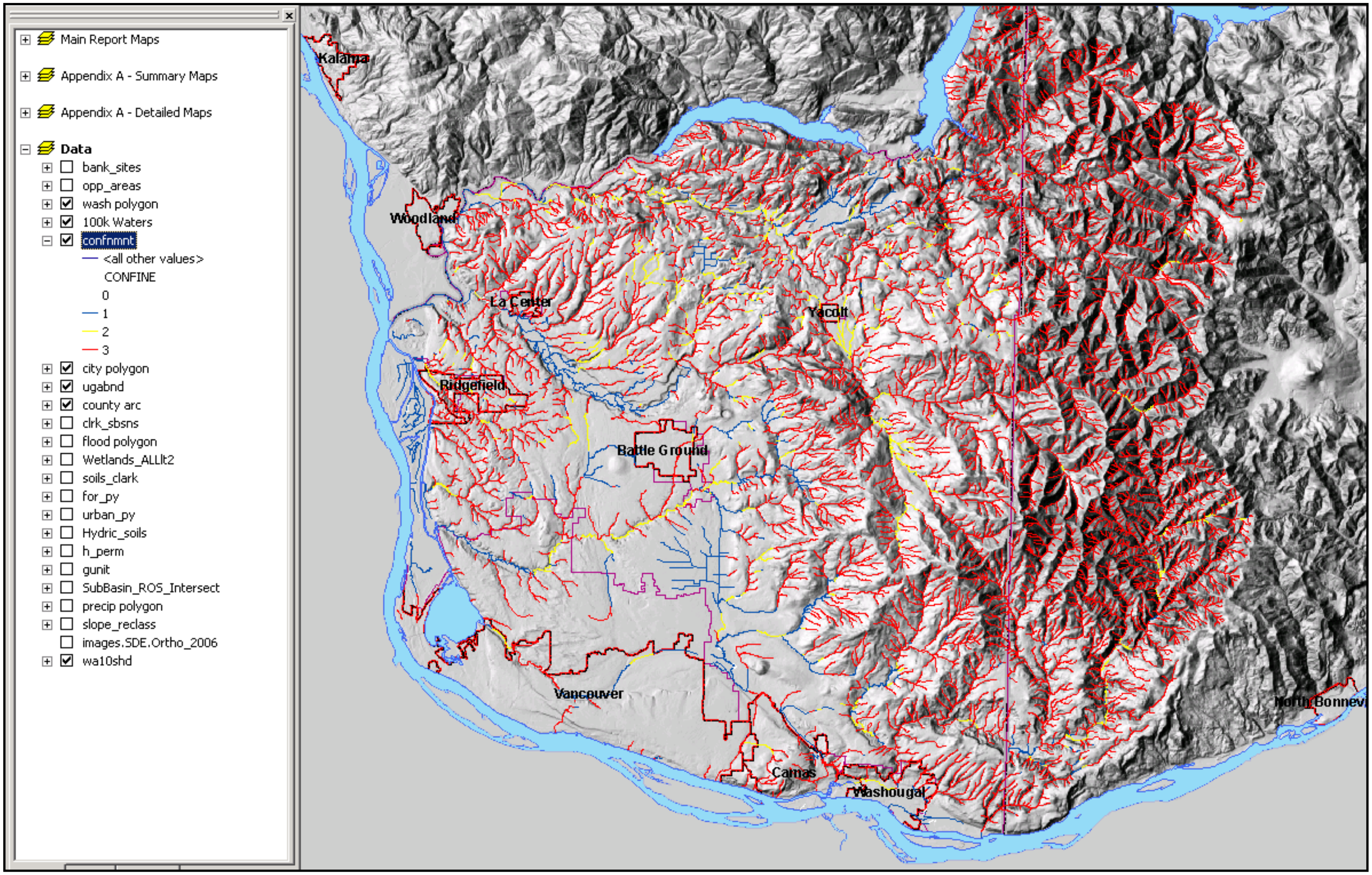

Figure C-28. Streams and Degree of Confinement. Streams shown in red are confined (very little floodplain relative to stream channel); streams in yellow have moderate confinement; and streams in blue are unconfined (floodplain > 4X stream channel). (Supplemental edits to SSHIAP)