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APPLICATION OF THE SYNOPTIC APPROACH TO WETLAND DESIGNATION: A CASE STUDY IN WASHINGTON

APPLICATION OF THE SYNOPTIC APPROACH TO WETLAND DESIGNATION:

A CASE STUDY IN WASHINGTON

FINAL REPORT

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DISCLAIMER

The research described in this report has been funded wholly or in part by the United States Environmental Protection Agency under Contract #68-C8-0006 to NSI Technology Services Corporation. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

ABSTRACT

The synoptic approach is a rapid assessment method designed to provide a context for evaluating landscape sensitivity to cumulative wetland loss and to complement site specific information used in reviewing permit applications to alter wetlands. The objectives of this study were to: 1. test the utility of the synoptic approach in prioritizing wetland "functional uses" (including State surface water designated uses) within the state of Washington; 2. demonstrate and improve this method's ability to identify wetland resources that are ecologically important or sensitive to change; 3. investigate the applicability of the synoptic approach in the landscape assessment of a relatively small watershed; and 4. implement the transfer of the research products to State wetland managers. Readily available data were compiled for Washington into a set of map overlays. The overlays were synthesized to produce indices of landscape input and wetland capacity for hydrologic, water quality, and life support functions, cumulative impacts and future wetland losses for watersheds within the State. The synoptic approach identifies wetland functions not included in Washington's designated uses of surface waters. The approach is appropriate for a state with a generalized set of water quality standards such as Washington's, i.e., one that has no specific designated uses relative to wetland hydrologic and water quality improvement functions. The products of this assessment will be useful in regional planning and in the development of State wetland conservation plans.

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INTRODUCTION

Wetland protection under Section 404 of the Clean Water Act has typically taken a traditional approach to impact assessment. Under this approach, a permit for placement of dredged and fill material is issued if significant impact will not occur to waters of the United States. When considered together, however, the aggregate impact of individually permitted activities could cause significant degradation and damage to the environment. The quantification of these impacts, pursuant to the Clean Water Act, has been hampered by the lack of a standardized approach to cumulative impact assessment. The goal of cumulative impact assessment is to evaluate the cumulative effects of these individual impacts occurring over the entire landscape and through time (Bedford and Preston 1988; Gosselink and Lee 1989).

Compliance with the National Environmental Policy Act requires cumulative impacts to be considered. However, few cumulative impact assessment (CIA) tools are currently available. Dickert and Tuttle (1985) applied a CIA method to a small watershed that emphasizes field measurements and interpretation of land use changes over the past 50 years to develop a model land use planning system appropriate for California coastal watersheds. Walker et al. (1987) used maps of historical changes in Prudhoe Bay, Alaska, to assess the indirect effects of oil field developments. Johnston et al. (1988) analyzed land use and water quality data from different years with a Geographic Information System and statistical methods to identify empirical relationships between resource loss and environmental degradation. While these approaches yield valuable information on landscape function, they do not provide an easily executed, standardized method for assessing landscape sensitivity to wetland loss. All of the above mentioned approaches rely on data that may not be available in many parts of the country or would be prohibitively expensive or time consuming to collect for broad scale studies. The Wetlands Research Program (WRP) of the U.S. Environmental Protection Agency (EPA) has ongoing research to examine the environmental effects of cumulative wetlands loss. As part of this effort, a method is being developed that assembles generally available data into a scientific framework that ranks watersheds according to the relative importance of wetland function and wetland loss. This method provides a landscape perspective and is referred to as the synoptic approach (Abbruzzese et al. 1990a submitted). The approach is being developed as a rapid and inexpensive assessment technique for use in routine 404 permit requests.

To further development of the synoptic approach, WRP sought opportunities to conduct statewide pilot applications. Coincident with this, EPA's Office of Wetlands Protection (OWP) expressed interest in determining whether the synoptic approach could be used in the development of state wetland water quality standards. The federal Clean Water Act grants to the states broad authority for developing standards that protect their water resources. By extending these water quality standards to include wetlands, the states can exert direct control over projects in or affecting wetlands (U.S. EPA 1989). This application of state standards requires that specific classes of wetland be assigned

appropriate "designated uses."

A synoptic case study could offer insight on how a landscape perspective may influence the assignment of designated uses to wetlands. EPA Region 10 selected Washington for this pilot study, through its Regional Applied Research Effort Program (RARE), to support a major program initiative of Region 10 and OWP involving the development of water quality standards for wetlands. Also, EPA presumed that data generated by the study could be used to help design new regulatory strategies for protecting the State's remaining wetlands. A similar case study was conducted in the State of Louisiana (Abbruzzese, et al. 1990b).

The study described in this document was conducted to determine whether the synoptic approach could be used in the development of state water quality standards. Development of the synoptic approach is not complete; an explicit goal of this pilot project was to improve the method. The results of the synoptic analysis are not meant to be final or conclusive, and should only be taken to illustrate the utility of this method in developing state water quality standards.

OBJECTIVES

The primary objective of this research was to test the utility of the synoptic approach in prioritizing wetland "functional uses" (including State surface water designated uses) at the watershed scale. The second objective was to demonstrate and improve this method's ability to identify wetland resources that are ecologically important or sensitive to change. A third, and ancillary, objective was to investigate the applicability of the synoptic approach in the landscape assessment of a relatively small watershed for wetland planning activities i.e., Millcreek, Appendix VI. A fourth objective was to interactively implement the transfer of the research products to state wetland managers. The specific approach was to:

1. Evaluate and comparatively rank wetland landscapes (i.e., watersheds) based on their functional attributes and sensitivity to change;

2. Identify potential wetland functions and values from maps depicting the ranked wetland landscapes;

3. Compare the potential wetland functions and values with existing adjacent or contiguous surface water use designations;

4. Identify ecologically important wetlands or those sensitive to change based on the comparative rankings;

5. Develop a workplan for the analysis of wetland landscape data on a selected small watershed (Appendix VI); and

6. Transfer to appropriate EPA Regional and Washington State natural resource management staff the ongoing status and technical results of the pilot project.

OVERVIEW OF THE SYNOPTIC APPROACH

The synoptic approach is a rapid, inexpensive method for assessing the cumulative effects of wetland loss on landscape function. The method was designed for use in routine wetland evaluation and management work. It should serve to complement existing management practices, including the assessment of local value and function, by providing an anticipatory approach to wetland protection.

The approach can be applied to a variety of geographic scales and regulatory issues, including: 1. the identification of priority areas for research and wetland protection at the national scale; 2. providing a context for wetland permitting and advance wetland planning at the regional or state scale; and 3. identification of sites where wetland restoration and creation efforts could be beneficial at the watershed scale.

The approach uses generally available maps and data to derive relative rankings of watersheds within a study area using indices of the ecological function wetlands perform (Preston and Bedford 1988; Leibowitz and Preston, pers. comm.). The functions are grouped into three general categories, including: 1. hydrology--the ability of wetlands to attenuate peak hydrologic flow, desynchronize floods, and stabilize shorelines; 2. water quality--the capability of wetlands to retain, remove, or detoxify pollutants; and 3. life support--the ability of wetlands to supply the required habitat and food chain support of wetland dependent biota.

The assessment indices were developed as part of a conceptual landscape model (Leibowitz and Preston, pers. comm.). They provide relative measures of the functions wetlands contribute to the landscape, the risk of loss of landscape function from wetland loss or alteration, and the social significance of such loss.

The first four indices (primary indices) are based on data we have collected and interpreted. Three additional derived indices (secondary indices) are based on the primary indices and are addressed in the Discussion section of this report. The primary indices are:

1. Landscape Input--materials produced by the landscape which can potentially be processed or supported by wetlands; thus, an index of the opportunity for wetlands to contribute to landscape function within a cumulative impact area (watershed).

2. Wetland Capacity--the potential ability of wetlands to promote landscape function through processing or support of landscape inputs.

3. Cumulative Impacts--wetland losses that have occurred historically.

4. Future Loss--wetland impacts that are likely to occur in the future.

Since data are not generally available to summarize the relationships characterized by these indices, surrogate measures of the indices were chosen. For example, to calculate landscape input for hydology (i.e., hydrologic input), measures of watershed area, precipitation, runoff potential, slope and channel length were used. The following approach summarizes how the relative rankings of watersheds were produced: 1. selection of the appropriate surrogate measure for each index (Table 1); 2. collection of mapped and tabular data; 3. analysis of the data to derive primary data layers; and 4. combination of the data layers to produce the relative watershed rankings.

TABLE 1. Summary of measures used to estimate landscape indices.

Landscape Index	Definition
Hydrologic Input	$\frac{\text{Precipitation x area x runoff x (1+slope)}}{\text{Length}}$
Precip (cm) =	precipitation contours digitized from Cummans et al. (1975) prorated to watershed boundaries
Area (ha) =	area of water resource inventory areas from Washington Department of Water Resources (1969)
Runoff (percent) =	runoff curve number as illustrated in Table 2
Slope (m/m) =	slope calculated from USGS 1:250,000 topographic maps, by subtracting the elevation
Length (m) =	length of the main channel planimetered from 1:250,000 USGS topographic maps
Water Quality Input	Length of Polluted Streams
Length of Polluted Streams (km) =	length of streams listed as "partially supporting" or "nonsupporting" of designated uses in State 304(1) Report.
Life Support	Rare, Threatened & Endangered Species
Rare Threatened & Endangered Species (number) =	total number of rare, threatened, and endangered species per WRIA from Washington Department of Wildlife (1990) and Washington Department of Natural Resources (1990)

TABLE 1. (cont.)

Landscape Index	Definition
Wetland Capacity	Wetland Area
Wetland area (ha) =	proportion of wetland area derived from dot grid samples of 1:250,000 USGS Land Use/Land Cover maps
Cumulative Impacts	Hydric Area-Current Wetland Area
Hydric Area-Current Wetland Area (ha) =	Area of hydric soils from county soil surveys and SCS hydric soils list (Hydric Soils Committee 1987) prorated to WRIA using dot grid samples. Current wetland area as above
Future Loss	Risk x Wetland Area
Risk =	agricultural growth x 87/95 + population growth x 8/95
agricultural growth =	$\frac{\text{Agr 84 - Agr 72}}{\text{Agr 72}}$ / 8 — Agricultural land (US Bureau of the Census 1974, 1982a) prorated by Appendix II.
population growth =	$\frac{\text{pop 80 - pop 70}}{\text{pop 70}}$ / 10 — Human Population (US Bureau of the Census, 1972, 1982b) prorated by Appendix II.
wetland area =	see above

ANALYSIS OF WASHINGTON DATA

DATA COLLECTION

Sixty two watersheds (Figure 1) were delimited using Washington Department of Ecology's (DOE) "water resource inventory areas" (WRIA) (Washington Department of Water Resources 1969).

Data for calculating the four primary indices for each watershed were collected from a variety of federal and State agencies, including the U.S. Geological Survey, U.S. Bureau of the Census, DOE, Washington Wildlife and Natural Resources and Washington State University. In addition, existing State surface water use designations were mapped for comparison with synoptic watershed rankings. Other agencies were contacted for information, including the Department of State Parks and Washington Nature Conservancy.

The quality assurance of the data was assessed in terms of its: 1. level of general availability (nationwide) and comparability with data sets for other states; 2. scale of resolution; 3. the degree of replication of techniques employed in obtaining the data. A 5% quality control check was performed on areal, linear and elevation measurements taken from maps and data recorded from other sources. An error level less than 5% was the target. A person, other than the original data collector, replicated every twentieth measurement to check for accuracy. The result of the check was that the 5% accuracy criterion for measurements taken from maps was always met. This accuracy only applies to primary data measurements, and not the final combined maps.

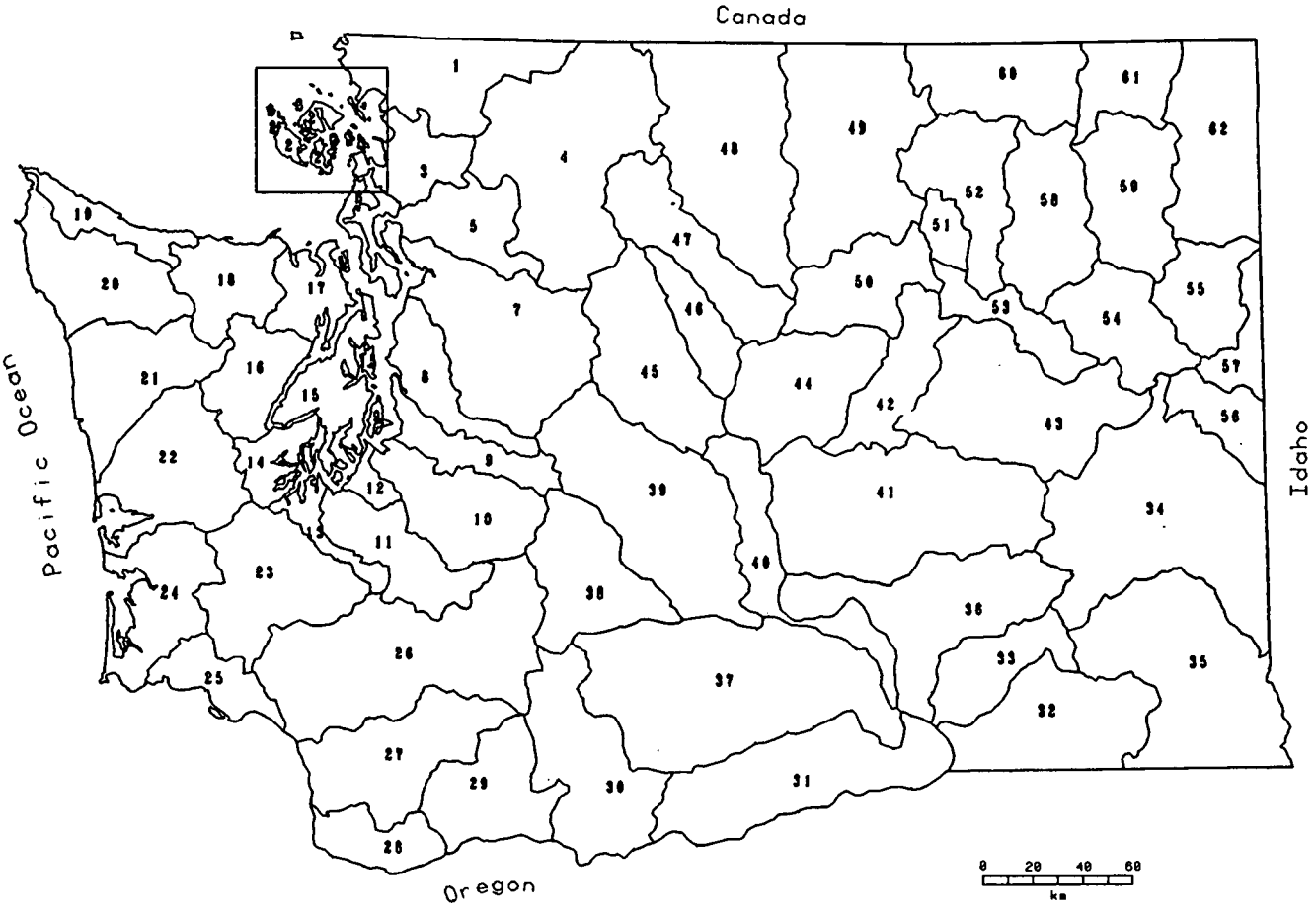
MAP DEVELOPMENT

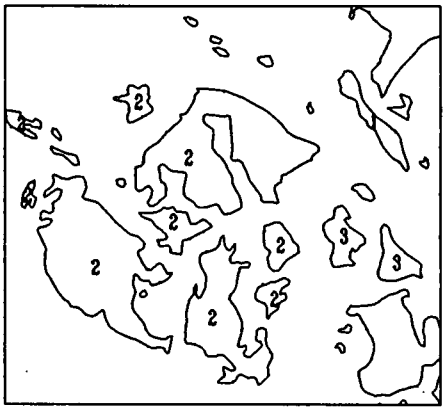
To produce a map for a particular index, it was first necessary to produce maps of the index components (Appendix I). Several of the maps, e.g. cumulative impacts, are presented in both the non-normalized and normalized forms to illustrate potential applications to particular management questions, i.e., absolute loss vs. percent loss. Following is a brief description of the components and data sources for these maps (maps produced using the ARC/INFO Geographic Information System):

Hydrologic Input

The estimate of hydrologic input (peak discharge) has both a spatial and temporal dimension; it is calculated as the product of precipitation, watershed area, runoff potential, and stream channel slope divided by channel length (Figure 2).

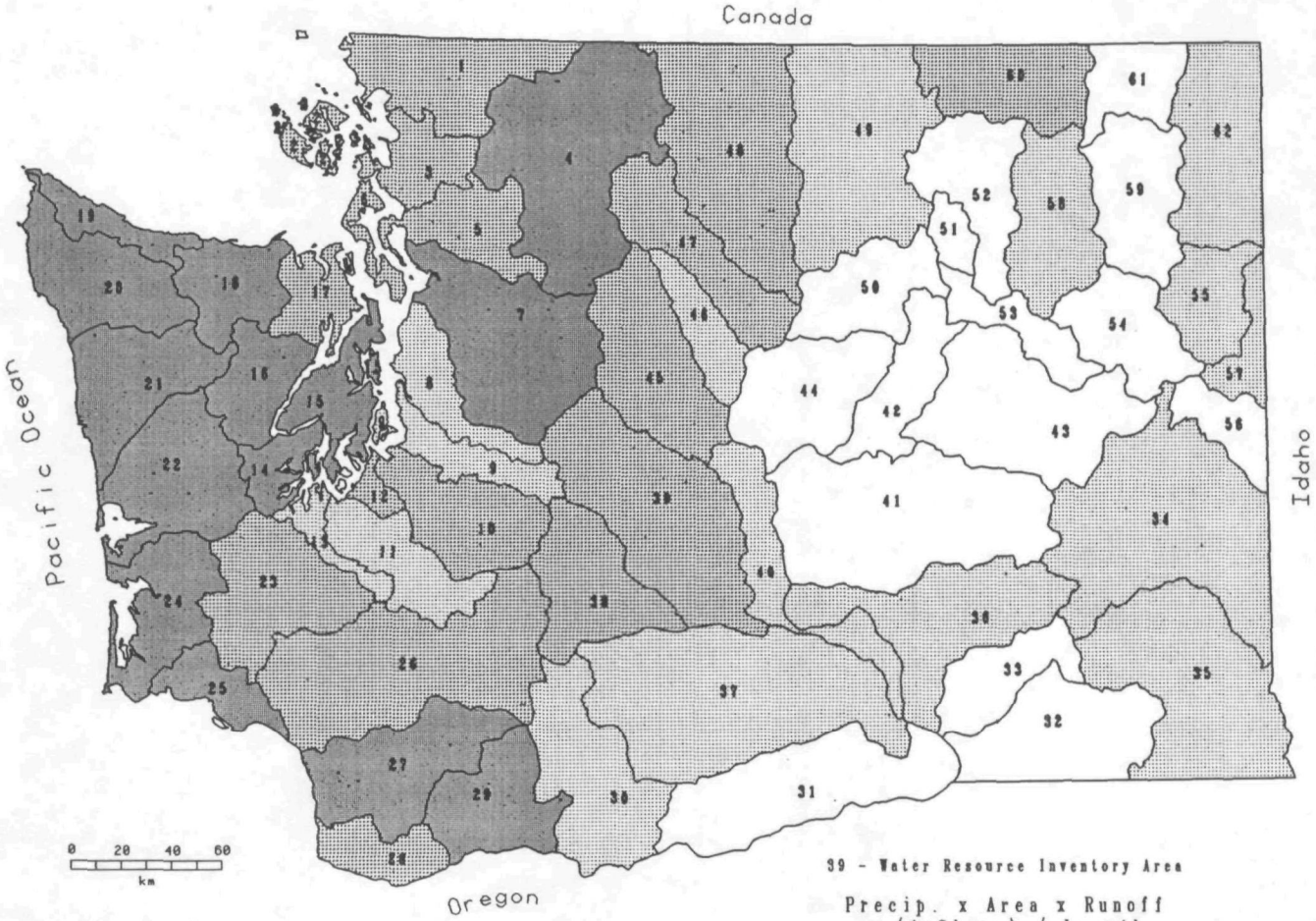
Figure 1





Water Resource
Inventory Areas

HYDROLOGIC INPUT



39 - Water Resource Inventory Area

Precip. x Area x Runoff
x (1+Slope) / Length

35 -	90
90 -	190
190 -	410
410 -	1070

Figure 2

1 - 408	2 - 406	3 - 197	4 - 1068	5 - 245	6 - 395
7 - 586	8 - 174	9 - 145	10 - 280	11 - 183	12 - 219
13 - 101	14 - 491	15 - 588	16 - 575	17 - 341	18 - 498
19 - 671	20 - 600	21 - 713	22 - 592	23 - 288	24 - 701
25 - 456	26 - 408	27 - 420	28 - 303	29 - 478	30 - 171
31 - 42	32 - 75	33 - 37	34 - 94	35 - 108	36 - 104
37 - 127	38 - 257	39 - 240	40 - 167	41 - 82	42 - 35
43 - 58	44 - 73	45 - 331	46 - 119	47 - 216	48 - 242
49 - 118	50 - 57	51 - 39	52 - 67	53 - 40	54 - 51
55 - 102	56 - 66	57 - 108	58 - 109	59 - 85	60 - 224
61 - 87	62 - 184				

[Water Resource Inventory Area]

Prepared by USEPA Wetlands Research Program, USEPA Environmental Research Lab, Corvallis, Oregon

Mean annual precipitation contours (Cummans et. al. 1975) were digitized and then pro-rated to watershed units. An estimate of the volume of water entering the system is obtained by multiplying precipitation by drainage area for each watershed.

Runoff potential is derived from a modification of the Soil Conservation Service's (SCS) curve number (Rawls et al. 1981; SCS 1986). The percent runoff for a drainage unit is calculated as the weighted average of the runoff value for each pairwise combination of hydrologic soil group and land use. Proportions of land uses and hydrologic soil groups were estimated from dot grid samples of 1:250,000 scale U.S. Geological Survey (USGS) Land Use/Land Cover maps and a State soil map (Loomis et. al. 1985), respectively. Runoff values for these combinations (Table 2) were adapted from Rawls et al. (1981); the joint percentage of the soil and land use areas is used as weights. Thus, runoff is given by:

$$\text{Runoff}_{total} = \sum_i \sum_j \text{Runoff}_{i,j} \times \text{Weight}_{i,j}$$

$$= \sum_i \sum_j \text{Runoff}_{i,j} \times \text{Area}_i/\text{Area}_{total} \times \text{Area}_j/\text{Area}_{total}$$

where i is an index for the four soil groups and j is an index for the six land uses. As an example, assume a drainage unit with half of all soils belonging to group A and the other half to group C, and with agriculture representing 25% of total land use and the remaining 75% in forest. Using Table 2 to obtain the pairwise runoff values, percent runoff for that unit would then be (63 x [0.5 x 0.25]) + (43 x [0.5 x 0.75]) + (77 x [0.5 x 0.25]) + (75 x [0.5 x 0.75]) = 61.75.

Total discharge is obtained by multiplying the volume of precipitation by percent runoff. To estimate the temporal distribution, total discharge was multiplied by channel slope and divided by channel length, since peak discharge for a given event increases with slope and shorter channel lengths. Slope was calculated by subtracting the elevation at 10% of the channel length from elevation at 85% of the channel length, then dividing the difference by 75% of the total channel length (Cummans et al. 1985). Length of the main channel was measured using an electronic planimeter. It should be emphasized here that this method provides an estimate. The units of measurement were arbitrarily chosen. Also, since we do not currently have a method for calculating water retention by upstream wetlands, the estimate does not include the import of water from upstream units.

Water Quality Input

Water quality input (Figure 3), or the degree of point and nonpoint source pollution, was estimated from State water quality data, since data on pollutant loading rates are not readily available. Input was calculated as the length of streams inventoried that

were listed as "partially supporting" or "nonsupporting" of State and federal designated uses (such as "swimmable" or "fishable") in the State's 304(1) Report (Washington Department of Ecology 1989). No data were recorded in the State 304(1) Report for twelve of the Sixty-two WRIA's, suggesting that streams were not sampled in those units. Those units were assigned a "no data" value and a rank of 1 to indicate a probable low degree of pollution (Figure 3).

Waterbodies located in multiple WRIA's, i.e., portions of the Columbia River, were omitted from the study to avoid double counting of stream reaches. Length of polluted streams is the surrogate used; however we do not know what proportion of all streams this represents, since the intensity of stream sampling is not known.

Life Support Input

We used the number of rare, threatened or endangered wetland dependent species present as a surrogate for life support input (Figure 4) (Washington Department of Wildlife 1990; Washington Department of Natural Resources 1990). This is based on the assumption that these species represent the portion of wetland biota that are most sensitive to habitat destruction.

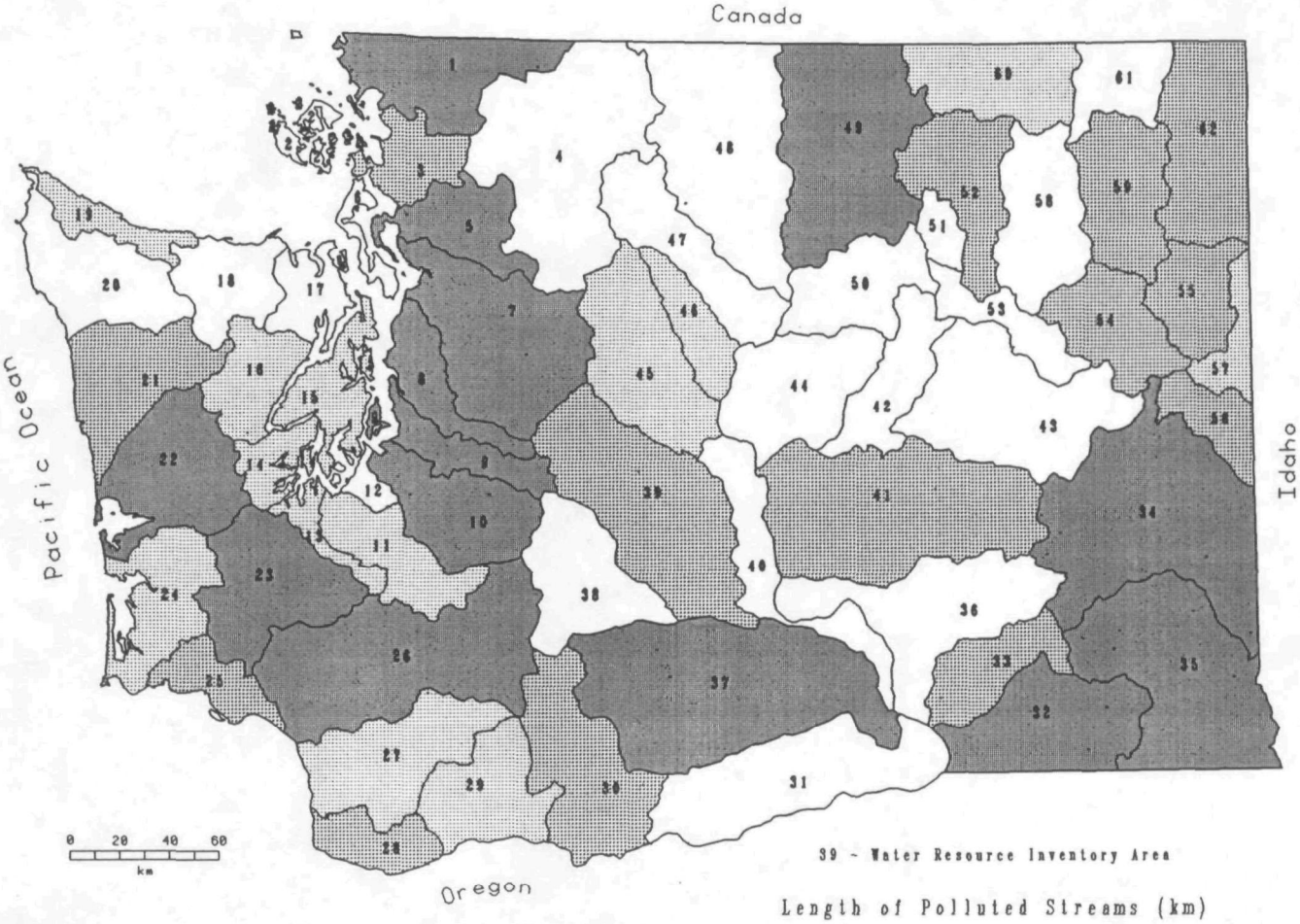
Wetland Capacity

Wetland capacity (Figure 5) is a measure of the ability of wetlands to attenuate peak hydrologic flow, process pollutants and provide habitat. These complex relationships are difficult to evaluate because of a lack of existing data; therefore, wetland area derived from USGS Land Use/Land Cover maps, as described above, is used as a surrogate for wetland capacity. Note that twenty three of the WRIA's show a zero value for wetland area (Figure 5). This is probably due to the scale of the analysis, rather than an absolute absence of wetlands in the watersheds. Either the map scale (1:250,000) is too small to depict small wetlands present on the ground or the dot grid used was too widely spaced to count a small percentage of wetlands present on the map.

TABLE 2. Curve number (percent runoff) for pairwise combinations of hydrologic soil groups and land uses (adapted from Rawls et al. 1981).

	Hydrologic Soil Group			
Land Use	A	B	C	D
Agricultural Land	63	69	77	82
Forest Land	43	64	75	81
Miscellaneous/ Barren Land	68	78	84	86
Urban or Built-up Land	55	71	83	88
Water	100	100	100	100
Wetland	45	66	77	83

WATER QUALITY INPUT (NON-NORMALIZED)



39 - Water Resource Inventory Area

Length of Polluted Streams (km)

- 0 - 0
- 0 - 73
- 73 - 120
- 120 - 470

Figure 3

1 - 467	2 - 0	3 - 82	4 - 0	5 - 228	6 - 0
7 - 230	8 - 235	9 - 153	10 - 227	11 - 71	12 - NO DATA
13 - 56	14 - 70	15 - 45	16 - 48	17 - 0	18 - 0
19 - 66	20 - 0	21 - 78	22 - 230	23 - 253	24 - 64
25 - 105	26 - 151	27 - 70	28 - 110	29 - 21	30 - 73
31 - NO DATA	32 - 158	33 - 113	34 - 236	35 - 171	36 - NO DATA
37 - 202	38 - 0	39 - 103	40 - NO DATA	41 - 74	42 - NO DATA
43 - NO DATA	44 - NO DATA	45 - 44	46 - 44	47 - 0	48 - 0
49 - 171	50 - NO DATA	51 - NO DATA	52 - 104	53 - NO DATA	54 - 83
55 - 78	56 - 92	57 - 39	58 - NO DATA	59 - 85	60 - 53
61 - NO DATA	62 - 115				

[Water Resource Inventory Area]

Prepared by USEPA Wetlands Research Program, USEPA Environmental Research Lab, Corvallis, Oregon

Cumulative Impacts

Wetland impacts that have occurred in the past were estimated as the amount of original wetland area lost (Figure 6). Area of hydric soils was used as a surrogate for historic wetland area, using county soil surveys and the SCS hydric soils list (Hydric Soils Committee 1987). County soil data were prorated to WRIA's using dot grid samples from the WRIA map overlaid on a Washington State map, with county boundaries, at the same scale. Many lands in federal ownership in Washington have no county soil surveys or other soils data available from which to estimate area of hydric soils, i.e.: Makah and Quinalt Indian Reservations; Mt. Rainier, Olympic and North Cascades National Parks; Ft. Lewis and Bremerton Military Reservations; and Okanogan, Mt. Baker-Snoqualmie, Gifford Pinchot, Kaniksu and Umatilla National Forests. In these areas estimates were derived from a state soil association map (Loomis et. al. 1988) and averaged with estimates from neighboring counties. Current wetland area was obtained as described above. It should be noted that some areas, especially around lakes and estuaries, show a net wetland gain using this method. This is probably an error caused by inconsistencies in the classification of wetlands and open water in county soil surveys and the U.S. Geological Survey land use/land cover maps. However, there may be net wetland gains in some watersheds in the Columbia Basin area of the State, e.g., WRIA's numbers 39, 44 and 45, associated with increases in irrigated agriculture (Office of Technology Assessment 1984).

Future Loss

Agricultural conversion and urban expansion have historically accounted for 85 and 10% of national wetland loss, respectively (Tiner 1984). Thus, risk of future wetland loss was based on recent trends in agricultural and population growth. We derived a risk factor by using a weighted average of the annual rate of agricultural growth between 1974 and 1982 (U.S. Bureau of the Census 1974, 1982a) and population growth between 1970 and 1980 (U.S. Bureau of the Census 1972, 1982b) (Appendix II). Since these data are reported by county, the county data were prorated to the watershed units using the weighting factors in Appendix III. The proportions of wetland loss reported by Tiner (1984) were used as weights. The risk factor was multiplied by current wetland area to derive future loss (Figure 7).

Designated Uses of Surface Waters

Four use categories were derived from State wetland water quality standards (Washington Code Revisor 1988): 1. Class AA (extraordinary); 2. Class A (excellent); 3. Class B (good); 4. Class C (fair). Streams assigned to the above uses were mapped (Figure 8) according to their water body identification number (Washington Department of Ecology 1989). No streams were listed as Class C.

TECHNICAL INFORMATION TRANSFER

Information transfer to EPA Region 10 and Washington resource agency staff was accomplished through technical seminars. Fundamental to this strategy was the participation of EPA and State technical staff in the preparation and review of map products and narrative reports. Two technical seminars were attended by EPA regional staff and representatives from Washington's DOE. The objectives of these seminars were to: 1. introduce the synoptic approach (July, 1989); and 2. present preliminary results of the Washington analysis (April, 1990). As a result of discussions at the July, 1989 meeting, an amendment was made to the study design to include a summary of how the synoptic approach could be used in wetland planning for a small watershed. Questions and concerns about the approach and its applications, raised at the April, 1990 meeting, were addressed in subsequent phone conversations and correspondence. A third seminar will be scheduled in fall of 1990 to present final results.

LIFE SUPPORT INPUT

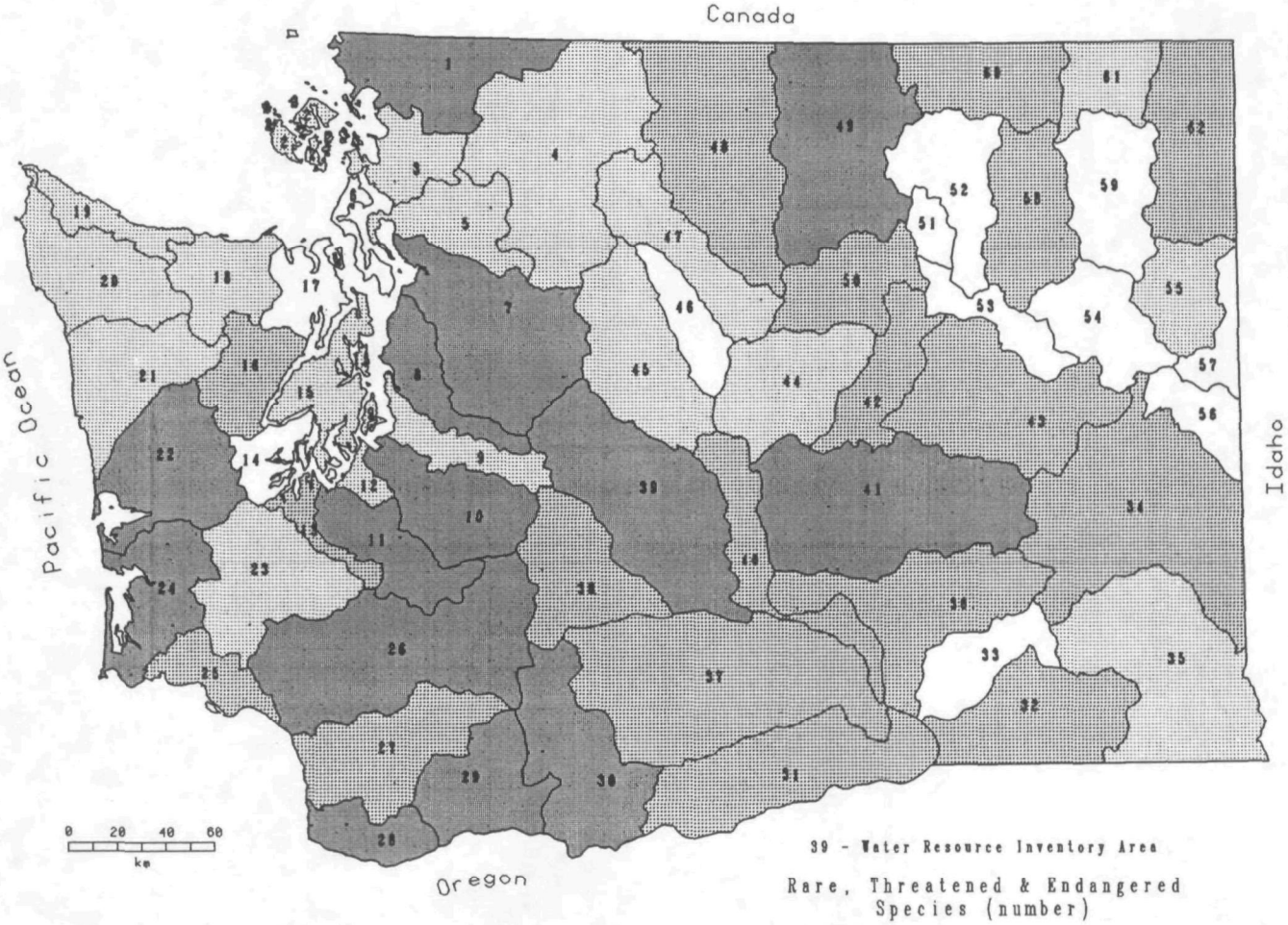


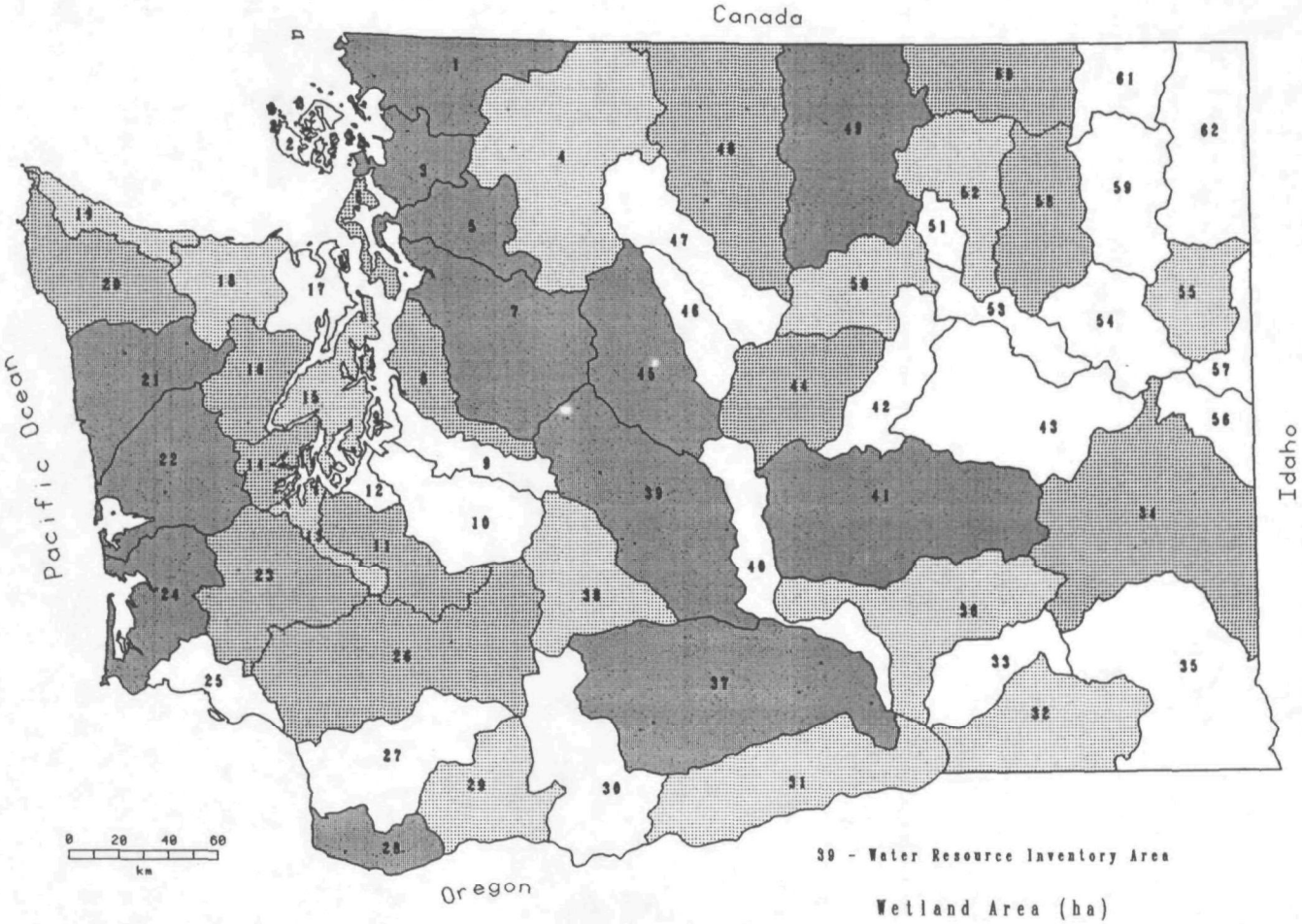
Figure 4

1 - 11.0	2 - 6.0	3 - 6.0	4 - 6.0	5 - 5.0	6 - 4.0
7 - 12.0	8 - 10.0	9 - 5.0	10 - 10.0	11 - 10.0	12 - 6.0
13 - 8.0	14 - 4.0	15 - 5.0	16 - 7.0	17 - 4.0	18 - 5.0
19 - 5.0	20 - 5.0	21 - 6.0	22 - 11.0	23 - 6.0	24 - 11.0
25 - 6.0	26 - 10.0	27 - 9.0	28 - 10.0	29 - 10.0	30 - 10.0
31 - 9.0	32 - 7.0	33 - 2.0	34 - 7.0	35 - 6.0	36 - 9.0
37 - 9.0	38 - 7.0	39 - 11.0	40 - 9.0	41 - 10.0	42 - 6.0
43 - 8.0	44 - 5.0	45 - 6.0	46 - 2.0	47 - 6.0	48 - 9.0
49 - 12.0	50 - 7.0	51 - 3.0	52 - 4.0	53 - 3.0	54 - 3.0
55 - 5.0	56 - 0.0	57 - 3.0	58 - 7.0	59 - 4.0	60 - 7.0
61 - 5.0	62 - 8.0				

[Water Resource Inventory Area]

Prepared by USEPA Wetlands Research Program, USEPA Environmental Research Lab, Corvallis, Oregon

WETLAND CAPACITY



39 - Water Resource Inventory Area

Wetland Area (ha)

	0 - 0
	0 - 560
	560 - 1975
	1975 - 10845

Figure 5

1 - 2321	2 - 0	3 - 7227	4 - 525	5 - 2051	6 - 1206
7 - 2448	8 - 691	9 - 0	10 - 0	11 - 1425	12 - 0
13 - 419	14 - 1068	15 - 449	16 - 1387	17 - 0	18 - 348
19 - 288	20 - 1934	21 - 6771	22 - 4450	23 - 1626	24 - 3510
25 - 0	26 - 1566	27 - 0	28 - 2559	29 - 496	30 - 0
31 - 497	32 - 500	33 - 0	34 - 1050	35 - 0	36 - 527
37 - 10841	38 - 539	39 - 2620	40 - 0	41 - 7848	42 - 0
43 - 0	44 - 566	45 - 2110	46 - 0	47 - 0	48 - 1518
49 - 4874	50 - 511	51 - 0	52 - 545	53 - 0	54 - 0
55 - 521	56 - 0	57 - 0	58 - 1200	59 - 0	60 - 1092
61 - 0	62 - 0				

[Water Resource Inventory Area]

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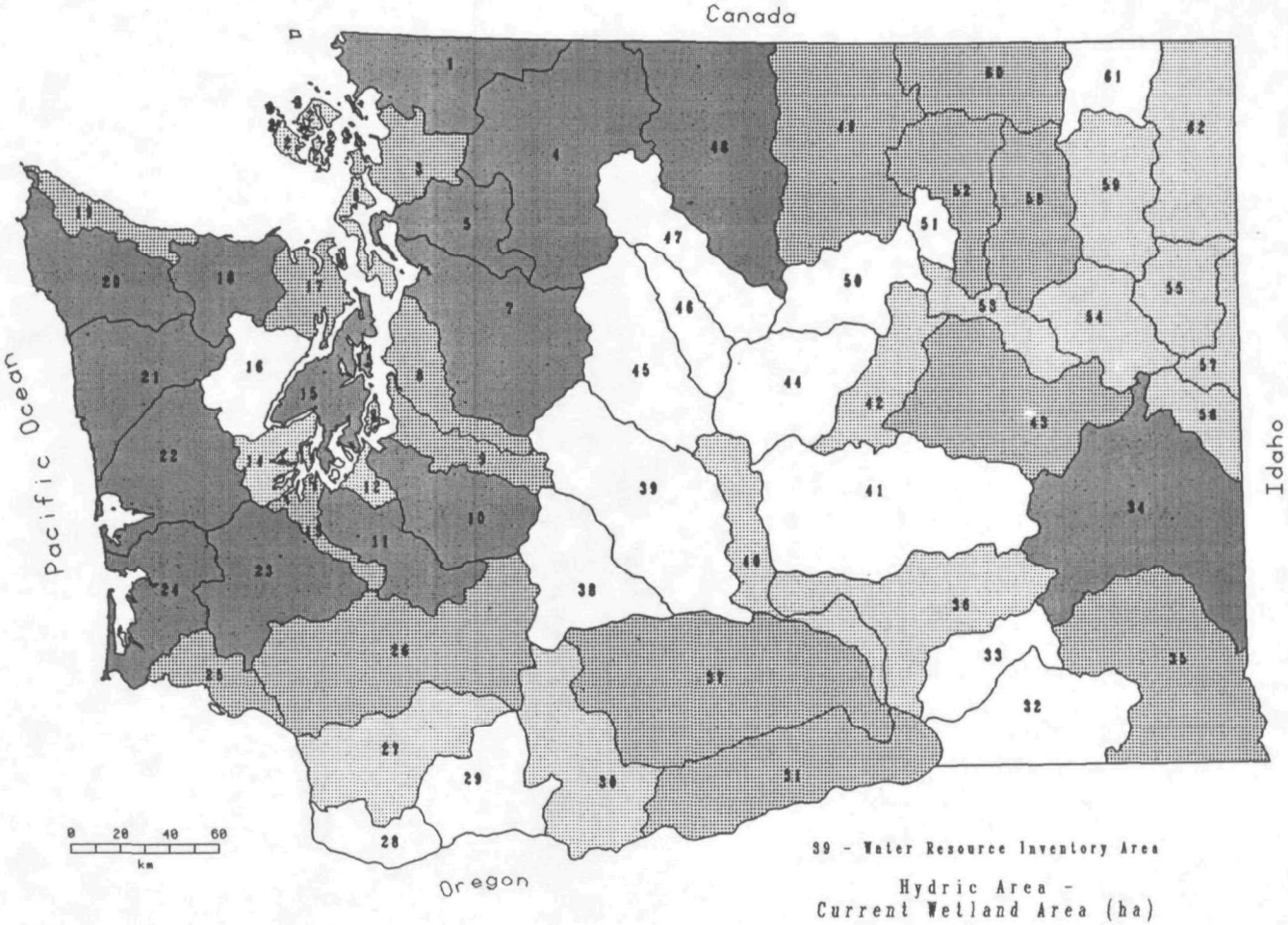
CUMULATIVE IMPACTS (NON-NORMALIZED)



39 - Water Resource Inventory Area

Hydric Area - Current Wetland Area (ha)

-1055 - 1640	
1640 - 3025	
3025 - 6625	
6625 - 22605	

Figure 6

1 - 16617	2 - 2278	3 - 4254	4 - 15464	5 - 8753	6 - 2944
7 - 21931	8 - 4668	9 - 4615	10 - 9023	11 - 8420	12 - 2049
13 - 4204	14 - 2875	15 - 9216	16 - 932	17 - 6155	18 - 8414
19 - 6441	20 - 8493	21 - 10737	22 - 8982	23 - 13822	24 - 9716
25 - 3802	26 - 4902	27 - 2346	28 - -863	29 - 844	30 - 2089
31 - 3558	32 - 850	33 - 316	34 - 7186	35 - 5171	36 - 2458
37 - 5051	38 - 331	39 - -955	40 - 1723	41 - 840	42 - 2397
43 - 3412	44 - -238	45 - -1054	46 - 382	47 - 819	48 - 22603
49 - 5173	50 - -2	51 - 1462	52 - 5754	53 - 1689	54 - 2872
55 - 2702	56 - 2593	57 - 1812	58 - 4436	59 - 2656	60 - 3106
61 - 1499	62 - 2601				

[Water Resource Inventory Area]

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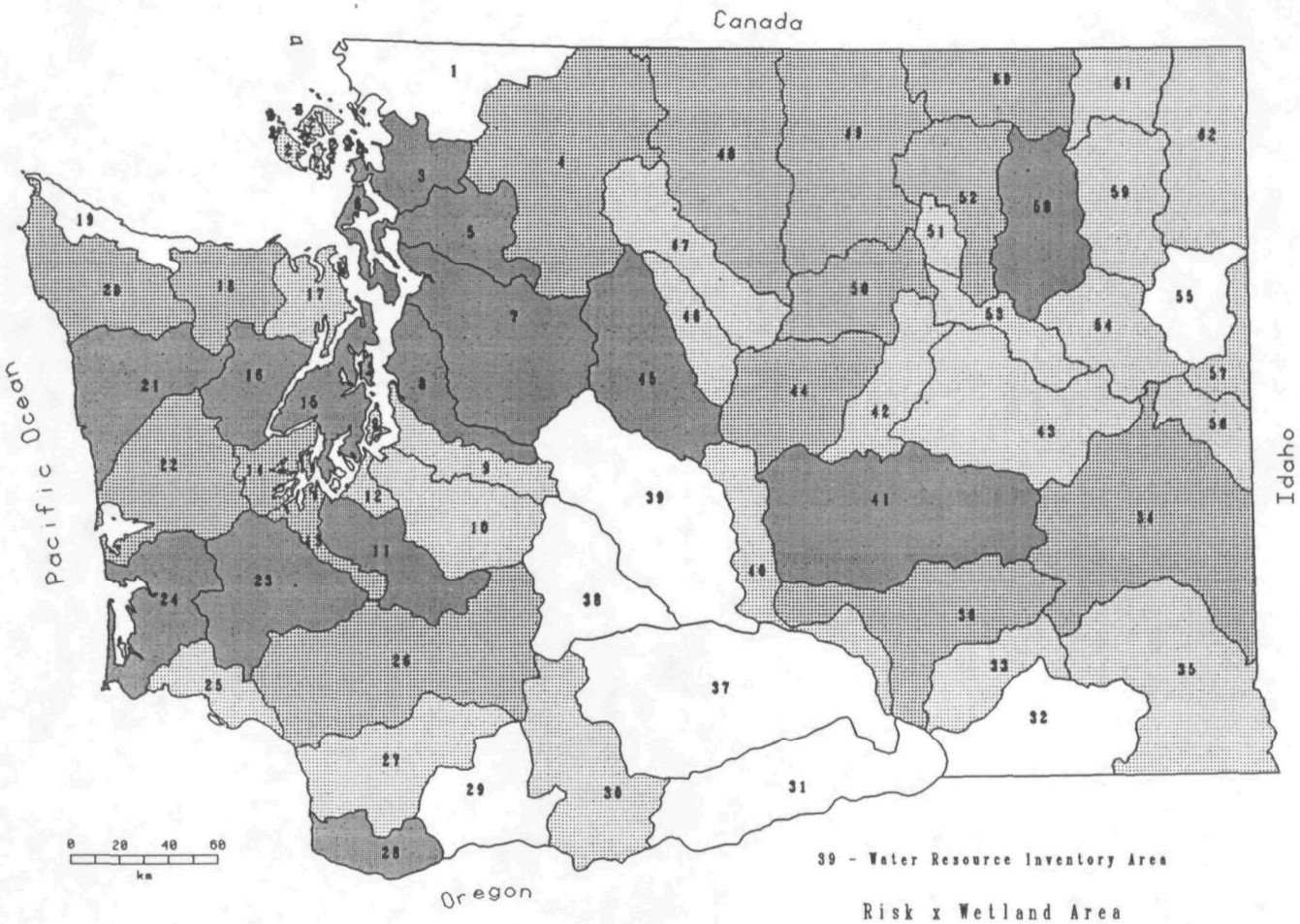
FUTURE LOSS



39 - Water Resource Inventory Area

Risk x Wetland Area

	-29.3 - -0.1
	-0.1 - 0.0
	0.0 - 6.4
	6.4 - 72.4

Figure 7

1 - -2.8	2 - 0.0	3 - 18.3	4 - 2.3	5 - 28.9	6 - 7.4
7 - 52.6	8 - 14.0	9 - 0.0	10 - 0.0	11 - 11.3	12 - 0.0
13 - 3.7	14 - 5.7	15 - 15.4	16 - 12.4	17 - 0.0	18 - 0.3
19 - -1.0	20 - 4.4	21 - 61.9	22 - 1.0	23 - 8.5	24 - 45.0
25 - 0.0	26 - 4.1	27 - 0.0	28 - 17.0	29 - -2.7	30 - 0.0
31 - -1.5	32 - -1.8	33 - 0.0	34 - 2.5	35 - 0.0	36 - 3.2
37 - -19.9	38 - -1.2	39 - -29.3	40 - 0.0	41 - 25.2	42 - 0.0
43 - 0.0	44 - 2.5	45 - 72.4	46 - 0.0	47 - 0.0	48 - 2.1
49 - 4.7	50 - 2.0	51 - 0.0	52 - 2.6	53 - 0.0	54 - 0.0
55 - -3.7	56 - 0.0	57 - 0.0	58 - 9.1	59 - 0.0	60 - 6.1
61 - 0.0	62 - 0.0				

[Water Resource Inventory Area]

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WASHINGTON DESIGNATED USES OF SURFACE WATERS

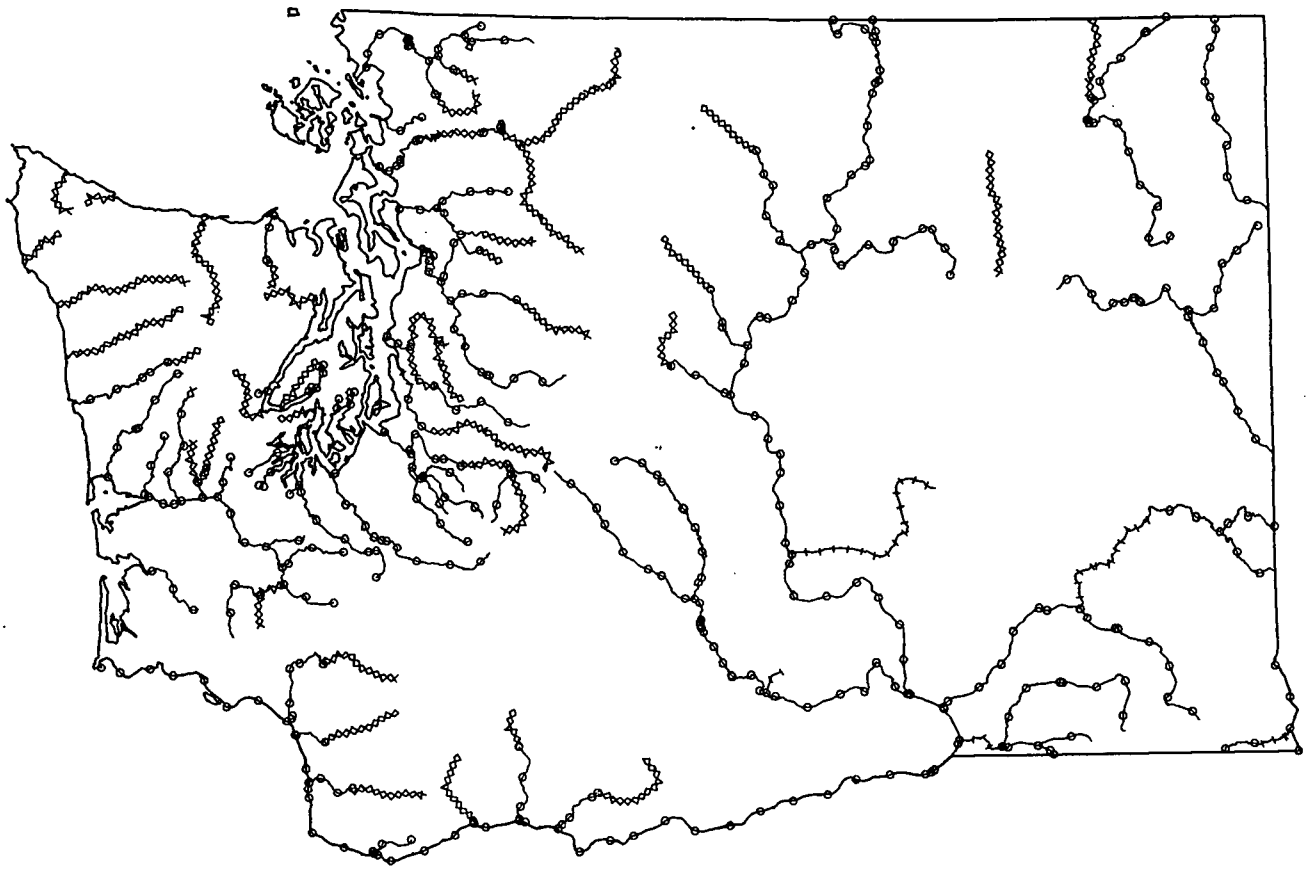

Figure 8

Class AA (Extraordinary)

Class A (Excellent)

Class B (Good)

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FINAL PRODUCTS

The final products of this pilot study are the following:

1. Maps, generated with the ARC/INFO Geographic Information System, depicting rankings of Washington's "water resource inventory areas" according to the synoptic indices and the component data layers for each index, including:

   - Hydrologic input

     --mean annual precipitation
     --total drainage area
     --potential runoff
     --stream channel slope
     --channel length

   - Water quality input

     --nonpoint water quality input

   - Life support input

   - Wetland capacity

   - Cumulative impacts

   - Future risk

     --agricultural growth (1974-1982)
     --human population growth (1970-1980)

   - Future loss

2. Map of Washington's "designated uses" of surface waters

3. Floppy diskette with all data collected for the study

4. ARC/INFO data tapes (for use with Geographic Information System)

DISCUSSION

The derived (secondary) indices, mentioned in the "Overview of the Synoptic Approach" section of this report, can be discussed in terms of wetland functions and sensitivity to change. The concepts incorporated in the indices are central to the synoptic approach, although methods to measure the indices are still in the developmental stage. The derived indices are defined here and some of the maps generated for them (Appendix IV) are used for illustrative purposes:

Landscape Sensitivity--landscape input into wetlands divided by wetland capacity. This is an index of the potential "loading" of wetlands by landscaping inputs.

Sensitivity = Input/Capacity

Since sensitivity is the input divided by capacity, the twenty three units with zero wetland capacity (Figure 5) were assigned an "undefined" value for sensitivity and a rank of 4 to reflect "infinite" sensitivity (Figure IV.1-IV.3). Units, such as unit 12 with no water quality input data and zero wetland capacity were assigned a "no data" value for water quality sensitivity and a rank of 1 (Figure IV.2). The same logic was applied to cumulative effects (Figure IV.7-IV.14) and wetland significance (Figure IV.15-IV.17).

Cumulative Effects--the likelihood of changes in landscape function caused by wetland impacts, estimated as the product of sensitivity and impacts (historic and future).

Cumulative Effects = Sensitivity x Cumulative Impacts

Wetland Significance--the significance of wetland loss to potential beneficiaries of wetland function, calculated by multiplying cumulative effects by some specific use (i.e., a population of interest or area of some land use).

Wetland Significance = Cumulative Effects x 1980 population

The identification of relative wetland function can be achieved by comparing landscape inputs with wetland capacity for a given function. Several of the WRIA's surrounding the Puget Sound can be used to illustrate the concept. For example, compare values for hydrologic inputs in units 1 (Nooksack), 3 (Lower Skagit-Samish) and 5 (Stillaguamish) east of the Sound with values in units 15 (Kitsap), 16 (Skokomish-Dosewallips) and 18 (Elwha-Dungeness) west of the sound (Figure 2). Hydrologic inputs in units 1, 3 and 5 are relatively low compared to inputs in units 15, 16, and 18. On the other hand, wetland capacity in units 1, 3 and 5 (Figure 5) is relatively high, compared to wetland capacity in units 15, 16 and 18. This suggests that units 15, 16 and 18 are relatively more sensitive

than units 1, 3 and 5 to the hydrologic effects of wetland loss, as illustrated by the "hydrologic sensitivity" map (Appendix IV).

The addition of the cumulative impacts component to the indices for wetland function provides a tool for identifying landscapes that have potentially suffered from wetland loss. Cumulative impacts for units 15 and 18 (Figure 6) are relatively high compared to those for unit 3; high sensitivity and high impacts suggests greater likelihood of loss of landscape function as illustrated by the map for "hydrologic effects" (Appendix IV). In addition, the relatively high human population density in the units surrounding the Sound implies that such loss of the hydrologic function performed by wetlands could have high social significance, as illustrated by the "hydrologic significance to humans" map (Appendix IV).

The products of the Washington statewide assessment can be used to identify functions (or "uses") (U.S. EPA 1990) and areas sensitive to impacts, at the regional or watershed scale, not identified in existing surface water use designations. Washington's Water Quality Standards (Washington Code Revisor 1988) list a suite of uses (such as water supply, wildlife and navigation) and physical, chemical and biological criteria according to each "criteria class" which range in value from "extraordinary" to "fair." Wetlands are not mentioned in the definition of "surface waters of the State," and the "water use" classes do not include any indicator of the hydrologic or water quality improvement provided by wetlands. Therefore, a classification system is needed for identifying wetland functions in Washington.

Additional protection for wetlands could be provided by designating watersheds for "hydrologic use" where the relative hydrologic sensitivity is high. The same principle could be applied to water quality and life support functions where existing "use" designations do not appear to provide adequate protection for the wetland functions identified by the synoptic maps. It should be emphasized that the synoptic approach is not intended to make value judgements, or management decisions, with respect to which wetland functions are most important to protect within a geographic area. The index or suite of indices used for designating wetland "use" or assessing cumulative impacts must be determined by the regulatory agencies involved.

Outstanding national resource waters are defined as waters and wetlands of "exceptional ecological significance" (U.S. EPA 1990). To designate candidate wetlands and wetland complexes for "Outstanding State Resource Waters," a protocol could be developed by combining existing surface water designated uses with synoptic wetland function identification or cumulative effects ranking. For example, Appendix V summarizes the rankings of watersheds for hydrology, water quality and life support cumulative effects. Those units with low rankings for a particular function, e.g., a rank of 1 through 10, are likely to have a high potential for processing landscape inputs for that function and are likely to be relatively unimpacted. Watersheds that have low cumulative effects rankings for all functions, e.g., units 45, 28 and 39, might be considered to have wetlands of

relatively high functional value and therefore identified for special protection as "Outstanding State Resource Waters." The rankings could be further refined by weighting the watersheds by wetland patch size, the existence of state wetland heritage sites or the wetland rating system being developed by the Washington DOE.

CONCLUSION

The synoptic approach is a framework for assessing the cumulative effects of wetland loss on landscape function, designed to complement existing management practices. The approach can be applied to a variety of spatial scales and regulatory issues and can be modified according to the concerns of a particular regulatory agency. An assessment can be completed in a matter of months at a relatively low cost, providing the capability of rapidly ranking watersheds or regions according to their sensitivity to future Wetland losses.

The synoptic approach does provide a landscape perspective on wetland function and identifies wetland functions not included in Washington's designated uses of surface waters. Additional protection could be afforded to Washington's wetlands by using the synoptic approach to differentiate functions (uses) performed by wetlands, which may be quite different from adjacent lakes and streams due to differences in hydrology and biotic composition. In comparing the results of the Washington and Louisiana pilot studies (Abbruzzese et. al. 1990b), we conclude that the approach may be more appropriate for a state, such as Washington, with a generalized set of water quality standards than a state such as Louisiana which has specific surface water use categories, such as "oyster propagation", "public water supply", and "agriculture". However, the approach does not supersede the need for site specific information on wetland value and function and does not provide adequate information for decisions regarding a particular wetland site, due to the broad scale of the study. Thus, the approach should not be used for site specific decisions or for engineering purposes, e.g. locating sites for bridges, since the relative location of different components of the ecosystem becomes critically important for such decisions.

The need for greater precision in the approach, e.g., using higher resolution maps where available, is accentuated in Washington because of the high spatial variability in landforms, soil association and precipitation patterns, wetland density and availability of data, compared to Louisiana. For example, wetland area in WRIA's with zero values for wetland area (see Figure 5 and section on Wetland Capacity) should be calibrated by comparison with a random sample of wetland area depicted on U.S. Fish and Wildlife Service National Wetland Inventory maps. Also, the lack of soil surveys for a substantial portion of the state made it difficult to compare, even in a relative sense, wetland losses in different WRIA's. A cooperative effort to map soils on federal lands would alleviate this problem and contribute, in general, to comprehensive planning in Washington.

The Washington pilot study can provide a "first cut" at identifying wetland "designated uses" in the state and identify areas where additional study is needed. The assessment may also be useful in regional planning and the development of State Wetlands Conservation Plans in accordance with recommendations of the National Wetlands Policy Forum (National Wetlands Policy Forum 1988), or as a tool for nonpoint source pollution

assessment. Ultimately, the utility of the synoptic approach in providing information useful to the development of wetland water quality standards and the strategy for wetland "use designation" in the study area must be decided by resource management agencies.

The synoptic approach was developed to provide a tool, in addition to existing management practices, for evaluating the cumulative effects of wetland loss in regulatory decisions that must be made quickly and with limited resources. The approach is a common sense logic structure based on many simplifying assumptions whose consequences are not fully understood. These assumptions include the following: 1. precipitation based processes determine hydrologic function; 2. data on polluted streams from state 305B reports are valid indicators of pollutant loading rates; 3. number of rare, threatened and endangered wetland dependant species present are representative of wetland biota most sensitive to habitat destruction; 4. wetland area is proportional to wetland capacity to process landscape inputs, regardless of location in the watershed; 5. hydric soils can be used to estimate past wetland losses; and 6. recent trends in agricultural and population growth can be used to predict future wetland losses.

The method is still developmental. For example, hydrologic input does not currently include upstream imports, and therefore downstream input is underestimated. Also, we currently have no way of quantifying the overall confidence level of the approach. Future research strategies, including quantification of upstream import, validation of the above mentioned assumptions, establishment of confidence levels for the surrogates, and additional data will be incorporated as they are developed. The final product of the Wetland Research Program's cumulative impacts research will be the completion of a Cumulative Impact Assessment manual in 1991.

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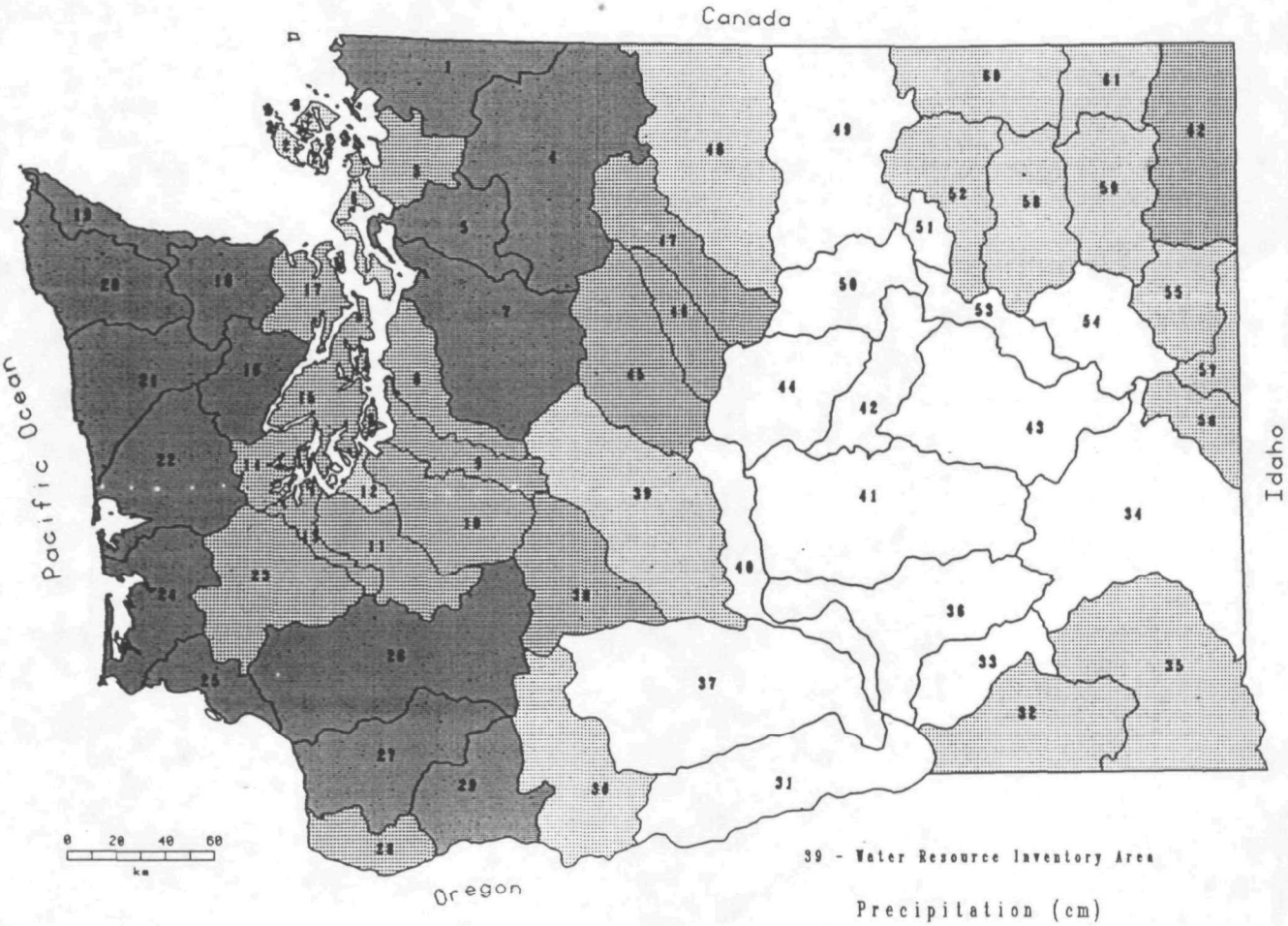
APPENDIX I. Maps of overlay components used for deriving synoptic indices.

MEAN ANNUAL PRECIPITATION



39 - Water Resource Inventory Area

Precipitation (cm)

- 25 - 40
- 40 - 90
- 90 - 175
- 175 - 360

Figure 1.1

1 - 178	2 - 74	3 - 109	4 - 268	5 - 176	6 - 43
7 - 224	8 - 136	9 - 162	10 - 174	11 - 154	12 - 83
13 - 139	14 - 169	15 - 127	16 - 294	17 - 102	18 - 205
19 - 239	20 - 294	21 - 359	22 - 275	23 - 160	24 - 231
25 - 216	26 - 193	27 - 242	28 - 172	29 - 194	30 - 88
31 - 27	32 - 42	33 - 26	34 - 30	35 - 46	36 - 25
37 - 39	38 - 133	39 - 88	40 - 30	41 - 25	42 - 25
43 - 25	44 - 25	45 - 184	46 - 104	47 - 150	48 - 88
49 - 40	50 - 25	51 - 35	52 - 42	53 - 25	54 - 29
55 - 54	56 - 52	57 - 69	58 - 53	59 - 48	60 - 55
61 - 67	62 - 93				

[Water Resource Inventory Area]

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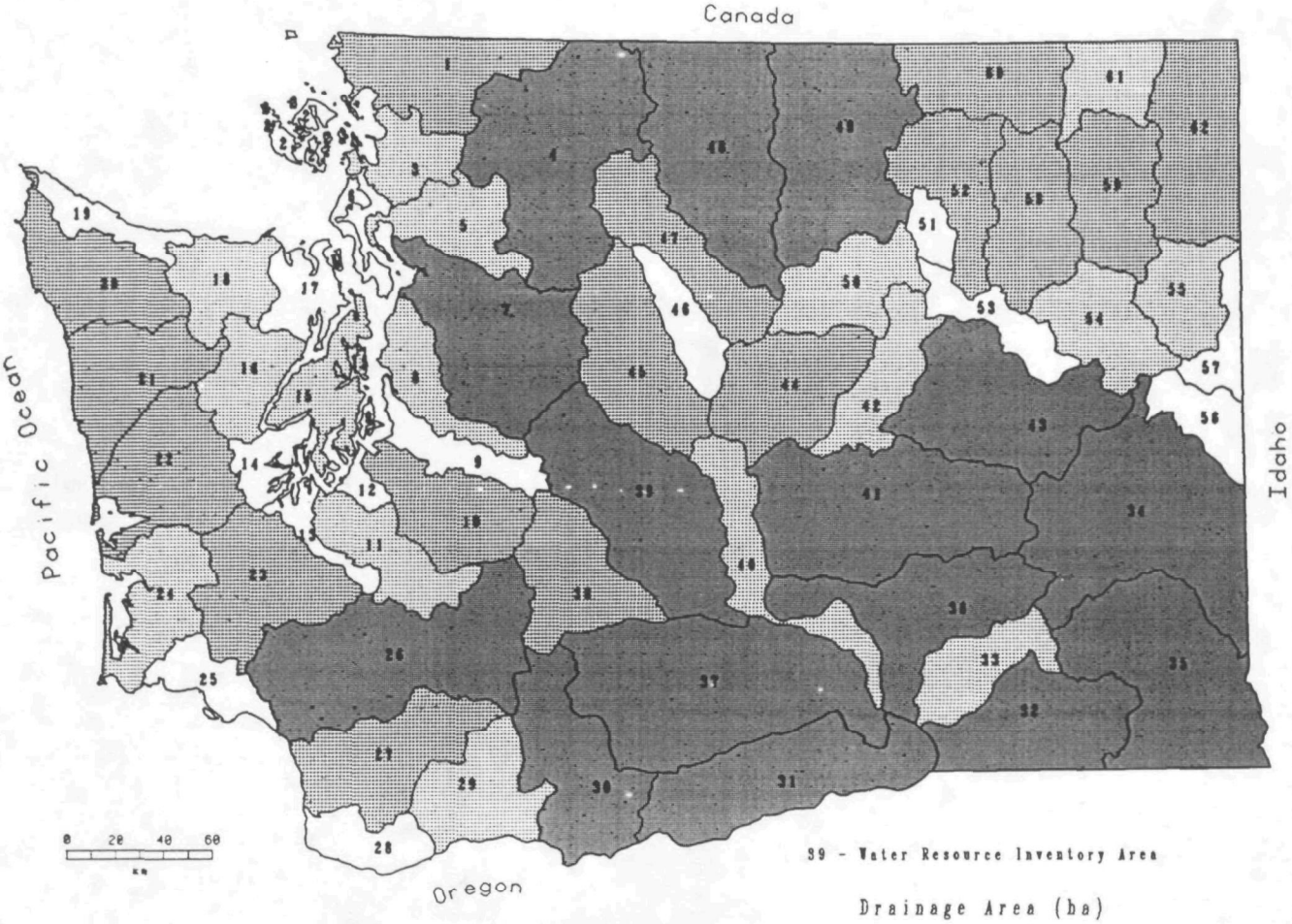
TOTAL DRAINAGE AREA



39 - Water Resource Inventory Area

Drainage Area (ha)

38160 - 142590

142590 - 251570

251570 - 357900

357900 - 749320

Figure 1.2

1 - 315624	2 - 38168	3 - 143506	4 - 639536	5 - 180072	6 - 54947
7 - 487564	8 - 162396	9 - 139845	10 - 269720	11 - 200923	12 - 41080
13 - 72966	14 - 84707	15 - 168663	16 - 158617	17 - 110072	18 - 187698
19 - 113573	20 - 298271	21 - 296472	22 - 338700	23 - 334913	24 - 246579
25 - 109430	26 - 646808	27 - 335095	28 - 113113	29 - 223376	30 - 365514
31 - 406011	32 - 360152	33 - 186109	34 - 726039	35 - 583176	36 - 425162
37 - 749313	38 - 290140	39 - 554818	40 - 224899	41 - 654525	42 - 195730
43 - 483231	44 - 307743	45 - 357154	46 - 128671	47 - 273014	48 - 546492
49 - 543196	50 - 225282	51 - 58197	52 - 256561	53 - 135523	54 - 231277
55 - 175694	56 - 119703	57 - 78577	58 - 286118	59 - 263779	60 - 258717
61 - 145079	62 - 323152				

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POTENTIAL RUNOFF (CURVE NUMBER)

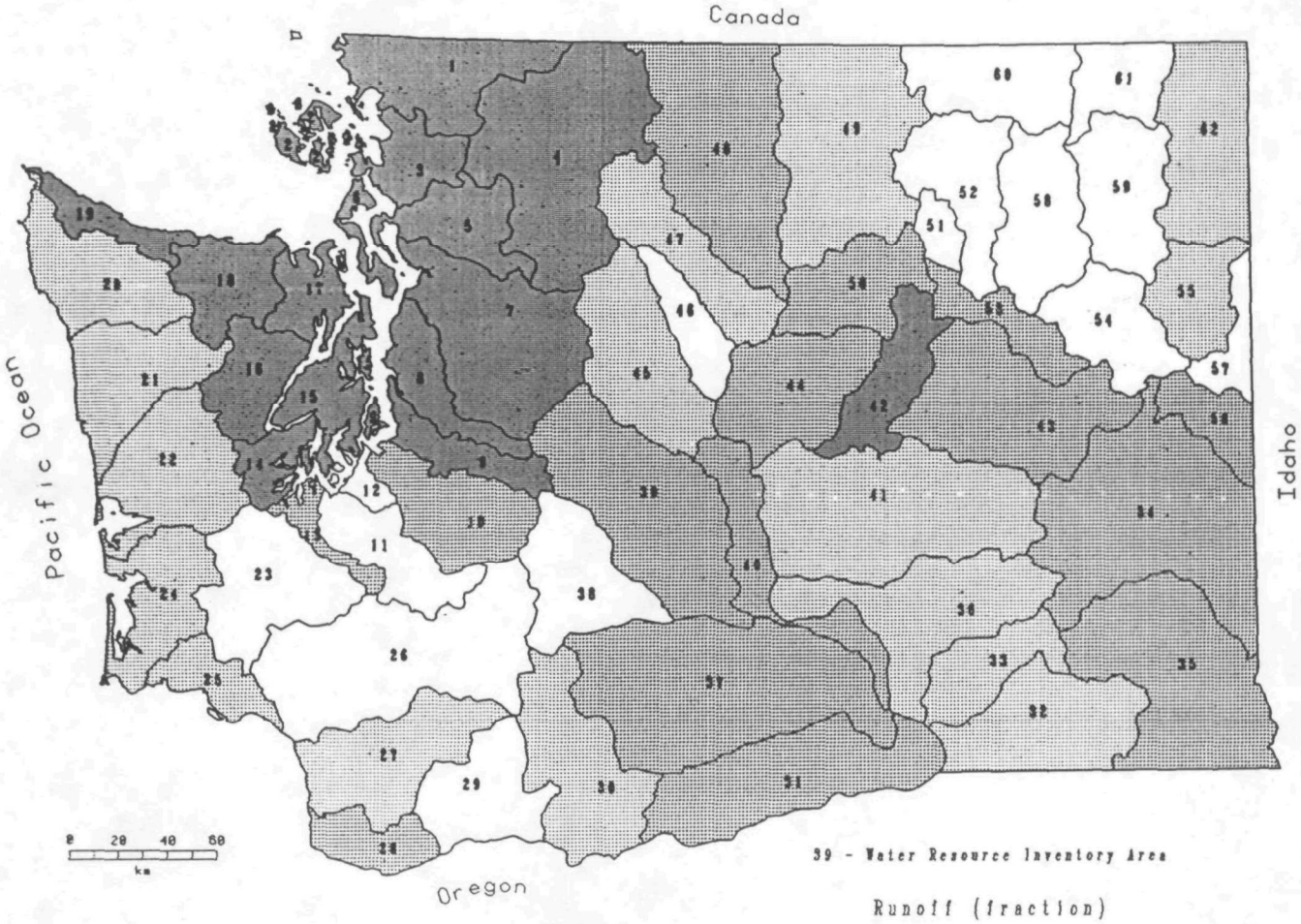

Figure 1.3

1 - 0.83	2 - 0.93	3 - 0.83	4 - 0.75	5 - 0.76	6 - 0.91
7 - 0.77	8 - 0.83	9 - 0.81	10 - 0.74	11 - 0.64	12 - 0.66
13 - 0.74	14 - 0.77	15 - 0.84	16 - 0.76	17 - 0.84	18 - 0.83
19 - 0.84	20 - 0.70	21 - 0.70	22 - 0.68	23 - 0.66	24 - 0.72
25 - 0.69	26 - 0.67	27 - 0.68	28 - 0.75	29 - 0.67	30 - 0.69
31 - 0.74	32 - 0.69	33 - 0.71	34 - 0.73	35 - 0.73	36 - 0.71
37 - 0.73	38 - 0.68	39 - 0.74	40 - 0.75	41 - 0.72	42 - 0.76
43 - 0.74	44 - 0.73	45 - 0.69	46 - 0.68	47 - 0.70	48 - 0.72
49 - 0.69	50 - 0.72	51 - 0.67	52 - 0.67	53 - 0.75	54 - 0.68
55 - 0.70	56 - 0.73	57 - 0.66	58 - 0.66	59 - 0.67	60 - 0.67
61 - 0.63	62 - 0.68				

[Water Resource Inventory Area]

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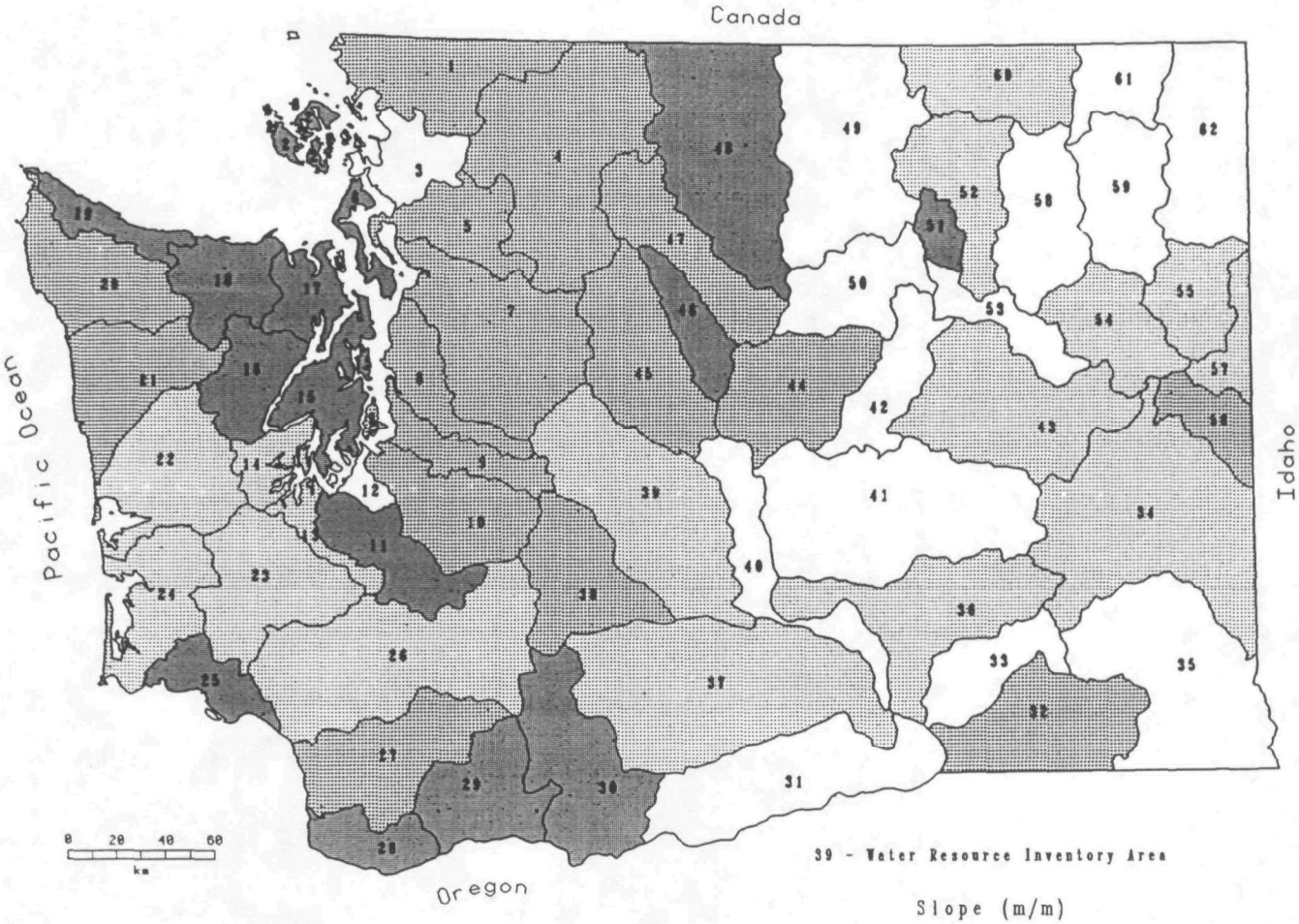
STREAM CHANNEL SLOPE



39 - Water Resource Inventory Area

Slope (m/m)

- 0.00E-3 - 1.17E-3
- 1.17E-3 - 4.46E-3
- 4.46E-3 - 7.11E-3
- 7.11E-3 - 4.81E-2

Figure 1.4

1 - 0.67E-2	2 - 0.48E-1	3 - 0.00E+0	4 - 0.54E-2	5 - 0.58E-2	6 - 0.74E-2
7 - 0.45E-2	8 - 0.69E-2	9 - 0.57E-2	10 - 0.65E-2	11 - 0.75E-2	12 - 0.00E+0
13 - 0.43E-2	14 - 0.36E-2	15 - 0.79E-2	16 - 0.12E-1	17 - 0.45E-1	18 - 0.13E-1
19 - 0.71E-2	20 - 0.63E-2	21 - 0.54E-2	22 - 0.38E-2	23 - 0.13E-2	24 - 0.28E-2
25 - 0.90E-2	26 - 0.24E-2	27 - 0.67E-2	28 - 0.11E-1	29 - 0.19E-1	30 - 0.10E-1
31 - 0.32E-3	32 - 0.58E-2	33 - 0.88E-3	34 - 0.33E-2	35 - 0.45E-3	36 - 0.33E-2
37 - 0.12E-2	38 - 0.71E-2	39 - 0.36E-2	40 - 0.00E+0	41 - 0.56E-3	42 - 0.00E+0
43 - 0.21E-2	44 - 0.52E-2	45 - 0.60E-2	46 - 0.16E-1	47 - 0.46E-2	48 - 0.84E-2
49 - 0.65E-3	50 - 0.11E-2	51 - 0.39E-1	52 - 0.44E-2	53 - 0.00E+0	54 - 0.19E-2
55 - 0.25E-2	56 - 0.46E-2	57 - 0.24E-2	58 - 0.00E+0	59 - 0.81E-3	60 - 0.19E-2
61 - 0.00E+0	62 - 0.00E+0				

[Water Resource Inventory Area]

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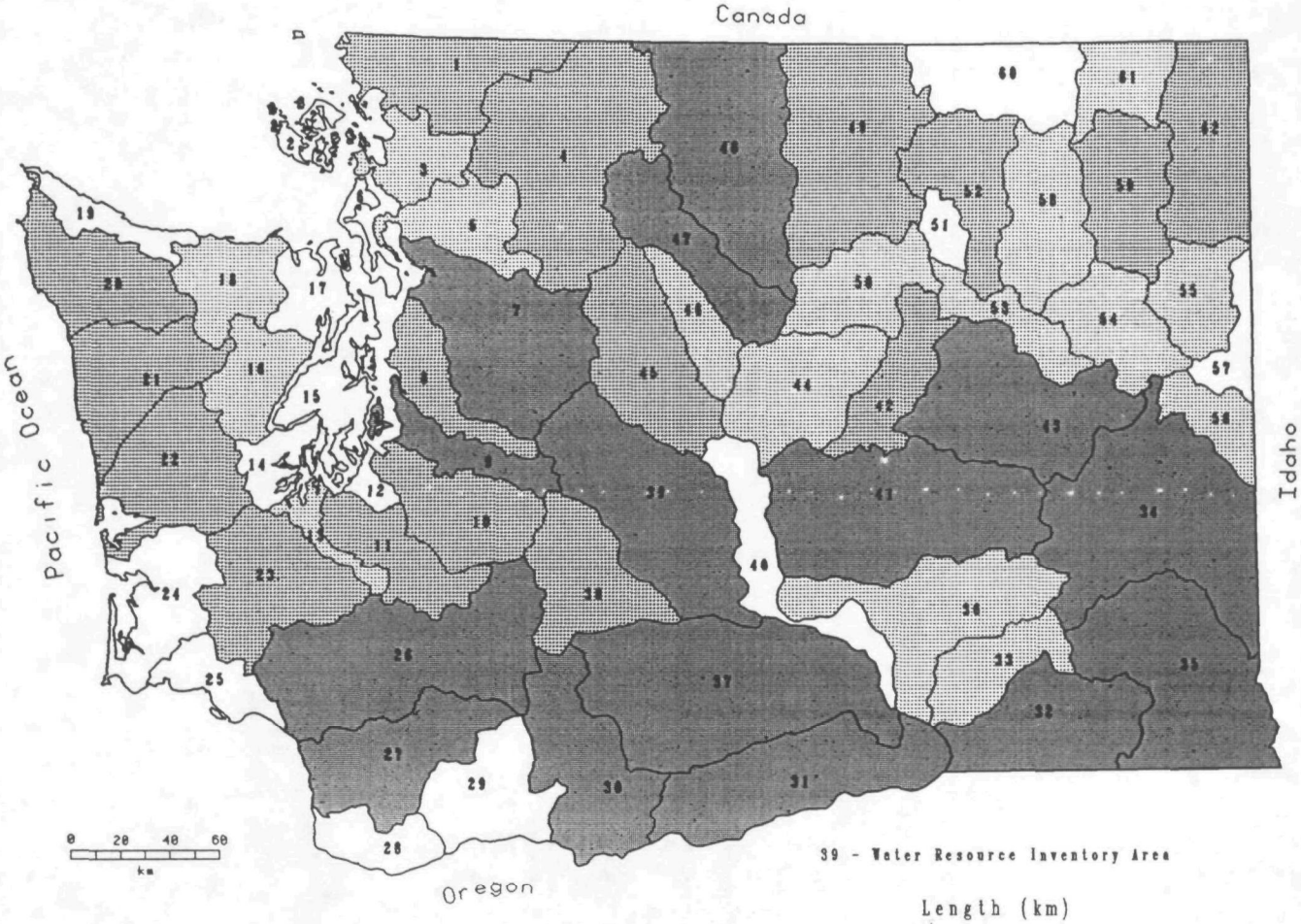
CHANNEL LENGTH



39 - Water Resource Inventory Area

Length (km)

5470 - 61950	
61950 - 99440	
99440 - 126070	
126070 - 204350	

Figure 1.5

1 - 114561	2 - 6758	3 - 65969	4 - 121319	5 - 98632	6 - 5471
7 - 144488	8 - 105872	9 - 127755	10 - 124858	11 - 108447	12 - 10298
13 - 74979	14 - 22526	15 - 30732	16 - 62107	17 - 28962	18 - 64682
19 - 34272	20 - 102976	21 - 104907	22 - 107481	23 - 123571	24 - 58568
25 - 36203	26 - 204343	27 - 132582	28 - 48270	29 - 61464	30 - 129846
31 - 189862	32 - 140305	33 - 92839	34 - 172485	35 - 181495	36 - 74914
37 - 170876	38 - 102976	39 - 150120	40 - 30410	41 - 145775	42 - 106999
43 - 156395	44 - 78358	45 - 122928	46 - 76267	47 - 132582	48 - 145454
49 - 125502	50 - 72405	51 - 35559	52 - 110538	53 - 65004	54 - 87530
55 - 65325	56 - 70313	57 - 33467	58 - 92839	59 - 100241	60 - 42478
61 - 70796	62 - 111504				

[Water Resource Inventory Area]

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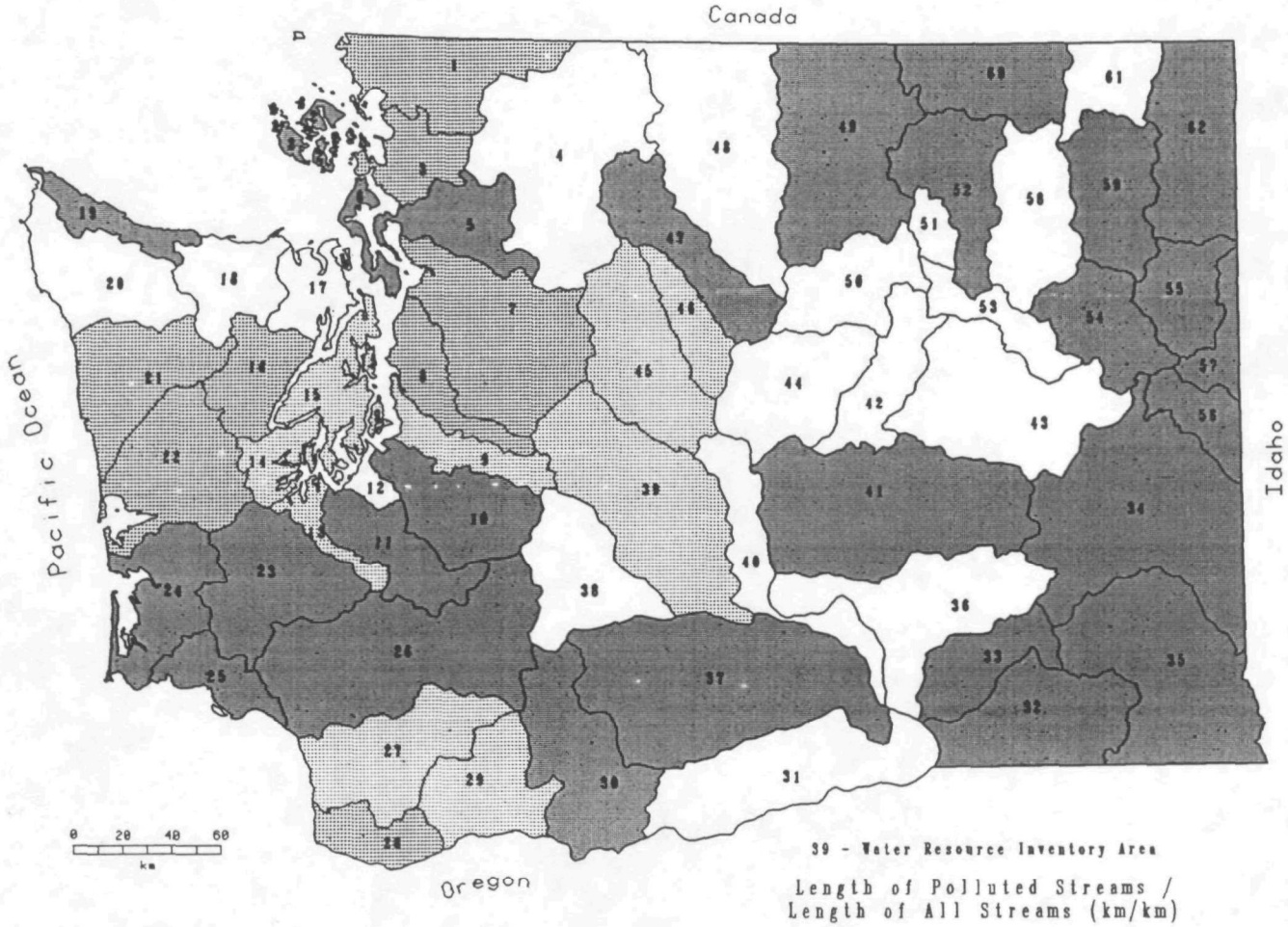
WATER QUALITY INPUT (NORMALIZED)



39 - Water Resource Inventory Area

Length of Polluted Streams / Length of All Streams (km/km)

- 0.00 - 0.00
- 0.00 - 0.65
- 0.65 - 0.99
- 0.99 - 1.00

Figure 1.6

1 - 0.72	2 - 1.00	3 - 0.67	4 - 0.00	5 - 1.00	6 - 1.00
7 - 0.66	8 - 0.85	9 - 0.62	10 - 1.00	11 - 1.00	12 - NO DATA
13 - 0.80	14 - 0.50	15 - 0.38	16 - 0.77	17 - 0.00	18 - 0.00
19 - 1.00	20 - 0.00	21 - 0.77	22 - 0.82	23 - 1.00	24 - 1.00
25 - 1.00	26 - 1.00	27 - 0.49	28 - 0.99	29 - 0.18	30 - 1.00
31 - NO DATA	32 - 1.00	33 - 1.00	34 - 1.00	35 - 1.00	36 - NO DATA
37 - 1.00	38 - 0.00	39 - 0.62	40 - NO DATA	41 - 1.00	42 - NO DATA
43 - NO DATA	44 - NO DATA	45 - 0.50	46 - 0.57	47 - 1.00	48 - 0.00
49 - 1.00	50 - NO DATA	51 - NO DATA	52 - 1.00	53 - NO DATA	54 - 1.00
55 - 1.00	56 - 1.00	57 - 1.00	58 - NO DATA	59 - 1.00	60 - 1.00
61 - NO DATA	62 - 1.00				

[Water Resource Inventory Area]

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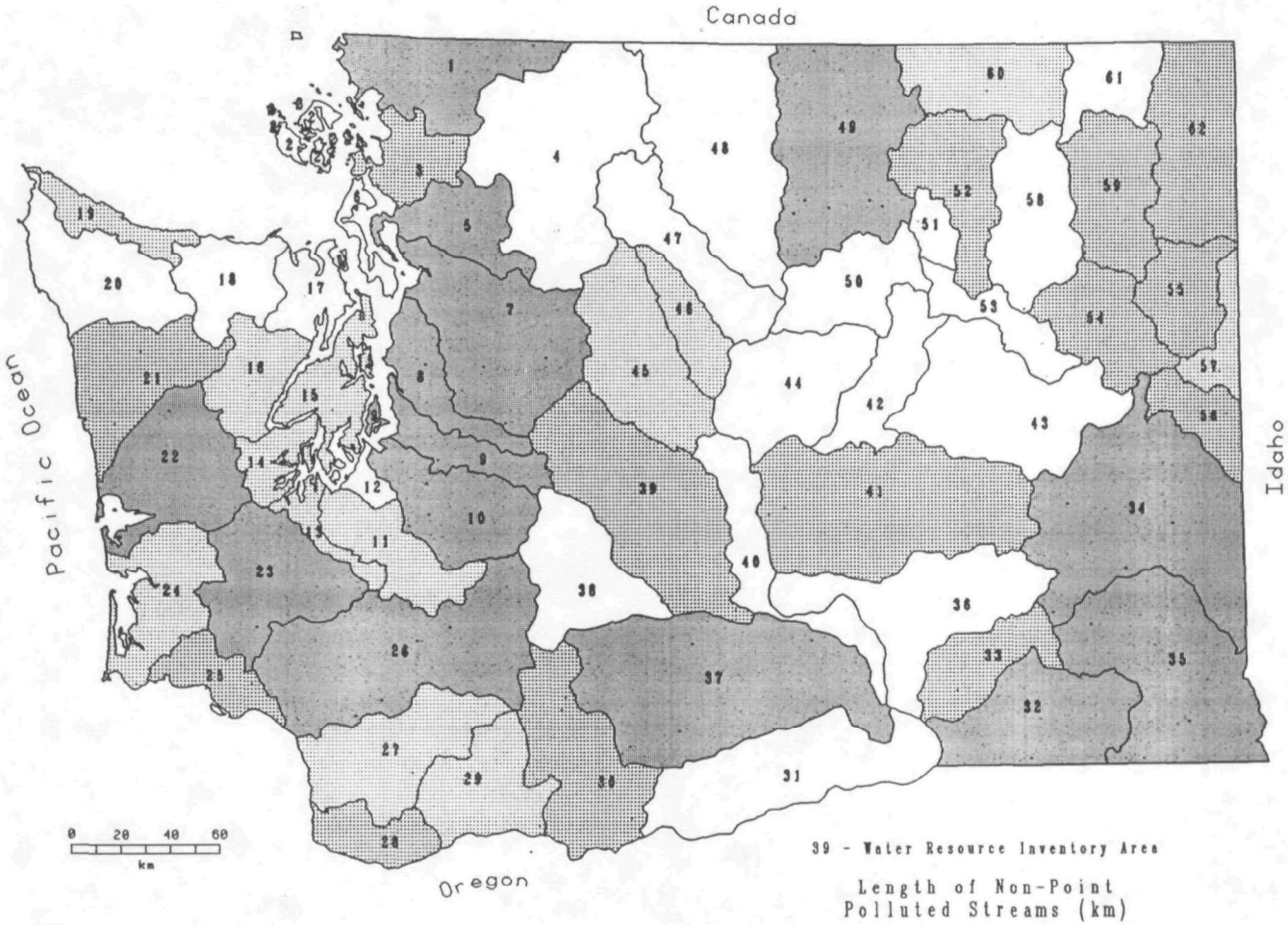
NON-POINT WATER QUALITY INPUT (NON-NORMALIZED)



39 - Water Resource Inventory Area

Length of Non-Point Polluted Streams (km)

- 0 - 0
- 0 - 73
- 73 - 120
- 120 - 470

Figure 1.7

1 - 467	2 - 0	3 - 82	4 - 0	5 - 228	6 - 0
7 - 230	8 - 235	9 - 153	10 - 227	11 - 71	12 - NO DATA
13 - 56	14 - 70	15 - 45	16 - 48	17 - 0	18 - 0
19 - 66	20 - 0	21 - 78	22 - 230	23 - 253	24 - 64
25 - 105	26 - 151	27 - 70	28 - 110	29 - 21	30 - 73
31 - NO DATA	32 - 158	33 - 113	34 - 236	35 - 171	36 - NO DATA
37 - 202	38 - 0	39 - 103	40 - NO DATA	41 - 74	42 - NO DATA
43 - NO DATA	44 - NO DATA	45 - 44	46 - 44	47 - 0	48 - 0
49 - 171	50 - NO DATA	51 - NO DATA	52 - 104	53 - NO DATA	54 - 83
55 - 78	56 - 92	57 - 39	58 - NO DATA	59 - 85	60 - 53
61 - NO DATA	62 - 115				

[Water Resource Inventory Area]

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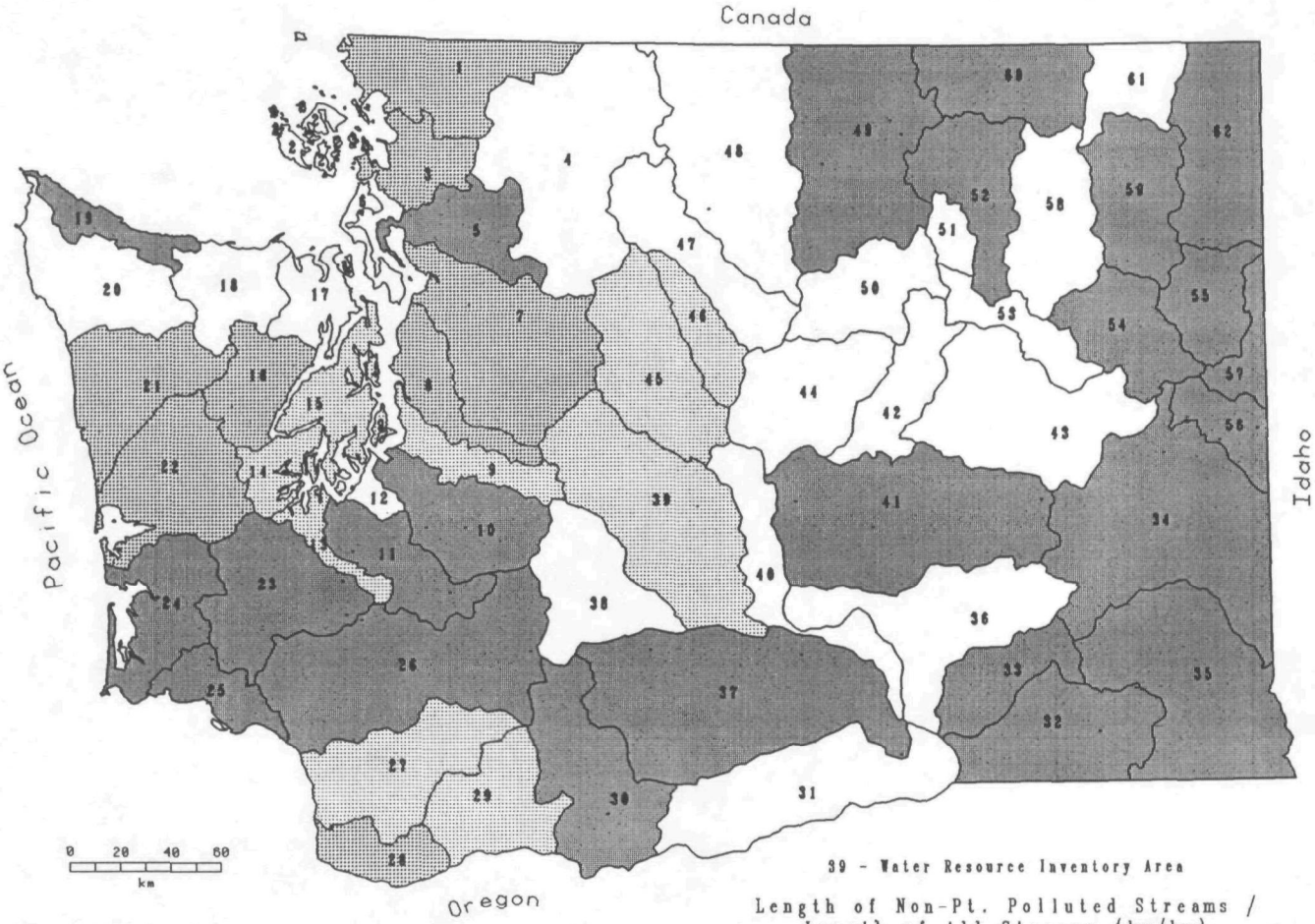
NON-POINT WATER QUALITY INPUT (NORMALIZED)



39 - Water Resource Inventory Area

Length of Non-Pt. Polluted Streams / Length of All Streams (km/km)

- 0.00 - 0.00
- 0.00 - 0.65
- 0.65 - 0.99
- 0.99 - 1.00

Figure 1.8

1 - 0.72	2 - 0.00	3 - 0.67	4 - 0.00	5 - 1.00	6 - 0.00
7 - 0.66	8 - 0.85	9 - 0.62	10 - 1.00	11 - 1.00	12 - NO DATA
13 - 0.60	14 - 0.50	15 - 0.38	16 - 0.77	17 - 0.00	18 - 0.00
19 - 1.00	20 - 0.00	21 - 0.77	22 - 0.82	23 - 1.00	24 - 1.00
25 - 1.00	26 - 1.00	27 - 0.49	28 - 0.99	29 - 0.18	30 - 1.00
31 - NO DATA	32 - 1.00	33 - 1.00	34 - 1.00	35 - 1.00	36 - NO DATA
37 - 1.00	38 - 0.00	39 - 0.62	40 - NO DATA	41 - 1.00	42 - NO DATA
43 - NO DATA	44 - NO DATA	45 - 0.50	46 - 0.57	47 - 0.00	48 - 0.00
49 - 1.00	50 - NO DATA	51 - NO DATA	52 - 1.00	53 - NO DATA	54 - 1.00
55 - 1.00	56 - 1.00	57 - 1.00	58 - NO DATA	59 - 1.00	60 - 1.00
61 - NO DATA	62 - 1.00				

[Water Resource Inventory Area]

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CUMULATIVE IMPACTS (NORMALIZED)

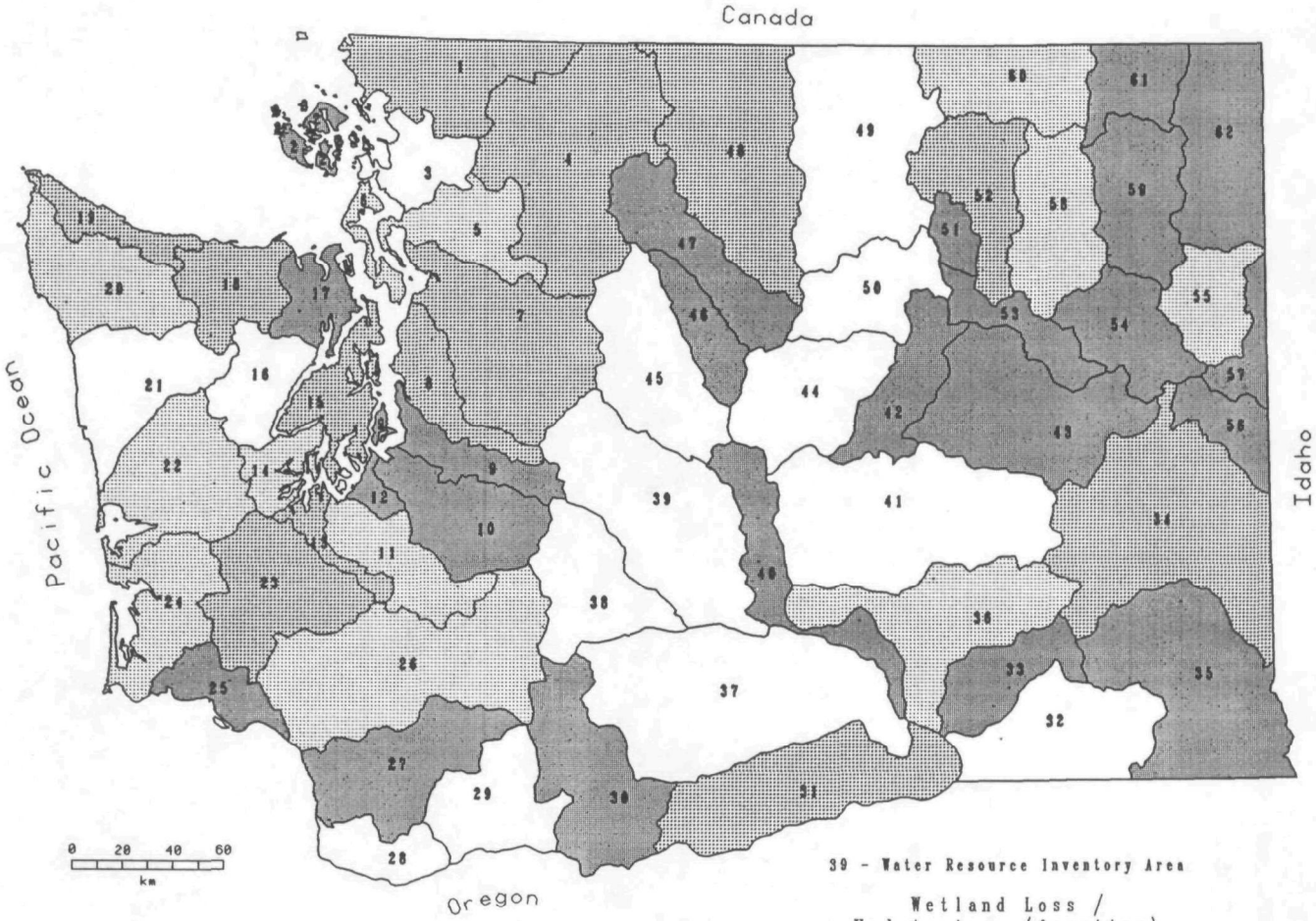

Figure 1.9

1 - 0.9	2 - 1.0	3 - 0.4	4 - 1.0	5 - 0.8	6 - 0.7
7 - 0.9	8 - 0.9	9 - 1.0	10 - 1.0	11 - 0.9	12 - 1.0
13 - 0.9	14 - 0.7	15 - 1.0	16 - 0.4	17 - 1.0	18 - 1.0
19 - 1.0	20 - 0.8	21 - 0.6	22 - 0.7	23 - 0.9	24 - 0.7
25 - 1.0	26 - 0.8	27 - 1.0	28 - -0.5	29 - 0.6	30 - 1.0
31 - 0.9	32 - 0.6	33 - 1.0	34 - 0.9	35 - 1.0	36 - 0.8
37 - 0.3	38 - 0.4	39 - -0.6	40 - 1.0	41 - 0.1	42 - 1.0
43 - 1.0	44 - -0.7	45 - -1.0	46 - 1.0	47 - 1.0	48 - 0.9
49 - 0.5	50 - 0.0	51 - 1.0	52 - 0.9	53 - 1.0	54 - 1.0
55 - 0.8	56 - 1.0	57 - 1.0	58 - 0.8	59 - 1.0	60 - 0.7
61 - 1.0	62 - 1.0				

[Water Resource Inventory Area]

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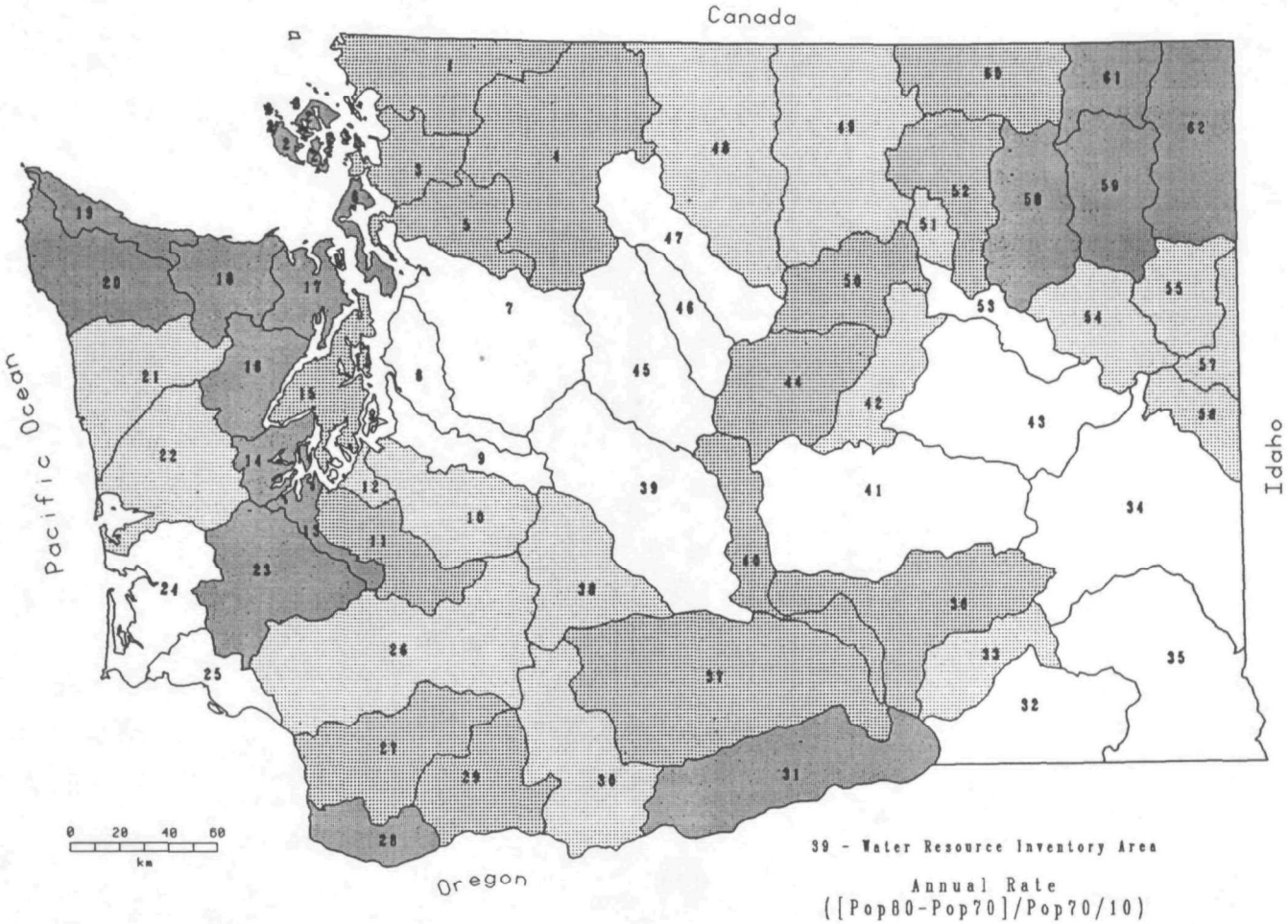
HUMAN POPULATION GROWTH (1970-1980)



39 - Water Resource Inventory Area

Annual Rate
([Pop80-Pop70]/Pop70/10)

- 8.54E-3 - 1.48E-2
- 1.48E-2 - 2.30E-2
- 2.30E-2 - 4.40E-2
- 4.40E-2 - 1.03E-1

Figure I.10

1 - 0.30E-1	2 - 0.10E+0	3 - 0.23E-1	4 - 0.27E-1	5 - 0.29E-1	6 - 0.63E-1
7 - 0.13E-1	8 - 0.10E-1	9 - 0.98E-2	10 - 0.17E-1	11 - 0.25E-1	12 - 0.18E-1
13 - 0.61E-1	14 - 0.54E-1	15 - 0.40E-1	16 - 0.48E-1	17 - 0.49E-1	18 - 0.49E-1
19 - 0.49E-1	20 - 0.49E-1	21 - 0.21E-1	22 - 0.15E-1	23 - 0.44E-1	24 - 0.99E-2
25 - 0.12E-1	26 - 0.19E-1	27 - 0.41E-1	28 - 0.50E-1	29 - 0.32E-1	30 - 0.21E-1
31 - 0.54E-1	32 - 0.11E-1	33 - 0.23E-1	34 - 0.14E-1	35 - 0.11E-1	36 - 0.31E-1
37 - 0.30E-1	38 - 0.16E-1	39 - 0.85E-2	40 - 0.36E-1	41 - 0.15E-1	42 - 0.16E-1
43 - 0.10E-1	44 - 0.28E-1	45 - 0.12E-1	46 - 0.90E-2	47 - 0.13E-1	48 - 0.20E-1
49 - 0.19E-1	50 - 0.29E-1	51 - 0.19E-1	52 - 0.32E-1	53 - 0.97E-2	54 - 0.21E-1
55 - 0.20E-1	56 - 0.19E-1	57 - 0.19E-1	58 - 0.63E-1	59 - 0.66E-1	60 - 0.40E-1
61 - 0.66E-1	62 - 0.45E-1				

[Water Resource Inventory Area]

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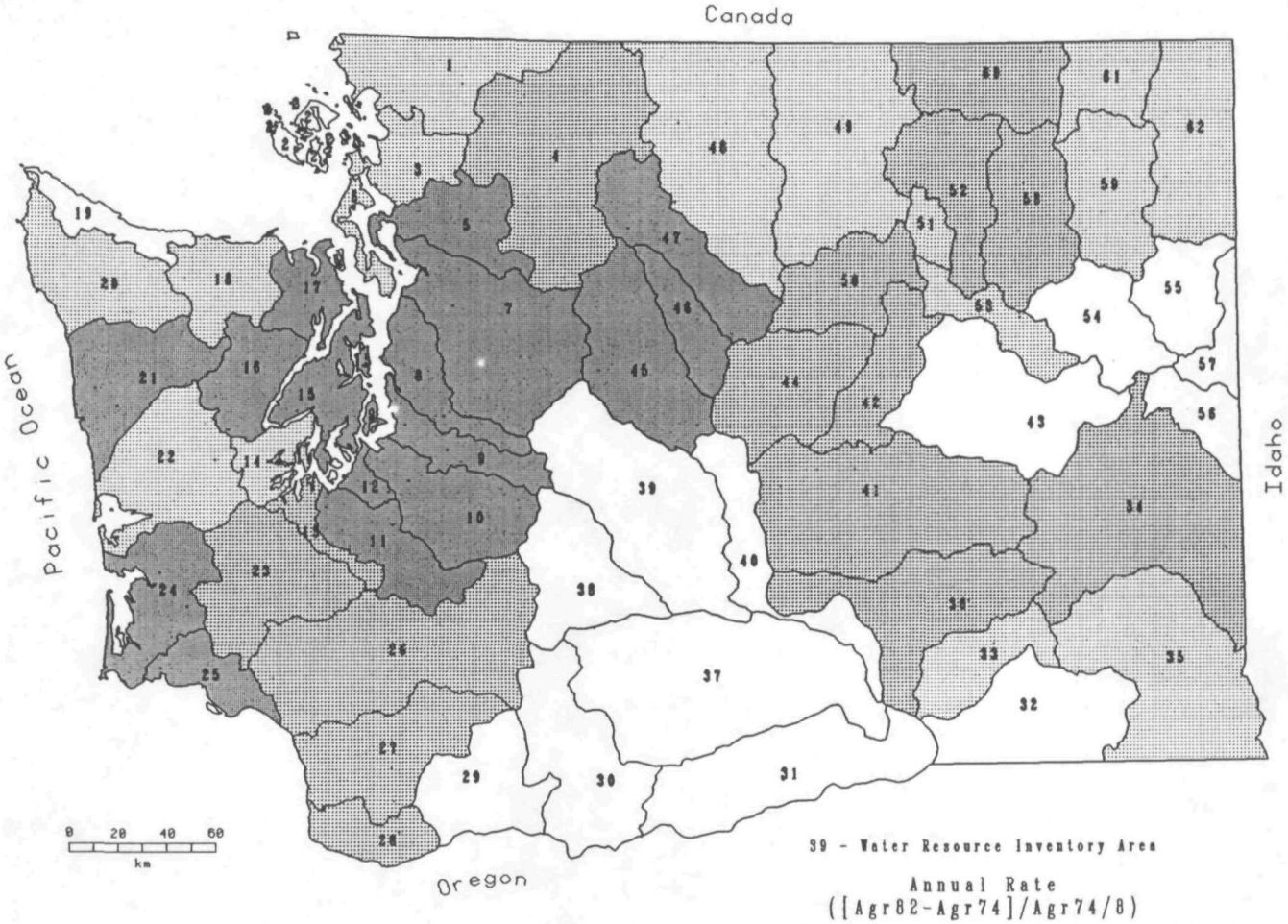
AGRICULTURAL GROWTH (1974-1982)



39 - Water Resource Inventory Area

Annual Rate
([Agr82-Agr74]/Agr74/8)

-1.33E-2 - -4.08E-3	
-4.08E-3 - 1.01E-3	
1.01E-3 - 4.72E-3	
4.72E-3 - 5.36E-2	

Figure 1.11

1 - -0.40E-2	2 - -0.13E-1	3 - 0.54E-3	4 - 0.23E-2	5 - 0.13E-1	6 - 0.95E-3
7 - 0.22E-1	8 - 0.21E-1	9 - 0.20E-1	10 - 0.14E-1	11 - 0.63E-2	12 - 0.14E-1
13 - 0.41E-2	14 - 0.89E-3	15 - 0.34E-1	16 - 0.54E-2	17 - 0.12E-1	18 - -0.35E-2
19 - -0.81E-2	20 - -0.20E-2	21 - 0.81E-2	22 - -0.11E-2	23 - 0.16E-2	24 - 0.13E-1
25 - 0.48E-2	26 - 0.11E-2	27 - 0.41E-2	28 - 0.27E-2	29 - -0.88E-2	30 - -0.73E-2
31 - -0.84E-2	32 - -0.50E-2	33 - -0.53E-3	34 - 0.13E-2	35 - 0.41E-3	36 - 0.38E-2
37 - -0.47E-2	38 - -0.42E-2	39 - -0.13E-1	40 - -0.96E-2	41 - 0.22E-2	42 - 0.31E-2
43 - -0.48E-2	44 - 0.23E-2	45 - 0.36E-1	46 - 0.54E-1	47 - 0.43E-1	48 - -0.28E-3
49 - -0.65E-3	50 - 0.16E-2	51 - -0.32E-3	52 - 0.22E-2	53 - -0.40E-2	54 - -0.64E-2
55 - -0.95E-2	56 - -0.93E-2	57 - -0.11E-1	58 - 0.25E-2	59 - -0.31E-2	60 - 0.24E-2
61 - -0.29E-2	62 - -0.34E-2				

[Water Resource Inventory Area]

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FUTURE RISK

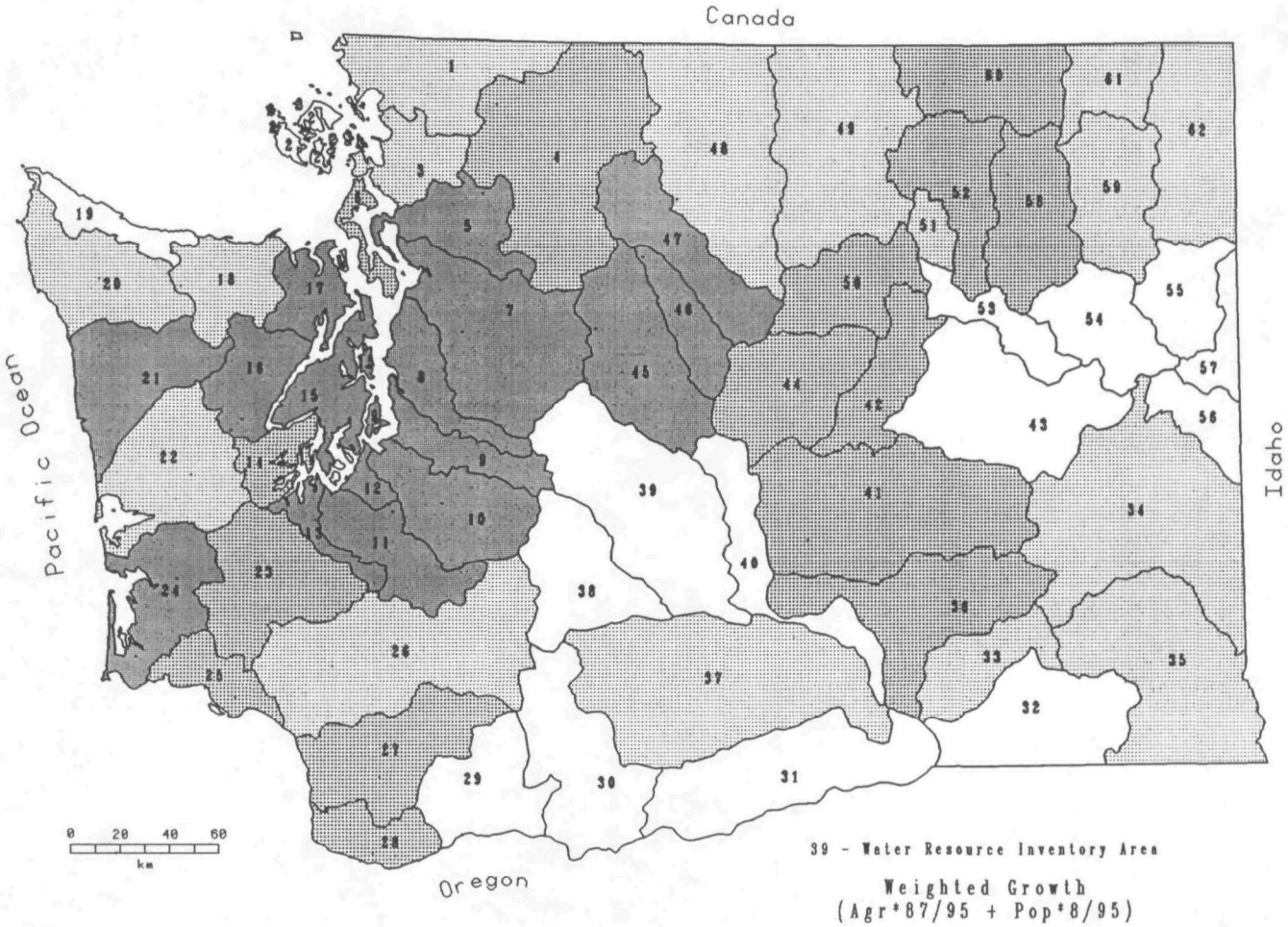


Figure 1.12

1 - -0.12E-2	2 - -0.35E-2	3 - 0.25E-2	4 - 0.44E-2	5 - 0.14E-1	6 - 0.62E-2
7 - 0.21E-1	8 - 0.20E-1	9 - 0.19E-1	10 - 0.14E-1	11 - 0.79E-2	12 - 0.14E-1
13 - 0.89E-2	14 - 0.53E-2	15 - 0.34E-1	16 - 0.89E-2	17 - 0.16E-1	18 - 0.90E-3
19 - -0.33E-2	20 - 0.23E-2	21 - 0.91E-2	22 - 0.22E-3	23 - 0.52E-2	24 - 0.13E-1
25 - 0.54E-2	26 - 0.26E-2	27 - 0.72E-2	28 - 0.66E-2	29 - -0.54E-2	30 - -0.49E-2
31 - -0.31E-2	32 - -0.36E-2	33 - 0.14E-2	34 - 0.24E-2	35 - 0.13E-2	36 - 0.62E-2
37 - -0.18E-2	38 - -0.23E-2	39 - -0.11E-1	40 - -0.58E-2	41 - 0.32E-2	42 - 0.43E-2
43 - -0.35E-2	44 - 0.44E-2	45 - 0.34E-1	46 - 0.50E-1	47 - 0.40E-1	48 - 0.14E-2
49 - 0.97E-3	50 - 0.39E-2	51 - 0.13E-2	52 - 0.48E-2	53 - -0.28E-2	54 - -0.40E-2
55 - -0.70E-2	56 - -0.69E-2	57 - -0.84E-2	58 - 0.76E-2	59 - 0.27E-2	60 - 0.56E-2
61 - 0.30E-2	62 - 0.69E-3				

[Water Resource Inventory Area]

Prepared by USEPA Wetlands Research Program, USEPA Environmental Research Lab, Corvallis, Oregon

APPENDIX II. **Human population[1] (1970 and 1980), agricultural acreage[2] (1974 and 1982), and (RTE) by county.**

County	Population		Agricultural Acreage	
	1970	1980	1974	1982
Adams	12014	13267	1147185	1155524
Asotin	13799	16823	277692	287052
Benton	67540	109444	720930	676837
Chelan	41355	45061	94214	134619
Clallam	34770	51648	30300	28342
Clark	128454	192227	99587	101660
Columbia	4439	4057	317312	338643
Cowlitz	68616	79548	38020	40809
Douglas	16787	22144	955630	970528
Ferry	3655	5811	778280	800517
Franklin	25816	35025	600959	632519
Garfield	2911	2468	361184	337134
Grant	41881	48522	1081599	1113170
Grays Harbor	59553	66314	49581	49141
Island	27011	44048	20701	20853
Jefferson	10661	15965	12563	15525
King	1156633	1269749	51368	59813
Kitsap	101732	147152	7788	10974
Kittitas	25039	24877	457051	393516
Klickitat	12138	15822	786736	725048
Lewis	45467	56025	137078	135531
Lincoln	9572	9604	1469010	1404250
Mason	20918	31184	15441	15232
Okanogan	25867	30639	1340031	1332990
Pacific	15796	17237	34178	38515
Pend Oreille	6025	8580	65845	63998
Pierce	411027	485643	62079	68936
San Juan	3856	7838	21113	18862
Skagit	52381	64138	108972	109834
Skamania	5845	7919	8330	8940
Snohomish	265236	337720	78170	92820
Spokane	287487	341835	687162	626780
Stevens	17405	28979	593099	578060
Thurston	76894	124264	65211	67628
Wahkiakum	3592	3832	15748	15915
Walla Walla	42176	47435	805948	755240
Whatcom	81950	106701	132921	128371

County	Population		Agricultural Acreage	
	1970	1980	1974	1982
Whitman	37900	40103	1365589	1400743
Yakima	144971	172508	1767297	1714809

Data Sources:

[1]U.S. Bureau of the Census 1972, 1982b.
[2]U.S. Bureau of the Census 1974, 1982a.

APPENDIX III. Hydrologic unit composition of counties. Total area is given for each county, along with the partial area for each component hydrologic unit (a hydrologic unit need not be entirely contained within one county, but may cross several). The percent is the proportion of total county area found in that hydrologic unit.

County/Unit	Area	Percent
Adams	4997.0	100.00
34	1514.8	30.32
36	1189.3	23.80
41	2132.5	42.68
43	160.3	3.21
Asotin	1644.3	100.00
35	1644.3	100.00
Benton	4583.6	100.00
31	2134.7	46.57
32	7.4	0.16
33	4.9	0.11
36	114.9	2.51
37	1667.7	36.38
40	653.9	14.27
Chelan	7814.4	100.00
4	19.0	0.24
39	0.6	0.01
40	276.1	3.53
44	209.2	2.68
45	3198.6	40.93
46	1271.2	16.27
47	2483.3	31.78
48	313.3	4.01
50	43.0	0.55
Clallam	4550.3	100.00
17	289.5	6.36
18	1372.3	30.16
19	979.8	21.53
20	1908.7	41.95

APPENDIX III. Continued.

County/Unit	Area	Percent
Clark	1706.2	100.00
27	851.5	49.91
28	854.6	50.09
Columbia	2236.4	100.00
32	948.8	42.43
33	47.8	2.14
34	1.5	0.07
35	1238.3	55.37
Cowlitz	2964.1	100.00
23	13.0	0.44
25	231.8	7.82
26	1757.1	59.28
27	962.2	32.46
Douglas	4763.7	100.00
41	33.9	0.71
42	317.1	6.66
44	2704.4	56.77
47	14.2	0.30
49	11.7	0.25
50	1623.8	34.09
51	5.5	0.12
53	53.0	1.11
Ferry	5898.1	100.00
51	29.5	0.50
52	1559.2	26.44
53	205.9	3.49
54	6.2	0.11
58	2248.7	38.13
59	13.9	0.24
60	1785.7	30.28
61	48.9	0.83

APPENDIX III. Continued.

County/Unit	Area	Percent
Franklin	3313.7	100.00
33	1015.6	30.65
34	97.6	2.95
36	2200.5	66.41
Garfield	1817.0	100.00
35	1817.0	100.00
Grant	7207.4	100.00
36	622.9	8.64
40	16.1	0.22
41	4235.5	58.77
42	1586.1	22.01
43	495.1	6.87
44	222.8	3.09
50	0.1	0.00
53	29.0	0.40
Grays Harbor	4946.5	100.00
14	6.1	0.12
16	37.2	0.75
21	1062.7	21.48
22	2867.8	57.98
23	461.0	9.32
24	511.7	10.35
Island	519.4	100.00
5	90.0	17.33
6	429.4	82.67
Jefferson	4631.9	100.00
16	688.0	14.85
17	857.2	18.51
18	468.8	10.12
20	905.6	19.55
21	1706.7	36.85
22	5.6	0.12

APPENDIX III. Continued.

County/Unit	Area	Percent
King	5670.5	100.00
7	2503.7	44.15
8	1335.7	23.56
9	1379.2	24.32
10	227.1	4.00
38	11.5	0.20
39	148.6	2.62
45	64.8	1.14
Kitsap	996.5	100.00
15	996.5	100.00
Kittitas	6034.6	100.00
7	0.2	0.00
9	1.4	0.02
36	12.5	0.21
38	208.9	3.46
39	4442.7	73.62
40	1077.2	17.85
41	133.5	2.21
44	2.5	0.04
45	155.8	2.58
Klickitat	5001.3	100.00
29	635.1	12.70
30	2162.3	43.24
31	1994.8	39.89
37	209.1	4.18
Lewis	6407.6	100.00
11	520.6	8.13
13	82.3	1.29
23	1851.2	28.89
24	0.2	0.00
25	23.8	0.37
26	3816.3	59.56
30	33.4	0.52
38	79.8	1.24

APPENDIX III. Continued.

County/Unit	Area	Percent
Lincoln	6050.5	100.00
34	286.4	4.73
41	70.8	1.17
42	33.6	0.56
43	4069.1	67.25
53	920.6	15.22
54	669.9	11.07
Mason	2474.3	100.00
14	796.3	32.18
15	281.6	11.38
16	961.8	38.87
21	14.8	0.60
22	419.7	16.96
Okanogan	13675.6	100.00
4	3.0	0.02
47	19.1	0.14
48	5121.7	37.45
49	5528.1	40.42
50	625.8	4.58
51	543.0	3.97
52	973.5	7.12
53	137.0	1.00
60	724.4	5.30
Pacific	2412.6	100.00
22	1.4	0.06
23	273.3	11.33
24	1855.5	76.91
25	282.5	11.71
Pend Oreille	3720.0	100.00
55	355.1	9.55
57	65.3	1.76
59	2.6	0.07
61	25.9	0.70
62	3271.2	87.93

APPENDIX III. Continued.

County/Unit	Area	Percent
Pierce	4299.8	100.00
9	4.4	0.10
10	2450.6	56.99
11	1049.3	24.40
12	337.1	7.84
15	250.0	5.81
26	136.0	3.16
38	72.4	1.68
San Juan	431.1	100.00
2	431.1	100.00
Skagit	4587.2	100.00
1	132.5	2.89
3	1305.4	28.46
4	2441.4	53.22
5	540.0	11.77
47	109.7	2.39
48	58.3	1.27
Skamania	4369.8	100.00
26	700.0	16.02
27	1488.7	34.07
28	398.0	9.11
29	1781.2	40.76
30	1.8	0.04
Snohomish	5412.2	100.00
3	1.1	0.02
4	1457.0	26.92
5	1247.4	23.05
6	1.5	0.03
7	2313.8	42.75
8	210.5	3.89
45	130.1	2.40
47	50.8	0.94

APPENDIX III. Continued.

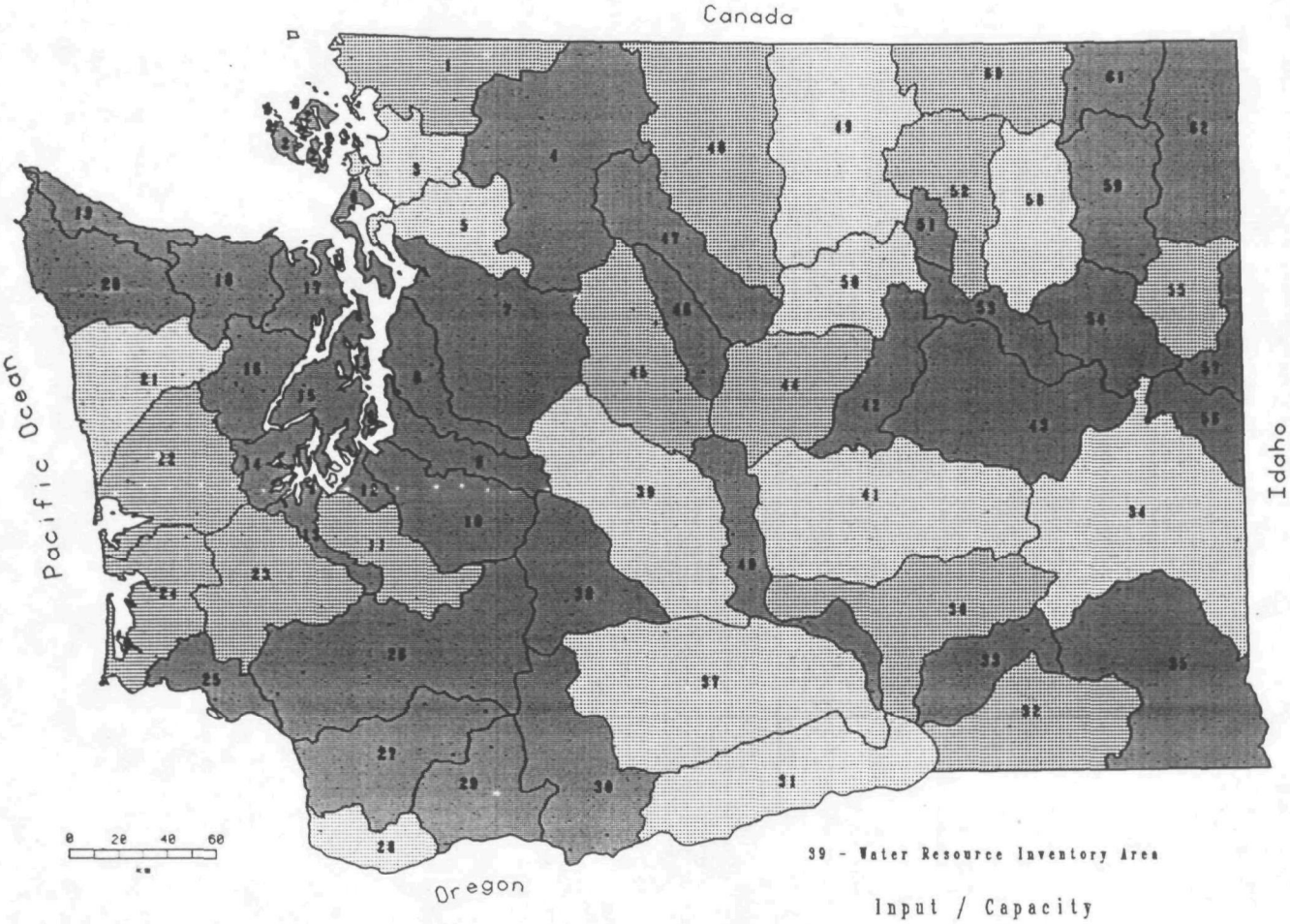
County/Unit	Area	Percent
Spokane	4627.1	100.00
34	880.8	19.04
43	89.0	1.92
54	630.0	13.61
55	1072.7	23.18
56	1129.9	24.42
57	824.7	17.82
Stevens	6548.4	100.00
54	991.6	15.14
55	353.7	5.40
58	619.6	9.46
59	2696.5	41.18
60	137.6	2.10
61	1482.4	22.64
62	267.0	4.08
Thurston	1882.6	100.00
11	470.4	24.99
13	566.7	30.10
14	100.1	5.31
23	745.4	39.59
Wahkiakum	637.8	100.00
23	2.0	0.31
25	635.8	99.69
Walla Walla	3340.7	100.00
31	2.4	0.07
32	2561.8	76.69
33	769.6	23.04
34	4.8	0.15
35	2.0	0.06

APPENDIX III. Continued.

County/Unit	Area	Percent
Whatcom	5590.1	100.00
1	2870.3	51.35
3	94.8	1.70
4	2455.6	43.93
48	169.4	3.03
Whitman	5666.5	100.00
34	4542.4	80.16
35	1030.9	18.19
56	93.2	1.64
Yakima	11104.7	100.00
26	18.8	0.17
29	46.2	0.42
30	1501.8	13.52
31	266.5	2.40
36	37.5	0.34
37	5630.2	50.70
38	2439.7	21.97
39	965.9	8.70
40	198.1	1.78

APPENDIX IV. Derived index maps.

HYDROLOGIC SENSITIVITY



Input / Capacity

- 0.00 - 0.00
- 0.00 - 0.12
- 0.12 - 0.23
- 0.23 - 2.35

Figure IV.1

1 - 0.18	2 - UNDEFINED	3 - 0.03	4 - 2.04	5 - 0.12	6 - 0.33
7 - 0.24	8 - 0.25	9 - UNDEFINED	10 - UNDEFINED	11 - 0.13	12 - UNDEFINED
13 - 0.24	14 - 0.46	15 - 1.31	16 - 0.41	17 - UNDEFINED	18 - 1.43
19 - 2.34	20 - 0.31	21 - 0.11	22 - 0.13	23 - 0.18	24 - 0.20
25 - UNDEFINED	26 - 0.26	27 - UNDEFINED	28 - 0.12	29 - 0.96	30 - UNDEFINED
31 - 0.09	32 - 0.15	33 - UNDEFINED	34 - 0.09	35 - UNDEFINED	36 - 0.20
37 - 0.01	38 - 0.48	39 - 0.09	40 - UNDEFINED	41 - 0.01	42 - UNDEFINED
43 - UNDEFINED	44 - 0.13	45 - 0.16	46 - UNDEFINED	47 - UNDEFINED	48 - 0.16
49 - 0.02	50 - 0.11	51 - UNDEFINED	52 - 0.12	53 - UNDEFINED	54 - UNDEFINED
55 - 0.20	56 - UNDEFINED	57 - UNDEFINED	58 - 0.09	59 - UNDEFINED	60 - 0.21
61 - UNDEFINED	62 - UNDEFINED				

[Water Resource Inventory Area]

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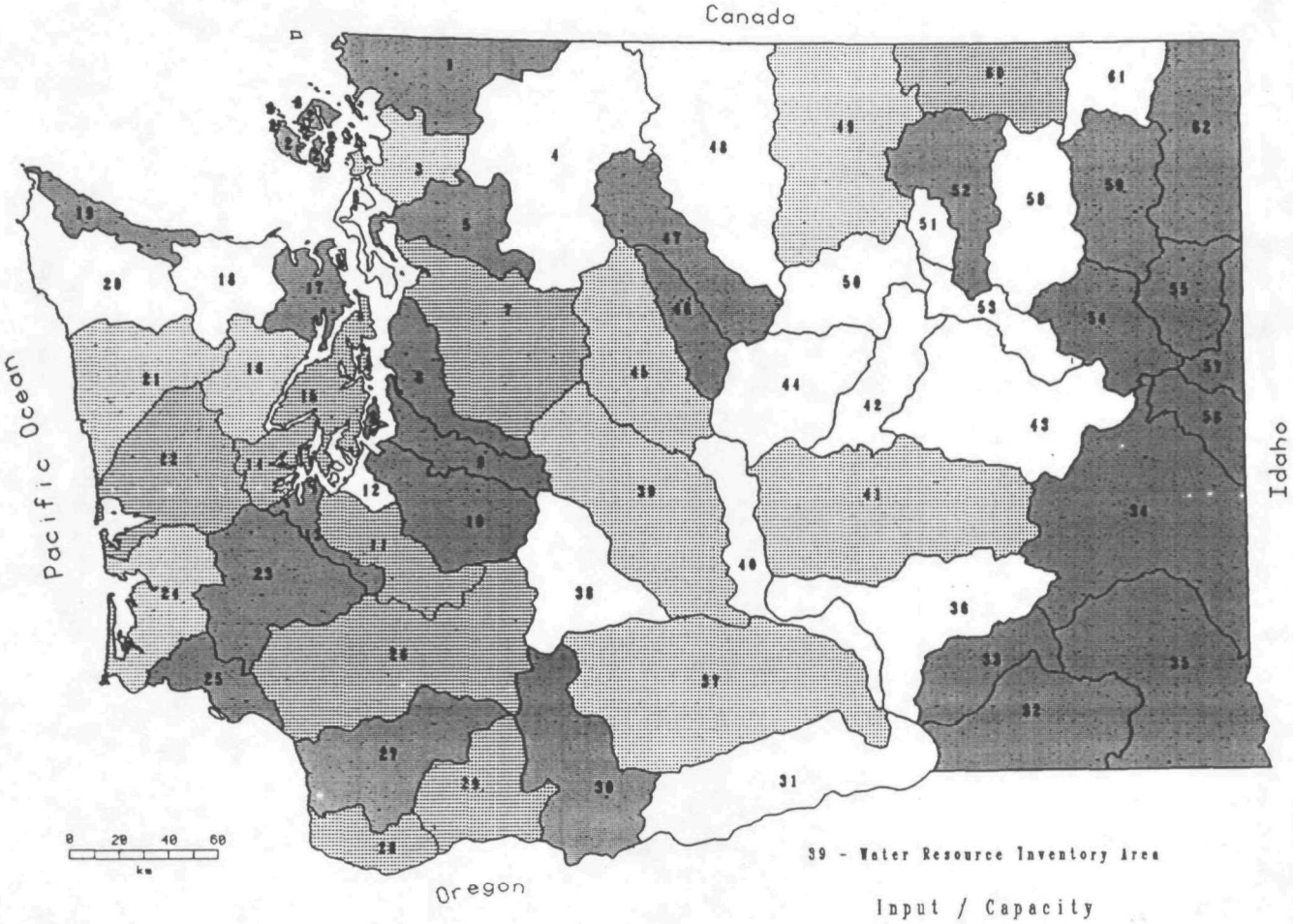
WATER QUALITY SENSITIVITY (NON-NORMALIZED)



39 - Water Resource Inventory Area

Input / Capacity

- 0.00 - 0.00
- 0.00 - 0.04
- 0.04 - 0.11
- 0.11 - 0.34

Figure IV.2

1 - 0.20	2 - UNDEFINED	3 - 0.01	4 - 0.00	5 - 0.11	6 - 0.06
7 - 0.09	8 - 0.34	9 - UNDEFINED	10 - UNDEFINED	11 - 0.05	12 - NO DATA
13 - 0.13	14 - 0.07	15 - 0.10	16 - 0.03	17 - UNDEFINED	18 - 0.06
19 - 0.23	20 - 0.00	21 - 0.01	22 - 0.05	23 - 0.16	24 - 0.02
25 - UNDEFINED	26 - 0.10	27 - UNDEFINED	28 - 0.04	29 - 0.04	30 - UNDEFINED
31 - NO DATA	32 - 0.32	33 - UNDEFINED	34 - 0.22	35 - UNDEFINED	36 - NO DATA
37 - 0.02	38 - 0.00	39 - 0.04	40 - NO DATA	41 - 0.01	42 - NO DATA
43 - NO DATA	44 - NO DATA	45 - 0.02	46 - UNDEFINED	47 - UNDEFINED	48 - 0.06
49 - 0.04	50 - NO DATA	51 - NO DATA	52 - 0.19	53 - NO DATA	54 - UNDEFINED
55 - 0.15	56 - UNDEFINED	57 - UNDEFINED	58 - NO DATA	59 - UNDEFINED	60 - 0.05
61 - NO DATA	62 - UNDEFINED				

[Water Resource Inventory Area]

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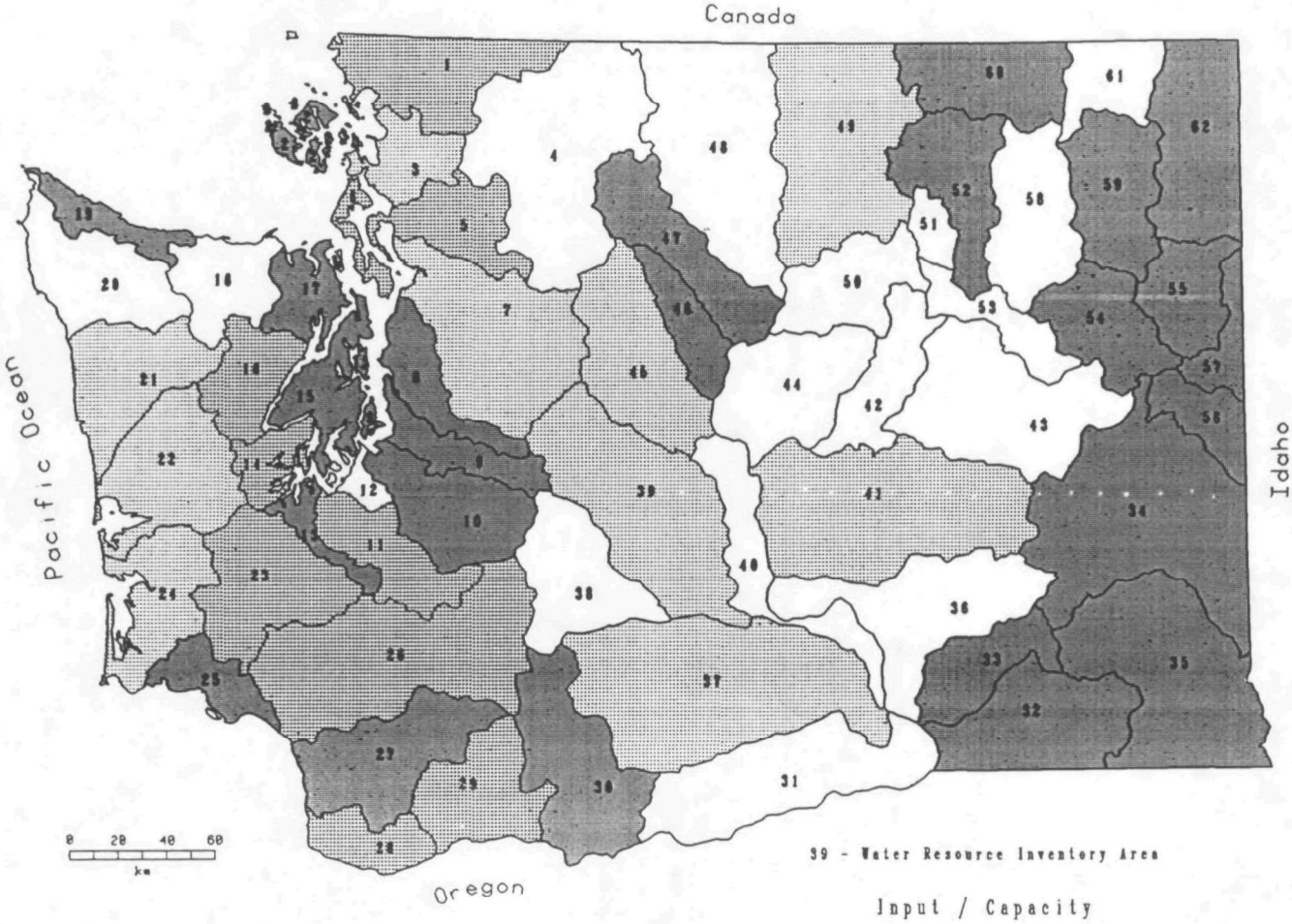
WATER QUALITY SENSITIVITY (NORMALIZED)



39 - Water Resource Inventory Area

Input / Capacity

- 0.00E-4 - 0.00E-4
- 0.00E-4 - 3.00E-4
- 3.00E-4 - 8.50E-4
- 8.50E-4 - 3.48E-3

Figure IV.3

1 - 0.31E-3	2 - UNDEFINED	3 - 0.92E-4	4 - 0.00E+0	5 - 0.49E-3	6 - 0.83E-3
7 - 0.27E-3	8 - 0.12E-2	9 - UNDEFINED	10 - UNDEFINED	11 - 0.70E-3	12 - NO DATA
13 - 0.14E-2	14 - 0.47E-3	15 - 0.85E-3	16 - 0.55E-3	17 - UNDEFINED	18 - 0.00E+0
19 - 0.35E-2	20 - 0.00E+0	21 - 0.11E-3	22 - 0.18E-3	23 - 0.62E-3	24 - 0.28E-3
25 - UNDEFINED	26 - 0.64E-3	27 - UNDEFINED	28 - 0.39E-3	29 - 0.35E-3	30 - UNDEFINED
31 - NO DATA	32 - 0.20E-2	33 - UNDEFINED	34 - 0.95E-3	35 - UNDEFINED	36 - NO DATA
37 - 0.92E-4	38 - 0.00E+0	39 - 0.24E-3	40 - NO DATA	41 - 0.13E-3	42 - NO DATA
43 - NO DATA	44 - NO DATA	45 - 0.24E-3	46 - UNDEFINED	47 - UNDEFINED	48 - 0.00E+0
49 - 0.21E-3	50 - NO DATA	51 - NO DATA	52 - 0.18E-2	53 - NO DATA	54 - UNDEFINED
55 - 0.19E-2	56 - UNDEFINED	57 - UNDEFINED	58 - NO DATA	59 - UNDEFINED	60 - 0.92E-3
61 - NO DATA	62 - UNDEFINED				

[Water Resource Inventory Area]

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NON-POINT WATER QUALITY SENSITIVITY (NON-NORMALIZED)

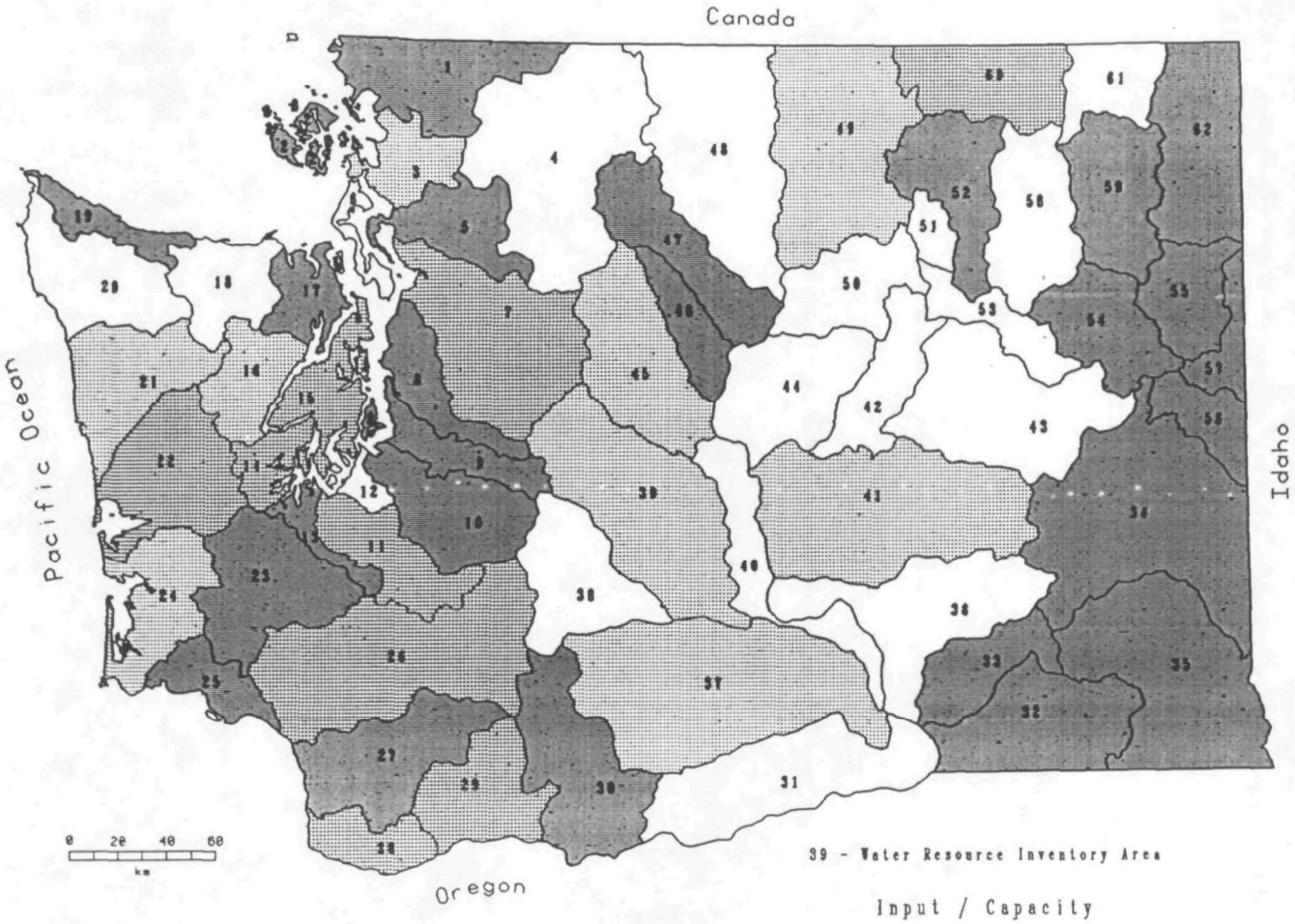

Figure IV.4

1 - 0.20	2 - UNDEFINED	3 - 0.01	4 - 0.00	5 - 0.11	6 - 0.00
7 - 0.09	8 - 0.34	9 - UNDEFINED	10 - UNDEFINED	11 - 0.05	12 - NO DATA
13 - 0.13	14 - 0.07	15 - 0.10	16 - 0.03	17 - UNDEFINED	18 - 0.00
19 - 0.23	20 - 0.00	21 - 0.01	22 - 0.05	23 - 0.16	24 - 0.02
25 - UNDEFINED	26 - 0.10	27 - UNDEFINED	28 - 0.04	29 - 0.04	30 - UNDEFINED
31 - NO DATA	32 - 0.32	33 - UNDEFINED	34 - 0.22	35 - UNDEFINED	36 - NO DATA
37 - 0.02	38 - 0.00	39 - 0.04	40 - NO DATA	41 - 0.01	42 - NO DATA
43 - NO DATA	44 - NO DATA	45 - 0:02	46 - UNDEFINED	47 - UNDEFINED	48 - 0.00
49 - 0.04	50 - NO DATA	51 - NO DATA	52 - 0.19	53 - NO DATA	54 - UNDEFINED
55 - 0.15	56 - UNDEFINED	57 - UNDEFINED	58 - NO DATA	59 - UNDEFINED	60 - 0.05
61 - NO DATA	62 - UNDEFINED				

[Water Resource Inventory Area]

Prepared by USEPA Wetlands Research Program, USEPA Environmental Research Lab, Corvallis, Oregon

NON-POINT WATER QUALITY SENSITIVITY (NORMALIZED)

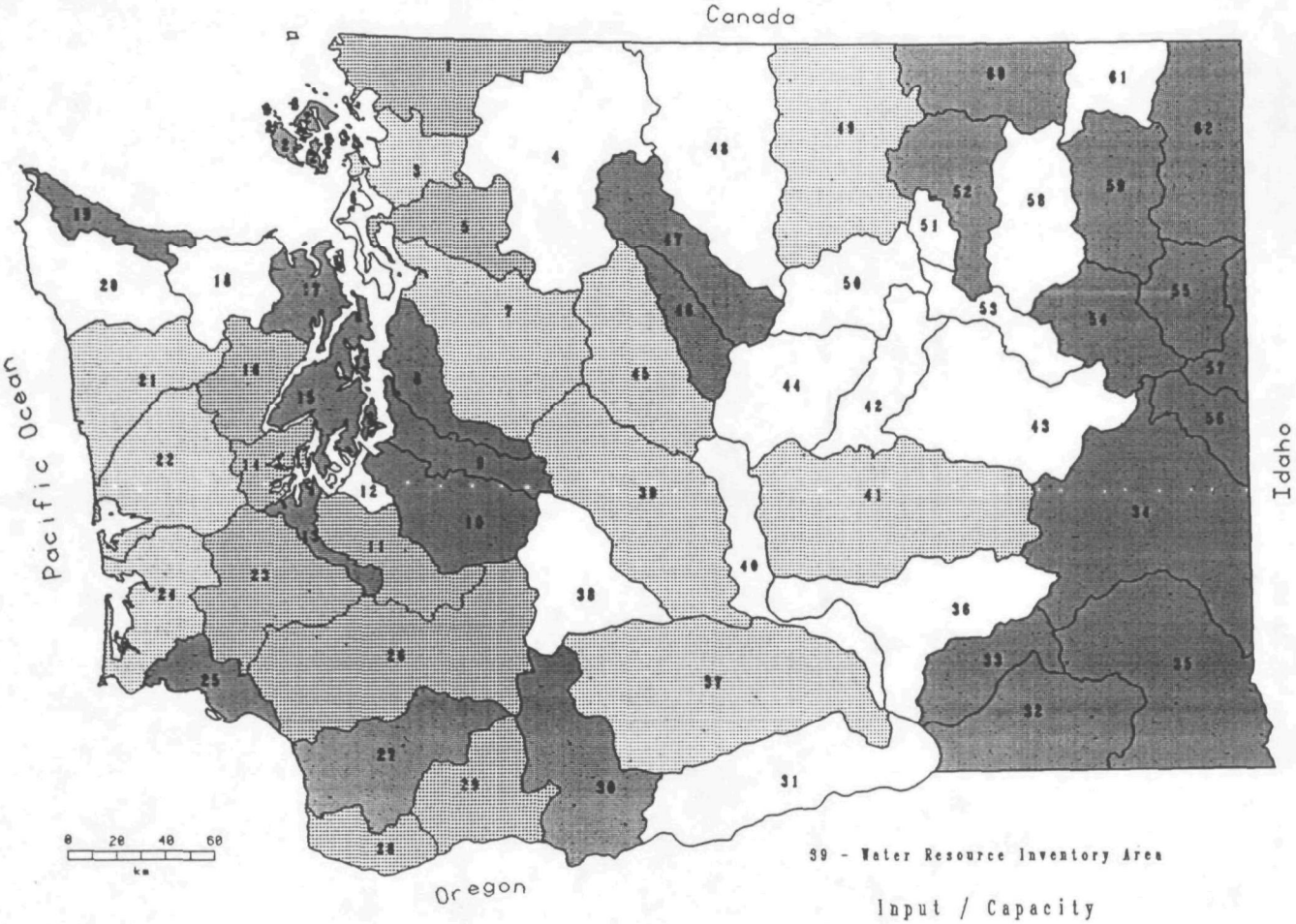

Figure IV.5

1 - 0.31E-3	2 - UNDEFINED	3 - 0.92E-4	4 - 0.00E+0	5 - 0.49E-3	6 - 0.00E+0
7 - 0.27E-3	8 - 0.12E-2	9 - UNDEFINED	10 - UNDEFINED	11 - 0.70E-3	12 - NO DATA
13 - 0.14E-2	14 - 0.47E-3	15 - 0.85E-3	16 - 0.55E-3	17 - UNDEFINED	18 - 0.00E+0
19 - 0.35E-2	20 - 0.00E+0	21 - 0.11E-3	22 - 0.18E-3	23 - 0.62E-3	24 - 0.28E-3
25 - UNDEFINED	26 - 0.64E-3	27 - UNDEFINED	28 - 0.39E-3	29 - 0.35E-3	30 - UNDEFINED
31 - NO DATA	32 - 0.20E-2	33 - UNDEFINED	34 - 0.95E-3	35 - UNDEFINED	36 - NO DATA
37 - 0.92E-4	38 - 0.00E+0	39 - 0.24E-3	40 - NO DATA	41 - 0.13E-3	42 - NO DATA
43 - NO DATA	44 - NO DATA	45 - 0.24E-3	46 - UNDEFINED	47 - UNDEFINED	48 - 0.00E+0
49 - 0.21E-3	50 - NO DATA	51 - NO DATA	52 - 0.18E-2	53 - NO DATA	54 - UNDEFINED
55 - 0.19E-2	56 - UNDEFINED	57 - UNDEFINED	58 - NO DATA	59 - UNDEFINED	60 - 0.92E-3
61 - NO DATA	62 - UNDEFINED				

[Water Resource Inventory Area]

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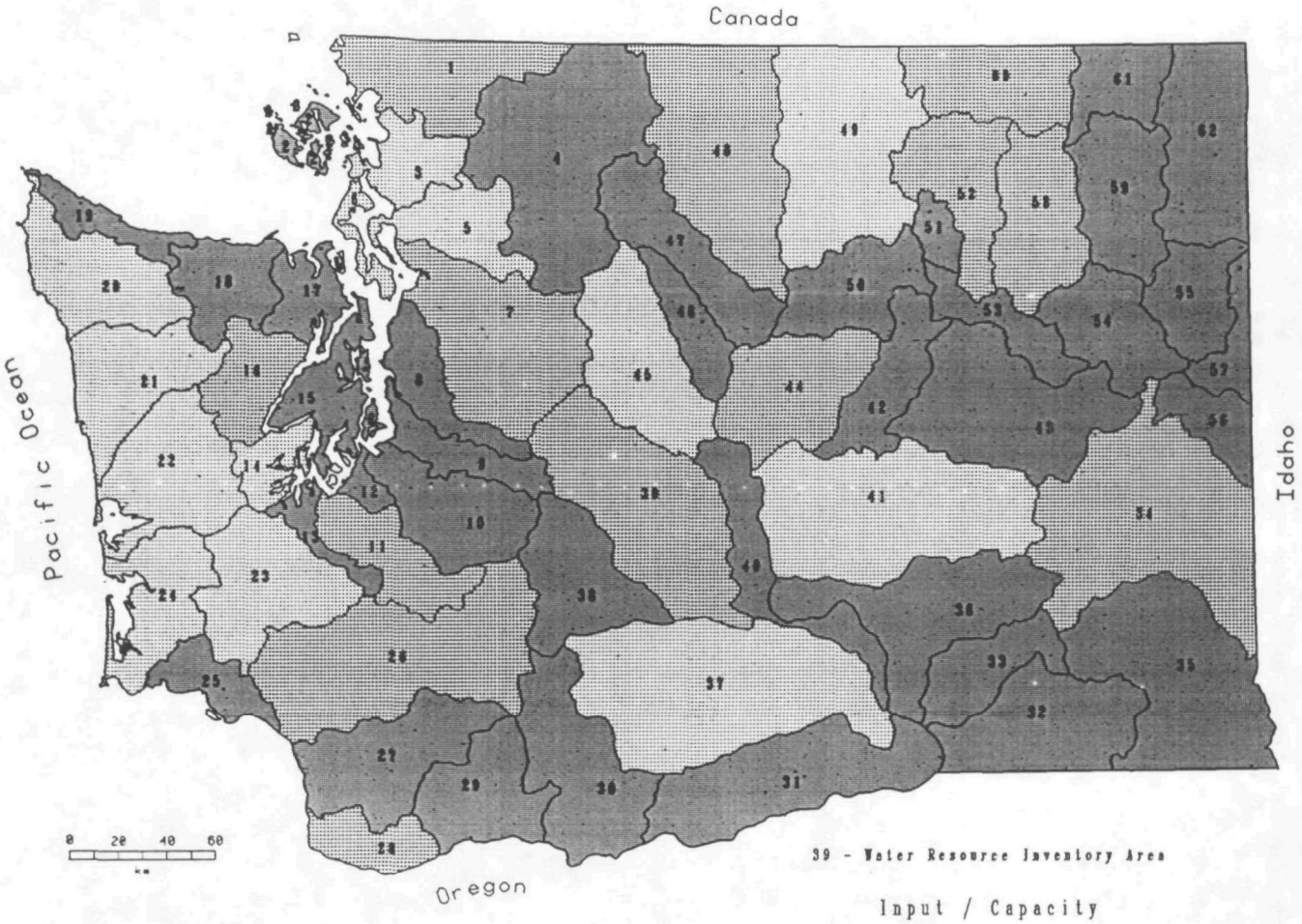
LIFE SUPPORT SENSITIVITY



39 - Water Resource Inventory Area

Input / Capacity

- 0.00E-3 - 0.00E-3
- 0.00E-3 - 3.80E-3
- 3.80E-3 - 9.00E-3
- 9.00E-3 - 2.01E-2

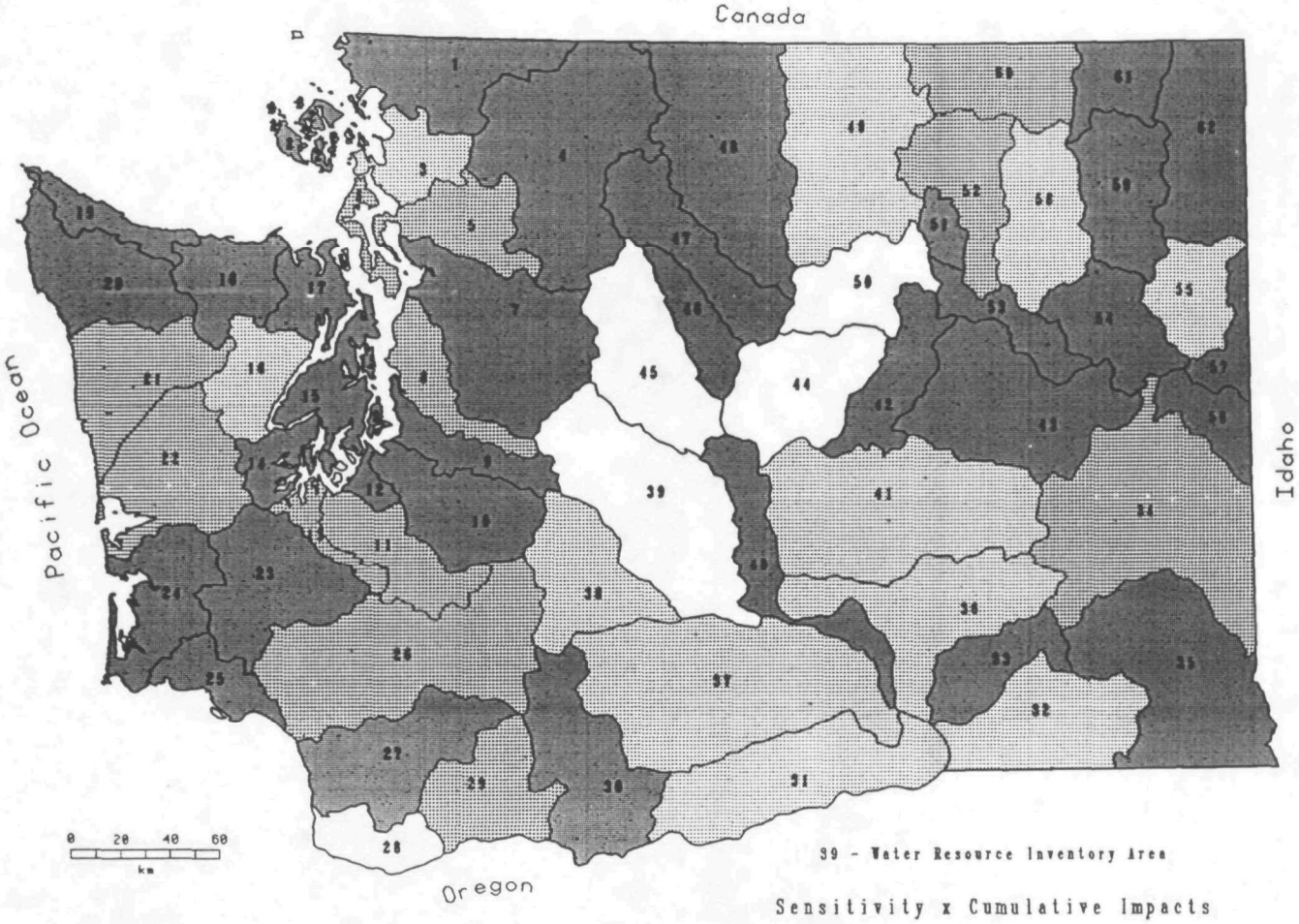
Figure IV.6

1 - 0.47E-2	2 - UNDEFINED	3 - 0.83E-3	4 - 0.11E-1	5 - 0.24E-2	6 - 0.33E-2
7 - 0.49E-2	8 - 0.14E-1	9 - UNDEFINED	10 - UNDEFINED	11 - 0.70E-2	12 - UNDEFINED
13 - 0.19E-1	14 - 0.37E-2	15 - 0.11E-1	16 - 0.50E-2	17 - UNDEFINED	18 - 0.14E-1
19 - 0.17E-1	20 - 0.26E-2	21 - 0.89E-3	22 - 0.25E-2	23 - 0.37E-2	24 - 0.31E-2
25 - UNDEFINED	26 - 0.64E-2	27 - UNDEFINED	28 - 0.39E-2	29 - 0.20E-1	30 - UNDEFINED
31 - 0.18E-1	32 - 0.14E-1	33 - UNDEFINED	34 - 0.67E-2	35 - UNDEFINED	36 - 0.17E-1
37 - 0.83E-3	38 - 0.13E-1	39 - 0.42E-2	40 - UNDEFINED	41 - 0.13E-2	42 - UNDEFINED
43 - UNDEFINED	44 - 0.88E-2	45 - 0.28E-2	46 - UNDEFINED	47 - UNDEFINED	48 - 0.59E-2
49 - 0.25E-2	50 - 0.14E-1	51 - UNDEFINED	52 - 0.73E-2	53 - UNDEFINED	54 - UNDEFINED
55 - 0.96E-2	56 - UNDEFINED	57 - UNDEFINED	58 - 0.58E-2	59 - UNDEFINED	60 - 0.64E-2
61 - UNDEFINED	62 - UNDEFINED				

[Water Resource Inventory Area]

Prepared by USEPA Wetlands Research Program, USEPA Environmental Research Lab, Corvallis, Oregon

HYDROLOGIC EFFECTS (NON-NORMALIZED)



Sensitivity x Cumulative Impacts

-165 -	0
0 -	625
625 -	1300
1300 -	31495

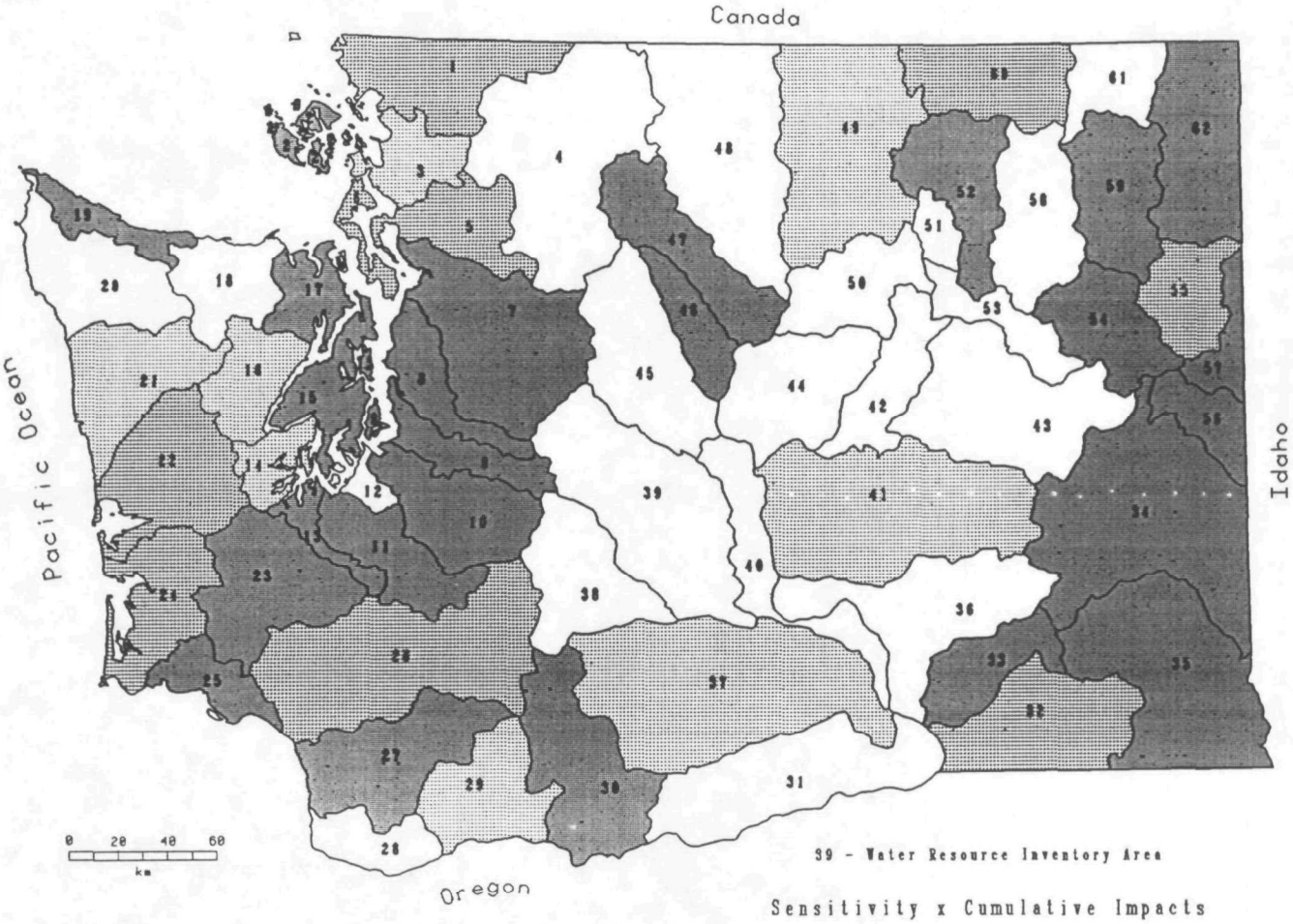
Figure IV.7

1 - 2923	2 - UNDEFINED	3 - 116	4 - 31493	5 - 1044	6 - 965
7 - 5247	8 - 1178	9 - UNDEFINED	10 - UNDEFINED	11 - 1081	12 - UNDEFINED
13 - 1008	14 - 1322	15 - 12071	16 - 386	17 - UNDEFINED	18 - 12033
19 - 15040	20 - 2635	21 - 1131	22 - 1195	23 - 2447	24 - 1939
25 - UNDEFINED	26 - 1277	27 - UNDEFINED	28 - -102	29 - 812	30 - UNDEFINED
31 - 303	32 - 127	33 - UNDEFINED	34 - 640	35 - UNDEFINED	36 - 483
37 - 59	38 - 158	39 - -88	40 - UNDEFINED	41 - 9	42 - UNDEFINED
43 - UNDEFINED	44 - -31	45 - -165	46 - UNDEFINED	47 - UNDEFINED	48 - 3663
49 - 126	50 - 0	51 - UNDEFINED	52 - 704	53 - UNDEFINED	54 - UNDEFINED
55 - 527	56 - UNDEFINED	57 - UNDEFINED	58 - 404	59 - UNDEFINED	60 - 637
61 - UNDEFINED	62 - UNDEFINED				

[Water Resource Inventory Area]

Prepared by USEPA Wetlands Research Program, USEPA Environmental Research Lab, Corvallis, Oregon

WATER QUALITY EFFECTS (NON-NORMALIZED)



39 - Water Resource Inventory Area

Sensitivity x Cumulative Impacts

	-0.3 - 0.0
	0.0 - 1.6
	1.6 - 5.7
	5.7 - 22.4

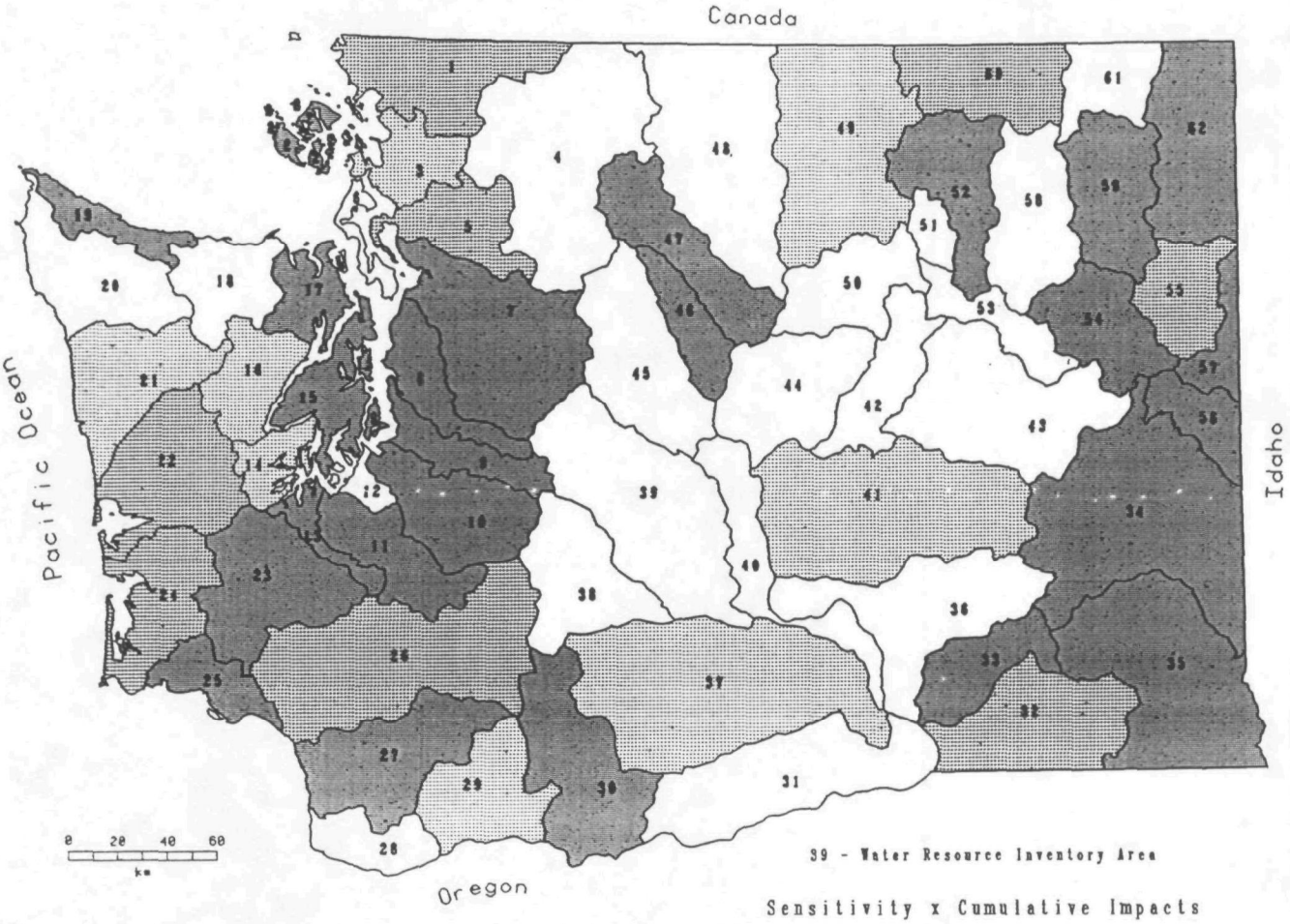
Figure IV.8

1 - 5.1	2 - UNDEFINED	3 - 0.4	4 - 0.0	5 - 4.3	6 - 2.4
7 - 5.9	8 - 5.8	9 - UNDEFINED	10 - UNDEFINED	11 - 5.9	12 - NO DATA
13 - 6.0	14 - 1.4	15 - 7.9	16 - 0.5	17 - UNDEFINED	18 - 0.0
19 - 22.4	20 - 0.0	21 - 1.2	22 - 1.7	23 - 8.5	24 - 2.8
25 - UNDEFINED	26 - 3.1	27 - UNDEFINED	28 - -0.3	29 - 0.3	30 - UNDEFINED
31 - NO DATA	32 - 1.7	33 - UNDEFINED	34 - 6.8	35 - UNDEFINED	36 - NO DATA
37 - 0.5	38 - 0.0	39 - -0.2	40 - NO DATA	41 - 0.1	42 - NO DATA
43 - NO DATA	44 - NO DATA	45 - -0.2	46 - UNDEFINED	47 - UNDEFINED	48 - 0.0
49 - 1.1	50 - NO DATA	51 - NO DATA	52 - 10.6	53 - NO DATA	54 - UNDEFINED
55 - 5.2	56 - UNDEFINED	57 - UNDEFINED	58 - NO DATA	59 - UNDEFINED	60 - 2.8
61 - NO DATA	62 - UNDEFINED				

[Water Resource Inventory Area]

Prepared by USEPA Wetlands Research Program, USEPA Environmental Research Lab, Corvallis, Oregon

NON-POINT WATER QUALITY EFFECTS (NON-NORMALIZED)



39 - Water Resource Inventory Area

Sensitivity x Cumulative Impacts

- -0.3 - 0.0
- 0.0 - 1.5
- 1.5 - 5.6
- 5.6 - 22.4

Figure IV.9

1 - 5.1	2 - UNDEFINED	3 - 0.4	4 - 0.0	5 - 4.3	6 - 0.0
7 - 5.9	8 - 5.8	9 - UNDEFINED	10 - UNDEFINED	11 - 5.9	12 - NO DATA
13 - 6.0	14 - 1.4	15 - 7.9	16 - 0.5	17 - UNDEFINED	18 - 0.0
19 - 22.4	20 - 0.0	21 - 1.2	22 - 1.7	23 - 8.5	24 - 2.8
25 - UNDEFINED	26 - 3.1	27 - UNDEFINED	28 - -0.3	29 - 0.3	30 - UNDEFINED
31 - NO DATA	32 - 1.7	33 - UNDEFINED	34 - 6.8	35 - UNDEFINED	36 - NO DATA
37 - 0.5	38 - 0.0	39 - -0.2	40 - NO DATA	41 - 0.1	42 - NO DATA
43 - NO DATA	44 - NO DATA	45 - -0.2	46 - UNDEFINED	47 - UNDEFINED	48 - 0.0
49 - 1.1	50 - NO DATA	51 - NO DATA	52 - 10.6	53 - NO DATA	54 - UNDEFINED
55 - 5.2	56 - UNDEFINED	57 - UNDEFINED	58 - NO DATA	59 - UNDEFINED	60 - 2.0
61 - NO DATA	62 - UNDEFINED				

[Water Resource Inventory Area]

Prepared by USEPA Wetlands Research Program, USEPA Environmental Research Lab, Corvallis, Oregon

LIFE SUPPORT EFFECTS (NON-NORMALIZED)

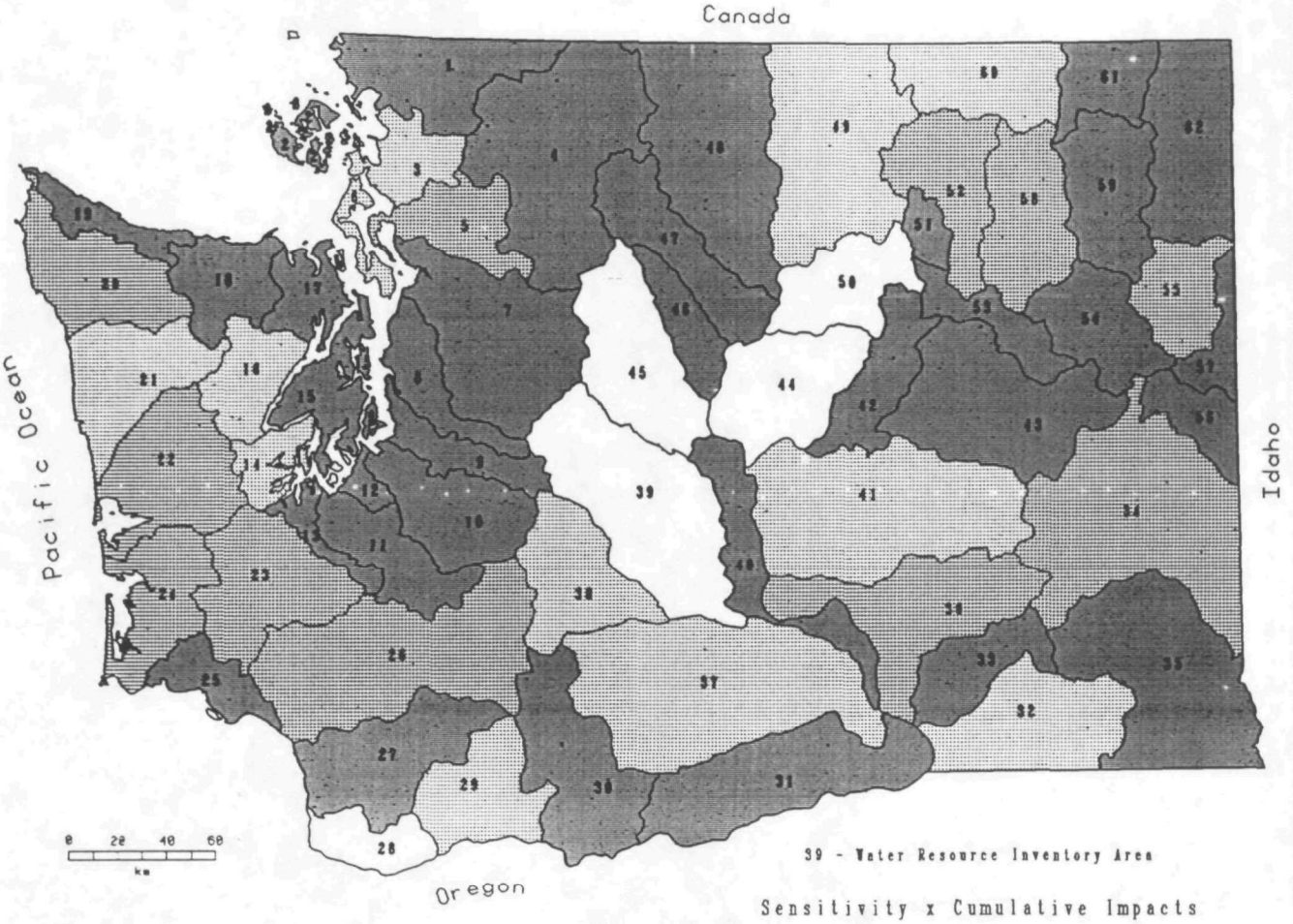


Figure IV.10

1 - 78.8	2 - UNDEFINED	3 - 3.5	4 - 176.9	5 - 21.3	6 - 9.8
7 - 107.5	8 - 67.5	9 - UNDEFINED	10 - UNDEFINED	11 - 59.1	12 - UNDEFINED
13 - 80.2	14 - 10.8	15 - 102.6	16 - 4.7	17 - UNDEFINED	18 - 120.8
19 - 112.0	20 - 22.0	21 - 9.5	22 - 22.2	23 - 51.0	24 - 30.4
25 - UNDEFINED	26 - 31.3	27 - UNDEFINED	28 - -3.4	29 - 17.0	30 - UNDEFINED
31 - 64.4	32 - 11.9	33 - UNDEFINED	34 - 47.9	35 - UNDEFINED	36 - 41.9
37 - 4.2	38 - 4.3	39 - -4.0	40 - UNDEFINED	41 - 1.1	42 - UNDEFINED
43 - UNDEFINED	44 - -2.1	45 - -3.0	46 - UNDEFINED	47 - UNDEFINED	48 - 134.0
49 - 12.7	50 - 0.0	51 - UNDEFINED	52 - 42.3	53 - UNDEFINED	54 - UNDEFINED
55 - 25.9	56 - UNDEFINED	57 - UNDEFINED	58 - 25.9	59 - UNDEFINED	60 - 19.9
61 - UNDEFINED	62 - UNDEFINED				

[Water Resource Inventory Area]

Prepared by USEPA Wetlands Research Program, USEPA Environmental Research Lab, Corvallis, Oregon

HYDROLOGIC EFFECTS (NORMALIZED)

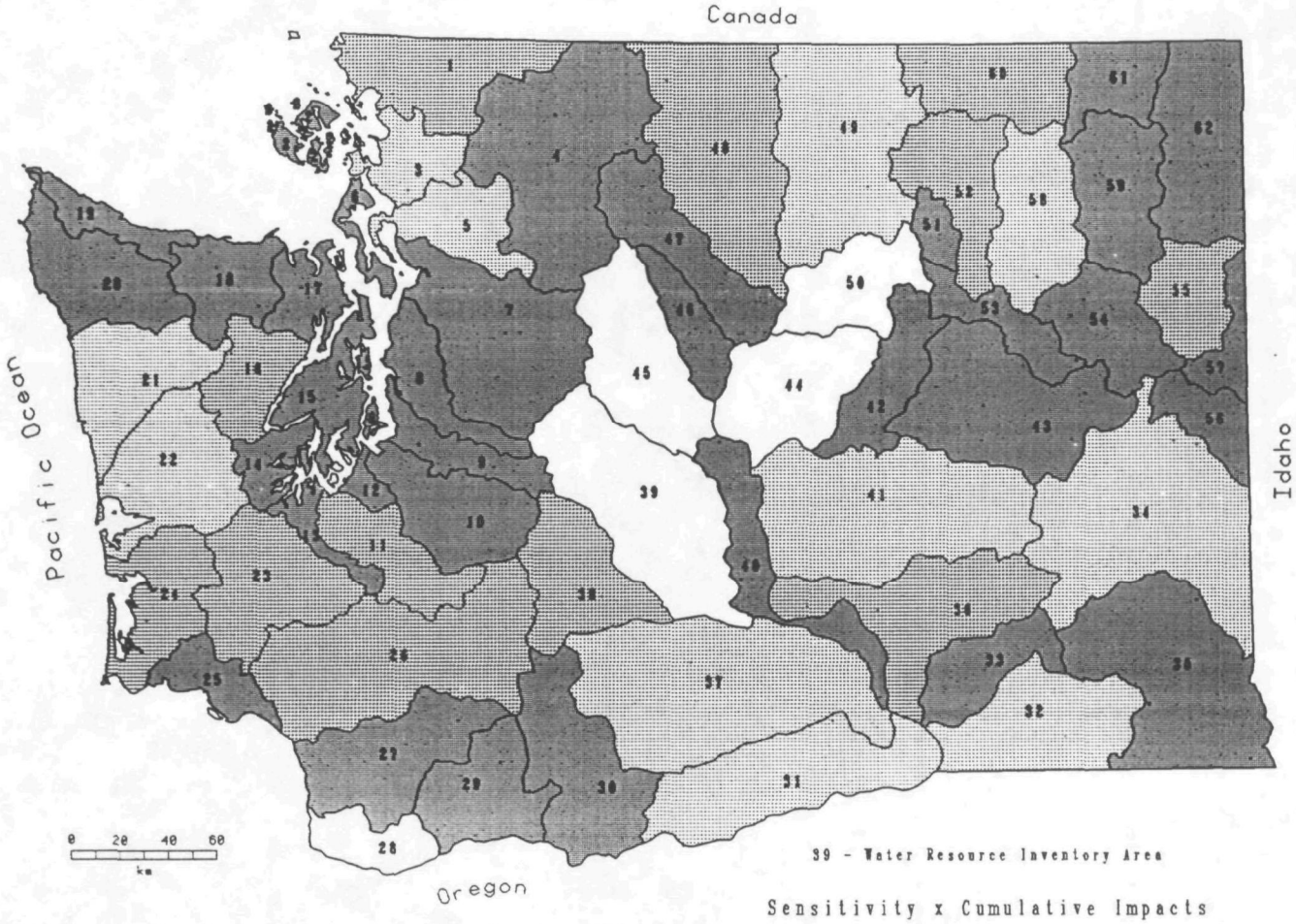


Figure IV.11

1 - 0.15	2 - UNDEFINED	3 - 0.01	4 - 1.97	5 - 0.10	6 - 0.23
7 - 0.22	8 - 0.22	9 - UNDEFINED	10 - UNDEFINED	11 - 0.11	12 - UNDEFINED
13 - 0.22	14 - 0.34	15 - 1.25	16 - 0.17	17 - UNDEFINED	18 - 1.37
19 - 2.24	20 - 0.25	21 - 0.06	22 - 0.09	23 - 0.16	24 - 0.15
25 - UNDEFINED	26 - 0.20	27 - UNDEFINED	28 - -0.06	29 - 0.61	30 - UNDEFINED
31 - 0.07	32 - 0.09	33 - UNDEFINED	34 - 0.08	35 - UNDEFINED	36 - 0.16
37 - 0.00	38 - 0.18	39 - -0.05	40 - UNDEFINED	41 - 0.00	42 - UNDEFINED
43 - UNDEFINED	44 - -0.09	45 - -0.16	46 - UNDEFINED	47 - UNDEFINED	48 - 0.15
49 - 0.01	50 - 0.00	51 - UNDEFINED	52 - 0.11	53 - UNDEFINED	54 - UNDEFINED
55 - 0.16	56 - UNDEFINED	57 - UNDEFINED	58 - 0.07	59 - UNDEFINED	60 - 0.15
61 - UNDEFINED	62 - UNDEFINED				

[Water Resource Inventory Area]

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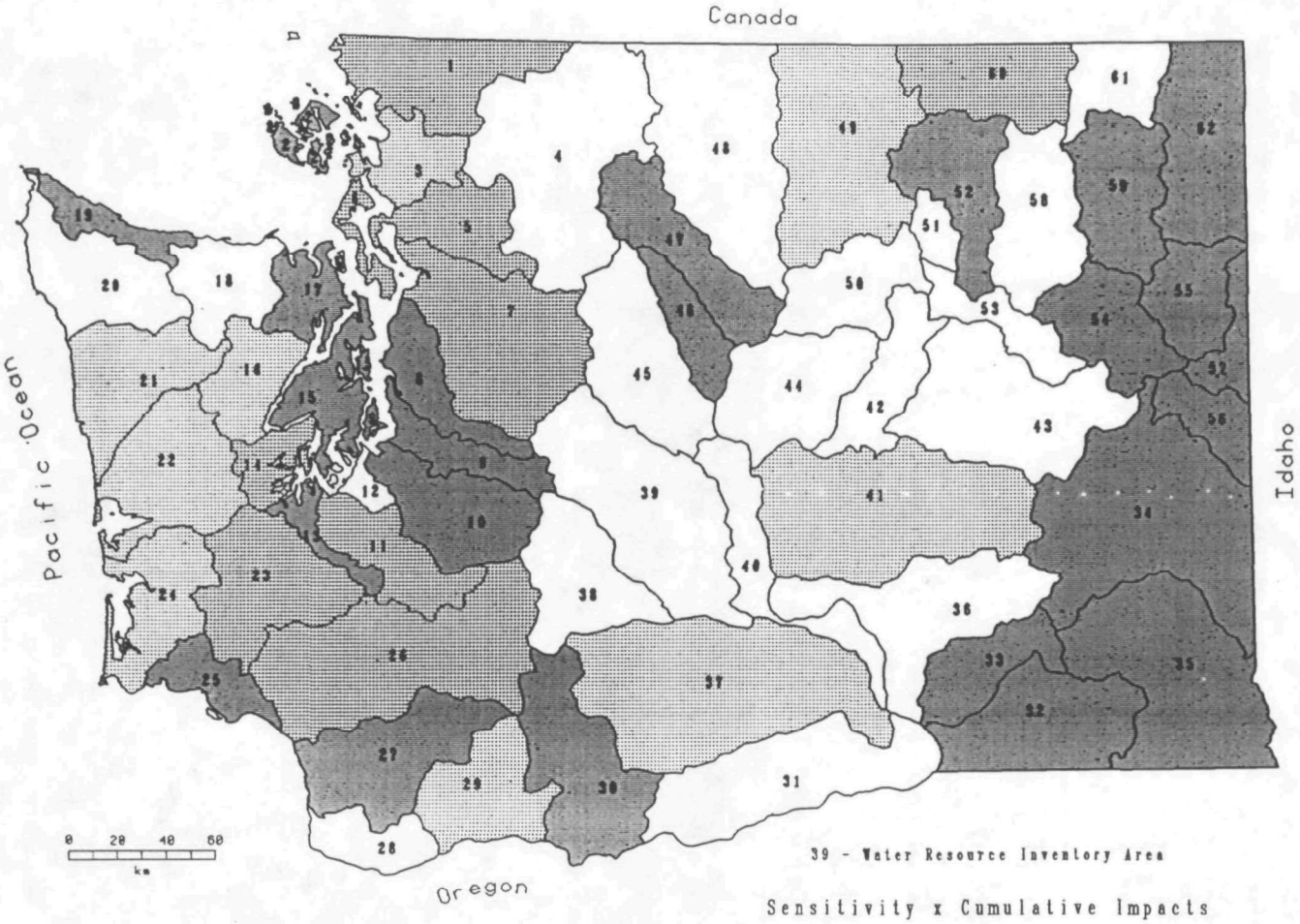
WATER QUALITY EFFECTS (NORMALIZED)



39 - Water Resource Inventory Area

Sensitivity x Cumulative Impacts

- -2.37E-4 - 0.00E-4
- 0.00E-6 - 2.33E-4
- 2.33E-4 - 7.11E-4
- 7.11E-4 - 3.33E-3

Figure IV.12

1 - 0.27E-3	2 - UNDEFINED	3 - 0.34E-4	4 - 0.00E+0	5 - 0.40E-3	6 - 0.59E-3
7 - 0.24E-3	8 - 0.11E-2	9 - UNDEFINED	10 - UNDEFINED	11 - 0.60E-3	12 - NO DATA
13 - 0.13E-2	14 - 0.34E-3	15 - 0.81E-3	16 - 0.22E-3	17 - UNDEFINED	18 - 0.00E+0
19 - 0.33E-2	20 - 0.00E+0	21 - 0.70E-4	22 - 0.12E-3	23 - 0.55E-3	24 - 0.21E-3
25 - UNDEFINED	26 - 0.48E-3	27 - UNDEFINED	28 - -0.20E-3	29 - 0.22E-3	30 - UNDEFINED
31 - NO DATA	32 - 0.13E-2	33 - UNDEFINED	34 - 0.83E-3	35 - UNDEFINED	36 - NO DATA
37 - 0.29E-4	38 - 0.00E+0	39 - -0.14E-3	40 - NO DATA	41 - 0.12E-4	42 - NO DATA
43 - NO DATA	44 - NO DATA	45 - -0.24E-3	46 - UNDEFINED	47 - UNDEFINED	48 - 0.00E+0
49 - 0.11E-3	50 - NO DATA	51 - NO DATA	52 - 0.17E-2	53 - NO DATA	54 - UNDEFINED
55 - 0.16E-2	56 - UNDEFINED	57 - UNDEFINED	58 - NO DATA	59 - UNDEFINED	60 - 0.68E-3
61 - NO DATA	62 - UNDEFINED				

[Water Resource Inventory Area]

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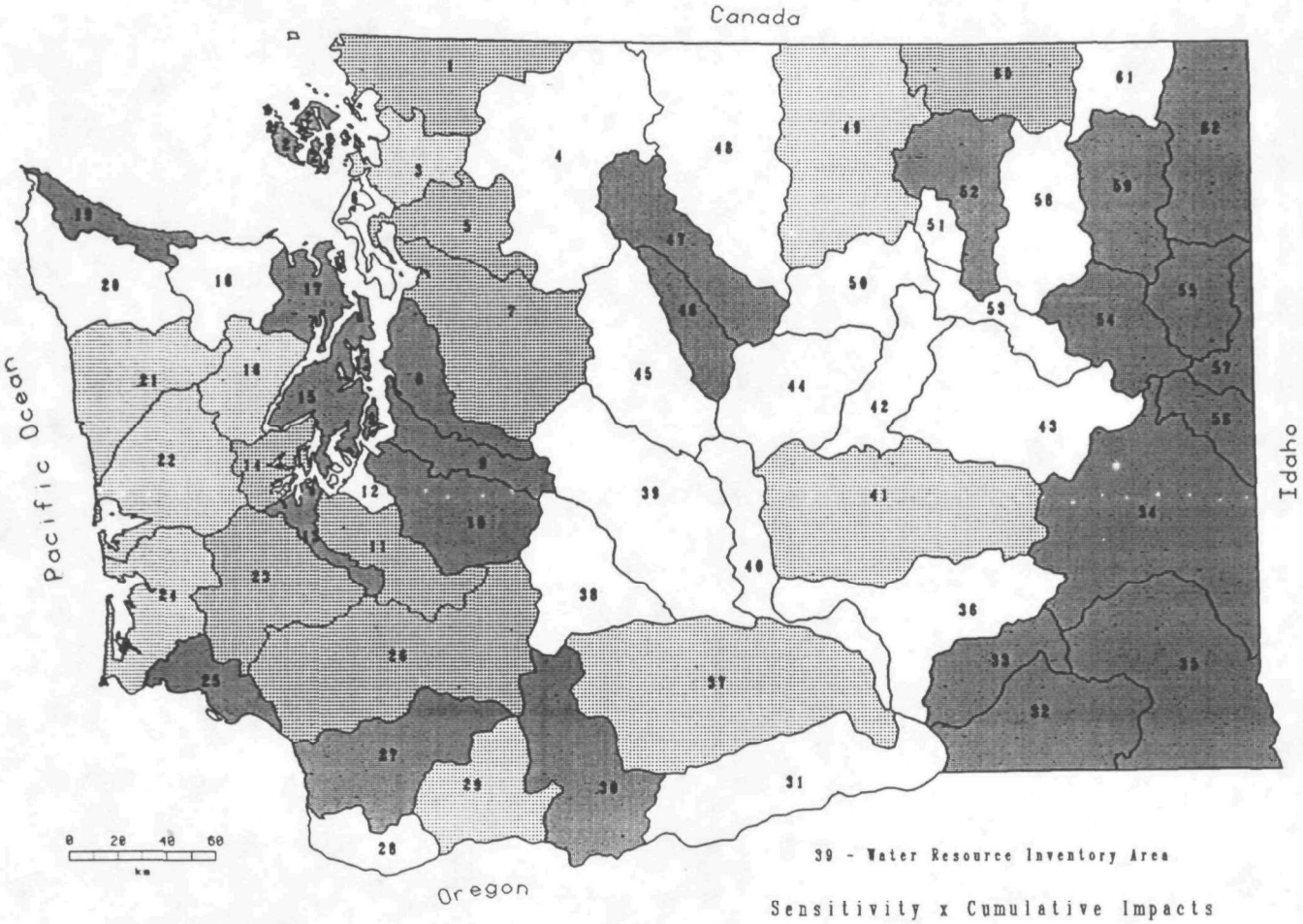
NON-POINT WATER QUALITY EFFECTS (NORMALIZED)



39 - Water Resource Inventory Area

Sensitivity x Cumulative Impacts

- -2.37E-4 - 0.00E-4
- 0.00E-4 - 2.25E-4
- 2.25E-4 - 7.11E-4
- 7.11E-4 - 3.33E-3

Figure IV.13

1 - 0.27E-3	2 - UNDEFINED	3 - 0.34E-4	4 - 0.00E+0	5 - 0.40E-3	6 - 0.00E+0
7 - 0.24E-3	8 - 0.11E-2	9 - UNDEFINED	10 - UNDEFINED	11 - 0.60E-3	12 - NO DATA
13 - 0.13E-2	14 - 0.34E-3	15 - 0.81E-3	16 - 0.22E-3	17 - UNDEFINED	18 - 0.00E+0
19 - 0.33E-2	20 - 0.00E+0	21 - 0.70E-4	22 - 0.12E-3	23 - 0.55E-3	24 - 0.21E-3
25 - UNDEFINED	26 - 0.48E-3	27 - UNDEFINED	28 - -0.20E-3	29 - 0.22E-3	30 - UNDEFINED
31 - NO DATA	32 - 0.13E-2	33 - UNDEFINED	34 - 0.83E-3	35 - UNDEFINED	36 - NO DATA
37 - 0.29E-4	38 - 0.00E+0	39 - -0.14E-3	40 - NO DATA	41 - 0.12E-4	42 - NO DATA
43 - NO DATA	44 - NO DATA	45 - -0.24E-3	46 - UNDEFINED	47 - UNDEFINED	48 - 0.00E+0
49 - 0.11E-3	50 - NO DATA	51 - NO DATA	52 - 0.17E-2	53 - NO DATA	54 - UNDEFINED
55 - 0.16E-2	56 - UNDEFINED	57 - UNDEFINED	58 - NO DATA	59 - UNDEFINED	60 - 0.68E-3
61 - NO DATA	62 - UNDEFINED				

[Water Resource Inventory Area]

Prepared by USEPA Wetlands Research Program, USEPA Environmental Research Lab, Corvallis, Oregon

LIFE SUPPORT EFFECTS (NORMALIZED)

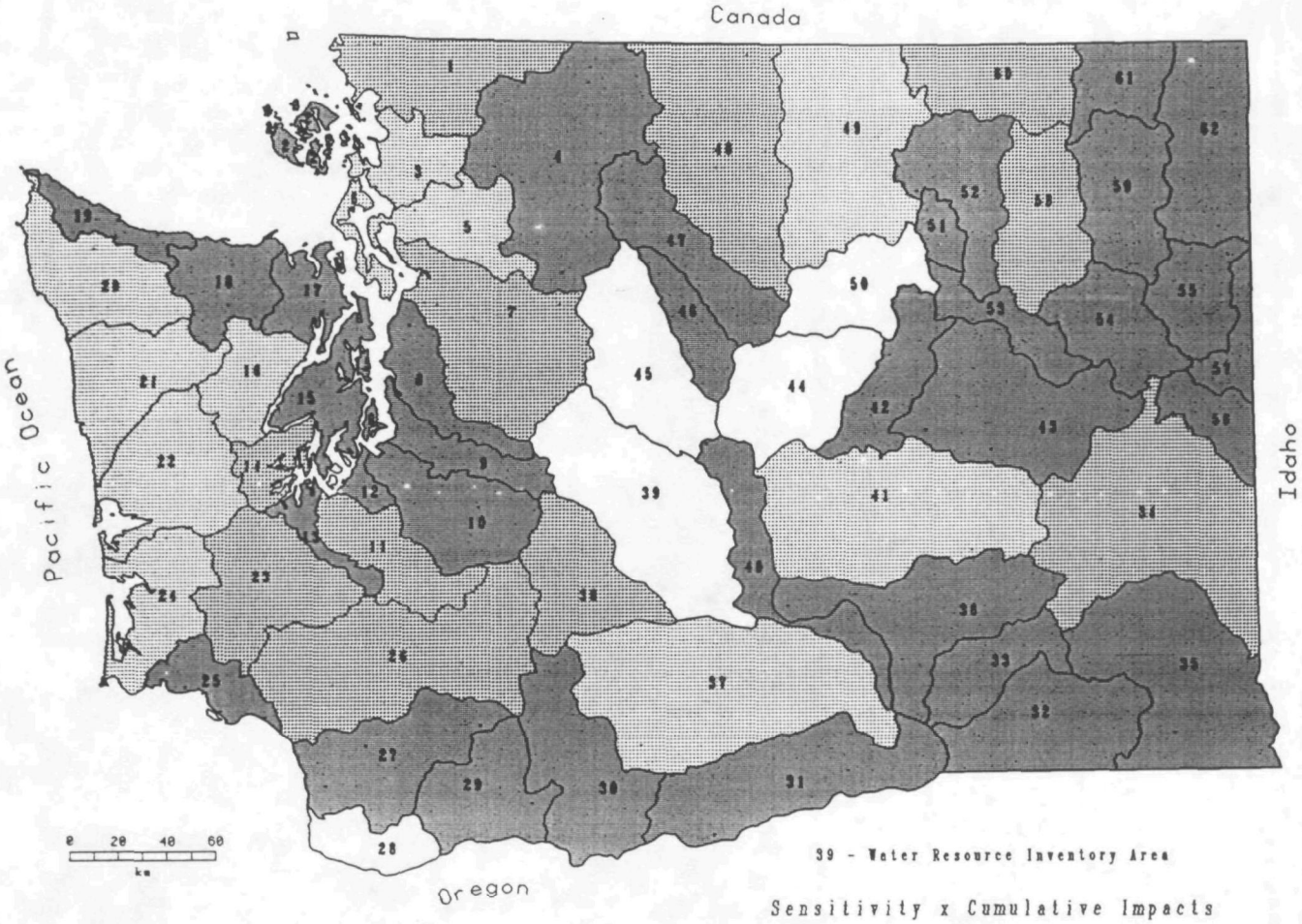


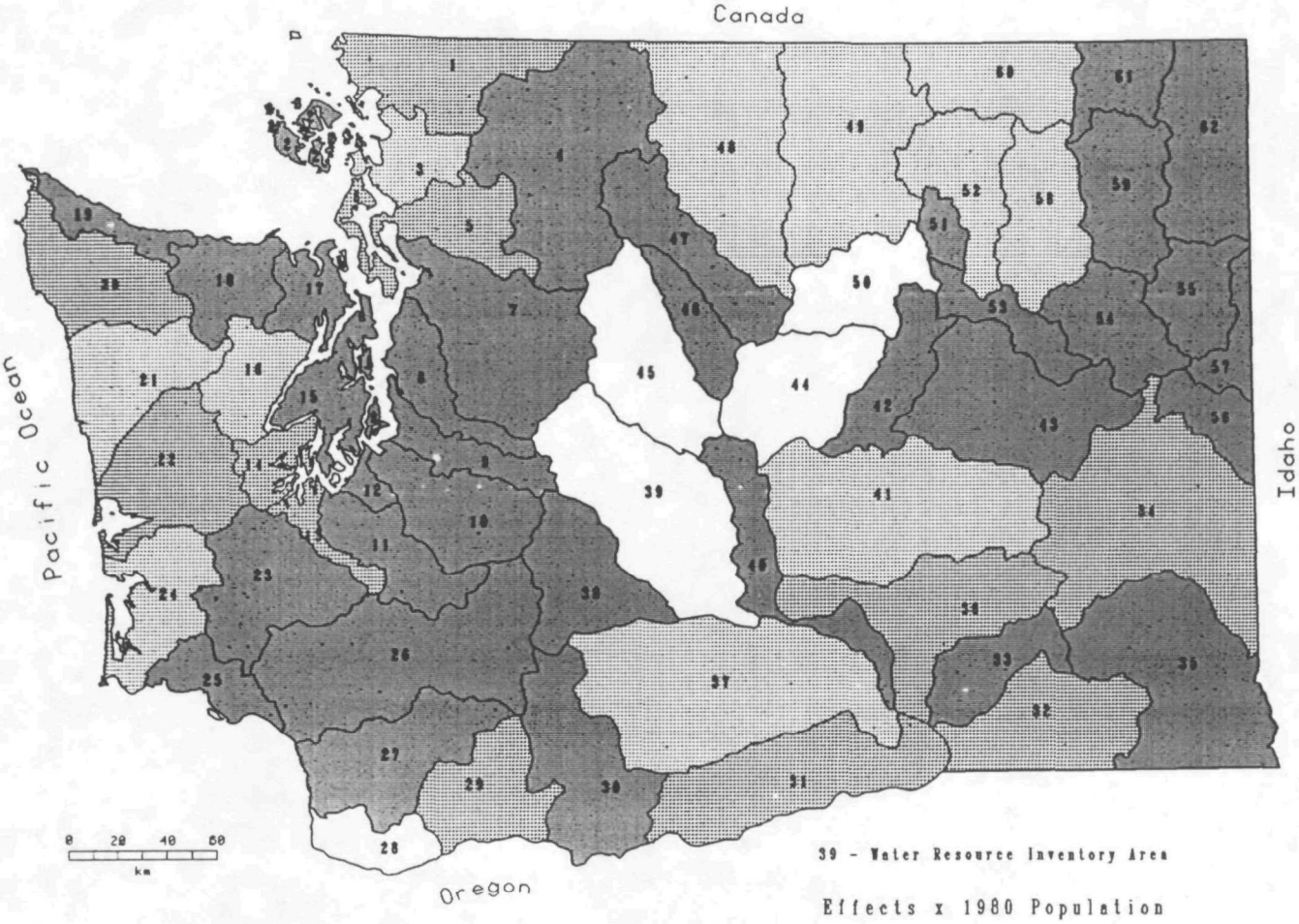
Figure IV.14

1 - 0.42E-2	2 - UNDEFINED	3 - 0.31E-3	4 - 0.11E-1	5 - 0.20E-2	6 - 0.24E-2
7 - 0.44E-2	8 - 0.13E-1	9 - UNDEFINED	10 - UNDEFINED	11 - 0.60E-2	12 - UNDEFINED
13 - 0.17E-1	14 - 0.27E-2	15 - 0.11E-1	16 - 0.20E-2	17 - UNDEFINED	18 - 0.14E-1
19 - 0.17E-1	20 - 0.21E-2	21 - 0.54E-3	22 - 0.17E-2	23 - 0.33E-2	24 - 0.23E-2
25 - UNDEFINED	26 - 0.48E-2	27 - UNDEFINED	28 - -0.20E-2	29 - 0.13E-1	30 - UNDEFINED
31 - 0.16E-1	32 - 0.88E-2	33 - UNDEFINED	34 - 0.58E-2	35 - UNDEFINED	36 - 0.14E-1
37 - 0.26E-3	38 - 0.49E-2	39 - -0.24E-2	40 - UNDEFINED	41 - 0.12E-3	42 - UNDEFINED
43 - UNDEFINED	44 - -0.64E-2	45 - -0.28E-2	46 - UNDEFINED	47 - UNDEFINED	48 - 0.56E-2
49 - 0.13E-2	50 - -0.57E-4	51 - UNDEFINED	52 - 0.67E-2	53 - UNDEFINED	54 - UNDEFINED
55 - 0.60E-2	56 - UNDEFINED	57 - UNDEFINED	58 - 0.46E-2	59 - UNDEFINED	60 - 0.47E-2
61 - UNDEFINED	62 - UNDEFINED				

[Water Resource Inventory Area]

Prepared by USEPA Wetlands Research Program, USEPA Environmental Research Lab, Corvallis, Oregon

HYDROLOGIC SIGNIFICANCE TO HUMANS



39 - Water Resource Inventory Area

Effects x 1980 Population

-6530 -	0
0 -	3200
3200 -	9000
9000 -	338870

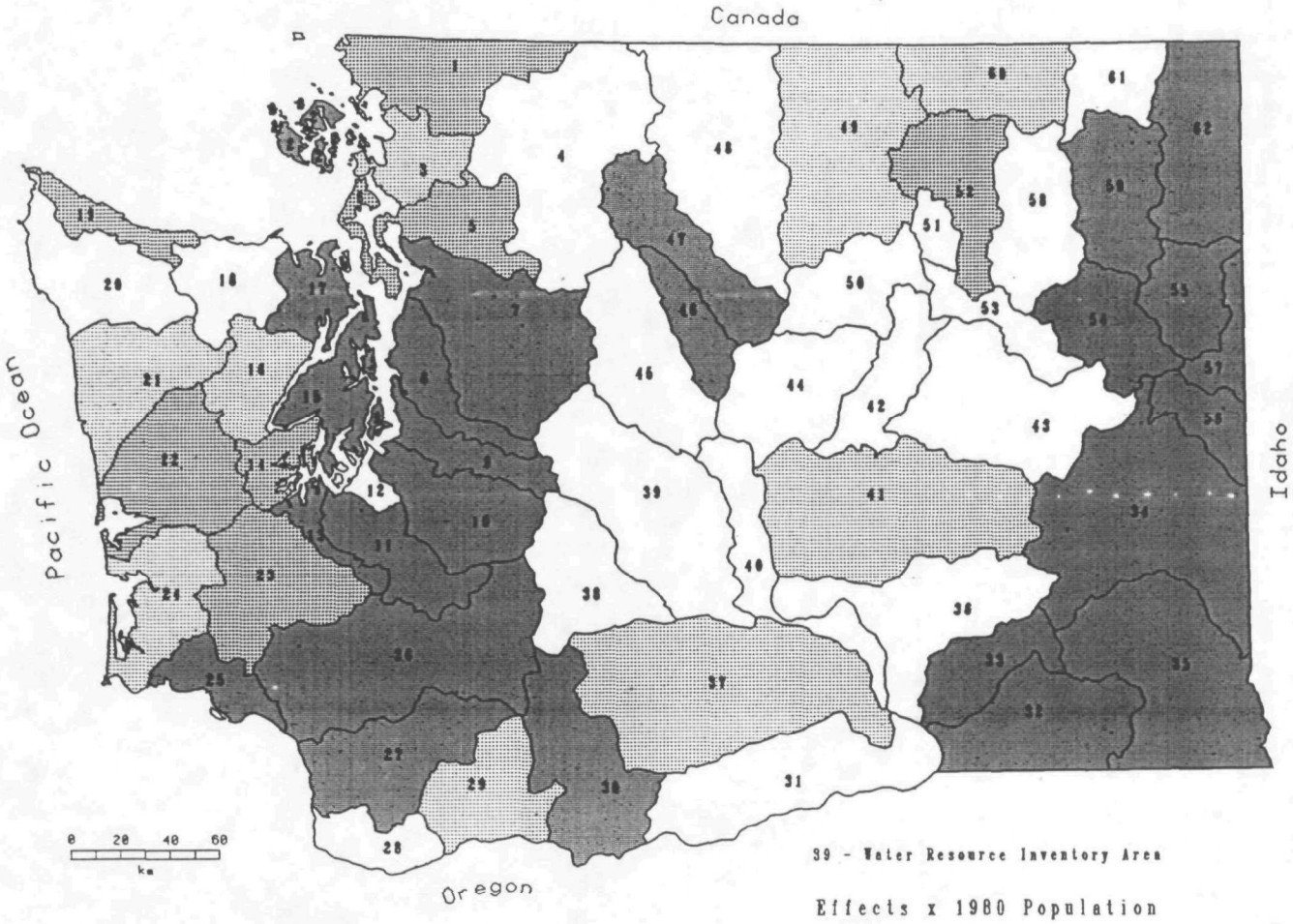
Figure IV.15

1 - 8742	2 - UNDEFINED	3 - 203	4 - 338866	5 - 8987	6 - 8488
7 - 151730	8 - 68860	9 - UNDEFINED	10 - UNDEFINED	11 - 16915	12 - UNDEFINED
13 - 8317	14 - 5605	15 - 223471	16 - 2498	17 - UNDEFINED	18 - 23609
19 - 24857	20 - 6263	21 - 1313	22 - 3895	23 - 11704	24 - 2950
25 - UNDEFINED	26 - 19237	27 - UNDEFINED	28 - -5848	29 - 3609	30 - UNDEFINED
31 - 4595	32 - 3594	33 - UNDEFINED	34 - 7988	35 - UNDEFINED	36 - 5494
37 - 476	38 - 9103	39 - -3501	40 - UNDEFINED	41 - 35	42 - UNDEFINED
43 - UNDEFINED	44 - -1432	45 - -8529	46 - UNDEFINED	47 - UNDEFINED	48 - 2589
49 - 156	50 - -4	51 - UNDEFINED	52 - 416	53 - UNDEFINED	54 - UNDEFINED
55 - 13348	56 - UNDEFINED	57 - UNDEFINED	58 - 355	59 - UNDEFINED	60 - 608
61 - UNDEFINED	62 - UNDEFINED				

[Water Resource Inventory Area]

Prepared by USEPA Wetlands Research Program, USEPA Environmental Research Lab, Corvallis, Oregon

WATER QUALITY SIGNIFICANCE TO HUMANS



39 - Water Resource Inventory Area

Effects x 1980 Population

-19.1 -	0.0
0.0 -	4.8
4.8 -	45.0
45.0 -	336.4

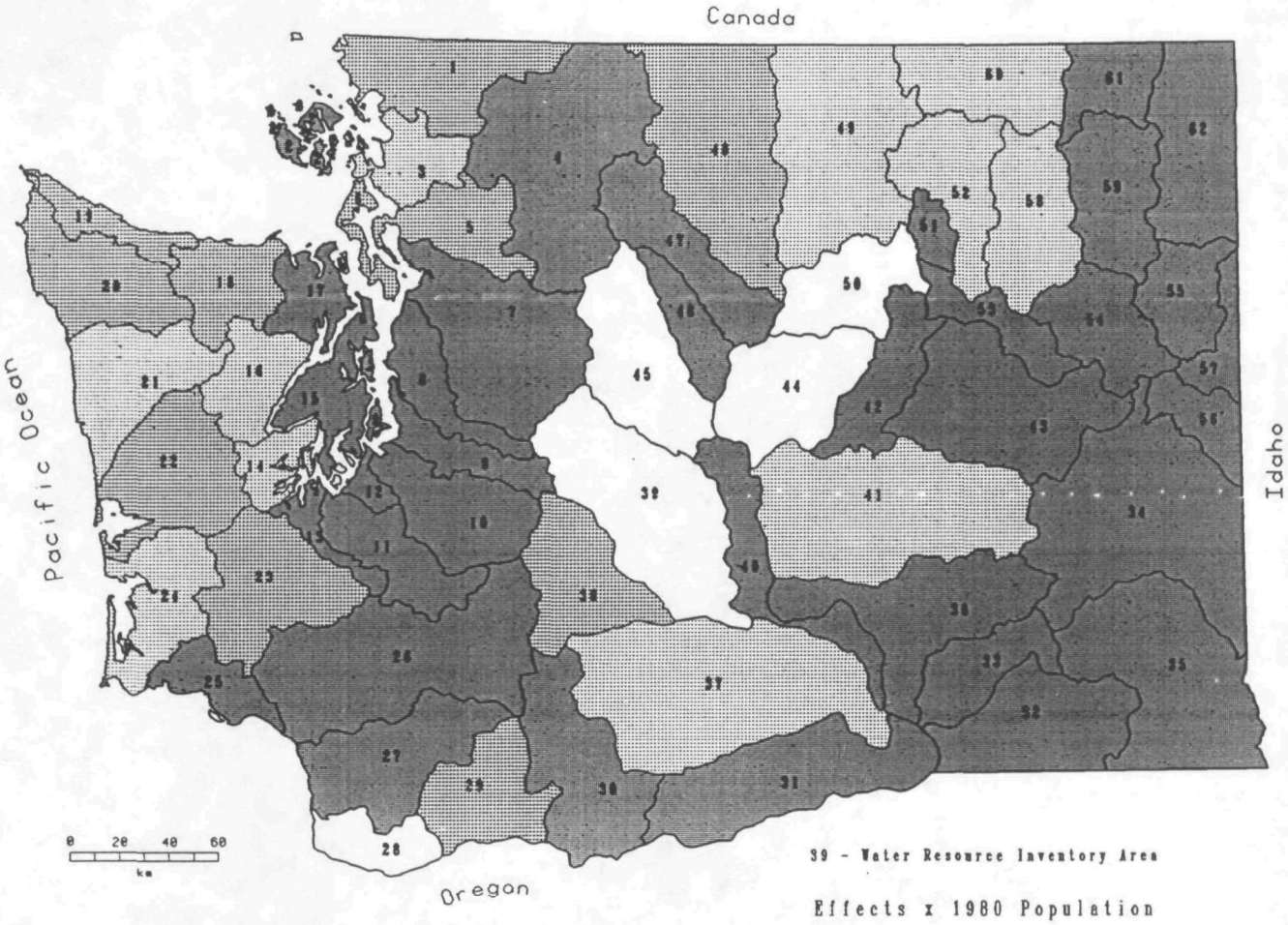
Figure IV.16

1 - 15.3	2 - UNDEFINED	3 - 0.7	4 - 0.0	5 - 38.7	6 - 21.5
7 - 171.2	8 - 336.4	9 - UNDEFINED	10 - UNDEFINED	11 - 92.5	12 - NO DATA
13 - 49.6	14 - 5.8	15 - 145.4	16 - 3.3	17 - UNDEFINED	18 - 0.0
19 - 37.0	20 - 0.0	21 - 1.4	22 - 6.4	23 - 40.7	24 - 4.2
25 - UNDEFINED	26 - 47.2	27 - UNDEFINED	28 - -19.1	29 - 1.3	30 - UNDEFINED
31 - NO DATA	32 - 48.2	33 - UNDEFINED	34 - 85.4	35 - UNDEFINED	36 - NO DATA
37 - 3.8	38 - 0.0	39 - -9.1	40 - NO DATA	41 - 0.4	42 - NO DATA
43 - NO DATA	44 - NO DATA	45 - -9.9	46 - UNDEFINED	47 - UNDEFINED	48 - 0.0
49 - 1.3	50 - NO DATA	51 - NO DATA	52 - 6.2	53 - NO DATA	54 - UNDEFINED
55 - 131.3	56 - UNDEFINED	57 - UNDEFINED	58 - NO DATA	59 - UNDEFINED	60 - 2.7
61 - NO DATA	62 - UNDEFINED				

[Water Resource Inventory Area]

Prepared by USEPA Wetlands Research Program, USEPA Environmental Research Lab, Corvallis, Oregon

LIFE SUPPORT SIGNIFICANCE TO HUMANS



39 - Water Resource Inventory Area

Effects x 1980 Population

-195 -	0
0 -	50
50 -	280
280 -	3935

Figure IV.17

1 - 236	2 - UNDEFINED	3 - 6	4 - 1903	5 - 184	6 - 86
7 - 3109	8 - 3935	9 - UNDEFINED	10 - UNDEFINED	11 - 925	12 - UNDEFINED
13 - 661	14 - 46	15 - 1899	16 - 30	17 - UNDEFINED	18 - 237
19 - 185	20 - 52	21 - 11	22 - 72	23 - 244	24 - 46
25 - UNDEFINED	26 - 472	27 - UNDEFINED	28 - -193	29 - 76	30 - UNDEFINED
31 - 977	32 - 337	33 - UNDEFINED	34 - 598	35 - UNDEFINED	36 - 477
37 - 34	38 - 248	39 - -160	40 - UNDEFINED	41 - 4	42 - UNDEFINED
43 - UNDEFINED	44 - -98	45 - -118	46 - UNDEFINED	47 - UNDEFINED	48 - 96
49 - 16	50 - -1	51 - UNDEFINED	52 - 25	53 - UNDEFINED	54 - UNDEFINED
55 - 656	56 - UNDEFINED	57 - UNDEFINED	58 - 23	59 - UNDEFINED	60 - 19
61 - UNDEFINED	62 - UNDEFINED				

[Water Resource Inventory Area]

Prepared by USEPA Wetlands Research Program, USEPA Environmental Research Lab, Corvallis, Oregon

APPENDIX V. Rankings of hydrologic units for hydrology, water quality, and life support cumulative effects.

Rank	Hydrology Unit	Hydrology Value	Water Quality Unit	Water Quality Value	Life Support Unit	Life Support Value
1	45	-165.245	12	NO DATA	39	-4.010
2	28	-102.264	31	NO DATA	28	-3.371
3	39	-87.512	36	NO DATA	45	-2.998
4	44	-30.715	40	NO DATA	44	-2.103
5	50	-0.239	42	NO DATA	50	-0.029
6	41	8.760	43	NO DATA	41	1.070
7	37	59.098	44	NO DATA	3	3.531
8	3	115.905	50	NO DATA	37	4.193
9	49	125.684	51	NO DATA	38	4.299
10	32	126.782	53	NO DATA	16	4.701
11	38	157.823	58	NO DATA	21	9.514
12	31	303.196	61	NO DATA	6	9.765
13	16	386.385	28	-0.333	14	10.771
14	58	403.658	45	-0.250	32	11.893
15	36	482.614	39	-0.228	49	12.736
16	55	527.130	4	0.000	29	16.994
17	60	636.834	18	0.000	60	19.914
18	34	639.944	20	0.000	5	21.340
19	52	704.145	38	0.000	20	21.962
20	29	812.081	48	0.000	22	22.203
21	6	965.118	41	0.107	58	25.867
22	13	1008.363	29	0.298	55	25.918
23	5	1043.738	3	0.392	24	30.449
24	11	1080.582	37	0.466	26	31.299
25	21	1131.079	16	0.515	36	41.944
26	8	1178.487	49	1.061	52	42.250
27	22	1195.298	21	1.220	34	47.907
28	26	1276.895	14	1.359	23	51.012
29	14	1321.734	22	1.655	11	59.089
30	24	1939.189	32	1.699	31	64.439
31	23	2447.272	6	2.441	8	67.549
32	20	2634.612	24	2.768	1	78.761
33	1	2923.109	60	2.845	13	80.193
34	48	3603.318	26	3.130	15	102.588
35	7	5246.556	5	4.268	7	107.521
36	18	12033.100	1	5.121	19	112.007
37	15	12070.530	55	5.184	18	120.814

APPENDIX V. Continued.

Rank	Hydrology		Water Quality		Life Support	
	Unit	Value	Unit	Value	Unit	Value
38	19	15039.970	8	5.775	48	134.006
39	4	31492.910	11	5.909	4	176.851
40	2	UNDEFINED	7	5.918	2	UNDEFINED
41	9	UNDEFINED	13	6.011	9	UNDEFINED
42	10	UNDEFINED	34	6.844	10	UNDEFINED
43	12	UNDEFINED	15	7.852	12	UNDEFINED
44	17	UNDEFINED	23	8.502	17	UNDEFINED
45	25	UNDEFINED	52	10.563	25	UNDEFINED
46	27	UNDEFINED	19	22.401	27	UNDEFINED
47	30	UNDEFINED	2	UNDEFINED	30	UNDEFINED
48	33	UNDEFINED	9	UNDEFINED	33	UNDEFINED
49	35	UNDEFINED	10	UNDEFINED	35	UNDEFINED
50	40	UNDEFINED	17	UNDEFINED	40	UNDEFINED
51	42	UNDEFINED	25	UNDEFINED	42	UNDEFINED
52	43	UNDEFINED	27	UNDEFINED	43	UNDEFINED
53	46	UNDEFINED	30	UNDEFINED	46	UNDEFINED
54	47	UNDEFINED	33	UNDEFINED	47	UNDEFINED
55	51	UNDEFINED	35	UNDEFINED	51	UNDEFINED
56	53	UNDEFINED	46	UNDEFINED	53	UNDEFINED
57	54	UNDEFINED	47	UNDEFINED	54	UNDEFINED
58	56	UNDEFINED	54	UNDEFINED	56	UNDEFINED
59	57	UNDEFINED	56	UNDEFINED	57	UNDEFINED
60	59	UNDEFINED	57	UNDEFINED	59	UNDEFINED
61	61	UNDEFINED	59	UNDEFINED	61	UNDEFINED
62	62	UNDEFINED	62	UNDEFINED	62	UNDEFINED

APPENDIX VI. A synoptic approach to wetland planning in small watersheds: Mill Creek feasibility analysis.

Representatives from the Wetlands Research Program at the Corvallis Environmental Research Laboratory met with U.S. Environmental Protection Agency (EPA) Region 10 and the State of Washington's Department of Ecology (DOE) staff in July, 1989 to discuss the application of the synoptic approach in the development of state water quality standards protective of wetlands. Interest in using concepts from the approach to develop more detailed analyses was expressed. The DOE wanted to identify the types of information and procedures needed for a statewide wetland inventory. The Region's interest was in developing a high resolution comprehensive approach for evaluating small watersheds targeted as critical "clean up areas." This section of the Washington pilot study addresses those interests.

The objective of this feasibility analysis was to examine the feasibility of using the synoptic approach for wetland planning in a small watershed. Specifically, the goal was to determine whether the approach could be used to develop an ecosystem management strategy for protecting the hydrologic, water quality and life support functions of wetlands.

The Mill Creek Drainage Basin (Fig. VI.1) in southern King County, Washington, was chosen for this effort to complement concurrent planning studies in the basin funded, in part, by EPA Region 10 (U.S. EPA 1989). Several government agencies (federal, state and local) are participating in the study of Mill Creek because it is one of the more pristine areas of southern King County, has a relatively high percentage of wetlands (ca. 21% of the land area), and is under great development pressure from surrounding communities (Eric Stockdale, pers. comm.)

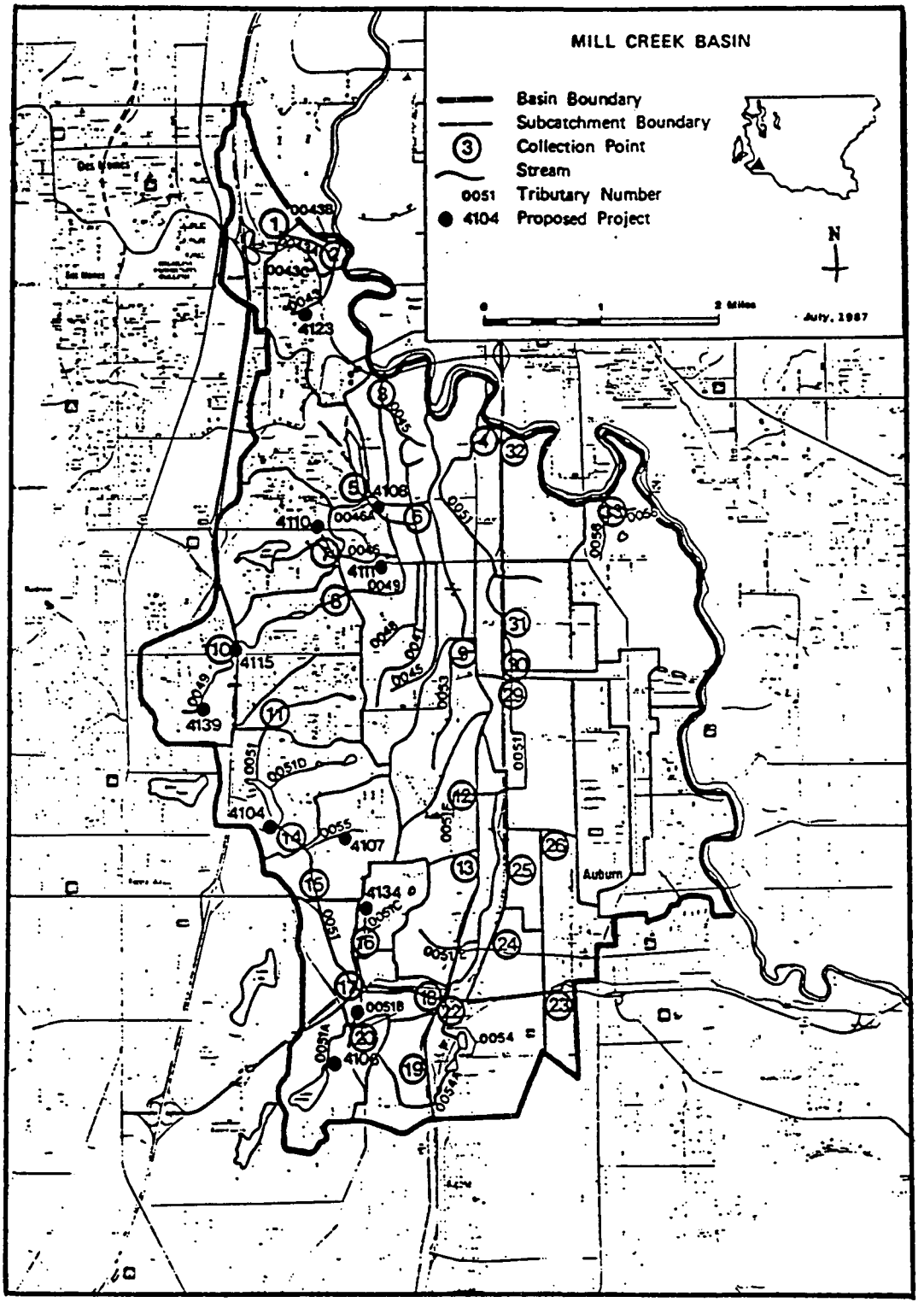
APPROACH

The approach to this analysis consisted of identifying the data requirements particular to the scale of study, contacting the appropriate agencies for data sources and ongoing studies of Mill Creek, and developing a plan for the analysis of wetland landscape data.

SCALE CONSIDERATIONS

The synoptic approach is based on the assumption that data can be organized and summarized to characterize the extent of processes affecting landscape function (landscape inputs), the contribution of wetlands to enhancing landscape function (wetland capacity), and the extent of impacts to wetlands (cumulative impacts). The synoptic framework can be applied at a variety of geographic scales and thus is independent of scale (Abbruzzese et al. submitted). However, the type of data required is dependent on the scale of analysis. The method assumes that the contribution of different ecosystems to landscape function is independent of ecosystem location. For example, wetland capacity is estimated

Figure VI.1 Mill Creek Drainage Basin



using total wetland area alone, without considering location, since locational information requires a greater level of analysis. This assumption will be valid as long as the watershed is large enough so that site specific effects become negligible, or as long as any site specfic effects are consistent between watershed units, allowing them to be ignored. At the regional or watershed scale, these conditions should be met. At the subwatershed level, however, the area of a unit may not be large enough to dampen site specific effects, and thus spatially explicit data are necessary. For example, the effects of bridges, roads, and sewer outfalls on local hydrology and water quality become critical at the local level. In addition, since more detailed data sources may be available at the county or local scale than at the state or national scale, these sources should be considered in selecting surrogates for the indices of wetland function and impacts.

IDENTIFICATION OF DATA SOURCES

A variety of agencies were contacted to identify potential data to serve as surrogates for the synoptic indices, including: EPA Region 10, the Corps of Engineers (COE)--Seattle District, Washington DOE and Department of Natural Resources, Puget Area Council of Governments, King County Planning and Surface Water Management Divisions, University of Washington and the Municipality of Metropolitan Seattle. It appears that adequate data exist, or are being generated, to characterize and develop management strategies for the Mill Creek watershed. Coordination of the agencies managing Mill Creek and integration of their research efforts is probably the most important need. Following is a list of data sources identified for each synoptic index:

Hydrologic Input--

A. Hydrologic data on discharge for sub-basins as it becomes available through the COE for the Special Area Management planning process.
B. Runoff potential--Hydrologic soil groups from King County Soil Survey (U.S. Department of Agriculture, Soil Conservation Service. Map scale 1:20,000). Land use/Land Cover from King County land use maps. Map scale 1:2,000.
C. Slope and channel length--U.S. Geological Survey topographic maps. Map scale 1:24,000.
D. Hydrologic modifications--COE and Public Works departments of King County and cities of Auburn and Kent.

Water Quality Input--

A. Point and Non-point water quality data--Municipality of Metropolitan Seattle (range of variables measured monthly or annually since 1970's at mouth of Mill Creek), King County Surface Water Management Division (monitoring of Mullins Slough and outfalls into Mill Creek), Green River Community College (monitoring of physical, biological, and chemical variables at four points in Mill Creek watershed since 1987).

B. Locations of point and non-point pollutant source areas--King County Planning Department (Wetland Inventory, Land Use maps, High Erosion Potential maps).

Life Support Input--

A. Observed plant and animal species--King County Wetland Inventory conducted in accordance with Sensitive Areas Ordinance.

B. Rare, threatened or endangered species--Department of Natural Resources Heritage Program and Department of Wildlife Non-game data system.

Wetland Capacity

A. Wetland area and type--U.S. Fish and Wildlife Service National Wetland Inventory maps. Map scale 1;24,000.

C. Storage capacity, water quality improvement capacity and habitat quality--ratings for all wetlands, based on collected data, provided in King County Wetland Inventory.

D. Flood prone areas--King County Comprehensive Plan

Cumulative Impacts--

A. Current wetland area--as described under Wetland Capacity above.

B. Original wetland area--hydric soil area from King County soil survey.

Future Loss--

A. Population--Puget Sound Council of Governmnents--census tract data and population projections for the next thirty years.

B. Land Use--Data on zoning and planned land use patterns and recent land use trends, population growth--King County Planning Department Comprehensive Plan.

PLAN FOR ANALYSIS OF WETLAND LANDSCAPE DATA

OBJECTIVE

The objective of the analysis is to develop an ecosystem management strategy to protect wetland functions, specifically to:

1. Characterize the wetland population.
2. Locate wetlands providing hydrologic, water quality and life support functions.
3. Characterize threat to wetland function.
4. Identify areas where wetland creation would be most useful.

METHOD

1. Collect data and map, by sub-watershed, to characterize synoptic indices of hydrologic, water quality, and life support inputs, wetland capacity, cumulative impacts and future loss from data sources identified.

2. Create map overlays depicting range of values for each index, manually or with a Geographic Information System.

3. Delineate areas, watersheds or other units, of relative homogeneity relative to wetland function (e.g. areas with excess capacity, areas where capacity is exceeded, areas sensitive to future loss).

4. Develop matrix with criteria for protection, wetland restoration and enhancement, etc.

5. Comparatively rank subunits according to criteria developed.

CONCLUSION

This feasibility analysis suggests that adequate data do exist for the Mill Creek watershed to be used in a synoptic approach assessment for wetland planning. An assessment at this scale would contribute information useful to fine tuning the synoptic approach. It should be kept in mind, however, that in performing an analysis at the subwatershed scale, particular attention will have to be focused on determining any site specific factors that might be so important as to overwhelm the general trends described by a synoptic approach.

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Abbruzzese, B., S.G. Leibowitz, F.L. Morris, P.R. Adamus, C.B. Johnson, and E.M. Preston. 1990. A synoptic approach to the assessment of cumulative effects of wetland loss on landscape function. Submitted to Environmental Management.

Stockdale, Eric, King County, Washington, Planning and Community Development Division, personal communication, 1990.

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