Component IV
Hydrology and Water Use

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Component IV
Hydrology and Water Use

INTRODUCTION

The Watershed Fundamentals component of this manual presents an overview of the natural hydrologic cycle and potential impacts of human activities. Alterations to the natural hydrologic cycle potentially cause increased **peak flows**[1] and/or reduced **low flows** resulting in changes to water quality and aquatic ecosystems. The degree to which hydrologic processes are affected by land use depends on the location, extent, and type of land use activities. When potential impacts are recognized, **best management practices** (BMPs) can be followed to minimize some of the potential hydrologic impacts; mitigation will be necessary to address other impacts.

Evaluating potential impacts from land and water use on the **hydrology** of a watershed is the focus of this component. It is important to recognize that hydrologic processes are complicated; we have attempted to provide enough direction for you to identify how land uses may be affecting your watershed's hydrology. Figure 1 provides an overview of the steps you will be following to complete the Hydrology and Water Use Assessment component. This assessment does not attempt to address every hydrologic process potentially affected; the goal is to gain an understanding of the major potential impacts.

The assessment process is separated into two sections (Figure 1). Section I characterizes the hydrology of the watershed and assesses the locations and type of potential impacts. Section II evaluates the consumptive water uses and identifies locations and types of potential impacts associated with water use. Each section may be completed independently by different people who collaborate at the end to complete a map of potential hydrologic impacts and reaches of water use concerns. Appendix IV-A contains all the forms necessary to complete both sections of the assessment. Appendix IV-B includes reference tables to help complete the forms. Appendix IV-C provides information on resources to obtain necessary data. Finally, Appendix IV-D provides additional background information on how land uses can impact the hydrologic function of a watershed, and information on water rights law.

LINKAGES TO OTHER COMPONENTS

Information on peak-flow history in the watershed (Step 3) will be used in the Historical Conditions Assessment component. Withdrawal of water from a stream during the driest and hottest times of the year potentially stresses aquatic organisms. Information from the Fish and Fish Habitat Assessment component will be required to determine specific stream reaches that are sensitive to water use impacts. The Water Quality and Riparian/Wetlands assessments require an understanding of the hydrology and water use in the watershed.

During the Watershed Condition Evaluation component, subwatersheds where potential hydrologic impacts are identified will be evaluated for evidence of channel response (i.e., widening, loss of complexity, etc.) to changes in flow.

[1] Terms that appear in bold italic throughout the text are defined in the Glossary at the end of this component.

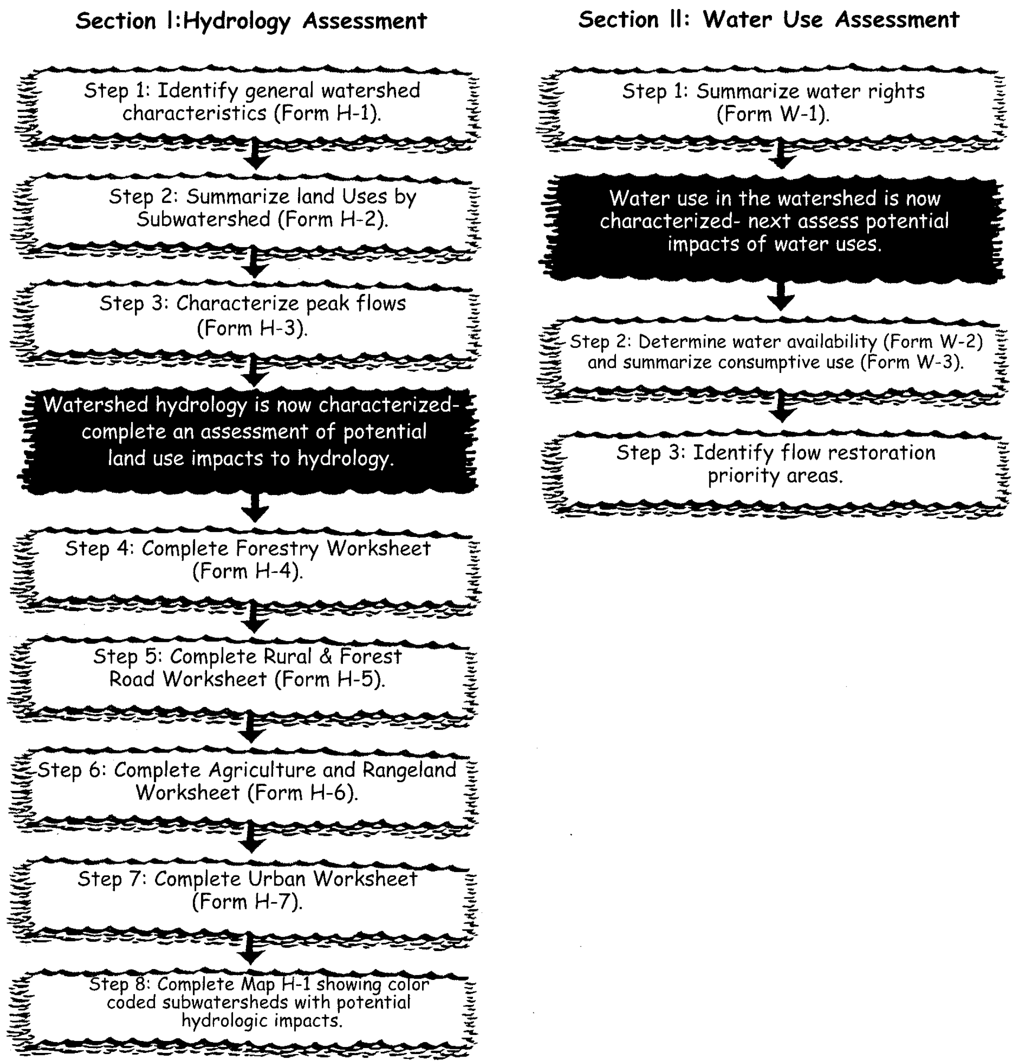

Figure 1. The screen for potential forestry impacts on hydrology focuses on timber harvest in this step and follows the pathways shown in this flow chart. Subwatersheds that end up in the shaded box at the bottom left have the potential for peak-flow impacts from forestry.

SECTION I: HYDROLOGY

Critical Questions

1. What land uses are present in your watershed?
2. What is the flood history in your watershed?
3. Is there a probability that land uses in the basin have a significant effect on peak flows?
4. Is there a probability that land uses in the basin have a significant effect on low flows?

Assumptions

- Urbanization (including industrial use), agriculture, range-land use, and forestry are the primary land uses that may impact hydrology.

- Peak flows and low flows are the hydrologic processes most significantly impacted by land use activities.

- Hydrologic soil condition is an indicator of **infiltration** rate.

- **Groundwater** impacts are implicitly addressed through the changes in infiltration rates.

- In forested basins, the greatest potential for peak-flow increases over background conditions are due to road rerouting of water and changes in snow accumulation and melt in harvested areas during **rain-on-snow events**.

- The decreased **evaporation** and **transpiration** from tree removal more than offset the reduced infiltration; therefore, low flows tend to increase in the short-term due to forest harvesting.

- BMPs to mitigate peak-flow impacts will also mitigate low-flow impacts from agricultural and urban land uses.

- Impervious surfaces and roads are good indicators of urbanization and subsequent impacts to the hydrology of a watershed.

Materials Needed

- Watershed Base Map (from Start-Up and Identification of Watershed Issues component)

- Refined Land Use Map with subwatersheds identified (from Start-Up and Identification of Watershed Issues component)

- **Ecoregion** map for the watershed (from Start-Up and Identification of Watershed Issues component)

- Aerial photographs and/or **orthophoto** quadrangle maps (most recent)

- Mean annual precipitation map, available from one of the sources listed in the box below

- Map of *2-year, 24-hour precipitation* (Miller et al. 1973). This map is available on line at the Desert Research Institute, Western Regional Climate Center (see list in the box below for Internet address), or can be ordered (for a cost of $9) from National Weather Service Office of Hydrology, W/OH2 Station 7144, 1325 East-West Highway, Silver Spring, MD 20910; (301) 713-1669.

Oregon Climate Service	**Desert Research Institute**	**State Service Center for GIS**
Strand Hall, Room 326	Western Regional Climate Center	Dept. of Administrative Services
Oregon State University	P.O. Box 60220	155 Cottage Street NE
Corvallis, OR 97331-2209	Reno, NV 89506-0220	Salem, OR 97310
(541) 737-5705	(702) 677-3143	(503) 378-2166
Internet address:	*Internet address:*	*Internet address:*
http://www.ocs.orst.edu/	http://www.wrcc.dri.edu/	http://www.sscgis.state.or.us/

STREAMFLOW DATA SOURCES	
USGS Portland District Office 10615 SE Cherry Blossom Drive Portland, OR 97216 (503) 251-3265 *Internet address:* http://wwworegon.wr.usgs.gov/	• Digital data available at Web site • US Geological Survey, Open-File Report 90-118, "Statistical Summaries of Streamflow Data in Oregon: Volume 1: Monthly and Annual Streamflow, and Flow-Duration Values" • US Geological Survey, Open-File Report 93-63, "Statistical Summaries of Streamflow Data in Oregon: Volume 2: Annual Low and High Flow, and Instantaneous Peak Flow" Prepared in cooperation with the Oregon Water Resources Department (OWRD, 1993).
Oregon Water Resources Department 158 12th Street NE Salem, OR 97310 (503) 378-8455 *Internet address:* http://www.wrd.state.or.us/	• Digital data available at Web site

- Daily average and peak streamflow data and map of streamflow collection sites. Available from the sources listed at the top of this page.

- Natural Resources Conservation Service (NRCS) county soil survey. Your local library or county extension agent will probably have copies. If not, order a copy from the State Conservationist, Federal Building Room 1640, 1220 SW 3rd Avenue, Portland, OR 97204-3221; (503) 414-3201s; Internet address http://www.statlab.iastate.edu/soils/nssc/

- Other relevant published reports and/or unpublished documents from city, county, state, or federal agencies or private consultants (local, regional, or statewide), such as Basin Plans written by the Oregon Water Resources Department (OWRD) and others.

Necessary Skills

Characterization of watershed hydrology requires mathematical, statistical, and technical tools. The analyst would benefit from a familiarity with computer spreadsheets and/or use of a calculator, as well as an understanding of simple statistics such as the mean (or average) and ratios. Internet access will provide the analyst with more readily available sources of data.

Final Products of the Hydrology Section

Form H-1: General Watershed Characteristics
Form H-2: Land Use Summary
Form H-3: Annual Peak Flow Summary
Form H-4: Forestry Worksheet
Form H-5: Agriculture and Range Land Worksheets
Form H-6: Forest and Rural Road Worksheet
Form H-7: Urban and Rural Residential Worksheet
Form H-8: Hydrologic Issue Identification Summary
Map H-1: Potential Risks of Land Use on Hydrology

Hydrologic Condition Characterization

Step 1: Identify General Watershed Characteristics (Form H-1)

For each subwatershed, fill in the information requested on Form H-1. This form is designed to help you compile watershed-specific information that relates to the local hydrology. You will identify basic watershed features such as drainage area, minimum and maximum **elevations**, and mean annual precipitation. If you have **Geographic Information System** (GIS) support, some of the information can be calculated using GIS. Otherwise, use the Watershed Base Map or US Geological Survey (USGS) topographic maps and a map of mean annual precipitation to find the information. Subwatershed drainage areas can be estimated by using GIS, a **planimeter,** or the grid method described in the Start-Up and Identification of Watershed Issues component.

Step 2: Summarize Land Uses in the Watershed (Form H-2)

Enter the estimated areas of each land use in each subwatershed onto Form H-2. Consult the Refined Land Use Map from the Start-Up component to identify the different land uses present in the watershed and subwatersheds. The areas in each land use can be either estimated using GIS, a planimeter, or the grid method.

Step 3: Characterize Peak Flows (Form H-3)

The purpose of this step is to identify the peak-flow-generating processes within your watershed and to graph the peak-flow history over time. Identification of the peak-flow-generating processes are needed to complete the hydrologic condition assessment (page 8), and will help you understand the type of conditions that generate peak flows in your watershed. Compiling and graphing information on flood history will provide context for understanding the extent of channel disturbance found in your watershed, help you to understand the cycles of flooding in the watershed, and confirm or dispel public perceptions about flood history.

Identifying Peak-Flow-Generating Processes

The Ecoregion Appendix provides information on peak-flow-generating processes by elevation zone within each ecoregion of Oregon. For watersheds located in western Oregon you can also check to see if any stream gage(s) in your watershed were analyzed in the hydrologic process identification study conducted by Greenberg and Welch (1998). Using the ecoregion map and the base map (showing subwatersheds), estimate the acres and percent area in each subwatershed that fall into one of the following peak-flow-generating processes categories: rain (including thunderstorms), rain-on-snow, **spring snowmelt**. Record this information on Form H-3.

Graphing Peak-Flow History

Identify the USGS streamflow gage(s) that are in or near your watershed (see streamflow data sources in the Materials Needed section and Appendix IV-C). Some watersheds in Oregon contain one or more stream gages while many unfortunately have none. If no gage is or was present in your watershed, find the closest gages in adjacent watersheds in the same ecoregion. Gages located in adjacent watersheds will not necessarily be representative of conditions in your watershed (see Criteria sidebar at the top of page 8). The USGS Web site is a good starting point to find stream gages in your area. (Gages are listed by county and river basin, and close-up maps can be viewed

CRITERIA* FOR GAGE SELECTION FOR RECORD EXTENSION OR UNGAGED BASINS

1) Basin areas within same order of magnitude
2) Similar mean basin elevation above gage
3) Similar precipitation
4) Similar geology and topography
5) No or insignificant out-of-stream diversions

* Robison 1991.

online that show gage location.) Records of peak flow can also be downloaded from the USGS Web site. The **annual peak flow** series (through 1995) have also been compiled for selected gages in western Oregon by Greenberg and Welch (1998) and may be adequate for this portion of the assessment.

To obtain representative data for a watershed, the gage records should be at least 10 years in length. It is not necessary that the **gaging station** be currently in operation. Historic records can be extremely useful data sources. Gage records should represent unregulated streamflow; a gage downstream of a reservoir will not record natural peak flows, but will reflect the modified streamflow.

On Form H-3, list in chronological order the **water year**[2], peak-flow amount, and date of peak flow for each of the annual peak-flow events. Use additional copies of Form H-3 if more than one gage is located in your watershed. Also on Form H-3, rank each peak flow with a number from highest to lowest (i.e., the largest peak flow is assigned the number 1). Alternatively, the **recurrence interval** associated with each peak flow can be given in place of the ranking. Recurrence intervals may be available for the gage records in your area (see streamflow data sources in the Materials Needed section), or you could calculate them, although a discussion of determining recurrence intervals is beyond the scope of this document. Graph the annual peak flow using a spreadsheet, or use the blank graph provided on Form H-3.

Hydrologic Condition Assessment

The hydrologic condition assessment is a "screening" process designed to identify land use activities that have the **potential** to impact the hydrology of your watershed. The techniques presented here are not definitive; more technical analyses are necessary to determine the magnitude of impacts. For instance, this manual uses a simple percentage of watershed in roads as an indicator of peak-flow increase potential but, in reality, the condition and location of roads is at least as or more important than the quantity of roads. Roads that are on ridge-tops or not hydrologically connected to stream channels, because they use adequate drainage, should not contribute as much to change the hydrology as a "well-connected road." The techniques listed in this document can be used to assess whether the potential problems may increase peak flows or reduce low flows. If, at the end of this assessment, the watershed council believes that land uses have a probability of impacting flows, they may choose to pursue more definitive assessment techniques.

We have developed a simple set of methods to prioritize those subwatersheds most likely to need restoration from a hydrologic perspective. Because hydrology is such a complex subject, the screening process only deals with the most significant hydrologic process affected by land use (i.e., **runoff**). Four separate worksheets were developed to evaluate land uses in the watershed:

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2 A water year is measured from October 1 of the previous year through September 30 of the current year. For example, water year 1960 started on October 1, 1959, and ended on September 30, 1960.

1. Forestry
2. Agriculture and range lands
3. Forest and rural roads
4. Urban and/or rural residential development

Figure 1 illustrates the steps to work through depending on the land uses in your basin. You need not fill out the worksheets for those land uses not present in your watershed. The potential risks from land uses on hydrology will be summarized on Form H-8. Form H-8 can be used, in conjunction with other assessments in this manual, to determine potential restoration opportunities. Special attention should be made to connecting the hydrologic information to the Channel Modification Assessment component. If potential peak-flow problems are identified in a subwatershed, the first step would be to cross-reference with the Channel Modification analyst to determine whether there is corroborating evidence of channel changes in the stream. Hydrologic impacts to aquatic resources are, to a large degree, a function of the **Channel Habitat Type** (CHT). Some CHTs can withstand large changes in flow without substantial change to the hydraulic characteristics, whereas others are very susceptible to peak-flow changes. If low-flow problems are identified, corroborating evidence of channel dewatering should be obtained.

Step 4: Complete Forestry Worksheet (Form H-4)

The screen for potential forestry impacts on hydrology focuses on timber harvest in this step and follows the pathways shown in the flow chart presented in Figure 2. Record your answers on Form H-4. Any subwatersheds that end up in the shaded box at the bottom left of the flow chart have the potential for peak-flow impacts from forestry. Timber harvest in the Rocky Mountains has been found to produce increased spring snowmelt peak flows (Troendle and King 1985); however, it is unknown if the underlying processes would be the same in the moister, more maritime conditions that are found in Oregon. If your watershed is in an area in which spring snowmelt produces the annual maximum flows, you may wish to consider some alternative analysis beyond the scope of this methodology.

Before starting the forestry worksheet, **first read through the tasks listed below**. This will help you be more efficient in answering all the questions found in the flow chart in Figure 2. Refer back to the flow chart to gain an overall perspective on where these steps are leading you. Use the information you collected on earlier forms (where available) to help you with the tasks. Also have Form H-8 handy.

Task 1: Identify the peak-flow-generating processes for each subwatershed. Using Form H-3, note the percent area in each subwatershed that is in the rain, rain-on-snow, and spring snowmelt categories. If more than 75% of any subwatershed is in the rain category mark Column 5 on Form H-4 as low potential risk of peak-flow enhancement (WFPB 1997). If all subwatersheds are more than 75% in the rain category, skip the remainder of this step and go on to Step 5. If more than 75% of any subwatershed is in the spring snowmelt category, mark Column 5 on Form H-4 as unknown potential risk of peak-flow enhancement. If all subwatersheds are more than 75% in the spring snowmelt category, skip the remainder of this step and go on to Step 5.

Timber Harvest Assessment Tasks

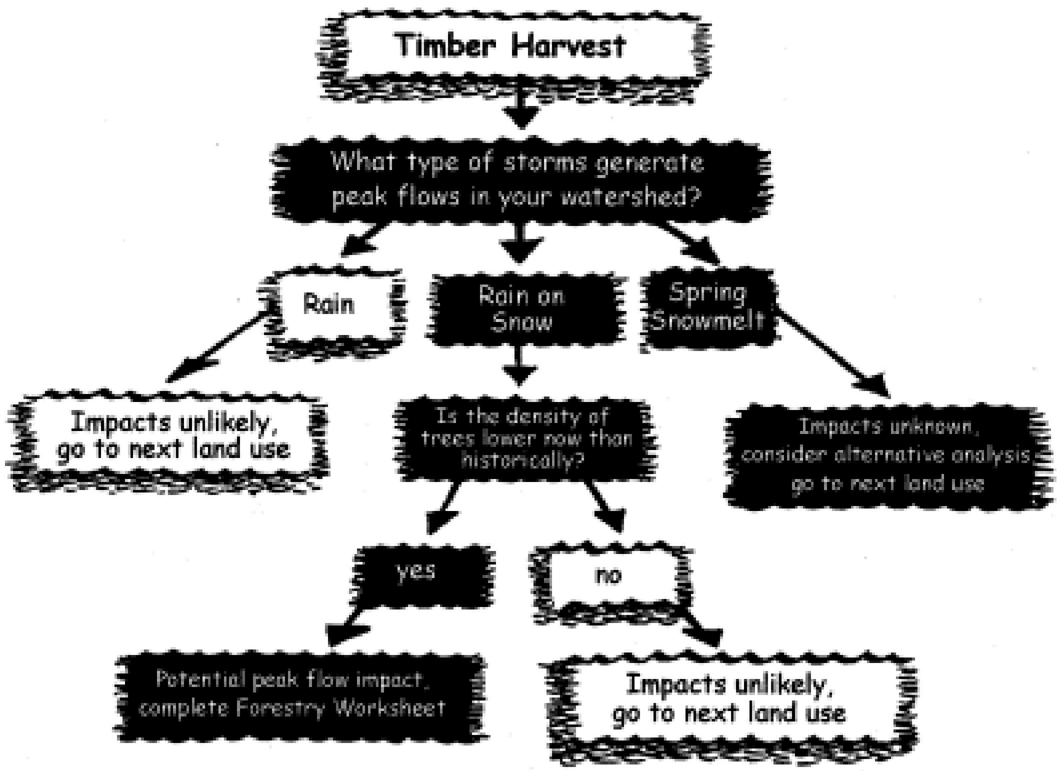

Figure 2. Overview of the steps you will be following to complete the Hydrology and Water Use Assessment component.

Task 2: For the subwatersheds that have not been eliminated in the previous task, estimate the **historic crown closure** for the portions of each subwatershed that are in the rain-on-snow areas, and record this information on Form H-4. (You may need to sketch the boundaries of the rain, rain-on-snow, and/or spring snowmelt areas on your base map. See the Ecoregion Appendix for guidance on how to define these areas). The Ecoregion Appendix includes historic crown closure estimates for each ecoregion in Oregon. Other possible sources to consult include US Forest Service (USFS) plant association documents or watershed analyses, or a local forester or fire ecologist (Oregon Department of Forestry [ODF] or private timber landowner) familiar with the lands in your watershed. If any subwatershed had less than 30% historic crown closure, mark Column 5 on Form H-4 as low potential risk of peak-flow increases. If all subwatersheds had less than 30% historic crown closure, skip the remainder of this step and go on to Step 5.

Task 3: For the subwatersheds that have not been eliminated in previous tasks, estimate the percent of the rain-on-snow areas that **currently** have less than 30% crown closure, and record this information on Form H-4. Use published information if possible, such as USFS watershed analyses or other watershed studies. If published information is not available, contact the forester (ODF and/or private timber companies) in charge of lands in the watershed of interest and request crown closure data; it is preferable that this information be derived from aerial photo coverage or ground inventory and not LANDSAT data. If crown closure coverage is not available from the landowners in the watershed, you will need to determine these areas by examining aerial photographs. If you are not familiar with viewing aerial photographs, consult with a technical specialist who can assist you with this step.

Task 4: Using the information you have entered on Form H-4, and Figure 3, estimate the risk of peak-flow enhancement for the remaining subwatersheds, and record this information on Form H-4. Also enter the results from Columns 4 and 5 onto Form H-8 Column 2.

The graph in Figure 3 is adapted from the Washington State Department of Natural Resources (1991) Interim Rain-on-Snow Rules. Although the graph was derived for Washington State, it was developed using rules of thumb applicable to the Pacific Northwest. For the purpose of screening forested areas of hydrologic concern in Oregon, the risk classes used in the Washington graph were aggregated from three classes to two classes: low risk and potential risk. The boundary between the two classes was set at a lower threshold of concern, based on personal communication with the original author of the Washington graphs (Brunengo, personal communication, 1998). The lines were also tested using the Washington State Forest Practices Board rain-on-snow model for a watershed in the Rogue Basin and a watershed on the western slope of the Cascades in northern Oregon. The line appears to roughly represent peak-flow increases of 8 to 10%, which represents the lower boundary of detectability; the accuracy of good streamflow measurements are within 10% of the true value (USGS 1997) (WFPB 1997).

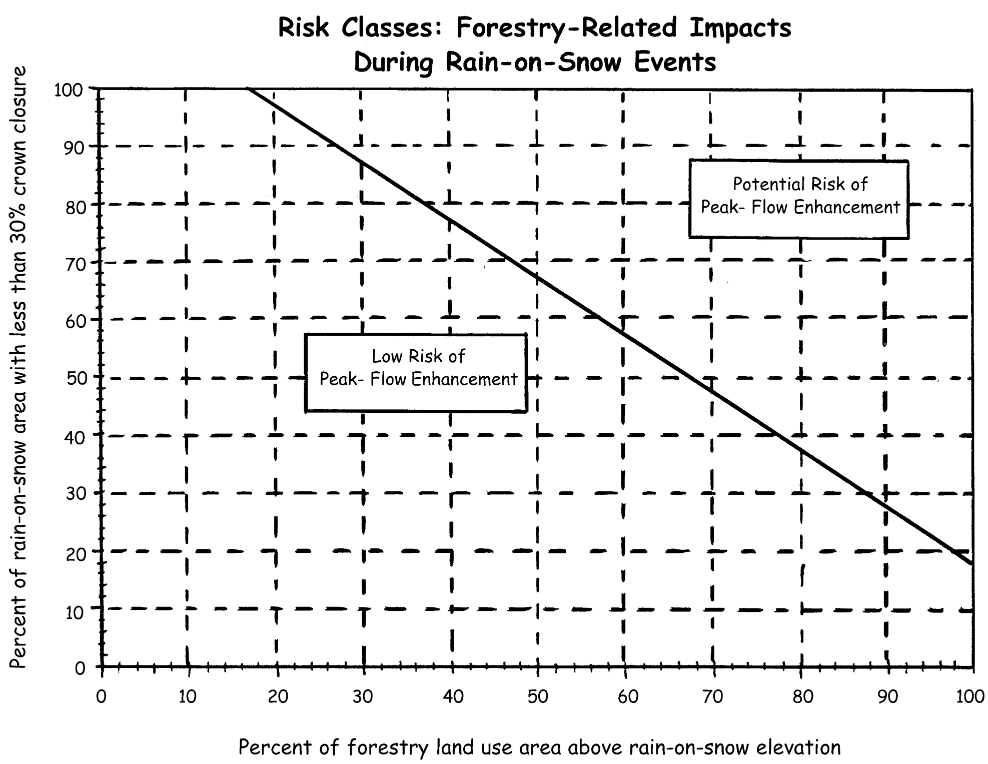

Figure 3. This graph is used to help you estimate the risk of peak-flow enhancement to subwatersheds from forestry-related impacts during rain-on-snow events.

Step 5: Complete Agriculture and Range-Land Worksheet (Form H-5)

The agricultural and range-land screening procedure (Figure 4) is designed to first identify **hydrologic soil groups** (HSG), cover types, and treatments occurring on agricultural lands and range lands in your watershed. Secondly, using tables from the US Department of Agriculture Natural Resources Conservation Service (NRCS) (formerly Soil Conservation Service) methods (USDA 1986), **runoff curve numbers** are assigned to each combination of three parameters: soil group, cover type, and treatment. The hydrologic response will be bracketed using both good hydrologic condition and poor hydrologic condition curve numbers. Comparisons between these runoff values and "background conditions" will serve as the basis for highlighting watersheds that may require further analysis of agricultural impacts.

Three reference tables providing runoff curve numbers are located in Appendix IV-B (Tables B-1 through B-3). The first two tables are for use in humid regions and the third table is for use in arid and semiarid range lands. There is one reference table (B-4) providing runoff depths for the combination of a curve number and a rainfall amount.

For more background information of agricultural and range-land impacts, please refer to Appendix IV-D. Before starting the worksheet, **first read through the tasks listed below**. Also have Form H-8 handy.

Task 1: Using the NRCS soil survey for your county, identify the hydrologic soil groups that are currently being farmed or grazed in your watershed and enter in Column 3 on Table 1 (Form H-5). Fill in Columns 1 and 2 on Table 1 (Form H-5) from Form H-2.

Task 2: Select the subwatershed with the highest percent in agricultural use or utilization of range lands. Complete Task 3 through Task 15 for each hydrologic soil group in this subwatershed.

Task 3: Identify the cover types and treatment practices for the primary hydrologic soil group occurring in the subwatershed selected in Task 2. Use soil survey maps and aerial photos, orthophotos, and anecdotal information from discussions with NRCS or Conservation District personnel (See Tables B-1 through B-3 in Appendix IV-B) to complete this task. Enter the results in Column 1 of Table 2 (Form H-5). (Use a separate Table 2 for each hydrologic soil group in each subwatershed.)

Task 4: The NRCS has defined hydrologic condition classes of good, fair, and poor. Determine the hydrologic condition of each cover type and treatment practice by referring to the footnotes in Tables B-1 through B-3. If conditions are unknown, the hydrologic response can be bracketed by using good and poor categories. Enter the results in Column 2 of Table 2 on Form H-5.

Task 5: Select a curve number using Tables B-1 through B-3 (Appendix IV-B) for the combination of information in Columns 1 and 2 of Table 2 of Form H-5. Enter the selected curve number in Column 3 of Table 2 of Form H-5.

Task 6: Background curve numbers can be determined from Tables B-1 and B-2 for humid regions and Table B-3 for arid/semiarid regions. The background curve number for humid regions may, in many cases, have been "woods" in "good" condition (see shaded row in Table B-2). If this is the case for your subwatershed, select the curve number for the proper hydrologic soil group. If the land was not historically wooded, select the appropriate cover type and associated curve number for the proper hydrologic soil group. Enter the results in Column 4 of Table 2 on Form H-5.

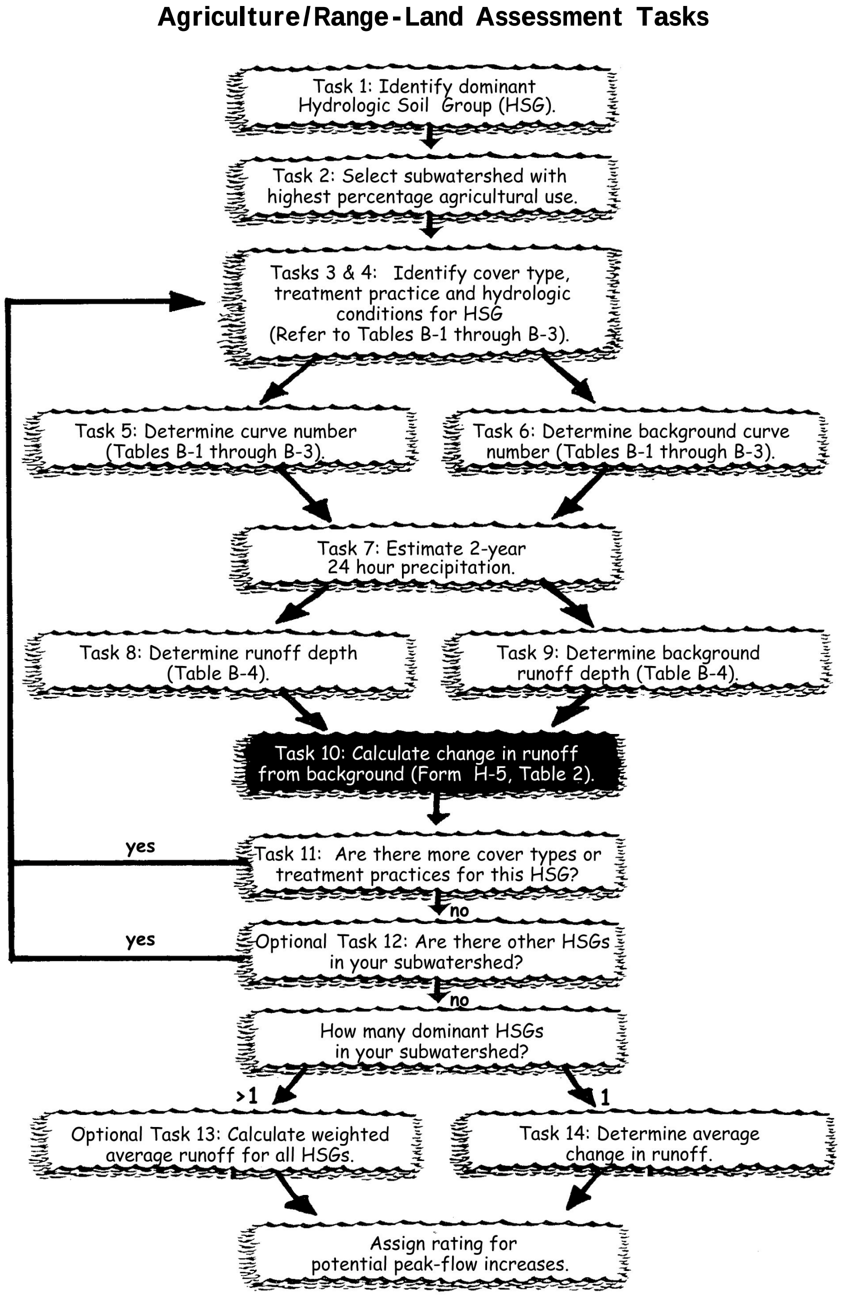

Figure 4. The agricultural and range-land screening procedure, which you will perform following these steps, helps you identify watersheds that may require further analysis of agricultural impacts.

Task 7: Estimate the 2-year, 24-hour precipitation (i.e., annual maximum 24-hour precipitation with a recurrence interval of 2 years or 50% probability of occurring in any given year) for each subwatershed. This information can be obtained from the map in Miller et al. (1973). See the Materials Needed section for information on how to obtain this map. Enter the results in Column 5 of Table 2 on Form H-5.

Task 8: Using the current curve number in Column 3 and rainfall depth in Column 5, read the runoff depth from Table B-4 for each cover type/treatment combination. Interpolate the values shown to obtain runoff depths for curve numbers or rainfall amounts not shown. Enter the results in Column 6 of Table 2 on Form H-5.

Task 9: Using the background curve number in Column 4 and rainfall depth in Column 5, read the runoff depth from Table B-4. Enter the results in Column 7 of Table 2 on Form H-5.

Task 10: Calculate the change in runoff depth from background conditions to current conditions using the following formula:

Column 8 = Column 6 – Column 7

Task 11: Calculate the average change from background for all the combinations of cover type/treatment and hydrologic condition. Add up Column 8 and divide by the number of rows. Enter the result in Column 3 of Table 3 on Form H-5. For that same row, transfer the percentage from Table 1 Column 3 A, B, C, or D to Column 2 of Table 3. If only one dominant hydrologic soil group is present in your subwatershed, go to Task 15 and disregard Columns 4, 5, and 6 on Table 3.

Task 12 (optional): If more than one hydrologic soil group is dominant in your subwatershed, repeat Tasks 3 through 11 and enter the result in Column 5 of Table 3. For that same row, transfer the percentage from Column 3 A, B, C, or D to Column 4 of Table 3.

Task 13 (optional): Compute the weighted average and enter the result in Column 6 of Table 3. For instance, if approximately 45% of agriculture occurs on hydrologic soil group A and 55% occurs on C, then the resultant averages will need to be weighted as follows:

Weighted average = (0.45 x average change from background on HSG A soils) + (0.55 x average change from background on HSG C soils)

Task 14: Using the subwatershed average change from background (Table 3, Column 3) or the weighted average (Table 3, Column 6), select the potential hydrologic risk from the table to the right and enter it into Column 7 of Table 3 on Form H-5.

Task 15: Enter the results in Columns 6 and 7 of Table 3 onto Form H-8 Columns 3 and/or 4. If the results for this subwatershed indicate a low potential for peak-flow enhancement and the distribution of HSGs is similar in the other subwatersheds, assume low potential in those subwatersheds. If the other subwatersheds show substantial differences in the distribution of HSGs then complete these steps for the next subwatershed with significant agriculture land use.

Potential Risk of Agriculture and/or Range Lands[1]

Change in Runoff From Background (inches)	Relative Potential for Peak-Flow Enhancement
Westside watersheds	
0 to 0.5	Low
0.5 to1.5	Moderate
>1.5	High
Eastside watersheds	
0 to 0.25	Low
0.25 to 0.75	Moderate
>0.75	High

1 Personal Communication (NRCS 1999)

Step 6: Complete Forest and Rural Road Worksheet (Form H-6)

The assessment of forest and rural roads relies on research from several small basins (39 to 750 acres) in the Oregon Coastal Range that documented significant increases (~20%) in peak flows (of smaller floods) after road building when roads occupied greater than 12% of the watershed (Harr et al. 1975). This study also found that in watersheds where roads occupied <5% of the basin, peak-flow changes due to roads were small, inconsistent, and statistically nonsignificant. Recent research from the University of Washington (Bowling and Lettenmaier 1997) documented that road networks in two western Washington watersheds significantly increased the channel network density and tended to show a corresponding increase in peak flows. This study revealed that roads can begin to impact streamflow (~ increase peak of 11%) at lower percent roaded area (estimated 3 to 4% of basin) than the 12% value found in Harr et al. (1975). Based on the range of roaded areas (4% and 12%) and associated peak-flow increases (11% and 20%) documented in these two studies, three categories have been established for the purpose of screening for road impacts to basin hydrology. This assessment assigned a threshold of concern (**high** potential for peak-flow enhancement) of 8% roaded area in order to screen for potential hydrologic impacts prior to a peak-flow increase of 20%. In other words, when the percent roaded area in a subwatershed exceeds 8%, road issues **may** cause hydrologic impacts and further investigation is warranted. A **moderate** category of potential hydrologic impact was established when roaded area occupies from 4 to 8% of a subwatershed, and a **low** potential was assigned to watersheds with roaded areas less than 4% of the total area of the subwatershed.

The focus of the road assessment is to determine the quantity of roads within the watershed but does not account for the condition of the roads. A more refined scale to separate out well-built roads that do not accelerate the delivery of water or sediment to the channel from roads that are poorly constructed is beyond the scope of this section. For example, extension of the surface-water drainage network by roadside ditches is often a major influence of increased flows. Roads with proper culvert placement and frequency may alleviate some of these impacts.

This worksheet is designed to guide you in determining what area of the forestry-designated portion of each subwatershed is occupied by roads, as well as by rural roads in agricultural or range-land areas, and to rate subwatersheds for potential hydrologic impacts. Before starting the worksheet, **first read through the tasks listed below and review Figure 5, which outlines the process**. Also have Form H-8 handy.

Task 1: Using the information from Form H-2, fill in Columns 1 through 3 of Tables 1 and 2 on Form H-6.

Task 2: From the Sediment Sources Assessment component, enter the total linear distance of forest roads in Column 4 of Table 1, Form H-6, and the linear distance of rural roads in Column 4, Table 2 of Form H-6.

Task 3: Determine the area of each subwatershed occupied by roads by multiplying Column 4 by the width of the road (in miles) on Tables 1 and 2. The average width can be determined by measurement of several sites in the field, or determine the width from recent aerial photographs or use a default width of 25 feet (0.0047 miles) for forest roads and 35 feet (0.0066 miles) for rural roads.

Task 4: Compute the percent of the subwatershed in roads by dividing the roaded area value in Column 5 by the forested or rural area in Column 3 and then multiply by 100 for both Tables 1 and 2. Enter the result in Column 6 of Tables 1 and 2, respectively, which represents the percent of the subwatershed occupied by roads.

Task 5: Assign a relative potential for forest and rural road impacts to each subwatershed using the table at lower right. Enter the risk into Column 7 of Tables 1 and 2, Form H-6. Watersheds with a high risk warrant further investigation of road issues.

Task 6: Enter the results in Columns 6 and 7 of Tables 1 and 2 onto Form H-8, Column 5 (Forest Roads) and Column 6 (Rural Roads).

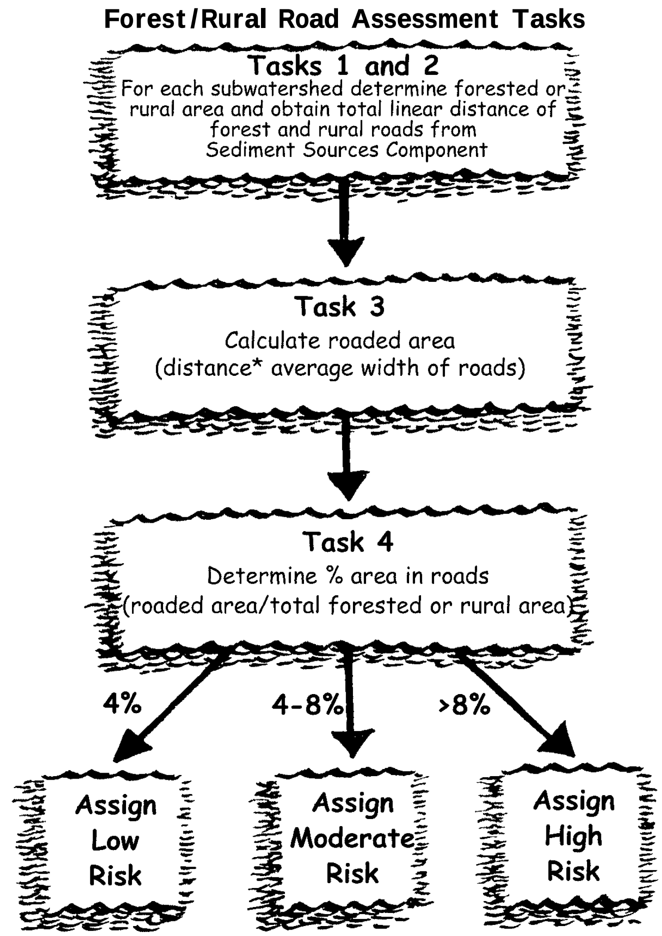

Figure 5. This procedure is designed to guide you in determining what area of the forestry-designated portion of each subwatershed is occupied by roads, as well as by rural roads in agricultural or range-land areas, and to rate subwatersheds for potential hydrologic impacts.

Step 7: Complete Urban and Rural Residential Worksheet (Form H-7)

The urban assessment relies on the results from several studies in which the percent of **imperviousness** in a watershed was related to stream quality. Research has identified that the altered hydrologic regime of a watershed under urban conditions is the leading cause of physical habitat changes (May et al. 1997). Schueler (1994) reviewed key findings from 18 urban stream studies relating urbanization to stream quality and concluded that stream degradation occurs at relatively low levels of imperviousness, around 10% Total Impervious Areas (TIA). May et al. (1997) recommends that for Puget Sound lowland streams in Washington, imperviousness must be limited (<5 to 10% TIA) to maintain stream quality, unless extensive riparian buffers are in place.

Potential Risk for Peak-Flow Enhancement

Percent of Forested Area in Roads	Potential Risk For Peak-Flow Enhancement
Less than 4%	Low
4% to 8%	Moderate
Greater than 8%	High

Estimating the area in each subwatershed that is impervious will be the basis for determining potential hydrologic impacts from urbanization. For the purpose of screening these urban impacts, this assessment assigns a high potential for impact to a subwatershed exceeding 10% TIA; when the percent impervious area in a subwatershed exceeds 10%, further investigation is warranted. A moderate potential for impact is assigned to subwatersheds with impervious percentages between 5 and 10%.

Imperviousness is the most common measure of watershed development; however, it can be a time-consuming exercise and costly to calculate percent TIA. If difficulties arise in estimating imperviousness, the extent of development can be expressed in terms of road density. May et al. (1997) established a relationship between watershed urbanization (in % TIA) and sub-basin road density (in mi/mi^2) which can be used to represent the percent imperviousness. Choose either Method 1: Impervious Area Calculation, or Method 2: Urban Road Density Calculation, and proceed to the appropriate table below. **First read through the tasks listed below and review Figure 6, which outlines the process**. Also have Form H-8 handy.

Urban/Residential Land Use Assessment Tasks

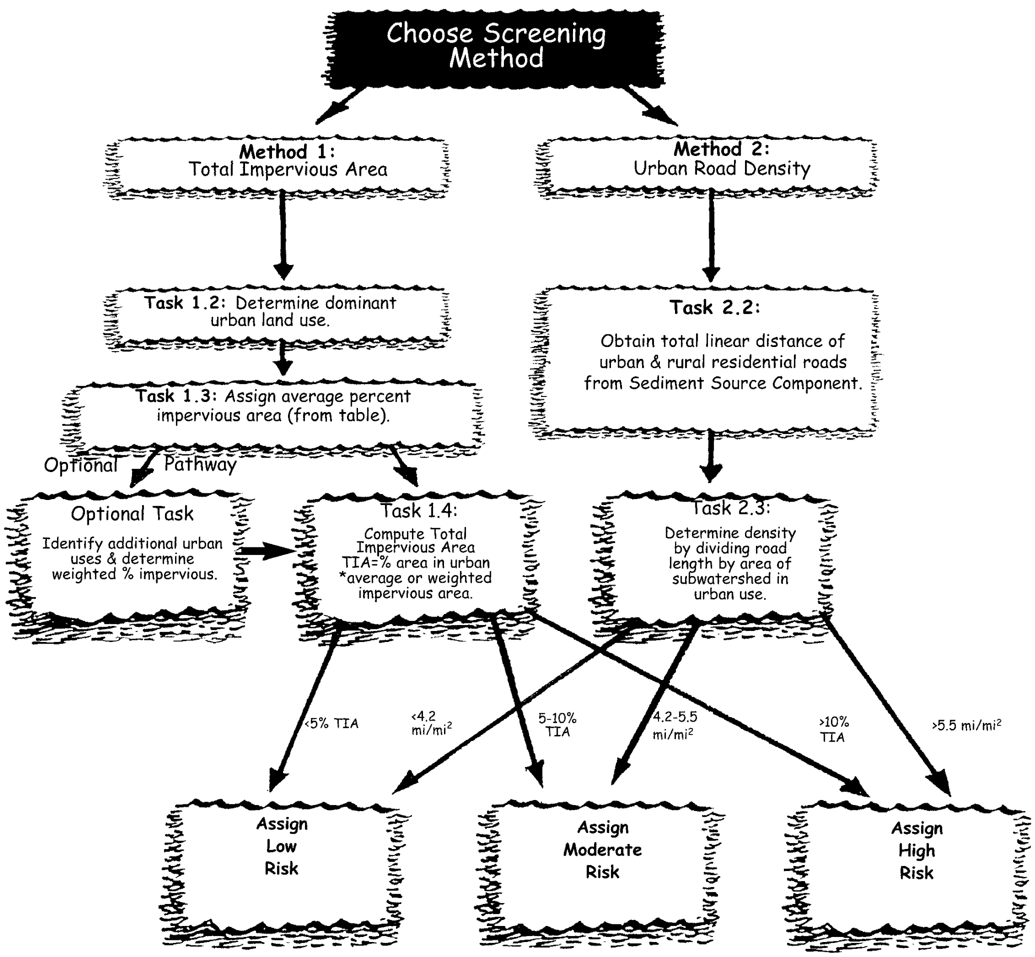

Figure 6. Urban and residential land use can be assessed through one of two screening methods, as described in this flow chart.

Method 1. Impervious Area Calculation

Task 1.1: Using information from Form H-2, fill in Columns 1 and 2 of Table 1, Form H-7.

Task 1.2: Determine the dominant type of urban land use from inspecting aerial photos. Select the type of land use from the table at the right and record in Table 1, Column 3.

Task 1.3: Select the average impervious surface associated with the type of urban land development from the table to the right. Record this information in Column 4 of Table 1, Form H-7.

Optional assessment: Select more than one land type and compute a weighted average of impervious surface by the following equation:

Average Impervious Surfaces, Urban and Residential Development

Type of Land Development	Average Impervious Area* (%)
Urban Districts:	
Commercial and Business	85
Industrial	72
Residential Districts by Average Lot Size:	
1/8 acre or less (town houses)	65
1/4 acre	38
1/3 acre	30
1/2 acre	25
1 acre	20
2 acre	12

* From USDA TR55 1986.

Weighted % Impervious = (% area in land type 1) x (avg. impervious surface) + (% area in land type 2) x (avg. impervious surface)

Task 1.4: Compute the total percent of the basin that is in impervious surfaces by multiplying the percent of the subwatershed designated urban land use (Column 2) by the percent of impervious surfaces in the subwatershed (Column 4). Record this information in Column 5 of Table 1, Form H-7.

Task 1.5: Assign a relative potential for hydrologic impacts using the table to the right. Record this information in Column 6 of Table 1, Form H-7.

Task 1.6: Enter the results of Columns 5 and 6 onto Form H-8, Column 7. Circle the words "Urban Impervious" in the column header to indicate which method you used.

Potential Risk of Peak-Flow Enhancement (Impervious Surface)

Percent of Impervious Surface	Potential for Peak-Flow Enhancement
Less than 5%	Low
5% to 10%	Moderate
Greater than 10%	High

At this point, linkage to the Channel Modification Assessment component should be made to reveal if any field evidence of channel changes has been noted. Channel modifications have been categorized and recorded, and associated degree of impact noted. Channel changes in the urban areas can include any one or more of the following: disconnecting channel from its floodplain, channelizing (straightening channels), and restricting lateral movement by diking or bank armoring, etc.

Method 2. Urban Road Density

May et al. (1997) established a relationship between watershed urbanization (in % TIA) and sub-basin road density (in mi/mi^2) which can be used to represent the percent imperviousness. The regression equation developed by May et. al. (1997) was used to determine the road density that would be expected to correspond to 5% TIA and 10% TIA; the thresholds used in Method 1. In urban areas, when road densities equal or exceed 5.5 mi/mi^2, percent TIA probably exceeds 10% TIA (May et al. 1997). Road densities of 4.2 mi/mi^2 were associated with a percent TIA in the subwatershed of approximately 5%.

Task 2.1: Using information from Form H-2, fill in Columns 1, 2, and 3, Table 2 (Form H-7).

Task 2.2: From the Sediment Sources component, enter the road length in urban and/or rural residential areas in Column 4 of Table 2, Form H-7.

Task 2.3: Divide the road length in Column 4 by the urban area in Column 3. Enter the resulting road density into Column 5.

Task 2.4: Assign a relative potential for peak-flow enhancement to each subwatershed. Watersheds with a road density of greater than 5.5 mi/mi^2 (associated with 10% TIA) should be assigned a high probability of peak-flow enhancement and further investigation of urban issues is warranted. Subwatersheds in which road densities are in the range of 4.2 to 5.5 mi/mi^2 would be expected to have between 5% to 10% TIA and therefore should be assigned a moderate risk as in Method 1. Enter results in Column 6.

Potential Risk of Peak-Flow Enhancement (Road Density)

Road Density (mi/mi²)	Potential Risk for Peak Flow Enhancement
Less than 4.2	Low
4.2 to 5.5	Moderate
Greater Than 5.5	High

Task 2.5: Enter the results in Columns 5 and 6 onto Form H-8, Column 7, and circle the words "Urban Roads" in the column header to indicate which method you used.

Step 8: Summarize Potential Risk of Land Use on Hydrology (Form H-8)

Steps 4 through 7 have required you to work through a series of tasks and fill out a series of corresponding tables. The last task in each step is to insert the results into the appropriate column on Form H-8. This table now provides an overview of potential peak-flow enhancement from land use activities. Using a new copy of the Base Map, or a Mylar overlay, color-code each subwatershed by the potential risks determined above. Label this Map H-1: Potential Risks of Land Use on Hydrology.

SECTION II: WATER USE

Water use is generally defined by beneficial use categories such as municipal, industrial, irrigated agriculture, etc. Background on these different types of water uses and their associated impacts on a stream system can be found in Appendix IV-D. In this section you will summarize the water rights in your basin and gain an understanding of what beneficial uses these water withdrawals are serving. The assessment of water use is primarily focused on low-flow issues. While low-flow issues can be extremely important, they are difficult to characterize at the screening level. Water use activities can impact low flows, yet the low flows can be enhanced through adopting water conservation measures to keep more water in the stream system.

Critical Questions

- For what beneficial use is water primarily used in your watershed?
- Is water derived from a groundwater or surface-water source?
- What type of storage has been constructed in the basin?
- Are there any withdrawals of water for use in another basin (interbasin transfers)? Is any water being imported for use in the basin?
- Are there any illegal uses of water occurring in the basin?
- Do water uses in the basin have an effect on peak flows?
- Do water uses in the basin have an effect on low flows?

Assumptions

- Water use most significantly impacts low flows, with the exception of storage, which can reduce peak flows downstream of the structure.

Materials Needed

- Tabulation of water rights information from the Oregon Water Resources Department (OWRD; see contact information in the Water Rights Information sidebar)

- Map of surface and groundwater right locations, amounts, and priorities (from the OWRD)

Final Products of the Water Use Section

- Form WU-1: Water Rights Summary
- Form WU-2: Water Availability Summary
- Form WU-3: Consumptive Use Summary
- Map WU-1: Water Rights and In-Stream Flow Rights

WATER RIGHTS INFORMATION

Oregon Water Resources Department (OWRD)
158 12th Street NE
Salem, OR 97310
(503) 378-8455 phone
(503) 378-2496 fax

Internet address:
http://www.wrd.state.or.us

For assistance with access to the Water Rights Information System (WRIS) or the Water Availability Reports System (WARS), contact:

Manager of Information Systems
Oregon Water Resources Department
158 12th Street, NE
Salem, OR 97310
(800) 624-3100
(503) 378-8455 phone
(503) 378-2496 fax

Water Use Characterization

Step 1. Summarize Surface- and Groundwater Rights (Form WU-1 and Map WU-1)

The best way to characterize water use in your watershed is to tabulate both the surface-water and groundwater rights that are on file with OWRD. This can be accomplished by either (1) contacting your local Watermaster, or (2) using the OWRD Web page (see Water Rights Information sidebar) to download the data.

Tabulate water rights on Form WU-1 (or use printout from OWRD), and obtain a map showing the points of diversion of the water rights from OWRD. Also, identify where in-stream flow rights exist. Label this Map WU-1.

Water Use Assessment

Potential channel dewatering (zero flow in the channel) can present problems for spawning and fish passage. Typically, the spawning period that coincides with the lowest flow begins on approximately September 1 and extends through October. Rearing habitat in the summer also requires flow levels to be maintained. While these are the critical times of year, flow levels throughout the year need to be maintained to cover all life stages of all species present in a watershed.

The basis for the water use assessment will be the output from the Water Availability Reports System (WARS) and other data provided by the OWRD. Their system has accounted for **consumptive use** and presents the best available information at this time. You will assess the data and gain an understanding of the location and magnitude of low-flow problems in the watershed.

Step 2. Determine Water Availability (Form WU-2)

Task 1: Obtain the water availability reports at the 50% exceedance level for each month for each water availability basin (WAB) in your watershed. These will correspond to the 5th and/or 6th field **Hydrologic Unit Codes** (HUCs). However, not all subwatersheds will be a designated WAB, so use the WABs rather than the subwatersheds in this task.

The water availability reports can be obtained directly from the OWRD via your local Watermaster or can be retrieved from the OWRD Web site on the Internet (http://www.wrd.state.or.us). Select Water Availability Reports System (WARS) and when a login ID is requested, type “wars.” Follow the menu to acquire the information desired. Select the 50% exceedance streamflow from this database/model for review of water availability at this level.

Task 2: Identify on your map the WABs for which water availability has been calculated. Determine which subwatersheds coincide with or are situated within the WABs.

Task 3: Column 8 of the WARS report lists the net available flow. Enter the net water available for each month onto Form WU-2 for each WAB and highlight the WABs that do not have water available. If the “net water available” column is negative or zero, water is not available at this exceedance level. The streamflow in these WABs is insufficient to meet the demand for all in-stream and out-of-stream uses; conservation measures may help mitigate low-flow problems.

Task 4: Compute the percentage of consumptive use (CU) for each monthly natural streamflow and enter the result onto Form WU-3. From the Water Availability Reports System, Columns 3 and 5, report consumptive use before and after 1993. Column 2 of WARS reports the natural streamflow. Use the following formula to compute %CU:

$$\%CU = \frac{\text{Column 3} + \text{Column 5}}{\text{Column 2}} \times 100$$

Task 5: Highlight the CU values on Form WU-3 that are greater than 10%.

Step 3. Flow-Restoration Priority Areas

If your watershed is not located in one of the following five regions: North Coast, Mid Coast, South Coast, Umpqua, or Rogue, call OWRD to determine if the flow restoration prioritization has been completed.

Task 1: Determine if any of the subwatersheds are within priority WABs for flow restoration. The information can be found through ODFW's Web page. Look for the box entitled "Streamflow Restoration Priorities." Find the location of your watershed: North Coast, South Coast, Mid Coast, Umpqua or Rogue.

Task 2: Highlight the WABs on Form WU-3 that are designated flow-restoration priority basins.

Task 3: Of the WABs that are designated as flow-restoration priorities, the ones with the highest consumptive use (>10%) present the greatest opportunity for flow restoration through conservation measures, increased efficiency of use, and/or best management practices. Based on this information, rank the WABs from greatest to least flow-restoration potential.

CONFIDENCE IN ASSESSMENTS

The confidence in the work performed up to this point will be largely a function of the data limitations and/or your confidence in the methods used. For example, were difficulties encountered when estimating the acreage within each land use or clearcut? Was the type of urban land use and associated percent imperviousness difficult to determine?

You must assess the data limitations associated with the work performed up to this point (complete form HW-1). The most obvious data limitation will arise if a stream gage is not located in the basin. Using streamflow records from a nearby similar gage, while appropriate in the absence of basin-specific data, does incorporate error.

The assessment approach was designed to be conservative in that a referral for further analysis would ideally be triggered before the existence of significant hydrologic impacts. Hydrologic processes are complex, and the interaction of several variables makes assigning screening thresholds difficult. You can gain more confidence that your assessment has identified the problematic subwatersheds if you sought technical assistance as questions arose, and if you obtained corroborative evidence from other components of this process.

FURTHER ANALYSES

If the qualitative assessment identified that a specific land use or uses are potentially problematic in some subwatersheds, further study is warranted. All of the compilation of data you have done up to this point will provide the basic building blocks for any additional analyses. Although it is fairly straightforward to identify the potential existence of a problem, attempting to quantitatively assess the magnitude of the problem or the change in streamflow is complex. Technical users of this manual understand the myriad of hydrologic techniques available for use. The following list attempts to identify a few techniques appropriate for analyzing the issues at hand; it by no means constitutes a definitive list, because many options exist.

- **Washington State Forest Practices Board Watershed Analysis Methods**
  Washington Forest Practices Board Manual: Standard Methodology for Conducting Watershed Analysis Under Chapter 222-22 WAC, Version 4.0, November 1997.
- **Antecedent Precipitation Index (API) Model**
  Fedora, M.A. 1987. Simulation of Storm Runoff in the Oregon Coast Range. BLM Technical Note 378, US Department of the Interior, Bureau of Land Management.
- **Continuous models (Hydrologic Simulation Program in Fortran [HSPF], Distributed Hydrologic Soil and Vegetation Model [DHSVM], etc.)**
  Bicknell, B.R., J.C. Imhoff, J.L. Kittle, A.S. Donigian Jr., and R.C. Johanson. 1993. Hydrological Simulation Program FORTRAN (HSPF): User's Manual for Release 10. EPA-600/R-93/174. US Environmental Protection Agency, Athens, GA.
  DHSVM – Dennis Littenmeier, University of Washington
- **Water Resources Evaluation of Nonpoint Silvicultural Sources Model**
  US Department of Agriculture, Forest Service. 1980. An Approach to Water Resources Evaluation of Non-Point Silvicultural Sources (A Procedural Handbook). Published by EPA: EPA-600/8/80-012, August 1980.
- **Kendall Trend Analysis**
  Maidment, D.R. 1993. Handbook of Hydrology. McGraw-Hill, New York.
- **Double Mass Analysis**
  Linsley, R.K. Jr., M.A. Kohler, and J.L.H. Paulhus. 1975. Hydrology for Engineers. McGraw-Hill, Inc.
- **Gage Correlation Analysis**
  Robison, E.G. 1991. Methods for Determining Streamflows and Water Availability in Oregon. Hydrology Report #2, Oregon Water Resources Department, October 1991.
- **TR55 Methods (USDA 1986)**
  United States Department of Agriculture, Natural Resources Conservation Service. 1986. Urban Hydrology for Small Watersheds. Technical Release-55, June 1986.
- **Santa Barbara Unit Hydrograph Methods**
- Oregon Departments of Environmental Quality and Land Conservation and Development. Nonpoint Source Pollution Control Guidebook for Local Government. 1994. Available from ODEQ: (503) 229-6893.

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GLOSSARY

adjudication: A court proceeding to determine all rights to the use of water on a particular stream system or groundwater basin.

annual maximum 24-hour precipitation: The largest amount of precipitation that has occurred in a 24-hour period over the course of 1 year.

annual minimum flows: The lowest daily flows that have occurred within a given water year.

annual peak flow: The highest streamflow or discharge recorded at a stream gage during each water year. Annual peak flows are reported on a water-year basis, defined as October 1 through September 30.

aspect: Aspect of a slope is the direction toward which the slope faces.

best management practice (BMP): Structural, nonstructural, and managerial techniques recognized to be the most effective and practical means to reduce surface- and groundwater contamination while still allowing the productive use of resources.

canopy cover: The overhanging vegetation in a given area.

Channel Habitat Type (CHT): Groups of stream channels with similar gradient, channel pattern, and confinement. Channels within a particular group are expected to respond similarly to changes in environmental factors that influence channel conditions. In this process, CHTs are used to organize information at a scale relevant to aquatic resources, and lead to identification of restoration opportunities.

consumptive use: The quantity of water absorbed by the crop and transpired or used directly in the building of plant tissue, together with the water evaporated from the cropped area.

crown closure: The amount of canopy cover in a given area.

discharge: Outflow; the flow of a stream, canal, or aquifer.

elevation: The vertical reference of a site location above mean sea level, measured in feet or meters.

ephemeral: A stream that is dry for a portion of the year and most often contains water during and immediately after a rainfall event.

evaporation: As water is heated by the sun, its surface molecules become sufficiently energized to break free of the attractive force binding them together; they evaporate and rise as invisible vapor in the atmosphere.

evapotranspiration: The amount of water leaving to the atmosphere through both evaporation and transpiration.

gaging station: A selected section of a stream channel equipped with a gage, recorder, or other equipment for determining stream discharge.

Geographic Information System (GIS): A set of tools for modeling virtually all physical and biological components of natural or cultural resources. A system that can integrate information from diverse sources. Comprised of four subsystems 1) data input subsystems; 2) data storage and retrieval; 3) data manipulation and analysis and; 4) data reporting system. GIS databases can usually have a spatial component in the storage of the data; potential to store and create map-like products; and potential for performing multiple analyses or evaluations of scenarios of model simulations.

groundwater: Water stored in the earth that occupies pores, cavities, cracks, and other spaces in the crustal rocks and soil.

hydraulic continuity: The connection between groundwater and surface water such that withdrawal from an underground aquifer affects the streamflow level in the channel (surface water).

hydrograph: A graph of runoff rate, inflow rate, or discharge rate, past a specific point of a river plotted over a predefined time period (annual, storm, etc.).

hydrologic soil group (HSG): Soil classification to describe the minimum rate of infiltration obtained for bare soil after prolonged wetting.

Hydrologic Unit Code (HUC): US Geological Survey designations that correspond to specific watersheds, and are expressed in a hierarchical scale.

hydrology: The science of the behavior of water in the atmosphere, on the surface of the earth, and underground.

impervious surface: An area that is made impenetrable by water, such as paved roads, rooftops, and parking lots.

infiltration: The rate of movement of water from the atmosphere into the soil.

lag time: The interval between the center of mass of the storm precipitation and the peak flow of the resultant runoff. It is the delay between upstream production of flow and its arrival at a downstream location.

low flow: The minimum rate of flow for a given period of time.

nonpoint source pollution: Variable, unpredictable, and dispersed pollution sources from agriculture, silviculture, mining, construction, saltwater intrusion, waste disposition and disposal, and pollution from urban-industrial development areas. ("Point sources" are steady, predictable, and concentrated through "end of pipe" discharges from manufacturing or water treatment plants.)

orthophotograph: A combined aerial photograph and planimetric (no indications of contour) map without image displacements and distortions.

peak flow: The maximum instantaneous rate of flow during a storm or other period of time.

percolation: The act of **s**urface water moving downwards, or percolating, through cracks, joints, and pores in soils and rocks.

planimeter: An instrument for measuring the area of a plane (2-dimensional) figure by tracing its boundary line.

precipitation: The liquid equivalent (inches) of rainfall, snow, sleet, or hail, collected by precipitation storage gages.

Prior Appropriation Doctrine: A water law based on the principle of prior appropriation, which means the first person to obtain a water right on a stream is the last to be shut off in times of low streamflows.

rain-on-snow event: When snowpacks are melted by warm rains, causing peak-flow events where the melted snow augments the runoff derived from rainfall. Rain-on-snow events usually occur within an elevation zone in which transient snowpacks occur.

recurrence interval: The frequency of hydrologic events can be discussed in terms of either probability or recurrence interval (also called the return period or frequency of occurrence). Exceedance probability refers to the chance that the annual-maximum event of any year will equal or exceed some given value.

return flow: The portion of a diversion that returns to the river system via subsurface pathways. The rest of the diversion is lost to crop consumptive use.

runoff: Surface runoff is water that moves overland across the surface into creeks, ponds, lakes, and rivers that eventually take the water back to the ocean.

runoff curve number: An empirical rating of the hydrologic performance of a large number of soils, vegetative covers, and land use practices throughout the United States.

spring snowmelt: The time in spring when the seasonal snowpack melts out.

transpiration: The process by which water vapor is emitted from plant leaves. Every day, an actively growing plant transpires 5 to 10 times as much water as it can hold at once.

water table: The water table marks the change in the groundwater zone between the zone of aeration, where some pores are open, and the underlying zone of saturation, in which water fills all the spaces in the soil and rocks.

water year: The water year in North America is referred to as the 12-month period beginning October 1 in one year and ending September 30 of the following year. The water year is designated by the calendar year in which it ends. For instance, the annual peak flow for water year 1996 would be the highest flow recorded from October 1, 1995, through September 30, 1996.

Appendix IV-A
Forms and Worksheets

FORM H-1: GENERAL WATERSHED CHARACTERISTICS

Name of Analyst:____ Date:____________________

Watershed Name:____

Subwatershed information:

Subwatershed Name	Subwatershed Area (mi^2)	Mean Elevation (feet)	Minimum Elevation (feet)	Maximum Elevation (feet)	Mean Annual Precipitation (inches)
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
Total Watershed					

- Mean Annual Precipitation can be estimated from the Mean Annual Precipitation Map (from NOAA)
- Minimum and Maximum Elevations can be estimated from the Base Map or USGS quad maps.
- The State Service Center for GIS may also be able to provide the above information.

Describe the type and extent of natural storage (lakes, wetlands, etc.) in the watershed:

____

____

____

____

What watershed changes have occurred that will affect streamflows (i.e., dams, major diversions for urban water supply, irrigation diversions, industrial use etc.)?

____

____

____

____

Information on stream gages in basin: (Note: if more than one gage, fill out additional forms.)

Gage #:________________________

Gage Name:____

Gage Elevation:_________________________

Drainage Area to Gage:______________________________________

Storage or regulation upstream of gage (yes or no)? ____________ If yes, describe on back of sheet

Form H-2: Land Use Summary Form

Name of Analyst:____ Date:__________________
Watershed Name:____

Subwatershed information:

Subwatershed Name	Area (acres)	Forestry		Agriculture and/or Range Land		Urban		Other	
		Acres	%	Acres	%	Acres	%	Acres	%
1									
2									
3									
4									
5									
6									
7									
8									
9									
10									
Total Watershed									

Columns 3 through 10: If this information is not available from previous documents or agencies, it can be estimated from recent aerial photographs or orthophotographs.

640 acres = 1 square mile

Form H-3: Annual Peak Flow Summary Form

Name of Analyst:____ Date:____________________
Watershed Name:____

Subwatershed information:

Subwatershed Name	Area (acres)	Rain		Rain-on-Snow		Spring Snowmelt	
		Acres	%	Acres	%	Acres	%
1							
2							
3							
4							
5							
6							
7							
8							
9							
10							
Total Watershed							

Peak flows by water year (use additional sheets if more than one gage in watershed):

Station Name: ________________________________ Station #:____________________________
Drainage Area = ______________________________ Period of Record: ______________________
Gage is in watershed? (circle one): Yes No

Water Year (10/1-9/30)	Peak flow amount (cfs)	Date of Peak Flow	Rank or Recurr. interval

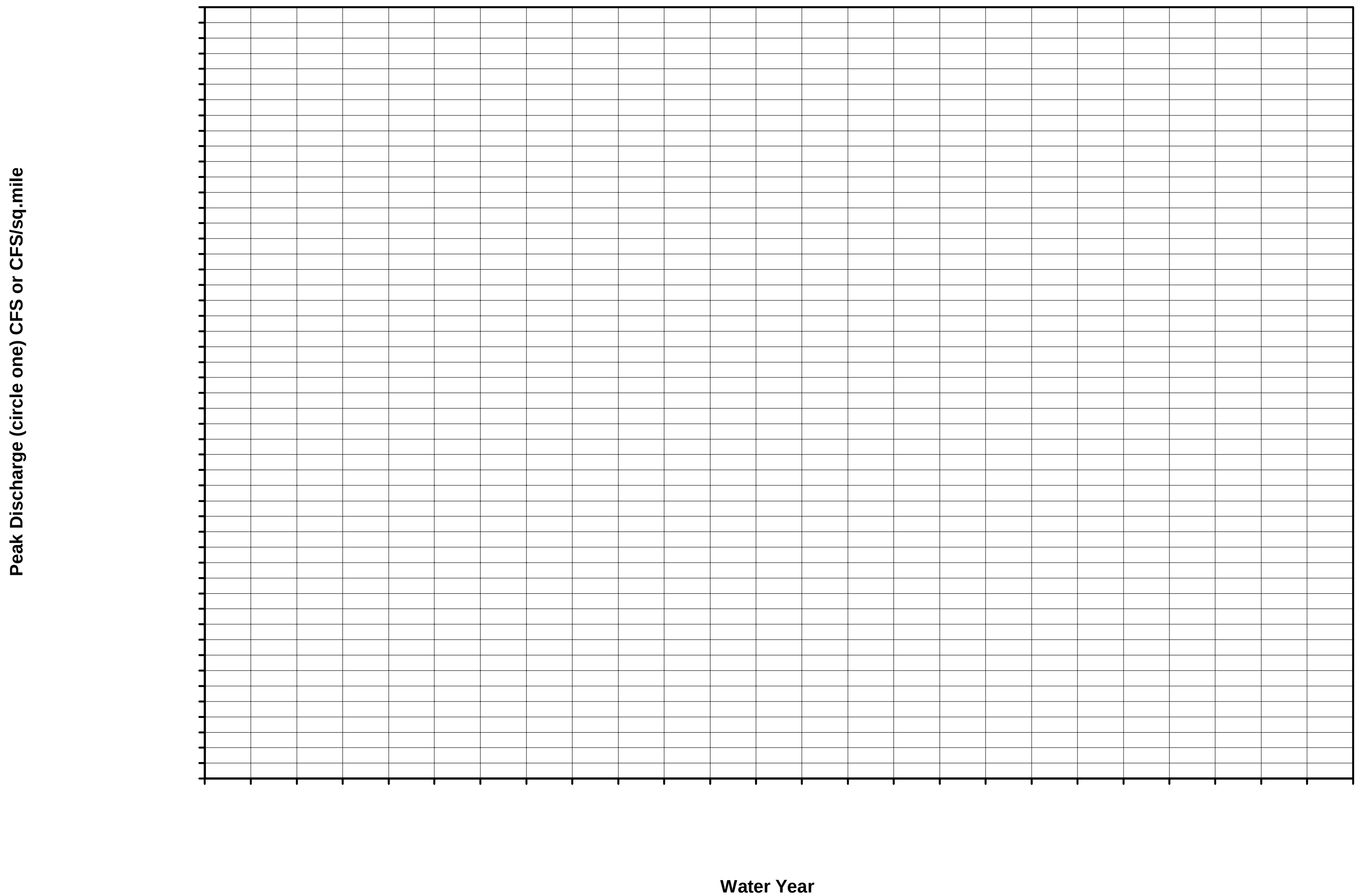
(Continue from Column to left)

Water Year (10/1-9/30)	Peak low amount (cfs)	Date of Peak Flow	Rank or Recurr. Interval

(Continue from Column to left)

Water Year (10/1-9/30)	Peak low amount (cfs)	Date of Peak Flow	Rank or Recurr. Interval

Form H-3: page 2.



Form H-4: Forestry Worksheet

Name of Analyst:____ Date:___________________
Watershed Name:____

1 Subwatershed Name or Number	2 Historic Crown Closure in Rain-on-Snow Areas (%)	3 Percent of subwatershed in Rain-on-Snow Areas (%)	4 Percent of Rain-on-Snow areas with <30% Current Crown Closure (%)	5 Risk of Peak-Flow Enhancement (either “Potential,” “Low,” or “Unknown”)
1				
2				
3				
4				
5				
6				
7				
8				
9				
10				
Entire Watershed				

Form H-5: Agriculture and Range-Land Worksheet

Name of Analyst:______________________________________ Date:__________________
Watershed Name:____

Table 1. Agricultural Land Use and Range-Land Use Summary

1 Subwatershed Name	2 Area of Subwatershed in Agriculture or Range-Land Use	3 Hydrologic Soil Groups in Agricultural Lands or Grazed Range Lands (by approximate percentage)			
		A	B	C	D
Entire Watershed					

Form H-5: page 2.

Table 2. Curve Number and Runoff-Depth Summary Table for Primary Hydrologic Soil Group

Subwatershed Name:				**Primary Hydrologic Soil Group:**			
1 **Cover Type/Treatment**	**2** **Hydrologic Condition**	**3** **Curve Number**	**4** **Background Curve Number**	**5** **Rainfall Depth (in)**	**6** **Current Runoff Depth (in)**	**7** **Background Runoff Depth (in)**	**8** **Change from Background Col. 6 - 7**
				Subwatershed average change from background:			

Form H-5: page 3.

Table 3. Agricultural/Range-Land Summary

1 Subwatershed Name or Number	2 Percent of Agric./Range Area in 1st Hydrologic Soil Group Table 1 Col. 3 A,B,C, or D	3 Average Change from Background Table 2 Col. 8	4 Percent of Agric./Range Area in 2nd Hydrologic Soil Group Table 1 Col. 3 A,B,C, or D	5 Average Change from Background Table 2, Col. 8	6[1] Weighted Average Change from Background [Cols. 2x3 + 4x5]	7 Potential Risk of Peak-Flow Enhancement
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
Entire Watershed						

1 If one hydrologic soil group is dominant, only Columns 2, 3, and 7 will be used. If two hydrologic soil groups are dominant, all seven columns will be used. If more than two hydrologic soil groups are dominant, add two columns per hydrologic soil group to table.

Form H-6: Forest and Rural Road Worksheet

Name of Analyst:_______________________________________ Date:__________________
Watershed Name:____

Table 1. Forest Road Area Summary

1 Subwatershed Name	2 Area (mi^2)	3 Area Forested (mi^2)	4 Total Linear Distance of Forest Roads (miles)	5 Roaded Area Column 4 x std. width (ft^2) std. width = 25 feet = .0047 miles	6 Percent Area in Roads Col. 5/3	7 Relative Potential for Impact
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
Entire Watershed						

Table 2. Rural Road Area Summary

1 Subwatershed Name	2 Area (mi^2)	3 Rural Area (Agric. + Range) (mi^2)	4 Total Linear Distance of Rural Roads (miles)	5 Roaded Area Column 4 x std. width (ft^2) std. width = 35 feet = .0066 miles	6 Percent Area in Roads Col. 5/3	7 Relative Potential for Peak-Flow Enhancement
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
Entire Watershed						

Form H-7: Urban and Residential Area Worksheet

Name of Analyst:____ Date:____________________
Watershed Name:____

Table 1. Method 1: Urban and Rural Residential Land Use Summary

1 Subwatershed Name	2 Percent of Area Urbanized/ Rural Residential	3 Dominant Type of Urban Land Use	4 Average Percent Impervious	5 Estimate of Percent Total Impervious Area Col. 2 x Col. 4	6 Relative Potential for Peak-Flow Enhancement

Table 2. Method 2: Urban Road Density Summary

1 Subwatershed Name	2 Area (mi^2)	3 Area Urban (mi^2)	4 Total Linear Distance of Roads (miles)	5 Road Density Col. 4/3 (mi/mi^2)	6 Relative Potential for Peak-Flow Enhancement
Entire Watershed					

Form H-8: Hydrologic Issue Identification Summary

Name of Analyst:______________________________________ Date:__________________
Watershed Name:____

Summary of Potential Risks from Land Use Impacts on Hydrology

1	2 Timber Harvest Form H-4 Table		3 Agriculture Form H-5 Table 3		4 Range Lands Form H-5 Table 3		5 Forest Roads Form H-6 Table 1		6 Rural Roads Form H-6 Table 2		7 Urban Impervious or Urban Roads* Form H-7 Table 1 or Table 2	
Subwatershed Name or Number	**Result**	**Risk**	**Result**	**Risk**	**Result**	**Risk**	**Result**	**Risk**	**Result**	**Risk**	**Result**	**Risk**
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												
Entire Watershed												

* Circle the method used.

Form WU-1. Water Rights Summary

Name of Analyst:____ Date:_____________________
Watershed Name:____

Water Rights on Record with OWRD

Watershed Name: _______________________________				**County:**			
Permit or Certificate #	**Status**	**Priority Date**	**Flow Rate (cfs)**	**Time of Diversion**	**Type of Use (Irrigation Stock Watering Domestic)**	**Location**	**WAB #**

Form WU-2: Water Availability Summary

Name of Analyst:____ Date:____________________
Watershed Name:____________________________ County:______________________________

Monthly Net Water Available by Water Availability Basin (cfs)

Water Availability Basins	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec

Form WU-3. Consumptive Use Summary

Name of Analyst:____ Date:____________________
Watershed Name:_____________________________ County:______________________________

Consumptive Use as a Percentage of 50% Exceedance Streamflow

Water Availability Basins	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec

Form HW-1. Confidence Evaluation

Name of Analyst:____ **Date:**___________________
Watershed:______________________________ **Area:**___________________________________

Technical expertise or relevant experience:____
____
____

Resources used:

USGS Web site
Hydrodata or Earthinfo CD-ROM
USGS Open File Report 90-118
USGS personnel
NRCS personnel
OWRD regional personnel
Oregon Climate Service Web site
NRCS Web site
USGS Water Supply Papers, Oregon
OWRD Web site
OWRD local Watermaster

Confidence in hydrology assessment

Low: Unsure of procedures and/or used minimal resources.
Low to moderate: Understood and followed most of the procedures, but minimal resources available and/or used.
Moderate: Understood and followed procedures, and used adequate number of resources, but had moderate understanding of outcome.
Moderate to high: Understood and followed procedures, used adequate number of resources, and had high understanding of outcome.
High: Understood and followed procedures, used numerous resources, and had high understanding of outcome.
If none of the above categories fit, describe your own confidence level and rationale:

Recommendations for further assessment or analysis:

Appendix IV-B
Reference Tables

Table B-1. Runoff Curve Numbers for Cultivated Agricultural Lands[1]

Cover Type	Treatment[2]	Hydrologic Condition[3]	Curve Numbers for Hydrologic Soil Group A	B	C	D
Fallow	Bare Soil	---	77	86	91	94
	Crop Residue Cover	Poor	76	85	90	93
		Good	74	83	88	90
Row Crops	Straight Row	Poor	72	81	88	91
		Good	67	78	85	89
	Straight Row + Crop Residue Cover	Poor	71	80	87	90
		Good	64	75	82	85
	Contoured	Poor	70	79	84	88
		Good	65	75	82	86
	Contoured + Crop Residue Cover	Poor	69	78	83	87
		Good	64	74	81	85
	Contoured and Terraced (C&T)	Poor	66	74	80	82
		Good	62	71	78	81
	Contoured and Terraced + Crop Residue Cover	Poor	65	73	79	81
		Good	61	70	77	80
Small Grain	Straight Row	Poor	65	76	84	88
		Good	63	75	83	87
	Straight Row + Crop Residue Cover	Poor	64	75	83	86
		Good	60	72	80	84
	Contoured	Poor	63	74	82	85
		Good	61	73	81	84
	Contoured + Crop Residue Cover	Poor	62	73	81	84
		Good	60	72	80	83
	Contoured and Terraced	Poor	61	72	79	82
		Good	59	70	78	81
	Contoured and Terraced + Crop Residue Cover	Poor	60	71	78	81
		Good	58	69	77	80
Close-Seeded or Broadcast Legumes Rotation Meadow	Straight Row	Poor	66	77	85	89
		Good	58	72	81	85
	Contoured	Poor	64	75	83	85
		Good	55	69	78	83
	Contoured and Terraced	Poor	63	73	80	83
		Good	51	67	76	80

1 Average runoff condition and $I_a = 0.2$ S
2 Crop Residue Cover applies only if residue is on at least 5% of the surface throughout the year.
3 Hydrologic condition is based on a combination of factors that affect infiltration and runoff, including (a) density and canopy of vegetative areas, (b) amount of year-round cover, (c) amount of grass or close-seeded legumes in rotations, (d) percent of residue cover on the land surface (good > 20%), and (e) degree of surface roughness.

Poor: Factors impair infiltration and tend to increase runoff.
Good: Factors encourage average and better-than-average infiltration and tend to decrease runoff.

From USDA Soil Conservation Service, TR55 (2nd edition, June 1986); Table 2-2a, page 2-5.

Table B-2: Runoff Curve Numbers for Other Agricultural Lands[1]

Cover Type	Hydrologic Condition	Curve Numbers for Hydrologic Soil Group			
		A	B	C	D
Pasture, grassland, or range – continuous forage for grazing[2]	Poor	68	79	86	89
	Fair	49	69	79	84
	Good	39	61	74	80
Meadow – continuous grass; protected from grazing and generally mowed for hay	---	30	58	71	78
Brush – brush-weed-grass mixture with brush the major element[3]	Poor	48	67	77	83
	Fair	35	56	70	77
	Good	30[4]	48	65	73
Woods – grass combination (orchard or tree farm)[5]	Poor	57	73	82	86
	Fair	43	65	76	82
	Good	32	58	72	79
Woods[6] Shaded area can be used as background if the land was originally wooded	Poor	45	66	77	83
	Fair	36	60	73	79
	Good	30[4]	55	70	77
Farmsteads – buildings, lanes, driveways, and surrounding lots	---	59	74	82	86

1 Average runoff condition and $I_a = 0.2$ S

2 **Poor:** <50% ground cover or heavily grazed with no mulch.
Fair: 50 to 75% ground cover and not heavily grazed.
Good: >75% ground cover and lightly or only occasionally grazed.

3 **Poor:** <50% ground cover.
Fair: 50 to 75% ground cover.
Good: >75% ground cover.

4 Actual curve number is less than 30; use curve number = 30 for runoff computations.

5 Curve numbers shown were computed for areas with 50% woods and 50% grass (pasture) cover. Other combinations of conditions may be computed from the curve numbers for woods and pasture.

6 **Poor:** Forest litter, small trees, and brush are destroyed by heavy grazing or regular burning.
Fair: Woods are grazed but not burned, and some forest litter covers the soil.
Good: Woods are protected from grazing, and litter and brush adequately cover the soil.

From USDA Soil Conservation Service, TR55 (2nd edition, June 1986); Table 2-2b, page 2-6.

Table B-3: Runoff Curve Numbers for Arid and Semiarid Range Lands

Cover Type	Hydrologic Condition	Curve Numbers for Hydrologic Soil Group			
		A[3]	B	C	D
Herbaceous – mixture of grass, weeds, and low-growing brush, with brush the minor element	Poor		80	87	93
	Fair		71	81	89
	Good		62	74	85
Oak-aspen – mountain-brush mixture of oak brush, aspen, mountain mahogany, bitter brush, maple, and other brush	Poor		66	74	79
	Fair		48	57	63
	Good		30	41	48
Pinyon-juniper – pinyon, juniper or both; grass understory	Poor		75	85	89
	Fair		58	73	80
	Good		41	61	71
Sagebrush with grass understory	Poor		67	80	85
	Fair		51	63	70
	Good		35	47	55
Desert shrub – major plants include saltbush, greasewood, creosotebush, blackbrush, bursage, palo verde, mesquite, and cactus	Poor	63	77	85	88
	Fair	55	72	81	86
	Good	49	68	79	84

1 Average runoff condition and $I_a = 0.2$ S.

2 **Poor:** <30% ground cover (litter, grass, and brush overstory).

Fair: 30 to 70% ground cover.

Good:>70% ground cover.

3 Curve numbers for Group A have been developed only for desert shrub.

From USDA Soil Conservation Service, TR55 (2nd edition, June 1986); Table 2-2c, page 2-7. For range in humid regions, use table 2-2c of TR55.

Table B-4: Runoff Depth for Selected Curve Numbers and Rainfall Amounts[1]

	Runoff Depth for Curve Number of…												
Rainfall	**40**	**45**	**50**	**55**	**60**	**65**	**70**	**75**	**80**	**85**	**90**	**95**	**98**
1.0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.08	0.17	0.32	0.56	0.79
1.2	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.07	0.15	0.27	0.46	0.74	0.99
1.4	0.00	0.00	0.00	0.00	0.00	0.02	0.06	0.13	0.24	0.39	0.61	0.92	1.18
1.6	0.00	0.00	0.00	0.00	0.01	0.05	0.11	0.20	0.34	0.52	0.76	1.11	1.38
1.8	0.00	0.00	0.00	0.00	0.03	0.09	0.17	0.29	0.44	0.65	0.93	1.29	1.58
2.0	0.00	0.00	0.00	0.02	0.06	0.14	0.24	0.38	0.56	0.80	1.09	1.48	1.77
2.5	0.00	0.00	0.02	0.08	0.17	0.30	0.46	0.65	0.89	1.18	1.53	1.96	2.27
3.0	0.00	0.02	0.09	0.19	0.33	0.51	0.71	0.96	1.25	1.59	1.98	2.45	2.77
3.5	0.02	0.08	0.20	0.35	0.53	0.75	1.01	1.30	1.64	2.02	2.45	2.94	3.27
4.0	0.06	0.18	0.33	0.53	0.76	1.03	1.33	1.67	2.04	2.46	2.92	3.43	3.77
4.5	0.14	0.30	0.50	0.74	1.02	1.33	1.67	2.05	2.46	2.91	3.40	3.92	4.26
5.0	0.24	0.44	0.69	0.98	1.30	1.65	2.04	2.45	2.89	3.37	3.8 8	4.42	4.76
6.0	0.50	0.80	1.14	1.52	1.92	2.35	2.81	3.28	3.78	4.30	4.85	5.41	5.76
7.0	0.84	1.24	1.68	2.12	2.60	3.10	3.62	4.15	4.69	5.25	5.82	6.41	6.76
8.0	1.25	1.74	2.25	2.78	3.33	3.89	4.46	5.04	5.63	6.21	6.81	7.40	7.76
9.0	1.71	2.29	2.88	3.49	4.10	4.72	5.33	5.95	6.57	7.18	7.79	8.40	8.76
10.0	2.23	2.89	3.56	4.23	4.90	5.56	6.22	6.88	7.52	8.16	8.78	9.40	9.76
11.0	2.78	3.52	4.26	5.00	5.72	6.43	7.13	7.81	8.48	9.13	9.77	10.39	10.76
12.0	3.38	4.19	5.00	5.79	6.56	7.32	8.05	8.76	9.45	10.11	10.76	11.39	11.76
13.0	4.00	4.89	5.76	6.61	7.42	8.21	8.98	9.71	10.42	11.10	11.76	12.39	12.76
14.0	4.65	5.62	6.55	7.44	8.30	9.12	9.91	10.67	11.39	12.08	12.75	13.39	13.76
15.0	5.33	6.36	7.35	8.29	9.19	10.04	10.85	11.63	12.37	13.07	13.74	14.39	14.76

1 Interpolate the values shown to obtain runoff depths for curve numbers or rainfall amounts not shown.

From USDA Soil Conservation Service, TR55 (2^{nd} edition, June 1986); Table 2-1, page 2-3.

Appendix IV-C
Resources for
Data Acquisition

RESOURCES FOR DATA ACQUISITION

USGS

Contact Information

Information Officer
US Department of the Interior, Geological Survey
10615 SE Cherry Blossom Drive
Portland, OR 97216
Telephone: (503) 251-3201
Fax: (503) 251-3470
Office hours: 7:30 a.m. to 4:30 p.m. Pacific Time
Internet address: http://waterdata.usgs.gov/nwis-w/OR

Internet Instructions

Access the Internet site referenced above. When you enter the State Surface Water Data Retrieval Page for Oregon, select the gage for which you want information, or, if you don't yet know the gage number, select the county list or the map from which to select the county. Select the gage from the county list. Summary information will appear and below that *Data Types Available*. Select *Peak Flow Data*; then select *Annual Peaks* and *Tab-Delimited Text Data File*. The largest instantaneous streamflow recorded for each year will be displayed along with the date of that peak flow. This data can be downloaded into a spreadsheet by saving it as a text file. The most recent peak flows will not be on the Internet and must be requested from the state USGS office.

CD-ROM

Hydrosphere and Earthinfo, both located in Boulder, Colorado, produce and distribute CD-ROMs containing USGS streamflow data. These CD-ROMs can be found in some libraries, especially at universities. If you wish to purchase a CD for use with your computer, you can order one directly from either of the above-mentioned businesses.

Publications

Frank, F.J., and A. Laenen. 1977. Water Resources of Lincoln County Coastal Area, Oregon. Prepared in cooperation with the Oregon Water Resources Department. US Geological Survey, Water Resources Investigations 76-90, Portland, Oregon.

Greenberg, J. and K.F. Welch. 1998. Hydrologic Process Identification for Western Oregon. Prepared for Boise Cascade Corp., Boise, Idaho.

Harris, D.D., L.L. Hubbard, and L.E. Hubbard. 1979. Magnitude and Frequency of Floods in Western Oregon. Prepared in cooperation with the Oregon Department of Transportation, Highway Division. US Geological Survey, Open File Report 79-553, Portland, Oregon.

Harris D.D., and L.E. Hubbard. 1983. Magnitude And Frequency Of Floods In Eastern Oregon. US Geological Survey WRIR 82-4078.

Moffatt, R.L., R.E. Wellman, and J.M. Gordon. 1990. Statistical Summaries of Streamflow Data in Oregon: Volume 1: Monthly and Annual Streamflow, and Flow-Duration Values. Prepared in cooperation with the Oregon Water Resources Department. US Geological Survey, Open-File Report 90-118, Portland, Oregon. Maps are located in the appendix of this document showing the location of streamflow gaging sites.

Wellman, R.E., J.M. Gordon, and R.L. Moffatt. 1993. A Statistical Summaries of Streamflow Data in Oregon: Volume 2: Annual Low and High Flow, and Instantaneous Peak Flow. Prepared in cooperation with the Oregon Water Resources Department. US Geological Survey, Open-File Report 93-63, Portland, Oregon.

Regional Offices of Oregon Water Resources Department (OWRD)

Northwest Region
158th 12th Street, NE
Salem, OR 97310
(503) 378-8455, ext. 281
Fax: (503) 378-8130

North Central Region
3920 Westgate
Pendleton, OR 97801
(541) 278-5456
Fax: (541) 278-0287

Southwest Region
Grants Pass Municipal Building
942 SW 6th Street Suite E
Grants Pass, OR 97526
(541) 471-2886; ext. 86
Fax: (541) 471-2876

Eastern Region
Baker County Courthouse
1995 3rd Street
Baker City, OR 97814
(541) 523-8224
Fax: (541) 523-7866

South Central Region
1340 NW Wall Street, Suite 100
Bend, OR 97701
(541) 388-6669
Fax: (541) 388-5101

Oregon State Department of Forestry

2600 State Street
Salem, OR 97301
(503) 945-7469
Fax: (503) 945-7490

Appendix IV-D
Background Hydrologic Information

BACKGROUND HYDROLOGIC INFORMATION

Land Use Impacts on Hydrology

Land use practices can modify the amount of water available for runoff, the routing of water to the streams, the **lag time** [1] (delay between rainfall and peak streamflow), the flow velocity, or the travel distance to the stream. Figure D-1 demonstrates how urbanization causes the peak flow (highest point on the curve) to increase and to occur sooner (the lag time has decreased). The same concepts are shown in Figure D-2, in which two streams respond differently to the same rainstorm: One stream drains a forested watershed and the other drains an urbanized watershed. Agricultural land would produce a similar but less pronounced response than the urban response shown in both Figures D-1 and D-2.

Land use practices that affect the rate of infiltration and/or the ability of the soil surface to store water are typically most influential in affecting the watershed's hydrology. Using this as an indicator for comparison among the land uses, forest harvesting produces the smallest change in the infiltration rate, thereby producing the smallest impacts to the hydrologic regime of a basin. Forest harvest practices have evolved such that land compaction can be minimized; however, roads and grazing in these watersheds decrease the infiltration rate. In contrast to forest harvest, agricultural practices, range-land utilization for grazing purposes, and urban development can all involve compaction of the soils and/or paved surfaces, resulting in substantial alteration of the infiltration rate. Agricultural practices and urban development directly involve altering the shape of the drainage system by ditching, channelizing, or using piped stormwater networks which decrease the infiltration and the travel time of subsurface flow to reach the channel. This effect can be exacerbated in high-flow conditions. Forest harvest, although not always practiced at a sustainable rate, is a temporary conversion of the vegetation, and the hydrologic effects diminish as vegetative

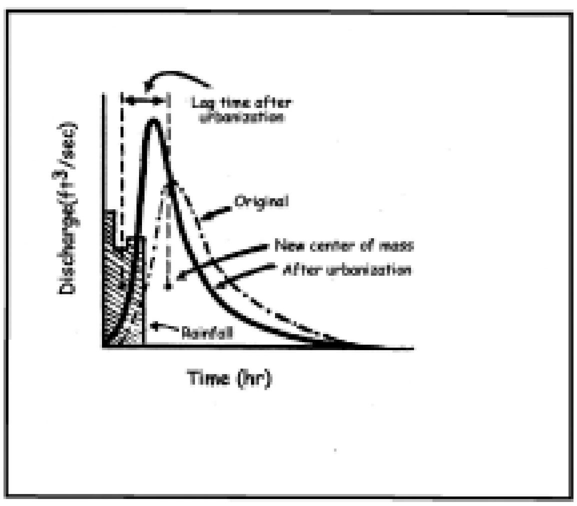


Figure D-1. Hypothetical unit hydrographs illustrating urbanization impacts on peak flows.

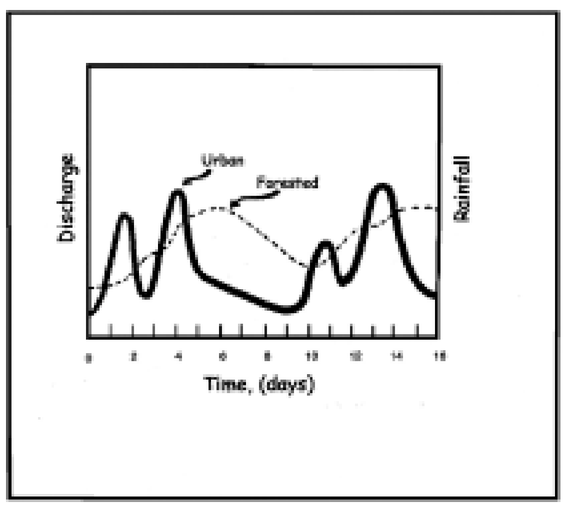


Figure D-2. Streamflow comparison of urban versus forested watersheds.

[1] Terms that appear in bold italic in this appendix are defined in the Glossary of the main text of this component.

regrowth occurs. Conversion of lands to agriculture or urbanization produces generally longer-lasting effects. Road construction, associated with all land uses, alters the rate of infiltration on the road surface and replaces subsurface flow pathways with surface pathways resulting in quicker travel time to the channel network.

Forestry

The potential effects of forest practices on hydrology include changes in peak flows, water yield, and low flows. There are two primary mechanisms by which forest practices in Pacific Northwest watersheds impact hydrologic processes: (1) the removal and disturbance of vegetation, and (2) the road network and related harvesting systems.

Removal of vegetation reduces interception and **evapotranspiration**, both of which allow additional water to reach the soil surface during rainstorms. Additionally, open areas accumulate more snowpack. The additional snowpack can potentially produce an increase in water yield (volume of water) that, in arid and semiarid regions, is viewed as a net benefit for water supply. The area with a decrease in **canopy cover** due to tree removal is subject to increased exposure to solar radiation and wind that can cause faster melting rates, potentially causing an increase in peak flows occurring earlier in the melt season. Harvest practices can also affect low flows, especially in spring snowmelt regimes. The quicker melting of the snowpack reduces the opportunities for groundwater recharge, the primary supply for baseflow conditions (streamflow during the driest part of the year). However, this decrease may be offset by the decreased evapotranspiration resulting from the reduction in canopy cover.

The size and structure of forest vegetation varies throughout the state primarily as a function of climatic variables, **aspect**, and elevation. In the eastern regions of the state, crown closure or vegetative cover was historically less dense than the thick forests of western Oregon. In some areas in eastern Oregon, the once-sparse forests now tend to be denser due to the prevention and control of forest fires. The suppression of fire on the landscape, in areas that historically experienced frequent fire, has led to the following general conditions: increased stand densities and canopy closure, smaller average stand diameter, changes in vegetative composition (i.e., fir or juniper invasion), decreased shrub/herb growth, increased litter/duff layer, and increased large woody debris and overall fuel loading (Agee 1994). Consequently, peak flows produced from undisturbed historic forests may have been higher compared to forests in which fires have been controlled. Due to this probable condition, potential hydrologic impacts in these regions may be minor.

The forestry-related effects on peak flows may be a function not only of harvest and vegetative cover issues, but also of the type of hydrologic process that occurs in a basin (MacDonald and Hoffman 1995). The greatest likelihood of causing problems from timber harvest is through increases in peak flows associated with rain-on-snow events (Harr 1981, 1986; Coffin and Harr 1992; and Washington Forest Practices Board 1997). While rain-on-snow conditions can occur at almost any elevation, given a specific combination of climatic variables, the probability of rain-on-snow enhancement of peak flows differs with elevation and, to a lesser degree, aspect. The highest probability of encountering rain-on-snow conditions occurs at mid-elevations where transient snowpacks develop but do not get too deep. The lowest probability occurs in the lowlands, where snowpack rarely occurs and, at the higher elevations, where winter temperatures are too cold to melt the snow. The elevation of the lower boundary of the rain-on-snow zone will vary geographically and often by ecoregion. For some portions of Oregon, the boundary has been defined systematically (Greenberg and Welch 1998), whereas for other portions of the state, you will need to contact a local hydrologist.

Agriculture

Agricultural practices have most often been implemented along valley bottoms, floodplains, and other adjacent low-gradient lands. An often long-lasting change in the vegetative cover has occurred from the conversion of the landscape from forested woodlands, prairie grasslands, or other natural environs. Clearing for pasture or crop production has also entailed landleveling or topographic changes of the landscape. Leveling and field drainage has resulted in the elimination of many wetlands and depressions that previously attenuated flood peaks by providing detention storage. Without wetlands and depressions, surface and subsurface runoff move more quickly to the channel network. In addition, extensive **nonpoint source pollution** often accompanies agricultural land use practices (see Water Quality component).

Ditches have been constructed to drain the land and streams have been channelized to maximize agricultural land use. These practices result in increased velocities of surface and subsurface flows that correspondingly decrease infiltration opportunities. Decreased infiltration produces increased runoff and subsequent decreased baseflows during the low-flow season.

The impact of agriculture on hydrology is dependent on specific practices such as the type of cover and management treatments, as well as the characteristics of the soil being farmed. The practices that alter the rate of infiltration are most influential in causing a change in the hydrologic regime. The infiltration rates of undisturbed soils vary widely. Agriculture has a greater affect on runoff in areas where soils have a high infiltration rate compared to areas where soils are relatively impermeable in their natural state (USDA 1986).

The Natural Resources Conservation Service (NRCS) has characterized and mapped the soils throughout the state. As part of the mapping process, soils are classified into one of four hydrologic soil groups (Table D-1) primarily as a function of their minimum infiltration rate on wetted bare soil. As part of the NRCS methods (USDA 1986), runoff curve numbers are assigned to areas for each of the combination of three parameters: (1) soil group, (2) cover type, and (3) treatment or farming practice.

Runoff curve numbers are used as part of a simplified procedure for estimating runoff in small agricultural and urban watersheds (USDA 1986). Curve numbers are assigned based on factors such as soils, plant cover, and impervious area. Rainfall is converted to runoff using Curve numbers.

Certain soil conditions can make farming difficult, so amending the soil structure by adding organic matter becomes a way in which farmers can maximize the use of their land. This practice can actually change the hydrologic soil group from, say, a C to a B. In this example, it is possible to reduce the runoff rather than increase it. To detect these changes at this screening level of assessment will be difficult. Voluntary actions and implementation of best management practices to improve soil texture and water holding capacity can be a benefit to the farmer as well as to the hydrology of the watershed.

Table D-1. NRCS hydrologic soil group classification (USDA 1986).

Hydrologic Soil Group	Characteristics of Soils	Minimum Infiltration Rate (mm/hr)
Low Runoff Potential A	High infiltration rates even when thoroughly wetted. Deep, well-drained sands or gravels with a high rate of water transmission. Sand, loamy sand, or sandy loam.	8 - 12
B	Moderate infiltration rates when thoroughly wetted. Moderately deep to deep, moderately well-drained to well-drained, moderately fine to moderately coarse textures. Silt loam or loam.	4 – 8
C	Slow infiltration rates when thoroughly wetted. Usually has a layer that impedes downward movement of water or has moderately fine to fine textured soils. Sand clay loam.	1 – 4
D High Runoff Potential	Very low infiltration rate when thoroughly wetted. Chiefly clay soils with a high swelling potential; soils with a high permanent water table; soils with a clay layer near the surface; shallow soils over near-impervious materials. Clay loam, silty clay loam, sandy clay, silty clay, or clay.	0 – 1

Range Lands

Grazing animals impact range lands in two ways: (1) removal of protective plant material, and (2) compaction of the soil surface. Both of these actions affect the infiltration rate (Branson et al. 1981). Cattle grazing on sparsely forested lands can have similar impacts and should be considered under this heading. In general, moderate or light grazing reduces the infiltration capacity to 75% of the ungrazed condition and heavy grazing reduces the infiltration by 50% (Gifford and Hawkins 1979). Soil compaction, which decreases the infiltration rate, correspondingly increases the overland flow or surface runoff. Surface runoff is the most common kind of runoff on range lands. This is evidenced in that most range-land stream channels are **ephemeral**. In other words, these channels flow with water only during the snowmelt season or after a high-intensity or long-duration rainfall (Branson et al. 1981).

Impacts associated with the use of range lands can be assessed in a similar manner as agricultural lands. There is no statistical distinction between the impact of light and moderate grazing intensities on infiltration rates. Therefore, they may be combined for purposes of assessment. (Gifford and Hawkins 1979).

Forest and Rural Roads

Road networks associated with forestry can alter the rate of infiltration on the road surface and potentially change the shape of the natural drainage. The surface of most forest roads is compacted soil that prevents infiltration of precipitation. Forest road networks primarily increase streamflow by replacing subsurface with surface runoff pathways (e.g., roadside ditches) (Bowling and Lettenmaier 1997). Roads can also intercept and divert overland flow and shallow subsurface flow, potentially rerouting the runoff from one small sub-basin to an entirely different subbasin (Harr et al. 1975 and 1979). Roads can potentially impact peak flows during rainfall events, rain-on-snow events, or spring snowmelt; therefore, the determination of percent of basin occupied by roads provides useful information regardless of the way in which peak flows are generated.

Rural roads associated with either agriculture or range lands can also affect streamflow and will be characterized in a similar manner as forest roads. Roadside ditches are more structured and maintained along rural roads and can significantly extend the stream network density, because their presence is additional to the natural channel. However, if natural channels are altered through straightening or channelizing, the stream network length may decrease. Channelizing streams results in increased velocities and potentially increases erosion rates of the banks and bed.

Roads along stream channels restrict lateral movement and can cause a disconnection between the stream or river and its floodplain. Restricting lateral movement can result in downcutting of the channel and decreased accessibility of flood waters to overbank storage, resulting in decreased flood peak attenuation.

Urban and Rural Residential

Urbanization has the highest impact on hydrology of the land uses addressed. In urban settings, a large portion of the land surface becomes impervious from roads, parking lots, shopping malls, buildings, sidewalks, etc. The streamflow regime is significantly altered from decreases in infiltration rates and recharge rates, corresponding increases in peak flows and volume of runoff, and a decrease in watershed response time (time to peak). Rainfall striking the ground surface moves more quickly from streets and roofs than from naturally vegetated areas; conveyance systems such as storm sewers and lined open channels increase the flow velocities, thereby decreasing the lag time or the time it takes for water to enter the stream channel. Low flows are affected by reduced groundwater recharge resulting from the increase in impervious surfaces. In addition, pervasive nonpoint source pollution often accompanies stormwater runoff in urbanized areas (see Water Quality component). As with agriculture, urbanization has a greater affect on runoff where soils have a high infiltration rate than in areas where soils are relatively impermeable in their natural state (USDA 1986).

Water Law and Water Use Background

Water law in the State of Oregon is based on the **prior appropriation doctrine** or “first in time, first in right,” subject to the physical availability of water and the ability to put it to beneficial use without waste. The most senior appropriator (the right with earliest date) has a right to divert water prior to any junior water right (a later date). The most senior right is the last one to be shut off from diverting water during low streamflows. Any person or entity withdrawing water from a stream or river must have a water right from the Oregon Water Resources Department (OWRD). These water rights are in various levels of use and certification or **adjudication**. For example, there are certificates, applications for certificates, water rights on record and not being used, and rights not using their full entitlement. Each water right has an instantaneous flow amount (the maximum rate at which water can be withdrawn at any point in time), an annual volume restriction (water duty), and a designated beneficial use, including agriculture, domestic, urban, industrial, commercial, fish and wildlife, power, recreation, etc.

In general, agriculture places the greatest demand on our water resources compared to other uses. Water is required for irrigation of crop lands, pasture, stock watering, and/or washdown. In most cases, the period of high demand for irrigation coincides with the period of low streamflow; crop water requirements tend to peak in August, when streamflows are usually the lowest. Water withdrawals are applied to the crop lands for irrigation, and part of that water is used by the crop (evapotranspiration), a portion **percolates** to deep groundwater, and a portion may be returned to another watershed; the total portion not returned to the river is called **consumptive use**. The portion of the diversion that returns to the stream system through subsurface avenues at points downstream is called the **return flow**.

Urban water supply can provide for residential, commercial, and some industrial uses. Water is diverted, treated, and then distributed throughout a municipality. Subsequently, the wastewater is delivered to a sewage treatment facility where it is treated to a "primary" or "secondary" level and discharged to a stream or bay at a distinct location. Much of the residential urban water is nonconsumptive, with the exception of lawn watering, and is returned to the stream network from the wastewater facilities. Lawn-irrigation return flow occurs through subsurface avenues.

Stormwater runoff from urban areas is generally not treated and discharged directly to the stormwater conveyance facilities that often deliver directly to the stream channel.

Industrial water uses can demand large quantities of water for operation of their facilities. Some have on-site treatment facilities and all are subject to discharge quantity and quality restrictions through National Pollution Discharge Elimination System (NPDES) permits.

National forests, national parks, US Bureau of Land Management lands, Indian reservations, etc., are federal reservations. These entities maintain federal reserved rights for the purposes for which the reservations were established. Their priority date is the date the reservation was created. In many cases, reservations were established in the mid- to latter part of the 19th century. Many of the federal reservation water rights have been tried in the courts of law, and, more often than not, case law has set the precedent of adjudicating federally reserved water rights (Winters Doctrine).

Water Rights

There are three primary types of surface water rights: (1) out-of-stream rights, (2) storage rights, and (3) in-stream rights. Out-of-stream rights are also called "direct flow" or "run of the river" diversions. These rights entail withdrawing water directly from the channel with subsequent application for a specific beneficial use such as irrigation, domestic or urban water supply, industrial use, etc. Storage rights can be for on-stream or off-stream reservoirs. On-stream reservoirs capture water as it flows into the reservoir. Water is stored until it is needed for the specified beneficial use, at which time it is released either into the channel and withdrawn downstream or released into conveyance facilities for delivery to the point of use. Off-stream reservoirs require diversion from the river to the storage site, and subsequent release and conveyance to the point of use. In-stream rights are those that require a designated quantity of water to remain in the stream or river for a specific beneficial use, most often for aquatic resources, wildlife, or aesthetics.

Water withdrawals reduce streamflows, potentially resulting in a negative impact on the biologic resources, particularly during the low-flow season. In recent years, in-stream rights have become more common as a means of protecting the biologic resources. In-stream water rights did not exist in Oregon prior to 1955. **Minimum flows** were established by administrative rule in 1955, but they did not carry the full weight of a water right. Between 1955 and 1980, the Oregon Department of Fish and Wildlife (ODFW) conducted basin investigations from which minimum flows were recommended and adopted by rule. In 1987, the legislature changed the administrative rulemaking into an application process for a water right. OWRD holds the water right, but ODFW, Department of Environmental Quality, and State Parks can apply for an in-stream right. Minimum flows were changed into in-stream rights, and the date minimum flows were adopted became the priority date. The in-stream rights can have the value up to but not exceeding the median flow. In-stream rights tend to be junior to the majority of the out-of-stream water rights; this reduces their ability to maintain effective streamflows in the channel. If federal reserved rights for in-stream flows have been adjudicated, they would usually have the most senior right in the basin, because federal reservations were established before the implementation of the Prior Appropriation Doctrine.

Water users with large demands generally have storage rights, because reservoirs provide more certainty of supply during low-streamflow conditions. The ability to capture streamflow during the high flows and use it during low flows can be a significant benefit to water users. In some instances, reservoirs are constructed as flood control facilities to provide attenuation of the peak flows and reduce downstream flooding and damage.

Groundwater rights are those attached to the withdrawal of water from a well. With some exceptions, all water users extracting groundwater as the source of supply must have a water right for the legal use of the water. There are exempt uses that do not require a right. The most significant of these is rural residential water users; these users are limited to 15,000 gallons per day for noncommercial use and irrigation of less than 0.5 acres.

Groundwater has the potential to influence surface water by what is called **hydraulic continuity**. Depending on the location of the well and the geology in the area, water withdrawn can have a corresponding effect on the streamflow. In other words, it is possible for the extraction of groundwater to dry up a nearby stream during low flows. Consequently, the State of Oregon manages surface- and groundwater rights conjunctively, which means there are times at which groundwater withdrawals will be shut down due to low flows in the channel.

Storage

Man-made storage facilities such as water supply reservoirs, flood control reservoirs, or multipurpose reservoirs impact the peak flows downstream of the impoundment. Each reservoir has its unique operating scheme, and therefore will requires more detailed hydrologic investigations, often including release schedules, reservoir routing, etc. If you have a reservoir in your watershed, further technical analyses will be required for the portion of your basin below the dam, while some of these exercises can be completed for the portion of the basin above the dam.

Water Availability

The OWRD has developed a computer model, Water Availability Reports System (WARS), which calculates water availability for any of their designated water availability basins (WABs) in the state. Water availability, as defined by the OWRD, refers to the natural streamflow minus the consumptive use from existing rights. If water is available, additional in-stream or out-of-stream rights may be issued. This value is dynamic and is often updated to account for issuance of new water rights. The *80% level of exceedance* is that which OWRD uses to determine whether additional water rights can be issued in a basin. The 80% exceedance flow is the streamflow that is in the river 80% of the time over a designated 30-year period, which accounts for wet- and dry-year cycles. In other words, that amount of water is in the channel for a given month at least 80% of the time (4 out of 5 years on average).

The following list is an outline of information provided by WARS.

- Month (1 = January, 2 = February, etc.)
- Natural streamflow
- Consumptive use and storage with dates before January 1, 1993
- Amount of water that is physically in the system after uses with priority dates before January 1, 1993
- Consumptive use and storage with dates after January 1, 1993
- Amount of water that is physically in the system after uses with priority dates after January 1, 1993
- Flow rate of any existing in-stream water rights
- Net water available for any potential water right

The WARS program produces both the 80% exceedance and the 50% exceedance flows, along with the associated water availability under each condition. The 50% exceedance flow is the same as the median flow value. The median flow value means half the time the natural flows are above this value and half the time flows are below this value. The 50% exceedance flows were those used as an upper limit in developing in-stream rights for aquatic species and other in-stream beneficial uses. Water rights for out-of-stream uses are issued only when water is available at the 80% exceedance level.

Water availability is the amount of water that is physically **and** legally available for future appropriation, and is determined by the following equation:

$$\mathbf{Q_a = Q_{80} - Q_{cu} - Q_{ir}}$$

where

Q_a = water available
Q_{80} = natural streamflow at the 80% exceedance level
Q_{cu} = consumptive use of diverted water
Q_{ir} = in-stream rights.

Streamflow Restoration Priority Areas

Oregon's Departments of Fish and Wildlife and Water Resources collaborated to develop the Streamflow Restoration Priority Areas (SRPA). This effort was an outcome of the Oregon Plan (1997), which is the broader framework for the Coastal Salmon Restoration Initiative (CSRI). The

CSRI mission is to restore coastal salmon populations and fisheries to sustainable levels. Three major factors were identified in CSRI as exacerbating the loss of fish populations: (1) fish resources, (2) fish habitat, and (3) loss of streamflow. The loss of streamflow is the focus of the SRPA analysis.

The identification of priority areas was based on a combination of biological factors and water use. ODFW identified priority areas to enhance fish populations. A rank was assigned to three categories under fisheries: (1) fish resources; (2) habitat integrity; and (3) risk factors such as a listing under the Endangered Species Act, in-stream flow protection, or natural low-flow problems. OWRD identified areas in which an opportunity existed to enhance in-channel flows. Concurrently, OWRD identified areas in which an opportunity existed to enhance in-channel flows, situations under which water could be saved through conservation, efficiency of use, etc. The criteria for water resources was assigned to two categories: (1) consumptive use by percentage of the median (50% exceedance) streamflow, and (2) number of months an in-stream water right is not met. A priority was established based on the combination of the two resulting factors: "need" (fisheries) and "optimism" (water resources). For example, in the Mid Coast Region (Table D-2), if the need is given a rank of 2 by ODFW and the optimism is given a rank of 1 by OWRD, the basin would not be selected as a priority for flow restoration. In the need and optimism column, 1 is the lowest rank and 4 is the highest.

Table D-2. Initial state restoration priority.

Basin	Flow-Restoration		
	Need	Optimism	Priority
North Coast and Rogue	1 or 2 3 or 4	1 or 2 3 or 4	No Yes
Umpqua	Any	1 2, 3, 4	No Yes
South Coast	1 or 2 3 or 4	1 2, 3, 4	No Yes
Mid Coast	1 2, 3, 4	1 2, 3, 4	No Yes

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