

Chapter 7– Sediment Sources

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Sediment Sources

Intercouncil Watershed
Assessment Committee
Questions/ Issues

- 1) What are the land use trends?
Are the trends contributing to higher sediment loads?
- 2) Inventory land use and describe its relationship to sediment loads.
- 3) Inventory highly erodible land within the watershed.
 - Soil, slope, geology
- 4) What is the sediment level?
How much is entering the creeks?
- 5) What activities contribute sediment to streams and where in the watershed are they? What is the composition of those sediments?
- 6) Does amount of sediment impact fish habitat?

Introduction

Sediment in streams comes from the erosion of upland areas, lateral movement of stream channels (i.e., meandering), and downcutting of streambeds. Soil erosion is the removal of surface material by wind and/or water. Erosion is a natural process that happens in all watersheds. In nature, sediment movement is often episodic, with most erosion and downstream soil movement occurring during intense runoff events. Fish and other aquatic organisms adapt to deal with sediment amounts that enter streams under normal ranges of disturbance (Watershed Professional Network 1999).

In addition to natural rates of erosion, human-induced erosion can occur. Accelerated soil erosion on cropland, forest roads and construction sites is a potential source of sediment pollution to surface waters. Sediments can fill natural depressions and drainages, road ditches, and pool in creeks, destroying fish and wildlife habitat (Ecosystems Northwest 1999).

Separating human-induced erosion from natural erosion can be difficult because of the highly variable nature of natural erosion patterns. Furthermore, human-caused erosion may also be variable in timing and pattern. It is nearly impossible to specify when a human-induced change in sediment is too much for a local population of fish and other aquatic organisms to handle. But in general, the greater a stream deviates from its natural sediment levels the greater the chance that the fish and other aquatic organisms are going to be affected (Watershed Professionals Network 1999).

This chapter will identify the primary sediment sources in Pringle, Glenn-Gibson, Claggett and Mill Creek watersheds. The role of human-induced erosion in the study area is included in the discussion.

Data Sources

Data for this chapter was collected from the following sources: Marion Soil and Water Conservation District (Marion SWCD), City of Salem, Marion County, and the Oregon Department of Geology and Mineral Industries (DOGAMI).

Two Aspects of Erosion

Loss of material from eroded soil and the production of sediments are two major aspects of erosion (Knox et al. 2000). In most cases, both aspects are detrimental. Loss of material tends to reduce the productivity, stability, or utility of the eroded soil, and sediments resulting from water erosion tend to damage soils, water quality, and waterways downslope.

The amount of soil redistributed downslope from an area experiencing erosion is known as “sediment yield.” Sediment yield is an important concept when discussing the connection between erosion and aquatic habitat degradation. In most instances, soil loss at an upland site will not directly impact aquatic habitat downslope. It is the amount of soil from the eroded site that actually reaches a stream or other waterbody (i.e., the sediment yield) that may impact aquatic habitat.

Sedimentation, the settling out of the soil particles that are transported by water, occurs when the velocity of water in which soil particles are suspended is slowed to a sufficient degree and for a sufficient period of time to allow the particles to settle out of suspension.

Importance of Sediments to Salmonids

The amount and type of sediments available in a stream is an important factor in determining adequate spawning habitat for salmonids. Although excessive sediments of any size (i.e., gravel, sand, silt) can negatively impact the survival and growth of salmonids, a certain amount of sediment, such as gravel, is necessary for spawning and for the survival and growth of juvenile salmonids. Coarse sediments also provide habitat for many of the aquatic insects that are a food source for salmonids.

Fine particles deposited on a streambed may blanket spawning gravels and reduce survival of fish eggs incubating in the gravel. Fine sediment may cover exposed rock surfaces preferred by aquatic insects, reducing the food supply to fish. Suspended sediments cause turbidity (clouding of the water), which limits visibility and prevents fish from feeding. Large deposits of coarse sediments can overwhelm the channel capacity, resulting in pool filling, burial of spawning gravels, and, in some cases, complete burial of the channel, resulting in subsurface stream flows (Watershed Professionals Network 1999).

Erosion Factors

Wind, ice, water and gravity all dislodge and relocate soil in the erosion process. Water is the primary means by which soil erosion leads to non-point source pollution. Water-based soil erosion processes are described below (Marion Soil and Water Conservation District 1982):

1. Raindrop erosion results from direct impact of raindrops upon soil particles. The impact dislodges soil particles, which can then be transported by the flow of surface runoff.
2. Sheet erosion is the removal of a layer of exposed soil by raindrop splash and runoff. The removal is by the movement of broad sheets of water over the land and is not confined to small depressions.
3. Rill and gully erosion occurs when runoff flows concentrate in rivulets, cutting several inches deep into the soil surface. These grooves are called rills. Gullies may develop in unrepaired rills or in other areas where a concentrated flow of water moves over the soil.
4. Stream and channel erosion can occur if the volume and velocity of runoff taxes the capacity of stream or channel banks and bottom.

Soil characteristics, vegetative cover, topography and climate interrelate to determine an area's erosion potential.

Soil Characteristics

Erodibility defines how susceptible a soil type is to erosion. Several specific factors determine actual soil erodibility (Marion Soil and Water Conservation District 1982):

1. Average particle size
2. Percentage of clay particles
3. Percentage of organic content
4. Soil structure

5. Soil permeability

Soils with a high percentage of sand and very fine silt are the most erodible. These materials are not tightly bound to other soil particles and are easily dislodged. As the amount of clay or organic matter increases, the soil's erodibility decreases. Clay serves to bond particles together and organic matter contributes to soil structure, thereby improving stability and permeability. Organic matter also increases soil capacity to absorb water, and thus reduce runoff (Marion Soil and Water Conservation District 1982).

The least erodible soils include well-drained gravel and gravel-sand mixtures with a minimum of silt. Long or steep slopes contribute to soil erodibility even for soils with low erodibility potential. In contrast, soils with high erodibility may erode very little in areas with gentle slopes or management practices that protect soils (Marion Soil and Water Conservation District 1982).

Vegetation

Vegetative cover is another factor in determining erosion potential. Its presence influences erosion in the following ways (Marion Soil and Water Conservation District 1982):

1. Shields the soil surface from the impact of falling rain
2. Slows the velocity of runoff by obstruction
3. Maintains the soil's capacity to absorb water
4. Holds soil particles in place

Promotion of land management practices that protect or restore existing vegetative cover and minimize exposed soil will significantly lessen soil erosion and related sedimentation. Preserving vegetation is particularly important in areas with high erosion potential, such as steep slopes, drainage ways and riparian areas (Marion Soil and Water Conservation District 1982).

Topography

A watershed's size and shape determine the quantity and rate of runoff, which influences the area's erosion potential. The greater the area's slope and runoff volume, the higher the potential for erosion (Marion Soil and Water Conservation District 1982).

The slope orientation contributes to erosion potential. A south-facing slope with minimal vegetation and unproductive soil may have difficulty re-establishing vegetation. To minimize potential erosion, bare slopes must be protected and replanted as soon as practical (Marion Soil and Water Conservation District 1982).

Climate

Erosion is also influenced by climatic factors, including the frequency, duration and intensity of precipitation. As runoff increases, its ability to transport soil directly also increases. Climate-related erosion potential varies seasonally according to temperature and rainfall (Marion Soil and Water Conservation District 1982).

Sediment Sources

There are many potential sources of sediments, but land use will determine which sources are important in a watershed. Pringle, Glenn-Gibson and Claggett Creek watersheds are highly urbanized or urbanizing watersheds. Land use in the Mill Creek watershed is predominately agricultural but the watershed is also experiencing a rapid rate of development as the cities of Salem, Turner, Aumsville, Sublimity and Stayton continue to grow. Important sediment sources in a landscape dominated by agricultural and urban land uses include the following:

1. Agricultural runoff (i.e., crop land and pasture)
2. Urban runoff
3. Eroding streambanks
4. Landslide hazard areas (i.e., hillsides that are unstable and vulnerable to landslides)

Agricultural Runoff

In rural areas, soil functions primarily as an ecological and hydrological resource that supports the growth of plants and controls the fate of precipitation (Knox et al. 2000). It provides water, nutrients, and mechanical support for natural or managed stands of vegetation, for animal populations, and for vegetation management practices.

Production of food, feed, and fiber is the primary motivation for vegetation management on farms (Knox et al. 2000). Soil loss from a crop field means a loss of nutrients, water retention, and a growing medium for plants. Healthy soil ensures the continual productivity of a farm operation. For this reason, soil retention on farm fields is of great importance.

Evaluating soil erosion from cropland is complicated, since it is related to many factors, such as the types of crops planted, soil type, farming practices, topography, and the timing of erosion-causing events (i.e., high intensity rainfalls, summer

thunderstorms, quick snowmelt). In order for much soil movement to occur, these erosion-causing events must coincide with the cropland being vulnerable to erosion. When a field is covered by vegetation with thick roots, a high-intensity rainfall will not create much erosion. Yet, when that same field is freshly plowed, a high-intensity rainfall may cause extensive erosion (Watershed Professionals Network 1999).

Farming practices that incorporate erosion control measures are extremely important in areas with a high potential for surface erosion. **Map 7-1** and **Map 7-2** show the location of “highly erodible lands” (HEL) in the four watersheds. HEL is determined by using information regarding the soil characteristics of different soil types and the local topography. To encourage the use of erosion control practices on HEL, the federal government requires all farmers enrolled in farm subsidy programs to have a farm conservation plan if they have HEL on their land. The farm conservation plan will outline erosion control measures that the farmer must follow in order to reduce erosion from his or her property.

Reducing erosion from cropland helps protect streams not only from excessive sediment, but also from elevated nutrient and pesticide loads. Nutrients, such as phosphorus, and chlorinated pesticides attach themselves to fine soil particles and can be transported to streams during erosion events. Some soils associated with HEL contain high amounts of silt and clay, fine particles that readily attach themselves to nutrients, pesticides, toxic substances, and trace elements.

The amount and location of HEL in each watershed varies. In the Mill Creek watershed most of the HEL is located in the headwaters, tributaries of Beaver Creek, hills north of the City of Turner, west side of McKinney Creek and scattered throughout the entire Battle Creek basin (**Map 7-1**). In the Pringle Creek watershed, HEL is located in the mid-portion of the watershed between south Commercial Street and the East Fork of Pringle Creek. HEL predominates throughout the Glenn-Gibson watershed except for the lower portion of watershed along Wallace Road. Finally, the small amount of HEL in the Claggett Creek watershed is mostly associated with steep slopes immediately adjacent to waterways (**Map 7-2**). According to the historical vegetation maps presented in the Overview of Watersheds chapter, most of the HEL was once upland closed forest or savanna.

There are approximately 2,546 farms in Marion County. Approximately 306,000 acres of land is farmed in the county (See maps in the Overview of Watersheds chapter). According to the Economic Information Office of Oregon State University Extension Service, the agricultural commodity sales of Marion County totaled over \$463 million dollars in 1998. Over 200 crops are grown in Marion County. The top ten agricultural commodities are shown in **Table 7-1**.

Table 7-1. Agricultural Commodity Sales (\$) Marion County, 1998

Commodity	Sales (in millions of dollars)
Nursery	91
Grass seed	71
Vegetables	51
Dairy	45
Berries	35
Greenhouses	31
Christmas trees	30
Horticulture	25
Eggs	20
Hops	16

Source: OSU Extension Service

Erosion control continues to improve on farms with the help of the Natural Resource Conservation Service (NRCS), the local soil and water conservation districts, and cooperating landowners. The agencies work with a landowner to develop a farm management plan customized to fit the needs of the farmer while improving soil retention on crop fields and pastures. Minimum tillage, crop residue management, cover crops, contour farming, cross-slope farming, filter strips and riparian buffers are some of the techniques used by farmers to prevent erosion and to reduce the amount of sediment entering local streams.

Efforts to reduce the amounts of pollution from agricultural and rural lands continue with the development and implementation of Agricultural Water Quality Management Area Plans (AgWQM). The AgWQM Area Plans and Rules were created pursuant to Senate Bill 1010 (AgWQM Act), passed by the 1993 Oregon Legislature.

A commitment to healthy streams and improved habitat for threatened and endangered aquatic species, known as the Oregon Plan for Salmon and Watersheds, was developed by the state of Oregon in 1997. The AgWQM Act has been incorporated into the Oregon Plan as the agricultural community's response to water quality issues.

The Oregon Department of Agriculture, in consultation with other state agencies, determines priority watersheds for development of AgWQM Area Plans. Through its locally based planners, ODA assembles a Local Advisory Committee consisting of stakeholders residing in the watershed. The committee is responsible for developing a draft action plan to address water quality issues arising from agricultural activities and soil erosion on rural lands.

AgWQM Area Plans describe water quality issues, goals and objectives for the watershed. It also details strategies for improving water quality, such as education,

funding for conservation projects, and one-on-one technical assistance for landowners. AgWQM Area Rules describe conditions that must be met on all agricultural lands, allowing landowners to decide how to meet the conditions. The intent of both Plans and Rules is to give landowners flexibility in meeting water quality standards and encourage water quality improvements through voluntary conservation as much as possible. Enforcement is used as a last resort when repeated attempts to develop a voluntary solution have failed.

The AgWQM Plan for the Mollala-Pudding-French Prairie-North Santiam Sub-basins (Mollala-Pudding-French Prairie-North Santiam Sub-basins Local Advisory Committee 2001) includes the rural lands found in the Mill Creek, Claggett Creek and Pringle Creek watersheds. An AgWQM Plan being developed for the Middle Willamette AgWQM Area in Polk and Benton Counties includes the Glenn-Gibson watershed.

Urban Runoff

In urban locations, sediment derived from erosion has a major environmental impact. In these developed areas, the primary source of sediments is from active construction sites. According to recent studies, construction sites transport sediment at 20 to 2,000 times greater the rate of other land uses (Schueler 2000a).

Approaches to soil management differ significantly between urban and rural areas. This has implications for sediment and erosion. At rural sites soil is treated as an economic, ecological and hydrological resource that is essential for crop growth. In urban locations soil is excavated and relocated to facilitate residential and commercial uses. Thus, erosion prevention and sediment control methods vary between urban and rural settings (Knox et al. 2000).

At urban construction sites, most of the erosion occurs during the brief period of actual construction. Less erosion takes place before construction begins, and it tapers off afterwards. One reason that construction sites have so much erosion is that in most cases construction start-ups include removal of the vegetation. Heavy equipment tends to compact soil surface layers. These bare soils are at risk for erosion, as are exposed agricultural lands before crops are planted (Knox et al. 2000).

Soil loss in rural areas has serious ramifications for agriculture, including lesser water retention and fewer nutrients for growing crops. In contrast, soil loss at urban construction sites is relatively small and can be replaced without major expense. Urban erosion is important because it is the source of potentially damaging sediments in local waterways. In urban locations, sediment yield often has more impact than loss of soil at the construction site (Knox et al. 2000).

In response to the listing of several salmonid species under the federal Endangered Species Act and growing concern over water quality in the Willamette Valley, many cities are beginning to adopt stricter erosion prevention and sediment control ordinances. The City of Salem has recently adopted a new Erosion Prevention and Sediment Control Program, found in Chapter 75 of the Salem Revised Code. The

ordinance was effective as of September 2001. The principal focus of the ordinance is to prevent erosion from all “ground-disturbing activities” such as new home and building construction, fill and removal activities, and other types of construction in which soil is exposed or moved. The intent of the new program is to minimize the amount of sediment and other pollutants reaching our waterways, wetlands, and the public storm drainage system and thus protect the environment during the life of the ground-disturbing activity. Permits and City of Salem compliance inspections are required with the new ordinance. The program also establishes “performance standards” which apply to all parcels and all land within the city, regardless of whether that property is involved in a construction or development activity (City of Salem 2001a).

Other Sources of Sediments in an Urban Setting

In addition to construction sites, other sources of sediment in urban areas include wind-deposited soil or atmospheric deposition (often from sources far removed from the local watershed), degrading pavement, and erosion from yards and other areas not covered by impervious surfaces. Stormwater sediments may include leaves, twigs, grass clippings, and pet waste.

Different types of land within an urban setting produce different amounts of sediment (Watershed Professionals Network 1999). Residential neighborhoods produce the least amount of sediment per square mile. Commercial areas produce moderate loads of sediment, and heavy industrial areas produce even higher amounts.

The importance of these sediments to water quality is evident not only in the amount of sediment that could potentially reach local streams, but also in the amount and kind of pollutants associated with the sediments. According to a study conducted in Alameda County, California (Mineart and Singh 2000), sediments found trapped in storm drain inlets were highly enriched in trace metals and petroleum hydrocarbons; residential areas had the highest concentration of petroleum hydrocarbons and commercial and industrial areas had the highest metal concentrations (i.e., copper, lead and zinc).

Street cleaning, frequent catch basin cleaning and the use of detention ponds are tools typically used in an urban environment to reduce the amount of sediments entering the stormwater system and waterways. The effectiveness of these tools can vary.

Street Cleaning

Regular street cleaning can make quite a difference in how much sediment ends up in the stormwater. Normal mechanical sweeping does a moderately good job of reducing sediment in curbs and parking lots. Vacuum-assisted cleaning following mechanical sweeping removes an even larger portion of surface sediments, especially those sediments that are lightweight or small and do not readily settle out in detention ponds (Watershed Professionals Network 1999).

The City of Salem regularly cleans its streets using regenerative air sweepers (City of Salem 2000). Salem sweeps its central business district and Capitol Mall area once a week, increasing the frequency of cleaning to two times a week during summer months. The frequency of residential sweeping is determined by debris accumulation rates identified in four categories: *Light, Medium, Heavy, and Very Heavy*. The *Very Heavy* debris accumulation zone contains five routes and is swept eight times per year. Eleven routes are ranked as *Heavy* accumulation zones and are swept six times per year. The *Medium* debris accumulation zone contains 13 routes and is swept four times per year. The 12 routes in the *Light* zone are swept twice a year. All accumulated debris is disposed of in the City's DEQ-approved landfill site located at the south end of the McNary Field Airport, near the shared watershed boundary of Pringle and Mill creek watersheds.

The City notes both quantity and quality of material collected by the street sweepers. According to the City of Salem (2000), the City swept 12,900 curb miles, collected 2,480 cubic yards of sweeping debris, and removed 4,500 cubic yards of leaves during the 2000-2001 fiscal year. The City plans to expand the street sweeping program. The annual budget of the program increased in fiscal year 2001-2002. Plans to increase the budget and add a fourth sweeping machine is targeted for the 2004-2005 budget. The City of Salem also uses volunteers through its Adopt-A-Street program to help keep streets clean. The program has been very successful. In fiscal year 2000-2001, 1050 volunteers collected 13,480 pounds of trash from our city streets.

Catch Basin Cleaning

Storm drains help convey urban runoff from streets to receiving waters. Depending on the design of the stormwater system, the system has some capacity to capture and temporarily store sediments and debris. Storage components include drop inlets, sump pits or catch basins (Mineart and Singh 2000).

Many public works departments across the U.S. annually remove the sediments that accumulate in storm drain inlets using vacuum trucks or manual methods. In Salem, catch basins are cleaned on a proactive basis, supplemented on an "as needed" basis based on complaints, storm conditions, and observations made by city crews (Downs pers. comm.). The "Catch Basin Rangers" clean all of the catch basin grates on a regular basis during the leaf season (normally October thru January). The goal of keeping the grates clear during the leaf season is to avoid local ponding/flooding conditions. From January to March, the catch basin themselves are cleaned of debris and sediment.

While catch basins are cleaned regularly, trash does still reach our streams. For this reason, the City of Salem supports the volunteer-based annual City-wide stream cleanup program. This program is now supplemented by the Public Works seasonal "stream team" which utilizes a team of twelve seasonal employees to walk the urban streams and remove trash and debris, including "log jams" and other similar blockages that impair the streams' flow and carrying capacities (City of Salem 2000). In 2000, over 47,000 pounds of trash and 33 cubic yards of recyclable material were recovered from

Salem's creeks, including 12,100 pounds from Clark and Pringle Creeks, 1,560 pounds from Glenn Creek, 16,120 pounds from Claggett Creek and 12,560 pounds from Mill Creek (including Shelton Ditch and Waln Creek).

The City of Salem has also initiated a storm drain stenciling program. Storm drain stencils remind citizens not to dump any wastes into their local storm drains. The total number of storm drains stenciled to date is unknown. From 1997 to 1999 approximately 1,020 storm drains had been stenciled (City of Salem 2000). Storm drain markers have recently been incorporated into the program. In 2001, curbside markers were applied to 350 storm drains in the Glenn-Gibson watershed. The markers are like stickers that are applied to a curb using an adhesive.

Finally, roadside maintenance practices have been improved to reduce the amount of sediment entering storm drains (City of Salem 2000). Roadway pavements are repaired as rapidly as resources and weather allow, thus decreasing the amount of degraded pavement entering storm drains. Where possible, potholes are now fixed with hot asphalt instead of "cold mix" asphalt. This helps reduce the amount of asphaltic debris migrating into drainage ditches and catch basins. Regenerative air street sweepers are regularly used to clean debris from roadways after repairs are made.

Where possible, graded shoulder widths are reduced to a minimum in order to promote vegetation growth near roads (City of Salem 2000). The vegetation helps stabilize slopes and retain aggregate in the shoulder area, filter road surface runoff, and still allow stormwater to properly drain from road surfaces. The type of rock used for shoulders has also been changed. Shoulder rock now being utilized is "fully fractured," which locks into place and has greatly reduced the amount of erosive aggregates into the creeks, ditches and catch basins.

Detention Ponds

The final tool used to reduce the amount of sediments entering stormwater systems and waterways is the construction of stormwater detention ponds. Stormwater ponds are one of the most effective techniques for providing channel protection and pollutant removal for urban streams (Schueler 2000b).

The City of Salem has 550+ on-site detention facilities (City of Salem 2000). These facilities were inventoried and field evaluated for their effectiveness in controlling stormwater quantity and quality during the summer of 1997. Each facility's location and identification number is now included in the City's GIS system for the stormwater infrastructure system. The detention facility field inventory and evaluation is being repeated during the spring/summer of 2001, with the resulting data and photos being incorporated into the City GIS system for quick reference and updating.

To improve the functions of stormwater detention ponds, the City of Salem has initiated a maintenance program that includes scheduled City inspections, public information regarding owner operation and maintenance responsibilities, and compliance assurance procedures to encourage proper maintenance and operation (City

of Salem 2000). The City is also pursuing the use of regional detention facilities. Consultants have been hired to evaluate the identified potential regional detention sites (see Hydrology chapter).

Marion County Best Management Practices

Marion County recently developed BMPs for routine road maintenance, parks and facilities maintenance, ferry operation, engineering design, and other activities. These BMPs include actions to reduce soil erosion. The intention of the BMPs is to guide specific Public Works activities in the County's on-going efforts to aid salmon recovery. The *Marion County Department of Public Works Best Management Practices* was adopted by the Marion County Board of Commissioners on July 11th, 2001 (Marion County Public Works Department 2001).

The BMPs and supporting documentation (Maps, Environmental Baseline Assessment, ODOT comparison matrix, etc.) to seek a programmatic limitation under Limit 10 of the Endangered Species Act's 4 (d) rules was submitted to the National Marine Fisheries Service in September of 2001 (Marion County Public Works Department 2001).

Channel Erosion

The appearance of a channel reflects site-specific, relatively short-term processes, such as flow energy, and broader resistive forces such as geology and climate. The complex interactions among these factors ensure that stream channels are seldom in a steady state. Channel erosion is an example of these dynamics. It is a natural process resulting from the flow energy being greater than the resistive forces. Channel erosion and meandering help create gravel deposits, deep pools, and areas of low water velocity that are critical to fish habitat. However, considerable damage can be done to a stream and the fish habitat it provides by drastically changing the relationship between flow energy and resistive forces (Watershed Professionals Network 1999).

Stream bank or channel erosion removes portions of the land surface above and adjacent to the bank. When high flows saturate soils and undercut the toes of banks, unprotected stream banks slough or collapse in large slabs, delivering sediments directly into the stream (Ecosystems Northwest 1999). Severe channel erosion destroys the productive capacity of the soil, vegetation, fences, roadways, and buildings on the undercut land.

Channel erosion is frequent in urban settings (Knox et al. 2000). Streets, buildings, and other impermeable surfaces reduce infiltration of precipitation to zero, transmit runoff efficiently in the short term, and concentrate water flow. Extensive areas of impervious surface in urban settings increase the total runoff and greatly

augment peak stream flows, thus increasing stream power. One study estimated that channel erosion rates were three to six times higher in a moderately urbanized watershed (14% impervious cover) than a comparable rural one, with less than 2% impervious cover (Neller 1988; Caraco 2000). Public and private landowners attempt to counteract the higher rates of erosion in urban areas by increasing the resistive forces of the stream banks. This is done by replacing the earthen banks with riprap (i.e., large chunks of concrete, rocks or other hard material) or retaining walls.

Channel erosion is exacerbated in urban areas even where attempts are made to preserve the natural character of the streams. In many parks and natural areas, recreation near or in streams results in a loss of streamside vegetation, compacted soils, and disturbance to the streambed. The number of humans and dogs climbing into creeks in urban areas is causing Salem's Parks Operations to consider designing appropriate "access points" on sensitive lands, such as at Woodmansee Park in South Salem.

Human-induced channel erosion also occurs in rural areas. Streambanks are vulnerable to intensive grazing. Livestock are attracted to the lush vegetation of riparian areas in late summer and fall when other foraging areas have become dry and less productive. When intense grazing occurs during this period, streambanks are left with sparse foliage and root mass during potential high-flow periods in winter and spring.

Eliminating riparian buffers and cropping to the top of bank can also increase rates of stream bank erosion. Annual crops do not provide the aboveground stem density or the belowground root mass necessary to keep soil in place. High flows in winter and spring can easily erode stream banks denuded of perennial vegetation and wash away fertile soil. Examples of this may be found along Mill Creek above Stayton.

Management practices that can help slow high rates of channel erosion include the establishment and maintenance of a riparian buffer, and limiting development and certain activities within the buffers. Flow energy can be decreased by incorporating stormwater detention ponds, restoring wetlands in floodplains, using bioengineering techniques for bank stabilization, and reducing the amount of impervious surface in a watershed.

No survey has been conducted on the location and extent of channel anchoring in local streams in the study area. No survey is available on the location and extent of stream banks that may be experiencing moderate to high rates of erosion.

Landslide Hazard Areas

Many hillsides, especially in Western Oregon, are unstable and vulnerable to landslides, debris flows, and mudflows. These can result from ground saturation, runoff, improper or poorly designed drainage systems or earthquakes. Landsliding is a natural process that tends to reduce the height and slope of mountains and ridges and is part of the normal ongoing process of smoothing topographical high points. Slides occur in natural materials and in placed fill materials. The process is simple: a mass of

earth slides when the forces from the weight of the slide mass exceeds the strength of the material holding it in place. Determining specifically when and where sliding will occur is difficult. Landslides and mudflows occur especially when prolonged heavy rainfall saturates the soil and rocks, and when human activities steepen the slopes, remove the toes of slopes, add weight or water to the slopes (City of Salem 2001b), or remove vegetation.

Map 7-3 shows the landslide hazard areas in the four watersheds within the Salem-Keizer UGB. The hazard areas delineated are actually the combination of three data layers: slopes greater than 25%, slopes that may be unstable during earthquakes, and areas that are susceptible to water-induced landslides. The latter two layers of data were developed by the Department of Geology and Mineral Industries (DOGAMI). Land was “scored” on its susceptibility to landslides based on the three parameters given above. Unfortunately, DOGAMI only had information regarding earthquake-susceptible slopes and water-induced landslides for West Salem and the southwest portion of Salem, so the remaining land within the Salem-Keizer UGB was only scored using the 25% slope criteria. This lack of information explains why many areas in the UGB scored no higher than “3” on their susceptibility to landslides. If information on the other two data layers was available, some of the areas scoring “3” or lower may actually score higher.

DOGAMI has developed earthquake-induced landslide hazard maps, and a report explaining how the maps were made, for small communities throughout Oregon, including Aumsville, Sublimity, and Stayton in the Mill Creek watershed (Madin and Wang 2000).

Landslides are a natural phenomenon, but the risk of human-induced landslides needs to be reduced in order to minimize human and physical losses. To reduce the risk of landslide hazard, local governments will need to use a variety of tools. These may include land use planning, building codes, zoning regulations, public education, open space preservation, and other activities. The City of Salem has a Landslide Hazard Ordinance.

Marion County has also passed a landslide ordinance, effective in 2002. The ordinance applies only to landslide hazard and excessive slope areas in the county that have been identified and mapped (Marion County Community Development Department 2001). In the four watersheds, steep slopes susceptible to landslides outside of the Salem-Keizer UGB are located in the Battle Creek basin and the upper portion of the Mill Creek watershed above Stayton.

Summary

Erosion is a natural process. Human-induced erosion accelerates natural background rates of erosion and can increase the sediment yield in streams, thus degrading aquatic habitat. Separating human-induced erosion from natural erosion is difficult because of the highly variable nature of natural erosion patterns. In addition, human-induced erosion also tends to be variable in timing and pattern (Watershed Professionals Network 1999).

The main sediment sources in the four watersheds include: agricultural runoff, urban runoff, channel erosion, and slopes susceptible to landslides. While the amount of sediment contributed from each of the sediment sources is unknown, steps are being taken to reduce erosion rates in both agricultural and urban settings. The implementation of Agricultural Water Quality Management Plans and farm conservation plans will facilitate the incorporation of erosion control measures on farmland. Changes in land use planning, building codes, construction site maintenance, and zoning regulations will help reduce erosion rates in urban areas. Open space preservation, strict riparian and wetland preservation ordinances, and restoring/enhancing riparian buffers will aid in reducing channel erosion and decreasing sediment loads in streams.

Recommendations

All Basins

1. Estimate surface erosion rates from cropland, pasture land, and fallow (unmanaged) land using a model based on the Universal Soil Loss Equation. This equation will require the collection of data on rainfall intensity, erodibility of soils, steepness and length of slopes, crop type, and type of farming practice (i.e., conservation tillage vs. no conservation tillage), and vegetation type in areas not farmed. Use the model to develop a map that shows the location of erosion “hot spots” in the rural portions of the watersheds.
2. Estimate surface erosion rates and sediment load estimates in urban areas using a land use-based model. Refer to the Long Tom Watershed Assessment (Thieman 2000) for more details on this kind of model.
3. Collect information on turbidity and flow in streams and use data to calibrate both the agricultural and urban model for erosion rates and sediment yields. The City of Salem has collected information on turbidity and total suspended solids (TSS) on a monthly basis for the four watersheds. This information was not analyzed in this assessment due to time constraints. The data collected can be used to determine background rates of turbidity and TSS.
4. Conduct a survey on the location and extent of channel armoring (i.e., riprap, retaining walls, gabions, etc.) in our creeks. Determine channel erosion “hot spots” and when feasible use bioengineering techniques, including restoring wetlands and riparian buffers, to alleviate erosion rates.
5. Support the City of Salem’s new Erosion Prevention and Sediment Control Program. Encourage county and other city governments to adopt ordinances that prevent erosion and control the amount of sediment entering our streams. Ordinances should include compliance inspections at construction sites to ensure erosion control measures are being followed. Ordinances should be updated and modified as new information on surface erosion rates, sediment loads, BMPs, and bioengineering techniques becomes available.
6. Limit development in riparian areas, wetlands and floodplains, which slows the rate of surface runoff, and reduces the sediment entering streams. These areas also reduce the rate of urban streamflow and decrease channel erosion. The protection of these natural areas decreases the need for expensive stormwater facilities.

7. Where natural watershed features can no longer manage urban stormwater runoff, support the construction of detention ponds that use native vegetation to provide improved water quality and wildlife habitat.
8. Provide education to maintenance crews, groundskeepers and construction crews on Best Management Practices (BMPs) for soil erosion. Support programs such as Salem's Parks Operations Sensitive Lands Management Program. Also help large landholders such as Willamette University and the State of Oregon, to use BMPs for soil erosion because their maintenance and construction activities have a significant impact on water quality.
9. Encourage local public works departments to continue incorporating street maintenance procedures that reduce erosion.
10. Provide volunteers for Adopt-A-Street, stream cleanups and storm drain stenciling programs.
11. Increase the efficiency of existing stormwater detention facilities by supporting the City of Salem's maintenance program for them. Provide public education to people who have stormwater detention ponds on their property and emphasize the importance of maintaining them for the health of local streams and the protection of property downstream.
12. Analyze data to determine what relationship exists between soils/sediments and pesticide/fertilizer residues. Specifically,
 - a. Determine which types of soils have the greatest propensity for binding with chemical pesticides and fertilizers.
 - b. Determine the potential cumulative effect of soils laced with pesticides coming into contact with urban runoff particulates and the substances concentrated in catch basins. For example, what is the carrying capacity of binding capability of HEL soils when placed in contact with industrial/parking lot runoff?
 - c. Determine if there are greater risks with pesticide or chemical-laced soils in the areas identified as being HEL.
 - d. Determine whether additional protections are merited in Salem's erosion control program and landslide hazard ordinances for areas with HEL.

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