The Washington Water

# RESOURCE

**The quarterly report of the Center for Urban Water Resources Management**

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CONTENTS



## Message from the Director

In this issue of the Newsletter, we highlight some of the variety of the graduate student research related to the management of urban water resources that has recently been completed on the University of Washington campus. Not all of the work is being done under the direct auspices of the Center, but it is all relevant to our collective interests and well worth broad exposure. This reflects one of the goals of the Center—to help provide access for outside people and agencies into the University community, be it for training, information, or research. Only a scant fraction of the relevant work will ever be done directly by any single group here; but a research center such as ours can improve the connections between researchers and users, wherever they may be located.

One project that the Center is fully involved in is the second annual Stream Temperature Survey, conducted on August 4th with the help of 108 individuals (see the last issue of the Newsletter). We have compiled the temperatures, flow, and riparian conditions for 786 sites this year, and we can already see some intriguing similarities and differences with last year's effort. We should have a much more complete report ready in the next few months; some of the preliminary results will be available at this year's Annual Review on October 15 (see accompanying article).

*Derek Booth* ❖

## Annual Review of Center Research

On *October 15th, 1999,* faculty and students affiliated with the Center will summarize our results from this last year's research. The presentations will take place from 9:00 AM until 12:00 noon at the Waterfront Activities Center (WAC) on the University of Washington campus. The WAC is a low building on the shore of Union Bay, southeast of Husky Stadium and northeast of the Montlake Bridge. To get there drive on SR 520 (Evergreen Point Bridge) towards the University from I-5 or I-405 and take the Montlake Boulevard NE exit northbound, cross the Montlake Bridge, continue north a few hundred yards through the major fork in the road at the Pacific Street traffic light and turn right at the next light, 0.1 mile beyond, immediately next to the stadium (a large sign, "West Plaza," will be on your right). Double back to the south to the parking kiosk ($6.00 for the day, pay as you enter). The WAC is at the rear of parking lot "E12" south of the stadium; we will be on the upper (parking-level) floor. Metro buses 43 and 44 also stop nearby.

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*Web address:*
http://depts.washington.edu/~cuwrm/



*ANNUAL REVIEW (from page 1)*

The schedule of presentations is still being confirmed as this newsletter goes to press, but the following reports are anticipated:

- Urban Stream Rehabilitation—status report of the three-year project
- Monitoring protocols for urban streams
- Results of the automated land cover classification and watershed impervious-area determinations from LANDSAT imagery
- Puget Lowland urban corridor geology and geologic hazards
- The second annual snapshot of regional stream temperatures
- Evaluation of road ditches and biofiltration swales for water-quality improvement of road runoff ❖

## 35th Annual AWRA Conference —*Watershed Management to Protect Declining Species*

DECEMBER 5-9, 1999, SEATTLE, WASHINGTON

There are many local, state and federal regulations that influence water resources policy in this country. In this decade emphasis at the federal level has been placed upon watershed-based planning efforts and control of non-point source pollution. But few regulations can have so immediate or dramatic effect upon water resource programs as the listing of a species under the Federal Endangered Species Act (ESA). The West Coast States have seen widespread listings for salmon and other aquatic species that may require major reallocation of water supplies. Dam operations on the Columbia, Colorado and the Platte Rivers are being greatly altered to more closely mimic natural flows. Other dams are being studied for removal altogether. Groundwater law in the State of Texas is being defined largely as a consequence of the need to protect several major springs supporting endangered species. A mammoth water restoration project in South Florida is being undertaken, in part, to restore threatened species. New ESA regulations are impacting water management in large metropolitan areas and even entire states.

The theme of the conference this year is *Watershed Management to Protect Declining Species*. One entire track of the conference will be devoted to aquatic ESA programs and water management. Ten sessions representing regions all over the country will present strategies which have evolved to meet the federal mandate of restoring endangered species. These sessions will emphasis changes made to traditional water resource management practices that have been driven by ESA. Emphasis will be placed on approaches that have been successful and those that have failed. Plenary sessions on the second and third day of the conference will feature expert panels who will provide broad perspective on water resource management and species preservation. Audience participation will be encourage and the discussions are bound to be lively. In addition two other tracks will be devoted to state-of-the-art presentations of the broader topics covered in an AWRA conference such as watershed analysis, water quality, hydrology and water policy. In addition, an exciting, concurrent symposium will be held: *Water Resources and the World Wide Web*. This symposium will cover the explosion in useful real-time and archived water resource information, which is literally a few mouse clicks from your PC screen.

The web site for the conference is:
http://www.awra.org/meetings/Seattle99/index.htm
❖

# Sediment Budget of a Mixed-Use Urbanizing Watershed

*By Erin Nelson, Graduate Research Assistant, Center for Urban Water Resources Management*

## INTRODUCTION

The Issaquah Creek basin is an urbanizing watershed of 144 square km in western Washington, where sediment aggradation of the main channel and delivery of fine sediment into a large downstream lake have raised serious local and regional concerns. The basin has many water quality problems associated with erosion occurring throughout the watershed. The water quality of Lake Sammamish, located at the outlet of the basin, is degrading with time, and fine sediment entering the lake from the watershed is a likely source of phosphorus during periods of lake anoxia. Additionally, flood-prone areas in the basin along the mainstem of Issaquah Creek in downtown Issaquah may be exacerbated by channel aggradation and subsequent reductions in flow conveyance. Another potential in-channel concern is the effect of fine sediment on spawning gravel for the salmon species that occupy Issaquah Creek. A sediment budget was constructed for this mixed-use, rapidly developing watershed to evaluate the relative effects of land-use practices, including urbanization, on watershed-scale sediment supply and delivery. It also can be used to identify the major sources of sediment, and thus guide the most effective remedial measures.

## METHODS

Sediment production was evaluated for the different land uses in the basin, which include urban development, construction, forest/timber harvesting, and landfill and gravel quarry operations. GIS (Geographic Information System) data were used to determine land use categories and areas, and to evaluate basin characteristics that should influence erosion and sediment delivery potential. Within each land-use category, the sediment production and delivery processes associated with each general land use were evaluated using a combination of methods described in the geomorphologic and engineering literature.

## RESULTS

The current annual sediment production rate is estimated at 44 tonnes $km^{-2}$ $yr^{-1}$, relative to a pre-development estimate of 33 tonnes $km^{-2}$ $yr^{-1}$. The main sources of sediment in the basin are landslides (50%), channel bank erosion (20%), and road surface erosion (15%) (Figure 1). Less significant sources of sediment included agriculture, construction, and landfill and gravel quarry operations. Although the Issaquah Creek basin is developing, forest lands still occupy over 70 % of the basin area and produce the majority of sediment, where steep slopes contribute to a high landslide rate and efficient sediment delivery to the channel network. Urban land uses account for only 18 % of the basin area and contribute very little sediment directly to the overall budget, because developed areas have only modest yields and a relatively small fraction of the basin is under construction at any given time.

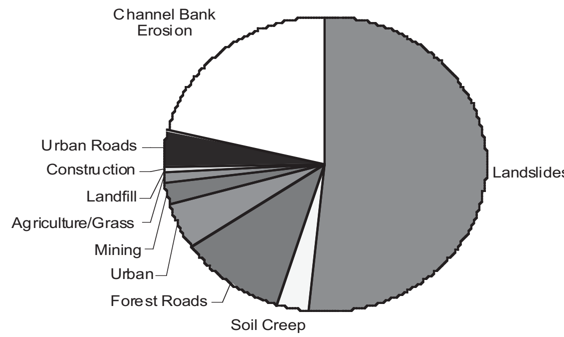


Figure 1. Relative Sediment Contributions from Different Land Uses/Processes

## SEDIMENT SIZE FRACTIONS

Watershed managers have specific concerns related to the different size fractions of sediment delivered to the channel network. Increased coarse sediment supply can lead to channel aggradation, whereas abundant fine sediment usually leads to a reduction in water quality. Fine sediment accounted for approximately 60% of the total sediment production in the Issaquah Creek basin, primarily from landslides, gravel roads and channel bank erosion.

## BALANCING THE SEDIMENT BUDGET

A number of different approaches were taken to check estimates of upland sediment production in the basin, including an evaluation of depositional and erosional areas within the mainstem of Issaquah Creek, an evaluation of the growth of the Issaquah Creek delta into Lake Sammamish, and a comparison of these results with other studies.

### Erosional and Depositional Areas in Issaquah Creek

Historical bridge survey records within the City of Issaquah indicate a net channel aggradation (ranging from 7 to 30 mm) in Issaquah Creek. The bridge survey data compared favorably to calculated channel aggradation rates (6 to 12 mm per year) based on estimates of upland sediment production and downstream routing transport in the mainstem of Issaquah Creek.

### Delta Growth Evaluation

The average annual growth rate of the Issaquah Creek delta into Lake Sammamish was estimated from a review of historical aerial photographs (1944 to 1995) to compare estimated rates of fine sediment production from the watershed. The growth rate was estimated to be approximately 2,600 tonnes/year, which compares to an estimated fine sediment input of 3,800 tonnes/year. Recognizing that a significant, though indeterminant, fraction of the fine sediment would be carried

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SEDIMENT BUDGET (from page 3)

in suspension far out into the lake, these results are fully consistent with the sediment-budget calculation.

### Comparison to Other Studies

In general, the calculated sediment production rate of 44 tonnes $km^{-2}$ $yr^{-1}$ for the Issaquah Creek basin is much less than rates calculated by others (Reid 1981, Madej 1982, Paulson 1997) for forested Pacific Northwest basins (which vary from 77 – 1800 tonnes $km^{-2}$ $yr^{-1}$). Regional urban sediment yields were reported at rates ranging from 10 to 35 tonnes $km^{-2}$ $yr^{-1}$ (City of Bellevue 1995).

### DISCUSSION

Based on current and pre-development estimates of sediment production rates in the Issaquah Creek basin, urbanization has increased basin-wide sediment production, primarily through channel bank erosion. Bank erosion resulting from channel enlargement, due to increased discharges, account for 20% of the total basin sediment budget and is a direct consequence of urbanization. More generally, channel bank erosion is probably the primary source of sediment in more urbanized watersheds. Trimble (1997) found channel bank erosion to be the primary source of sediment yield (67%) in San Diego Creek basin, a 50%-urbanized watershed in southern California. These results indicate yet another reason to mitigate impacts from stormwater runoff as rural areas are developed. Unlike more visible sources of sediment (such as construction runoff), channel enlargement is a process that can occur without much notice from human inhabitants until property is lost or structures are threatened.

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## Effects of Hydraulic Loadings and Temperature on the Pollutant Removal Efficiency of a Pacific Northwest Treatment Wetland

*By Kurt Marx, Graduate Research Assistant*

Wetlands are an essential link in the management of water resources due to their ability to protect or enhance water quality and to maintain hydrologic balances. The coexistence of aerobic and anaerobic environments in wetlands supports a diversity of microbes and vegetation with minimal human intervention and energy input. Accordingly, wetland systems have become an appealing water treatment option. Since the mid-twentieth century, treatment wetlands have increasingly been used as an alternative to improve the quality of various wastewaters. Treatment wetlands are one technology in the growing field of ecological engineering, which applies ecological principles along with engineering to meet society's needs while minimizing environmental impacts.

In 1993, the City of Stanwood, Washington constructed a free-water-surface wetland to demonstrate the effectiveness of treatment wetland technology. Weekly monitoring was conducted over 12 months. This project investigated the pollutant removal efficiency, design, and operation of a Pacific Northwest treatment wetland receiving pretreated sewage lagoon effluent.

The pilot wetland system treats an average of 18,000 gallons per day (approximately 7% of total flow to the wastewater plant). Wetlands influent was pretreated by a partially-mixed aerated pond and consisted, on average, of 56 mg/L BOD, 81 mg/L TSS, 20 mg/L ammonium ($NH_4$), 0.2 mg/L nitrate ($NO_3$), and 5.4 mg/L total phosphorus (TP). Four parallel wetland cells were loaded in a flow ratio of 1:2:3:4.

Each cell consists of a marsh area, followed by a wet meadow area. The marshes contain predominately *Scirpus acutus* (hardstem bulrush). Vegetation in the wet meadows consists mainly of *Juncus effusus* (soft rush), *Phalaris arundinacea* (reed canary grass), and *Typha latifolia* (cattail). Water quality, flow rate, and weather were monitored for 12 months. Monthly nutrient removal efficiencies quantified included $NH_4$, $NO_3$, and TP. Weekly BOD and TSS were also measured. Finally, a lithium tracer study was conducted to determine the actual hydraulic retention time (HRT) of each cell.

Annual ammonium mass removal ranged from 11% to 87%. Total phosphorus reduction ranged from 14% to 66%. Ammonium removal was found to be primarily a function of loading rate, temperature, retention time, and vegetation patterns. Total phosphorus removal varied according to hydraulic loading. Wetland effluent BOD and TSS concentrations were generally below current discharge limits. Actual hydraulic reten-

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*EFFECTS OF HYDRAULIC LOADINGS (from page 4)*

tion times were from 31% to 77% shorter than theoretical retention times. In general, the pollutant removal efficiency of this treatment wetland system was found to be comparable to similar FWS systems.

Three project objectives were achieved after 12 months of monitoring:

1. This marsh/wet meadow constructed wetland upgraded water quality in receiving waters by reducing concentrations of organics (BOD), solids (TSS), and nutrients in sewage lagoon effluent. The wetland cells further provided secondary treatment by removing organics, suspended solids, and nutrients. At times, the wetlands acted as nutrient sources instead of sinks, but they generally reduced the nutrient concentration.
2. The wetland system generally provided secondary BOD and TSS treatment equal to or surpassing the current discharge limits for the City of Stanwood, but the current design will not prove to be an adequate AKART (All Known and Reasonable Technology) for strict ammonium and phosphorus levels. With slight changes in design and operation this system would provide dependable municipal wastewater treatment, but provisions in permitting these systems would be necessary. However, with some design improvements, FWS treatment wetland in conjunction with pretreatment may prove to be a valid AKART for municipal wastewater treatment in the Pacific Northwest.
3. Future design recommendations:
   - Based on existing data, a maximum ammonium mass loading of 1.75 kg N/ha/day (under warm-weather conditions) could be used to obtain an effluent concentration of 2 to 4 mg/L $NH_4$-N.
   - A minimum hydraulic retention time (HRT) of 5-10 days is recommended for FWS wetlands.
   - To limit toxicity, biological treatment systems should be maintained at a pH 7-8.
   - Increasing the area of the wet meadow, or recycling effluent to the wet meadow, may improve nitrification efficiency.
   - Low ratios of actual to nominal HRT are problematic and require some hydraulic modifications. Although dense vegetation coverage may increase sub-surface oxygenation via root leakage, preliminary evidence from this study has shown that a combination of vegetated and open-water areas may be the best design to maximize organic and nitrogen removal. ❖

# Restabilization of Stream Channels in Urban Watersheds

*By Patricia C. Henshaw, Graduate Research Assistant, Center for Urban Water Resources Management*

## INTRODUCTION

The quality of urban streams has come to the forefront in the Pacific Northwest due to concern over the status of native salmon runs. In an effort to bolster the survival of ever fewer salmon returning to the local streams to spawn, land managers have begun extensive programs to rebuild or rehabilitate appropriate habitat that has been lost or degraded due to urban development. Although rebuilt habitat in a stabilized urban stream may not provide the level of ecological integrity required to maintain endangered salmon and other stream biota, physical stability is likely one necessary component of a healthy stream.

The deleterious influences of urbanization on the hydrology and geomorphology of small streams have been extensively explored and documented. The transition of a watershed from the natural, forested state to a predominantly urban condition encompasses removal of vegetation and canopy, compaction of soils, creation of impervious surfaces, and alteration of natural drainage networks. These actions result in increased surface runoff and changes to sediment budgets. These changes, in turn, induce a geomorphic response, commonly resulting in enlarged, unstable channels. However, any subsequent ability of the channel to restabilize over time is not well understood.

The purpose of this study was to determine whether channels in urban watersheds are capable of restabilizing over a period of years to decades. Based on a variety of field and historical data from several streams draining urban and urbanizing watersheds in the Puget Sound lowlands (PSL) of western Washington, we investigated the relationships between channel stability and watershed urbanization, and between stability and other factors that may also affect the timing or extent of geomorphic response.

## STUDY AREA & METHODS

The study channels drain small (5-40 $km^2$), moderately sloped (0.5-3%) PSL watersheds, ranging from the suburban fringe (50% urban land cover) to urban core (>95% urban land cover). Studied response patterns were limited to the commonly reported cross-sectional adjustments to hydrologic change associated with urbanization, and they excluded channels that have experienced rapid incision. Despite these constraints, the seven study channels are representative of a large population of PSL streams, including many that are being considered for or are already part of local stream rehabilitation projects.

The current level of channel stability was assessed from field measurements and observations using two methods: (1) cross-

*Continued on page 6*

*RESTABILIZATION (from page 5)*

sectional surveys and pebble counts were used to calculate relative bed stability (after Olsen et al., 1997), and (2) sites were grouped into four bank stability categories by visual observation of indicators such as bank erosion and vegetation extent. On three of the streams, current observations of bank stability were compared with monitored cross sections surveyed repeatedly over the past decade (Booth and Henshaw, in press) to test the observational technique as an indicator of longer term stability. Overall channel stability was determined as an aggregate of the available stability measures at each site.

To relate channel changes to urbanization and land use in the watershed, changes in land cover in each basin were tracked over time. Recent land cover data, from classified 30-meter-resolution LANDSAT-TM images, were analyzed using GIS software. Historical (pre-1991) development levels were determined from aerial photographs.

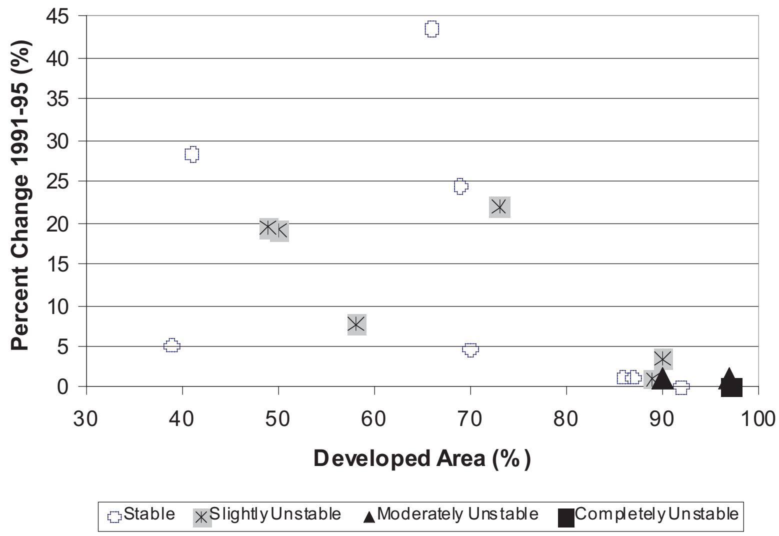


Figure 1. Channel stability as a function of developed area and change in development.

## RESULTS & DISCUSSION

Three of the study channels were determined to be stable, while the other four showed varying degrees of instability, from minor bank erosion to severe degradation. Stability ratings for 14 field sites on the seven study streams, as well as for five additional PSL streams with relatively low development in their watersheds, are shown in Figure 1. Physical channel form was surprisingly resilient to urbanization pressures in the watershed, with major channel instability observed only in basins with greater than 90% urban land cover. This complements the results of a related evaluation of channel stability (Booth and Henshaw, in press), where the selected channels for that study showed locally severe erosion with only modest watershed development but again no systematic relationship between the degree of urbanization and the level of channel instability. The *rate* at which urban development is occurring in the study watersheds also has no systematic effect on channel stability.

If channel stability in developed watersheds is tied only loosely to the magnitude or rate of land-cover change, other factors must play significant roles in determining whether a channel will destabilize and/or restabilize over time. The potential for restabilization, in particular, depends on both how changes in the watershed affect the channel's flow and sediment regimes and to what extent the channel is capable of responding to these changes. Relevant factors must therefore exist at both the watershed and channel scales. At the watershed scale, channel stability is influenced by the effect of land-use change on the hydrograph, which is determined by both development intensity and watershed geology. At the channel scale, channel substrate has a strong influence on the magnitude and mode of channel adjustment. Results also suggest that grade control and the condition of the riparian corridor can locally influence channel stability.

## CONCLUSIONS

Hydrologic, field, and historical data were used to classify the stability of channel cross sections in seven watersheds and, where sufficient data existed, to determine the rate and extent of change in channel form over time. The results indicate:

1) Restabilization of urban stream channels in the PSL can, and commonly does, occur even in highly urbanized watersheds. However, the degree of stability is not well predicted by either the magnitude or the rate of development.
2) Most, but not all, PSL streams are likely to restabilize naturally within 10 to 20 years of constant land cover in the watershed, and possibly even more rapidly.
3) The likelihood that a channel will restabilize depends primarily on hydrologic and geomorphic characteristics of the channel and its watershed, not the magnitude or rate of development. The hydrologic regime and geologic setting appear to be important controlling factors; extent of grade control and the extent and condition of the riparian corridor may also play noteworthy, but less influential, roles.

Restabilization does not imply a return of the channel to its natural state. A restabilized cross section will typically be larger and less geomorphically complex than the pre-urbanization channel form. This change affects aquatic biology through loss of habitat and altered flow patterns, velocities, and organic inputs (*e.g.*, Karr and Chu, 1999). Further assessment and rehabilitation will likely be required to restore the biological integrity of the stream, even when geomorphic stability is achieved, and the success of such additional efforts is by no means assured.

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RESTABILIZATION (from page 6)

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## Evaluating the Benefits and Costs of the Endangered Species Act on Water Supply Systems in Puget Sound

*By Sherrill Nelligan-Doran, Graduate Research Assistant*

Although the Puget Sound area is noted for its rich water resources, recent droughts have demonstrated that municipal water supply systems may not be able to meet increasing demands during the next 40 years. The region is also facing major new challenges associated with the March 1999 listing of Chinook salmon and steelhead species under the Endangered Species Act (ESA). This listing means that scarce water must be allocated more effectively between a growing population and declining salmon stocks. Numerous municipalities, including the cities of Seattle and Tacoma, manage individual water supply systems in conjunction with county and federal agencies such as the Army Corps of Engineers. Based on input from these water providers, the Cascade Regional Yield SimulaTion and AnaLysis (CRYSTAL) model was developed to evaluate the long-term regional allocation of available water between out-of-stream uses and instream uses dictated by regional habitat conservation plans over a 40-year planning horizon. Findings suggest that because of current instream flow commitments, the new ESA listing of salmon will *not* significantly diminish the ability of either Seattle or Tacoma to provide water to its customers over the next 40 years. Furthermore, the expected annual costs associated with potential shortfalls after ESA policies are implemented are estimated to be only 16% higher than shortfall costs associated with current instream flow requirements. However, as new sources are brought online to meet growing municipal demands, remaining instream volumes will decline, flows are expected to be at minimum requirements more often, and the natural variability of the flows may decrease. These trends may be detrimental to the instream ecosystem, independent from whether minimum instream flow requirements are being met. Water managers should continue to operate the systems to mimic natural variability to the extent possible, as managing the systems only to meet minimum requirements may not benefit instream resources as a whole. ❖

## The Sorption Capacity of Aluminum in Alum-Treated Lake Sediments

*By Brian Huser, Graduate Research Assistant*

Aluminum sulfate (alum) has been used as a lake restoration technique to control internal phosphorus (P) loading from lake sediments for over three decades. When applied to lakes, alum reacts to form an insoluble aluminum hydroxide floc. This floc settles to the sediment where it reduces internal P loading through sorption. Currently, alum is dosed based on lake alkalinity and not according to the amount of sediment P which must be bound to prevent internal loading. In order to maximize alum treatment effectiveness, dosing must be based on the amount of sediment P bound by the added aluminum (Al). However, the sorption capacity of Al in lake sediments, in terms of P, is unknown. There is also some uncertainty regarding the mobility of Al bound P, especially in shallow lakes.

For this study, sediment cores were collected from 12 alum treated lakes in the State of Washington. These cores were analyzed for their mobile and permanently bound P fractions as well as Al content. Mobile forms of P included ion-exchangeable, iron bound and organic P while the permanent forms included Al and calcite bound P. By separating the sediment P fractions, it was possible to determine the amount of P that the added Al sorbed. With these data, the sorption capacity of the Al was calculated and an Al to Al-bound-P ratio ($AL:P_{Al}$) was derived.

An example of this calculation is shown using data collected from Medical Lake, WA, which was treated with 960 tons of alum in the fall of 1977:

Al in the sediment from the alum treatment, 79.1 g $m^{-2}$
Al-bound-lakes P formed with the added Al, 7.7 g $m^{-2}$
$Al:P_{Al} = 79.1 \text{ g m}^{-2} / 7.7 \text{ g m}^{-2} = 10.3$

The average $Al:P_{AL}$ ratio for the study lakes was 11:1 ± 1. The ratio was consistent between stratified, polymictic, hard and soft-water lakes suggesting the Al-P bond is permanent and effective at binding sediment P in a variety of lake types.

This information can be used to develop optimal alum dosing strategies as well as predict the longevity of alum treatments. The method will also make calculations possible for long-term cost effectiveness of alum treatments for lake restoration. ❖

## Professional Engineering Practice Liaison (PEPL) Program

The PEPL (Professional Engineering Practice Liaison) Program, in cooperation with the Center for Urban Water Resources Management, offers a continuing education program in urban water resources management.

As part of the benefits extended to supporters of the Center for Urban Water Resources Management, member organizations are eligible for a discount if sending groups of three or more to the same course. For further information, please contact:

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## Professional Engineering Practice Liaison (PEPL) Courses

October 13 and 14, 1999
*Fundamentals of Urban Surface Water Management*

December 3 and 4, 1999
*Seismic Site Response Analysis*

December 8, 1999
*Effective Project Negotiation Skills*

December 9 and 10, 1999
*Creating Winning Technical Presentations*

January 11 and 12, 2000
*Construction Site Erosion and Pollution Control*

February 16 and 17, 2000
*Geology and Geomorphology of Stream Channels*

<http://www.engr.washington.edu/epp/PEPL/peplcal.html>

# Oak Lake Creek—A Case Study of Fish Passage Through Culverts

*By David A. Tucker, Graduate Research Assistant*

Pacific Salmon's dwindling numbers have focused many on trying to improve native habitat in an effort to boost these numbers. One method to increase the amount of spawning and rearing habitat for salmonids is to remove migration barriers. Many of these barriers have been created by poor installations of road culverts. The state and provincial governments of Alaska, California, Idaho, Oregon, Washington, and British Columbia have commissioned several studies into the effects of such blockages. These studies have resulted in new standards for creating road crossings that allow fish passage. This paper explores recent state guidelines for designing road culverts to maximize fish passage. These documents as well as other relevant literature are examined for their applicability to a specific field site, Oak Lake Creek located in northern Mason County, Washington.

Fish passage problems are widespread throughout the traditional Pacific salmonid migratory, spawning, and rearing territory of Alaska, California, Oregon, Idaho, Washington, and British Columbia. Kane et al. (1985) surveyed 100 culverts in western Alaska and determined that over 60% had some sort of fish passage problem. The Washington State Department of Fish and Wildlife (WDFW) estimates that approximately 3,000 miles of anadromous fish habitat is inaccessible due to culvert blockages in Washington State (http: pugetsound.org; http: Culprit Culverts; http: WSDOT Salmon Research). The Oregon State Department of Transportation Needs Analysis for 1999 lists culvert retrofits for fish passage as 7$^{th}$ in its list of 11 critical funding areas (http://www.odot.state.or.us). Additionally, Kurt Beardslee, executive director of Washington Trout estimates that "about 80% of all culverts surveyed are blocked to fish passage" (http: pugetsound.org).

All of the western states (California, Oregon, Idaho, Washington, and Alaska), British Columbia, and the US Federal Government (Federal Highway Administration [FHWA], and the US Forest Service [USFS]) have passed laws prohibiting the impairment of fish passage. Each of these agencies has adopted guidelines to assist designers in the creation or retrofit of culverts that allow fish passage (e.g., Bates et al., 1999). The aim of these documents is not to remove all barriers to fish passage through culverts, but to mitigate those barriers.

Oak Lake Creek, located in northern Mason County, Washington, is the site of a recent unsuccessful attempt to restore fish passage through a road crossing previously occupied by a pair of perched culverts. It was used as a case study to demonstrate how a preferred design protocol for fish passage through culverts could be developed, and the result is compared to the study site's original design to provide recommendations for improved fish passage.

Based on this analysis, four research needs were identified that could ultimately improve fish passage through culverts:

1. Hydraulic and hydrologic design standards. Most guidelines contain a common design protocol framework. Their basic steps are:
   1) Selection of the "design fish"
   2) Evaluation of crossing geometry
   3) Determination of basin hydrology
   4) Selection of crossing structure type
   5) Hydraulic calculations
   6) Grade control, and
   7) Bank stabilization.

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OAK LAKE CREEK (from page 8)

Five of these seven steps do not vary significantly from state to state. The two critical steps that make each state agency's design protocol unique are those for hydrology and hydraulics. Both Oregon and Washington define the highest flow that a culvert must allow fish passage ($Q_{hp}$) as the flow that is exceeded less than 10% of the time during the migration period. However, in the absence of stream gage data, each state defines this flow by a different formula. These formulas can give $Q_{hp}$ values that differ so greatly for the same basin that under the Washington definition (Powers et al., 1998), the design allows fish passage, while the $Q_{hp}$ derived using the Oregon definition (ODFW, 1997) does not predict passage for the same design. This disparity should be resolved through the development of a peer-reviewed formula that can accurately predict small watershed 10% exceedence flows.

2. Prediction of velocities. The traditional hydraulic method used to determine the average barrel velocity may not always be adequate in determining whether a fish can successfully navigate a culvert (Behlke et al., 1991).
3. Migration of juvenile fish. Although most attention is paid to upstream-migrating adults, more research is needed to determine the extent, purpose, and importance of juvenile upstream migration. Researchers (Beechie et al., 1994; Kahler et al., 1998) have noted that juveniles do travel upstream at various times, but the exact purpose and periodicity of this migration is not known. Therefore, impact of upstream migration delays cannot be accessed for juveniles. Recent research (Powers, 1997; Barber and Downs, 1996; Kahler et al., 1998) has addressed these issues but has not provided any conclusive answers.
4. Influence of pipe-wall design. A low-velocity zone exists near the boundary of any flow. This "boundary-layer effect" aids juvenile fish passage but need further research. Powers (1997) produced results that indicated juvenile fish passage success was greater under some circumstances for smooth walls than corrugated pipes. Additionally, two recent studies have produced contrary hypotheses about the type of corrugation that creates the most beneficial boundary layer characteristics. Barber et al. (1996) concluded that annular corrugations created the most favorable conditions for juvenile passage while Powers (1997) concluded that spiral corrugations were superior. Clearly, further research in this area is needed to determine the best type of culvert wall material for juvenile fish passage.

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*Guidelines for Landscaping with Compost-Amended Soils* by Tracy Chollak and Paul Rosenfeld: report prepared for the City of Redmond, 1998.

This publication provides direction for the incorporation of compost as a soil amendment prior to vegetation establishment. Primary focus is placed on amending soil types found in the City of Redmond and the Puget Sound Area, and planting this amended soil with turf. The projected payback periods have been calculated for turf grown on compost-amended soil versus the most common variations of lawn installation methods currently practiced. Results show that turf grown on tilled compost-amended soil by hydroseed application pays for itself between the fifth and sixth year when compared to topsoil-seed, during the first year when compared to topsoil-sod, between the sixth and seventh year when compared to minimum-seed, and between the second and third year when compared to minimum-sod.
Publication K21; on Center's web page with no charge to download <http:/depts.washington.edu/~cuwrm>.

*The Effects of Subsampling on the Performance of Macroinvertebrate Biomonitoring* by Craig P. Doberstein, M.S. Thesis, Department of Civil Engineering, University of Washington, 1998, 57 p.

Biological monitoring is an invaluable component of all aquatic resource protection and rehabilitation efforts. If used correctly, biomonitoring provides scientists with crucial information about the condition, or "health," of the biological communities that inhabit rivers and streams, and therefore the overall condition of an aquatic system. The focus of this study was to determine the management consequences of deciding how many actual organisms should be evaluated in a macroinvertebrate-based stream assessment, independent of the original sample size. Some argue that the proper way to analyze macroinvertebrate samples is to count and identify all the organisms collected; others believe that such "whole-sample" processing is too time-consuming for the amount of information returned, and therefore suggest subsampling the field samples to as few as 100 organisms to yield adequate information with significantly less expended effort.

The results led to the conclusion that the common practice of subsampling benthic samples to as few as 100 organisms introduces considerable variability among different replicates from the same population, which in turn introduces serious uncertainties about the reliability of any single measurement. As a result, the discriminatory power of the B-IBI is drastically reduced as subsample size declines.

As an example, counting all of the organisms collected from a high quality creek (e.g. the set of approximately 1200 organisms collected from a sample at King County's Rock Creek) generates a B-IBI score accurate enough to discriminate nearly 6 possible classes of stream condition. In contrast, the uncertainty associated with subsampling this same population by using only 100 organisms reduces B-IBI's discriminatory capabilities to only 2 classes of stream condition (e.g., "good" and "bad"). Yet most water resource decisions require discrimination beyond just two classes of stream quality. Indeed, two classes of stream condition can be discriminated with casual field observations alone; counting invertebrates is not even needed to make such a coarse evaluation.
Price = $8.50 (Publication E15)

*A Rapid Land Cover Classification Method for Use in Urban Watershed Analysis: Progress Report and Preliminary Results* by Erik Botsford and Kristina Hill, Department of Landscape Architecture

This report presents an approach using Landsat satellite imagery to produce a land-cover characterization for use in hydrologic evaluation and modeling. The methodology attempts to achieve maximum utility and consistency for a particular group of users—individuals and agencies needing to assess watershed conditions in the urban, and urbanizing, parts

*Continued on page 11*

PUBLICATIONS (from page 10)

of western Washington. The classes of land cover produced have been chosen to reflect the categories that can be readily distinguished in the satellite data and to have important differences in their associated runoff and watershed characteristics.

The report, sample maps, evaluation of classification groups, and the entire 1991 classified image are available as Publication E16 on the Center's web page with no charge to download <http:/depts.washington.edu/~cuwrm>.

*Evaluation of Wet Ponds for Phosphorus Reduction* by Karen Comings, M.S.C.E. Thesis, Department of Civil Engineering, University of Washington, 1998, 100 p.

This study investigated the magnitude of phosphorous removal from urban stormwater runoff occurring through two detention/retention ponds of alternative designs, located in southeastern Bellevue and draining into Lake Sammamish. Removal of pollutants from stormwater runoff by the ponds generally ranged from one-quarter to three-quarters of the measured constituents. Of those measured, total suspended solids (TSS) exhibited the greatest removal efficiency, with removal of phosphorus ranging from 29% (retrofitted pond) to 49% (originally designed water-quality pond).
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