Independent Science Panel
Report 2003-1
June 2003

Review of "Stormwater Management Manual for Western Washington" (August 2001)

Independent Science Panel
PO Box 43135
Olympia, WA 98504-3135
(360) 902-2216 FAX (360) 902-2215

Kenneth P. Currens, PhD
Hiram W. Li, PhD
John D. McIntyre, PhD
Walter F. Megahan, PhD
Dudley W. Reiser, PhD

Executive Summary

The Independent Science Panel concludes that the Department of Ecology has done a credible job in developing the guidelines and standards presented in the 2001 *Stormwater Management Manual for Western Washington* (manual). The manual is one of the most comprehensive in the United States and is impressive in its scope, coverage and quality. It includes discussions on initial planning for selection of devices, sequences of controls, and maintenance components that are typically lacking in most manuals and the discussion on emerging technologies is appropriate and well done.

Although we raise technical considerations and issues concerning specific standards or requirements in our review, we believe that individually or collectively the scientific issues are insufficient to preclude use of the manual. We believe that most of these issues can be resolved by refinements to existing standards, planning processes, and development of a monitoring – adaptive management process.

We identified areas for improvement, especially where stormwater issues intersect with other mandates for beneficial uses of water and streams. For example:

- The project area approach presented in the manual is a necessary first step in dealing with potential downstream channel stability and water quality problems at the source. Ultimately, however, a larger watershed-scale perspective is also needed in order to assure that desired goals are met in concert with all of the other land uses and downstream water issues, including salmon. This expanded perspective could be attained by bolstering incorporation of stormwater management into watershed-scale assessment and planning activities.

- Monitoring plans should be developed and implemented to assure implementation, effectiveness, and validation of stormwater control practices onsite and downstream, and to assure proper extrapolation of procedures to new locations.

- An adaptive management process needs to be developed and implemented to assure that problems detected by monitoring are corrected in a timely manner and that better scientific information is incorporated as it becomes available.

In addition, we believe that the manual could be improved by making it easier for engineers to find the answers to their questions. The manual provides considerable guidance on selection of practices, but such guidance may be spread out over multiple sections, making it confusing and appearing to offer conflicting advice. This is especially so for determining how practices and performance standards are aligned. Supplementary summary charts or matrices linking practices with performance standards would help users find and cross-reference all required practices more easily.

Implementation of the provisions in the manual should help prevent further degradation of stream channels associated with stormwater. However, reversal of declining trends in indices of habitat quality and quantity for salmon is not a specific goal. Information needed to design adequate guidelines to prevent "fish kills" is generally lacking, especially for the effects of interacting pollutants.

Introduction

In the *Statewide Strategy to Recover Salmon: Extinction is Not an Option* (strategy) (GSRO 1999), the State of Washington identified stormwater runoff as a major factor in the degradation of salmon streams in developed areas. The strategy recommended that the Department of Ecology (Ecology) update its 1992 Puget Sound stormwater management manual to "provide guidance for applying most recent stormwater management science and technology to new development and redevelopment." In 2001, Ecology completed the *Stormwater Management Manual for Western Washington* (manual) (Washington Department of Ecology 2001). The manual provides guidance for new development and redevelopment regarding control of the quantity and quality of stormwater to comply with water quality standards and contribute to the protection of beneficial uses of the receiving waters.

The Independent Science Panel (ISP) was created in 1998 by the Legislature to provide scientific oversight and review of the State's salmon recovery efforts. Following a request by Ecology, the Governor's Salmon Recovery Office (GSRO) formally asked the ISP to review the manual[1] and answer the following questions:

1. To what extent was the applicable scientific literature used in the development of the manual, with special attention to the development of the flow control standard, and the treatment standard? If you think other information is appropriate to use or has emerged since completion of the manual, please identify it and clarify why you think it should be included.

2. Are the practices outlined in the manual reasonable and consistent with the scientific information used to develop the manual? If not, what changes would you recommend and why?

3. What scientific studies would you recommend to address the most important gaps in knowledge associated with the issues?

This report describes our approach to reviewing the manual, provides answers to each of the assigned questions, and briefly reviews the association between stormwater and salmon in urban and urbanizing watersheds. An appendix to this report provides supporting documentation about a workshop we used to gather information for our review.

[1] September 18, 2002 memo from Steve Meyer to the Independent Science Panel.

Approach

The five members of the ISP are nationally recognized scientists with expertise in stream ecology, salmon habitat, hydrology, genetics, hatcheries, and fisheries. In addressing tasks that require additional expertise, we adopt an approach that is used by the scientific community to obtain peer reviews and evaluate scientific findings. In such cases, the ISP reviews the problem and obtains additional reviews from other independent experts. The ISP then evaluates and develops conclusions based on all information provided. This approach proceeds in the following three steps:

- Identification of experts to assist in the analysis
- Collection of relevant information
- Synthesis and communication of findings

Identification of Experts

We identified approximately 25 nationally known experts in stormwater issues as candidates to help with our review. At the ISP's request, Ecology also provided: a list of experts they relied upon in developing the manual, key research publications, and names of potential reviewers. Based on this information we enlisted five experts who had not been directly involved in the development of the manual to help with the review. These experts (adjunct advisors) were:

- Dr. Wayne Huber (Oregon State University)
- Dr. Rhett Jackson (University of Georgia)
- Dr. Lee MacDonald (Colorado State University)
- Dr. Robert Pitt (University of Alabama)
- Mr. Tom Schueler (Center for Watershed Protection, Maryland).

These adjunct advisors helped gather relevant information, participated in discussions and commented on the manual.

Collection of Information

We gathered information from Ecology, through a scientific workshop on stormwater (see Appendix 1), from discussions with local researchers on stormwater issues and review of scientific literature. Ecology provided: copies of the manual, background information in four subjects (flow control, treatment, thresholds, and impacts of urbanization), copies of scientific publications used in the development of the manual, and an oral presentation to introduce the manual. This information is available from Ecology online at: http://www.ecy.wa.gov/programs/wq/stormwater/index.html#review

Interested parties provided scientific information on stormwater to us at a workshop held on February 12, 2003, in SeaTac, Washington (Appendix 1). The purpose of the workshop was to identify key scientific perspectives on the three assigned questions and identify related supporting information. Policy questions and engineering and application issues – though relevant to stormwater management – were not within the scope of the workshop. The ISP invited and heard presentations and received comments from attendees.

The ISP and adjunct advisors discussed stormwater issues with local researchers, Drs. Derek Booth and Richard Horner (University of Washington). We also met with ecotoxicologists, Drs. Tracy Collier and Nathaniel Scholz (NOAA Northwest Fisheries Science Center, Seattle, Washington).

Findings

We conclude that Ecology has done a credible job in developing the guidelines and standards presented in the manual. The manual is one of the most comprehensive in the United States and is impressive in its scope, coverage and quality. It includes discussions on initial planning for selection of devices, sequences of controls, and maintenance components that are typically lacking in most manuals and the discussion on emerging technologies is appropriate and well done.

Although we raise technical considerations and issues concerning specific standards or requirements in our review, we do not believe that individually or collectively the scientific issues are sufficient to preclude use of the manual. We believe that most of these issues can be resolved by refinements to existing standards, planning processes, and the development of a monitoring – adaptive management process.

Given the wide scope of the manual and the need for better scientific information on stormwater issues, it should not be surprising that we identified areas for improvement, especially where stormwater issues intersect with other mandates for beneficial uses of water and streams. For example:

- The project area approach presented in the manual is a necessary first step in dealing with potential downstream channel stability and water quality problems at the source. Ultimately, however, a larger watershed-scale perspective is also needed in order to assure that desired goals are met in concert with all of the other land uses and downstream water issues, including salmon. Incorporating stormwater management into watershed-scale assessment and planning activities could attain this expanded perspective. We acknowledge the existence of linkages between stormwater and watershed-scale planning referenced in the manual, and urge that more clarification and guidance be developed and applied.

- Monitoring plans should be developed and implemented to assure implementation, effectiveness, and validation (ISP 2000) of stormwater management practices onsite and downstream. For example, monitoring would help determine whether it is appropriate to extrapolate the hydrologic modeling parameters and anticipated channel responses from the baseline study areas used to develop the manual to other locations, and whether additional research is needed.

- Adaptive management processes need to be developed and implemented to assure that problems detected by monitoring are addressed in a timely manner and that better scientific information is incorporated as it becomes available.

The utility of the manual depends not only on the validity of the scientific information used to develop it but also on how easily engineers can find the answers to their questions. We found the manual to be somewhat disjointed and hard to use. The manual provides considerable guidance on selecting practices, but such guidance may be spread out over multiple sections, which is confusing and can appear to offer conflicting advice. This is especially so for determining how practices and performance standards are aligned. For example, a biofilter may meet the basic treatment standard, but cannot meet the Enhanced Treatment Rule (ETR) or Flow Duration Standard (FDS). Summary charts or matrices linking practices with performance standards would help users find all required practices more easily.

Response to Specific Questions

Question 1: *To what extent was the applicable scientific literature used in the development of the manual, with special attention to the development of the flow control and treatment standards? If you think that other information is appropriate to use or has emerged since completion of the manual, please identify it and clarify why you think it should be included.*

<u>Flow Duration Standard</u> – The technical basis for the FDS with respect to channel stability is reasonably well defined for the lower bound (0.5Q2) but not the upper bound (Q50). Although some variation exists, the lower bound is based on an estimate of the "channel forming flow" and is supported by scientific literature. The scientific information used to develop the selection of the upper bound was not well documented.

<u>Enhanced Treatment Rule</u> – Ecology's application of the rule to all high density or high traffic developments that drain to fish-bearing streams represents a policy decision about what is acceptable given current scientific information on the water chemistry of the receiving water. However, Ecology's review of the scientific information on toxicity of heavy metals indicated that the hardness of the receiving water is key to the toxicity. It is possible that enhanced treatment might not be as necessary everywhere, depending on water hardness. This illustrates the potential usefulness of watershed-scale assessments and planning, where survey and standards for water chemistry of the receiving waters might indicate that alternative treatments are possible and more efficient.

Effects on Baseflows – The manual recommends non-structural practices and on-site infiltration to help reduce reductions in baseflows, but it provides no clear basis or criteria to define recharge or base flow performance. Indeed, studies have shown that urbanization in some localities has varied affects on baseflows (Konrad and Booth 2002). Both increases and decreases in base flows can occur with increases likely from reduced evapotranspiration, increased irrigation, sewage and septic system outflows, conveyance system losses and interbasin transfers of water. Decreases can occur from reduced infiltration, interbasin transfers of water, increased consumption of water and more rapid runoff. Other states and communities have set recharge targets to promote non-structural practices and on-site infiltration, based on regional recharge rates. Given glacial till and other unique soil conditions in western Washington, it is unlikely such approaches can be directly imported from elsewhere in the country without modification.

Hydrologic Modeling – Ecology's use of the Hydrologic System Prediction, FORTRAN (HSPF) model and its derivative, the Western Washington Hydrology Model (WWHM) is appropriate and consistent with the existing scientific information. The use of continuous modeling represents the most advanced use of scientific modeling in hydrological forecasting and is superior to single event modeling for stormwater control facilities. The WWHM model was developed as a streamlined version of the HSPF model for routine application to size stormwater control facilities for new development and redevelopment projects throughout western Washington (manual Appendix 111-B). A third model, the King County Runoff Time Series (KCRTS) model also uses continuous flow hydrographs from HSPF coupled with hydraulic analysis routines and can be applied to stormwater management issues.

The general use of the models requires the assumption that local conditions are similar to the conditions for which the model was developed, or that the limitations of the model do not significantly affect the outcome, in absence of other information. Because the information used to develop and validate the WWHM is the best available information, this does not contraindicate the use of the models, but it does indicate that local monitoring and validation is needed to confirm the predictions of the models when the information is applied to other areas. For example, Dinicola (2001) noted that uncertainty in results for any basin could be greatly reduced if at least one year of observed rainfall and stream flow data were available to allow model calibration.

Dinicola (2001) described general assumptions and potential limitations of this modeling approach, but the specific assumptions related to applying the model throughout western Washington were not acknowledged in the discussion in Appendix 3B of the manual. For example, assumptions whose validity should be clarified include:

- Extrapolation of generalized parameters from western King, Snohomish, Thurston, and Pierce counties to other areas of western Washington.

- Application of the generalized parameter values for catchments smaller than the subbasins commonly delineated under the manual (about 100 acres). For example, the manual recommends that the WWHM be used on project areas ranging from 1 to 320 acres.

- Use of individual fluxes or storages of water simulated for land segments, such as recharge or soil moisture, which were not validated when the model was calibrated or validated to stream flow.

Extrapolation of Channel Stability Assessments – Channel stability assessments used in the manual are based on well-documented research illustrating effects of changes in stream flow on channel stability for channels with gravel substrates. The manual does a reasonable job of assessing the potential for channel destabilization from stream flow changes, especially at the lower threshold. The extrapolation of this to all of western Washington provides a first approximation of what may occur in many streams but it would be much more accurate if it considered variations in channel conditions, especially the nature of the channel substrate. Channel substrates other than gravel may respond differently. Cobble and even boulder substrates are common in other channel locations in western Washington and would all be expected to experience lower channel erosion risks than channels with gravel substrates. Booth and Henshaw (2001) showed that channel erosion rates were about an order of magnitude higher in channels with sand substrates as compared to channels with silt-clay substrates. Also, other factors including sediment supply (both size and amount) and large woody debris (LWD) loading also have been shown to affect channel stability. The manual does attempt to deal with issues of sediment supply through the use of a variety of Best Management Practices (BMPs) but ignores effects of LWD loading, which could be assessed through watershed-scale assessments and riparian management.

Project Versus Watershed-scale Issues – In general, the manual is designed primarily for application to individual project areas without analytical consideration for the larger, downstream watershed areas where the cumulative effects of individual projects are manifest. This holds for channel stability issues as well as other effects on stream beneficial uses including water quality and stream ecology. Downstream responses can vary considerably depending on the location and timing of upstream project areas as well as other activities outside of project areas that affect downstream responses. We stress that watershed-scale planning is needed to effectively coordinate the objectives of stormwater management and other beneficial uses of water and streams. The utility of watershed-scale planning is mentioned in the manual (manual Appendix I-A) but only to the point of altering minimum requirements. We recommend that stormwater management be an integral part of watershed-scale planning processes for these reasons:

- A watershed context provides perspective for assessing potential benefits (watershed-scale risks and values) versus costs within and between different watersheds. A watershed-scale approach recognizes that all locations do not have the same potential to benefit from rigid project scale requirements. This may be especially true with respect to salmon recovery. The watershed-scale approach provides a means to optimize the application costs of stormwater management in locations with the potential for greatest benefits.

- The manual uses standard procedures for evaluating project specifications for development and re-development projects. This is done regardless of the level of development in the watershed in question in order to attain long-term channel stability and water quality goals. No information is provided to document the validity of such an assumption nor is any procedure described to evaluate its probability of success. A watershed-scale approach is needed to make such evaluations.

- The manual implicitly assumes that effects are additive. This provides much of the justification for regulating the disturbance associated with single-family homes as well as larger sites in the absence of other information. On page 2-1, the manual states "Controlling flows from small sites is important because the cumulative effect of uncontrolled flows from many small sites can be as damaging as those from a single large site." Watershed-scale assessment and planning allows planners to identify where this may not be the case, by considering the size and location of proposed developments throughout a watershed and fully evaluating potential impacts. The development of small sites will certainly increase the amount of surface runoff, for example, but the net effect on peak flows will depend on the extent to which these flows are delivered to the location of concern, and the timing of these flows relative to the rest of the watershed. Runoff from developed areas in the lower part of a watershed might precede the peak flow from the rest of the watershed and thus have less effect. Alternatively, development in the upper parts of a watershed may accelerate the delivery of runoff to the stream and possibly synchronize peak flows. Similarly, the delivery of sediment and other pollutants can vary according to site size and location, so the sum of the effect of many small sites may or may not equal the effect from one large development of comparable size.

- Biological responses including aquatic ecosystem components and fish could be evaluated or accounted for with watershed-scale assessment and planning, whereas they are not with the project approach.

- Watershed-scale water quality concerns (including Total Maximum Daily Loads) are not evaluated. The manual discusses the possible effects of urbanization on stream temperatures (manual page 1-17), but these were largely not documented. Removal of riparian vegetation will increase the amount of incoming solar radiation and increase summer temperatures, but we know of no studies that document an increase in summer water temperatures when riparian zones have remained intact, all else being equal. Likewise, watershed-scale concerns such as increased stream temperatures as a result of smaller groundwater inputs, even if urbanization does not reduce base flows, can be evaluated. Similar uncertainties exist for the affects of urbanization on altered winter water temperatures.

- The project approach ignores riparian management questions, such as role of large wood in channel stability, water temperature effects, and buffer zone effectiveness for chemical removal and biological impacts.

- We share a concern expressed by workshop participants about the appropriateness of applying a "one-size-fits-all" project level approach to all watersheds across western Washington (e.g., "natural forest" conditions for hydrologic modeling on project areas). The choice of an acceptable risk-averse standard to accomplish the objectives is fundamentally a policy decision, but the broad applicability of the standard or an alternative that could accomplish the same thing could be informed by scientific information from assessments and watershed-scale analyses. A watershed context could provide guidance for fine-tuning the general standards to local conditions based on variability of site conditions throughout a watershed. For example, mass erosion risks may indicate that infiltration should be discouraged rather than encouraged in some areas.

Applicability of the Manual to Roads – We have several questions or concerns about the applicability of the manual to roads, especially in rural areas. Issues of concern include: (1) the effects of traffic levels on pollutant loading from highways, (2) the benefits of BMPs when applied to road corridors, (3) the effects of road sanding on water quality, and (4) how well effects of roads are evaluated in hydrologic models. These concerns arise in part from the different scales involved. Most of the manual focuses on project or site-specific planning whereas roads by their nature involve larger geographic scales. This points to the need for Ecology, the Washington Department of Transportation, and others, to coordinate their stormwater management efforts through watershed-scale assessments and planning, and to monitor treatments to ensure their effectiveness.

Question 2: *Are the practices outlined in the manual reasonable and consistent with the scientific information used to develop the manual? If not, what changes would you recommend and why?*

Best Management Practices – The manual promotes the use of a combination of BMPs to meet water quality concerns for the various source areas and water resource objectives (e.g., manual Volume V, Table 2.1). This treatment approach is reasonable and consistent with the scientific information, especially the perspective of process engineering. It could be improved by providing performance and pollutant removal rates for BMPs applied in series from monitoring data.

Stormwater Pollution Control Practices – Specific comments and recommendations on the manual's stormwater treatment control practices are listed below.

- The practices for separating oil and water (e.g., manual Volume I, pages 4-6; Volume V, Table 4-2) are consistent with available scientific information but expectations for their performance and capabilities may be unreasonably optimistic. These devices are designed and extensively used to treat industrial wastewaters and have been shown to be effective in those applications. They perform best at very high levels of oil contamination, such as may be found at some industrial locations. Approximately 90% reductions in oil are possible, if the influent oil concentrations are greater than about 10,000 mg/L (and the associated oil globules are large). Reductions of about 50% would occur at influent oil concentrations of about 200 mg/L. Very little reduction is expected at levels less than about 100 mg/L (and for emulsified oil). Little information is available demonstrating their effectiveness in treating stormwater, which usually has oil contamination levels of much less than 100 mg/L. Research suggests these devices are inappropriate for effective stormwater control, although they may be suitable for spill control.

- Infiltration is consistent and reasonable with scientific information for "marginal" soils, especially if amended (manual Volume I, Table 4-3).

- The construction site controls (manual Volume II) may not provide reasonable expectations of success given the scientific information. Few performance data are available on these, but those available show that many popular controls are ineffective. One solution is to stress preventative measures (e.g., erosion control), along with a few relatively robust controls (such as wet sediment ponds that are properly-sized and mulching for soil protection at the earliest opportunity). Timing construction activities to minimize site disturbance is much more effective than the use of filter fences or inlet barriers, for example. For references on performance and recent research see http://civil.eng.ua.edu/~rpitt/Class/Erosioncontrol/MainEC.html from Texas and California.

- Volume III of the manual is a critical component, as hydraulics (and hydrology) determine the overall performance of most stormwater controls. The HSPF model, locally calibrated over the range of rains of interest, is reasonable and consistent with the hydrologic scientific information but may not properly predict water quality conditions during the smaller events that are of greatest interest for stormwater quality evaluations. An alternative approach might be to use the locally calibrated HSPF to predict the runoff volume for the design storm for sizing a wet pond and to route drainage design events through the planned system in conjunction with a suitable water quality model, such as the Source Loading and Management Model (SLAMM), that has been used for several decades in Wisconsin to assist with their non-point source program.

- The site suitability criteria for infiltration at industrial areas should not be expected to be effective. The pre-settling basin mentioned will likely be inadequate, as will an oil/water separator. These devices may be needed to protect the device from gross contamination, but they will not prevent groundwater contamination in critical areas. An effective alternative is to use a treatment that includes sedimentation (to 5 μm) followed by mixed media filtration, such as peat and sand.

- We recommend that BMPs for streets also be extended to include parking areas. High efficiency street cleaners are expected to also be effective in those areas, where the affects on water quality would be difficult to control otherwise.

- The "emerging controls" discussion is reasonable and consistent with the scientific information, until local data become available. The filter discussions could be expanded to consider other media besides sand, especially when considering different treatment objectives and flows.

- The manual requires most of the treatment in grass swales by infiltration. The approach in the manual is reasonable and consistent with information used to develop the manual but recent information indicates that it may not be appropriate if the water is flowing at very shallow depths. Under those conditions, the standard Stillwater, Oklahoma, VR-n curves are not applicable. It may also be necessary to consider use of amended soils in the bottoms of the swales to protect groundwater, to enhance evapotranspiration/infiltration, and to hasten the drying of the swales after rains.

- We suggest the manual include use of sumps in catch basins (probably at least 1 m below the discharge location) with a hood over the outlet to be most effective, and considering the use of lamella plates or inclined tube settlers in wetvaults. These can be inexpensive additions that dramatically increase performance (and decrease scour). Subsurface units having standing water also may need to be screened from mosquitoes.

Question 3: *What scientific studies would you recommend to address the most important gaps in knowledge associated with the issues?*

Below we outline both scientific processes and questions we believe that if addressed, would improve stormwater management in western Washington.

<u>Watershed-scale Issues and Assessments</u> – We recommend that procedures be developed to better incorporate stormwater management in watershed-scale planning, and that watershed-scale planning deliberately address stormwater management. A variety of these processes are currently underway in Washington, including those initiated under the Watershed Planning Act (SSB 2514), subbasin planning under the Northwest Power and Conservation Council's Fish and Wildlife Program, and regional efforts such as the Puget Sound Shared Strategy for salmon recovery. These efforts raise issues of scale that need to be resolved if both the manual and watershed- and regional-scale planning processes are ultimately to succeed. For example, local governments may or may not plan on a

small site basis, the scale addressed by the manual, and it is not clear to us that local developers have incentives to become involved in watershed-scale planning.

Monitoring – The manual is based on several policy and scientific assumptions that have implications for monitoring. These assumptions include:

- The FDS and its implementation through use of the WWHM should be sufficient in most cases to prevent accelerated stream channel erosion and geomorphologic impacts that are caused by runoff from new development.

- The default flow duration standard and the requirement to match flows estimated for an historic land cover condition (i.e., forested in most cases) are appropriate to use in all watersheds, regardless of their current level of development.

- The generic treatment requirements are necessary and sufficient to prevent violations of state water quality standards in most situations.

- The project size thresholds for triggering stormwater management requirements are appropriate and necessary for protecting water resources from cumulative impacts.

- The manual is a necessary tool as part of a more comprehensive strategy to protect salmonid resources from impacts due to land development.

The scientific credibility of these assumptions depends on development and implementation of rigorous monitoring and adaptive management programs to test and reduce the uncertainties that could influence the effectiveness of stormwater management. Key questions that, if answered, would improve the planner's ability to predict and evaluate the success of stormwater management include:

- What are the best parameter values estimated from local conditions for using HSPF or WWHM models for hydrological predictions in counties in western Washington that were not part of the original studies?

- Is extrapolation of the channel stability procedure appropriate for all western Washington channels?

- Are BMPs performing as intended?

- Is application of the manual achieving expected results for channel stability, water quality and fish mortality?

- What are the effects of urbanization on summer and winter water temperatures?

- What are the effects of urbanization on base flows?

- What are the recharge rates necessary to promote non-structural practices and on-site infiltration given unique conditions in western Washington?

- What are the characteristics of dissolved metals and hydrocarbons in storm water runoff?

- How effective are practices to remove dissolved metals and hydrocarbons?

Adaptive Management – Monitoring is merely an academic exercise if the information from it is not used for making decisions. We recommend that processes be established that will allow Ecology to use the information gained from monitoring and watershed-scale planning efforts to revise and update the manual as necessary.

Water Quality Modeling – We recommend that Ecology incorporate a model or process for assessing water quality responses as an integral part of the watershed-scale planning processes. The SLAMM model is an example of one such approach.

Toxicology Studies – Toxicological research suggests the potentially complex interactions and pathways of many toxicants in water and their affects on humans and fish and wildlife will remain unknown for the foreseeable future. We believe that research should be focused on developing strategies to prevent entry of toxicants to the state's waters.

Literature Review – The manual could be improved by incorporating expected BMP performance information and updating the references. Many older references are used, which is appropriate, but some newer and relevant material is lacking. Substantial local and regional stormwater and receiving water information exists for western Washington. This could be used to prepare a technical background document of supporting information for the manual. For example, annotated annual literature reviews for wet weather flow are available online at:

> http://civil.eng.ua.edu/~rpitt/Publications/Wetweatherlit/1996%20to%202000%20WWF%20lit%20reviews.pdf

> http://civil.eng.ua.edu/~rpitt/Publications/Wetweatherlit/2001%20WWF%20lit%20review.pdf

Stormwater and Salmon

The general framework for increasing salmonid abundance in Washington is outlined in the *Statewide Strategy to Recover Salmon* (GSRO 1999). Under that approach, recovery depends on improvements in four areas: habitat, hatcheries, harvest, and hydropower. Because stream channel structure and water quality are key elements of both the stormwater program and habitat for salmonids, the ISP is interested in how the manual contributes to Washington's salmonid recovery program.

Salmon have adapted to their environments over many generations throughout their evolutionary history. Environmental conditions at any single location have varied annually, but on average, conditions across the landscape provided food and space resources sufficient for salmon to reproduce and maintain themselves. Physical characteristics contributing to habitat productivity for stream salmonids include water temperature and chemistry, substrate composition, gradient, aspect, and flow. Because species adapted in the context of the spatial and temporal variability of conditions existing in undeveloped watersheds, species are likely to decline when the critical characteristics of their habitat are altered by many factors, including development. For example, undeveloped waterways have been shown to have the highest productivity for chinook salmon (Paulsen and Fisher 2001).

Quantitative relations between habitat alteration and habitat productivity for salmonids are poorly defined (ISP 2002). Stormwater investigators have found that indices of aquatic insect abundance, channel structure, hydrology, and habitat for salmon all degrade as the relative area of impervious surfaces increases in a watershed (CWP 2003). Reversal of these trends should help to improve conditions for salmonids.

The manual should help prevent further degradation of stream channels associated with stormwater and may reduce the risk of direct kills of fish from pollutants, but reversal of declining trends in these indices is not a specific goal of the manual. Because significant degradation of fish, fish food, and fish habitat indices occur when impervious surfaces are greater than 5-10%, and many developed areas have values for impervious surfaces that far exceed these levels, situations exist whereby protecting channels as they exist at present cannot be expected to restore salmon.

The manual is also intended to help prevent harm to humans and direct kill of fish from pollutants in stormwater. Uncertainties in the present state of knowledge regarding the effects of pollutants in stormwater on salmon suggests this goal will not be attained in the near term. Some of the direct and indirect effects of single toxicants have been studied, but combined effects of all toxicants in stormwater cannot be predicted accurately and this continues a risky situation. Information needed to design adequate guidelines is generally lacking, especially for the effects of interacting pollutants, and is not likely to be available in the foreseeable future.

We conclude that the levels of impervious surfaces at which degradation begins to occur seem to preclude dramatic improvement in salmon habitat resulting solely from the actions required by the manual. Also, by themselves, water quality requirements of the manual are not likely to restore conditions needed for expansion of salmonids in western Washington. Ecology also acknowledged these issues, noting that

> "Ecology understands that despite the application of appropriate practices and technologies identified in the manual, some degradation of urban and suburban receiving waters will continue and some beneficial uses will continue to be impaired or lost due to new development. This is because land development, as practiced today, is incompatible with the achievement of sustainable ecosystems."

We emphasize our primary recommendation that stormwater management and land use planning be integrated and coordinated through watershed-scale planning, assessments, monitoring, and adaptive management.

References

Booth, D.B. and P.C. Henshaw. 2001. Rates of channel erosion in small urban streams. *In*: Land use and watersheds: human influence on hydrology and geomphology in urban and forest areas. Water science and application Volume 2, pages17-38, American Geophysical Union.

Center for Watershed Protection (CWP). 2003. Impacts of impervious cover on aquatic systems. Watershed Protection Research Monographs No. 1, Center for Watershed Protection, Ellicott City, MD. 141p.

Dinicola, R. S. 2001. Validation of a numerical modeling method for simulating rainfall-runoff relations for headwater basins in western King and Snohomish counties, Washington, U. S. Geological Survey Water Supply Paper 2495, 162 p.

Governor's Salmon Recovery Office (GSRO). 1999. Statewide strategy to recover salmon: extinction is not an option. Governor's Salmon Recovery Office, Olympia, WA. 324p.

Independent Science Panel (ISP). 2000. Recommendations for monitoring salmonid recovery in Washington State. ISP Report 2000-2. Olympia, WA. Available online at: http://www.governor.wa.gov/gsro/science/documents.htm

Independent Science Panel (ISP). 2002. Responses of salmon and trout to habitat changes. ISP Technical Memorandum 2002-2. Olympia, WA. Available online at: http://www.governor.wa.gov/gsro/science/documents.htm

Konrad, C.P. and D.B. Booth. 2002. Hydrologic trends resulting from urban development in Western Washington streams. U.S. Geological Survey Water Resources Investigations Report 02-4040. Department of Interior, Washington, DC. 40p.

Paulsen, C.M. and T.R. Fisher. 2001. Statistical relationship between parr-to-smolt survival of Snake River spring-summer chinook salmon and indices of land use. Transactions of the American Fisheries Society 130:347-358.

Washington Department of Ecology. 2001. Stormwater Management Manual for Western Washington, Publication Numbers 99-11 through 99-75, Washington Department of Ecology, Olympia, WA.