White Paper: Peak and Ecological Flow; a Scientific Framework for Implementing Oregon HB 3369

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Executive Summary

In the summer of 2009, the Oregon Legislature passed House Bill 3369 which provides grant and loan programs for water conservation and development projects. The bill further allows that proposed storage projects include analyses of peak and ecological flows to standards set by the Oregon Water Resources Department. Protection levels will likely be defined by these analyses which will be completed by grant and loan applicants who perform the studies. Protective flows can be set for the stream and river reaches affected by storage projects funded through the grant and loan program. Throughout this paper reference is made to reaches within water bodies including streams, large streams, small streams, rivers, etc. In all cases it is intended that these references relate to reaches within the entire water conveyance systems residing within watershed boundaries located in Oregon, wherever there may be a possibility of withdrawal for storage purposes.

The purpose of this white paper is to provide technical information about peak and ecological flows in terms of 1) defining what they are, 2) describing methods that are commonly used to determine them, and 3) providing recommendations regarding how these methods might be applicable to Oregon. This technical information may be used by policy makers in crafting rules, guidance, or other strategies to implement HB 3369.

Generally, progress by various jurisdictions in protecting surface water for ecological purposes has advanced under the broad category of ecological flows, including peak and other sub-categories. HB 3369 appears to make a distinction between the two. Although discussions herein may at times refer to the all encompassing term, ecological flows, it is understood that the intent is to address peak flows and ecological flows consistent with HB 3369.

Ecological flow functions in scientific literature are often grouped into the following categories:

1) Baseflow functions such as subsistence and minimum or optimum habitat flows. These represent the low flow functions of a stream that provide minimal direct habitat for fish and other aquatic organisms. They can also represent minimal flows that are sufficient in quantity to overcome the potential for threats to aquatic life from harmful pollutants or stream heating.

2) Biological triggering flows represent elevated streamflows that may trigger a behavior in an aquatic organism that is essential for its survival such as migration or spawning.

3) Channel habitat maintenance flows are elevated streamflows (often flood or peak flows) that rework the channel or its streambed rejuvenating or cleaning gravel, reforming habitat features, replenishing/rejuvenating riparian vegetation, and/or re-establishing connectivity with off channel habitats.

This paper discusses these ecological flow categories including elevated or peak flows.

Methods for determining peak and ecological flows vary with the type of ecological function being examined and between hydrological, hydraulic, and holistic approaches within each group. Instream flow protection employed by other states was examined to better understand prior experience with establishing ecological flows. One conclusion from this examination is to set criteria to categorize low, medium and high impact projects. Separate and appropriate levels of analysis can then be assigned accordingly. The approach California took for five northern coastal counties appears to be promising for Oregon. It consists of three criteria including seasonal restriction, baseflow bypass, and a percent threshold related to the 1.5 year peak flow. A similar approach for consideration in Oregon would use commonly available and established streamflow parameters. In summary the three criteria might be applied to Oregon in the following way:

1) Seasonal flow restriction: This restriction can be a subset or the full "storage season." The storage season is usually from November to April. Depending on local conditions the seasonal flow restriction can vary from the whole season to a couple of months. The extent of this season can be developed for each region of the state based on local hydrology, as well as known biological triggering flow concerns.

2) Baseflows: In the California approach an equation based on estimated mean annual flow was used as the needed baseflow amount that would be bypassed as a condition of the water right. Unlike California, Oregon has a water availability model and database that incorporates instream flow studies conducted on hundreds of stream reaches, and monthly median or "50% exceedance" flows. For Oregon, instream water rights, instream flow study results and 50% exceedance flows are deemed as protective and easily applicable methods for setting baseflow for a storage application.

3) Elevated flows for channel habitat maintenance can be set as a percentage of a peak flow that occurs once on average every two years ("two year peak flow"). Water could be available for appropriation in the amount of 5-10% of the calculated peak flow event. In the north coast California study appropriation of 5-10% of the 1.5 year peak flow was determined to be negligible in the effect on appropriate protection levels. The percentage is considered protective when it varies between 5-10% because a small change in the overall peak will cause little or no change. This is a threshold calculation which could vary within the proposed percentage range by basin or region.

A threshold approach requires some attention as to which type of evaluation methods and what criteria to use for methods chosen for projects that have greater impacts. One way to organize criteria would be to use a three tier approach. As postulated, this "tiered approach" would have increasing levels of scrutiny for higher impact projects and/or for projects on stream systems with greater sensitivity or value.

Following are some basic considerations:

1) To be consistent with the consensus of scientific understanding regarding ecological streamflows, the definition of ecological flows must include baseflows, peak flows and the range of flows that create or maintain key ecosystem functions and habitat features.

2) The inclusion of relatively simple screening criteria to define low impact storage projects and set a level of analysis for higher impact projects might be considered. Several suggestions for parameters are given.

3) When more in-depth analysis is needed to define ecological flows related to a storage project, it is critical to classify the stream hydrologically and geomorphologically early in the process to understand which evaluation methods are appropriate. A statewide classification of hydrological regions would facilitate this.

4) The complexity of methods used to evaluate ecological flow protection for a proposed storage project could be related to the size or impact of the project, as well as the value and sensitivity of the stream to additional water withdrawals. Consideration also needs to be given to the previous and cumulative impacts of other projects when deciding on specific analytical methodologies. Along with other relevant, cumulative impacts of existing projects it is necessary to consider the effects of construction of new dams on salmonids that are already limited by existing migration barriers.

Acknowledgements

This work represents a joint effort of the Ecological Flows Technical Advisory Group (EFTAG). A listing of the members of the Group is given in Appendix A. In large measure, it represents a consensus viewpoint. Appendix C provides any final comments about the report members of the Group have chosen to include.

Appreciation is given for the extensive peer review effort without which this paper would not have been possible. These reviews are provided in Appendix D. They are extensive and an essential part of this final document.

Peer review was provided by:

Independent Multidisciplinary Science Team

The Independent Multidisciplinary Science Team is a scientific review panel charged with advising the State of Oregon on matters of science related to the Oregon Plan for Salmon and Watersheds. This work includes fish recovery, water quality improvements, and enhancing watershed health.

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Additionally, thanks to George Robison, PhD, who as a member of the EFTAG provided staff functions to the EFTAG in development of the original draft that was submitted for peer review.

Special thanks to Ken Stahr for his assistance in editing and for providing example scenarios in the application of selected criteria at specific locations (Appendix B).

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Introduction

In the summer of 2009, the Oregon Legislature passed HB 3369[1] which provides grant and loan programs for water conservation and development projects. The bill eventually requires grant and loan applicants to complete studies on instream peak and ecological flows that conform to standards set by the Oregon Water Resources Department in consultation with ODFW. These flows will then likely be set for the stream and river reaches affected by storage projects funded through the grant and loan programs. The Oregon Department of Fish and Wildlife has developed a peak flow guidance which prescribes methods and thresholds for channel and habitat maintenance flows based on the morphology and setting of the stream. However, Oregon lacks a clear and specific definition regarding what exactly an ecological flow entails. The purpose of this white paper is to provide technical information about ecological flows in terms of 1) defining what they are, 2) describing methods that are commonly used to determine them, and 3) providing recommendations regarding how these methods might be applicable to Oregon. This technical information can be used by policy makers in crafting rules, guidance, or other strategies to implement HB 3369.

Generally progress by various jurisdictions in protecting surface water for ecological purposes has advanced under the broad category of ecological flows, including peak and other sub-categories. HB 3369 appears to make a distinction between the two. Although discussions herein may at times refer to the all encompassing term "ecological flows," it is understood that the intent is to address peak flows and ecological flows consistent with HB 3369.

Ecological flows are a subset of instream flows that are directly tied to the ecology of the stream system. Typically, these flows can be thought of in terms of their ecological functions such as providing direct habitat (depth, velocity, cover) for aquatic organisms, mitigating water quality impairment, triggering specific biological life stage responses, and creating and maintaining habitat through geomorphic work and other factors. Ecological flows are important because, when not protected, ecological functions can be lost with the ensuing loss of populations of aquatic organisms. Many authors discuss streamflow as the "master" or "controlling" variable.[2] With this line of thought, the hydrological regime is the foundation on which the stream ecosystem is built. An adequately protected flow regime not only contains minimal baseflows, but also contains a variety of elevated flows that provide other habitat and ecosystem functions.[3] HB 3369 specifically calls for the determination of adequate "peak and ecological flows.[4]" For this reason, much of this white paper will focus more on elevated flow protection over baseflow protections.

History and Current Status of Ecological Flow Protection in Oregon

In 1915, the first instance of instream flow protection in Oregon involved scenic resources. Specifically, it involved legislation prohibiting out of stream water allocations for streams that form waterfalls in the Columbia Gorge.[5] The first protection of "ecological flow" values in Oregon water law occurred in 1955 by adopting administrative rules that set minimum streamflow at selected points along streams to support, among other things, aquatic life.[6] In 1987 the Oregon Legislature passed the Instream Water Rights Act, which authorized the Department of Fish and Wildlife, Department of Environmental Quality and the State Parks and Recreation Department to apply for instream flow water rights. The Act also included provisions for instream water right transfers and mandated the conversion of minimum perennial flow points established from the 1950's - 1970's to instream water rights.

Additional aspects of instream flow protections include consideration of instream water rights in water availability calculations for new water right applications. They also include, in administrative rules, provisions that public interest values (including ecological values) be considered in water allocation decisions.[7] Moreover, the 1997 Oregon Plan called upon ODFW and WRD to develop a Peak Flow Policy to ensure protection of peak flows needed by salmon.

Studies that form the basis of instream flows that were applied for by the Oregon Department of Fish and Wildlife Department (ODFW) in the 1990's are almost universally based on Basin Investigation Reports (BIRs).[8] Minimum and optimum habitat for spawning, rearing, and fish passage were determined using the "Oregon Method." [9] The Oregon Method is a habitat based method that determines the degree of habitat at different streamflow rates. It requires repeated measurements at different flows. The criteria cover fish spawning, adult migration, and rearing habitat. The desired flow levels are determined by examining flow vs. habitat graphs for different flow levels. The Oregon Method is one of the approved methods for determining baseflow levels for instream water rights. Standards for conducting flow studies to apply for fish and wildlife related instream water rights are covered in rule.[10] There were over 2000 stream reaches studied covering all geographic regions of the state. To date, there are approximately 1,457 instream water rights resulting from ODFW applications and converted minimum flow points. Approximately 450 of these are based on perennial streamflow points determined in the 1950's with priority dates ranging from 1950's to 1970's. The remaining instream water rights are based on BIRs and have priority dates in the 1990's. In addition, there are hundreds of water right transfers and leases. These transfers and leases usually involve smaller volumes of water, but often have earlier priority dates sometimes dating back to pre-water code (1909) dates.

A key component of instream flow protection is the consideration of water availability before any new out of stream allocation occurs.[11] The water availability program in Oregon began in 1989 and has gone through several generations of improvement. In the mid 1990's, the Oregon Water Resources Department (WRD) established "water availability basins" (WABs) as a means to determine if water is available for appropriation. There are approximately 2,200 WABs throughout Oregon, all residing within the 18 Oregon Administrative Basins created by the Department. WABs are significant because they represent locations where water availability is analyzed. Water availability is a key criterion in deciding whether to allow water to be allocated for off stream uses during the irrigation season. The water availability analyses include estimates of natural streamflow, consumptive water right allocation, and instream water rights (ISWRs) along the reach and downstream.[12] Water availability is calculated on a monthly basis as the amount of water available after all water rights, including instream water rights, are subtracted from the unimpaired natural streamflow estimate.

In 1996, Oregon Administrative Rules Chapter 690 Division 33 was adopted to establish definitions, additional procedures and standards to aid the Water Resources Department in determining whether a proposed use will impair or be detrimental to the public interest with regard to sensitive, threatened or endangered fish species. The rules include applications intended to store water or construct a reservoir and apply to applications for water upstream from Bonneville Dam in the Columbia/Snake Basin.

All of the currently applied protections described above (with the exception of Division 33 rules - public interest review) involve base or minimum flow protection. Allowance for stream discharge to maintain channel form and provide for biological triggering responses is alluded to in several places in Oregon Statutes and rules.[13] These statutes and rules have been in place since the 1990's. However, there are no elevated streamflows for channel maintenance or ecological triggering flows protected by instream water rights. Furthermore, in terms of currently applied protections one example of elevated flow protection for biological triggering is the elevated flows to aid downstream migration of juvenile steelhead on the Willamette River.[14] For channel habitat maintenance flows, there is consideration of high flows in recent protection measures for the Deschutes River, Mill Creek (near Walla Walla), and Butter Creek (Umatilla basin).

The only widespread protection process for peak flows occurs as guidance that is used in public interest reviews by ODFW staff.[15] This guidance includes criteria for weighing determinations of biological life stage triggering flows and outlines methods for determining channel habitat maintenance flows. The Water Resources Department has a policy of evaluating water availability at the median (50% exceedance) flow for storage projects. The 50% exceedance flow represents the halfway point in a given set of data for a time series with half the values greater and half less. This internal and administratively based policy has through an empirically based process provided a level of ecological flow protection.

Beyond state water law, there are also federal government protections for instream flows. First, there is the Federal Energy Regulatory Commission (FERC) process for relicensing non-federally owned hydroelectric projects. It requires considerable studies and negotiations in an effort to update flow protections on existing projects. Also, under the Endangered Species Act Section 7, consultation between federal agencies can lead to flow protection measures downstream from federal dams and water projects. The federal Clean Water Act may also be relevant where pollution abatement is an issue. The Oregon Department of Environmental Quality can apply for an instream water right to address this issue.

Defining Ecological Flows

Overall Definition

The term "*instream flow*" is a broad term that encompasses a range of values related to recreational, aesthetic and environmental flows.[16] The term "*environmental flows*" is often used to distinguish ecosystem-based (e.g. wildlife/fish habitat) needs from other instream flow needs.[17] Similar to environmental flows, "***ecological flows***", which are not currently defined by statute, *are instream flows needed to sustain ecosystem functions that native fish and wildlife species require to survive and flourish.* An adequately protected ecological flow regime includes baseflows as well as a variety of elevated flows that provide habitat maintenance and other ecosystem functions.

In HB3369, the term "***peak flows***" may refer to ODFW guidance[18] that discusses considerations and methods for how to determine needed flow protection for peak and elevated streamflows for fish and wildlife needs. HB 3369 specifically requires peak and ecological flow determination and protection where water is diverted for storage projects that are funded by grants and loans related to the legislation. This reflects the need to protect peak and ecological flows in addition to the base and subsistence flows that have been traditionally protected in the past. Another instream flow term (often used with large dams) is "*bypass flows*" which usually represent required streamflows that are to be released from reservoirs to meet regulatory requirements for fish passage and water quality.

Types of Ecological Flows

Environmental/ecological flows are typically broken down based on the ecological "functions" different types of streamflow provide to the ecosystem. These functional streamflows include:

1) Low flow thresholds called "subsistence flows" to prevent direct mortality of aquatic species;
2) "Baseflows" to provide minimal or optimum habitat for target aquatic species;
3) Elevated "biological triggering flows" that stimulate and facilitate important life stage behavior such as migration or spawning for target species; and
4) Elevated "channel and habitat maintenance flows" needed to maintain and create instream and riparian/floodplain habitat.

Subsistence Flows

Subsistence flows are often used as short-term emergency bypass flows needed to keep species alive and avoid fish kills or other serious acute impacts due to poor water quality. Subsistence flows are not considered protective of fish populations, except for very short time periods during emergency water conditions. Very little consideration is given to subsistence flows in the remainder of this paper.

Base (or Minimum) Flows

Base flows encompass flows that occur outside of freshets and storm events (Figures 1, 2 & 3). The biological functions of baseflows include providing adequate habitat, and upstream/downstream and mainstream/tributary connectivity (such as fish passage flows).[19] Even though baseflows have less variation than elevated flows, they do have variation based on the number of days since the last storm event and other factors.

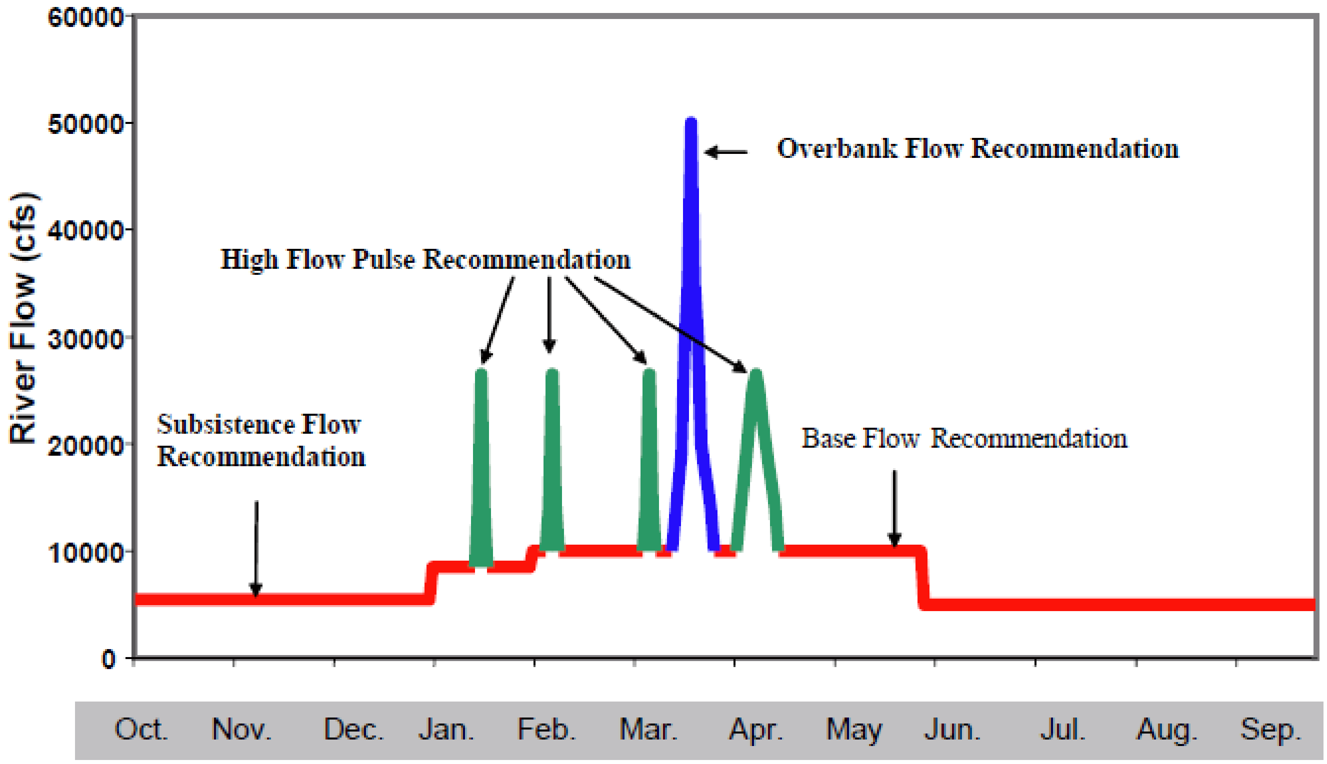

Figure 1. National Academy of Sciences depiction of the Texas instream flow program breakdown of different flow types on an annual hydrograph.[20]

Figure 2 is the scenario that the Texas Commission on Environmental Quality used in their technical overview. (see footnote 21). An alternate scenario would suggest the water table adjacent to a subsistence flow condition could be declining away from the stream channel exacerbating a low flow condition, and the water table adjacent to a base flow condition could be inclining thereby supporting inflow to the base flow condition. Certainly, any number of water table vs. streamflow relationships could exist in Oregon where there are diverse climatic and geologic conditions.

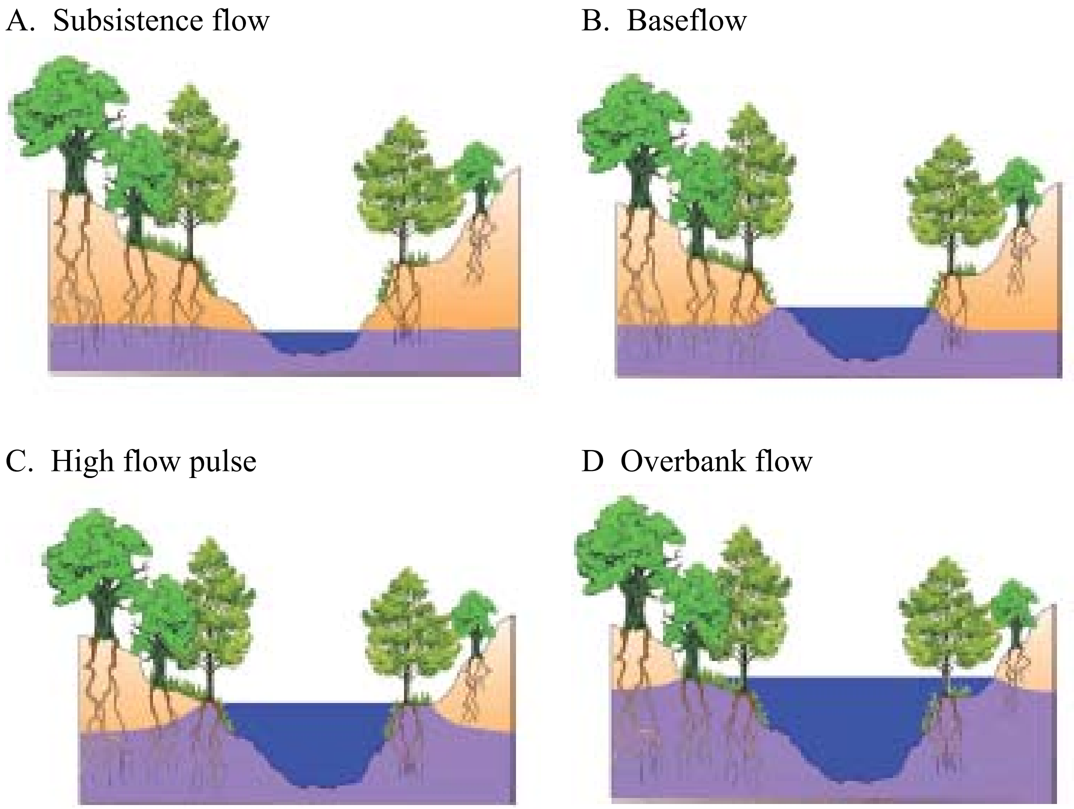

Figure 2. Texas Commission on Environmental Quality breakdown of different flow types based on cross-sectional depictions.[21]

Biological Triggering Flows

Aquatic organisms key certain activities such as migration or spawning to changes in environmental conditions such as water temperature, turbidity, daily sunlight, or flow rate.[22] Some known scenarios where variability in streamflow or elevated flows cause aquatic organisms to initiate important phases of their life cycle include:[23]

- Increases in flows to initiate upstream or downstream migration of fish[24]
- Elevated flows to initiate spawning activity[25]
- Elevated flow periods to allow for the use of off channel, floodplain, or side channel habitat on large and small rivers[26]; and
- Changes in flow that initiate different life stage activities in aquatic insects[27]

The above bulleted items have been provided without any order to priority. All are equally important for consideration, and may be ordered in priority depending to site specific conditions. There are potentially numerous separate and interconnected combinations of flow vs. life stage (spawning, rearing, and migration) interactions. These possible combinations grow as additional species and life stages are considered.

Habitat Maintenance flows

Elevated habitat maintenance flows serve many purposes including:[28]

1) Moving existing cobbles and gravels which removes fines (silt, sand, fine gravel) thereby improving fish spawning and rearing habitat and microinvertebrate rearing habitat in the medium and long-term;[29]
2) Scouring and filling the stream channel to prevent the encroachment of riparian vegetation; this allows the stream to retain its bed form rather than losing conveyance capacity and stream habitat space;
3) Retaining bed configuration that supports the formation and maintenance of riffles, pools and other channel unit habitat,[30] off-channel habitat creation and maintenance;
4) Creating conditions for the replenishment of streamside vegetation such as cottonwoods (*Populus sp.*) to maintain long-term riparian functions;[31] and
5) Maintaining large wood recruitment into and movement and functionality within the stream.

The highest flows can achieve certain functions such as channel formation. Other functions such as gravel cleaning on fine bed streams can occur at flows that are less than over bank flows. Like biological triggering flows, this is not meant to be a complete list but rather give a range of the types of purposes these flows serve.

Techniques Commonly Used to Determine Ecological Flows

Techniques for determining ecological flows differ depending upon which functional streamflow types are being considered:

1) Subsistence flows are often based on water quality concerns and mixing equations, and are often set at the 7 day 10 year exceedance low flow because these are the basis of water quality mixing equations.[32] Again, they serve only to estimate flow needs during short-term, emergency conditions and are not considered long-term flow protection measures for fish and other aquatic life.

2) Baseflows are usually determined using one or more of the following methods:
    a. hydrological methods,
    b. hydraulic methods,
    c. habitat simulation methods, and
    d. holistic methods that may represent combinations of methods. [33]

3) Biological triggering flows are often estimated based on observations of the reactions of fish or other aquatic organisms to changes in streamflow.[34]

4) Channel or habitat maintenance flows are determined by site specific studies (or modeling) of how elevated flows re-work channels, move sediment or reset riparian vegetation.[35] They also can be based on a percentage of bankfull flow or a percent of high flow.[36]

The techniques favored for a given stream will also be determined by the basic channel morphology, size and ecological setting of the stream. For instance, a high gradient and boulder dominated stream with many channel unit types likely requires a different modeling approach for baseflows than a low gradient, sand dominated stream that lacks substantial structure.[37] Another example is the recently published guidance from ODFW (2007)[38] which prescribes methods and thresholds for channel and habitat maintenance flows based on the morphology and setting of the stream.

Base Flow Methods

There are four main types of methods for determining the baseflow component for a flow regime:

1) Hydrologic methods are those that use historical streamflow statistics to guide recommendations. The Tennant method[39] bases categories of protection on percentages of the mean annual flow (MAF). It was one of the first methods for determining base flow protection. Currently, it is used sparingly in the initial phases of project review to provide a general idea of potential impacts. However, most of the work that has recently been completed in the area of defining ecological flow protections makes use of newer, alternative methods. Oregon Administrative rules provide a list of acceptable technical sources for recommending habitat criteria on which to develop instream flow requirements. This method is not among those listed.[40]

2) Hydraulic methods use direct physical measurements at the site as a basis for flow recommendations. Analyzing the wetted width and/or wetted perimeter[41] are two common hydraulic methods. Usually a cross-section is surveyed and flow vs. width/perimeter is measured or mathematically modeled at different discharges. Essentially, an x/y graph is created and the inflection point of the width/perimeter vs. discharge function is the recommended flow for a stream.[42] One approach called the "toe width method" uses a single on-site measurement of the cross-section and a species-specific equation to generate flow recommendations. This "toe width method" is in wide use in western Washington.[43]

3) Habitat simulation methods use detailed on-site cross-sectional transect measurements to classify channel transects according to depth, velocity, substrate, and cover conditions. These transect values are then extrapolated to represent a reach by multiplying the transect values by the channel length they represent. These combinations of conditions are then multiplied by habitat suitability for various life stages of fish or other aquatic organisms to determine a weighted usable habitat area (WUA). WUA is then summed over a sampled reach to determine the total habitat available for various life stages of fish and sometimes other aquatic organisms, including insects. The WUA is then modeled for different flow rates. The Physical Habitat Simulation (PHABSIM) is the most widely used of these methods.[44]

   The Oregon Method,[45] a precursor of PHABSIM and developed before the widespread use of computers, was based on repeated transect measurements at different streamflows. The Oregon Method had hydraulic thresholds for fish passage, and suitability criteria for spawning habitat. The fish passage and spawning criteria are currently used in many studies. The rearing habitat analysis was less precise and has been replaced by habitat suitability criteria determined from field studies in which fish behavior and habitat use were observed and quantified.[46] The Oregon Method characterized minimum and optimum baseflows for fish passage, spawning and baseflow for each month of the year for approximately 2500 stream reaches. About 1000 instream water rights are based directly on data determined using this method. In some cases even the minimum flow points (and approximate 450 instream flow rights developed from them) were partially based on these studies. These studies represent the largest source of data in Oregon regarding needed baseflows for fish. The Oregon Method along with PHABSIM studies (based on habitat suitability curves) are the prescribed methods for determining instream water right monthly flow levels in Oregon rules.[47]

River2D and other two-dimensional models are additional tools that provide habitat suitability methods useful for divided flows, backwater, and other complexities.[48] Two dimensional models use on site bathymetry measurements. They require transects supplemented by detailed topographic measurements throughout the stream reach. The reach is then broken down into small triangular cells of similar depth, velocity and habitat suitability. Then the cells are summed for different flow rates to determine at which flow maximum suitable habitat occurs.

Expert Habitat Mapping is an alternative to the hydraulic habitat modeling approaches of PHABSIM and River2D.[49] This mapping approach has advantages in some situations, because it can simultaneously incorporate qualitative and quantitative factors (shear zones, turbulence, cover, professional judgment). Also, it does not use mean column velocities, the applicability of which varies widely among species and life stages.

4) <u>"Holistic" methods</u> are those that attempt to deal with the entire physical and biological stream system, rather than focus on one or a few species habit preferences at different life stages. The Instream Flow Incremental Methodology (IFIM) usually includes habitat simulation, and is designed to incorporate hydrology, water quality, sediment transport, and other factors as well.[50] The Indicators of Hydrologic Alteration (IHA) method[51] is a hydrologic method based on the Natural Flow Paradigm which asserts that most, if not all, characteristics of the natural flow regime are biologically important. Therefore, the IHA calculates and compares a large number of flow statistics for historic vs. alternative conditions, and measures the degree to which natural flow conditions have been altered. This is in contrast to earlier hydrologic methods (such as the Tennant method) that tended to focus on one or two flow indicators.

In general, predictive models are employed on a site specific basis and provide results that cannot be considered general in nature. In their peer review, the Independent Multidisciplinary Science Team (IMST) cites Fausch et al (1988) as a reference.

Biological Triggering Flows

As stated above, streamflow along with other environmental conditions such as water temperature, turbidity, and sunlight, have been know to “trigger” certain activities such as spawning or migration.[52] Biological triggering flows are pivotal to species survival because of their affects on the timing of migration and spawning. Known scenarios where streamflow variability or elevated flows are associated with aquatic organisms initiating important phases of their life cycles include:

1) Increases in flows that initiate upstream or downstream fish migration; [53]
2) Elevated flows that initiate spawning activity; [54]
3) Elevated flow periods that facilitate fish use of off channel, floodplain, or side channel habitat on large and small rivers; [55] and
4) Changes in flows that initiate different life stage activity in aquatic insects.[56]

Methods for determining the significance of individual triggering flows can vary with the types of effects they have, but typically fall into one of the categories given below:

1) Examples of direct behavioral observation
   a. Radio tagging individual fish and noting when the onset of upstream migration occurs in relation to changes in flow.
   b. Observation of fish through viewing windows correlated with changes in flow.
   c. Observation of changes in life stage of insects at the onset of flow changes.

2) Statistical correlation of population responses to ranges of elevated streamflow:
   Example: study of statistical correlation for Willamette River steelhead outmigration flows vs. returning steelhead numbers two years later.[57]

In their peer review of this document the IMST offered the following comment regarding use of the term “triggering”: “Again, the use of the term “triggering” is misleading and not very comprehensive. It could be possible for someone to show that for some given ecological function the flow is not actually “triggering” or causal and therefore should be ignored in a proposed management activity. As mentioned earlier, using a different term such as “facilitating” or some variation that does not require causality may be more relevant.”

Channel Habitat Maintenance Flows

There are numerous techniques for determining channel habitat maintenance flows because there are several components of habitat structure, each maintained by different flow events. Different channel types also require different types of flow events for their maintenance.

The basic geomorphologic setting for a stream channel is an important factor in determining the type of streamflow regime necessary for maintaining habitat.[58] For example, overbank flows that serve to re-establish willows and cottonwood trees are not as important to a high gradient tightly confined mountain stream as they will be for a low gradient, unconfined, meandering stream. The types of events needed to move bed materials are also predicated on channel type. High gradient, confined mountain streams generally have, as a consequence of their physical characteristics, excellent capacity to transport sediment. Consequently, sediment transport capacity in these stream reaches exceeds sediment supply. These streams may only have a channel moving event every 5-10 years or even less frequently. A sand or small gravel bedded stream may have a sediment moving event every year or two.[59] For these reasons, most methods such as the ODFW guidance and the Texas approach (described below) prescribe channel typing as a first step in deciding which methods to apply. These characterizations may need to occur at multiple locations of interest downstream and upstream of a proposed project because the project in combination with other existing projects can have cumulative effects downstream and upstream.

Along with the geomorphic context, the hydrologic context needs to be analyzed prior to deciding which methods or approaches to take.[60] A stream, such as the groundwater fed upper Metolius River where flow variability is limited and peak flow events are comparatively minor, would require different methods for determining an appropriate channel habitat maintenance flow regime than a "flashy" south coast stream in which peak flows can be over 500 times the mean annual flow. For a groundwater supplied stream, channel habitat maintenance flows are not large and the stream ecosystem is adapted to a less variable system. For the south coast stream the channel shape and character are likely formed by infrequent, large events to which the channel is constantly adjusting.

When determining channel habitat maintenance analysis methods the ecological setting of the stream must be considered. Understanding the needs of a target species at different life stages gives context to the kind of habitat features that may be important. For instance, if the primary concern is for a salmonid species that spawns and immediately leaves the stream for the ocean, the biggest analysis need may be for flushing flows to clean gravels.[61] In other situations the concern may be for a fish or aquatic organism that rears in the stream for its entire life cycle and occupies different habitat types at different times; therefore the analysis needs to focus on techniques that evaluate flows that create and maintain those habitat types.

The methods used for determining habitat maintenance flows are largely determined by:

1) Hydrologic guidelines based on past case studies,
2) hydraulic modeling of when sediment moves or other channel forming events take place, and
3) direct monitoring and assessments to determine which conditions create habitat maintenance features.

Within each of these broad categories there are several methods that can be used to determine channel habitat maintenance flows. Below is a more detailed discussion of each category:

1) <u>Hydrologic guidelines</u> usually prescribe a habitat maintenance flow in relation to streamflow statistics for the stream in question. For instance, in the ODFW guidance for gravel bed streams, a flow rate related to the peak streamflow that is met or exceeded on average every two years is determined and all flows greater than this amount may be protected.[62] In North Coast California, 5% of the 1.5 year peak is set as the limit for out of stream storage allocation.[63] Likewise, methods using the Ecological Limits of Hydrologic Alteration (ELOHA) techniques use existing and new studies to determine a percentage of the peak streamflow or annual streamflow that is considered a low risk to impair ecological functions.[64] The methods listed vary greatly from one to another, but carry the common characteristic of using hydrology to create guidelines and conditions.

2) Hydraulic studies for channel habitat maintenance flows can be very simple such as prescribing that all flows greater than (or a percentage of) bankfull flow[65] be retained. Bankfull flow is the flow that occurs when the channel is full. It corresponds to a peak flow event and the frequency of that event, and can be anything from an annual flood event to something that only happens once in a decade or more depending on stream geomorphic conditions.[66]

   More complicated hydraulic studies can involve determining the time at which sediment movement occurs based on traction equations or other methods. There is considerable research and there are numerous techniques for determining this flow level.[67] Techniques include hydraulic modeling[68] and field testing of marked sediment correlated with streamflow discharges.

   Another factor that is often examined is the flow level at which a stream flows overbank and connects with off channel features such as wetlands and alcoves.[69]

   Prescribing flows for establishing and maintaining riparian vegetation usually involves allowing for streamflows that are large enough to flow overbank. Water levels needed for overbank flow can be determined from hydraulic modeling of reach and cross-sectional data using tools such as HEC-RAS.[70] There are also numerous case studies describing the process and the needed flow for riparian vegetation habitat maintenance.[71] Other considerations in evaluation of overbank flow level protection include connecting off stream features such as wetlands and alcoves, large wood recruitment, and seed dispersal and establishment of riparian trees.

3) Direct monitoring: In the use of hydraulic modeling often there will be calibration measurements or experiments to support the modeling. These are all examples of direct monitoring or monitoring in support of modeling representing a mixture of two methods. It should not be construed from this discussion that direct modeling is simply a means for model calibration. This application can, at the discretion of an expert, be much more comprehensive, depending on specific site needs and characteristics.

There are also other features that are created or maintained by high flows and, in many cases, are developed through empirical processes. They include large wood recruitment from bank scour, flows needed to limit the invasion and spread of non-native fish species and conveyance maintenance by high flows scouring encroaching vegetation. For an overview of the importance of wood to rivers, see Gregory et al. (2003, AFS, Bethesda, MD) and Sedell and Froggatt (1984 22: Verh, Int. Verein. Limmol. 1828-1834).

Technical Considerations for Applying Techniques to Oregon

Recent Efforts that Incorporate Elevated Ecological Flow Evaluation and Protection

Oregon Department Fish and Wildlife Guidance: 2007

The purpose of the guidance[72] is to give criteria and methods to ODFW staff for making comments and recommendations to the Oregon Water Resource Department (OWRD) concerning water storage applications intending use of elevated, wintertime flows. There are three primary uses for the ODFW guidance: 1) Applications seeking water beyond water availability during the storage season; 2) Applications on reaches that have outstanding fishery/aquatic values, and/or; 3) Applications where the storage/diversion project will take a significant portion of flows even though water is generally available during the storage season. The authority for providing these comments is within the Division 33 rules regarding public values.[73] The guidance considers flow needed to provide for ecological and geomorphic stream functions vs. the amount of flow available for appropriation to surface storage or other off stream uses such as aquifer storage and recovery and groundwater remediation once instream needs are met. It also discusses alternatives to condition permits to allow for allocation of water for storage while protecting the stream ecosystem. The guidance and analyses are reserved for streams that are subject to geomorphic adjustment. Channels constrained by levees and rock walls, typical of channels in urban areas, can not properly employ elevated flows for channel habitat maintenance.

Criteria are given regarding acceptable information for biological triggering flows, but the bulk of the guidance relates to channel and habitat maintenance flows. A step by step process is given for channel habitat maintenance flows. However there is considerable latitude as to which methods can be used for each step. The steps are as follows (taken directly from guidance):

1) *Determine the channel type: sand bed, gravel bed vs. coarse bed using channel measurements and/or channel habit unit types.*

2) *Prescribe flows to be reserved based on the stream bed type.*
    a. *For sand bed streams channel maintenance needs would cover the full range of flows. Not all flows would be needed to maintain the character of the stream, but a portion of each flow level would be needed.*
    b. *For gravel bed streams, trigger levels would need to be determined to estimate when channel bed movement events would occur. This estimated trigger can be different for different gravel bed streams based on the gravel size vs. stream characteristics but will vary from 80% of the "bankfull flow" to a streamflow that occurs only once every two years or more. If asking for a trigger level beyond a bankfull flow some analysis and justification would need to be provided regarding sediment size and streamflow forces that show a stable bed at higher flows. Flows greater than the trigger flow level would be preserved instream for channel maintenance functions along with transitional ramping flows to insure the stream does not drop too fast once the stream gets below the trigger level.*
    c. *Coarse bed and bed rock controlled stream may only require water being protected during very high flow events recurring only once every two years or less.*

3) *Depending on the situation, a hydrologic analysis can also be conducted to determine how often the recommended protection flows occur over a historical record to examine the impact of peak flow reservation on allocations and whether the off stream diversion or storage allocation is even feasible when factoring baseflow water needs, water availability, and elevated flow needs. This step becomes critically important when little or no water is available.*

Several examples are given as to how this guidance can be applied for given situations. The guidance, while basing triggers on bankfull flow, allows for the use of other methods including hydraulic modeling and pure hydrologic thresholds.

North Coast Flow Protections – California: 2010

Since 2001, California has been developing standards for instream water protection related to new applications for storage projects in the north coast.[74] The protective measures involve 1) season of diversion, 2) minimum bypass flow[75], and 3) maximum cumulative diversion. The work focuses on creating "regionally protective criteria" (RPC) that are protective and relatively simple to determine and apply for a given site. Sites that meet the RPC do not require in-depth analysis to move forward. To determine if proposed RPC for instream flow levels are considered protective, several studies were conducted. One of the more detailed examples is a sensitivity study for nine stream reaches (validation sites) where different types of protective formulas for minimum bypass and maximum cumulative diversion rates were tested over actual stream conditions for spawning and fish passage.[76] Currently, the protective measures for minimum bypass flows are a function of the estimated unimpaired mean annual flow. The equation is varied based on the size of the watershed, and it is applied at multiple locations of interest to consider cumulative effects of a proposed project with other existing projects. A table of equations is provided in Table 2.1, page 6, Policy for Maintaining Instream Flows in Northern California Coastal Streams, May 2010. The locations of interest usually represent places where new tributaries join the mainstem and change the dynamics of streamflow and water diversion. The sensitivity study mentioned above also evaluates other criteria including annual and monthly 50% exceedance flows and found them generally protective in larger watersheds, but not protective for smaller watersheds.

The season of diversion is limited to a portion of the "storage season"[77] which typically runs from October to May. The RPC sets the time period from December 15 – March 31, however site specific studies can be used to modify the diversion time period. The season is limited to this time period due to concerns that fall flows need stronger protection because of spawning adult salmon migrating into the north coast streams.

Maximum cumulative streamflow diverted is compared to the 1.5 year peak flow in order to determine impact on channel habitat maintenance flows. The policy sets the RPC at 5% of the 1.5 year peak flow event. The 1.5-year peak flow is the hydrologic metric used in California to estimate bankfull flow and effective channel habitat maintenance flow. A 1.5 year peak flow event is a runoff event that is met or exceeded on average once every 1.5 years. This means that during the storage season the cumulative total of all diversions above a point of consideration is limited to 5% of the 1.5 year peak amount. Experts in California determined that in limiting the maximum rate at which water is withdrawn by all water diverters in a watershed so that peak streamflows are reduced by no more than a small fraction of the 1.5-year instantaneous peak flow, the result is only a relatively small change to channel geometry, and the natural flow variability and the various biological functions that are dependent on that variability remain protected. The sensitivity analysis[78] considered other levels and approaches as protective, but the 5% criteria was the one chosen in their current policy.[79]

The north coast policy allows for site specific studies and gives specific habitat suitability criteria for minimum bypass flow studies using tools such as PHABSIM. Included in the policy are specific criteria for site specific maximum cumulative diversion amounts. Also, there are requirements for reporting assumptions for modeling, documenting results and, field studies. Tolerance limits related to the amount of streamflow depletion that may be allowed in the use of a site specific study are also provided. They are usually expressed as stream stage (water level) criteria to ensure that riffles or other key habitat features are not dewatered.

Texas Instream Flow Studies: 2008

The Texas program, which has been evolving since state legislative action in 2001, does not attempt to prescribe instream flow levels for protection. Rather, it gives criteria and groundwork for conducting extensive instream flow studies. Two features of this program set it apart from earlier Texas efforts and efforts in other states. First, it specifically calls for studying the entire flow regime, not just baseflow or one type of streamflow. Second, it targets considerable effort to properly define a stream type in a geomorphic context. These tasks are completed before the flow study is conducted. The program has received significant input and peer review, and there is a great deal of published literature including a final technical overview[80] and a review of the program in 2005 by the National Research Council (NRC).[81]

The first step in conducting an instream flow study in this program is to properly discern the stream types in terms of channel gradient (steepness), hydrology, sediment supply, valley size and other factors. This is accomplished using a classification system called "River Styles" that was developed in Australia.[82] Once a study area is classified investigations are made to evaluate four different flow types that represent important parts of the flow regime from an ecosystem function perspective. These include (refer to Figure 2):

1) Subsistence flows (low flows for water quality and for maintenance of water tables that protect riparian systems during drought periods).

2) Base flows (general base flow levels to maintain minimum or optimum habitat for targeted aquatic organisms).

3) High flow pulses (small peak events that can trigger biological behavior or recharge the near stream aquifer).

4) Overbank flows (flows that perform channel habitat maintenance functions, such as bed cleaning, and reconnect side and near channel water features with the main channel).

Methods to determine flow values vary with the type of streamflow being analyzed. The technical overview document recommends specific modeling software, but does not prescribe specific approaches to using the software. Flows determined from studies are thoroughly reviewed and evaluated through consensus based committees before being adopted. This represents a very involved, long-term process. Flow recommendations are studied on a large basin by large basin scale in order to economize the process. Each basin eventually has unique flow techniques applied based on the geomorphology of given stream reaches and recommendations from the consensus process. The entire process to develop this system incorporates a wealth of information about stream classification techniques and instream flow evaluation methods.

Ecologic Limits of Hydrologic Alteration ELOHA Applications

The Ecologic Limits of Hydrologic Alteration (ELOHA)[83] is an approach based on a comparison of a current or proposed flow regime to the unimpaired or "natural" flow regime within a target reach. The key to this method is to have adequate information to understand the natural flow regime. For this reason, the first and most important step in the process is developing the hydrographs and overall hydrology for both the baseline (unimpaired) conditions and the developed conditions. The following steps constitute the ELOHA method:

1) Develop a "hydrologic foundation" by acquiring the overall hydrology of the basin via gaging and/or hydrologic modeling for both impaired and unimpaired conditions. The resolution of this can vary with the level of concern, amount of funding and number of evaluation points.

2) Classify each "node" or location of concern. This requires hydrologic and geomorphic classification.

3) Complete an analysis of flow alteration for impaired and unimpaired flow for each node or location of interest. There are numerous parameters for flow alteration available.[84] Choosing the appropriate parameters requires considerable judgment.

4) Acquire and evaluate flow vs. ecology relationships for different classes of streams within the region being evaluated. From this evaluation develop specific streamflow vs. ecology response relationships to insure ecological structures and processes are created and maintained.

5) Set flows through negotiations and consideration of other economic and social concerns. The flow standards in terms of allowable alteration are set based on allowable alteration and protective standards that can be applied to specific locations based on degree of previous alteration.

The difficulty with this method is getting adequate flow vs. ecological response relationships. This is particularly difficult with anadromous salmonids because there are so many other variables in their life histories that affect their responses and their life cycles that range from 3-5 years.[85] It takes several life cycles to show an ecologically and statistically convincing positive or negative population response to flow alterations. In addition, some factors such as ocean conditions and downstream fish passage occur outside the site location and even beyond local watershed boundaries. For factors such as channel habitat maintenance, the confounding factors are especially difficult because channel habitat maintenance events are infrequent and habitat maintenance is only one factor affecting salmonid ecology.

This framework has had broad implementation throughout the world. In the United States there have been initiatives to implement at least some parts of ELOHA in several states including Washington. The Texas program is an application of the ELOHA framework as well. A current listing of applications can be found at ConserveOnline.[86] For further explanation of this complex technique the reader is encouraged to consult the referenced literature that is easily available online.

ODFW Guidance vs. Other Flow Protection Methods

The ODFW guidance protects all flows above the trigger flow, while the California north coast approach and other practiced methods allow a percentage of the moderate and high peak flows to be removed. This is an important distinction between the ODFW guidance and methods used elsewhere.

Complexity and Cost of Methods

The methods for baseflow determination are the most developed and have the most information about costs. Simple methods such as the Oregon Method can determine needed baseflows for a reach with costs below $5,000. Habitat modeling with 2D models or habitat mapping can cost over $100,000 per reach. The degree of complexity and costs for studies of peak and ecological flows are difficult to estimate because they can range from a simple hydrological analysis to modeling that could include extensive field work in some situations. The cost can range from a few hundred dollars to as much as $100,000 per stream reach. Studies for biological triggering flows involving only a literature search can be low cost, but any study requiring field measurements can have very high costs.

Applications of Methods to Oregon

Considerations Between Jurisdictions

To apply methods from other states and jurisdictions to Oregon, several factors must be considered:

1) What quantitative tools does Oregon have in comparison with other states?

2) What are the target species (if any) of the ecological evaluation and do the aquatic organisms in Oregon have needs different from populations in other states?

3) Oregon is very diverse hydrologically and geomorphically. How many different regions need to be defined?

4) What is Oregon’s current method for screening storage projects? Can that process serve as a basis to create meaningful criteria for ecological flows?

In examining quantitative tools, Oregon has several advantages over neighboring states. First, instream flow basin investigations have been completed for baseflow needs for fish on approximately 2500 stream reaches. Another advantage is that Oregon has a sophisticated water availability program, with water availability evaluated for approximately 2200 "water availability basins" (WABs).[87] The water availability calculations include monthly estimates of the 50% and 80% exceedance natural flow, and a tally of water rights including instream water rights for watersheds and stream reaches respectively. A 50% exceedance flow is the flow that would be expected to occur or be exceeded 50% of the time, while the 80% exceedance flow is the flow that would be expected to occur or be exceeded 80% of the time. Oregon also has a robust and consistent method for predicting peak streamflows that can be applied at any watershed location. peak flow numbers have already been calculated at gages and water availability basins.[88] Calculated values include the 2, 5, 10, 20, 25, 50, 100, 500 year peak flow events. From a practical perspective, policies that protect flows should build on and incorporate these tools whenever possible.

In most cases, target species for ecological flow analysis in Oregon have been salmonids (such as salmon and trout). While there are other aquatic organisms of concern, the vast majority of habitat suitability criteria have been developed for various life stages of salmonids. Studies of habitat features vs. stream ecology have usually been focused on salmonid survival and production. Salmonids generally have lower tolerance to high water temperatures and lower tolerance to pollutants compared to many other fish species.[89] Also, many species are anadromous (spawn in fresh water and mature at sea) so factors outside the watershed can affect populations. This hinders making strong inferences between habitat features and fish based measures of ecological health.

Oregon is a diverse state with differing climate, geology, and hydrology. Southeast Oregon is a desert region, while northwest Oregon is a rain forest. Dominant peak flow drivers include snowmelt events, rain on snow precipitation events and pure rainfall events. Texas (in terms of rainfall) and California exhibit similar environmental variability. The effort in coastal northern California was over a relatively homogenous region compared with the variation in Oregon. Because Oregon is so diverse characterization of the hydrology and geomorphology of stream reaches becomes important to guide the types of analysis and parameters needed for evaluation. An important source for information as these assessments are made is data that has been collected by watershed councils in their use of the Oregon Watershed Assessment Manual (http://www.oregon.gov/OWEB/docs/pubs/OR_wsassess_manuals.shtml).

Oregon's current screen for determining water availability for storage applications is a comparison of the 50% exceedance estimated natural streamflow with the instream and out of stream flow rights. Values for the 50% exceedance flow are calculated for each month of the year. The total of all consumptive use, storage, and instream flow allocation is subtracted from each monthly value. If the remaining value is a positive number, water is considered to be available for a new appropriation. The "storage season" typically spans from November through April, with some variation regionally. The 50% criteria, although partially protective, does not take into consideration peak flow events and what percentage of water is being proposed for a project, nor does it consider the total yield of a basin and the extent to which projects are encroaching on that yield. For stream reaches that lack instream water rights, the 50% exceedance criteria provides little protection for aquatic life because there will usually be water available for new appropriations, even when there is a considerable amount of diversion activity that already exists in the area.

Creating a Screen for Low Impact Projects to Reduce Study Costs and Streamline Evaluations

Understanding the cost and effort of trying to evaluate ecological flow needs might lead to the impetus for simple criteria to differentiate between projects with low impact and projects with high impact. This information could be used to prevent an applicant from having to expend unreasonable effort on studies when the outcome is already known.

Based on what was done in California, policy makers may find it desirable to approve low impact projects with simpler evaluations than what would be required for higher impact, cumulative or more complex projects. There are precedents for taking such an approach in environmental regulations in Oregon rules. For instance, the Department of State Lands has general authorizations for some waterway projects that may have lower impacts or be beneficial. Likewise, Oregon Forest Practice rules have a streamlined review process for certain activities, and the rules require more detailed review for other activities. In consideration of this approach it is necessary to determine which criteria might be used to create a streamlined process and what factors or indicators can be used.

The recently adopted north coast California rules have Regionally Protective Criteria (RPC) that allow lower impact projects to be approved without in depth, costly studies. The criteria are used to evaluate a project by season of use, quickly determine baseflow bypass discharges, and simply calculate a threshold cumulative flow amount that is related to the percentage of a peak flow event. Oregon could emulate this approach as a screen to allow low impact projects to be evaluated with minimal review and justification.

A problem for Oregon will be creating criteria that cover the diversity of Oregon. For instance, the storage season for the RPC in California is from December 15 through March. This is largely based on the concern for fall spawning anadromous fish. In Oregon, such a concern would apply to Oregon Coast streams, but different criteria would apply east of the Cascades and in southeast Oregon. In some cases the storage season for RPC may need to be closed earlier to allow for out migration of winter steelhead. Defining regions and specific season dates is beyond the scope of this white paper. However, if a screening approach is adopted with RPC that allow for abbreviated review, dividing Oregon into regions with different storage windows will probably be necessary.

As summarized above, the north coast California policy consists of the following RPC:

1) Season of diversion (December 15 through March)

2) Bypass baseflows for projects related to an equation that employs mean annual flow, with different equations for smaller vs. larger watersheds. The assumption is that smaller streams need higher flows because they are both shallower on average and tend to be more variable, so a 50% exceedance flow, for instance, may not be protective.

3) A threshold check in which the total of the rate of diversion for out of stream uses and storage projects during the storage season is less than 5% of the 1.5 year peak flow.

The generalized Texas hydrograph shown as Figure 2 was modified for illustration of the types of flow protection that might be used in Oregon. (Fig 3). Of note is the elimination "subsistence flows" because of the relatively extensive program that exists in Oregon for establishment of base flow limits.

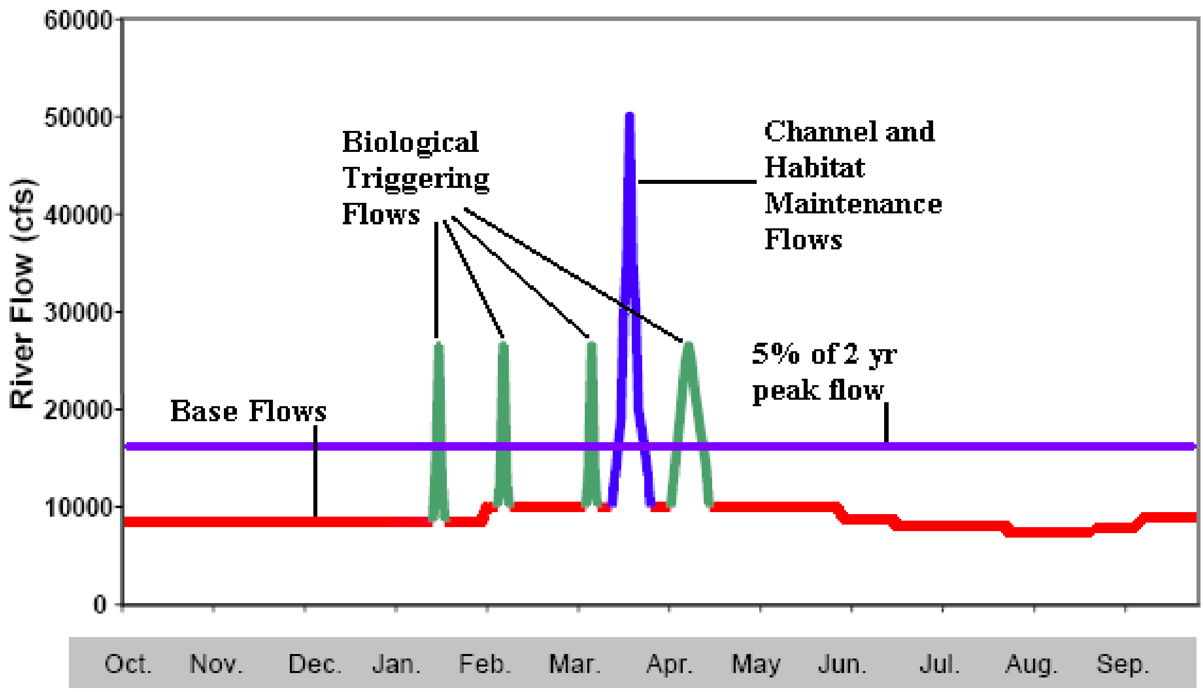

Figure 3. Modified Texas hydrograph illustrating breakdown of different flow types on an annual hydrograph including the threshold calculation for 5% of the 2 year peak flow.

An application of a modified California north coast approach for flow protections is provided in Figure 4. The protected base flow level is illustrated as a variable flow throughout the year. Additionally, both 5% and 10% threshold limits are illustrated for comparison. The hydrograph illustrates the historical, mean daily flow record for the 1969 water year. The 5% threshold is shown as a solid, horizontal line at the 302 cfs flow point, and the amount of water that would be available for appropriation is illustrated as a filled area between the protected base flow and the 5% threshold. The 10% threshold is illustrated as a solid, horizontal line at the 603 cfs flow point, and the amount of additional water that would be available for appropriation is illustrated as additional filled area between the two threshold limits.

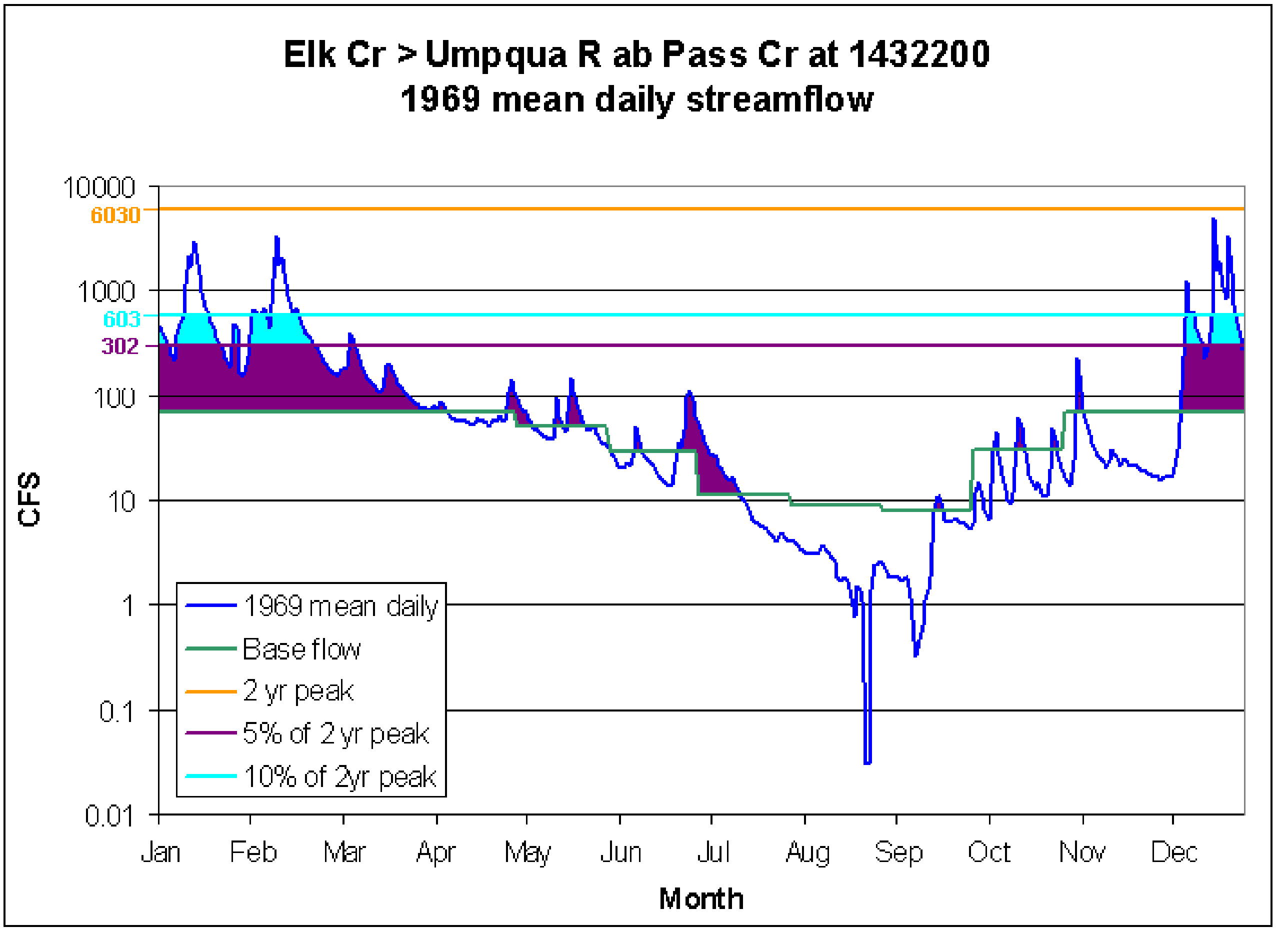

Figure 4. Mean daily hydrograph illustrating flow protection thresholds similar to the California north coast program.

RPC could be developed for Oregon that would be the same over broad regions using the same three criteria used in the California example, but modified somewhat to take advantage of the tools that are currently available and easily accessible. The new criteria could be used in addition to WRD's current 50% water availability screening. The three new criteria might look something like this:

1) Season of diversion: (varies by region but generally a subset of the time period from November 1 to April 30 – a map of Oregon could be produced with these variations)

2) Bypass flow discharges could be set at the instream water right level for reaches that have instream water rights. For streams that lack these values, Basin Investigation Reports where available can be checked and those values can be used as bypass flows. Other flow studies based on PHABSIM analysis or similar methods can also be examined. For streams that lack an instream water right or flow study value, the monthly 50% exceedance flow can be used as a bypass flow for larger watersheds (size criteria for the watershed will vary regionally). For smaller watersheds, the monthly 50% exceedance criteria may be

multiplied by some factor to increase its relative flow.[90] However, because there is greater certainty on instream flow values this may not always be necessary.

3) The screen for a channel habitat maintenance flow threshold could be based on a percentage of the two year peak flow that will be determined by gaging where available or by modeling where gaging is not available.[91] This percentage may also vary regionally, but could fall somewhere in the range of 5-15% based on results from the California study. The two year flow is proposed instead of the 1.5 year flow used in California because the peak flow model for Oregon is available and readily calculates a two year value. Another reason is that many Oregon streams are sediment limited (i.e. they have more transport capacity than sediment supply) and consequently have heavily armored streambeds that are likely to move less frequently[92] thereby requiring greater intervals between bed moving events. Another screen would be to compare 5-15% of the peak flow event to the total cumulative out-of-stream allocation. If the total amount, including any additional or proposed diversion, is below the threshold the proposed diversion could be allowed under the RPC.

Like the coastal California policy, the evaluation of these criteria would need to be conducted at several locations downstream. Locations of interest often correspond to places where major tributaries join and change the dynamics of basin yield, as well as locations of storage and off stream allocation. These locations will often correspond to WABs where many hydrologic parameters have been pre-calculated for both peak flow and water availability.

A key consideration relates to the level of protection provided by the RPC given above. The only definitive answer would come after years of study, but investigations done for north coast systems in California indicate the criteria proposed above are protective for coastal streams.[93] Adding use of instream water rights, Oregon Method results from Basin Investigation Reports, and use of the 50% exceedance flow as a backup threshold for baseflows consistent with current practice increases confidence in the level of protection provided.

A test of the RPC process provided above was conducted for several stream reaches in Oregon. The results demonstrate how use can be made of existing hydrologic information and the level of resulting restrictions. The following sites were evaluated (see also Table 1):

Sites evaluated in ODFW Guidance 2007[94]:

- Mussel Creek at mouth near Gold Beach; off stream above ground storage project
- Deschutes River above Tumalo Creek near downtown Bend; off stream aquifer recharge storage project

Other sites of interest:

- Drews Creek at mouth near Lakeview, type of project not specified but assumed off stream
- Drift Creek at mouth with Siletz River near Lincoln City; project type not specified
- Asbury Creek at mouth near Cannon Beach; project type not specified

Table 1. Evaluation of example RPC for five sites in Oregon

Site Name	Proposed storage season	Proposed baseflow method and range of streamflow over season* (cfs)	Calculated two year recurrence peak flow (cfs)	Would project meet criteria if the channel maintenance threshold was set at 5% of peak flow?	Would project meet criteria if the channel maintenance threshold was set at 10% of peak flow?
Mussel Creek near Gold Beach	November – March	ISWR 34 cfs	1200 cfs	Yes for all storage season months.	Yes for all storage season months.
Deschutes River near downtown Bend	November – March	ISWR 660-1000 cfs	2430 cfs	No for all storage season months.	No for all storage season months.
Drews Creek at Mouth near Lakeview	December - March	ISWR 12-94 cfs	767 cfs	No for all storage season months.	No for all storage season months.
Drift Creek at mouth near Lincoln City	November – March	ISWR 100 cfs	3650 cfs	Yes for all storage season months.	Yes for all storage season months.
Asbury Creek at mouth near Cannon Beach Oregon	November – March	50% exceedance 4-24 cfs	215 cfs	No for all storage season months	Yes for Jan, Mar, and Nov

* ISWR (In Stream Water Right) refers to the method used to determine the amount of streamflow for baseflow bypass. Other methods include using basin investigation report numbers or the 50% exceedance monthly flows over the storage season. Baseflow protection levels vary by month and location. The baseflow values shown are quantified at the lowest downstream point in their respective Water Availability Basins. Detailed information for these locations of interest is available in Appendix B.

For each of these sites the three RPC criteria described above were addressed and each site was evaluated as to the low impact threshold for an off stream storage project. Overall results of the analysis are given in Table 1. A more in depth presentation of these results is given in Appendix B. The results show that for the two coastal basins (Mussel Creek and Drift Creek), there is considerable availability for more storage at the 5% and 10% criteria. Heavily allocated basins such as the Deschutes River and Drews Creek go beyond the threshold and would require more detailed analysis using methods such as those in the ODFW ecological flow guidance.

The time it took to conduct these analyses was minimal and made use of information readily available from the OWRD website. For a simple site such as Mussel Creek with no downstream locations of interest to analyze, the analysis can be accomplished in one to two hours. For more complex sites that may have multiple areas of interest or may require the baseflows to be checked in the Basin Investigation Reports, the analysis can take four to five hours.

Creating a Screening Criterion to Identify High Impact Projects on Highly Altered Systems

A higher percentage of the 2 year peak flow could be used as a high end screen to identify high impact projects or projects on already heavily altered watersheds. A threshold of 20% - 25% of the two year peak flow may serve this function. As opposed to the proposed 5%-10% threshold previously provided, appropriation above 20%-25% would have expected impacts. For the five sites evaluated, only the Deschutes River at Bend would have been identified as high impact when using a 20% criteria. This river is altered by numerous storage projects including Crane Prairie and Wickiup Reservoirs, and Crescent Lake Dam which already can store much of the water moving through the system. Drews Creek would have also been identified high impact if the analysis was performed further upstream. However, at the mouth the influx of lower elevation water places it within the 20% threshold.

In consideration of a screening process to differentiate high impact projects other considerations might include the condition of the stream channel and/or flood plain health. These factors can highly influence the amount of streamflow necessary to achieve certain functions. As an example, a more developed or channelized stream with less habitat diversity, less floodplain connectivity and/or water quality issues may be limited as to an ability to accomplish certain ecological functions thereby requiring higher streamflows. Where available other information such as recommended instream flow levels for ESA-listed species might be readily available and used to help determine if an “unacceptable” high level of past alteration negatively effecting ecological flow functions has already occurred.

For streams that have already been heavily impacted by encroachment and channelization, the possibility of regaining rearing habitat through habitat improvements should be recognized and considered for mitigation as part of a proposed project.

Technical Considerations when Conducting more Detailed Analysis

If an off stream project is in a moderately altered reach and the RPC indicates that further analysis is warranted, there is the immediate question as to what standards should be applied to the evaluation for ecological flows, and what kind of restrictions might be required for the project. In Oregon, there are no formal standards for conducting instream flow studies except for base flow studies used to create instream water rights. For those studies, only the Oregon Method or habitat suitability curve based methods such as PHABSIM (IFIM) or the Forest Service method are referenced in Oregon Administrative Rules (see Endnote 40). During the 1960’s and 1970’s the Oregon Method was used to derive streamflow values which are considered to be the best available data for the determination of instream flow needs, unless there has been a more recent study. Hydrological methods (such as the Tennant method) are not permitted by rule to be used for this purpose.

For elevated flows there are no current standards except the 2007 ODFW guidance. The guidance is used by ODFW staff in making public comments on proposed storage projects. From examining the California, Texas, and various ELOHA applications, along with the ODFW guidance, common considerations are apparent. First, the hydrology and geomorphology must be understood to guide the types of evaluations needed. Second, especially apparent in the California rules, is the need to evaluate the impact of a project at several locations downstream to limit downstream effects, even when the localized effects appear to be minor. Following analysis of the stream type and hydrology, methods for evaluating channel maintenance flows should be determined. As stated above, the methods for elevated channel habitat maintenance flows can be based on a hydrologic metric such as a percentage of a peak flow, hydraulic methods based on bankfull flow, or modeling key hydraulic features using advanced software. Different stream types and ecological settings will have different channel habitat maintenance needs. Therefore different steam types will require different methods to determine ecological flows during the winter high flow season. However, there are some general principles that can be gleaned from related literature developed in Oregon and in other states:

1) The method chosen should be tailored to the type of stream being studied. For instance, there is no need to use a hydraulic model to investigate backwatering into floodplains for wetland habitat on confined streams. The hydrology and the geomorphic setting of the stream system at locations of interest should be determined early in the process. The ODFW guidance proposes using the stream classification system used in watershed assessments for Oregon. Many watersheds already have this typing completed. The hydrologic stream type should also be evaluated with characteristic hydrographs in the watershed or nearby watersheds that likely have similar runoff processes. Some of the characterizations used within the ELOHA framework may be useful as well. Already discussed was the Texas method and the considerable literature review given for the development of the Texas recommendations.

2) The complexity of methods used should be related to the perceived value of the stream ecosystem in question, as well as the projected impact of the project. For instance, in the Oregon Guidance (2007), a project on the Deschutes River had a much more detailed analysis than a project on the Long Tom River. The Deschutes project was on a reach already heavily altered by other reservoirs, and the fish considered in the reach included redband trout and anadromous fish. In the Long Tom example, the reach was upstream of a large reservoir, had few impacts from other projects upstream, and the fish species of concern were resident cutthroat trout and non-native fish. These determinations might be made on a mixture of policy and science creating levels or tiers of analysis for various projects of different size and impact. Tiers could include:

    - **Tier 1** – Basic scoping analysis using season of use, existing baseflow criteria and channel habitat maintenance threshold criteria based on percentage of peak flow amount. If a project diverts water out of stream to a location that is not influenced by streamflow conditions (as opposed to a main channel project) and is within criteria, no further analysis is necessary. Essentially, this is the RPC criteria described above for Oregon.

- **Tier 2** – Use of the existing Oregon criteria for baseflow and use of hydrologic methods to condition water rights to protect channel habitat maintenance flows. Conditions may include time periods of non-use, planned releases, and trigger flow shut offs such as discussed in the ODFW guidance. This tier could be used for projects that exceed RPC criteria or are within criteria that involve existing or proposed main channel dams or structures. Great care is needed to design projects with appropriate and effective flow bypass, and upstream and downstream fish passage.

- **Tier 3** – In depth studies for major storage projects on high value streams that have a target species of concern (perhaps a State or Federal listed aquatic species under the Endangered Species Act). This level of analysis may include new baseflow studies using habitat suitability based methods and field assessment or modeling of high flow conditions that assess the effects of channel and riparian maintenance. Analyses may also include behavioral studies of target fish species in relation to biological triggering flows. Project proponents wishing to use more water that otherwise available in Tier 1 or Tier 2 could opt to carry out more complex studies under the Tier 3 approach to justify increased diversions.

Deciding when a project requires a Tier 2 study is relatively simple in this framework (i.e. goes beyond the RPC threshold or is a main channel structure). Tier 2 does not require considerably more effort than Tier 1 because it uses existing information and is based on using readily available calculated peak flows. However Tier 3 requires orders of magnitude more effort and cost. Attempting to determine if a project is deserving of a Tier 3 study should be based on the size of the project relative to the watershed yield, the degree of impact of other storage projects upstream and downstream and a rigorous ecological evaluation of the stream system's overall ecological value in terms of listed species and other criteria. Many of these choices would be based on societal concerns and balancing of use issues. Again, the science framework provided in this white paper can serve as a basis for making policy decisions about implementation of protections for peak and ecological flow. The goal of the above framework is not to propose a three tier system, but to give an example of how different projects could be given different consideration based on their size and impact on a system, along with the stream/watershed sensitivity and vulnerability.

While criteria for determining an RPC and how to calculate values for a project are relatively straight forward, and the approach makes the most of existing information (water availability, peak flow and Basin Investigation Report information), criteria for more in depth analyses (e.g. Tier 2 and 3 level analysis) are more difficult to prescribe. The reason for this is that analysis needs vary with reach type. The framework given in the ODFW guidance with the addition of a hydrologic characterization (i.e. the type of hydrology locations of interest exhibit, such as being flashy or spring fed) can serve as guidance for elevated flows for more in-depth analyses. Criteria for baseflow studies is lacking, but there are many considerations such as how to choose appropriate habitat suitability criteria, extent of sampling, intensity of sampling (such as number of cross-sections for PHABSIM), number of flow events calibrated on etc. that can influence model output. Perhaps some sort of criteria as developed for Washington State and previously noted could be imported or modified for Oregon. The scope of most in-depth studies for large scale storage projects[95] will probably be similar to the level of effort that is seen for hydropower licensing or re-licensing evaluations.

Generally, the approach for establishment of protection flow levels would result from a process that 1) identifies streams/rivers in Oregon into a small subset (5-8) of stream types based on hydrology/geomorphology; 2) identifies RPC/s for those stream types, including the timing of no withdrawal for protecting ecological flows; 3) identifies a small number (1-3) accepted methods for doing more detailed assessment of peak/ecological flows if an applicant wishes to go beyond the RPC and use a process identified in Tier 2 or Tier 3.

Conclusions and Recommendations

The purpose of this white paper is (1) to provide a usable working definition for peak and ecological stream flows consistent with current scientific understanding; (2) elaborate on methods used to determine peak and ecological streamflows for different ecosystem functions, and (3) provide a perspective as to how to apply these methods to HB 3369 loan and grant program criteria while keeping in mind current tools and constraints. This paper addresses these issues in a manner that combines peak flows under the general definition of "ecological flow."

Peak and ecological flows can be defined as: "*instream flows needed to sustain ecosystem functions that native fish and wildlife species require to survive and flourish. These streamflows include baseflows and flow protections over a range of flows that provide habitat maintenance and other ecological functions".*

Methods for determining peak and ecological flows vary with the type of ecological function being examined; and between hydrological, hydraulic, habitat simulation and holistic approaches. Instream flow protection methods developed in other states were examined to better understand the range of approaches possible. From these examinations, it is clear that, in the interest of efficiency, some criteria should be developed to distinguish low, medium and high impact projects. Low impact projects may not require as detailed an analysis as would high impact projects. The approach California took for five coastal counties appears to be promising for apparent low-impact projects in Oregon. It consists of three criteria including seasonal restriction, baseflow bypass, and a percent threshold related to the 1.5 year peak flow. Those criteria were applied to proposed Oregon projects using commonly available and established parameters similar to those used in the California approach.

In addition to a criteria threshold approach to screen projects, this paper examines various available evaluation methods and criteria for projects with greater projected impacts. A three tier approach is postulated that could have increasing levels of scrutiny for higher impact projects and/or for projects on stream systems with greater sensitivity or value. Criteria can be developed to determine if a project is high impact enough for a Tier 3 analysis.

Following are some basic considerations:

■ The definition of ecological flows must include baseflows and a range of flows that create or maintain key ecosystem functions and habitat features.

■ The inclusion of relatively simple screening criteria for evaluating low impact storage projects may be something for policy makers to consider. A screen for high impact projects and the concept of tiers for the level of analysis effort based on quantitative criteria may also be desirable to policy makers.

■ When in-depth analyses are needed for ecological flows, it is essential to classify the stream hydrological behavior and geomorphologic setting early in the process. This information is necessary to develop an understanding of which evaluation methods should be used. A statewide hydrogeomorphological classification would facilitate this. Considerable work has already been done by others including the USGS. This work will be important as a starting point when a statewide classification is developed.

■ The degree of intensity of methods used to evaluate and protect peak and ecological streamflows as they relate to the effects of a proposed storage project should relate to the size or impact of the project, and the value and sensitivity of the stream to new withdrawals. Also necessary is consideration of the previous and cumulative impacts of other projects when deciding on specific analytical methods.

Appendix A: Ecological Flow Technical Advisory Group (EFTAG)

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Appendix B: Analysis of Regionally Protective Criteria for Five Sites in Oregon

Contents

73209 MUSSEL CR > PACIFIC OCEAN AT MOUTH (Details for analysis follow at the end of this appendix)

10.2 sq-mi

	2yr peak flow	5%	10%	20%	30%
cfs	1200	60.0	120	240	360

50% exceedance

Month	Natural Stream Flow (NSF) (cfs)	Consumptive Use (CU) (cfs)	Expected Stream Flow (NSF-CU) (cfs)	In Stream Water Right (ISWR) (cfs)	Baseflow (CU + ISWR) (cfs)	Storage Allowed? (Y/N)	**5%** (cfs)	(ac-ft)	**10%** (cfs)	(ac-ft)	**20%** (cfs)	(ac-ft)	**30%** (cfs)	(ac-ft)
JAN	87.0	0.03	87.0	34.0	34.0	Y	26.0	1567	86.0	5187	206	12428	326	19668
FEB	97.2	0.05	97.1	34.0	34.1	Y	26.0	1566	86.0	5186	206	12426	326	19667
MAR	85.9	0.02	85.9	34.0	34.0	Y	26.0	1568	86.0	5188	206	12428	326	19669
APR	45.0	0.00	45.0	34.0	34.0	N	0	0	00	0	0	0	0	0
MAY	20.0	0.00	20.0	20.0	20.0	N	0	0	0	0	0	0	0	0
JUN	20.3	0.00	20.3	20.0	20.0	N	0	0	0	0	0	0	0	0
JUL	13.6	0.00	13.6	13.0	13.0	N	0	0	0	0	0	0	0	0
AUG	8.52	0.00	8.52	8.50	8.50	N	0	0	0	0	0	0	0	0
SEP	5.61	0.00	5.61	5.59	5.59	N	0	0	0	0	0	0	0	0
OCT	7.48	0.00	7.48	7.46	7.46	N	0	0	0	0	0	0	0	0
NOV	43.5	0.00	43.5	34.0	34.0	Y	26.0	1569	86.0	5189	206	12429	326	19670
DEC	96.0	0.05	96.0	34.0	34.1	Y	26.0	1566	86.0	5186	206	12426	326	19667
Total (ac-ft)								7,835		25,936		62,138		98,341

70487 DREWS CR > GOOSE L - AT MOUTH

230 sq-mi

	2yr peak flow	**5%**	**10%**	**20%**	**30%**
cfs	767	38.4	76.7	153	230

50% exceedance

Month	Natural Stream Flow (NSF) (cfs)	Consumptive Use (CU) (cfs)	Expected Stream Flow (NSF-CU) (cfs)	In Stream Water Right (ISWR) (cfs)	Baseflow (CU + ISWR) (cfs)	Storage Allowed? (Y/N)	**5%** (cfs)	(ac-ft)	**10%** (cfs)	(ac-ft)	**20%** (cfs)	(ac-ft)	**30%** (cfs)	(ac-ft)
JAN	31.7	78.6	-46.9	20.0	98.6	Y	-60.3	-3635	-21.9	-1321	54.8	3306	132	7934
FEB	57.5	108	-50.7	41.0	149	Y	-111	-6676	-72.3	-4362	4.40	265	81.1	4893
MAR	186	145	40.9	94.0	239	Y	-201	-12107	-162	-9793	-85.6	-5165	-8.90	-537
APR	193	169	24.4	160	329	N	0	0	0	0	0	0	0	0
MAY	116	104	11.9	114	218	N	0	0	0	0	0	0	0	0
JUN	39.6	85.2	-45.6	35.3	121	N	0	0	0	0	0	0	0	0
JUL	7.63	25.7	-18.1	6.42	32.1	N	0	0	0	0	0	0	0	0
AUG	2.92	13.8	-10.9	4.80	18.6	N	0	0	0	0	0	0	0	0
SEP	2.59	12.1	-9.52	10.3	22.4	N	0	0	0	0	0	0	0	0
OCT	3.24	7.31	-4.07	3.00	10.3	N	0	0	0	0	0	0	0	0
NOV	4.98	17.2	-12.2	3.00	20.2	N	0	0	0	0	0	0	0	0
DEC	19.1	75.1	-56.0	12.0	87.1	Y	-48.8	-2941	-10.4	-628	66.3	4000	143	8628
Total (ac-ft)								0		0		7,572		21,456

446 DRIFT CR > SILETZ BAY - AT MOUTH

41.1 sq-mi

	2yr peak flow	**5%**	**10%**	**20%**	**30%**
cfs	3650	183	365	730	1095

50% exceedance

Month	Natural Stream Flow (NSF) (cfs)	Consumptive Use (CU) (cfs)	Expected Stream Flow (NSF-CU) (cfs)	In Stream Water Right (ISWR) (cfs)	Baseflow (CU + ISWR) (cfs)	Storage Allowed? (Y/N)	**5%** (cfs)	(ac-ft)	**10%** (cfs)	(ac-ft)	**20%** (cfs)	(ac-ft)	**30%** (cfs)	(ac-ft)
JAN	345	8.09	337	100	108	Y	74.4	4490	257	15501	622	37524	987	59547
FEB	360	8.10	352	100	108	Y	74.4	4489	257	15501	622	37524	987	59547
MAR	296	8.09	288	100	108	Y	74.4	4490	257	15501	622	37524	987	59547
APR	178	8.08	170	100	108	N	0	0	0	0	0	0	0	0
MAY	104	8.07	95.9	100	108	N	0	0	0	0	0	0	0	0
JUN	64.4	8.07	56.3	40.0	48.1	N	0	0	0	0	0	0	0	0
JUL	39.5	8.08	31.4	25.0	33.1	N	0	0	0	0	0	0	0	0
AUG	25.2	8.08	17.1	22.0	30.1	N	0	0	0	0	0	0	0	0
SEP	24.1	8.07	16.0	22.0	30.1	N	0	0	0	0	0	0	0	0
OCT	50.3	8.07	42.2	80.0	88.1	N	0	0	0	0	0	0	0	0
NOV	232	8.07	224	100	108	Y	74.4	4491	257	15502	622	37526	987	59549
DEC	374	8.10	366	100	108	Y	74.4	4489	257	15501	622	37524	987	59547
Total (ac-ft)								22,448		77,506		187,622		297,737

30120103- ASBURY CR > PACIFIC OCEAN - AT MOUTH

2.54 sq-mi

	2yr peak flow	**5%**	**10%**	**20%**	**30%**
cfs	215	10.8	21.5	43	65

50% exceedance

Month	Natural Stream Flow (cfs)	Consumptive Use (cfs)	Expected Stream Flow (NSF-CU) (cfs)	In Stream Water Right * (cfs)	Baseflow CU + ISWR (cfs)	Storage Allowed ? (Y/N)	**5%** (cfs)	(ac-ft)	**10%** (cfs)	(ac-ft)	**20%** (cfs)	(ac-ft)	**30%** (cfs)	(ac-ft)
JAN	19.4	0.43	19.0	19.4	19.8	Y	-9.08	-548	1.7	101	23	1398	45	2695
FEB	22.0	0.43	21.6	22.0	22.4	Y	-11.7	-705	-0.9	-56.4	21	1241	42	2538
MAR	17.7	0.43	17.3	17.7	18.1	Y	-7.38	-446	3.4	203	25	1500	46	2798
APR	10.2	0.43	9.8	10.2	10.6	N	0	0	0	0	0	0	0	0
MAY	6.11	0.43	5.68	6.11	6.54	N	0	0	0	0	0	0	0	0
JUN	5.90	0.43	5.47	5.90	6.33	N	0	0	0	0	0	0	0	0
JUL	4.12	0.43	3.69	4.12	4.55	N	0	0	0	0	0	0	0	0
AUG	3.36	0.43	2.93	3.36	3.79	N	0	0	0	0	0	0	0	0
SEP	3.54	0.43	3.11	3.54	3.97	N	0	0	0	0	0	0	0	0
OCT	4.87	0.43	4.44	4.87	5.30	N	0	0	0	0	0	0	0	0
NOV	18.9	0.43	18.5	18.9	19.3	Y	-8.58	-518	2.2	131	24	1428	45	2725
DEC	24.0	0.43	23.6	24.0	24.4	Y	-13.7	-826	-2.9	-177	19	1120	40	2417
Total (ac-ft)								0		434		6,687		13,173

* The 50% exceedance natural stream flow was used as a substitute for the instream water right

197 DESCHUTES R > COLUMBIA R - AB TUMALO CR

Summary of limiting watersheds

Limiting watersheds @ 50% exceedance

Month	Limiting Watershed ID	Stream Name	Water Available?	Net Water Available
JAN	30530643	DESCHUTES R > COLUMBIA R - AB SHITIKE CR	NO	-601
FEB	30530643	DESCHUTES R > COLUMBIA R - AB SHITIKE CR	NO	-130
MAR	197	DESCHUTES R > COLUMBIA R - AB TUMALO CR	NO	-179
APR	197	DESCHUTES R > COLUMBIA R - AB TUMALO CR	NO	-553
MAY	197	DESCHUTES R > COLUMBIA R - AB TUMALO CR	NO	-1950
JUN	197	DESCHUTES R > COLUMBIA R - AB TUMALO CR	NO	-2140
JUL	197	DESCHUTES R > COLUMBIA R - AB TUMALO CR	NO	-2580
AUG	197	DESCHUTES R > COLUMBIA R - AB TUMALO CR	NO	-2430
SEP	197	DESCHUTES R > COLUMBIA R - AB TUMALO CR	NO	-2030
OCT	197	DESCHUTES R > COLUMBIA R - AB TUMALO CR	NO	-901
NOV	30530643	DESCHUTES R > COLUMBIA R - AB SHITIKE CR	NO	-316
DEC	30530643	DESCHUTES R > COLUMBIA R - AB SHITIKE CR	NO	-788

This table illustrates the greatest downstream demands that influence the amount of water available in the target watershed (197).

An evaluation of each of these downstream watersheds must be performed before determining how much water would be available for appropriation. The following three tables are examples of this scenario.

Table A is the uppermost watershed, where the hypothetical storage proposal might occur.
Table B is the next downstream watershed.
Table C is the aggregate of tables A and B, showing the effect of downstream requirements.

197 DESCHUTES R > COLUMBIA R - AB TUMALO CR

Table A - Uppermost watershed.

197 DESCHUTES R > COLUMBIA R - AB TUMALO CR
1810 sq-mi

	2yr peak flow	5%	10%	20%	30%
cfs	2500	125	250	500	750

50% exceedance

Month	Natural Stream Flow (NSF) (cfs)	Consumptive Use (CU) (cfs)	Expected Stream Flow (NSF-CU) (cfs)	Reserved Stream Flow (RSF)	In Stream Water Right (ISWR) (cfs)	Baseflow (CU + ISWR) (cfs)	Storage Allowed? (Y/N)	5% (cfs)	(ac-ft)	10% (cfs)	(ac-ft)	20% (cfs)	(ac-ft)	30% (cfs)	(ac-ft)
JAN	1250	554	696	0	660	1214	Y	-1089	-65707	-964	-58165	-714	-43081	-464	-27996
FEB	1270	453	817	0	660	1477	Y	-1352	-81576	-1227	-74034	-977	-58949	-727	-43865
MAR	1270	449	821	0	1000	1821	Y	-1696	-102332	-1571	-94790	-1321	-79705	-1071	-64621
APR	1430	983	447	0	1000	1447	N	0	0	0	0	0	0	0	0
MAY	1530	1880	-353	0	1600	1247	N	0	0	0	0	0	0	0	0
JUN	1610	2150	-537	0	1600	1063	N	0	0	0	0	0	0	0	0
JUL	1280	2260	-977	0	1600	623	N	0	0	0	0	0	0	0	0
AUG	1250	2080	-827	0	1600	773	N	0	0	0	0	0	0	0	0
SEP	1280	1710	-427	0	1600	1173	N	0	0	0	0	0	0	0	0
OCT	1310	1210	98.8	0	1000	1099	N	0	0	0	0	0	0	0	0
NOV	1250	845	405	0	660	1065	Y	-940	-56717	-815	-49175	-565	-34091	-315	-19006
DEC	1270	726	544	0	660	1204	Y	-1079	-65104	-954	-57562	-704	-42477	-454	-27393
Total (ac-ft)									0		0		0		0

197 DESCHUTES R > COLUMBIA R - AB TUMALO CR

Table B - Next watershed downstream.

30530643 DESCHUTES R > COLUMBIA R - AB SHITIKE CR

7790 sq-mi

	2yr peak flow	**5%**	**10%**	**20%**	**30%**
cfs	15000	750	1500	3000	4500

50% exceedance

Month	Natural Stream Flow (NSF) (cfs)	Consumptive Use (CU) (cfs)	Expected Stream Flow (NSF-CU) (cfs)	Reserved Stream Flow (RSF) (cfs)	In Stream Water Right (ISWR) (cfs)	Baseflow (CU + RSF + ISWR) (cfs)	Storage Allowed? (Y/N)	**5%** (cfs)	(ac-ft)	**10%** (cfs)	(ac-ft)	**20%** (cfs)	(ac-ft)	**30%** (cfs)	(ac-ft)
JAN	4660	642	4020	119	4500	5261	Y	-5261	-317434	-3761	-226928	-2261	-136422	-761	-45917
FEB	5190	701	4490	119	4500	5320	Y	-5320	-320994	-3820	-230488	-2320	-139982	-820	-49476
MAR	5710	972	4740	119	4500	5591	Y	-5591	-337345	-4091	-246839	-2591	-156334	-1091	-65828
APR	6380	991	5390	119	4000	5110	N	0	0	0	0	0	0	0	0
MAY	5890	1170	4720	119	4000	5289	N	0	0	0	0	0	0	0	0
JUN	5590	1240	4350	119	4000	5359	N	0	0	0	0	0	0	0	0
JUL	4560	1020	3540	119	4000	5139	N	0	0	0	0	0	0	0	0
AUG	4260	892	3370	119	3500	4511	N	0	0	0	0	0	0	0	0
SEP	4320	765	3560	119	3800	4684	N	0	0	0	0	0	0	0	0
OCT	4430	775	3660	119	3800	4694	N	0	0	0	0	0	0	0	0
NOV	4440	837	3600	119	3800	4756	Y	-4756	-286964	-3256	-196458	-1756	-105952	-256	-15446
DEC	4590	759	3830	119	4500	5378	Y	-5378	-324493	-3878	-233988	-2378	-143482	-878	-52976
Total (ac-ft)									0		0		0		0

197 DESCHUTES R > COLUMBIA R - AB TUMALO CR

Table C - Final analysis with downstream demands considered.

Month	Limiting Watershed ID	Natural Stream Flow (NSF) (cfs)	Consumptive Use (CU) (cfs)	Expected Stream Flow (NSF-CU) (cfs)	Reserved Stream Flow (RSF) (cfs)	In Stream Water Right (ISWR) (cfs)	Baseflow (CU + RSF + ISWR) (cfs)	Storage Allowed? (Y/N)	5% (cfs)	(ac-ft)	10% (cfs)	(ac-ft)	20% (cfs)	(ac-ft)	30% (cfs)	(ac-ft)
JAN	30530643	4660	642	4020	119	4500	5261	Y	-5261	-317434	-3761	-226928	-2261	-136422	-761	-45917
FEB	30530643	5190	701	4490	119	4500	5320	Y	-5320	-320994	-3820	-230488	-2320	-139982	-820	-49476
MAR	197	1270	449	821	0	1000	1449	Y	-5591	-337345	-4091	-246839	-2591	-156334	-1091	-65828
APR	197	1430	983	447	0	1000	1983	N	0	0	0	0	0	0	0	0
MAY	197	1530	1880	-353	0	1600	3480	N	0	0	0	0	0	0	0	0
JUN	197	1610	2150	-537	0	1600	3750	N	0	0	0	0	0	0	0	0
JUL	197	1280	2260	-977	0	1600	3860	N	0	0	0	0	0	0	0	0
AUG	197	1250	2080	-827	0	1600	3680	N	0	0	0	0	0	0	0	0
SEP	197	1280	1710	-427	0	1600	3310	N	0	0	0	0	0	0	0	0
OCT	197	1310	1210	98.8	0	1000	2210	N	0	0	0	0	0	0	0	0
NOV	30530643	4440	837	3600	119	3800	4756	Y	-4756	-286964	-3256	-196458	-1756	-105952	-315	-19006
DEC	30530643	4590	759	3830	119	4500	5378	Y	-5378	-324493	-3878	-233988	-2378	-143482	-878	-52976
Total (ac-ft)										0		0		0		0

Explanation of data table elements and calculations using Mussel Creek as an example.

The watershed chosen for this example is Mussel Creek, a tributary to the Pacific Ocean, located in the South Coast Basin. In order to proceed with the proposed method, surface water availability and peak stream flow analysis must be performed. Water availability has been estimated for over 2200 watersheds in Oregon. It should be noted however, that there are a number of watersheds in Oregon that have not been evaluated for surface water availability. The analysis for Mussel Creek has been completed and can be accessed on the Oregon Water Resources Department's website at: http://apps2.wrd.state.or.us/apps/wars/wars_display_wa_tables/search_for_WAB.aspx.

The following table is the water availability analysis for Mussel Creek from the Department's website.

Water Availability Analysis

Water Availability Analysis
Detailed Reports

MUSSEL CR > PACIFIC OCEAN - AT MOUTH
SOUTH COAST BASIN
Water Availability as of 9/9/2010

Watershed ID #: 73209 | Exceedance Level: 50%
Date: 9/9/2010 | Time: 10:30 AM

Water Availability Calculation | Consumptive Uses and Storages | Instream Flow Requirements | Reservations
Water Rights | Watershed Characteristics

Water Availability Calculation

Monthly Streamflows in Cubic Feet per Second
Storage at 50% Exceedance in Acre-Feet

Month	Natural Stream Flow	Consumptive Uses and Storages	Expected Stream Flow	Reserved Stream Flow	Instream Flow Requirement	Net Water Available
JAN	87.00	0.03	87.00	0.00	34.00	53.00
FEB	97.20	0.05	97.10	0.00	34.00	63.10
MAR	85.90	0.02	85.90	0.00	34.00	51.90
APR	45.00	0.00	45.00	0.00	34.00	11.00
MAY	20.00	0.00	20.00	0.00	20.00	0.00
JUN	20.30	0.00	20.30	0.00	20.00	0.30
JUL	13.60	0.00	13.60	0.00	13.00	0.60
AUG	8.52	0.00	8.52	0.00	8.50	0.02
SEP	5.61	0.00	5.61	0.00	5.59	0.02
OCT	7.48	0.00	7.48	0.00	7.46	0.02
NOV	43.50	0.00	43.50	0.00	34.00	9.50
DEC	96.00	0.05	96.00	0.00	34.00	62.00

http://apps2.wrd.state.or.us/apps/wars/wars_display_wa_tables/display_wa_details.aspx?ws_id=73209&exlevel=50&scenario_id=1 (1 of 2)9/9/2010 10:31:29

The estimation of peak discharge was determined using a tool accessible on the Department's website at: http://www.wrd.state.or.us/OWRD/SW/peak_flow.shtml. This tool can be used on virtually any stream in Oregon.

Page one of the report, Estimation of Peak Discharges for Mussel Creek.

http://www1.wrd.state.or.us/cgi-bin/flood_wab_analysis.pl?wid=73209

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Estimation of Peak Discharges

```
                    PEAK DISCHARGES FOR SELECTED FREQUENCIES

    Report prepared for:
    Time:  10:22                                    Date:  09/09/2010

    Watershed Name: MUSSEL CR > PACIFIC OCEAN - AT MOUTH


               PEAK DISCHARGE CALCULATION BY PREDICTION EQUATION

    Peak discharges for the ungaged watershed have been determined from a
    set of hydrologic prediction equations derived using generalized least
    squares.  The models relate peak discharges to physical watershed
    characteristics such as area and precipitation.  The equations take
    this form:

            Q(T)=(10.0^C0(T))*(CHR1^C1(T))* . . . (CHRn^Cn(T))
            --------------------------------------------------
               Q(T)   =  Peak Discharge for Return Period T
               Cx(T)  =  Coefficient x for Return Period T
               CHR1   =  The First Watershed Characteristic
               CHRn   =  The nth Watershed Characteristic
            --------------------------------------------------
               Note: * = multiplication, ^ = exponentiation


    For this ungaged watershed, peak discharges were estimated using
    prediction equations for this flood region:

                           COASTAL WATERSHEDS

                Prediction Equation for Coastal Watersheds
   ------------------------------------------------------------------------
   Q(T)=(10.0^C0(T))*(X1^C1(T))*(X2^C2(T)*(X3^C3(T))*(X4^C4(T))*(X5^C5(T))
   ------------------------------------------------------------------------
      Q(T)   =  Peak Discharge for Return Period T
      Cx(T)  =  Coefficient x for Return Period T
      X1     =  Drainage area                           (square miles)
      X2     =  2-year 24-hour precipitation intensity  (inches)
      X3     =  Soil permeability                       (inches/hour)
      X4     =  Mean maximum January temperature        (degrees F)
      X5     =  Soil storage capacity                   (inches)
   ------------------------------------------------------------------------
               Note: * = multiplication, ^ = exponentiation

                     Prediction Equation Coefficients
   ------------------------------------------------------------------------
   Return                        Coefficients
   Period
     T        C0(T)      C1(T)      C2(T)      C3(T)      C4(T)      C5(T)
   ------------------------------------------------------------------------
       2 -1.296E+00  9.489E-01  1.360E+00 -1.576E-01  1.280E+00 -4.421E-01
       5 -1.881E+00  9.385E-01  1.272E+00 -2.234E-01  1.738E+00 -5.026E-01
      10 -2.095E+00  9.324E-01  1.226E+00 -2.552E-01  1.926E+00 -5.267E-01
      20 -2.248E+00  9.273E-01  1.190E+00 -2.812E-01  2.069E+00 -5.438E-01
      25 -2.291E+00  9.258E-01  1.179E+00 -2.888E-01  2.109E+00 -5.484E-01
      50 -2.410E+00  9.215E-01  1.151E+00 -3.111E-01  2.223E+00 -5.605E-01
     100 -2.516E+00  9.176E-01  1.126E+00 -3.319E-01  2.325E+00 -5.701E-01
     500 -2.723E+00  9.099E-01  1.078E+00 -3.770E-01  2.527E+00 -5.855E-01
```

http://www1.wrd.state.or.us/cgi-bin/flood_wab_analysis.pl?wid=73209 (1 of 3)9/9/2010 10:23:26

Page two of the report, Estimation of Peak Discharges for Mussel Creek.

Required Watershed Characteristics

Drainage area	(square miles)	10.200
2-year 24-hour precipitation intensity	(inches)	4.790
Soil permeability	(inches/hour)	1.060
Mean maximum January temperature	(degrees F)	51.700
Soil storage capacity	(inches)	0.205

PEAK DISCHARGE ESTIMATES BASED ON PREDICTION EQUATIONS

Return Period years	Peak Flow cfs	95% Confidence Lower Limit cfs	Upper Limit cfs
2	1200	704	2050
5	1770	1070	2940
10	2170	1300	3620
20	2560	1510	4350
25	2690	1580	4580
50	3090	1770	5370
100	3490	1950	6260
500	4480	2340	8580

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Wiley, J.B., Atkins, Jr., J.T., and Tasker, G.D., 2000, Magnitude and frequency of peak discharges for rural, unregulated streams in West

As shown in the table on page two of the report, Estimation of Peak Discharges, the two year peak flow for Mussel Creek at the mouth is 1200 cubic feet per second (cfs). 5, 10, 20, and 30 percent of the two year peak flow are calculated as:

5% = 0.05 X 1200cfs = 60cfs
10% = 0.1 X 1200cfs = 120cfs
20% = 0.2 X 1200cfs = 240cfs
30% = 0.3 X 1200cfs = 360cfs

There is a certificated in stream water right on Mussel Creek. These in stream flow values, quantified in cfs, are assigned by month. Please refer to column 6 of the Water Availability Analysis on page 1 for the monthly stream flow values. There is also a small amount of consumptive water use associated with one or more out of stream water rights. These monthly values are displayed in column 3 of the Water Availability Analysis.

With this information, the following data table can be developed:

73209 - MUSSEL CR > PACIFIC OCEAN AT MOUTH

10.2 sq-mi

	2yr peak flow	**5%**	**10%**	**20%**	**30%**
cfs	1200	60.0	120	240	360

Column

50% exceedance

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Month	Natural Stream Flow (NSF) (cfs)	Consumptive Use (CU) (cfs)	Expected Stream Flow (NSF-CU) (cfs)	In Stream Water Right (ISWR) (cfs)	Base Flow (CU + ISWR) (cfs)	Storage Allowed? (Y/N)	**5%** (cfs)	(ac-ft)	**10%** (cfs)	(ac-ft)	**20%** (cfs)	(ac-ft)	**30%** (cfs)	(ac-ft)
JAN	87.0	0.03	87.0	34.0	34.0	Y	26.0	1567	86.0	5187	206	12428	326	19668
FEB	97.2	0.05	97.1	34.0	34.1	Y	26.0	1566	86.0	5186	206	12426	326	19667
MAR	85.9	0.02	85.9	34.0	34.0	Y	26.0	1568	86.0	5188	206	12428	326	19669
APR	45.0	0.00	45.0	34.0	34.0	Y	26.0	1569	86.0	5189	206	12429	326	19670
MAY	20.0	0.00	20.0	20.0	20.0	N	0	0	0	0	0	0	0	0
JUN	20.3	0.00	20.3	20.0	20.0	N	0	0	0	0	0	0	0	0
JUL	13.6	0.00	13.6	13.0	13.0	N	0	0	0	0	0	0	0	0
AUG	8.52	0.00	8.52	8.50	8.50	N	0	0	0	0	0	0	0	0
SEP	5.61	0.00	5.61	5.59	5.59	N	0	0	0	0	0	0	0	0
OCT	7.48	0.00	7.48	7.46	7.46	N	0	0	0	0	0	0	0	0
NOV	43.5	0.00	43.5	34.0	34.0	Y	26.0	1569	86.0	5189	206	12429	326	19670
DEC	96.0	0.05	96.0	34.0	34.1	Y	26.0	1566	86.0	5186	206	12426	326	19667
Total (ac-ft)								9,404		31,125		74,568		118,010

Explanation of the preceding table:

Column #:

1. Month
2. The estimated Natural Stream Flow (NSF) in cfs. This value is found in column two of the Water Availability Analysis displayed on page one.
3. Out of stream Consumptive Use (CU) in cfs. Found in column three of the Water Availability Analysis.
4. Expected Stream Flow is calculated by subtracting CU from NSF.
5. In Stream Water Right (ISWR). Found in column six of the Water Availability Analysis. In instances where there is no ISWR, the 50% exceedance NSF is substituted.
6. Base Flow is calculated by adding CU to the ISWR. Where applicable, reserved stream flow (RSF) is also included in the equation. Base flow in this table, can be described as the amount of stream flow that must be present before any more storage can be allocated.
7. Storage Allowed? Is used as a switch turning on (Y) or off, (N) the opportunity to divert water for storage during the respective month.
8. Calculated by subtracting the monthly base flow from 5% of the two year peak. For the month of January, 60 cfs (or 5% of 1200) - 34 cfs (Base Flow) = 26 cfs.
9. The monthly acre foot equivalent of the value in column 8. For the month of January, 26 cfs x 1.9835 = 1567 ac-ft.
10. Columns 10-15 repeat the previously described equation for 10, 20 and 30 percent of the two year peak flow.

The last or bottom row of the table is the yearly total in acre-feet. The yearly total is calculated by summing the monthly acre-foot values. Negative monthly values are considered to be effectively zero when determining the year end total.

All values are rounded:
To hundredths below 10;
Tenths below 100;
Nearest whole number 100 and above.

Appendix C: EFTAG Final Comments

The Nature Conservancy
Protecting nature. Preserving life.™

The Nature Conservancy in Oregon
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Portland, OR 97214-2537

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Final Comments on
White Paper: Peak and Ecological Flows; a Scientific Framework for
Implementing Oregon HB 3369
Leslie B. Bach, Ph.D.
Director of Freshwater Programs
The Nature Conservancy
November 23, 2010

As a member of the Ecological Flows Technical Advisory Group (EFTAG), I had the pleasure of working with some of the top scientific experts on this subject in Oregon. The combined knowledge and experience in this group, and the cooperative and collegial nature of the committee members, created the potential for well thought out and useful white paper on ecological flows. I commend the Oregon Water Resource Department for putting together such a strong committee, and I very much appreciated the opportunity to participate.

As pointed out by the Independent Multidisciplinary Science Team (IMST) in their review of the report, the committee and the white paper could have done more. In particular, I do not feel that the committee was given sufficient time or direction to fully meet their assigned task. My expectation had been that we would not only briefly summarize a variety of methods for determining ecological flows, but that we would evaluate these methods in the context of HB 3369 and Oregon's specific instream and out of stream needs, and provide some guidance as to which methods are best used under what circumstances. The IMST comments make a number of references to lack of details about the actual methods, no discussion of pros and cons, and only brief reference to the limitations of the methods. A deeper evaluation of the methods, and a thorough examination of their value and limitations, could have added great value to future efforts by policy makers to set standards for peak and ecological flow analysis and protection in Oregon.

A significant aspect of the white paper is the suggestion of "Regionally Protective Criteria" (RPC). I support that concept, and think that an RPC-type approach could provide significant ecological benefits while at the same time streamline the process for water conservation and development projects. By identifying and protecting key ecological flows using straight-forward and relatively simple methods, project applicants can move forward with more confidence that they will be able to meet future needs for water while at the same time insuring the ecological health of our rivers and streams. I do not however view an RPC concept as related to "high impact" or "low impact" projects as stated in the white paper. As pointed out by several peer reviews, these terms are very subjective. I would envision an approach that would set RPCs for different river and stream types in Oregon. If the RPC is acceptable to a project applicant, they can move forward on their project based on the remaining available water, per appropriate

Oregon laws and statutes. If the applicant feels that the RPC is too restrictive, they can elect to do additional studies to determine the appropriate peak and ecological flows for the river and river reaches in question. These studies would use specific methods that were identified by the state as acceptable approaches. Again, the committee could, and should, help review, vet and select those methods.

In terms of the actual RPCs proposed in the white paper, I feel that a number of clarifications are warranted. First and foremost, RPCs need to be protective, and build upon existing water allocation rules and practices. Although the report and the appendices evaluate how the RPCs would play out from an allocation standpoint, they do not evaluate how the RPCs would affect instream flows. An analysis of flow records for several of the example rivers shows that 5% of the 2-year peak flow would be at least as protective as current policies, while 10% or 15% would be less protective. This type of analysis should have been done during the committee process, so that the RPC suggestions could have been refined.

As well stated in the paper, an RPC should protect both channel maintenance flows and a subset of key flows critical to supporting and maintaining biological processes. In the paper, the RPC refers to using a percent of the 2-year peak flow as a screen for the "channel habitat maintenance flow threshold", but the examples then apply this percentage to the entire storage season. In my opinion this criteria should only be used to determine the channel maintenance portion of ecological flows, not the biologically-significant flows. Other methods are needed for determining biological flow requirements. This is another area that the committee could, and should, have focused more attention. We spent very little time identifying and evaluating potential methods for determining the biological portion of ecological flows. The paper suggests dealing with the biological flow needs by limiting the season of use. I think this is inadequate from the instream flow protection standpoint and potentially overly restrictive from the water use perspective. Specifically identifying the magnitude, duration and timing of the biologically-significant flows could potentially better meet both instream and out-of-stream needs.

Overall, I would envision RPCs to consist of 1) a protection for very high flows that perform channel forming and maintenance functions. The 5% criteria, applied to flows over a certain threshold, could work very well; 2) a small number of biologically-significant flows. These would be identified by river/stream type, and would be quantified in terms of their magnitude, duration and timing. I believe the EFTAG has the expertise and capacity to help facilitate that work; and 3) minimum, or bypass flows based on instream water rights or 50% exceedance flows. Once these RPCs are identified, projects could move forward quickly, or project applicants could choose to undertake more detailed studies using one or more of the approved methods.

It is important to note that the science of peak and ecological flows, and quantitative standards to protect these flows, are still emerging areas of study. At this point it is critical to gain quantitative information that will improve the implementation of such policies in the future. This kind of adaptive management is best accomplished with quantitative, long-term monitoring and evaluation to determine the effectiveness of the program.

Again, I am honored to have worked with the EFTAG on this very important issue. I truly believe that we can, and need, to find a way to balance water needs for both people and ecosystems. I am very committed to continuing to participate in discussions on methods and approaches for determining and protecting peak and ecological flows.

MEMORANDUM
Oregon Department of Fish and Wildlife

Date: November 23, 2010

To: Barry Norris, Water Resources Department

From: Tim Hardin and Rick Kepler

Subject: ODFW comments on the October 29, 2010 version of the "White Paper: Peak and Ecological Flow; a Scientific Framework for Implementing Oregon HB 3369"

ODFW has reviewed the October 29, 2010 version of the Peak and Ecological Flow White Paper and submits the following for Appendix C as ODFW's EFTAG Final Comments.

ODFW believes that the revised Oct 2010 version has addressed most of the comments ODFW provided for the June 2010 version, and the paper is better focused and clearer. ODFW does have a key concern with the percent-of-peak flow method described in "Use of Screening Criteria for Low Impact Projects" (Tier 1) which allows storage based on a percentage of the 1-in-2-year peak flow event. This method appears at times to be less protective than WRD's current policy of allowing storage up to the 50% exceedance levels, and may cause a stream to flow at base flows too much of the time. ODFW also includes some general presentation comments.

<u>Use of Screening Criteria for Low Impact Projects</u> – ODFW's understanding of the tiered approach was that Tier 1 would allow for minor reductions in flows that would not be ecologically significant; more rigorous ecological analysis for additional storage could be done under Tiers 2 and 3. Tier 1 withdrawals would be intended to maintain a variable hydrograph for ecological needs, and thus a Tier 1 project could proceed with a streamlined review of environmental impacts.

ODFW examined the data used in Figure 4 and Appendix B of the White Paper. Using this information, we developed a series of hydrographs, calculated the amount and percentage of flow that would remain in the stream under different scenarios, and compared the results to the existing WRD 50% exceedance flow policy currently used for storage. We found that a 5% rule (i.e. storage of a fixed amount of water equal to 5% of the 1-in-2 year peak flow) is similar to existing WRD storage policy.

For example, using the Elk Creek data from the White Paper (Figure 4, page 21), the 5% rule would allow slightly <u>more</u> storage than the current WRD policy. At higher percentages of peak flows, far more storage than current policy would be allowed. The paper proposes a possible range of 5-15% (page 22). However, even a 10% rule would severely curtail the hydrograph compared to the existing policy (See Figure A, below). Instream flow would be restricted to base flow somewhat more often for the 5% rule vs. existing policy, but nearly twice as often with a 10% rule (See Table A, below).

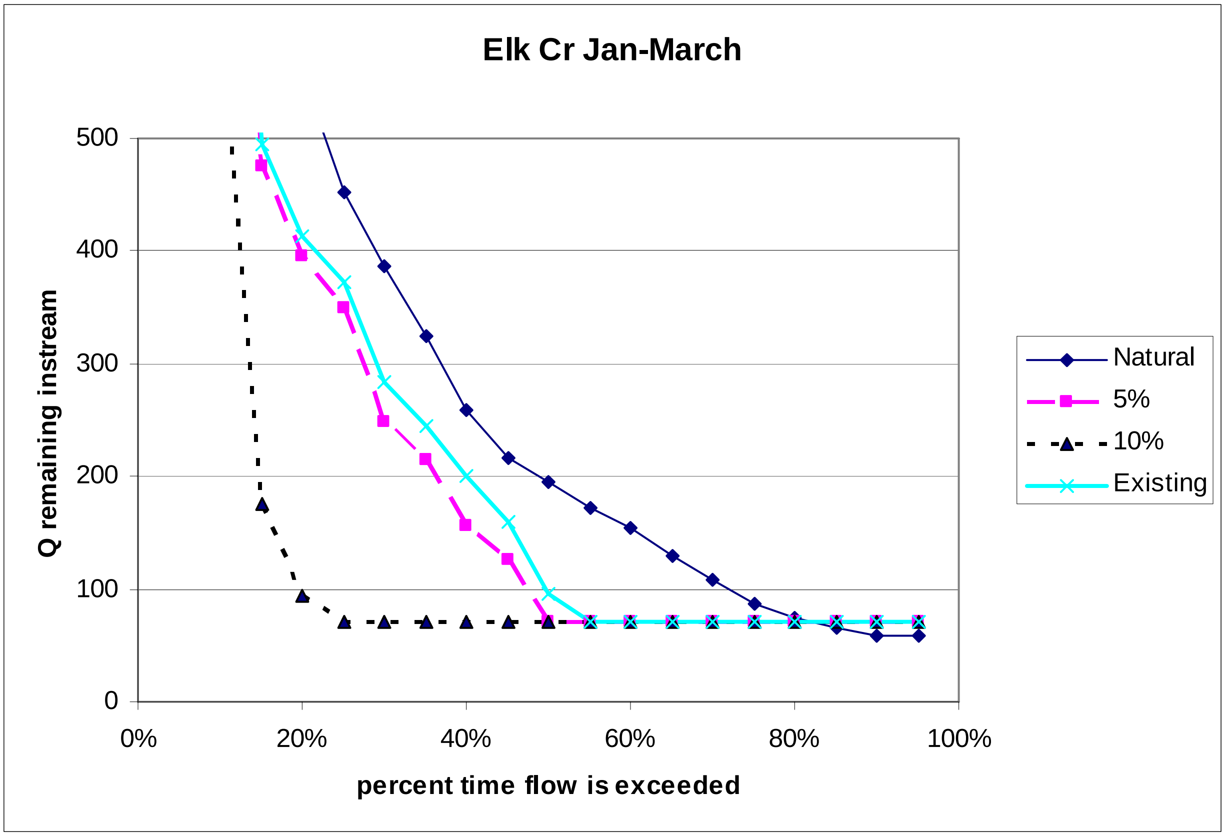

Figure A. Flow remaining instream in Elk Creek, January-March, for existing WRD storage policy vs. the proposed 5% and 10% of peak flow storage guidelines. Note that a) the 5% rule allows slightly <u>more</u> storage vs. existing policy; b) flow would be limited to base flow nearly 80% of the time with the 10% scenario.

Table A. Amount of time Elk Creek would be at base flow under existing, 5% and 10% scenarios

[1]	Natural	Existing	5%	10%
# days at base flow	0	36	46	70
% of days at base flow	0	40%	51%	78%

1 Based on 90 days of gaged flows January –March 1969 as used in Figure 4, page 21 of White Paper.

It appears that if the ratio between the median flow and peak flow is small, the 5% method allows a bit less water to be stored than the 50% exceedance method; however, as the ratio between the two grows, more water is allowed to be stored than under the 50% exceedance policy. So in more flashy streams (where the 2 year peak flow very high compared to the median flow) removal and storage of 5% of the peak flow could result in a flat-line hydrograph, with the stream flowing at just the base flow much of the time. This is because the method allows for a constant <u>amount</u> (not a constant percentage) to be withdrawn over a wide range of flows. This means that as streamflow decreases from the peak toward the base flow, a higher and higher <u>percentage</u> of existing flow is removed.

The ODFW Peak Flow guidance (recommended in tier 2) also could flat-line flows at the base flows, but that would be only after a review and analysis of necessary ecological flows and their protection.

A major stated purpose of the proposed diversion guidelines is to streamline the review process for low-impact storage projects. If so, then these new guidelines should be more protective than current WRD policy. As written in the White Paper, they are not more protective than current policy. Thus our main concerns are that these proposed guidelines:

- allow too much water to be removed from the system and stored without first reviewing ecological needs, and
- eliminate much of the variability in the hydrograph without first evaluating the impact.

For this first tier ODFW would recommend taking a smaller percentage of flow for storage by either:

- basing the amount of storage on a percentage of the median flow rather than the peak flow;
- allowing diversion of a small <u>percentage of the actual flow</u>, rather than diversion of a <u>relatively large fixed amount ;</u>
- <u>reducing the return flow interval for peak flow values from 1-in-2 to 1-in-1.5 or less (this would reduce the percentage of actual flow);</u> or
- remaining with the 50% exceedance flow storage policy.

<u>Other comments</u>

- California used a percentage of the 1-in-1.5 year flow. The White Paper proposes the 1-in-2 year flow. It should be pointed out that the 2-year peak flow is a larger number, and an estimate of the difference should be included.
- The magnitude of the 2-year peak flow exerts too much control on the process. In flashy systems, the 2-year peak is large compared to median flows. This means that even with only a 5% diversion allowance, a large amount of storage is allowed.

<u>General presentation comments</u>:

- As described in the text subsistence and base flows are different. However, Figure 1 (page 5) labels subsistence flows and base flows as the same. The line should be labeled as base flows, and a lower line should be added which would be subsistence flows. (Normally this would be a 7Q10 flow if considering water quality. ODFW does not develop subsistence flow values for fish and wildlife.)
- On page 21-22, there is some confusion about California policy on base flows. California defaults to a percentage of Mean Annual flow, not a percentage of monthly 50% exceedance flow.
- Also on page 21-22 ODFW has never considered adjusting base flows by a factor related to size of the watershed. We would suggest leaving this out.
- Table 1 (page 23) seems to be missing some information. At least two additional columns should be added after column 4: “Existing Consumptive Use and Storage” and a “Net Remaining Available Water”. Otherwise it is hard to understand how the conclusions in the final columns were arrived at.

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November 17, 2010

Dear Barry,

Thank you for the opportunity to participate in the review of the EFTAG document. I find the current draft to be a good overview of definitions and approaches to regulating ecological flows. Further, I appreciate the difficult challenge that OWRD faces in implementing HB3369 and am, like the rest of the committee, enthusiastic to see a program developed that considers the needs of both people and the environment. However, I have some lingering concerns, both about the document and about the process for developing the document.

If the purpose is indeed for it to be used as a scientific framework by policy makers who will develop a method to implement ecological flow protections, then the following concerns are relevant:

- Despite being a contributor to the document, I feel that the process for engaging the committee limited the development of a more meaningful contribution. Given the substantial expertise of the EFTAG, I find that the document is limited in its ability to inform implementation plans. This document is more of a methodological review, without a deep analysis of how the various approaches could be applied in Oregon and without providing a clear set of recommendation for implementation. The "Applications of Methods to Oregon" section lacks important detail. For example, a decision framework/tree could be developed to inform a process for implementing the ecological flow regulations in Oregon. Further, analysis is needed to consider what each approach achieves in terms of environmental benefits relative to water costs. Such an overarching framework will be needed to coordinate with and explore how these flows compliment or contradict other flow requirements (e.g. ODFW, BiOps). More time and a more collaborative process would have allowed for a thorough analysis of the described approaches and their relevance to and limitations in Oregon.
- Detailed comments were provided to OWRD by members of the EFTAG (e.g. implementation of cumulative effects, nonstationarity) and IMST that are not addressed in this document. The lack of response is likely because there are not easy answers to questions and comments posed by the committee and IMST. Rather than pressing forward without addressing these comments, the committee could have continued to work together collaboratively, through intensive work sessions for example, to develop more meaningful guidance for policymakers.
- A process-based approach, as has been proposed in California's Bay Delta and other basins, that relates flow targets to specific ecological functions is likely a more efficient use of water and more environmentally beneficial than the proposed approach.

- Regardless of whether a process-based approach is used, some level of evaluation of the protectiveness/effectiveness of the regulation is needed. This was suggested as an important component of the current document early in its development. As with any new environmental management policy, effectiveness monitoring is a critical component of adaptive implementation.
- As a member of EFTAG, my contributions to the document are more representative of a reviewer, rather than a co-author, providing feedback on a document that was largely developed by an individual. I suggest that future policy-informing documents regarding HB 3369 be developed with more thorough contributions from the available expertise that was not fully utilized on the EFTAG. Despite the volunteer-nature of our contributions to the development of this document, substantial interest in a progressive and effective instream flows program was apparent in our committee.

More detailed analysis is needed on the implications and effectiveness of the recommendations for developing regulations to support HB 3369, including an adaptively developed program for implementation. If anything, I find that this document introduces concepts that are likely to be less protective, rather than more protective, of instream needs. The implications of this policy are profound, both for the people and aquatic ecosystems of Oregon, and I believe that more time is needed to understand those implications.

Thank you,

Desiree Tullos, PhD
Biological and Ecological Engineering, Oregon State University

Appendix D: Peer Review Comments

Independent Multidisciplinary Science Team (IMST)

State of Oregon

Michael J. Harte
Robert M. Hughes
Victor Kaczynski
Nancy Molina
Carl Schreck
Clint Shock
J. Alan Yeakley

c/o
Oregon State University
Department of Fisheries & Wildlife
104 Nash Hall
Corvallis OR 97331-3803

July 26, 2010

Barry F. Norris, State Engineer
Oregon Water Resources Department
725 Summer St NE, Suite A
Salem, OR 97301-1266

Dear Mr. Norris,

As per your request (letter dated February 24, 2010) the Independent Multidisciplinary Science Team (IMST) has reviewed the Ecological Flows Technical Advisory Committee's (EFTAC) document *White Paper: Ecological Flows; a scientific framework for implementing Oregon HB 3369* (June 4, 2010 draft). In your letter, you asked the IMST to consider 10 questions during its review. This review provides brief answers to those questions plus some more general comments on the document. In addition, a few IMST members provided significant editorial suggestions that may be useful to the EFTAC as they revise the draft. We will send these directly to Dr. George Robison.

In general, the IMST found the document to be very well written and informative. We hope that these comments will assist the OWRD as work progresses on ecological flows.

Sincerely,

Carl Schreck
IMST Co-Chair

Nancy Molina
IMST Co-Chair

Attachment
Cc:
George Robison, OWRD
Sue Knapp, GNRO
Tom Byler, OWEB
IMST

IMST Review of Oregon Water Resources Department's
***White Paper: Ecological flows; a scientific framework for implementing Oregon HB 3369* (June 4 *2010 draft*)**

Released on July 26, 2010

Independent Multidisciplinary Science Team
Oregon Plan for Salmon and Watersheds
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Citation: Independent Multidisciplinary Science Team. 2010. IMST Review of Oregon Water Resources Department's White Paper: Ecological Flows; a scientific framework for implementing Oregon HB 3369 (June 4, 2010 draft). Oregon Watershed Enhancement Board, Salem, Oregon.

Review Preparation: This review was prepared by the IMST based on an initial draft by an IMST subcommittee (Bob Hughes, Clint Shock, and Alan Yeakley with Kathy Maas-Hebner providing technical support). George Robison (Oregon Water Resources Department) briefed the IMST at its January 27, 2010 public meeting. The IMST discussed and unanimously adopted (Hughes absent) at its July 26, 2010 public meeting.

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ACRONYMS AND ABBREVIATIONS

ELOHA	ecological limits of hydrologic alteration
HB	House Bill
IMST	Independent Multidisciplinary Science Team
OWRD	Oregon Water Resources Department
USGS	US Geological Society

INTRODUCTION

The Independent Multidisciplinary Science Team (IMST) reviewed the document titled *White Paper: Ecological Flows; a scientific framework for implementing Oregon HB 3369* (June 4, 2010 draft) at the request of the Oregon Water Resources Department (OWRD; letter from Barry Norris dated February 24, 2010). In particular, OWRD asked the IMST to review the draft document in regard to 10 questions listed in the letter (and repeated below). The IMST offers the following comments with the purpose of improving the final document by increasing the clarity of information presented and by better explaining the strengths and weaknesses of the methods presented in the White Paper. This review provides brief answers to those questions plus general comments on the draft document

The IMST commends the members of the Ecological Flows Technical Advisory Committee for developing a well written, comprehensive document. IMST recognizes the scientific and technical difficulties associated with the task charged to the Advisory Committee.

Regarding Ecological Flows:

1. **Is the overall classification of ecological flows adequate or is there a better way to characterize them?**

   There are some uncertainties about the classification. In particular, the term "triggering flows" implies cause-and-effect, and there are cases of ecological functions that are triggered by other causes (such as life cycle changes) and changes in flow conditions may merely facilitate (rather than cause) some ecosystem functions.

2. **Are the definitions clearly delineated and do they represent mainstream thinking on this subject?**

   No, there are problems with some of the definitions. In particular, the definition of ecological flows includes stream flows defined as "flow protections" which implies management rather than naturally occurring ecosystem functions. Also, as discussed in Question 1, the term "triggering flows" does not seem appropriate.

3. **Do the definitions give enough information to allow policy makers to understand some of the different ways they are determined?**

   No, the definitions do not address methods of how these flows are determined, and hence on their own do not give policy makers enough information to make that determination.

Regarding Methods:

4. **Are the methods and techniques described in the White Paper representative of the range of options that are available or are there some missing approaches?**

   To our knowledge and without extensive literature review, it appears that the range of options provided in the White Paper is representative of what may be currently available.

5. **Are methods or approaches emphasized that are considered as fringe methods while more commonly used methods were not adequately covered?**

   The methods covered appear to be ones that are commonly used, and not “fringe”.

6. **Does the description of methods naturally lead into the more applied parts of the report that follows, or is better exposition needed?**

   The description of the methods is only done in a summary way, and nearly all the details are missing. The report requires the reader to obtain the cited references and learn about the methods on his/her own. The report provides Table 1 and Appendix B, but this is only a set of outcomes without describing how these outcomes were reached. An additional appendix that details the methods described, including providing steps and examples of applications, would help the reader greatly.

7. **Are the limitations and advantages of the various methods for each type of ecological flow adequate to provide the reader an understanding of inferences made in the later sections of the report?**

   The limitations are discussed somewhat, but not in great detail. We feel the reader will have to conduct a non-trivial amount of trial and error to determine the limitations of the methods listed.

<u>Regarding Applications/Recommendations/Conclusions</u>:

8. **The paper includes various determination methods and techniques that relate to the narrow situations needing full detailed analysis. Do the related inferences and recommendations regarding their application flow logically from the information in methods, or are more background information and linkages necessary?**

   The background provided is reasonable. The problem is that the lack of details about the actual methods renders the document to appear more implicit than explicit. Actual methods could be provided in additional appendices.

9. **Do any of the recommendations or conclusions seem to be introduced awkwardly without the logical linkage back to the definitions and methods? If so, what information needs to be added or how does the recommendation need to be altered to better correlate with information given in previous sections?**

   The recommendations appear to jump ahead somewhat of what was actually presented in the methods. It would be preferable to present a conclusion composed of a breakdown of methods, including their pros and cons and areas of specific application. Instead the conclusions seem to focus on policy considerations.

<u>Overall</u>:

10. **Is there information that you feel should be added to strengthen the report or any information that needs clarification?**

    As mentioned above, there appear to be several gaps in terms of actually applying the methods reviewed. The reader who may be trying to implement these methods would be greatly aided if more detailed steps including explicit examples were added.

SPECIFIC COMMENTS

Page ii, 1st paragraph – A definition of how stream and river reaches are used in the document is lacking.

Page ii, 2nd paragraph – The term "*flow protection*" seems management oriented. Here it would be more appropriate to base descriptions of flow on ecology and/or hydrology based

Page ii, 3rd paragraph, item 1 – The use of "*abate and dilute pollutants such as chemicals or stream heating*" is vague and could be to be more specific as some "*chemicals*" are naturally occurring and beneficial, and it´s not clear what "*abate*" means here

Page ii, 3rd paragraph, item 2 – As discussed above, "*triggering flows*" implies causality. In other words, for this to be appropriate, all such flows would necessarily "*trigger*" or "*cause*" the ecological functions desired. Clearly some high flows just happen to be synchronous with ecological functions, and other triggering mechanisms are actually happening, including endogenous biological (e.g. life cycle) causes. In fact the text on the bottom of page 8 states as much, describing streamflow as only one of many causes. Consider changing this term to something more appropriate to cover both causal and non-causal (but synchronous and still important) higher flow conditions so that the definition is more comprehensive. Perhaps consider "*biological facilitating flows*" or some such variation in place of "*biological triggering flows*". Or define both types of flows and use them accordingly.

Page ii, 4th paragraph, 5th line – Why was a 1.5 year peak flow chosen? Presumably these are the mean recurrence intervals of bank full flows that do most of the work on stream channel morphology. But this is not well justified in the document or here in the Executive Summary. As written, it appears to assumes that the reader is a hydrologist or familiar with hydrology.

Page iii, bullet 2 – Why is 50% exceedence for baseflows used? What is the justification here? Obviously this number will vary depending on topographic, groundwater and climate conditions.

Page iii, bullet 3 – The definition for "*year return flow*" here and elsewhere is misleading. The definition would be enhanced by replacing "occurs" with "is exceeded" here and elsewhere throughout the document. Generally, it is not easy to understand what this item is saying, particularly the 2nd and 3rd lines. Also, could "bank-full flows" be used instead of "year peak flows"?

Page iii, 3rd paragraph, item 4 – What does "*effects of and condition a proposed storage project to protect ecological stream flows*" mean, exactly? Please clarify. IMST is concerned about the effects of construction of new dams and reservoirs on salmonids that are already limited by such migration barriers.

Page 3, 2nd paragraph – Does the federal Clean Water Act also apply here for pollution dilution flows?

Page 3, 3rd paragraph – Same comment as in Executive Summary regarding "flow protections"

Page 4, 1st paragraph – As discussed above, "biological triggering flows" has causal implications and does not cover cases where flows do not cause but rather just facilitate ecosystem functions.

Page 5, Figure 2 – The depiction of baseflow seems inaccurate or at least not comprehensive. This figure depicts streamflow at a significantly higher elevation than near-stream water table levels. This may occur in some cases, but a more general case would have the water table elevation near the stream at the same elevation and then increasing in elevation moving away from the stream. Isn't the primary difference between subsistence flow and baseflow relate to the depth of the water table (here they are shown at the same level but it would seem that in subsistence flow it should be generally lower than at baseflow) and to the longitudinal character of the stream/groundwater interface (rather than at a specific cross-section)?

Page 5, 1st paragraph, footnotes 24-25 – Based on their titles, these papers appear to suggest synchrony rather than cause-effect relationships, is that correct?

Page 5, bulleted list – Providing specific examples, maybe a paragraph per bullet, would help illustrate the importance of higher flows that facilitate (or in some cases cause) ecological functions.

Page 6, item 3 under Habitat Maintenance flows – Off-channel habitat creation and maintenance are also critical to healthy streams and healthy streams populations.

Page 6, 2nd paragraph, 1st line – This observation seems accurate, and it makes one wonder how such high flow events can actually be managed or what policy could effectively be applied to govern them? Such events are rare and hard to predict.

Page 7, 2nd paragraph – Consider replacing "almost always less then" with "by definition less than or equal to".

Page 7, item 1 – This item suggests that such methods are no longer relevant. Please clarify.

Page 7, item 2 – Is a single site based method actually useful? It seems that this would provide only very limited information and perhaps be either not comprehensive enough or even misleading. Somewhere there needs to be clarification as to which of these methods are useful.

Page 8, item 4 – This section could be summarized with the conclusions reached by Fausch *et al.* (1988), i.e., that predictive models are site specific and not general.

Page 8, bottom paragraph –This first sentence argues that high flows are only one of many "triggering" or causal factors. Again, the use of the term "triggering" is misleading and not very comprehensive. It could be possible for someone to show that for some given ecological function the flow is not actually "triggering" or causal and therefore should be ignored in a proposed management activity. As mentioned earlier, using a different term such as “facilitating” or some variation that does not require causality may be more relevant.

Page 9, 3rd paragraph, 4th line – The phrase “*have more capacity to transport sediment than sediment suppl*y” is not clear. Please clarify.

Downstream and upstream effects are both important. Consider work by Pringle (1997) and Pringle *et al.* (2000). This is especially important regarding the import of nutrients to ogliotrophic streams by spawning salmon.

Page 9, 4th paragraph, 2nd line – In reference to the statement about the Metolius River, explain better how some streams do “*not experience peak flows*”? Clearly there will be some elevated flows following rain or rain-on-snow events for any stream, even those that are spring fed.

Page 10, item 1, 2nd line – Consider replacing “occurs” with “is exceeded”.

Page 10, item 1– Why was 5% chosen? This percentage needs in-depth discussion that relates both to ecological function and to general hydrologic science. Why was 5% used in California and why would it be relevant in Oregon?

Page 11, item 3 – This item could be expanded to include more on direct monitoring. As written, this item implies that direct monitoring is just model calibration, and that is not accurate or comprehensive

Page 11, paragraph beneath item 3 – Ignoring the importance of wood in rivers is a serious oversight. Consider work by Sedell &Froggatt (1984) and Gregory et al. (2003). Additionally, high flows are also needed to limit the invasion and spread of non-native fish species (see Meffee 1984; Hughes *et al.* 2005).

Page 13, 1st paragraph, 5th line – “*This equation*” needs to be explicitly presented. In general, all equations and calculations need to be presented somewhere in this document (either in the appendix or in the text) to be useful to the reader.

Page 13, 3rd paragraph, 3rd line –As discussed above, these “year event” definitions are not accurately described at various places in the report, such as here.

Page 13, 3rd paragraph – A process based rationale for 5% is missing.

Page 14, ELOHA – The summary does not present the information well as described by Poff *et al.* (2010). Perhaps a figure from Poff *et al.* would be helpful.

Page 14, bulleted list – Reference back to Figure 2 would be helpful.

Page 14, 3rd paragraph, following last sentence – But then what happens? With no flow levels prescribed, this approach (Texas) seems rather “toothless”.

Page 15, last paragraph – The cost in dollars would be more informative if it was tagged to a specific year. Also using other metrics (such as person-hours, field time and data requirements) would provide a more fundamental way to evaluate costs

Page 16, 2nd paragraph – It would be helpful if specific details (either here or in an appendix) on these methods were presented so that the reader could implement them.

Page 16, last paragraph, 4th line – This is misleading as Texas only varies in terms of rainfall (which is admittedly highly variable in the state); snow storage and melt and rain-on-snow are negligible there.

Page 17, 1st paragraph – This paragraph is not clear, yet it appears to be a key piece of the discussion. A figure may help the reader to understand the text. Also, as written, the current screen for determining water availability does not appear protective of aquatic species. Is this correct?

Page 17, 2nd paragraph – What is the cumulative effect of multiple small projects? And how do the methods take cumulative effects into consideration?

Page 17, last paragraph – Can the California rules also reject proposed projects with in-depth and short-term studies?

Page 18, second item 2 – "*However, since we have greater certainty on instream flow values this may not be necessary*." This statement assumes that knowledge of past flow is an accurate predictor of future flows. Climate change will likely change this, especially rain-on-snow event frequency and increased droughts in semi-arid areas. How will increased urbanization-driven runoff and demands on ground water affect the ability to predict future flows?

Page 20, Table 1–The table would be more usable and understandable if the text were to describe how the information in the columns was determined, same goes for Appendix B. Also, rather than just referring to Appendix B and Table 1, it would greatly aid the reader if the details on how the designations in these tables were made, were presented as explicit descriptions in the text. It is not readily apparent how the values listed in Table 1 were derived from Appendix B. In the footnote, what exactly does "*ISWR stands for using the instream water right for baseflow bypass*" mean?

Page 21, 2nd paragraph, line 1 – How is "high impact" determined for a given project?

Page 24, item 7. Consider USGS (2003) on hydrogeomorphological classifications and a potential statewide classification.

Appendix B – It is very difficult to decipher the tables in the Appendix. Clearly defining abbreviations and acronyms would greatly assist the reader. Units are also missing. Additionally, providing an example describing how the calculations were made and why the specific variables were subtracted from the flows would increase the clarity of the results.

Endnotes 53, 54, 55 are identical with Endnotes 24, 25, 26

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Joint Water Commission
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July 9, 2010

E. George Robison, PhD; PE; D.WRE
Dam Safety Coordinator
Oregon Water Resources Department
725 Summer St. NE Suite A
Salem, OR 97301

Subject: Peer Review of White Paper: Ecological Flows; a Scientific Framework for Implementing Oregon HB 3369

Dear George,

Thank you for the opportunity to provide peer review comments on the draft White Paper: Ecological Flows; A Scientific Framework for Implementing Oregon HB 3369 (June 4, 2010). Overall, the White Paper was well written, provided a thorough assessment of the entire issue, and included the best available hydrologic and hydraulic methodologies available for assessing a stream's flow regime. The White Paper acknowledges the complexities of flow regimes that exist in different ecoregions throughout the state. The study also illustrates the challenges associated with setting criteria that would apply broadly and may be too restrictive or not protective enough for various ecological functions.

While reviewing the White Paper and associated legislation, it appears that the biggest challenge for the HB 3369 grant and loan program is that the legislative policy did not define the target species for ecological flow protection (page 16 paragraph 3). The majority of scientific research has focused on protecting listed and endangered species. Deviating from these methods to a more "holistic" approach seems to render this program inoperable. The White Paper illustrates the fact that the entire flow regime could be tied to any ecological function (page 8, number 4 "Holistic" methods); therefore potentially prohibiting funding opportunities for all future projects in this program.

The White Paper acknowledges this issue and attempts to move forward with some basic recommendations for project screening. Screening would assist with the level of effort and costs associated with the degree of impact on the flow regime. This method seems appropriate, but ecological flow conditions should ultimately depend on site specific advice developed by the Oregon Department of Fish and Wildlife due to the complexities and variability of flow conditions throughout the state.

Specific comments of the draft White Paper are attached. Additional comments relate to the following:

- Requested clarifications on various definitions, methods, and proposed approaches

- Focusing the effort on the HB 3369 loan and grant program, and not other programs and permitting processes in Oregon in general
- Comments related to water right processes being distinct and completely different than the conditions established for a grant and loan program
- Level of cost estimates for these studies being estimated too low

Thanks again for the opportunity to review the White Paper on ecological flows. If you have any questions or comments related to this peer review, please contact me at 503-615-6770 or via email at nikii@ci.hillsboro.or.us.

Sincerely,

Niki Iverson
Water Resources Manager
City of Hillsboro
Joint Water Commission

Peer Review

DATE: July 9, 2010

TO: E. George Robison, PhD; PE; D.WRE, Water Resources Department

FROM: Niki Iverson, Water Resources Manager, City of Hillsboro and Joint Water Commission

RE: Peer Review of White Paper: Ecological Flows; a Scientific Framework for Implementing Oregon HB 3369

Technical Comments

This analysis focused on the science rather than policy issues in the white paper. It evaluated the definitions, methods, and proposed approaches integrating those methods.

Based on this review, the following is a list of content in the White Paper that could use elaboration or revision:

- General comment: Be consistent with "stream flow" or "streamflow"
    - The two are used interchangeably in the document
- Executive Summary, pg iii, "3) Elevated flows for channel maintenance"
    - The percentage considered protective needs to be clarified: Is it 5% or 10%? Why the range?
    - The last sentence under #3 is a fragment and unclear
    - A comparison to California could be added here
- Page 1, paragraph 2:
    - "…creating and maintaining habitat through geomorphic work and other factors"
        - This phrase is vague and hard for the lay-person to decipher
        - Further elaboration and examples would improve understanding of the diverse ecological functions of streams, as well as provide reasons for caring about ecological flows
    - "Ecological flows are important because…"
        - Expand here. Why they are important is critical to convey and can be done so fairly easily with references to previous sentences or examples.
- Page 3, paragraph 1:

- “The term “instream flow” is a broad term that encompasses all types of within the stream flow needs”
  - A word is missing
  - Rephrasing “Stream flow needs” should be considered
- “The term “Environmental flows” is often used…”
  - Include in this sentence is: “Other instream flow needs.” A brief elaboration on this concept would be appropriate.
- The ecological flows definition is very broad
  - What are “other ecological functions?” This could be clarified.

- Page 6, #2(c) and page 7, #3: the method names are inconsistent
  - The name of the method in #2 “c” on pg 6 should correspond with #3 on page 7 to prevent confusion
    - Use either "Habitat simulation methods" or "Incremental habitat modeling or measurements" as the name of the method in both places
- Page 12, the first bullet under the “Prescribed flows to be reserved based on the stream bed type.”
  - “For sand bed streams channel maintenance needs would cover the full range of flows. Not all flows would be needed to maintain the character of the stream, but a portion of each flow level would be needed.”
    - This statement is unclear. Smaller diameter sediment generally takes a smaller velocity for movement, and therefore it is unclear why a full range of flows is required.
    - Examples would be helpful.
- Page 15, Paragraph preceding “Complexity and cost of methods” section
  - “…there have been initiatives to implement at least some parts of ELOHA in several states including Washington”
    - Examples of what parts of ELOHA they implemented would be useful information
    - What was Washington State’s experience with the method?
- Page 16, second to last paragraph, “In many cases, target species for ecological flow analysis in Oregon have been salmonids (fish species such as salmon and trout)”
  - Would target species just be listed species or a larger suite of species? Have target species just been listed species in Oregon and elsewhere?
- Page 18, first paragraph
  - “If a screening approach is adopted with RPC that allows for less review, dividing Oregon into regions and having different windows for storage will probably be necessary.”
    - Yes, region-specific criteria would increase the likelihood that the methods will more appropriately determine ecological flows.
- Page 19, first paragraph, “compare 5-15% of the peak flow event…”
  - This is a very large range. Some explanation of these numbers is needed, perhaps what differences in the stream systems/environment result in the different percentages.
  - On what basis will ODFW determine what the appropriate “threshold” percentage of the 2-year peak flow should be used to eliminate high impact projects? The document (page 21) describes several different percentages with no guidance on how to pick which is most appropriate for a given stream.
- Page 22, #2, Tier 1

  - "off stream" should be more clearly defined
- Page 22, #2, Tiers 1-3
  - Defining the tiers in greater detail should be explored since they will affect the level of effort and funding needed for projects.
  - Each tier could have a diverse array of ecological flow issues. Perhaps down the road there could be further categorization within tiers or addition of tiers to help streamline analysis even more, saving time and money. It would also give stakeholders a clearer sense of the steps involved in the determination process for particular projects.
- Page 23, last paragraph: "between hydrological, hydraulic, and holistic approaches…"
  - Shouldn't habitat simulation be included here?

Other comments:

- The paper did a good job introducing ecological flows and various methods for assessing the different types of flows. However, there is no clear statement as to why methods from California and Texas were highlighted. Are these the best methods out there or are there approaches taken by other states that should be mentioned? It would also be helpful to explain whether the state conducts these ecological flow studies or the state requires the applicants to conduct the studies.

- The paper nicely explained the complexities of implementing the methods. It also appropriately emphasized the diversity among regions in Oregon, stream within regions, and stream reaches.

- The paper put proper emphasis on geomorphology along with hydrology.

- The paper provided a good start for consideration of how different projects will require a different level of analysis, including investment of time and resources.

- It appears that this document defines ecological flows (page 3) as potentially all flows, because all flows can be said to have "ecological functions". This is particularly true for stream reaches considered to be sensitive. This definition and approach is relatively vague and provides ODFW a lot of flexibility for defining these flows. This is understandable given the complexities involved with defining ecological functions; however, it will make it exceedingly difficult to assess without more clarity.

- Methods that employ developing relationships between flow and ecology relationships (ecological response functions and water requirements) are going to be extremely difficult to apply due to a lack of information on ecological response and the number of factors that can affect the response. For this reason, the "holistic" approach may not initially be an appropriate methodology.

- The cost to conduct a full analysis of peak and ecological flows could be significantly more that the $100K mentioned in the document, particularly if a model must be constructed and data collected to address data gaps that are likely. In addition, it is unlikely that there will be many streams where a simple screening will take a couple of hours or less than half a day. For complicated projects, the cost of doing the analysis AND negotiating the conditions could be double what the science alone portion would be. For projects receiving state funds, this could consume a significant portion of the project budget.

- The Endnotes section is difficult to utilize, as the cross referencing becomes cumbersome and hard to track the specific references. It may be easier to add the text included in the "Endnotes" into the report and list the references by number and in a peer review journal format.

General Comments

The following high-level comments pertain to policy issues and focus primarily on the how the white paper relates to HB 3369.

The white paper begins with a recognition that it stems from the passage of HB 3369. (HB 3369 requires studies of ecological flows for some projects receiving a grant from the Water Investment Grant Fund or a loan from the Water Development Fund, and allows OWRD to require projects receiving such grants or loans to protect peak and ecological flows. It also includes protection of ecological flow as one of the conditions that could be improved to demonstrate the "net environmental public benefit" of storage projects.) After this initial recognition, however, the white paper appears to adopt a broader scope or, at least, it fails to continue to reflect the narrow scope provided by HB 3369. For example, the white paper includes the following sentence on page 16, second paragraph: "From a technical perspective, polices to determine and protect flows whenever possible should build on and incorporate these tools whenever possible."

As another example, the paper recommends a statewide classification to facilitate an in-depth analysis for needed ecological flows related to storage projects (page 24). Given the limited circumstances when HB 3369 would require or allow consideration of peak and ecological flows (only for applications for grants or loans from OWRD's specified programs), a statewide assessment appears excessive compared to the scope of the bill.

The white paper does not identify what species should be the focus of an ecological flow assessment. However, as stated previously HB 3369 includes protection of ecological flow as one of the conditions that could be improved to demonstrate the "net environmental public benefit" of storage projects and "net environmental public benefits" are defined and include Section 18(2)(a) "...provide for critical life history needs of state or federally listed sensitive, threatened or endangered fish species and that maintain or enhance population viability of those species." Furthermore, "net environmental public benefits" include (b) stream flow conditions that support the life stages of native fish species or that will allow for the reintroduction of native fish species."

The white paper considers criteria to identify low-impact and high-impact projects without reference to the criteria described in HB 3369. The bill provides that applicants for grants or loans must analyze (among other things) ecological flows if the proposed project "will receive surface water impounded from a perennial stream, water diverted from a stream that supports sensitive, threatened or endangered fish, or more than 500 acre-fee of diverted surface water annually." Although HB 3369 sets a very low bar for when ecological flows should be studied, these criteria should be reflected in the white paper. With this inclusion, the white paper makes a good suggestion to identify additional criteria that would classify projects meeting the HB 3369 criteria as being low-impact (or high-impact).

The white paper appears to over-state the significance of the ecological flow analysis. For example, on page 21, second paragraph, the white paper states: "A higher percentage of the 2 year peak flow could possibly be used as a high end screen to eliminate high impact projects or projects on already heavily impacted watersheds." HB 3369 does not, however, call for or authorize "elimination" of such projects. Under the bill, some projects receiving a grant or loan must study ecological flow; OWRD may require that a project receiving a grant or loan protect ecological flow (to the extent determined by ODFW); and ecological flows may be considered as part of the "net environmental public benefit" analysis for storage projects. The bill does not preclude projects that could have high impacts or projects on heavily impacted watersheds. Nor does HB 3369 preclude OWRD from providing grants or loans to such projects. (It appears that improving ecologic flows for storage projects could, but is not required, to be part of a project's "net environmental public benefit.") Moreover, HB 3369 does not mandate that OWRD require that a project protect ecological flows, but only allows the agency to require protection of such flows to the extent determined by ODFW to be necessary. For example, ODFW could determine that protection of ecological flows in a heavily impacted watershed was unnecessary if the stream was piped through an urban area and did not support native fish and wildlife. For these reasons, the white paper's reference to "eliminating" certain projects appears inappropriate.

It is unclear whether the methods considered and recommended by the white paper are methods that OWRD and/or ODFW would use to determine whether and how ecological flows were to be protected, or if these are the standards to which the applicants' studies would need to conform if their project met the criteria for requiring additional studies.

Recommendation 6 on page 24 appears to misconstrue the context for ecological flows considered by the white paper. It states: "The inclusion of a relatively simple to apply screening criteria to approve low impact storage projects is both desirable and feasible…" Approval of a storage project was not the focus of HB 3369, and should not be the focus of this white paper. The bill only provides for consideration of ecological flows when an applicant is applying for a grant or loan from one of the programs specified in the bill. It is worth noting that a requirement of both the grant and loan programs is that the applicant already have a final order for the necessary limited license or water use permits. Thus, it appears very clear that HB 3369 does not require an ecological flow assessment for water right applications.

Recommendation 8 on page 24 appears to similarly misconstrue the context for the ecological flow assessment considered by the white paper. It states: "The degree of intensity of methods used to evaluate the effects of and condition a proposed storage project to protect ecological stream flows should be related …" As described above, the white paper should be clear that at the point when ecological flows would be considered, OWRD has already approved the necessary water right or limited license. OWRD's potential requirement for an applicant to protect ecological flows is in the context of providing a loan or grant. It is not in the context of including conditions on a water right for a proposed project.

Memorandum

TO: Barry Norris (Department of Water Resources)
FROM: Steve Cramer
SUBJECT: Ecological Flows White Paper
DATE: July 12, 2010

On behalf of the Oregon Water Resources Congress, I have reviewed the IMST review draft white paper: "Ecological Flows; a Scientific Framework for Implementing Oregon HB 3369." I offer the following comments.

The white paper provides an informative review of studies and regulatory frameworks that have been evaluated by the IMST, and describes general concepts that IMST believes should be included in Oregon's rules for protecting ecological flows. The paper does not derive specific guidelines for how protection of ecological flows will be regulated, so there is still opportunity to shape the strategies and details for those guidelines.

I am very impressed with the members and their expertise on the Ecological Flow Technical Advisory Group that authored the white paper. They certainly have the know how to connect flow regimes to the potential habitat values that can be sustained for fish. I am encouraged that the team began by considering the experiences of other states on these issues, and is attempting to learn from both their successes and failures. I am also encouraged by some of the practical considerations the team has recommended for use in the ecological flow guidelines. These include the use of differing guidelines for different regions of the state, and a screening process that seeks to scale the intensity of evaluation for each site-specific situation to the potential level of ecological impact.

I still have concerns about what is missing from this white paper, and I recognize that some of my concerns may not have been within the purview of this team. All watershed uses involve tradeoffs, and the white paper does not address what the tradeoffs will be when adding regulations for ecological flows or how a balancing of tradeoffs might be evaluated. I will describe my concerns about three types of tradeoffs; (1) water allocation between physical functions, (2) water allocation between ecological benefits, and (3) water allocation between State benefits.

Water Allocation Between Physical Functions

Regulatory guidelines always seek to simplify the issue to be regulated, so that enforceable limits are easily understood and practical to enforce. Such an approach has its benefits, but the potential for negative, unintended consequences of such an approach is likely to increase as the complexity and inherent variation increases for the issues being regulated. The issue of ecological flows is such a case, and the white paper acknowledges that adaptability of rules for regional and even site specific circumstances would be wise for application of ecological flows. With this in mind, we should recognize that simple standards will not deliver optimal benefits of our water resources. Whatever standards we choose, we must back them up with analytical tools that enable full evaluation of resource tradeoffs.

The present treatment of channel maintenance flows is too simplistic. It should provide guidelines for frequency, duration, and magnitude of peak flows. These parameters all relate to functions of channel maintenance. At present, the guidelines suggest that any flows above a threshold level should be unregulated. This would be unnecessarily damaging to the present population, which suffers the immediate consequences of bed scour. Instead, guidelines should allow for storage when flood flows are sufficient to accomplish the channel maintenance function. Protection of ecological flows should not mean an end to flood control. Note that our streams naturally experience spike events that provide more stream power (and bed scour) and for longer periods of time than necessary to maintain channels. Is the channel of a coastal stream better than a channel in eastern Oregon? Yet, each is maintained by different magnitudes, frequencies, and durations of peak flow.

In my experience in over 35 years of analyzing limiting factors to salmonid populations in the western United Sates, summer base-flows are consistently a more serious limiting factor that channel maintenance flows. Further, channel scour during flood flows is consistently a key mortality factor for fish eggs and juveniles. This is not to say that channel maintenance flows are unimportant, but rather that the optimum allocation of flows between base flows and maintenance flows is not just a simple trade between the two. We cannot achieve optimal use of our water resources in Oregon if this need to balance the allocation of water yield is treated without analysis of benefit tradeoffs.

Water Allocation Between Ecological Benefits

I am concerned that focus remains on physical processes without an equal consideration for connecting the physical process to a quantitative assessment of the ecological function. Without the translation of physical outcomes into biological benefits, it is not possible to analyze tradeoffs in terms of resource benefits that result from allocating flows across an annual regime. The term “ecological flows” implies a focus on the ecological outcomes related to flow. Thus, ecological outcomes, not just physical outcomes, should be the central focus of the decision process for choosing the allocation of flows. I see this issue as being a key stumbling block where water supplies are limited. In water limited cases, restrictions on storage of peak flows will translate into reduced abilities to offer enhancement of summer base flows.

The white paper appears to start with a foundational assumption that the natural flow regime in each streams is best for ecological function of that stream. This assumption is accurate from the perspective of preserving the natural balance of species that make use of that specific stream. It is true that native species, both terrestrial and aquatic, have adapted life history strategies that rely on the natural flow regime, including its temporal and spatial variation. Given the variation that exists in geology and climate across the Oregon landscape, it is readily apparent that different species and life history adaptations can be found in different places. Is one better than another? If the balance of species and life-histories in a basin is altered by the hydrologic changes from human use of a watershed, is change necessarily bad? If so, then the concepts of watershed enhancement, aquatic habitat enhancement, and water quality enhancement are all misplaced.

Some of our most ecologically productive streams in the state are those with moderate to low variability in flows (e.g. the McKenzie River, the lower Deschutes River). Low flow variability does not make a stream poor for ecological function. Instead of simply assuming the natural template is best, we ought to be evaluating the balance of gains and losses in ecological function that are likely to result from changes in flow regime. In some basins, the ecological response to a change in flows will be greater than in others.

Potential trade-offs are most obvious longitudinally in a basin, in that changes in flow and temperature can create new advantages to cold-water fishes in one stream reach, but disadvantages in another. The stream continuum concept is an illustration that upstream-downstream trade-offs occur naturally in our river basins. In central Oregon rivers, we have tail-water fisheries on dense populations of trout made possible by release of cold water below dams (e.g. Bowman Dam on the Crooked River). Such releases provide cool-water habitat that did not persist through the summer naturally in the area. In another example, dams that store water for downstream uses may be many miles upstream of the point where water is to be diverted, and the result is substantial baseflow enhancement in the reach from the dam to the diversion. It is not clear to me from the white paper whether or how such trade-offs would be considered.

Water Allocation Between State Benefits

HB 3369 states its intent that water development projects should be designed to simultaneously benefit commercial development, the natural environment, and fiscal responsibilities of the state. Thus, these three factors must fit together in the same picture, and will likely require careful consideration to achieve a desirable balance. Thus, it is crucial that each of these factors be evaluated in the development of ecological flow guidelines.

Recommendations:

1. Provide more careful analysis of channel maintenance flows. Guidelines for frequency, duration, and magnitude of peak flows should be provided so as to clarify situations in which flows exceeding those needs could be stored.

2. Provide a mechanism to evaluate trade-offs of ecological benefits between different flow regimes. It would be prudent to develop an analytical framework capable of estimating ecological benefits across a range of incremental changes to flow regimes. Such a framework is not available off the shelf, but the state of our science on fish biology and hydrology is sufficiently advanced to provide the foundation for such a tool using salmonids as the primary indicator of ecological function. Over time, this tool could be improved, just as weather forecasting has improved. Although such a tool would be imperfect in its prediction, it could provide valuable relative comparisons, and would likely be far more accurate than simply relying on expert opinion. It would also provide and explicit track of the information applied to inform a management decision.
3. Provide guidelines for mitigation. Such guidelines should provide opportunities to sustain ecological function through alternate means to the standard flow metrics. The focus of these mitigations should be on ecological function, rather than the form of a regulatory metric.
4. Determination of ecological flow needs should also review extenuating circumstances that may exist in the stream network of the watershed. This may be implied by the White Paper's recommendation that flow impacts should be considered at key points downstream of the project. There are a variety of reasons that placement of a water storage project might have greater or lesser effect on ecological function of the basin, depending on its position in the watershed network.
5. Provide a process for innovation on the part of water development. Do the guidelines provide a mechanism for consideration of innovative solutions that maintain ecological function and simultaneously allow for other beneficial uses of water?
6. Mechanisms should be built into the rules that provide for adaptive approaches as condition change in the future. We expect climate changes, growing human populations, and increasingly acute needs for water.

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July 7, 2010

Barry F. Norris, State Engineer
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Review of Ecological Flows Technical Advisory Group Draft White Paper

Dear Barry:

Thank you for allowing me to submit comments on the draft white paper on behalf of the natural resource industries in the state. The technical advisory group (TAG) did an admirable job in a very difficult situation, yet left too much undone. The following comments focus on broad issues raised in HB 3369 and the white paper. Asking the TAG to work within the constraints of the bill to provide guidance to state regulatory and resource agencies on ecological flow is asking them to nail Jello® to the wall. Considering the subjectivity inherent in the subject and the lack of specificity in the bill, they did a very good job. My comments are intended to guide revision of the draft white paper to address these issues.

White Paper Context

The House Bill does not provide a context for requiring establishment of peak and ecological flows for new storage projects funded with Oregon Water Resources Department (WRD) grants or loans. Therefore, the TAG should define the context in which they fit their discussion. In other words, what is the problem for which these requirements of HB 3369 are the solution? To explain why this is important we need to understand the purpose of a white paper. This definition is from Wikipedia[1]:

> "A white paper is an authoritative report or guide that often addresses issues and how to solve them. White papers are used to educate readers and help people make decisions. They are often used in politics, business, and technical fields. In

[1] http://en.wikipedia.org/wiki/White_paper

> commercial use, the term "white paper" has also come to refer to documents used by businesses as a marketing or sales tool."

Because the TAG offers solutions to the ecological flow issues raised in HB 3369 the white paper needs to describe the issues as the TAG understands them.

It would be very helpful to agencies relying on the white paper as a basis for their rule-making (and for politicians making policy decisions) for the white paper to provide a technical basis for limiting determinations of appropriate peak and ecological flows only to new projects funded with loans or grants from the WRD. If this is a critical issue for the state, what are the implications for making such determinations only for future projects and not existing ones? And what would it mean if potential grantees find the obligations too onerous and seek project funding that does not include WRD grants or loans? Such issues should be discussed by the TAG in order to determine the appropriate methods to identify and implement peak and ecological flow values on specific reaches or systems. More importantly, a more comprehensive description of the issues will assist state regulatory and resource agencies in developing appropriate regulations and policies.

Another context that should be considered by the TAG in their white paper is the potential value of peak and ecological flow studies on new storage projects in a state that has at least 1105 existing dams in the WRD database (following map).

Ownership of these dams includes federal (140), state (16), local government (86), public utilities (50), private (706), and undefined (107). Approximately 512 dams have irrigation as their exclusive or partial use which means their effects on river flows are seasonal. Another 26 dams were built specifically for flood control and stormwater runoff management. How implementation of HB 3369 by all state agencies fits the context of existing dams should be explained in the white paper.

White Paper Integration

The white paper references the 2007 Oregon Department of Fish and Wildlife (ODFW) white paper by George Robison titled, *Calculating Channel Maintenance/Elevated Instream Flows When Evaluating Water Right Applications for Out-of-Stream and Storage Water Rights* The TAG white paper should discuss where this ODFW white paper does not adequately address HB 3369's issues. If the state already has suitable guidance, it should be adopted by reference to satisfy the requirements of the bill. This seems reasonable as the ODFW notes (in the Executive Summary),

> "The purpose of this memorandum is to provide guidance to ODFW staff as they make recommendations to Oregon Water Resource Department (OWRD) on the use of peak flows. The guidance could also be used by OWRD staff and private consultants to understand ODFW's reasoning for their recommendations and to determine when and how much of these peak flows should be retained instream. The guidance considers how much flow to provide for ecological and geomorphic functions of streams vs. how much can be appropriated to storage or for other off stream uses such as aquifer storage and recovery, groundwater remediation etc. The policy basis for setting aside a portion of elevated flows, as well as techniques for determining how much or which flows to set aside, are discussed.
>
> "The following guidance is for use especially when 1) applicants are asking for water beyond water availability during the storage season (i.e. skimming water from peak flows), 2) the reach where water is being diverted has outstanding fishery/aquatic values, and/or 3) the size of the storage/diversion project will take a significant portion of elevated flows even though water is generally available during the storage season. Evaluations using this guidance should be reserved for streams that can have geomorphic adjustment. Channels constrained by levees and rock walls, typical of channels in urban areas (i.e., Mitigation Category 6) can not properly utilize elevated flows for channel maintenance."

If there are subtle differences between the ODFW white paper of 2007 and the current WRD TAG white paper these differences will cause problems in the future.

Water Rights

Both the 2007 ODFW white paper and the current draft WRD white paper make explicit references to water rights. This integration of peak and ecological flows with water rights is a serious concern. Water rights are issued and adjudicated within the WRD according to laws established a very long time ago. This TAG white paper will probably be read and used for regulatory and policy decisions by other state agencies (among them the Departments of Agriculture, Environmental Quality, Fish and Wildlife, and State Lands). None of these other agencies have regulatory or decision-making authority with water right applications, modifications, or adjudication of conflicting claims. HB 3369 requires setting peak and ecological flows for new storage projects funded by grants or loans from WRD; it says nothing about water rights. The TAG white paper should either delete all references to water rights or explain explicitly and in detail how they are related to peak and ecological flows, and in what situations or conditions.

Not clarifying or eliminating the cross-references will lead to confusion and potential litigation that can be avoided by separating the issues.

If there are reasons to join the peak and ecological flow requirements of HB 3369 to water rights the reasons for the connection should be clearly and fully explained in the white paper. The TAG should also consider that the human environment consists of three categories: economic, natural, and societal. Decisions on flows, water storage projects, and consideration of in- versus out-of-stream water needs might benefit from applying the approach defined by Congress when it passed the National Environmental Policy Act (NEPA) in 1969:

> "The Congress, recognizing the profound impact of man's activity on the interrelations of all components of the natural environment, particularly the profound influences of population growth, high-density urbanization, industrial expansion, resource exploitation, and new and expanding technological advances and recognizing further the critical importance of restoring and maintaining environmental quality to the overall welfare and development of man, declares that it is the continuing policy of the Federal Government, in cooperation with State and local governments, and other concerned public and private organizations, to use all practicable means and measures, including financial and technical assistance, in a manner calculated to foster and promote the general welfare, to create and maintain conditions under which man and nature can exist in productive harmony, and fulfill the social, economic, and other requirements of present and future generations of Americans."[2]

All too often in environmental policy one category is declared more important than the other two. This invariably leads to problems that are difficult and expensive to correct. The TAG should consider how all state agencies can implement compliance with HB 3369's peak and ecological flow requirements without harming the economic and societal functions of Oregon. While true under any situations, it is particularly important with the state's economy in bad shape. Severely imbalanced state and local budgets, high unemployment rates, and the third-highest house foreclosure rate in the nation suggest that the state depends on its natural resource industries, and especially agriculture, which are the base that allows the state to survive and grow. Such considerations are appropriate when advising on the technical aspects of implementing statutes.

Project/Effects Size

The TAG white paper acknowledges the serious problems that do or could occur when attempting to create regulations from measurements, observations, and modeling results in highly variable ecosystems. One such problem which the white paper discusses but leaves unsolved is that of the appropriate level of effort (and costs) based on storage project size or postulated effects. The TAG suggests that "small" projects be identified for a lower level of study (amount of field measurements and modeling efforts) because they do not warrant the intensity and costs involved in long term measurements (to include inherent high variability) and detailed

[2] 42 USC §4331; Sec. 101 (a)

hydrologic and hydraulic modeling that might be appropriate on larger projects. They do not offer a definition of "small" which is understandable because this is not a directly measurable quantity.

Environmental statutes and regulations are filled with words called *linguistic variables* because they have variable meaning. This leads to ambiguities and mis-communications and, in the regulatory arena, to administrative appeals and lawsuits. "Small" and "large" are examples of linguistic variables. We can measure areas, lengths, flow rates and other physical attributes of a proposed project but we cannot measure small or large. Everyone has a different definition of small and this leads to problems when such terms are applied to regulatory thresholds. (Linguistic variables can be measured using multi-value sets but this explanation will not be presented here.) Perhaps the next white paper draft (or the final version if there are no further drafts) can recommend that measurements and analytical efforts be appropriately scaled to the project size or anticipated influences rather than to "small" or "large" projects.

Aquatic Biota

The purpose of the white paper is to provide technical information about ecological flows by defining what they are, describing methods commonly used to determine them, and providing recommendations based how these methods might be applicable to Oregon. The definition of ecological flows is presented as, "…instream flows needed to sustain ecosystem functions that native fish and wildlife species depend upon to survive and flourish. These stream flows not only include baseflows but can include flow protections over a range of flows to protect habitat maintenance and other ecological functions."

If the white paper is to be used by policy makers in crafting rules, guidance, or other strategies in order to implement HB 3369 it is incomplete without detailed discussion of the native fish and wildlife species dependent on specified flows at specific reaches, organism life stages, and dates during the year. This information is critical for policy makers, regulators, and resource agency staff to make appropriate decisions on what flows might be appropriate by location, time of year, and even time of day[3]. Such information can be included by reference in the white paper, as long as detailed information is provided so species distribution, life histories in different drainage basins, and postulated or established flow regimes can be applied by rule and policy makers.

It is important to set ecological flow recommendations in the proper biological contexts. Anadromous salmon species reproduce once per generation and have evolved a very high degree of genetic and behavioral plasticity (that is, quick adaption to changed conditions) over hundreds of thousands of years and generations of fish. This means that they are well adopted to current conditions in Oregon rivers and streams. Steelhead trout (the ocean-going variety of rainbow trout) may breed multiple times during their lives, but they also have adapted to existing conditions. These factors need to be considered when flow requirements are altered or restrictions placed on water use.

[3]For example, in summer resident fish need daytime refugia from too-warm waters and predation; at night they feed in the main channel on macroinvertebrates drifting downstream shortly after sunset.

Methods of Measuring/Modeling River and Stream Flows

Regardless of what flow determinations are to be made using basin hydrology or channel hydraulics a lot of detailed measurements are required as input to the various models used. Much of the white paper covers this topic. What is not discussed is the relationship between level of effort and information gained. Flowing water systems are the most highly variable ecosystems with changes observable on diurnal, daily, monthly, seasonal, and annual periods. This is certainly true in Oregon streams and rivers which are highly regulated by the 1105 dams, development, and other processes.

The TAG should consider the value of measurements taken within a limited time span as input values to various hydrologic, hydraulic, and habitat models. Without such high variability we could make better decisions based on limited measurements. However, for how long measurements are taken, where those measurements are located, and which numeric or spatial model to use can always be challenged. This is because of the well-established dichotomy of numerical models of natural ecosystems. A model can be sufficiently general to be useful everywhere, but not sufficiently useful at any given reach or segment to support management decisions specific to that reach or segment. Alternatively, a model of a reach or segment can be built that is highly useful there, but completely inappropriate anywhere else. The former type of model is less expensive and time consuming to build, while the latter type would be needed for the degree of detail that seems to be required by HB 3369 as interpreted by the TAG. Any policy or regulations that are based on the white paper would also need to address the boundary conditions (drought, excessively wet years, other natural weather and seismic occurrences) to accommodate the inherent high variability of natural systems and the limitations of models we use to simplify the complexity we see and measure.

These comments are submitted with the intention of helping the TAG to refine and improve the white paper and make it more technically sound and legally defensible.

Sincerely,

Richard B. Shepard

Dr. Richard B. Shepard
President

Endnotes

[1] Full text of HB 3369 is available at: http://www.leg.state.or.us/09reg/measpdf/hb3300.dir/hb3369.en.pdf . The bill amends ORS 536.220, 541.700, 541.705, 541.710, 541.720, 541.730, 541.740, 541.765, 541.770, 541.785, 541.830, 541.845 and 541.850; and repealing ORS 541.755

[2] The idea of the master or controlling variable being the flow regime is discussed in several places including: Annear, T., I. Chisholm, H. Beecher, A. Locke, P. Aarrestad, C. Coomer, C. Estes, J. Hunt, R. Jacobson, G. Jobsis, J. Kauffman, J. Marshall, K. Mayes, G. Smith, R. Wentworth, and C. Stalnaker. 2004. Instream Flows for Riverine Resource Stewardship - Revised Edition. Instream Flow Council, Cheyenne, WY.
Another reference that focuses on this concept is: Poff, N. L., J. D. Allan, M. B. Bain, J. R. Karr, K. L. Prestegaard, B. Richter, R. Sparks, and J. Stromberg. 1997. The natural flow regime: a new paradigm for riverine conservation and restoration. BioScience 47:769-784.

[3] For a discussion of the importance of a full flow regime including flow variation and elevated flows see: Poff, N. L., J. D. Allan, M. B. Bain, J. R. Karr, K. L. Prestegaard, B. Richter, R. Sparks, and J. Stromberg. 1997. The natural flow regime: a new paradigm for riverine conservation and restoration. BioScience 47:769-784.

[4] The precise term "peak and ecological flows" is used at least four times in HB 3369 (see link above). On pages 16(#6), 17(#g(2)), 19 near top of page, and 20(#6). In context it is used in recommending and then mandating (after a transition period) to OWRD and ODFW to approve methods for determination of them and set them respectively.

[5] The law is originally codified as:, Chapter 36, 1915 Or. Laws 49, 49–50: "An Act: To preserve the scenic beauty of certain waterfalls and streams in view of, or near the Columbia River Highway". (Act of Feb. 9, 1915). Involved water withdrawals for scenic purposes for 23 streams in the Columbia Gorge.

[6], Chapter 707, 1955 Oregon Laws 924. Act of May 26, 1955. A more full discussion on the history of Oregon Water law in terms Oregon efforts in preserving instream flows can be found in: Neuman J., A. Squier, and G. Achterman. 2006. Sometimes a great notion: Oregon's Instream flow Experiments. Environmental Law 36: 1125-1155. See especially pages 1139-40 regarding discussion of 1955 law and its implementation.

[7] Oregon Administrative Rules - OAR 690-033

[8] A listing of all Basin Investigation Reports are available at:
http://www.dfw.state.or.us/fish/water/docs/List_of_Basin_Investigation_Reports.pdf

[9] The most detailed paper regarding the Oregon Method is by: Thompson, K.E. 1972. Determining instream flows for fish life. Pp. 31-50 in: Proceedings of the instream flow requirement workshop. Pacific Northwest River Basins Commission, Portland, Oregon. A scanned copy is available at:
http://www.dfw.state.or.us/fish/water/docs/thompson_1972.pdf

[10] Instream water right standards are in the following rules:
http://arcweb.sos.state.or.us/rules/OARS_600/OAR_635/635_400.html

[11] Water availability needs to be determined before application can be processed and approved: OAR 690-310-0080 under application review

[12] The most comprehensive guide as to how water availability is calculated in Oregon is available in the publication: Cooper, R.M. 2002. Determining surface water availability in Oregon. State of Oregon, Water Resources Department. Open File Report SW 02-002. Salem Oregon June 2002. 157 p. Available at:
http://www1.wrd.state.or.us/pdfs/reports/SW02-002.pdf

[13] For instance, "Public Use" under ORS 537.332 (5)(b) includes "Conservation, maintenance and enhancement of aquatic and fish life, wildlife, fish and wildlife habitat and any other ecological values". High flows are explicitly allowed in Water Resource Department rules in approving instream water rights even though they are higher than the mean estimated natural flow in OAR 690-077-0015 (4). Also: When evaluating a given water right application, "instream values" should be considered by the Water Resources Department even if there is not an instream water right or for issues that were not included in the original instream water right as a general policy (OAR 690-410-030 (2 (a)). Specifically, for water allocation, water right applications are to be conditioned to protect instream values (OAR 690-410-0070 (2(a))). This applies explicitly to water storage projects (OAR 690-410-0070 (2(c))).

[14] ODFW has advocated and received higher flow releases in the spring outmigration period for steelhead from the Federal Project dams on the Willamette River.

[15] ODFW guidance for determining elevated ecological flows is available from:
http://www.dfw.state.or.us/fish/water/docs/ODFW_Guidance_on_Allocating_Peak_Flows.pdf

[16] A textbook source for consensus definitions for instream and environmental flows is given in Gordon, N.D., T.A. McMahon, B.L. Finlayson, C.J. Gippel, and R.J. Nathan. 2004. Stream hydrology: An introduction for Ecologists. 2nd Ed. John Wiley and Sons, Toronto. (see p. 286-319).
[17] For example review this quote: "Environmental flows are defined in the Brisbane Declaration …as the 'quantity, timing and quality of water flows required to sustain freshwater and estuarine ecosystems and the human livelihood and well-being that depend on these ecosystems'." Quote taken from: Poff, N.L., and 18 others. 2010. The ecological limits of hydrologic alteration (ELOHA): a new framework for developing regional environmental flow standards. Freshwater Biology 55, 147-170.
[18] ODFW guidance for determining elevated ecological flows is available from: http://www.dfw.state.or.us/fish/water/docs/ODFW_Guidance_on_Allocating_Peak_Flows.pdf
[19] Functions of base and subsistence flows are discussed and referenced in many publications but succinct coverage was developed for the Texas instream program and is given in: Texas Commission on Environmental Quality. 2008. Texas Instream Flow Studies: Technical Overview. Texas Commission on Environmental Quality; Report Number 369. 137p.
[20] Figure is adapted from: National Academy of Sciences. 2006. The Science of Instream flows: A review of the Texas Instream flow program. Committee on Review of Methods for Establishing Instream Flows for Texas Rivers, National Research Council; ISBN: 0-309-54808-X, 162 pages, 6 x 9, (2005); http://www.nap.edu/catalog/11197.html
[21] Figure 2 is an adapted composite of several figures from: Texas Commission on Environmental Quality. 2008. Texas Instream Flow Studies: Technical Overview. Texas Commission on Environmental Quality; Report Number 369. 137p.
[22] Discussed in: Poff, N. L., J. D. Allan, M. B. Bain, J. R. Karr, K. L. Prestegaard, B. Richter, R. Sparks, and J. Stromberg. 1997. The natural flow regime: a new paradigm for riverine conservation and restoration. BioScience 47:769-784.
[23] These examples taken from: ODFW guidance for determining elevated ecological flows - available from: http://www.dfw.state.or.us/fish/water/docs/ODFW_Guidance_on_Allocating_Peak_Flows.pdf
[24] Examples of this in literature include: Montgomery W.L., S.D. McCormick, R.J. Naiman, F.G.Whoriskey, and G.A. Black. 1983. Spring migratory synchrony of salmonid, catostomid, and cyprinid fishes in Riviere la Truite, Quebec. Canadian Journal of Zoology 61: 2495-2502 AND Trepanier, S, M.A. Rodriguez, P. Magnan. 1996. Spawning migrations in landlocked Atlantic salmon: time series modeling of river discharge and water temperature effects. Journal of Fish Biology 48: 925-936.
[25] Example of this function in: Nesler T.P., R.T. Muth, A.F. Wasowicz. 1988. Evidence for baseline flow spikes as spawning cues for Colorado Squawfish in the Yampa River, Colorado. American Fisheries Society Symposium 5: 68-79.
[26] Examples of this effect include: Sommer, T.R., M.L. Nobriga, W.C. Harrell, W. Batham, and W.J. Kimmerer. 2001. Floodplain rearing of juvenile Chinook salmon: evidence of enhanced growth and survival. Can. Jour. Fish. Aquat. Sci. 58: 325-333. AND Morley, S.A., P.S. Garcia, T.R. Bennett, and P. Roni. 2005. Juvenile salmonid (Oncorhynchus spp.) use of constructed and natural side channel in Pacific Northwest rivers. Can. Jour. Fish. Aquat. Sci. 62:2811-2821.
[27] Aquatic insect behavior and biology discussed generally in: Merritt, R.W. and K.W. Cummins (eds). 1984. An introduction to the aquatic insects of North America 2nd Edition. Kendall Hunt Publishing Co. Dubuque Iowa. 722 p.
[28] This list is similar to that given in: ODFW guidance for determining elevated ecological flows - available from: http://www.dfw.state.or.us/fish/water/docs/ODFW_Guidance_on_Allocating_Peak_Flows.pdf
[29] Example of a method to determine this type of flow for gravel bed streams: Schmidt, L.J. and J.P. Potyondy, 2004, Quantifying channel maintenance instream flows: An approach for gravel-bed streams in the western United States, General Technical Report RMRS-GTR-128, Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, 33 pp.
[30] High flow morphological effects discussed in: Knighton, D. 1998. Fluvial Forms and Processes: A New Perspective. Oxford University Press N.Y. N.Y. 383p. as well as other references.
[31] Many studies regarding this effect one example is: Richter, B.D. and H.E. Richter. 2000. Prescribing flood regimes to sustain riparian ecosystems along meandering rivers. Conservation Biology 14:1467-1478.
[32] Mixing equations formulations and statistical techniques to determine the 7 day 10 year flow are given in most standard Hydrology textbooks. These flows are normally less than baseflows and are not relevant setting flow protection levels because the baseflows invariably come out greater.
[33] The division of baseflow methods into hydrology, hydraulic, habitat modeling and other methods including holistic methods is a common characterization found in compilation works such as: Tharme, R.E. 2003. A global perspective

on environmental flow assessment: emerging trends in the development and application of environmental flow methodologies for rivers. Rivers Research and Application 19: 397-441.

[34] Several examples of ecological triggering flows given in: Poff, N. L., J. D. Allan, M. B. Bain, J. R. Karr, K. L. Prestegaard, B. Richter, R. Sparks, and J. Stromberg. 1997. The natural flow regime: a new paradigm for riverine conservation and restoration. BioScience 47:769-784.

[35] Some key papers discussing riparian vegetation maintenance or establishment include: Richter, B.D. and H.E. Richter. 2000. Prescribing flood regimes to sustain riparian ecosystems along meandering rivers. Conservation Biology 14:1467-1478. and Hill, M.T., W.S. Platts, and R.L. Beschta. 1991. Ecological and geomorphologic concepts for instream and out-of-channel flow requirements. Rivers 2(3) p. 198-210. for Channel sediment movement some key papers include: Reiser, D.W., M.P. Ramey, and T.A. Wesche. 1989. Flushing flows. Pp. 91-135 in: J.A. Gore and G.E. Petts, editors. Alternatives in regulated river management. CRC Press, Boca Raton, Florida. And Schmidt, L.J. and J.P. Potyondy, 2004, Quantifying channel maintenance instream flows: An approach for gravel-bed streams in the western United States, General Technical Report RMRS-GTR-128, Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, 33 pp.

[36] The recently produced policy for California Coastal streams uses a percentage of a 1.5 year recurrence peak flow for channel maintenance guidelines for new reservoir projects: State of California Water Resources Control Board. 2010. Policy for maintaining instream flows in Northern California Coastal Streams Draft. Revised Feb. 2010

[37] A boulder laced stream may require more complex modeling or direct measurements at different streamflows because of the complexity of the hydraulics in and around boulders while a stream with less structure may be modeled with fewer measurements of a few cross-sections with tools such as PHABSIM.

[38] ODFW guidance for determining elevated ecological flows - available from: http://www.dfw.state.or.us/fish/water/docs/ODFW_Guidance_on_Allocating_Peak_Flows.pdf

[39] Tennant, D. L. 1976. 'Instream flow regimens for fish, wildlife, recreation, and related environmental resources', in Osborn, J. F. and Allman, C. H. (Eds), Proceedings of the Symposium and Specialty Conference on Instream Flow Needs II. American Fisheries Society, Bethesda, Maryland. pp. 359–373.

[40] For a list of accepted methods see list of accepted instream flow study methods for establishing instream water rights in Oregon rules: OAR: 635-400-0015. These are methods exclusively for determining needed baseflows for fish habitat lifestage needs.

[41] Wetted width refers to the width of a stream at a certain flow (discharge) measured in feet or meters while wetted perimeter refers to the length of channel bottom that is wetted at a given flow and is also a measured length.

[42] A general discussion on hydraulic methods is available in: Gordon, N.D., T.A. McMahon, B.L. Finlayson, C.J. Gippel, and R.J. Nathan. 2004. Stream Hydrology: An Introduction for Ecologists. 2nd Ed. John Wiley and Sons, Toronto. (see p. 286-319).

[43] A short overview of common methods used in Washington State Including the toe width method can be found at: http://www.ecy.wa.gov/biblio/0911019.html

[44] Discussed at length in: Bovee, K.D., B.L. Lamb, J.M. Bartholow, C.D. Stalnaker, J. Taylor, and J. Henriksen. 1998. Stream habitat analysis using the Instream Flow Incremental Methodology. U.S. Geological Survey, Biological Resources Division, Information and Technical Report USGS/BRD-1998-0004. viii+131 pp. There are many other similar methods to PHABSIM as well as competing software. A listing of the different software and methods is available in: Annear, T., I. Chisholm, H. Beecher, A. Locke, P. Aarrestad, C. Coomer, C. Estes, J. Hunt, R. Jacobson, G. Jobsis, J. Kauffman, J. Marshall, K. Mayes, G. Smith, R. Wentworth, and C. Stalnaker. 2004. Instream Flows for Riverine Resource Stewardship - Revised Edition. Instream Flow Council, Cheyenne, WY.

[45] The most detailed exposition on the Oregon Method is: Thompson, K.E. 1972. Determining instream flows for fish life. Pp. 31-50 in: Proceedings of the instream flow requirement workshop. Pacific Northwest River Basins Commission, Portland, Oregon. A scanned copy is available at: http://www.dfw.state.or.us/fish/water/docs/thompson_1972.pdf

[46] Suitability curve data is determined from observing fish and their preferences in field and control studies. Suitability curves are compiled in several places. The state of Washington has compiled dozens of them in their guidance for instream flow studies at: http://www.ecy.wa.gov/pubs/0411007.pdf

[47] As described in OAR 635-400-0015 at: http://www.dfw.state.or.us/OARs/400.pdf Note that these rules also call for the maintenance of habitat which implies channel maintenance flows but the only methods prescribed are three baseflow methods – The Oregon Method, IFIM (PHABSIM suitability curve based methods), and the Forest Service Method which is similar to PHABSIM.

[48] River 2D is available for free on the internet at: http://www.river2d.ualberta.ca/ There are also other two dimensional habitat models including Streamflow modeling system (SMS) applications but these are proprietary.

[49] Habitat mapping has been used in several circumstances in reference to hydro relicensing in Oregon. The method tends to be much more intensive and expensive than other methods. However, sometimes it is necessary in situations with complex structure that causes streamflow to flow in different directions. An example of its use: McBain and Trush. 2003. Estimating salmonid habitat availability in the lower Oak Grove Fork using expert habitat mapping: summary of methods and preliminary results. Prepared for Clackamas Instream Flow/Geomorphology Subgroup, Portland General Electric, Portland, Oregon by McBain and Trush, Arcata, California.

[50] This holistic approach is discussed in: Stalnaker, C.B., B.L. Lamb, J. Henriksen, K. Bovee, and J. Bartholow. 1995. The instream flow incremental methodology: a primer for IFIM. National Biological Service Biological Report 29. 45 pp. It should be noted that in many IFIM studies, they do tend to be focused on a key species and tend to descend into negotiations on flow amounts among stakeholders.

[51] As discussed in: The Nature Conservancy, 2009. Indicators of Hydrologic Alteration Version 7.1 User's Manual.

[52] This triggering is discussed in: Poff, N.L., J.D. Allan, M.B. Bain, J.R. Karr, K.L. Prestergaard, B. Richter, R. Sparks, and J. Stromberg. 1997. The natural flow regime: a paradigm for river conservation and restoration. Bioscience 47: 769-784. In addition there are literally dozens of papers that discuss specific cause effect reactions for different species and life stages.

[53] Examples of flow initiating migration: Montgomery W.L., S.D. McCormick, R.J. Naiman, F.G.Whoriskey, and G.A. Black. 1983. Spring migratory synchrony of salmonid, catostomid, and cyprinid fishes in Riviere la Truite, Quebec. Canadian Journal of Zoology 61: 2495-2502. AND Trepanier S, M.A. Rodriguez, P. Magnan. 1996. Spawning migrations in landlocked Atlantic salmon: time series modeling of river discharge and water temperature effects. Journal of Fish Biology 48: 925-936.

[54] An example of spawning activity initiated by a flow spike: Nesler T.P., R.T. Muth, A.F. Wasowicz. 1988. Evidence for baseline flow spikes as spawning cues for Colorado Squawfish in the Yampa River, Colorado. American Fisheries Society Symposium 5: 68-79.

[55] Examples of fish accessing off channel habitat at high flows: Sommer, T.R., M.L. Nobriga, W.C. Harrell, W. Batham, and W.J. Kimmerer. 2001. Floodplain rearing of juvenile Chinook salmon: evidence of enhanced growth and survival. Can. Jour. Fish. Aquat. Sci. 58: 325-333. AND Morley, S.A., P.S. Garcia, T.R. Bennett, and P. Roni. 2005. Juvenile salmonid (Oncorhynchus spp.) use of constructed and natural side channel in Pacific Northwest rivers. Can. Jour. Fish. Aquat. Sci. 62:2811-2821.

[56] For a general treatise on insects see: Merritt, R.W. and K.W. Cummins (eds). 1984. An introduction to the aquatic insects of North America 2nd Edition. Kendall Hunt Publishing Co. Dubuque Iowa. 722 p. For a more specific accounting of flow vs. aquatic insects see: R2 Resource Consultants. 2005. Effect of pulse type flows on benthic macroinvertebrates and fish: A review of the literature. Prepared for Pacific Gas and Electric Company. December 2005. 139 p.

[57] Unpublished reports on statistical correlations between returning fish and out migration streamflows is available from the Oregon Department of Fish and Wildlife Fish Division by request. Main author is Mary Buckman.

[58] A full discussion and proposed method for examining stream type prior to performing an analysis of needed channel maintenance flows is given in the ODFW guidance which is available at: http://www.dfw.state.or.us/fish/water/docs/ODFW_Guidance_on_Allocating_Peak_Flows.pdf The typing method used in Oregon is based on the Oregon Watershed Assessment Manual's approach and this stream channel typing has already been done for most watersheds in Oregon. There are many other types of channel classification systems that are popular. The Federal Government uses the Rosgen Stream Classification System for many applications while Texas uses the "River Styles" framework. A full discussion of stream typing methods is available in the Texas Technical Overview:
http://www.twdb.state.tx.us/publications/reports/GroundWaterReports/GWReports/R369_InstreamFlows.pdf

[59] An extreme example of sediment transport only occurring rarely once in decades period of time is given in: Grant, G.E. and Wolff, A.L. 1991. Long-term patterns of sediment transport after timber harvest, western Cascade Mountains, Oregon, USA. In: Walling, D.E. and Peters, N. (eds) Sediment and Stream Water Quality in a Changing Environment, Proceedings of the Vienna IAHS Symposium, International Association of Hydrological Sciences Publ. No. 203, Oxfordshire, U.K. p. 31-40. In other cases sediment transport for fine bed streams can happen every year and in extreme cases every year for lower gradient streams in which there is more sediment supply than transport capacity. Examples are given in: Knighton, D. 1998. Fluvial Forms and Processes: A New Perspective. Oxford University Press N.Y. N.Y. 383p.

[60] A recent discussion of the need to cover the hydrology and understand its regime early in the process is given in: Poff et al. 2010. The ecological limits of hydrologic alteration (ELOHA): a new framework for developing regional environmental flow standards. Freshwater Biology 55, 147–170.

[61] Everest, F. H., et al. 1987. Fine sediment and salmonid production— a paradox, p. 98-142. In E. Salo and T. Cundy Editors. Streamside management and forestry and fishery interactions. University of Washington, College of Forestry Resources, Cont. 57, Seattle, WA.
[62] ODFW guidance for determining elevated ecological flows - available from: http://www.dfw.state.or.us/fish/water/docs/ODFW_Guidance_on_Allocating_Peak_Flows.pdf
[63] State of California – State Water Control Board. 2010. Policy for maintaining instream flows in Northern California Coastal Streams Draft April 27, 2010. This policy and several supporting documents and policies available at: http://www.waterboards.ca.gov/waterrights/water_issues/programs/instream_flows/

[64] Poff et al. 2010. The ecological limits of hydrologic alteration (ELOHA): a new framework for developing regional environmental flow standards. Freshwater Biology 55, 147–170.
[65] Bankfull flow determination in the field is as much of an art as a science. Training for determining bankfull or active channel flow are given in Forest Service videos (USFS, 2003 and 2005) along with textbooks Rosgen (1996), Knighton, (1998) and Gordon et al. (2004) (References immediately below). Also critical is determining the actual bankfull flow or active channel flow stage level for the cross section(s). Tools such as "WinXSPro" (Hardy et al. 2006) can be used with representative stream cross-sections to estimate the discharge at bankfull flow or when overbank flows occur. Once this is done, perhaps a trigger flow can be prescribed to allow for bypass of streamflows higher than that trigger.

- Gordon, N.D., T.A. McMahon, B.L. Finlayson, C.J. Gippel, and R.J. Nathan. 2004. Stream Hydrology: An Introduction for Ecologists, 2nd Ed. Wiley and Sons N.Y. 444 p.
- Hardy, T.; P. Panja; and D. Mathias. 2005 WinXSPRO, A Channel Cross Section Analyzer, User's Manual, Version 3.0. Gen. Tech. Rep. RMRS-GTR-147. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 94 p.
- Knighton, D. 1998. Fluvial Forms and Processes: A New Perspective. Oxford University Press N.Y. N.Y. 383p.
- Rosgen, D. L. 1996. Applied river morphology 2nd Edition. Wildland Hydrology. Pagosa Springs Colorado.
- U.S. Department of Agriculture, Forest Service (USFS). 2003. Identifying bankfull stage in forested streams in the Western United States: Rocky Mountain Research Station, Stream Systems Technology Center, video. 1 DVD.
- U.S. Department of Agriculture, Forest Service (USFS). 2005. Guide to identification of bankfull stage in the northeastern United States: Rocky Mountain Research Station, Stream Systems Technology Center, General Technical Report RMRS-GTR-133-CD, 4 CDs.

[66] For a discussion of bankfull flow versus peak flow flood events see the Knighton and Gordon et.al. references given immediately above.
[67] There are numerous case studies for determining initiation of bed movement and also overturning of gravels for gravel bed cleaning. A discussion of studies and methods is given in: Schmidt, L.J. and J.P. Potyondy, 2004, Quantifying channel maintenance instream flows: An approach for gravel-bed streams in the western United States, General Technical Report RMRS-GTR-128, Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station, 33 pp.
A specific example of using hydraulic analysis to determine a channel maintenance flow is given in: Wilcock, P.R., G.M. Kondolf, W.V.G. Matthews, and A.F. Barta. 1996. Specification of sediment maintenance flows for a large gravel river. Water Res. Res. 32(9): 2911-2921.
Finally, a simpler more field based review of methods is also available: Reiser, D.W., M.P. Ramey, and T.A. Wesche. 1989. Flushing flows. Pp. 91-135 in: J.A. Gore and G.E. Petts, editors. Alternatives in regulated river management. CRC Press, Boca Raton, Florida.
[68] Consultants are using modules within established models such as MIKE or HEC-RAS in order to determine when bed movement will occur. HEC-RAS is by far the most heavily used and is available at: Brunner, G.W. 2002. HEC-RAS River System Analysis Users Manual. U.S. Army Corp of Engineers. Software downloads along with user manual are available at: http://www.hec.usace.army.mil/software/hec-ras/
[69] An example of overbank flow and lateral connectivity to wetlands and other features include: Sommer, T.R., M.L. Nobriga, W.C. Harrell, W. Batham, and W.J. Kimmerer. 2001. Floodplain rearing of juvenile Chinook salmon: evidence of enhanced growth and survival. Can. Jour. Fish. Aquat. Sci. 58: 325-333. The Texas Technical Overview also discusses this issue at length and is available at: Texas Commission on Environmental Quality. 2008. Texas Instream Flow Studies: Technical Overview. Texas Commission on Environmental Quality; Report Number 369. 137p.
[70] See Endnote #68 for referencing on HEC-RAS.

[71] An example of studies in Oregon include: Chapin, D.M, R.L. Beschta, H.W. Shen. 2002. Relationships between flood frequencies and riparian plant communities in the Upper Klamath Basin, Oregon. Jour. Water Res. Assoc. 38(3): 603-617. AND Hill, M.T., W.S. Platts, and R.L. Beschta. 1991. Ecological and gemorphological concepts for instream and out-of-channel flow requirements. Rivers 2(3) p. 198-210. For another paper that includes examples outside Oregon: Richter, B.D. and H.E. Richter. 2000. Prescribing flood regimes to sustain riparian ecosystems along meandering rivers. Conservation Biology 14:1467-1478.
[72] ODFW guidance for determining elevated ecological flows - available from: http://www.dfw.state.or.us/fish/water/docs/ODFW_Guidance_on_Allocating_Peak_Flows.pdf
[73] Oregon Administrative Rules OAR 690-033 (Water Resources Department Rules)
[74] State of California – State Water Control Board. 2010. Policy for maintaining instream flows in Northern California Coastal Streams Draft April 27, 2010. This policy and several supporting documents and policies available at: http://www.waterboards.ca.gov/waterrights/water_issues/programs/instream_flows/
[75] The North Coast California policy for instream flow defines minimum by pass flows as instantaneous flow rates of water that is important for managing the protection of steelhead and salmon life history needs, such as: (1) maintaining natural abundance and availability of spawning habitat; (2) minimizing unnatural adult exposure, stress, vulnerability, and delay during adult spawning migration; and (3) sustaining high quality and abundant juvenile salmonid winter rearing habitat. With certain exceptions the minimum bypass flow must be met on an instantaneous basis at the point of diversion (POD) before water may be diverted using the regional criteria. The streamflow may naturally fall below the minimum bypass flow. A minimum bypass flow requirement prevents water diversions during periods when streamflows are at or below the flows needed for spawning, rearing, and passage.
[76] Stetson Engineers and R2 Resource Consultants. 2009. North Coast Instream flow Policy Water Diversion – Passage and Spawning habitat sensitivity study. Prepared for: California State Water Resources Control Board Division of Water Rights 1001 I Street, Sacramento, CA 95814. 74 p. Available at: http://www.waterboards.ca.gov/waterrights/water_issues/programs/instream_flows/
[77] Storage season is a term often used to describe the time period of the year when water is not being used for direct off stream uses such as irrigation. The non storage season termed the "irrigation season" and the water diverted out of the stream is often termed "live flow." In Oregon, the storage season generally extends from November thru April, different regions may have slightly different extents due to local climatic conditions and some may have none.
[78] See endnote #75 above.
[79] See endnote #74 above. As of April, 27, 2010.
[80] Texas Water Quality Commission and others. 2008. Texas Instream Flow Studies: Technical Overview. Texas Commission on Environmental Quality P.O. Box 13087 Mail Code 160 Austin, TX 78711-3087. http://www.twdb.state.tx.us/publications/reports/GroundWaterReports/GWReports/R369_InstreamFlows.pdf
[81] NRC (National Research Council), 2005, The science of instream flows—A review of the Texas Instream Flow Program: Washington, D.C., National Academies Press.
[82] Brierley, G.J., and Fryirs, K., 2005, Geomorphology and river management—applications of the River Styles framework: Oxford, England, Blackwell Publishing.
[83] A good review and explanation of ELOHA can be found in: Poff, N.L., and 18 others. 2010. The ecological limits of hydrologic alteration (ELOHA): a new framework for developing regional environmental flow standards. Freshwater Biology 55, 147-170. AND A more brief explanation is given in a brochure available from ConserveOnline at: http://conserveonline.org/workspaces/eloha . This website has several papers and examples regarding the application of this framework.
[84] In the following publication cited below, Gao et al. states that there are over 170 possible indicators of hydrological alteration. Choosing between these indicators that can be for base flow or high flows requires considerable thought and judgment.
Gao et al. 2009. Development of representative indicators of hydrologic alteration. Jour. Hydro. 374 (2009) 136–147
[85] Bisson, P.A. and 3 others. 1992. Best management practices, cumulative effects, and long-term trends in fish abundance in Pacific Northwest Streams. IN R.J. Naiman (Editor): Watershed Management Balancing Sustainability and Environmental Change. p. 189-232.
[86] The listing is available at: http://conserveonline.org/workspaces/eloha/documents/template-kyle
[87] The techniques used for water availability are described in: Cooper, R.M. 2002. Determining Surface Water Availability in Oregon. State of Oregon, Water Resources Department. Open File Report SW 02-002. Salem Oregon June 2002. 157 p. Access to water availability numbers is found on the OWRD website.
[88] Techniques for peak flows are described in the following publications: Cooper, R.M. 2005. Estimation of Peak Discharges for Rural, Unregulated Streams in Western Oregon: U.S. Geological Survey Scientific Investigations Report

2005–5116, 134 p. and Cooper, R.M. 2006. Estimation of Peak Discharges for Rural, Unregulated Streams in Eastern Oregon: U.S. Geological Survey Scientific Investigations Draft Report 2006. 152 p. Automated procedures are described and available at: http://www.wrd.state.or.us/OWRD/SW/peak_flow.shtml

[89] A listing and discussion of habitat requirement for salmonids can be found in: Bjornn, T.C. and D.W. Reiser. 1991. Chapter 4. Habitat requirements of salmonids in streams. p. 83-138. IN: W.R. Meehan (Ed). Influences of forest and rangeland management on salmonid fishes and their habitats. American Fisheries Soc. Spec. Publ. 19. 751 p.

[90] Water availability has been determined at approximately 2200 sites in Oregon called Water Availability Basins or WABs. A computer lookup program that allows for searches by basin, stream name or water right numbers is available on the OWRD website. Descriptions on techniques on how water availability is determined is also available at http://www1.wrd.state.or.us/pdfs/reports/SW02-002.pdf. For flows based on Basin Investigation Reports that were not converted into water rights, copies of these investigations are available form Oregon Department of Fish and Wildlife. A listing of all Basin Investigation Reports available can be found at: http://www.dfw.state.or.us/fish/water/docs/List_of_Basin_Investigation_Reports.pdf

[91] Automated procedures to quickly obtain peak flows were created for equations from the following publications: Cooper, R.M. 2005. Estimation of Peak Discharges for Rural, Unregulated Streams in Western Oregon: U.S. Geological Survey Scientific Investigations Report 2005–5116, 134 p. And Cooper, R.M. 2006. Estimation of Peak Discharges for Rural, Unregulated Streams in Eastern Oregon: U.S. Geological Survey Scientific Investigations Draft Report 2006. 152 p. Automated procedures are described and available at: http://www.wrd.state.or.us/OWRD/SW/peak_flow.shtml

[92] A discussion of the balancing between supply and transport limited streams and its role in armoring a streambed and changing the frequency of bed moving events is given in: Knighton, D. 1998. Fluvial Forms and Processes: A New Perspective. Oxford University Press N.Y. N.Y. 383p.

[93] In a study done for California the season, baseflow and channel maintenance criteria were considered protective for spawning, fish passage and channel maintenance issues regarding salmonids for those types of streams. However, Oregon's criteria for baseflow would be based on 50% exceedance in order to take advantage of available information and because instream water rights are generally limited to this amount in rule. The study indicated that 50% exceedance of most parameters of winter base flow was protective for watersheds greater than 5 miles squared. There criteria for channel maintenance was based on the theory of reducing a winter peak by 5% would not change the system to a larger degree but adjustments would happen. By the same argument a higher percentage could be used but probably should not be more than 15%. The study citation: Stetson Engineers and R2 Resource Consultants. 2009. North Coast Instream flow Policy Water Diversion – Passage and Spawning habitat sensitivity study. Prepared for: California State Water Resources Control Board Division of Water Rights 1001 I Street, Sacramento, CA 95814. 74 p. Available at: http://www.waterboards.ca.gov/waterrights/water_issues/programs/instream_flows/

[94] For a more detailed analysis for Mussel Creek and the Deschutes River, see appendix B and appendix C in ODFW guidance for determining elevated ecological flows - available from: http://www.dfw.state.or.us/fish/water/docs/ODFW_Guidance_on_Allocating_Peak_Flows.pdf

[95] What would constitute a "large scale storage project?" This is a policy decision. Perhaps it would be 5000 acre-feet or more and impact a stream system that has considerable ecological value. The specific thresholds are more of a policy decision.

Note to the reader: Endnotes 53, 54, 55 are identical with endnotes 24, 25, 26