17.0 Stormwater Impact Assessment

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The state of stormwater science is constantly evolving as new studies are completed. Previous assessment tools (HI-RUN) do not consider the most recent and/or full suite of relevant science. Washington State Department of Transportation (WSDOT) will strive to incorporate new scientific findings in future project designs and effects analyses/determinations. Given the sheer numbers of pollutants in stormwater and the speed at which research is being conducted it is certain that additional compounds will be identified as harmful. Rapidly emerging science will necessitate close communication and adaptive management across National Marine Fisheries Service (NMFS), U.S. Fish and Wildlife Service (USFWS), Federal Highway Administration (FHWA), and WSDOT, as these and other agencies work to incorporate major advances in analytical chemistry, treatment technologies, and decision support tools for salmon conservation and recovery planning. Furthermore, other factors, such as climate change, influence stormwater characteristics (volume, frequency, etc.) and will need to be considered when evaluating transportation project effects. WSDOT will remain adaptable with internal processes that can anticipate and respond to new information as the science underlying stormwater ecotoxicology advances. It is critical that BA authors stay informed about stormwater issues. As stormwater science advances and our understanding of how pollutants affect fish, marine mammals, and their habitat, this chapter will be updated.

Chapter Summary

As part of a biological assessment, WSDOT assesses stormwater effects in receiving waters and the function and performance of stormwater best management practices (BMPs) in the action area. This chapter provides background information on stormwater management as it relates to highway projects (Section 17.1), a summary of stormwater and wastewater pollutants documented in wastewater discharge, and solids (Section 17.2), guidance to describe and quantify effects to water quality, quantity, possible exposures (for listed species, individuals), and possible measurable effects to habitat function, (Section 17.3), guidance on analyzing water quality effects stemming from development or land use change that can be linked to transportation projects (Section 17.4), a glossary of terms (Section 17.5), and a list of online resources (Section 17.6). This chapter provides an overview of the WSDOT *Highway Runoff Manual* but does not address the selection of BMPs that are incorporated into the project plans (Section 17.1.1). The selection process is outlined in the WSDOT *Highway Runoff Manual.*

The chapter also summarizes the BMP types identified in the WSDOT *Highway Runoff Manual* so that biologists who are writing BAs can be more familiar with stormwater treatment designs and options (Section 17.1.2). BMPs for managing runoff treatment are described in Section 17.1.2.3, and BMPs for managing stormwater flow control are described in Section 17.1.2.4. This section describes the importance of maintenance of BMPs to ensure they function properly (Section 17.1.2.1) and describes design flows and volumes (Section 17.1.2.2).

Instructions are provided for incorporating a stormwater analysis into the BA in a stepwise fashion (Section 17.3), including:

- Step 1: Obtaining the Endangered Species Act Stormwater Design Checklist (Section 17.3.1)
- Step 2: Incorporating information about the selected BMPs into the project description (Section 17.3.2)
- Step 3: Incorporating or including stormwater effects when determining and defining the action area (Section 17.3.3)
- Step 4: Determining species use, and presence of critical habitat and Essential Fish Habitat (EFH) within the action area (Section 17.3.4)
- Step 5: Describing existing environmental conditions including modeled pre-project existing sources of stormwater runoff and discharge (Section 17.3.5)
- Step 6: Describe and quantify effects to water quality, quantity, possible exposures, and possible measurable effects to habitat function
- Step 7: Examining site-specific conditions that may moderate or mediate stormwater effects which cannot be fully captured in modeling results (Section 17.3.7)
- Step 8: Double-checking the action area to ensure it incorporates all anticipated physical, biological, chemical effects (Section 17.3.8)
- Step 9: Pulling it all together: completing a comprehensive exposure response analysis for listed species and critical habitat (Section 17.3.9)
- Step 10: Finally, quantitative and qualitative guidance is provided to estimate stormwater effects and make effect determinations in accordance with Section 7 of the ESA (Section 17.3.10)

Online resources for stormwater are provided in Section 17.6.

It is important to understand that not all projects will have stormwater effects on listed species, proposed or designated critical habitat, or EFH due to location, absence of the species and habitats, or a project type that does not have new pollution generating impervious surface (PGIS), does not include stormwater retrofits, and does not alter flow conditions. These project types need not complete a detailed stormwater analysis. However, these projects are still expected to include a brief stormwater discussion as part of the project description and to document project effects (or lack thereof) on listed species along with supporting rationale in the effects analysis section of the BA. These types of projects may include bridge seismic retrofits, ACP overlays, guardrail installations, project areas that are located a great distance from surface water, and projects that can naturally disperse or infiltrate all runoff due to highly permeable soils. It is important that the BA describe the baseline condition, including the PGIS and its stormwater inputs, whether there is treatment or not for those discharges, and the water quality condition of the receiving water body.

17.1 Background Information on Stormwater Management for Highway Projects

Existing impervious surfaces of the transportation infrastructure, as a baseline condition, already discharge pollutant loads via stormwater to many streams and rivers in Washington State. Projects that construct new PGIS are also likely to adversely affect the quantity and quality of runoff originating from within the project area for the following reasons:

- Impervious surface prevents rainwater from infiltrating, can reduce groundwater recharge, and affect base flows of nearby surface water.
- Conversion of pervious surfaces (e.g., vegetated areas) to impervious surface can result in increased surface runoff. Changes to the pattern or rate of surface runoff may increase peak flows in receiving waters.
- The presence of impervious surface provides a platform that collects settled air pollutants, contaminants from vehicles and road maintenance activities, and sediment from the surrounding environment. These pollutants are mobile and become a part of the runoff that moves through the watershed.

WSDOT incorporates stormwater BMPs into the project design to manage the quality and quantity of runoff. Stormwater BMPs are designed to reduce and remove pollutants and attenuate peak flows and volumes associated with stormwater runoff. Some temporary BMPs are used only during the construction phase of a project. Permanent BMPs are used to control and treat routine, intermittent and seasonal stormwater runoff from highways, park-and-ride lots, rest areas, ferry holding areas, and other transportation infrastructure. Properly designed, constructed and maintained stormwater BMPs can provide important reductions in impacts. However, stormwater BMPs do not eliminate all stormwater pollutants. Projects that construct new PGIS need to address the potential short- and long-term effects that will be added to the baseline condition, on listed species, designated critical habitat, and habitat function under the Endangered Species Act (ESA).

Project biologists must evaluate all the temporary and permanent stormwater effects associated with a project. These effects include:

- Changes in flow or local hydrology and how altered flows and timing may affect habitat quality and function
- Changes in pollutant loads and concentrations, and how pollutant loads and concentrations may present or cause exposures and effects to individuals (species and life stage) and/or affect habitat quality and function
- Installation or construction of stormwater treatment elements (BMPs, conveyance, ditches, outfalls, etc.)

17.1.1 Summary of WSDOT *Highway Runoff Manual*

The WSDOT *Highway Runoff Manual* provides uniform technical guidance and establishes minimum requirements for avoiding and mitigating water resource impacts associated with the development of state-owned and operated transportation infrastructure systems, and for reducing water resource impacts associated with redevelopment of those facilities.

The *Highway Runoff Manual* is used by project stormwater engineers and designers as guidance to evaluate site conditions, to help characterize the stormwater treatment needs for proposed projects and to identify and appropriately size BMPs to provide treatment and flow control for stormwater runoff.

The *Highway Runoff Manual* provides design guidance to meet stormwater management standards established by the Washington Department of Ecology to achieve compliance with federal and state Clean Water Act requirements. These regulations require stormwater treatment systems to be properly designed, constructed, maintained, and operated to achieve the following goals:

- Prevent pollution of state waters, protect water quality, and comply with state water quality standards
- Satisfy state requirements for all known, available, and reasonable methods of prevention, control, and treatment of wastes prior to discharge to waters of the state
- Satisfy the federal technology-based treatment requirements under 40 CFR 125.3
- Prevent further water quality impairment resulting from new stormwater discharges and make reasonable progress in addressing existing sources of water quality impairment.

The *Highway Runoff Manual* reflects the best available science in stormwater management to ensure that WSDOT projects protect environmental functions and values. There are established procedures under State law whereby the *Highway Runoff Manual* is routinely updated. WSDOT considers this manual to include all known, available, and reasonable methods of prevention, control, and treatment for stormwater runoff discharges, consistent with state and federal law for water quality. These measures may not meet ESA conditions for listed aquatic species.

To uphold federal and state wetland regulations, WSDOT strives to maintain the extent, quality and existing hydrology of wetlands to which its stormwater facilities discharge. WSDOT attempts to avoid discharges to wetlands that provide habitat for listed species. However, some wetlands are dependent upon the inputs from roadway runoff to maintain their hydrologic characteristics so stormwater-related flows to these systems are maintained.

Projects that design, construct and maintain stormwater BMPs in a manner consistent with the *Highway Runoff Manual* are considered by the Department of Ecology to have satisfied their Clean Water Act requirements. However, as projects undertake the ESA consultation process, additional analyses may be required to adequately assess and describe potential effects, and additional treatment or flow control may be necessary or recommended to more fully avoid and minimize exposures and effects to listed species and their habitat.

A summary of BMP types in the *Highway Runoff Manual* is provided in the section below. This information is provided so that biologists will better understand the information they are provided by project engineers.

17.1.2 Summary of WSDOT *Highway Runoff Manual* Stormwater BMPs

This section provides background information to biologists who are writing BAs to familiarize them with stormwater management concepts. The section describes the design flows and volumes (Section 17.1.2.2), and the function and effectiveness of the BMPs included in the *Highway Runoff Manual*. There are 22 BMPs for runoff treatment (water quality – Section 17.1.2.3) and 9 BMPs for flow control (water quantity – Section 17.1.2.4) in the *Highway Runoff Manual*. The experimental and low-preference BMPs described herein may be used in unusual situations with project-specific approval. For further information on stormwater BMPs, the *Highway Runoff Manual* (or other documents referenced in the following sections) should be consulted. This manual can be found at: <http://www.wsdot.wa.gov/Publications/Manuals/M31-16.htm>.

17.1.2.1 Maintenance of BMPs

The effectiveness of runoff treatment and flow control BMPs is highly dependent on adequate and frequent maintenance. Lack of maintenance can result in excessive sediment buildup in ponds, which can reduce storage volume; die-off of vegetation in vegetated BMPs, leading to reduced pollutant uptake and filtration; and clogging of outlets and orifices, affecting hydraulic function. BMP effectiveness claims and assumptions are only applicable to maintained facilities. Maintenance standards for WSDOT BMPs are described in the *Highway Runoff Manual*. For ESA-related consultations, it is assumed that stormwater BMPs and conveyance and discharge structures will be maintained as described in the *Highway Runoff Manual.* BA authors should include statements in the project description describing BMP maintenance activities that will be conducted in the future.

17.1.2.2 BMP Design Flows and Volumes

Runoff treatment BMPs are designed using runoff volume (wet pool facilities) or discharge rates. Flow control BMPs are designed based on peak discharge rates and durations. In western Washington, wet pool runoff treatment BMPs (e.g., wet ponds, stormwater treatment wetlands) are designed with a wet pool volume that is equal to or greater than the runoff volume from 91st percentile, 24-hour storm event. In eastern Washington, wet pool BMPs are designed with a wet pool volume that is equal to the runoff volume from a 6-month, long duration storm event. In western Washington, discharge-based runoff treatment BMPs (e.g., biofiltration swales, media filters) located upstream of detention facilities (if present) are designed to treat the flow rate at or below the 91 percent annual runoff volume. In eastern Washington, discharge-based runoff treatment BMPs upstream of detention facilities (if present) are designed to treat the peak runoff discharge from a 6-month, short duration storm event. If discharge-based runoff treatment BMPs are located downstream of a detention facility in either western or eastern Washington, they are designed to treat the 2-year release rate from the facility.

Flow control BMPs are designed to meet the following criteria:

- In western Washington, stormwater discharges must match developed discharge durations to predeveloped durations for the range of predeveloped discharge rates from 50 percent of the 2-year peak flow up to the full 50-year peak flow.

- In eastern Washington, limit the peak release rate of the post-developed 2-year runoff volume to 50 percent of the predeveloped 2-year peak and maintain the predeveloped 25-year peak runoff rate.

BMPs can be configured as **on-line** BMPs, in which all runoff is conveyed through the facility, or as **off-line** facilities, in which flows exceeding the design discharge rate bypass the BMP. All volume-based (wet pool) runoff treatment BMPs and flow control BMPs are designed as on-line facilities. Discharge-based runoff treatment BMPs can be designed as off-line or on-line facilities. However, on-line discharge-based runoff treatment BMPs in western Washington will be larger so that they can meet the 91 percent runoff volume treatment goal. This is because on-line discharge-based BMPs do not effectively treat runoff when flows exceed the design flow. Off-line BMPs do treat the design flow as excess flows bypass the facility.

17.1.2.3 BMPs for Runoff Treatment

Stormwater runoff is certain to continue to deliver toxic and potentially lethal contaminants from urban and rural areas if left untreated. Because the effectiveness of treatment methods on multiple pollutants is unknown, treated stormwater is also assumed to result in adverse effects to ESA-listed salmonids and SRKW prey species and their habitats. Depending on the project location marine species present in the Puget Sound may also be affected. It can be expected that EFH will be affected similarly. BMP effectiveness in removing 6PPD-quinone, microplastics, PBTs, PAHs, and others is largely unknown; however, BMPs are constantly evolving to address pollutants other than metals. Runoff treatment BMPs are organized into four runoff treatment types:

1. **Basic Treatment** BMPs are designed to effectively remove suspended solids from stormwater (80 percent removal) through physical treatment processes (sedimentation/settling, filtration). The basic treatment target applies to most projects that generate and discharge stormwater runoff to surface waters.

2. **Enhanced Treatment** BMPs are designed to remove dissolved metals from stormwater through enhanced treatment mechanisms (chemical and biological processes). Enhanced treatment BMPs also remove suspended solids from stormwater as or more effectively than basic treatment BMPs. The enhanced treatment target applies to runoff from higher-traffic roadways in some cases.

3. **Oil Control** BMPs are designed to remove non-polar petroleum products from stormwater through flotation and trapping. The oil control treatment target applies to runoff generated in high-use intersections, rest areas, and maintenance facilities statewide; and in higher-traffic roadways in eastern Washington.

4. **Phosphorus Control** BMPs are designed to remove phosphorus from stormwater (50 percent removal) through enhanced sedimentation, as well as chemical and biological processes. The phosphorus control treatment target applies to runoff generated in areas that discharge to phosphorus-sensitive surface water bodies.

Multiple treatment targets may apply to individual threshold discharge areas (TDAs) and to different TDAs within a project. The *Highway Runoff Manual* defines TDAs as follows: *An on-site area draining to a single natural discharge location or multiple natural discharge locations that combine within 1/4 mile downstream (as determined by the shortest flow path)*.

The following runoff BMP types are described in the subsections below:

- Infiltration BMPs
- Dispersion BMPs
- Biofiltration BMPs
- Wet Pool BMPs
- Media Filtration BMPs
- Oil Control BMPs

Infiltration BMPs

Infiltration is the discharge of stormwater to groundwater through porous soils. Infiltration BMPs treat stormwater through filtration and chemical soil processes (adsorption and ion exchange). The *Highway Runoff Manual* includes the following four infiltration BMPs:

1. Bioinfiltration pond (eastern Washington only)
2. Infiltration pond
3. Infiltration trench
4. Infiltration vault

Along with dispersion (described in the section below), infiltration is a preferred method of treatment, offering the highest level of pollutant removal. To use infiltration for runoff treatment, native soils must meet (or be amended to meet) specific permeability and chemical criteria. In addition to treatment, infiltration BMPs provide effective flow control by reducing the volume and peak surface water discharge rates. Another important advantage to using infiltration is that it recharges the ground water, thereby helping to maintain summertime base flows in streams and reducing stream temperature naturally. These are important factors in maintaining a healthy habitat for instream biota.

Infiltration facilities must be preceded by a presettling basin to remove most of the sediment particles that would otherwise reduce the infiltrative capacity of the soil. Infiltration strategies intended to meet runoff treatment goals may be challenging for many project locations in western Washington due to strict soil and water table requirements. Eastern Washington generally offers more opportunities for the use of infiltration BMPs.

Bioinfiltration ponds are vegetated ponds that store and infiltrate stormwater while also removing pollutants through vegetative uptake. This BMP, developed and used more commonly in eastern Washington, functions as both a biofiltration BMP and an infiltration BMP and can meet basic, enhanced and oil control treatment targets. Bioinfiltration ponds can only be applied in eastern Washington, and because of limitations on ponding depth they require a large footprint to meet flow control requirements.

Infiltration ponds are open-water facilities that store and infiltrate stormwater vertically through the base. Implementation of infiltration ponds can be challenging due to their large space requirements. Because treated runoff is removed from the surface water system, specific treatment targets are not applicable to this BMP.

Infiltration trenches (also called infiltration galleries) are gravel-filled trenches designed to store and infiltrate stormwater. They commonly include perforated pipe for conveyance of stormwater throughout the trench. Limitations of infiltration trenches are similar to those of infiltration ponds, but they can be configured to more easily fit into constrained sites and linear roadway corridors. Below-ground infiltration BMPs such as infiltration trenches may also be subject to underground injection control (UIC) rules.

Infiltration vaults are below-ground storage facilities (tanks, concrete vaults) with perforations or open bases, allowing stormwater to infiltrate. Limitations of infiltration vaults are similar to those of infiltration ponds, but they can fit more constrained sites – even located beneath pavement. An additional challenge for infiltration vaults is the maintenance access challenges that below-ground facilities pose – potentially requiring confined-space entry by maintenance personnel. Like infiltration trenches, infiltration vaults may be subject to underground injection control (UIC) rules.

Dispersion BMPs

Dispersion BMPs treat stormwater by vegetative and soil filtration and shallow infiltration of sheet flow discharge. The two dispersion BMPs included in the *Highway Runoff Manual* are natural dispersion and engineered dispersion.

Natural dispersion is sheet flow discharge of runoff into a preserved, naturally vegetated area where infiltration occurs. It is perhaps the single most effective way of mitigating the effects of highway runoff in nonurban areas. Natural dispersion can meet the basic and enhanced treatment targets by making use of the pollutant-removal capacity of the existing naturally vegetated area. The naturally vegetated area must have topography, soil, and vegetation characteristics that provide for the removal of pollutants.

Natural dispersion has several notable benefits: it can be very cost-effective, it maintains and preserves the natural functions, and it reduces the possibility of further impacts on the natural areas adjacent to constructed treatment facilities. In most cases this method not only meets the requirements for runoff treatment but also provides flow control. However, if channelized drainage features are near the runoff areas requiring treatment, then engineered dispersion or other types of engineered solutions may be more appropriate.

Despite the benefits described above, natural dispersion requires a substantial area of land adjacent to the runoff source area. This area must be protected from future development with a conservation easement or other measure. Because of this, applicability of this BMP is limited for roadway/highway projects.

Engineered dispersion is sheet flow dispersion of concentrated stormwater (using flow spreaders). This BMP uses the same removal processes as natural dispersion and can also meet basic and enhanced treatment targets. For engineered dispersion, a manmade conveyance system directs concentrated runoff to the dispersion area (via storm sewer pipe or ditch, for example). The concentrated flow is dispersed at the end of the conveyance system to mimic sheet-flow into the dispersion area. Engineered dispersion techniques coupled with compost-amended soils and additional vegetation enhance the modified area. These upgrades help to ensure that the dispersion area has the capacity and ability to infiltrate surface runoff.

The limitations described under natural dispersion above also apply to engineered dispersion.

Biofiltration BMPs

Biofiltration BMPs treat stormwater through vegetative and soil filtration and uptake. The *Highway Runoff Manual* includes the following six biofiltration BMPs:

1. Vegetated filter strip – basic, narrow, and compost-amended
2. Biofiltration swale
3. Wet biofiltration swale
4. Continuous inflow biofiltration swale
5. Media filter drain (previously called ecology embankment)
6. Bioretention area

Vegetated filter strips are gradually sloping areas adjacent to the roadway that treat runoff by maintaining sheet flow, reducing runoff velocities, filtering out sediment and other pollutants, and providing some infiltration into underlying soils. The flow can then be intercepted by a ditch or other conveyance system and routed to a flow control BMP or outfall. Vegetated filter strips can the meet basic treatment target and are well suited for linear roadway projects where sheet flow can be maintained from the roadway surface (no curbs, gutters, or channelized drainage at the edge of pavement). In addition to the basic vegetated filter strip, there are two modifications to the vegetated filter strip BMP: the narrow area vegetated filter strip, and the compost-amended vegetated filter strip.

The **narrow-area vegetated filter strip** is similar to the basic vegetated filter strip but is simpler to design. This BMP is limited to impervious flow paths of 30 feet or less, and meets the basic treatment target.

The **compost-amended vegetated filter strip** (CAVFS) is an enhanced version of the basic vegetated filter strip. By incorporating compost amendment and subsurface gravel courses, CAVFS can meet basic, enhanced, phosphorus control, and oil control treatment targets.

Biofiltration swales are relatively wide (compared to conveyance ditches) vegetated channels that treat runoff by filtering concentrated flow through grassy vegetation with a shallow flow depth. The swale functions by slowing runoff velocities, filtering out sediment and other pollutants, and providing some infiltration into underlying soils. Biofiltration swales can meet the basic treatment target.

Biofiltration swales can also be integrated into the stormwater conveyance system, as they are typically designed as on-line BMPs (no bypass of flows exceeding design discharge). Existing roadside ditches may be good candidates for upgrading to biofiltration swales. Biofiltration swales are not recommended for use in arid climates. In semi-arid climates, drought-tolerant grasses should be specified.

The **wet biofiltration swale** is a variation of a basic biofiltration swale that is applicable where the longitudinal slope is slight, the water table is high, or continuous low base flow tends to cause saturated soil conditions. The wet biofiltration swale typically uses different vegetation that is suitable for saturated conditions and meets the basic treatment target.

The **continuous inflow biofiltration swale** is another variation of the biofiltration swale that is applicable where water enters a channel continuously along the side slope rather than being concentrated at the upstream end. This BMP also meets the basic treatment target.

The **media filter drain** (previously called ecology embankment) is a BMP that incorporates a treatment train of pollutant removal mechanisms immediately adjacent to a raised roadway and meets the basic, enhanced, and phosphorus control treatment targets. Unconcentrated runoff enters the media filter drain through a narrow grass strip and is filtered through a shallow subsurface media consisting of mineral aggregate, dolomite, gypsum, and perlite. The media filter drain also provides infiltration through the base of the media gallery but is not approved for use as a flow control BMP. The media filter drain integrates soil amendments in the grass strip, providing significant pollution reduction and flow attenuation. Its application is limited to raised highways located in relatively flat terrain. This BMP can often be constructed with little or no additional right-of-way, making it a cost-effective solution to managing highway runoff.

Bioretention areas provide enhanced runoff treatment by using an imported soil mix that has a moderate design filtration rate. They are applied to small drainage areas near the source of stormwater.

Wet Pool BMPs

Wet pool BMPs treat runoff by reducing velocities and settling particulate material. Vegetated portions of wet pool BMPs also treat runoff with vegetative and soil filtration and uptake. The *Highway Runoff Manual* includes the following four BMPs:

1. Wet pond
2. Combined wet/detention pond
3. Constructed stormwater treatment wetland
4. Combined stormwater treatment wetland/detention pond

In addition to the BMPs included in the *Highway Runoff Manual*, underground **wet vaults** are sometimes used for runoff treatment when site area constraints do not allow for a large surface pond facility. Wet vaults are the least preferred method of runoff treatment, and are not included in the *Highway Runoff Manual*.

A **wet pond** is a constructed basin containing a permanent pool of water throughout the wet season. Wet ponds function primarily by settling suspended solids and can meet the basic treatment target. Wet ponds can also be sized larger to meet the phosphorus control treatment target. Biological action of plants and bacteria provides some additional treatment. Wet ponds are usually more effective and efficient when constructed using multiple cells (i.e., a series of individual smaller basins), where coarser sediments become trapped in the first cell, or forebay. Wet ponds are less effective in treating dissolved pollutants.

Combined wet/detention pond SR 500
WSDOT Highway Runoff Manual M 31-16.05. April 2019

Because the function of a wet pond depends upon maintaining a permanent pool of water to provide treatment, wet ponds are generally not recommended for use in arid or semi-arid climates. Cold-climate applications can be problematic, and additional modifications must be considered. The spring snowmelt may have a high pollutant load and produce a larger runoff volume to be treated. In addition, cold winters may cause freezing of the permanent pool or freezing at inlets and outlets. High runoff salt concentrations resulting from road salting may affect pond vegetation, and sediment loads from road sanding may quickly reduce pond capacity.

Wet ponds can be configured to provide flow control by adding **detention** volume (live storage) above the permanent wet pool. This is called a **combined wet/detention pond**. **Constructed stormwater treatment wetlands** are similar to wet ponds but are configured to include shallower zones with substantial vegetation for enhanced filtration and uptake. This BMP can meet basic and enhanced treatment targets. Sediment and associated pollutants are removed in the first cell of the system via settling. The processes of settling, biofiltration, biodegradation, and bioaccumulation provide additional treatment in the subsequent cell or cells. In general, constructed stormwater treatment wetlands could be incorporated into drainage designs wherever water can be collected and conveyed to a maintainable artificial basin.

Constructed stormwater treatment wetlands offer a suitable alternative to wet ponds or biofiltration swales and can also provide treatment for dissolved metals. The landscape context for stormwater wetland placement must be appropriate for creation of an artificial wetland (i.e., ground water, soils, and surrounding vegetation). Natural wetlands cannot be used for stormwater treatment purposes.

Constructed stormwater wetlands can be a preferred stormwater management option over other surface treatment and flow control facilities. In general, this option is a more aesthetically appealing alternative to ponds.

Constructed stormwater treatment wetlands can be configured to provide flow control by adding **detention** volume (live storage) above the permanent wet pool. This is called a **combined stormwater treatment wetland/detention pond**.

Oil Control BMPs

BMPs that have the primary function of removing oil from stormwater include the following:

- Oil containment boom
- Baffle-type oil/water separator
- Coalescing plate separator
- Catch basin inserts

Of these BMPs, only the oil containment boom is included in the *Highway Runoff Manual*. The baffle-type oil/water separator and the coalescing plate separator are not included in the *Highway Runoff Manual* because of maintenance challenges associated with them. The following other BMPs can perform the oil control function in addition to meeting other runoff treatment functions:

- Bioinfiltration pond (eastern Washington only; see Infiltration BMPs section above)
- Compost-amended vegetated filter strip (see Biofiltration BMPs section above)

Oil containment booms contain sorptive material that captures oil and grease at the molecular level. These booms are applied to open water stormwater treatment BMPs including wet ponds and capture floating petroleum product. An oil control BMP should be placed as close to the source as possible but protected from sediment. Sorptive oil containment booms can be placed on top of the water in sediment control devices and can be used in ponds and vaults.

Baffle-type oil/water separators and **coalescing plate separators** are below-ground vault facilities that collect oil and grease by trapping the floating material. These BMPs are configured as below-ground vault-type facilities, are expensive to maintain, and usually pose safety hazards for maintenance workers who must work in confined spaces or out in roadway traffic. Moreover, it is difficult to verify whether these BMPs are working effectively. Baffle oil/water separators and coalescing plate devices should be installed downstream of primary sediment control devices and can be used at pond outlets. For more information on these oil control BMPs, see the *Stormwater Management Manual for Western Washington* (Ecology 2019).

Catch basin inserts with sorptive media are appropriate only for the very lowest sediment yield areas because they can easily plug and cause roadway flooding. Catch basin inserts must be maintained (inspected and replaced) frequently to effectively remove pollutants from stormwater.

Media Filtration BMPs

Media filtration BMPs treat stormwater through physical filtration (straining) of particulates when using inert media, as well as chemical processes (e.g., adsorption, ion exchange) when media are reactive. The *Highway Runoff Manual* does not include any media filtration BMPs. However, some media filtration BMPs that can be used with approval from the regional WSDOT Hydraulics Office and Maintenance Supervisor include:

- Sand filter basin
- Linear sand filter
- Sand filter vault
- Proprietary canister filters

Media filtration BMPs capture and temporarily store stormwater runoff and then slowly filter it through a bed of granular media such as sand, organic matter, perlite, soil, or combinations of organic and inorganic materials. In this process, stormwater passes through the filter medium, and particulate materials either accumulate on the surface of the medium (which strains surficial solids) or are removed by deep-bed filtration. Silica sands are relatively inert materials for sorption and ion exchange. However, sands that contain significant quantities of calcitic lime, iron, magnesium, or humic materials can remove soluble pollutants such as heavy metals or pesticides through precipitation, sorption, or ion exchange. For more information on media filtration BMPs, see the *Stormwater Management Manual for Western Washington* (Ecology 2019).

The **sand filter basin** is a pond-type open water facility where water is stored and travels vertically through the media filter in the bed of the basin. Sand filter basins require a substantial amount of area, and like all media filtration BMPs require intensive maintenance. In general, surface sand filters are not recommended where high sediment loads are expected, because sediments readily clog the filter. Sodding the surface of the filter bed can reduce clogging to some degree. This treatment method is not reliable in cold climates because water is unable to penetrate the filter bed if it becomes frozen.

The **linear sand filter** is a below-ground sand filter configuration that can be installed at the edge of impervious areas and can fit more constrained sites than the sand filter basin.

The **sand filter vault** is a below-ground facility incorporating a settling chamber and a filtration bed. While the underground configuration allows for application in more constrained sites than the above-ground sand filter basin, the already intensive maintenance requirements are more challenging due to access constraints.

Proprietary **canister filters** (including the CONTECH StormFilter and the CONTECH MFS) are vault-style facilities that provide filtration of stormwater through replaceable cartridge cylinders filled with filter media. These BMPs can be configured as above-ground or below-ground vaults, and the media can be designed for specific treatment needs.

Media filtration BMPs are <u>not</u> included in the *Highway Runoff Manual*.

Runoff Treatment Trains

Runoff treatment is often achieved using a series of BMPs rather than a single facility. However, the *Highway Runoff Manual* does not recognize treatment trains as a viable approach to meeting enhanced or phosphorus control treatment targets without project-specific approval.

Treatment trains often involve a basic treatment BMP such as wet pool or biofiltration followed by a media filtration BMP. This provides settling of the coarser solid material in stormwater before additional removal of finer material can be achieved. By removing solids prior to filtration, the rate at which the media filter clogs can be reduced, extending the maintenance cycle of the facility.

See Table 17-1 for a list of runoff treatment BMPs, their treatment type and regional applicability.

17.1.2.4 BMPs for Stormwater Flow Control

Stormwater flow control BMPs are designed to control the flow rate or the volume of runoff leaving a developed site. The primary flow control mechanisms are dispersion, infiltration, and detention. Increased peak flows and increased durations of sustained high flows can cause downstream damage due to flooding, erosion, and scour, as well as degradation of water quality and instream habitat through channel and stream bank erosion. These physical effects are pronounced, and substantially degrade habitat function, where peak flows are not controlled (including where older infrastructure provides no controls). The following provides an overview of the most used flow control BMPs for highway application.

Table 17-1. Runoff treatment Best Management Practices.

BMP #	Runoff Treatment BMP	Treatment Type				Regional Applicability	
		Basic Treatment	Enhanced Treatment	Phosphorus Control	Oil Control	Western Washington	Eastern Washington
IN.01	Bioinfiltration Ponds	X	X		X		X
IN.02	Infiltration Ponds	*	*	*		X	X
IN.03	Infiltration Trenches	*	*	*		X	X
IN.04	Infiltration Vaults	*	*	*		X	X
FC.01	Natural Dispersion	X	X				
FC.02	Engineered Dispersion	X	X				
RT.02	Basic Vegetated Filter Strip	X				X	X
RT.02	Narrow Area Vegetated Filter Strip	X				X	X
RT.02	Compost-Amended Vegetated Filter Strip	X	X	X	X	X	X
RT.04	Biofiltration Swale	X				X	X
RT.05	Wet Biofiltration Swale	X				X	X
RT.06	Continuous Inflow Biofiltration Swale	X				X	X
RT.07	Media Filter Drain	X	X	X		X	X
RT.08	Bioretention Area	X	X			X	
RT.12	Wet Pond (basic)	X				X	X
RT.12	Wet Pond (large)	X		X		X	X
CO.01	Combined Wet/Detention Pond (basic)	X				X	X
CO.01	Combined Wet/Detention Pond (large)	X		X		X	X
RT.13	Constructed Stormwater treatment wetlands	X	X			X	X
CO.02	Combined stormwater treatment wetland/ detention pond	X	X			X	X
RT.14	Sand Filter Basin (basic)	X				CAT 1	CAT 1
RT.14	Sand Filter Basin (large)	X	X	X		CAT 1	CAT 1
RT.15	Linear Sand Filter (basic)	X			X	CAT 1	CAT 1
RT.15	Linear Sand Filter (large)	X	X		X	CAT 1	CAT 1
RT.16	Sand Filter Vault (basic)	X				CAT 1	CAT 1
RT.16	Sand Filter Vault (large)	X		X		CAT 1	CAT 1

X = BMP meets this treatment type
* = BMP does not discharge to surface water – runoff treatment goals are not applicable.
CAT 1 = this BMP is approved by Ecology, but are not included in the Highway Runoff Manual because they are not considered viable options for treatment of highway runoff. Project-specific approval is needed to use these BMPs on WSDOT projects.

Infiltration BMPs

Infiltration BMPs reduce the volume of runoff discharged to surface waters from a site. If surface discharge is not completely eliminated, infiltration BMPs can reduce the flow rates and the durations of sustained high flows. The *Highway Runoff Manual* includes the following six infiltration BMPs for flow control:

1. Bioinfiltration pond (eastern Washington only)
2. Infiltration pond
3. Infiltration trench
4. Infiltration vault
5. Drywell
6. Permeable pavement systems

Bioinfiltration ponds, **infiltration ponds**, **infiltration trenches**, and **infiltration vaults** are described in Section 17.1.2.3 BMPs for Stormwater Runoff Treatment. **Bioinfiltration ponds** are restricted to eastern Washington and may not be able to fully meet flow control criteria.

Drywells, which function similar to infiltration trenches, are subsurface concrete structures that convey stormwater runoff into the soil matrix. Drywells can be used to meet flow control requirements, but do not provide runoff treatment. Uncontaminated or properly treated stormwater must be discharged to drywells in accordance with the Ecology Underground Injection Control (UIC) program.

Permeable pavement systems are alternative paving materials that allow infiltration of rainfall directly to the pavement base. Permeable pavement types include permeable concrete, permeable asphalt, and paver systems. Permeable pavement cannot be used alone to meet flow control criteria, but can reduce the size of downstream BMPs.

Dispersion BMPs

Dispersion BMPs control flows through shallow infiltration, which reduces the volume of surface runoff. Sheet flow in the dispersion area increases the runoff travel time, decreasing flow rates. The *Highway Runoff Manual* includes the following two dispersion BMPs for flow control: natural dispersion and engineered dispersion.

Natural dispersion and engineered dispersion are described in Section 17.1.2.3, BMPs for Stormwater Runoff Treatment.

Detention BMPs

Detention BMPs control flows by storing runoff and releasing it at reduced rates. The three detention BMPs included in the *Highway Runoff Manual* are the following:

1. Detention pond
2. Detention vault
3. Detention tank

Detention ponds are open-water basins that store runoff and release it at reduced rates. These BMPs can be configured as a dry pond to control flow only, or it can be combined with a wet pond or constructed stormwater treatment wetland to also provide runoff treatment within the same footprint. These combined facilities, called combined wet/detention ponds and combined stormwater wetland/detention ponds, are described in Section 17.1.2.3, BMPs for Stormwater Runoff Treatment. Detention ponds generally require a substantial area of land.

Detention vaults and **detention tanks** are below-ground storage facilities that are commonly used for projects that have limited space and thus cannot accommodate a pond. Although vaults and tanks require minimal right-of-way, they are difficult to maintain due to poor accessibility and effort required for visual inspection. Typically, the increased construction and maintenance expenses quickly offset any initial cost benefits derived from smaller right-of-way purchases. Consequently, underground detention is the least preferred method of flow control.

17.2 Stormwater Pollutants and Effects

Stormwater runoff is a major contributing factor to water quality impairments throughout Washington State (EPA 2020). Impervious surfaces, such as roads and parking lots, alter the natural infiltration of vegetation and soil, and accumulate many diverse pollutants. During heavy rainfall or snowmelt events, accumulated pollutants are mobilized and transported in runoff from roads and other impervious surfaces. Individual stormwater outfalls and non-point source runoff ultimately discharge to streams, rivers, lakes, and marine waters. Hence, cumulative stormwater inputs from multiple outfalls can ultimately degrade habitat conditions (water quality) for salmon and other aquatic species at a watershed or sub-basin scale. These impacts also extend to physical habitat processes; for example, the hydrologic effects of stormwater runoff increase erosion and streambank scouring, downstream sedimentation and flooding, and channel simplifications (Jorgensen et al. 2013; Jonsson et al. 2017). Motor vehicles are the primary source of pollutants present in stormwater runoff from impervious surfaces. Pollutants and contaminants include those derived from tire wear (e.g., 6PPD-quinone), brake pads (e.g., copper and other metals), and exhaust (e.g., phenanthrene and other polycyclic aromatic hydrocarbons, or PAHs). Stormwater may also include additional contaminants depending on the surrounding land use (e.g., herbicides and pesticides) and proximity to industrial facilities (i.e., facilities with inadequate source controls).

Multiple pollutants found in stormwater (Table 17-2) degrade water quality, a feature of designated critical habitat for all ESA listed salmonids in the freshwater environment, negatively impact ESA-listed fish and marine mammals in both fresh and estuarine areas and affect water quality in EFH in marine, estuarine, and freshwater habitats. Pollutants in stormwater can be transported far from the point of delivery either dissolved in solution, attached to suspended sediments, or through bioaccumulation. Water currents may transport pollutants that are in solution or suspended far downstream to estuaries and the ocean, degrading habitats along the way, including designated

Table 17-2. Pollutants commonly found in stormwater runoff in Washington state.

Pollutant Class	**Examples**	**Urban Sources**
PBT (persistent bio-accumulating toxicants)	POPs (persistent organochlorine pollutants) PCBs (polychlorinated biphenyls) PBDEs (polybrominated diphenyl ethers) PFCs (poly- and per-fluorinated compounds) Pharmaceuticals (estrogen, antidepressant)	Eroding soils, solids, development, redevelopment, vehicles, emissions, industrial, consumer products
Petroleum hydrocarbons	PAHs (poly aromatic hydrocarbons)	Roads (vehicles, tires), industrial, consumer products
Microplastics	6PPD/6PPD-q	Vehicle tires
Metals	Mercury, copper, chromium, nickel, titanium, zinc, arsenic, lead	Roads, electronics, pesticides, paint, waste treatment
Common use pesticides, surfactants	Herbicides (glyphosate, diquat), insecticides, fungicides, adjuvants, surfactants (detergents, soaps)	Roads, railways, lawns, levees, golf courses, parks
Nutrients and sediment	Nitrogen, phosphorus fertilizers, fine-grained inorganic sediment	Fertilizer, soil erosion
Temperature and dissolved oxygen	Warm water, unvegetated exposed surfaces (soil, water, sediments)	Impervious surfaces, rock, soils (roads, parking lots, railways, roofs)
Bacteria	*Escherichia coli*	Livestock waste, organic solids, pet waste, septic tanks

critical habitat. Pollutants bound to solids typically settle on substrates, where some are buried by sedimentation and sequestered to deep sediments away from most aquatic biota. Wind waves, water currents, and changing water levels erode substrates and resuspend contaminated sediments that are then transported farther downstream (Johnson et al. 2005). Sedimentation of contaminated material occurs in habitats with slower currents (wider or deeper sections of channel, reservoir backwaters, coves, and shorelines). In soil, sediments, and water, various metals and changes in oxygen, pH, and temperature can alter toxicity, binding properties, volatility, and degradation patterns and persistence of contaminants (Johnson et al. 2005). Metals especially serve as redox catalysts, chelating or binding other contaminants or eluting them from their bound state. Benthic prey communities can accumulate body load of contaminants from contaminated sediments.

In turn, aquatic organisms including ESA-listed fish and marine mammals may accumulate contaminants by direct contact in water and sediments, ventilation in water, or ingestion of contaminated plankton, invertebrates, detritus, or sediment. The intensity of effects largely depends on the pollutant, its concentration, and the duration of exposure. Pollutants can have individual as well as synergistic and additive effects on exposed species. Responses can range from behavioral changes to injury or to death, depending on the contaminant and concentration.

Stormwater runoff occurs following heavy rainfall or snowmelt over impervious surfaces where post construction, vehicular, and industrial pollutants are picked up, carried, and deposited into aquatic environments (Dressing et al. 2016). Stormwater can discharge at any time of year, with the potential to expose individuals (salmonids, rockfish, SRKW, etc.). Concentration levels and toxicity of chemical mixtures are seasonally influenced. First-flush rain events after long periods without rain that most typically occur in September in western Washington are expected to have extremely high levels of toxic pollutants (Peter et al. 2020). Higher concentrations are also expected to occur between March and October in any given year—as there would be more dry periods during rain events. However, the occurrence of these events would occur with less frequency. In Western Washington, most discharge would occur between October and March, concurrent with when the region receives the most rain. Any action that is reasonably certain to result in increased urbanization and/or commercial development is expected to lead to a general increase in stormwater volume and a decrease in water quality in the surrounding aquatic environments, unless stormwater management and treatment is adequately addressed in the proposed action. . Construction activities that include installing new pollution-generating impervious surface (PGIS) provide a pathway for numerous pollutants from diffuse sources to be mobilized by stormwater runoff and transported to waterways.

It is important to recognize that (a) stormwater runoff and discharge becomes a long-term environmental impact, (b) effects to flow and duration become persistent, and may degrade long-term habitats conditions and functions, and (c) effects to water quality present intermittent/episodic exposures, but also alter and degrade water and sediment quality more permanently, or at least with a signature that persists over long durations (i.e., years and decades).

Urban stormwater is commonly a major contributing factor to water quality impairments throughout Washington (EPA 2020). Urban development alters the natural infiltration of vegetation and soil and generates or collects many diverse pollutants that accumulate on impervious surfaces and compacted and poor soils. Precipitation runs off these surfaces and is quickly drained through a system of conveyances into streams, rivers, and lakes. The hydrologic effects of these alterations and climate change increase erosion and streambank scouring, downstream sedimentation and flooding, and channel simplifications, which can affect aquatic life (Jorgensen et al. 2013; Jonsson et al. 2017).

Contaminants become entrained in stormwater from a variety of sources in the urban landscape. Roads generate a broad range and large load of pollutants that accumulate and run off impervious surfaces into stormwater drains and into streams, rivers, and lakes. Vehicle wear and emissions are primary sources of tire tread particles, metallic particles (particularly copper and chromium); persistent bio-accumulating toxicants (PBTs) from upholstery, plastic, and carpet; and polycyclic aromatic hydrocarbons (PAHs), nickel, and zinc from exhaust and leakage.

Stormwater conveyances are also likely to include common-use herbicides and pesticides, nutrients (nitrogen, phosphorus), silt and sediment, chlorides, metals, petroleum hydrocarbons, livestock fecal matter (bacteria), pharmaceuticals, surfactants (detergents, cleaners, pesticide adjuvants), along with several PBTs and their metabolites. Other pollutants present in water and sediments throughout Washington state include mercury, copper, and other metals; chlorinated pesticides (DDT) and their degradation products (DDD and DDE), polychlorinated dibenzo-p-dioxins and furans, polychlorinated biphenyls (PCBs), polybrominated diphenyl ethers (PBDEs), PAHs, and many others (Hinck et al. 2006; Seiders et al. 2007; Johnson et al. 2006; Johnson et al. 2013a; Alvarez et al. 2014; Counihan et al. 2014; Ecology 2006). Persistent organochlorine pollutants (POPs), some of which were discontinued 15 to 30 years ago and still exceed benchmarks for human health, aquatic life, and fish-eating wildlife in water, bed-sediment, and fish tissue samples in areas such as the Snake and Columbia rivers (Johnson and Norton 2005; Hinck et al. 2006; Seiders et al. 2011; Johnson et al. 2007; Johnson et al. 2013b; Nilsen et al. 2014; Alvarez et al. 2014; Ecology 2021). These common and legacy pollutants are often present regardless of land use within a drainage. Other parameters such as temperature, pH, hardness, and conductivity may also be pollutants or indicators that other pollutants are negatively impacting receiving waters.

17.2.1 Sediment

Sediment introduced into streams can degrade spawning and incubation habitat, and negatively affect primary and secondary productivity. Elevated sediment loads and turbidity may also disrupt feeding and other normal and essential behaviors. Research indicates that chronic exposure can cause physiological stress responses that can increase maintenance energy and reduce feeding and growth (Lloyd et al. 1987; Servizi and Martens 1991). And, a large fraction of the total cumulative toxic load present in stormwater runoff (treated or untreated) is often bound or complexed with or carried by the sediments and sediment fraction (Grant et al. 2003).

Quantifying turbidity levels and their effects on listed fish is complicated by several factors. First, turbidity from an activity will typically decrease as distance from the activity increases. How quickly turbidity levels attenuate within the water column is dependent upon the quantity of materials in suspension (e.g., mass or volume), the particle size of suspended sediments, the amount and velocity of receiving water (dilution factor), and the physical and chemical properties of the sediments. Second, the impact of turbidity on fish is not only related to the turbidity levels, but also the particle size of the suspended sediments. Also, the life stage of the fish at exposure, and water temperature influence the effects that fish will experience.

Effects of suspended sediment, either as turbidity or suspended solids, on fish are well documented (Bash et al. 2001). Suspended sediments can affect fish behavior and physiology and result in stress and reduced survival. Temperature acts synergistically to increase the effect of suspended sediment. The severity of effect of suspended sediment increases as a function of the sediment concentration and exposure time, or dose (Newcombe and Jensen 1996; Bash et al. 2001). Suspended sediments can cause sublethal effects such as elevated blood sugars and cough rates (Servizi and Martens 1991), physiological stress, and reduced growth rates. Elevated turbidity levels can reduce the ability of salmonids to detect prey, cause gill damage (Sigler et al. 1984; Lloyd et al. 1987; Bash et al. 2001), and cause juvenile steelhead to leave rearing areas (Sigler et al. 1984). Additionally, studies indicate that short-term pulses of suspended sediment influence territorial, gill-flaring, and feeding behavior of salmon under laboratory conditions (Berg and Northcote 1985). Also, a potentially positive reported effect is providing refuge and cover from predation, though this circumstance is considered to be limited. Salmonids have evolved in systems that periodically experience short-term pulses (days to weeks) of high suspended sediment loads, often associated with flood events, and are adapted to such high pulse exposures. Adult and larger juvenile salmonids appear to be little affected by the high concentrations of suspended sediments that occur during storm and snowmelt runoff episodes (Bjornn and Reiser 1991).

Fine sediment can also affect food for juvenile salmonids. Embedded gravel and cobble reduce access to microhabitats (Brusven and Prather 1974), entombing and suffocating benthic organisms. When fine sediment is deposited on gravel and cobble, benthic species diversity and densities have been documented to drop significantly (Cordone and Pennoyer 1960; Herbert et al. 1961; Bullard, Jr. 1965; Reed and Elliot 1972; Nuttall and Bilby 1973; Bjornn et al. 1974; Cederholm et al. 1978). Predictive models of egg-to-fry survival in Chinook, coho, chum and steelhead show survival dropping rapidly when percent fines less than 0.85 mm exceeded 10 percent, with coho survival declining more rapidly per unit sediment increase (Jensen et al. 2009).

17.2.2 Metals

Metals, such as copper, zinc, cadmium, or mercury, can have a range of acute and chronic physiological and behavior effects on fish. Recent literature demonstrates that exposure to stormwater pollutants such as petroleum-based hydrocarbons and metals can affect salmonids, with effects ranging from avoidance to mortality depending on the pollutant and its concentration (Feist et al. 2011; Gobel et al. 2007; McIntyre et al. 2012; Meadore et al. 2006; Sandahl et al. 2007; Spromberg et al. 2015). All stormwater discharge is expected to contain concentration levels of constituents and chemical mixtures that are toxic to fish and aquatic life (NMFS 2012, or “Oregon Toxics Opinion”). The Oregon Toxics Opinion concluded that for chronic saltwater criteria for metal compounds, fish exposed to multiple compounds, versus a single compound exposure, are likely to suffer toxicity greater than the assessment effects (e.g., 50 percent mortality) such as mortality, reduced growth, impairment of essential behaviors related to successful rearing and migration, cellular trauma, physiological trauma, and reproductive failure.

There are three known physiological pathways of metal exposure and uptake within salmonids: (1) gill surfaces can uptake metal ions which are then rapidly delivered to biological proteins (Niyogi et al. 2004); (2) olfaction (sense of smell) receptor neurons (Baldwin et al. 2003), and; (3) dietary uptake. Of these three pathways, the mechanism of dietary uptake of metals is least understood. For dissolved metals, the most direct pathway to aquatic organisms is through the gills (Kerwin and Nelson 2000).

Relative toxicity of metals can be altered by hardness, water temperature, pH, suspended solids, and presence of other metals. Water hardness affects the bio-available fraction of metals from gill surfaces; as hardness increases; metals are less bio-available, and therefore less toxic (Kerwin and Nelson 2000; Hansen et al. 2002; Niyogi et al. 2004). However, Baldwin et al. (2003) did not find any influence of water hardness on the inhibiting effect of copper on salmon olfactory functions. Olfactory inhibition can decrease the ability of salmon to recognize and avoid predators and navigate back to natal streams for spawning, resulting in reduced spawning success, and increased predation (Baldwin et al. 2003).

The annual loadings of water quality contaminants from untreated or poorly treated road stormwater runoff can result in sublethal effects that occur sooner and/or more often relative to existing conditions. Exposure to metal mixtures may result in sublethal effects that reduce growth or immune system functions that could persist after Chinook leave their natal streams. Arkoosh et al. (1998) determined that alteration in disease resistance was sustained even after Chinook were removed from the source of pollutants for 2 months (and kept in hatcheries) and concluded that immune alteration in early life stages may persist into early ocean residency of Chinook.

Most published literature concerns the acute toxicity of most metals on an individual basis, though in aquatic receiving bodies most metals typically exist in mixtures, and are known to interact with each other (Niyogi et al. 2004). These mixtures interacting at gill (and olfaction) mediums likely result in adverse effects, and the physiological consequence of metal mixtures is a continuing area of study (Niyogi et al. 2004). However, individual metal concentrations, and some mixture concentrations and combinations have been tested with a variety of *Oncorhynchus* (i.e., Chinook, coho, and rainbow trout), and *Salvelinus* (bull and brook trout) species. Tested endpoints range from lethal to sublethal effects, which include reduced growth, fecundity, avoidance, reduced stamina, and neurophysiological and histological effects on the olfactory system. For example, mixtures containing copper and zinc were found to have greater than additive toxicity to a wide variety of aquatic organisms including freshwater fish (Eisler 1998), and other metal mixtures also yielded greater than additive toxic effects at low dissolved metal concentrations (Playle 2004).

17.2.2.1 Mercury

Sources of mercury are diverse and include natural emissions and weathering of metallic ores, human activities (mining, emissions from the burning and refining of coal and petroleum fuels, paper mills, cement production), and consumer products (thermostats, automotive switches, fluorescent lights, and dental fillings (Ecology 2021). Air emissions from industrial activities are by far the major source of mercury in most locations. Mercury is a common stormwater contaminant (EPA 2020). Mercury contaminates aquatic habitats and food webs, including rearing and migrating salmonids in the action area. Mercury concentrations in resident fish exceed Washington's water quality criteria for human health concentrations in the action area (Ecology 2021). All forms of mercury are toxic to fish, invertebrates, other animals, and humans (Eisler 1987; Broussard et al. 2002). Mercury ions produce toxic effects by protein precipitation, enzyme inhibition, and generalized corrosive action (Broussard et al. 2002).

Mercury is a mutagen, teratogen, and carcinogen, and causes embryocidal, cytochemical, and histopathological effects (Eisler 1987). Significant adverse sub-lethal effects for sensitive aquatic species are observed at 0.03-0.1 μg/L and water quality criteria of 0.012 μg/L provide only limited protection (Eisler 1987; NMFS 2014a). Mercury species are transformed by organic and inorganic processes to methylmercury (MeHg), which bio-accumulates throughout aquatic food webs and biomagnifies through trophic levels. Bettaso and Goodman (2010) found that lamprey ammocetes, which filter-feed from burrows in contact with sediments and ingest more benthos-dependent prey, bio-accumulated 12-25 times greater concentrations of mercury in their bodies than did mussels, which feed from water columns. In reservoir habitats of the action area, juvenile salmonids ingest large numbers of benthic invertebrates. Smaller fish tend to ingest smaller invertebrates, which may accumulate higher concentrations of metals (Farag et al. 1998). Daily feeding on potentially contaminated invertebrates, long migrations, depleted lipid stores, and bursts of energy to escape predators, increase ventilation and growth. Together, these factors increase bioaccumulation rates and adverse effects to juvenile salmonids.

17.2.2.2 Copper

Copper from automobiles is one of the most common heavy metals contaminating stormwater, especially stormwater originating from parking lots. Copper is highly toxic to aquatic biota and ESA-listed salmon and steelhead can experience a variety of acute and chronic lethal and sub-lethal effects (NMFS 2014a). Copper bio-accumulates in invertebrates and fish (Feist et al. 2005; Layshock et al. 2021), is redox-active, and interacts with or alters many compounds in mixtures (Gauthier et al. 2015). Copper-PAH mixtures, which synergistically interact are highly toxic through several exacerbating mechanisms: copper weakens cell membranes increasing absorption of PAHs, copper chelates or hastens and preserves the bio-accumulative toxicity of PAHs; and PAHs in turn increase the bio-accumulative and redox properties of Copper (Gauthier et al. 2015). Sub-lethal effects of copper include avoidance at very low concentrations (Hecht et al. 2007) and reduced chemosensory function at slightly higher concentrations, which in turn causes maladaptive behaviors, including inability to avoid copper or to detect chemical alarm signals (McIntyre et al. 2012). Sandahl et al. (2007) demonstrated that copper concentration as low as 2 micrograms/liter can significantly impair the olfactory system of salmonids and hinder their predator avoidance behavior. Thus any fish that are exposed to stormwater containing high concentrations of copper may experience diminishment of predator avoidance ability and would be at greater risk of predation. Appreciable adverse effects can be expected with increases as small as 0.6 μg/L above background concentrations (NMFS 2014a).

Copper concentrations typically increase during spring-summer high flows when migrating juvenile salmonids are most actively feeding and growing at greatest rates (NMFS 2014a). Copper toxicity increases significantly during conditions of low calcium carbonate ($CaCO_3$), low pH, and low DOC (NMFS 2014a). Survival of juvenile salmon and steelhead, particularly during migration, is strongly size and season dependent (Mebane and Arthaud 2010). Small reductions in size and slower growth may slow or delay migration and will result in disproportionately larger reductions in survival during migration and entry into saltwater (Tattam et al. 2013, Thompson and Beauchamp 2014).

17.2.2.3 Chromium

Sources of chromium include phosphate fertilizers, chrome plating, paper mills, sewage, and solid wastes from the disposal of consumer products and chromium is a common pollutant found in stormwater UAs and along roadways (Eisler 1986a; Tables 8 and 13). While the pure metallic form is absent naturally, it is commonly found in three oxidation states: Cr II, Cr III, and Cr VI (Bakshi and Panigrahi 2018). Chromium is a redox-active metal, causing oxidative stress and oxidative-induced alterations of DNA in fish and other aquatic organisms (Eisler 1986a; Sevcikova et al. 2011). Hook et al. (2006) found that Cr VI caused oxidative stress in rainbow trout. Toxicity and uptake of Cr VI increases when pH is 7.8 or lower, low DOC, and low hardness (Vanderputte et al. 1981; Eisler 1986a). Comprehensive reviews show that chromium is taken up by fish and aquatic organisms through the gastrointestinal tract, respiratory tract, and skin (Eisler 1986a; Farag et al. 2006; Sevcikova et al. 2011; Bakshi and Panigrahi 2018). Dietary uptake of Cr VI may cause chronic sub-lethal toxicity in juvenile salmonids and is likely to increase the toxic and absorptive properties of PBTs and other metals.

17.2.2.4 Zinc

Major sources of zinc include electroplaters, smelting and ore processors, mine drainage, domestic and industrial sewage, combustion of solid wastes and fossil fuels, road surface runoff (vehicle emissions, motor oils, lubricants, tires, and fuel oils), corrosion of zinc alloys and galvanized surfaces, and erosion of agricultural soils (Eisler 1993). Several species of zinc are highly mobile in aquatic environments, are often transported many miles downstream, and eventually load to sediments. Zinc interacts with many chemicals and aquatic conditions of reduced pH and dissolved oxygen, low DOC, and elevated temperatures increase zinc toxicity, causing altered patterns of accumulation, metabolism, and toxicity (Eisler 1993; Farag et al. 1998). Many aquatic invertebrates and some fish may be adversely affected from ingesting zinc-contaminated particulates (Farag et al. 1998). In freshwater fish, excess zinc affects the gill epithelium, which leads to internal tissue hypoxia, reduced immunity, and may acutely include osmoregulatory failure, acidosis, and low oxygen tensions in arterial blood (Eisler 1993). Toxicity of zinc mixtures with other metals is mostly additive; however, toxicity of zinc-copper mixtures is more than additive (or synergistic) for freshwater fish and amphipods (Skidmore 1964; de March 1988).

17.2.2.5 Titanium

Consumer products using bulk and nanoparticles of titanium dioxide (TiO2) are increasing worldwide in paints, pigments, varnishes, plastics, sewage treatment, among others (Sharma and Agrawal 2005; Nunes et al. 2018). Recent research finds that nanoparticles in freshwater and saltwater continually aggregate into larger micro-particles and bind with high affinity to mixtures of metals and other contaminants (Nunes et al. 2018). Titanium dioxide nanoparticles physically cling to fish gills, causing some physical injuries (oedema and thickening of lamellae) that may reduce efficiency of gas exchange and significantly decrease the proportion of time rainbow trout spent swimming at high speed (Boyle et al. 2013). When rainbow trout were exposed to high concentrations, titanium oxide caused oxidative stress, disrupted signal transducing in gills and intestine, decreased intracellular calcium, altered homeostasis and resting potential, changed tissue copper and zinc levels, and may decrease enzyme activity in the brain (Federici et al. 2007). TiO2 nanoparticles physically fill or clog digestive tracts of some aquatic invertebrates causing increased feeding rates and reduced digestion, which increases oxidative stress and may lead to lethality (Das et al. 2013). Large loads of TiO2 at high concentrations are likely to kill and contaminate prey (e.g., amphipods), cause chronic sub-lethal toxicity in juvenile and adult salmonids, and increase toxic and absorptive properties of PBTs and other metals.

17.2.2.6 Nickel

Sources of nickel in urban areas and highways include metal emissions from tires, petroleum combustion, household waste, and fertilizers (Sharma and Agrawal 2005). Nickel is a redox-active metal (Gauthier et al 2015) that can interact with other metals and PBTs to increase toxicity, oxidative stress, and immune defense depletion in fish and invertebrate prey (Eisler 1985, 1998; Stohs and Bagchi 1995; Sevicikova et al. 2011; Palermo et al. 2015). Stormwater discharges of nickel will degrade water and sediment quality and can reduce and contaminate prey and cause sub-lethal toxicity in juvenile salmonids and increase toxic and absorptive properties of PBTs and other metals in the aquatic environment.

17.2.3 Persistent Bioaccumulative Toxicants (PBTs)

A large fraction of the total cumulative toxic load present in stormwater runoff (treated or untreated) is often bound or complexed with, or carried by the sediments and sediment fraction (Grant et al. 2003). Lipophilic chemicals such as PCB's, PBDE's, or PAH's tend to bioaccumulate in the tissues of organisms, particularly those at the top of trophic food chains such as salmonids and SRKW's. Increased levels of PAHs, oils, and other contaminants would be widely dispersed, and can have detrimental effects at very low levels of exposure either directly or indirectly through the consumption of contaminated prey or exposure to contaminants in the water column. This would impair the value of critical habitat for growth and maturation of each of the listed species. As the concentration of these constituents increases in the environment the likelihood that organisms such as SRKW's are harboring dangerous chemical loads increase concurrently. Environmental and biological accumulation of these chemicals can result in adverse long-term ecosystem impacts including altering species behavior, reproduction, and growth.

PBTs are an expansive grouping (WAC 2021) of chemical compounds (and some metals) that may persist several years while maintaining high toxicity, often move readily among air, water, sediment, and food webs, and may bioaccumulate in listed salmonids and other fish from exposure to water, sediments, and from their diet of zooplankton, invertebrates, and other fish. PBTs often bind to sediments and are typically found in diverse mixtures in aquatic environments along with a broad range of pesticides, nutrients, metals, and PAHs (Johnson et al. 2006; Laetz et al. 2009; Baldwin et al. 2009; Johnson et al. 2013a). PBTs include POPs (persistent organochlorine pollutants) as described by Sloan et al. (2010), which include PCB congeners, PBDE congeners, DDT and metabolites, dioxins and furans, other organochlorinated compounds, and pesticides (hexachlorocyclohexane, hexachlorobenzene, chlordanes, aldrin, dieldrin, mirex, and endosulfan I).

PBTs typically include similar modes of toxicity and are often carcinogens, endocrine and reproductive disruptors, and transgenerational disruptors. PBTs may cause neurological and developmental disorders, oxidative stress, weakened immune systems, and may cause mortality of invertebrates and fish in aquatic ecosystems (Soto et al. 1994; Major et al. 2020; Ecology 2021). PBTs are often found in mixtures together with a broad range of PAHs and metals, to which PBTs readily bind and interact; often-increasing toxicity and mobility. The following PBTs are expected to have these generally similar effects and are likely to be present in the state of Washington depending on current and legacy land use.

17.2.3.1 Persistent Organochlorine Pollutants (POPs)

A large fraction of the total cumulative toxic load present in stormwater runoff (treated or untreated) is often bound or complexed with, or carried by the sediments and sediment fraction (Grant et al. 2003). POPs include organochlorinated pesticides and metabolites (DDT, DDE), toxaphene, dieldrin, and other DDT-like compounds, and polychlorinated dibenzo-p-dioxins and furans. Some POPs that were discontinued 15 to 30 years ago continue to be reported at toxic concentrations in fish (Johnson et al. 2013a and 2013b). DDT, toxaphene, and dieldrin are major agricultural insecticides that were often used on cereal grains and fruit orchards, in mosquito abatement programs, and to kill fish in ponds (Eisler 1970; Ecology 2021). Most POPs are likely to enter stormwater from wind and water erosion or construction disturbance of legacy-contaminated soils. Some POPs are volatile and often deposit in the atmosphere where they are highly mobile and are likely to settle on impervious surfaces and enter stormwater drainage systems. Dioxins and furans are most likely to be absorbed to particulate matter when entering stormwater. Common sources are air emissions from regional forest fires and from trash burning and stack emissions from industries in and around the Lewiston UA. Construction activities or erosion of soils may disturb recent or legacy deposits of POPs that become entrained in stormwater runoff and drain into receiving waters and sediments.

17.2.3.2 Polychlorinated Biphenyls (PCBs)

A large fraction of the total cumulative toxic load present in stormwater runoff (treated or untreated) is often bound or complexed with, or carried by the sediments and sediment fraction (Grant et al. 2003). PCBs are very persistent and are found in over 209 synthetic compounds, typically occurring in complex mixtures. Sources include food packaging, electronic transformers and capacitors, plasticizers, wax and pesticide extenders, lubricants, inks and dyes, and legacy sealants (Ecology 2021) and are likely to occur in stormwater runoff that is discharged into receiving waters. PCB concentrations in resident fish often exceed Washington's water quality criteria for human health concentrations (Ecology 2021).

17.2.3.3 Polybrominated Diphenyl Ethers (PBDEs)

PBDEs are flame retardants added to foam, plastics, and textiles, and are often found in car seats, electronics, building insulation, and older upholstered furniture and mattresses (Ecology 2021; Eisler 1986b). Studies show PBDEs have been spreading from these common items in UAs and roadways and entering stormwater that partitions to biota and sediments in receiving waters (Hites 2004; Ecology 2021; Stone 2006). PBDEs are rapidly increasing in the environment, doubling every 2-5 years (Ecology 2021) and other pollutants (nutrients and other wastewater contents; O'Neill et al. 2020) increase their toxicity. Salmon ingest contaminated terrestrial and aquatic prey in the action area and assimilate some PBDE congeners throughout life (Stone 2006; Arkoosh et al. 2017). Even low concentrations of some PBDEs cause sub-lethal effects in salmonids such as alteration of thyroid hormone levels or thyroid function and neurological disorders (Sloan et al. 2010). Arkoosh et al. (2017) found thyroid hormone concentrations were altered in juvenile Chinook salmon when fed environmentally relevant concentrations of some PBDE congeners for 5-40 days. Most migrating Chinook salmon smolts spend at least five days and as long as several weeks or months rearing in freshwater before migrating to the marine waters of the Puget Sound or the ocean. This exposure is likely to cause sub-lethal disruption of thyroid hormones that impact critical functions salmonids require for growth, smolting, and migration (Iwata 1995).

17.2.4 Polycyclic Aromatic Hydrocarbons (PAHs)

A large fraction of the total cumulative toxic load present in stormwater runoff (treated or untreated) is often bound or complexed with or carried by the sediments and sediment fraction (Grant et al. 2003). Petroleum-based contaminants are usually in the form of two or more condensed aromatic carbon rings, include more than 100 different chemicals, and usually occur as complex mixtures in the environment. Major human-related sources released to the environment are from wood stoves, creosote treated wood, and vehicle emissions, plastics including tire wear particles, improper motor oil disposal, leaks, and asphalt sealants (Ecology 2021). PAHs are lipophilic, persistent, interact synergistically with bio-accumulative and redox-active metals and other contaminants, and may disperse long-distances in water (Gauthier et al. 2014, 2015; Arkoosh et al. 2011; Ecology 2021). Metabolites are commonly more toxic than the parent, some are carcinogenic, neurotoxic, and cause genetic damage. Although biotransformation of PAHs causes oxidative stress with subsequent cellular damage and increased energy is required at the cost of growth, many organisms (including salmon) can eliminate at least the lower density PAHs from their bodies as part of metabolism and excretion (Arkoosh et al. 2011). However, plants and some aquatic organisms, such as mussels and lamprey, have limited ability to metabolize or degrade PAHs, which may bioaccumulate over several years (Tian et al. 2019; Nilsen et al. 2015). PAHs and metabolites are acutely toxic to salmonids and may cause narcosis at low levels of exposure, can in some cases bioaccumulate through food webs (water, groundwater, soil, and plants; Bravo et al. 2011; Zhang et al. 2017), and can also cause chronic sub-lethal effects to aquatic organisms at very low levels (Neff 1985; Varanasi et al. 1985; Meador et al. 1995). PAHs can affect DNA within the nucleus of cells, cause genetic damage, and are classified as carcinogens (Collier et al. 2014).

17.2.5 Microplastics

Microplastics (MPs) are generally found in higher numbers near urbanized areas. Campanale et al. (2020) detailed sources of MPs were mostly from electrical and electronics, building and construction, transport, and textiles. Brahney et al. (2021) found that stormwater runoff from roads in urbanized areas in the western U.S. produced 84 percent of MPs compared to the remainder of urbanized areas, which produced only 0.4 percent. Agricultural runoff produced five percent of MPs and 11 percent were legacy MPs from the ocean. City roads produced fewer MPs in stormwater because surrounding buildings and trees reduced wind and dust and because vehicles emit fewer microplastics (tire tread particles) at slow speeds. Highways and roads with higher speed limits and increased exposure produced vastly more MPs, because vehicles produce their own buffeting winds and tire tread wears at much greater rates (Brahney et al. 2021). Ingested MPs can interfere with food capture and digestion, particularly for benthic filter feeders, leading to decreased feeding, oxidative stress, or mortality of sensitive aquatic invertebrates and fish (Kapp and Yeatman 2018). MPs are infused with PBT additives and when released to aquatic environments strongly attract other PBTs, PAHs, and metals (especially copper and zinc). Some MPs sink to sediments and others are transported long distances downstream, including through and over dams (Rochman et al. 2013; Wang et al. 2018; Campanale et al. 2020). MPs are also transported into the ocean and can carry PBTs and several metals (Rochman et al. 2014). Many MPs eventually enter the hydrologic cycle to be re-deposited throughout the western U.S. (Brahney et al. 2021). Mounting evidence shows MPs bioaccumulate in benthic invertebrates (e.g., amphipods, prawns) (Campanale et al. 2020), which are primary food sources for juvenile salmonids. Some MPs in fish, breakdown into smaller particles that can enter the circulatory system and bioaccumulate to higher trophic predators (Wang et al. 2018). PBTs and other contaminants leach from the MPs and bioaccumulate in tissues (Rochman et al. 2013; Campanale et al. 2020).

After years of forensic investigation, the urban runoff coho mortality syndrome has now been directly linked to motor vehicle tires, which deposit the compound 6PPD and its abiotic transformation product 6PPD-quinone (6PPD-q) onto roads. 6PPD or [(N-(1, 3-dimethylbutyl)-N'-phenyl-p-phenylenediamine] is used to preserve the elasticity of tires. 6PPD can transform in the presence of ozone (O3) to 6PPD-q. 6PPD-q is ubiquitous to roadways (Sutton et al. 2019) and was identified by Tian et al. (2020) as the primary cause of urban runoff coho mortality syndrome described by Scholz et al. (2011). Laboratory studies have demonstrated that juvenile coho salmon (Chow et al. 2019), juvenile steelhead, and juvenile Chinook salmon (NMFS, unpublished results, 2020) are also susceptible to varying degrees of mortality when exposed to urban stormwater. Fortunately, recent literature has also shown that mortality can be prevented by infiltrating road runoff through soil media containing organic matter, which removes 6PPD-q and other contaminants (Fardel et al. 2020; Spromberg et al. 2016; McIntrye et al. 2015). Research and corresponding adaptive management surrounding 6PPD is rapidly evolving. Nevertheless, key findings to date include:

- 6PPD/6PPD-quinone has been killing coho in Puget Sound urban streams for decades, dating back to at least the 1980s, likely longer (McCarthy et al. 2008; Scholz et al. 2011)

- Wild coho populations in Puget Sound are at a very high risk of localized extinction, based on field observations of adult spawner mortality in > 50 spawning reach stream segments (Spromberg and Scholz 2011).

- Source-sink metapopulation dynamics (mediated by straying) are likely to place a significant drag on the future abundances of wild coho salmon in upland forested watersheds (the last best places for coho conservation in Puget Sound). In other words, urban mortality syndrome experienced in one part of the watershed could lead to abundance reductions in other populations because fewer fish are available to stray (Spromberg and Scholz 2011)

- Coho are extremely sensitive to 6PPD-q, more so than most other known contaminants in stormwater (Scholz et al. 2011; Chow 2019; Tian 2020).

- Coho juveniles appear to be similarly susceptible to the acutely lethal toxicity of 6PPD/6PPD-q (McIntyre et al. 2015; Chow 2019).

- The onset of mortality is very rapid in coho (i.e., within the duration of a typical runoff event) (NWFSC unpublished data).

- Once coho become symptomatic, they do not recover, even when returned to clean water (Chow 2019)

- It does not appear that dilution will be the solution to 6PPD pollution, as diluting Puget Sound roadway runoff in 95% clean water is not sufficient to protect coho from the mortality syndrome (NWFSC unpublished data).

- Preliminary evidence indicates an uneven vulnerability across other species of Puget Sound salmon and steelhead, and a need to further investigate sublethal toxicity to steelhead and Chinook. For example, McIntyre et al. (2018) indicate that chum do not experience the lethal response to stormwater observed in coho salmon.

- Following exposure the onset of mortality is more delayed in steelhead and Chinook salmon (NWFSC unpublished data).

- The mechanisms underlying mortality in salmonids is under investigation, but are likely to involve cardiorespiratory disruption, consistent with symptomology. Therefore, special consideration should be given to parallel stressors that also affect the salmon gill and heart, and which nearly always co-occur with 6PPD such as elevated temperature, reduced dissolved oxygen (as a proxy for climate change impacts at the salmon population-scale) and PAHs.

- Simple and inexpensive green infrastructure mitigation methods are promising in terms of the protections they afford salmon and stream invertebrates, but much more work is needed (McIntyre 2014, 2015, 2016a and b; Spromberg et al. 2016).

- The long-term viability of salmon and other Puget Sound aquatic species is the foremost conservation management concern for NOAA, and thus it will be important to incorporate effectiveness monitoring into future mitigation efforts – i.e., evaluating proposed stormwater treatments not only on chemical loading reductions, but also the environmental health of salmon and other species in receiving waters (Scholz et al. 2011).

WSDOT acknowledges the emerging research related to urban runoff mortality syndrome caused by 6PPD-quinone. FHWA, WSDOT, and Ecology are closely tracking efforts to gather critical additional information on this topic, such as 6PPD-quinone's fate and transport in the environment, concentration thresholds for acute and sublethal toxicity and the extent of potential effects on other salmonids. Currently, what is known about 6PPD-quinone is it is a ubiquitous chemical in tires that is introduced to streams in road runoff. Effective treatment occurs from applying bioinfiltration techniques using compost. Not much else is known about BMP efficacy for this pollutant's removal.

17.2.6 Pesticides and Nutrients

Pesticides and fertilizers are ubiquitous in urbanized areas and are applied annually on lawns, pastures, orchards, and other interspersed agricultural lands (Gilliom et al. 2006; Gilliom 2007). Terrestrial pesticides, adjuvants, and fertilizers can be highly persistent and toxic upon entering aquatic environments, causing acute and chronic effects to salmonids and their invertebrate prey (Scholtz et al. 2012). Glyphosate-based-herbicides (e.g., Roundup) are mostly likely to runoff of roads and railways (Botta et al. 2009), riprap and levees, and areas of limited and poor soil with intensive vegetation control (Kjaer et al. 2011). Highest concentrations (75-90 µg/L) of glyphosate in streams are commonly from urban sewers during storms (Botta et al. 2009) and were concentrated in soil, sediments, and solid matter (Primost et al. 2017), even as water levels remained low. Effective vegetation removal by herbicides increases erosion of soil that may contain legacy POPs and mercury (Jonsson et al. 2017). Glyphosate and other contaminants in biofilms of wetlands can be 2-3 orders of magnitude higher than surrounding water and represent concentrated exposures to higher trophic levels (Beecraft and Rooney 2021). Commonly used terrestrial herbicide formulations and adjuvants may include bio-accumulating metals and PAHs, which are added to enhance performance and increase toxicity of active ingredients (Defarge et al. 2018). Additives are often labeled as proprietary "inert" ingredients but consist primarily of petroleum-based oxidized molecules and trace metals (arsenic, chromium, cobalt, lead, nickel, and others), which accumulate in soils, organic solids, sediments, and biofilms. Glyphosate significantly increases the bio-accumulation of mercury in zooplankton (Tsui et al. 2005). Mammals, mussels, amphibians, several insects, and many aquatic invertebrates are sensitive to sub-lethal and lethal toxicity of several pesticides, including glyphosate-based herbicides and their surfactants (Bringolf et al. 2007; Relyea and Diecks 2008; Janssens and Stoks 2017; Motta et al. 2018; Scully-Engelmeyer et al. 2021). Some pesticides are endocrine disruptors and may include transgenerational effects (Kubsad et al. 2019; Major et al. 2020). Pulses and cumulative loads of common-use herbicides and other biocides are likely to reduce and contaminate prey, cause acute and chronic sub-lethal toxicity in juvenile and adult salmonids, and increase toxic and absorptive properties of PBTs and metals.

Stormwater discharges of nutrients (nitrogen, nitrite, nitrate, phosphorus) and sediment contribute to the impairment of aquatic ecosystems throughout Washington. Water and sediment quality impairments from siltation and excessive nutrients degrade spawning and rearing habitat by clogging substrates, reducing interstitial oxygen required by incubating eggs, and altering and reducing cover. Nitrite and nitrate can also be toxic to fish. Davidson et al. (2014) found nitrate concentrations of 80-100 mg/L were related to increased mortality and other chronic health impacts (abnormal swimming behavior) in juvenile rainbow trout. Nutrients from agriculture and wastewater may increase toxicity of PBTs to juvenile Chinook salmon (O'Neill et al. 2020). Chronic exposure by fathead minnows to environmentally relevant nitrate levels may cause endocrine disruption, alter steroid hormone synthesis and metabolism in male and female fish, and may include transgenerational effects (Kellock et al. 2018). Sediment and nutrient loads are likely to reduce and contaminate prey and cause chronic lethal and sub-lethal toxicity in incubating eggs and juvenile steelhead.

17.2.7 Fate and Transport

Pollutants travel long distances when in solution, adsorbed to suspended particles, or else they are retained in sediments, particularly clay and silt, which can only be deposited in areas of reduced water velocity until they are mobilized and transported by future sediment moving flows (Alpers et al. 2000a; Alpers et al. 2000b; Anderson et al. 1996); A large fraction of the total cumulative toxic load present in stormwater runoff (treated or untreated) is often bound or complexed with, or carried by the sediments and sediment fraction (Grant et al. 2003).

Santore et al. (2001) indicates that the presence of natural organic matter and changes in pH and hardness affect the potential for toxicity (both increase and decrease). Additionally, organics (living and dead) can adsorb and absorb other pollutants such as PAHs. The variables of organic decay further complicate the path and cycle of pollutants. The fate and transport of many pollutants, including 6PPD-quinone, are not known or poorly understood.

The following brief summaries from toxicological profiles (ATSDR 1995; ATSDR 2004a; ATSDR 2004b; ATSDR 2005; ATSDR 2007) provide examples of how the environmental fate of each contaminant and the subsequent exposure of listed species and critical habitats varies widely, depending on the transport and partitioning mechanisms affecting that contaminant, and the impossibility of linking a particular discharge to specific water body impairment (NRC 2009):

17.2.7.1 DDT

DDT and its metabolites, dichlorodiphenyldichloroethylene (DDE) and dichlorodiphenyltrichloroethane (DDD) (all collectively referred to as DDx) may be transported from one medium to another by the processes of solubilization, adsorption, remobilization, bioaccumulation, and volatilization. In addition, DDx can be transported within a medium by currents, wind, and diffusion. These chemicals are only slightly soluble in water, therefore loss of these compounds in runoff is primarily due to transport of particulate matter to which these compounds are bound. For example, DDx have been found to fractionate and concentrate on the organic material that is transported with the clay fraction of the wash load in runoff. Sediment is the sink for DDx released into water where it can remain available for ingestion by organisms, such as bottom feeders, for many years.

17.2.7.2 PAH

The environmental fate of each type of PAH depends on its molecular weight. In surface water, PAHs can volatilize, photolyze, oxidize, biodegrade, bind to suspended particles or sediments, or accumulate in aquatic organisms, with bioconcentration factors often in the 10-10,000 range. In sediments, PAHs can biodegrade or accumulate in aquatic organisms or non-living organic matter. Most do not easily dissolve in water. Some evaporate into the air from surface waters, but most stick to solid particles and settle into sediments. Changes in pH and hardness may increase or decrease the toxicity of PAHs, and the variables of organic decay further complicate their environmental pathway (Santore et al. 2001).

17.2.7.3 PCB

PCBs are globally transported and present in all media. Atmospheric transport is the most important mechanism for global dispersion of PCBs. PCBs are physically removed from the atmosphere by wet deposition (i.e., rain and snow scavenging of vapors and aerosols); by dry deposition of aerosols; and by vapor adsorption at the air-water, air-soil, and air-plant interfaces. The dominant source of PCBs to surface waters is atmospheric deposition; however, redissolution of sediment-bound PCBs also accounts for water concentrations. PCBs in water are transported by diffusion and currents. PCBs are removed from the water column by sorption to suspended solids and sediments as well as from volatilization from water surfaces. Higher chlorinated congeners are more likely to sorb, while lower chlorinated congeners are more likely to volatilize. PCBs also leave the water column by concentrating in biota. PCBs accumulate more in higher trophic levels through the consumption of contaminated food.

17.2.7.4 Copper

Due to analytical limitations, investigators rarely identify the form of a metal present in the environment. Nonetheless, much of the copper discharged into waterways is in particulate matter that settles out. In the water column and in sediments, copper adsorbs to organic matter, hydrous iron and manganese oxides, and clay. In the water column, a significant fraction of the copper is adsorbed within the first hour of introduction, and in most cases, equilibrium is obtained within 24 hours.

17.2.7.5 Zinc

For zinc, sorption onto hydrous iron and manganese oxides, clay minerals, and organic material is the dominant reaction, resulting in the enrichment of zinc in suspended and bed sediments. The efficiency of these materials in removing zinc from solution varies according to their concentrations, pH, redox potential, salinity, nature and concentrations of complexing ligands, cation exchange capacity, and the concentration of zinc. Precipitation of soluble zinc compounds appears to be significant only under reducing conditions in highly polluted water.

In western Washington, a quantitative model has been developed for analyzing project-specific water quality impacts; the *Highway Runoff Dilution and Loading Model* (HI-RUN). The HI-RUN model provides a risk-based tool for evaluating zinc, copper, and total suspended solid loads, effluent concentrations, and mixing or dilution. These can, in turn, be used to assess exposures and potential effects on listed species and their habitats. HI-RUN results may suggest qualitative changes in overall pollutant loadings, but provides quantitative results only for zinc, copper, and total suspended solids.

17.2.7.6 Lead

A significant fraction of lead carried by river water occurs in an undissolved form, which can consist of colloidal particles or larger undissolved particles of lead carbonate, lead oxide, lead hydroxide, or other lead compounds incorporated in other components of surface particulate matter from runoff. Lead may occur either adsorbed ions or surface coatings on sediment mineral particles, or it may be carried as a part of suspended living or nonliving organic matter in water. The ratio of lead in suspended solids to lead in dissolved form has been found to vary from 4:1 in rural streams to 27:1 in urban streams. Sorption of lead to polar particulate matter in freshwater and estuarine environments is an important process for the removal of lead from these surface waters.

17.2.8 Effects on ESA-Listed Species, Designated Critical Habitat, and Essential Fish Habitat

Stormwater runoff is certain to continue to deliver toxic and potentially lethal contaminants from urban and rural areas if left untreated. Because the effectiveness of treatment methods on multiple pollutants is unknown, treated stormwater is also assumed to result in adverse effects to ESA-listed salmonids and SRKW prey species and their habitats. Depending on the project location marine species present in the Puget Sound may also be affected. It can be expected that EFH will be affected similarly.

The incremental addition of small amounts of these pollutants over time are a source of adverse effects to salmon, steelhead, rockfish, and SRKW prey. Adverse effects occur even when the source load cannot be distinguished from ambient levels because many pollutants bioaccumulate in the tissues of aquatic organisms and in benthic sediments. Contaminants accumulate in both the tissues and prey of salmon and steelhead and can cause a variety of lethal and sublethal effects (Hecht et al. 2007). Repeated and chronic exposures, even at very low levels, are likely to injure or kill individual fish, by themselves and through synergistic interactions with other contaminants already present in the water (Baldwin et al. 2009; Feist et al. 2011; Hicken et al. 2011; Spromberg and Meador 2006; Spromberg and Scholz 2011). Because contaminants accumulate in the tissues of salmon and steelhead, SRKW are also exposed as they feed on PS Chinook salmon and steelhead (to a lesser degree). Other ESA-listed species in the Puget Sound such as Puget Sound Georgia Basin (PS/GB) bocaccio, PS/GB yelloweye rockfish, southern DPS green sturgeon, Pacific Eulachon, or humpback whales may also be exposed as chemicals are transported to and accumulate in the estuarine and marine environments.

Lipophilic chemicals such as PCB's, PBDE's, or PAH's tend to bioaccumulate in the tissues of organisms, particularly those at the top of trophic food chains such as salmonids and SRKW's. Increased levels of PAHs, oils, and other contaminants would be widely dispersed, and can have detrimental effects at very low levels of exposure either directly or indirectly through the consumption of contaminated prey or exposure to contaminants in the water column. This would impair the value of critical habitat for growth and maturation of each of the listed species. As the concentration of these constituents increases in the environment the likelihood that organisms such as SRKW's are harboring dangerous chemical loads increase concurrently. Environmental and biological accumulation of these chemicals can result in adverse long-term ecosystem impacts including altering species behavior, reproduction, and growth.

In an examination of effect on juvenile salmon, McIntyre et al (2015) exposed sub yearling coho salmon to urban stormwater. One hundred percent of the juveniles exposed to untreated highway runoff died within 12 hours of exposure. McIntyre et al (2018) later examined the pre-spawn mortality rate of coho salmon exposed to urban stormwater runoff. In their experiments one hundred percent of coho salmon exposed to stormwater mixtures expressed abnormal behavior (lethargy, surface respiration, loss of equilibrium, and immobility) within 2 to 6 hours after exposure. Recent studies have shown that coho salmon show high rates of pre-spawning mortality when exposed to chemicals that leach from tires (McIntyre et al. 2015). Researchers have recently identified a tire rubber antioxidant (6PPD-quinone) as the cause (Tian et al. 2020), and dilution does not appear to reduce toxicity. Although Chinook and steelhead did not experience the same level of mortality, tire leachate is still a health concern for all salmonids. Traffic residue also contains many unregulated toxic chemicals such as pharmaceuticals, PAHs, fire retardants, and emissions that have been linked to deformities, injury and/or death of salmonids and other fish (Trudeau 2017; Young et al. 2018).

Several large classes of nearly ubiquitous environmental pollutants, including certain PAHs, PCBs, and dioxins are known to be cardiotoxic to fish early life stages. Tricyclic PAHs derived from a wide variety of environmental sources can initiate several cardiotoxicity-based adverse outcome pathways (AOPs), and these have been characterized in a variety of laboratory and wild fish species. These effects range from outright embryonic heart failure and mortality at relative high PAH exposures (Adams et al., 2014a,b; Esbaugh et al., 2016; Incardona et al., 2014, 2013; Jung et al., 2013, 2015; Madison et al., 2015; Martin et al., 2014; McIntyre et al., 2016a,b; Sørhus et al., 2015), to more subtle effects on heart shape and delayed impacts on cardiovascular performance at lower concentrations (Hicken et al., 2011; Incardona et al., 2015). These latter, protracted physiological impacts likely contributed to the delayed mortality and poor population recruitment previously observed both in (1) mark-recapture studies with pink salmon exposed to crude oil during embryogenesis (Heintz, 2007; Heintz et al., 2000) and (2) the losses of wild pink salmon spawned in shoreline habitats that were oiled in the aftermath of the 1989 Exxon Valdez disaster (Rice et al., 2001; Incardona and Scholz 2016)

Water quality supports SRKW's ability to forage, grow, and reproduce free from disease and impairment. Water quality is essential to the whales' conservation, given the whales' present contamination levels, small population numbers, increased extinction risk caused by any additional mortalities, and geographic range (and range of their primary prey) that includes highly populated and industrialized areas. Water quality is especially important in high-use areas where foraging behaviors occur and contaminants can enter the food chain. Water quality impaired by contaminants can inhibit reproduction, impair immune function, result in mortality, or otherwise impede the growth and the species' recovery.

SRKW can be exposed to contaminants directly (e.g. oil spills), or indirectly when their prey are contaminated through their own exposure to reduced water quality. These harmful pollutants, through consumption of contaminated prey species, are stored in the killer whale's blubber. Pollutants are redistributed to other tissues when the whales metabolize the blubber in response to food shortages or reduced acquisition of food energy that could occur for a variety of other reasons. The release of pollutants can also occur during gestation or lactation. Once the pollutants mobilize into circulation, they have the potential to cause a toxic response. Therefore, nutritional stress from reduced Chinook salmon populations may act synergistically with high pollutant levels in Southern Residents and result in adverse health effects.

Various adverse health effects in multiple species have been associated with exposures to persistent pollutants. These pollutants have the ability to cause endocrine disruption, reproductive disruption or failure, immunotoxicity, neurotoxicity, neurobehavioral disruption, and cancer (Reijnders 1986, de Swart et al. 1996, Subramanian et al. 1987, de Boer et al. 2000; Reddy et al. 2001, Schwacke et al. 2002; Darnerud 2003; Legler and Brouwer 2003; Viberg et al. 2003; Ylitalo et al. 2005; Fonnum et al. 2006; Viberg et al. 2006; Darnerud 2008; Legler 2008; Bonefeld-Jørgensen et al. 2001). Southern Residents are exposed to a mixture of pollutants, some of which may interact synergistically and enhance toxicity, influencing their health. High levels of these pollutants have been measured in blubber biopsy samples from Southern Residents (Ross et al. 2000; Krahn et al. 2007; Krahn et al. 2009), and more recently, these pollutants were measured in fecal samples collected from Southern Residents (Lundin et al. 2016a; Lundin et al. 2016b).

Based on the above, even when BMPs and treatment are included with new PGIS, it is reasonable to make a "likely to adversely affect" call in the BA based on stormwater exposure and effects to salmon, steelhead, bull trout, and other listed aquatic species.

17.3 Stepping through a Stormwater Analysis

The project biologist should integrate the discussion about stormwater and the stormwater BMPs into the various sections of the BA, including project description, existing environmental conditions, action area, effects analyses, and effect determinations. Other sections of the BA such as the species and critical habitat section contain relevant information that will be incorporated into the stormwater analysis. The species and critical habitat section provides information on the presence and timing of various life stages of species within the action area that will be used to help to identify the potential for exposure to those months when each of the species may be present. Some species and lifestages exhibit distinct seasonality whereas others may be present year-round. It is important to note that, as previously described, stormwater discharges generally cause long-term effects to receiving waterbody conditions. Discharges may be episodic in nature but occur in perpetuity. The analysis of effects must take these persistent indirect effects into account to understand long-term project effects on habitat, habitat-forming processes and the functionality of habitat characteristics or existing environmental conditions. The potential exposure(s) of individual fish to these discharges over time hinges upon the life history strategy and timing of various life stages of species within the action area.

The following sections describe the appropriate documentation of stormwater elements and impacts within the BA and step through the process of evaluating stormwater and stormwater BMP effects on species and habitat for eastern and western Washington. Ten steps are outlined below for completing a stormwater analysis:

1. Step 1: Obtain the Endangered Species Act Stormwater Design Checklist (Section 17.3.1)

2. Step 2: Incorporate information about the selected BMPs into the project description (Section 17.3.2)

3. Step 3: Incorporating or including stormwater effects when determining and defining the action area (Section 17.3.3)

4. Step 4: Determine species use and presence of critical habitat within the action area (Section 17.3.4)

5. Step 5: Describe existing environmental conditions (Section 17.3.5)

6. Step 6: Describe and quantify effects to water quality, quantity, possible exposures, and possible measurable effects to habitat function (Section 17.3.6)

7. Step 7: Examine site-specific conditions that may moderate or mediate stormwater effects but which cannot be fully captured in modeling results (Section 17.3.7)

8. Step 8: Re-evaluate the action area to ensure it incorporates all anticipated physical, biological, chemical effects (Section 17.3.8)

9. Step 9: Pull it all together: complete a comprehensive exposure-response analysis for listed species and critical habitat (Section 17.3.9)

10. Step 10: Identify stormwater effects and make effect determinations in accordance with Section 7 of the ESA (Section 17.3.10).

17.3.1 STEP 1: Obtain the Endangered Species Act Stormwater Design Checklist and Review Project Plans

The project biologist describes stormwater management plans in the BA based on the information presented by the project engineer in the ESA stormwater design checklist and project plans. The project biologist should request the project engineer to fill out this checklist. Checklist templates (one for western Washington and one for eastern Washington) are available, along with other stormwater guidance, on WSDOT's Biological Assessment website at: < http://www.wsdot.wa.gov/environment/technical/fish-wildlife/policies-and-procedures/esa-ba/preparation-manual >.

The checklist breaks down the analysis of stormwater elements and impacts into areas draining to specific outfalls or into "threshold discharge areas" or TDAs. The *Highway Runoff Manual* defines TDAs as follows: *An on-site area draining to a single natural discharge location or multiple natural discharge locations that combine within 1/4 mile downstream (as determined by the shortest flow path)*.

Project plans may also be useful in determining locations of proposed BMPs and outfalls. These locations must be known to assess environmental impacts of the BMPs themselves, and to accurately describe the proposed conveyance system and how its configuration influences the potential for exposure. The project biologist should be prepared to ask for additional information during or before site visits, because the location of the displaced habitat must be identified in the field.

The completed checklist should not be attached to the BA; rather, the information summarized in the checklist should be incorporated into the appropriate sections of the BA.

17.3.2 STEP 2: Incorporate Stormwater Information into the Project Description

17.3.2.1 Describe Proposed Changes to Impervious Surface

For each TDA, the project description should clearly convey how the project plans to change the existing configuration of impervious surface within the action area. For projects with numerous TDAs (more than 10 TDAs), information should be compiled and presented by waterbody or subwatershed.

Following is a list of information that should be included in the project description in the BA. The bulk of this information will be provided to the biologist via the ESA stormwater design checklist.

- Existing impervious surface area (acres) and treatment
    - Acreage receiving runoff treatment (basic; enhanced)
    - Acreage receiving no runoff treatment
    - Acreage receiving flow control prior to discharge
    - Acreage that infiltrates
    - Acreage receiving no flow control prior to discharge
- New impervious surface area (acres) and treatment
    - Total area of impervious surface draining into each proposed BMP (acres), outfall, and/or TDA.
    - Acreage that will receive runoff treatment (basic; enhanced)
    - Acreage that will receive no runoff treatment
    - Acreage that will receive flow control prior to discharge
    - Acreage that infiltrates
    - Acreage that will receive no flow control prior to discharge
- Impervious surface area to be removed (acres) as a result of the proposed project, and anticipated final condition of the areas where it will be removed
    - If a project will remove a large quantity of impervious surface in one or more TDAs, this should be clearly described in the BA and these changes should be quantified.
    - It may be appropriate to summarize “net new” impervious surface for these projects.
Net New Impervious = New Impervious Area – Removed Impervious Area
- Existing impervious surface area that will be retrofitted as a result of the proposed project
    - Existing acreage retrofitted for runoff treatment
    - Existing acreage retrofitted for flow control
- Identify the receiving water(s) for flow or runoff from each BMP/outfall and/or TDA

The project description should also identify and describe all project changes or improvements to arterial or surface streets, frontage roads, and facilities.

Occasionally, transportation projects are associated with delayed effects in the form of urban and suburban development or changes in land use. As a result, the biologist may also need to characterize, more generally or qualitatively, the existing conditions within these additional areas. See CHAPTER 10, INDIRECT EFFECTS and Section 17.3 for more information on completing this assessment.

17.3.2.2 Describe Proposed Stormwater BMPs

Linear projects such as highways often span several drainage basins or watersheds. As a result, different methods of stormwater treatment may be proposed for new impervious surfaces in different basins. The project engineer will likely refer to these different drainage areas as threshold discharge areas and will summarize each TDA in the ESA stormwater design checklist prepared for the project. The project engineer will identify an appropriate BMP(s) for each TDA as necessary.

The project description should first fully describe existing water quality treatment (runoff) and flow control BMPs. Name and describe the existing BMPs and indicate where they are located. The general information on BMPs provided earlier (Section 17.1.2) may inform this description. For projects using unconventional or experimental stormwater designs, BAs should clearly describe the proposed designs and how they will manage water quality or flow control. Also describe the existing stormwater conveyance system (i.e., is it an open like an unlined ditch or closed system like a pipe). When describing the conveyance system, clearly describe the distance to and/or conveyance channel characteristics from discharge points or outfalls to receiving waterbodies. Most of this information is supplied to the project biologist through the ESA stormwater design checklist. In summary:

- Describe the existing water quality (runoff) treatment and flow control
- Describe the existing BMPs and their locations
- Describe the existing conveyance system and discharge points or outfalls

Next, the project biologist should describe the proposed runoff treatment and flow control BMPs. If BMPs already exist at a project site and will not be altered or retrofitted in any way, this should be disclosed. Similarly, if removal, alteration, discontinuation or retrofitting of existing BMPs is proposed, this must be clearly explained in the project description. For new stormwater elements (BMPs, conveyance, outfalls, etc.), name and describe the proposed element and indicate where they are located, whether they are temporary or permanent, and how they are to be constructed (e.g., heavy equipment, or installed below the surface). For those stormwater elements that will partially or completely infiltrate runoff, the project engineer should provide the project biologist with justification for the anticipated level of infiltration to include in the project description of the BA. This justification must be included in the BA and should properly account for and address all of the following conditions:

- Seasonal variations in precipitation intensity and soil moisture
- Permeability of embankment fill and native soils
- Seasonal variations in depth to groundwater
- Vegetation present to provide evapotranspiration

The project biologist should work with the project engineer or designer to determine the anticipated infiltration rates and hydrologic performance of media filter drains (previously called ecology embankments) and compost-amended vegetated filter strips if these BMPs are components of a project's design. The performance of these BMPs will vary based upon site-specific designs and conditions. Monitoring data can provide the justification for assumed infiltration / water loss for other BMPs as well. The infiltration performance of these and other BMPs is being continually studied, and additional information may exist.

The project description should also explain how the proposed stormwater treatment is consistent with the *Highway Runoff Manual*, as represented by the project engineer in the ESA stormwater design checklist.

The project description should describe all stormwater elements (BMPs, conveyance, outfalls, etc.), construction activities associated with them, and related impact minimization measures. Examples include the excavation to install underground pipe that directs runoff from the roadway, construction of a swale that directs runoff from the roadway to the point of discharge, installation of a new outfall or discharge site, installation of riprap at the outlet pipe, or upgrades of an existing detention pond.

The project biologist should also accurately describe the proposed stormwater conveyance system (i.e., is it an open or closed system). When describing the conveyance system, provide the distance to and/or conveyance channel characteristics from discharge points or outfalls to receiving waterbodies. The project designer, via the ESA stormwater design checklist, will provide the biologist with this information.

The project description should characterize any flow control or runoff treatment exemptions the project qualifies for, in accordance with the *Highway Runoff Manual* and as presented in the ESA stormwater design checklist. If the project designer indicates that proposed stormwater BMPs will drain to any of the following waterbodies: **Puget Sound; Columbia River; and Lakes Sammamish, Silver, Union, Washington and Whatcom**, the biologist may not need to evaluate potential project effects to flow conditions or hydrology in the BA, because these are waterbodies considered flow exempt by USFWS and some of them are also considered flow exempt by NMFS (meaning the rate and volume of discharge will not alter volume or flow conditions of the receiving waterbody; water quality still must be evaluated).

- USFWS considers all the waterbodies listed above as flow exempt.
- NMFS only considers Puget Sound, the Columbia River, and Lake Washington flow exempt.

If the discharge is to an HRM flow-exempt waterbody but not on the USFWS or NMFS list above, the project biologist should work with project designers and hydrologists to provide rationale as to why the flow effects are minor or work with project designers to analyze or model anticipated project effects on flow in the analysis of effects section of the BA. In summary:

- Describe the proposed runoff treatment and flow control
- Describe the proposed stormwater elements and their locations
- Justify incidental infiltration rates chosen for each proposed BMP or other stormwater element
    - Justification should be based on soil infiltration rates and abilities, presence or absence of a lining in the BMP or stormwater element, depth to ground water table, slope, and vegetation.
    - Justification should properly account for and address seasonal variation and conditions in excess of the "design storm."
- Describe construction sequence, activities, and impact minimization measures for installing proposed stormwater elements
- Describe the proposed conveyance system and points of discharge (or outfalls) to receiving waterbodies
- Determine if runoff will discharge to waterbodies that are considered exempt (by the Services) from flow control requirements. If discharge is to a waterbody requiring flow control, coordinate with project designers to generate description of proposed flow control and assess effects to hydrology and flow conditions.

17.3.2.3 Quantify and Describe Habitat Impacts from Construction

The installation of several project elements, including stormwater components may require clearing of existing vegetation, in-water work to install an outfall, placement of rock to inhibit erosion or scour at the outfall location, alteration of the landscape or topography, or temporary disturbance to habitat while equipment is placed underground.

For each project element, it is important to quantify the extent of anticipated impacts, indicate whether the habitat displacement will be temporary or permanent, and provide enough detail to support later discussions of how the impacts may affect listed species and habitat. For projects with indirect effects, see CHAPTER 10, INDIRECT EFFECTS and Section 17.3 for guidance on determining the extent of impacts. Additional guidance for quantifying project impacts is discussed in detail in the ACTION AREA section (8.0) of this manual. The project description should quantify anticipated impacts on habitat in terms of:

- Approximate habitat area affected by the activity
- Location of impacts relative to sensitive habitats or species
- Habitat and/or vegetation type
- Terrain and how topography might enhance or inhibit potential project impacts extending to sensitive habitats or species

17.3.3 STEP 3: Define the Action Area for the Proposed Project: Describe the Project's Stormwater Related Effects

The action area represents the full geographic extent of all anticipated physical, biological and chemical effects in the environment that are a reasonably foreseeable consequence of the proposed action or project. The direct and indirect effects from proposed stormwater elements constitute one component of this larger action area defined for the project in its entirety. The geographic extent of water quality effects and changes in flow or hydrology would define the stormwater component of the action area. Contaminants in stormwater can be transported far from the point of delivery either dissolved in solution, attached to suspended sediments, or through bioaccumulation. Water currents may transport contaminants that are in solution or suspended far downstream to large rivers, estuaries and the ocean.

The fate and transport of many stormwater constituents in the environment are not well known. For individual consultations, use the guidance in Table 17-3 to define the extent of potential stormwater effects when describing the aquatic portion of the action area in freshwater systems. There is no existing guidance for direct discharges to marine waters. In those cases, discussions with the Services during early coordination will be required.

Table 17-3. Extent of potential stormwater effects when describing the aquatic portion of the action area in freshwater systems[1]

Project Location	Extent of Stormwater Effects
Puget Sound watershed	Discharge location to Puget Sound
Coastal drainages	Discharge location to marine waters
Columbia River basin	Discharge location to the Columbia River
Snake River basin	Discharge location to the Snake River

[1] Not every project creating a stormwater discharge implies action areas of this scale. Important considerations include the location, scope, and scale of the project, conditions of receiving waters, and the mitigating stormwater BMPs and controls that are built into the project, especially those that substantially control existing untreated discharges or peak flows and durations.

Procedures for determining the extent of changes in flow or hydrology are described in the *Analyzing Effects on Flow and Duration* subsections of 17.3.6.1 (eastern Washington) and 17.3.6.2 (western Washington). In these same sections, the protocols for analyzing water quality effects are focused specifically on estimating changes in pollutant loadings NOT on defining the full geographic extent of all foreseeable water quality effects. In other words, the HI-RUN dilution subroutine does not predict the full extent of effects on water and sediment quality.

Similarly, development(s) identified as a consequence of transportation projects may affect the size of the action area and therefore the extent of the water quality and quantity impacts to be analyzed. Guidance for determining whether development can be attributed to a transportation project is provided in the INDIRECT EFFECTS (CHAPTER 10.0) of the manual, and for assessing water quality impacts generated by development and changes in land use is provided in Section 17.4 below.

The Service(s) may or may not agree with the action area that is defined in the BA. This is within their authority and responsibility (i.e., to make an independent evaluation of foreseeable effects),but it is something that the biologist should be aware of. The Service(s) may with their decision document(s), consider additional effects, or have a different interpretation of the foreseeable effects.

17.3.4 STEP 4: Determine Species Use and Presence of Critical Habitat within the Action Area

Within receiving waters in the action area, and in the vicinity of the discharge location(s) or outfall(s) associated with each TDA, the biologist should determine the potential use and presence of species, the presence of suitable habitat for various life stages, critical habitat, and the related physical or biological features. The biologist should identify the timing of various life stages to determine what months are of interest (a key input in the western Washington HI-RUN model) for the stormwater analysis for each species and to determine the potential for exposure to stormwater discharge. Ultimately this information, coupled with information from steps 5 and 6 will help the biologist assess how and where listed species or their habitat may be exposed to the project's stormwater effects. Step 9 (Section 17.2.9) describes the synthesis of this information as part of the exposure-response analysis.

17.3.5 STEP 5: Describe the Baseline Condition in the Action Area

Existing environmental conditions in the project's receiving waters may influence the type of analysis that will be required. Stormwater effects are generally more pronounced in small receiving water bodies, and/or in water bodies that already exhibit signs of impairment. BAs must characterize the conditions that prevail in any water bodies (including wetlands) to which stormwater will be discharged.

Conditions within receiving waterbodies should be clearly described in the existing environmental conditions section. The NMFS and USFWS matrices of Pathways and Indicators (NOAA 1996;

USFWS 1998) provide useful frameworks for completing this task. NMFS no longer requires inclusion of its matrix within biological assessments that are submitted to them for consultation, but relevant components of their matrix have been provided below for reference (Tables 17-4 and 17-6). For bull trout, USFWS still requires inclusion of its matrix in biological assessments submitted for consultation (Tables 17-5 and 17-7). For projects with potential water quality impacts, existing conditions for temperature, sediment/turbidity, and chemical contamination/nutrients should be established. A summary of these criteria is provided in the tables below (Tables 17-4 and 17-5).

For projects with potential impacts to habitat (i.e., effects from BMP construction, alteration of flows, or addition of contaminants) it is important to include information on the existing conditions of the habitat types or characteristics within the action area, including stream type and aquatic habitat features, descriptions of substrate conditions, flow conditions (seasonal or perennial), and riparian habitat. In addition, the biologist should describe the suitability of habitat within the action area for a given species and life stage. All this information helps the biologist to gauge whether there is potential for listed species to be exposed to stormwater discharges and resulting effects (i.e., altered/degraded water quality, altered flows, altered/degraded habitat quality and function), and if there is exposure, what possible responses can be anticipated. If critical habitat is addressed in the BA, describe the physical or biological features that currently exist within the action area and their condition. This information helps the biologist gauge whether there is the potential for impacts to critical habitat.

Providing a thorough description of existing conditions in the BA will help better explain what changes might take place and better support the ESA and EFH effects analyses and effect determinations.

A summary of information that should be included is provided in the list below:

1. Describe existing habitat conditions within the action area paying particular attention to those habitat features and receiving water characteristics that may be affected by the proposed project. For bull trout describe existing conditions as specified in the USFWS Matrices of Pathways and Indicators.

   - For those indicators that will be potentially affected by the proposed project, include a detailed description within the text of the BA (in addition to the USFWS Pathways and Indicators summary matrix or checklist [described in CHAPTER 9 – ENVIRONMENTAL BASELINE]).

   - For those projects addressing stormwater discharges and effects to receiving water quality, be sure to address the indicators summarized in Tables 17-4 and 17-5 below.

- For those projects addressing stormwater impacts to flow, be sure to address the habitat and hydrology indicators summarized in the Tables 17-6 and 17-7 below.
- For those indicators that will not be affected by the project, provide a summary of their condition in the matrix with a brief textual summary, and include your more detailed write-up of the indicator in an appendix of the BA.

Table 17-4. Water quality indicators identified in the NMFS matrix of pathways and indicators.

	Indicators	Properly Functioning	At Risk	Not Properly Functioning
Water Quality	Temperature	50–57ºF [a]	57-60º (spawning) 57-64º (migration &rearing) [b]	> 60º (spawning) > 64º (migration & rearing) [b]
	Sediment/turbidity	<12% fines (<0.85 mm) in gravel [c], turbidity low	12-17% (west-side), [c] 12-20% (east-side), [b] turbidity moderate	>17% (west-side), [c] >20% (east side) [b] fines at surface or depth in spawning habitat [b], turbidity high
	Chemical contamination and nutrients	Low levels of chemical contamination from agricultural, industrial and other sources, no excess nutrients, no Clean Water Act 303(d) designated reaches	Moderate levels of chemical contamination from agricultural, industrial and other sources, some excess nutrients, one Clean Water Act 303(d) designated reach. [d]	High levels of chemical contamination from agricultural, industrial and other sources, high levels of excess nutrients, more than one Clean Water Act 303(d) designated reach. [d]

[a] Bjornn, T.C. and D.W. Reiser. 1991. Habitat Requirements of Salmonids in Streams. American Fisheries Society Special Publication 19:83-138. Meehan, W.R., ed.

[b] Biological Opinion on Land and Resource Management Plans for the: Boise, Challis, Nez Perce, Payette, Salmon, Sawtooth, Umatilla, and Wallowa-Whitman National Forests. March 1, 1995.

[c] Washington Timber/Fish Wildlife Cooperative Monitoring Evaluation and Research Committee. 1993. Watershed Analysis Manual (Version 2.0). Washington Department of Natural Resources.

[d] A Federal Agency Guide for Pilot Watershed Analysis (Version 1.2), 1994.

Table 17-5. Water quality indicators identified in the USFWS matrix of pathways and indicators.

Diagnostic or Pathway	Indicators	Functioning Appropriately	Functioning at Risk	Functioning at Unacceptable Risk
Water Quality	Temperature	7-day average maximum temperature in a reach during these life history stages: [a, b] Incubation 2 – 5ºC Rearing 4 – 12ºC Spawning 4 – 9ºC Also, temperatures do not exceed 15ºC in areas used by adults during migration (no thermal barriers).	7-day average maximum temperature in a reach during the following life history stages: [a, b] Incubation <2ºC or 6ºC Rearing <4ºC or 13 - 15ºC Spawning <4ºC or 10ºC Also, temperatures in areas used by adults during migration sometimes exceeds 15ºC.	7-day average maximum temperature in a reach during the following life history stages: [a, b] Incubation <1ºC or >6ºC Rearing >15ºC Spawning <4ºC or > 10ºC also temperatures in areas used by adults during migration regularly exceed 15ºC (thermal barriers present).
	Sediment (in areas of spawning & incubation; address rearing areas under *substrate embeddedness*)	Similar to Chinook salmon, [a] for example: <12% fines (<0.85 mm) in gravel, [c] ≤20% surface fines ≤6 mm. [d, e]	Similar to Chinook salmon: [a] e.g., 12-17% fines (<0.85mm) in gravel, [c] e.g., 12-20% surface fines. [f]	Similar to Chinook salmon [a]: e.g., >17% fines (<0.85mm) in gravel;[c] e.g., >20% fines at surface or depth in spawning habitat. [f]
	Chemical contamination & nutrients	Low levels of chemical contamination from agricultural, industrial, and other sources; no excess nutrients; no Clean Water Act 303(d) designated reaches. [g]	Moderate levels of chemical contamination from agricultural, industrial and other sources, some excess nutrients, one Clean Water Act 303(d) designated reach. [g]	High levels of chemical contamination from agricultural, industrial and other sources, high levels of excess nutrients, more than one Clean Water Act 303(d) designated reach. [g]

[a] Rieman, B.E. and J.D. McIntyre. 1993. Demographic and habitat requirements for conservation of bull trout. USDA Forest Service, Intermountain Research Station, Boise, ID.

[b] Buchanan, D.V. and S.V. Gregory. 1997. Development of water temperature standards to protect and restore habitat for bull trout and other cold water species in Oregon. In W.C. Mackay, M.K. Brewin, and M. Monita, eds. Friends of the Bull Trout Conference Proceedings. P8.

[c] Washington Timber/Fish Wildlife Cooperative Monitoring Evaluation and Research Committee, 1993. Watershed Analysis Manual (Version 2.0). Washington Department of Natural Resources.

[d] Overton, C.K., J.D. McIntyre, R. Armstrong, S.L. Whitewell, and K.A. Duncan. 1995. User's guide to fish habitat: descriptions that represent natural conditions in the Salmon River Basin, Idaho. U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Gen Tech. Rep. INT-GTR-322.

[e] Overton, C.K., S.P. Wollrab, B.C. Roberts, and M.A. Radko. 1997. R1/R4 (Northern/Intermountain regions) Fish and Fish Habitat Standard Inventory Procedures Handbook. U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Gen Tech. Rep. INT-GTR-346.

[f] Biological Opinion on Land and Resource Management Plans for the: Boise, Challis, Nez Perce, Payette, Salmon, Sawtooth, Umatilla, and Wallowa-Whitman National Forests. March 1, 1995.

[g] A Federal Agency Guide for Pilot Watershed Analysis (Version 1.2), 1994.

Table 17-6. Channel condition and hydrology indicators identified in the NMFS matrix of pathways and indicators.

	Indicators	Properly Functioning	At Risk	Not Properly Functioning
Channel Condition & Dynamics:	Width/depth ratio	<10 [a,b]	10–12	>12
	Stream bank condition	>90% stable; i.e., on average, less than 10% of banks are actively eroding [a]	80–90% stable	<80% stable
	Floodplain connectivity	Off-channel areas are frequently hydrologically linked to main channel; overbank flows occur and maintain wetland functions, riparian vegetation and succession	Reduced linkage of wetland, floodplains and riparian areas to main channel; overbank flows are reduced relative to historic frequency, as evidenced by moderate degradation of wetland function, riparian vegetation/succession	Severe reduction in hydrologic connectivity between off-channel, wetland, floodplain and riparian areas; wetland extent drastically reduced and riparian vegetation/succession altered significantly
Flow/Hydrology:	Change in peak/base flows	Watershed hydrograph indicates peak flow, base flow and flow timing characteristics comparable to an undisturbed watershed of similar size, geology and geography	Some evidence of altered peak flow, base flow and/or flow timing relative to an undisturbed watershed of similar size, geology and geography	Pronounced changes in peak flow, base flow and/or flow timing relative to an undisturbed watershed of similar size, geology and geography
	Increase in drainage network	Zero or minimum increases in drainage network density due to roads [c d]	Moderate increases in drainage network density due to roads (e.g., 5%) [c, d]	Significant increases in drainage network density due to roads (e.g., 20-25%) [c, d]

[a] Biological Opinion on Land and Resource Management Plans for the: Boise, Challis, Nez Perce, Payette, Salmon, Sawtooth, Umatilla, and Wallowa-Whitman National Forests. March 1, 1995.

[b] A Federal Agency Guide for Pilot Watershed Analysis (Version 1.2), 1994.

[c] Wemple, B.C. 1994. Hydrologic Integration of Forest Roads with Stream Networks in Two Basins, Western Cascades, Oregon. M.S. Thesis, Geosciences Department, Oregon State University.

[d] e.g., see Elk River Watershed Analysis Report, 1995. Siskiyou National Forest, Oregon.

Table 17-7. Channel condition and hydrology indicators identified in the USFWS matrix of pathways and indicators.

Diagnostic or Pathway	Indicators	Functioning Appropriately	Functioning at Risk	Functioning at Unacceptable Risk
Channel Condition & Dynamics	Average wetted width/ maximum depth ratio in scour pools in a reach	≤10 [a, b]	11–20 [a]	>20 [a]
	Stream bank condition	>80% of any stream reach has ≥90% stability.[a]	50–80% of any stream reach has ≥90% stability [a]	<50% of any stream reach has ≥90% stability [a]
	Floodplain connectivity	Off-channel areas are frequently hydrologically linked to main channel; overbank flows occur and maintain wetland functions, riparian vegetation and succession.	Reduced linkage of wetland, floodplains and riparian areas to main channel; overbank flows are reduced relative to historic frequency, as evidenced by moderate degradation of wetland function, riparian vegetation/succession	Severe reduction in hydrologic connectivity between off-channel, wetland, floodplain and riparian areas; wetland extent drastically reduced and riparian vegetation/succession altered significantly
Flow/Hydrology	Change in peak & base flows	Watershed hydrograph indicates peak flow, base flow and flow timing characteristics comparable to an undisturbed watershed of similar size, geology, and geography.	Some evidence of altered peak flow, base flow and/or flow timing relative to an undisturbed watershed of similar size, geology and geography	Pronounced changes in peak flow, base flow and/or flow timing relative to an undisturbed watershed of similar size, geology and geography
	Increase in drainage network	Zero or minimum increases in active channel length correlated with human caused disturbance.	Low to moderate increase in active channel length correlated with human caused disturbance	Greater than moderate increase in active channel length correlated with human caused disturbance

[a] Overton, C.K., S.P. Wollrab, B.C. Roberts, and M.A. Radko. 1997. R1/R4 (Northern/Intermountain regions) Fish and Fish Habitat Standard Inventory Procedures Handbook. U.S. Department of Agriculture, Forest Service, Intermountain Research Station, Gen Tech. Rep. INT-GTR-346.

[b] A Federal Agency Guide for Pilot Watershed Analysis (Version 1.2), 1994.

2. Describe the condition of the habitat relative to the species' habitat needs. Describe suitability for each species and life stages that may occur within the action area. For example, is it suitable rearing or spawning habitat? Is the habitat FMO (foraging, migratory or overwintering habitat) for bull trout? By establishing clearly what habitat types are present within the action area and whether they are suitable for various life stages, the biologist can more clearly define the scope of their effects analysis for each species.

3. For critical habitat, evaluate the existing condition for each of the identified physical or biological features that occur within the project action area.

4. Gather additional information on the receiving waterbodies' characteristics. The biologist may need to request support from the project hydrologist in gathering this information:

   - ☐ Channel bed/bank condition and geometry (e.g., substrate condition/embeddedness, bed and bank instability or scour depth, velocity, channel width, slope, or Mannings Roughness, etc.)

   - ☐ Water chemistry (e.g., hardness, representative background concentrations for each water quality parameter of interest. Currently the following stormwater pollutants are being analyzed: Total Suspended Solids, dissolved and total copper, dissolved and total zinc).

   - ☐ Water and sediment quality (i.e., temperature, other potential pollutants such as PAHs, microplastics, pesticides, dissolved oxygen, etc). Waterbody- or site-specific quantitative data may be unavailable for some (even many) pollutants, so the biologist may use a qualitative approach (including road densities and urban development in the basin) to assess water and sediment quality on a coarse scale.

If there is no data available, you will not be able to document the existing site-specific conditions in the receiving body. In this case, it may be possible to find existing data for a comparable system. Check with the WSDOT Stormwater Branch Manager before using data from a comparable system. In addition, WSDOT liaisons at NMFS and USFWS should be consulted to ensure there is mutual agreement regarding the surrogate system that is chosen for analysis.

When selecting data sources, strive to utilize data that has been quality controlled. Potential information sources include:

- MGSFlood Hydrologic Model for precipitation data

- Department of Ecology (DOE) 303(d) list

Department of Ecology Environmental Information Management (EIM) system for water quality data: < http://www.ecy.wa.gov/eim/ >

- The Limiting Factors Analysis by Washington State Conservation Commission
- Local agencies
- USGS Annual Washington State Data Reports: <http://wa.water.usgs.gov/data>
- Additional water quality information may be available from the Environmental Protection Agency and the United States Geological Survey.

The last section of this chapter provides a list of on-line resources that provide existing information on existing receiving water conditions including, water quality, flow, and if it is an exempt waterbody.

17.3.6 STEP 6: Describe and Quantify Effects to Water Quality, Quantity, Possible Exposures, and Possible Measurable Effects to Habitat Function

The guidance provided for analyzing effects on flow and duration can be used to assess direct and indirect effects upon listed species, their habitat, critical habitat, and EFH. The protocols outlined for analyzing stormwater effects to water quality are more focused in that they provide guidance specifically for assessing direct and indirect water quality exposures and effects to listed species, their habitat, critical habitat and EFH, but are not for describing the full geographic extent of water quality effects.

Projects that will not have stormwater effects on listed species or proposed or designated critical habitat due to location, absence of the species and habitats, or a project type that does not have new impervious surface and does not alter flow conditions (e.g., bridge seismic retrofit, ACP overlay, guardrail installation, a project area that is located a great distance from surface water, a project that can infiltrate all runoff due to highly permeable soils, etc.) need not complete a detailed stormwater analysis. These projects are expected to include a brief stormwater discussion as part of the project description and to document project effects (or lack thereof) on listed species along with supporting rationale in the effects analysis section of the BA.

Stormwater BMPs reduce impacts resulting from PGIS, runoff, and discharges. Although BMPs reduce effects, they do not eliminate the effects to either flow (base, peak or duration) or water quality for many projects.

For those projects that could expose and potentially affect listed species, their habitat, or proposed or designated critical habitat, documentation and analyses are required. A BA's stormwater analysis consists of two parts:

1. An analysis of the effects of changes in flow
2. An analysis of the effects of changes in water quality

While the flow analysis protocols are similar for projects in eastern and western Washington, two distinct procedures have been developed for analyzing the water quality aspects of stormwater effects in eastern Washington and western Washington. In addition, supplemental guidance has been developed to address water quality impacts resulting from stormwater runoff associated with development identified as an indirect effect of transportation projects in western Washington (see Section 17.4). A step-by-step description of how to implement the components of a BA stormwater analysis is outlined in the subsections below.

17.3.6.1 Analyzing Effects on Flow Conditions and Local Hydrology

Changes in flow conditions and local hydrology can result in direct and indirect effects to listed species, their habitats, critical habitats, and EFH, including: changes to channel, bank, and bed conditions and characteristics (pool/riffle/run configuration; bank stability; etc.) due to scour; substrate impacts due to fines (often introduced by bank instability or scour and deposition); introduction of excess fines and related effects to substrate conditions and/or the food base; direct effects to active redds, eggs, or emerging fry resulting from scour and/or deposition; and indirect effects to temperature associated with reduced base flows.

To analyze potential effects on peak flow rates, the rational method or single event hydrograph methods (Soil Conservation Service [SCS] or Santa Barbara Unit Hydrograph [SBUH]) can be used. To provide a detailed quantitative analysis of potential project effects on flow durations, a continuous hydrologic simulation model would be needed but no such model is available for use in eastern Washington and therefore a surrogate analysis method using a single event hydrograph method should be employed. The *Highway Runoff Manual* provides flow control design guidance for eastern Washington for use with a unit hydrograph model that approximates the peak flow reduction needed to prevent an increase in the durations of channel-forming peak flows. This guidance can be used as a surrogate threshold to determine if proposed flow control measures are adequate to prevent this impact.

MGSFlood is the primary continuous simulation model for use with WSDOT projects in western Washington and is used to design flow control and runoff treatment BMPs. Other continuous simulation models that can be used to analyze flow and durations include the Western Washington Hydrology Model (WWHM) and King County Runoff Time Series (KCRTS).

Occasionally, transportation projects are associated with indirect effects in the form of urban and suburban development or changes in land use. As a result, the biologist may also need to characterize, how these associated changes could affect flow patterns within these additional areas, and in turn how these changes would affect conditions within receiving water bodies.

This analysis should be completed by qualified WSDOT or consultant staff as determined by the WSDOT project manager. The project biologist will need to coordinate with the WSDOT project manager to ensure that they receive results from this analysis for inclusion in the biological assessment.

Once the project biologist has received the results of the analysis described above, they should work with the hydrologist or modeler to describe the following:

- What changes to flows are anticipated (base, peak)?
- How do anticipated flows compare to, and how will they affect existing conditions?
- How may changes in flow potentially affect habitat characteristics, and conditions in the project's receiving waterbodies?
- Will altered flows or local hydrology affect habitat for listed species (or habitat forming processes) in a manner that impairs function, reduces suitability, or otherwise disrupts normal behavior (feeding, moving, sheltering, etc.)?

The BA must evaluate the effects of stormwater discharges and proposed flow control measures over time, including describing the expected performance standards (at and below the design storm event) and known limitations of the proposed flow control measures if storm events exceed or greatly exceed the design storm event. For stormwater runoff that runs through an infiltration BMP, water will only be discharged into receiving water when the rainfall event exceeds the capacity of the BMP. Some BMPs discharge at their designed discharge storm events.

A project will minimize its effects on flows and durations if it can fully disperse or infiltrate all runoff from the new impervious surfaces/PGIS, without discharging this runoff either directly or indirectly through a conveyance system to surface waters. Most of the projects occurring in eastern Washington are expected to use infiltration or dispersion for flow control. Very few projects will require a detailed flow analysis.

In eastern Washington, NMFS and USFWS consider there will be no effect to flow of the receiving waters for projects discharging to the Columbia River. NMFS considers there will be no effect to flow only when water is not transferred from contributing watersheds with ESA or EFH resources. Discharges to any HRM exempt waterbody (except the Columbia River) requires providing in the BA either the rationale as to why there is no effect on flow or a detailed description of anticipated project impacts to flow. Use the Exempt Surface Waters List (see Online Resources in Section 17.6) to determine if your water body is exempt from flow control requirements and the farthest upstream point and/or reach for the exemption (if applicable). A project may have discountable flow effects on listed species if the project discharges to an HRM exempt water body and the project engineers can provide sufficient rationale or documentation that the project will have insignificant effects on flow within a receiving water body. These conclusions must be supported in the BA.

In western Washington, the USFWS consider there will be no effect to flow of the receiving waters for projects discharging to the following waterbodies: Puget Sound; Columbia River; and Lakes Sammamish, Silver, Union, Washington, and Whatcom. NMFS considers there will be no effect to flow of the receiving waters for projects discharging to the following western Washington waterbodies: Puget Sound, Columbia River, and Lake Washington, and only when water is not transferred from contributing watersheds with ESA or EFH resources. Discharges to any HRM exempt waterbody not on the USFWS and/or NMFS list requires providing in the BA either the rationale as to why there is no effect on flow or a detailed description of anticipated project impacts to flow. Use the Exempt Surface Waters List (see Online Resources in Section 17.6) to determine if your water body is exempt and the farthest upstream point and/or reach for the exemption (if applicable).

If a project could measurably affect flows or durations in a receiving water body, the biologist must evaluate whether the anticipated changes will affect the function or suitability of habitat or the quality and/or functionality of any primary constituent elements of critical habitat. Factors to consider that may reduce habitat quality or functionality include:

- Changes to channel, bank, and bed conditions and characteristics (pool/riffle/run configuration; bank stability; etc.) due to scour
- Substrate impacts due to fines introduced via bank destabilization or scour depositional areas
- Introduction of excess fines and related effects to substrate conditions or the food base
- Direct effects to active redds, eggs, or emerging fry resulting from scour and/or deposition
- Indirect effects to temperature associated with reduced base flows

The impacts to habitat resulting in direct or indirect effects to the listed species or critical habitat will inform conclusions regarding potential adverse effects and the proper effect determination(s) for the species, critical habitat, and project as a whole. The project biologist must also determine whether specific life-stages could be exposed to the effects of altered flows or durations. If exposure could occur, determining the anticipated response (including for specific life stages) will also help to inform the proper effect determination(s).

17.3.6.2 Analyzing Effects on Water Quality in Eastern Washington

The steps for completing a water quality analysis in eastern Washington requires the biologist to answer two questions:

Step 1: "Can the proposed stormwater system be designed to prevent surface water discharges?" The design may prevent surface water discharges through infiltration or dispersion of all runoff from new PGIS, or supplemental flow controls and/or water quality treatment. The biologist must work with the project hydrologist and stormwater engineer to fully describe the treatment strategy and anticipated discharges from the proposed project.

If the project can prevent surface water discharges or provide complete infiltration or dispersion, the project will not affect listed species, designated critical habitat, or EFH.

If the project cannot prevent discharges to surface waters that have a connection to habitats potentially occupied by listed fish species, then go to Step 2.

Step 2: "Is the project so far from receiving water that runoff will effectively infiltrate before reaching it?" This may be the case in unlined channel conveyances that have adequate soils, surface area, and contact time to allow for complete infiltration before surface water discharge. Answering yes to this question will require a discussion of the following items in the BA for justification:

- Type of conveyance – Conveyance must be an unlined open channel or ditch, not a pipe or lined conveyance ditch. Describe the general configuration.
- Distance to receiving water – This will affect the contact time and the capacity of the channel base to infiltrate runoff.
- Other inputs – Does the unlined open channel or ditch collect and/or convey substantial flow from off-site areas?
- Infiltration rate of soils – Soils at the unlined open channel or ditch must have relatively high infiltration rate (Hydrologic Type A or B). See Section 17.6 Online Resources for Stormwater for sources of existing soil information.
- Depth to groundwater – Seasonal high groundwater table must not meet the unlined open channel or ditch base or be shallow. As a guideline, separation between seasonal high groundwater and the unlined open channel flow line should be 5 feet or greater for acceptable infiltration (criteria for infiltration BMPs – see Section 5-4.2.1 of the *Highway Runoff Manual* for more information).
- Observations of existing flow conditions – Document any observations of flow during a storm event or evidence of flow conditions in the unlined open channel or ditch during conditions that could potentially deliver stormwater to receiving waters (e.g., excessive snow melt during seasonally high groundwater period). If surface discharge of runoff to the receiving water is evident, answer "no" to the question.

The project biologist, hydrologist and stormwater engineer would need to work together to ensure this information was included in the BA.

If the answer is no to this question, the biologist must assume that the project will have stormwater effects to species and habitats. In this situation, the BA must include a qualitative assessment of how the discharges will change or alter existing conditions, and how those changed conditions will affect listed species, their habitat, critical habitat primary constituent elements, and EFH in the aquatic portion of the action area where stormwater effects are anticipated.

17.3.6.3 Analyzing Effects on Water Quality in Western Washington

In western Washington, a stormwater assessment must include a qualitative analysis of all pollutants and their potential effects on listed species, their habitat, critical habitat, and EFH. The analysis may also include a quantitative analysis using the Highway Runoff Dilution and Loading Model (HI-RUN) model. This model was developed for analyzing project-specific water quality impacts in western Washington. The HI-RUN model provides a risk-based tool for evaluating zinc, copper, and total suspended solids exposure and potential effects on listed species. HI-RUN results may suggest and quantify changes in overall pollutant loadings, but provides quantitative results only for zinc, copper, and total suspended solids.

Qualitative Analysis

The project biologist must determine whether listed species (individuals) and specific life-stages are potentially present (temporally or spatially) and could be exposed to the water quality effects of the proposed project. If exposure could occur, determining the geographic extent and timing of these exposures will help the biologist determine the anticipated response of affected fish. The biologist must also evaluate whether the anticipated changes to water quality will have any short- or long-term effect on the suitability of habitat or the quality or functioning of any primary constituent elements.

If a project will result in new PGIS and stormwater (treated or untreated) will be discharged to receiving waters that support listed fish, the biologist must assume that the project may have adverse stormwater effects to those species and habitats.2 In this situation, the BA must include an assessment of how the discharges will alter or degrade (less commoinly, improve) existing conditions, and how those changed conditions will affect listed species, their habitat, critical habitat primary constituent elements, and EFH in the aquatic portion of the action area where stormwater effects are anticipated.

In the "Effects of the Action" chapter of the BA, a brief discussion of each stormwater pollutant (see Table 17.2), its fate and transport (if known), and effects to listed species, their habitats, and designated critical habitat should be provided. The discussion of total suspended solids, copper, and zinc can be augmented with HI-RUN loading and dilution results. The loading results can

2 Not every project creating a stormwater discharge implies an adverse effect. Important considerations include the location, scope, and scale of the project, conditions of receiving waters, and the mitigating stormwater BMPs and controls that are built into the project, especially those that substantially control existing untreated discharges or peak flows and durations.

also be used to qualitatively assess stormwater treatment effectiveness by comparing pre- and post-project loadings. It can be inferred that loading reductions in the HI-RUN pollutants may indicate reductions in other pollutant loadings. A large fraction of the total cumulative toxic load present in stormwater runoff (treated or untreated) is often bound or complexed with or carried by the sediments and sediment fraction. That means, control of TSS is fundamentally important to control of the total cumulative toxic load present in stormwater runoff.

Quantitative Analysis (HI-RUN)

Stormwater analyses included in biological assessments have focused for a number of yearsd on total suspended solids and total and dissolved copper and zinc. The Services, FHWA, and WSDOT previously agreed that HI-RUN results could be used as a surrogate or indicator for other stormwater pollutants and contaminants. In 2020, the Services began questioning the suitability of HI-RUN for analyzing potential exposure to these other pollutants and contaminants. NMFS and USFWS now consider the potential effects of several additional stormwater pollutants and contaminants when preparing biological opinions, many of them having different characteristics for transport, exposure, and response. This analytical tool should be considered optional as it is likely to underrepresent the area of effect. If this analytical tool is used in a BA, the biologist must include a rationale explaining if and how this analytical tool has been used.

The HI-RUN model can be used to conduct two quantitative primary analyses using separate subroutines:

1. End-of-pipe loading subroutine – Evaluation of existing and proposed pollutant loading values from a specific TDA, or the entire project area. Evaluation of existing and proposed zinc, copper, and total suspended solids concentrations at specific outfall discharge locations is also provided as output from this routine. Although these results can only serve as a possible indicator for other pollutant loadings, they do indicate if the project is generally improving or degrading water quality.

2. Receiving water dilution subroutine – Relative to the effects threshold, evaluation of existing and proposed zinc and copper concentrations at specific outfall discharge locations after mixing within the associated receiving water. Like loading results, these are no longer used as a surrogate for other pollutants and define the stormwater extent of effects.

The procedure for analyzing potential water quality effects (of total suspended solids, copper, and zinc) includes an examination of the anticipated dissolved zinc loadings at end-of-pipe. As mentioned in the existing environmental conditions section above, the existing environmental conditions (i.e., conditions within the receiving waterbody) may influence what analytical steps and model outputs are required for a given project. If existing conditions in the action area are “properly functioning” or “functioning at acceptable levels of risk” and if the end-of-pipe loading subroutine indicates the project will likely decrease annual pollutant loadings, it is generally unnecessary to run or provide outputs from the HI-RUN dilution subroutine.

The HI-RUN Users Guide provides detailed step-by-step guidance to this procedure, but a summary is included here so that biologists can use this guidance to begin their stormwater analyses and refer to the Users Guide only if additional information or clarification is needed.

Occasionally, transportation projects are associated with indirect effects in the form of urban and suburban development or changes in land use. The HI-RUN model only addresses a few of the water quality impacts resulting from highway runoff and cannot be used to address water quality impacts stemming from these other land cover types and impervious surfaces. For this reason, a separate procedure, summarized in Section 17.4, has been developed to characterize potential water quality effects resulting from these changes and is available on the WSDOT website. The method for analyzing water quality changes stemming from development that is indirectly related to a transportation project is intended to provide a coarse scale analysis of the changes in annual load for three stormwater pollutants from changes in land use and or impervious surface. This method uses a simple “wash-off” model that relies upon unit area annual pollutant loads (pounds/acre/year) for individual land uses to predict annual pollutant yields (pounds/year) from the changes in land use associated with the indirect effects of the project for the existing and projected conditions following completion of the transportation project. It is only applicable to projects in Western Washington and is only capable of predicting changes in pollutant loading, not changes in concentration or potential dilution zones.

The first step in using HI-RUN to evaluate water quality effects is to run the end-of-pipe loading subroutine to assess the potential of the proposed project to increase the delivery of pollutants to the receiving water when compared to the existing condition. The HI-RUN end-of-pipe loading subroutine can estimate loadings of five pollutants (total suspended solids, total copper, dissolved copper, total zinc, and dissolved zinc), and all five should be analyzed and reported in the BA. Model outputs from this subroutine provide estimates of pollutant loadings and a set of probabilities that may be used to assess whether the project is likely to increase or decrease annual pollutant loadings in each TDA (or receiving waterbody). The end-of-pipe subroutine should be run for the following:

- Run the end-of-pipe subroutine for each individual project TDA.
- If multiple TDAs discharge to the same receiving waterbody, the end-of-pipe subroutine can be run for the aggregate (combined) area of those TDAs to get a summary of overall loading to the system. However, results from this analysis should not be used as the basis for an analysis using the receiving water dilution subroutine. The dilution analysis is run for individual outfalls only.
    - For example, if three TDAs in a single project discharge to Hylebos Creek, calculating aggregate loading from all three TDAs to Hylebos Creek will help summarize total impacts to the fish populations utilizing that system.

To analyze multiple TDAs in aggregate, conduct an additional end-of-pipe loading analysis model run where:

- All the baseline area information from each individual TDA is added to together and entered into the corresponding rows in the model input page, and
- All the proposed area information from each individual TDA is added together and entered into the corresponding rows in the model input page.
    - As a hypothetical example, the three Hylebos Creek TDAs mentioned above have 2.5 acres, 1.3 acres, and 0 acres respectively of impervious area in the baseline condition that receive basic treatment with no incidental infiltration. To analyze aggregate loading to Hylebos Creek, conduct a new model run where 3.8 acres would be entered in the "Subbasin 1" cell of the input spreadsheet, corresponding to this treatment/infiltration combination. This combination of values would be repeated for each row (i.e., applicable treatment type and incidental infiltration category) for the baseline and proposed conditions tables.

If requested during consultation, or if it is considered useful by the project or Services biologist, the model can also be run for all project TDAs to summarize the overall loading associated with the project. The results from this analysis should not be used as the basis for a receiving water dilution analysis but should simply provide a "big picture" summary of project related loading. This can contribute to the qualitative stormwater analysis.

Once this step has been completed, the biologist follows the process outlined in Figure 17-1 below to determine whether the HI-RUN dilution subroutine is required. Once the outputs from the HI-RUN end-of-pipe loading subroutine are available, the biologist completes the following steps:

- The biologist reviews the results of the TDA-specific end-of-pipe loading subroutine (comparison of dissolved zinc [DZn], in particular the probability statistics [P(exceed)] for loading) to determine the need for a detailed mixing zone analysis in the receiving water (HI-RUN receiving water dilution subroutine).
    - If the P(exceed) value for loading in a single TDA is greater than the 0.45 threshold, outputs from the HI-RUN receiving water dilution subroutine are required for the outfalls in that TDA.
    - If the P(exceed) value obtained from the end-of-pipe loading subroutine for DZn in the TDA is less than or equal to the 0.45 threshold value identified above, a second P(exceed) threshold value of 0.35 is examined.
    - If the P(exceed) value for loading in the TDA is greater than the 0.35 threshold, an alternate, less rigorous "land-area based" dilution analysis must be performed.

- To perform the land-area based dilution analysis, the contributing impervious area for a TDA or the project drainage basin is compared to the total contributing basin area for the receiving water upstream of the project discharge.

  - If the TDA or project drainage basin represents 5 percent or less of the total upstream basin area, it is assumed that the receiving water will have sufficient dilution capacity to mitigate potential impacts from the project **if** background water quality conditions are not degraded. To determine if the project drainage basin is greater than 5 percent of the total basin area (contributing drainage area upstream of project discharge point in receiving water), the total basin area can be delineated using the on-line GIS-based tool StreamStats, developed by USGS: <http://water.usgs.gov/osw/streamstats/index.html>. It is important when using StreamStats to review the delineated drainage basin and confirm that it is accurate.

  - Analyses using the receiving water dilution subroutine would still be required if the water quality indicators show the receiving water is functioning *at risk* or *not properly functioning*. Water quality conditions in the receiving water are described by the water quality indicators in the NMFS or USFWS Pathways and Indicators Matrices.

- If the P(exceed) value for loading is less than or equal to the 0.35 threshold, the background water quality conditions of the receiving waterbody must be examined.

  - If the water quality criteria are *not properly functioning*, then the alternate, "land-area based" dilution analysis must be performed as described above.

  - If the water quality criteria are *at risk* or *properly functioning*, then the project's water quality impacts are likely insignificant and the biologist would need to document why this is the case (see Step 4 above for how to document).

The annual loadings of water quality contaminants from untreated or treated road stormwater runoff may result in adverse effects to fish and habitat. Projects that can demonstrate that they will reliably achieve a reduction of pollutant loadings (for all pollutants of interest and in all or most TDAs) should use this information in a discussion in the BA on the general adequacy of the proposed stormwater design.

If HI-RUN receiving water dilution subroutine modeling predicts exposure above the established biological thresholds for zinc and copper could occur, or that there is an increase in the area of potential exposure when comparing baseline versus proposed conditions, the biologist must then evaluate whether site-specific conditions could potentially mitigate or reduce these estimated impacts (i.e., does runoff flow directly to treatment BMPs or is there flow over vegetated or permeable surfaces prior to reaching the BMP, are there unlined conveyance elements or ditches that could result in additional infiltration, etc.). This may be a qualitative or quantitative analysis that accompanies modeling results. Factors to consider in this analysis are summarized in Step 7 below.

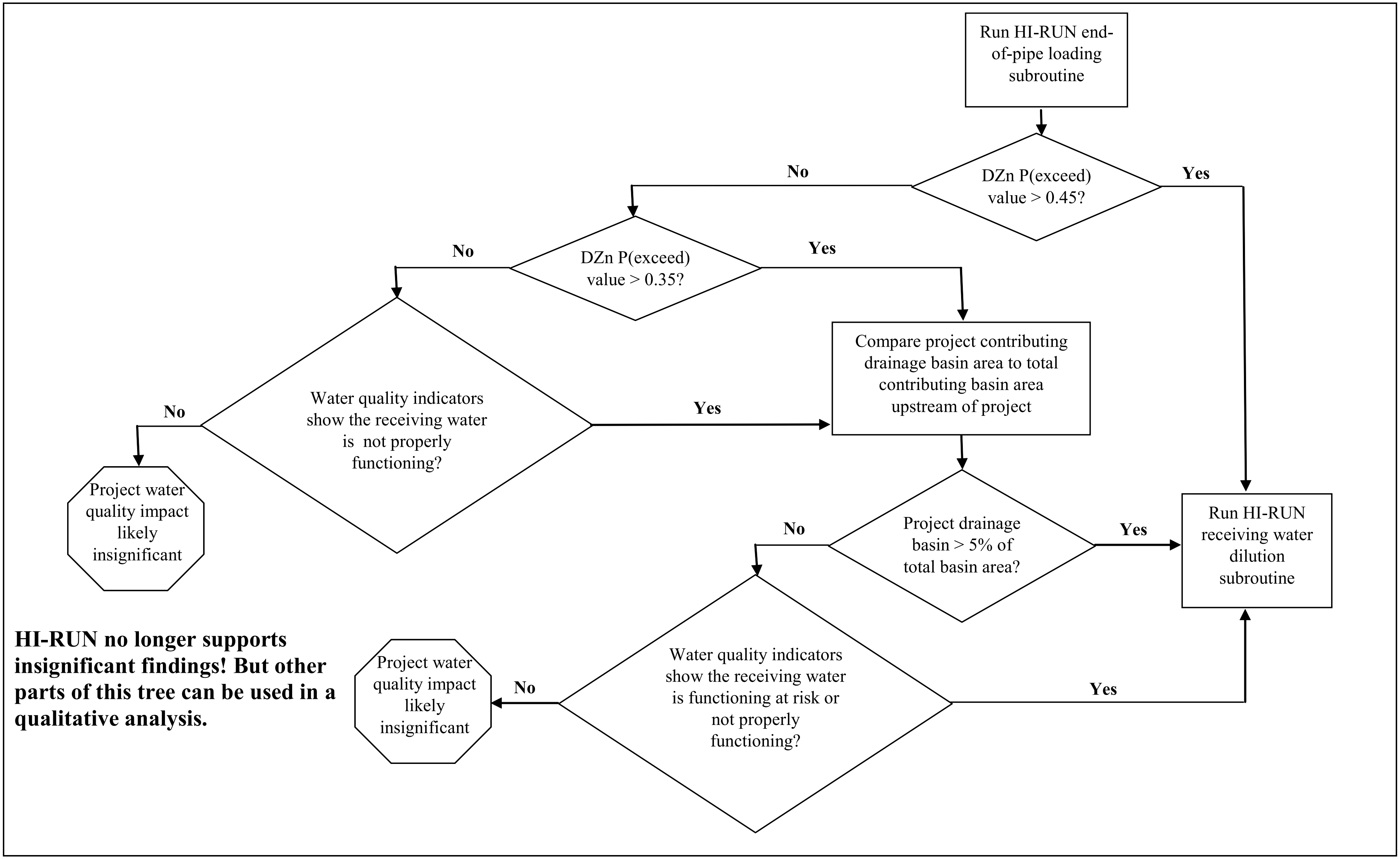


Figure 17-1. HI-RUN model stormwater analysis decision tree: Western Washington.

To assess impacts to species, critical habitat, and EFH, the project biologist should work with the project engineer or water quality modeler to describe the following:

- When project related changes to water quality are anticipated
- How anticipated changes to water quality compare to and affect existing conditions
- How changes to water quality will potentially affect habitat suitability and species

The project biologist must determine whether listed species (individuals) and specific life-stages are potentially present (temporally or spatially) and could be exposed to the water quality effects of the proposed project. If exposures could potentially occur, determining the geographic extent and timing of these exposures will help the biologist determine the anticipated response of affected fish. The biologist must also evaluate whether the anticipated changes to water quality will have any short- or long-term effect on the suitability of habitat or the quality and function of any primary constituent elements.

Two case studies are presented below, based upon the case studies contained in the HI-RUN Users Guide, to demonstrate use of the HI-RUN model in the stormwater quality effects analysis process and how to interpret model results for analyzing the effects of zinc, copper, and total suspended sediments on species and critical habitat. Case Study #1 involves using the end-of-pipe loading subroutine, but not the receiving water dilution subroutine. Case Study #2 involves the use of both routines. The case studies below differ from what is presented in the User's Guide in that they provide additional detail regarding how model outputs are interpreted.

Case Study #1. Completing the End-of-Pipe Loading Subroutine

The hypothetical project evaluated in Case Study #1 has the following characteristics:

- Existing roadway area: 10 acres
- Existing treatment: none
- Proposed roadway area: 12 acres (2 additional acres)
- Proposed treatment: biofiltration swale (sized for 2 acres) and media filter drain (previously referred to as ecology embankments) sized for 4 additional acres (retrofit)
- Outfall: All runoff in the TDA discharges through a single outfall (only one subbasin)
- Incidental infiltration: Due to sufficient separation between the base of the media filter drain and the seasonal high water table elevation, it is determined that the facility will achieve approximately 60 percent infiltration on an annual runoff volume basis. The biofiltration swale is not expected to have substantial incidental infiltration. The project biologist should work with the project engineer or designer to determine the anticipated infiltration rates and hydrologic performance of media filter

drains (previously called ecology embankments) and compost-amended vegetated filter strips if these BMPs are components of a project's design. The performance of these BMPs will vary based upon site-specific designs and conditions.

- Detention: Detention is not planned for this TDA because the receiving water is exempt from flow control requirements.

ESA-listed fish species present in the project receiving water include Puget Sound Chinook salmon and Puget Sound steelhead. The example focuses on evaluating the potential water quality effects of highway runoff on rearing steelhead in the month of February. However, the determination of which months to run the model for must be based on the potential presence of both steelhead and Chinook in the action area. If they are expected to be present year-round, then the model should be run for all 12 months. If the action area is rearing habitat for both species, and they are not expected to be present during July, August, and September due to low or no flow conditions and temperature, then the model would only need to be run for the other 9 months. Complete documentation for why only 9 months was analyzed must be included in the document.

The model inputs for Case Study #1 are described in detail in the HI-RUN Users Guide, and the resulting output for the End-of-Pipe Loading Subroutine for Case Study #1 appears in Figure 17-2 below.

The P(exceed) value for dissolved zinc loading is used to determine what level of analysis (if any) is needed of water quality effects in the receiving water. Based upon the thresholds for dissolved zinc described in the flow chart (Figure 17-1), the resulting P(exceed) value (0.438) is less than the upper threshold value of 0.45, but greater than the lower threshold value of 0.35. Therefore, a simplified dilution analysis must be conducted as a next step.

The model output should be provided in an appendix to the BA. But the results from the model output should be summarized within the BA. For a biologist, the P(exceed) values for all the pollutants evaluated can be used in the BA to describe the general effect of the project on annual loads relative to existing conditions. In this case, the loads for dissolved zinc occurring post project are higher than existing loads 44 percent of the time and lower than existing loads 56 percent of the time, indicating a slight improvement in water quality conditions is likely to result from the proposed project (at least for dissolved zinc; and perhaps, as an indicator for other pollutants). The loads for dissolved copper occurring post project are higher than existing loads 46 percent of the time and lower than existing loads 54 percent of the time, indicating a slight improvement in water quality conditions is likely to result from the proposed project (at least for dissolved copper; and perhaps, as an indicator for other pollutants). The results for the annual load analysis for all five pollutants of concern (TSS, total and dissolved copper and zinc) should be included in a summary table in the BA. Table 17-8 provides a generalized format summarizing these data. Note this table presents purely hypothetical data and does not directly incorporate results from Case Study #1. The actual model output/report should be placed in an appendix.

Highway Runoff Dilution and Loading model (HI-RUN) Version 2.0

End of Pipe Loading Subroutine Report

This model is for stormwater analysis associated with biological assessments, and is not a design tool.

Input Summary

Run Date/Time: 12/30/10 13:56
Outfall ID: SR 13, MP 12.2, TDA 3
Rain Gauge: Puget East 40
Description: Case Study #1 - 11/29/10

Location Information

Discharge Areas

Subbasin 1 - Baseline Conditions - 10 acres
no treatment - 0% infiltration - 10 acres

Baseline Conditions

Subbasin 1 - Proposed Conditions - 12 acres
basic treatment - 0% infiltration - 2 acres
enhanced treatment - 60% infiltration - 4 acres
no treatment - 0% infiltration - 6 acres

Location Information

Load Analysis

	Dissolved Copper Load (lb/yr)		Dissolved Zinc Load (lb/yr)	
	Baseline	**Proposed**	**Baseline**	**Proposed**
Max	8.75	5.6	126	30
75th Percentile	0.464	0.36	3.77	2.7
Median	0.268	0.24	2	1.6
25th Percentile	0.154	0.16	1.05	1
Min	0.005	0.031	0.033	0.18
P (exceed)		0.463		0.438

Annual Loading Statistics

P to Exceed

P to Exceed Copper

P to Exceed Zinc

Concentration Analysis

Subbasin 1	Dissolved Copper Conc (mg/L)		Dissolved Zinc Conc (mg/L)	
	Baseline	**Proposed**	**Baseline**	**Proposed**
Max	0.061	0.062	0.929	0.74
75th Percentile	0.006	0.005	0.05	0.039
Median	0.004	0.004	0.027	0.024
25th Percentile	0.002	0.003	0.014	0.016
Min	0	0.001	0.001	0.004
P (exceed)		0.51		0.476

End of Pipe Concentration Statistics

Figure 17-2. End-of-pipe loading subroutine results – Case Study #1.

Table 17-8. Example table format for summarizing results from annual pollutant load analysis from the HI-RUN end-of-pipe subroutine.

Parameter	Median Existing Load (lbs/year)	Median Proposed Load (lbs/year)	P(exceed) Value
TSS	4,513	2927	0.39
TCu	1.16	0.81	0.38
DCu	0.268	0.230	0.46
TZn	7.03	4.80	0.38
DZn	1.99	1.60	0.44

The results provided in the highlighted column indicate the following:

- 39 percent of the time, total suspended solid loads for the proposed condition exceed the existing condition (end-of-pipe). This indicates the proposed project will generally result in improved conditions.
- 38 percent of the time, total copper loads for the proposed condition exceed the existing condition (end-of-pipe). This indicates the proposed project will generally result in improved conditions.
- 46 percent of the time, dissolved copper loads for the proposed condition exceed the existing condition (end-of-pipe). This indicates the proposed project may or may not result in improved conditions. Completing a dilution analysis, if this analytical step is triggered by the P(exceed) values for dissolved zinc exceeding HI-RUN thresholds, would help to better determine effects and the likelihood of adverse effects.
- 38 percent of the time, total zinc loads for the proposed condition exceed the existing condition (end-of-pipe). This indicates the proposed project will generally result in improved conditions.
- 44 percent of the time, dissolved zinc loads for the proposed condition exceed the existing condition (end-of-pipe). This indicates the proposed project may or may not result in improved conditions. Note that the resulting P(exceed) value (0.44) is less than the upper threshold value of 0.45, but greater than the lower threshold value of 0.35. Therefore, a simplified dilution analysis must be conducted as a next step.

In addition, the biologist might use the other summary statistics provided to describe the effect of the proposed project on existing conditions. The maximum values provide a worst-case load estimate for comparing the existing and proposed conditions. Similarly, the median values provide the most likely load estimate for comparing the proposed and existing conditions. The percentile values provide an indication of the overall distribution of the loading estimates. For example, the 75th percentile value represents the load estimate at which 75 percent of the values will be lower and 25 percent will be higher. These statistics can help the biologist describe the relative risk associated with impacts resulting from the proposed project. In this case study, the proposed project will reduce the load of both dissolved copper and dissolved zinc in all cases except the 25^{th} percentile for dissolved copper and the minimum for both dissolved copper and dissolved zinc indicating that there is a very low risk that the project will increase annual loads for both dissolved copper and zinc.

In addition, the end of pipe loading routine provides end-of-pipe concentrations summary statistics and concentrations for various durations of storm/discharge. The end-of-pipe concentrations do not accurately reflect the conditions fish would be exposed to within the receiving waterbody. As a result, concentration output from the end-of-pipe loading subroutine should be used to describe the quality of stormwater discharged to the receiving waterbody not to support any detailed discussions regarding effects of stormwater to species or habitat within the receiving waterbody itself.

Case Study #1 then completes a simplified dilution analysis that indicates that the impervious surface area within this project TDA is less than 5 percent of the receiving water drainage basin. To complete this analysis, complete the following steps:

- Estimate the area (in square miles or acres) of the receiving water drainage basin upstream of the project discharge point.
    - ◻ Receiving water drainage basin area can be estimated using StreamStats, an online tool developed by USGS (<http://water.usgs.gov/osw/streamstats/Washington.html>).
    - ◻ Other topographic mapping could also be used to determine this area.
- The simplified dilution analysis consists of a simple comparison of the project drainage area (TDA) to this greater receiving water drainage basin.
    - ◻ If the impervious area of the TDA being analyzed represents more than 5 percent of the receiving water drainage basin, then the receiving water dilution subroutine must be conducted (see Case Study #2 for step-by-step instructions).
    - ◻ If not, a final check of receiving water indicators must be conducted.

This outcome requires the project biologist to revisit the water quality criteria to determine if the water quality indicators are functioning at risk or not properly functioning (see Figure 17-1). In this case, the receiving water existing conditions are properly functioning, and there is no additional stormwater dilution modeling required.

The biologist should summarize and discuss the results of the stormwater analysis in the “Analysis of Effects” section as follows:

- Describe project-generated differences in the pre- and post-project loading; compare loading estimates (Table 17-8 provides a generalized format for presenting these results).
- Describe the location of the outfall(s)/ point(s) of discharge with reference to habitat suitability, species occurrence, and potential for exposure.
- Report the results of the simplified dilution analysis by including the results of the watershed analysis. Include information like the size of the watershed in relation to the size of the TDA, and any information about the watershed (e.g., the amount of impervious surface) that may be available and relevant to discussion of water quality in the watershed. Include a discussion of the water quality existing indicators. Stormwater effects are generally more pronounced in small receiving waterbodies and/or in watersheds that already exhibit signs of impairment.
- Discuss the potential for exposure of listed fish to stormwater discharge. Include information on the life stage that may be exposed. If there is a potential for exposure, include a general discussion on potential responses (of species or life stage) to increased or decreased pollutant loads.

In general, changes in loading affect baseline conditions in the receiving water body, which in turn may affect the suitability of habitat for listed species. Increased pollutant loads contribute to the continued or increased degradation of baseline water quality conditions. Changes in loading may contribute to lethal and sublethal effects to listed species and degrade (or less commonly, improve) habitat conditions.

The fate of stormwater constituents in the receiving water will vary based on their chemistry and the chemistry of the receiving water. Some chemicals may bind tightly to sediment and eventually settle into the substrate. Only fish species and habitat components that are closely associated with the substrate during periods of stability or those that are present during events that resuspend sediments are likely to be exposed through absorption or ingestion. Depending on the environmental and biological fate of the stormwater constituent, exposure to other species may occur through food web interactions.

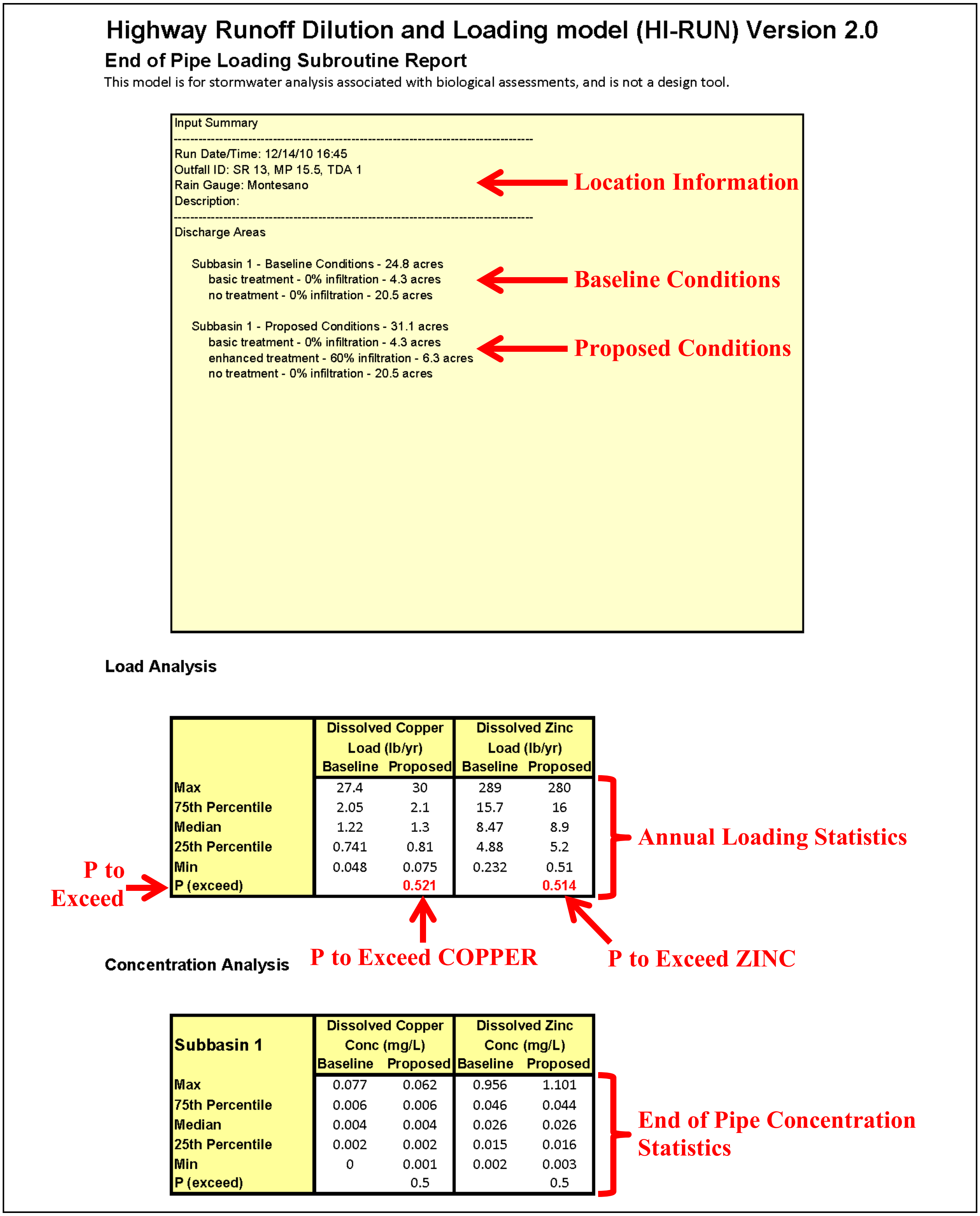
Some stormwater constituents may remain in the water column and be more available to species that use the site. Depending on the species length of time at the site and their life stage, they may be exposed through absorption and ingestion. Again, depending on the environmental and biological fate of the chemical of concern, exposure to other species may occur through food web interactions. Though the HI-RUN model does not include cadmium, lead, chromium, PAHs and 6PPD-quinone, these are other pollutants that can potentially affect fish. Lead levels in stormwater runoff have declined to extremely low levels following the removal of lead from gasoline.

Case Study #2. Completing the Dilution Subroutine

The hypothetical project evaluated in Case Study #2 has the following characteristics:

- Existing roadway area: 24.8 acres
- Existing treatment: biofiltration swale (sized for 4.3 acres)
- Proposed roadway area: 31.1 acres (6.3 additional acres)
- Proposed treatment: media filter drain (previously referred to as ecology embankments) sized for 6.3 new acres. Existing biofiltration swale remains (sized for 4.3 acres).
- Outfall: All runoff in the TDA discharges through a single outfall (only one subbasin).
- Incidental infiltration: Due to sufficient separation between the base of the media filter drain and the seasonal high water table elevation, it is determined that the facility will achieve approximately 60 percent infiltration on an annual runoff volume basis. The biofiltration swale is not expected to have substantial incidental infiltration.
- Detention: Detention is planned for this TDA to meet the Highway Runoff Manual flow control requirements.
- ESA-listed fish species present in the project receiving water includes Puget Sound Chinook salmon. An analysis will be performed to evaluate the potential water quality effects of highway runoff on rearing Chinook salmon in the months of August and September. If rearing Chinook are expected to be present during other months, those months should also be included in the analysis.
- Background water quality data from a site upstream of the project outfall is available from a previous watershed assessment effort. The median values for DCu and DZn are 0.002 and 0.003 mg/L, respectively.
- Receiving water quality indicators are properly functioning.

The model inputs for Case Study #2 are described in detail in the HI-RUN Users Guide, and the resulting output for the End-of-Pipe Loading Subroutine for Case Study #2 appears in Figure 17-3 below.



Highway Runoff Dilution and Loading model (HI-RUN) Version 2.0

End of Pipe Loading Subroutine Report

This model is for stormwater analysis associated with biological assessments, and is not a design tool.

Input Summary

Run Date/Time: 12/14/10 16:45
Outfall ID: SR 13, MP 15.5, TDA 1
Rain Gauge: Montesano
Description:

Discharge Areas

Subbasin 1 - Baseline Conditions - 24.8 acres
basic treatment - 0% infiltration - 4.3 acres
no treatment - 0% infiltration - 20.5 acres

Subbasin 1 - Proposed Conditions - 31.1 acres
basic treatment - 0% infiltration - 4.3 acres
enhanced treatment - 60% infiltration - 6.3 acres
no treatment - 0% infiltration - 20.5 acres

Load Analysis

	Dissolved Copper Load (lb/yr)		Dissolved Zinc Load (lb/yr)	
	Baseline	Proposed	Baseline	Proposed
Max	27.4	30	289	280
75th Percentile	2.05	2.1	15.7	16
Median	1.22	1.3	8.47	8.9
25th Percentile	0.741	0.81	4.88	5.2
Min	0.048	0.075	0.232	0.51
P (exceed)		0.521		0.514

Concentration Analysis

Subbasin 1	Dissolved Copper Conc (mg/L)		Dissolved Zinc Conc (mg/L)	
	Baseline	Proposed	Baseline	Proposed
Max	0.077	0.062	0.956	1.101
75th Percentile	0.006	0.006	0.046	0.044
Median	0.004	0.004	0.026	0.026
25th Percentile	0.002	0.002	0.015	0.016
Min	0	0.001	0.002	0.003
P (exceed)		0.5		0.5

Figure 17-3. End-of-pipe loading subroutine summary results – Case Study #2.

The P(exceed) value for dissolved zinc loading is 0.514. Because this P(exceed) value is greater than the 0.45 threshold depicted on Figure 17-1, a detailed dilution analysis using the receiving water dilution subroutine must be conducted as a next step.

The model output should be provided in an appendix to the BA. But the results from the model output should be summarized within the BA. The P(exceed) values and additional summary statistics would be used by the biologist in the BA as described in Case Study #1 to generally describe the difference between the post-project and existing conditions with regard to water quality. This discussion would be followed by a more rigorous description of potential effects uising the HI-RUN Receiving Water Dilution Subroutine results.

The inputs for the HI-RUN Receiving Water Dilution Subroutine, are provided for Case Study #2 in the HI-RUN Users Guide. The summary output generated by the model (Figure 17-4), indicates that the biological threshold for zinc would be exceeded at distance of up to 17 feet downstream of the outfall in both existing and proposed conditions during the month of September, while the biological thresholds would only be exceeded at a distance of up to 7 feet was for both conditions during the month of August. The biological threshold for dissolved copper is not estimated to be exceeded at distance of greater than 1 foot from the outfall for both the existing and proposed conditions; this is the minimum distance that HI-RUN will evaluate. >.

The maximum distance downstream during any month defines the area within which ESA-listed aquatic species could be exposed to pollutant concentrations sufficient to cause adverse effects. In the example output from Case Study #2 (Figure 17-4), this distance is 17 feet for the month of September. This information is not considered by the author of the biological assessment when making a proper effect determination. Remember that new PGIS and subsequent discharge to surface waters is generally considered an adverse effect. These quantitative results only apply to zinc and copper, not to the numerous other pollutants present in stormwater.

A more detailed assessment (quantitative or qualitative) of the project should be performed to determine whether there are mitigating factors that are not reflected in the output of the HI-RUN model (see Step 7 below). Step 7 below summarizes factors that would be considered when completing this assessment. In general this assessment would examine potential site characteristics not addressed in the HI-RUN model that influence water quality or flow impacts (i.e., open conveyance, distance from outfall to receiving waterbody), quality and suitability of habitat within the receiving waterbody for various lifestages of species, and anticipated timing of discharges relative to the anticipated use and timing of species in the receiving waterbody.

Highway Runoff Dilution Summary Results

Project: SR 13, MP 15.5, TDA 1
Precipitation Series: Montesano
Description: Case Study 2

Background Concentrations (mg/L)
Dissolved Copper: 0.002
Dissolved Zinc: 0.003

Baseline Conditions: 24.8 acres
Basic Treatment Infiltration 0% - 4.3 acres
No Treatment Infiltration 0% - 20.5 acres

Proposed Conditions: 31.1 acres
Enhanced Treatment Infiltration 60% - 6.3 acres with detention
Basic Treatment Infiltration 0% - 0 acres with detention
Basic Treatment Infiltration 0% - 4.3 acres
No Treatment Infiltration 0% - 20.5 acres

Background Pollutant Concentrations

Baseline Conditions

Proposed Conditions

Receiving Water Inputs

		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Depth (ft)									1.55	1.5			
Velocity (fps)									0.53	0.5			
Width (ft)									10.5	10			
Slope									0.004	0.004			
Discharge Distance (ft)									0	0			
Distance Downstream in feet to Meet Biological Threshold													
Dissolved Copper	Baseline								< 1	< 1			
	Proposed								< 1	< 1			
Dissolved Zinc	Baseline								7	17			
	Proposed								7	17			

Distance Downstream

Figure 17-4. Overview of detailed receiving water dilution subroutine results – Case Study #2.

The HI-RUN model automatically calculates the adverse sub-lethal effect thresholds for dissolved zinc and copper, based upon the background concentrations of these metals in the receiving waterbody (Figure 17-4). The dissolved copper and dissolved zinc existing concentrations and concentrations resulting in the post-project condition are presented relative to the adverse sub-lethal effect thresholds, above which, adverse sub-lethal effects may occur:

- The current adverse sub-lethal effect threshold for DZn is 5.6 µg/L over background zinc concentrations between 3.0 µg/L and 13 µg/L (Sprague 1968).
- The HI-RUN model currently calibrates to the receiving water's actual background concentration regardless of whether it falls within the range provided by the threshold described above. Model outputs will automatically calculate a 0.0056 mg/L (5.6 microgram/liter) increase in DZn over the receiving water's background concentration.
- The adverse sub-lethal effect threshold for DCu is 2.0 µg/L over background levels of 3.0 µg/L or less (Sandahl et al. 2007).
- The HI-RUN model currently calibrates to the receiving water's actual background concentration regardless of whether it falls below a background of 3.0 µg/L or less. Model outputs will automatically calculate a 0.002 mg/L (2.0 microgram/liter) increase in DCu over the receiving water's background concentration.
- 1 mg/L (milligram per liter) = 1,000 µg/L (micrograms per liter). To convert model outputs from mg/l to µg/L, move the decimal place three places to the right.

The model output should be provided in an appendix to the BA. But the results from the model output should be summarized within the BA. Table 17-9 provides a generalized format summarizing these data for each individual parameter. Note this table presents purely hypothetical data and does not directly incorporate results from Case Study #2. Values in this table represent distances downstream from the outfall (in feet) where receiving water concentrations will exceed the applicable threshold for biological effects with a 5 percent probability. Separate values are presented for the proposed and existing conditions, respectively.

Table 17-9. Example table format for summarizing results from dilution analyses performed using the HI-RUN dilution subroutine.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	MAX
Species A	7/6	5/4	4/3	8/7							7/6	8/7	8/7
Species B			4/3	8/7	9/7	10/9							10/9
Species C	7/6	5/4	4/3	8/7	9/7	10/9	8/7	5/4	6/5	5/4	7/6	8/7	10/9
Species D	7/6	5/4	4/3	8/7							7/6	8/7	8/7

Existing condition/proposed condition. Dilution distance in feet.

In the detailed model output, the left-hand column for both existing and proposed conditions is highlighted in green. This column depicts the probability of concentrations falling within the following ranges:

- The bottom row: Zero to the background (established by the biologist and/or project hydrologist based upon available existing water quality data) (Figure 17-5)
- The middle row: Background to the biological threshold (for dissolved copper or zinc) (Figure 17-5)
- The top row: Above the biological threshold (for dissolved copper or zinc) (Figure 17-5)

By providing summary data for pollutant concentrations in this way, the model allows the biologist to effectively describe the potential for biological thresholds to be exceeded between the established point of interest downstream of the project and the discharge point or outfall. For example, based upon the output provided above, concentrations of dissolved copper in a given runoff event during the month of August have a 4.7 percent probability of exceeding the biological threshold under baseline conditions, and a 4.6 percent probability under proposed conditions (Figure 17-5). Similarly, for dissolved zinc, there is a 4.9 percent probability that concentrations will exceed the biological threshold during a runoff event in the month of August under both baseline and proposed conditions (Figure 17-5).

The model outputs also describe the potential for different ranges of discharge durations (the cells along the bottom of the output tables highlighted in green) occurring in a given month (taking into account the proposed BMPs and how they affect discharge within the TDA). The biologist can use this information to help describe the likelihood that a discharge event of a given duration will occur. The biologist can also examine the probability of certain concentration ranges occurring during discharge events of specific duration. This helps to describe how long fish may be exposed.

The biologist should summarize and discuss the results of the stormwater analysis in the "Analysis of Effects" section as follows:

- Describe project-generated differences in the pre- and post-project loading; compare loading estimates
- Analyze the location of the outfall/discharge point and the modeled zone of effect (distance downstream to the point of interest) relative to habitat suitability, species occurrence, and timing of the species relative to when and where stormwater discharges are anticipated to evaluate the potential for exposure

4.7 percent probability of exceeding copper biological threshold – baseline conditions

Dissolved Copper - September probability of occurrence for baseline conditions downstream distance = 1 feet

Baseline Conditions

Conc. (mg/L)		0 - 3	3 - 6	6 - 12	12 - 24	24 - 48	48 - 96	96 - 192	>192
> 0.004	0.047	0.006	0.013	0.015	0.009	0.003	0.001	0.000	0.000
0.002 - 0.004	0.775	0.094	0.220	0.247	0.152	0.051	0.010	0.001	0.000
0 - 0.002	0.178	0.022	0.051	0.057	0.035	0.012	0.002	0.000	0.000
		0.121	0.284	0.319	0.196	0.066	0.013	0.001	0.000

Proposed Conditions

Conc. (mg/L)		0 - 3	3 - 6	6 - 12	12 - 24	24 - 48	48 - 96	96 - 192	>192
> 0.004	0.081	0.000	0.001	0.005	0.016	0.027	0.022	0.009	0.002
0.002 - 0.004	0.771	0.000	0.006	0.044	0.155	0.255	0.208	0.084	0.018
0 - 0.002	0.147	0.000	0.001	0.008	0.030	0.049	0.040	0.016	0.004
		0.000	0.008	0.057	0.202	0.331	0.270	0.108	0.024

Discharge Duration (hrs)

4.6 percent probability of exceeding copper biological threshold – proposed conditions

Dissolved Copper - September probability of occurrence for proposed conditions downstream distance = 1 feet

Baseline Conditions

Conc. (mg/L)		0 - 3	3 - 6	6 - 12	12 - 24	24 - 48	48 - 96	96 - 192	>192
> 0.004	0.081	0.010	0.023	0.026	0.016	0.005	0.001	0.000	0.000
0.002 - 0.004	0.741	0.090	0.207	0.237	0.145	0.050	0.010	0.001	0.000
0 - 0.002	0.178	0.022	0.050	0.057	0.035	0.012	0.002	0.000	0.000
		0.121	0.280	0.321	0.196	0.067	0.014	0.001	0.000

Proposed Conditions

Conc. (mg/L)		0 - 3	3 - 6	6 - 12	12 - 24	24 - 48	48 - 96	96 - 192	>192
> 0.004	0.046	0.000	0.000	0.003	0.009	0.015	0.013	0.005	0.001
0.002 - 0.004	0.807	0.000	0.006	0.047	0.163	0.266	0.218	0.088	0.019
0 - 0.002	0.147	0.000	0.001	0.009	0.030	0.048	0.040	0.016	0.003
		0.000	0.007	0.058	0.202	0.330	0.270	0.109	0.023

Discharge Duration (hrs)

4.9 percent probability of exceeding zinc biological threshold – baseline conditions

Dissolved Zinc - September probability of occurrence for baseline conditions downstream distance = 17 feet

Baseline Conditions

Conc. (mg/L)		0 - 3	3 - 6	6 - 12	12 - 24	24 - 48	48 - 96	96 - 192	>192
> 0.0086	0.049	0.006	0.014	0.016	0.010	0.003	0.001	0.000	0.000
0.003 - 0.0086	0.950	0.115	0.267	0.303	0.187	0.064	0.013	0.001	0.000
0 - 0.003	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		0.121	0.281	0.319	0.197	0.067	0.014	0.001	0.000

Proposed Conditions

Conc. (mg/L)		0 - 3	3 - 6	6 - 12	12 - 24	24 - 48	48 - 96	96 - 192	>192
> 0.0086	0.029	0.000	0.000	0.002	0.006	0.010	0.008	0.003	0.001
0.003 - 0.0086	0.971	0.000	0.007	0.056	0.195	0.322	0.261	0.107	0.022
0 - 0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		0.000	0.008	0.057	0.201	0.331	0.269	0.110	0.023

Discharge Duration (hrs)

4.9 percent probability of exceeding zinc biological threshold – proposed conditions

Dissolved Zinc - September probability of occurrence for proposed conditions downstream distance = 17 feet

Baseline Conditions

Conc. (mg/L)		0 - 3	3 - 6	6 - 12	12 - 24	24 - 48	48 - 96	96 - 192	>192
> 0.0086	0.031	0.004	0.009	0.010	0.006	0.002	0.000	0.000	0.000
0.003 - 0.0086	0.967	0.117	0.277	0.308	0.187	0.065	0.013	0.001	0.000
0 - 0.003	0.001	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		0.121	0.286	0.318	0.193	0.067	0.014	0.002	0.000

Proposed Conditions

Conc. (mg/L)		0 - 3	3 - 6	6 - 12	12 - 24	24 - 48	48 - 96	96 - 192	>192
> 0.0086	0.049	0.000	0.000	0.003	0.010	0.016	0.013	0.005	0.001
0.003 - 0.0086	0.951	0.000	0.007	0.055	0.193	0.316	0.254	0.103	0.024
0 - 0.003	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		0.000	0.007	0.058	0.202	0.332	0.267	0.109	0.025

Discharge Duration (hrs)

Figure 17-5. Detailed receiving water dilution subroutine results – Case Study #2.

- If there is potential for exposure, the biologist would include general discussions on 1) the anticipated timing and duration of exposure (based upon the HI-RUN model outputs regarding probability of occurrence for storm events of various durations – see Figure 17-5), 2) the potential response of species or critical habitat to increased or decreased pollutant loads (based upon guidance provided in Case Study #1 regarding loading), and 3) toxicity related to the anticipated pollutant concentrations (based upon general information regarding effects of stormwater constituents on fish provided earlier in this chapter and the guidance provided in the paragraph immediately below).

In general, elevated pollutant concentrations can result in adversde lethal and sublethal effects to listed aquatic species via absorption from gill surfaces, olfactory inhibition, and ingestion. If a project alters the concentrations of pollutants, the biologist must first compare projected concentrations to known biological threshold concentrations for dissolved zinc and copper to determine if there is potential for adverse effects (including injury) to individual fish. The biologist then considers any changes in concentrations in an environmental context (see Step 7 below) to further define or characterize the potential for exposure or injury to occur. For example, the biologist would consider current baseline water quality conditions in relation to the projected concentrations; the anticipated extent of altered concentrations in the receiving water body (the dilution zone) in relation to the habitat type(s) that would be exposed to altered concentration; and finally what life stage(s) could be exposed to altered concentrations based upon when, how long, and how frequently exposure would occur.

The toxicity of the stormwater constituents is species-specific and effects may be visible at various levels of biological organization (i.e., on a molecular, cellular, tissue, or whole-organism level). Often, research has not been conducted on ESA-listed species and results must be extrapolated based on physiological and environmental similarities. Laboratory studies are useful due to the ability to control for multiple variables, thus providing the ability to determine cause-and-effect relationships.

However, the laboratory studies have not been verified with field studies. Currently there is limited peer reviewed science on the effects of pollutants of concern on listed species in the natural environment. The focus of the BA analysis will be on the changes the project is having on the existing conditions and on the potential for exposure for listed species to concentrations exceeding the established biological thresholds.

17.3.7 STEP 7: Examine Site-Specific Conditions that May Moderate or Mediate Stormwater Effects

In some cases, site-specific conditions may help to lessen or may magnify the predicted effects. Qualitative or quantitative factors to consider and that may influence potential stormwater impacts include:

- Soils that support infiltration: Soils that support infiltration will reduce the amount of stormwater that reaches the receiving waterbody.
- Outfall configuration: Is it a single pipe? Does it end in a diffuser or flow spreader that could increase dilution (and therefore decrease pollutant concentrations) within the receiving waterbody?
- Runoff conveyance characteristics: Is it a closed system with no opportunity for evapo-transportation or infiltration, or does runoff flow through a broad/unlined/open channel?
- Distance from the outfall to a receiving waterbody: If the outlet does not end directly at a riprap pad within the OHWL of the receiving waterbody, then there is the opportunity for dispersion and infiltration of flows. The longer the distance from the receiving waterbody, the greater the opportunity for dispersion, evaporation, infiltration and even additional treatment through the interaction of the stormwater with soils and vegetation. This factor may be considerably less important under "wet season" conditions when soils are saturated.
- Characteristics of the receiving waterbody: Is it an ephemeral channel? Is the point of discharge within a wetland or riparian buffer? Is the wetland reliant upon stormwater discharges to maintain its hydrology? Is it an emergent wetland that will provide additional treatment and mixing prior to discharging to the receiving water body? Is the wetland and/or receiving waterbody used by fish for habitat? All these considerations will influence potential effects and exposure.
- Does the outfall or project discharge to a dynamic, fast-moving receiving water body or to a slower-moving receiving waterbody? Describe the temporal and spatial effects this condition could have on potential exposure.

All these factors working individually or together can influence the amount and quality of the stormwater prior to it entering the receiving water.

Similarly, site-specific factors related to habitat and species in the receiving water need to be reconsidered to accurately assess and describe anticipated exposures. The significance of these site-specific factors is that they potentially affect:

- Quality and suitability of habitat within the receiving waterbody for various lifestages of species resulting from impacts to water quality, flow, or local hydrology
- Anticipated timing of discharges relative to the anticipated use and timing of species in the receiving waterbody

- Potential exposure(s) and anticipated response(s) of fish to stormwater concentrations in exceedance of biological effect thresholds.

17.3.8 STEP 8: Revisit Action Area Extent to Reflect Effects from Stormwater BMP Construction and Stormwater Runoff.

The project biologist will not be able to complete this step until after stormwater effects have been identified and their physical, chemical, and biological effects assessed. This includes the stormwater effects associated with the induced growth. It is important to remember from the outset that stormwater is only one component used in defining the action area. The project biologist will need to revisit how the action area has been defined as the anticipated effects associated with various project elements are more fully understood or more accurately estimated (see CHAPTER 8 – ACTION AREA).

17.3.9 STEP 9: Assess Potential Exposure and Response of Species and Critical Habitat

The biologist must evaluate all the direct and indirect effects resulting from the proposed stormwater management and discharges when providing rationale in support of proper effect determinations for listed species and critical habitat. This requires the biologist fully integrate all the preceding steps into a coherent analysis and discussion. The biologist must consider all the stormwater effects and risks for exposure identified in Step 6 (Section 17.3.6) and modified in Step 7 (Section 17.3.7), taking into consideration the biology of the species and habitat (Step 4 – Section 17.3.4), within the context of existing conditions identified in Step 5 (Section 17.3.5).

- The project may result in insignificant, incremental or significant effects, and may persistently or episodically affect pollutant loads, pollutant concentrations, flow and/or local hydrology. The biologist must consider all these short- and long-term effects.

- The biologist must assess whether, how, and where listed species or their habitat may be exposed (temporally and spatially) to these direct and indirect effects and how they affect conditions in the receiving waters over time.

- The biologist must describe how listed species (individuals) or their habitat will respond to exposure:

    - Will individuals experience significant disruption to their normal behaviors (feeding, moving, or sheltering) or essential behaviors (spawning, egg incubation, etc.)?

    - Will habitat conditions be altered in a way(s) that measurably affect suitability and function for the listed species? This applies to both ESA and EFH.

- The biologist must evaluate whether anticipated effects to existing conditions within the receiving waterbody will influence the potential for exposure, and the projected responses of listed species and their habitat.

17.3.10 STEP 10: Factor Stormwater Exposures and Effects into Effect Determinations

The BA provides a single effect determination for each listed species, which considers the effects of the entire project including stormwater discharges and new and modified stormwater elements. As a preliminary step in reaching that determination, the project biologist focuses on assessing just the stormwater effects (i.e., changes to the pattern or rate of runoff, peak flows, flow durations, and base flow, as well as changes in pollutant loads and pollutant concentrations) and makes an effect determination for each species or habitat related to anticipated stormwater effects. However, these effect determinations are then considered in conjunction with all the effect determinations generated for other project elements (noise, in-water work, indirect effects) to arrive at a single overall effect determination for each species addressed in the BA.

17.3.10.1 Determination of No-Effect Based on No Exposure

If listed species amnd their habitats do not temporally or spatially overlap with the areas that will be affected by changes in stormwater pollutant loading, water quality, flow, or local hydrology (or areas that lie within the BMP or conveyance system footprint, including the outfall), then the species and habitat will not be exposed. Examples of stormwater treatment scenarios that would warrant a *no effect* determination include:

- 100% infiltration via BMP
- Natural or engineered dispersion that does not enter fish-bearing waters or waters that do not have connectivity with fish-bearing waters
- Discharge to natural or constructed wetlands that have no connectivity with fish-bearing waters

If species or habitat is not exposed to the stormwater discharges or new or modified BMPs and related infrastructure, a *no-effect* determination is warranted for this element of the project. Remember that the overall effect determination for each species is based on effects of the entire project, not just the stormwater discharges and stormwater and infrastructure.

17.3.10.2 Determination of May Affect, Not Likely to Adversely Affect

Where the effects of the stormwater discharges and proposed stormwater designs (i.e., BMPs, conveyance, points-of-discharge) on a listed species or habitat are judged to be beneficial, discountable, or insignificant, a *may affect, not likely to adversely affect* determination is warranted for the stormwater element of the project. Stormwater effects that are discountable or insignificant will be dependent upon project conditions, receiving waterbodies, stormwater treatment levels, existing conditions, and presence of species or habitat.

A project biologist who has reached this effect determination has provided all the analysis required and has clearly outlined any stormwater effects (i.e., changes in water quality, flow, and local hydrology), the footprint of the BMPs, outfall locations, conveyance system characteristics and potential for influencing project stormwater effects, and temporary and permanent effects. The project biologist has also identified the habitat availability and historical use by the species in the action area and relative to the anticipated temporal and spatial extent of stormwater effects and has documented the extent of exposure in the effects analysis. All predicted effects have been adequately supported and identified as discountable or insignificant (see discussion of each of these terms below) in the effects analysis.

Discountable Effects

If the project biologist determines that exposure to stormwater effects is extremely unlikely to occur, and this can be supported with best available science, then the effect is discountable. For example, effects related to changes in water quality may be discountable if the species is extremely unlikely to be present when stormwater discharges will occur (i.e., there is little chance for exposure to occur). The rationale for concluding that the effects are discountable must be explained in the effects analysis. Where the effects are discountable, *a may affect, not likely to adversely affect* determination is warranted for the stormwater element of the project.

Insignificant Effects

Perhaps exposure to the stormwater effects is likely, but the response of the listed species or habitat is expected to be so small that it cannot be meaningfully measured, detected, or evaluated. The project biologist could infer this if the probability of pollutant concentrations exceeding the established biological thresholds is extremely low (i.e., less than 1 percent) and/or if changes to annual pollutant loads, flows or local hydrology relative to existing conditions are negligible (i.e., predicted plume size is extremely small or discharges will be infrequent). In each of these cases, the project biologist should explain the rationale for concluding that the effects are insignificant in the effects analysis. Where the effects are insignificant, a *may affect, not likely to adversely affect* determination is warranted.

It is anticipated that very few WSDOT projects that increase and/or replace PGIS (especially in western Washington) will result in discountable or insignificant effects to listed species and designated critical habitat.

17.3.10.3 Determination of May Affect, Likely to Adversely Affect

Effects on listed species and critical habitat that are not beneficial, discountable, or insignificant warrant a *may affect, likely to adversely affect* determination for the stormwater element of the project.

If an effect is not beneficial, discountable, or insignificant, then it is an adverse effect. Adverse effects can be either direct, on or to the individual, or indirect, on or to its habitat and/or prey. Stormwater discharges that result in measurable adverse exposures or effects to listed species, their habitat, or critical habitat may include changes to the pattern or rate of runoff, peak flows, flow durations, or base flow, and may include changes in pollutant loads and pollutant concentrations (from projects that create significant amounts of pollution generating impervious surface and/or projects that occur in watersheds with degraded baseline or existing conditions). These assessments must be supported by pertinent existing information on the habitat elements, species life history, and number of individuals and life stages that may be affected.

Stormwater effects that present or have adverse lethal or sub-lethal consequences, or that significantly interfere with or impair an individual's ability to shelter, forage, move freely, reproduce, or survive (i.e., if significant disruptions to normal or essential behaviors are likely or foreseeable), will likely result in *take*. These are the endpoints used to quantify or describe the adverse effect on a species.

A project biologist who has reached this effect determination has provided all the content recommended in Section 17.3 and has clearly outlined the existing and proposed stormwater treatment and design in the project description, including temporary and permanent facilities, outfall locations, and existing and proposed conveyance. The project biologist has also identified the habitat availability and historical use by the species and has described the relevant water quality indicators and habitat characteristics in the existing environmental conditions and has documented the spatial and temporal extent of exposure of the stormwater and proposed stormwater discharges and BMPs in the effects analysis. All predicted impacts on an individual animal's ability to survive, reproduce, move freely, forage, or seek shelter are supported with best available science and are addressed in the effects analysis.

Prior to 2020, HI-RUN results that estimated an exposure distance of less than one foot from the end-of-pipe typically warranted a *not likely to adversely affect* determination for listed salmonids. Since 2020, NMFS has generally considered any stormwater (treated or untreated) discharged to fish-bearing waters or waters that have connectivity with fish-bearing waters within the action area as an adverse effect. Rationale supporting this conclusion may include quantitative data, such as HI-RUN results focusing on zinc, copper, and total suspended solids, and qualitative rationale for other contaminants.

17.4 Indirect Effects Stormwater Runoff Analytical Method

In January 2011, the multi-agency Project Management Team (PMT) (consisting of representatives from USFWS, NMFS, FHWA, and WSDOT developed guidance for assessing stormwater quality impacts from development indirect effects that can be directly associated with a transportation project. The *Indirect Effects Stormwater Runoff Analytical Method* serves as an addition to the guidance presented in the technical memorandum issued on June 17, 2009 by the

PMT titled *Endangered Species Act (ESA), Transportation and Development; Assessing Indirect Effects in Biological Assessments*.

The method is intended to provide a coarse scale analysis of the changes in annual loads for three stormwater pollutants from changes in land use and or impervious surface. This method should only be used to assess development related indirect effects that can be directly associated with a transportation project per the Project Management Team technical memorandum. It should also be noted that this method does not address potential changes in stormwater quantity from development related indirect effects.

This method is a simple "wash-off" model that relies upon unit area annual pollutant loads (pounds/acre/year) for individual land uses to predict annual pollutant yields (pounds/year) from the changes in land use associated with the indirect effects of the project for the existing and projected conditions following completion of the transportation project. It is based upon Method 2: Applying Literature Values as described in the 2009 WSDOT guidance document, *Quantitative Procedures for Surface Water Impact Assessments*, but it replaces the land use type categories and annual pollutant loading rates used in Method 2 with more current data that is specific to Western Washington. As a result, this method is only applicable to projects in Western Washington.

The model utilizes unit area annual pollutant loads for three parameters (total suspended solids, total zinc, and total copper) and the following four land use types:

- Forest: generally refers to second growth coniferous forests with only minor commercial timber harvesting activities.
- Agricultural: generally refers to irrigated cropland for food production and low to medium density livestock grazing.
- Low- to Medium Density Development: generally refers to low and medium density single family residential development with one to six dwellings per acre.
- High-Density Development: generally refers to commercial, industrial, multi-family residential development and/or high density single family residential development (> six dwellings per acre).

The method is available on the WSDOT website at < http://www.wsdot.wa.gov/environment/technical/fish-wildlife/policies-and-procedures/esa-ba/stormwater-guidance >.

17.4.1 Steps for Analyzing Annual Pollutant Loadings Associated with Development Related Indirect Effects

1. First identify the areas within the action area that will be changed as an indirect effect of the proposed project (see PMT technical memorandum cited above).

2. For the existing condition, estimate the area (in acres) of land, within the portion of the action area that will be changed that is currently represented by each land use type in Table 1.

3. Multiply the area for each land use type by the appropriate unit area loading rate in Table 1 for that land use to obtain annual load estimates for each land use type under the existing condition. An example of how these calculations are performed is provided in Attachment B.

4. Add the annual load estimates for all land use types to produce an estimate of the total load from changed portion of the action area under the existing condition.

5. For the projected condition following completion of the transportation project (or each proposed alternative for the project), estimate the number of acres of land, within the portion of the action area that will be changed, that will be represented by each land use type in Table 1. An example of how these calculations are performed is provided in Attachment B.

6. Multiply the area for each land use type by the appropriate unit area loading rate in Table 1 for that land use to obtain annual load estimates for each land use type under the projected condition.

7. Add the annual load estimates for all land use types to produce an estimate of the total load from the changed portion of the action area under the projected condition.

Note, if there are multiple basins or receiving waters within the action area that will be affected by development indirect effects from the proposed transportation project or project alternatives, it may be necessary to provide additional tables depicting how many acres will be affected in each of these individual basins and to quantify the annual loading effects of each alternative on each basin, in addition to the overall action area. To do this, the biologist would need to complete the following additional steps:

8. In order to calculate areas for each land use type by basin, the biologist would need to determine the extent of the drainage basin /receiving water basin. The total basin area, for each basin, can be delineated using the on-

line GIS-based tool StreamStats, developed by USGS: <http://water.usgs.gov/osw/streamstats/index.html>.

9. Once the extent of the basin(s) has been established, the biologist would then determine the extent of each land use type within each basin.

10. As described in steps 1 through 6 above, calculations would be completed, by basin (rather than action area) for existing and projected conditions to discern the changes between existing and projected land use and loading conditions by basin.

Once the project-specific loading rates have been established for the existing and projected conditions within the action area, the biologist can analyze changes in land use and loading by comparing the differences between the areal extent of land uses and associated loading within the action area between the existing and projected conditions. The biologist should summarize these results within the indirect effects section of the biological assessment and provide a qualitative discussion regarding chemical, biological and ecological effects of stormwater runoff pollutant loadings.

In general, changes in loading affect baseline conditions in the receiving water body, which in turn may affect the suitability of habitat for listed species. Increased pollutant loads contribute to the continued or increased degradation of baseline water quality conditions. Conversely, decreased loads contribute to improvement of baseline conditions. Though changes in loading may contribute to sublethal effects to listed aquatic species via ingestion or food chain interactions, these changes can rarely be linked directly to injury of listed aquatic species. As a result, the indirect effects analysis above will allow the biologist to generally characterize potential changes to baseline conditions not to describe potential direct effects to fish.

17.5 Glossary of Terms

basic (water quality) treatment (versus enhanced water quality treatment) The Washington State Department of Ecology's performance goal is to achieve 80% removal of total suspended solids for influent concentrations that are greater than 100mg/l, but less than 200mg/l. For influent concentrations greater than 200mg/l, a higher treatment goal may be appropriate. For influent concentrations less than 100mg/l, the facilities are intended to achieve an effluent goal of 20mg/l total suspended solids.

basin The area of land drained by a river and its tributaries that drains water, organic matter, dissolved nutrients, and sediments into a lake or stream (see watershed). Basins typically range in size from 1 to 50 square miles.

best available science The best available scientific knowledge and practices.

best management practices (BMPs) The structural devices, maintenance procedures, managerial practices, prohibitions of practices, and schedules of activities that are used singly or in combination to prevent or reduce the detrimental impacts of stormwater, such as pollution of water, degradation of channels, damage to structures, and flooding.

biofilter A designed treatment facility using a combined soil and vegetation system for filtration, infiltration, adsorption, and biological uptake of pollutants in stormwater when runoff flows over and through it. Vegetation growing in these facilities acts as both a physical filter that causes gravity settling of particulates by regulating velocity of flow, and as a biological sink when direct uptake of dissolved pollutants occurs. The former mechanism is probably the most important in western Washington, where the period of major runoff coincides with the period of lowest biological activity.

biofiltration The process of reducing pollutant concentrations in water by filtering the polluted water through biological materials, such as vegetation.

bioinfiltration The process of reducing pollutant concentrations in water by infiltrating the polluted water through grassy vegetation and soils into the ground.

bioretention The removal of stormwater runoff pollutants using the chemical, biological, and physical properties afforded by a natural terrestrial community of plants, microbes, and soil. The typical bioretention system is set in a depressional area and consists of plantings, mulch, and an amended planting soil layer underlain with more freely draining granular material.

catch basin A chamber or well, usually built at the curb line of a street, for the admission of surface water to a sewer or subdrain, having at its base a sediment sump designed to retain grit and detritus below the point of overflow.

catch basin insert (CBI) A device installed under a storm drain grate to provide runoff treatment through filtration, settling, or adsorption (also called inlet protection).

catchment Surface area associated with pavement drainage design.

channel A feature that conveys surface water and is open to the air.

channel erosion The widening, deepening, and headward cutting of small channels and waterways resulting from erosion caused by moderate-to-large floods.

channel stabilization Erosion prevention and stabilization of velocity distribution in a channel using vegetation, jetties, drops, revetments, or other measures.

closed depression A low-lying area that has either no surface water outlet or such a limited surface water outlet that, during storm events, the area acts as a retention basin

compost Organic residue, or a mixture of organic residues and soil, that has undergone biological decomposition until it has become relatively stable humus. The Washington State Department of Ecology's Interim Guidelines for Compost Quality (1994) defines compost as "the product of composting; it has undergone an initial, rapid stage of decomposition and is in the process of humification (curing)." Compost to be used should meet specifications shown in Standard Specification 9-14.4(8).

concentrated flow Water flowing in a channel as opposed to a thin sheet.

constructed stormwater treatment wetland A wetland intentionally created on a site that is not a wetland, for the primary purpose of wastewater or stormwater treatment. Constructed wetlands are normally considered part of the stormwater collection and treatment system.

converted pervious surface Land cover changed from native vegetation to lawn, landscape, or pasture areas. (See also pollution-generating impervious surface.)

conveyance A mechanism for transporting water from one point to another, including pipes, ditches, and channels.

conveyance system The drainage facilities, both natural and constructed, that collect, contain, and provide for the flow of surface water and stormwater from the highest points on the land down to a receiving water. The natural elements of the conveyance system include swales and small drainage courses, streams, rivers, lakes, and wetlands. Constructed elements of the conveyance system include gutters, ditches, pipes, channels, and most retention/ detention facilities.

design flow rate The maximum flow rate to which certain runoff treatment BMPs are designed for required pollutant removal. Biofiltration swales, vegetated filter strips, and oil/water separators are some of the runoff treatment BMPs that are sized based on a design flow rate.

design storm A rainfall event of specified size and return frequency that is used to calculate the runoff volume and peak discharge rate to a stormwater facility. A prescribed hyetograph and total precipitation amount (for a specific duration recurrence frequency) are used to estimate runoff for a hypothetical storm for the purposes of analyzing existing drainage, designing new drainage facilities, or assessing other impacts of a proposed project on the flow of surface water. (A hyetograph is a graph of percentages of total precipitation for a series of time steps representing the total time during which the precipitation occurs.)

design storm frequency The anticipated period in years that will elapse before a storm of a given intensity or total volume will recur, based on the average probability of storms in the design region. For instance, a 10-year storm can be expected to occur on the average once every 10 years. Facilities designed to handle flows that occur under such storm conditions would be expected to be surcharged by any storms of greater amount or intensity.

design volume For western Washington, the water quality design volume is the 91st percentile, 24-hour runoff volume indicated by MGSFlood or an approved continuous runoff model (see Table 3-3). In eastern Washington, the water quality design volume is the volume of runoff predicted from a 24-hour storm with a 6-month return frequency.

detention The temporary storage of stormwater runoff in a stormwater facility, which is used to control the peak discharge rates and provide gravity settling of pollutants; the release of stormwater runoff from the site at a slower rate than it is collected by the stormwater facility system, with the difference held in temporary storage.

detention facility An aboveground or below-grade ground facility, such as a pond or tank, that temporarily stores stormwater runoff and subsequently releases it at a slower rate than it is collected by the drainage facility system. There is little or no infiltration of stored stormwater.

discharge Runoff leaving a new development or redevelopment via overland flow, built conveyance systems, or infiltration facilities; a hydraulic rate of flow, specifically fluid flow; or a volume of fluid passing a point per unit of time, commonly expressed in cubic feet per second, cubic meters per second, gallons per minute, gallons per day, or millions of gallons per day.

discharge point The location where a discharge leaves the permittee's MS4 to another permittee's MS4 or a private or public stormwater conveyance. "Discharge point" also includes the location where a discharge leaves the permittee's MS4 and discharges to ground, except where such discharge occurs via an outfall.

dispersion Release of surface water and stormwater runoff in such a way that the flow spreads over a wide area and is located so as not to allow flow to concentrate anywhere upstream of a drainage channel with erodible underlying granular soils.

dry pond A facility that provides stormwater quantity control by containing excess runoff in a detention basin, then releasing the runoff at allowable levels.

dry vault or tank A facility that provides stormwater quantity control by detaining runoff in underground storage units and then releasing reduced flows at established standards.

drywell A well completed above the water table so that its bottom and sides are typically dry except when receiving fluids. Drywells are designed to disperse water below the land surface and are commonly used for stormwater management in eastern Washington. (See also underground injection control [UIC] well.)

effective impervious surface For determining whether a particular TDA has exceeded Minimum Requirement 6 (Flow Control), the net-new impervious surfaces plus any applicable replaced impervious surfaces minus those new and applicable replaced impervious surfaces that are flowing into an existing dispersion area (noneffective new impervious surfaces and noneffective replaced impervious surfaces).

effective impervious surface = net new impervious surface + applicable replaced impervious surface – noneffective new impervious surface – noneffective replaced impervious surface

effective pollution-generating impervious surface (PGIS) For determining whether a particular TDA has exceeded Minimum Requirement 5 (Runoff Treatment), the new PGIS plus applicable replaced PGIS minus those new PGIS areas and applicable replaced PGIS areas that are flowing into an existing dispersion area (noneffective new PGIS and noneffective replaced PGIS).

effective PGIS = new PGIS + applicable replaced PGIS – noneffective new PGIS – noneffective replaced PGIS

emerging BMP technologies BMP technologies that have not been evaluated using approved protocols, but for which preliminary data indicate they may provide a desirable level of stormwater pollutant removal. In some instances, an emerging technology may have already received a pilot use or conditional use designation from the Washington State Department of Ecology, but does not have a general use designation.

energy dissipater A means by which the total energy of flowing water is reduced, such as rock splash pads, drop manholes, concrete stilling basins or baffles, and check dams. In stormwater design, an energy dissipater is usually a mechanism that reduces velocity prior to or at discharge from an outfall in order to prevent erosion.

enhanced runoff treatment, enhanced water quality treatment (versus basic water quality treatment) The use of runoff treatment BMPs designed to capture dissolved metals at a higher rate than basic treatment BMPs.

equivalent area An impervious surface area equal in size, located in the same TDA, and having an ADT that is greater than or equal to the original impervious surface area . The equivalent area concept can also apply to pervious areas but would also have to meet the same above requirements for impervious areas. The equivalent area concept generally applies to engineered dispersion areas and may apply to natural dispersion areas, as described in the following: The existing TDA currently collects runoff in a ditch or pipe and discharges to a surface water. By changing this condition to natural dispersion (BMP FC.01), a surface discharge is eliminated, resulting in a flow control improvement. Equivalent area trades for natural dispersion are allowed for this specific case.

exfiltration The downward movement of runoff through the bottom of an infiltration facility into the soil layer, or the downward movement of water through soil.

filter berm A berm of compost, mulch, or gravel to detain and filter sediment from sheet flow.

filter fabric A woven or nonwoven water-permeable material, typically made of synthetic products such as polypropylene, used in stormwater management and erosion and sediment control applications to trap sediment or to prevent fine soil particles from clogging the aggregates.

filter strip A grassy area with gentle slopes that treats stormwater runoff from adjacent paved areas before it can concentrate into a discrete channel.

flow control (formerly called water quantity treatment or detention)

flow control facility A drainage facility (BMP) designed to mitigate the impacts of increased surface water and stormwater runoff flow rates generated by development. Flow control facilities are designed to either hold water for a considerable length of time and then release it by evaporation, plant transpiration, or infiltration into the ground, or to hold runoff for a short period of time and then release it to the conveyance system at a controlled rate.

flow duration The aggregate time that peak flows are equal to or above a particular flow rate of interest. For example, the amount of time that peak flows are equal to or above 50% of the 2-year peak flow rate for a period of record.

flow frequency The inverse of the probability that the flow will be equaled or exceeded in any given year (the exceedance probability). For example, if the exceedance probability is 0.01 or 1 in 100, that flow is referred to as the 100-year flow.

flow path The route that stormwater runoff follows between two points of interest.

flow rate The amount of a fluid passing a certain point in a given amount of time. In stormwater applications it is usually expressed in cubic feet per second or gallons per minute.

flow splitter A device with multiple outlets, each sized to pass a specific flow rate at a given head.

flow spreader A device with a wide enough outlet to efficiently distribute concentrated flows evenly over a large area, having common components such as trenches, perforated pipes, and berms.

GIS Workbench An ArcView geographic information system tool maintained by the WSDOT HQ Geographic Services Office and the HQ Office of Information Technology to provide staff with access to comprehensive, current, and detailed environmental and natural resource management data.

groundwater Water in a saturated zone or stratum beneath the land surface or a surface water body.

groundwater table The free surface of the groundwater, which is subject to atmospheric pressure under the ground and is seldom static, generally rising and falling with the season, the rate of withdrawal, the rate of restoration, and other conditions.

heavy metals Metals of high specific gravity, present in municipal and industrial wastes, that pose long-term environmental hazards. Such metals include cadmium, chromium, cobalt, copper, lead, mercury, nickel, and zinc.

hydrologic soil groups A soil characteristic classification system defined by the U.S. Soil Conservation Service in which a soil may be categorized into one of four soil groups (A, B, C, or D) based upon infiltration rate and other properties (based on Water Quality Prevention, Identification, and Management of Diffuse Pollution by Vladimir Novotny and Harvey Olem; Van Nostrand Reinhold, New York, 1994, page 109). Soil groups include:

Type A – Low runoff potential. Soils having high infiltration rates, even when thoroughly wetted and consisting chiefly of deep, well-drained to excessivelydrained sands or gravels. These soils have a high rate of water transmission.

Type B – Moderately low runoff potential. Soils having moderate infiltration rates when thoroughly wetted and consisting chiefly of moderately fine to moderately coarse textures. These soils have a moderate rate of water transmission.

Type C – Moderately high runoff potential. Soils having slow infiltration rates when thoroughly wetted and consisting chiefly of soils with a layer that impedes downward movement of water, or soils with moderately fine to fine textures. These soils have a slow rate of water transmission.

Type D – High runoff potential. Soils having very slow infiltration rates when thoroughly wetted and consisting chiefly of clay soils with a high swelling potential; soils with a permanent high water table; soils with a hardpan, till, or clay layer at or near the surface; soils with a compacted subgrade at or near the surface; and shallow soils or nearly impervious material. These soils have a very slow rate of water transmission.

impaired waters Water bodies not fully supporting their beneficial uses, as defined under the federal Clean Water Act, Section 303(d). (See the Washington State Department of Ecology 303(d) list at: https://ecology.wa.gov/Water-Shorelines/Water-quality/Waterimprovement/Assessment-of-state-waters-303d.)

impervious surface A hard surface area that either prevents or retards the entry of water into the soil mantle as occurs under natural conditions (prior to development) and from which water runs off at an increased rate of flow or in increased volumes. Common impervious surfaces include but are not limited to rooftops, walkways, patios, driveways, parking lots, storage areas, concrete or asphalt paving, gravel roads, packed earthen materials (such as compact dirt), and oiled or macadam surfaces. Open, uncovered retention/detention facilities are not considered impervious surfaces for the purpose of determining whether the thresholds for application of minimum requirements are exceeded. Open, uncovered retention/detention facilities are considered impervious surfaces for the purpose of runoff modeling. For Minimum Requirement determination, permeable pavement is considered an impervious surface. A gravel area would be considered an impervious area and PGIS (when determining minimum requirements or stormwater modeling) when it is extending the usable shoulder between the edge of paved shoulder and the slope break point (see HRM FAQs for drawings of Case B, Case C, and Case D). Gravel areas beyond the slope break point are not considered impervious or PGIS (see HRM FAQs for drawings of Case A, Case C, Case D, and Case E). The exception to this is when the gravel area is extending the usable shoulder as shown in Case B.

infiltration The downward movement of water from the surface to the subsoil. infiltration facility or system A drainage facility designed to use the hydrologic process of surface and stormwater runoff soaking into the ground (commonly called percolation), to dispose of surface and stormwater runoff.

infiltration pond A facility that provides stormwater quantity control by containing excess runoff in a detention facility, then percolating that runoff into the surrounding soil.

infiltration rate The rate, usually expressed in inches per hour, at which water moves downward (percolates) through the soil profile. Short-term infiltration rates may be inferred from soil analysis or texture or derived from field measurements. Long-term infiltration rates are affected by variability in soils and subsurface conditions at the site, the effectiveness of pretreatment or influent control, and the degree of long-term maintenance of the infiltration facility.

level spreader A temporary erosion and sedimentation control device used to distribute stormwater runoff uniformly over the ground surface as sheet flow (not through channels), in order to enhance infiltration and prevent concentrated, erosive flows.

media filter A filter that includes material for removing pollutants (such as compost, gypsum, perlite, zeolite, or activated carbon).

media filter drain (previously known as the ecology embankment) A stormwater treatment facility typically constructed in the pervious shoulder area of a highway, consisting of a novegetation zone, a grass strip, a filter media mix, and a drain component that keeps the facility free draining.

National Pollutant Discharge Elimination System (NPDES) The part of the federal Clean Water Act that requires point source dischargers to obtain permits, called NPDES permits, which in Washington State are administered by the Washington State Department of Ecology.

new impervious surfaces Those surfaces that receive direct, run-on, or blow-in of rainfall and (1) expand the existing roadway prism or (2) are upgraded from gravel to bituminous surface treatment (BST), asphalt, or concrete pavement. Note that existing gravel surfaces are considered impervious surfaces with the exceptions laid out in the impervious surface definition. However, a gravel surface that is upgraded to a more impervious surface (gravel to BST, ACP, or PCCP) is defined as a new impervious surface. Also note that for Minimum Requirement determination, permeable pavement is considered an impervious surface.

net-new impervious surface The total area of new impervious surface being added to the TDA minus the total area of existing impervious surface being removed from the TDA. To use this concept, the existing impervious surface removal area must fully revert to a natural condition as specified in HRM Section 4-3.5.3. The concept of net-new impervious surface applies only to Minimum Requirement 6 (Flow Control) and is applied at the threshold discharge area level. (See the definition for effective impervious surface and Figure 3.3, Step 8.)

Non-effective impervious surfaces Those new, applicable replaced, or existing impervious surfaces that are being managed by existing natural dispersion areas meeting the natural dispersion BMP criteria in HRM Section 5-4.1.2.

Non-effective pollution-generating impervious surface (PGIS) Those new, applicable replaced, or existing PGIS surfaces that are being managed by existing natural dispersion areas meeting the natural dispersion BMP criteria in HRM Section 5-4.1.2.

Non-pollution-generating surface (NPGS) A surface that, based on its use, is an insignificant or low source of pollutants in stormwater runoff. For example, roofs that are subject only to atmospheric deposition or have normal heating, ventilation, and air conditioning vents; paved bicycle pathways and pedestrian sidewalks that are separated from roads used by motor vehicles; fenced fire lanes; infrequently used maintenance access roads; and in-slope areas of roads. Sidewalks that are regularly treated with salt or other deicing chemicals are considered pollution-generating impervious surfaces.

outfall Point source as defined by 40 CFR 122.2 at the point where a discharge leaves the permittee's MS4 and enters a receiving water body or receiving waters. Outfall also includes the permittee's MS4 facilities/BMPs designed to infiltrate stormwater.

outlet The point of water disposal from a stream, river, lake, tidewater, or artificial drain.

permeable soils Soil materials having a sufficiently rapid infiltration rate so as to greatly reduce or eliminate surface and stormwater runoff; generally classified as Soil Conservation Service hydrologic soil types A and B.

pollution-generating impervious surface (PGIS) An impervious surface that is considered a significant source of pollutants in stormwater runoff, including surfaces that receive direct rainfall (or run-on or blow-in of rainfall) and are subject to vehicular use; industrial activities; or storage of erodible or leachable materials, wastes, or chemicals. Erodible or leachable materials, wastes, or chemicals are substances that, when exposed to rainfall, measurably alter the physical or chemical characteristics of the rainfall runoff. Examples include erodible soils that are stockpiled, uncovered process wastes, manure, fertilizers, oily substances, ashes, kiln dust, and garbage container leakage. Metal roofs are also considered pollutiongenerating impervious surfaces unless they are coated with an inert, nonleachable material (such as a baked-on enamel coating). A surface, whether paved or not, is considered subject to vehicular use if it is regularly used by motor vehicles. The following are considered regularly used surfaces: roads, permeable pavement, unvegetated road shoulders, bicycle lanes within the travel lane of a roadway, driveways, parking lots, unfenced fire lanes, vehicular equipment storage yards, and airport runways. The following are not considered regularly used surfaces: paved bicycle pathways separated from roads for motor vehicles, fenced fire lanes, and infrequently used maintenance access roads. A gravel area would be considered an impervious area and PGIS (when determining minimum requirements or stormwater modeling) when it is extending the usable shoulder between the edge of paved shoulder and the slope break point (see HRM FAQs for drawings of Case B, Case C, and Case D). Gravel areas beyond the slope break point are not considered impervious or PGIS (see HRM FAQs for drawings of Case A, Case C, Case D, and Case E). The exception to this is when the gravel area is extending the usable shoulder as shown in Case B. pollution-generating pervious surface (PGPS) Any nonimpervious surface subject to the ongoing use of pesticides and fertilizers or loss of soil, such as lawns, landscaped areas, golf courses, parks, cemeteries, and sports fields. Grass highway shoulders and medians are not subject to such intensive landscape maintenance practices and are not considered pollution-generating pervious surfaces. It is WSDOT policy to create self-sustaining, native plant communities that require no fertilizer and little to no weed control after they are established. During the plant establishment period, usually the first three years after planting, WSDOT revegetation and mitigation projects are intensely managed to aid plant establishment. However, throughout the life of the project, WSDOT practices integrated vegetation management (IVM), which recognizes herbicides as tools in maintaining planting are as (one of many tools available). Questions regarding whether a specific area may be considered a pollution-generating pervious surface should be directed to the local maintenance area superintendent or the region landscape architect.

receiving waters or receiving water body Naturally and/or reconstructed naturally occurring surface water bodies, such as creeks, streams, rivers, lakes, wetlands, estuaries, and marine waters, to which a discharged occurs via an outfall or via sheet/dispersed flow. Receiving waters may also include ground water to which a discharge occurs via facilities/BMPs designed to infiltrate stormwater.

replaced impervious surface Those roadway areas that are excavated to a depth at or below the top of the subgrade (pavement repair work excluded) and replaced in kind. The subgrade is taken to be the crushed surfacing directly below the pavement layer (ACP, PCCP, BST). If the removal and replacement of existing pavement does not go below the pavement layer, as with typical PCCP grinding, ACP planing, or "paver" projects, the new surfacing is not considered "replaced impervious surface." Certain situations that do not include excavation of the existing roadway are also considered replaced impervious surface. (See the HRM Revisions website's FAQs for a discussion of these situations.)

replaced PGIS Those PGIS areas that are removed and replaced in kind by the project, or for roadway areas that are excavated to a depth at or below the top of the subgrade (pavement repair work excluded) and replaced in kind. The subgrade is taken to be the crushed surfacing directly below the pavement layer (ACP, PCCP, BST). If the removal and replacement of existing pavement does not go below the pavement layer, as with typical PCCP grinding, ACP planing, or "paver" projects, the new surfacing is not considered "replaced PGIS." Certain situations that do not include excavation of the existing roadway are also considered replaced PGIS. (See the HRM Revisions website's FAQs for a discussion of these situations.)

retention The process of collecting and holding surface and stormwater runoff with no surface outflow.

retention/detention facility (R/D) A type of drainage facility designed either to hold water for a considerable length of time and then release it by evaporation, plant transpiration, or infiltration; or to hold surface and stormwater runoff for a short period of time and then release it to the surface and stormwater management system.

retrofit The renovation of an existing structure or facility to meet changed conditions or to improve performance.

runoff treatment Pollutant removal to a specified level via engineered or natural stormwater management systems.

runoff treatment BMP A BMP specifically designed for pollutant removal.

sheet flow Runoff that flows over the ground surface as a thin, even layer, not concentrated in a channel.

soil drainage As a natural condition of the soil, the frequency and duration of periods when the soil is free of saturation. In well-drained soils, the water is removed readily, but not rapidly; in poorly drained soils, the root zone is waterlogged for long periods unless artificially drained, and the roots of ordinary crop plants cannot get enough oxygen; and in excessively drained soils, the water is removed so completely that most crop plants suffer from lack of water. Strictly speaking, excessively drained soils are a result of excessive runoff due to steep slopes or low available water-holding capacity due to small amounts of silt and clay in the soil material. The following classes are used to express soil drainage:

- Well drained – Excess water drains away rapidly; no mottling occurs within 36 inches of the surface.
- Moderately well drained – Water is removed from the soil somewhat slowly, resulting in small but significant periods of wetness; mottling occurs between 18 and 36 inches.
- Somewhat poorly drained – Water is removed from the soil slowly enough to keep it wet for significant periods but not all the time; mottling occurs between 8 and 18 inches.
- Poorly drained – Water is removed so slowly that the soil is wet for a large part of the time; mottling occurs between 0 and 8 inches.
- Very poorly drained – Water is removed so slowly that the water table remains at or near the surface for a greater part of the time. There may also be periods of surface ponding. The soil has a black-to-gray surface layer with mottles up to the surface.

soil permeability The ease with which gases, liquids, or plant roots penetrate or pass through a layer of soil.

stormwater That portion of precipitation that does not naturally percolate into the ground or evaporate, but flows via overland flow, interflow, pipes, and other features of a stormwater drainage system into a defined surface water body or a constructed infiltration facility.

stormwater facility A constructed component of a stormwater drainage system, designed or constructed to perform a particular function or multiple functions. Stormwater facilities include but are not limited to pipes, swales, ditches, culverts, street gutters, detention ponds, retention ponds, constructed wetlands, infiltration devices, catch basins, oil/water separators, and biofiltration swales.

Stormwater Management Manual for Eastern Washington (SWMMEW) A technical manual prepared by the Washington State Department of Ecology containing BMPs intended to prevent, control, and treat pollution in stormwater and to reduce other stormwater-related impacts on waters of the state. The stormwater manual provides guidance on measures necessary in eastern Washington to control the quantity and quality of stormwater runoff from new development and redevelopment.

Stormwater Management Manual for Western Washington (SWMMWW) A technical manual prepared by the Washington State Department of Ecology containing BMPs intended to prevent, control, and treat pollution in stormwater and to reduce other stormwater-related impacts on waters of the state. The stormwater manual provides guidance on measures necessary in western Washington to control the quantity and quality of stormwater runoff from new development and redevelopment.

stormwater outfall Any location where concentrated stormwater runoff leaves WSDOT right of way. Outfalls may discharge to surface waters or groundwater.

swale A natural depression or shallow drainage conveyance with relatively gentle side slopes, generally with flow depths less than 1 foot, used to temporarily store, route, or filter runoff.

threshold discharge area (TDA) An on-site area draining to a single natural discharge location or multiple natural discharge locations that combine within ¼ mile downstream (as determined by the shortest flow path).

total suspended solids (TSS) That portion of the solids carried by stormwater that can be captured on a standard glass filter.

turbidity Dispersion or scattering of light in a liquid, caused by suspended solids and other factors; commonly used as a measure of suspended solids in a liquid. Turbidity is a stateregulated parameter. Turbidity can be measured in the field with a hand-held meter and is recorded in nephelometric turbidity units (NTU).

vegetated filter strip A facility designed to provide runoff treatment of conventional pollutants (but not nutrients) through the process of biofiltration.

water body Surface waters including rivers, streams, lakes, marine waters, estuaries, and wetlands.

water quality A term used to describe the chemical, physical, and biological characteristics of water, usually in respect to its suitability for a particular purpose.

water quality standards The minimum requirements for water purity for uses like drinking water supply, contact recreation (such as swimming), and aquatic support (such as fishing). The Washington State Department of Ecology sets water quality standards for Washington State. Surface water and groundwater standards are established in WAC 173-201A and WAC 173-200, respectively.

watershed A geographic region within which water drains into a particular river, stream, or body of water. Watersheds can be as large as those identified and numbered by the state of Washington as water resource inventory areas (WRIAs), defined in WAC 173-500.

wet pond A facility that provides water quality treatment for stormwater by using a permanent pool of water to remove conventional pollutants from runoff through sedimentation, biological uptake, and plant filtration. Wet ponds are designed to (1) optimize water quality by providing retention time in order to settle out particles of fine sediment to which pollutants such as heavy metals absorb and (2) to allow biological activity to occur that metabolizes nutrients and organic pollutants.

wet vault or tank Underground storage facility that treats stormwater for water quality through the use of a permanent pool of water that acts as a settling basin. It is designed (1) to optimize water quality by providing retention time in order to settle out particles of fine sediment that absorb pollutants such as heavy metals and (2) to allow biological activity to occur that metabolizes nutrients and organic pollutants.

17.6 On-line Resources for Stormwater

17.6.1 WSDOT Resources

WSDOT *Highway Runoff Manual*
< http://www.wsdot.wa.gov/Publications/Manuals/M31-16.htm >.

Exempt Surface Waters List (see table 3-5 in the WSDOT *Highway Runoff Manual*)

WSDOT NPDES Progress Reports
< https://www.wsdot.wa.gov/environment/technical/permits-approvals/clean-water-act-section-402 >.

17.6.2 Existing Soil/Water Quality and Stream Flow Information

Washington Ecology – River and Stream Water Quality Monitoring
< http://www.ecy.wa.gov/programs/eap/fw_riv/index.html >.

Washington Ecology – Environmental Information Management
<http://www.ecy.wa.gov/eim/>

Snohomish County – Surface Water On-line Data
http://www.snohomishcountywa.gov/1058/Data

USGS National Water Quality Assessment Program – Data Warehouse
http://cida.usgs.gov/nawqa_public/apex/f?p=136:1:0

Washington State's Water Quality Assessment
<http://www.ecy.wa.gov/programs/wq/303d/2002/2002-index.html>.

Department of Ecology 303d List
< http://www.ecy.wa.gov/programs/wq/303d/index.html>.

Limiting Factors Analysis (example) by Washington State Conservation Commission < http://www.co.snohomish.wa.us/documents/Departments/Public_Works/surfacewatermanagement/watershed/fr_cr_wshed_mgmt_plan_tech_sup/FC_Limtng_Factors_Analysis_8.pdf >

Background Soil Metals Concentrations for Washington State
Publication #94-115
<http://www.ecy.wa.gov/biblio/94115.html>.

17.6.3 Water Quality Standards

U.S. EPA Water Quality Standards
<http://www.epa.gov/waterscience/standards/>.

State Water Quality Standards
<http://www.ecy.wa.gov/programs/wq/swqs/new-rule.html>.

17.6.4 Stormwater References

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17.6.5 Stormwater Science Publications

Stormwater science publications from NOAA's Northwest Fisheries Science Center (Ecotoxicology Program). This bibliography of peer-reviewed studies is current as of September 2021.

17.6.5.1 Research papers and synthesis papers describing the urban runoff morality syndrome – causes, consequences, and initial research on green infrastructure treatment effectiveness. Authors representing federal agencies (NOAA and USFWS) are in bold.

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McIntyre, J.K., **Lundin, J.I., Cameron, J.R.,** Chow, M.I., **Davis, J.W.**, **Incardona, J.P., and Scholz, N.L.**(2018). Interspecies variation in susceptibility of adult Pacific salmon to toxic urban stormwater runoff. *Environmental Pollution*, 238:196-203.

McIntyre, J.K., Prat, J., **Cameron, J.,** Wetzel, J., Mudrock, E., Peter, K.T., Tian Z., Mackenzie, C., **Lundin, J.**, Stark, J.D., **King, K., Davis, J.W**., and **Scholz, N.L.** (2021). Treading water: tire wear particle leachate recreates an urban runoff mortality syndrome in coho but not chum salmon. *Environmental Science and Technology*, In press.

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17.6.5.2 Research papers describing copper toxicity to the fish olfactory system and lateral line, implications for predation vulnerability, and the influence of water chemistry parameters that are known to be important for biotic ligand modeling (e.g., DOC).

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Baldwin, D.H. and **Scholz, N.L.** (2005). The electro-olfactogram: an *in vivo* measure of peripheral olfactory function and sublethal neurotoxicity in fish. In: *Techniques in Aquatic Toxicology, Volume 2.* G.K. Ostrander (ed.), CRC Press, Inc. Boca Raton, FL. pp. 257-276.

Hecht, S.A., Baldwin, D.H., Mebane, C.A., Hawkes, T., Gross, S.J., and **Scholz, N.L.** (2007). An overview of sensory effects on juvenile salmonids exposed to dissolved copper: Applying a benchmark concentration approach to evaluate sublethal neurobehavioral toxicity. NOAA Technical Memorandum NMFS-NWFSC-83, 39 p.

Linbo, T.L., Baldwin, D.H., McIntyre, J.K., and **Scholz, N.L.** (2009). Effects of water hardness, alkalinity, and dissolved organic carbon on the toxicity of copper to the lateral line of developing fish. *Environmental Toxicology and Chemistry,* 28:1455-1461.

Linbo, T.L., Stehr, C.M., Incardona, J.P., and **Scholz, N.L.** (2006). Dissolved copper triggers cell death in the peripheral mechanosensory system of larval fish. *Environmental Toxicology and Chemistry,* 25:597-603.

McIntyre, J.K**., Baldwin, D.H., Meador, J.P.,** and **Scholz, N.L.** (2008). Chemosensory deprivation in juvenile coho salmon exposed to dissolved copper under varying water chemistry conditions. *Environmental Science and Technology*, 42:1352-1358.

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Sandahl, J.F., **Baldwin, D.H.,** Jenkins, J.J., and **Scholz, N.L**. (2007). A sensory system at the interface between urban stormwater runoff and salmon survival. *Environmental Science and Technology,* 41:2998-3004.

Tierney, K.B., **Baldwin, D.H.,** Hara, T.J., Ross, P.S., **Scholz, N.L.**, and Kennedy, C.J. (2010). Olfactory toxicity in fishes. *Aquatic Toxicology*, 96:2-26.

17.6.5.3 Research papers describing PAH toxicity to fish early life stages (embryos and larvae), with a particular emphasis on the developing heart and delayed sublethal impacts on cardiac function, swimming performance, and survival. Note that, as far as NOAA trust resources are concerned, "oil spill" and "stormwater" are largely interchangeable; both are environmental sources of the same cardiotoxic PAHs in fish spawning habitats, with similar risks across species (e.g., Chinook, Pacific herring). These and related studies represent a "technology transfer" opportunity, where lessons learned in one management context (e.g., Deepwater Horizon in the northern Gulf of Mexico) can inform stormwater research and planning in Puget Sound.

Brette, F., Machado, B., Cros, C., **Incardona, J.P.**, **Scholz, N.L.**, and Block, B.A. (2014). Crude oil impairs cardiac excitation-contraction coupling in fish. *Science*, 343:772-776.

Brette, F., Shiels, H.A., Galli, G.L.J, Cros, C., **Incardona, J.P., Scholz, N.L.**, and Block, B.A. (2017). A novel cardiotoxic mechanism for a globally pervasive environmental pollutant. *Scientific Reports*, 7:41476.

Carls, M.G., Holland, L., Larsen, M., Collier, T.K., Scholz, N.L., and Incardona, J.P. (2008). Fish embryos are damaged by dissolved PAHs, not oil particles. *Aquatic Toxicology*, 88:121-127.

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Esbaugh, A.J., Mager, E.M., Stieglitz, J.D., Hoenig, R., **Brown, T.S., French, B.L., Linbo, T.L., Scholz, N.L., Incardona, J.P.**, Benetti, D.D., and Grosell, M. (2016). The effects of weathering and chemical dispersion on Deepwater Horizon crude oil toxicity to mahi mahi (*Coryphaena hippurus*) early life stages. *Science of the Total Environment,* 543:644-651.

Gardner, L.D., **Peck, K.A., Goetz, G.W., Linbo, T.L., Cameron, J., Scholz, N.L.**, Block, B.A., and **Incardona, J.P.** (2019). Cardiac remodeling in response to embryonic crude oil exposure involves unconventional NKX family members and innate immunity genes. *Journal of Experimental Biology*, 222:jeb205567.

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Incardona, J.P., Collier, T.K., and **Scholz, N.L.** (2004). Defects in cardiac function precede morphological abnormalities in fish embryos exposed to polycyclic aromatic hydrocarbons. *Toxicology and Applied Pharmacology*, 196:191-205.

Incardona, J.P., Carls, M.G., Teraoka, H., **Sloan, C.A., Collier, T.K.,** and **Scholz, N.L.** (2005). Aryl hydrocarbon receptor-independent toxicity of weathered crude oil during fish development. *Environmental Health Perspectives*, 113:1755-1762.

Incardona, J.P., Day, H.L., Collier, T.K., and **Scholz, N.L.** (2006). Developmental toxicity of 4-ring polycyclic aromatic hydrocarbons in zebrafish is differentially dependent on AH receptor isoforms and hepatic cytochrome P4501A metabolism. *Toxicology and Applied Pharmacology*, 217:308-321.

Incardona, J.P., Carls, M.G., Day, H.L., Sloan, C.A., Bolton, J.L., Collier, T.K., and **Scholz N.L.** (2009). Cardiac arrhythmia is the primary response of embryonic Pacific herring (Clupea pallasi) exposed to crude oil during weathering. *Environmental Science and Technology*, 43:201-207.

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