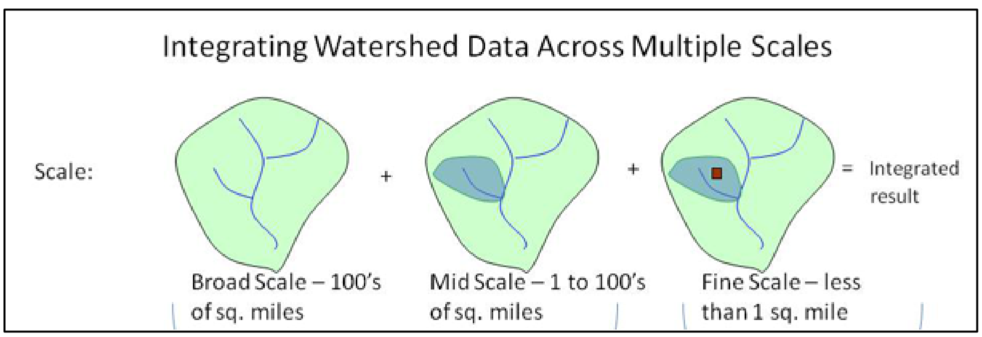
6PPD priority area assessment strategies:

Scope I – Watershed scale (Summer of 2022 – this report): Produce a sub-watershed broad scale assessment of priority areas that consider primary indicators including transportation, ecosystem and watershed attributes.

Scope II – Stream scale (Winter of 2023): Incorporate stream attribute information on a catchment scale, while funding and coordinating field and lab based 6PPD assessments. Complete a web-based coho mortality, water quality, salmon recovery and stormwater treatment interactive map (storymap) that will help standardize, collect and share data across interest groups. Support assessment, modeling, and mapping efforts to hone our joint road runoff mitigation strategies and salmon bearing stream water quality enhancement efforts.

Scope III – Project scale (Ongoing): Incorporate new information regarding the scope and scale of 6PPD-quinone in the environment. Cross-reference and coordination fish passage barrier and local and state transportation stormwater retrofit, and salmon recovery project prioritizations. Consider Pacific salmonid habitat and population assessment when weighing the cost and benefits of proposed projects.



Figuer X. Example of a multi-scale framework for integrating data across scales from the Puget Sound Watershed Characterization Project (Volume 3).

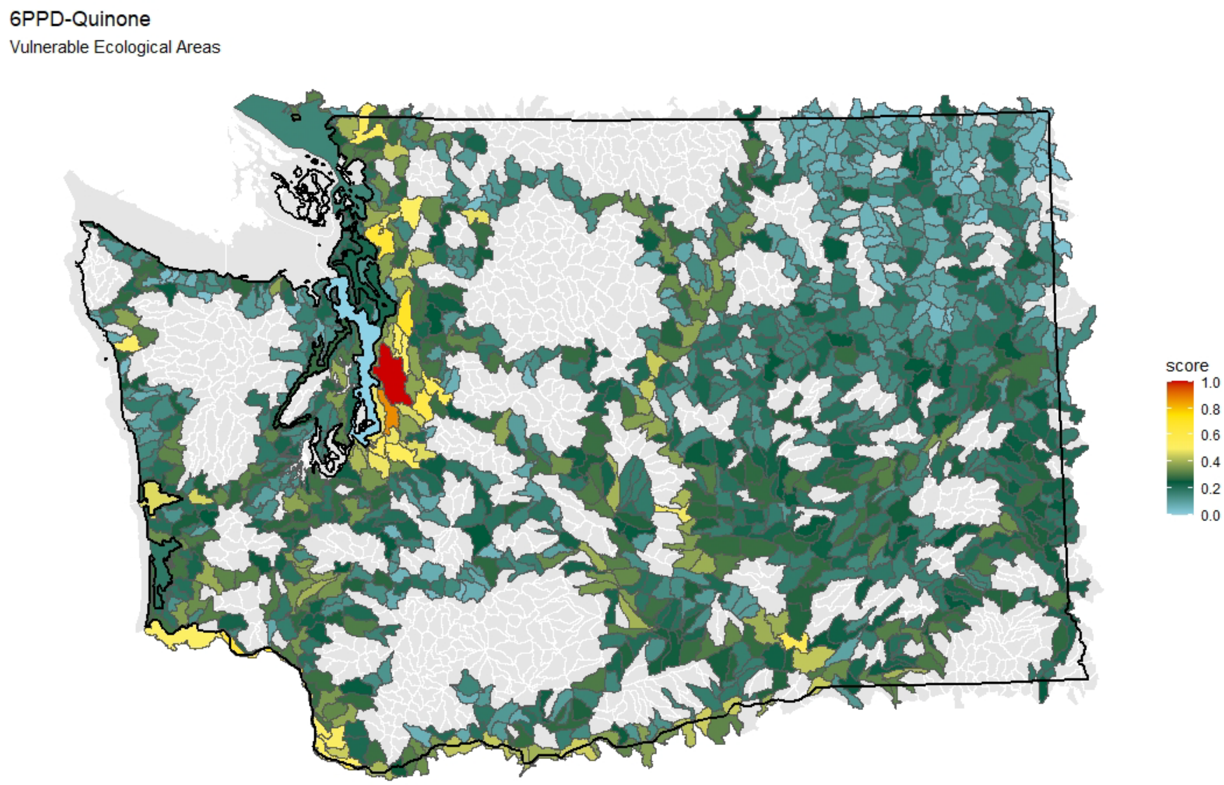
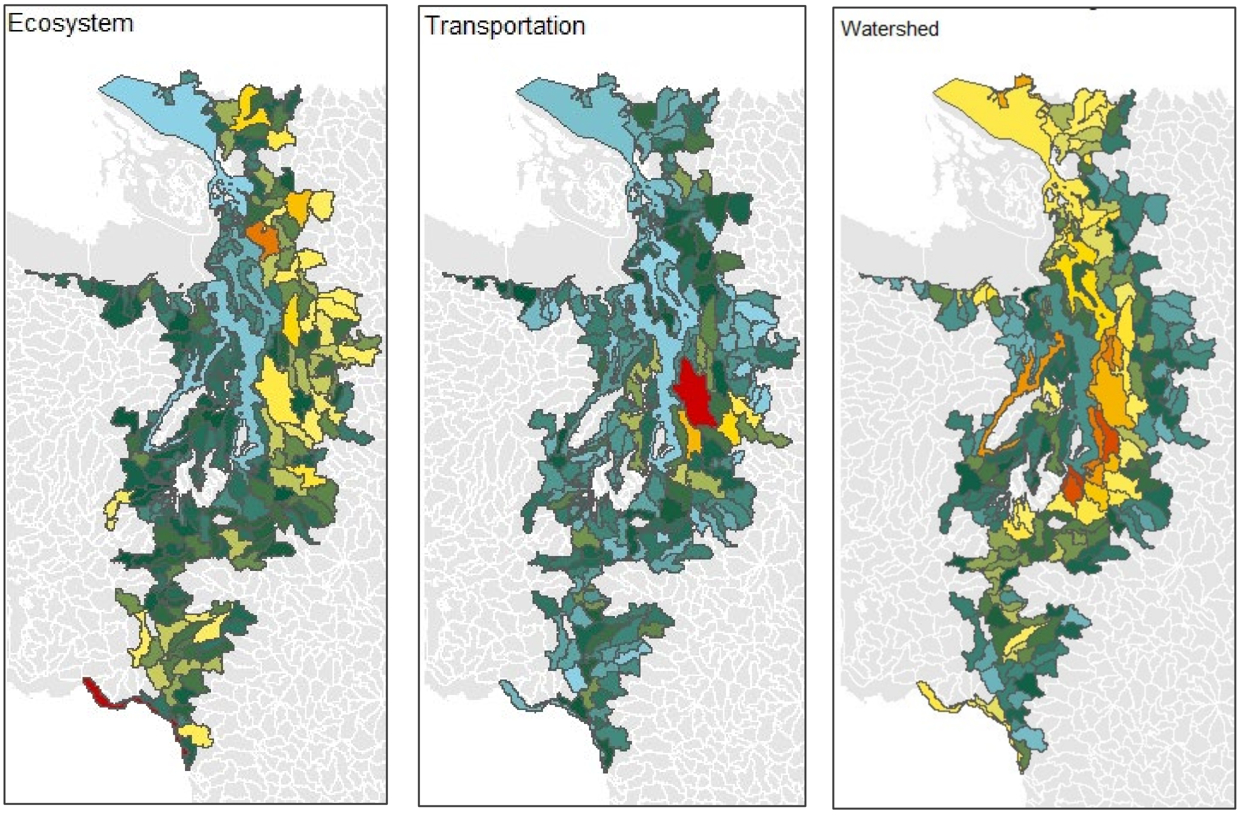


Figure 1. Sub-watersheds scored using selected ecosystem, transportation and watershed indicators for vulnerable ecological areas and tire emissions exposure. The greater the score, the more vulnerable areas and tire exposure occur in that sub-watershed[12].



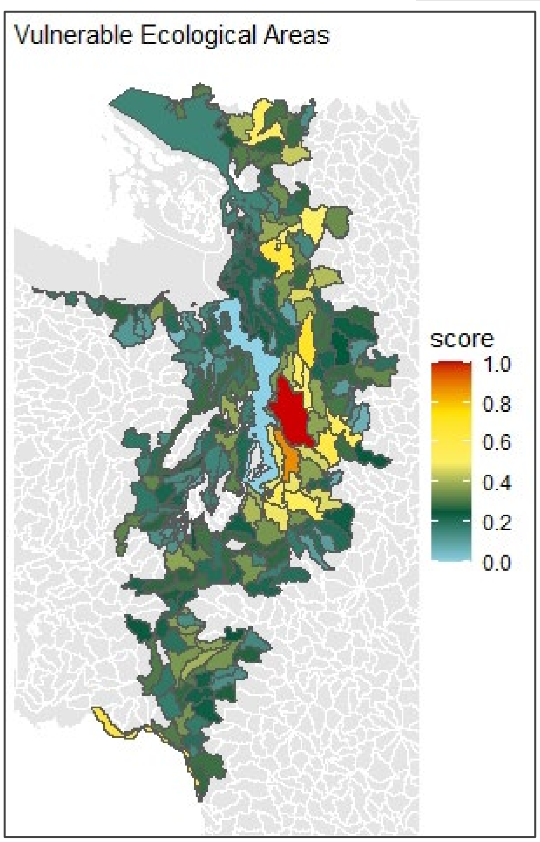
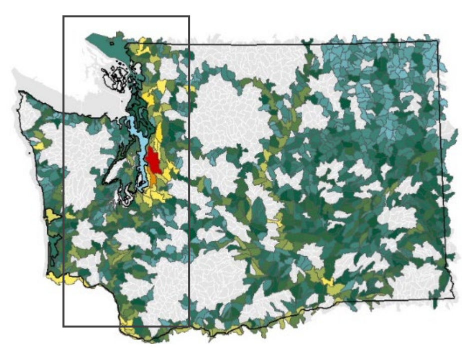


Figure 2. Puget Sound Region sub-watershed 6PPD-q mapping process. Ecosystem, transportation, and watershed scores are combined for a total 6PPD-q exposure to vulnerable ecological areas score.



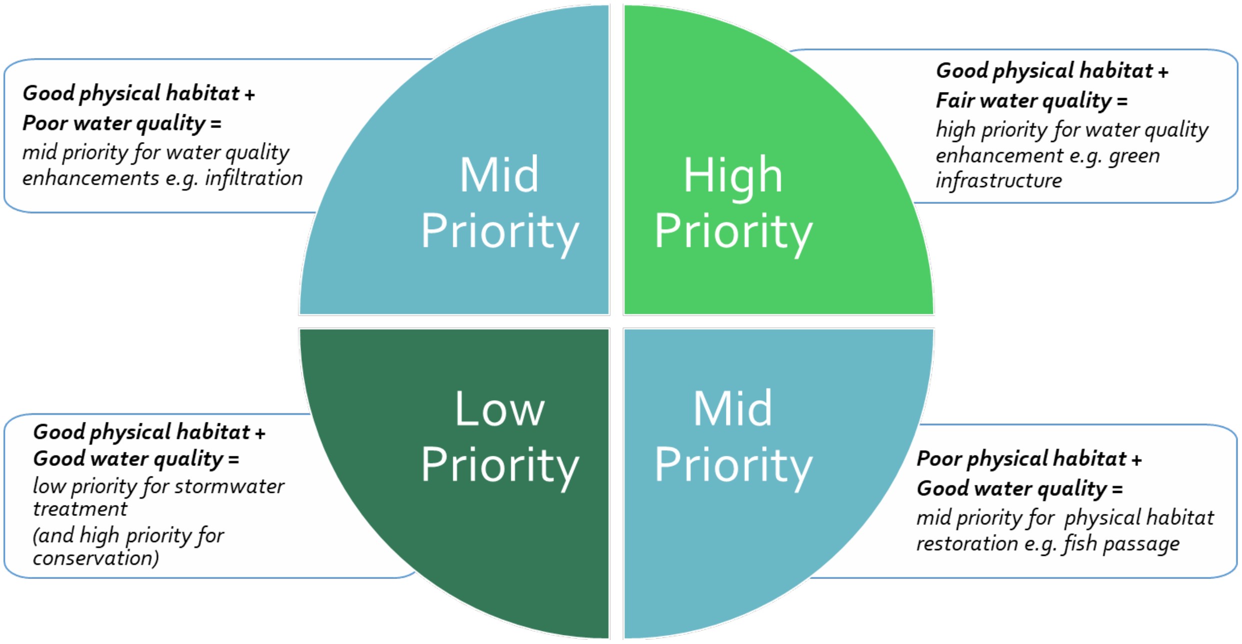


Figure 4. Proposed matrix for prioritization of stormwater treatment focus. Identify and fund projects that have existing salmon habitat features for all life stages (connectivity and accessibility of rearing and spawning grounds), but they are impacted by stormwater pollution.

Table 1. Scope 1 primary indicators of vulnerable habitats exposed to road pollution for this report.

Primary Indicators	Indicator Type
Salmon habitat type by species	Ecosystem
Salmon habitat distribution by species	Ecosystem
Salmon stocks per watershed all species	Ecosystem
Salmon stream habitat length	Ecosystem
Traffic counts (AADT)	Transportation
Road distance	Transportation
Road type	Transportation
Vehicle type	Transportation
Road and stream crossings	Transportation
Land cover	Watershed
Stream characteristics	Watershed
Land use	Watershed
Precipitation	Watershed

Scope II indicators of stream and salmon habitat health and 6PPD-q exposure.

Secondary Indicators	Indicator Type
Stream conductivity	Watershed
Stream temperature	Watershed
Stream flows	Watershed
Flood risk	Watershed
Total suspended solids	Watershed
Soils	Watershed
Stream biological communities (B-IBI)	Ecosystem
Beaver ponds	Ecosystem
Salmon habitat connectivity	Ecosystem
Zinc	Transportation
Copper	Transportation
Stormwater infrastructure	Transportation
Stormwater retrofit projects	Transportation
Outfalls	Transportation
Bridges	Transportation
Fish barriers	Transportation
Critical environmental areas of concern	Transportation
Slopes along roadways	Transportation
Roads within riparian buffers	Transportation

Spatial Data Conditioning

The gathered information was converted from a COMID (StreamCAT ID) or a WRIA (Watershed Resource Inventory Area) to the corresponding HUC12 ID. The conversions and conditioning steps were completed by the data resource curators of the salmon (SWIFD), transportation (WSDOT), and watershed (Ecology) spatial data. A more detailed account of the metrics can be found in Appendix F. The following sections describes the HUC12 data clipping, converting, and summarizing methods:

ECOSYSTEM DATASETS

Salmon distribution – SWIFD/Salmonscape – co-curated by NWIFC and WDFW. The salmon distribution map was adapted to help identify 6PPD-q priority areas.

Salmon streams

Salmon stream lengths (m) are clipped at the state boundary. Total stream length is from NHD flowlines (unfiltered). Linear referenced SaSI polygons over SWIFD and traced each stock downstream to the ocean (except resident bull trout), to create a flat table showing the number of layers generating each line segment.

ESA listed stocks

ESA status layer is from the un-merged SaSI line layer, these layers were created from snapshots that haven't been updated for more than two years.

For the table and GIS polygon feature class

WBD_HUC12_count, USGS WBDHUC12 were used as the base polygon feature class. All of the polygons were deleted that do not intersect Washington State or are entirely oceanic. Linear measurements were calculated in NAD_1983_HARN_StatePlane_Washington_South_FIPS_4602_Feet and converted to meters. Sources for counts and linear measurements included Total Stream Length, NHDFlowline clipped at the state boundary. All flowline feature types were included in the analysis: Spawning, Rearing, and Presence by Species Run, SWIFD version 2022.1, SASI Stock Count, ESA Threatened Count, ESA Endangered Count, SASI linear and polygon feature classes created in 2019 and SASI tabular data updated 2022

Total stream length

March 2022 version of SWIFD was used to calculate linear length of spawning, rearing and presence. All distribution types were included (*MapServices/SWIFD/Salmonscapes).*

TRANSPORTATION DATASETS

All datasets were summarized within HUC12 boundaries using ArcGIS Pro Tools. Point features were summarized as total counts or averaged with mean values. Line feature values are in mileage based on state routes. Exported tables were organized by HUC12 boundary IDs (*wa.gov)*.

WATERSHED AND STREAM DATASETS

Each StreamCAT area was associated to a HUC12 (based on the center point of the StreamCAT area). StreamCAT percentage values were converted to land area and summed by HUC12. Recalculated percentage values were recalculated based on the HUC12 area. FW Explorer and the majority of StreamCAT data will be incorporated into the Scope II evaluation (Read me[1] Hill et al. 2016; FW Explorer[2])

Spatial Data Analysis

Once the individual attribute data was gathered and summarized by unique HUC12 ID the data was merged and summarized per sub-watershed across the State of Washington (Figure 15).

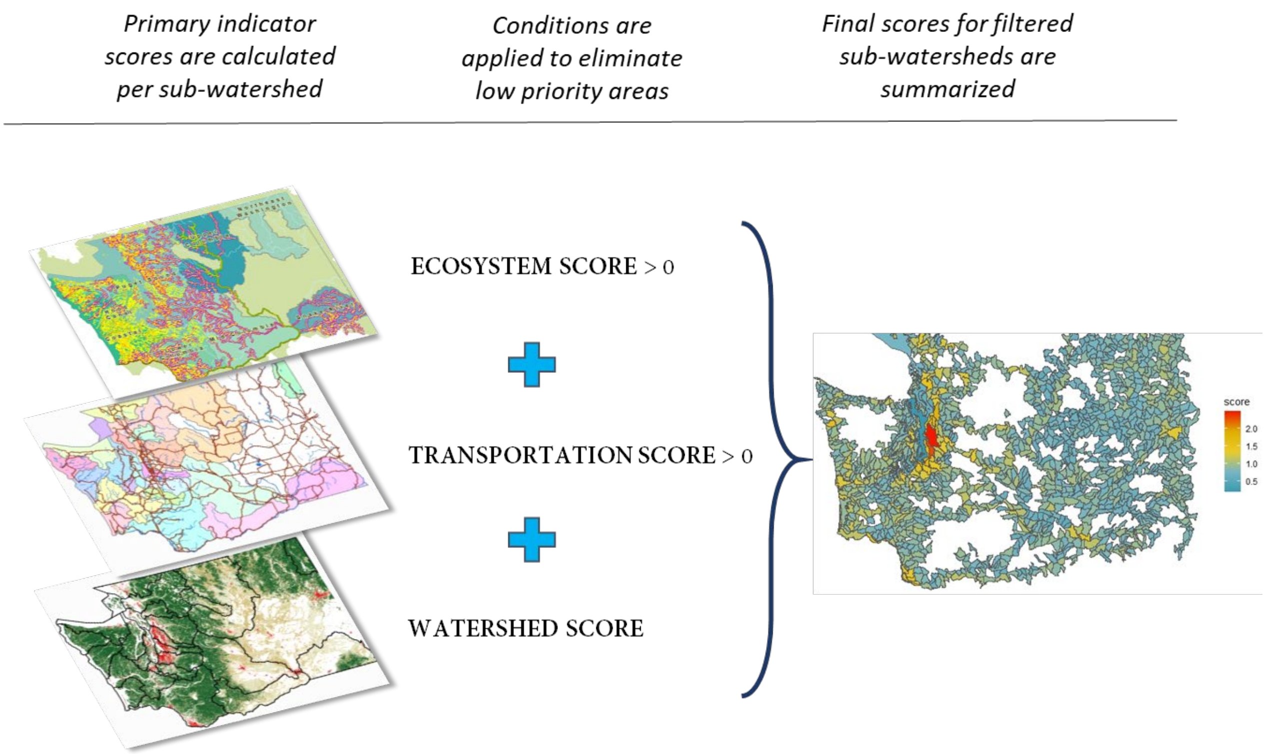


Figure 5. Watershed scale Scope I method for visualizing vulnerable ecological areas to 6PPD-quinone exposure[3].

Qualitative scores were assigned to each attribute based on best professional judgment and relative importance (e.g., coho got were scored greater than Chum, who are relatively more tolerant to 6PPD-q). Federal (NMFS, USFW, USGS and EPA) partners have plans to develop more quantitative correlations between 6PPD mass loading, transport and coho mortality that will hopefully be available for phase III

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[1] StreamCat Dataset - ReadMe | US EPA

[2] Freshwater Explorer | US EPA

[3] Source: R. Smith, WA Ecology

prioritizations. In general, watersheds characterized by 1) greater impervious land cover and annual precipitation, 2) greater number of fish stocks and spawning and rearing habitat and 3) more traffic and miles of roads scored higher. The higher the score the more vulnerable an area is to 6PPD-q exposure.

Once the data was merged by HUC12 in R studio, each attribute (column) was scaled or normalized from 0 to 1 (rescale) to account for the variable ranges of each metric. Once scaled the data frame was multiplied by the corresponding score, transformed by HUC12 and attribute, then binned by metric type (transportation, ecosystem and watershed). After binning the data per metric type per HUC12, the three remaining primary columns associated with each of the 2,730 HUC12s (were rescaled between 0 to 1). Watersheds were filtered to keep only those that hosted both fish and traffic, reducing the number of watersheds from 2,730 to 1,190 vulnerable watersheds State-wide. The majority of removed watersheds were in the foothills of the Cascades and Olympic mountains where development is logistically challenging or conservation measures have preserved state and national parks and forests. The salmon habitat within the headwaters of many of the watersheds are potentially subject to different human disturbances, however, stream protection from forestry and mining practices and water quality improvement plans have been developed and provide guidance for reducing sedimentation to the upland watersheds.

The result of our sub-watershed analysis further supports the potential scope of the 6PPD-quinone problem across the lowland streams (Figure 16). The maps can be customized to more specific objectives including comparison of local versus highway traffic, specific salmonid species, impervious surface thresholds, and precipitation. The final scores can be filtered to help visualize the most vulnerable areas as well (Figure 17 and 18).

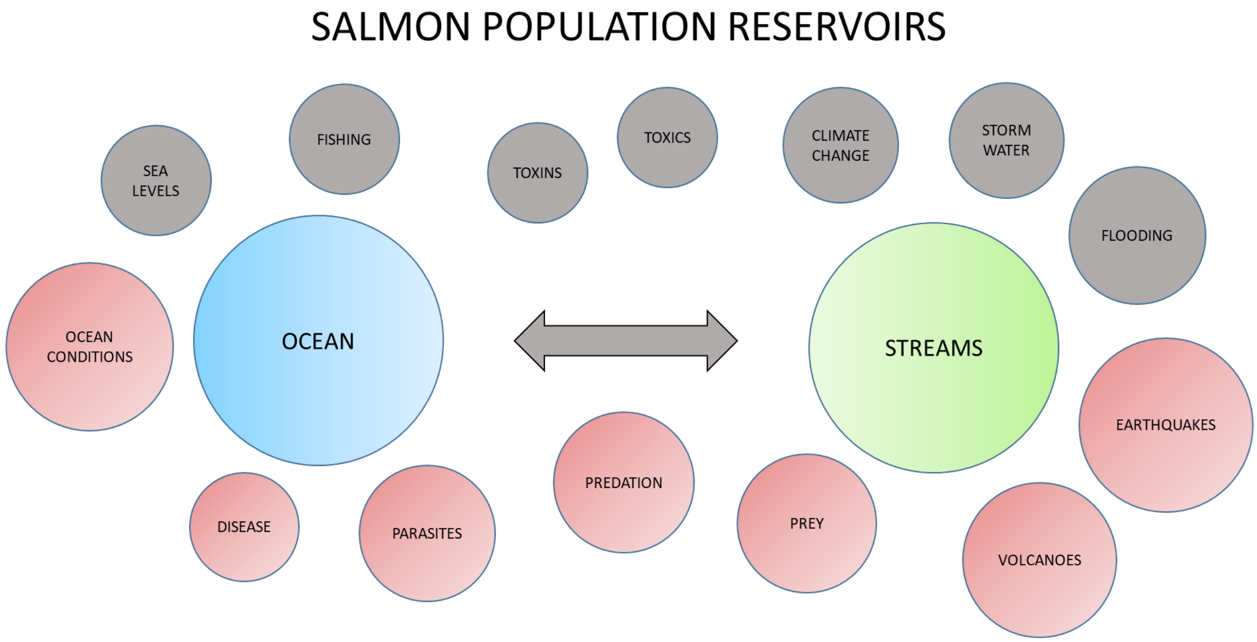

Figure 6. Salmon divide their lives between the marine and freshwater environments each of which host challenges for salmon survival[4].

[4] Graphic by R. Smith

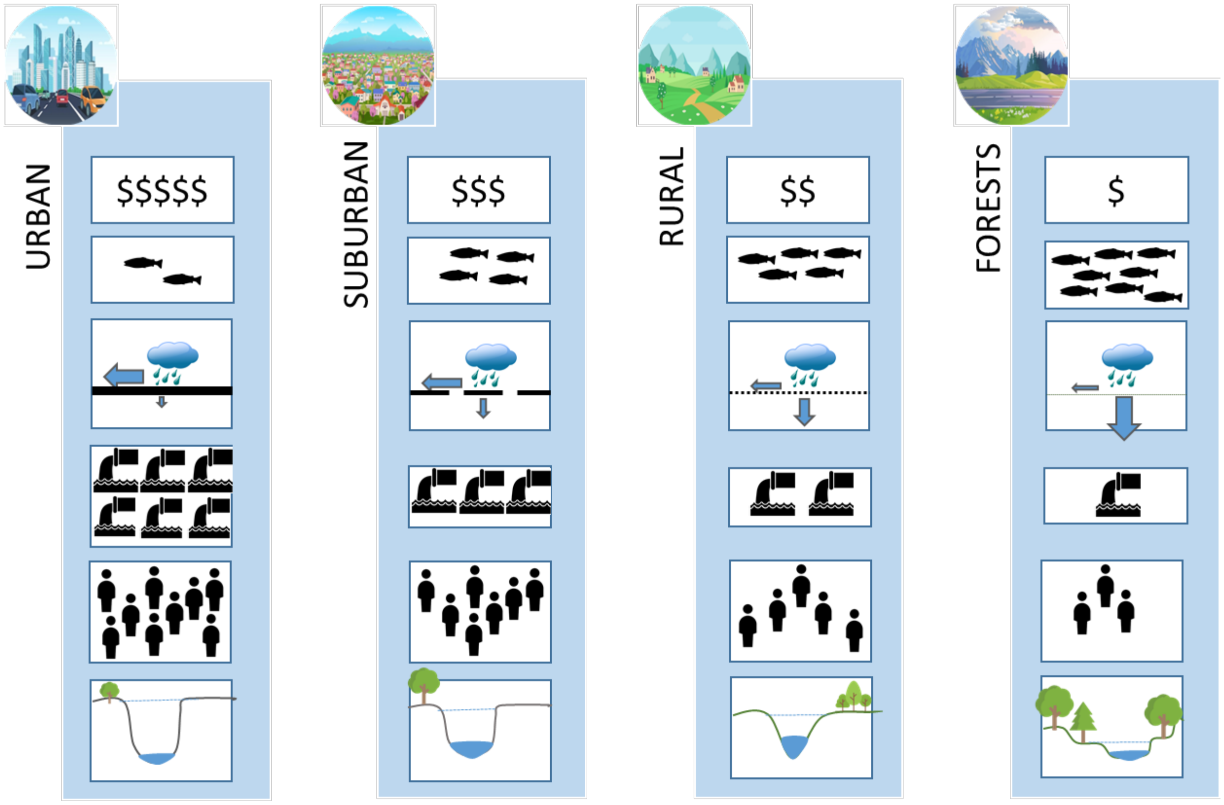

Figure 7. Stormwater mitigation prioritization becomes more complex, more costly, and therefore requires more time and resources to assess the best placement and type of structural stormwater treatment installments. Projects that have additional co-benefits above and beyond protecting aquatic life and reducing toxic impacts should be factored into decision making as well (clip art courtesy of [Freepik.com] and [Iconpacks.net], conceptual diagram by R. Smith).