Quality Assurance Project Plan

Puget Sound Watershed Characterization Technical Assistance

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Each study funded by the U.S. Environmental Protection Agency (EPA) must have an approved Quality Assurance Project Plan (QAPP). The plan describes the objectives of the study and the procedures to be followed to achieve those objectives. After completing the study, the author will post the final report of the study on Ecology's website. This QAPP describes a project selected by the EPA's National Estuary Program (NEP) in support of Near-Term Action (NTA) 2018-0669.

This Quality Assurance Project Plan is available upon request from the author.

Data for this project are available in EPA's Water Quality Exchange (WQX) database (https://www.epa.gov/waterdata/water-quality-data-wqx). This QAPP is valid through five years from the date of approval.

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Puget Sound Watershed Characterization Technical Assistance

NTA 2018-0669

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2.0 Abstract

The Puget Sound Watershed Characterization Project (PSWC) provides a set of water and habitat indices that compare areas within a watershed for their relative restoration and protection value. The PSWC provides information for regional, county, and watershed-based planning. The information it provides allows local and regional governments, as well as non-governmental organizations (NGOs), to base their decisions regarding land use on a systematic analytic framework that prioritizes specific geographies on the landscape as focus areas for protection, restoration, and conservation of our region's natural resources, and that also identifies areas that are likely more suitable for development. Application of this framework should support future land use patterns that protect the health of Puget Sound's terrestrial and aquatic resources while also helping to direct limited financial resources to the highest priority areas for restoration and protection.

The Washington State Department of Ecology (Ecology) provides a Watershed Characterization Technical Assistance Team (WCTAT) to support the use of the water and habitat indices by local governments and natural resource managers. The WCTAT's main objectives are to adapt the application of the indices to local management decisions, ensure appropriate interpretation of index results, and keep the indices up-to-date with as current input data layers as possible. This QAPP describes the indices and how technical assistance is provided in a way, which meets the expected standards of quality.

3.0 Background

3.1 Introduction and problem statement

Initial Puget Sound watershed characterization work, pioneered by Ecology (see Stanley et al. 2005, Stanley and Grigsby 2008) and other scientists, demonstrated the need to consider watershed scale processes in planning and restoration actions (NRC 1996 and 2001, Spence et al. 1996, Dale et al. 2000). This led to the development of the PSWC, a set of water and habitat indices described in four volumes (see section 3.2.2 for detailed descriptions) that compare areas within a watershed for restoration and protection value as well as identifying the best location for development. It also provides a decision-support framework that helps integrate these indices into an assessment, across multiple scales for use in watershed based planning at the regional, county, and city levels.

In 2012, with funding from the EPA's National Estuary Program, the WCTAT was created to work with local governments and resource managers using the indices. The team, when fully funded is generally comprised of technical experts from the Washington State Departments of Ecology, Fish and Wildlife (WDFW), and Commerce (Commerce). Expertise can include (depending on funding) hydrology, geomorphology, habitat biology, landscape ecology, watershed science, and spatial analysis. Current funding as of this QAPP covers the senior watershed ecologist and spatial analyst. Expertise in interpreting the habitat indices can be requested from WDFW's senior scientist, who leads development of those assessments (described in PSWC Volume 2, Wilhere et al. 2013).

This QAPP describes how the WCTAT provides technical support to users of the PSWC indices. It does not describe specific applications of the indices that will occur. Rather, it describes the indices and data used as well as the process of quality control when local and regional governments and NGOs request technical assistance from Ecology.

3.2 Study area and surroundings

The study area encompasses the entire Puget Sound region, including Clallam, Island, Jefferson, King, Kitsap, Lewis, Mason, Pierce, San Juan, Skagit, Snohomish, Thurston, and Whatcom counties, and 19 Water Resource Inventory Areas (WRIAs). All of the study area is located west of the Cascade Range and has mild marine-type climate typical of Western Washington. Summers are cool and relatively dry while winters are mild and wet (WRCC, 2021). Figure 1 illustrates the Puget Sound Basin study area and associated WRIAs that nest within it.

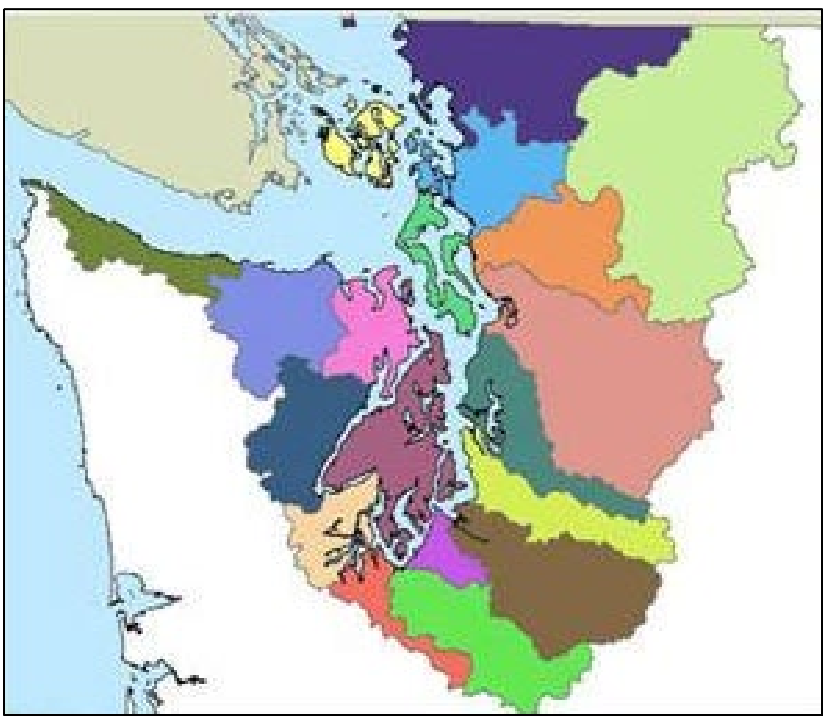

Figure 1. Map of the Puget Sound Basin and the Water Resources Inventory Area (WRIA) boundaries within which the Puget Sound Watershed Characterization indices can be applied.

3.2.1 History of study area

The PSWC project occurs in the 13 Western Washington counties listed above. Starting in the mid 1880's until the mid-1990s, these areas have been subject to intense logging, agricultural and land development. Despite the dramatic land use change over the past 100 years, the rural areas of these counties still have moderate to high ecological value (Stanley et al. 2016). However, growing populations are threatening to increase the conversion of these rural lands to more urban uses, resulting in the loss of ecological processes and biological diversity within these watersheds.

3.2.2 Summary of previous studies and existing data

The PSWC consists of four volumes published between 2012 and 2019. Volume 1, published in April 2012, updated in 2016 (Stanley et al. 2016), with an addendum produced in 2019 (Hume et al. 2019), describes the overall conceptual decision support framework for the PSWC and details the assessment of water resources using analyses of watershed processes. It also includes Watershed Characterization Tool (WCT) 1, which assesses the relative level of importance and degradation for water flow processes, and WCT2 for assessing water quality processes.

Volume 2, published in December 2013 by Wilhere et al., compares relative fish and wildlife habitat values across multiple environments and includes a series of tools (WCT3) for assessing the habitats in those environments (freshwater habitat, terrestrial habitat, and marine shorelines).

Volume 3, published in June 2013 by Stanley et al., explains how to synthesize the results of each preceding volume into an integrated decision support framework to support protection and restoration actions over multiple scales. It is intended to help users integrate and apply the assessment information in a systematic, consistent manner across multiple scales within an analytical watershed framework in order to achieve ecologically based land use and management decisions.

In Volume 4, Phase 1, published in July 2019 by Stanley et al., the Department of Ecology initiated development of a new “mid-scale” assessment tool (WCT4) known as the Hydrologic Condition Index (HCI) for potential further development to be applied throughout Puget Sound watersheds. Phase 2 of the project, expected to be completed by the end of 2022, will further the development of the HCI approach based on recommendations made during Phase 1, and seek to utilize a more regionally dispersed and rural watershed dataset. The QAPP for phase 2 is currently in development.

Table 1 describes the spatial scale at which the various Watershed Characterization Tools are most appropriately used, and how to integrate them into the decision support framework established in Volume 4.

Table 1. The Puget Sound Watershed Characterization Tools which are established in Volumes 1-4 and how they are best applied.

Application	WRIA-wide	Sub-basin	Reach to sub-basin
Spatial Scale	**Broad-scale :** 10 to 100s of sq. miles (1000s of acres).	**Mid-scale:** 0.5 sq. mile to 10 sq. miles (100s of acres).	**Fine-scale:** 10s of acres
Toolbox	Puget Sound Watershed Characterization Broad Scale Tools (WCT): WCT1 – Water Flow Processes WCT2 – Water Quality WCT3 – Fish & Wildlife	HCI tool and Comprehensive Integration of PSWC results with HCI scores, including high pulse counts (HPC). WCT4 – HCI Tool (New) WCT5- Decision Support Framework (New)	Finer scale hydrologic models (e.g. Hydrological Simulation Program – FORTRAN [HSPF]) and local data
Application of Tools	Use PSWC broad-scale results (importance and degradation) to support landscape-level prioritization for protection, restoration, & development actions.	Use sub-basin tools such as the HCI to determine overall existing and future condition of watershed, to assist in build out analysis, and to select the best development patterns through alternative futures scenarios.	Sub-basin based alternative future scenarios. Use finer scale hydrologic models to develop specific location and design of proposed development.

3.2.3 Parameters of interest and potential sources

The PSWC does not assess environmental pollutants or contaminants. Rather, the indices assess the presence, absence, or relative quantity of indicators of water flow and water quality processes (Volume 1), habitat value (Volume 2), and hydrologic health (Volume 4) using readily available spatial datasets (see section 4.3 below). Appendices B, C, and D of Volume 1 describe in detail how the spatial datasets are used to assess the indicators. Section 4.2.1 of Volume 2 describes the spatial datasets used in the habitat assessments.

3.2.4 Regulatory criteria or standards

Not Applicable. The study objectives do not include assessing regulatory compliance.

3.3 Water quality impairment studies

Not applicable.

3.4 Effectiveness monitoring studies

Not applicable. This is not an effectiveness monitoring study.

4.0 Project Description

Local governments and resource management agencies in the Puget Sound Basin make hundreds of decisions each year that affect the health and sustainability of our terrestrial and aquatic ecosystems. Rarely are those decisions informed by a full understanding of watershed processes and actual watershed conditions or adequate data on the cumulative implications of those decisions across time and space. The goal of the PSWC Project is to remedy this problem by giving local land use planners and resource manager's better tools for making decisions about watershed protection, restoration, and development. The PSWC has been used in places such as Duvall, Birch Bay, Mukilteo, and WRIA 7 to identify actions that improve forest cover, water quality, and wildlife habitat and that direct future development in ways that protect and restore watershed processes.

4.1 Project goals

The goals of the WCTAT as it works with the various PSWC indices are to:

- Develop, prioritize, and implement solutions to environmental problems based on an understanding of processes at watershed or landscape scales;
- Replace planning based on jurisdictional or statutory boundaries (e.g., shorelines of the State) with coordinated regional planning;
- Provide a watershed-scale context to help guide site-scale reviews that not only meet regulatory requirements but also more fully achieve their intended outcomes;
- Move toward integrated resource planning and management grounded in a landscape-scale understanding of how ecosystems work.

4.2 Project objectives

The objectives of the PSWC Project and the WCTAT are to:

- Identify and solicit projects that inform land use, stormwater, and Puget Sound recovery planning needs, which can benefit from incorporating an understanding of watershed processes and habitats.
- Provide access to the publications, information, and "out-of-the-box" spatial data and maps through the PSWC website.
- Work with users to design "tailored" assessments specific to their planning needs and geography.
- Provide locally "tailored" assessments using the indices to produce maps and provide spatial data.
- Work with users of the indices so that results are interpreted appropriately when informing planning processes.
- Participate in technical advisory groups where requested by local project sponsors.
- Update and refine the indices with new data as it becomes available.

4.3 Information needed and sources

Data used as inputs into the index algorithms can come from two basic sources; regional datasets and local datasets, which can represent indicators of watershed processes and habitats. The regional data are assembled and documented in Volumes 1 (Stanley et. al 2016 and Hume et al. 2019), 2 (Wilhere et al. 2013), and 4 (Stanley et al. 2019). These data are from reputable sources and are consistent in resolution/accuracy across the entire extent of Puget Sound. Tables 2, 3, 4, and 5 below summarize the regional datasets that are used in the "out-of-the-box" results available on Ecology's website (https://apps.ecology.wa.gov/coastalatlas/wc/landingpage.html).

Table 2. A list of original version 1.0 data sources for PSWC indices. Yellow highlighted and asterisk (*) entries (Precipitation, Hydrography, C-CAP Land Cover) are those which were updated for version 2.0 (Hume et al. 2019).

Data	Scale	Source
Precipitation	1:2,000,000	Washington Department of Natural Resources (DNR), Forest Practices Division*
Rain-on-Snow & Snow-Dominated zones	1:250,000	Washington Department of Natural Resources
Surficial Geology	1:100,000	Washington Department of Natural Resources
Soils	1:12,000 – 1:63,000	U.S. Department of Agriculture Natural Resources Conservation Service – Soil Survey Geographic Database (SSURGO)
Topography (Digital Elevation Model)	10 Meter	University of Washington Puget Sound Lidar Consortium
Hydrography (streams & lakes)	1:24,000	Washington Department of Natural Resources*
Wetlands	1:24,000	United States Fish & Wildlife Service – National Wetland Inventory (NWI), also SSURGO – see above
Channel confinement & gradient	1:24,000	Washington Department of Fish & Wildlife, North West Indian Fisheries Commission – Salmon and Steelhead Habitat Inventory and Assessment Program (SSHIAP)
Mass wasting	10 Meter (Western WA)	Washington Department of Natural Resources, Forest Practices Division – Shaw Johnson landslide risk model
Land Cover (2016)	30 Meter Grid	National Oceanic and Atmospheric Administration – Coastal Change Analysis Program (C-CAP)*

As Table 2 indicates, the data used in the characterization models is coarse-scale. This reflects that the intent of the PSWC is to use regionally available data, to provide results that compare areas relative to each other, and to support planning level decisions. Most of the data are statewide or region-wide, and updates to these are infrequent.

GIS datasets used and produced adhere to the following Washington State standards requirements:

- Horizontal datum: NAD 83 HARN
- Vertical datum: NAVD-88
- Project system: Lambert Conic Conformal
- Coordinate system: Washington State Plane Coordinates
- Coordinate zone: South
- Coordinate units: U.S. Survey Feet
- Accuracy standard: +/-40 feet or better
- Vector import format: Shapefile, File Geodatabase, Personal Geodatabase
- Raster import format: TIFF, BIL/BIP/BSQ, ESRI Grid, ERDAS Imagine
- Metadata: Federal Geographic Data Committee (FGDC), Metadata Content Standards

For more information, please see https://ecology.wa.gov/Research-Data/Data-resources/Geographic-Information-Systems-GIS/Standards.

Table 3. Summary of fish and wildlife data used in the indices of PSWC Volume 2 (Wilhere et al. 2013).

Taxon	PHS[1]	Occur. model[4]	Description	Units	Source[5]
Northern abalone	X	X	documented occurrences	Square feet	WDF 1992
Clams; intertidal hardshell	X	X	beds that could be commercially harvested or have significant recreational usage		WDF 1992
Clams; subtidal	X	X			
Dungeness Crab	X	X			
Pacific oyster	*X*	X	non-native *Crassostrea gigas*		WDF 1992
Geoduck	X	X	beds that could be commercially harvested		WDF 1992
Pandalid shrimp	X	X	pink, coonstripe, and spot shrimp		WDF 1992
Sea Urchins	X	X	documented occurrences of red and green sea urchins		WDF 1992

Taxon	PHS[1]	Occur. model[4]	Description	Units	Source[5]
Herring Holding Areas	X		where adults congregate each winter prior to spawning	Square feet	WDFW 1992
Herring Spawning Areas	X		regular surveys over 10 years		WDFW 2000-2009
Surf smelt	X	X	data represent more than 30 years of spawning beach surveys	feet	WDFW 1972-2008
Pacific Sand lance	X	X			WDFW 1972-2008
Bull Trout	X		number of stream mouths inhabited by species that intersect shoreline segment	count	WDFW Fishdist[6]
Chinook Salmon	X				
Chum Salmon	X				
Coastal Cutthroat Trout	X				
Coho Salmon	X				
Pink Salmon	X				
Sockeye	X				
Steelhead Trout	X				
Bald Eagle Communal roosts	X		zone around roost site; radius = 400 m	Square feet	WDFW WSDM[2]
Bald Eagle nest	X		zone around nest site; radius = 200 m		
Great Blue Heron colonies	X		zone around occurrence point; radius = 1000 ft.		
Black Oystercatcher nests			survey data from 2010	count	
Shorebird	X		large regular concentrations	Square feet	
Waterfowl	X		large regular concentrations		
Important Bird Areas (IBA)			support species of concern or high densities of birds		Audubon 2001
Bird Density			median density of all birds from 2000 to 2009	birds / km^2	WDFW PSAMP[3]
"At-Risk" Bird density			density of "at risk" birds from 2005 to 2009		
Seal/sea lion haul-out	X		both natural (e.g., islands) and artificial (e.g., buoys) haul outs	count within	WDFW WSDM[2]

Taxon	PHS[1]	Occur. model[4]	Description	Units	Source[5]
			for harbor seals and California sea lions	400 m of shore	

[1] PHS: WDFW's priority habitat and species list

[2] WSDM: WDFW's Wildlife Survey Data Management

[3] PSAMP: Puget Sound Ambient Monitoring Program

[4] Uses a Likelihood of Occurrence model based on the degree of association a species has with a given habitat type

[5] Dates indicate years used from each dataset

[6] https://data-wdfw.opendata.arcgis.com/search?tags=fish

Table 4. Summary of plant and wetland data used in the indices of PSWC Volume 2 (Wilhere et al. 2013)

<table>
<tr><th>Taxon</th><th>Description</th><th>Units</th><th>Source</th></tr>
<tr><td>dune grass</td><td>salt-tolerant grasses, dominated by Leymus mollis</td><td rowspan="9">Amount = shoreline length x bioband density

<u>Density</u>
0 = Absent; 1 =
0-50% cover; 2 =
50-100% cover</td><td rowspan="9">DNR Shorezone
(Berry et al. 2001a, 2001b)</td></tr>
<tr><td>sedges</td><td>brackish/ freshwater wetlands assemblages; found at freshwater streams and river mouths</td></tr>
<tr><td>high salt marsh</td><td>brackish/ freshwater wetlands assemblages; Triglochin/Salicornia/
Deschampsia/Distichlis</td></tr>
<tr><td>low salt marsh</td><td>dominated by Salicornia</td></tr>
<tr><td>surfgrass</td><td>Phyllospadix spp. of lower intertidal</td></tr>
<tr><td>eelgrass</td><td>Zostera marina and introduced Z. japonica</td></tr>
<tr><td>brown kelp</td><td>large bladed Laminaria / Saccharina spp.</td></tr>
<tr><td>chocolate brown kelp</td><td>Laminaria setchellii, Eisenia and/or Pterygophora, Hedophyllum, Egregia</td></tr>
<tr><td>bull kelp</td><td>Nereocystis luetkeana</td></tr>
</table>

Taxon	Description	Units	Source
giant kelp	*Macrocystis spp.*		
wetlands (NWI)	all wetlands except marine sub-tidal	square feet	USFWS 1989

Table 5. Datasets used in the Hydrologic Condition Index of Volume 4 (Stanley et al. 2019). Sources and scales may change when accuracy improves or local project data are substituted in analyses.

Data	Scale	Source
Surficial Geology	1:100,000	Washington Department of Natural Resources
Soils (SSURGO)	1:12,000 – 1:63,000	Natural Resources Conservation Service
Topography (Digital Elevation Model)	30 Meter	University of Washington
Hydrography (streams & lakes)	1:24,000	United States Geological Survey
Wetlands (NWI)	1:24,000	United States Fish & Wildlife Service
Land Cover (C-CAP)	30 Meter	National Oceanic and Atmospheric Administration
Watershed Boundaries	Varies	Varies

Local data can be, and has been, used in combination with regional data sources where they are more accurate, or up-to-date. These data are reviewed by the WCTAT to ensure that they match the intent of the model inputs for identifying indicators of specific watershed processes. The use of any data requires an understanding of the accuracy and appropriate application for the scale of the data. As with any analysis, greater confidence in the accuracy of the data results in a higher degree of certainty in the conclusions. Whenever more accurate data are available, they should be used, especially when modeling smaller areas. Typical local datasets that are requested for use are land cover and stream layers.

4.4 Tasks required

Typical technical assistance using the PSWC products can include:

- Providing support to use of "out-of-the-box" results downloadable on Ecology's website which often includes:
  - Presentations to potential users about the indices, which often occurs at conferences or other similar venues.
  - Meeting with users to explain the indices and potential applications to their planning process.
  - Helping with the download of relevant data and understanding how to navigate through the geodatabases to find the information specific to their needs.
  - Support with mapping results.
- Producing a locally tailored assessment. A typical work-flow when working on local assessments, with or without using local datasets, includes:
  - Meeting with the local user(s) to explain the indices available to them and understand their planning needs
  - Working with local users to delineate the watershed boundaries and produce Project Assessment Units (PAUs), a term used to distinguish locally developed boundaries from the Assessment Units (AUs) used for the "out-of-the-box" results.
  - Determine which indices will be useful for the specific planning needs and run the models using the AUs or PAUs selected for the project.
  - Review and provide quality control of the results by ensuring all script was executed correctly and as designed by the local project sponsor.
  - Produce draft maps, which display the results, provide high-level interpretation of the results, and deliver to the project sponsor for their review and input. This often also includes participating in a technical advisory group meeting convened by the project sponsor.
  - Finalizing the results after feedback is received from the project sponsor that they meet expectations. This can in some limited cases also include production of an Ecology publication (e.g. Hume et al. 2015) but is typically delivered in PowerPoint with the spatial data files.
  - Support the local project sponsor at meetings where the results are being presented to inform their planning process.

4.5 Systematic planning process

Not applicable. This QAPP is about providing technical assistance utilizing a set of previously developed and peer reviewed spatial indices in planning processes.

5.0 Organization and Schedule

5.1 Key individuals and their responsibilities

Table 6 shows the responsibilities of those who will be involved in this project.

Table 6. Organization of project staff and responsibilities.

Staff	Title	Responsibilities
Colin Hume Washington Department of Ecology Phone: 425-395-5283	Project Manager/Principal Investigator	Clarifies scope of the projects taken on. Guides analyses and reviews draft/final products. Writes the QAPP, coordinates internal review of the QAPP and approves the final QAPP.
Jennifer Konwinski Washington Department of Ecology Phone: 360-407-6007	Spatial Analyst	Performs model runs, works with clients to interpret results, and performs quality control on model outputs.
Britta Voss Department of Ecology Phone: 360-407-6070	NEP Quality Coordinator	Reviews the draft QAPP and recommends the final QAPP for approval.
Arati Kaza Department of Ecology Phone: 360-407-6964	Quality Assurance Officer	Reviews and approves the draft QAPP and the final QAPP.

QAPP: Quality Assurance Project Plan
NEP: National Estuary Program

5.2 Special training and certifications

Mr. Hume is a trained ecologist with specialization in wildlife biology, freshwater ecology, and landscape ecology. Colin has managed the Puget Sound Watershed Characterization Project for 9 years and is experienced in developing and working with large-scale watershed assessments and models.

Ms. Konwinski is a geospatial data specialist with expertise in modeling, hydrology, and stream geomorphology.

5.3 Organization chart

Not applicable. See Table 6.

5.4 Proposed project schedule

Not applicable. This QAPP is for general technical assistance to occur as projects come in to Ecology.

5.5 Budget and funding

The source of funds for this Contract is the U.S. Environmental Protection Agency, National Estuary Program Stormwater Strategic Initiative grant *(CFDA# 66.123).* Total budget available for the project is $120,000.

6.0 Quality Objectives

6.1 Data quality objectives

Not applicable. No new environmental data will be collected for this project.

6.2 Measurement quality objectives

Not applicable. No new environmental data will be collected for this project.

6.2.1 Targets for precision, bias, and sensitivity

Not applicable. No new environmental data will be collected for this project.

6.2.1.1 Precision

Not Applicable. No new environmental data will be collected for this project.

6.2.1.2 Bias

Not Applicable. No new environmental data will be collected for this project.

6.2.1.3 Sensitivity

Not Applicable. No new environmental data will be collected for this project.

6.2.2 Targets for comparability, representativeness, and completeness

6.2.2.1 Comparability

Not Applicable. No new environmental data will be collected for this project.

6.2.2.2 Representativeness

Not Applicable. No new environmental data will be collected for this project.

6.2.2.3 Completeness

Not Applicable. No new environmental data will be collected for this project.

6.3 Acceptance criteria for quality of existing data

All model and index input data are either obtained from reputable federal/state sources and are widely used. The model methods, described in Volumes 1, 2, and 4, are the result of significant peer review and comment from advisory teams. We believe the methods provide a useful and scientifically credible relative comparison across the landscape. Even so, these methods are the product of subjective judgments and data limitations, both of which display varying levels of uncertainty. The addendum to Volume 1 (Hume et al. 2019) describes some of this uncertainty in detail.

The water resource assessments (Volume 1) are part of a coarse-scale, decision support tool, intended to support regional, county, and watershed planning. The methods are adaptable to a range of planning questions and issues that require different spatial extents. These spatial extents may involve single or multiple watersheds and may cross between one or more WRIAs. In some cases, the AUs may have to be reduced in size (generally termed PAUs) to match smaller watersheds and to address planning objectives for smaller jurisdictions.

As in any GIS analysis, the scale and accuracy of the source data dictates the confidence level in the output. If finer scale data are available, they can replace the source layers currently referenced. Primary requirements are that any data used are geographically complete for the area of interest (see section 10 for more information about evaluation of local datasets) and conform to the standards described in section 4.3. In any case, care is necessary to ensure application of the methods is within the bounds of the intended uses and data limitations. Though the results can provide a landscape context for locating protection or restoration actions, they cannot be used to inform specific site locations or project design. In all cases the methods represent a decision support tool and not a decision making tool and should not be used in lieu of finer scale data or other methods designed for assessing processes and functions at finer scales.

For local watershed assessments, more accurate, high-resolution data sources like updated land cover, wetlands, streams, and groundwater recharge areas as well as refined PAUs can help define model results in smaller watersheds.

6.4 Model quality objectives

Model quality objectives for Volumes 1 and 2 were to find readily available spatial data from trusted sources that could be applied at a consistent scale (spatial grain and extent) across the Puget Sound basin. When using local data, the same objectives apply, just at a smaller extent. All local data proposed for use are reviewed for meeting these objectives prior to input in the model and index algorithms.

Draft model outputs are presented to appropriate staff and/or project steering committees for review and feedback prior to finalization. This is often an iterative process and may include adjustments to input data sources, analytical approaches, how AUs or PAUs are delineated, how Water Flow Importance and Degradation scores are categorized from low-high in the importance and degradation indices based upon the raw ranking (0-1 normalized values), and how the AUs or PAUs are categorized into the Management Matrix. Alternative methods of categorization can be based upon applying a natural-breaks quartering method or creating scatter plots of Importance versus Degradation scores which provide groupings that are visually distinguished from each other, or a combination of the two. The Addendum to Volume 1 (Hume et al. 2019) describes implications of using alternative approaches to categorization and model sensitivity.

Model quality objectives for the HCI (Volume 4) are the subject of a current project covered by a separate QAPP. Generally, though, as a stream's HCI value increases, the number of observed high pulse counts should increase when compared against measured stream gage data. Furthermore, the HCI index value should also increase for watersheds that have increasingly higher levels of development; thus, there should be a significant correlation between the actual HPC values measured at a stream gage and the calculated HCI value. Where these trends do not occur, the HCI would be deemed not to meet our model quality objectives and would not be used in those scenarios.

7.0 Study Design

7.1 Study boundaries

The study area for the PSWC project is the entirety of the Puget Sound Basin. Figure 2 illustrates the AUs available for use depending on the scale of the assessment and planning questions the process is intended to address. Table 7 describes the size ranges of assessment units available for use at certain extents of analysis.

Table 7. Size statistics for assessment units available for use. Units (n=3,265) range in size depending on whether they occur in coastal, lowland, mountain, or large lake landscapes.

Landscape Group	Min. Size (sq. mi.)	Max. Size (sq. mi.)	Mean Size (sq. mi.)
Coastal	0.1	5.9	1.1
Lowland	0.25	15.5	3.2
Mountain	0.3	20.6	9
Large Lakes	0.1	18	7.8

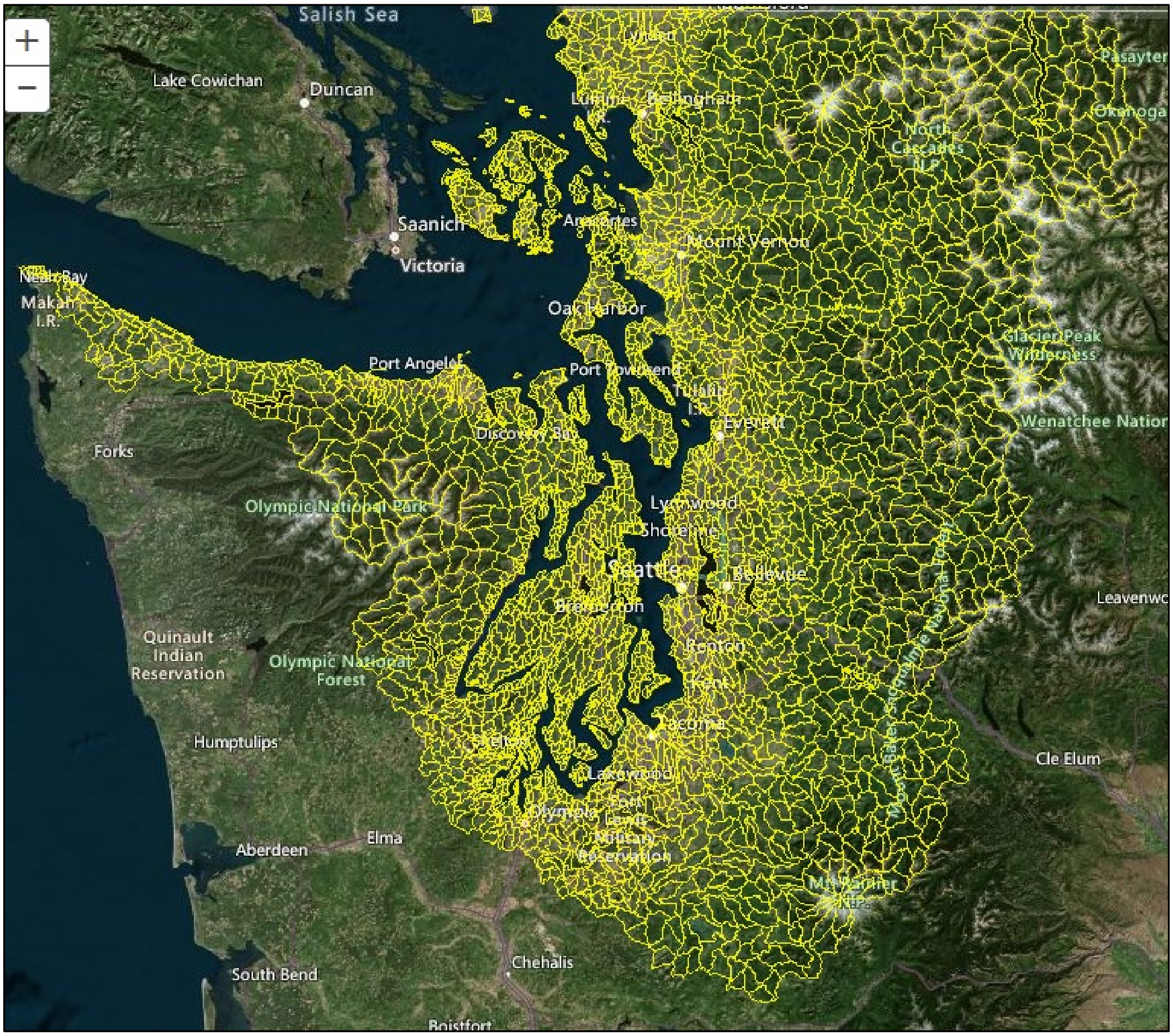

Figure 2. Map of the study area. Puget Sound Basin with all assessment units that are used to quantify and compare indicators of watershed processes and habitats (PSWC Volumes 1-3).

As described previously, some projects occurring at a smaller scale will develop PAUs to better fit their planning needs. As an example, Figure 3 illustrates how the City of Duvall delineated PAUs that were smaller, and generally nested within the “out-of-the-box” AUs, and better fit their planning needs at that scale.

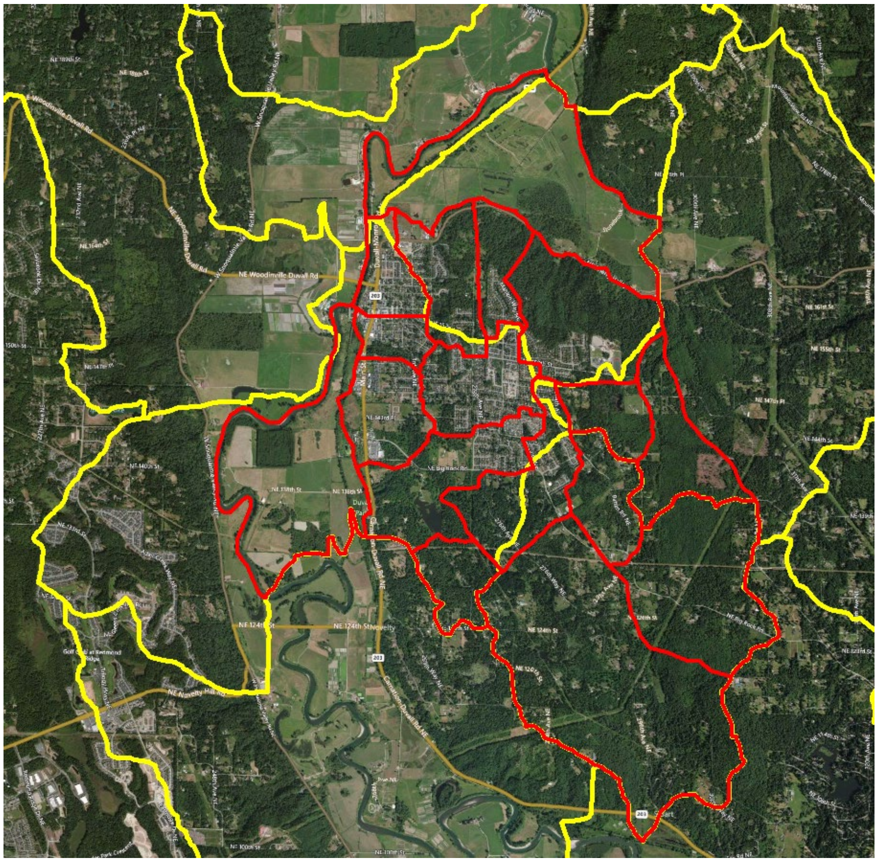

Figure 3. Map illustrating "out-of-the-box" assessment units (yellow lines) and the delineated project assessment units (red lines) ultimately used by the City of Duvall in their watershed planning process.

Volumes 1, 2, and 4 describe in detail how existing data were chosen for the indices and models. Volumes 1 and 2 underwent a significant literature review, described in their respective appendices, to find data, which would best represent indicators of watershed processes and habitats. All data had to be consistent in scale (extent and grain) across the entire study area. When working at smaller extents (e.g. City of Duvall example in Figure 3 above), local data can be incorporated where it provides greater accuracy in the assessment of a given indicator(s).

7.2 Field data collection

Not applicable. There is no field data collected.

7.2.1 Sampling locations and frequency

Not applicable. There is no sampling associated with this project.

7.2.2 Field parameters and laboratory analyses to be measured

Not applicable. No new environmental data are collected for this project.

7.3 Modeling and analysis design

7.3.1 Analytical framework

The PSWC incorporates the multi-scale framework (Table 1 above), emphasizing integration of abiotic and biotic assessments and data interpreted at broad scales in support of management needs. In describing the details of the framework, we distinguish between those with an explicitly water resources focus (those of water flow and water quality) and those that, in part, depend on the movement of materials and energy across watershed boundaries (particularly those of the terrestrial and marine nearshore environments).

Integrating information from several assessments results in a more robust characterization of a watershed, and ultimately more effective management recommendations, than any single assessment can provide. Developing this kind of integrated approach requires at its foundation a conceptual model that reflects the basic workings of the ecosystem. Figure 4 offers such a model for the three primary environments of the Puget Sound basin (freshwater, terrestrial, and marine), reflecting the importance of integrating information from assessments for these environments across multiple spatial scales. Implementing the core attributes of this model within a framework of regional planning and decision-making should result in more effective, more successful restoration and protection actions and ultimately increase the overall health of Puget Sound.

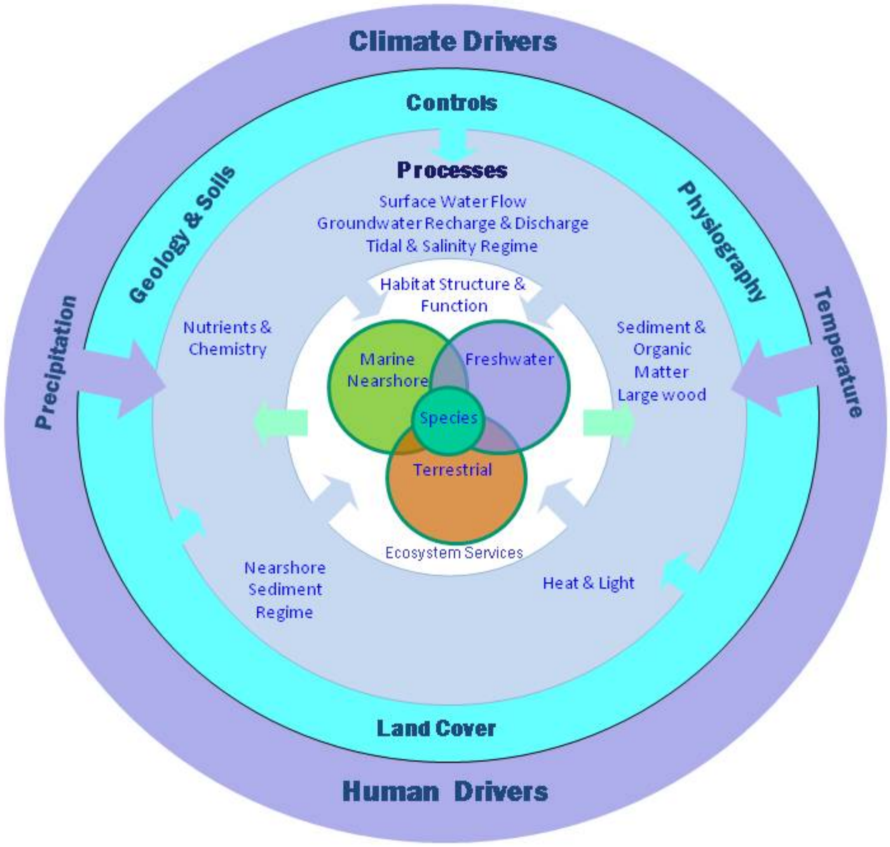

Figure 4. Conceptual model for the Puget Sound ecosystem illustrating relationships between drivers, controls, processes, and habitat structure and function for freshwater, terrestrial and marine nearshore environments (EPA).

The patterns we observe in ecosystems are the result of events occurring at multiple spatial scales of organization (Figure 4). Large-scale drivers (outermost ring in Figure 4), such as climate and ocean dynamics together with such human activities as urbanization and deforestation, operate at a regional scale and directly interact with the controls of watershed processes. Those watershed controls include such physical attributes as geomorphology, geology, and soils (turquoise ring in Figure 4); they also include the wide variety of human actions that individually and collectively affect watershed processes. Those processes (inner gray ring in Figure 4) include the movement, delivery, and loss of water, sediment, nutrients, and wood. Together, the interaction of these natural and human-induced drivers and controls govern the processes, structure, function and, finally, ecological "health" (Beechie and Bolton 1999, Dale et al. 2000, Gove et al. 2001, Hidding and Teunissen 2002, Beechie et al. 2010). This expresses the scientific consensus that proper functioning of our most highly valued ecosystems depends on what happens in the larger landscape, not just at the site or reaches scale. This is particularly true of aquatic ecosystems, which express most directly the connectivity between different parts of a landscape.

Although the results of the PSWC indices can be directly applied only at appropriately coarse spatial scales, they can provide a context for more detailed evaluation by a WCTAT (which ideally is composed of experts from a variety of pertinent disciplines, including geomorphology, hydrology, ecology, wildlife biology, fisheries biology, and water quality) to assist in the interpretation and application of assessment results at finer scales and smaller extents.

Watersheds (e.g. AUs) are useful units for considering the relationship between human actions and freshwater environments. Watersheds can also be useful for integrating proposed aquatic conservation with terrestrial and marine nearshore environments. There is no single watershed size suitable for all planning or management activities—multiple scales of watersheds will be required in almost any planning and management effort.

Analyses of indicators of watershed processes and habitats were developed within the Model Builder application of ArcGIS Version 10.x, a commercial GIS software product of Environmental Systems Research Institute, Inc. (ESRI™). The purpose of creating the models was to provide an efficient way to ensure:

- Repeatability of the analyses,
- Saleable applications,
- Standardized methods, and
- Transparent documentation

The result of this is a collection of models and scripts organized as a ‘toolbox’. The guidance document detailing description of these tools is available in the PSWC Volume 1 (Stanley et al. 2019).

Volumes 1-4 contain details on format, data development, analysis input/output, graphics examples, and data/analysis updates. Appendix D (2016 revision) covers spatial analyses performed for Volume 1.

7.3.2 Model setup and data needs

As described previously, the geographic scale of the PSWC is the Puget Sound Basin. All data representing specific indicators of watershed processes or habitats used at that scale of analysis are consistent in grain/extent across the entire Basin. There is no temporal scale in the assessment of these indicators. Rather, they represent a “snapshot” in time of the presence, quantity, and condition of these indicators.

The broad-scale indices described in Volumes 1-3 rely on comparing indicators within AUs (or PAUs where developed locally) to produce a relative score for each given AU in the assessment. Therefore, the score produces a relative ranking of the AUs, which are then categorized into Low-High quantiles. Water Flow and Water Quality results can combine relative rankings of Importance and Degradation into a Management Matrix (See Figure 5) which can help prioritize the general type of strategies for a given AU. AUs are described in detail below.

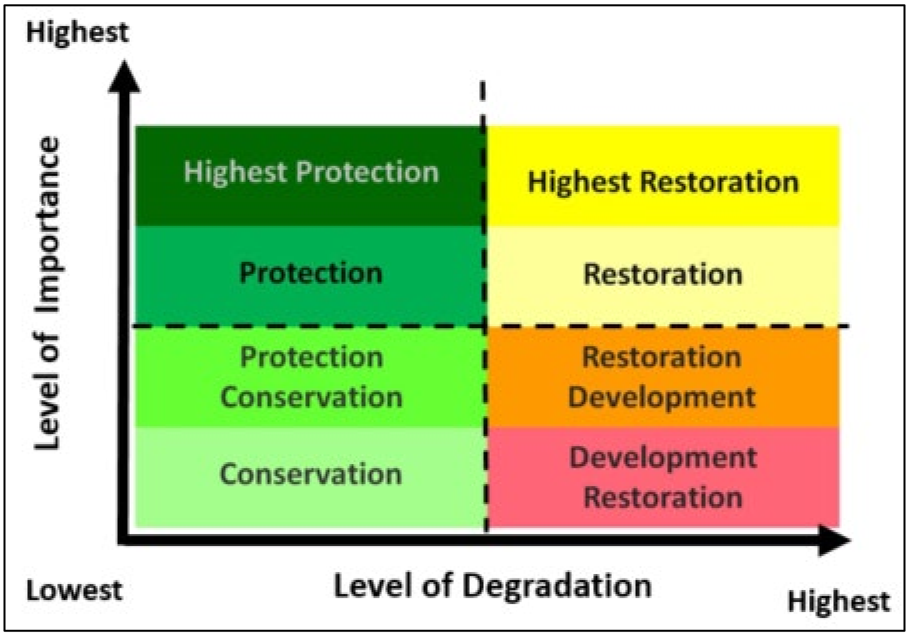

Figure 5. Simplified 8-cell Management Matrix for Water Flow indices which combine an assessment of relative level of Importance and Degradation to water flow processes.

Assessment Units

Significant effort was spent determining the most appropriate size for the analysis units. They are the foundational unit for summarizing and displaying all the analyses, so choosing a scale that provided meaningful and useful results was critical. The *AquaScape* catchments (described below) provided the most robust and comprehensive data coverage, as well as the possibility of linking to other data sources. For these reasons, they became the foundation of our analysis units, with minor adjustments described below.

<u>Version 1 (v1.0) Assessment Units</u>

The source data for creating version 1.0 (Stanley et al. 2016) AUs came from two existing data sets:

- SSHIAP *AquaScape* Segment Catchments – these were the basis for all AUs except those in WRIA 2 & 6 where these data did not exist. The *AquaScape* catchments were developed by the Northwest Indian Fisheries Commission and represent drainage areas based on Habitat Segments and DNR Shorezone segments. The habitat segments were defined by gradient and confinement, and then habitat type.
- Puget Sound Nearshore Ecosystem Restoration Project (PSNERP) Drainage Units (DUs) – these were the basis for AUs within WRIA 2 and 6, the island WRIAs. The PSNERP and represent drainage units based on drift cells developed them.

The catchments in both these layers were not consistently appropriate in scale to be used directly as analysis units for our assessments across Puget Sound. To create more consistency, we used the following criteria in making adjustments to the source layers for development of our analysis units:

- SSHIAP catchments were not further divided, but were aggregated where needed to achieve a more consistent size. This aggregation follows hydrologic principles as much as possible. (See Federal Guidelines, Requirements, and Procedures for the National Watershed Boundary Dataset, USGS, and USDA, 2013).
- PSNERP catchments (for WRIAs 2 and 6) will be grouped or divided to more consistently mirror SSHIAP catchments.

The catchments were delineated primarily as salmon habitat catchments, which over time have been realized to not always be congruent with features important in the control of watershed processes. In addition, the catchments are not always consistent with more recently developed higher resolution data sets not available at the beginning of the PSWC. For these reasons, a general update of the assessment units became necessary and in 2019 was released as part of the addendum to Volume 1 (Hume et al. 2019).

Version 2.0 (v2.0) Assessment Units

Edits to the AU boundaries began with adjustments to make boundaries coincide with higher accuracy data. First, the outer boundaries of AUs along the WRIA borders were edited to match Ecology's updated WRIA layer. Additionally, all interior boundaries were edited to coincide with the current updated stream layer, namely the U.S. Geological Survey's 1:24,000 National Hydrography Dataset (NHD). This primarily involves adjustments along all boundaries where NHD streamlines cross the original AU boundary. Forty-foot contour lines produced from a 10-meter Digital Elevation Model (DEM) were also used to refine these edits and to help determine the best AU boundary location.

The most significant changes to the AU boundaries involved incorporating floodplain areas as separate assessment units. We used the coarse-scale "ecological floodplain" (Konrad 2015) as the basis for delineating floodplain assessment units within Puget Sound. An ecological floodplain encompasses all water flow and ecological processes within the area of valley bottoms, high floodplains, low floodplains, and river areas. This contrasts with other regulatory floodplain maps, which are developed to establish flood hazard risk. Konrad (2015) modeled several versions of floodplain, which were considered, and for our purposes, the "valley-wall to valley-wall" was selected, as it most appropriately represents the historic geomorphic floodplain.

For analysis purposes, assessment units are coded into one of five landscape groups, defined by the geomorphic criteria below:

Mountainous unit (M) – generally above 500 feet elevation (with more than half of the catchment above); this commonly captures areas dominated by bedrock, rain-on-snow or snow dominated areas, high precipitation, and high slope. Generally, they have less diverse land cover, lower development pressure, and often include federal land. They average ~10-15 square miles in size.

Lowland unit (L) – generally below 500 feet elevation (with more than half of the catchment below); this generally captures geology dominated by glacial deposits, rain dominated precipitation, landforms of terraces and large river valleys with predominately floodplain hydrology (overbank flooding and groundwater discharge). These areas have more diverse land cover and higher development pressure. They average ~3-5 square miles in size.

Coastal unit (C) – generally captures small drainages to the marine shoreline of 1st or 2nd order streams, and groups of remnant, wedge-shaped areas creating a contiguous *composite* unit. It does not include larger, complex river systems. They average ~ 1 square mile in size.

Delta unit (D) – this captures three of the large delta systems that have important water flow or habitat value.

Lake unit (LK) – this captures the small drainages of 1st or 2nd order streams, and remnant areas between them, that drain to the largest lakes.

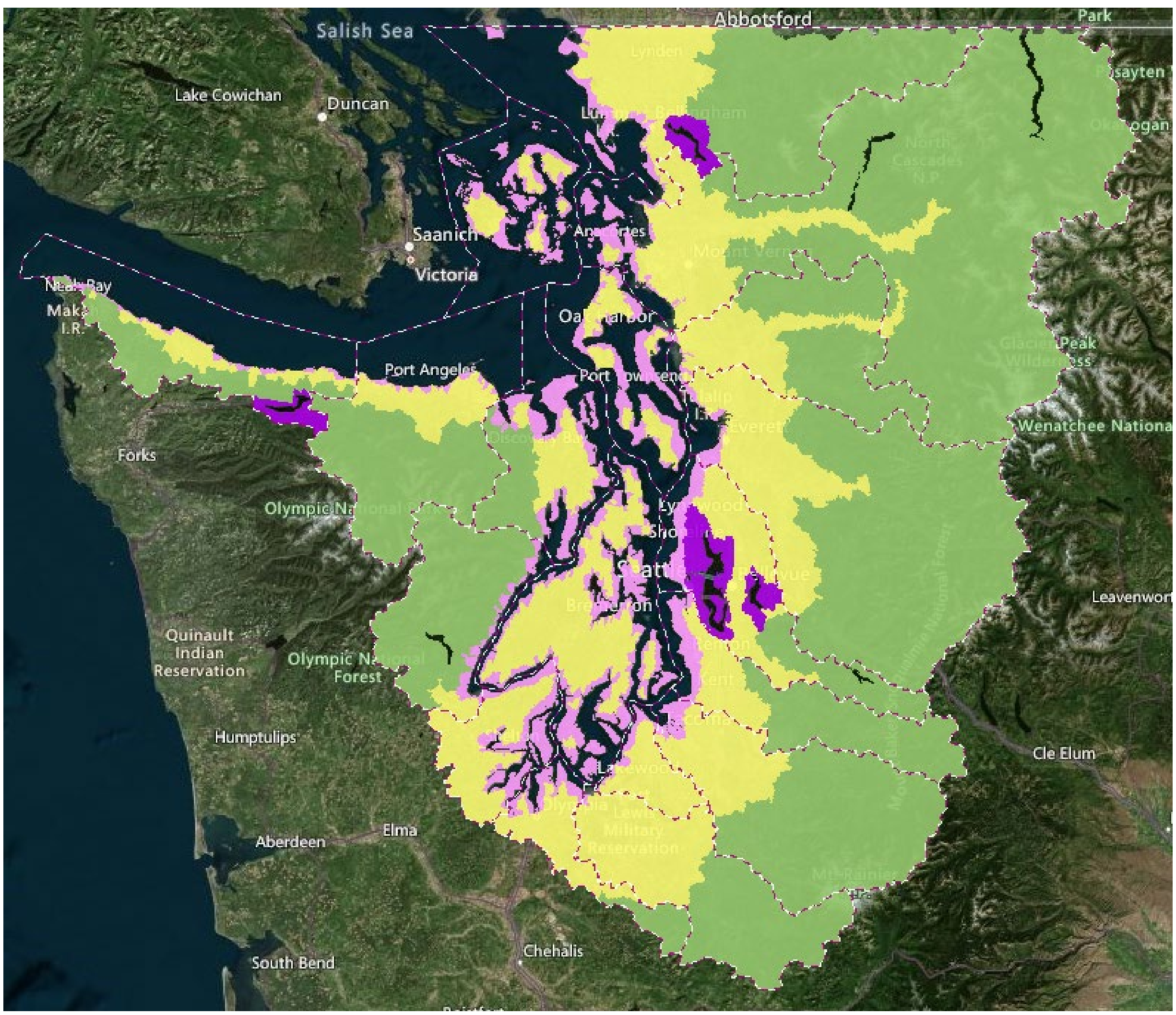

Figure 6. Landscape Groups used in certain analyses of Water Flow Importance. Green shades = Mountainous, Yellow = Lowland, Pink = Coastal, Purple = Large Lakes

7.4 Assumptions of study design

Assumptions of the PSWC indices are documented in Volumes 1, 2, and 4. Assumptions generally relate to:

- Spatial data used as proxies of watershed processes and habitats appropriately represent the indicator they intend to and with enough accuracy to do so.
- Index algorithms representing specific watershed processes are valid to quantify the relative importance or level of degradation of an AU for those given processes.
- Categorization of AUs into quantiles for mapping purposes is appropriate and based upon a valid statistical approach and/or best professional judgement of a technical team with knowledge of the data and study area.

7.5 Possible challenges and contingencies

Not applicable. This is not relevant to a generalized QAPP for technical assistance.

7.5.1 Logistical problems

Not applicable. This is not relevant to a generalized QAPP for technical assistance.

7.5.2 Practical constraints

Not applicable. This is not relevant to a generalized QAPP for technical assistance.

7.5.3 Schedule limitations

Not applicable. This is not relevant to a generalized QAPP for technical assistance.

8.0 Field Procedures

8.1 Invasive species evaluation

Not applicable. There is no field work associated with this project.

8.2 Measurement and sampling procedures

Not applicable. There is no field work associated with this project.

8.3 Containers, preservation methods, holding times

Not applicable. There is no field work associated with this project.

8.4 Equipment decontamination

Not applicable. There is no fieldwork associated with this project.

8.5 Sample ID

Not applicable. There is no field work associated with this project.

8.6 Chain of custody

Not applicable. There is no fieldwork associated with this project.

8.7 Field log requirements

Not applicable. There is no fieldwork associated with this project.

8.8 Other activities

Not applicable. There is no fieldwork associated with this project.

9.0 Laboratory Procedures

9.1 Lab procedures table

Not applicable. There is no laboratory work associated with this project.

9.2 Sample preparation method(s)

Not applicable. There is no laboratory work associated with this project.

9.3 Special method requirements

Not applicable. There is no laboratory work associated with this project.

9.4 Laboratories accredited for methods

Not applicable. There is no laboratory work associated with this project.

10.0 Quality Control Procedures

Quality control procedures are iterative throughout a given project that uses PSWC indices. The following are steps and procedures, which occur throughout a typical workflow:

- Review watershed delineations (AUs or PAUs) which will be used in the assessment using PSWC indices. Generally, these delineations will conform to the topographical "catchment" whereby water flows to a common pour point at the bottom of the slope. However this does not always occur, particularly in low-gradient floodplain areas.
- If using local datasets, review them for the credibility of the source, that the resolution and accuracy meets project's needs, and that they appropriately reflect the indicator(s) they intend to.

- After a model-run, review scripts to ensure that no errors occurred. Verify all tables and fields were generated in the resulting geodatabase. Review that field values are in the typical range expected.
- When maps have been generated, they are reviewed with technical team members familiar with the area to ensure that they generally conform to expectations, or if not, there is a rational explanation after a review of data inputs.

10.1 Table of field and laboratory quality control

Not applicable. There is no field or laboratory work associated with this project.

10.2 Corrective action processes

The corrective action process generally involves:

1) reviewing output maps to see if they fit expected outcomes;
2) identifying any problems (e.g., if output shows anomalies or doesn't align with expected outcomes);
3) identifying solutions (based on findings in Step 2, staff will identify any needed corrective actions); and
4) Implementing solutions or corrections and reviewing revised output. If revised output does not address original problem, Steps 2 through 4 will be repeated.

11.0 Data Management Procedures

11.1 Data recording and reporting requirements

Not applicable. There are no data collected.

11.2 Laboratory data package requirements

Not applicable. There is no laboratory work with this project.

11.3 Electronic transfer requirements

Not applicable. There is no laboratory data associated with this project.

11.4 Data upload procedures

Not applicable. No data generated are appropriate for upload to WQX or EIM.

11.5 Model information management

PSWC modeling information is currently managed as follows:

- Versions of input and output data and information from historic and current modeling runs are stored on agency-managed networked drives. Examples of types of information and data stored include GIS input and output datasets for internal and external use, Model Builder models, Python scripts, text files, tables, and documentation in the form of Word documents, PDFs, PowerPoint presentations, graphics files, spreadsheets, and reports. These datasets and documents currently use approximately 450 GB of disk space.
- The version of the model is currently determined by input data updates. When a previous version is retired, it is archived.
- Future data storage needs depend on the number and extent of projects and focus of the output. It also depends on the resolution of input datasets. As data quality improves, storage space needed typically increases. Input datasets are also prepared for model use, which may result in intermediate working copies. Versions which cover the Puget Sound (19 WRIAs) are generally run once and then provided for external use through map services and data downloads. Project runs are stored separately.

Estimate of GIS data storage needs (final file geodatabase format):

- Input = 7 GB
- Output (19 WRIAs, both water flow and water quality) = 20 GB

12.0 Audits and Reports

12.1 Audits

Not applicable. No audits are planned for this project.

12.2 Responsible personnel

Not applicable.

12.3 Frequency and distribution of reports

Brief progress reports on the technical assistance provided will be submitted to the NEP grant manager quarterly until the end of the grant.

12.4 Responsibility for reports

The senior watershed scientist, Colin Hume, is responsible for any reports generated related to the projects which the WCTAT takes on.

13.0 Data Verification

13.1 Field data verification, requirements, and responsibilities

Not applicable. There will be no data collected for this project.

13.2 Laboratory data verification

Not applicable. There is no laboratory work in this project.

13.3 Validation requirements, if necessary

Not applicable. There will be no data collected for this project.

13.4 Model quality assessment

Draft model outputs are generally presented to a project steering committee or technical advisory group for review and feedback. This is often an iterative process and may include adjustments to how the AUs or PAUs are delineated, how the index scores are categorized from low high based upon the raw ranking (0-1 normalized values), and how they ultimately are categorized into the Management Matrix. Methods of categorization can be based upon applying a natural-breaks quartiling method or scatter plots of Importance versus Degradation scores, which provide groupings that, are visually distinguished from each other, or a combination of the two. The Addendum to Volume 1 (Hume et al. 2019) describes implications of using alternative approaches to categorization and model sensitivity.

13.4.1 Calibration and validation

A quantitative validation of a relative index of this nature was deemed impossible by the initial Technical Advisory Group, which established Volumes 1 and 2. Instead, best professional judgement of the given project steering committee or technical advisory group is used as described above to compare mapped outputs with on-the-ground knowledge of the study area. Where a committee or technical advisory group is not used, the project sponsor requesting the data is responsible for validating the results with their own knowledge of the area in discussion with the WCTAT.

Calibration and validation for the HCI (Volume 4) is occurring as a part of phase 2 of the project and is covered under a separate QAPP. The High Pulse Count (HPC) coefficients used in the HCI model were initially developed by King County using a calibrated HSPF model. This process is outlined in their study of 9 test watersheds in King County (Lucchetti et al. 2014). Validation of the HCI was performed by using existing hydrologic data from stream gages, including the annual number of high pulses. Calibration and validation of the model is documented and published in Volume 4 of the PSWC (Stanley et al. 2019).

13.4.1.1 Precision

Not applicable for Volumes 1 and 2 indices. For use of the HCI (Volume 4) model precision will be measured using regression analysis to measured stream gage high pulse counts. Precision is based on testing the following hypothesis: The correlation (coefficient of determination) between observed high pulses counts (independent variable) and HCI values (dependent variable) for test watersheds will exceed 0.6 (explaining 60% of the variance between the dependent and independent variables of the test).

13.4.1.2 Bias

Bias is not applicable to the Volumes 1 and 2 indices. Volume 4 bias will be assessed for the HCI model by calculating the percent error (average of paired observed-modeled values divided by observed value). This will require normalizing the observed high pulse counts and obtaining a 0 to 1 value.

13.4.1.3 Representativeness

The PSWC Volumes 1 and 2 indices was initially designed to cover the larger Puget Sound Basin but has subsequently been used to assess sub-watersheds of the region. Although the data from this model output will be at a different scale, the information will be representative of the same approach used to disseminate information on the wider Puget Sound.

The HCI (Volume 4) will be representative of the conditions present in the test watersheds since the coefficients for the model were developed in watersheds, using a calibrated HSPF model with similar geologic, landform, cover, and precipitation characteristics.

13.4.1.4 Qualitative assessment

See section 13.4

13.4.2 Analysis of sensitivity and uncertainty

The Addendum to Volume 1 (Hume et al. 2019) describes uncertainty of the categorization of index results into Low-High quantiles when using different methods of index formulas and normalization processes. Volume 2 describes in detail uncertainty testing that was performed in the creation of index formulas (Wilhere et al. 2013). Work with the HCI (Volume 4) currently underway and covered by a separate QAPP will involve sensitivity testing to watershed characteristics such as drainage network density, size, and soils.

14.0 Data Quality (Usability) Assessment

14.1 Process for determining project objectives were met

The original creation of Volumes 1, 2, and 4 indices involved rigorous literature review, peer review, and technical advisory group feedback to determine if they could meet the objectives of informing broad-scale watershed-based land use and stormwater planning processes. At the project scale, this occurs through the quality control process described previously in section 10.0 as well as ongoing support to the project sponsor (e.g. local jurisdiction) from the WCTAT as they bring the information to decision-makers, stakeholders, and other technical groups engaged in the given planning process. Where feedback is received that the project objectives are not being met, the WCTAT proposes solutions if they are able to adapt the assessment to better meet the needs of the project sponsor.

14.2 Treatment of non-detects

Not Applicable.

14.3 Data analysis and presentation methods

The detailed appendices (B, C, and D) of Volume 1, 4, and the main body of Volume 2, describe how data were assembled through a literature review process and identification of regional datasets from reputable sources which represent specific indicators of watershed processes and habitats.

Results of the modeling are always summarized in maps of the study area and often in tables, which display actual index values. Where publications are produced by Ecology, we host them on our website for public use. Good example applications may be described in a story map on Ecology's PSWC website (https://apps.ecology.wa.gov/coastalatlas/wc/landingpage.html).

14.4 Sampling design evaluation

The ranking and scoring assigned to the AUs or PAUs at the completion of the final model run are often developed iteratively through input from the steering committee and subject matter experts with on-the-ground experience in the project area. Any discrepancies in the data or model outputs are discussed at each stage and adjusted to the extent possible. After final GIS, modeling is complete and the results have been used in the prioritization matrix, the steering committee will often reconvene to discuss and document lessons learned.

14.5 Documentation of assessment

Documentation of adjustments to the study approach and usability typically occurs in the primary deliverables provided by the WCTAT to the project sponsor. This is often in the summary PowerPoint, which is provided and describes any models or sub models, which are not deemed usable after review from technical advisory groups or best professional judgment of the WCTAT and project sponsor. If a publication or final report is produced by the WCTAT, any indices or model results deemed not usable will be identified.

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16.0 Appendices

Appendix A. Glossaries, Acronyms, and Abbreviations

Glossary of General Terms

Assessment: The use of one more Puget Sound Watershed Characterization indices to analyze the characteristics of a given area for the presence and condition of indicators of watershed processes and habitats.

Baseflow: The component of total streamflow that originates from direct groundwater discharges to a stream.

Clean Water Act: A federal act passed in 1972 that contains provisions to restore and maintain the quality of the nation's waters. Section 303(d) of the Clean Water Act establishes the TMDL program.

National Pollutant Discharge Elimination System (NPDES): National program for issuing, modifying, revoking and reissuing, terminating, monitoring, and enforcing permits, and imposing and enforcing pretreatment requirements under the Clean Water Act. The NPDES program regulates discharges from wastewater treatment plants, large factories, and other facilities that use, process, and discharge water back into lakes, streams, rivers, bays, and oceans.

Pollution: Contamination or other alteration of the physical, chemical, or biological properties of any waters of the state. This includes change in temperature, taste, color, turbidity, or odor of the waters. It also includes discharge of any liquid, gaseous, solid, radioactive, or other substance into any waters of the state. This definition assumes that these changes will, or are likely to, create a nuisance, or render such waters harmful, detrimental, or injurious to (1) public health, safety, or welfare, or (2) domestic, commercial, industrial, agricultural, recreational, or other legitimate beneficial uses, or (3) livestock, wild animals, birds, fish, or other aquatic life.

Reach: A specific portion or segment of a stream.

Sediment: Soil and organic matter that is covered with water (for example, river, or lake bottom).

Stormwater: The portion of precipitation that does not naturally percolate into the ground or evaporate but instead runs off roads, pavement, and roofs during rainfall or snowmelt. Stormwater can also come from hard or saturated grass surfaces such as lawns, pastures, playfields, and from gravel roads and parking lots.

Streamflow: Discharge of water in a surface stream (river or creek).

Total Maximum Daily Load (TMDL): A distribution of a substance in a water body designed to protect it from not meeting (exceeding) water quality standards. A TMDL is equal to the sum of all of the following: (1) individual waste load allocations for point sources, (2) the load allocations for nonpoint sources, (3) the contribution of natural sources, and (4) a margin of safety to allow for uncertainty in the waste load determination. A reserve for future growth is also generally provided.

Watershed: A drainage area or basin in which all land and water areas drain or flow toward a central collector such as a stream, river, or lake at a lower elevation.

Acronyms and Abbreviations

AU	Assessment Unit
BMP	Best management practice
DNR	Washington Department of Natural Resources
e.g.	For example
Ecology	Washington State Department of Ecology
EIM	Environmental Information Management database
EPA	U.S. Environmental Protection Agency
et al.	And others
GIS	Geographic Information System software
GPS	Global Positioning System
HPC	High Pulse Count
HSPF	Hydrologic Simulation Program - FORTRAN
i.e.	In other words
NPDES	National Pollutant Discharge Elimination System
PAU	Project Assessment Unit
PSWC	Puget Sound Watershed Characterization
QA	Quality assurance
QC	Quality control
SOP	Standard operating procedures
TMDL	Total Maximum Daily Load
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
WAC	Washington Administrative Code
WCTAT	Watershed Characterization Technical Assistance Team
WDF	Washington Department of Fisheries

WDFW	Washington Department of Fish and Wildlife
WRIA	Water Resource Inventory Area

Units of Measurement

cfs	cubic feet per second
cms	cubic meters per second, a unit of flow
ft.	feet
km	kilometer, a unit of length equal to 1,000 meters
m	meter
sq. mi.	square mile

Quality Assurance Glossary

Accreditation: A certification process for laboratories, designed to evaluate and document a lab's ability to perform analytical methods and produce acceptable data (Kammin, 2010). For Ecology, it is defined according to WAC 173-50-040: "Formal recognition by [Ecology] that an environmental laboratory is capable of producing accurate and defensible analytical data."

Accuracy: The degree to which a measured value agrees with the true value of the measured property. USEPA recommends that this term not be used, and that the terms *precision* and *bias* be used to convey the information associated with the term *accuracy* (USEPA, 2014).

Analyte: An element, ion, compound, or chemical moiety (pH, alkalinity) which is to be determined. The definition can be expanded to include organisms, e.g., fecal coliform, Klebsiella (Kammin, 2010).

Bias: Discrepancy between the expected value of an estimator and the population parameter being estimated (Gilbert, 1987; USEPA, 2014).

Blank: A synthetic sample, free of the analyte(s) of interest. For example, in water analysis, pure water is used for the blank. In chemical analysis, a blank is used to estimate the analytical response to all factors other than the analyte in the sample. In general, blanks are used to assess possible contamination or inadvertent introduction of analyte during various stages of the sampling and analytical process (USGS, 1998).

Calibration: The process of establishing the relationship between the response of a measurement system and the concentration of the parameter being measured (Ecology, 2004).

Check standard: A substance or reference material obtained from a source independent from the source of the calibration standard; used to assess bias for an analytical method. This is an obsolete term, and its use is highly discouraged. See Calibration Verification Standards, Lab Control Samples (LCS), Certified Reference Materials (CRM), and/or spiked blanks. These are all check standards but should be referred to by their actual designator, e.g., CRM, LCS (Kammin, 2010; Ecology, 2004).

Comparability: The degree to which different methods, data sets, and/or decisions agree or can be represented as similar; a data quality indicator (USEPA, 2014; USEPA, 2020).

Completeness: The amount of valid data obtained from a project compared to the planned amount. Usually expressed as a percentage. A data quality indicator (USEPA, 2014; USEPA 2020).

Continuing Calibration Verification Standard (CCV): A quality control (QC) sample analyzed with samples to check for acceptable bias in the measurement system. The CCV is usually a midpoint calibration standard that is re-run at an established frequency during the course of an analytical run (Kammin, 2010).

Control chart: A graphical representation of quality control results demonstrating the performance of an aspect of a measurement system (Kammin, 2010; Ecology 2004).

Control limits: Statistical warning and action limits calculated based on control charts. Warning limits are generally set at +/- 2 standard deviations from the mean, action limits at +/- 3 standard deviations from the mean (Kammin, 2010).

Data integrity: A qualitative DQI that evaluates the extent to which a data set contains data that is misrepresented, falsified, or deliberately misleading (Kammin, 2010).

Data quality indicators (DQI): Commonly used measures of acceptability for environmental data. The principal DQIs are precision, bias, representativeness, comparability, completeness, sensitivity, and integrity (USEPA, 2006).

Data quality objectives (DQO): Qualitative and quantitative statements derived from systematic planning processes that clarify study objectives, define the appropriate type of data, and specify tolerable levels of potential decision errors that will be used as the basis for establishing the quality and quantity of data needed to support decisions (USEPA, 2006).

Data set: A grouping of samples organized by date, time, analyte, etc. (Kammin, 2010).

Data validation: The process of determining that the data satisfy the requirements as defined by the data user (USEPA, 2020). There are various levels of data validation (USEPA, 2009).

Data verification: Examination of a data set for errors or omissions, and assessment of the Data Quality Indicators related to that data set for compliance with acceptance criteria (MQOs). Verification is a detailed quality review of a data set (Ecology, 2004).

Detection limit (limit of detection)**:** The concentration or amount of an analyte which can be determined to a specified level of certainty to be greater than zero (Ecology, 2004).

Duplicate samples: Two samples taken from and representative of the same population, and carried through and steps of the sampling and analytical procedures in an identical manner.

Duplicate samples are used to assess variability of all method activities including sampling and analysis (USEPA, 2014).

Field blank: A blank used to obtain information on contamination introduced during sample collection, storage, and transport (Ecology, 2004).

Initial Calibration Verification Standard (ICV): A QC sample prepared independently of calibration standards and analyzed along with the samples to check for acceptable bias in the measurement system. The ICV is analyzed prior to the analysis of any samples (Kammin, 2010).

Laboratory Control Sample (LCS)/LCS duplicate: A sample of known composition prepared using contaminant-free water or an inert solid that is spiked with analytes of interest at the midpoint of the calibration curve or at the level of concern. It is prepared and analyzed in the same batch of regular samples using the same sample preparation method, reagents, and analytical methods employed for regular samples. Monitors a lab's performance for bias and precision (USEPA, 2014).

Matrix spike/Matrix spike duplicate: A QC sample prepared by adding a known amount of the target analyte(s) to an aliquot of a sample to check for bias and precision errors due to interference or matrix effects (Ecology, 2004).

Measurement Quality Objectives (MQOs)**:** Performance or acceptance criteria for individual data quality indicators, usually including precision, bias, sensitivity, completeness, comparability, and representativeness (USEPA, 2006).

Measurement result: A value obtained by performing the procedure described in a method (Ecology, 2004).

Method: A formalized group of procedures and techniques for performing an activity (e.g., sampling, chemical analysis, data analysis), systematically presented in the order in which they are to be executed (USEPA, 2001).

Method blank: A blank prepared to represent the sample matrix, prepared and analyzed with a batch of samples. A method blank will contain all reagents used in the preparation of a sample, and the same preparation process is used for the method blank and samples (Ecology, 2004; Kammin, 2010).

Method Detection Limit (MDL): The minimum measured concentration of a substance that can be reported with 99% confidence that the measured concentration is distinguishable from method blank results (USEPA, 2016). MDL is a measure of the capability of an analytical method of distinguished samples that do not contain a specific analyte from a sample that contains a low concentration of the analyte (USEPA, 2020).

Minimum level: Either the sample concentration equivalent to the lowest calibration point in a method or a multiple of the method detection limit (MDL), whichever is higher. For the purposes of NPDES compliance monitoring, EPA considers the following terms to be synonymous: "quantitation limit," "reporting limit," and "minimum level" (40 CFR 136).

Parameter: A specified characteristic of a population or sample. Also, an analyte or grouping of analytes. Benzene and nitrate + nitrite are all parameters (Kammin, 2010; Ecology, 2004).

Population: The hypothetical set of all possible observations of the type being investigated (Ecology, 2004).

Precision: The extent of random variability among replicate measurements of the same property; a data quality indicator (USGS, 1998).

Quality assurance (QA): A set of activities designed to establish and document the reliability and usability of measurement data (Kammin, 2010).

Quality Assurance Project Plan (QAPP): A document that describes the objectives of a project, and the processes and activities necessary to develop data that will support those objectives (Kammin, 2010; Ecology, 2004).

Quality control (QC): The routine application of measurement and statistical procedures to assess the accuracy of measurement data (Ecology, 2004).

Relative Percent Difference (RPD): RPD is commonly used to evaluate precision. The following formula is used:

$$RPD = [Abs (a-b)/ ((a + b)/2)] * 100\%$$

Where "Abs ()" is absolute value and a and b are results for the two replicate samples. RPD can be used only with 2 values. Percent Relative Standard Deviation is (percentageRSD) is used if there are results for more than 2 replicate samples (Ecology, 2004).

Relative Standard Deviation (RSD): A statistic used to evaluate precision in environmental analysis. It is determined in the following manner:

$$RSD = (100\% * s)/x$$

Where s is the sample standard deviation and x is the mean of results from more than two replicate samples (Kammin, 2010).

Replicate samples: Two or more samples taken from the environment at the same time and place, using the same protocols. Replicates are used to estimate the random variability of the material sampled (USGS, 1998).

Reporting level: Unless specified otherwise by a regulatory authority or in a discharge permit, results for analytes that meet the identification criteria (i.e., rules for determining qualitative presence/absence of an analyte) are reported down to the concentration of the minimum level established by the laboratory through calibration of the instrument. EPA considers the terms "reporting limit," "quantitation limit," and "minimum level" to be synonymous (40 CFR 136).

Representativeness: The degree to which a sample reflects the population from which it is taken; a data quality indicator (USGS, 1998).

Sample (field): A portion of a population (environmental entity) that is measured and assumed to represent the entire population (USGS, 1998).

Sample (statistical): A finite part or subset of a statistical population (USEPA, 1992).

Sensitivity: In general, denotes the rate at which the analytical response (e.g., absorbance, volume, meter reading) varies with the concentration of the parameter being determined. In a specialized sense, it has the same meaning as the detection limit (Ecology, 2004).

Spiked blank: A specified amount of reagent blank fortified with a known mass of the target analyte(s); usually used to assess the recovery efficiency of the method (USEPA, 2014).

Spiked sample: A sample prepared by adding a known mass of target analyte(s) to a specified amount of matrix sample for which an independent estimate of target analyte(s) concentration is available. Spiked samples can be used to determine the effect of the matrix on a method's recovery efficiency (USEPA, 2014).

Split sample: A discrete sample subdivided into portions, usually duplicates (Kammin, 2010).

Standard Operating Procedure (SOP): A document, which describes in detail a reproducible and repeatable organized activity (Kammin, 2010).

Surrogate: For environmental chemistry, a surrogate is a substance with properties similar to those of the target analyte(s). Surrogates are unlikely to be native to environmental samples. They are added to environmental samples for quality control purposes, to track extraction efficiency and/or measure analyte recovery. Deuterated organic compounds are examples of surrogates commonly used in organic compound analysis (Kammin, 2010).

Systematic planning: A step-wise process which develops a clear description of the goals and objectives of a project, and produces decisions on the type, quantity, and quality of data that will be needed to meet those goals and objectives. The DQO process is a specialized type of systematic planning (USEPA, 2006).

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