Quality Assurance Project Plan

Aquatic Plant Monitoring in Washington State Lakes, Rivers, and Streams

June 2023

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Publication Information

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COVER PHOTO: Aquatic plants at Silver Lake, Whatcom County, Washington.
PHOTO BY WESLEY GLISSON.

Quality Assurance Project Plan

Aquatic Plant Monitoring in Washington State Lakes, Rivers, and Streams

by Wesley Glisson

June 2023

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EAP: Environmental Assessment Program
WQP: Water Quality Program

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2.0 Abstract

In response to growing concern about the impacts of invasive aquatic plants to waters of Washington state, in 1991 the legislature established the Washington State Department of Ecology's (Ecology's) Freshwater Aquatic Weeds Management Program (FAWMP) (RCW 43-21A.660). The FAWMP provides technical assistance, public education, and grants for invasive aquatic plant prevention and management. In 1994, the FAWMP was fully staffed, and the Aquatic Plant Monitoring Program (APMP) was established to support the FAWMP.

The goal of the APMP is to improve management and prevention of invasive aquatic plants in Washington through understanding the distribution of freshwater invasive and native plant populations. The objectives of the APMP are as follows:

- Find new populations of invasive aquatic plant species in waterbodies throughout the state.
- Monitor known invasive aquatic plant populations for expansion or decline.
- Maintain a database of all aquatic plant species present in inventoried waterbodies.
- Monitor and study the results of invasive aquatic plant control efforts.

The resulting aquatic plant data help Ecology, state and local governments, tribes, lake associations, and others with invasive aquatic plant management. This Quality Assurance Monitoring Plan (QAPP) describes the ongoing APMP, its objectives, and details the types of data collected to satisfy those objectives.

3.0 Background

3.1 Introduction and problem statement

Legislative action in 1991 (RCW 43-21A.660) established the Washington State Department of Ecology's (Ecology's) Freshwater Aquatic Weeds Management Program (FAWMP). The FAWMP provides technical assistance, public education, and grants for invasive aquatic plant prevention and management. To help provide technical assistance and public education, the FAWMP has supported the statewide Aquatic Plant Monitoring Program (APMP) since 1994.

The APMP was needed to provide baseline information on aquatic plant distributions in Washington. The main goal of the APMP has since evolved to track aquatic plant community changes in lakes and rivers, concentrating on invasive species. In addition, targeted studies on invasive aquatic plant control methods are conducted to inform prevention and management techniques. The aquatic plant data and study results aid Ecology, state and local governments, tribes, lake associations, and others with aquatic plant management throughout the state.

The results of the APMP were reported annually from 1994 to 2002. Since 2003, results have been reported on Ecology's EIM database (study ID: FW_MACROPHYTE) and the Washington State lakes environmental database: https://apps.ecology.wa.gov/lakes/.

This Quality Assurance Project Plan (QAPP) updates the previously published plan (Parsons 2011).

3.2 Study area and surroundings

The study area includes all freshwater waterbodies in Washington, including lakes, rivers, and streams (Figure 1). Areas designed as wetlands, without an adjoining waterbody, are not included in the study area. The focus of the APMP is waterbodies with a public motorized boat launching ramp. Examples are those maintained by the Washington Department of Fish and Wildlife (WDFW), Washington State Parks, and the Washington State Department of Natural Resources (WDNR). Waterbodies without a public boat launch can be included in the study area if they harbor a highly invasive species (e.g., a Class A noxious weed such as *Hydrilla verticillata* L.f. Royle) that could spread to other waterbodies.

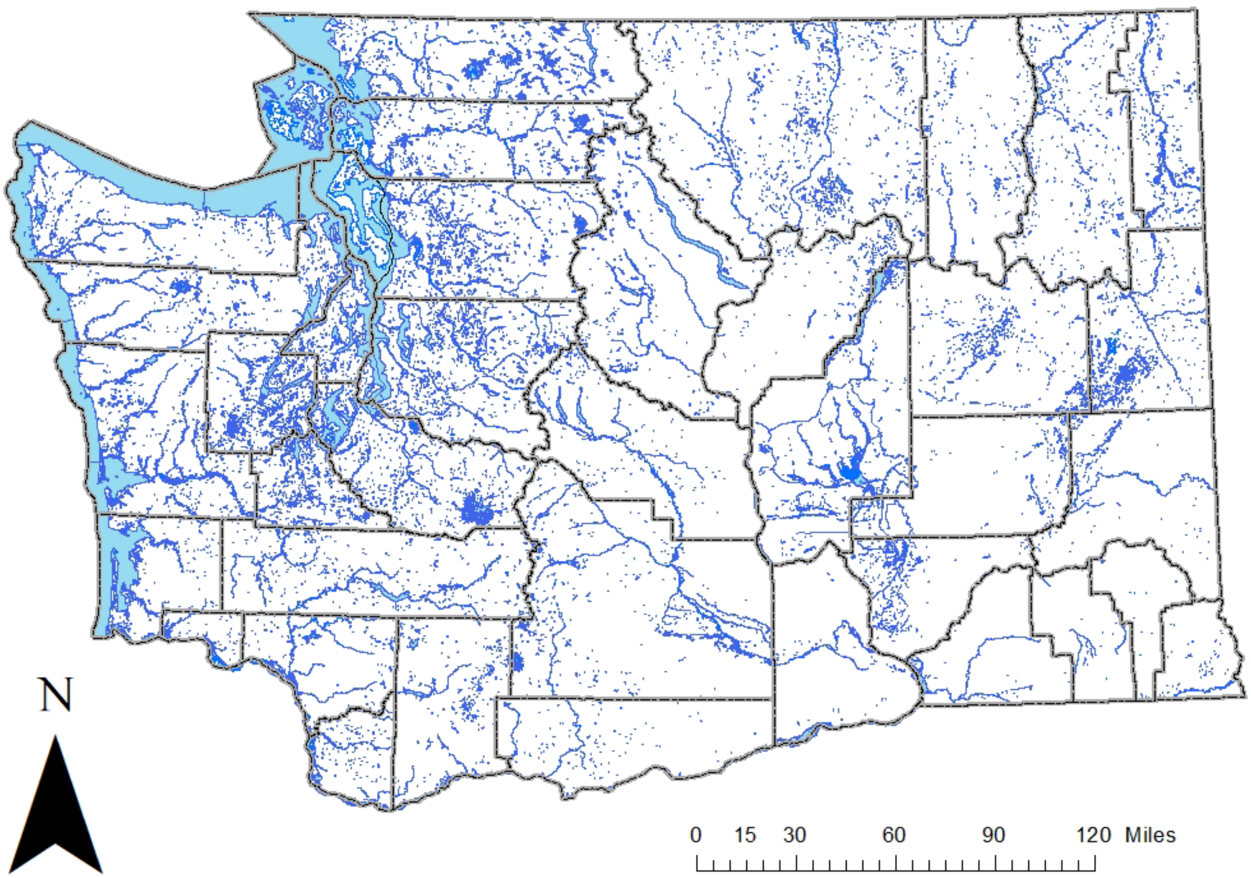

Figure 1. Waterbodies in Washington State.

3.2.1 History of study area

Because the study area encompasses all freshwater waterbodies in Washington, a historical account is not applicable.

3.2.2 Summary of previous studies and existing data

In 1991, the Washington State legislature, "[found] that Eurasian water milfoil and other freshwater aquatic weeds can adversely affect fish populations, reduce habitat for desirable plant and wildlife species, and decrease public recreational opportunities. The legislature further [found] that the spread of freshwater aquatic weeds is a statewide problem and requires a coordinated response among state agencies, local governments, and the public" (RCW 43.21A.650). To address these issues, the legislature created the FAWMP (RCW 43-21A.660) funded by the Freshwater Aquatic Weeds Account (RCW 43.21A.650). The Freshwater Aquatic Weeds Account is funded by an annual $3.00 fee for boat trailer licenses in Washington. Boats and boat trailers are a primary means of spread for invasive aquatic plants; therefore, the funding was considered an appropriate user-based fee.

Since the FAWMP's creation and staffing of an Aquatic Plant Specialist in 1994, over 500 waterbodies, including river and stream sections, have been surveyed, and over 23,000 aquatic plant observations have been made. These data are housed in an internal APMP database, Ecology's EIM database, and the Washington State lakes environmental database: https://apps.ecology.wa.gov/lakes/. Additionally, several studies on invasive aquatic plant control methods have been implemented through the APMP, resulting in peer reviewed publications. These include Parsons et al. (2000, 2001, 2004, 2007, 2009, 2019). Ongoing work will build on these data and studies.

3.2.3 Parameters of interest and potential sources

The primary parameters of interest are the presence and distribution of invasive aquatic plant species. For projects evaluating invasive aquatic plant control methods, additional parameters may include wet-weight and dry-weight biomass as well as rake abundance of native and invasive aquatic plant species. Environmental parameters include water temperate (°C) and Secchi depth (m). These parameters are described in detail in the sections below.

3.2.4 Regulatory criteria or standards

Not applicable. The study objectives do not include assessing regulatory compliance status.

4.0 Project Description

4.1 Project goals

The goal of the APMP is to improve prevention and management of invasive aquatic plants in Washington through understanding the distribution of freshwater invasive and native plant populations. Achieving this goal improves the use of the Freshwater Aquatic Weeds Account to (1) target populations of invasive aquatic plants and (2) improve Ecology's ability to advise federal, state, and local governments, and other lake managers on the best invasive aquatic plant control methods.

4.2 Project objectives

The objectives of the APMP are to:

- Find new populations of invasive aquatic plant species in waterbodies throughout the state.
- Monitor known invasive aquatic plant populations for expansion or decline.
- Maintain a database of all aquatic plant species present in inventoried waterbodies.
- Monitor and study the results of invasive aquatic plant control efforts.

4.3 Information needed and sources

Ecology staff have entered data from the APMP into a database maintained by program personnel from 1994 to present. These data are entered each year into Ecology's EIM database and the Washington State lakes environmental database (https://apps.ecology.wa.gov/lakes/) for accessibility and mapping. These databases are used to help plan and prioritize ongoing sampling events.

We employ different sampling methods based on the level of detail the specific waterbody, location, and situation requires. All sampling methods require identifying aquatic plants to the lowest taxonomic group possible and compiling a list of observed species. Also, we collect data on water clarity and water temperature. We record a qualitative estimate of each species' distribution at waterbodies where we inventory a majority of the littoral zone.

When undertaking more intensive studies to evaluate the effectiveness of invasive aquatic plant control methods, we collect plant frequency and abundance (e.g., biomass) data in addition to the above listed parameters. For such studies, we analyze data for treatment effectiveness using standard statistical analyses and software.

Details on the types of data collected and data analysis can be found in sections 6.0, 7.0, and 8.0.

4.4 Tasks required

We at Ecology will complete the following tasks each year to address the objectives of the APMP:

- Meet with program partners in Ecology's Water Quality Program (WQP) to determine sampling locations and plan scheduling for the upcoming field season.
- Respond to requests to survey waterbodies where invasive aquatic plants may be present.
- Conduct surveys at waterbodies:
    - With known infestations of invasive aquatic plants.
    - Where invasive aquatic plants have been reported but unconfirmed.
    - That are connected to a waterbody with a known or reported invasive aquatic plant infestation.
    - Where ongoing management of invasive aquatic plants is occurring.
- Enter all data into the APMP database and subsequently into EIM following the field season.
- Work with Ecology personnel to ensure EIM data are transferred to the Washington State lakes environmental database.

We will conduct all sampling during the growing season, typically April–October. Surveys will be conducted with occasional assistance from other Ecology programs, county noxious weed boards, federal and local government agencies, and private citizens.

4.5 Systematic planning process

This QAPP accomplishes the systematic planning process for the APMP.

5.0 Organization and Schedule

5.1 Key individuals and their responsibilities

Table 1 shows the responsibilities of those who will be involved in this project.

Table 1. Organization of project staff and responsibilities.

Staff[1]	Title	Responsibilities
Lizbeth Seebacher Water Quality Program Phone: 360-628-7516	Program Partner	Clarifies scope of the project. Provides internal review of the QAPP and approves the final QAPP.
Wesley Glisson TSU, SCS Phone: 360-688-8811	Project Manager/ Principal Investigator	Writes the QAPP. Oversees field sampling. Conducts QA review of data, analyzes and interprets data, and enters data into EIM.
Seasonal staff SCS Phone: 360-280-7712	Field Assistant	Helps with field data collection, records field information, and assists with EIM data verification.
James Medlen TSU, SCS Phone: 360-480-6175	Unit Supervisor for the Project Manager	Reviews the project scope and budget, tracks progress, reviews the draft QAPP, and approves the final QAPP.
Jessica Archer SCS Phone: 360-890-2721	Section Manager for the Project Manager and for Study Area	Approves the budget, approves internal review of the QAPP, and approves the final QAPP.
Arati Kaza Phone: 360-407-6964	Ecology Quality Assurance Officer	Reviews and approves the draft QAPP and the final QAPP.

[1]All staff except the program partner are from EAP.
EAP: Environmental Assessment Program
EIM: Environmental Information Management database
QAPP: Quality Assurance Project Plan
SCS: Statewide Coordination Section
TSU: Toxics Studies Unit

5.2 Special training and certifications

The project manager/principal investigator has over 10 years of experience sampling aquatic plants; collecting, validating, and analyzing scientific data; and writing results for peer-reviewed publications (Glisson et al. 2015, 2018, 2020, 2022). Other project personnel have similar experience with invasive aquatic plants and field sampling in aquatic systems. New field staff will be trained by the project manager prior to collecting or recording data.

5.3 Organization chart

Not Applicable. See Table 1.

5.4 Proposed project schedule

Tables 2 – 4 list key activities, due dates, and lead staff for this project.

Table 2. Schedule for completing field and laboratory work

Task	Due date	Lead staff
Field work	April – October, annually	Wesley Glisson
Lab analyses	Not applicable	Not applicable

Table 3. Schedule for data entry

Task	Due date	Lead staff
EIM data loaded*	December, year of data collection	Wesley Glisson
EIM QA	January, year following data collection	Seasonal staff
EIM complete	February, year following data collection	Wesley Glisson

*EIM Project ID: FW_MACROPHYTE
EIM: Environmental Information Management database

Table 4. Schedule for annual update of Washington State lakes environmental database web page: https://apps.ecology.wa.gov/lakes/

Task	Due date	Lead staff
Aquatic plant data sent to lakes web page manager, Darby Veeck	February, year following data collection	Wesley Glisson
Data reviewed and any issues resolved	March, year following data collection	Wesley Glisson and Darby Veeck
Final data added to lakes database webpage	March, year following data collection	Wesley Glisson and Darby Veeck

5.5 Budget and funding

The APMP is permanently funded by the Freshwater Aquatic Weeds Account (RCW 43.21A.650), as appropriated by the Washington State Legislature.

6.0 Quality Objectives

6.1 Data quality objectives

The main data quantity objective (DQO) of the APMP is to accurately identify invasive and native aquatic plants. Auxiliary data collected at each waterbody include water temperature and Secchi depth measurements. Finally, for projects that evaluate the effectiveness of invasive aquatic plant control methods, accurate and representative abundance data will be collected. For all data, we will adhere to the measurement quality objectives (MQOs) described below for precision, bias, sensitivity, representativeness, comparability, and completeness.

6.2 Measurement quality objectives

The primary focus of the APMP is to identify invasive and native aquatic plants. Identification is not a measured variable, and thus, not subject to the standard MQOs of precision, bias, and sensitivity. Nonetheless, accuracy of aquatic plant identification is important because misidentification can lead to inappropriate decisions and management actions.

To obtain the most accurate and consistent species identifications possible, we collect voucher specimens of all initial invasive plant sightings and maintain representative samples of all other species in an herbarium. When someone other than the project manager collects the data, the principal investigator will verify the identification of the samples of all species collected at the sample site. A list of manuals and field guides used to identify aquatic plants can be found in Parsons (2001). If the project manager is unable to identify a plant with confidence, it is preserved and sent to an expert in that taxonomic group for identification. For example, members of the *Myriophyllum* genus (watermilfoils; Haloragaceae) may be sent for genetic analysis with the Thum Lab at Montana State University.

Invasive aquatic plants monitored by the APMP are listed below by scientific name and botanical authority, followed by the common name in parentheses. Plants listed as noxious weeds by the Washington State Noxious Weed Control Board are indicated with a bold A, B, or C, denoting the weed class to which it belongs (see https://www.nwcb.wa.gov/classes-of-noxious-weeds). Also, those on the Washington State Department of Agriculture's quarantine list (WAC 16-752-610) are labeled with a "q". This list is subject to updates as new invasive aquatic plant species are found in the state.

- *Aponogeton distachyos* L.f. (cape pondweed)
- *Butomus umbellatus* L. (flowering rush) **A** q
- *Cabomba caroliniana* Gray (fanwort) **B** q
- *Egeria densa* Planch. (Brazilian elodea or egeria) **B** q
- *Eichornia crassipes* (Mart.) Solms (water hyacinth)
- *Epilobium hirsutum* L. (hairy willow herb) **B** q
- *Glyceria maxima* (Hart.) E. Holmb. (reed sweetgrass) **A** q
- *Hydrilla verticillata* (L.) Royle (hydrilla) **A** q
- *Hydrocharis morsus-ranae* L. (European frog-bit) q
- *Iris pseudacorus* L. (yellow flag iris) **C** q
- *Juncus bulbosus* L. (bulbous rush)

- *Limnobium laevigatum* (Humb. & Bonpl. Ex Willd.) Heine (South American spongeplant) **A** q
- *Ludwigia hexapetala* (Hook. & Arn.) Zardini, Gu & Raven (water primrose) **B** q
- *Ludwigia peploides* (Kunth) Raven (floating primrose willow) **A** q
- *Lysimachia vulgaris* L. (garden loosestrife) **B** q
- *Lythrum salicaria* L. (purple loosestrife) **B** q
- *Marsilea mutica* Mett. (Australian water clover) q
- *Myriophyllum aquaticum* (Vell.) Verd. (parrotfeather) **B** q
- *Myriophyllum heterophyllum* Michx. (variable-leaf watermilfoil) **A** q
- *Myriophyllum heterophyllum* × *Myriophyllum hippuroides* (hybrid watermilfoil)
- *Myriophyllum spicatum* L. (Eurasian watermilfoil) **B** q
- *Myriophyllum spicatum* × *Myriophyllum sibiricum* (hybrid watermilfoil) **C**
- *Nymphaea odorata* Ait. (fragrant waterlily) **C**
- *Nymphoides peltata* (Gmelin) O. Kuntze (yellow floating heart) **B** q
- *Phalaris arundinacea* L. (reed canarygrass) **C**
- *Phragmites australis* subsp. *australis* (Cav.) Trin. ex Steud. (common reed) **B**
- *Potamogeton crispus* L. (curly-leaf pondweed) **C**
- *Sagittaria graminea* Michx. (grass leaf arrowhead) **B** q
- *Schoenoplectus mucronatus* (L.) Palla (rice field bulrush) **A** q
- *Typha angustifolia* L. (narrowleaf cattail) **C**
- *Typha* X *glauca* Godr. (hybrid cattail) **C**
- *Utricularia inflata* Walt. (floating bladderwort) q

6.2.1 Targets for precision, bias, and sensitivity

The MQOs for parameters measured in the field and laboratory are described in Table 5 and in the following sections.

Table 5. Measurement quality objectives

Parameter	Field or lab duplicate RPD	Expected range
Secchi depth	10%	0 – 20 m
Water temperature	10%	4 – 30 °C
Wet-weight biomass	5%	0 – 5000 g
Dry-weight biomass	5%	0 – 500 g

6.2.1.1 Precision

We will collect duplicate measurements for 10% of all Secchi depth, water temperature, and biomass samples to ensure acceptable precision values are met for relative percent difference (RPD; Table 5).

6.2.1.2 Bias

We will routinely check field and lab equipment to ensure the equipment is in working order so that measurements are free from bias. Specifically, prior to conducting field and lab work, we will test scales against known weights and the field thermometer against a known water temperature.

6.2.1.3 Sensitivity

For biomass measurements, a minimum of 0.01 g of plant material is necessary for reliable measurement. Quantities below this value will be listed as “trace” or “present”. Sensitivity MQOs for water temperature and Secchi depth are not applicable, as these measurements are always detectable.

6.2.2 Targets for comparability, representativeness, and completeness

6.2.2.1 Comparability

Ecology staff will follow the Aquatic Plant Sampling Protocols (Parsons 2001) for sampling, analysis, and data reduction, as well as to ensure comparability between projects. Specifically, consistent naming conventions will be used for aquatic plants and waterbody locations to ensure comparability to (1) previously collected data, (2) individual studies conducted by the APMP, and (3) outside studies of similar taxa and waterbodies. Aquatic plant names are checked yearly for accuracy and consistency using the University of Washington’s Burke Herbarium name checker program (https://burkeherbarium.org/waflora/namechecker.php). All waterbody locations have a unique location name in EIM that has been kept consistent for the duration of the APMP and is used to match data from the same waterbodies over time.

6.2.2.2 Representativeness

We visit waterbodies at the expected time of peak plant abundance to ensure that we are capturing a representative sample of the aquatic plant community (see section 7.2.1). Nonetheless, environmental conditions (e.g., wind, cloud cover, turbidity) may impair our ability to document all plant species within the littoral zone. Moreover, there may not be time or need for a full survey of the littoral zone of a given waterbody.

We indicate on the field data sheets (1) how much of the littoral zone was surveyed during the visit, and (2) any environmental conditions that may have impacted the survey (see section 8.7). These notes are kept with the data and entered into Ecology’s EIM database and the Washington State lakes environmental database. When most of the littoral zone is not surveyed (e.g., < 80%), species distribution values are not estimated for each species (see section 8.0 for an explanation of the field species distribution assessment). For more intensive studies evaluating invasive species control methods, data will be collected only when similar environmental conditions exist in treatment and control sites and before and after treatment.

6.2.2.3 Completeness

Given the opportunistic nature of sampling for the APMP, there are no criteria for completeness. Rather, a reasonable attempt will be made to visit waterbodies on an as-needed basis using the criteria outlined in section 7.2.1.

6.3 Acceptance criteria for quality of existing data

Existing aquatic plant data for the APMP have been collected by a single project manager using well-established methods for over 25 years (Parsons 2001). These data were collected under the previous QAPP (Parsons 2011) and have been verified and entered into the EIM database.

6.4 Model quality objectives

Statistical models may be implemented for studies evaluating invasive aquatic plant control methods. The types of analyses and specific models will vary depending on the goals and design of each study. In all situations, we will follow standard practices for evaluating model assumptions and model fit, and adjust our models as needed. For example, we will apply standard data transformations (e.g., log-transformation) when needed to satisfy assumptions of normality, and we will examine residual error and calibration plots to ensure model fit is acceptable. In all situations, analytical methods will be compared to those currently used in the field to ensure comparability to similar studies. For additional information on the types of statistical models typically implemented for the APMP, see Parsons (2001).

7.0 Study Design

7.1 Study boundaries

The study area includes all freshwater waterbodies in Washington, including lakes, rivers, and streams; therefore, the study boundary is the Washington State border. See section 3.2 and Figure 1.

7.2 Field data collection

Sampling strategies for the APMP are described in detail in Ecology's Aquatic Plant Sampling Protocols (Parsons 2001). Individual sampling strategies will be based on the goals for each waterbody and situation. Most sampling events will entail a surface inventory of aquatic plants with a focus on detecting new infestations of invasive aquatic plant species, creating an aquatic plant species list, and determining the relative extent of invasive species infestation (see Table 1 in Parsons, 2001). This will be accomplished with a survey by boat of the littoral zone of a waterbody, with more time spent near high-priority areas for new infestations, including boat launches, docks, and inflows.

For projects to evaluate the effectiveness of invasive aquatic plant control methods, sampling strategies will vary based on the needs of the project, species of interest, and waterbody. To the extent possible, a robust sampling design will be used to determine the impacts of management approaches on invasive aquatic plants. This will include systematic sampling transects and/or grids that are commonly used in aquatic plant sampling, e.g., the point-intercept method (Madsen and Wersal 2017). When possible, sampling will be employed in a before-after-control-impact (BACI) framework to distinguish impacts of treatment versus natural seasonal fluctuations in plant growth.

We will attempt to include as many sampling locations as possible within and among lakes to determine the effects of aquatic plant control methods. Often, sample size is restricted by the extent of practical management efforts. However, when possible, we will conduct a power analysis to determine the number of samples needed for each treatment and control area necessary to detect a statistically significant difference in the response variable of interest (e.g., plant biomass or frequency).

7.2.1 Sampling locations and frequency

All Washington freshwater waterbodies that support aquatic plants are potential sampling locations (see section 3.2). Because the APMP is funded with boat trailer license fees, we concentrate our efforts on waterbodies with public boat launch facilities. Private lakes, or lakes without public boat launches, are visited when requested and when we believe there is a valid concern regarding invasive species that may spread to other waterbodies or harm the environment. Because the number of potential sampling sites is much greater than the time available to visit them, we use the following criteria to select waterbodies to be surveyed. Waterbodies we survey are those:

- Requested by Ecology, local government, or county noxious weed board personnel.

- Known to host invasive species, especially Washington State listed Class A noxious weeds. Current Class A listed aquatic plants can be found in section 6.2.
- Considered to be at high risk for invasion (e.g., near—or connected to—an infested waterbody).
- With projects funded by grants from the FAWMP.
- With ongoing plant monitoring projects.
- Selected for studies to evaluate the effectiveness of invasive aquatic plant control methods.

Waterbodies selected for evaluations of invasive aquatic plant control methods are chosen in collaboration with personnel managing the Freshwater Aquatic Weeds Management Grants Program within Ecology's Water Quality Program; for details on the granting process and eligibility, see Seebacher, 2022. Generally, waterbodies selected for evaluations of invasive aquatic plant control methods must satisfy the following criteria:

- They contain nuisance levels of the target study plant (e.g., a Washington State listed Class A noxious weed).
- They are located where public benefit will be high and where logistical problems are kept to a minimum.
- There is the cooperation and support of the surrounding community and local government.

Routine field sampling typically occurs April−October but may vary some years depending on weather conditions that impact plant growth. This timing allows us to collect plants when they are actively growing or at their peak abundance, facilitating a relatively complete species list and easier detection of invasive species.

7.2.2 Field parameters and laboratory analytes to be measured

The parameters listed below will be measured in the field, with the exception of dry-weight biomass (Parsons 2001). Samples collected for dry-weight biomass will be sorted, dried, and weighed as specified in Parsons (2001) at the Environmental Assessment Program (EAP) Operations Center in Lacey, WA. See sections 6.0 and 8.2 for more details on these parameters.

- Native and invasive aquatic plant species present (list of names identified to the lowest taxonomic group possible).
- Plant distribution value for each plant species observed (1 – 5; see 8.2 for definitions).
- Water temperature (°C).
- Secchi depth (m).
- Parameters measured to evaluate the effectiveness of aquatic plant control methods for individual species:
  - Wet-weight biomass (g).
  - Dry-weight biomass (g).
  - Rake abundance (1 – 3): an index of abundance based on the amount of the plant-sampling rake covered by each species (following Hauxwell et al. 2010).

7.3 Modeling and analysis design

No novel models or analyses will be developed; however, standard statistical models will be used as needed for evaluations of invasive aquatic plant control methods. Examples of statistical methods that may be used for analysis include Chi-square and t-tests, analysis of variance, linear models, generalized linear models, and linear and generalized linear mixed models. These analyses will be implemented with the standard statistical software R version 4.0+ (R Core Development Team 2022), and packages therein. Methods will be determined by the type of data collected (e.g., biomass versus frequency) and the sampling design implemented (e.g., BACI or before-after [BA] design). Further details on standard statistical methods for analyzing data collected for the APMP can be found in Parsons (2001); see also, section 6.4.

7.3.1 Analytical framework

See section 7.3.

7.3.2 Model setup and data needs

See section 7.3.

7.4 Assumptions underlying design

As described in section 7.2, the typical sampling design for the APMP is opportunistic, rather than systemic or random. This sampling approach aligns with the FAWMP's focus on technical assistance to local governments and the public (RCW 43.21A.660). For more intensive studies of aquatic plant control methods, we will use well-established methods for study and sampling design described in Parsons (2001) and Madsen and Wersal (2017).

7.5 Possible challenges and contingencies

7.5.1 Logistical problems

Potential logistical problems and associated contingencies include:

- Access to private waterbodies where invasive aquatic plants occur and threaten nearby waterbodies.
    - We will coordinate with property owners where private access is required. We have good relationships with private landowners where access has been needed for past and current projects. Moreover, the public has historically been receptive to our assistance in monitoring their waterbodies.
- Access to public waterbodies during peak times for summer recreation. Access may be delayed or limited at popular recreation and fishing lakes. Additionally, recreation such as waterskiing and swimming may limit the extent to which we can survey a waterbody, including key areas near docks and launches.
    - We will attempt to arrive early in the day at popular waterbodies and survey areas near public boat launches before peak times for recreation. For recreation on a waterbody, we will take such delays into account for each field day to ensure we have enough time to survey important areas.

- Timing of fieldwork to correspond with peak aquatic plant abundance and key life history events important for identification (e.g., flowering and fruiting).
    - We will monitor weather conditions each field season and coordinate with regional partners throughout the state to ensure that we are monitoring at the optimal times for collecting a complete plant list and accurate identification of all observed taxa.

7.5.2 Practical constraints

Practical constraints could include the availability of field assistance throughout the field season as well as issues with equipment failure or damage (e.g., boat motor or sampling devices). We will work with colleagues within EAP and outside of Ecology if field assistance is not available for a given sampling event. Historically, the APMP has relied on assistance from technicians within Ecology, as well as other state agency personnel (e.g., WDFW, WDNR) and county noxious weed board personnel. We will ensure that all equipment is routinely checked and in working order, including yearly systematic checks and oil changes on boat motors.

7.5.3 Schedule limitations

Depending on the severity of the issue, the constraints listed above may delay the planned field schedule by several hours to days. Given the length the time in which plants are abundant in the growing season (typically April–October), there will usually be enough time to reschedule sampling events within each season. When a planned waterbody cannot be visited in a given year, it will be prioritized for sampling the following year.

8.0 Field Procedures

8.1 Invasive species evaluation

We will routinely encounter invasive aquatic plant species and may come in contact with other aquatic invasive animals and pathogens. We will strictly adhere to the measures outlined in Ecology's standard operating procedure (SOP) to minimize the spread of invasive species (Parsons et al. 2023). Details of procedures are outlined in the SOP, but in brief, we will: (1) inspect and clean our boat, trailer, and all sampling equipment when leaving a waterbody and/or before visiting another waterbody, (2) drain all water from the boat and motor upon leaving each waterbody, and (3) apply further decontamination procedures when the risk of spread of aquatic invasive species is highest and/or we are sampling in an area identified as "extreme concern" (Table A-1 in Parsons et al. 2023).

8.2 Measurement and sampling procedures

The APMP will follow Ecology's Aquatic Plant Sampling Protocols (Parsons 2001) for all field sampling. Additional measurements that may be collected are outlined below in sections.

8.2.1 and 8.2.2. All data are recorded on waterproof paper data sheets developed specifically for the APMP (see section 8.7). All measurements are collected in the field except for dry-weight biomass.

8.2.1 Aquatic plant distribution and abundance

After a waterbody has been surveyed and all species recorded, each species is assigned a whole-lake distribution value based on the distribution index described in Table 6. These values are reserved for sampling events where the entire littoral, or most of the littoral, area is surveyed (see section 8.7). Distribution values are determined by a mix of visual observations from the surface and rake samples (Parsons 2001).

Table 6. Aquatic plant distribution index

Distribution index value	Description
1	Plant species is rare in the waterbody, only observed in one or a few places.
2	Plant species common, though not dominant.
3	Plant species in scattered, sometimes dense patches, co-dominant with other plants.
4	Plant species dominates the lake in thick, nearly monospecific patches.
5	Plant species growing very densely at the exclusion of other species—a pattern usually restricted to invasive species.

For evaluations of invasive aquatic plant control methods, additional abundance metrics may be measured, including rake abundance, wet-weight biomass, and/or dry-weight biomass. Dry-weight biomass measurement procedures are described in the Aquatic Plant Sampling Protocols (Parsons 2001). Rake abundance and wet-weight biomass are described here. Rake abundance (or density) is an index of aquatic plant abundance based on the amount of each species retrieved on a plant-sampling rake (Deppe and Lathrop 1992). Following other statewide aquatic plant monitoring programs, we will use abundance values of 1 – 3, corresponding to the coverage of plants on the rake-head, with 1 indicating a few plant fragments and 3 indicating a completely covered rake-head (Hauxwell et al. 2010). Wet-weight biomass will be determined by collecting plants by rake or hand-removal, as specified in Parsons (2001). Collected plants will be spun in a large salad spinner for ≥ 20 spins to remove excess water and then weighed with a Pesola scale in the field to the nearest 0.1 g (following Bickel & Perrett 2016; Glisson et al. 2022).

8.2.2 Environmental data

Secchi depth is measured at the deepest part of the lake if the lake bathymetry is known. If the bathymetry is not known, best judgement is used to determine the sampling location. The measurement is obtained by lowering a standard Secchi disk from the shaded side of the boat (to reduce surface glare). The disk is lowered until it can no longer be seen, then raised until it can be seen; this measurement is then recorded. Staff remove sunglasses during the procedure. If the Secchi depth is greater than the deepest part of the lake (i.e., the disk hits the bottom of the lake before disappearing), staff note that on the data sheet as "on bottom".

Surface water temperature is measured by holding a hand-held thermometer just below the water's surface until a constant temperature is attained.

8.3 Containers, preservation methods, holding times

No water or chemical samples will be collected for this work. Aquatic plants that need to be identified in the lab or preserved in Ecology's herbarium will be collected in sealable plastic bags partially filled with water and labeled with the lake name, date, and putative species identity. These bags will be stored and transported in plastic tubs to Ecology's Operations Center for later identification and preservation.

8.4 Equipment decontamination

We will not be collecting samples at locations with high levels of contaminants or harmful bacteria. The aquatic plant sampling rake and other equipment will come in contact with aquatic plants and the waterbody substrate, and thus, organic materials. We will decontaminate the plant rake and all other equipment using the methods described in section 8.1 and Parsons et al. (2023).

8.5 Sample ID

Aquatic plant samples will be labeled with the waterbody name, date, and putative species identity. Specimens collected for identification and preservation will be denoted on the paper field data sheet, which will include additional descriptive language about the species and the environment where it was found (see 8.7).

8.6 Chain of custody

Not applicable. No routine environmental water or substrate samples will be collected and retained for the APMP.

8.7 Field log requirements

There will be an individual waterproof data sheet for each waterbody sampled each field season. Data sheets will be kept in a clipboard with a latched compartment and then taken to Ecology headquarters after the field day/trip is complete. All data sheets will be scanned to pdf format after they are reviewed by headquarters staff. Information recorded on each data sheet includes:

- Waterbody name and county.
- Name and/or location of boat access used.
- Date and time when the survey began.
- Field personnel and affiliation(s).
- General weather conditions (e.g., temperature, wind, and cloud cover).
- Secchi depth (m).
- Water temperature (°C).
- The extent of the survey (entire littoral, most of littoral, limited sections, one area only).
- Aquatic plant species observed during the survey.
- The distribution index value of each aquatic plant species observed.
- Any notes or comments regarding each aquatic plant species observed (e.g., flowering, fruiting, growth pattern), including whether photos were taken and/or a voucher was collected for identification.
- General notes about the waterbody, sampling event, weather, and/or any unusual circumstances that may affect interpretation of results.

8.8 Other activities

Seasonal field staff will be trained in plant identification and data collection prior to collecting any data. For returning staff, refresher training will be completed at the beginning of each field season.

9.0 Laboratory Procedures

9.1 Lab procedures table

Not applicable. There are no environmental samples collected for lab analysis for the APMP.

9.2 Sample preparation method(s)

Not applicable. There are no environmental samples collected for lab analysis for the APMP.

9.3 Special method requirements

Not applicable. There are no environmental samples collected for lab analysis for the APMP.

9.4 Laboratories accredited for methods

Not applicable. There are no environmental samples collected for lab analysis for the APMP.

10.0 Quality Control Procedures

Before and after visiting a waterbody, we will check the previous data and species list for that waterbody to guide surveys and ensure consistency with previously collected data. We will carry the most up-to-date aquatic plant field guides during surveys and consult them as needed. If needed, we will check species identification in larger manuals and botanical keys upon returning to Ecology headquarters or Operations Center. We will collect voucher specimens of all initial invasive plant sightings and any species we are unable to identify in the field (see section 6.1). Also, we will photograph difficult-to-identify plants in the field to aid in later identification.

If the project manager is unable to identify a plant with confidence in the field or from a voucher specimen, it is preserved and sent to an expert in that taxonomic group for identification (photographs are occasionally sent to an expert in lieu of a preserved specimen). Local county weed board personnel and local botanists also routinely accompany the project manager on surveys and can provide expertise for specific plants in a given waterbody. Routine meetings with field staff will ensure consistency of species identification and data collection.

For water temperature, Secchi depth, and dry- and wet-weight biomass, we will take duplicate measurements for 10% of samples to ensure MQOs are met (see section 6.2).

For data analysis, we will follow procedures specified in section 6.4 for model checking and also routinely re-run model codes to ensure that the models are correctly specified and provide consistent results.

10.1 Table of field and laboratory quality control

See section 6.0 and Table 5 above.

10.2 Corrective action processes

If any of the following issues arise, we will take the corresponding corrective actions:

- A plant is mis-identified.
  - Review any potentially affected data and make corrections, as needed. If necessary, we will revisit previously surveyed locations to ensure consistent and accurate identification.
- Duplicate water temperature, Secchi depth, or biomass measurement fails to meet RPD.
  - Inspect equipment for damage or issues and make needed repairs or replacement; test again once corrections are taken and repeat if necessary.
- Statistical models fail to run or do not meet model assumptions.
  - Re-check input data and model specification, ensure the most up-to-date R and package versions are installed, and, if necessary, try a different model or consult with a statistician.

11.0 Data Management Procedures

11.1 Data recording and reporting requirements

The EIM Study ID for this project is FW_MACROPHYTE. Data entered into EIM include plants species name, aquatic plant distribution index value for each species, notes and comments for each species, general comments regarding the waterbody and/or sampling event (e.g., weather conditions), the extent of the survey (e.g., entire littoral, most of littoral), Secchi depth, and survey date (see section 8.2 for more details on these data).

Before staff enter data into EIM, they enter APMP data into an MS Access database at the end of the field season. As data are entered, the plant species list is checked against any existing data for that waterbody for consistency. After the data are entered into the APMP Access database, a query is produced to check for any entry errors prior to submitting data to EIM (see 11.4). For projects evaluating invasive aquatic plant control methods, all data will be similarly check for accuracy and compiled with MS Excel spreadsheets and/or an individual Access database, depending on the nature of the study and data.

11.2 Laboratory data package requirements

Not applicable. No samples will be collected for lab analysis.

11.3 Electronic transfer requirements

Not applicable. No samples will be collected for lab analysis.

11.4 EIM data upload procedures

We will follow all guidelines for entering APMP data specified in Ecology's EIM Data Entry Review Procedure (Ecology 2022). We will also complete the EIM Data Entry Review Checklist.

11.5 Model information management

All model information will be managed with R statistical software, version 4.0+ (R Core Development Team 2022). R Studio software (Posit Software, PBC; Boston, MA) project folders will be used to store data files, R code files, and figures, within a single folder for each study.

12.0 Audits and Reports

12.1 Field, laboratory, and other audits

We do not anticipate audits for the APMP.

12.2 Responsible personnel

Not applicable. We do not anticipate audits for the APMP.

12.3 Frequency and distribution of reports

The results of the APMP were reported annually from 1994 to 2002. Since 2003, results have been reported annually to Ecology's EIM database and the Washington State lakes environmental database (https://apps.ecology.wa.gov/lakes/). Reports for studies of invasive aquatic plant control methods are prepared as manuscripts submitted for publication in peer-reviewed journals. Examples of past reports as peer-reviewed publications include Parsons et al. (2000, 2001, 2004, 2007, 2009, 2019).

12.4 Responsibility for reports

The project manager will submit all data to EIM and be the primary author of any manuscripts resulting from studies of invasive aquatic plant control methods. Ecology field technicians and project partners outside of Ecology (e.g., county noxious weed board personnel) may be coauthors on manuscripts.

13.0 Data Verification

13.1 Field data verification, requirements, and responsibilities

After each waterbody survey, data recorded on field datasheets will be verified by the project manager and field staff before leaving the field site. Species that cannot be confidently identified in the field will be identified following the methods described in 6.2. Data will again be verified by the project manager upon entry into the APMP's Access database and compared against existing data. Finally, all data will be checked by the project manager and verified for entry into EIM.

13.2 Laboratory data verification

Not applicable. No samples will be collected for lab analysis.

13.3 Validation requirements, if necessary

Not applicable. No samples will be collected for lab analysis.

13.4 Model quality assessment

See sections 6.4, 7.3, and 10.0 for statistical model quality assessment procedures.

14.0 Data Quality (Usability) Assessment

14.1 Process for determining project objectives were met

To ensure that the APMP's objectives (4.2) are met, the project manager will oversee the procedures outlined in this QAPP for data collection, entry, analysis, and publication. We are confident that data will meet quality standards specified in this QAPP to advance the goals and objectives of the APMP because (1) the history of this program in producing yearly data updates and peer-reviewed publications, (2) the quality of existing data, and (3) the experience of the project manager and field staff.

14.2 Treatment of non-detects

Not applicable but see section 6.2.1.3.

14.3 Data analysis and presentation methods

Data for evaluations of invasive aquatic plant control methods will be entered into Excel spreadsheets and/or a study-specific Access database. Spreadsheets that are entered into R for analysis will be filed in R Studio project folders specific to that project. As described in section 7.3, standard statistical models will be implemented as needed for evaluations of invasive aquatic plant control methods. Analyses will be implemented with R version 4.0+, R Studio software, and packages therein. Methods will be determined by the type of data collected (e.g., biomass versus frequency) and the sampling design implemented (e.g., BACI or before-after [BA] design); these will be determined on a case-by-case basis. Further details on standard statistical methods for analyzing data collected for the APMP can be found in Parsons (2001).

14.4 Sampling design evaluation

Sampling designs for evaluations of invasive aquatic plant control methods will be based on the needs of the project, species of interest, and waterbody. See section 7.2 for more details.

14.5 Documentation of assessment

Any potential limits to data quality will be entered along with the project data in EIM (e.g., extent of survey, weather conditions, uncertainty of species identification [section 6.2.2.2]) and discussed in any resulting peer-reviewed manuscripts.

15.0 References

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16.0 Appendix. Glossaries, Acronyms, and Abbreviations

Glossary of General Terms

Invasive species: A non-native species introduced by humans (either intentionally or unintentionally), that does—or has the potential to—cause environmental, economic, and/or human harm. Typically, species considered to be invasive have the following additional traits: (1) can survive outside of cultivation, (2) have self-sustaining populations, (3) can reproduce sexually or asexually, (4) have spread beyond the point of initial introduction, and (5) create new populations that that also survive, sustain, reproduce, and can subsequently spread (Blackburn et al. 2011).

Littoral zone: The area of a waterbody that receives enough light for aquatic plants to grow. The extent of this zone varies by waterbody depending largely on water clarity, but typically extends from the lakeshore to approximately 15 ft.

Native species: A species that occurs naturally in a specified geographic area.

Non-native species: A species that does not occur naturally in a specified geographic area, typically introduced to the new area by humans. Not all non-native species are considered invasive or noxious weeds.

Noxious weed: A legal definition that in Washington State refers to a plant, "that when established is highly destructive, competitive, or difficult to control by cultural or chemical practices" (RCW 17.10.010).

Pathogen: Disease-causing microorganisms such as bacteria, protozoa, viruses.

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

Surface waters of the state: Lakes, rivers, ponds, streams, inland waters, salt waters, wetlands and all other surface waters and water courses within the jurisdiction of Washington State.

Turbidity: A measure of water clarity. High levels of turbidity can have a negative impact on aquatic life.

Weed: A cultural term used for a plant that is unwanted in a given situation. This general term can be used for native, non-native, and invasive plants**.**

303(d) list: Section 303(d) of the federal Clean Water Act, requiring Washington State to periodically prepare a list of all surface waters in the state for which beneficial uses of the water – such as for drinking, recreation, aquatic habitat, and industrial use – are impaired by pollutants. These are water quality-limited estuaries, lakes, and streams that fall short of state surface water quality standards and are not expected to improve within the next two years.

Acronyms and Abbreviations

APMP	Aquatic Plant Monitoring Program
Ecology	Washington State Department of Ecology
e.g.	For example
EIM	Environmental Information Management database
EPA	U.S. Environmental Protection Agency
FAWMP	Freshwater Aquatic Weeds Management Program
et al.	And others
i.e.	In other words
MEL	Manchester Environmental Laboratory
MQO	Measurement quality objective
QA	Quality assurance
QC	Quality control
RCW	Revised Code of Washington
RPD	Relative percent difference
RSD	Relative standard deviation
SOP	Standard operating procedures
WAC	Washington Administrative Code
WDFW	Washington Department of Fish and Wildlife
WDNR	Washington Department of Natural Resources

Units of Measurement

°C	degrees centigrade
dw	dry weight
Ft	feet
g	gram, a unit of mass
Kg	kilograms, a unit of mass equal to 1,000 grams
km	kilometer, a unit of length equal to 1,000 meters
m	meter
ww	wet weight

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. For Ecology, it is "Formal recognition by (Ecology)…that an environmental laboratory is capable of producing accurate analytical data." [WAC 173-50-040] (Kammin, 2010)

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* (USGS, 1998).

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: The difference between the sample mean and the true value. Bias usually describes a systematic difference reproducible over time and is characteristic of both the measurement system and the analyte(s) being measured. Bias is a commonly used data quality indicator (DQI) (Kammin, 2010; Ecology, 2004).

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, 1997).

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, 1997).

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: An analyte-specific and sample-specific process that extends the evaluation of data beyond data verification to determine the usability of a specific data set. It involves a detailed examination of the data package, using both professional judgment and objective criteria, to determine whether the MQOs for precision, bias, and sensitivity have been met. It may also include an assessment of completeness, representativeness, comparability, and integrity, as these criteria relate to the usability of the data set. Ecology considers four key criteria to determine if data validation has actually occurred. These are:

- Use of raw or instrument data for evaluation.
- Use of third-party assessors.
- Data set is complex.
- Use of EPA Functional Guidelines or equivalent for review.

Examples of data types commonly validated would be:

- Gas Chromatography (GC).
- Gas Chromatography-Mass Spectrometry (GC-MS).
- Inductively Coupled Plasma (ICP).

The end result of a formal validation process is a determination of usability that assigns qualifiers to indicate usability status for every measurement result. These qualifiers include:

- No qualifier – data are usable for intended purposes.
- J (or a J variant) – data are estimated, may be usable, may be biased high or low.
- REJ – data are rejected, cannot be used for intended purposes.
  (Kammin, 2010; Ecology, 2004).

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, 1997).

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): 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 (USEPA, 1997).

Matrix spike: A QC sample prepared by adding a known amount of the target analyte(s) to an aliquot of a sample to check for bias 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 (EPA, 1997).

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): This definition for detection was first formally advanced in 40CFR 136, October 26, 1984 edition. MDL is defined there as the minimum concentration of an analyte that, in a given matrix and with a specific method, has a 99% probability of being identified, and reported to be greater than zero (Federal Register, October 26, 1984).

Percent 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).

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:

[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 (%RSD) is used if there are results for more than 2 replicate samples (Ecology, 2004).

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).

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, 1997).

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, 1997).

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, 1997).

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).

References for QA Glossary

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