

## **CHAPTER 14 WETLANDS AND STORMWATER MANAGEMENT GUIDELINES**

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If you are unfamiliar with these guidelines, read the description of the approach and organization that follows. If you are familiar, proceed directly to the appropriate guide sheet(s) for guidelines covering your issue(s) or objective(s):

Guide Sheet 1: Comprehensive Landscape Planning for Wetlands and Stormwater Management--page 202

Guide Sheet 2: Wetlands Protection Guidelines-- page 209

### APPROACH AND ORGANIZATION OF THE MANAGEMENT GUIDELINES

#### *Introduction*

The Puget Sound Wetlands and Stormwater Management Research Program performed comprehensive research with the goal of deriving strategies that protect wetland resources in urban and urbanizing areas, while also benefiting the management of urban stormwater runoff that can affect those resources. The research primarily involved long-term comparisons of wetland ecosystem characteristics before and after their watersheds urbanized, and between a set of wetlands that became affected by urbanization (treatment sites) and a set whose watersheds did not change (control sites). This work was supplemented by shorter term and more intensive studies of pollutant transport and fate in wetlands, several laboratory experiments, and ongoing review of relevant work being performed elsewhere. These research efforts were aimed at defining the types of impacts that urbanization can cause and the degree to which they develop under different conditions, in order to identify means of avoiding or minimizing impacts that impair wetland structure and functioning. The program's scope embraced both situations where urban drainage incidentally affects wetlands in its path, as well as those in which direct stormwater management actions change wetlands' hydrology, water quality or both.

This document presents preliminary management guidelines for urban wetlands and their stormwater discharges based on the research results. The set of guidelines is the principal vehicle to implement the research findings in environmental planning and management practice.

#### *Guidelines Scope and Underlying Principles*

Note: For terms in **boldface** type see item 1 under Support Materials below.

1. These provisions currently have the status of guidelines rather than requirements. Application of these guidelines does not fulfill assessment and permitting requirements

that may be associated with a project. It is, in general, necessary to follow the stipulations of the State Environmental Policy Act and to contact such agencies as the local planning agency; the Washington Departments of Ecology, Fisheries, and Wildlife; the U. S. Environmental Protection Agency; and the U. S. Army Corps of Engineers.

2. Using the guidelines should be approached from a problem-solving viewpoint. The “problem” is regarded to be accomplishing one or more particular planning or management objectives involving a **wetland** potentially or presently affected by stormwater drainage from an urban or urbanizing area. The objectives can be broad, specific, or both. Broad objectives involve comprehensive planning and subsequent management of a drainage catchment or other **landscape unit** containing one or more wetlands. Specific objectives pertain to managing a wetland having particular attributes to be sustained. Of course, the prospect for success is greater with ability to manage the whole landscape influencing the wetland, rather than just the wetland itself.

3. The guidelines are framed from the standpoint that some change in the landscape has the potential to modify the physical and chemical **structure** of the wetland environment, which in turn could alter biological communities and the wetland’s ecological **functions**. The general objective in this framework would be to avoid or minimize negative ecological change. This view is in contrast to one in which a wetland has at some time in the past experienced negative change, and consequent ecological degradation, and where the general objective would be to recover some or all of the lost structure and functioning through **enhancement** or **restoration** actions. Direct attention to this problem was outside the scope of the Puget Sound Wetlands and Stormwater Management Research Program. However, the guidelines do give information that applies to enhancement and restoration. For example, attempted restoration of a diverse amphibian community would not be successful if the water level fluctuation limits consistent with high amphibian species richness are not observed.

4. The guidelines can be applied with whatever information concerning the problem is available. Of course, the comprehensiveness and certainty of the outcome will vary with the amount and quality of information employed. The guidelines can be applied in an iterative fashion to improve management understanding as the information improves. Appendix A lists the information needed to perform basic analyses, followed by other information that can improve the understanding and analysis.

5. These guidelines emphasize avoiding structural, hydrologic, and water quality **modifications** of existing wetlands to the extent possible in the process of urbanization and the management of urban stormwater runoff.

6. In pursuit of this goal, the guidelines take a systematic approach to management problems that potentially involve both urban stormwater (quantity, quality, or both) and wetlands. The consideration of wetlands involves their areal extent, **values**, and functions. This approach emphasizes a comprehensive analysis of alternatives to solve the identified problem. The guidelines encourage conducting the analysis on a landscape scale and considering all of the possible stormwater management alternatives, which may or may not involve a wetland. They favor **source control best management practices** (BMPs) and **pre-treatment** of stormwater runoff prior to release to wetlands.

7. Furthermore, the guidelines take a holistic view of managing wetland resources in an urban setting. Thus, they recognize that urban wetlands have the potential to be affected structurally and functionally whether or not they are formally designated for stormwater management purposes. Even if an urban wetland is not structurally or hydrologically engineered for such purposes, it may experience altered hydrology (more or less water), reduced water quality, and a host of other impacts related to urban conditions. It is the objective of the guidelines to avoid or reduce the negative effects on wetland resources from both specific stormwater management actions and incidental urban impacts.

#### *Support Material*

1. The guidelines use certain terms that require definition to ensure that the intended meaning is conveyed to all users. Such terms are printed in **boldface** the first time that they appear in each guide sheet, and are defined in Appendix B.
2. The guideline provisions were drawn principally from the available results of the Puget Sound Wetlands and Stormwater Management Research Program, as set forth in Sections 2 and 3 of the program's summary publication, *Wetlands and Urbanization, Implications for the Future* (Horner et al. 1996). Where the results in this publication are the basis for a numerical provision, a separate reference is not given. Numerical provisions based on other sources are referenced. See Appendix C for references.
3. Appendix D presents a list of plant species native to wetlands in the Puget Sound Region. This appendix is intended for reference by guideline users who are not specialists in wetland botany. However, non-specialists should obtain expert advice when making decisions involving vegetation.
4. Appendix E compares the water chemistry characteristics of *Sphagnum* bog and fen wetlands (termed **priority peat wetlands** in these guidelines) with more common wetland communities. These bogs and fens appear to be the most sensitive among the Puget Sound lowland wetlands to alteration of water chemistry, and require special water quality management to avoid losses of their relatively rare communities.

## GUIDE SHEET 1: COMPREHENSIVE LANDSCAPE PLANNING FOR WETLANDS AND STORMWATER MANAGEMENT

**Wetlands** in newly developing areas will receive urban effects even if not specifically "used" in stormwater management. Therefore, the task is proper overall management of the resources and protection of their general **functioning**, including their role in storm drainage systems. Stormwater management in newly developing areas is distinguished from management in already developed locations by the existence of many more feasible stormwater control options prior to development. The guidelines emphasize appropriate selection among the options to achieve optimum overall resource protection benefits, extending to downstream receiving waters and ground water aquifers, as well as to wetlands.

The comprehensive planning guidelines are based on two principles that are recognized to create the most effective environmental management: (1) the best management policies for the protection of wetlands and other natural resources are those that prevent or minimize the development of impacts at potential sources; and (2) the best management strategies are self-perpetuating, that is they do not require periodic infusions of capital and labor. To apply these principles in managing wetlands in a newly developing area, carry out the following steps.

### *Guide Sheet 1A: Comprehensive Planning Steps*

1. Define the **landscape unit** subject to comprehensive planning. Refer to the definition of landscape unit in Appendix B for assistance in defining it.
2. Begin the development of a plan for the landscape unit with attention to the following general principles:
  - Formulate the plan on the basis of clearly articulated community goals. Carefully identify conflicts and choices between retaining and protecting desired resources and community growth.
  - Map and assess land suitability for urban uses. Include the following landscape features in the assessment: forested land, open unforested land, steep slopes, erosion-prone soils, foundation suitability, soil suitability for waste disposal, aquifers, aquifer recharge areas, wetlands, floodplains, surface waters, agricultural lands, and various categories of urban land use. When appropriate, the assessment can highlight outstanding local or regional resources that the community determines should be protected (e. g., a fish run, scenic area, recreational area, threatened species habitat, farmland). Mapping and assessment should recognize not only these resources but also additional areas needed for their sustenance.
3. Maximize natural water storage and infiltration opportunities within the landscape unit and outside of existing wetlands, especially:

- Promote the conservation of forest cover. Building on land that is already deforested affects basin hydrology to a lesser extent than converting forested land. Loss of forest cover reduces interception storage, detention in the organic forest floor layer, and water losses by evapotranspiration, resulting in large peak runoff increases and either their negative effects or the expense of countering them with structural solutions.
- Maintain natural storage reservoirs and drainage corridors, including depressions, areas of permeable soils, swales, and intermittent streams. Develop and implement policies and regulations to discourage the clearing, filling, and channelization of these features. Utilize them in drainage networks in preference to pipes, culverts, and engineered ditches.
- In evaluating infiltration opportunities refer to the stormwater management manual for the jurisdiction and pay particular attention to the selection criteria for avoiding groundwater contamination and poor soils and hydrogeological conditions that cause these facilities to fail. If necessary, locate developments with large amounts of impervious surfaces or a potential to produce relatively contaminated runoff away from groundwater recharge areas. Relatively dense developments on glacial outwash soils may require additional runoff treatment to protect groundwater quality.

4. Establish and maintain **buffers** surrounding wetlands and in riparian zones as required by local regulations or recommended by the Puget Sound Water Quality Authority's wetland guidelines. Also, maintain interconnections among wetlands and other natural habitats to allow for wildlife movements.

5. Take specific management measures to avoid general urban impacts on wetlands and other water bodies (e. g., littering, vegetation destruction, human and pet intrusion harmful to wildlife).

6. To support management of runoff water quantity, perform a hydrologic analysis of the contributing drainage catchment to define the type and extent of flooding and stream channel erosion problems associated with existing development, redevelopment, or new development that require control to protect the beneficial uses of receiving waters, including wetlands. This analysis should include assembly of existing flow data and hydrologic modeling as necessary to establish conditions limiting to attainment of beneficial uses. Modeling should be performed as directed by the stormwater management manual in effect in the jurisdiction.

7. In wetlands previously relatively unaffected by human activities, manage stormwater quantity to attempt to match the **pre-development hydroperiod** and **hydrodynamics**. In wetlands whose hydrology has been disturbed, consider ways of reducing hydrologic impacts. This provision involves not only management of high runoff volumes and rates of flow during the wet season, but also prevention of water supply depletion during the dry season. The latter guideline may require flow augmentation if urbanization reduces existing surface or groundwater inflows. Refer to Guide Sheet 2, Wetland Protection Guidelines, for detail on implementing these guidelines.

8. Assess alternatives for the control of runoff water quantities as follows:

a. Define the runoff quantity problem subject to management by analyzing the proposed land development action.

b. For existing development or redevelopment, assess possible alternative solutions that are applicable at the site of the problem occurrence, including:

- Protect health, safety, and property from flooding by removing habitation from the flood plain.
- Prevent stream channel erosion by stabilizing the eroding bed and/or bank area with **bioengineering** techniques, preferably, or by structurally reinforcing it, if this solution would be consistent with the protection of aquatic habitats and beneficial uses of the stream (refer to Chapter 173-201A of the Washington Administrative Code (WAC) for the definition of beneficial uses).

b. For new development or redevelopment, assess possible regulatory and incentive land use control alternatives, such as density controls, clearing limits, impervious surface limits, transfer of development rights, purchase of conservation areas, etc.

c. If the alternatives considered in Steps 8a or 8b cannot solve an existing or potential problem, perform an analysis of the contributing drainage catchment to assess possible alternative solutions that can be applied **on-site** or on a **regional** scale. The most appropriate solution or combination of alternatives should be selected with regard to the specific opportunities and constraints existing in the drainage catchment. For new development or redevelopment, on-site facilities that should be assessed include, in approximate order of preference:

- Infiltration basins or trenches;
- Retention/detention ponds;
- Below-ground vault or tank storage;
- Parking lot detention.

Regional facilities that should be assessed for solving problems associated with new development, redevelopment, or existing development include:

- Infiltration basins or trenches;
- Detention ponds;
- **Constructed wetlands;**

- Bypassing a portion of the flow to an acceptable receiving water body, with treatment as required to protect water quality and other special precautions as necessary to prevent downstream impacts.

d. Consider structurally or hydrologically engineering an existing wetland for water quantity control only if upland alternatives are inadequate to solve the existing or potential problem. To evaluate the possibility, refer to the Stormwater Wetland Assessment Criteria in Guide Sheet 1B.

9. Place strong emphasis on water resource protection during construction of new development. Establish effective erosion control programs to reduce the sediment loadings to receiving waters to the maximum extent possible. No preexisting wetland or other water body should ever be used for the sedimentation of solids in construction-phase runoff.

10. In wetlands previously relatively unaffected by human activities, manage stormwater quality to attempt to match pre-development water quality conditions. To support management of runoff water quality, perform an analysis of the contributing drainage catchment to define the type and extent of runoff water quality problems associated with existing development, redevelopment, or new development that require control to protect the beneficial uses of receiving waters, including wetlands. This analysis should incorporate the hydrologic assessment performed under step 6 and include identification of key water pollutants, which may include solids, oxygen-demanding substances, nutrients, metals, oils, trace organics, and bacteria, and evaluation of the potential effects of water pollutants throughout the drainage system.

11. Assess alternatives for the control of runoff water quality as follows:

a. Perform an analysis of the contributing drainage catchment to assess possible alternative solutions that can be applied on-site or on a regional scale. The most appropriate solution or combination of alternatives should be selected with regard to the specific opportunities and constraints existing in the drainage catchment. Consider both **source control BMPs** and **treatment BMPs** as alternative solutions before considering use of existing wetlands for quality improvement according to the following considerations:

- Implementation of source control BMPs prevent the generation or release of water pollutants at potential sources. These alternatives are generally both more effective and less expensive than treatment controls. They should be applied to the maximum extent possible to new development, redevelopment, and existing development.
- Treatment BMPs capture water pollutants after their release. This alternative often has limited application in existing developments because of space limitations, although it can be employed in new development and when redevelopment occurs in already developed areas. Following is a list of treatment BMPs that should be considered. Each has appropriate and inappropriate applications and advantages and disadvantages and must be carefully selected,

designed, constructed, and operated according to the specifications of the stormwater management manual in use in the jurisdiction.

- Infiltration basins or trenches;
- Constructed wetlands;
- Wet or extended-detention ponds;
- Biofiltration facilities (vegetated swales or filter strips);
- Filters with sand, compost, or other media;
- Water quality vaults;
- Oil/water separators.

b. Consider structurally or hydrologically engineering an existing wetland for water quality control only if upland alternatives are inadequate to solve the existing or potential problem. Use of Waters of the State and Waters of the United States, including wetlands, for the treatment or conveyance of wastewater, including stormwater, is prohibited under state and federal law. Discussions with federal and state regulators during the research program led to development of a statement concerning the use of existing wetlands for improving stormwater quality (**polishing**), as follows. Such use is subject to analysis on a case-by-case basis and may be allowed only if the following conditions are met:

- If **restoration** or **enhancement** of a previously **degraded** wetland is required, and if the upgrading of other wetland functions can be accomplished along with benefiting runoff quality control, and
- If appropriate source control and treatment BMPs are applied in the contributing catchment on the basis of the analysis in Step 10a and any legally adopted water quality standards for wetlands are observed.

If these circumstances apply, refer to the Stormwater Wetland Assessment Criteria in Guide Sheet 1B to evaluate further.

12. Stimulate public awareness of and interest in wetlands and other water resources in order to establish protective attitudes in the community. This program should include:

- Education regarding the use of fertilizers and pesticides, automobile maintenance, the care of animals to prevent water pollution, and the importance of retaining buffers;
- Descriptive signboards adjacent to wetlands informing residents of the wetland type, its functions, the protective measures being taken, etc.

- If beavers are present in a wetland, educate residents about their ecological role and value and take steps to avoid human interference with beavers.

*Guide Sheet 1B: Stormwater Wetland Assessment Criteria*

This guide sheet gives criteria that disqualify a natural wetland from being structurally or hydrologically engineered for control of stormwater quantity, quality, or both. These criteria should be applied only after performing the alternatives analysis outlined in Guide Sheet 1A.

1. A wetland should not be structurally or hydrologically engineered for runoff quantity or quality control and should be given maximum protection from overall urban impacts (see Guide Sheet 2, Wetland Protection Guidelines) under any of the following circumstances:

- In its present state it is primarily an **estuarine** or **forested wetland** or a **priority peat system**.
- It is a rare or irreplaceable wetland type, as identified by the Washington Natural Heritage Program, the Puget Sound Water Quality Preservation Program, or local government.
- It provides **rare, threatened, or endangered species** habitat that could be impaired by the proposed action. Determining whether or not the conserved species will be affected by the proposed project requires a careful analysis of its requirements in relation to the anticipated habitat changes.

In general, the wetlands in these groups are classified in Categories I and II in the Puget Sound Water Quality Authority's draft wetland guidelines.

2. A wetland can be considered for structural or hydrological modification for runoff quantity or quality control if most of the following circumstances exist:

- It is classified in Category IV in the Puget Sound Water Quality Authority's draft wetland guidelines. In general, Category IV wetlands have monotypic vegetation of similar age and class, lack special habitat features, and are isolated from other aquatic systems.
- The wetland has been previously **disturbed** by human activity, as evidenced by agriculture, fill, ditching, and/or introduced or **invasive weedy plant species**.
- The wetland has been deprived of a significant amount of its water supply by draining or previous urbanization (e. g., by loss of groundwater supply), and stormwater runoff is sufficient to augment the water supply. A particular

candidate is a wetland that has experienced an increased summer dry period, especially if the drought has been extended by more than two weeks.

- Construction for structural or hydrologic modification in order to provide runoff quantity or quality control will disturb relatively little of the wetland.
- The wetland can provide the required storage capacity for quantity or quality control through an outlet orifice modification to increase storage of water, rather than through raising the existing overflow. Orifice modification is likely to require less construction activity and consequent negative impacts.
- Under existing conditions the wetland's experiences a relatively high degree of water level fluctuation and a range of velocities (i. e., a wetland associated with substantially flowing water, rather than one in the headwaters or entirely isolated from flowing water).
- The wetland does not exhibit any of the following features:
  - Significant priority peat system or forested zones that will experience substantially altered hydroperiod as a result of the proposed action;
  - Regionally **unusual biological community types**;
  - Animal habitat features of relatively high value in the region (e. g., a protected, undisturbed area connected through undisturbed corridors to other valuable habitats, an important breeding site for protected species);
  - The presence of protected commercial or sport fish;
  - Configuration and topography that will require significant modification that may threaten fish stranding;
  - A relatively high degree of public interest as a result of, for example, offering valued local open space or educational, scientific, or recreational opportunities, unless the proposed action would enhance these opportunities;
- The wetland is threatened by potential impacts exclusive of stormwater management, and could receive greater protection if acquired for a stormwater management project rather than left in existing ownership.
- There is good evidence that the wetland actually can be restored or enhanced to perform other functions in addition to runoff quantity or quality control.
- There is good evidence that the wetland lends itself to the effective application of the Wetland Protection Guidelines in Guide Sheet 2.

- The wetland lies in the natural routing of the runoff. Local regulations often prohibit drainage diversion from one basin to another.
- The wetland allows runoff discharge at the natural location.

## GUIDE SHEET 2: WETLAND PROTECTION GUIDELINES

This guide sheet provides information about likely changes to the ecological **structure** and **functioning** of **wetlands** that are incidentally subject to the effects of an urban or urbanizing watershed or are **modified** to supply runoff water quantity or quality control benefits. The guide sheet also recommends management actions that can avoid or minimize deleterious changes in these wetlands.

### *Guide Sheet 2A: General Wetland Protection Guidelines*

1. Consult regulations issued under federal and state laws that govern the discharge of pollutants. Wetlands are classified as "Waters of the United States" and "Waters of the State" in Washington.
2. Maintain the wetland **buffer** required by local regulations or recommended by the Puget Sound Water Quality Authority's draft wetland guidelines.
3. Retain areas of native vegetation connecting the wetland and its buffer with nearby wetlands and other contiguous areas of native vegetation.
4. Avoid compaction of soil and introduction of exotic plant species during any work in a wetland.
5. Take specific site design and maintenance measures to avoid general urban impacts (e. g., littering and vegetation destruction). Examples are protecting existing buffer zones; discouraging access, especially by vehicles, by plantings outside the wetland; and encouragement of stewardship by a homeowners' association. Fences can be useful to restrict dogs and pedestrian access, but they also interfere with wildlife movements. Their use should be very carefully evaluated on the basis of the relative importance of intrusive impacts versus wildlife presence. Fences should generally not be installed when wildlife would be restricted and intrusion is relatively minor. They generally should be used when wildlife passage is not a major issue and the potential for intrusive impacts is high. When wildlife movements and intrusion are both issues, the circumstances will have to be weighed to make a decision about fencing.
6. If the wetland inlet will be modified for the stormwater management project, use a diffuse flow method, such as a spreader swale, to discharge water into the wetland in order to prevent flow channelization.

### *Guide Sheet 2B: Guidelines for Protection from Adverse Impacts of Modified Runoff Quantity Discharged to Wetlands*

1. Protection of wetland plant and animal communities depends on controlling the wetland's **hydroperiod**, meaning the pattern of fluctuation of water depth and the frequency and duration of exceeding certain levels, including the length and onset of drying in the summer. A hydrologic assessment is useful to measure or estimate elements of the hydroperiod under existing **pre-development** and anticipated **post-development** conditions. This assessment should be performed with the aid of a qualified hydrologist. Post-development estimates of watershed hydrology and wetland hydroperiod must include the cumulative effect of all anticipated watershed and wetland modifications. Provisions in these guidelines pertain to the full anticipated build-out of the wetland's watershed.

This analysis hypothesizes a fluctuating water stage over time before development that could fluctuate more, both higher and lower after development; these greater fluctuations are termed **stage excursions**. The guidelines set limits on the frequency and duration of excursions, as well as on overall water level fluctuation, after development.

To determine existing hydroperiod use one of the following methods, listed in order of preference:

- Estimation by a continuous simulation computer model--The model should be calibrated with at least one year of data taken using a continuously recording level gage under existing conditions and should be run for the historical rainfall period. The resulting data can be used to express the magnitudes of depth fluctuation, as well as the frequencies and durations of surpassing given depths. [Note: Modeling that yields high quality information of the type needed for wetland hydroperiod analysis is a complex subject. Providing guidance on selecting and applying modeling options is beyond the scope of these guidelines but is being developed by King County Surface Water Management Division and other local jurisdictions. An alternative possibility to modeling depths, frequencies, and durations within the wetland is to model durations above given discharge levels entering the wetland over various time periods (e. g., seasonal, monthly, weekly). This option requires further development.]
- Measurement during a series of time intervals (no longer than one month in length) over a period of at least one year of the maximum water stage, using a crest stage gage, and instantaneous water stage, using a staff gage--The resulting data can be used to express water level fluctuation (WLF) during the interval as follows:

$$\text{Average base stage} = (\text{Instantaneous stage at beginning of interval} + \text{Instantaneous stage at end of interval})/2$$

$$\text{WLF} = \text{Crest stage} - \text{Average base stage}$$

Compute mean annual and mean monthly WLF as the arithmetic averages for each year and month for which data are available.

To forecast future hydroperiod use one of the following methods, listed in order of preference:

- Estimation by the continuous simulation computer model calibrated during pre-development analysis and run for the historical rainfall period--The resulting data can be used to express the magnitudes of depth fluctuation, as well as the frequencies and durations of surpassing given depths. [Note: Post-development modeling results should generally be compared with pre-development modeling results, rather than directly with field measurements, because different sets of assumptions underlie modeling and monitoring. Making pre- and post-development comparisons on the basis of common assumptions allows cancellation of errors inherent in the assumptions.]
- Estimation according to general relationships developed from the Puget Sound Wetlands and Stormwater Management Program Research Program, as follows (in part adapted from Chin 1996):
  - Mean annual WLF is very likely (100% of cases measured) to be < 20 cm (8 inches or 0.7 ft) if total impervious area (TIA) cover in the watershed is < 6% (roughly corresponding to no more than 15% of the watershed converted to urban land use).
  - Mean annual WLF is very likely (89% of cases measured) to be > 20 cm if TIA in the watershed is > 21% (roughly corresponding to more than 30% of the watershed converted to urban land use).
  - Mean annual WLF is somewhat likely (50% of cases measured) to be > 30 cm (1.0 ft) if TIA in the watershed is > 21% (roughly corresponding to more than 30% of the watershed converted to urban land use).
  - Mean annual WLF is likely (75% of cases measured) to be > 30 cm, and somewhat likely (50% of cases measured) to be 50 cm (20 inches or 1.6 ft) or higher, if TIA in the watershed is > 40% (roughly corresponding to more than 70% of the watershed converted to urban land use).
  - The frequency of stage excursions greater than 15 cm (6 inches or 0.5 ft) above or below pre-development levels is somewhat likely (54% of cases measured) to be more than six per year if the mean annual WLF increases to > 24 cm (9.5 inches or 0.8 ft).
  - The average duration of stage excursions greater than 15 cm above or below pre-development levels is likely (69% of cases measured) to be more than 72 hours if the mean annual WLF increases to > 20 cm.

2. The following hydroperiod limits characterize wetlands with relatively high vegetation species richness and apply to all zones within all wetlands over the entire year. If these limits are exceeded, then species richness is likely to decline. If the analysis described above forecasts exceedences, one or more of the management strategies listed in step 5 should be employed to attempt to stay within the limits.

- Mean annual WLF (and mean monthly WLF for every month of the year) does not exceed 20 cm. Vegetation species richness decrease is likely with: (1) a mean annual (and mean monthly) WLF increase of more than 5 cm (2 inches or 0.16 ft) if pre-development mean annual (and mean monthly) WLF is greater than 15 cm, or (2) a mean annual (and mean monthly) WLF increase to 20 cm or more if pre-development mean annual (and mean monthly) WLF is 15 cm or less.
- The frequency of stage excursions of 15 cm above or below pre-development stage does not exceed an annual average of six.
- The duration of stage excursions of 15 cm above or below pre-development stage does not exceed 72 hours per excursion.
- The total dry period (when pools dry down to the soil surface everywhere in the wetland) does not increase or decrease by more than two weeks in any year.
- Alterations to watershed and wetland hydrology that may cause perennial wetlands to become **vernal** are avoided.

3. The following hydroperiod limit characterizes **priority peat wetlands** (bogs and fens as more specifically defined by the Washington Department of Ecology) and applies to all zones over the entire year. If this limit is exceeded, then characteristic bog or fen wetland vegetation is likely to decline. If the analysis described above forecasts exceedence, one or more of the management strategies listed in step 5 should be employed to attempt to stay within the limit.

- The duration of stage excursions above the pre-development stage does not exceed 24 hours in any year.
- Note: To apply this guideline a continuous simulation computer model needs to be employed. The model should be calibrated with data taken under existing conditions at the wetland being analyzed and then used to forecast post-development duration of excursions.

4. The following hydroperiod limits characterize wetlands inhabited by breeding native amphibians and apply to breeding zones during the period 1 February through 31 May. If these limits are exceeded, then amphibian breeding success is likely to decline. If the analysis described above forecasts exceedences, one or more of the management strategies listed in step 5 should be employed to attempt to stay within the limits.

- The magnitude of stage excursions above or below the pre-development stage does not exceed 8 cm, and the total duration of these excursions does not exceed 24 hours in any 30 day period.
- Note: To apply this guideline a continuous simulation computer model needs to be employed. The model should be calibrated with data taken under

existing conditions at the wetland being analyzed and then used to forecast post-development magnitude and duration of excursions.

5. If it is expected that the hydroperiod limits stated above could be exceeded, consider strategies such as:

- Reduction of the level of development;
- Increasing runoff infiltration [Note: Infiltration is prone to failure in many Puget Sound Basin locations with glacial till soils and generally requires **pretreatment** to avoid clogging. In other situations infiltrating urban runoff may contaminate groundwater. Consult the stormwater management manual adopted by the jurisdiction and carefully analyze infiltration according to its prescriptions.];
- Increasing runoff storage capacity; and
- Selective runoff bypass.

6. After development, monitor hydroperiod with a continuously recording level gauge or staff and crest stage gauges. If the applicable limits are exceeded, consider additional applications of the strategies in step 5 that may still be available. It is also recommended that goals be established to maintain key vegetation species, amphibians, or both, and that these species be monitored to determine if the goals are being met.

*Guide Sheet 2C: Guidelines for Protection from Adverse Impacts of Modified Runoff Quality Discharged to Wetlands*

1. Require effective erosion control at any construction sites in the wetland's drainage catchment.
2. Institute a program of **source control BMPs** to minimize the generation of pollutants that will enter storm runoff that drains to the wetland.
3. Provide a water quality control facility consisting of one or more **treatment BMPs** to treat all urban runoff entering the wetland and designed according to the following criteria:
  - The facility should be designed to remove at least 80 percent of the total suspended solids in the runoff.
  - If the catchment could generate a relatively large amount of oil (e. g., certain industrial sites, bases handling large vehicles, areas where oil may be spilled or improperly disposed), the facility should include an appropriate oil control device.
  - If the wetland is a **priority peat wetland** (bogs and fens as more specifically defined by the Washington Department of Ecology), the facility should include a BMP with the most advanced ability to control nutrients (e. g., an infiltration device, a wet pond or constructed wetland with residence time in the pooled storage of at least two weeks). [Note: Infiltration is prone to failure in many Puget Sound Basin locations with glacial till soils and generally requires **pretreatment** to avoid clogging. In other situations infiltrating urban runoff may contaminate groundwater. Consult the stormwater management manual adopted by the jurisdiction and carefully analyze infiltration according to its prescriptions.] Refer to Appendix E for a comparison of water chemistry conditions in priority peat versus more typical wetlands.

Refer to the stormwater management manual to select and design the facility. Generally, the facility should be located outside and upstream of the wetland and its buffer.

4. Design and perform a water quality monitoring program for priority peat wetlands and for other wetlands subject to relatively high water pollutant loadings. The research results (Horner 1989) identified such wetlands as having contributing catchments exhibiting either of the following characteristics:
  - More than 20 percent of the catchment area is committed to commercial, industrial, and/or multiple family residential land uses; or
  - The combination of all urban land uses (including single family residential) exceeds 30 percent of the catchment area.

A recommended monitoring program, consistent with monitoring during the research program, is:

- Perform pre-development **baseline sampling** by collecting water quality grab samples in an open water pool of the wetland for at least one year, allocated through the year as follows: November 1-March 31--4 samples, April 1-May 31--1 sample, June 1-August 31--2 samples, and September 1-October 31--1 sample (if the wetland is dry during any period, reallocate the sample(s) scheduled then to another time). Analyze samples for pH; dissolved oxygen (DO); conductivity (Cond); total suspended solids (TSS); total phosphorus (TP); nitrate + nitrite-nitrogen (N); fecal coliforms (FC); and total copper (Cu), lead (Pb), and zinc (Zn). Find the median and range of each water quality variable.
- Considering the baseline results, set water quality goals to be maintained in the post-development period. Example goals are: (1) pH--no more than “x” percent (e. g., 10%) increase (relative to baseline) in annual median and maximum or decrease in annual minimum; (2) DO--no more than “x” percent decrease in annual median and minimum concentrations; (3) other variables --no more than “x” percent increase in annual median and maximum concentrations; (4) no increase in violations of the Washington Administrative Code (WAC) water quality criteria.
- Repeat the sampling on the same schedule for at least one year after all development is complete. Compare the results to the set goals.

If the water quality goals are not met, consider additional applications of the source and treatment controls described in steps 2 and 3. Continue monitoring until the goals are met at least two years in succession.

Note: Wetland water quality was found to be highly variable during the research, a fact that should be reflected in goals. Using the maximum (or minimum), as well as a measure of central tendency like the median, and allowing some change from pre-development levels are ways of incorporating an allowance for variability. Table 14-1 presents data from the wetlands studied during the research program to give an approximate idea of magnitudes and degree of variability to be expected. Nonurbanized watersheds (N) are those that have both < 15% urbanization and < 6% impervious cover. Highly urbanized watersheds (H) are those that have both lost all forest cover and have > 20% impervious cover. Moderately urbanized watersheds (M) are those that fit neither the N nor H category.

Table 14-1. Water quality ranges found in study wetlands.

Metric	N			M			H		
	Median	Mean	Std.Dev./n <sup>a</sup>	Median	Mean	Std.Dev./n <sup>a</sup>	Median	Mean	Dev./n <sup>a</sup>
pH <sup>b</sup>	6.4	6.4	0.5/162	6.7	6.5	0.8/132	6.9	6.7	0.6/52
DO (mg/L)	5.9	5.7	2.6/205	5.1	5.53.6/17 3	6.3	5.4	2.9/67	
Cond. (µS/cm)	46	73	64/190	160	142	73/161	132	151	86/61
TSS (µg/L)	2.0	4.6	8.5/204	2.8	9.2	22/175	4.0	9.2	15/66
TP (µg/L)	29	52	87/206	70	93	92/177	69	110	234/67
N (µg/L)	112	368	485/206	304	598	847/177	376	395	239/67
FC (no./100mL)	9.0	271	1000/206	46	2665	27342/173	61	969	4753/66
Cu (µg/L)	<5.0	<3.3	>2.7/93	<5.0	<3.7	>1.9/78	<5.0	<4.1	<2.5/29
Pb (µg/L)	1.0	<2.7	>2.8/136	3.0	<3.4	>2.7/122	5.0	<4.5	>4.0/44
Zn (µg/L)	5.0	8.4	8.3/136	8.0	9.8	7.2/122	20	20	17/44

<sup>a</sup> Std. Dev.--standard deviation; n--number of observations.

<sup>b</sup> Values do not apply to priority peat wetlands. The program did not specifically study these wetlands but measured pH in three wetlands with "bog-like" characteristics. The minimum value measured in these wetlands was 4.5, and the lowest median was 4.8; but pH can be approximately 1 unit lower in wetlands of this type. Refer to Appendix E for a comparison of water chemistry conditions in priority peat versus more typical wetlands.

*Guide Sheet 2D: Guidelines for the Protection of Specific Biological Communities*

1. For wetlands inhabited by breeding native amphibians:

- Refer to step 4 of Guide Sheet 2B for hydroperiod limit.
- Avoid decreasing the sizes of the open water and aquatic bed zones.
- Avoid increasing the channelization of flow. Do not form channels where none exist, and take care that inflows to the wetland do not become more concentrated and do not enter at higher velocities than accustomed. If necessary, concentrated flows can be uniformly distributed with a flow-spreading device such as a shallow weir, stilling basin, or perforated pipe. Velocity dissipation can be accomplished with a stilling basin or rip-rap pad.
- Limit the post-development flow velocity to < 5 cm/s (0.16 ft/second) in any location that had a velocity in the range 0-5 cm/s in the pre-development condition.
- Avoid increasing the gradient of wetland side slopes.

2. For wetlands inhabited by forest bird species:

Retain areas of coniferous forest in and around the wetland as habitat for forest species.

Retain shrub or woody debris as nesting sites for ground-nesting birds and downed logs and stumps for winter wren habitat.

Retain snags as habitat for cavity-nesting species, such as woodpeckers.

Retain shrubs in and around the wetland for protective cover. If cover is insufficient to protect against domestic pet predation, consider planting native bushes such as rose species in the buffer.

3. For wetlands inhabited by **wetland obligate** bird species:

- Retain **forested zones**, sedge and rush meadows, and deep open water zones, both without vegetation and with submerged and floating plants.
- Retain shrubs in and around the wetland for protective cover. If cover is insufficient to protect against domestic pet predation, consider planting native bushes such as rose species in the buffer.
- Avoid introducing **invasive weedy plant species**, such as purple loosestrife and reed canarygrass.
- Retain the buffer zone. If it has lost width or forest cover, consider re-establishing forested buffer area at least 30 meters (100 ft) wide.
- If human entry is desired, establish paths that permit people to observe the wetland with minimum disturbance to the birds.

4. For wetlands inhabited by fish:

- Protect fish habitats by avoiding water velocities above tolerated levels (selected with the aid of a qualified fishery biologist to protect fish in each life stage when they are present), siltation of spawning beds, etc. Habitat requirements vary substantially among fish species. If the wetland is associated with a larger water body, contact the Department of Fisheries and Wildlife to determine the species of concern and the acceptable ranges of habitat variables.
- If stranding of protected commercial or sport fish could result from a structural or hydrologic modification for runoff quantity or quality control, develop a strategy to avoid stranding that minimizes disturbance in the wetland (e. g., by making provisions for fish return to the stream as the wetland drains, or avoiding use of the facility for quantity or quality control during fish presence).

## APPENDIX A: INFORMATION NEEDED TO APPLY GUIDELINES

The following information listed for each guide sheet is most essential for applying the Wetlands and Stormwater Management Guidelines. As a start, obtain the relevant soil survey; the National Wetland Inventory, topographic and land use maps, and the results of any local wetland inventory.

### *Guide Sheet 1*

1. Boundary and area of the contributing watershed of the wetland or other landscape unit
2. A complete definition of goals for the wetland and landscape unit subject to planning and management
3. Existing management and monitoring plans
4. Existing and projected land use in the landscape unit in the categories commercial, industrial, multi-family residential, single-family residential, agricultural, various categories of undeveloped, and areas subject to active logging or construction (expressed as percentages of the total watershed area)
5. Drainage network throughout the landscape unit
6. Soil conditions, including soil types, infiltration rates, and positions of seasonal water table (seasonally) and restrictive layers
7. Groundwater recharge and discharge points
8. Wetland category (I - IV in draft Puget Sound Water Quality Authority wetland protection guidelines); designation as rare or irreplaceable. Refer to the Washington Natural Heritage Program data base. If the needed information is not available, a biological assessment will be necessary.
9. Watershed hydrologic assessment
10. Watershed water quality assessment
11. Wetland type and zones present, with special note of estuarine, priority peat system, forested, sensitive scrub-shrub zone, sensitive emergent zone and other sensitive or critical areas designated by state or local government (with dominant plant species)
12. Rare, threatened, or endangered species inhabiting the wetland
13. History of wetland changes

14. Relationship of wetland to other water bodies in the landscape unit and the drainage network
15. Flow pattern through the wetland
16. Fish and wildlife inhabiting the wetland
17. Relationship of wetland to other wildlife habitats in the landscape unit and the corridors between them

*Guide Sheet 2*

1. Existing and potential stormwater pollution sources
2. Existing and projected landscape unit land use (see number 4 under Guide Sheet 1)
3. Existing and projected wetland hydroperiod characteristics
4. Wetland bathymetry
5. Inlet and outlet locations and hydraulics
6. Landscape unit soils, geologic and hydrogeologic conditions
7. Wetland type and zones present (see number 11 under Guide Sheet 1)
8. Presence of breeding populations of native amphibian species
9. Presence of forest and wetland obligate bird species
10. Presence of fish species

## APPENDIX B: DEFINITIONS

**Baseline sampling:** Sampling performed to define an existing state before any modification occurs that could change the state.

**Bioengineering:** Restoration or reinforcement of slopes and stream banks with living plant materials.

**Buffer:** The area that surrounds a wetland and that reduces adverse impacts to it from adjacent development.

**Constructed wetland:** A wetland intentionally created from a non-wetland site for the sole purpose of wastewater or stormwater treatment. These wetlands are not normally considered Waters of the United States or Waters of the State.

**Degraded (disturbed) wetland (community):** A wetland (community) in which the vegetation, soils, and/or hydrology have been adversely altered, resulting in lost or reduced functions and values; generally, implies topographic isolation; hydrologic alterations such as hydroperiod alteration (increased or decreased quantity of water), diking, channelization, and/or outlet modification; soils alterations such as presence of fill, soil removal, and/or compaction; accumulation of toxicants in the biotic or abiotic components of the wetland; and/or low plant species richness with dominance by invasive weedy species.

**Enhancement:** Actions performed to improve the condition of an existing degraded wetland, so that functions it provides are of a higher quality.

**Estuarine wetland:** Generally, an eelgrass bed; salt marsh; or rocky, sandflat, or mudflat intertidal area where fresh and salt water mix. (Specifically, a tidal wetland with salinity greater than 0.5 parts per thousand, usually semi-enclosed by land but with partly obstructed or sporadic access to the open ocean).

**Forested communities (wetlands):** In general terms, communities (wetlands) characterized by woody vegetation that is greater than or equal to 6 meters in height; in these guidelines the term applies to such communities (wetlands) that represent a significant amount of tree cover consisting of species that offer wildlife habitat and other values and advance the performance of wetland functions overall.

**Functions:** The ecological (physical, chemical, and biological) processes or attributes of a wetland without regard for their importance to society (see also Values). Wetland functions include food chain support, provision of ecosystem diversity and fish and wildlife habitat, flood flow alteration, groundwater recharge and discharge, water quality improvement, and soil stabilization.

**Hydrodynamics:** The science involving the energy and forces acting on water and its resulting motion.

**Hydroperiod:** The seasonal occurrence of flooding and/or soil saturation; encompasses the depth, frequency, duration, and seasonal pattern of inundation.

**Invasive weedy plant species:** Opportunistic species of inferior biological value that tend to out-compete more desirable forms and become dominant; applied to non-native species in these guidelines.

**Landscape unit:** An area of land that has a specified boundary and is the locus of interrelated physical, chemical, and biological processes.

**Modification, Modified (wetland):** A wetland whose physical, hydrological, or water quality characteristics have been purposefully altered for a management purpose, such as by dredging, filling, forebay construction, and inlet or outlet control.

**On-site:** An action (here, for stormwater management purposes) taken within the property boundaries of the site to which the action applies.

**Polishing:** Advanced treatment of a waste stream that has already received one or more stages of treatment by other means.

**Pre-development, post-development:** Respectively, the situation before and after a specific stormwater management project (e. g., raising the outlet, building an outlet control structure) will be placed in the wetland or a land use change occurs in the landscape unit that will potentially affect the wetland.

**Pre-treatment:** An action taken to remove pollutants from runoff before it is discharged into another system for additional treatment.

**Priority peat systems:** Unique, irreplaceable fens that can exhibit water pH in a wide range from highly acidic to alkaline, including fens typified by *Sphagnum* species, *Rhododendron groenlandicum* (Labrador tea), *Drosera rotundifolia* (sundew), and *Vaccinium oxycoccos* (bog cranberry); marl fens; estuarine peat deposits; and other moss peat systems with relatively diverse, undisturbed flora and fauna. Bog is the common name for peat systems having the *Sphagnum* association described, but this term applies strictly only to systems that receive water income from precipitation exclusively.

**Rare, threatened, or endangered species:** Plant or animal species that are regional relatively uncommon, are nearing endangered status, or whose existence is in immediate jeopardy and is usually restricted to highly specific habitats. Threatened and endangered species are officially listed by federal and state authorities, whereas rare species are unofficial species of concern that fit the above definitions.

**Redevelopment:** Conversion of an existing development to another land use, or addition of a material improvement to an existing development.

**Regional:** An action (here, for stormwater management purposes) that involves more than one discrete property.

**Restoration:** Actions performed to reestablish wetland functional characteristics and processes that have been lost by alterations, activities, or catastrophic events in an area that no longer meets the definition of a wetland.

**Source control best management practices (BMPs):** Actions that are taken to prevent the development of a problem (e. g., increase in runoff quantity, release of pollutants) at the point of origin.

**Stage excursion:** A post-development departure, either higher or lower, from the water depth existing under a given set of conditions in the pre-development state.

**Structure:** The components of an ecosystem, both the abiotic (physical and chemical) and biotic (living).

**Treatment best management practices (BMPs):** Actions that remove pollutants from runoff through one or more physical, chemical, biological mechanisms.

**Unusual biological community types:** Assemblages of interacting organisms that are relatively uncommon regionally.

**Values:** Wetland processes or attributes that are valuable or beneficial to society (also see Functions). Wetland values include support of commercial and sport fish and wildlife species, protection of life and property from flooding, recreation, education, and aesthetic enhancement of human communities.

**Vernal wetland:** A wetland that has water above the soil surface for a period of time during and/or after the wettest season but always dries to or below the soil surface in warmer, drier weather.

**Wetland obligate:** A biological organism that absolutely requires a wetland habitat for at least some stage of its life cycle.

**Wetlands:** Lands transitional between terrestrial and aquatic systems that have a water table usually at or near the surface or a shallow covering of water, hydric soils, and a prevalence of hydrophytic vegetation.

## APPENDIX C: REFERENCES

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## APPENDIX D: NATIVE AND RECOMMENDED NONINVASIVE PLANT SPECIES FOR WETLANDS IN THE PUGET SOUND BASIN

Caution: Extracting plants from an existing wetland donor site can cause a significant negative effect on that site. It is recommended that plants be obtained from native plant nursery stocks whenever possible. Collections from existing wetlands should be limited in scale and undertaken with care to avoid disturbing the wetland outside of the actual point of collection. Plant selection is a complex task, involving matching plant requirements with environmental conditions. It should be performed by a qualified wetlands botanist. Refer to *Restoring Wetlands in Washington* by the Washington Department of Ecology for more information.

### *Plants preferred in Puget Sound Basin freshwater wetlands*

#### **Open water zone:**

*Potamogeton* species (pondweeds)  
*Nymphaea odorata* (pond lily)  
*Brasenia schreberi* (watershield)  
*Nuphar luteum* (yellow pond lily)  
*Polygonum hydropiper* (smartweed)  
*Alisma plantago-aquatica* (broadleaf water plantain)  
*Ludwigia palustris* (water purslane)  
*Menyanthes trifoliata* (bogbean)  
*Utricularia minor*, *U. vulgaris* (bladderwort)

#### **Emergent zone:**

*Carex obnupta*, *C. utriculata*, *C. arcta*, *C. stipata*, *C. vesicaria*, *C. aquatilis*, *C. comosa*, *C. lenticularis* (sedge)  
*Scirpus atricinctus* (woolly bulrush)  
*Scirpus microcarpus* (small-fruited bulrush)  
*Eleocharis palustris*, *E. ovata* (spike rush)  
*Epilobium watsonii* (Watson's willow herb)  
*Typha latifolia* (common cattail) (Note: This native plant can be aggressive but has been found to offer certain wildlife habitat and water quality improvement benefits; use with care.)  
*Veronica americana*, *V. scutellata* (American brookline, marsh speedwell)  
*Mentha arvensis* (field mint)  
*Lycopus americanus*, *L. uniflora* (bugleweed or horehound)  
*Angelica* species (angelica)  
*Oenanthe sarmentosa* (water parsley)  
*Heracleum lanatum* (cow parsnip)  
*Glyceria grandis*, *G. elata* (manna grass)  
*Juncus acuminatus* (tapertip rush)

*Juncus ensifolius* (daggerleaf rush)  
*Juncus bufonius* (toad rush)  
*Mimulus guttatus* (common monkey flower)

**Scrub-shrub zone:**

*Salix lucida*, *S. rigida*, *S. sitchensis*, *S. scouleriana*, *S. pedicellaris* (willow)  
*Lysichiton americanus* (skunk cabbage)  
*Athyrium filix-femina* (lady fern)  
*Cornus sericea* (redstem dogwood)  
*Rubus spectabilis* (salmonberry)  
*Physocarpus capitatus* (ninebark)  
*Ribes species* (gooseberry)  
*Rhamnus purshiana* (cascara)  
*Sambucus racemosa* (red elderberry) (occurs in wetland-upland transition)  
*Lonicera involucrata* (black twinberry)  
*Oemleria cerasiformis* (Indian plum)  
*Stachys cooleyae* (Stachy's horsemint)  
*Prunus emarginata* (bitter cherry)

**Forested zone:**

*Populus balsamifera*, ssp. *trichocarpa* (black cottonwood)  
*Fraxinus latifolia* (Oregon ash)  
*Thuja plicata* (western red cedar)  
*Picea sitchensis* (Sitka spruce)  
*Alnus rubra* (red alder)  
*Tsuga heterophylla* (hemlock)  
*Acer circinatum* (vine maple)  
*Maianthemum dilatatum* (wild lily-of-the-valley)  
*Ivzula parviflora* (small-flower wood rush)  
*Torreyochloa pauciflora* (weak alkaligrass)  
*Ribes species* (currants)

**Bog:**

*Sphagnum species* (sphagnum mosses)  
*Rhododendron groenlandicum* (Labrador tea)  
*Vaccinium oxycoccos* (bog cranberry)  
*Kalmia microphylla*, ssp. *occidentalis* (bog laurel)

*Exotic plants that should not be introduced to existing, created, or constructed Puget Sound Basin freshwater wetlands*

*Hedera helix* (English ivy)  
*Phalaris arundinacea* (reed canarygrass)  
*Lythrum salicaria* (purple loosestrife)  
*Iris pseudacorus* (yellow iris)  
*Ilex aquifolia* (holly)  
*Impatiens glandulifera* (policeman's helmet)  
*Lotus corniculatus* (birdsfoot trefoil)

*Lysimachia thyrsiflora* (tufted loosestrife)  
*Myriophyllum* species (water milfoil, parrot's feather)  
*Polygonum cuspidatum* (Japanese knotweed)  
*Polygonum sachalinense* (giant knotweed)  
*Rubus discolor* (Himalayan blackberry)  
*Tanacetum vulgare* (common tansy)

*Native plants that should not be introduced to existing, created, or constructed Puget Sound Basin freshwater wetlands*

*Potentilla palustris* (Pacific silverweed)  
*Solarum dulcimara* (bittersweet nightshade)  
*Juncus effusus* (soft rush)  
*Conium maculatum* (poison hemlock)  
*Ranunculus repens* (creeping buttercup)

APPENDIX E: COMPARISON OF WATER CHEMISTRY CHARACTERISTICS IN  
*SPHAGNUM* BOG AND FEN VERSUS MORE TYPICAL WETLANDS

Water Quality Variable	Typical Wetlands	<i>Sphagnum</i> Bogs and Fens
pH	6 - 7	3.5 - 4.5
Dissolved oxygen (mg/L)	4 - 8	Shallow surface layer oxygenated, anoxic below
Cations	Divalent Ca, Mg common	Divalent Ca, Mg uncommon; Univalent Na, K predominant
Anions	HCO <sub>3</sub> <sup>-</sup> , CO <sub>3</sub> <sup>2-</sup> predominant	Cl <sup>-</sup> , SO <sub>4</sub> <sup>2-</sup> predominant; almost no HCO <sub>3</sub> <sup>-</sup> , CO <sub>3</sub> <sup>2-</sup> (organic acids form buffering system)
Hardness	Moderate	Very low
Total phosphorus (µg/L)	50 - 500	5 - 50
Total Kjeldahl nitrogen (µg/L)	500 - 1000	~ 50

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