ORWAP Version 3.1 September 2016
Errata Sheet

This sheet includes corrections and changes needed for consistency with the final ORWAP Version 3.1 November 2016 (released after the manual was published in September 2016).

On page i
Replace in the first paragraph, “An accompanying document *Guidance for Using the Oregon Rapid Wetland Assessment Protocol (ORWAP) in State and Federal Permit Programs (Oregon Department of State Lands, August 2016*”
with “An accompanying document *Guidance for Using the Oregon Rapid Wetland Assessment Protocol (ORWAP) in State and Federal Permit Programs (Oregon Department of State Lands, November 2016)”*

On page 22
Under OF8 **Replace** “less than 10% of the AA” **with** “more than 10% of the AA” and **replace** “<10% of the AA” **with** “>10% of the AA.”

On page 28
Add to Figure 3-10 “Note – for this site’s RCA, presence of the road north of the wetland is irrelevant because it was bordered by ditches that redirected runoff from the slopes into the stream before entering the wetland. If this had not been true, the RCA would have extended upslope (minus the stream and banks) creating a U shape RCA.”

On page 36
Replace in the second paragraph, “The *Guidance for Using the Oregon Rapid Wetland Assessment Protocol (ORWAP) in State and Federal Permit Programs (Oregon Department of State Lands, September 2016)”* **with** “The *Guidance for Using the Oregon Rapid Wetland Assessment Protocol (ORWAP) in State and Federal Permit Programs (Oregon Department of State Lands, November 2016)*”

On page 42
Replace Tidal wetland definition
with “A wetland that receives tidal water at least once during a normal year, regardless of salinity, and dominated by emergent or woody vegetation. Tidal flooding occurs on a 6-hour cycle DURING THE TIME it is flooded by tide, which may be as infrequent as once per year.”

Appendix B (page 59 – 81)
Replace Appendix B **with** the attached revised Appendix B

Appendix C (page 84-85)
Replace references to HUC4 **with** HUC8
Replace references to HUC5 **with** HUC10
Replace references to HUC6 **with** HUC12

Appendix B. Narrative Descriptions of the ORWAP Scoring Models

WATER STORAGE AND DELAY (WS)

Function Definition: The effectiveness of a wetland for storing water or delaying the downslope movement of surface water for long or short periods (but for longer than a tidal cycle), and in doing so to potentially influence the height, timing, duration, and frequency of inundation in downstream or downslope areas.

Scientific Support for This Function in Wetlands Generally: Moderate to High. Being flat areas located low in the watershed; many wetlands are capable of slowing the downslope movement of water, regardless of whether they have significant storage capacity. When that slowing occurs in multiple wetlands, flood peaks further downstream are muted somewhat. When wetlands are, in addition, capable of storing (not just slowing) runoff, that water is potentially available for recharging aquifers and supporting local food webs.

FUNCTION MODEL

Full model structure: A non-tidal wetland is automatically scored “10” for this function if it lacks an outlet. If the site has surface water for fewer than seven consecutive days during an average growing season, the score increases with decreasing wetland gradient (2/3 of the score) and with greater microtopographic variation, coarser soil texture, denser ground cover, and lack of evidence of significant groundwater inputs (the average score of these counting for 1/3). For all other wetlands, 3/4 of the score is from the average of the scores for outlet duration (shorter periods of outflow indicating potential for more water storage) and *Live Storage*, and the other 1/4 of the score is from the average of the scores for *Friction* and *Subsurface Storage*. The submodels are described below.

Submodel structures:

- *Friction* reflects an average of the following: flatter gradient, greater ponding, constrictedness of the outlet, microtopographic variation, ground cover, and surface throughflow that encounters woody vegetation and takes an indirect path through the wetland.
- *Subsurface Storage* is represented by organic or coarse soil texture, absence of evidence of discharging groundwater, and smaller runoff and streamflow contributing areas relative to the size of wetland.
- *Livestore* is higher when soils are periodically unsaturated and water ponds over a larger area during the wet season (2/3 of the score), and when a smaller portion of the wetland has permanent water and the water fluctuation in the wetland during the year is higher (1/3 of the score).

If the wetland is tidal, it is automatically scored “0” for this function.

Approach for Future Validation: The volume, duration, and frequency of water storage could be measured in a series of wetlands that encompass the scoring range, and flows could be measured at their outlets if any, and at various points downstream. Measurements should especially be made during major storm or snowmelt events. Procedures are partly described by Warne & Wakely 2000, US Army Corps of Engineers 2005, and NJ Dept. of Environmental Protection 2007.

VALUES MODEL

Full model structure: When there is evidence of or potential for river flood-related damage to downslope areas containing infrastructure or row crops, the value score is equivalent to the score for flood damage (*Fdam*). Otherwise, the value score results from averaging *Fdam* (1/2 of the score) with an average reflecting the relative scarcity in the watershed of other wetlands likely to effectively perform this function, a zoning classification of Development or (secondarily) Agriculture, and increasing water yield from the wetland's contributing area (*Yield*). The submodels are described below.

Submodel structures:

- *Fdam* increases with evidence of flood-damage to downslope areas, particularly in areas with damage to infrastructure, and close proximity of the wetland to a river.
- *Yield* increases with decreasing elevation in the watershed (weight of 3); the for increasing impervious surface in the contributing area, greater transport capacity in the contributing area, and smaller ratio of wetland area to wetland catchment area (the average score for these counting as a weight of 2); and percent cover of trees within 100 feet upslope of the wetland (weight of 1).

SEDIMENT RETENTION AND STABILIZATION (SR)

Function Definition: The effectiveness of a wetland for intercepting and filtering suspended inorganic sediments thus allowing their deposition, as well as reducing energy of waves and currents, resisting excessive erosion, and stabilizing underlying sediments or soil. The performance of this function has both benefits (e.g., reduction in turbidity in downstream waters) and negative values (e.g., progressive sedimentation of productive wetlands, slowing of natural channel migration).

Scientific Support for This Function in Wetlands Generally: High. Being flat areas located low in the landscape, many wetlands are areas of sediment deposition, a process facilitated by wetland vegetation that intercepts suspended sediments and stabilizes (with root networks) whatever sediment has been deposited.

FUNCTION MODEL

Full model structure: If the site is not tidal or an outlet is lacking, the site is automatically scored a “10”. If the site has an outlet but the site has surface water for fewer than seven consecutive days during an average growing season, the score is equivalent to the score for *Dry Interception.* For all other wetlands, the score is a weighted average of three groups: *Hydrologic Connectivity* (weight of 3), the average of *Hydrologic Entrainment* and *Live Storage* (weight of 2), and the average of *Dry and Wet Interception* (weight of 1). The submodels are described below.

Submodel structures:
- *Live Storage* is the average of increasing percentage of the wetland that floods only seasonally, and intermediate water level fluctuations.
- *Hydrologic Entrainment* is the capacity of the wetland to capture and retain suspended sediment and is represented by the average of increasing water depth, wetland width, and area of emergent vegetation.
- *Dry Interception* is the average of two groups. One group is the average of flatter gradient and smaller runoff and streamflow contributing areas relative to wetland size. The other group is the average of increasing ground cover and microtopographic variation, and lack of severe grazing and soil disturbance.
- *Wet Interception* is the average of increasing area and percent cover of emergent vegetation, greater wetland width and diversity of water depths, and more sinuous water path through the wetland.
- *Hydrologic Connectivity* is the average of decreasing outflow duration and greater constriction of the wetland outlet.

If the wetland is tidal, the score is the average of two groups. One group reflects increasing percentage of the wetland that is high marsh and wider wetland width (whichever scores higher). The other group is the average of decreasing wave exposure, denser ground cover, and brackish salinity (which facilitates precipitation of clay particles).

Approach for Future Validation: The volume of accreted sediments could be measured in a series of wetlands that encompass the scoring range. This might be done with sediment markers, with isotopic analysis of past sedimentation rates, or with SET tables (Boumans & Day 1993). Suspended sediment could be measured at inlets and outlets if any, with simultaneous measurement of changes in water volume and flow rate (e.g., Detenbeck et al. 1995).

VALUES MODEL

Structure: For non-tidal wetlands, the value is reflected by the weighted average of one indicator and four groups. The indicator is a representation of whether the wetland's watershed has few other wetlands that are likely to retain suspended sediment. However, most of the value score is driven by one group that indicates presence of sedimentation or turbidity problems in waters a short distance up or downslope from the wetland, or presence of erosion or impervious surfaces in the wetland's contributing area (the maximum score for these counting for 3/7). A second group is the average of increasing transport potential for runoff to the wetland, presence of a tributary, and potential for development upslope. The third group is the average of decreasing buffer width and more of the wetland perimeter with an upland perennial buffer. A fourth group reflects lowland location and proportionally large contributing area. For tidal wetlands, a very similar but simplified version of the non-tidal wetland model was used.

PHOSPHORUS RETENTION (PR)

Function Definition: The effectiveness for retaining phosphorus for long periods (>1 growing season) as a result of chemical adsorption, or from translocation by plants to belowground zones with less potential for physically or chemically remobilizing phosphorus into the water column.

Scientific Support for This Function in Wetlands Generally: Moderate to high. Many wetlands do not retain phosphorus for long periods, but may be significant by converting inorganic to organic forms. Sediment dynamics (erosion-deposition) and local geology largely determine whether a wetland is a source, sink, or converter of phosphorus over the long term.

FUNCTION MODEL

Full model structure: If the non-tidal wetland lacks an outlet, it is automatically scored "10" for this function. If the wetland contains surface water for fewer than seven consecutive days during the growing season, its score is the average of *Dry Interception* and *Adsorption* (see below for definitions). For all other non-tidal wetlands, higher scores are determined by the weighted average of *Adsorption* (weight of 3), the average of *Desorption* and *Connectivity* (weight of 2), and the average of *Wet and Dry Interception*. The submodels are described below.

Submodel structures:

- *Intercept Dry* is represented by the average of flatter gradient (half the group score) and the average for a group consisting of increasing ground cover and microtopographic variation, larger ratio of wetland area to area of the wetland's contributing areas, and absence of soil disturbance.
- *Intercept Wet* is the average of increasing wetland width, emergent vegetation area and percentage, shorter duration of ice cover, and a more circuitous water path through the wetland.
- *Connectivity* is the average of decreasing outflow duration and greater constriction of the wetland outlet.
- *Adsorption* is considered optimal where soil is clay and salinity is brackish. Scores for these indicators are averaged.
- *Desorption* is considered to be minimized if the wetland has not recently been created, little or none of the wetland contains surface water persistently, and when surface water is present it is moderately shallow, not extensively covered with algae or duckweed, and its level does not fluctuate significantly. Scores for these indicators are averaged.

If the wetland is tidal, higher scores are determined by four indicators or groups weighted equally: (1) soils are clayey, (2) the site is in the upper estuary or has low salinity, (3) the larger of scores reflecting greater width and percentage of high marsh, and (4) the average of scores reflecting less wave exposure and denser ground cover.

Approach for Future Validation: Among a series of wetlands spanning the scoring range, total phosphorus could be measured simultaneously at wetland inlet and outlet, if any, and adjusted for any dilution occurring from groundwater or runoff (or concentration effect from evapotranspiration) over the intervening distance. Measurements should be made at least once monthly and more often during major runoff events (e.g., Detenbeck et al. 1995). A particular focus should be on the relative roles of soil composition vs. vegetation, as they affect chemical adsorption vs. uptake.

VALUES MODEL

Structure: For non-tidal wetlands, a wetland's value for the Phosphorus Retention function is reflected by the weighted average of four groups. One group, accounting for half the value score, is the average of scores that reflect connectivity to nutrient problems upstream or downstream (or downslope). A second represents presence of a tributary, potentially erosive adjoining slopes, more impervious surface in the runoff and streamflow contributing areas, and large potential for runoff reaching the wetland. A third is the average of decreasing buffer width, a zoning designation of Development or Agriculture, and being in a watershed believed to be relatively limited in other wetlands that can store nutrients effectively. The fourth group reflects location near the bottom of a watershed and small ratio of a wetland's area to that of its contributing area. For tidal wetlands, a very similar but simplified version of the non-tidal wetland model was constructed.

NITRATE REMOVAL AND RETENTION (NR)

Function Definition: The effectiveness for retaining particulate nitrate and converting soluble nitrate and ammonia to nitrogen gas, primarily through the microbial process of denitrification, *while generating little or no nitrous oxide* (a potent "greenhouse gas"). Note that most published definitions of Nitrate Removal do not include the important restriction on N_2O emission.

Scientific Support for This Function in Wetlands Generally: High. Wetlands are perhaps the most effective component of the landscape for removing nitrate from surface water.

FUNCTION MODEL

Full model structure: If the non-tidal wetland lacks an outlet, it is automatically scored "10" for this function. If the wetland contains surface water for fewer than seven consecutive days during an average growing season, its score is the average of *Warmth* and *Organic* (see below for definitions). For all other non-tidal wetlands, higher scores are determined by the weighted average of increasing *Redox* (weight of 3), *Hydrologic Isolation* (weight of 2), and *Warmth, Interception,* and *Organic Content* (each with a weight of 1). The submodels are described below.

Submodel structures:

- *Warmth* averages the scores for increasing growing season length, groundwater input, and diminished extent of shading woody vegetation.
- *Interception* averages the scores for flatter gradient, greater vegetated width, denser ground cover, and more diffuse throughflow.
- *Hydrologic Isolation* is the average of decreasing outflow duration and greater constriction of the wetland outlet.

- *Organic Content* score increases with increasing emergent vegetation percentage, moss cover, and peat soils. Those are averaged and count for 3/4 of the Organic Content score. The other component is an average of soil intactness and wetland is not a new wetland.
- *Redox* is represented by increasing percentage of the wetland that is flooded only seasonally (half the score) with the average of scores that represent intermediate percentage of persistent surface water, greater interspersion of vegetation and water, minimal water level fluctuation, more microtopographic variation, and larger edge-to-area ratio.

If the wetland is tidal, Nitrate Removal is represented by the average of denser ground cover and greater wetland width, as well as lower estuarine position (or higher salinity).

Approach for Future Validation: Among a series of wetlands spanning the function scoring range and a range of wetland condition (integrity), nitrate and ammonia could be measured simultaneously at wetland inlet and outlet, if any, and adjusted for any dilution occurring from groundwater or runoff (or concentration effects from evapotranspiration) over the intervening distance. Measurements should be made at least once monthly and more often during major runoff events (e.g., Detenbeck et al. 1995). Denitrification rates (at least potential), the nitrogen fixing rates of particular wetland plants, and nitrous oxide emissions should also be monitored.

VALUES MODEL

Structure: A non-tidal wetland's value for the Nitrate Removal function is higher if there are domestic drinking water wells nearby, the wetland is in an Oregon DEQ-designated drinking water contributing area or groundwater risk area, or if the value of Phosphorus Retention is high (because many of the factors that reflect Phosphorus Retention value, such as a zoning designation of Agriculture or Development, are similarly reflective of Nitrate Removal value). For tidal wetlands, the value is higher if the wetland is in a lower estuary position, if the value of Phosphorus Retention is high, and cover by potential nitrate sources such as alder is higher. Proximity to wells or vulnerable aquifers are not factors in judging tidal wetland value.

ANADROMOUS FISH HABITAT (FA)

Function Definition: The capacity to support an abundance of native anadromous fish (chiefly salmonids) for functions other than spawning. See worksheet *WetVerts* in the *ORWAP_SuppInfo* file for list of the species. The model described below will not predict habitat suitability accurately for every species, nor is it intended to assess the ability to restore fish access to a currently inaccessible wetland.

Scientific Support for This Function in Wetlands Generally: Moderate-high, depending mainly on accessibility of a wetland to anadromous fish. Many accessible wetlands provide rich feeding and rearing opportunities, shelter from predators, and thermal refuge (especially if groundwater is a significant water source).

FUNCTION MODEL

Full model structure: For non-tidal wetlands, a score of “0” is assigned if anadromous fish cannot access any part of the wetland, if the wetland is not connected to a stream or other water body within 0.5 mile that has been designated as Essential Indigenous Anadromous Salmonid Habitat (ESH), or if the wetland contains surface water for fewer than seven consecutive days during an average growing season. Otherwise, the function score is the average of wetland *Hydrologic Regime, Structure, Cool Water, Landscape* condition, and a lack of human-related *Stressors.* The submodels are described below.

Submodel structures:

- *Hydrologic Regime* score increases as the duration of connection to other waters increases, as more of the wetland has surface water at least seasonally, and as both flowing and deep ponded water are present. Scores for these indicators are averaged.
- *Structure* beneficial to anadromous fish is represented by a group average representing increased channel braiding, cover of emergent vegetation, and large instream wood. A score is not calculated for this submodel if the site retains surface water for 4 weeks or less during an average growing season.
- *Cool Water* is indicated by a group average based on evidence of groundwater input, wetland location near headwaters of a watershed, larger percent of the wetland and its buffer that is forested, and larger percent of the wetland's surface water that is shaded.
- *Landscape* condition is assumed to be better when land cover in the runoff and streamflow contributing areas and area closest to the wetland is mostly natural and lacking impervious surfaces. Scores for these indicators are averaged.
- *Stressors* are represented by known or suspected contaminants, other sediment inputs in excessive concentrations, altered flows, algal blooms, and non-native fish. Scores for these indicators are averaged. The score is actually the reverse of these conditions, such that their absence raises the overall score for this function.

If the wetland is tidal, the score for Anadromous Fish Habitat is set to “0” if anadromous fish cannot access the wetland. Otherwise, the score is the weighted average of three groups. One group represents increasing frequency of connection between the tidal marsh and marine waters (2/3 of score). A second group's average reflects greater internal channel complexity, adjacency to an accessible non-tidal wetland, more large partly-submerged wood, and a larger portion of the water being shaded. The third group's average reflects increasing wetland width, less impervious surface in the wetland's contributing area, and natural conditions within its buffer.

Approach for Future Validation: Among a series of wetlands spanning the function scoring range and a range of wetland condition (integrity), the number of anadromous fish and their duration of use would need to be measured regularly throughout the times when usually expected to be present, and weight gain during the period of wetland habitation should be measured (for techniques see Johnson et al. 2007, Lestelle et al. 1996, Scheuerell et al. 2006).

VALUES MODEL

Structure: The value score is automatically set at "10" if the wetland adjoins or is connected to a stream or other water body within 0.5 mile that has been designated as Essential Indigenous Anadromous Salmonid Habitat (ESH). Otherwise, the score is the average of scores for three indicators: a zoning designation of Development or Agriculture, located in a watershed where Anadromous Fish Habitat in wetlands may be deficient, and having a relatively high score for Waterbird Feeding Habitat.

RESIDENT FISH HABITAT (FR)

Function Definition: The capacity to support an abundance and diversity of *native* non-anadromous fish (both resident and visiting species). See worksheet *WetVerts* in the *ORWAP_SuppInfo* file for list of the species. The model described below will not predict habitat suitability accurately for every species, nor is it intended to assess the ability to restore fish access to a currently inaccessible wetland.

Scientific Support for This Function in Wetlands Generally: High. Many accessible wetlands provide rich feeding opportunities, shelter from predators, and thermal refuge (especially if groundwater is a significant water source). Even isolated (inaccessible) wetlands are important to some fish species, such as Oregon chub.

FUNCTION MODEL

Full model structure: For non-tidal wetlands, a score of "0" is assigned if it is an alkaline playa, or if it has surface water for fewer than seven consecutive days during the growing season, or if known to contain no fish (not even seasonally). For all other non-tidal wetlands, the score is the average of *Hydrologic Regime*, *Structure*, and *Stressors*. The submodels are described below.

Submodel structures:

- *Hydrologic Regime* is assumed most favorable for resident fish when surface water is present persistently or at least seasonally and there is at least a temporary connection to other surface waters, both ponded and flowing water are present, groundwater is likely to flow into the wetland, and a variety of water depths is present in fairly equal proportions. These indicators are considered equally predictive and so are averaged.
- *Structure* beneficial to resident fish is represented by increasing area and percent cover of emergent and submersed aquatic vegetation, extensive amounts of partly submerged wood, and presence of a more complex internal channel network, especially one that intersects woody vegetation. Scores for these indicators are averaged. A score is not calculated for this submodel if the site retains surface water for 4 weeks or less during an average growing season.
- *Stressors* are represented by the presence of non-native fish (half the score) with the average of two groups of scores. The first group represents known and accelerated toxicity of contaminants in the input water, more persistent connection with this input water, excessive sediment inputs, and artificially altered flow timing. The second group

is the average of winter ice cover and a shorter growing season. The *Stressors* score is actually the reverse of these conditions, such that their absence raises the overall score for this function.

If the site is tidal, the function model is the same as for Anadromous Fish Habitat in tidal wetlands.

Approach for Future Validation: Among a series of wetlands spanning the function scoring range and a range of wetland condition (integrity), the number of native non-anadromous fish and their onsite productivity and diversity would need to be measured regularly. For visiting species, the duration of use and weight gain throughout the times when usually expected to be present should be determined.

VALUES MODEL

Structure: If the wetland contains a rare fish species the value score is automatically set at "10". Otherwise its value score reflects an average based on some evidence for rare species in the vicinity, evidence of fishing, a zoning designation of Development or Agriculture, and the function score for Feeding Waterbird Habitat.

AMPHIBIAN AND REPTILE HABITAT (AM)

Function Definition: The capacity of a wetland to support an abundance and diversity of native amphibians and native wetland-dependent reptiles, e.g., western pond turtle. See worksheet *WetVerts* in the *ORWAP_SuppInfo* file for list of the species. The model described below will not predict habitat suitability accurately for **every** species.

Scientific Support for This Function in Wetlands Generally: High. Many frog and turtle species in Oregon occur almost exclusively in wetlands. Densities of amphibians can be exceptionally high in some wetlands, partly due to high productivity of algae and invertebrates, and partly because submerged vegetation provides shelter and sites for egg-laying.

FUNCTION MODEL

Full model structure: For non-tidal wetlands, the function score is represented by the average of three indicator groups. One of the groups is the average of *Hydrologic Regime*, *Aquatic Structure*, *Terrestrial Structure*, *Landscape*, and *Biological Stressors*. A second group is *Waterscape* and a third is *Physical & Water Quality Stressors*. The submodels are described below.

Submodel structures:

- *Hydrologic Regime* is the average of increasing water persistence and ponding, decreasing water level fluctuation, higher likelihood of beaver activity, and flatter wetland gradient.

- *Aquatic Structure* that is more suitable for amphibians is represented by a larger percent cover and wider zone of emergent or submersed aquatic vegetation, or presence of abovewater wood, and large interspersion of intermediate proportions of vegetation and ponded water.
- *Terrestrial Structure* is considered to be best for amphibians where a wetland has a large buffer of natural vegetation, a moderate density of ground cover, extensive microtopographic variation, much downed wood, and a longer growing season. Scores for these indicators are averaged.
- *Waterscape* is represented by greater vegetated connectivity to another wetland, proximity to a ponded water, and located in a watershed with relatively large total wetland area and diversity of wetland types. Scores for these indicators are averaged.
- *Landscape* conditions are considered better for amphibians where natural cover comprises a large and proximate part of the upland cover, and the wetland is in an area of relatively high annual precipitation. Scores for these indicators are averaged.
- *Physical & Water Quality Stressors* of potential detriment to amphibians are represented by higher salinity, proximity to a road, and presence of likely contaminant sources. Scores for these indicators are averaged. The score is actually the reverse of these conditions, such that their absence raises the overall score for this function.
- *Biological Stressors* are represented by human visitation frequency and actual or potential presence of fish. Scores for these indicators are averaged. The score is actually the reverse of these conditions, such that their absence raises the overall score for this function.

If the wetland is tidal, the score is the result of one indicator multiplied by a weighted average of three groups. For the indicator, Salinity, increased scores correspond with decreasing salinity. The first group (weight of 3) represents a higher position in the watershed, a greater proportion of low marsh, and decreased salinity. The second group (weight of 2) represents a wider vegetated area, greater connectivity to non-tidal wetlands, and decreased outflow duration. The third group (weight of 1) represents closer proximity to ponded water, a larger buffer with perennial cover, and further distance from roads.

<u>Approach for Future Validation</u>: Among a series of wetlands spanning the function scoring range and a range of wetland condition (integrity), amphibian and reptile species richness, density, and (ideally) productivity and survival would need to be measured during multiple years and seasons by comprehensively surveying (as applicable) the eggs, tadpoles, and adults.

VALUES MODEL

<u>Structure</u>: The value of Amphibian Habitat receives a “10” if the non-tidal wetland is known to support a rare amphibian or reptile species. Otherwise, the value score reflects an average based on some evidence for rare species in the vicinity, the wetland containing one of the only patches of herbaceous or woody vegetation within 0.5 mile, a zoning designation of Development or Agriculture, is in one of the drier watersheds in the state, is in a watershed believed to have relatively few other wetlands that provide good amphibian habitat, and has a high function score for Feeding Waterbird Habitat.

WATERBIRD NESTING HABITAT (WBN)

Function Definition: The capacity to support an abundance and diversity of wetland-breeding waterbirds, such as ducks, grebes, bitterns, and rails. See worksheet *WetVerts* in the *ORWAP_SuppInfo* file for list of the species. The model described below will not predict habitat suitability accurately for every species in this group.

Scientific Support for This Function in Wetlands Generally: High. Dozens of waterbird species nest almost exclusively in wetlands. Breeding densities can be exceptionally high in some non-tidal wetlands, partly due to high productivity of vegetation and invertebrates, and partly because wetland vegetation provides nest sites in close proximity to preferred foods. It is recognized that some waterbirds may occasionally nest in tidal wetlands where the tidal water is relatively fresh and water level fluctuation due to tidal inundation is infrequent, but such nesting is rare.

FUNCTION MODEL

Full model structure: Non-tidal wetlands are automatically scored "0" for this function if they have more than a 10% slope. If they contain surface water for 4 weeks or less during the growing season, their score is the average of a longer hydroperiod, a larger percentage of unshaded herbaceous cover, *Waterscape*, *Landscape*, and *Stressors*. Otherwise, the function score is represented by the average of the scores for *Water Regime*, *Structure & Size*, and *Waterscape* (2/3 of the score) and the average of the scores for *Stressors*, *Landscape*, and *Productivity* (1/3 of the score). The submodels are described below.

Submodel structures:

- *Water Regime* is indicated by increased persistence of ponded surface water but with some seasonally inundated portions, moderate water level fluctuation, flatter wetland gradient, a diversity of water depths with moderately shallow water predominating, and large area of ponded open water. The scores of these are averaged.
- *Structure & Size* is represented by the average of three indicators or groups. One group average represents increasing wetland width and proportion of herbaceous vegetation that is unshaded and not overgrazed. Another reflects intermediate cover of emergent vegetation especially cattail/bulrush, a high degree of interspersion between vegetation and open water, and presence of islands for nesting. The third indicates greater amounts of emergent vegetation.
- *Stressors* are indicated by likely pollution sources in the wetland's contributing area and higher frequency of human visitation. Scores for these indicators are averaged. The score is actually the reverse of these conditions, such that their absence raises the overall score for this function.
- *Waterscape* influence is represented by closer proximity to ponded water, and being located in a watershed having more extensive and collectively diverse wetlands. Scores for these indicators are averaged.
- *Landscape* influence is represented by closer proximity to open land and greater percent of the surrounding landscape that is open land, decreasing percent of open water that is shaded, and decreasing percent of the wetland perimeter occupied by trees. Scores for these indicators are averaged.

- *Productivity* of the wetland is indicated by increased cover of submersed aquatic plants and algae, longer growing season, and paucity of moss cover. The scores of these are averaged.

If the wetland is tidal, the function score is automatically set at "0".

Approach for Future Validation: Among a series of wetlands spanning the function scoring range and a range of wetland condition (integrity), nesting waterbird species richness and density would need to be determined during the usual breeding period -- approximately April through July (see USEPA 2001 for methods). Ideally, nest success and juvenile survival rates should be measured.

VALUES MODEL

Structure: A wetland gets a "10" if it is known to support a rare waterbird species during the nesting season, or is within an area that has been officially designated as an Important Bird Area (IBA). Otherwise, its value score reflects an average based on some evidence for rare species in the vicinity, zoning designation of Developed or Agriculture, increased visibility of the wetland from a public road, the site being one of the only herbaceous wetlands within 0.5 mile, and being located in one of the drier watersheds in the state.

WATERBIRD FEEDING HABITAT (WBF)

Function Definition: The capacity to support an abundance and diversity of feeding waterbirds, primarily outside of the usual nesting season. See worksheet *WetVerts* in the *ORWAP_SuppInfo* file for list of the species. The model described below will not predict habitat suitability accurately for every species in this group.

Scientific Support for This Function in Wetlands Generally: High. Dozens of waterbird species occur almost exclusively in wetlands during migration and winter. Densities can be exceptionally high in some wetlands, partly due to high productivity of vegetation and invertebrates, and partly wetland vegetation provides shelter in close proximity to preferred foods.

FUNCTION MODEL

Full model structure: Non-tidal wetlands are automatically scored "0" for this function if they have more than a 10% slope. If they contain surface water for fewer than seven consecutive days during the growing season, their score is the average of a longer hydroperiod, a larger percentage of unshaded herbaceous cover, *Waterscape, Landscape,* and *Stressors*. Otherwise, the function score is represented by a longer hydroperiod averaged with the scores for *Water Regime, Structure & Size*, and *Waterscape* (weight of 2) and the average of the scores for *Stressors, Landscape*, and *Productivity* (weight of 1). The submodels are described below.

Submodel structures:

- *Water Regime* is indicated by increased persistence of ponded surface water but with some seasonally inundated portions, flatter wetland gradient, a diversity of water depths with moderately shallow water predominating, and large area of open water. Scores for these indicators are averaged.
- *Structure & Size* is represented by the average of two indicators and two groups. The two indicators are a large area of mud flats and larger extent of emergent vegetation. One group average represents increasing proportion of unshaded herbaceous vegetation, intermediate cover of emergent vegetation, absence of a single dominant herbaceous plant species, and increasing wetland width. Another is the presence of islands or a high degree of interspersion between vegetation and open water.
- *Stressors* are indicated by likely pollution sources in the wetland's contributing area and higher frequency of human visitation. Scores for these indicators are averaged. The score is actually the reverse of these conditions, such that their absence raises the overall score for this function.
- *Waterscape* influence is represented by closer proximity to ponds, lakes, and tidewater, as well as being located in a watershed having more extensive and collectively diverse wetlands. Scores for these indicators are averaged.
- *Landscape* influence is represented by proximity to open land and percent of the surrounding landscape that is open land, increasing proportion of the surrounding land that is perennial land cover, and decreasing percent of the wetland perimeter occupied by trees. Scores for these indicators are averaged.
- *Productivity* of the wetland is indicated by increased cover of submersed aquatic plants and algae, decreased duration of ice cover, and lack of invasive plant and moss cover. The scores of these are averaged.

If the wetland is tidal, the score is represented by the weighted average of three indicator groups. One group (1/2 of total score) indicates increasing wetland area, width, and proportion of wetland flooded daily by tide. A second group (1/3 of total score) indicates increasing area of mud flat, tidal channel complexity, adjacency to non-tidal wetlands, and diversity of vegetation forms. The third group (1/3 of total score) reflects decreasing extent of disturbance by human visitors and absence of powerlines and other hazards to flying waterbirds.

Approach for Future Validation: Among a series of wetlands spanning the function scoring range and a range of wetland condition (integrity), feeding waterbird species richness and density would need to be determined monthly and more often during migration (see USEPA 2001 for methods). Ideally, daily duration of use and seasonal weight gain should be measured.

VALUES MODEL

Structure: A wetland gets a “10” for this function if it is known to support a rare waterbird species outside of the nesting season, or is within an area that has been officially designated as an Important Bird Area (IBA). Otherwise, its value score reflects an average based on some evidence for rare species in the vicinity, zoning designation of Developed or Agriculture, increased visibility of the wetland from a public road, and the site being one of the only herbaceous wetlands within 0.5 mile.

AQUATIC INVERTEBRATE HABITAT (INV)

Function Definition: The capacity to support an abundance and diversity of invertebrate animals which spend all or part of their life cycle underwater or in moist soil. Includes dragonflies, midges, crabs, clams, snails, crayfish, water beetles, shrimp, aquatic worms, and others. See worksheet *WetInverts* in the *ORWAP_SuppInfo* file for list of freshwater aquatic invertebrates known or likely to occur in Oregon wetlands. The model described below will not predict habitat suitability accurately for every species.

Scientific Support for This Function in Wetlands Generally: High. All wetlands support invertebrates, and many wetlands support aquatic invertebrate species not typically found in streams, thus diversifying the local fauna. Densities of aquatic invertebrates can be exceptionally high in some wetlands, partly due to high primary productivity and partly because submerged vegetation provides additional structure (vertical habitat space).

FUNCTION MODEL

Full model structure: For non-tidal wetlands, half of the score is determined by *Structure* and half by the average of *Hydroperiod, Landscape* and *Stressors.* The submodels are described below.

Submodel structures:

- *Structure* is assumed to increase with increases in three indicators and one indicator group average. The indicators are interspersion of water and emergent vegetation, complexity of surface water flow paths through the wetland, and percent cover of submersed aquatic vegetation. Less influential is the average of increasing emergent vegetation area, emergent vegetation percentage, herbaceous plant diversity, depth diversity, ground cover, downed wood, nitrogen fixing plants, and microtopographic variation.
- *Hydroperiod* is assumed most favorable when a moderate to large percentage of the wetland contains surface water persistently (1/2 of score), and secondarily, when most of the water is ponded, levels fluctuate moderately and seasonally, depths are shallow, there is evidence of groundwater discharging to the wetland, and there is an intermediate proportional extent of persistent water (scores for those indicators are averaged).
- *Landscape* condition is assumed better for invertebrates when land cover in the contributing area is mostly natural, as represented by the average of three indicators which reflect that.
- *Stressors* are represented partly by the average of increased soil disturbance, excessive sediment inputs, and altered timing of the water regime. The score is actually the reverse of these conditions, such that their absence raises the overall score for this function.

If the wetland is tidal, the score is the weighted average of one indicator and two groups. A higher score results from having proportionally more area as low marsh (accounting for half the score), as well as a group average that accounts for one-third the score and reflects greater internal channel complexity, adjacency to a connected non-tidal wetland, greater diversity of vegetation forms, unaltered tidal exchange regime, and non-sandy soils. The other group average reflects lower risk of invasive marine invertebrates being present and increased amount of driftwood, large partly-submerged wood, ground cover, and shade.

Approach for Future Validation: Among a series of wetlands spanning the function scoring range and a range of wetland condition (integrity), the aquatic invertebrate richness, density, and (ideally) productivity would need to be measured regularly throughout the year.

VALUES MODEL

Structure: If the wetland is tidal, the value score for Invertebrate Habitat is the average of the function scores for Resident Fish Habitat, Feeding Waterbird Habitat, and Songbird-Raptor-Mammal Habitat. For non-tidal wetlands, the value is the maximum of (1) documentation of a rare invertebrate species within the wetland, (2) the wetland's watershed is relatively lacking in good invertebrate habitat, (3) the zoning designation is Development or Agriculture, (4) there is some evidence for rare species in the vicinity the wetland or the wetland contains nearly the only patch of herbaceous or woody vegetation within 0.5 mile, and (5) the average of the scores for the following functions is large: Resident Fish Habitat, Amphibian Habitat, Feeding Waterbird Habitat, Songbird-Raptor-Mammal Habitat.

NATIVE PLANT DIVERSITY (PD)

Function Definition: The capacity to support, at multiple spatial scales, a diversity of native, hydrophytic, vascular and non-vascular (e.g., bryophytes, lichens) plant species, communities, and/or functional groups, especially those that are most dependent on wetlands or water. See worksheet *P_WetIndic* in the *ORWAP_SuppInfo* file for list of the species.

Scientific Support for This Function in Wetlands Generally: High. Many plant species grow only in wetlands and thus diversify the local flora, with consequent benefits to food webs and energy flow.

FUNCTION MODEL

Full model structure: If a tidal or non-tidal wetland has more than 10 percent cover of invasive herbaceous plants and more than 80 percent cover of all non-native plants, its function score is “0”. Otherwise, for non-tidal wetlands the function score is the weighted average of the scores for *Species-Area* (weight of 3), *Stressors* (weight of 2), *Aquatic Fertility*, *Competition/Light*, and *Landscape.* The submodels are described below.

Submodel structures:

- *Species-Area* reflects the fact that wetland plant species richness often increases rapidly with increasing wetland size. This is represented by the average of increasing emergent vegetation area, wetland width, wetland buffer width and extent, and increasing percentage of the wetland that is inundated only seasonally.
- *Stressors* are indicated by the average of two indicators. One represents greater percent cover of non-native or invasive plants, and the other is a group average of greater

proximity to roads, larger percent cover of invasive plants along the upland edge, higher frequency of human visitation, altered timing of runoff, soil disturbance, and overgrazing. The score is actually the reverse of these conditions, such that their absence raises the overall score for this function.

- *Aquatic Fertility* of the wetland is indicated by presence of a tributary, circuitous water path through the wetland, organic soils, mildly fluctuating water level with relatively even distribution of multiple water depth classes, a higher degree of interspersion of vegetation and open water, stronger evidence of groundwater input, and not being recently constructed or restored. The scores of these indicators are averaged.
- *Competition/Light* influence scores highest where there are intermediate proportions of emergent and woody vegetation, lack of any strongly dominant herbaceous species, and extensive microtopographic variation. The scores of these indicators are averaged.
- *Landscape* influence is represented by greater proximity and connectivity to large tracts of natural land cover (especially forest), and presence of beaver. The scores of these indicators are averaged.

For tidal wetlands, the function score is an average that reflects less cover of invasive plants, lack of altered timing of runoff, lower salinity (or location closer to head-of-tide); a group that includes greater marsh area, width, and less daily inundation; a group that includes greater vegetation form diversity and lack of overgrazing or a strongly dominant species; a group that emphasizes larger buffer width and extent; and a group that reflects greater channel complexity, microtopographic variation, and non-sandy soils.

<u>Approach for Future Validation</u>: Among a series of wetlands spanning the function scoring range and a range of wetland condition (integrity), all plant species would be surveyed and percent-cover determined at their appropriate flowering times during the growing season. Standardized protocols for wetland plant surveys are well-established.

VALUES MODEL

<u>Structure</u>: A non-tidal wetland gets a "10" for this function if it known to support an especially rare plant species or is a rare wetland type. Otherwise, its value score reflects an average based on some evidence for rare species in the vicinity, proximity to a large area of perennial cover, a zoning designation of Developed or Agriculture, high function scores for Pollinator Habitat and Songbird-Raptor-Mammal Habitat, and is one of the only herbaceous or wooded wetlands within 0.5 mile. A tidal wetland gets a "10" if it is a tidal forested wetland. Otherwise, its value score reflects an average based on support of or proximity to rare species, a zoning designation of Developed or Agriculture, and high function scores for Pollinator Habitat and Songbird-Raptor-Mammal Habitat.

POLLINATOR HABITAT (POL)

<u>Function Definition:</u> The capacity to support pollinating insects, such as bees, wasps, butterflies, moths, flies, and beetles.

Scientific Support for This Function in Wetlands Generally: Moderate. Many wetlands may be important to pollinators because they host different plant species than those in surrounding uplands, which implies they may flower at different times than those in the uplands, and may do so over a prolonged season due to greater water availability in wetlands. Little is known about pollinators in tidal wetlands.

FUNCTION MODEL

Full model structure: A non-tidal wetland is automatically scored "0" if it is almost entirely and persistently flooded. Otherwise, the function score is represented by the average of the scores for *Pollen Onsite*, *Pollen Offsite*, and *Nest Sites*. The submodels are described below.

Submodel structures:

- *Pollen Onsite* is represented by the average of the scores for greater percent cover of forbs (1/2 of score) and an average reflecting less cover of invasive plants, lack of one dominant herbaceous species, and intermediate extent of ground cover (1/2 of score).
- *Pollen Offsite* is represented by the average of the scores for increased buffer width and extent, proximity to perennial cover, and the percentage and proximity to open land.
- *Nest Sites* available for pollinating insects are assumed to increase with increased snags, large-diameter trees, downed wood, microtopographic variation, and cliffs. Loose rock associated with cliffs or talus slopes provides nest areas for some pollinating insects. The scores of these indicators are averaged.

For tidal wetlands, the function score is the weighted average of two groups. One group accounts for two-thirds of the score and reflects greater forb cover, a larger proportion of high marsh, and greater marsh width. The other group reflects lack of a single dominant plant species and proximity to cliffs.

Approach for Future Validation: Among a series of wetlands spanning the function scoring range and a range of wetland condition (integrity), the frequency with which flowers of dominant wetland plants are visited by various pollinating species should be monitored throughout the periods when each species is flowering.

VALUES MODEL

Structure: A wetland gets a higher value score for this function if it has a zoning designation of Agriculture (due to pollinator importance to crops), is surrounded by very little other natural cover, provides one of the only patches of herbaceous, shrub, or forested land within 0.5 mile, and/or hosts a rare plant species. The scores of these indicators are averaged.

SONGBIRD, RAPTOR, AND MAMMAL HABITAT (SBM)

Function Definition: The capacity to support an abundance and diversity of songbirds, raptors, and mammals, especially species that are most dependent on wetlands or water. See worksheet

WetVerts in the *ORWAP_SuppInfo* file for list of the species. The model described below will not predict habitat suitability accurately for every species in this group.

Scientific Support for This Function in Wetlands Generally: High. Dozens of songbirds, raptors, and mammals depend almost exclusively in wetlands. Densities can be exceptionally high in some wetlands, partly due to high productivity of vegetation and invertebrates, and partly because wetland vegetation provides nest sites in close proximity to preferred foods.

FUNCTION MODEL

Full model structure: The function score for non-tidal wetlands is represented by the weighted average of the scores for *Structure* (30% of the total score), *Productivity* (30%), *Landscape* (20%), *Waterscape* (20%) and *Stressors* (10%). The submodels are described below.

Submodel structures:

- *Structure* is represented by the average of increasing emergent vegetation area (1/2 of total score) and a group average of 13 indicators. Those indicators reflect intermediate levels of shrub and herbaceous vegetation cover especially emergents and cattail/bulrush, extensive woody cover next to surface water, a high degree of interspersion between vegetation and open water, intermediate extent of ground cover, large microtopographic variation, and increased extent of snags, down wood, large trees, and cliffs.
- *Productivity* of the wetland is indicated by longer growing season, larger percentage of the wetland that is flooded only seasonally, and larger wetland width. The scores of these are averaged.
- *Landscape* influence is represented by increasing width, coverage and perimeter complexity of a vegetated buffer, proximity to large tracts of natural land cover, percent forest cover within 2 miles, and lack of developed land within that distance. The scores of these are averaged.
- *Waterscape* is represented by presence of beaver, greater vegetated connectivity to another wetland, proximity to a ponded water, and located in a watershed with relatively large total wetland area and diversity of wetland types. The scores of these are averaged.
- *Stressors* are indicated by greater proximity to roads and higher frequency of human visitation. The score is actually the reverse of these conditions, such that their absence raises the overall score for this function.

If the wetland is tidal, the function score is automatically set to "10" if the wetland is a forested tidal wetland (those are rare in Oregon and likely provide excellent songbird habitat). Otherwise, it is the weighted average of three groups. One group (1/2 of the total score) is the average of scores for greater tidal wetland area, width, and percentage not flooded daily by tides. Another group (1/3 of the total score) averages the scores indicating fresher salinity, a wider and more extensive buffer of natural vegetation, and adjacency to a non-tidal wetland. The third group indicates denser ground cover, presence of multiple vegetation forms with none strongly dominant, and proximity to cliffs or banks.

Approach for Future Validation: Among a series of wetlands spanning the function scoring range and a range of wetland condition (integrity), species richness and density of songbirds, raptors, and mammals would need to be determined monthly and more often during migration or seasonal movements (see USEPA 2001 for methods). Ideally, daily duration of use and seasonal weight gain of key species should be measured.

VALUES MODEL

Structure: A wetland gets a score of "10" for this function if it is known to support a rare songbird, raptor, or mammal species. Otherwise, its value score reflects an average based on some evidence for rare species in the vicinity, a zoning designation of Developed or Agriculture, is one of the only herbaceous or wooded wetlands within 0.5 mile, is highly visible to the public, or is located in one of the drier watersheds in the state.

WATER COOLING (WC)

Function Definition: The effectiveness of a wetland for maintaining or reducing summertime water temperature, and in some cases, for moderating winter water temperature. In earlier versions of ORWAP this was called Thermoregulation.

Scientific Support for This Function in Wetlands Generally: Low to moderate. Most wetlands are areas of groundwater discharge, and ground water tends to be cooler than surface water, so wetlands have the potential to mediate wide daily and seasonal fluctuations in surface water temperature. However, wetlands are also wide flat areas with long water retention times, and the influence of those factors on surface water temperature can sometimes offset the influence of groundwater input.

FUNCTION MODEL

Full model structure: For non-tidal wetlands, the function score increases if evidence of groundwater input is strong. That accounts for half of the score. Another one-fourth of the score is increasing extent of surface water shaded by woody wetland vegetation during the summer, averaged with a group representing greater wetland width, larger proportion of the wetland containing woody or emergent vegetation, and denser ground cover. The remaining one-fourth of the score represents less ponding of water, presence of surface water for shorter periods, and deeper water depth. If the site has surface water for 4 weeks or less during the growing season, the function score results from averaging groundwater influence (2/3 of score) with a group average representing denser ground cover and a larger portion of area containing woody vegetation.

If the wetland is tidal, the site is scored a "0" because the volume of water flowing out of tidal wetlands is typically dwarfed by the huge volume of water exchanged hourly within the connected estuary, thus virtually nullifying the thermal effects of tidal wetlands on the estuary.

Approach for Future Validation: Among a series of wetlands spanning the function scoring range and a range of wetland condition (integrity), water temperature could be measured continuously at wetland inlet and outlet, if any, using thermodata loggers (Dunham et al. 2005).

Alternatively, when appropriate, ORWAP scores could be compared with results from more deterministic models such as Shade-o-Lator (Boyd & Kasper 2003).

VALUES MODEL

Structure: If there is no outflow or temporary outflow from the wetland, the value is set to "0". Otherwise, half the value of this function is attributed to the zoning designation of the location, with water cooling assumed to be valued most where Agriculture or Development is the designation. The other half of the value score increases with an increasing weighted average of four groups. One group, with a weight of 4, reflects the presence of anadromous fish habitat (ESH), connection to known problems with excessively warm water, or a wetland being located in a watershed identified as being deficient in wetlands with water cooling capacity. A second group reflects increasing persistence of outflow from the wetland. A third reflects absence of a wide wetland buffer and increasing extent of impervious surfaces in the wetland contributing area. The fourth is an average of scores for increasing ratio of wetland area to area of the wetland's streamflow contributing area, headwater position, lower elevation, and longer growing season.

ORGANIC MATTER EXPORT (OE)

Function Definition: The effectiveness of a wetland for producing and subsequently exporting organic matter, either particulate or dissolved.

Scientific Support for This Function in Wetlands Generally: Moderate-High. Wetlands which have outlets are potentially major exporters of organic matter to downstream waters. That is partly because many wetlands support exceptionally high rates of primary productivity. Numerous studies have shown that watersheds with a larger proportion of wetlands tend to export more dissolved and/or particulate carbon that is important to downstream food webs, compared with watersheds that have few wetlands. Value to food webs depends partly on the quality and timing of the exported carbon.

FUNCTION MODEL

Full model structure: For non-tidal wetlands, the site scores "0" for this function if it has no surface water outlet. Otherwise, the score is the weighted average of *Export Potential* (weight of 3), *Productivity* (weight of 2), and *Historical Accumulation*. The submodels are described below.

Submodel structures:

- *Export Potential* increases according to the average of (1) increased duration of surface water outflow, (2) flatter wetland gradient, (3) location in part of the state with higher annual precipitation, and (4) a group average based on less outlet constriction, less ponding, narrower vegetated width, more submersed aquatic plant cover, lower elevation in a watershed, and greater interspersion of vegetation and open water.

- Current *Productivity* is comprised of three factors that are averaged: *Frozen Duration, Nutrient Availability*, and *Plant Cover*. These are described as follows:
  - *Frozen Duration* is assumed to decrease with longer growing season and presence of discharging groundwater. The scores of these are averaged.
  - *Plant Cover* available for rapid export is assumed to be greater with greater area of emergent vegetation, averaged with a group average of decreasing bare ground extent, shallower water depth, and greater percentage of the wetland occupied by emergent vegetation.
  - Greater *Nutrient Availability* is reflected by moderately fluctuating water levels, increased cover of nitrogen fixing plants, greater proportion of the wetland that is inundated only seasonally, more flowing than ponded water, and the wetland not being recently constructed. These are considered equally predictive of Nutrient Availability and so their scores are averaged.
- *Historical Accumulation* (existing carbon store or stock) is based on soil texture, with organic soils considered most important, averaged with extent of moss ground cover, with moss wetlands typically having limited opportunity to export organic matter.

If the wetland is tidal, the score increases with the average of four indicator groups. The most influential of these, accounting for half the score, is an average that reflects increasing percentage of the site that is tidally inundated daily, unimpeded tidal exchange, and multiple blind channels. A second group average is greater if the marsh is steeply sloping but wide, has a tributary with steep slope, an unconstricted outlet, and is exposed to waves. A third group is the greater of salinity or proximity to the ocean (estuarine position). The fourth is the average for increasing shading of tidal waters (an indirect indicator of detrital input), increasing connection to non-tidal wetlands, lack of a single dominant plant species, and greater dominance by emergent or woody vegetation.

VALUES MODEL: No model is provided because this function's values are diffused throughout all receiving water bodies.

CARBON SEQUESTRATION (CS)

<u>Function Definition</u>: The effectiveness of a wetland both for retaining incoming particulate and dissolved carbon, and through the photosynthetic process, converting carbon dioxide gas to organic matter (particulate or dissolved), and to then retain that organic matter on a net annual basis for long periods *while emitting little or no methane* (a potent "greenhouse gas"). Note that most published definitions of Carbon Sequestration do not include the important limitation on methane emission.

<u>Scientific Support for This Function in Wetlands Generally</u>: Although many wetlands support exceptionally high rates of primary productivity, many other factors determine whether a wetland is a net source or sink for carbon. Artificial disturbances or extreme events, such as increased frequency of drought, wildfire, or increased water levels (e.g., from global warming, tsunamis, artificial drainage), can quickly reverse gains in the amount of carbon sequestered in a

wetland. Moreover, some of the most productive non-tidal wetlands also tend to be among the most significant emitters of methane, a potent greenhouse gas.

FUNCTION MODEL

Full model structure: For non-tidal wetlands, the score is higher if (1) its existing ("legacy") carbon stores (*Historical Accumulation*) are large or the wetland has a great ability to physically retain organic matter it produces or receives from upgradient sources (*Physical Accumulation*), (2) the average of *Warmth* and *Plant Cover* indicates higher productivity, and (3) it lacks factors that suggest it has substantial methane emissions (*Methane Limitation*). In the final model, *Methane Limitation* is weighted equally with the accumulated score of the other processes (those which indicate carbon retention). The submodels are described below:

Submodel structures:

- *Historical Accumulation* (existing carbon store) considers first if this is a new wetland. If so, Historical Accumulation is based only on its estimated age. If not, this factor is calculated as the average of greater extent of moss cover, organic soils, and lack of soil disturbance. To a lesser degree, the score for this factor increases with increasing percent cover of trees and shrubs, outlet constriction, wetland vegetated width, and a shorter growing season.
- *Physical Accumulation* is half-attributable to less persistent outflow and half to the average of a flatter wetland gradient, an intermediate percentage of ponded water, and an artificial (presumably more constricted) outlet if an outlet is present at all.
- *Warmth* facilitates plant productivity and is indicated by longer growing season and lack of evidence of groundwater input. The scores of these indicators are averaged.
- *Plant Cover* score is half-attributable to wetland vegetated width and half to the average of increasing ground cover density, shallow water depth, and extensive cover of either woody or emergent vegetation.
- *Nutrient Availability* is assumed greater if some water level fluctuation occurs and results in a large percentage of the wetland being inundated only seasonally. The scores of these indicators are averaged.
- *Methane Limitation* is considered to occur if the wetland has higher salinity, little permanent surface water, tree cover (if any) that is coniferous, and extensive moss cover. These are considered equally predictive of Methane Limitation and so are averaged.

If the wetland is tidal, the score is the average of five indicators or groups. One is the greater of the scores for estuarine position (closer proximity to ocean is preferable) and salinity (more saline is preferable). A second represents vegetation form, with emergent herbaceous and especially woody considered more likely to support Carbon Sequestration much more than eelgrass and seaweed. A third is time elapsed since restoration, if the wetland is a restored wetland. A fourth is soil texture, with organic and fine-texture soils considered to have the highest carbon content. The fifth represents increasing wetland width, ground cover density, and percentage of the wetland that is inundated daily.

Approach for Future Validation: Among a series of wetlands spanning the function scoring range and a range of wetland condition (integrity), particulate and dissolved organic carbon would need to be measured regularly at wetland inlet and outlet, if any, along with measurements of changes in water volume. Equally important, emissions of methane and carbon dioxide would need to be measured regularly throughout the year and throughout the day/night cycle. Plant productivity rates (especially belowground), hydrology, and carbon accumulation in sediments or soils would require measurement as well. Results might be extrapolated to a broader range of conditions using existing site-scale models that require such detailed data (e.g., Frolking et al. 2002, St. Hilaire et al. 2008).

VALUES MODEL: No model is provided because this function's values are diffused throughout the planet.

PUBLIC USE & RECOGNITION (PU)

Definition: Prior designation of the wetland, by a natural resource or environmental protection agency, as some type of special protected area. Also, the potential and actual capacity of a wetland to sustain low-intensity outdoor recreation (such as hiking or nature photography), education, and research. The model assumes that more human use of a wetland means that the particular wetland is more valued by the public. However, it is recognized that some individuals would value more those wetlands that receive less human use because heavy use compromises the solitude sought and valued by some.

Full model structure: The score for Public Use & Recognition, for both tidal and non-tidal wetlands, is assumed to increase with an increase in scores for Ownership (1/2 of score) and the average of Zoning, *Convenience & Outputs*, and *Investment* (1/2 of score). The submodels are described below.

Submodel structures:

- *Convenience & Outputs*: For non-tidal wetlands, the score is greater where most of wetland is physically accessible and visited often, is near a road and mostly visible from it, has a zoning designation of Development, is near a visitor center or has similar educational or recreational enhancements, has evidence that multiple sustainable resources (e.g., hay, timber, fish) are harvested, and adjoins a large expanse of open water. Scores for these are averaged. For tidal wetlands, the model is the same except visibility from a road and proximity to a large expanse of open water are not used as indicators.
- *Investment:* This is intended to reflect positively any past expenditure of public funds for the wetland's conservation, as well as designation as a mitigation site or regular use for scientific research or non-regulatory monitoring. The metric's score is based on the maximum of these indicator scores.

WETLAND SENSITIVITY (SEN)

Definition: the lack of intrinsic resistance and resilience of the wetland to human and natural stressors (Niemi et al. 1990), including but not limited to changes in water chemistry, shade, frequency and duration of inundation or soil saturation, water depth, biological invasion, habitat fragmentation, and others as described in the USEPA report by Adamus et al. (2001).

Full model structure: The function score for non-tidal wetlands is represented by the average of the scores for Rare Wetland Type, *Abiotic Resistance/ Sensitivity, Biotic Resistance/ Sensitivity, Resilience/ Recovery Duration- Colonizer Availability Influence*, and *Resilience/ Recovery Duration- Veg Growth Rate Influence*. The submodels are described below.

- *Abiotic Resistance* is assumed to be less (i.e., more sensitive) in wetlands that either (1) have organic or clay soil, (2) are a rare wetland type, (3) lack a persistent surface water outlet, or (4) are in a headwater location, have more ponded water than flowing water, have extensive pavement in the runoff contributing area, have shallow water depth and artificial drainage. The maximum score of these four indicator groups is selected to represent the overall submodel score.
- *Biotic Resistance* is assumed to be less (i.e., wetland more sensitive) in wetlands that either (1) host a rare wetland plant species, or (2) contain one of the only patches of herbaceous or woody vegetation within 0.5 mile, have relatively intact native vegetation with no strongly dominant species, or are a newly established wetland with sparse ground cover. The maximum score of these two indicator groups is selected to represent the overall submodel score.
- *Resilience/ Recovery Duration- Colonizer Availability Influence* is calculated as the greater of two group averages. One reflects smaller and less extensive buffer width, and farther distance to the nearest big tract of perennial cover. The other reflects farther distance and poorer vegetative connectivity to the nearest other pond or wetland, and generally low diversity and area of wetlands in the associated watershed.
- *Resilience/ Recovery Duration- Veg Growth Rate Influence* averages the scores for increasing moss cover, shorter growing season, absence of nitrogen fixing plants, greater wooded extent (especially older-growth trees), presence of beaver, and location in a relatively arid watershed.

If the wetland is tidal, its sensitivity score is the average of three indicators and one group. The group is the average of fewer vegetation forms, sparser ground cover, less extensive cover of invasive plants, and higher native plant diversity. The three indicators reflect rare wetland types, soil texture (organic and clayey soils considered more sensitive), and a narrow width of vegetated wetland.

WETLAND ECOLOGICAL CONDITION (EC)

Definition: The integrity or health of the wetland as defined primarily by its vegetation composition (because that is the only meaningful indicator that can be estimated rapidly). More broadly, the structure, composition, and functions of a wetland as compared to reference wetlands of the same type, operate within the bounds of natural or historic disturbance regimes. However, in the case of ORWAP, no attempt was made to normalize the model outputs to least-altered reference wetlands.

Structure: Wetlands that are scored as being in the best ecological condition (i.e., have the highest integrity) are those that contain rare species, no plant or animal pest species, a large wide portion that is flooded only seasonally, extensive microtopographic variation, dense ground cover, have no strongly dominant species, and haven't been overgrazed. The indicator scores of these are averaged. For tidal sites, the score is the average of the scores for percent cover of invasive plants and extent of overgrazing.

WETLAND STRESSORS

Definition: The degree to which the wetland is or has recently been altered by, or exposed to risk from, primarily human-related factors capable of reducing one or more of its functions.

Structure: Wetlands are automatically scored a "10" if input water has a water quality issue. Otherwise, the score is the maximum of *Hydrologic Stressors*, *Water Quality Stressors*, *Fragmentation Stressors*, and *Disturbance Stressors*. These submodels are described below.

- *Hydrologic Stressors* represents altered timing of water inputs, changes in confinement where surface water exists the wetland, and for non-tidal wetlands a relatively large proportion of the precipitation in the runoff contributing area reaching the wetland quickly. The scores of these indicators are averaged.
- *Water Quality Stressors* indicates accelerated inputs of nutrients, contaminants, and sediment from the runoff of stream contributing area. The scores of these indicators are averaged.
- *Fragmentation Stressors* represents fewer, smaller and more distant areas of perennial cover, few other connected wetlands, and lack of buffers. The scores of these indicators are averaged.
- *Disturbance Stressors* is an average of scores representing proximity to a road and higher visibility, frequent visitors to a larger portion of the wetland, and a higher percentage of invasive plants along the edge of the wetland.

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