Appendix F. Descriptions of the WESPAK-SE Models[1]

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1.0 Organization of This Appendix

This appendix begins with a discussion of general principles used to score WESPAK-SE's indicator variables (questions in data forms) and to structure the WESPAK-SE models of wetland functions and values which the indicators are intended to predict. The narrative then proceeds to describe, for each function and its value, specifically how the indicator variables were combined in scoring models. The indicators mentioned in the descriptions in section 3.0 of this appendix are shorthand versions of indicators that are defined and explained fully in the WESPAK-SE data forms: worksheets OF (office form), F (field form), and S (stressor form) in the WESPAK-SE Excel calculator spreadsheet. The appendix ends with a description of a few other methods available for assessing wetlands in Southeast Alaska.

2.0 Principles Used to Score Indicators and Structure the Models

2.1 Introduction

Many models in ecology and especially hydrodynamics are deterministic. That is, rates are first estimated or measured for individual processes that comprise (for example) a river channel function, and then mathematical formulas (e.g., hydraulic or thermodynamic equations) are prescribed to combine variables that determine those processes into an actual rate for a function, e.g., grams of phosphorus retained per square meter per year. However, in the case of wetlands, generally applicable measurements of the processes and the variables that determine them simply do not exist for the types of wetlands occurring in Southeast Alaska. Due to the lack of data involving direct measures of wetland function from a broad array of wetlands, WESPAK-SE uses a different approach to model the various things that wetlands do naturally. Rather than being deterministic, that approach is at times speculative but logic-based and heuristic. Such approaches are well-regarded as an interim or alternative solution when knowledge of system behaviour is scant (e.g., Haas 1991, Starfield et al. 1994, Doyle 2006).

2.2 Indicators

For most WESPAK-SE models, physical or biological *processes* that influence a given function were first identified and then *indicators* of those processes were chosen and grouped accordingly. (The term *indicators* is comparable to the term *metrics* used by some other methods). The indicators then were phrased as questions in the data forms. None of WESPAK-SE's field-level indicators require *measurement*; they all are based on visual estimates. While the *precision* of measurements is typically greater than for visual estimates, their *accuracy* in predicting functions may or may not be. That is because it is often difficult to obtain sufficient measurements of an indicator, in the span of time typically available to wetland regulators or consultants, to create a full representation of any particular indicator of wetland function, let alone all the 129 indicators needed to reasonably assess a common suite of functions and values.

WESPAK-SE's indicators were mainly drawn from inferences based on scientific literature and the author's experience throughout North America (e.g., Adamus et al. 1987, 2013, Adamus et al. 1992, 2009). Indicators used by other methods for rapidly assessing functions and values of wetlands were also considered. To qualify as an indicator, a variable not only had to be correlated with or determining of the named process or function, but it also had to be rapidly observable during a single visit to a typical wetland during the growing season, or information on the indicator's condition had to be obtainable from aerial imagery, existing spatial data, and/or landowner interview.

When developing models of any kind, the factors that contribute to the output can be categorised in three ways: (1) unknown influencers, (2) known influencers that are difficult to measure within a reasonable span of time, and (3) influencers that can be estimated visually during a single visit and/or from existing spatial data. WESPAK-SE provides an incomplete estimate of wetland functions because it incorporates only #3. Also, some of the indicator variables it uses may be *correlates* of wetland functions rather than actual influencers. For example, changes in water levels are correlated with changes in nutrient cycling, but it is the difficult-to-measure changes in sediment oxygen and pH that induce the changes in nutrient cycling, not the water level changes themselves (which happen to correlate loosely with those changes in oxygen and pH). These types of limitations apply to all rapid assessment methods.

For regulatory and management applications (e.g., wetland functional enhancement), it's often helpful to understand to which of four categories an indicator belongs:
1. *Onsite modifiable*. These indicators are features that may be either natural or human-associated and are relatively practical to manage. Examples are water depth, flood frequency and duration, amount of large woody debris, and presence of invasive species. More important than the simple presence of these are their rates of formation and resupply, but those factors often are more difficult to control.

2. *Onsite intrinsic*. These are natural features that occur within the wetland and are not easily changed or managed. Examples are soil type and groundwater inflow rates. They are poor candidates for manipulation when the goal is to enhance a particular wetland function.
3. *Offsite modifiable.* These are human or natural features whose ability to be manipulated in order to benefit a particular wetland function depends largely on property boundaries, water rights, local regulations, and cooperation among landowners. Examples are watershed land use, stream flow in wetland tributaries, lake levels, and wetland buffer zone conditions.
4. *Offsite intrinsic*. These are natural features such as a wetland's topographic setting (catchment size, elevation) and regional climate that in most cases cannot be manipulated. Still, they must be included in a wetland assessment method because of their sometimes-pivotal influence on wetland functions and values.

2.3 Weighting and Scoring

WESPAK-SE assigns relative weights or scores at three junctures:
1. Scoring of the *conditions* of an indicator, as they contribute to that indicator's prediction of a given wetland process, function, value, or other metric.
2. Scoring of *indicators* (metrics) relative to each other, as they together may predict a given wetland process, function, value, or other metric.
3. Scoring of wetland *processes*, as they together may predict a given wetland function or other attribute.

Each of these is now described. Note that WESPAK-SE does not assign weights to the functions and values that it scores, e.g., does not assume that Amphibian Habitat is any more or less important than Nitrate Removal.

2.3.1 Weighting of Indicator Conditions

As an example of #1, consider the following conditions of the indicator *Open Ponded Water – Extent*, as that indicator is applied to estimating the Waterbird Nesting Habitat function found in worksheet WBN of the calculator:

F17	Open Ponded Water - Extent	In aerial "duck's eye view", the percentage of the ponded water that is open (lacking emergent vegetation during most of the growing season) is:				0.67
		<1% or none, or largest pool occupies <100 sq. ft. Enter "1" and SKIP to F20.	0	1	0	
		1-5% of the ponded water. Enter "1" and SKIP to F20.	0	2	0	
		5-30% of the ponded water.	1	4	4	
		30-70% of the ponded water.	0	6	0	
		70-99% of the ponded water.	0	4	0	
		100% of the ponded water. SKIP to F18.	0	3	0	

Each row following the first describes a possible *condition* of the indicator, Open Ponded Water – Extent. WESPAK-SE users must select the one condition that best describes the wetland they are assessing (they do so by entering a "1" next to that condition in the column to the right of the text). In the column after that, WESPAK-SE's author previously assigned relative weights (which cannot be altered by WESPAK-SE users) to each of these conditions as they relate to the function, Waterbird Nesting Habitat. In this case, the third condition was considered moderately supportive of that function, other factors being equal, and so had been given a weight of 4. This does not necessarily mean it is 4 times more influential than the first condition which has a weight of 1, because this is not a deterministic model. However, available literature seemed to suggest that this intermediate condition is distinctly better than the second condition and less desirable than the fourth condition. When the same indicator is used to score a different function, the weight scheme might be reversed or otherwise differ.

In many instances, considerable scientific uncertainty surrounds the exact relationship between various indicator conditions and a function, and thus which weights should be assigned. However, keep in mind that the above indicator is just one of about 35 indicators used to assign a score to the Waterbird Nesting Habitat function. To some degree, the use of so many indicators (including several related ones that are averaged together with this one because they probably correlate highly with it) will serve to buffer the uncertainty in our knowledge of exact relationships.

WESPAK-SE users will also notice that the weighting scale for some indicators ranges from 1 to 8 (especially if there are 8 condition choices) while for others it ranges only from 0 to 2, or some other range. This does not mean that the first indicator is secretly being weighted 4 times that of the second, because before the indicators are combined, their scores are "normalized" to a 0 to 1.00 scale. The Excel spreadsheet accomplishes that by multiplying the "1" signifying a user's choice (here in the second column) by the pre-determined condition weight in the third column, and placing the product in the last column, whereupon a formula in the green cell (not visible here) takes the maximum of the values pertaining to this indicator in that last column and divides it by the maximum weight in the condition weight column. The formula in the green cell could just as easily have taken the only non-zero value in the last column and divided it by the maximum weight pre-assigned to the indicator conditions.

Note also that the weight scale for some indicators begins at 0 while for others it begins at 1. Often, "0" was reserved for instances where, if the indicator was the only one being used, that condition of the indicator would suggest a nearly total absence of the function. Because each of the indicator scores is normalized, this difference (0 vs. 1) at the bottom end of the scales for different indicators is probably trivial.

2.3.2 Weighting and Scoring of Indicators of Functions and Values

If one indicator is so important that occurrence of a particular condition of that indicator can solely determine whether a function even exists in a wetland, then conditional ("IF") statements are used in WESPAK-SE models to show that. For example, if a wetland dries up annually and it contains no inlets or outlets, the Resident Fish Habitat function is automatically scored "0". In this case, "access" (presence/absence of inlets or outlets) is a controlling indicator. If a few indicators are not individually so controlling but at least one is likely to be strongly limiting in some instances, WESPAK-SE takes the *maximum* among of the indicators, rather than the average. The latter is applied to situations where indicators are though to be compensatory, collinear, or redundant. WESPAK-SE uses averaging as the default operator unless situations can be identified where there is compelling evidence that an indicator is controlling or strongly limiting.

There also are instances where the condition of one indicator (such as wetland type) is used to determine the relevance of others for predicting a wetland function. For example, the effect of vegetation structure within a wetland on the wetland's ability to slow the downslope movement of water in a watershed can be ignored if the wetland has no outlet channel.

2.3.3 Weighting and Scoring of Wetland Processes That Influence Functions

For many functions, dozens of hydrologic (e.g., evapotranspiration) and/or ecological (e.g., juvenile dispersal) processes contribute to its ultimate level of performance. Often, too little is know about the relative importance of these processes in determining a wetland function, and for some processes there are no known indicators that can be estimated visually. Nonetheless, WESPAK-SE attempted to use processes as an organising framework for the many indicators it employs to score each function. Processes associated with a given function and indicators associated with each process are named in the ochre-colored cells near the bottom of each worksheet in the WESPAK-SE calculator file. For most functions, no more than 3 or 4 contributory processes are defined, with each containing a few to a dozen or more indicators. For most functions, the named processes are weighted like indicators and used as a "subscore" when computing the score for a function. For example, for the function Phosphorus Retention, the function model contains these processes:

[(3*AVERAGE(Adsorb, Desorb) + 2*Connectivity + AVERAGE(IntercepWet,IntercepDry)]/6

That means that the average of Adsorption and Desorption was given half (3/6) of the weight, the average of Connectivity was given one-third (2/6) of the weight, and the average of Dry Interception and Wet Interception was given 1/6 of the weight. They are divided by 6 because that is the sum of their weights (3 + 2 + 1) and the resulting function score, for the sake of clear comparisons, must be normalized to the 0 to 1 scale used by all functions (after being multiplied by 10).

3.0 Descriptions of the WESPAK-SE Models

3.1 SURFACE WATER STORAGE (WS)

<u>Function Definition:</u> 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.

<u>Scientific Support for This Function in Wetlands Generally</u>: Moderate to High. Many non-tidal wetlands are capable of slowing the downslope movement of water, regardless of whether they have significant storage capacity, simply because they are *relatively* flat areas in the landscape. 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.

<u>In Southeast Alaskan Wetlands</u>: Many of the region’s non-tidal wetlands should be capable of performing this function. Those intersected by channels and located on steep slopes are least capable. Where this function is performed to some degree, its *value* will depend partly on wetland location relative to areas potentially damaged by floods.

Flood damages to infrastructure in this region have been relatively infrequent and local, and have occurred mainly as the result of ice jams or wave action associated with storms in marine waters. Also, it is likely that <u>sub</u>surface storage of water in many parts of this region (e.g., in deep peat, alluvium, colluvium) is more substantial than surface water storage. Unfortunately, in most cases subsurface storage cannot be estimated reliably with a rapid assessment method. Typically, it requires measurements of soil depth and texture (at greater depth than is practical to dig during a rapid assessment) and an understanding of subsurface water levels, flow direction, and exchange rate during different seasons.

The model applies only to non-tidal wetlands. No model is provided for this function for tidal wetlands because most such wetlands have little or no effect on coastal flooding.

Non-tidal Wetlands – WS Function Model

<u>Structure</u>: At a coarse level, three types of wetlands are recognized as pertains to this function: (1) those that never contain surface water, (2) those that lack outlets, and (3) all others. A separate model is provided for each.

- If a wetland never contains surface water, its score increases with increasing predicted *Subsurface Storage*, decreasing gradient (flatter being better) and the average of two factors: shorter *Frozen Duration* (propensity to remain frozen for long periods) and greater *Friction*.
- If a wetland contains surface water but lacks a surface flow outlet (not even one that allows outflow seasonally), then it receives the highest possible score for this function.
- If the wetland has a surface water outlet, its score again increases with increasing score for *Subsurface Storage* but also with increasing score for *Friction* and *Live Storage*. The score is calculated as a weighted average, with *Live Storage* (weight of 4), *Friction* (weight of 2), and *Subsurface Storage* (unweighted).

In the above calculations:

- **Subsurface Storage** potential is assumed to be indicated by deep peat soils and lack of evidence of groundwater discharging at the surface (which suggests that subsurface storage areas are nearly full and cannot receive new runoff).
- **Live Storage** is assumed to be indicated by increasing amplitude of water level fluctuation and increasing percent of the wetland's area that floods only seasonally. These are averaged. If the wetland never has any surface water, *Live Storage* is set at 0.

- **Friction** is assumed to be indicated by the average of 3 indicators: shorter duration of outflow, flatter internal gradient, and a group average of four indicators: greater microtopographic variation and channel meandering within the wetland, and by presence of an artificial rather than natural outlet (the latter presumed to be less constricted). These indicators are averaged. If the wetland never has surface water, its *Friction* score is instead the weighted average of decreasing gradient (weight of 3) and the average of increasing ground cover and increasing ground roughness.
- **Frozen Duration** is assumed to decrease with decreasing elevation (relative position in watershed), warmer mean annual temperature, increasing tidal proximity, and south-facing aspect. These are averaged.

Important Note: The model does not account for the wetland's surface area, and obviously, larger wetlands can store more water. Because the model is estimating relative effectiveness per unit area, some smaller wetlands will have higher scores for this function than larger ones. Thus, in the case of this particular function, a multiplication of function score by effective wetland area may sometimes be appropriate.

<u>Potential for Future Validation</u>: 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 that might be used are partly described by Warne & Wakely (2000) and US Army Corps of Engineers (2005).

Non-tidal Wetlands – WS Values Model

<u>Structure</u>: If buildings or public infrastructure within 2 miles downriver from the wetland have been damaged or are in a mapped floodplain, the wetland receives the highest possible score for value. Otherwise, increasing value for the Water Storage function is influenced by the average of 2 factors which together reflect the magnitude of potential runoff reaching a wetland and thus increasing opportunity to perform this function. One of the factors represents the extent of unvegetated upslope surfaces -- more impervious or semi-pervious proportional surface indicates more opportunity for downslope wetlands to influence flood peaks. This factor is indicated by increases in the proportional area of the catchment that is unvegetated, connectivity and proximity to glacier-fed river, lower position in a regional watershed, and by the wetland comprising a larger portion of its catchment. The other factor, Transport, represents the

potential for runoff to be transported to a wetland as related to steeper slope and decreasing vegetation in its contributing area.

3.2 STREAM FLOW SUPPORT (SFS)

Function Definition: The effectiveness of a wetland for prolonging surface water in headwater streams during seasonally dry periods. This is important for fish passage and overall ecological support.

Scientific Support for This Function in Wetlands Generally: Moderate.

In Southeast Alaskan Wetlands: Many of the region's non-tidal wetlands should be capable of performing this function. If not feeding streams directly themselves, many wetlands at least are discharge sites for groundwater which in turn feeds streams. Higher in a watershed, some wetlands are capable of recharging groundwater, which ultimately discharges to wetlands and then streams lower in the watershed.

Non-tidal Wetlands – SFS Function Model

The model applies only to non-tidal wetlands. No model is provided for tidal wetlands because most tidal wetlands store water for (at most) a few hours and thus are unlikely to have measurable effects on the amount of marine water.

Structure: The model considers three factors: *Groundwater Input*, C*onnectivity*, and *Climate*. *Connectivity* is considered the controlling factor, so if the wetland lacks both a surface flow outlet (at any season) and is not immediately upslope from a stream channel, the score is set at 0. Otherwise, the *Connectivity* score is multiplied by the weighted average of *Groundwater Input* (weight of 2) and *Climate* (unweighted).

In the above calculations:

- **Connectivity** is considered greater in wetlands with longer-duration surface water outflows. Wetlands without outflows are scored "0" for this function unless they are very near streams, in recognition of the possibility of a subsurface connection.
- **Groundwater Input** is assumed to be more likely if a wetland is of a particular type (e.g., fen) or there are other clues that groundwater may be discharging significantly to the wetland. These 2 indicators are averaged.
- **Climate** is assumed to influence wetland contribution to streamflow, and is represented by longer duration of ice cover (slow-melting ice helps sustain early summer streamflow), northerly aspect, greater water depth, and presence of soils

with greater water-holding capacity, e.g., peat. All these indicators are considered to be about equally predictive and so are averaged together.

Important Note: The model does not account for the wetland's surface area, and obviously, larger wetlands could potentially deliver more water to streams if other factors support this function. Because the model for this function is estimating relative effectiveness per unit area, some smaller wetlands will have higher scores than larger ones. Thus, in the case of this particular function, a multiplication of function score by effective wetland area may sometimes be appropriate.

Non-tidal Wetlands – SFS Values Model

The value of the Streamflow Support function is assumed greater in wetlands that also have high scores for supporting habitat of invertebrates, anadromous fish, and/or resident fish, as well as those not being fed by glaciers and those in headwaters of large watersheds. These indicators are considered to be about equally predictive of the value of this function and so are averaged.

3.3 STREAMWATER COOLING (WC)

Function Definition: The effectiveness of a wetland for maintaining or reducing the water temperature, primarily in headwater streams.

Scientific Support for This Function in Wetlands Generally: Moderate.

In Southeast Alaskan Wetlands: Many of the region's non-tidal wetlands should be capable of performing this function. The model applies only to non-tidal wetlands. No model is provided for this function for tidal wetlands. In nearby British Columbia, one study found that logging raised water temperatures a maximum of 8^{o} C in streams, but where streams originated in headwater wetlands, the temperatures increased a maximum of only 1-2 ^{o} C (Rayne et al. 2008). Another study in British Columbia found that well-vegetated wetlands and lakes near the top of a watershed helped offset warming caused by logging above them, thus allowing more rapid return to normal temperatures as the stream flowed downhill (Mellina et al. 2002).

Non-tidal Wetlands – WC Function Model

Structure: Higher scores for a wetland result from increased *Groundwater Input* and decreased *Solar Heat*. If a wetland never contains surface water during the summer, then only Groundwater Input is considered by the model. In all other wetlands, the score is the average of groundwater input (various features suggest high likelihood of discharging groundwater), increases in percent shade, water depth, and proportion of wetland that lacks surface water or has only minimal proportion of open water, and decrease in the percent of the surface water that is ponded.

Important Note: The model does not account for the wetland's surface area, and obviously, larger wetlands could potentially provide a greater volume of cooled water if other factors support this function. Because the model for this function is estimating relative effectiveness per unit area, some smaller wetlands will have higher scores than larger ones. Thus, in the case of this particular function, a multiplication of function score by effective wetland area may sometimes be appropriate.

Non-tidal Wetlands – WC Values Model

Wetlands are assumed to be more valuable for this function if (a) accessible to anadromous fish, and/or (b) are at low elevation, surrounded by impervious surfaces, not a fringe wetland, are south-facing, and have an input tributary that is not fed by glacier water and whose water is predicted to be warmer than that in the wetland itself. The conditions in (b) are all considered to be equally influential so are averaged. That average is considered to be as important as access to anadromous fish (a) so the two are averaged. Then, that average is multiplied by the duration of the wetland's outlet flow, because longer outflows imply greater opportunity to deliver this function.

3.4 STREAMWATER WARMING (WW)

Function Definition: The effectiveness of a wetland for increasing the water temperature, primarily in headwater streams. Water warming by lakes and some wetlands helps support instream rearing habitat for overwintering coho and sockeye salmon, as well as helping stimulate early-season primary production in both headwaters and estuarine waters. It might also boost amphibian productivity and survival.

Scientific Support for This Function in Wetlands Generally: Moderate to High.

In Southeast Alaskan Wetlands: Many of the region's non-tidal wetlands should be capable of performing this function. The model applies only to non-tidal wetlands.

Non-tidal Wetlands – WW Function Model

Structure: The model uses the same indicators as for Water Cooling (WC), but the scoring ramps for each indicator are reversed.

Non-tidal Wetlands – WW Values Model

Structure: The capacity of a wetland to warm the water is assumed to be more valuable if the wetland also scored high for Amphibian Habitat, is near marine waters, at low elevation, north-facing, glacially-fed, not surrounded by impervious surfaces, and/or is not a fringe wetland. These indicators are considered about equally predictive so are averaged. That average is multiplied by the duration of the wetland's outlet flow, because longer outflows imply greater opportunity to deliver this function.

3.5 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 reduce current velocity, resist erosion, and stabilize underlying sediments or soil.

Scientific Support for This Function in Wetlands Generally: High. Being relatively 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) much of the sediment that is deposited.

In Southeast Alaskan Wetlands: Many of the region's wetlands should be capable of performing this function. Those intersected by channels and located on steep slopes are least capable. In this region the abundance of glaciers, clearcuts, logging roads, landslides, and wind-exposed shorelines provides many opportunities for wetlands to trap sediment and/or stabilize underlying soils and sediments. Potentially, the performance of this function has both positive and negative values. Positives include reduction in turbidity in downstream waters, provision of substrate for outward expansion of marsh vegetation into deeper water (especially important in tidal wetlands), and improved detoxification of some contaminants associated with the retained sediment. Sediment serves as a carrier for heavy metals, phosphorus, and some toxic household chemicals, which routinely bind to surfaces of suspended clay particles (Hoffman et al. 2009, Kronvang et al. 2009). Negative values potentially include progressive sedimentation of productive wetlands, slowing of natural channel migration, and increased exposure of organisms within a wetland to contaminants. The values models address only the opportunity to perform this function, not its potential positive or negative effects, which are too difficult to estimate with a rapid method.

Non-tidal Wetlands – SR Function Model

<u>Structure</u>:
At a coarse level, three types of non-tidal wetlands are analyzed separately as pertains to this function: (1) those that never contain surface water, (2) those that lack outlets, and (3) all others.

- If a wetland never contains surface water, its ability to stabilize underlying soil increases if its *Interception/Erosion Resistance (dry)* is great – see below for description.
- If a wetland lacks a surface-flow outlet, i.e., is isolated, then the highest possible score for this function (10.00) is assigned automatically.
- For all other wetland types, the score is the average of a wetland's increased *Hydrologic Entrainment* capacity (weighted 2x), *Storage Space* (weighted 2x), *Interception/Erosion Resistance* (average of terrestrial and aquatic), and decreased *Frozen Duration.*

In the above calculations:

- **Interception/Erosion Resistance in the terrestrial** (dry) environment is assumed to increase with increasing ground cover, microtopographic variation, and decreasing wetland gradient. These are averaged, except that the gradient is assigned a weight equal to that of the others combined, which are all considered to be equally predictive. It is assumed that wetlands without surface water can only stabilize soil, not trap suspended sediment carried in by surface flow.
- **Interception/Erosion Resistance in the aquatic** (wet) environment is assumed to increase with increasing width of the vegetated zone, which is given the same weight as the combined average of scores for increased cover of emergent plants, meandering of flow paths through the wetland, and presence of relatively equal amounts of vegetation and open water arranged in a patchwork. This factor and its indicators are ignored in the calculations if none of the vegetation is ever flooded or if the wetland contains no ponded areas.

- **Hydrologic Entrainment** capacity is assumed to be indicated by decreased wetland shoreline gradient and increased flow path length, ponded extent, water depth, ponded extent, and decreased duration of outflow. These are all considered equally predictive and so are averaged.
- **Storage Space** is assumed to be indicated by increasing amplitude of water level fluctuation and increasing percent of the wetland's area that floods only seasonally. These are considered equally predictive and so are averaged.
- **Frozen Duration** is assumed to decrease with decreasing elevation (relative position in watershed) as well as with increasing mean annual temperature, tidal proximity and south-facing aspect. These are considered equally predictive and so are averaged.
- A decrease in **Connectivity** (i.e., lack of a persistently-flowing outlet) also favors sediment retention, and is assumed to be indicated by decreased wetland outflow duration, presence of an artificial (presumably constricted) outlet, and increased extent of pools within the wetland during the dry season. These are all considered equally predictive and so are averaged.

Important Note: The model does not account for the wetland's surface area, and obviously, larger wetlands could potentially trap and store more sediment if other factors support this function. Because the model for this function is estimating relative effectiveness per unit area, some smaller wetlands will have higher scores than larger ones. Thus, in the case of this particular function, a multiplication of function score by effective wetland area may sometimes be appropriate.

Non-Tidal Wetlands – SR Values Model

The value of the Sediment Retention function is based on two factors. First, if water quality data indicates contamination (within 1 mile upstream) has occurred with metals and other substances that readily adsorb to sediment, this counts for half the score. The other half is the average of 5 factors (4 individual indicators plus one group average). The indicators are the presence of inflowing tributaries, steeper gradient of those tributaries, close proximity to silt-bearing glaciers, and greater percent of the wetland that is flooded only seasonally. Those are averaged with the average of a group consisting of increased presence of recent erosive land use activities upslope from the wetland, greater amounts of impervious surface and less natural cover in the wetland's contributing area, steeper slopes surrounding the wetland, large water level fluctuations, lower elevation, and younger wetland age.

Tidal Wetlands – SR Function Model

If the site is tidal, the sediment retention function is assigned the maximum score if condition (a) below is true. If not, then the score is based on (b).
(a) Review of historical aerial imagery indicates the *wetland is expanding outward or landward*, at least during the time period covered by the imagery or other data, *OR:*
(b) The wetland is *wide* (measured perpendicular to upland runoff direction), is *topographically sheltered* (minimal fetch), is *not shrinking* (as viewed in imagery), has *dense ground cover*, is *mostly low marsh*, and contains a *wide adjoining mudflat.* These are all considered equally indicative of sediment trapping function and so are averaged.

Tidal Wetlands – SR Values Model

If the site is tidal, the sediment retention is predicted to be most *valued* where either *eelgrass* is present downgradient, or where *opportunity* for sediment inputs is greatest.

- Opportunity is assumed to be greatest where the wetland potentially receives glacier water inputs (which contain significant amounts of P), and the immediately adjoining upland area as well as the contributing area is steep, has little natural cover, the non-natural cover is largely impervious surfaces. Opportunity also is greatest where transport of upland sediments to the wetland is likely, as indicated by presence of a steep intersecting tributary or at least proximity to one, or by wetland being associated with a river rather than a bay or marine shoreline. All these indicators are considered equally predictive of value and so are averaged.

<u>Potential for Future Validation</u>: The volume of accreted sediments could be measured in a series of wetlands that encompass the scoring range. This might be done with isotopic analysis of past sedimentation rates, or (going forward) with ground-level LiDAR imaging, SET tables (Boumans & Day 1993), or various sediment markers. 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).

3.6 PHOSPHORUS RETENTION (PR)

<u>Function Definition:</u> The effectiveness for retaining phosphorus for long periods (>1 growing season) as a result of chemical adsorption and complexation, or from translocation by plants to belowground zones or decay-resistant peat such that there is less potential for physically or chemically remobilizing phosphorus into the water column.

<u>Scientific Support for This Function in Wetlands Generally</u>: High. Being relatively 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) much of the sediment. Because phosphorus (P) is commonly adsorbed to the suspended solids, it will consequently be deposited. Also, soluble forms of P can be chemically precipitated from the water column if there are sufficient levels of certain elements (iron, aluminum, calcium), the water is aerobic, and the pH is acidic (with iron, aluminum) or basic (calcium). This chemical precipitation of P also results in retention within a wetland. Subsequently, a variable proportion of the P will re-enter the water column (i.e., be desorbed from sediments or leached from organic matter) which makes it vulnerable to being exported from the wetland. This can happen when sediments or the water column become anaerobic or the pH changes. That can result from excessive loads of organic matter, rising temperature, and/or reduced aeration due to slowed water exchange rates, increased water depth, or ice that seals off diffusion of atmospheric oxygen into the water. The wetland's P balance also depends on the physical stability of deposited sediments or soil. Wind can resuspend sediments rich in P making the sediments and their associated P vulnerable to being exported downstream by currents, but wind can also aerate the water column, which helps retain the P in the sediments. Plant roots also can facilitate P retention by aerating the sediment and translocating aboveground P to belowground areas where P-bearing sediments are less likely to be eroded. Phosphorus can potentially accumulate in wetlands more rapidly than nitrogen, and a state can be reached (perhaps after several decades of increased P loading) where sediments become saturated and no more P is retained, at least until some is desorbed and exported.

The **values** model (as opposed to the function model) addresses only the opportunity to perform this function, not its potential positive or negative effects on ecosystems, which are too difficult to estimate with a rapid method. Phosphorus is essential for plant growth but in high concentrations can shift species composition and habitat structure in ways that sometimes are detrimental to rare plants, aquatic food chains, and valued species (Carpenter et al. 1998, Anderson et al. 2002).

Non-tidal Wetlands – PR Function Model

<u>Structure</u>:
At a coarse level, three types of non-tidal wetlands are analyzed separately as pertains to this function: (1) those that never contain surface water, (2) those that lack outlets, and (3) all others.

- If a wetland never contains surface water, its ability to retain phosphorus is assumed to increase with decreased duration of ice cover and increased *Interception/Erosion Resistance (terrestrial)* and *Adsorption Potential* (see below for description of these terms). These are considered equally predictive so are averaged.
- If a wetland lacks a surface-flow outlet, i.e., is isolated, then the highest possible score (10.00) for this function is assigned automatically, based on an assumption that most phosphorus is associated with suspended sediment. However, some amount of phosphorus is soluble and could still escape in groundwater. That pathway cannot be estimated with a rapid assessment method.
- For all other wetland types, a high score depends on the average of a wetland's increased *Adsorption* and decreased *Desorption* potential (averaged together and weighted 3x), its reduced *Connectivity* (weighted 2x), and the average (unweighted) of shorter *Frozen Duration* (unweighted), greater *Interception/Erosion Resistance* in the wetland's dry zone, and the same in the aquatic zone.

In the above calculations:

- **Adsorption potential** is represented by the average of soil texture (greater in clay and peat soils, and lower in coarse-textured soils) and salinity (greater in more saline wetlands).
- **Desorption potential** is assumed to be least in wetlands with deep persistent water with stable water levels. These are considered about equally predictive and so are averaged. Soil respiration, carbon accumulation rate, and subsurface water table fluctuation can be important to phosphorus adsorption and desorption but cannot be assessed accurately with a rapid assessment method.
- **Connectivity** is assumed to be less in wetlands that have no outlets, are lakes, or export surface water through a ditch or artificial outlet, have low gradient, and a long flow path. These are considered about equally predictive and so are averaged.
- **Frozen Duration** is assumed to decrease with warmer mean annual temperature, decreasing elevation (relative position in watershed), and increasing proximity to tidal waters. These are considered equally predictive and so are averaged.
- **Interception/Erosion Resistance in the terrestrial** (dry) environment is assumed to increase mainly with a decrease in gradient and lengthening flow path. The remaining 1/3 of the score for this process is based on the average of increased ground cover, microtopographic variation, and wetland size in proportion to catchment size.
- **Interception/Erosion Resistance in the aquatic** (wet) environment is assumed to increase if the wetland is ponded, and has greater cover of emergent plants distributed in a patchy manner, and increased meandering of surface water as it travels through the wetland. These are considered equally predictive and so are

averaged, and that average is then averaged with wetland width. This factor and its indicators are ignored in the calculations if none of the vegetation is ever flooded.

Important Note: The model does not account for the wetland's surface area, and obviously, larger wetlands could potentially retain more phosphorus if other factors support this function. Because the model for this function is estimating relative effectiveness per unit area, some smaller wetlands will have higher scores than larger ones. Thus, in the case of this particular function, a multiplication of function score by effective wetland area may sometimes be appropriate.

Potential 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 vs. vegetation characteristics, as they affect adsorption vs. uptake processes.

Non-Tidal Wetlands – PR Values Model

This function is considered most valuable if a wetland has greater opportunity to perform it. The score is calculated by first averaging 10 indicators of increased phosphorus delivery to the wetland, such as buffer slope, upland erodibility, lack of undisturbed upland cover. That average is then averaged with presence of an inlet and increased tributary gradient and glacial meltwater input. Finally, that average is then compared with the score for potential nutrient exposure from the Stressor data form, and the greater of the two is used.

3.7 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. The values models address only the opportunity to perform this function, not its potential positive or negative effects, which are too difficult to estimate with a rapid method. Nitrate is essential for plant growth but in chronically high concentrations, such as from urban and agricultural runoff, can be a significant "nonpoint source" that shifts species composition and habitat structure in ways that sometimes are detrimental to rare plants, aquatic food chains, and valued species (Carpenter et al. 1998, Anderson et al. 2002). High concentrations of nitrate in well water also are a human health hazard, and some levels of ammonia impair aquatic life. When excessive algal growths are triggered by abnormally high levels of nutrients in the tidal or marine water column, they block light needed by eelgrass (Williams & Ruckelshaus 1993), a submersed plant very important to fish and wildlife. Nitrate concentrations as low as 1 mg/L can change the structure of freshwater algae communities of streams (Pan et al. 2004) and contribute to blooms of toxic algae in lakes and wetlands.

Non-tidal Wetlands – NR Function Model

Structure:
At a coarse level, four types of non-tidal wetlands are analyzed separately as pertains to this function: (1) those that never contain surface water, (2) those that lack outlets, (3) all others.

- If a wetland lacks a surface-flow outlet, i.e., is isolated, then the highest possible score (10.00) for this function is assigned automatically.
- If a wetland never contains surface water, its ability to remove N is assumed to be greater if it has limited connection to downslope water bodies (*Connectivity*, weight of 2), is less erodible, and is likely to capture sediment that enters it (*Interception/Erosion Resistance*), and has a relatively warm microclimate (*Warmth)* , highly organic substrate (*Organic*), and strong potential for spatially and temporally alternating reducing conditions *(Redox).* The weighted average of these terms is calculated. Their indicators are described below.
- For all other wetlands, the same model is used but in calculating the weighted average, *Redox* is weighted more heavily (3x).

In the above calculations:

- Decreased **connectivity** is defined by shorter duration of surface outflow, flatter wetland gradient, and lack of any artificial drainage. These 3 indicators are considered equally predictive so are averaged.
- **Warmth** is assumed to increase with decreasing elevation (relative position in watershed), closeness to tidal waters, warmer mean annual temperature, south-facing aspect, lack of tree canopy, and strong evidence of groundwater input. These are considered equally predictive and so are averaged.

- **Interception/Erosion Resistance** is assumed to increase mainly with increasing flow path length, flatness of wetland gradient, vegetated width, ground cover density, interspersion of open water and vegetation, and size of wetland relative to size of its catchment. These are considered equally predictive and so are averaged.
- **Organic** content is assumed greater in peatlands, older wetlands, and wetlands with extensive plant cover and with little or no history of soil disturbance.
- **Redox** conditions favorable to denitrification are assumed likeliest to occur where a large portion of the wetland is inundated only seasonally. Considered equally important is the average of 4 indicators: presence of many upland inclusions, large ratio of upland edge to wetland area, greater water level fluctuation, and extensive microtopography.

Important Note: The model does not account for the wetland's surface area, and obviously, larger wetlands could potentially remove more nitrate if other factors support this function. Because the model for this function is estimating relative effectiveness per unit area, some smaller wetlands will have higher scores than larger ones. Thus, in the case of this particular function, a multiplication of function score by effective wetland area may sometimes be appropriate.

Potential 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). Monitoring should also measure denitrification rates (at least potential), the nitrogen fixing rates of particular wetland plants, and nitrous oxide emissions.

Non-tidal Wetlands – NR Values Model

Greater value is assigned based on the average of 4 factors: (a) either domestic wells are present within 1000 feet downslope from the wetland or the wetland is within an ADEC-designated Public Drinking Water Protection Area, (b) a tributary is present, (c) potential sources of N are present; this is calculated as the maximum of 6 indicators: presence of spawning anadromous fish, N-fixing plants, septic systems and various other human activities, closeness to populated areas, extent of impervious surface near the wetland, and wetland contributing areas with limited extent of natural cover. The fourth factor pertains to the potential for N transport into the wetland. That is assumed greater if the wetland is not in a headwater location and slopes nearest the wetland are steep and covered with sparse or no vegetation.

3.8 CARBON SEQUESTRATION (CS)

Function Definition: 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.

Scientific Support for This Function in Wetlands Generally: Although wetlands with high rates of primary productivity would seem to sequester (store) more carbon more rapidly, at northern latitudes it is likely that the amount of carbon that remains in storage will depend more on how slowly what has initially been sequestered will be decomposed. Artificial disturbances or extreme events, such as increased frequency of drought (e.g., from global warming, artificial drainage, glacial rebound) and perhaps flood (e.g., from glacier melt, tsunamis) 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.

In Southeast Alaskan Wetlands: Due partly to the northerly latitude (with cool temperatures and limited light), vegetation grows slowly in the region's wetlands and thus plants probably sequester carbon at a relatively slow rate. However, both cumulatively and on a per-unit-area basis, the carbon reserves (mainly in the form of peat) in these wetlands are enormous due to slow rates at which fixed carbon (plant organic matter) decomposes.

Non-tidal Wetlands – CS Function Model

Structure:

A wetland is scored higher if its existing ("legacy") carbon stores (*Historical Accumulation*) are large, *Decomposition* of that carbon is likely to occur slowly, the wetland has a great ability to physically retain organic matter it produces or receives from upgradient sources (*Physical Accumulation*), and it lacks factors that suggest it has substantial methane emissions (*Methane Limitation*). In the final model, *Methane Limitation* is weighted equally with the average of *Historical Accumulation, Decomposition*, and *Physical Accumulation*.

In the above calculations:

- **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 (i.e., wetland is older than 100 years), this factor is calculated as the average of 3 items. One is vegetated width. A second is the group average of wetland type favorability (open peatland> forested peatland> fen/marsh> floodplain> uplift meadow), peat depth (but depths >16 inches are not measured due to equipment constraints), moss cover, cold temperature, and percent cover of non-deciduous trees. The third group is the minimum (worst) of soil disturbance, recent drying conditions, and wetland age.
- **Decomposition** is assumed to be slower (thus facilitating carbon sequestration) when indicated by higher elevation, cooler mean annual temperature, longer duration of freezing, wetland type is peatland, and moss cover is extensive. These are considered equally predictive so are averaged and then are averaged with the rating for wetland water depth, wherein intermediate water depths are hypothesized to support an optimal combination of elevated productivity and slowed decomposition.
- **Physical Accumulation** is assumed to increase with flatter wetland gradient, less persistent outflow, and an artificial (presumably more constricted) outlet if an outlet is present at all. These are considered equally predictive and so are averaged.
- **Methane emissions** are considered to be least when the wetland is not a sedge fen, tree cover (if any) is coniferous, moss cover is extensive, water level fluctuations and groundwater inputs are probably minimal, and the wetland has not recently shifted to a persistently flooded condition. These are considered equally predictive of Methane Limitation and so are averaged.

Tidal Wetlands – CS Function Model

<u>Structure</u>:
A tidal wetland is scored higher if its existing carbon stores *(Historical Accumulation)* are assumed to be large, its current *Productivity* is high, and it lacks factors that suggest it

has substantial methane emissions *(Methane Limitation).* In the final model, Methane Limitation (a negative factor) is weighted equally with the sum of Historical Accumulation and Productivity (positive factors).

In the above calculations:

- **Historical Accumulation** is assumed to be greater in wetlands that show a pattern of expanding, especially over long time periods. Where data on trends are lacking or no change in marsh area is apparent, then accumulation is assumed greater in tidal wetlands that are wide (at low tide), sheltered, and with organic sediments. These indicators are considered equally predictive and so are averaged.
- **Productivity** is assumed to be greater in high and mid-elevation marshes that are wide (at high tide), are not on tidal rivers (where ice cover is greater) but are sheltered, and have relatively dense ground. These indicators are considered equally predictive and so are averaged.
- **Methane emissions** are assumed to be lower in tidal wetlands that are along waters that are more saline, e.g., closer to outer coast, no river inputs.

Important Note: The model does not account for the wetland's surface area, and obviously, larger wetlands could potentially retain more carbon if other factors support this function. Because the model for this function is estimating relative effectiveness per unit area, some smaller wetlands will have higher scores than larger ones. Thus, in the case of this particular function, a multiplication of function score by effective wetland area may sometimes be appropriate.

<u>Potential for Future Validation</u>: 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), decomposition rates, hydrology, and net carbon accumulation in sediments or soils would require measurement as well.

3.9 ORGANIC NUTRIENT EXPORT (OE)

<u>Function Definition:</u> The effectiveness of a wetland for producing, rapidly cycling, and subsequently exporting organic matter, either particulate (detritus) or dissolved, and including net export of nutrients (C, N, P, Si, Fe) comprising that matter. It does not

include exports of carbon in gaseous form (methane and carbon dioxide) or as animal matter (e.g., emerging aquatic insects, fish).

Scientific Support for This Function in Wetlands Generally: Moderate-High. Wetlands which have outlets are potentially major exporters of organic matter to downstream or marine waters. That is partly because many wetlands support exceptionally high rates of primary productivity (i.e., carbon fixation, which provides more carbon that is available for export) or have large legacy reserves of undecomposed carbon. Numerous studies have shown that watersheds with a larger proportion of wetlands tend to export more dissolved and/or particulate carbon, as well as iron and other substances important to downstream and estuarine food webs (Bjorkvald et al. 2008). Value of the exported matter to food webs depends partly on the quality and timing of the export, but those factors cannot be estimated with a rapid assessment method.

In Southeast Alaskan Wetlands: Both cumulatively and on a per-unit-area basis, the carbon reserves (mainly in the form of peat) in Southeast Alaskan wetlands are enormous, and due to large annual precipitation much of this carbon is exported to streams, rivers, lakes, and marine waters (D' Amore et al. 2015a, b). Once there, much of it can be expected to support food chains important to fish, wildlife, and people. As part of developing WESPAK-SE, and with assistance from the Juneau office of The Nature Conservancy, we spatially modeled the potential contribution of each Southeast Alaska non-tidal wetland to salmonid streams, based on distance and slope. The resulting database (HydroDist) is a worksheet in the WESPAK-SE nontidal wetland calculator.

Non-tidal Wetlands – OE Function Model

Structure: If no surface flow ever exits a wetland, its OE function is automatically scored 0. For all other wetlands, the score is the weighted average of greater *Historical Accumulation, Export Potential* (weight of 3), and current *Productivity* (weight of 2).

In the above calculations:

- **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 a new wetland (i.e., wetland is older than 100 years), this factor is calculated as the average of increased soil organic content and water stain.
- **Export Potential** is predicted by 4 items which are averaged: flow path length within the wetland, duration of surface water outflow, wetland gradient, and the group average based on less outlet constriction, less ponding, narrower vegetated width,

more glacial meltwater input, 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 decreasing elevation (relative position in watershed), warmer mean annual temperature, proximity to tidal waters, and presence of discharging groundwater. These are considered equally predictive of Frozen Duration and so are averaged.
  - *Plant Cover* input available for rapid export is assumed to be greater with more extensive cover of emergent and deciduous woody vegetation, decreasing bare ground extent, and shallower water depth. These are averaged.
  - Greater *Nutrient Availability* is reflected by wetland type (fen/marsh > floodplain wetland > uplift meadow > forested peatland > open peatland), absence of underlying granitic bedrock, presence of karst formations, moderately fluctuating water levels, increased cover of nitrogen fixing plants, greater proportion of the wetland that is inundated only seasonally. These are considered equally predictive of Nutrient Availability and so are averaged.

Tidal Wetlands – OE Function Model

Structure: The score takes into account a tidal wetland's existing carbon stores *(Historical Accumulation*), its current *Productivity*, and the *Exporting Opportunity* of the landscape in which it exists. The scores for the first two factors are averaged, and then that is considered to be as important as the third, so is averaged with that.

In the above calculations:

- **Historical Accumulation** is assumed to be greater in tidal wetlands that show a pattern of expanding, especially over long time periods. Where data on trends are lacking or no change in marsh area is apparent, then accumulation is assumed greater in tidal wetlands that are wide (at low tide), sheltered, not ditched or drained, and with deep organic sediments. These indicators are considered equally predictive and so are averaged.
- **Productivity** is assumed to be greater marshes at high and mid tidal elevations that are wide (at high tide) and are geographically closer to the ocean (less ice cover) but are sheltered, and have relatively dense ground cover and perhaps nitrogen-fixing

plants along their upland edge. These indicators are considered equally predictive and so are averaged.
- **Exporting Opportunity** is assumed to be greater in tidal wetlands that are mostly low marsh. This accounts for half the score for Exporting. The other half is a group average representing wetlands that are narrow, unsheltered, close to the ocean (less ice cover) or along rivers (currents facilitate export), with freshwater tributaries, unrestricted outlets, complex internal channel networks, and steep adjoining upland slopes and tributary channels

Important Note: The model does not account for the wetland's surface area, and obviously, larger wetlands could potentially export more carbon if other factors support this function. Because the model for this function is estimating relative effectiveness per unit area, some smaller wetlands will have higher scores than larger ones. Thus, in the case of this particular function, a multiplication of function score by effective wetland area may sometimes be appropriate. Also, this model is limited inasmuch as it does not attempt to estimate the immediate availability of the exported carbon to food chains. Some "more labile" forms of carbon are known to transform and then be taken up beneficially by aquatic organisms more quickly than other forms.

Non-tidal Wetlands – OE Values Model

The value of the carbon and other nutrients exported from a wetland is assumed to be greater the closer the wetland is hydrologically to a salmonid-bearing stream. This is scored two ways, and the larger of the two scores is used. One way is by using a score based on multiplying wetland distance-to-stream by mean-slope-to-stream. For this project, that calculation was done for all mapped wetlands in Southeast Alaska by Dave Albert and Colin Shanley in the Juneau office of The Nature Conservancy. The other way to estimate potential value of a wetland's nutrient export is based on the average of its relative elevation (lower scores higher), proximity to tidal waters, and presence of glacier water inflows (which themselves are often carbon-rich, thus diminishing the proportional contribution of a wetland's carbon to downstream waters).

No *values* model is provided for organic nutrient export from **tidal** wetlands because this function's values are diffused throughout all receiving water bodies.

<u>Potential for Future Validation</u>: 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 and flow rate.

3.10 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 *WildlifeList* 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 potential 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 opportunities, shelter from predators, and a beneficial thermal environment.

Non-tidal Wetlands – FA Function Model

Structure: Wetlands are scored 0 if not accessible to anadromous fish or if no surface water is ever present. In all other wetlands, the score increases with increasing fish *access* to the wetland and persistence of the wetland's *outflow.* The scores for these two factors are averaged and then multiplied by the average of increased wetland *Productivity, Structure, Hydrologic Regime, Landscape Condition,* and a lack of human-related *Stressors.* This assumes these last 3 factors are moot if access is lacking and/or are less important if outflow persistence is less. In these calculations:

- **Productivity** is assumed to be greater where the wetland contains or is adjoined by alder, is situated in karst terrain, is at low elevation, near marine waters, is a floodplain wetland or fen/marsh, and there is evidence of significant groundwater input. These indicators are considered equally predictive and so are averaged.
- **Structure** beneficial to anadromous fish is represented by the average of beaver presence (considered a positive indicator) and a group average for increased shade and cover of aquatic plants, large woody debris, presence of both ponded and flowing water, and more favorable wetland type (Floodplain wetland > Fen/marsh > Uplift meadow > Forested peatland > Open peatland.
- **Hydrologic Regime** is considered optimal when all or nearly all of the wetland has surface water at least seasonally and water depths are moderate. The remaining one-third of the score for this factor is based on the average of interspersion of patches of vegetation and open water, wetland adjacency to a lake, wetland intersected by channels that wind indirectly and intersect flooded trees, and either a moderate proportion of habitat that remains persistently inundated or is inundated only seasonally.

- **Landscape** condition is assumed to be better when land cover in the contributing area and area closest to the wetland is mostly natural.
- **Stressors** are represented by absence of known or suspected contaminants, absence of turbid glacial meltwater input, lack of other sediment inputs in excessive concentrations, and lack of altered flows. These indicators are considered equally predictive and so are averaged.

Non-tidal Wetlands – FA Values Model

A wetland with the potential to support anadromous fish is assumed to be more valuable if it is in a conservation priority watershed for anadromous fish (from Schoen & Dovichin 2007, one-quarter of the score), or has a high habitat score for Feeding Waterbirds or Songbirds & Mammals (one-quarter of the score), or if it is near a known focal area for fisheries-based Subsistence (one-quarter of the score), and/or if the group average (one-quarter of the score) of the following was high: observed evidence of fishing, frequent human visitation, near a population center, near a road.

Tidal Wetlands – FA Function Model

<u>Structure</u>: The model first addresses a tidal wetland's accessibility to anadromous fish. If there is even minimal fish *Access* to the wetland, the model then considers the likely extent and duration of access, potentially predictive *Landscape*-scale factors, and secondarily the wetland's potential *Productivity* and general *Habitat Structure*. The latter two together are given the same weight as each of the former.

In the above calculations:

- **Access** is assumed to be greater in wetlands having extensive areas that fish can reach even at monthly low tide, and those with extensive internal channel networks and natural outlets. These indicators are considered equally predictive and so are averaged. However, if there is no fish access, this factor is set to zero.
- **Productivity** is assumed to be greater in tidal wetlands with wide vegetation zones, groundwater seeps, large adjoining trees (especially deciduous), having or being near tributaries, and with no existing data that indicate presence of toxic pollution levels in or near the wetland. These indicators are considered equally predictive and so are averaged.
- **Structure** is assumed to be greater in tidal wetlands that have a variety of complementary marine shoreline types within 1 mile, and either are wooded or have much large woody debris or other fish cover. These indicators are considered equally predictive and so are averaged.

- **Landscape** factors that favor anadromous fish include whether the wetland is located in a priority watershed for anadromous fish within its biogeographic province (subregion) in Southeast Alaska (from Schoen & Dovichin 2007). This accounts for half the Landscape score. Considered equally influential, and thus accounting for the other half, is the average of 5 indicators: geographic position (outer coast, inner coast, mainland), location along a major river or in a bay/lagoon, proximity to eelgrass, the average of the distance to the nearest other tidal wetland and extent of tidal wetlands generally in the associated watershed, and the average of the proximity to connected freshwater ponds/wetlands (positive), and percent of the upland buffer that is natural land cover (positive).

Tidal Wetlands – FA Values Model

Structure: This function is presumably valued to a greater degree if the wetland is known to be in or near a focal area for subsistence, or if (the average of these three: is in a priority watershed for anadromous fish, and/or is in a watershed with good bear habitat or there is evidence of use for fishing.

Potential 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.

3.11 RESIDENT FISH HABITAT (FR)

Function Definition: The capacity to support an abundance and diversity of *native* non-anadromous fish. See worksheet *WildlifeList* in the *WESPAK_SE* calculator 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. No model is provided for tidal wetlands because of lack of information on which variables contribute to differences in non-anadromous fish abundance and diversity among tidal wetlands in Southeast Alaska.

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).

Non-tidal Wetlands – FR Function Model

Structure: A wetland automatically scores a 0 if there is no fish access and it is not known to contain resident fish, or if it never contains surface water. For all other wetlands, the score increases with increased wetland *Productivity, Hydrologic Regime,* and habitat *Structure,* and decreased *Stressors* and risk of winterkill from *Anoxia*. These 5 factors are considered equally predictive of resident fish habitat suitability and so are averaged.

In the above calculations:

- **Productivity** is assumed to be greater where the wetland contains both an inlet and outlet, contains or is adjoined by extensive alder, is situated in karst terrain, has evidence of significant groundwater input, is not on granitic bedrock, has not been recently deglaciated, and (in order of decreasing productivity) is a Floodplain wetland > Fen/marsh > Uplift meadow > Forested peatland > Open peatland. These indicators are considered equally predictive and so are averaged.
- **Structure** beneficial to resident fish is represented by the average of beaver presence (considered a positive indicator) and a group average that again includes wetland type (see ranking above) as well as increased shade, extensive aquatic plants, and other aquatic cover.
- **Hydrologic Regime** is assumed most favorable for resident fish when surface water is present persistently or at least seasonally, both ponded and flowing water are present, interspersion of patches of vegetation and open water is good, there are complex internal channel networks that intersect woody vegetation, and a variety of water depths is present in fairly equal proportions. These indicators are considered equally predictive and so are averaged.
- **Stressors** are represented by the average of: lack of known toxicity of contaminants, lack of artificially altered flow timing, and lack of turbid glacier-water inputs. These are considered equally predictive.
- **Anoxia Risk** is assumed to increase with two factors that are averaged. The first is represented by the average of increasing water depth and outflow persistence. The second is the average of decreasing elevation (relative position in watershed), warmer temperature, proximity to tidal waters, and lakeside (as opposed to small isolated pond) location. These are considered equally predictive of resident fish winterkill and so are averaged.

Potential 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 transient species, the duration of use and weight gain throughout the times when usually expected to be present should be determined.

Non-tidal Wetlands – FR Values Model

Structure: This function is presumably valued to a greater degree if its feeding waterbird score is high or if it is in a region ranked high for Subsistence, of if the average of 4 other indicators is large: evidence of fishing, minimal distance to a population center, minimal distance to a road, and greater accessibility of the wetland to people.

3.12 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, on the water surface, or in moist soil. Includes dragonflies, aquatic flies, clams, snails, crustaceans, aquatic beetles, aquatic worms, aquatic bugs, and others, including semi-aquatic species. The model described below will not predict habitat suitability accurately for every species, nor the importance of any species or functional group in the diet of important fish or birds. No model is provided for tidal wetlands because of lack of information on which variables contribute to differences in invertebrate abundance and diversity among tidal wetlands in Southeast Alaska.

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 or lakes, thus diversifying the local fauna. Densities of aquatic invertebrates can be exceptionally high in some wetlands, partly due to high primary productivity and warmer water temperatures, and partly because submerged, floating, and emergent vegetation provide additional structure (vertical habitat space).

Non-tidal Wetlands – INV Function Model

Structure: In all types of non-tidal wetlands, the score is the unweighted average of 3 factors, and the score increases as each of these increase: *Productivity (Food), Habitat Structure*, and the group average of four similarly-predictive factors: wetland hydroperiod, connectivity, naturalness of the surrounding land cover (Landscape), and absence of human-related stressors. In these calculations:

- **Productivity** score is based half on wetland type and half on a group average of several indicators: greater hardwood cover (especially alder), downed wood, situated in karst (not granitic) area, shallower water depth, closer to tidal waters, and not fed by nearby glacial meltwater.

- **Structure** is assumed to increase with increased ground cover, microtopographic variation, downed wood, large woody debris. These indicators are considered equally predictive and so are averaged. That group average is then weighted equally with cover of aquatic plants (intermediate cover being considered optimal).
- **Landscape** condition is assumed better for invertebrates when land cover in the contributing area is mostly natural, as represented by the average of 3 indicators which reflect that.
- **Hydroperiod** is assumed most favorable when water levels fluctuate moderately and seasonally, there is evidence of groundwater discharging to the wetland, and there is an intermediate proportional extent of persistent water.
- **Connectivity** is reflected by a balanced mix of ponded and flowing water, greater patchiness of open water, greater interspersion of patches of vegetation and open water, and more sinuous internal channels that intersect woody vegetation. These indicators are considered equally predictive and so are averaged.
- **Stressors** are represented partly by the average of increased soil disturbance, excessive sediment inputs, and altered timing of the water regime. That group average counts for half the stressor component, and the other half is represented by fish access (considered deleterious to wetland invertebrate richness).

<u>Potential for Future Validation</u>: The aquatic invertebrate richness, density, and (ideally) productivity would need to be measured regularly throughout the year among a series of wetlands spanning the function scoring range and a range of wetland condition (integrity).

Non-tidal Wetlands – INV Values Model

<u>Structure</u>: The value score for Invertebrate Habitat is the maximum of 3 indicators. One is the presence in the wetland of a land cover class which is less common in the surrounding 2 mile circle, and if present, the proximity to that class. The third is the group average for several other functions which Invertebrates support: Amphibians, Anadromous Fish, Resident Fish, Feeding Waterbirds, Nesting Waterbirds, and Songbirds & Mammals.

3.13 AMPHIBIAN HABITAT (AM)

<u>Function Definition:</u> The capacity of a wetland to support an abundance and diversity of native amphibians (frogs, toads, salamanders). See worksheet *WildlifeList* for list of

the species. Ecological descriptions can be found in Carstensen et al. 1992 (2014 revised) and other regional sources. The model described below will not predict habitat suitability accurately for **every** species. No model is provided for tidal wetlands because of absence of amphibians from most such wetlands, and lack of information on which variables contribute to differences in amphibian use among the high-marsh tidal wetlands in Southeast Alaska that are sometimes used.

<u>Scientific Support for This Function in Wetlands Generally</u>: High. Many amphibian species occur almost exclusively in wetlands. Densities of amphibians can be noticeably higher in some wetlands, partly due to high productivity of algae and invertebrates, and partly because submerged vegetation provides shelter and sites for egg-laying and larval rearing.

Non-tidal Wetlands – AM Function Model

<u>Structure</u>: The function score is the average of three indicators. One is the documented presence of an amphibian in the wetland. A second is the wetland type, with types ranked for amphibian suitability as follows: Marsh/Fen > Uplift Meadow> Forested Peatland > Peatland Flat > Floodplain Wetland. The third is the average of scores for *Climate*, *Hydrologic Regime*, *Aquatic Structure*, *Terrestrial Structure*, wetland *Productivity*, *Waterscape*, *Landscape*, and minimal impacts from human *Stressors*.

In the above calculations:
- **Climate** is considered more suitable for amphibians in wetlands at lower elevations, with shorter duration of ice cover, closer to marine waters, and warmer mean annual temperature. These indicators are considered equally predictive and so are averaged.
- **Hydrologic Regime** is assumed more suitable in ponded wetlands with evidence of groundwater inputs and only minor water level fluctuations.
- **Aquatic Structure** that is more suitable for amphibians is represented by a wide zone of aquatic plants, some large woody debris, and large interspersion of intermediate proportions of vegetation and open water. These indicators are considered equally predictive and so are averaged.
- **Terrestrial Structure** is considered to be best for amphibians in wetlands with moderate ground cover and cover of shrubs, extensive microtopographic variation, and some upland inclusions, and much downed wood.
- **Productivity** is assumed to be highest in flat-gradient south-facing wetlands with larger-diameter trees, especially if in karst areas, and which are not newly created or

in recently deglaciated areas or on granitic bedrock. All these indicators of productivity are considered equally predictive so are averaged together.

- **Waterscape** is represented by increasing number and proportion of ponded areas within 2 miles of a wetland, and increasing proximity to the nearest other ponded wetland. These are averaged.
- **Landscape** conditions are considered better for amphibians when natural cover comprises a large and proximate part of the upland cover. Seven indicators of this are averaged.
- **Stressors** of potential detriment to amphibians are considered to include increasing proximity to nearest road, documented toxicity from contaminants, glacially-fed tributaries (high turbidity), frequent human visitation, and lack of fences and other measures to limit trampling of soil and vegetation. These indicators are averaged and the average considered equally with actual or potential presence of fish, which can be a powerful stressor in many situations.

Note that some assessment methods, as an indicator of biodiversity, include "number of wetland types" or "number of hydroperiod types" present within a single wetland AA. WESPAK-SE does not use those because the lines between such types are seldom clearly distinguishable either in the field or from aerial imagery. WESPAK-SE addresses habitat heterogeneity (both within and surrounding an AA) using other indicators.

<u>Potential for Future Validation</u>: Among a series of wetlands spanning the function scoring range and a range of wetland condition (integrity), amphibian 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.

Non-tidal Wetlands – AM Values Model

<u>Structure:</u> The value score for Amphibian Habitat is the maximum of 2 group averages. One group average is computed from 3 indicators: (a) the presence of a wetland class that is relatively uncommon in the particular watershed, and (b) presence of a vegetation form (tree, shrub, herbaceous, or moss) or woody plant density does not predominate in the surrounding 2 mile circle, and (c) wetland is situated on a small marine island, where amphibian movements are constricted by marine waters, thus making more sensitive and valuable whatever habitat is present. The second group is the average of scores for Feeding Waterbird Habitat and Songbird-Raptor-Mammal

habitat, because amphibians are important food sources for some species in those groups.

3.14 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 *WildlifeList* 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 because wetland vegetation provides shelter in close proximity to preferred foods.

Non-tidal Wetlands – WBF Function Model

Structure: Wetlands are scored 0 if they are a forested peatland or if no water is ever present. In all other wetlands, half the score is accounted for by wetland *Productivity*, and the other half by the average of more favorable *Climate* and *Structure*, optimal *Hydrologic Regime*, good *Landscape* condition, and less impact from human-associated *Stressors*. These 5 factors are considered about equally predictive of wetland suitability for feeding (principally migratory) waterbirds, so are averaged.

In the above calculations:

- Wetlands with higher **Productivity** for feeding waterbirds are assumed to include those with extensive duckweed or algae, flatter gradients, fish access, adjoining lakes, and/or belonging to wetland types favored by waterbirds in this order: Floodplain Wetland > Marsh/Fen > Uplift Meadow > Open Peatland > Forested Peatland Slope. These indicators are considered equally predictive of aquatic productivity and so are averaged.
- **Climate** is considered more suitable for feeding waterbirds in wetlands at lower elevations, closer to marine waters, with shorter duration of ice cover, and warmer

mean annual temperature. These indicators are considered equally predictive of a climate favorable for feeding waterbirds and so are averaged.
- Habitat **Structure** is calculated as the average of 5 indicators. These include wetland size, extent of mudflats, extent of ponded open water, lack of trees, and the group average for herbaceous cover proportion and interspersion with open water, and complexity of channels (if a flow-through wetland).
- **Hydrologic Regime** is assumed to be more suitable in shallow ponded wetlands with a large proportion of vegetation that is inundated persistently or only seasonally, and with a variety of depth classes in relatively equal proportions. These indicators are considered equally predictive and so are averaged.
- **Landscape** context which is considered most important to predicting the abundance and diversity feeding waterbirds in Southeast Alaska is proximity to major mainland rivers (Stikine, Taku, etc.) and the proximity to lakes. These comprise nearly half the Landscape score. The rest is influenced equally by proximity to nearest pond, proportion of landscape comprised of ponded areas, nearest openland area (e.g., marsh, field, treeless bog), proportion of landscape comprised of openland, and the actual or potential presence of beaver.
- **Stressors** of significant concern to feeding waterbirds include harmful concentrations of metals and other contaminants, and frequent visitation of nearly the entire wetland by people.

<u>Potential for Future Validation</u>: 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.

Non-tidal Wetlands – WBF Values Model

This function's value is based on the maximum score of 3 indicators. One is whether the wetland has been officially designated an IBA (Important Bird Area). A second is whether it is known to host a rare migratory waterbird species. The third is a group average of 5 indicators: increased scarcity of herbaceous vegetation (if it is an herbaceous wetland) within 2 miles and/or within the watershed, documented use by hunters, near a population center, and most of wetland is visible. The last 3 of these suggest potential for more frequent enjoyment by recreationists.

Tidal Wetlands – WBF Function Model

<u>Structure</u>: The suitability of tidal wetlands for migratory and wintering waterbirds is assumed to be greater with increased aquatic *Productivity*, *Structure*, *Landscape* condition, and availability of *Refugia* (areas mostly free from frequent disturbance by humans). The model assigns half the score to the Landscape metric and half to the remaining three metrics, which are averaged. These are determined as follows:

- **Landscape-**scale indicators of waterbird feeding in tidal wetlands are assumed to include proximity to major mainland rivers (Stikine, Skagway, etc.), proximity to other tidal marshes, and proportion of the wetland's watershed occupied by tidal wetlands.
- **Productivity** is assumed to be greater in tidal wetlands that have a large vegetated width; are a freshwater tidal wetland or are intersected by a stream; are known to not be contaminated by toxic substances; and are on a shoreline having many distinct tidal habitats including eelgrass.
- **Structure** desired by the most feeding waterbirds in tidal wetlands is assumed to include a general lack of woody vegetation, substantial portions of the wetland still covered with water at low tide, a complex internal channel network, and extensive adjoining mudflats.
- **Refugia** are comprised of areas where feeding waterfowl can find shelter from coastal storms or temporary escape from recreationists. This factor is assumed to be reflected by small open-water distance (fetch), estuarine position (sheltered embayments and river deltas preferred), proximity to a lake, and to a lesser extent: limited wetland visitation by people on foot, proximity to a pond, and a large proportion of the surrounding landscape occupied by openlands and ponds. The first three indicators together are given 75% of the weight for Refugia.

Tidal Wetlands – WBF Values Model

This function is assumed to be more valuable where a tidal wetland (a) has been officially designated an IBA (Important Bird Area), or (b) is known to host a rare migratory waterbird species, or (c) the average of: near a population center, visible from roads, distant from other tidal wetlands. The value score is the maximum of (a-c), but a minimum score of 5.0 is set in recognition of the known importance of most tidal marshes in Southeast Alaska to feeding waterbirds.

3.15 WATERBIRD HABITAT - BREEDING (WBN)

Function Definition: The capacity to support an abundance and diversity of nesting waterbirds. See worksheet *WildlifeList* in the WESPAK-SE calculator for list of the species. The model described below will not predict habitat suitability accurately for every species in this group. No model is provided for tidal wetlands because it appears that few waterbirds place their nests within tidal wetlands.

Non-tidal Wetlands – WBN Function Model

Structure: The model first eliminates (assigns a score of 0) any wetlands on slopes of greater than 10 percent. Although a few waterbird species do nest along steep-sloped streams (e.g., harlequin duck, American dipper), and some in sloping muskeg, they nest more often in the drier upland areas near those streams than in floodplains or wetlands. The model then eliminates wetlands that never contain surface water. For all remaining types of wetlands, the weighted average is taken of 3 groups. One group (with weight of 3) is the average of increased wetland size, aquatic plant cover, preferred wetland type, and *Waterscape* indicators (described below). A second group (weight of 2) is the average of *Hydrologic Regime, Structure*, and *Productivity* (described below). The third group (unweighted) is the average of *Stressors* and *Landscape* indicators. These are determined as follows:

- **Waterscape** is represented by increasing proximity to lakes and ponds, proportion of ponded areas within 2 miles, and actual or potential presence of beaver. These are assumed to be equally predictive so are averaged.
- **HydroRegime** is assumed to be more suitable in moderately shallow ponded wetlands with a large proportion of vegetation that is inundated persistently or only seasonally, with only mild annual water level fluctuation, and with a variety of depth classes in relatively equal proportions. These indicators are considered equally predictive and so are averaged.
- **Structure** is assumed to be more suitable in herbaceous ponded wetlands that have intermediate amounts of open water interspersed well with aquatic plants. This counts for half the *Structure* score, with the other half based on the group average of several indicators: increasing vegetated width, snags suitable for cavity-nesting ducks, total area and proportion of aquatic plants, and complexity of channel networks within the wetland.

- **Productivity** is assumed to be greater in non-acidic, fish-accessible wetlands at lower elevations near tidal waters, with flat gradients and mostly flat shorelines, that contain an island and are a more productive wetland type (in descending order, this is believed to be: Floodplain Wetland > Marsh/Fen > Uplift Meadow > Open Peatland > Forested Peatland Slope. These indicators are assumed to be equally predictive so are averaged.
- **Stressors** are represented by increased proportion of the wetland visited often by people on foot, lack of measures to reduce human disturbance of nesting waterbirds, and evidence of toxic contaminants. These are averaged.
- **Landscape** factors beneficial to nesting waterbirds are assumed to include increased wetland distance from roads, and extensive natural cover contiguous with the wetland and/or in its upland buffer. These are averaged.

Potential 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.

Non-tidal Wetlands – WBN Values Model

This function's value is based on the maximum score of 3 indicators. One is whether the wetland has been officially designated an IBA (Important Bird Area). A second is whether it is known to host a rare migratory waterbird species. The third considers whether the wetland is a rare wetland class within 2 miles and/or within its watershed.

3.16 SONGBIRD, RAPTOR, AND MAMMAL HABITAT (SBM)

Function Definition: The capacity to support, at multiple spatial scales, an abundance and diversity of songbirds, raptors, and mammals, especially species that are most dependent on wetlands or water. See worksheet *WildlifeList* 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. Several large mammals, such as moose and bear, as well as several species of songbirds and raptors, depend on Southeast Alaska's wetlands. Densities can be exceptionally high in some wetlands, due partly to high productivity of vegetation and invertebrates, and partly because wetland vegetation provides nest sites in close proximity to preferred foods.

Non-tidal Wetlands – SBM Function Model

Structure: In the unlikely event that the entire assessment area is always >99% water-covered, the model assigns the lowest score (0). For all other wetland types, half of the score is based on the wetland having relatively little surface water (thus more habitat space and structure for songbirds and most mammals), and the other half on the average of 6 metrics: *Productivity, StructureA, StructureB, Landscape, Waterscape*, and *Stressors*. The metrics are described as follows:

- **Productivity** is assumed to be greatest in wetlands with more hardwood cover, nitrogen-fixing plants, at low elevation, near marine waters, with high edge-to-area ratio and numerous upland inclusions. These are all considered to be equally predictive of SBM habitat, and their average is multiplied by the average of the scores for the wetland's size and vegetated width.
- **StructureA** is a group of indicators that together represent some beneficial components of SBM habitat. This includes cliffs, snags, downed wood, mature cedar stands, increased ground cover, and varied microtopography. These indicators are assumed to be equally predictive so are averaged.
- **StructureB** is another group of indicators that together reflect beneficial components of SBM habitat. This includes increased amounts of tree and shrub cover in and around the wetland, more mature trees, some small forest gaps, and a diversity of shrubs. These indicators are assumed to be equally predictive so are averaged.
- **Landscape** condition is assumed better for SBM if the wetland is on the mainland, and has a large proportion of natural vegetation in the wetland's contributing area and areas within 2 miles, as represented by 8 indicators which are assumed to be equally predictive and so are averaged.
- **Waterscape** condition is assumed better for SBM where a large proportion of the surrounding area is ponded areas, the wetland itself is near a pond or is a fringe wetland, has vegetation that is well-interspersed with patches of open water, and is actually or potentially used by beaver. These indicators are assumed to be equally predictive so are averaged.
- **Stressors** which could affect SBM use of a wetland include frequent human visitation, proximity to population centers, proximity to a road, and road blockage of wildlife access to the wetland. These indicators are assumed to be equally predictive so are averaged.

Note that some assessment methods, as an indicator of biodiversity, include "number of wetland types" or "number of hydroperiod types" present within a single wetland AA. WESPAK-SE does not use those because the lines between such types are seldom clearly distinguishable either in the field or from aerial imagery. WESPAK-SE addresses habitat heterogeneity (both within and surrounding an AA) using other indicators.

Potential 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.

Non-tidal Wetlands – SBM Values Model

This function is assumed to be more valuable where a wetland has been officially designated an IBA (Important Bird Area), or is known to host a rare breeding songbird or raptor species, or has the largest local patch of a major vegetation form.

Tidal Wetlands – SBM Function Model

Structure: Half the score depends on the amount of high marsh (increasing with the extent of that) while the other half is the average of 3 metrics: Productivity, Structure, and Landscape. These are calculated as follows:

- **Productivity** of the tidal wetland is assumed to be greater with increased freshwater inputs from tributaries, adjoined by a non-tidal wetland, sheltered location, and located in a priority habitat area for bear as indicated in the Southeast Alaska Conservation Assessment (Schoen & Dovichin 2007). These indicators are assumed to be equally predictive so are averaged.
- **Structure** beneficial to SBM is represented by increased proportion of the wetland which is high marsh; greater vegetated width of the high marsh; presence of a convoluted wetland edge with uplands; a mature (not recently deglaciated or uplifted) successional condition, and the greater of: driftwood extent or other large woody debris extent. These 4 indicators are assumed to be equally predictive of SBM so are averaged.
- **Landscape** score is comprised one-third by location (tidal wetlands along the Stikine or in other mainland rivers are scored the highest), one-third by wetland size, and one-third by the average of several indicators, which include some stressors:

proximity to a cliff (e.g., potential for seabird nesting), proportion of landscape comprised of natural land cover at two scales, isolation from population centers, and absence of barriers that could hinder mammal movements.

Tidal Wetlands – SBM Values Model

For tidal wetlands, this function is assumed to be more valuable where a wetland has been officially designated an IBA (Important Bird Area), or is known to host a rare songbird, raptor, or mammal species. If neither, the wetland is nonetheless assigned some value (1.0) for this functoin.

3.17 NATIVE PLANT HABITAT (PH)

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

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. Plant communities of tidal marshes are relatively simple, with high redundancy among tidal wetlands (e.g., Phillips 1977, Burg et al. 1980).

Non-tidal Wetlands – PH Function Model

Structure: The model is the weighted average of 7 factors: *Aquatic Fertility* (weighted 3x), *Terrestrial Fertility* (weighted 3x), *Species-Area* (weighted 2x), *Landscape* (weighted 2x), and unweighted: *Climate, Competition/Light* and *Stressors*. These are calculated as follows:

- **Aquatic Fertility** is assumed to increase with increased evidence of groundwater input, lower elevation, presence of a tributary, not recently deglaciated, shallow water depth, high interspersion of vegetation and open water, large proportion of wetland is flooded only seasonally, and has moderate water level fluctuation. These indicators are assumed to be equally predictive so are averaged.

- **Species-Area** score increases with increased wetland size, vegetated width, and the proportion of the wetland that is inundated only seasonally. The scores these are averaged.
- **Terrestrial Fertility** is assumed to increase (up to 75% cover) with increased cover of hardwoods (particularly nitrogen-fixers), karst substrate, presence of finer-textured and moderately organic soils, limited cover of moss, lack of granitic bedrock, and wetland type (in this order of descending assumed fertility: Riparian Wetland > Marsh/Fen > Uplift Meadow > Open Peatland > Forested Peatland). These indicators are all assumed to be equally predictive so are averaged.
- **Climate** assumes greater wetland plant diversity where mean annual temperatures are warmer, closer to marine waters, and south-facing aspect of the wetland's contributing area. These indicators are assumed to be equally predictive so are averaged.
- **Landscape** condition is assumed better for native plants where the proximate upland land cover is mostly natural, ponded areas are numerous and nearby, a landslide has occurred in or near the wetland, and actual or potential use by beaver has been noted. These indicators are assumed to be equally predictive and so are averaged.
- **Competition/ Light** encompasses several indicators. An absence of invasive plant species (both in the wetland and adjoining uplands) counts for half the score. The other half is the average of: intermediate tree canopy, lack of strongly dominant species in the shrub and herbaceous layers, varied microtopography, and more herbaceous than woody cover.
- **Stressors** are represented by increased wetland visitation by humans without measures to minimize soil disturbance; proximity to roads and population centers; not on an island free of deer/elk; more-altered timing of runoff reaching the wetland; and increased soil disturbance. These indicators are assumed to be equally predictive and so are averaged.

Note that some assessment methods, as an indicator of biodiversity, include "number of wetland types" or "number of hydroperiod types" present within a single wetland AA. WESPAK-SE does not use those because the lines between such types are seldom clearly distinguishable either in the field or from aerial imagery. WESPAK-SE addresses habitat heterogeneity (both within and surrounding an AA) using other indicators.

<u>Potential 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.

Non-tidal Wetlands – PH Values Model

To represent the value of native plant habitat, the model takes the maximum of: (a) rare plant species is present in or near the wetland, (b) average of vegetation form uniqueness at the 2-mile and watershed scales, (c) wetland scores averaged for Songbird & Mammal Habitat, Pollinator Habitat, and Subsistence.

Tidal Wetlands – PH Function Model

<u>Structure</u>: For tidal wetland plant habitat, the model is the average of 5 weighted metrics: *Salinity* (weighted 2x), *Substrate* (weighted 2x), *Structure, Invasive Potential*, and *Landscape*. These are calculated as follows:

- **Salinity** decrease, which may enhance tidal plant diversity, is assumed to occur where a tidal wetland is located along a major mainland river (especially if nearer the head of tide) or there is high likelihood of groundwater discharge.
- **Substrate** conditions beneficial to tidal plant diversity are assumed to be coarser-textured or organic soils, large proportion of high and mid-elevation marsh, and large marsh width.
- **Structure** that is assumed to be predictive includes mature marsh age (not recently uplifted), more forb than graminoiod cover, moderate ground cover, and absence of one or two strongly dominant plant species.
- **Invasive Potential** by non-native plants is assumed to be greatest among small wetlands in which a large proportion is physically accessible to people, located near population centers, with only limited natural cover in their contributing area and upland buffer.
- **Landscape** conditions beneficial to tidal plant diversity are assumed to include proximity to natural land cover and located in a watershed considered to be a priority habitat area for bear as indicated in the Southeast Alaska Conservation Assessment.

Tidal Wetlands – PH Values Model

Tidal wetlands with high plant diversity are assumed to be valued more highly if they are in a watershed with few other tidal wetlands, or contain a rare plant species. If neither, the wetland is nonetheless assigned some value (1.0).

3.18 POLLINATOR HABITAT (POL)

Function Definition: The capacity to support pollinating insects, such as bees, wasps, butterflies, moths, flies, and beetles, and also pollinating birds (hummingbirds and perhaps others). No model is provided here for tidal wetlands due to their presumed limited capacity to support pollinating insects and birds, and due to lack of knowledge of features that would be predictive.

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.

In Southeast Alaskan Wetlands: Very little is known about the habitat requirements of pollinators in this region, and there have been no studies specifically of wetlands.

Non-tidal Wetlands – POL Function Model

Structure: The model is comprised of 2 metrics: *Pollen Onsite* and *Nest Sites*. These indicators are assumed to be equally predictive so are averaged. They are calculated as follows:

- **Pollen Onsite** is calculated as the average of 4 indicators. One is decreased coverage by persistent surface water. A second is greater cover of herbaceous relative to woody plants. A third is more forb cover, and the fourth is the average of scores for 4 indicators: moderate ground cover density, lack of invasive or strongly dominant herbaceous species, and south-facing aspect,
- **Nest Sites** available for pollinating insects are assumed to increase with increased snags, large-diameter trees, downed wood, microtopographic variation, and cliffs, as well as with less soil disturbance. Loose rock associated with cliffs or talus slopes provides nest areas for some pollinating insects.

Potential for Future Validation: Among a series of wetlands spanning the function scoring range and a range of wetland condition (integrity).

Non-tidal Wetlands – POL Values Model

Pollination is presumably valued to a greater degree if a wetland contains a rare plant (although not all plants are insect-pollinated), or contains the only patch type of a particular vegetation form within 2 miles or in the watershed.

3.19 PUBLIC USE & RECOGNITION (PU)

Definition: The potential and actual capacity of a wetland to sustain low-intensity human uses such as hiking, 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. Whether active or passive, outdoor recreation on public lands in Southeast Alaska is a major contributor to the regional economy (Colt & Fay n.d.).

Non-tidal Wetlands

Structure: The score for Public Use value of a wetland is assumed to increase with an increase in scores for 3 metrics: *Convenience*, *Investment*, and *Recreation Potential.* These are considered equally predictive so are averaged. They are comprised of the following indicators:

- **Convenience**: score is greater where most of wetland is physically accessible, publicly owned (especially as a conservation area), visible from roads, at low elevation, near marine waters and a population center. Scores for these are averaged.
- **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.
- **Recreation Potential**: score is greater if wetland is on a lake and has trails, visitor center, and similar educational or recreational enhancements, while also featuring best management practices to reduce ecological impacts of overuse. Scores for these are averaged.

Tidal Wetlands

The model is similar to that for non-tidal wetlands, except that the final average includes consideration of the rarity of tidal wetlands in the watershed (if rare, Public Use value is considered to be greater).

3.20 SUBSISTENCE & PROVISIONING SERVICES (Subsis)

Definition: The passive and sustainable providing of tangible natural items of potential commercial or subsistence value.

Non-tidal Wetlands

Wetlands considered more valuable are those in which humans harvest natural products sustainably and with minimal impact. If a wetland is located in a designated Non-Subsistence Use area, its assigned score is 0. For all other non-tidal wetlands, the score is based on whichever score is higher: (a) a score based on ADFW Subsistence Area maps, or (b) the average of these indicators: lower elevation, increased proximity to a population center, tidal waters, or (c) average of these indicators: location in a area with highly suitable wintering habitat for deer, location in a priority watershed for salmon (according to the Southeast Alaska Conservation Assessment), intersected by stream accessible to anadromous fish, and direct evidence of wild game or fish harvest.

Tidal Wetlands

The score is based on whichever score is higher: (a) a score based on ADFW Subsistence Area maps, or (b) the average of these indicators: lower elevation, increased proximity to a population center, tidal waters, or (c) average of these indicators: location in a priority watershed for salmon (according to the Southeast Alaska Conservation Assessment), located in a watershed with few other tidal wetlands, intersected by stream accessible to anadromous fish, direct evidence of wild game or fish harvest, proximity to a population center.

3.21 WETLAND SENSITIVITY (Sens)

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).

Non-tidal Wetlands

Structure: The model assumes that wetland sensitivity, especially to human activities, can be represented by the unweighted average of the following 6 metrics, all considered equally predictive:

- **Abiotic Resistance** is assumed to be less (i.e., wetland more sensitive) in shallow ponded wetlands at higher elevations, with relatively small contributing areas, steep surrounding slopes, long duration freezing, constricted outlets, and seasonal-only inundation.

- **Biotic Resistance** is assumed to be less (i.e., wetland more sensitive) in wetlands that are small; have a narrow vegetated width; are already dominated by native plant species; also support rare amphibians, waterbirds, songbirds, mammals, or plants; and (less predictably) have limited ground cover, convoluted upland edge, and few shrub species. Indicators in this last group are averaged, and their average is then combined with the average of the preceding more-predictive indicators.
- **Site Fertility** is assumed to speed recovery time from disturbance, which is a component of Wetland Sensitivity. It is predicted to be greater in wetlands that have not been deglaciated recently, have more cover of nitrogen-fixing plants, and are a type of wetland that typically has greater nutrient availability. Thus, wetlands with the least nutrient availability are likely to be the most sensitive. In order of *increasing* nutrient availabililty, they are: Open Peatland > Forested Peatland > Uplift Meadow > Fen/Marsh > Floodplain Meadow.
- **Climate** also influences recovery rate. The most sensitive wetlands are assumed to be those in regions with colder mean annual temperature, distant from tidal waters, and in headwater locations.
- **Availability of Colonizers** also affects the recovery rate. Recovery times in wetlands might be greater if surrounding lands are dominated by natural land cover, including a high proportion and proximity of ponded wetlands and lakes, and no herbaceous species is strongly dominant, and wetland is not on a small island.
- **Growth Rates** of wetland vegetation, and thus the time to full recovery, also depend on the plant species. Trees grow the slowest and live the longest, so if a wetland contains much tree cover, especially of large-diameter trees, and that is removed, full recovery takes longer. Thus, such wetlands could be considered less resilient and more sensitive.

Tidal Wetlands

The most sensitive tidal wetlands are assumed to be those that are narrow, mostly unsheltered from waves, have shrunk in size in recent years, lack nitrogen-fixing vegetation, are distant from other tidal marshes, are in watersheds that have little tidal wetland area, are adjoined by steep slopes with limited natural cover, and support a waterbird or other wildlife or plant species of conservation concern. These indicators are assumed to be equally predictive so are averaged.

3.22 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, operating within the bounds of natural or historic disturbance regimes. However, in the case of WESPAK-SE, the model outputs were not scaled to reference wetlands. A model is hypothesized only for non-tidal wetlands, as too few **rapid** indicators relevant to tidal wetlands could be identified.

Non-tidal wetlands in excellent ecological condition often have varied microtopography, little bare ground, no strongly dominant herbaceous or shrub species, beaver, and at least one species of conservation concern. However, many wetlands perceived to be in excellent condition – like most of those in Southeast Alaska – do not have any of these characteristics.

3.23 WETLAND STRESS (STR)

Definition: The degree to which the wetland is or has recently been altered by, or exposed to risk from, human-related factors that degrade its ecological condition and/or reduce its capacity to perform one or more of the functions listed in this document.

Non-tidal Wetlands

If toxic levels of contaminants have been measured at the site, a stressor score of 10 is assigned automatically. Otherwise, half of the stressor score is the maximum of the scores of the 9 stressor categories used in form S:

Wetter Water Regime - Internal Causes
Wetter Water Regime - External Causes
Drier Water Regime - Internal Causes
Drier Water Regime - External Causes
Altered Timing of Water Inputs
Accelerated Inputs of Nutrients, Contaminants, and/or Salts
Excessive Sediment Loading from Contributing Area
Soil or Sediment Alteration Within the Assessment Area
Vegetated Cover Removal Within the Assessment Area

The other half is an average of the following, indicating increased stress:

- greater cover of invasive plants along a wetland's upland edge
- greater proportion of a wetland is accessible to humans on foot

- closer proximity to a population center
- closer proximity to a road
- greater portion of wetland is visible from a road
- wildlife access to and from a wetland is limited by roads or other barriers
- contributing area has a large extent of impervious surface
- contributing area has a limited extent of natural vegetation
- not public lands

Tidal Wetlands

If toxic levels of contaminants have been measured at the site, a stressor score of 10 is assigned automatically. Otherwise, the stressor score is the average of the following groups:

Group A: This is the average of the 9 stressor categories listed above.

Group B: The average of: proximity to a road, large portion of wetland visible from roads, close to a population center, barriers to animal movements.

Group C: The average of: distance to natural vegetation, size of that patch, extent of impervious surface near the wetland.

Group D: Just one indicator (available data indicate toxic levels of contaminants but not necessarily onsite).

4.0 Examples of Other Methods for Rapid Assessment of Wetlands in Southeast Alaska

For a more comprehensive review of such methods, see:

CH2M Hill. 2010. Evaluation of wetland assessment methods and credit-debit systems for in-lieu fee mitigation of coastal aquatic resources in Southeast Alaska. Report to Southeast Alaska Land Trust, Juneau, AK. http://southeastalaskalandtrust.org/wetland-mitigation-sponsor/

1. **Juneau Wetlands Management Plan** (and subsequent modified criteria)

This includes the following documents:

- Adamus Resource Assessment, Inc. (ARA). 1987. Juneau Wetlands: Functions and Values. Community Development Department, City and Borough of Juneau, AK.

- Community Development Department (CDD), City and Borough of Juneau. 1997. Revised City and Borough of Juneau Wetlands Management Plan. CDD, Juneau, AK.
- Bosworth, K. and P.R. Adamus. 2006. Delineation and Function Rating of Jurisdictional Wetlands on Potentially-developable City-owned Parcels in Juneau, Alaska. Community Development Department, City and Borough of Juneau, AK.

The first document provided technical information (field data, literature synthesis, and technical criteria) that was needed for the first prioritization of Juneau wetlands, which occurred in the second document and was based on estimates of functions and values of all mapped Juneau wetlands. The third document included a limited attempt by ARA, Inc. to update the technical criteria and apply them to several properties owned by the City-Borough of Junean (CBJ). Prioritization was based on assigning wetlands to qualitative categories (High, Moderate, Low etc.) rather than using a continuous numeric scale. Local and state agencies were extensively involved during the development of the 1987 and 1997 documents. In 2014-2015, the CBJ is using WESPAK-SE to assess functions and values of nearly 400 wetlands.

2. **Hydrogeomorphic (HGM) Method**

This is the following document:

- Powell, J, D. D'Amore, R. Thompson, T. Brock, P. Huberth, B. Bigelow, and M.T. Walter. 2003. Wetland functional assessment guidebook operational draft guidebook for assessing the functions of riverine and slope river proximal wetlands in coastal Southeast & Southcentral Alaska using the HGM approach. Report to the Alaska Dept. of Environmental Conservation, Juneau, AK.

During the development of this method, data on 18 variables were collected from about 33 streams and wetlands in the Juneau area. The data were used to inform numeric criteria and data forms that can be applied to assess functions of stream-associated wetlands. Data collection requirements associated with the final method are more intensive than for other wetland assessment methods. It appears this method, with its restricted focus on riverine wetlands, has had only limited use since its publication in 2003.

3. **NatureServe Method**

This is represented by the following document:

- Kittel, G. and D. Faber-Langendoen. 2011. Watershed Approach to Wetland Mitigation: A Framework for Juneau, Alaska. Prepared by NatureServe, Arlington, VA.

This method attempts to focus on one aspect of wetlands, their ecological integrity ("condition"). The relationship of this attribute to each wetland function or value (e.g., salmon rearing habitat, recreational use) is unknown. The method is a spinoff of a similar method NatureServe developed in Colorado. There is little in the method's data forms to suggest that it has been modified specifically to address conditions unique to Juneau or Southeast Alaska. Method users employ a combination of GIS-compiled spatial data (e.g., wetland type abundance, position in watershed, roads, rare species) and onsite data (e.g., vegetation, soils, hydrology, stressors) to categorically assess wetland integrity. Users then combine the categories into a single numeric condition score for each wetland. The conversion is based on simply summing the weighted indicators within each group (Landscape, Size, Condition, Vegetation, Hydrology, Soils) without recognition of their potential interactions or relationship to wetland type. Four wetland types are recognized (Estuarine Wetland, Bog/Fen, Emergent, Forested/Shrub) and prioritized based on their local rarity and restorability. Users must be able to identify wetland plants to species. NatureServe applied the method to 12 Juneau-area wetlands in 2010. There appears to have been little or no coordination with or involvement of local agencies. The method apparently has not been used in Alaska since that original application.

4. Habitat Equivalency Analysis (HEA)

This is an approach to computing mitigation credits, used experimentally in various parts of the United States by the US Army Corps of Engineers and NOAA. In Southeast Alaska, its use was demonstrated in the following project:

- Houghton, J. and M. Havey. 2010. Proposed Sitka Airport Improvement Projects – Mitigation Plan for Marine Impacts of the Preferred Alternatives. Report to Alaska Dept. of Transportation and Public Facilities and the Federal Aviation Administration.

Although this approach is for marine intertidal habitats it could be applied to wetlands. It is an accounting approach, not a standardized technical protocol that anybody can use to assess the functions and values of an area. For every individual project, relative levels of functions and values of different wetland *types* must be assigned beforehand by a "committee of experts" or less desirably, by a single expert. Doing so assumes that defining those types using just a few features, such as elevation and dominant vegetation, is sufficient to rank them based on all their functions and values, and that then applying those uniform rankings to all wetlands of that type is justified. However, doing that is not supported by current science. Even when the rankings of the types seem correct, the arbitrary basis for the coefficients assigned to each type (e.g., that open water is only 20% as "functional" as kelp beds) is unsupported by research. Either implicitly or explicitly, it requires that multiple functions of each type be combined into a single score or weighting factor that may reflect everything from primary production to fish to seabirds. Many stakeholders were involved in the application of this approach to the Sitka Airport mitigation.

5. Proper Functioning Condition (PFC)

This approach is described in:

- Pritchard, D. (coordinator). 1994. Process for Assessing Proper Functioning Condition for Lentic Riparian-Wetland Areas. Technical Reference 1737-11 1994. USDI Bureau of Land Management, Denver, CO.
- Pritchard, D. (coordinator). 1998. A User Guide to Assessing Proper Functioning Condition and the Supporting Science for Lotic Areas. Technical Reference 1737-15 1998. USDI Bureau of Land Management, Denver, CO.

This is a checklist approach that contains no models or formulas to automatically generate a score for an area. A group of resource professionals visits a wetland or stream reach and answers a short series of questions about their impressions of the condition of various natural processes within that unit. It is then up to the group to decide if the assessment unit is in Proper Functioning Condition, Functional-At-Risk, or Nonfunctional. Specific functions and values are not rated. Considerable expertise in interpreting stream geomorphic processes and classification is needed in order to generate consistent ratings. See: http://www.fs.usda.gov/detail/tongass/maps-pubs/?cid=stelprdb5413899

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