WASHINGTON NATURAL HERITAGE PROGRAM

Applying NatureServe's Ecological Integrity Assessment Methodology to Washington's Ecological Systems

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1.0 Overview of Ecological Integrity Assessments

This document describes the Ecological Integrity Assessment methodology and its development and application for monitoring and assessing ecological conditions.

1.1 What is an Ecological Integrity Assessment?

Building on the related concepts of biological integrity and ecological health, ecological integrity is a broad and useful endpoint for ecological assessment and reporting (Harwell et al. 1999). "Integrity" is the quality of being unimpaired, sound, or complete. Ecological integrity can be defined as "the structure, composition, and function of an ecosystem operating within the bounds of natural or historic disturbance regimes" (adapted from Lindenmayer and Franklin 2002, Young and Sanzone 2002, Parrish et al. 2003). To have ecological integrity, an ecosystem should be relatively unimpaired across a range of ecological attributes and spatial and temporal scales (De Leo and Levin 1997). The notion of naturalness depends on an understanding of how the presence and impact of human activity relates to natural ecological patterns and processes (Kapos et al. 2002). Identification of reference or benchmark conditions based on natural or historic ranges of variation, although challenging, can provide a basis for interpretation of ecological integrity (Swetnam et al. 1999). For the Ecological Integrity Assessment (EIA) methodology, ecological integrity is defined as an ecosystem having the full range of organisms and ecological processes expected with no or minimal human influence.

The EIA is a multi-metric index designed to document degradation of key biotic and abiotic attributes along a continuum from reference standard to degraded. The EIA approach to assessing ecological integrity is similar to the Index of Biotic Integrity (IBI) approach. The original IBI interpreted stream integrity from twelve metrics that reflected the health, reproduction, composition and abundance of fish species (Karr and Chu 1999). Each metric was rated by comparing measured values with values expected under relatively unimpaired (reference standard) conditions, and the ratings were aggregated into a total score. NatureServe[1] has developed an index of ecological integrity based on metrics of biotic and abiotic condition, size, and landscape context intended to measure current ecological condition[2] as compared to the reference standard (Harwell et al. 1999, Andreasen et al. 2001, Parrish et al. 2003). Each metric is rated by comparing measured values with values expected under relatively unimpaired (reference standard) conditions, and the ratings are aggregated into a total score. The EIA uses a scorecard matrix to communicate the results of the assessment. A rating or score for individual metrics, as well as an overall index of ecological integrity are presented in the scorecard.

[1] In 2004, NatureServe formed the Ecological Integrity Assessment Workgroup to develop the EIA approach. Members of this group included ecologists from the Arkansas, Colorado, Idaho, and North Carolina Natural Heritage Programs/Data Conservation Centers as well as ecologists from NatureServe and The Nature Conservancy.

[2] *Ecological condition* represents the current state of a resource compared to reference standards or benchmarks for physical, chemical, and biological characteristics.

The EIA can be applied to multiple spatial scales (e.g., landscape or site-scale) and with a variety of data types (e.g., GIS or field-based). The EIAs are developed for individual ecological systems (Comer et al. 2003) using a three level approach to identify a suite of metrics, including Level 1 (remote sensing), Level 2 (rapid ground-based), and Level 3 (intensive ground-based) metrics (EPA 2006). This three-level approach provides a hierarchical, spatially integrated framework for monitoring and assessment resulting in effective strategies and efficient use of resources (EPA 2006). In summary, the EIA framework provides a standardized currency of ecosystem integrity across all terrestrial ecosystem types. This information can then be used for setting conservation and restoration strategies as well as effectiveness monitoring. When site-level ecological integrity information is synthesized across a large spatial scale (e.g., watershed, ecoregion, state, etc.) status and trend reports about specific ecosystems can be produced.

NatureServe has a developed a series of general EIA templates that are broadly applicable (Faber-Langendoen et al. 2006; 2008a, 2008b). These general templates can be fine-tuned for ecological systems specific to a particular geographic area. For example, regionally specific EIAs have been developed for upland, wetland, and riparian ecological systems throughout the United States (Faber-Langendoen 2007; Faber-Langendoen et al. 2006, 2008a, 2009a, 2010; Faber-Langendoen 2008; Unnasch et al. 2009; NatureServe 2006, 2010; Rocchio and Crawford 2009, Lemly and Rocchio 2009, Rocchio 2006, Vance et al. *In progress*, White et al. *In progress*, Tierney et al. 2009).

The Washington Natural Heritage Program has utilized adapted the general EIA templates framework and adapted it to Washington's Ecological Systems (Rocchio and Crawford 2008; see http://www1.dnr.wa.gov/nhp/refdesk/communities.html).

Ecological Integrity Assessments are developed using the following steps:

1) outline a general conceptual model that identifies the major ecological attributes, provide a narrative description of declining integrity levels based on changes to those ecological attributes, and introduce the metrics-based approach to measure those attributes and assess their levels of degradation.
2) use ecological classifications at multiple classification scales to guide the development of the conceptual models, allowing improved refinement of assessing attributes, as needed.
3) use a three level assessment approach – (i) remote sensing, (ii) rapid ground-based, and (iii) intensive ground-based metrics – to guide development of metrics. The 3-level approach is intended to provide increasing accuracy of ecological integrity assessment, recognizing that not all conservation and management decisions need equal levels of accuracy.
4) identify ratings and thresholds for each metric based on "normal' or "natural range of variation" benchmarks.
5) provide a scorecard matrix by which the metrics are rated and integrated into an overall index of ecological integrity.

A general note of caution: ecosystems are far too complex to be fully represented by a suite of key ecological attributes, indicators, and metrics. As such, our efforts to assess ecological integrity are approximations of our current understanding of any ecosystem which means the metrics, indices and scorecards presented in this report must be flexible enough to allow change over time as our knowledge grows.

1.2 Importance of Ecological Classification

1.2.1 Classification and Natural Range of Variation

Classification is a necessary component to both using and developing an EIA as it constrains natural variability and thus helps clarify whether differences in ecological condition are due to natural or anthropogenic causes. To successfully develop indicators of ecological integrity, an understanding of the structure, composition, and processes that govern the wide variety of ecosystem types is needed. Ecological classifications help ecologists to better cope with natural variability within and among types so that differences between occurrences with good integrity and poor integrity can be more clearly recognized. In other words, classification helps us differentiate between signals (indicators of degradation) from noise (natural variability). Classifications are also important in establishing "ecological equivalency" which is especially important for establishing restoration targets and benchmarks. There are a variety of classification schemes and ecoregional frameworks for structuring ecological integrity assessments. The EIA presented here are based on the International Vegetation Classification and Ecological Systems classification.

1.2.2 The International Vegetation Classification and Ecological Systems Classification

The International Vegetation Classification (IVC) covers all vegetation from around the world. In the United States, its national application is the U.S. National Vegetation Classification (NVC), supported by the Federal Geographic Data Committee (FGDC 2008), NatureServe (Faber-Langendoen et al. 2009c), and the Ecological Society of America (Jennings et al. 2009), with other partners. The IVC and NVC were developed to classify both wetlands and uplands, and identify types based on vegetation composition and structure and associated ecological factors.

The NVC meets several important needs for conservation and resource management. It provides:

- a multi-level, ecologically based framework that allow users to address conservation and management concerns at scales relevant to their work.
- characterization of ecosystem patterns across the entire landscape or watershed, both upland and wetland.
- information on the relative rarity of types. Each association has been assessed for conservation status (extinction risk).
- relationships to other classification systems are explicitly linked to the NVC types
- a federal standard for all federal agencies, facilitating sharing of information on ecosystem types (FGDC 2008).

A related classification approach, the Ecological Systems classification (Comer et al. 2003), can be used in conjunction with the IVC and NVC. Ecological systems provide a spatial-ecologic perspective on the relation of associations and alliances (fine-scale NVC types), integrating vegetation with natural dynamics, soils, hydrology, landscape setting, and other ecological processes. They can also provide a mapping application of the NVC, much as soil associations help portray the spatial-ecologic relations among soil series in a soil taxonomic hierarchy. Ecological systems types facilitate mapping at meso-scales (1:24,000 – 1:100,000; Comer and Schulz 2007) and a comprehensive ecological systems map exists for Washington State (www.landscope.org). Ecological systems are somewhat comparable to the Group level of the revised NVC hierarchy, and can be linked to higher levels of the NVC hierarchy, including macrogroups and formations. Ecological systems meet several important needs for conservation, management and restoration, because they provide:

- an integrated biotic and abiotic approach that is effective at constraining both biotic and abiotic variability within one classification unit.
- comprehensive maps of all ecological system types are becoming available.
- explicit links to the USNVC, facilitating crosswalks of both mapping and classifications.

Both the NVC and Ecological Systems classifications can be used in conjunction to sort out the ecological variability that may affect ecological integrity. **Ecological Systems were used as the foundation from which Washington's EIAs were developed. It is recommended that the *Draft Field Guide to Washington's Ecological Systems* (Rocchio and Crawford 2008) be used to identify the ecological system in question to ensure that the correct EIA is used.** However, the EIA can be used with fine-scale NVC units (e.g. plant associations) as long as the Ecological System associated with the NVC unit is identified and the corresponding EIA is used. In such cases, the user should cautiously consider whether all the EIA metrics are applicable to the NVC unit.

1.2.3 Integration of Classification and Ecological Integrity Assessment

The purpose of intersecting the various classifications approaches with that of the EIA methods is that as the level of assessment intensifies we may find (but not always) that a greater (or lesser) level of ecosystem classification detail is needed. Finer classes allow for greater specificity in developing conceptual models of the natural variability and stressors of an ecological system and the thresholds that relate to impacts of stressors. On the other hand, coarser classes allow the development of metrics that are more likely to be applicable across classes since the specificity of these metrics is limited by scale. Because the Ecological Systems classification remains comparable to coarser or finer-scale levels of the NVC, the flexibility to tailor or adapt EIAs to NVC types is possible. For example, there are some metrics which are broadly applicable across any classification scale. For example, the percent cover of native species is a metric that is likely useful for any classification type, whether coarse or fine-scale. Likewise, some metrics are very specific regardless of scale, such as the Floristic Quality Index which requires detailed knowledge of the floristics of any classification unit. Thus, consideration of both the level of metric resolution and the scale of classification that is desired is taken into account in order to accurately develop the metric. In summary, the EIA is both practical and flexible for a range of assessment types spanning broad to local scale and from extensive to intensive detail and effort.

1.3 Conceptual Ecological Models

A conceptual model helps guide the selection of indicators, organized across a standard set of ecological attributes and factors (e.g., Harwell et al. 1999, Young and Sanzone 2002, Parrish et al. 2003). With a specific Ecological System type in mind, a conceptual model describing linkages between key ecosystem attributes and known stressors is developed and used for identifying and interpreting metrics with high ecological and management relevance (Noon 2003; Faber-Langendoen et al. 2009a). The first component to the conceptual model is identifying the key ecological attributes associated with the overall structure, composition and ecological processes which are considered primary drivers or have a very important functional role in maintaining the integrity of the ecological system. In other words, the conceptual models identify the key ecological drivers that are most valuable to measure for assessing ecological integrity. The models can be narrative or a graph. Next, the primary stressors impacting the ecological system are identified and incorporated into the conceptual model. With stressors incorporated, the conceptual model is then used to describe the predicted relationships between ecological components and their potential stressors.

1.4 Ecological Indicators and Metrics

1.4.1 Use of Indicators and Metrics

The conceptual model provides guidance as to which specific indicators and metrics will be useful for distinguishing a highly impacted, degraded or depauperate state from a relatively unimpaired, intact and functioning state. The difference between indicators and metrics is subtle yet important to distinguish. **Indicators** provide the specificity needed to assess the key ecological attributes. Example indicators for vegetation include structure, composition, diversity, life history, tolerance, alien taxa and examples for hydrology include water depth or flooding duration. **Metrics** are measureable expressions of an indicator. For example, metrics for the alien plant taxa indicator might include percent alien species richness, relative alien cover, or number of invasive alien species.

For this report, metrics are the focus. Any use of indicators is for conceptual organization of metrics but indicators are not included in the EIA Scorecards and thus are not ranked or scored in the EIA method. However, if this would be useful for monitoring, indicators could be added into the framework.

1.4.2 Selecting Metrics

The selection of metrics is focused on those that can detect changes in a key ecological attributes due to a response that attribute to stressors. In other words, not all measures of various characteristics in an ecosystem are useful for measuring ecological integrity. Metrics that can be used to measure a key ecological attribute and is sensitive to changes from stressors are referred to here as "**condition metrics**." Stressors themselves can also be measured, but information from these metrics provides only an indirect measure of ecological condition – we will need to infer that changes in the stressor correspond to changes in the condition of the system. Such metrics are referred to as "**stressor metrics.**" It is preferable to use condition metrics separate from stressors metrics, in order to independently assess the effects of stressors on condition at a site to guide interpretation and possible correlations between ecological integrity and stressors (e.g. stressor checklists; Section 2.9). However, when measuring condition is challenging or not cost-effective a stressor metric may be substituted. However, if a stressor index is used to test, verify, or validate the EIA model then it is important to remove stressor metrics from the analysis (Section 1.10). Table 1 shows how metrics relate to the key ecological attributes identified in the conceptual ecological model, which are themselves organized by rank factors. Stressor checklists are also shown within the context of this model (Table 1).

Metrics are identified using a variety of expert-driven processes and through a series of data-driven calibration tests. The scientific literature is searched to identify existing and vetted metrics that could be useful for measuring ecological integrity. Some of the metrics used to develop the Washington EIAs were derived from a national effort to select metrics for rapid assessment and monitoring of ecological integrity of wetlands (Faber-Langendoen et al. 2006; Faber-Langendoen et al. 2008). Many of these metrics are also applicable to some upland ecological systems. In addition, a variety of existing rapid assessment and monitoring materials, particularly the California Rapid Assessment Manual (Collins et al. 2006, 2007, 2008), the Ohio Rapid Assessment Manual (Mack 2001), indicators of rangeland health (Pellant et al. 2005), Natural Resources Conservation Service ecological site descriptions, and literature sources were referenced for suitable metrics. From these resources, a list of potential metrics was compiled and then filtered through the following criteria to determine which would be most useful for use in the EIA (Andreasen et al. 2001, Kapos et al. 2002, Kurtz et al. 2001):

a) useful at multiple spatial scales;
c) grounded in natural history and ecologically relevant;
d) practically relevant to managers, decision-makers, and the public;
e) flexible,
f) feasible, to implement and measure, with relevant target or threshold settings; and
g) responsive, including to changes from stressors.

1.4.2 Protocols for Measuring Metrics

Protocols are written to ensure consistent and clear methods are used measure each metric. The protocol documentation includes the following pieces of information for each metric:

- definition of metric
- source(s) for metric and/or metric ratings
- rationale for selection of the metric
- measurement protocols
- rationale for scaling metric ratings

Protocols for many of the Washington EIAs can be found in Rocchio and Crawford (2009). Other protocols can be found in Faber-Langendoen 2007, Faber-Langendoen et al. (2006, 2008, 2009a), and Rocchio 2006. Protocols for the remaining metrics used in the Washington EIAs are in progress.

Table 1. Conceptual Ecological Model for a wetland. Stressors are described using checklists (see Section 2.9).

Rank Factor	Key Ecological Attribute	Metric
LANDSCAPE CONTEXT	**Landscape Structure**	Landscape Connectivity
		Buffer Index
		Surrounding Land Use Index
	Landscape Stressors	Landscape Stressors Checklist
SIZE	**Size**	Patch Size Condition
		Patch Size
CONDITION	**Vegetation**	Vegetation Structure
		Organic Matter Accumulation
		Vegetation Composition
		Relative Cover of Native Plant Species
	Vegetation Stressors	Vegetation Stressors Checklist
	Soils/Physiochemical	Physical Patch Types
		Water Quality
		Soil Surface Condition
	Soil Stressors	Soil Stressors Checklist
	Hydrology	Water Source
		Hydroperiod
		Hydrologic Connectivity
	Hydrology Stressors	Hydrology Stressors Checklist

1.5 The Three Level Approach to Metric Development

The selection of metrics to assess ecological integrity can be done at three levels of intensity depending on the purpose and design of the data collection effort (Brooks et al. 2004, Tiner 2004, EPA 2006). This ”three-level approach” to assessments, summarized in Table 2, allows the flexibility to develop data for many sites that cannot readily be visited or intensively studied, permits more widespread assessment, while still allowing for detailed monitoring data at selected sites. The three-level approach is intended to provide increasing accuracy of ecological integrity assessment, recognizing that not all conservation and management decisions need equal levels of accuracy. The three-level approach also allows users to choose their assessment based in part on the level of classification that is available or targeted. If classification is limited to the level of forests vs. wetlands vs. grasslands, the use of remote sensing metrics may be sufficient. If very specific, fine-scale forest, wetland, and grassland types are the classification target then one has the flexibility to decide to use any of the three levels, depending on the need of the assessment. In other words, there is no presumption that a fine-level of classification requires a fine-level of ecological integrity assessment.

Because the purpose is the same for all three levels of assessment (to measure the status of ecological integrity of a site) it is important that the Level 1 assessment use the same kinds of metrics and major attributes as used at levels 2 and 3.

Level 1 Remote Assessments rely almost entirely on Geographic Information Systems (GIS) and remote sensing data to obtain information about landscape integrity and the distribution and abundance of ecological types in the landscape or watershed (Mack 2006, EPA 2006, Faber-Langendoen et al. 2009a). Level 1 metrics are usually developed from readily available, processed imagery or existing GIS coverages. Limited ground-truthing may be a component of some assessments.3

Level 2 Rapid Assessments use relatively rapid field-based metrics that are a combination of qualitative and narrative-based rating with quantitative or semi-quantitative ratings. Field observations are required for many metrics, and observations will typically require professional expertise and judgment (Fennessy et al. 2007).

Level 3 Intensive Assessments require more rigorous, intensive field-based methods and metrics that provide higher-resolution information on the integrity of occurrences within a site. They often use quantitative, plot-based protocols coupled with a sampling design to provide data for detailed metrics (Barbour et al. 1996, Blocksom et al. 2002). Often indices of biological condition such as the Floristic Quality Index or Vegetation Index of Biotic Integrity (Rocchio 2007a, 2007b, DeKeyser et al. 2003, Mack 2004, Miller et al. 2006) are solely used as the Level 3 assessment since vegetation has been found to be an effective integrator of condition of many ecological attributes (Mack 2004). However, quantitative metrics for soils, hydrology, birds, fish, amphibians, invertebrates, and other major ecological attributes can be used. These attributes are typically more time-consuming and costly to measure, but their response may differ enough from that of the vegetation that they provide additional valuable information on ecological integrity.

Although the three levels are integrated, each level is developed as a stand-alone method for assessing ecological integrity. **When conducting an ecological integrity assessment, one need only complete a single level that is appropriate to the study at hand.** Typically only one level may be needed, desirable, or cost effective. But for this reason it is very important that each level provide a comparable approach to assessing integrity, else the ratings and ranks will not achieve comparable information if multiple levels are used. It is also possible to use the three levels together. One might first assign a Level 1 rating or rank to all occurrences, then choose or prioritize among them to conduct a Level 2 EIA, and finally, focus on a few of those with a Level 3 assessment. The process should lead to an increasing accuracy of assessment. Where information is available for all three levels across multiple sites, it is desirable to calibrate the levels, to ensure that there is an increase in accuracy of the assessment as one goes from Level 1 to 3. To ensure that the three-level approach is consistent in how ecological integrity is assessed

[3] It should be pointed out that although remote sensing metrics are usually thought of as "coarser" or less accurate than field-based rapid or intensive metrics, this is not always the case. Some information available from imagery may be very accurate and more intensive than can be gathered in the field. Such information may also be more time-demanding and expensive.

Table 2. Summary of Three-level approach to conducting ecological integrity assessments (adapted from Brooks et al. 2004, USEPA 2006).

Level 1 – Remote Assessment	Level 2 – Rapid Assessment	Level 3 – Intensive Assessment
General description: Landscape condition assessment	**General description:** Rapid site condition assessment	**General description:** Detailed site condition assessment
Evaluates: Condition of individual areas/occurrences using remote sensing indicators	**Evaluates:** Condition of individual areas/occurrences using relatively simple field indicators	**Evaluates:** Condition of individual areas/occurrences using relatively detailed quantitative field indicators
Based on: • GIS and remote sensing data • Layers typically include: – Land cover / use – Other ecological types	**Can be based on:** • Stressor metrics (e.g., ditching, road crossings, and pollutant inputs); and • Condition metrics (e.g., hydrologic regime, species composition)	**Can be based on:** • Indicators that have been calibrated to measure responses of the ecological system to disturbances (e.g., indices of biotic or ecological integrity)
Potential uses: • Identifies priority sites • Identifies status and trends of acreages across the landscape • Identifies condition of ecological types across the landscape • Informs targeted restoration and monitoring	**Potential uses:** • Promotes integrated scorecard reporting • Informs monitoring for implementation of restoration or management projects • Supports landscape / watershed planning • Support s general conservation and management planning	**Potential uses:** • Promotes integrated scorecard reporting • Identifies status and trends of specific occurrences or indicators • Informs monitoring for restoration, mitigation, and management projects
Example metrics: -Landscape Development Index - Land Use Map - Road Density - Impervious Surface	**Example metrics:** - Landscape Connectivity - Vegetation Structure - Invasive Exotic Plant Species - Forest Floor Condition	**Example metrics:** - Landscape Connectivity - Structural Stage Index - Invasive Exotic Plant Species - Floristic Quality Index (mean C) - Vegetation Index of Biotic Integrity - Soil Calcium:Aluminum Ratio

among levels, a standard framework or conceptual model for choosing metrics is used (as shown in Table 1). Using this model, a similar set of metrics are chosen across the three levels, organized by the standard set of ecological attributes and factors - landscape context, size, condition (vegetation, hydrology, soils). This approach facilitates working between levels for a specific assessment. For example, if the goal is simply to estimate ecological integrity as accurately as possible, given limitation on time and resources, it maybe that landscape context and size are measured using level 1 metrics, soils and hydrology using level 2 metrics, and vegetation using level 3 metrics.

1.6 Definitions of the Ecological Integrity Ranking Scale

As noted previously, ecological integrity can be defined as the natural range of variability associated with the structure, composition, and function of an ecosystem exposed to minimal human-induced impacts. Impairment is defined as deviation from the natural range of variation as described by the ecological condition of reference or benchmark sites. A critical aspect of linking ecological integrity to reference sites is to distinguish natural ranges of variation from variation caused by a variety of negative anthropogenic impacts *i.e.*, those impacts that directly or indirectly degrade occurrences of an ecosystem. In other words, an understanding of how the presence and impact of human activity relates to natural ecological patterns and processes is needed to define ratings of individual metrics according to their deviation from the natural range of variation (Kapos et al. 2002). Ideally, measurements of each metric are collected from sites exposed to various degrees of human-induced disturbance ranging from those possessing minimal impact to those highly degraded by human activity, providing an ecological dose-response curve from which to assess the relationship between each metric and human disturbance. This process allows each metric to be quantitatively described along a continuum of human disturbance and provides a means of assessing the deviation of condition from its natural range of variation (Karr and Chu 1999). Each metric is then individually scored on a comparable scale then combined to produce an overall index score.

Regardless of which metric is being measured a standard ecological integrity ranking scale is used to score each measurement. A report-card style scale is used and metrics, key ecological attributes or overall ecological integrity is ranked from "excellent" to "degraded" or A", "B", "C" or "D" (Table 3). In order to make such rankings operational, the general ranking definitions need to be more specifically described. A suite of attributes that are assumed to be important to assessing various grades of ecological integrity are used to describe, in more detail, the overall condition each of these rankings are intended to reflect (Table 4). These descriptions provide guidance when developing specific metric rankings (Section 1.8). The helps ensure that all metrics, regardless of the actual unit of measurement of the field value, is ranked or scored on a comparable scale.

Table 3.Basic Ecological Integrity Ranks

Ecological Integrity Rank	Description
A	Excellent estimated ecological integrity
B	Good estimated ecological integrity
C	Fair estimated ecological integrity
D	Poor estimated ecological integrity

Table 4. Ecological Integrity Rank Definitions (Faber-Langendoen et al. 2009a)

Rank Value	Description
A	Occurrence is believed to be, on a global or range-wide scale, among the highest quality examples with respect to major ecological attributes functioning within the bounds of natural disturbance regimes. Characteristics include: the landscape context contains natural habitats that are essentially unfragmented (reflective of intact ecological processes) and with little to no stressors; the size is very large or much larger than the minimum dynamic area ; vegetation structure and composition, soil status, and hydrological function are well within natural ranges of variation, exotics (non-natives) are essentially absent or have negligible negative impact; and, a comprehensive set of key plant and animal indicators are present.
B	Occurrence is not among the highest quality examples, but nevertheless exhibits favorable characteristics with respect to major ecological attributes functioning within the bounds of natural disturbance regimes. Characteristics include: the landscape context contains largely natural habitats that are minimally fragmented with few stressors; the size is large or above the minimum dynamic area, the vegetation structure and composition, soils, and hydrology are functioning within natural ranges of variation; invasives and exotics (non-natives) are present in only minor amounts, or have or minor negative impact; and many key plant and animal indicators are present.
C	Occurrence has a number of unfavorable characteristics with respect to the major ecological attributes, natural disturbance regimes. Characteristics include: the landscape context contains natural habitat that is moderately fragmented, with several stressors; the size is small or below, but near the minimum dynamic area; the vegetation structure and composition, soils, and hydrology are altered somewhat outside their natural range of variation; invasives and exotics (non-natives) may be a sizeable minority of the species abundance, or have moderately negative impacts; and many key plant and animal indicators are absent. Some management is needed to maintain or restore[4] these major ecological attributes.
D	Occurrence has severely altered characteristics (but still meets minimum criteria for the type), with respect to the major ecological attributes. Characteristics include: the landscape context contains little natural habitat and is very fragmented; size is very small or well below the minimum dynamic area; the vegetation structure and composition, soils, and hydrology are severely altered well beyond their natural range of variation; invasives or exotics (non-natives) exert a strong negative impact, and most, if not all, key plant and animal indicators are absent. There may be little long-term conservation value without restoration, and such restoration may be difficult or uncertain.[5]

[4] Ecological restoration is: "the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed. Restoration attempts to return an ecosystem to its historic trajectory" (SER 2004).

[5] D-ranked types present a number of challenges. First, with respect to classification, a degraded type may bear little resemblance to examples in better condition. Whether a degraded type has "crossed the line" ("transformed" in the words of SER 2004) into a semi-natural or cultural type is a matter of classification criteria. These criteria specify whether sufficient diagnostic criteria of a type remain, bases on composition, structure, and habitat.

1.7 Natural Range of Variation and Reference Conditions

As noted above, the Ecological Integrity Rankings in the EIA are based or benchmarked in the concept of natural range of variability (NRV). In other words, the NRV provides a baseline from which biotic or abiotic variables can be assessed to determine whether ecological integrity has been degraded at a site. Thus, defining and describing the NRV for each ecological system is extremely important to maintaining consistency in how each metric is ranked within and among ecological systems. The conceptual ecological models associated with each ecological system summarize the key ecological factors associated with how the system functions within the bounds of the NRV. The specific values or description of the NRV for each of the key ecological attributes are represented by the "A" ranks for each associated metric.

The concept of the natural range of variability (NRV) is based on the temporal and spatial range of climatic, edaphic, topographic, and biogeographic conditions under which contemporary ecosystems evolved (Morgan et al. 1994; Quigley and Arbelbide 1997). Whitlock (1992) suggest modern vegetation patterns in the Pacific Northwest began about 5,000 – 1,500 years before present although notes that climate and vegetation response is constantly shifting. Thus, the NRV is not considered to be static for any given variable but rather a range of responses to climatic fluctuations which have occurred over the past few thousand years.

Another consideration for describing the NRV is the degree to which anthropogenic impacts have altered natural ecosystems. There is disagreement over whether disturbances resulting from Native Americans' interaction with the landscape occurred over spatial and temporal scales in which native flora and fauna were able to adapt (see Vale 1998 and Denevan 1992). The hypothesis offered by Vale (1998), which notes that Native American impacts were not ubiquitous across the landscape, is accepted for this project. Furthermore, where Native American impacts did occur (i.e. intentional burning of ecosystems), it is accepted here that they occurred over spatial and temporal scales in which native biota were able to adapt and thus are included within the NRV (Quigley and Arbelbide 1997; Wilhelm and Masters 1996). Modern (European/Asian) settlement of Washington is presumed to have introduced a myriad of land uses and impacts that, because of their intensity, frequency, and duration were novel changes to the ecological template upon which most contemporary ecosystems evolved.

The description of the NRV is based on historical evidence and current status of natural variation. The current status of NRV is best measured by collecting data from sites with minimal human-induced stress. These conditions, also referred to as the **reference standard condition**, represent one end of a continuum ranging from sites with minimal or no exposure to human-induced disturbance to those in a highly degraded condition due to such impacts (Stoddard et al. 2006). This continuum is also called the **reference condition** and characterizes the full range of common circumstances – from seemingly 'intact' or benchmark sites to highly degraded sites – so that metrics may be developed and applied that adequately characterize that full range of conditions on the landscape. Sampling ecological conditions associated with the entire spectrum of human-induced stress allows the construction of multi-metric indices as well as a framework for interpreting changes in ecological condition (Davies and Jackson 2006). This requires collection of data from sites exposed to varying types and intensities of human disturbance in order to characterize how metrics respond to increasing human-induced stress. Historical information can also be used to define what ecological conditions were like prior to major human alterations. Only through such sampling and incorporation of historical information can the full range of metric values be sufficiently analyzed and interpreted to provide for rigorous and repeatable ecological integrity assessment ranks.

1.8 Development of Metric Rankings

Each metric is rated according to deviation from its natural range of variability based on an understanding of how each metric responds to increasing human disturbance. The further a metric deviates from its natural range of variability the lower rating (the same applies to the overall index of ecological integrity). The EIA uses four rating categories to describe the status of each metric relative to its natural variability (Section 1.6). There are two important thresholds associated with these ranks. **The B-C threshold indicates the level below which conditions are not considered acceptable for sustaining ecological integrity.** The C-D threshold indicates a level below which system integrity has been drastically compromised and restoration is very difficult and/or very costly.

What is natural or historical may be difficult to define for many ecosystems/metrics, given our inability to document this range of variation over sufficient spatial and temporal scales and the relative extent of human disturbance over time. However, through reflections on historical data, and analysis of data gathered from the full range of reference sites, we can often distinguish the effects of intensive human uses and begin to describe an expected natural range of variation for ecological attributes that maintain the occurrence over the long-term.

For the Washington EIAs, existing information (e.g. literature, existing data sets, best professional judgment, etc.) was used to make some initial hypotheses about specific semi-quantitative values as they relate to the standardized metric rating descriptions (Table 4). Minimally, this process incorporates expert opinion and existing data into a standardized format so that a qualified ecologist could apply the EIA in a rapid and standardized manner to get an estimate of a site's ecological integrity. Ideally, the next phase in EIA development would be to field test and validate these initial hypotheses by determining their ability to discriminate between sites exposed to varying degrees of human-induced stress through collection of field data (see Section 1.10).

1.9 Stressor Checklist

As noted above, the measurement of stressors independently from that of ecological condition provides a means for assessing the possible correlations between ecological integrity and specific stressors. Such correlations might help in guiding management recommendations, restoration actions, and conservation measures at a variety of spatial scales. NatureServe has developed a simple method for documenting the type, scope, and severity of stressors associated with each Rank Factor (Faber-Langendoen et al. 2009a, Master et al. 2009). The stressor checklists are not presented in this document or the Washington EIAs but their use, alongside the EIA Scorecards, are recommended.

1.10 Field Testing and Validating the EIA Model

The development of an ecological assessment tool can be categorized into three major phases: initial development, field testing, and validation (Wakeley and Smith 2001, Collins et al. 2008):

(1) **Initial Development:** The overall framework or model of the assessment is designed and describes the overall purpose and method of the assessment. Conceptual models are used to identify the key ecological attributes and metrics useful for measuring ecological integrity. Natural variability and the response of each metric to human-induced disturbance is described and used to establish ranking thresholds. These tasks are accomplished through an intensive literature review, expert consultation, and use of best professional judgment. A protocol for rating each of the attributes or sites is developed.

(2) **Field Testing (Verification):** Determines whether the ecological attributes and metrics identified during initial development adequately describe ecological integrity. In addition, this exercise may reveal other useful attributes and metrics which hadn't been previously identified. The sensitivity of the metrics to changes in ecological condition is checked as well as the repeatability of metric scores in wetlands of similar condition. The consistency of metric scores between different users is also assessed. Details concerning EIA instructions and field forms are informed by field testing. All necessary changes are made to ensure the assessment adequately describes and discerns different states of ecological condition and that the results of the assessment are repeatable among different users.

(3) **Validation:** The accuracy or reliability of the EIA is tested by comparing it to an independent measure of integrity (e.g., vegetation index of biotic integrity). The EIA Scorecards are recalibrated to ensure that the best possible fit is achieved with the independent measure. This may include reassessing the metrics included in the EIAs, altering metric rating criteria, or simply changing the weights associated with each metric to more accurately reflect their influence on the overall scores.

The Washington EIAs have only progressed through initial development. Although these initial models could be (and have been) immediately applied toward a monitoring and assessment, it is recommended that EIA development continue with field testing and validation. This allows for increased confidence in the sensitivity, accuracy, and precision of the EIA to measure ecological integrity.

Field testing is accomplished by sampling sites across a human disturbance gradient (from relatively intact to highly impacted) for each ecological system. These sample sites are referred to as **reference sites** (or **reference set**) and represent the range of variability that occurs in an ecological system as a result of natural processes as well as anthropogenic alterations. Data collected from reference sites establish a basis for defining what constitutes the natural range of variability and how each metric responds to human-induced stress. **Reference standard sites** are the subset of reference sites that are the least altered (or minimally disturbed) in the least altered landscapes (Stoddard et al. 2006). In other words, these are the sites currently functioning with their NRV and would typically have “A” (excellent) ratings for individual metrics and categories. In order to determine the level of anthropogenic alteration and thus ensure that the entire range of reference sites is sample, the level of human disturbance at each site can be rated using NatureServe’s stressor checklist (Master et al. 2009), a human disturbance index (Rocchio 2007a), and/or a Landscape Stressor Model (Comer and Hak 2009).

Data from the reference set are then used to conduct the analyses associated with the field testing phase described above. To conduct validation, an independent measure of ecological integrity must be collected at each of the reference sites. The three-level approach to EIA development also lends itself to the validation phase. For example, sites where a Level 3 index of vegetation or ecological integrity had been measured could be used to calibrate a Level 1 remote-sensing assessment (Mack 2006; Mita et al. 2007, Lemly and Rocchio 2009). Level 3 could also be used in a similar manner to validate a Level 2 EIA. This process of validation results in relatively consistent information about ecological integrity being provided at the three levels of assessment, with improved interpretations as the level of intensity goes up.

1.11 Calculating and Reporting EIA Ranks: The EIA Scorecard

The EIA uses a transparent and simple tabular format to report scores or ranks from the various hierarchical scales of the assessment depending on which best meets the user’s objectives. For example, the user may not wish to synthesize (or ‘roll-up’) metric ranks into aggregated ranks of integrity and instead utilize metric rankings for monitoring and assessment. Conversely, the user may wish to synthesize or integrate the ratings of the individual metrics and produce an overall score for the three **rank factor** categories (Table 1): (1) Landscape Context; (2) Condition; and (3) Size. These rank factor rankings can then be combined into an Overall Ecological Integrity Rank. This ‘site’ rank can then be used to prioritize conservation or restoration activities. All of these characteristics make the EIA a practical, transparent, and easily communicable approach to assessing ecological integrity.

There are a number of approaches that could be used to produce an Overall Ecological Integrity Rank The approach used by the Washington Natural Heritage Program is a simple **non-interaction point-based approach**. The metrics are integrated into a rank factor ranking by plugging each metric score into a simple, weight-based algorithm. These algorithms are constructed based on expert scientific judgment regarding the interaction and corresponding influence of these metrics on ecological integrity (e.g., as done by NatureServe 2002, Parrish et al. 2003). Rankings for each metric are converted to a point value for that rank (A = 5 points, B = 4, C=3, D=1). The points are then multiplied by the weight to get a score for the metric. The scores (weighted points) for all metrics within a rank factor are summed and divided by the sum of the weights to get a rank factor score. The rank factor scores are summed and divided by the total number of factors to get an overall score, which is converted to an Index of Ecological Integrity (Table 5).

The Washington Natural Heritage Program has yet to recommend specific weights to the metrics in each of the Washington EIAs. Until those are completed, it is recommended that uses apply equal weight to each metric when calculating EIA ranks.

Table 5. Ecological Integrity Assessment Scorecard Example for a Level 2 Assessment.

KEY ECOLOGICAL ATTRIBUTES (KEA) **Metric**	**Assigned Metric Rating**	**Assigned Metric Points**	**Weight (W)**	**Metric Score (M)**	**KEA Score (M/W)**	**KEA Rank**	**Ecological Integrity Score**	**Ecological Integrity Rank (EO rank)**
LANDSCAPE CONTEXT					4.3	B		
Buffer Length	A	5	1	5				
Buffer Width	B	4	1	4				
Buffer Condition	B	4	1	4				
Connectivity	B	4	1	4				
			• =4	• =17				
SIZE					4.3	B		
Relative Size	A	5	0.5	2.5				
Absolute Size	B	4	1	4				
			• =1.5	• =6.5				
VEGETATION (BIOTA)					3.4	C		
Cover of Native Plants	C	3	1	3				
Cover of Invasive Species	C	3	0.5	1.5				
Cover of Native Increasers	B	4	1	4				
Species Composition	B	4	1	4				
Regeneration of Woody Species	C	3	1	3				
Canopy Structure	C	3	1	3				
Organic Matter Accumulation	B	4	0.5	2				
			• =6	• =20.5				
HYDROLOGY					4.0	B		
Water Source	C	3	1	3				
Channel Stability	B	4	1	4				
Hydrologic Connectivity	A	5	1	5				
			• =3	• =12				
SOILS (PHYSICOCHEMISTRY)					4.0	B		
Physical Patch Types	B	4	0.5	2				
Water Quality	B	4	1	4				
Soil Surface Condition	B	4	1	4				
			• =2.5	• =10				
					• =20			
RATING **A**=4.5-5.0, **B** = 3.5-4.4, **C**=2.5-3.4, **D**=1.0-2.4							4	B

2.0 Applying Ecological Integrity Assessments for Monitoring and Assessment

Below are general guidelines as to how a Level 2 or 3 EIA would be implemented (adapted from Collins et al. 2006). A comprehensive field operating manual has not yet been produced for the Washington EIAs but additional details regarding the steps below can be found in Collins et al. (2006), Rocchio (2007a, 2007b), Faber-Langendoen et al. (2008a).

Step 1: Assemble background information about the management and history of the site.
Step 2: Classify the site using *Draft Field Guide to Washington's Ecological Systems* (Rocchio and Crawford 2008) to ensure that the correct EIA is used.
Step 3: Determine the extent and size of the ecological system.
Step 4: Determine the boundary and estimate the size of the assessment area (if it is not the same as the ecological system occurrence) and allocate observation points or plots (if plots or points are to be used).
Step 5: Establish the landscape context boundary for the occurrence
Step 6: Verify the appropriate season and other timing aspects of field assessment.
Step 7: Consult metric protocols to ensure they are measured systematically
Step 8: Conduct the office assessment of stressors, landscape context and on-site conditions of the assessment area.
Step 9: Conduct the field assessment of stressors and on-site conditions of the assessment area.
Step 10: Complete assessment scores and QA/QC Procedures.
Step 11: Upload results into BIOTICS Database or other regional and statewide information systems.

2.1 Defining the Assessment Area

Once a site has been chose for assessment, an 'assessment area' needs to be delineated. This should first be done using GIS and, if necessary, AA boundaries can be refined based on field observations. The assessment area (AA) defines the boundaries within which the EIA is applied. There are many different ways to delineate the assessment area. However, caution is warranted when element occurrence specifications (section 2.1.1.) are NOT used for defining the assessment. In such cases, some metrics (or metric rankings) may not be applicable. Whichever approach is used, the user should always convey how the assessment area was delineated when reporting EIA results.

2.1.1 Using Element Occurrence Specifications for Defining the Assessment Area

Since the EIA were developed for the concept of Ecological Systems (Comer et al. 2003; Rocchio and Crawford 2009), it is recommended that specifications for delineating element occurrences be used (NatureServe 2002) to define assessment area boundaries. Elements are the For ecological elements, element occurrences are an area of land where a patch or stand of an ecological system or plant association is or was present (NatureServe 2002).

The process for delineating an element occurrence are (see NatureServe 2002 for more details):

- Use ecological system (Rocchio and Crawford 2008) or plant association (NatureServe 2011) descriptions to guide a determination of the stand or patch boundaries
- Apply minimum size criteria to determine whether the stand/patch is considered large enough to be an element occurrence (general guidelines are: 2 ha for matrix, 0.4 ha for large patch, 0.05 ha for small patch, and 30 meter in length for linear types)
- Apply separation distance criteria to determine whether disparate patches should be lumped as a single or considered distinct element occurrences (NatureServe 2002)

Ecological system descriptions (Rocchio and Crawford 2008) should be used to guide a subjective determination of the target system's boundaries (using GIS or in the field). A confounding factor is that ecological systems often co-occur in the landscape. For example, fens may occur together with wet meadows. For such scenarios, minimum size criteria are used to determine whether such a wetland 'complex' constitutes two separate element occurrences. If the both the wet meadow and fen met its minimum size would be considered a unique element occurrence/AA. If an ecological system 'patch' is less than its minimum size then it would be considered to be an inclusion within the ecological system type in which it is embedded.

Element occurrences for matrix and large patch ecological systems (or plant associations) can be extremely large. For such occurrences, a probability-based monitoring design such as the Generalized Random Tessellation Stratified (GRTS) survey design could be used to create a spatially balanced random sample of points within the occurrence (Stevens & Olsen 1999). Alternatively, the use of sub-element occurrences (sub-EOs; see NatureServe 2002) which are used to sub-divide large element occurrences based on ecological or practical criteria, could be delineated such that they provide a practical assessment area for EIA application.

For small patch ecological systems (and possible some large patch types), the element occurrence specifications will typically result in a reasonably sized assessment area that allows practical application of the EIA. When this is not the case, the use of probability-based monitoring design or sub-EOs is warranted.

2.1.2 Alternative Methods for Defining the Assessment Area

Some ecological assessments may be driven by project objectives that demand a different approach to establishing an assessment area boundary such as those associated with regulatory projects. Guidelines for establishing AA boundaries for these types of projects are numerous for wetland and riparian ecological systems (Mack 2001, Hruby 2004, Rocchio 2007). These guidelines may be applicable or adaptable to many upland ecological systems.

2.2 Applying the Level 1, 2, and 3 EIAs

EIAs can be used to assess ecological integrity of a specific site (e.g. element occurrence or assessment area) as well as an integrated framework for monitoring ecological conditions across large spatial scales. Below, the Level 1, 2, and 3 EIAs roles in both approaches are discussed.

Assessing ecological integrity of a particular site is useful for determining conservation, restoration, and management needs and monitoring progress of conservation, restoration, and management activities.

A monitoring framework designed to track the status and trends of ecological systems across a large spatial scale might be best organized around a hierarchical, multi-scale approach to monitoring and assessment. Because the EIA is scalable in terms of its applicability to multi-scaled classification systems and the scale and intensity of application, it is suited to serve as a foundation for a monitoring framework designed to accommodate site-scale and landscape objectives. For example, a Level 1 EIA might be used as a means of prioritizing sites for field visits where a Level 2 or Level 3 assessment is completed. Prioritization could be based on which sites may be at risk of moving away from desired ecological conditions (as determined by Level 1 metric rankings). Level 2 could serve a similar purpose but with increased accuracy and detail about sites in need of a Level 3 EIA. Figure 2 depicts how the integration of Levels 1, 2, and 3 EIAs can be used for a multi-scale monitoring framework

2.2.1 Level 1 Assessment

Site-Scale Application

When field visits are not feasible, a Level 1 EIA can be used to provide a remotely-sensed assessment of ecological integrity of a particular site (e.g. element occurrence or assessment area). Level 1 EIAs are less accurate than field visits, nonetheless they can be very helpful as a filter mechanism to determine whether an individual site (or sites) merits a field visit.

Use within an Integrated Framework

A Level 1 EIA is a comprehensive generic approach that is applicable to all natural ecosystems and is based primarily on metrics derived from remote sensing imagery (see Section 1.5). A Level 1 EIA could be used as a means of prioritizing sites for field visits, where a Level 2 or Level 3 assessment is completed. Level 1 EIAs can also be used as a measure of integrity whenever a field visit cannot be completed. Because the objective of all three EIA levels is the same (i.e. to measure the status of ecological integrity of a site) it is important that the Level 1 assessment use the same kinds of metrics and major attributes as used at levels 2 and 3.

A very basic Level 1 EIA might include an overall assessment of landscape integrity using a Landscape Condition Model (LCM; Comer and Hak 2009). The LCM is similar to the Landscape Development Intensity Index (Brown and Vivas 2005), human footprint model (Leu et al. 2008), and anthropogenic stress model (Danz et al. 2009) all which have been used for similar purposes elsewhere. The LCM integrates various GIS land use layers (roads, land cover, water diversions, groundwater wells, dams, mines, etc.) at a 30-90 m or 1 km pixel scale. These layers are the basis for various stressor-based metrics. The metrics are weighted according to their perceived impact on ecological integrity, into a distance-based, decay function to determine what effect these stressors have on landscape integrity. The result is that each grid-cell (30 m or more) is assigned a stressor “score”. The product is a landscape or watershed map depicting areas according to their potential “integrity.” We can segment the index into four rank classes, from Excellent (slightly impacted) to Poor (highly impacted) (Figure 1). This landscape model is valuable in its own right for landscape scale planning, site selection, etc.

An example of how to implement a Level 1 assessment is as follows: Locations are chosen within State Wildlife Areas. These locations may be a subset or all examples of an ecosystem type that is of interest identified to specified level of ecosystem classification. Points or polygons are established for each of these locations, and these are overlain on the Landscape Condition Model. A landscape context area is defined around the occurrence (Figure 1). The landscape condition model provides the data for the “landscape condition model” metric, based on the average score of the pixels within the landscape context. Connectivity and Size can be readily assessed as well. Together these metrics provide a simple means of characterizing the ecological integrity of an occurrence of any ecological system.

The results from this analysis can be used in multiple ways:

- To provide a cost efficient way of estimating ecological integrity of every ecosystem which occur on State Wildlife Areas. This alone could be used for guiding management decisions.
- To prioritize where Level 2 or 3 EIA should be conducted. The ecological integrity rank of each occurrence, relative to desired ecological conditions, best attainable conditions or triggers, could be used as the criteria for needing to conducting Level 2/3 assessments
- To integrate the status and trends of extent and condition of an ecological system to monitor long-term changes of ecological systems on State Wildlife Areas.

A Level 1 assessment can also help determine best attainable conditions of any particular occurrence or site. For example, the best attainable condition of occurrence embedded in a landscape or part of an occurrence with poor integrity might be constrained to an ecological state outside desired ecological conditions. In other words, due to the surrounding landscape, it might not be possible to restore or manage the site toward desired ecological conditions. For such a scenario, best attainable condition would describe (using ecological integrity ranks) the ecological conditions that could be feasibly managed for.

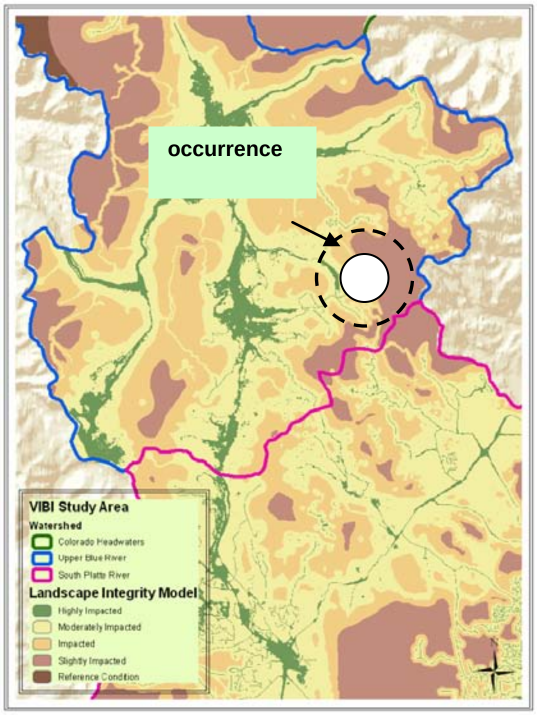

Figure 1. Demonstration of Level 1 Assessment based on a Landscape Condition Model. Values for landscape context metrics and condition metrics for an occurrence can be derived from this approach. (from Rocchio 2007a).

2.2.2 Level 2 Assessment

Site-Scale Application

Level 2 EIAs are used for relatively rapid (~2 hours per small patch up to full day for matrix types) site assessments to determine its current ecological integrity. Level 2 EIAs provide more accuracy than a Level 1 EIAs but use qualitative or semi-quantitative metric ratings to assess ecological condition. When validated/calibrated with independent quantitative data (e.g., Level 3 EIA), Level 2 EIAs are an efficient and effective means of assessing ecological integrity. The Washington Natural Heritage Program mostly uses the Level 2 EIA to assess ecological integrity of potential conservation targets.

Use within an Integrated Framework

The Level 2 EIA can be considered the 'workhorse' within the context of a hierarchical monitoring framework as it provides a compromise between efficiency of application and assessment accuracy. The Level 2 EIA could be a very useful method for implementing a probability-based approach to monitoring ecological conditions across a large spatial scale. Probability-based monitoring designs such as the Generalized Random Tessellation Stratified (GRTS) survey design create a spatially balanced random sample of points (Stevens & Olsen 1999). Using a Level 2 EIA to determine ecological integrity of these sites results in a rigorous estimate of overall ecological integrity for the targeted ecological systems for the geographic area in question. This information can be used to determine if, on average, a particular ecological system is functioning within or outside desired ecological conditions. Those systems functioning near or outside the threshold of desired ecological conditions would require Level 3 assessments to obtain more detailed information about current ecological conditions.

A probability-based Level 2 assessment could also be useful for identifying sensitive or vulnerable ecological systems within a given geographic area through the development of ecological system ‘profiles’. These profiles would include: (1) total extent of each ecological system of interest; (2) changes in extent with time; and (3) overall ecological integrity of a system throughout extent of the profile. The current and historical extent would be determined using comprehensive maps such as NatureServe’s Ecological Systems map. The profile could then be used to prioritize management actions for ecological systems. For example, depending on the type, abundance, and overall ecological integrity of each ecological system, they can be categorized into “action” categories, thereby providing a systematic means of prioritizing protection, restoration, and enhancement actions.

Finally, the Level 2 assessment can be used to test and calibrate a Level 1 EIA. This is accomplished by correlating Level 1 with Level 2 ecological integrity ranks from multiple occurrences, ideally spanning the full range of ecological conditions.

2.2.3 Level 3 Assessment

Site-Scale Application

Level 3 assessments are intended for more intensive sampling objectives such as detailed assessment of ecological integrity or quantitative site-scale monitoring. Level 3 assessments are also time-consuming, costly and may required extended commitments. They are most valuable where it is important to assess in detail the status and trends of a particularly important site. The Level 3 assessment is essentially an intensification of the metrics collected for Level 2 EIAs through use of a more rigorous sampling design to collective quantitative data.

Use within an Integrated Framework

Within a multi-scaled monitoring framework, Level 3 assessments will typically be used only when a Level 2 assessment has indicated that a specific ecological system type or occurrences is near (i.e. a trigger has occurred) or outside desired ecological conditions. The Level 3 assessment will confirm the results of the Level 2 assessment and provide additional detail about specific conditions for each key ecological attribute. The Level 3 EIA can also be used to set and monitor attainment of specific performance measures for restoration or management actions.

Finally, the Level 3 assessment can be used to test and calibrate a Level 2 (or Level 1) EIA using the same approach described above.

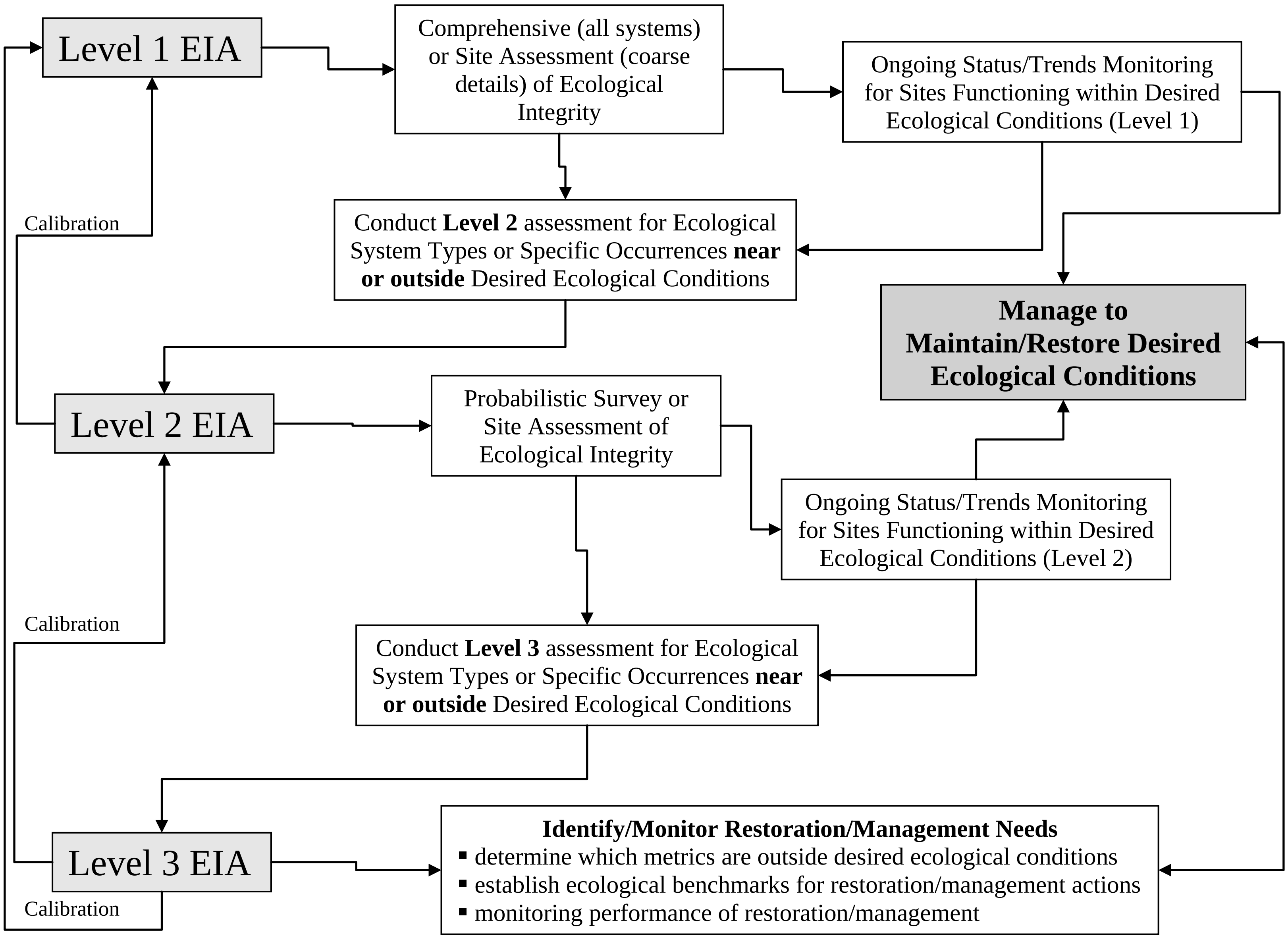

Figure 2. Generalized Schematic of Integrated Monitoring Framework

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