Mapping Biodiversity in Whatcom County: Data and Methods

Submitted to the Whatcom Legacy Project

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Regan Nelson

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Chapter 1 – Introduction

1.1 Introduction to this report

This report, and the Whatcom Biodiversity Database which it describes, was commissioned by the Whatcom Legacy Project, whose mission is to "help our community create and implement an inspiring and enduring vision to sustain Whatcom County's natural environment, economic prosperity, and community values over the next century." The purpose of this report is to compile all pertinent studies and data regarding ecologically important lands and habitat into on flexible Geographic Information System database. This includes the integrity of terrestrial and freshwater ecosystems, and their component species (i.e. mammals, birds, amphibians and reptiles).[1]

Like many counties in Washington, Whatcom County is sustaining an impressive growth rate. Between 1990 and 2000, the county experienced a 30% growth rate in its resident population, and this is projected to nearly double (78% increase) between 2000 and 2025 (see OFM 2002) Accommodating this number of people, while maintaining the services that a healthy ecosystem provides, such as fresh drinking water, biodiversity, and air purification, will require informed planning. The goal of this report is to provide Whatcom County residents with data and information on the ecological values of the land so that informed land use decisions can be made by the public.

This database and report are not a conservation plan. Instead, the database is a decision support tool that can enable the community to better understand which lands are ecologically important within the County. The report details the data and methods used to create this database. Selecting where and how much land will be designated for conservation is a societal choice. This database and report are intended to aid with future decisions by the public. In addition, if care is taken, it may be possible to preserve the elements of conservation values even as certain lands are used for other purposes, so it is not necessary to "lock-up" lands in preservation status only.

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[1] A lack of adequate marine data precluded analysis of the marine environment.

Ultimately, if Whatcom County desires to "sustain its natural environment", a network of lands that are set aside primarily for their conservation value should be identified, and managed accordingly. It will be imperative for these lands to be monitored over time to ensure that they are meeting the goals of maintaining the County's environmental health. This report is merely a starting point; as new information becomes available, it will be imperative to update the database which this report describes and adapt the conservation network as needed. There are many unknowns looming in our future and care must be taken to incorporate ongoing scientific knowledge into the database so that it remains useful over time

This report documents the data analysis, modeling and methods used to evaluate and map biodiversity in Whatcom County. As with any analysis, there were a number of data gaps, limitations and assumptions that were used during the process. These shortcomings are identified in two ways: 1) the report documents data gaps, limitations and assumptions at the end of each analysis chapter, and 2) spatial data which comprises the associated database were systematically assigned "data confidence" values which were based on a number of determinant factors which are also documented in each analysis chapter. These do not compensate for the shortcomings of this analysis; rather they are intended to help users of this information understand and consider the range of certainty associated with the provided information.

On a final note, it is important to stress that our scientific knowledge of what ensures a healthy environment is extremely limited. Even if all lands identified as "high-value" in this report were preserved tomorrow, there is still a large likelihood that something will have been missed. It is not possible to achieve certainty when planning for the future. However, we can be fairly confident that if no steps are taken to protect known areas of conservation value, we will continue to experience environmental decline. The impacts of this decline could lead to a decline in biodiversity and affect community health, economic well-being, and our quality of life. Therefore, it is better to act with the best information we have rather than to wait, likely indefinitely, for perfect knowledge.

This report is augmented by appendices that describe the technical approach to various components of the analysis. Maps generated by this report are available for viewing at the Whatcom Legacy Project office. Spatial data is stored in a computer database; access to this database is restricted because of legal agreements between the source agencies and the Whatcom Legacy Project.

1.2 Selecting a Decision-Support System

The first objective of this report was to identify and select a decision-support system that has the capability to support local land-use decisions by enabling stakeholders to explore alternative scenarios and to establish conservation goals that reflect the socio-economic and political realities of the planning region. Lessons learned from previous studies (see Theobald et al. 2000, Pierce et al. 2005, Wilhere et al. 2007) were distilled to create criteria for selecting a decision-support system for Whatcom County. These criteria were:

1. The information system must be dynamic in its ability to store and display data, and allow users to explore alternative scenarios in order to decide upon appropriate conservation endpoints for their community.
2. The information system must be able to integrate and address socio-economic and other values in order to inform trade-off analysis among stakeholders.
3. The information system must be able to incorporate and communicate uncertainties associated with biological data.
4. The information system must be user-friendly and must provide a mechanism for which complex data is easily communicated to stakeholders.
5. The information system must be compatible with computer hardware and software technologies commonly used at the local planning scale; primarily desktop level computer systems and geographic information systems (GIS).

Based on these criteria, an internet search was conducted to identify potential information systems. While many information systems existed to support various types of planning exercises, the only information system that met all of the criteria and was available for purchase and use was NatureServe's Vista Decision Support System. NatureServe is a non-profit organization whose mission is to "to provide the scientific basis for effective conservation."[2] NatureServe's Vista is "a decision-support system that integrates conservation information with land-use patterns and policies, providing planners, resource managers, and communities with tools to help manage their natural resources. It enables users to create, evaluate, implement, and monitor land-use and resource management plans that operate within the existing economic, social, and political context to achieve conservation goals."[3]

Vista version 1.3 was selected for use in this report. Vista runs as an extension to ArcGIS 9, a commonly-used geographic information system. Vista has two major requirements in order to run. First, an information database must be developed that describes the spatial distribution, integrity and/or viability of selected biodiversity surrogates within the planning region. This database must also document the certainty of the data used to represent the biodiversity surrogates. Second, Vista houses several analytical tools that can be used to explore alternative conservation scenarios based on various filtering and weighting systems, and these filtering and weighting systems must be devised and created. Once these steps are completed, Vista can run analyses to depict a spatially-explicit representation of the relative conservation value of lands within the planning landscape. Stakeholders can then use these various displays to inform different alternative futures that respond to development and conservation opportunities within their landscape. Vista also has the ability to directly link with other planning software systems, like CommunityViz, which are used by to evaluate potential opportunities for development on a landscape.

1.3 Overview of Methodology for creating Vista's Biodiversity Database

Creation of the biodiversity database is the first step in enabling the Vista decision-support system. Extensive data collection and development is involved in preparing the biodiversity database, which is stored within the Vista software program.

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[2] NatureServe mission retrieved online 7.31.07 at www.natureserve.org
[3] Vista software description retrieved online 7.31.07 at www.natureserve.org

Creation of the biodiversity database closely conforms to methods of systematic conservation assessment (Margules and Pressey 2000, Groves 2003, Knight et al. 2006). A description of the methods required to build the information database is provided below.

1) Identify Conservation Targets – A target is a feature of biological diversity (e.g. an ecological system type, a plant or animal species) that is included in an assessment process. For this report, targets were selected using the coarse-filter/fine-filter method (Groves 2003). This method is essentially a hypothesis which states that protecting representative and viable ecological systems and communities on a landscape will effectively conserve many of the species that occupy them. These "coarse-filter" targets can compensate for conservation of unknown or poorly studied species like invertebrates. "Fine-filter" targets are specific species which may not be adequately captured by protecting coarse-filter targets.

2) Identify known locations and/or distribution of targets – Once targets were selected using the coarse-filter/fine-filter method, all current and available data were collected and assembled regarding the known occurrences (e.g. the mapped location of an individual, population or aerial extent of a species or community) of each target. In some cases, known occurrences of an individual species were augmented by Predictive Distribution Modeling (PDM) to create a probable range for the species within Whatcom County. PDM uses known occurrences to calibrate probable distribution of a species based on a number of spatially-referenced biophysical variables.

3) Evaluate known viability or integrity of each target – Once data is assembled for known locations of each target, an integrity or viability value is assigned to each occurrence that determines the likelihood of that target's ability to persist over time in that particular location. Occurrences with high integrity have been less

impacted by anthropogenic sources, and have a better chance of maintaining ecologic function if preserved than an occurrence with lower integrity.

4) Identify confidence values for assembled data – Once the above data is assembled, a data confidence value is assigned for each record (e.g. each occurrence of each target). The confidence value communicates the level of certainty associated with the accuracy and precision of each data record, including spatial confidence (certainty that the mapped location is indicative of the true location of an element), and temporal confidence (certainty that the mapped location is still extant).

NOTE: Steps 1- 4 were completed for both terrestrial and freshwater systems in Whatcom County, and are described in detail in Chapters 3 and 4. Steps 5-7 describe the requirements necessary to enable the analytical tools in Vista, and are described in further detail in Chapter 5.

5) Identify target filters – Target filters are used to select a subset of elements within the information database on the basis of their attributes or location. Filters can make it easy to examine analyses based on arrangements of different targets that might be used to direct conservation goals. For example, filters can be used to select for elements that are legally considered endangered or threatened, or elements for which there is a particular economic interest in the region (i.e. birding, hunting, fishing).

6) Identify target weighting systems – Weighting systems are used to provide a means to weight elements according to factors that may make them more important than others in the planning region. For example, weighting systems could include weighting species that are considered of local conservation concern. Weighting systems can be useful to help articulate values of stakeholders when it comes to protecting certain elements. Target filters and target weighting systems

can be used individually, together, or not at all when running analytical tools. They are intended to help stakeholders understand which areas rank high in conservation value, and why.

7) Set goals for each target – Vista is compatible with several reserve-selection programs that can be used to generate potential reserve networks within the planning region. These reserve-selection programs (e.g. MARXAN and SPOT) require goals that indicate the number or range of elements needed to sustain biodiversity for the planning region. In reality, the lack of information about targets makes setting goals to maintain "viable" populations or extents of these elements nearly impossible (Smith et al. 2006). However, using reserve-selection programs is useful to generate potential complementary reserve networks within a planning region. Therefore, goals were set in this assessment to represent relative low and high-risk scenarios of conservation failure. These goals, though based on rational thresholds, are arbitrary, and should not be construed to be definitive conditions to ensure long-term maintenance of biodiversity.

1.4 Assessments consulted while building the biodiversity database

This report was informed by a number of previous conservation assessments that have been completed for, or include, Whatcom County. These earlier assessments provide a strong foundation from which to better understand Whatcom County's important ecological areas. By aggregating the work of these efforts, the information database created for this report represents the culmination of many individuals work, and the most comprehensive assessment for Whatcom County to date. The following assessments were consulted for this report:

- Assessment of Freshwater Systems for Washington State (Skidmore 2006)
- North Cascades Ecoregional Assessment (Iachetti et al. 2006)
- Washington State Comprehensive Wildlife Conservation Strategy (WDFW 2005)
- Washington State Gap Analysis Program (Cassidy et al. 1997)

- Willamette Valley – Puget Trough – Georgia Basin Ecoregional Assessment (Floberg et al. 2004)
- Whatcom County Critical Areas
- Whatcom County Natural Heritage Plan
- Whatcom County Shoreline Management Plan
- Whatcom County Wildlife Atlas
- Whatcom Land Trust Salmon, Eagle and Elk Analysis (TerraLogic 2000)

1.5 Limitations of the biodiversity database

Data used in developing the information database represented the most current data available at the time of this thesis. However, the information database represents merely a snapshot in time, and will lose its relevance unless care is taken to incorporate new data as it is made available. As discussed above, an information system was selected that allows for easy integration of new data. As new data are included in the information database, analyses will need to be rerun to reflect the updates. Users of the information database must also consider the following limitations of the information database:

1. The data collected to build the information database is meant to inform stakeholders of the distribution of lands of relative conservation value within their planning region for the purposes of aiding land-use decisions. The database should be used only within this context, and is not meant to replace ongoing and legally required scientific analyses, like establishing recovery plans for endangered species.
2. The information database does not house, and therefore does not address, any marine-related targets or elements. Data for such elements was sparse, at best. Efforts to use this limited information to inform decisions about uses impacting marine resources could direct activities to the wrong location and result in increased, rather than decreased, risk to marine elements. For this reason, marine elements were not addressed. It is recommended that a separate conservation assessment be completed to address marine ecosystems and elements, as their

conservation is as critical for ongoing environmental health as is the conservation of terrestrial and freshwater biodiversity.

3. The information database does not describe a static landscape; rather ecological and social processes are constantly acting upon the landscape, changing the composition, structure and function of both the built and natural environment. Social processes include continued development activities and changing land ownership patterns. In western Washington, conversion of working forestlands to residential use and development is a major driver of landscape fragmentation (Bradley et al. 2007). With ongoing population growth, continued land conversion activities in Whatcom County are likely, and may shift conservation priorities. Ecological processes must also be considered. While some ecological processes are known and can be planned for (e.g. forest succession), others are dynamic and unpredictable, but will need to be considered during conservation planning activities. Disturbance agents such as fire, wind, insects and pathogens drive ecological processes and are a necessary and desirable part of ecological systems, and accommodating their occurrence by calculating minimum dynamic areas will be necessary for ecosystem integrity (Pickett and Thompson 1978). Conservation planning activities will also benefit from consideration of the impacts of global climate change. Projections of the potential impacts of climate change in the Pacific Northwest include changes in water supply patterns due to reduced snowpack, increased rainfall and increased summer drought; increased risk of forest fire and insect and pathogen outbreaks; and shifts in life-history traits and distribution patterns of various species (Mote et al. 2003). Planning activities are likely to be more efficient and effective at capturing examples of conservation targets if climate change scenarios are considered early in the planning process (Hannah et al. 2007). Possible mitigation efforts to increase conservation success in light of a changing climate include capturing elevational gradients in protected areas, providing connectivity corridors that allow migration of conservation targets as range patterns shift, and in some cases allowing or initiating disturbances like wildfire to restore natural processes to altered

environments that may be more vulnerable to climatic changes (Williams et al. 2005, Rouget et al. 2006, Hannah et al. 2007).

Finally, there were a number of data gaps, limitations, and assumptions that were used in the development of the information database. These shortcomings are identified in two ways: 1) the report documents data limitations explicitly at the end of each analysis chapter (and often throughout the explanation of methods as well), and 2) spatial data were systematically assigned "data confidence" values which were based on a number of determining factors which are also documented in each analysis chapter. These do not compensate for the shortcomings of this analysis; rather they are intended to help user's of this information understand, and consider, the limitations of the information database.

Chapter 2: Terrestrial Targets

This chapter identifies the terrestrial ecological systems that were selected as coarse-filter targets for planning, as well as the terrestrial organisms that were selected as fine-filter targets. The criteria for target selection and the methods for data collection and development corresponding to each target are documented. Finally, data limitations are discussed.

2.1 Coarse-filter Targets

2.1.1 Target Selection and Data Collection

The U.S. National Vegetation Classification was the first consistent nation-wide effort to classify terrestrial vegetation. This approach created a classification hierarchy whose smallest unit is the plant alliance or association (generally micro-scale units) that are nested within a formation type (generally macro scale) (Grossman et al. 1998). While this classification is useful for describing the biotic and abiotic conditions of a small site, it is not ideal for planning at the landscape level. For example, the Puget Trough Ecoregional Assessment used this classification system and identified ecological systems by grouping 204 plant associations into 19 ecological communities (Floberg et al. 2004). This process was very laborious and required a significant amount of expert involvement.

Recognizing the need for a classification system with discrete and functional units at a meso-scale, the "ecological system" unit was defined and used to classify the entire United States (Comer et al. 2003). Ecological systems are defined as "recurring groups of biological communities that are found in similar physical environments and are influenced by similar dynamic ecological processes, such as fire or flooding" (Comer et al. 2003). These units are much more manageable for landscape-level planning, as they typically occur in a landscape at intermediate geographic scales of 10s to 1,000s of acres and persist for 50 years or more (Comer et al. 2003).

Based upon these classification attributes and the recent availability of distribution maps for the Pacific Northwest, ecological systems were selected as the appropriate terrestrial coarse-filter unit for this project.

Ecological Systems:

Distribution maps of ecological systems were derived from the Landfire Project, which is a nation-wide effort undertaken by the United States Geologic Service (USGS), the United States Forest Service (USFS) and The Nature Conservancy (TNC) to consistently classify and map all ecological systems in the United States.[4] Vegetation is mapped using predictive landscape models that were based on extensive field referenced data collected from local agencies and researchers, satellite imagery, biophysical gradient layers, and classification and regression trees. By using multiple types of data sources, the Landfire project represented the most comprehensive and current source for vegetation data for the Pacific Northwest at the time of this publication.

Landfire Existing Vegetation Types (EVT) digital and tabular data for Whatcom County were downloaded from the Landfire website (www.landfire.gov). Original EVT data (published in 2006 as a 30-meter pixel resolution raster grid) showed 39 ecological systems[5]. These ecological systems were individually examined to determine their value as coarse-filter targets for Whatcom County. Two ecological systems were determined by the Washington Natural Heritage Program to not occur in Washington State, so their appearance in the maps was assumed to be a misclassification error attributed to the landscape models created by Landfire. These two systems were eliminated from the list and re-mapped as their largest nearest neighbor. Three ecological systems that had a very limited extent in Whatcom County, and are considered by the Washington Natural Heritage Program to be "similar ecosystem types" were merged together to form the East Cascades Mesic Montane Merged Systems.

Next, ecological systems that were considered peripheral systems (i.e. they are matrix-forming systems, but occur only in small patches in Whatcom County) were also re-mapped as their largest nearest neighbor. This decision was based on the fact that these "peripheral" systems are better addressed in the region which they primarily occur and therefore do not need special attention at the county level.

[4] The Landfire Project also classified and mapped fuel characteristics and fire regimes for the United States. All data is available for download at www.landfire.gov

[5] Agricultural and urban categories were retained as land cover classes, but not listed as ecological targets due to their developed state.

In total, 27 ecological systems were selected as coarse-filter targets, and are listed in Table 2.1. Table 2.2 shows the ecological systems that were not included as targets and the rationale for their exclusion. (For those readers of the electronic version of this report, each ecological system is hyper-linked to the NatureServe Explorer database which describes each system in great detail). Appendix 1 schematically describes the analysis conducted in a GIS to prepare original Landfire data for entry into NatureServe Vista.

Old-growth Forest Ecosystems:

Following the lead of Iachetti et al. (2006), old-growth forest ecosystems were also included as a distinct target. Old-growth forested ecosystems have declined by as much as 87% in Washington State from pre-European settlement levels (Gamon 2007). Because a number of the imperiled species in Whatcom County are associated with late-seral forests, these forests were aggregated as a coarse-filter target regardless of the ecological system they inhabited. The old-growth forest ecosystem layer was created using quadratic mean diameter stand data for Zones 2 and 3 (Western Washington Lowlands and Western Washington Cascades) from the Interagency Vegetation Mapping Project (IVMP).[6] These data were created using 1996 satellite imagery, and was mapped at the 30 meter scale, consistent with Landfire project data. Old-growth forests were assumed to be those forest stands with a quadratic mean diameter of 50 inches or more.

Table 2.1: Terrestrial Coarse-filter Targets

	ECOLOGICAL SYSTEM TARGETS
1	East Cascades Mesic Montane Merged Systems
2	North Pacific Alpine and Subalpine Dry Grassland
3	North Pacific Avalanche Chute Shrubland
4	North Pacific Broadleaf Landslide Forest and Shrubland
5	North Pacific Dry-Mesic Silver Fir-Western Hemlock-Douglas-fir Forest
6	North Pacific Dry Douglas-fir Forest and Woodland
7	North Pacific Dry and Mesic Alpine Dwarf-Shrubland Fell-Field and Meadow

[6] Data accessed May 7, 2007 at ftp://ftp.blm.gov/pub/OR/gisweb/ivmp/Interagency%20Vegetation%20Mapping%20Project.pdf

8	North Pacific Hypermaritime Sitka Spruce Forest
9	North Pacific Hypermaritime Western Red-cedar Western Hemlock Forest
10	North Pacific Lowland Riparian Forest and Shrubland
11	North Pacific Maritime Dry-Mesic Douglas-fir-Western Hemlock Forest
12	North Pacific Maritime Mesic-Wet Douglas-fir-Western Hemlock Forest
13	North Pacific Maritime Mesic Subalpine Parkland
14	North Pacific Mesic Western Hemlock-Silver Fir Forest
15	North Pacific Montane Riparian Woodland and Shrubland
16	North Pacific Montane Shrubland
17	North Pacific Mountain Hemlock Forest
18	North Pacific Sparsely Vegetated Systems
19	North Pacific Swamp Systems
20	North Pacific Wooded Lava Volcanic Flowage
21	Northern Rocky Mountain Subalpine Woodland and Parkland
22	Pseudotsuga menziesii - Quercus garryana Woodland
23	Pseudotsuga menziesii Giant Forest Alliance
24	Rocky Mountain Alpine/Montane Sparsely Vegetated Systems
25	Rocky Mountain Aspen Forest and Woodland
26	Rocky Mountain Subalpine Dry-Mesic Spruce-Fir Forest and Woodland
27	Rocky Mountain Subalpine Mesic Spruce-Fir Forest and Woodland
28	Old-Growth Forests

Table 2.2: Ecological Systems not selected as coarse-filter targets

	ECOLOGICAL SYSTEM	RATIONALE FOR DELETION
1	Artemisia tridentata ssp. vaseyana Shrubland Alliance	Mis-classified; doesn't occur in Washington
2	Inter-Mountain Basins Big Sagebrush Steppe	Peripheral occurrence
3	Inter-Mountain Basins Montane Sagebrush Steppe	Peripheral occurrence
4	North Pacific Montane Grassland	Misclassified; doesn't occur in Washington

5	Northern_Rocky_Mountain_Dry-Mesic_Montane_Mixed_Conifer_Forest	Merged w/ East_Cascades_Mesic_Montane Mixed Conifer_Forest_and_Woodland
6	Northern_Rocky_Mountain_Lower_Montane-Foothill-Valley_Grassland	Peripheral occurrence
7	Northern_Rocky_Mountain_Lower_Montane_Deciduous_Shrubland	Peripheral occurrence; also not listed in NatureServe Explorer database (no info)
8	Northern_Rocky_Mountain_Ponderosa_Pine_Woodland	Peripheral occurrence
9	Rocky_Mountain_Lodgepole_Pine_Forest	Merged w/ East_Cascades_Mesic_Montane_Mixed-Conifer_Forest_and_Woodland
10	Tsuga_mertensiana_-_Abies_amabilis_Woodland_Alliance	Added as a fine-filter

2.1.2 Using Landscape Integrity to Calculate System Viability

As mentioned above, coarse-filter targets have two major roles in protecting biodiversity: (1) they act as surrogates for many of the undescribed or poorly known organisms that exist in that system and (2) they act as surrogates for maintaining the natural physical, chemical and biological processes that provide ecosystem services such as clean water, clean air, and nutrient cycling. However, in order to understand how well the coarse-filter targets are performing their surrogate roles, it is necessary to evaluate the integrity of these targets across the landscape. Protecting ecological integrity has been called the "ultimate goal of conservation planning" (Mattson and Angermeier 2007).

Assessing ecological integrity is challenging as no index characterizing the integrity of terrestrial ecosystems exists.[7] Andreasen et al. (2001) introduced a Terrestrial Index of Ecological Integrity, but stressed that this index was merely a first step, and should be thought of as a tool for research and testing. Without a comprehensive index, we again have to rely on a surrogate index that could be a good indicator, but which is not a true measure of ecological integrity.

A surrogate ecological integrity index was created for Whatcom County by identifying landscape metrics that impact the drivers of ecological systems. The metrics

[7] A separate ecological integrity layer was made for aquatic systems and can be found in that chapter.

were identified by consulting the recently released report "Washington's Biodiversity: Status and Threats" (Gamon 2007), the suitability analyses conducted for the Puget Trough and North Cascades Ecoregional Assessments (Floberg et al. 2004, Iachetti et al. 2006), as well as a literature review of conservation assessments that identified impacts to ecological integrity (Andreasen et al. 2001, Groves 2003, Mattson and Angermeier 2007). Next, spatially-explicit data were acquired for each indicator in the index, and these layers were weighted and combined to create a "landscape integrity raster" which was then intersected with the ecological systems distribution layers. A brief discussion of the landscape metrics selected as inputs follows.

Landscape Metrics:

Wallington et al. (2005) stated that ecosystems are spatially dynamic, meaning that ecological systems interact with one another across spatial scales, and these interactions influence ecosystem processes as well. In essence, the landscape context has a direct influence on a specific patch. Therefore, understanding the spatial composition of a landscape is important to understanding the ecological integrity of a patch. Fragmentation through introduced land-uses (such as residential, industrial or commercial development, and road, railroad and power-line networks) all influence the function of existing natural areas to some degree (Forman 1995).

The following land-uses were identified as indicators of impacts to ecological integrity and for which geographic (spatially-explicit) data was available:

- ♦ Road density – All classes of roads including logging roads and railroads but NOT trails or power-lines
- ♦ Converted Lands - Urban and Urbanized Areas (includes residential, commercial and industrial lands), Agriculture
- ♦ Areas dominated by Invasive Species
- ♦ Areas of Expected Future Growth - Urban Growth Areas
- ♦ Pollution – Superfund sites, leaking underground storage, hazardous waste sites
- ♦ Ownership and Management Status – Management Policies

The metrics selected range in their severity (potential impact to ecological integrity) and extent (the distance effect of an indicator on ecological integrity). To account for this variation, relative weights and distance intervals were assigned to each indicator. Weights to represent indicator severity were assigned following the default weighting system suggested by NatureServe's Vista user's manual: 1000=high severity, 500=moderate severity, 100=low severity (NatureServe 2006). Extent of impact was assigned with a distance interval, which represents the point at which the impact can no longer be ascertained. There is no way to fully test the assumptions behind weights and distance intervals, so these values should be considered an approximation of potential impact.

Table 2.3: Description of landscape metrics used to calculate ecological integrity values for coarse-filter targets

METRIC	WEIGHT (Severity)	DISTANCE INTERVAL (Extent – in meters)	DESCRIPTION/SOURCE
Roads:			*Source: Department of Transportation*
Primary & Secondary Highways	1000	600	All-weather/hard surface
Light-duty	800	480	All-weather/improved surface
Unimproved and Unknown	500	300	Fair or dry weather only
Railroads	250	150	All ownerships
Converted Lands:			*Sources: Office of Financial Management; Landfire Project; Whatcom County Planning Department*
Urban	1000	800	2000 Census Urbanized Areas;

			Landfire Developed Areas
Intensive Agriculture	500	390	Cultivated Crops & Small grains merged Landfire data
Non-intensive Agriculture	250	180	Pasture/Hay & Fallow Crop merged Landfire data
Expected Urban Growth:			*Source: Whatcom County*
Urban Growth Boundaries	400	800	Exported UGA from Whatcom County Zoning Polygon Data
Pollution:			*Source: Department of Ecology*
EPA Facilities	500	180	X,Y coordinate points; EPA regulated sites, including Federal Superfund sites, Hazardous Waste sites, etc.
Invasive Species:			*Source: 2006 Landfire Data*
Non-native vegetation	500	90	Introduced Upland Vegetation
Ownership & Management Status:			*Source: Whatcom County Planning Department; Washington State DNR*
Privately-owned forest lands	300	60	Whatcom County Parcel Data
State-owned lands without Habitat Conservation Plan	200	30	DNR parcel data with “owl” parcel data erased
State-owned lands with Habitat Conservation Plan	100	30	DNR “Owl” parcel data

The rationale for metric selection, and the research conducted to support weights and distance interval values, follows.

ROADS

Roads can alter ecological processes in a number of ways: by altering stream and wetland drainage; by spreading exotic and invasive species; by blocking migration routes of certain species and subdividing populations; by causing avoidance of near-by habitat by sensitive species; and by contributing to population decline by road-kill (Forman and Deblinger 2000).

To assign weights, it was assumed that all roads are not equal, and that the larger and busier a road, the more ecological impact it could be expected to have. Four classes of roads were developed and assigned incremental weights corresponding to their capacity and level of use, with busy highways assuming the largest weight, and railroads with the least weight.

Forman and Deblinger (2000) conducted a “road-effect zone” analysis, which evaluated impacts to ecological processes, from a four-lane highway. They found that the road-effect zone averaged 600m in width, with some processes affected up to 1km.

To assign distance intervals, we used the "road-effect zone" average distance of 600m for primary and secondary highways. For each subsequent road class, the distance interval was reduced by the same increment that the road-class weight decreased.

CONVERTED LANDS & EXPECTED URBAN GROWTH

Hansen et al. (2005) reported that species richness decreased for many plant and animal communities as housing density increased along the rural–urban gradient, and Maestas et al. (2003) found that as human land-uses intensified, impacts on species and underlying ecological processes increased. Based on this information, land-uses were assigned weights depending on the intensity of human-use and disturbance, from urban to agriculture. Note that Expected Future Urban Growth has a lower weight than Urban Areas. This is to reflect the fact that while these lands are slated for future growth, conversion has not yet happened and so these lands may still maintain ecological processes that could be protected if so decided.

While the urban-rural gradient is well documented, no studies were found that documented an "effect zone" that would directly translate to distance interval assignments. Due to this paucity of information, an arbitrary but reasonable distance interval effect of approximately 0.5 mile was assigned to Urban lands. Distance intervals for agricultural land-uses were reduced by the same proportion as their weighted value.

POLLUTION

Impacts to ecological integrity from pollution were represented by facilities currently regulated by the Environmental Protection Agency. These regulated facilities include registered Superfund sites, Hazardous Waste Management sites, Underground Storage Tanks (including ones known to be leaking) among others. Because of the difficulty of evaluating each facility (there are 703 currently permitted sites in Whatcom County) for their individual potential impacts, a mid-weight was assigned to each point, although we can assume some of these facilities are managed to produce little or negligible amounts of pollution.

Distance intervals were also assigned using a fixed number, although this number likely does not adequately reflect the level of impact on ecological integrity. For example, older sites that emanated pollution in the past may have ongoing effects;

Superfund sites likely have bigger effects than fully sealed and environmentally safe underground storage tanks. The distance interval was assigned by assuming that the average size of a regulated facility is 90m^2, and the expected impact is twice the size of the facility, or 180m^2.

INVASIVE SPECIES

Andersen et al. (2004) report that "the entry, establishment, and spread of non-indigenous species in new environments can cause major economic damage, irreversible ecological changes, and significant public health impacts". In 2006, Washington State, recognizing the need for a coordinated approach to invasive species management, passed a bill to form the Washington State Invasive Species Coalition. The Coalition has stated that invasive species "profoundly alter ecological processes".[8] For these reasons, invasive species warrant a very high weight. However, a spatially-explicit database of invasive species locations was not located for Whatcom County. Landfire data (see www.landfire.gov) identified areas of "introduced upland vegetation" for Whatcom County, which was used to represent invasive species for the landscape integrity layer. However, because of the potential inaccuracies of this data (it was interpreted from satellite imagery), a lower weight was assigned to this indicator.

As with the pollution metric, assigning distance intervals to invasive species is very difficult, primarily because invasive species represent a number of different taxa with potentially very different life-history traits (e.g. different seed-dispersal distances, or different colonizing abilities). An arbitrary value of 90m was assigned. However, invasive species are highly-correlated to intensive land-uses (e.g. roads, urban areas), so it is presumed that many invasive specie locations will be captured in the distance intervals provided for *Converted Land Uses* and *Roads*.

OWNERSHIP AND MANAGEMENT STATUS

Gamon (2007) reported that timber harvest practices have impacted ecological processes in Washington State by changing patterns of forest age, structure and species composition. Fortunately, timber practices have improved in recent years (Gamon, 2007)

[8] See http://www.invasivespeciescoalition.org/

and not all timber harvest practices are harmful; in fact, some silvicultural treatments can be beneficial to wildlife (Franklin et al. 2002). For these reasons, lands that practice commercial forestry were included as an indicator, but were weighted relatively low compared to other land uses.

Weights were assigned by referencing the North Cascades Ecoregional Assessment, which used the "pair-wise comparison" method to weight ownership types in the North Cascades (Iachetti et al. 2006). The relative weight assigned to each land use by the North Cascades Ecoregional Assessment was normalized (divided by total weights of all selected land-uses) to derive a percentage representing relative contribution of each land-use in the overall weighting system. Point weights were then assigned that reflected the percent distribution.

Table 2.4: Weights assigned to land ownerships by a "pair-wise comparison" method used in the North Cascades Ecoregional Assessment, and subsequent assigned weights used in this report.

Ownership/Management Status	NCEA Weight = %	Assigned Weights
State HCP:	6.23 / 84.63 = 7%	100
State:	10.58 / 84.63 = 13%	200
Private:	53.05 / 84.63 = 63%	300

There is a well-documented "edge effect" associated with timber harvest practices. Such edge effects differ in magnitude, but have been shown to modify ecological, physical and biological conditions in many forests (see Lindenmayer and Franklin 2002). Clearcuts inside a forested patch will have the greatest effect, with lessening effects as more trees are retained. Some edge effects have been measured to be >240m, but the largest effects tend to be within the first 10-50m into a forest (Nelson and Halpern 2005). To assign distance intervals, it was assumed that most private lands will more resemble clear-cuts or shelterwood-cuts (which remove most trees) and thus have a more intense edge effect. For easier computation, distance intervals were assigned to be 60m (two cell sizes) for private lands, and 30m for state lands.

METRICS EVALUATED BUT NOT INCLUDED

Other threats to ecological integrity that were identified but not included as metrics include forest pests and diseases, and climate change. The Washington State Department of Natural Resources tracks forest pests and diseases in Washington State.

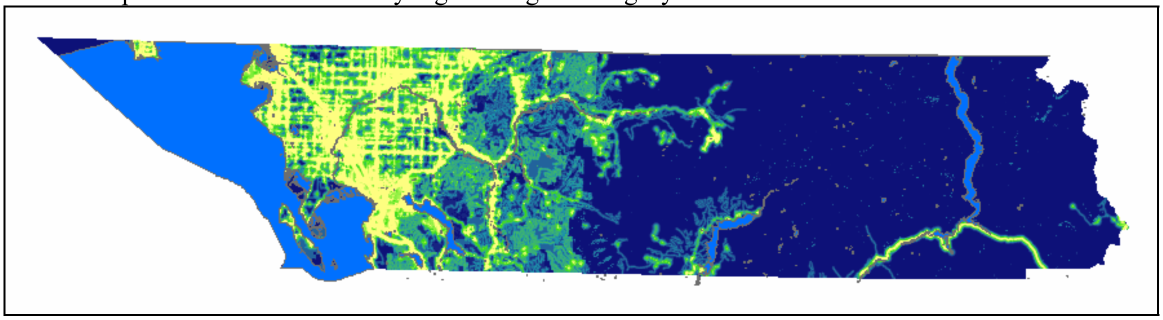
These data were excluded because pests and diseases are forest disturbance agents that can be vital to forest function. Pests and diseases can harm forest processes if they reach epidemic proportions, but there was no way to ascertain from the data which disturbances were within normal parameters, and which were not. Climate change was not included as a direct threat because, unlike the other indicators, any climate change data that could have been incorporated was speculative, rather than known. This uncertainty may have only confused the landscape integrity layer.

Wallington and others (2005) found that past efforts to protect biodiversity have largely failed to acknowledge that ecosystems are dynamic and that change in composition and structure can be expected over time. They recommended that disturbance regimes be incorporated into reserve networks. Specifying a Minimum Dynamic Area (MDA) for each ecological system has been identified as a way to accommodate disturbance drivers (Groves 2003). MDA has been defined as "the smallest area that is needed to maintain a natural habitat, community or population based on natural disturbance regimes and the ability of the biota to recolonize or restabilize component species" (Iachetti et al. 2006). Land cover data didn't allow for consideration of a minimum dynamic area because the high-resolution nature of the data meant that many forest types could be adjacent to one another, constituting a patch, but not of the same land cover type. Therefore a minimum patch size would have had the effect of ignoring many patches of existing contiguous forest cover because it would be trying to find patches of the same forest type. However, because the landscape integrity layer has a spatial relationship to impacts, by default contiguous patches on the landscape show a higher level of integrity because they are not impacted by the fragmentation of roads or human settlement patterns. Therefore this limitation is overcome somewhat, although specific attention to minimum dynamic area would be a better way to capture what is a minimum viable patch size.

It should be noted that federal lands were not included as one of the ownership/management indicators because the vast majority of federal lands within Whatcom County are managed for wilderness values. Thus, any measure of their negative impact to ecological integrity would have been difficult to quantify, and would be related primarily to recreational impacts, and management activities that are restorative in nature, with potential short-term impacts but long-term benefits to ecological integrity.

Figure 2.1 shows the result of landscape integrity analysis, which is the aggregated value of all metrics across the entire planning area. Appendix 2 details the methodology used to create the landscape ecological integrity layer.

Figure 2.1: Results of landscape integrity analysis. Yellow represents areas with low ecological integrity, and blue represents areas of relatively high ecological integrity



2.1.3 Assigning Data Confidence Values

The nature of data collection results in data sets that vary across time and space, and this variation produces uncertainty in the true "face value" of a dataset or analysis. Data on elements of biodiversity and their locations are typically subject to greater uncertainty than other types of planning data such as infrastructure or topography, because many anthropogenic, biotic and abiotic factors can influence the distribution of an element at a particular time in space. Furthermore, uncertainty can be introduced at almost any point in the planning process, from data collection and input, to data processing, to classification procedures and data categorization. Decision-making theory calls for explicit representation of uncertainty (e.g. potential errors) in datasets to help decision-makers and stakeholders in planning processes (Burgman et al. 2005, Barry and Elith 2006).

In the NatureServe Vista program, uncertainty values are assigned as "confidence" levels. According to the NatureServe Vista manual, a confidence value is "a measure of certainty that the element is actually present in a location [cell] designated in its' distribution layer," and can be derived from either a statistically-derived assessment of data accuracy, or from a qualitatively-derived assessment of data quality based on specific factors that contribute to uncertainty in data. High confidence values represent increased certainty of an element's existence in a designated space. Low confidence values do not necessarily imply that an element observed or predicted in a designated space are not present, but rather that the characteristics of the data (e.g. age of the observation, recent changes at a location) reduce certainty that the element is present. In places where confidence levels are low, efforts should be made to increase the confidence level by conducting on-site surveys.

As described above, coarse-filter target data were derived from The Landfire Project, which conducted statistical accuracy assessments for their land cover data for western Washington. An accuracy assessment, typically administered by a Kappa test, measures the overall accuracy of maps derived from remotely-sensed imagery to match actual conditions on the ground. Accuracy assessment results are usually reported as a percentage, which represents the ratio of times that a randomly selected cell of a particular land cover class is correctly classified based on known ground conditions. Typically, accuracy assessments are conducted for each land-cover class, as some land-cover classes are harder to classify than others (e.g. open water is usually easier to classify than variations in different forest types).

The Landfire Project reported distinct accuracy assessments for various aggregated land-cover classes, but provided no information on which ecological systems were included in each land-cover class (i.e. the format which accuracy assessments were reported did not cleanly relate to land cover attribute data used to generate ecological system land classes). Therefore, all of the distinct values (which ranged from 69% - 90%) were averaged, and the averaged value (85%) was used. While using an averaged value is not as precise, it was the best value that could be calculated with the information available.

2.1.4 Data Limitations

The goal of conservation planning is to protect ecological integrity (Mattson and Angermeier 2007). However, the processes for measuring and evaluating ecological integrity are still in their infancy. Faced with this limitation, a surrogate ecological integrity layer was created for use in the information database. However, this ecological integrity layer cannot be construed to be a definitive judgment of true ecological integrity. The results of assigning ecological integrity values can be thought of as a good first step, but again, both the surrogate index and the assigned values would need to be studied, tested and monitored before their validity as indicators of integrity can be verified. It is important to note that any surrogate measure of ecological integrity that informs decisions of areas to protect or areas to develop could have unforeseen future consequences, including species loss or extinction, and inability of systems to persist over time and the subsequent failure of these systems to provide ecosystem services.

Andreasen et al. (2001) unequivocally recommended that, while being cognizant of such limitations of assigning ecological integrity values, we must move forward with such assessments while recognizing they are based on imperfect knowledge. They argued that we do not have the luxury to wait for the perfect consensus index to be produced. Instead, it is imperative that planners and decision-makers provide for continued monitoring and adaptive management of the final network reserve that is selected during the planning process for the region.

2.2 Fine-filter Targets: Plants

In Washington State, over 60% of the recognized terrestrial plant associations occurring here are considered vulnerable, imperiled, or critically imperiled primarily as a result of land-conversion activities to built environments (Gamon 2007). For purposes of this report, plant species fine-filter targets include both plant associations and individual plant species.

2.2.1 Element Selection and Data Collection

Seven main data sources were consulted during the selection of plant fine-filter targets: the Washington Department of Fish and Wildlife Heritage database (current as of 5/2007); the Washington Department of Fish and Wildlife Priority Habitats and Species database (current as of 5/2007); the Whatcom County Wildlife Atlas database (original records used from 1994); the Whatcom County Critical Areas Ordinance (2005); the Willamette Valley-Puget Trough-Georgia Basin and North Cascades Ecoregional Assessments (completed 2004 and 2006 respectively); and the Washington State GAP Analysis database (completed 1997).

Plant species were selected as fine-filter targets if they met established selection criteria (Groves, 2003). Plant species and plant associations were selected if they met at least one of the following criteria, and were located within Whatcom County:

- Listed under the U.S. Federal- or Washington State-listed Endangered Species Act as endangered or threatened;
- Listed by NatureServe as globally imperiled, critically imperiled, or vulnerable (G1, G2, G3);
- Listed by the Washington Natural Heritage Program as imperiled, critically imperiled or vulnerable in the state of Washington (S1, S2, or S3)
- Species recommended as targets by expert opinion in the North Cascades and Puget Sound Ecoregional Assessments;

Digital records were obtained directly from the source agency. Any records mapped or confirmed before 1987 were considered outdated and were removed. In addition, data was obtained from The Nature Conservancy for plant associations and rare plant species that were identified by local biologists and included in the Puget Trough and North Cascades Ecoregional Assessments. There were 57 total fine-filter plant targets for Whatcom County, which are listed in Appendix 3.

2.2.2 Calculating viability of fine-filter targets

Comparable to assigning ecological integrity values to ecological systems, viability values were assigned to each fine-filter target occurrence. The viability value indicates the ability or likelihood for the particular target to persist in its location, and is represented by a 0.0 – 1.0 scale, with 1.0 representing highest viability.

The Washington Natural Heritage Program maintains Element Occurrence Rank data (EO Ranks) on most of its plant and plant association occurrences; EO Ranks represent the best data on the viability of an individual occurrence. According to NatureServe, "EO ranks are used to provide a succinct assessment of estimated viability, or probability of persistence (based on condition, size, and landscape context) of occurrences of a given Element. In other words, EO ranks provide an assessment of the likelihood that if current conditions prevail an occurrence will persist for a defined period of time, typically 20-100 years" (NatureServe 2002). EO ranks are based on information gathered from recent field surveys, and assigned by biologists familiar with the natural history of and landscape condition for each EO. While basic EO ranks use a letter system, the specifications that qualify each rank vary by element. Range ranks (i.e. ranks that include more than one letter) and the "?" qualifier are used to indicate uncertainty based on insufficient information. Table 2.5 shows the basic EO ranks that have been developed and their meaning.

Table 2.5: EO Ranks and their meaning

EO RANK	DESCRIPTION OF VIABILITY
A	Excellent estimated viability
B	Good estimated viability
C	Fair estimated viability
D	Poor estimated viability
E	Verified extant (viability not assessed)
H	Historical
F	Failed to find, but may still exist
X	Extirpated
AB	Excellent or good (A or B)
BC	Good or fair (B or C)
CD	Fair or poor (C or D)
AC	Excellent to fair (A, B, or C)
BD	Not excellent (B,C, or D

NatureServe Vista requires numerical viability values, so these letter ranks must be converted into numerical values. The NatureServe Vista user's manual recommends equivalent numerical values for A, B, C, and D ranks. Table 2.6 shows the numerical equivalents used to convert EO Ranks. EO Ranks expressed as ranges (e.g. AB, BC) were assigned the numerical mean between the two ranks.

Table 2.6: EO Ranks and their numerical equivalents as proposed by NatureServe

EO RANK	EQUIVALENT VIABILITY/INTEGRITY VALUE
A	1.0
AB	0.95
B	0.9
BC	0.75
C	0.6
CD	0.4
D	0.2
AC	0.83
BD	0.56
E	0.5
F, X	0.0

Unfortunately, not all records maintained by the Washington Natural Heritage Program have EO Ranks. As described above, the process for setting EO Ranks is comprehensive, looking at the condition, size and landscape context of each individual occurrence, and is the preferred method for assigning viability values to occurrences. However, it was not possible to assign EO Ranks in this study. Under this circumstance, the NatureServe Vista manual recommends using the terrestrial landscape integrity layer created for ecological systems to assign viability values to plant fine-filter species.[9]

To assign viability values using the terrestrial landscape integrity values, each occurrence was assigned the concomitant integrity value of the cell where it was located. For occurrences that were located in multiple cells, the mean cell value was assigned. Because the landscape integrity values are normalized on a 0.0-1.0 scale, using this value is a reasonable approximation of the viability scale used to convert EO Ranks (but see Chapter 2.2.3 for a discussion of how this affects data confidence values).

2.2.3 Assigning Data Confidence Values

According to the NatureServe Vista manual, a confidence value is "a measure of certainty that the element is actually present in a location [cell] designated in its' distribution layer." Data confidence values for plant fine-filter targets were assigned by evaluating four considerations of uncertainty pertaining either to data quality and/or

[9] Reference Chapter 3.1.2 of this report for a description of landscape ecological integrity values

mapping methods: locational precision, presence, map resolution and use of modeling. Once values are assigned to each of these factors, the following formula can be used to generate an overall confidence value:

Net confidence = (Locational precision * w1) * (Presence * w2) * (Map Resolution * w3) * (Modeled * w4)

where w1 – w4 represent the respected assigned weights for each factor.

A description of each factor, and an explanation of how these factors were evaluated for the plant fine-filter targets follows.

Locational precision:

Locational precision describes the confidence level that the boundary of an occurrence reflects the true location and extent of the element at that location, based on actual field observation. Locational precision can be affected by cell size used to portray point occurrences, which may misrepresent the true location of an occurrence, distort its true boundary, or misrepresent the known size of the occurrence.

For plant fine-filter targets, data regarding locational precision were given for all data from the Washington Natural Heritage program. Data from The Nature Conservancy and WDFW Priority Species and Habitats did not contain precision values for their data. Refer to Table 2.7 for locational precision confidence values for plant fine-filter targets.

Table 2.7: Locational precision confidence values for plant fine-filter targets

DATA TYPES	LOCATIONAL PRECISION CONFIDENCE VALUE	RATIONALE
WNHP Precision Code = S	1.0	Location is precise. Most likely mapped at 1:24,000 scale or better[a]
WNHP Precision Code = M	0.4	Location is believed to be accurate to within a 1-mile radius[a]

WNHP Precision Code = G	0.2	Location is known only from general information and believed to be accurate to within a 5-mile radius[ab]
No Precision Code available	0.5	Mid-range value to avoid penalization or propping due to unknown value

[a] = Taken directly from Washington Natural Heritage Program metadata
[b] = No records for Whatcom County actually carried a "G" code

Presence:

Presence is a type of temporal confidence, and is used to portray the confidence that an observed element actually exists at a given location. Presence confidence can be affected by the date of the original observation, and information on land-use changes since the last date of observation.

For plant fine-filter targets, presence confidence values were assigned by a straight linear decrease, where older observations were assigned lower confidence values than newer observations. Presence confidence values for plant fine-filter targets are shown in Table 2.8.

Table 2.8: Precision confidence values for plant fine-filter targets

DATE OF OBSERVATION	PRESENCE CONFIDENCE VALUE	RATIONALE
2005-2007	1.0	Oldest records
2002-2004	0.8	
1997-2001	0.6	
1992-1996	0.4	
1987-1991*	0.2	Newest records
No recorded observation date	0.5	Mid-range value to avoid penalization or reward due to unknown value

*Although observation data prior to 1987 was available, the data was high-graded, and all observations occurring prior to 1987 were discarded

Map Resolution / Integrity Confidence:

Map resolution is similar to locational precision, but represents confidence levels when original data sources do not match (e.g. when coarse-scale range distribution maps are used at fine-scales). For fine-filter plant targets, map resolution was the same for all species, so all values were set to 1.0, which represents a null value.

In lieu of a map resolution value, an "integrity" value was assigned which represented confidence in the viability value assigned to each fine-filter target. As discussed in Chapter 3.2.2, many targets were assigned EO Ranks to indicate the viability of each target occurrence. However, for those targets without assigned EO Ranks, the landscape integrity layer (see Chapter 3.1.2) was intersected with fine-filter target distributions to assign a viability level. As landscape integrity values are based on modeled data, as opposed to the assessment process that occurs when assigning EO Ranks, an "Integrity Confidence" value was assigned to reflect this difference. Refer to Table 3.9 for the Integrity Confidence values.

Table 2.9: Confidence in integrity values assigned to plant fine-filter targets

VIABILITY VALUE SOURCE	INTEGRITY CONFIDENCE VALUE	RATIONALE
EO Rank	1.0	EO Ranks assigned through comprehensive assessment process
Landscape Integrity Layer	0.5	Integrity layer is modeled, and has inherent uncertainty

Modeled confidence / Buffer uncertainty:

Modeled confidence is a value used to indicate that an element distribution is inferred from surrogates of its presence rather than actual sampling data. Examples of modeled data include remotely sensed data and predicted distribution models. Uncertainty is inherent in modeled data because distributions are not directly observed or measured in the field, but rather predicted from surrogate variables. In the case of fine-filter plant targets, modeled data was not used.

However, data obtained from The Nature Conservancy was in point format. These points were buffered with an 800-foot round buffer so they meet minimum mapping unit requirements. Buffering point locations introduces Locational uncertainty, which was accounted for by assigning all TNC data records a Buffer uncertainty value of 0.5. Because WNHP and WDFW PHS data records represented actual known locations of elements, these records were given a 1.0 in this category, which creates a "no effect" for the final net confidence calculations.

Weights:

All factors were considered to contribute equally to net confidence, so weights were not assigned for fine-filter plant targets.

2.2.4 Data Limitations, Gaps and Assumptions

The source datasets used to identify and locate the distributions of fine-filter targets are not typically the result of systematic sampling; rather they represent known locations of elements observed through infrequent and unsystematic collection methods. Therefore the records obtained for fine-filter targets is likely very incomplete in terms of representing plant species that are of conservation concern in Whatcom County. Furthermore, the known observations of these targets may not represent the "best areas" for species life history needs. However, they do represent the only spatial datasets on plant species available at the time of this research.

This recommendation is equivalent to using habitat quality as a surrogate to measure population persistence for each element. Lawler and Schumaker (2004) cautioned against using general habitat quality measures to judge potential population viability, and reported that more spatially-explicit analysis that incorporate landscape pattern may do a better job of estimating potential population persistence in a planning region. While the landscape integrity layer does not consider the dispersal needs of individual elements, its spatially-explicit nature does capture some process drivers related to landscape pattern.

2.3 Fine-filter Elements: Birds, Mammals, and Herpetofauna

2.3.1 Element Selection and Data Collection

Seven main data sources were consulted during the selection of bird, mammal and herpetofauna (e.g. reptile and amphibian) fine filter targets: the Washington Department of Fish and Wildlife Heritage database (current as of 5/2007); the Washington Department of Fish and Wildlife Priority Habitats and Species database (current as of 5/2007); the Whatcom County Wildlife Atlas database (original records used from 1994); the Whatcom County Critical Areas Ordinance (2005); the Willamette Valley-Puget Trough-Georgia Basin and North Cascades Ecoregional Assessments (completed 2004 and 2006 respectively); and the Washington State GAP Analysis database (completed 1997).

All species were assembled for Whatcom County that occur, where known to occur historically, and are predicted to occur through GAP habitat modeling. This initial list generated well over 100 bird and mammal species for the County. To select fine-filter elements, species were selected as targets if they met the following criteria:

- U.S. Federal- or Washington State-listed endangered or threatened species
- Imperiled Species (G1, G2, G3, S1, S2, or S3 ranked species)
- Non-ranked species that were considered by Partners-in-Flight (birds only) or GAP analysis to be declining or otherwise at-risk AND for which there existed occurrence data either through the WDFW databases or the Whatcom Wildlife Atlas.
- Species recommended as targets through expert opinion in the North Cascades and Puget Trough Ecoregional Assessments.

After this initial selection, the list was filtered again to eliminate targets that have been extirpated or who are assumed to be adequately captured by a coarse-filter or another species. Table 2.9 shows the fine-filter targets selected for analysis; table 2.10 shows species that met the above criteria but were eliminated from further analysis and the rationale for why they were eliminated from the list.

Table 2.10: Fine-filter terrestrial species included in this assessment

SCIENTIFIC NAME	COMMON NAME	FEDERAL STATUS	STATE STATUS	GLOBAL / STATE RANK
BIRDS				
Accipiter gentilis	Northern Goshawk	Candidate	Candidate	G5/S3
Aix sponsa	Wood Duck			G5/S3NS4B
Aquila chrysaetos	Golden Eagle		Candidate	G4G5/S3
Ardea herodias	Great Blue Heron		Monitor	G5/S4
Assemblage	Cavity Nesting Ducks			
Assemblage	Waterfowl concentrations			
Assemblage	Shorebird Concentrations			
Assemblage	Snag Rich areas			
Brachyramphus marmoratus	Marbled Murrelet	Threatened	Threatened	G3G4/S3
Cathartes aura	Turkey Vulture		Monitor	G5/S4
Chaetura vauxi	Vaux's Swift		Candidate	G5/S3
Columba fasciata	Band-tailed Pigeon			G5/S4
Cygnus buccinator	Trumpeter Swan			G4/S3
Falco peregrinus	Peregrine Falcon	Species of Concern	Sensitive	G4/S2B
Gavia immer	Common Loon		Sensitive	G5/S2
Haliaeetus leucocephalus	Bald Eagle		Threatened	G4/S3
Histrionicus histrionicus	Harlequin Duck		Sensitive	G5/S2
Pandion haliaetus	Osprey		Monitor	G5/S4
Pelecanus erythrorhynchos	American White Pelican		Endangered	G3/S1B
Poecile hudsonica	Boreal Chickadee		Monitor	G5/S3
Strix nebulosa	Great Gray Owl		Monitor	G5/S2B
Strix occidentalis	Northern Spotted Owl	Threatened	Endangered	G3/S3
MAMMALS				
Canis lupus	Gray Wolf	Threatened	Endangered	G4/S1
Ursus arctos	Grizzly Bear	Threatened	Endangered	G4/S1
Oreamnos americanus	Mountain Goat			G5/S2S3
Corynorhinus townsendii townsendii	Pacific Townsend's Big-eared Bat	Species of Concern	Candidate	G4/S2
Cervus elaphus	Rocky Mountain Elk			G5/S5
Gulo gulo	Wolverine	Species of Concern	Candidate	G4/S1
Lynx canadensis	Canada Lynx	Threatened	Threatened	G5/S1
HERPETOFAUNA				
Rana aurora	Red-legged Frog	Species of Concern		G4/S4
Rana cascadae	Cascade Frog		Monitor	G3G4/S4
Rana luteiventris	Columbia Spotted Frog	Species of Concern	Candidate	G4/S4
Ascaphus truei	Coastal Tailed Frog	Species of Concern	Monitor	G4/S4
Bufo boreas	Western Toad	Species of Concern	Candidate	G4/S3S4

Table 2.11: Fine-filter species not selected as targets

SCIENTIFIC NAME	COMMON NAME	RATIONALE FOR NOT SELECTING AS TARGET
BIRDS		
Aechmophorus occidentalis	Western Grebe	No occurrence data available
Branta bernicla	Brant	No occurrence data available
Chen caerulescens	Snow Goose	Considered “over-abundant” by Seattle Audubon Society
Dryocopus pileatus	Pileated Woodpecker	No occurrence data available
Empidonax traillii	Willow Fly-Catcher	No occurrence data available
Eremophila alpestris	Streaked Horned Lark	Extirpated from WA
Grus Canadensis	Sandhill Crane	Extirpated from WA
Histrionicus histrionicus	Harlequin Duck	Outdated records (all observations prior to 1987)
Lagopus leucura	White-tailed Ptarmigan	Outdated records (all observations prior to 1987)
Oreortyx pictus	Mountain Quail	Outdated records (all observations prior to 1987)
Pelecanus occidentalis	Brown Pelican	No occurrence data available
Phalacrocorax penicillatu	Brandt’s Cormorant	No occurrence data available
Picoides dorsalis	Three-toed Woodpecker	Outdated records (all observations prior to 1987)
Progne subis	Purple Martin	Outdated records (all observations prior to 1987)
Sialia mexicana	Western Bluebird	Outdated records (all observations prior to 1987)
MAMMALS		
Martes pennanti	Fisher	Extirpated – range captured by Grizzly Bear distribution
Synaptomys borealis	Northern Bog Lemming	Outdated records (all observations prior to 1987)
Sciurus griseus	Western Gray Squirrel	Outdated records (all observations prior to 1987)
Myotis keenii	Keen’s Myotis	No data available
HERPETOFAUNA		
Clemmys marmorata	Western Pond Turtle	Outdated records (all observations prior to 1987)

2.3.2 Data Development

Data records for the above species were collected from the source agencies, and then “high-graded”. That is, records of occurrences dating older than 1987, and any records not verified by a biologist, were discarded. The remaining points were given an 800-foot buffer to bring them up to the minimum mapping unit of 1 cell.

2.3.3 Element Distribution Modeling

As described above, data sources consulted for this report published the locations of element observations in point-occurrence form. That is, each file contained a number of points (representing latitude/longitude coordinates) that documented an observed occurrence of that species. These are known as species presence data. The advantage of species presence data is that they represent a confirmed occurrence of a particular element in a precise location. The disadvantage is that a single occurrence does not illustrate all the potential locations of occurrence, or distribution, of an element. Advances in ecological modeling have resulted in several statistical modeling programs that are able to generate predicted species' distribution based on presence-only data. Predicted species distribution modeling is "a process that maps environments predicted to be suitable for occupation (and, conversely, environments predicted to be unsuitable for occupation) by a given element" in a planning region (Beauvais et al. 2006). Such modeling can be extremely useful for conservation planning, particularly when the goal is to conserve biodiversity and only limited species data is available (Boone and Krohn 2000, Elith et al. 2006). It is important to note that predicted distribution models are not "habitat" models, as such models require knowledge of reproduction, survival and occupation of species, and this level of data was not readily available for this project. Predicted distribution modeling is best thought of as a representation of locations that are suitable for inhabitants based on what is known about current suitable conditions for that element.

Of the available statistical modeling programs, MaxEnt, a maximum entropy modeling software, has been shown repeatedly to be superior in performance in comparison to other programs, particularly when modeling species with limited observed occurrences (Williams et al. 2005, Elith et al. 2006, Hernandez et al. 2006, Phillips et al. 2006).

For a complete discussion of the statistical mechanics of maximum entropy, and initial testing of the MaxEnt software, see Phillips et al. (2006). Generally speaking, MaxEnt uses presence data (in the format of x,y coordinates) to predict the distribution of a species based on a number of environmental predictors (termed 'constraints'). Essentially, MaxEnt takes the empirical average of all constraints for every pixel across the landscape, and returns a predicted distribution that agrees with everything that is known. However, it avoids disagreeing with constraints that are unknown, thus returning the probability distribution of maximum entropy (Phillips et al. 2006). Because MaxEnt is a presence-only model, it selects random background points to produce a sample of environmental gradients across the study area, similar but not identical to producing pseudo-absences (see Pearson et al. 2007). MaxEnt can accommodate environmental predictors formatted as either continuous or categorical data, allowing for a full use of qualitative (e.g. land classes) and quantitative (e.g. elevation) predictors, and the model's algorithm is guaranteed to converge to the optimum probability distribution.

This project used MaxEnt, version 2.3 developed by S. Phillips and colleagues. Parameter values were set as follows: the convergence threshold was set as the recommended default (10^{-5}); maximum number of iterations was set at 10,000, the number of background points was limited to 100,000, and regularization values (which are included to reduce over-prediction of suitable areas) were set to "auto." MaxEnt assigns a probability of occurrence to each cell in the study area. Output values are returned as "cumulative probabilities" (i.e. the sum of probabilities of that cell and all other cells with equal or lower probability, multiplied by 100 to give a percentage). The "cumulative probability" is a continuous value ranging from 0 to 100, representing relative suitability (not probability of occurrence) of a given grid cell, with 0 being least suitable and 100 being most suitable.

Species Occurrence Data:

Several criteria were used to determine which species would be selected for modeling. MaxEnt has been shown to have considerable predictive success even at low sample sizes, though studies have shown that less than 5 samples can dramatically reduce model success, and that high locational precision and confidence of occurrence is most important for determining model success with limited sample sizes (Williams et al. 2005, Hernandez et al. 2006). To accommodate these model limitations, at least seven current, verified occurrences were required for each species. Occurrence records were eliminated if they were observed prior to 1987, and if they were not verified by a biologist. Data from the Priority Habitats and Species, and the Whatcom Atlas databases where comprised of polygon data. For each polygon, a point was assigned to the center of the polygon, and this point was exported as an occurrence record. Table 2.11 shows which species were selected for modeling, the number of records available for each, and sources which contributed current, verified occurrence data. The North Cascades Ecoregional Assessment conducted distribution modeling for the mountain goat, lynx, and elk, and these distributions were accepted for use in this project.

Table 2.12 Targets with distributions developed by predictive distribution modeling (PDM)

SPECIES	SOURCE(S)*	# of RECORDS
BIRDS		
BALD EAGLE	heritage/wpg_ea	237
BAND-TAILED PIGEON	phs/wpg_ea	8
CAVITY-NESTING DUCKS	atlas/phs	9
COMMON LOON	heritage	13
GREAT BLUE HERON	atlas/heritage	19
MARBLED MURRELETS	wdfw database	446
NORTHERN GOSHAWK	heritage	13
PEREGRINE FALCON	heritage/wpg_ea	16
VAUX'S SWIFT	heritage/wpg_ea	7
WOOD DUCK	atlas/phs	9
GOLDEN EAGLE	heritage	10
NORTHERN SPOTTED OWL	wdfw database	38
OSPREY	heritage	28
TRUMPETER SWAN	atlas/phs	7
MAMMALS		
WOLVERINE	heritage	22
MOUNTAIN GOAT	nc_ea	
GRIZZLY BEAR	heritage	19
GRAY WOLF	heritage	26
LYNX	nc_ea	
ELK	nc_ea	

*heritage = Washington Department of Fish and Wildlife Heritage points database
Wpg_ea = Willamette Valley-Puget Sound-Georgia Basin Ecoregional Assessment
Phs = Washington Department of Fish and Wildlife Priority Habitats & Species database
Atlas = Whatcom County Wildlife Atlas
Nc_ea = North Cascades Ecoregional Assessment

Environmental Predictors ('Constraints'):

Environmental predictors were selected based on Phillips et al. (2006), which recommend that variables be selected that are temporally relevant, and represent "bottom-up" variables that are likely to affect species distributions at meso- and micro-scales, like elevation, aspect, and percent canopy cover. Sixteen environmental variables were selected, and each species was modeled with all predictors present.[10] Table 2.12 lists the environmental variables and gives a brief description of each.

[10] MaxEnt conducts a jackknife test to determine environmental predictor importance for each species. Several species with various amounts of occurrence data were modeled with all environmental variables, and then again with only those environmental variables that were deemed in the prior model run to be most important. However, the gain and the area under the curve (AUC) of the model decreased with less environmental predictors in all cases, indicating decreased model predictive ability with less variables. For this reason, it was decided to model all species with all environmental predictors.

Table 2.13: Environmental predictors used to calibrate MaxEnt

ENVIRONMENTAL VARIABLE	ORIGINAL SOURCE	DESCRIPTION
Aspect	USGS 30M Digital Elevation Model	Slope direction in compass degrees
Biophysical setting	Landfire Project	Likely historical vegetation based on current biophysical environment and approximate disturbance regime
Distance to marine shoreline	Whatcom County Planning Department – SMP marine shoreline	Euclidean distance to the marine shoreline
Distance to streams and rivers	DNR 24K Hydrography data	Euclidean distance to rivers and streams
Distance to urban areas	Census 2000 Urban Areas	Euclidean distance to urban areas
Elevation	USGS 30M Digital Elevation Model	Height above sea-level
Lakes and ponds	DNR 24K Hydrography data	Lakes and ponds
Old-growth Forests	Washington Department of Fish and Wildlife	Location of old-growth forests inventoried and mapped in 1988 (newest version available)
Plant Association Group	Mt. Baker-Snoqualmie National Forest (Henderson)	Resampled 90M PAG zones generated from a 2006 model run
Slope	USGS 30M Digital Elevation Model	Measures the gradient of an incline (rise / run)
Successional Class	Landfire Project	Successional state of existing vegetation
Vegetation cover	Landfire Project	Average percent cover of existing vegetation per 30M cell
Vegetation height	Landfire Project	Average height of dominant vegetation per 30M cell
Vegetation type	Landfire Project	Vegetation currently present at a given site. Also includes low, med, & high-intensity development; various agricultural lands; water; snow/ice; developed open space and quarries/mines/gravel pits.

Suitable Habitat Thresholds:

Because MaxEnt returns cumulative probabilities of suitability for the entire landscape, it is desirable to set a threshold that distinguishes “suitable” from “less suitable” areas. There are a number of techniques that can quantify optimal threshold levels based on false-positive (Type I error or commission) and false-negative (Type II error or omission) error avoidance. However, these techniques are not appropriate for presence-only models, because no true absences are known (see Williams et al. 2005).

Because the purpose of species modeling for this report is to inform potential conservation planning activities, it is advantageous to achieve a distribution that represents the smallest predicted area that will not produce a high omission error (Elith et al. 2006). Conversely, it is important to limit over-prediction of suitable areas (e.g. reduce commission error), which can happen when the omission error rate is set to be very small or zero, especially with larger sample sizes[11]. Due to the fact that MaxEnt is a presence-only model, it cannot return a commission error rate (there are no confirmed absences from which to derive such a value). For this reason, a suitable technique for optimizing thresholds does not exist, and to date threshold setting decisions have been made somewhat arbitrarily (see Engler et al. 2004, Williams et al. 2005, Phillips et al. 2006). To overcome this limitation, and to provide the Whatcom Legacy Project with the most information to inform subsequent planning activities, three decision thresholds were set for each species, each attempting to minimize predicted area while addressing omission and potential commission errors. These thresholds include Lowest Presence Threshold (sensu Williams et al. 2005), which select only those pixels that are at least as suitable as those where a species occurrence has been recorded; the T10 threshold (sensu Phillips et al. 2006), which sets a fixed threshold where the cumulative probability of a cell is at least as high as 90% of the most suitable areas; and the "Balanced Statistic" threshold, which is a value threshold returned from the MaxEnt model which combines omission error, predicted area, and cumulative threshold values.

[11] Pearson et al. (2007) report that for small sample sizes (<10), any omission can be considered a clear error, and find it is appropriate to enforce a zero omission rate.

Filters:

Predicted distribution models for the mammal species (e.g. grizzly bear, gray wolf and wolverine) were filtered to exclude any areas that were found to be suitable for occurrence but were within city or county jurisdiction. This was done under the assumption that it is neither likely nor desired to protect areas for these particular mammals adjacent to areas of high human occupancy. No other filters were applied.

2.3.4 Calculating viability for bird, mammal and herpetofauna fine-filter targets

As with fine-filter plant species, Element Occurrence (EO) Ranks were used to assign viability values to occurrences of *non-modeled* species, when they were available (see Chapter 2.2.2 for a discussion of EO Ranks and their conversion values). For those *non-modeled* species for which no EO Ranks were available, viability was assigned by taking the zonal mean of each polygon when intersected with the landscape integrity layer (see Chapter 2.1.2 for a discussion of the landscape integrity layer, and Chapter 3.2.4 for a discussion of using the landscape integrity layer as a viability value surrogate).[12]

Viability values for *modeled* species were determined by combining two values: the suitability value returned for the predicted distribution for each species, and the landscape integrity layer. The suitability layer describes how suitable a particular cell is for the modeled species, and the landscape integrity layer describes the ecological integrity of that cell. The combination of these two values provides a useful surrogate representing the likelihood of an element's potential persistence for each cell. These values were combined by first converting the suitability layer to a 0 to 1 scale by dividing by 100, then calculating the mean of the two variables for every pixel that was contained in the predicted species' distribution. This returned a normalized value on a 0.0-1.0 scale; using this value is a reasonable approximation of the viability scale used to convert EO Ranks.

[12] Mountain Goat, Lynx and Elk were treated as non-modeled species, as they were not modeled using the MaxEnt program.

2.3.4 Assigning Data Confidence Values

The nature of data collection results in data sets that vary across time and space, and this variation produces uncertainty in the true "face value" of a dataset or analysis. Data on elements of biodiversity and their locations are typically subject to greater uncertainty than other types of planning data such as infrastructure or topography, because many anthropogenic, biotic and abiotic factors can influence the distribution of an element at a particular time in space. Furthermore, uncertainty can be introduced at almost any point in the planning process, from data collection and input, to data processing, to classification procedures and data categorization. Decision-making theory calls for explicit representation of uncertainty (e.g. potential errors) in datasets to help decision-makers and stakeholders in planning processes (Burgman et al. 2005, Barry and Elith 2006). In the NatureServe Vista program, uncertainty values are assigned as "confidence" levels. According to the NatureServe Vista manual, a confidence value is "a measure of certainty that the element is actually present in a location [cell] designated in its' distribution layer," and can be derived from either a statistically-derived assessment of data accuracy, or from a qualitatively-derived assessment of data quality based on specific factors that contribute to uncertainty in data. High confidence values represent increased certainty of an element's existence in a designated space. Low confidence values do not necessarily imply that an element observed or predicted in a designated space are not present, but rather that the characteristics of the data (e.g. age of the observation, recent changes at a location) reduce certainty that the element is present. In places where confidence levels are low, efforts should be made to increase the confidence level by conducting on-site surveys.

The NatureServe Users Manual recommends that confidence values be calculated through four considerations of uncertainty pertaining either to data quality and/or mapping methods: locational precision, presence, map resolution and use of modeling. Once values are assigned to each of these factors, the following formula can be used to generate an overall confidence value:

Net confidence = (Locational precision * w1) * (Presence * w2) * (Map Resolution * w3) * (Modeled * w4)

where w1 – w4 represent the respected assigned weights for each factor.

A description of each factor, and an explanation of how these factors were evaluated for the data used in this project follows.

Locational precision:

Locational precision describes the confidence level that the boundary of an occurrence reflects the true location and extent of the element at that location, based on actual field observation. Locational precision can be affected by cell size used to portray point occurrences, which may misrepresent the true location of an occurrence, distort its true boundary, or misrepresent the known size of the occurrence.

For this report, three main data types were used, all of which carry various potential errors in precision. Table 2.13 describes the data types used, the locational precision value assigned to each, and the rationale for selected value.

Table 2.14: Locational confidence values for bird, mammal and herpetofauna fine-filter targets

DATA TYPES	LOCATIONAL PRECISION CONFIDENCE VALUE	RATIONALE
For Non-Modeled Data:		
Polygon data (sources: Whatcom Wildlife Atlas and WDFW Priority Habitats and Species data)	0.9	Polygons georeferenced to actual mapped habitats – polygon shape and extent true to occurrence
Point occurrences (sources: WDFW Heritage Points; Ecoregional Assessments	0.7	Point occurrences were buffered to achieve minimum mappable size, thus producing uncertainty of occurrence location within the cell which it is indicated to occur.
For Modeled Data:		
MaxEnt Modeled distributions	0.5	Modeled data is inherently uncertain as the results are inferred rather than observed.
North Cascades Ecoregional Assessment Modeled distributions (e.g. Mountain Goat, Elk and Lynx)	0.8	Distributions come from critical habitat maps which were collaborated upon by multiple biologists.

Presence:

Presence is a type of temporal confidence, and is used to portray the confidence that an observed element actually exists at a given location. Presence confidence can be affected by the date of the original observation, and information on land-use changes since the last date of observation.

Presence confidence values for *non-modeled* were assigned differently depending on data type. Where point occurrences were used as distribution layers, confidence levels were assigned by a straight linear decrease, where older observations were assigned lower confidence values than newer observations. For *modeled* species, the presence confidence of a given cell is equal to the suitability of that cell (which is reported on a 1 to 100 scale) divided by 100 (to set it on a 0 to 1 scale).

Table 2.15: Presence confidence values for bird, mammal and herpetofauna fine-filter targets

DATE OF OBSERVATION	PRESENCE CONFIDENCE VALUE	RATIONALE
For Non-Modeled Data:		
1987-1991*	0.2	Oldest records
1992-1996	0.4	
1997-2001	0.6	
2002-2005	0.8	
2006-2007	1.0	Newest records
No Data	0.5	Unknown records
For Modeled Data:		
Modeled Distributions	(Suitability value / 100)	Cells determined to have high suitability should have higher presence opportunity
North Cascades Ecoregional Assessment Modeled distributions (e.g. Mountain Goat, Elk and Lynx)	1.0	Distribution layers were created in 2006

*Although observation data prior to 1987 was available, the data was high-graded, and all observations occurring prior to 1987 were discarded.

Map resolution:

Map resolution is similar to locational precision, but represents confidence levels when original data sources do not match (e.g. when coarse-scale range distribution maps are used at fine-scales).

All confidence values for this report were set to 1.0 to show no effect, as all data sets were mapped at the same resolution.

Modeled confidence:

Modeled confidence is a value used to indicate that an element distribution is inferred from surrogates of its presence rather than actual sampling data. Examples of modeled data include remotely sensed data and predicted distribution models. Uncertainty is inherent in modeled data because distributions are not directly observed or measured in the field, but rather predicted from surrogate variables.

For all non-modeled data, confidence levels were set to 1.0. For all modeled data, model confidence is set to 0.8.[13]

Table 2.16: Modeled confidence values for bird, mammal and herpetofauna fine-filter targets

DATA TYPE	MODELED CONFIDENCE VALUE	RATIONALE
Non-Modeled Data	1.0	Non-Modeled Data has highest certainty
Modeled Data	0.8	Modeled Data has lower certainty

2.3.5 Data Limitations

The source datasets used to identify and locate the distributions of fine-filter targets are not typically the result of systematic sampling; rather they represent known locations of elements observed through infrequent and unsystematic collection methods. Therefore the records obtained for fine-filter targets is likely very incomplete in terms of representing elements that are of conservation concern in Whatcom County. Furthermore, the known observations of these targets may not represent the “best areas” for species life history needs. However, they do represent the only readily-available spatial datasets on bird, mammal and herpetofauna species available at the time of this research.

[13] Initially model confidence values were set at 0.5, but this had the effect of returning very low confidence levels. In this setup, a pixel with a suitability value of 100 (typically associated with an original occurrence point) could return a confidence value no higher than 0.2.

Chapter 3: Freshwater Targets

In 2006, The Nature Conservancy completed and published an Assessment of Freshwater Systems for Washington State (Skidmore 2006). This report was initiated to achieve three key goals:

1. Classify and map the current distribution and status of freshwater ecological systems and native freshwater species at-risk in Washington State
2. Ascertain dominant future threats to freshwater biodiversity, and determine which watersheds are most susceptible to these threats in Washington.
3. Identify which watersheds represent the best opportunities for effective freshwater biodiversity conservation for the state.

The Assessment of Freshwater Systems for Washington State (AFSWS) is the most comprehensive peer-reviewed assessment of freshwater biodiversity that has been done for Washington State to date. The AFSWS compiled landscape condition, threats, habitats and species data from a wide range of sources, conducted analysis in collaboration with a scientific expert panel, and sought input from a number of biologists in the region who contributed expert knowledge to augment existing data.

The AFSWS were created and published for the purpose of aiding in freshwater conservation efforts, such as the Whatcom Legacy Project, and was used heavily in this report. However, in order to utilize all program functions in the NatureServe Vista software program, some manipulation of the AFSWS-generated data sets was required during data entry. All data manipulation is discussed in detail in this chapter, and the substance of all data remains true to the original analysis.

This chapter briefly summarizes the methods employed by the AFSWS analysis, and describes how AFSWS data was transformed for use in this report. Also described are additional data sources consulted, refinement of coarse and fine-filter freshwater target selection, and limitations associated with the data.

3.1 Coarse-filter Elements

Figure 3.1: Nested scales of aquatic classification

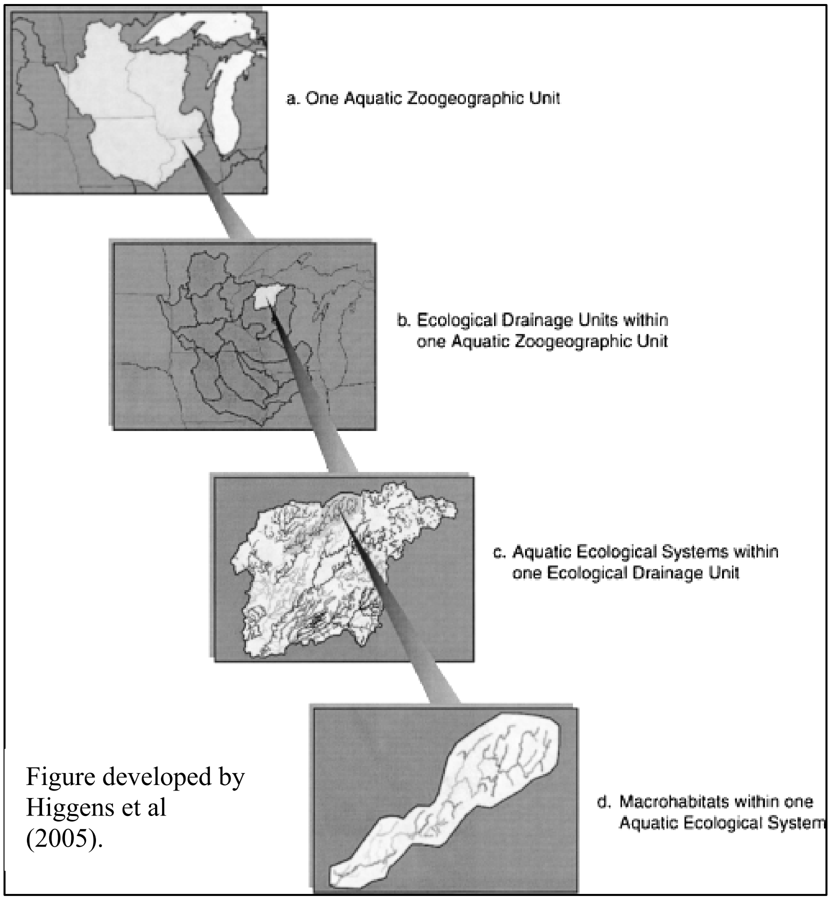
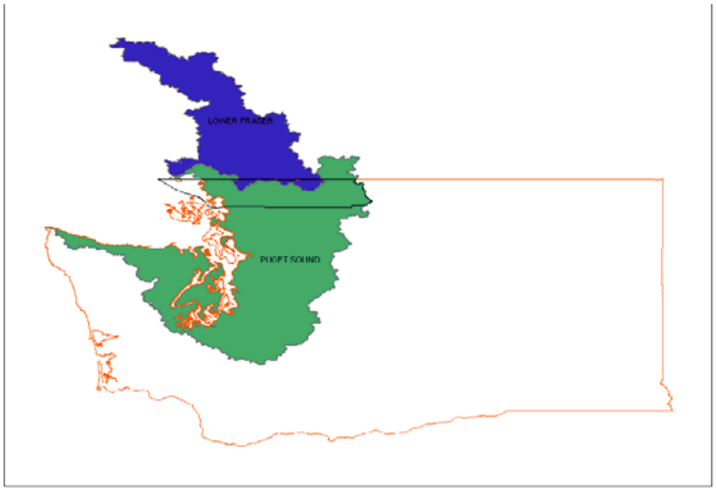


Figure developed by Higgens et al (2005).

Aquatic ecological systems were selected as coarse-filter targets for this report. The AFSWS report classified aquatic ecological systems using the classification approach developed by Higgens *et al.* (2005). This classification approach, which was developed specifically to generate freshwater coarse-filter targets for conservation planning, delineates four hierarchically-ordered spatial levels, which are meant to capture representative biodiversity (including biota, processes and patterns) at multiple scales. Starting from the smallest nested level and going up the scale, the four spatial levels are: aquatic macrohabitats; aquatic ecological systems; ecological drainage units; and aquatic zoogeographic units (see Figure 3.1). Aquatic macrohabitats are defined as river segments (reaches) and small- to medium-sized lakes with relatively homogenous abiotic factors that shape freshwater system structure and functions. These are grouped into aquatic ecological systems, which are stream and lake networks that represent areas with distinct geomorphological patterns tied together by similar environmental processes (e.g. hydrologic, nutrient and temperature regimes). The sum of aquatic ecological systems creates an ecological drainage unit, defined as a group of watersheds that share a common zoogeographic history as well as physiographic and climatic characteristics. Finally, an aquatic zoogeographic unit is the largest scale level and represents drainage basins that are distinguished by patterns of native fish distribution and account for climatic, geological and biological history.

Figure 3.2: Ecological Drainage Units in Whatcom County



According to the AFSWS, there are two ecological drainage units (EDUs) that intersect Whatcom County (see Figure 3.2); the Lower Fraser and Puget Sound EDUs. Aquatic ecological systems were classified by clustering statistically meaningful combinations of macrohabitats. Aquatic ecological systems are further classified into four distinct classes:

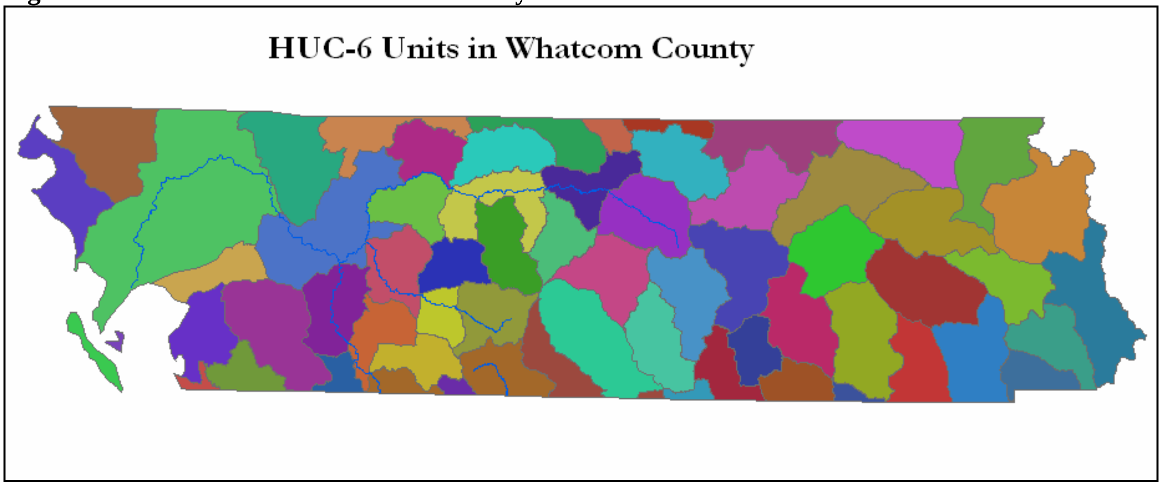
- Class 1 – Headwaters streams < 100 km^2 watershed
- Class 2 – Small rivers (tributaries) 100–999 km^2 watershed
- Class 3 – Medium rivers (rivers) 1000–10,000 km^2 watershed
- Class 4 – Large rivers >10,000 km^2 watershed

Whatcom County has twelve Class 1 ecological systems; five Class 2 ecological systems; two Class 3 ecological systems, and 0 Class 4 ecological systems. These ecological systems and their associated size classes are listed in Appendix 6, and represent the coarse-filter targets selected for this analysis.

3.1.1 Data Development

Data representing the distribution of freshwater aquatic ecological systems was obtained from The Nature Conservancy. For purposes of analysis, the AFSWS stratified ecological systems by USGS 12-digit Hydrologic Unit Codes (known as HUC6) watersheds. Ecological systems largely follow the same boundaries as HUC6s, but in some cases there might be 2 or more ecological systems within a single HUC6. Data entry requirements for use of the Vista program require information regarding ecological integrity values and data confidence for coarse-filter targets. In the AFSWS analysis, this information was generated for HUC6 units, and not for ecological systems individually. To meet data entry needs, as well as to maintain the integrity of the original AFSWS data, coarse-scale targets were entered as HUC6 units. There are a total of 68 HUC6 units in Whatcom County.

Figure 3.3: HUC-6 Units in Whatcom County



3.1.2 Calculating Element Integrity

Ecological integrity values were assigned to coarse-filter targets using the "Suitability Analysis" data generated in the AFSWS[14]. The suitability analysis evaluated each watershed in the state to determine how well, or how suitable, that watershed is for meeting biodiversity conservation objectives. Like this report's analysis of terrestrial ecological integrity, an index of indicators of ecology integrity was created, and weighted according to expected impact. The AFSWS expert scientific panel considered available data sources, and selected land use, road density, and existing dam density as indicators impacting freshwater ecological integrity. A study that examined the impacts of landscape metrics found that the amount of agriculture, riparian forests, atmospheric

[14]The AFSWS also conducted an "Irreplacability Analysis" to determine the uniqueness of each watershed in maintaining biodiversity. The "Suitabililty Analysis" and "Irreplacibility Analysis" were then combined to generate a measure of total "Conservation Utility" which estimates the total relative importance of each watershed. The "Suitability Analysis" was selected over these other analyses because its' metric most closely matches the "ecological integrity" data metric required by the Vista program. The "ecological integrity" metric helps to identify the value of individual parcels and so is more useful in this case than the other two analyses. However, these data sets are included in the final portfolio for freshwater watersheds detailed in Chapter 5.

nitrate deposition, and roads in the watershed explained the majority of variation among stream phosphorous, nitrogen and sediment levels in watersheds (Jones et al. 2001), so the AFSWS analysis was considered acceptable for the purposes of this report.

Land Use:

The AFSWS report used 30m resolution National Land Cover Data to delineate non-natural land uses, including residential, recreational, mines, cropland, orchards, vineyards, pasture, small grain and fallow fields. The scientific panel considered these land-uses to be a "primary determinant of sediment and chemical inputs to a stream and impacts to hydrologic regime" (Skidmore, 2006).

Dam Density:

Dam density, measured as the ratio of total dams to hectares within each watershed, was selected as an indicator, because "dams significantly impact the timing and magnitude of flows within a stream, water temperature, and geomorphologic processes" (Skidmore, 2006). Data were obtained from the StreamNet database. The AFSWS report acknowledged that the impact of dams to upstream and downstream habitat, biota and geomorphic processes vary according to dam size, and reports that dam density is a rough estimate of this impact.

Road Density:

Roads have been shown to have major physical and chemical effects on streams and wetlands by transporting run-off, changing stream flows, and by changing or altering stream courses (see Forman and Alexander 1998). The AFSWS selected watershed road density, which was measured as the ratio of total road length (meters) in the watershed to total stream length (meters) in the watershed.

To generate an ecological integrity value for each watershed, the three selected indicators were weighted equally as shown:

Cost Value = 1000*(0.33*A + 0.33 *B + 0.33*C), where:

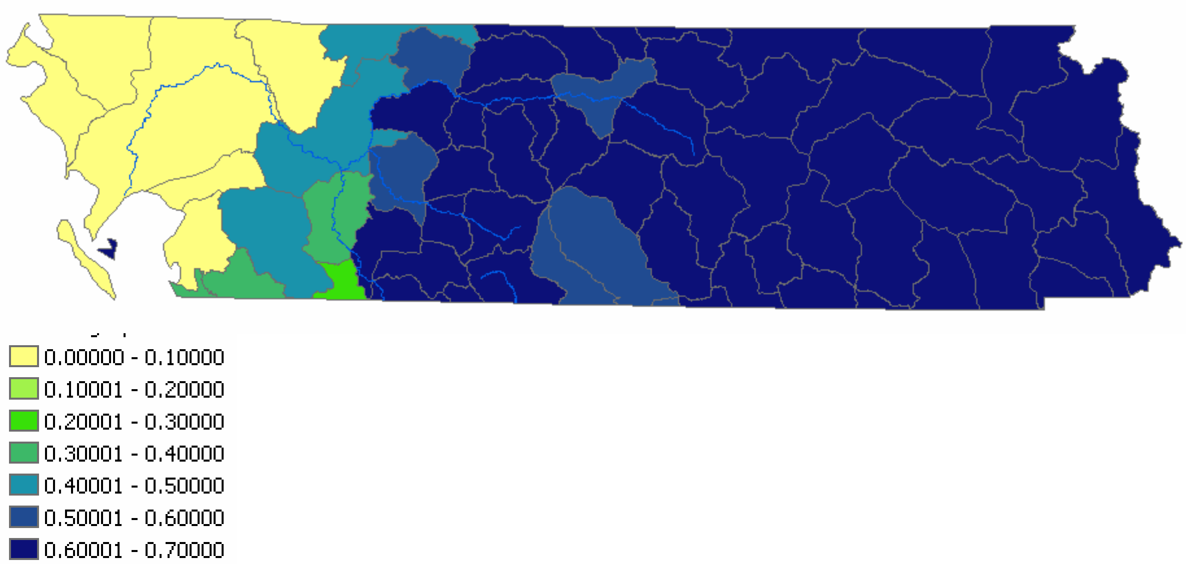
A = % non-natural land use (percent of area in AU)

B = normalized dam density (ratio of number of dams to AU area in hectares)

C = normalized road density (ratio of length of road to length of streams in AU)

The final suitability value generated by AFSWS ranged from zero to 0.7, with zero being the “most suitable” and 0.7 being “least suitable.” NatureServe’s Vista program requires ecological integrity values that are normalized on a scale of 0 to 1 with 1 representing sites with high ecological integrity and 0 representing areas with the little ecological integrity. To generate appropriate values for the Vista program, the original suitability values were first normalized (by dividing by highest value in the data set). Then, to flip the range, the normalized values were subtracted from 1. Next, to retain the original 0-0.7 scale created by the AFSWS, 0.3 was subtracted from each value, and any negative values were manually changed to 0. This resulted in the watersheds of relative highest ecological integrity represented by the value 0.7, and those watersheds with least ecological integrity listed with a value of 0. Figure 3.4 shows the range of ecological integrity across watersheds.

Figure 3.4: Results of freshwater ecological integrity analysis



3.1.3 Assigning Data Confidence Values

The nature of data collection results in data sets that vary across time and space, and this variation produces uncertainty in the true “face value” of a dataset or analysis.

Data on elements of biodiversity and their locations are typically subject to greater uncertainty than other types of planning data such as infrastructure or topography, because many anthropogenic, biotic and abiotic factors can influence the distribution of an element at a particular time in space. Furthermore, uncertainty can be introduced at almost any point in the planning process, from data collection and input, to data processing, to classification procedures and data categorization. Decision-making theory calls for explicit representation of uncertainty (e.g. potential errors) in datasets to help decision-makers and stakeholders in planning processes (Burgman et al. 2005, Barry and Elith 2006). In the NatureServe Vista program, uncertainty values are assigned as "confidence" levels. According to the NatureServe Vista manual, a confidence value is "a measure of certainty that the element is actually present in a location [cell] designated in its' distribution layer," and can be derived from either a statistically-derived assessment of data accuracy, or from a qualitatively-derived assessment of data quality based on specific factors that contribute to uncertainty in data. High confidence values represent increased certainty of an element's existence in a designated space. Low confidence values do not necessarily imply that an element observed or predicted in a designated space are not present, but rather that the characteristics of the data (e.g. age of the observation, recent changes at a location) reduce certainty that the element is present. In places where confidence levels are low, efforts should be made to increase the confidence level by conducting on-site surveys.

Assigning confidence values to coarse-filter freshwater systems was problematic. The AFSWS did not report an uncertainty or confidence value for their analysis. Alternatively, a qualitatively-derived assessment was also difficult as it would require tracking down source data, a prohibitively time-intensive endeavor. Instead, a constant confidence value of 0.50 was assigned to all freshwater coarse-filter targets, following the NatureServe Vista User's Manual recommendation that data without known values be assigned a mid-range value that avoids overdue penalization or reward (NatureServe 2006).

3.2 Freshwater Fine-Filter Targets: Resident and Non-resident Fish

3.2.1 Target Selection

Four main data sources were consulted during the selection of freshwater fine-filter targets: the Washington Department of Fish and Wildlife StreamNet database (current as of 4/2007); the Assessment of Freshwater Systems for Washington State (current as of 2006); the Whatcom County Wildlife Atlas database (original records used from 1994); and the WRIA 1 Watershed Plan (obtained from the Whatcom County Planning and Development Office 1/2007).

Data for resident and non-resident fish species and amphibians included in the AFSWS analysis were obtained directly from The Nature Conservancy. The AFSWS used a number of primary sources to map fine-filter target distributions, including the Washington Department of Fish and Wildlife Heritage database, the StreamNet database, and expert opinion. StreamNet is "a cooperative information management and dissemination project focused on fisheries and aquatic related data in the Columbia River basin and the Pacific Northwest" and acts as a clearinghouse for fisheries and aquatic data for all of Washington State, including Whatcom County.[15] A review of these primary data sources found two resident fish species that occur in Whatcom County but were not included as target species in the AFSWS (kokanee and rainbow trout). These species were added as fine-filter targets. In addition to the AFSWS, the WRIA 1 Watershed Plan database was reviewed, and two additional resident species (Tui chub and eastern Brook Trout) were added to the fine filter list. Table 4.1 shows the fine-filter targets selected for analysis.

[15] StreamNet mission statement: accessed online 5.11.2007 at http://www.streamnet.org/about-sn.html

Table 3.1: Freshwater fine-filter targets

SCIENTIFIC NAME	COMMON NAME	FEDERAL STATUS	STATE STATUS	GLOBAL/STATE RANK
NON-RESIDENT FISH				
Onchorhynchus clarkii	Searun Cutthroat Trout			G4/S4
Onchorhynchus gorbuscha	Pink Salmon - Odd-year			G5/S2
Onchorhynchus keta	Chum Salmon - Puget Sound/Straight of Georgia			G4/SNR
Onchorhynchus kisutch	Coho Salmon - Puget Sound/Straight of Georgia	Candidate		G4/SNR
Onchorhynchus mykiss	Steelhead - Puget Sound	Threatened		G5/SNR
Onchorhynchus nerka	Sockeye Salmon - Baker River			G5/SNR
Onchorhynchus tshawytscha	Chinook Salmon - Puget Sound	Threatened	Candidate	G5/S3S4
Salvelinus confluentus	Bull trout - Puget Sound	Threatened	Candidate	G4/S4
Salvelinus malma	Dolly Varden			G5/S3
RESIDENT FISH				
Onchorhynchus clarkii clarkii	Coastal Cutthroat trout - Puget Sound coastal			G4/SNR
Gila bicolor	Tui chub			G4/S2S3
Onchorhynchus nerka	Kokanee			G5/S2S3
Salvelinus fontinalis	Eastern Brook Trout			G5/SNR
Oncorhynchus mykiss	Rainbow Trout			G5/S5
Lampetra richardsoni	Pacific lamprey			G5/S3S4

Creating distributions for each of these species required some data transformation. Each source presented species distributions in line vector format. However, the process of digitizing streams often results in spatial differences between datasets, and merging these datasets to form a distribution layer often results in redundant stream channels that are not spatially aligned. To solve this problem, distribution layers from each source were first spatially joined to the Department of Natural Resources 2007 Hydrological Stream layer. The 2007 Hydrological layer represents the most accurate (1:12,000) and up-to-date stream layer available for Whatcom County. Joining source datasets to this hydrological layer essentially synced multiple data sources to a single spatially common layer (Search radius for Spatial Join tool was set at 600 feet). This allowed different source datasets to be merged together to create distribution shapefiles for individual species. Finally, each line vector distribution file was buffered by 400' to both transform the file to a polygon format (required by the Vista program) and to bring the streams up to the necessary minimum mapping size of one pixel.

3.2.2 Calculating viability of freshwater fine-filter targets

A viability value was assigned to represent the likelihood of a given element in a given location to persist over time under existing conditions (NatureServe 2006). The AFSWS conducted a threats assessment to measure the key sources of stress on freshwater species. The threats assessment differed from the suitability analysis in that it examined how changes in certain metrics will affect biodiversity over time. That is, threats represent ongoing sources of stress that will likely impact the ability of an element to persist over time. Threats were calculated for each HUC6 and were the sum of identified stressors which included:

- Population and development (projected rate of change)
- Land conversion (risk of conversion to residential, urban or industrial land use)
- Hydropower dams (risk of future dams)
- Exotic species (risk of non-native species introduction)
- Climate change (projected change in snow pack)

A complete description of the data used to create the threats assessment can be found in Appendix G of the AFSWS (Skidmore 2006). Because the threats assessment explicitly dealt with the ability of species to persist in their current locations, it was used to assign viability values to each fine-filter freshwater target.

NatureServe's Vista program requires viability values that are normalized on a scale of 0 to 1 with 1 representing occurrences with highest viability and 0 representing occurrences with little viability. To generate appropriate values for the Vista program, ASFWS threat assessment values were first normalized on a 0-1 scale by dividing all threat values by the highest threat value in the dataset. The normalized value was then subtracted from 1 so to order areas with highest threat closest to 0, and lowest threat closest to 1.[16] The two values with highest threat had viability equal to 0, and were located in watersheds most impacted by urban development. However, a viability value of 0 indicates that species are likely headed towards complete extirpation. However, urban stream restoration in these areas has occurred and will continue to occur, which increases the chance of survival by at least select species. Therefore, the threat values for these two watersheds were manually changed to .25 to reflect low, but not zero, viability.

3.2.3 Assigning Data Confidence Values

The nature of data collection results in data sets that vary across time and space, and this variation produces uncertainty in the true "face value" of a dataset or analysis. Data on elements of biodiversity and their locations are typically subject to greater uncertainty than other types of planning data such as infrastructure or topography, because many anthropogenic, biotic and abiotic factors can influence the distribution of an element at a particular time in space. Furthermore, uncertainty can be introduced at almost any point in the planning process, from data collection and input, to data processing, to classification procedures and data categorization. Decision-making theory calls for explicit representation of uncertainty (e.g. potential errors) in datasets to help decision-makers and stakeholders in planning processes (Burgman et al. 2005, Barry and Elith 2006). In the NatureServe Vista program, uncertainty values are assigned as "confidence" levels. According to the NatureServe Vista manual, a confidence value is "a measure of certainty that the element is actually present in a location [cell] designated in its' distribution layer," and can be derived from either a statistically-derived assessment of data accuracy, or from a qualitatively-derived assessment of data quality based on specific factors that contribute to uncertainty in data. High confidence values represent increased certainty of an element's existence in a designated space. Low confidence values do not necessarily imply that an element observed or predicted in a designated space are not present, but rather that the characteristics of the data (e.g. age of the observation, recent changes at a location) reduce certainty that the element is present.

[16] Because threat values were the sum of multiple threats per HUC6, higher values represented increased risk from identified threats. However, viability values are reversed; that is, values representing increased risk should be ordered closer to 0, with values closer to 1 representing lower threats and high viability.

In places where confidence levels are low, efforts should be made to increase the confidence level by conducting on-site surveys.

Data confidence values were assigned to fine-filter freshwater species based on presence values recorded by the StreamNet database. Where presence values were unknown (e.g. not available) a value of 0.5 was used as recommended by the NatureServe Vista User's Manual (NatureServe 2006).

Table 3.2 Confidence values for freshwater fine-filter targets

WDFW PRESENCE VALUE	CONFIDENCE VALUE
Presence – Documented	1.0
Presence – Documented Artificial	0.9
Presence – Presumed	0.7
Presence – Artificial Presumed	0.6
Presence – Potential	0.5
Unknown/Unavailable	0.5

3.2.4 Data Limitations for all freshwater targets

The source datasets used to identify and locate the distributions of fine-filter targets are not typically the result of systematic sampling; rather they represent known locations of elements observed through infrequent and unsystematic collection methods. Therefore the records obtained for fine-filter targets is likely very incomplete in terms of representing elements that are of conservation concern in Whatcom County. Furthermore, the known observations of these targets may not represent the "best areas" for species life history needs. However, they do represent the only readily-available spatial datasets on bird, mammal and herpetofauna species available at the time of this research.

Chapter 4: Decision Support Tools

Chapters 2 and 3 described the data collection and methods used to build a database of biodiversity that is specific to Whatcom County. Chapter 4 will describe specific analytical tools that were enabled to inform discussion about potential conservation opportunities and priorities within Whatcom County. As discussed in Chapter 1, the biodiversity database is housed in a Decision Support Software system (DSS) developed by NatureServe, called NatureServe Vista (version 1.3). NatureServe Vista has many decision-support tools, more than those described in this report. A full discussion of all decision-support tools can be found in the Vista User's Manual (NatureServe 2006). Each of these decision-support capabilities are designed to use the biodiversity database to answer questions and aid in future planning efforts.

The two decision-support tools that were enabled for use in this report are Conservation Value Summaries and Conservation Solutions optimization analysis. Conservation Value Summaries represent the cumulative conservation value of the lands within Whatcom County, and are displayed by data layers in ArcGIS that show the distribution of lands most important and least important for conservation. Conservation Solutions are generated by least-cost algorithms that use indicators of "cost" and element weights to identify a specific portfolio of lands that meet pre-programmed conservation goals.

The real advantage to a DSS is that the software can and should be used to reflect the sociopolitical, ecological, and economic realities facing Whatcom County, and to provide answers to questions largely centered around trade-offs among these areas. To aid in addressing trade-offs, there are various classifiers that were built into the Vista DSS for use by the Whatcom Legacy Project. These classifiers are described in detail below, with a brief description of how they might be used to aid in analyzing the trade-offs associated with land-use planning. Target Filters and Weighting Systems can be used in both Conservation Value Summaries and Conservation Solutions.

4.1 Conservation Value Summaries

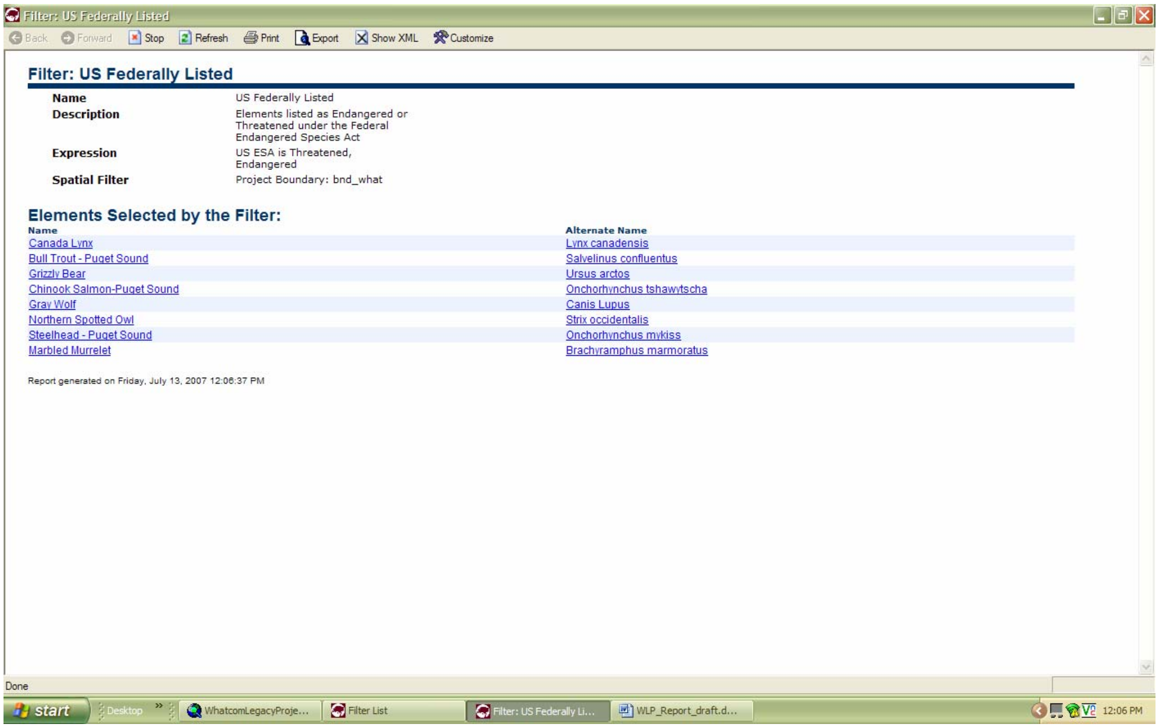
4.1.1 Target Filters

The biodiversity database consists of terrestrial and freshwater coarse- and fine-filter targets. These targets, and the criteria used for their selection, are described in detail in Chapters 2 and 3. In total, there are 131 terrestrial and freshwater elements included in the biodiversity database. Over time, it is anticipated that this number will increase as new data become available.

A number of filters were created to help users of the biodiversity database work with a subset of targets for analysis or reporting purposes. The filters are located in the NatureServe Vista DSS under NatureServe Vista Toolbar→Lists→Filter List. The Filter List names and describes each existing filter. By selecting "Report", a list of all species that fall within that filter is generated. New filters can be added and existing filters deleted as necessary. Filters can be used to organize or classify elements according to common features, such as element type, element conservation status, or spatial groupings of elements. For example, filters can be used to see how many and which elements are listed as Threatened under the federal Endangered Species Act; or how many and which species are considered to be of highest conservation concern in Washington State by the Washington Department of Fish and Wildlife.

Appendix 4 names and describes each filter created for this report. Figure 5.1 is an example of a report generated for the "US Federally Listed" filter, which includes all elements in Whatcom County listed as Threatened or Endangered under the Endangered Species Act.

Figure 4.1: Example of report generated by NatureServe Vista showing all targets classified under a specific filter



4.1.2 Target Weights

The Vista DSS offers the option of running analyses with a weighting system. A weighting system is used to provide a way to value some species over others when conducting analyses. Weights can be based on the perceived social value of targets, for example, weighting elements based on the value they return to the local economy. For purposes of this report, four weighting systems were created and stored in the Vista DSS system, and can be accessed at NatureServe Vista Toolbar→Lists→Weighting System Lists.

Weighting systems were assigned on the basis of the rarity and/or current conservation status of the target. The four weighting systems include:

1) Elements of global concern – This weighting system was based on the rarity of elements on a global scale and was assigned by the Global Rank of the element.
2) Elements of local concern - The second weighting system was based on the rarity of elements at a local scale, and was assigned by the State Rank of the element. Most elements do not have equivalent Global Ranks and State Ranks, so these two weighting systems will value species differently.

3) US ESA Elements – This weighting system weights only those species that are listed as Endangered, Threatened, Proposed Endangered, Proposed Threatened, Candidate, or a Species of Concern under the Federal Endangered Species Act. No other elements are weighted.
4) WA State and US ESA Elements – This weighting system weights only those species that are listed as Endangered, Threatened, Candidate, Sensitive or Species of Concern or Species to Monitor by the Washington State Department of Wildlife, OR those species that are listed as Threatened or Endangered under the Federal Endangered Species Act. Weights are based first on State listing, but if the element is federally listed but not state-listed, then the weight defaults to the weight assigned to federally-listed species.

Appendix 5 lists the actual weights assigned by category under each of the four weighting systems. New weighting systems can be created as needed by the Whatcom Legacy Project. Moreover, weighting systems are optional when running Conservation Value Summaries or Conservation Solutions, so the decision can be made to not weight elements at all.

4.2 Conservation Solution Software

The Vista DSS is built to interface with MARXAN, an analytical software program used to produce Conservation Solutions. MARXAN is an optimization software that is used to find “a reasonably efficient solution to the problem of selecting a system of spatially cohesive sites that meet a suite of biodiversity targets” (Possingham et al. 2000). MARXAN runs a sophisticated algorithm that identifies a suite of parcels that meet user-identified conservation goals with the least amount of cost. In order to run the model, the software requires the input of three attribute sets: (1) a parcel unit cost; (2) a goal set for all included elements (elements can be filtered or unfiltered, and weighted or unweighted using the filters and weights described above); and (3) identification of lands that are already protected for conservation purposes. The development of these attributes is described next.

4.2.1 Creating a parcel "cost" attribute

MARXAN requires the creation of a "cost" attribute that represents the relative cost of each parcel. The cost attribute can include the direct current appraisal cost of a parcel, but more often represents broader social and economic assumptions about the feasibility of setting aside a parcel of land for conservation.

The cost attribute for this report was calculated using a number of assumptions about what might make a parcel more costly and therefore less feasible for conservation efforts. These assumptions closely follow similar assumptions made for the same purpose in the North Cascades Ecoregional Assessment (Iachetti et al. 2006). The assumptions are:

1) **Existing publicly-owned parcels are less costly for conservation than existing privately-owned parcels.**

The North Cascades Ecoregional Assessment stated this assumption during the formulation of their suitability analysis for the ecoregion. They base this assumption on work of the Gap Analysis Program that found that "Oregon and Washington GAP projects rated nearly all public lands as better managed for biodiversity than most private lands" (Iachetti et al. 2006). This is particularly true in Whatcom County, where Federal National Forest lands are governed by the Northwest Forest Plan, which is a science-based recovery plan enacted to ensure the long-term survival of elements of biodiversity throughout the federal forests of Washington, Oregon and northern California (USDI 1994), and state lands are governed by the Forest and Fish Law, a comprehensive state law created to ensure full compliance of state and private forestland practices with the federal Endangered Species Act and the federal Clean Water Act (DNR 1999). As the North Cascades Ecoregional Assessment notes, this assumption is debatable. Some stakeholders would argue that private lands may be just as accessible and amenable to conservation efforts, due to the variety of tools like conservation easements and voluntary stewardship programs that exist. However, for purposes of this report, costs were assigned to land parcels on a 0-1 scale, with highest cost represented by 1.0 and lowest cost represented by 0.0.

Table 4.1: Cost value by ownership

Ownership	Assigned Cost Value
Federal	0.0
State	0.4
County	0.6
Private/Tribal	1.0

2) Urban parcels are more costly than rural parcels.

The Growth Management Act of Washington State requires Whatcom County to delineate Urban Growth Areas (UGAs), and advocates that existing Urban areas and UGAs accommodate the bulk of the population growth for this county (Washington State Growth Management Act 1990). Due to the focus on future growth occurring as in-fill in existing urban areas, the assumption was made that current parcels located in urban areas will be costlier for conservation efforts than parcels currently located in more rural areas. Costs were assigned to land parcels based on their current zoning configuration on a 0-1 scale, with highest cost represented by 1.0 and lowest cost represented by 0.0.

Table 4.2: Cost value by zone

Zoning Description	Assigned Cost Value
Urban/UGA/Industrial/ Res 1Du/2 and down Residential	1.0
Agricultural/Res 1Du/5 and up Residential	0.5
Forestry/Other	0.2

3) **The higher the relative real cost of a parcel will impact the total amount of potential conservation, as there are limited funds for which to dedicate to conservation.**

The fourth assumption is predicated on the real-cost value of a parcel, and assumes that there is a limit on the funding available to carry out conservation activities within Whatcom County. There are some problems with this assumption: namely, that parcels do not necessarily need to be bought outright and set aside as protected in order to contribute to biodiversity conservation. There are many voluntary and regulatory conservation tools that have been successfully applied within city limits to protect biodiversity without buying land parcels. However, assigning costs to parcels that are correlated to actual costs is a good surrogate for identifying lands that may be prime targets for competing uses (e.g. future development opportunities due to prime spatial location).

Actual appraised values for parcels were not available in spatial format at the time of this report, so cost values were estimated by summing together the following information for each parcel: total number of acres relative to all other parcels, number of improved acres relative to all other parcels, and square feet of built space relative to all other parcels. This summed value was then normalized to create a 0.0-1.0 scale where larger parcels with more improvements tend to cost more than smaller parcels with fewer improvements. Certainly there will be many exceptions to this simplified equation, but for purposes of creating the overall cost-attribute, it is a useful value.

4.2.2 Goal Sets

MARXAN requires goal sets that set quantitative and measurable goals regarding target representation to both prioritize conservation opportunities and to answer the question "how much land is enough?" within the given planning region. Sanderson (2006) discussed 18 different approaches that have been used for setting numerical objectives to meet conservation goals. These approaches range from objective, quantitative population viability assessments that require expert analysis of population genetics, inter- and intra-population interactions, and demographics, to approaches based on spiritual or aesthetic rationale of how much is "enough". Clearly, with so many diverse approaches, setting numerical objectives must be considered working hypotheses that reflect our best efforts to conserve species despite momentous data limitations.

Establishing conservation goals from a scientific perspective is extremely difficult. Currently, there is no scientific consensus on the methodology for setting goals in a systematic conservation assessment (Floberg et al. 2004, Tear et al. 2005, Wiersma and Nudds 2006). Information on most elements is too limited to establish the number and distribution of occurrences that will ensure an element's continued persistence. To date, many of the goals set for analyses done at the ecoregional level have relied on percent of historical distribution and/or species-area curves for ecological systems, and unpublished occurrence goals for fine-filter targets described by the national network of Natural Heritage Programs (e.g. NatureServe) (Floberg et al. 2004, Iachetti et al. 2006).

Typically, goal-sets should be derived from efforts to calculate the representation levels necessary to ensure the persistence of all targets within a landscape (Margules et al. 2002, Cowling and Pressey 2003), an level of effort that was not executable for this report. A less thorough approach, though one that ably places objective goal-setting into the context of human decision-making, is to develop a "risk" gradient of goal-sets, with low numerical goal-sets representing "higher-risk" scenarios for conserving biodiversity, and higher numerical objectives representing "lower-risk" scenarios (Comer et al. 2003).

This report creates three goal-sets which represent a low, medium and high-risk scenario of conserving existing biodiversity within Whatcom County. These goal-sets can be found in the Vista DSS under NatureServe Vista Toolbar→Lists→Goal Set List. Additional goal sets can be created as necessary. For example, goal sets that lower or raise the goals for select elements can be created to reflect value-based or economic importance of certain elements within the County. The Medium-Risk Goal Set was created following the recommendations of the NatureServe Vista User's Manual (NatureServe 2006) to establish goals based on the State or Global Rank assigned to elements by Natural Heritage programs. The Low and High-Risk scenarios are goals set that are relatively increased or decreased (respectively) from the Medium Risk goal set, and No-Risk Scenario maintains 100% of all current species occurrences. A discussion of each goal set follows.

LEAST-RISK SCENARIO

Under the least-risk scenario, all elements were set to maintain 100% of their existing distribution within Whatcom County. This scenario is not considered a feasible scenario, given the necessary and natural growth of the county. Instead this scenario is intended to be used as a baseline by which to compare all other scenarios, and to promote discussion and debate among Whatcom County citizens. Even if this scenario was adopted in an effort to maintain all existing mapped biodiversity in the county, population levels of species would still be expected to decline due to (1) impacts to species occurring in neighboring jurisdictions, and (2) to the fact that species decline tends to lag behind habitat loss, so populations today continue to adjust to habitat loss that occurred in Whatcom County over the last 20 years (Floberg et al. 2004).

MEDIUM-RISK SCENARIO

The NatureServe Vista User's Manual (2006) recommends that goal sets be based upon State or Global Ranks, because these ranks are assigned directly on the number of remaining occurrences of each element worldwide (Global Rank) or statewide (State Rank), and existing threats to the continued viability of existing occurrences (see NatureServe 2002 for a more complete discussion of how ranks are assigned). For the Medium-Risk Scenario, State Ranks are used instead of Global Ranks. State Ranks address the status of an element in a specific portion of its range, whereas Global Ranks addresses the global status of a species. Therefore, state ranks often show species as more vulnerable or imperiled than global ranks. For example, the grey wolf is considered secure worldwide, but is critically imperiled in the state of Washington, due to almost complete extirpation of the species from its range in the state. Goal sets for elements in the Medium-Risk scenario are assigned based on State Ranks, and are expressed as a percentage of existing occurrences. All terrestrial and freshwater ecological systems and those elements with modeled distributions were assigned a goal of 30% of extant distribution, except for elements listed under the Endangered Species Act which were assigned a goal of 40% of acres in the modeled distribution. For elements without a State Rank, the Global Rank was used as a State Rank equivalent (i.e. if Global Rank was G1, element was treated as S1).

Table 4.3 Goal Set for Medium-Risk Scenario

NatureServe State Rank	Goal (% of current distribution)
S1	100%
S2	100%
S3	90%
S4	40%
S5	30%
Ecological System (Terrestrial and Freshwater); Elements with	30%; 40% if elements are

area-based distributions	Endangered
Default (when a rank is not available)	GRANK equivalent, or 30%

LOW-RISK SCENARIO

The Low-Risk Scenario represents an increased probability of maintaining examples of all elements of biodiversity within Whatcom County. The Low-Risk Scenario goals are assigned according to State Rank, and represent an qualitative increase over the Medium-Risk Scenario. While the relative increase is arbitrary, it stands to reason that increasing the number of existing occurrences will increase the representativeness of those elements of biodiversity within Whatcom County. Among the three scenarios (not including the No Risk Scenario), the Low-Risk Scenario will demand the most amount of land to be conserved to meet goal-sets.

Table 4.4: Goal set for low-risk scenario

NatureServe State Rank	Goal (% of current distribution)
S1	100%
S2	100%
S3	100%
S4	70%
S5	40%
Elements with Modeled Distributions	50%; 60% if elements are Endangered
Ecological System (Terrestrial and Freshwater)	40%
Default (when a rank is not available)	GRANK equivalent, or 40%

HIGH-RISK SCENARIO

The High-Risk Scenario represents the highest risk to maintaining representative examples of elements of biodiversity in Whatcom County. In the High-Risk Scenario, goal sets were assigned on the basis of Global Rank. Global Ranks are assigned according to the worldwide status of an element. The High-Risk Scenario carries an increased probability of extirpation of elements that are vulnerable or imperiled within the state of Washington, and essentially assumes that populations elsewhere in the world will suffice as representations of that element on earth. The High-Risk Scenario will demand the least amount of land to be conserved of the four scenarios.

Table 4.5: Goal set for high-risk scenario

NatureServe State Rank	Goal (% of current distribution)
S1	100%
S2	100%
S3	100%
S4	70%
S5	40%
Elements with Modeled Distributions	20% 30% if elements are Endangered
Ecological System (Terrestrial and Freshwater)	30%
Default (when a rank is not available)	GRANK equivalent, or 30%

4.2.3 Locking-In Parcels

Finally, an attribute that denotes parcels that are already in a protected-area status is necessary to delineate the existing "core reserves" for MARXAN to build upon. The locked-in parcel attribute serves to allow MARXAN to function as a gap-analysis software, by identifying how many goals are met in existing protected areas, and then searching for the least-cost solution to complement the existing core reserves. Locked-in parcels were determined by querying existing parcel data for lands that are in a "park" land designation. All returned records were given "locked-in status", and include all lands designated as wilderness in the Mt. Baker-Snoqualmie and Okanogan National Forests, all lands within the North Cascades National Park, and all state, county and city designated parks that were at least 20-acres in size.

4.2.4 Data Limitations

The development of target filters and weighting systems was somewhat arbitrary. However, the purpose of these tools is simply to help arrange and value various conservation targets included in the information database. New filters and weighting systems can easily be developed and incorporated into Vista to aid in analyses that are relevant for land-use planners.

Development of the attributes necessary to run MARXAN was impacted by data limitations and assumptions. The assumptions used to develop the cost attribute are well described in Chapter 4.2.1. The establishment of goal sets was severely hindered by data limitations. These goal-sets should not be considered definitive goals that will ensure the long-term survival of species. Rather, these goal-sets provide a useful tool for creating a conservation portfolio that represents examples of the biodiversity in Whatcom County. Over time, as more information and resources become available to the Whatcom Legacy Project, these goal-sets should be modified to be more indicative of the requirements for continued persistence of an element in Whatcom County. In addition, the Whatcom Legacy Project should continue to work closely with regional efforts to ensure that efforts in Whatcom County are not negated by failures to secure species in adjacent jurisdictions.

Chapter 5: Conclusions

The Biodiversity Database described in this report was built to support the Whatcom Legacy Project, and their efforts to work with the citizens of Whatcom County to develop a long-term vision for the county. The biodiversity database described within this report is meant to aid in discussion of which areas in the county may be more appropriate for development and conservation activities over the long-term. This report builds off a number of existing assessments (listed in Chapter 1.4), and represents a first attempt towards integration of these assessments.

This report will help inform identification of areas that currently have high value for conservation, and can also help inform discussion about areas that might stand out as high-potential restoration areas. However, this database should only be used as a starting point. The limitations of this database are well described throughout this report, and these limitations should also inform discussion and debate. Ultimately, choices about selecting areas for conservation and development should be subjected to great debate with community members, local officials, and landowners. This report is intended to provide transparency around the methods and data used to build a biodiversity database for Whatcom County, and to clarify the strengths and weaknesses of the information.

Methods developed to build the biodiversity database follow peer-reviewed systematic methodology. Data used were obtained from sources that follow rigorous reporting procedures, and data were highgraded to ensure that only current and verified data were used.

This report has no regulatory authority, it is simply a guide to help inform prioritization of conservation and development activities within Whatcom County.

The Biodiversity Database is stored on a hard-drive at Conservation Northwest's Bellingham office. Direct access to the database is limited, due to license agreements signed between the author of this report and various natural resource agencies who oversee the location and distribution of species presence records in Washington State. As the Whatcom Legacy Project moves forward, it is expected that the NatureServe Vista software will be used to aid in development of alternative future scenarios whose goal is ultimately to aid in public discourse about the long-term future of Whatcom County.

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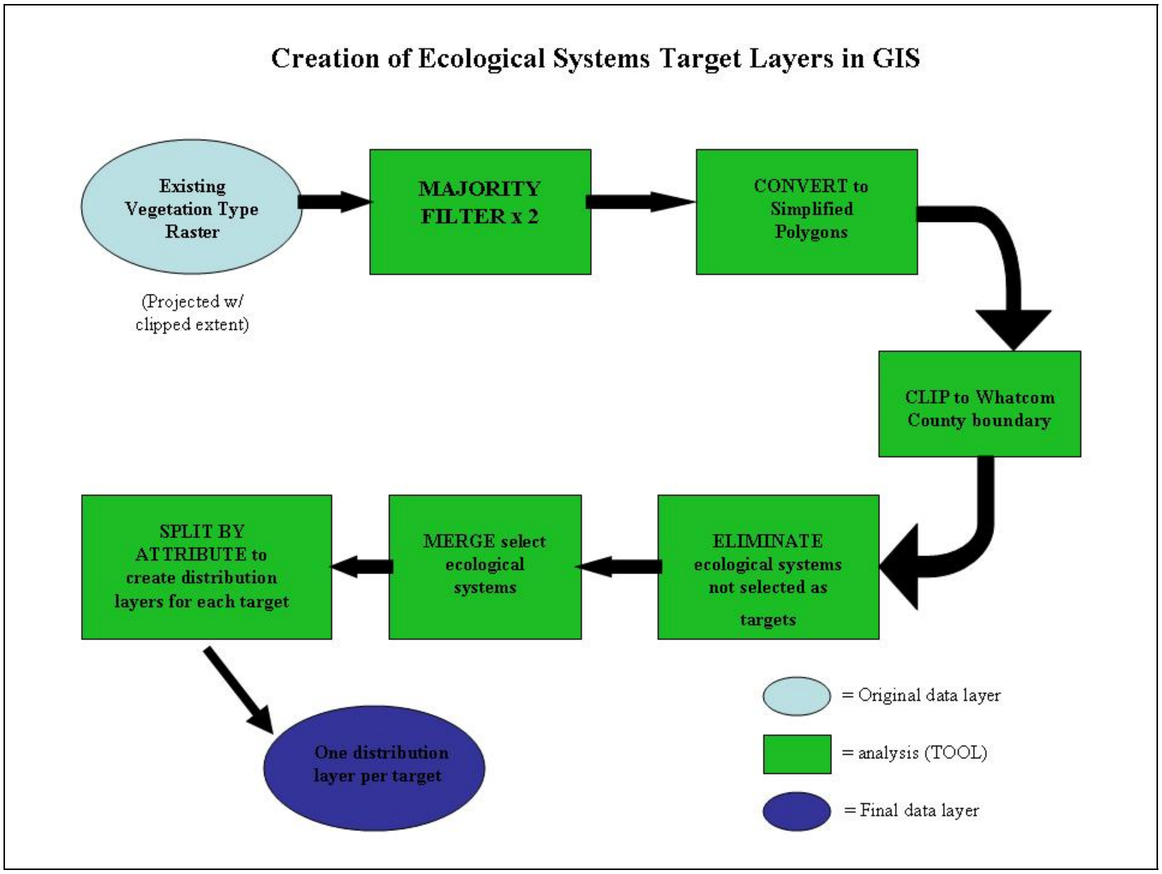
APPENDIX 1: Ecological Systems Data Preparation

The original EVT raster was twice run through the majority filter tool to "clean up" noise from the remote-sensing classification process. The majority filter works by absorbing any single cells into the sea of contiguous cells that surround it. Next, those ecological systems that were determined to be "mis-classified" in Whatcom County, or those ecological systems that were not well represented (determined by systems with only a scattering of pixels, usually 15 or less) were merged with their nearest neighbor. The EVT raster was then converted to polygons, and those polygons with an area less than 9,688 feet were also merged with their nearest neighbor. Finally, the EVT polygon feature class was split into individual shapefiles representing the distribution of each ecological system target.



APPENDIX 2: Methods used to calculate Terrestrial landscape ecological integrity

The rationale for selection of indicators used to determine landscape integrity, as well as their severity (weight) and extent (distance interval) are discussed in detail in Chapter 2.1.2. This appendix details the methodology for generating the landscape integrity layer. All analysis was completed using the Spatial Analyst extension in ArcGIS 9.2.

A raster was created for each indicator by converting vector shapefiles to rasters with a cell size of 30 meters (98.43 feet). A buffer was created around each raster using the straight-line tool with the max extent set to be the distance interval.

Once the indicator was buffered, these cells were weighted, using the slope-intercept equation:

$$y = mx - b$$

Setting y = weight, and x = max extent, this formula states that as distance (from indicator) increases, weight decreases. From this formula, a slope value is derived which can be used to assign proportionally decreasing weights to cells that are spatially further from the indicator. At the assigned maximum distance, the weight is 0, and the cells that represent the indicator itself bear the assigned weight.

Once all cells were assigned a value, each indicator raster was added together to create a composite layer, where cells with a high value represented most impacted areas, and cells with lower values represented least impacted areas. These values were inversed by taking the absolute value of the raster minus the highest value. Finally, the values were normalized on a 0.0 – 1.0 scale by dividing all cell values by the highest cell value.

EXAMPLE:
The urban indicator was weighted at 1000 with a distance interval of 2,640 feet. The straight-line tool max extent was set at 2,640 feet to generate the buffered indicator raster [buff_indicator]. Next the following calculations were performed using raster calculator:
1) [buff_indicator] / 2,640 = [Calc1]
2) -1000 * [Calc1] + 1000 = [Calc2]
3) con(isnull([Calc2]), 0, [Calc2]) (to provide 0 values for non-weighted cells)

This was done for every indicator. Once the composite raster was created, the cells with no-data were turned to 0 by the conditional statement con(isnull(Calc),0,Calc). Next, the absolute value was generated by Abs(Calc1-4377.43). Finally, the raster was normalized by Calc2 / 4377.43.

APPENDIX 3: Fine Filter Plant Species

SCIENTIFIC NAME (Common Name)	ELEMENT TYPE	S RANK	G RANK	Last OBS
Acer macrophyllum - Alnus rubra / Polystichum munitum - Tellima grandiflora Forest (Bigleaf Maple - Red Alder / Swordfern - Fringecup Community)	Community	S2	G2G3	1995
Alectoria nigricans	Lichen	S2	G5	1998
Alnus incana / Glyceria elata Shrubland (Mountain Alder / Tall Mannagrass)	Community	S3	G3?	1994
Aster sibiricus var. meritus (Arctic Aster)	Vascular Plant	S1S2	G5	2004
Betula papyrifera var. commutate – alnus rubra/polystichum munitum Forest (Paper birch – Red Alder / Swordfern)	Community	S3	G1	1994
Betula_pumila_var_glandulifera (Dwarf birch)	Vascular Plant	SNR	G5	
Botrychium ascendens (Triangular-lobed Moonwort)	Vascular Plant	S2S3	G2G3	1993
Botrychium pedunculosum (Stalked Moonwort)	Vascular Plant	S2S3	G2G3	2002
Calamagrostis canadensis Western Herbaceous Vegetation (Bluejoint Reedgrass)	Herbaceous Alliance	S3S4	G4	1991
Camassia quamash ssp maxima (Common Camas)	Vascular Plant	SNR	G3	
Carex (aquatilis var. dives, nigricans) - Caltha leptosepala ssp. howellii herbaceous vegetation (Sedge Spp. - Two-flowered Marsh Marigold)	Herbaceous Alliance	S2S3	G2G3Q	1990
Carex aquatilis var. dives Herbaceous Vegetation (Sitka Sedge)	Vascular Plant	S3S4	G4	1991
Carex comosa (Bristly Sedge)	Vascular Plant	S2	G5	2004
Carex exsiccata Herbaceous Vegetation [Provisional] (Beaked Sedge)	Plant Association	S2S3	G5	1990
Carex flava (Yellow Sedge)	Vascular Plant	S3	G5	2003
Carex pauciflora (Few-flowered Sedge)	Vascular Plant	S2	G5	1989
Carex pellita Herbaceous Vegetation (Woolly Sedge)	Plant Association	S1	G3	1991

Carex pluriflora (Several-flowered Sedge)	Vascular Plant	S1S2	G4	1991
Carex vulpinoidea (Fox Sedge)	Vascular Plant	SNR	G5	
Cicuta bulbifera (Bulb-bearing Water-hemlock)	Vascular Plant	S2	G5	1991
Cimicifuga elata (Tall Bugbane)	Vascular Plant	S3	G3	1996
Cladonia norvegica	Lichen	S2	G4G5	1991
Cystocoleus_ebeneus	Lichen	S1	GNR	
Draba aurea (Golden Draba)	Vascular Plant	S2	G5	2002
Eleocharis palustris Herbaceous Vegetation (Creeping Spikerush)	Plant Association	S3?	G5	1990
Eriophorum chamissonis / Sphagnum spp. Herbaceous Vegetation (Russet Cottongrass / Sphagnum Spp.)	Plant Association	S1	G4	1990
Erythronium oregonum ssp oregonum (Giant white fawn-lily)	Vascular Plant	SNR	G5	
Festuca rubra - (Camassia leichtlinii, Grindelia stricta var. stricta) Herbaceous Vegetation (Red Fescue - Great Camas - Oregon Gumweed)	Herbaceous Alliance	S1	G1	2005
Fritillaria camschatcensis (Black Lily)	Vascular Plant	S2	G5	1992
Glyceria leptostachya (Slim-head manna grass)	Vascular Plant	SNR	G3	
Herbaceous balds, bluffs and cliffs		SU	GU	
Hypericum majus (Canadian St. John's-wort)	Vascular Plant	S2	G5	2000
Known old growth forest patches		S1	GU	2003
Ledum groenlandicum - Kalmia microphylla / Sphagnum spp. Shrubland (Bog Labrador-tea - Bog-laurel / Sphagnum Spp.)	Shrubland	S3	G4	1991
Low elevation freshwater wetland PTN	Wetland	S1	G2	1990
Lycopodium dendroideum (Treelike Clubmoss)	Vascular Plant	S2	G5	2002
Lysichiton americanus Herbaceous Vegetation [Provisional] (Skunkcabbage)	Herbaceous Alliance	S3S4	G4?	1990
Mid-elevation freshwater wetland WC	Wetland	S3	GNR	1991

Mid-elevation sphagnum bog WC	Wetland	S2	GNR	1991
Neckera pennata	Non-vascular plant (moss)	S1	G5	
Platanthera obtusata (Small Northern Bog-orchid)	Vascular Plant	S2	G5	1991
Platanthera sparsiflora (Canyon Bog-orchid)	Vascular Plant	S1	G4G5	1989
Poa howellii (Howells bluegrass)	Vascular Plant	SNR	G3G5	
Pseudotsuga menziesii - Arbutus menziesii / Vicia americana Forest (Douglas-fir - Pacific Madrone / Hairy Honeysuckle)	Forest Alliance	S1?	G1G2Q	2005
Pseudotsuga menziesii - Tsuga heterophylla / Gaultheria shallon Forest (Douglas-fir - Western Hemlock / Salal)	Forest Alliance	S2	G3	2005
Pseudotsuga menziesii - Tsuga heterophylla / Polystichum munitum Forest (Douglas-fir - Western Hemlock / Swordfern)	Forest Alliance	S2	G3?	1995
Pseudotsuga menziesii / Gaultheria shallon - Holodiscus discolor Forest (Douglas-fir / Salal – Oceanspray)	Forest Alliance	S2	G2G3	2005
Pseudotsuga menziesii / Rosa gymnocarpa - Holodiscus discolor Forest (Douglas-fir / Baldhip Rose – Oceanspray)	Forest Alliance	S2	G2G3	1995
Pseudotsuga menziesii / Symphoricarpos albus - Holodiscus discolor Forest (Douglas-fir / Common Snowberry – Oceanspray)	Forest Alliance	S1	G1	2005
Quercus garryana / Carex inops - Camassia quamash Woodland (Oregon White Oak / Long-stolon Sedge - Common Camas)	Forest Alliance	S1	G1	2003
Salix sessilifolia (Soft-leaved Willow)	Vascular Plant	S2	G4	1988
Saxifraga rivularis (Pygmy Saxifrage)	Vascular Plant	S3	G5?	1998
Talus Slopes				
Umbilicaria cylindrical		S1	G3	1998
Umbilicaria decussate		S1	G3?	1998
Utricularia minor (Lesser Bladderwort)	Vascular Plant	S2?	G5	1997
Wetlands				1991

a = Values in normal typeface were converted from assigned EO Ranks. Values in italics were assigned using the landscape integrity layer
b = Multiple EOs for this species type – viability value ranges

APPENDIX 4: Target Filters

FILTER NAME	FILTER DESCRIPTION
Animal Kingdom – All	Includes all mammals, birds, reptiles, amphibians, freshwater and marine fish
Birds	All birds
Ecological Systems - All	Includes terrestrial and freshwater ecological systems
Fish – All	All resident and non-resident (anadromous) fish
Freshwater Ecological Systems	Freshwater coarse-filter targets
Globally Imperiled	All elements with a Global Rank (GRANK) of G1 or G2
Herpetofauna	All amphibians and reptiles
Mammals	All mammals
Non-resident fish	Non-resident (anadromous) fish that migrate to the ocean at some point during their lifecycle
Plants – All	Fine-filter plant species: Includes all vascular and non-vascular plants, fungus, and alga species, plus terrestrial plant associations
Rare or Federally Listed	Elements listed as Threatened or Endangered under the Federal Endangered Species Act or with a Global Rank (GRANK) of G1 or G2
Resident Fish	All freshwater fish that do not migrate to the ocean during any part of their lifecycle
Species of Conservation Concern	All elements listed under the Federal or Washington State Endangered Species Act; elements listed as critically imperiled, imperiled, or vulnerable; elements listed as proposed threatened, endangered, candidate or species of concern under the Federal or State ESAs; or as a State sensitive or State monitor species.
Terrestrial Ecological Systems	Terrestrial coarse-filter targets
US Federally Listed	Elements listed as Endangered or Threatened under the Federal Endangered Species Act
Washington State Listed Elements	All elements listed as Threatened or Endangered under the Washington State Endangered Species Act
Washington State Species of Concern	Species listed by the Washington Department of Fish and Wildlife (WDFW) as a State Endangered, Threatened, Candidate, Sensitive, Monitor or Concern species.

APPENDIX 5: Target Weighting Systems

WEIGHTING SYSTEM	ASSIGNED WEIGHT
Elements of Global Concern	
G1	1.00
G2	0.90
G3	0.80
G4	0.60
G5	0.30
Elements of Local Concern	
S1	1.00
S2	0.90
S3	0.80
S4	0.60
S5	0.30
US ESA Elements	
Endangered, Threatened	1.00
Proposed Endangered, Threatened	0.80
Candidate	0.7
Species of Concern	0.0
WA State & US ESA Elements	
Endangered, Threatened	1.00
Candidate	0.8
Sensitive	0.7
Monitor	0.6
Species of Concern	0.6

APPENDIX 6: Freshwater Ecological Systems

Aquatic ecological systems in Whatcom County were classified by The Nature Conservancy. A full report documenting the procedures to classify these systems is available by contacting The Nature Conservancy (Skidmore 2006).

CLASS SIZE	AQUATIC ECOLOGICAL SYSTEMS	# OF SYSTEM OCCURRENCES
		3
1	Cascade foothills headwaters - glacial drift and alluvium , low to mid elevation, mixed gradient	2
1	Cascade foothills headwaters - glacial drift, mid elevations, mixed gradient	2
1	Cascades headwaters, sedimentary, mid elevation	12
1	Cascades tributary headwaters - granitic, low to mid elevation	6
1	Fraser/Nooksack coastal plain - sandstone, low elevation, low gradient	3
1	Nooksack coastal plain headwaters - glacial drift and outwash, low elevation, low to moderate gradient	13
1	North Cascades - mafic , mid elevation, mixed gradient	3
1	North Cascades headwaters - mostly volcanic, mid to high elevation, moderate to high gradient	6
1	North Cascades headwaters - granitic , mid to high elevation, moderate to high gradient	38
1	Northern Cascades headwaters - sandstone, moderate to high elevation, moderate to high gradient	17
1	ONE_113	2
1	Puget uplands and islands headwaters - glacial drift, low to mid elevation, low to moderate gradient	5
2	Cascades middle river systems - predominantly granitic watershed, low to mid elevation, variable gradient	4
2	Cascades upper river systems - predominantly granite watershed, mid elevation, variable gradient	5
2	Fraser/Nooksack coastal plain - sedimentary, low elevation, low gradient	2
2	North Cascades tributary rivers - sedimentary and granitic watersheds, moderate to high elevation, mixed gradient	4
3	Cascades medium rivers - mixed watershed geology traversing glacial drift and alluvium, low elevation, low gradient	1
3	Northern Cascades medium rivers - predominantly granite watershed traversing glacial drift and alluvium, low to mid elevation, low gradient	1