Practical Methodology
for
Landscape Analysis and Zoning

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1. INTRODUCTION

This paper describes the methods used by Silva to perform landscape analysis and wholistic forest use planning.

The landscape analyses which Silva commonly performs have two broad aims:

1. To reach an understanding of basic landscape patterns and landscape ecological processes in a forest area, and then propose a protected network of landscape units which will protect and maintain these patterns and processes after human disturbance and resource use.
2. To allocate or zone forests by best use. Forest use categories frequently include culture zones, ecologically sensitive protected zones, wildlife protection zones, wilderness zones, recreation and tourism use zones, and timber management zones.

The methodology described below is a step by step guide to the practical aspects of using maps and photos to perform these assessments. More detailed information on the concepts, principles and objectives of landscape analysis and forest use zoning is contained in the Silva papers entitled:

Landscape Analysis and Planning - A Component of Wholistic Forest Use

Wholistic Forest Use

Wholistic Forest Use Zoning

The analysis methods described can help to create forest use plans which will protect the landscape ecology, or the connections and interactions in the forest landscape, during and after human use of forests. Stand level structures and stand level biodiversity must also be protected and maintained during human use in order to protect stand level ecology. The individual parts of the landscape, and the landscape as a whole, must function properly in order to have sustainable human use of forests. The planning processes outlined in this paper, coupled with ecologically responsible stand level practices, are positive steps towards achieving this goal.

2. DATA SOURCES AND SELECTION OF SCALE

Landscape planning should proceed from the general to the specific, making full use of maps, remote sensing data, computer map analysis procedures, field verification, field survey data and specialists' reports as required. Broad level landscape planning can be carried out using mainly stock map and remote sensing data with reconnaissance level field ground truthing. As more detailed levels of planning (e.g. small to medium watersheds) are carried out, the emphasis on field data must be increased. At the operational (stand) level of planning, information from field surveys should provide the basis for planning decisions.

The usual set of data acquired for a landscape analysis includes:

- Topographic Maps
- Forest Cover Maps
- Satellite Image Prints
- Air Photos

Digital forest cover maps and a Geographic Information System are very useful in this process, but are not essential.

The scale of the information utilized in the planning process varies with the level of planning and the size of the study area. Map and air photo coverage is often available at a variety of scales. A base map scale should be selected to achieve a reasonable compromise between the need to:

- Retain as much detail and precision as practical in the analysis.
- Use a map scale which provides reasonable operational efficiency for map analysis and measurement.

A close match between the scales of maps, air photos and satellite image prints used in the analysis is very convenient and highly recommended, although not essential. Using similar scales greatly reduces the stress level of the analyst, and helps to prevent errors.

Larger scale and increased detail on maps and air photos do not automatically equate to an increased level of understanding of landscape processes and relations. In fact, an inverse relationship often exists. Landscape features and relationships which are apparent on 1:70,000 photography may not be clear on 1:20,000 photography, as the same visual information is spread over 4 or more photo images in the latter situation. Establishing a landscape level perspective while constantly flipping from image to image is taxing and often ineffective.

The mapping scale should be determined for each mapping exercise, based on the analysis being considered, past experience, the information outlined here, and the scale of map and photo resources available. No one map scale is suitable for all projects.

Topographic maps are available at scales of 1:50,000, 1:100,000 and 1:250,000 for most areas in British Columbia. We have found that in most medium to large sized study areas, (100,000 hectares +/-), a 1:50,000 base map is not feasible. The time to analyze the large "paper area" often exceeds the provisions of the project budget, and the finished map may be too large for presentation use. On the other hand, a 1:250,000 scale base map would result in an unacceptable loss of detail. Therefore, we usually select a 1:100,000 scale base map as the best option for medium sized landscapes. A scale of 1:50,000 would be more suitable for a more detailed study, such as a small watershed (10,000 to 50,000 hectares).

Forest cover maps at 1:20,000 scale are a valuable resource for interpreting vegetation types, and also provide some information on ecologically sensitive sites. These 1:20,000 maps are used as a data source in some aspects of landscape analysis process, and are suitable base maps for detailed analyses.

3. AIR PHOTO PREPARATION

Aerial photography is a required tool for landscape analysis. As already indicated, broad scale analyses can be performed by experienced interpreters almost entirely from air photos, with moderate ground truthing. Inexperienced analysts should start working in an area with which they are familiar, or which is relatively accessible, so that they can correlate photo images with ground conditions to verify and improve their interpretations.

The air photos should be prepared as described below before analysis work is undertaken. Proper photo preparation helps to prevent duplication of effort, omissions, errors, and interpreter eye strain and fatigue.

1. Mark the principle points, conjugate principle points and aircraft flightline on each air photo. These terms and the methodology to perform these tasks are defined in "Basic Air Photo Geometry" in this syllabus. We normally use a fine tipped, black, permanent felt pen for this task.

   Marking the "photo geometry" on the photos allows the interpreter to line up the photos properly for stereoscopic viewing. This greatly reduces eyestrain and fatigue. Looking at misaligned photos for a few minutes is tolerable; interpreting misaligned photos for an 8 hour day can be detrimental to your health.

2. Using a flight line map, assemble the photos into "strips" which cover the study area. Assign each strip a consecutive number. Mark the number in red on a copy of the flight line map, and on a consistent corner of each individual air photo. Place the photos in separate file folders, by strip line.

   This filing arrangement prevents confusion during the analysis process. Any flight line can be quickly retrieved for checking, and, most importantly, for accurately extending type lines which cross from one flight line to another. Finding "Strip 4" in a separate file folder is much easier than locating photos "BC80112 564 to 569 and BC80113 012 to 018" in a stack of air photos filed by number.

3. Mark the direction of north on all photos, using a simple north arrow drawn in felt pen. Put the arrow in the north east or north west corner of all photos.

   The "logical north" on air photos changes between successive flight lines. On one trip across the study area, north will be the same edge of the picture as the air photo number. On the next strip, north will be the opposite edge. Marking the direction of north helps to reduce confusion, and aids in tying photo features to map and satellite image features.

4. Trim the blank boundary from the air photos. CHECK WITH THE OWNER OF THE PHOTOS BEFORE TAKING THIS STEP. Do not cut off the air photo numbers or the fiducial marks by accident.

The boundaries tend to obscure part of the stereoscopic image, unless a large mirror stereoscope is being used for the analysis. Trimming the photos reduces the amount of "fiddling" the interpreter must do to complete the task.

5. Delineate unique analysis areas on the air photos. For efficiency and clarity, each portion of the study area should only be typed once. However, each air photo is overlapped by neighboring photos on all four sides. If the entire surface area of all the air photos was typed, each hectare of the study area would be typed at least two, and often four, times. To prevent such duplication of effort and still ensure that all of the study area is examined, sets of unique geographic areas should be marked on the photos.

   In general, the unique central area of every second air photo in a flight line is delineated. The central area of an air photograph is expected to provide the clearest image with the least slope distortion. Wherever possible, locate the boundaries between these analysis areas on heights of land, or on prominent features where a height of land is not available.

   The lateral boundary between flight lines is also marked on the photos, at the approximate midpoint of the overlap. Ensure that the lateral boundaries are drawn in the same place on both the upper and lower flight lines.

   Once this process is completed, the lateral and vertical boundaries should form a box on every second air photo. The area inside the box is typed on that photo. Each portion of the study area is thus typed once and only once.

   Type lines which cross out of the marked central area on each second photo must be continued on the next neighboring photo. Use care when extending type lines. Do not omit any lines, and make sure that extended lines are put in the same place on each photo.

   These image selection conventions should be suspended when a non-central location on any photograph provides a significantly superior image due to sun angle or terrain features. This situation occurs fairly frequently in rugged terrain. In such cases, the better quality image should be selected for analysis, regardless of whether or not it is a second central image in the flight line series.

6. Mark the boundary of the study area on the appropriate photographs. This will prevent inadvertently typing an area outside of the study area.

Once these photo preparation tasks have been completed, the actual landscape analysis process can begin.

4. LANDSCAPE ANALYSIS PROCESS

4.1 Introduction

Landscape analysis can be divided into four main components:

1. Delineation of zones (includes protected landscape network and human use zones) on maps and photos.
2. Measurement of zone parameters.
3. Data Processing
4. Preparation of a report of findings.

This methodology addresses only the first of these steps in detail. Sections 4.3 and 4.4 explain the order or priority for delineating landscape units to establish a protected landscape network, and suggests parameters for unit size and boundaries. The methodology for describing human use zones is described in Section 4.5.

The reader should not follow this "cookbook" approach blindly. This methodology does not cover all circumstances. An understanding of the goals of each project, of what is being looked for, and why it is being looked for, are necessary before any zoning is carried out. Landscape analysis requires that an analyst have informed, logical reasons for making zoning choices. The parameters provided in this section are guides only, and should only be followed if they suit the map analysis task being performed.

Zones which are delineated by the analyst are marked directly on the air photo using a Staedtler Omnichrome marking pencil, or other type of wax marking pencil that can be easily erased from an air photo. A more subdued color such as green can be used for initial work, and then zones can be finalized in bright red Omnichrome or black felt pen.

The second and third steps of the analysis, measurement of parameters such as zone area, perimeter, elevation, slope, vegetation cover, and data processing are now often performed with a GIS (Geographic Information System). This produces digital information which is well suited to electronic data processing. Useful map analyses can be performed using hand measurement of areas (by dot grid or planimeter) and hand entry of basic map parameters such as polygon area and forest cover attributes (e.g. tree species, age, height, site quality, etc.) into databases. However, GIS offers very significant advantages.

A GIS can store and manipulate multiple layers of map information and data for any map area, and the relationships between selected layers of information can be used to greatly enhance landscape analysis. The data about any map feature can include measurements performed by the mapping software, or information entered into the database by the operator. Alterations, revisions and amendments of the GIS spatial data are straightforward, so the analysis can be easily refined or revised at any time (compared to a non-GIS analysis). GIS makes feasible detailed map analyses that would otherwise be too labor intensive and too expensive to contemplate.

Report writing, presentation, and explanation of results depend on the nature and goals of the project, and are beyond the scope of this methodology.

4.2 Similarities And Contrasts Between Wholistic Forest Use And Landscape Analysis And Planning.

Wholistic Forest Use Zoning (WFUZ) and Landscape Analysis and Planning (LSA) are two similar analysis and decision making processes which share some features in common, but which also have significant differences.

Landscape analysis is the process of describing and interpreting the landscape ecology of an area--the natural character and condition (alterations from human development) of the landscape. Ecological resource patches and a landscape network of connecting corridors are identified, described and classified. The patterns which are detected can then be used to assess the impacts of past disturbance (natural or human), and to plan and regulate further human resource use.

Landscape planning identifies and protects the landscape components necessary to maintain the stand ecology and the landscape ecology of forest areas during and after human use. Riparian zone corridors and cross valley corridors are identified to provide connections and movement paths across the landscape. These corridors are located to maintain natural flows of energy, nutrients, plants and animals across the landscape. Ecologically sensitive areas (e.g. steep slopes, broken slopes, shallow soils, very wet/very dry sites) are protected). At intervals along the corridors, protected old growth forest nodes are established. Old growth forests play a critical role in forest ecology, and must remain a part of the forest landscape to maintain natural ecological functions. Other forest types, representative of a particular landscape can also be included in a protected landscape network. However, many early successional forest types may be adequately provided by various human use zones. Landscape planning and wholistic zoning are ongoing processes that start with large landscapes (100,000 hectares+) and move systematically to smaller landscapes. Landscapes must be protected at all scales in order to protect and maintain ecosystem functioning. Landscape planning and wholistic zoning become increasingly more detailed as one moves from large areas to small areas. Figure 1 shows a protected landscape network for a large landscape, while Figure 2 provides a more detailed view of a portion of that same landscape at a higher resolution or more intensive level of planning.

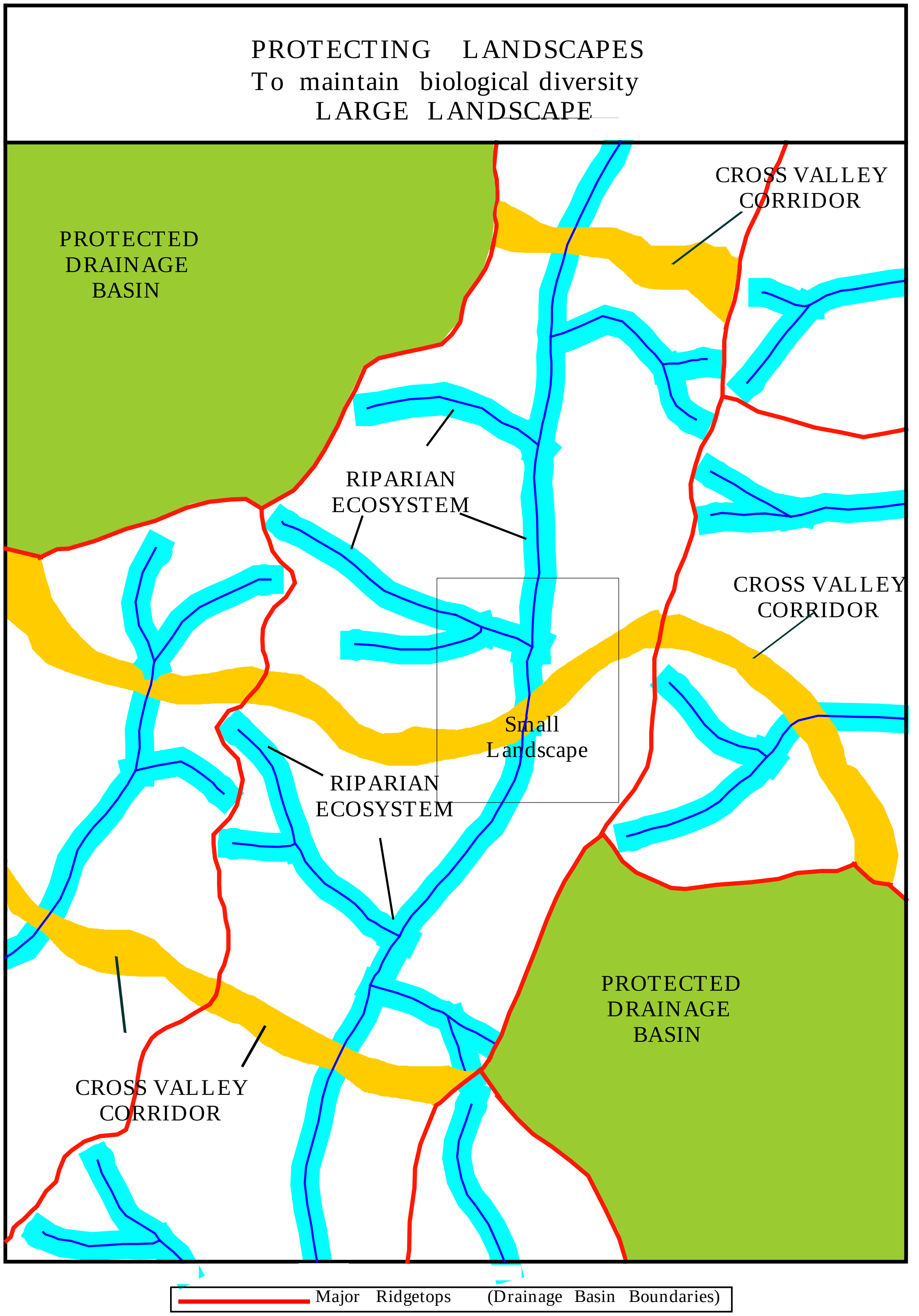

Figure 1: Large Landscape planning Area

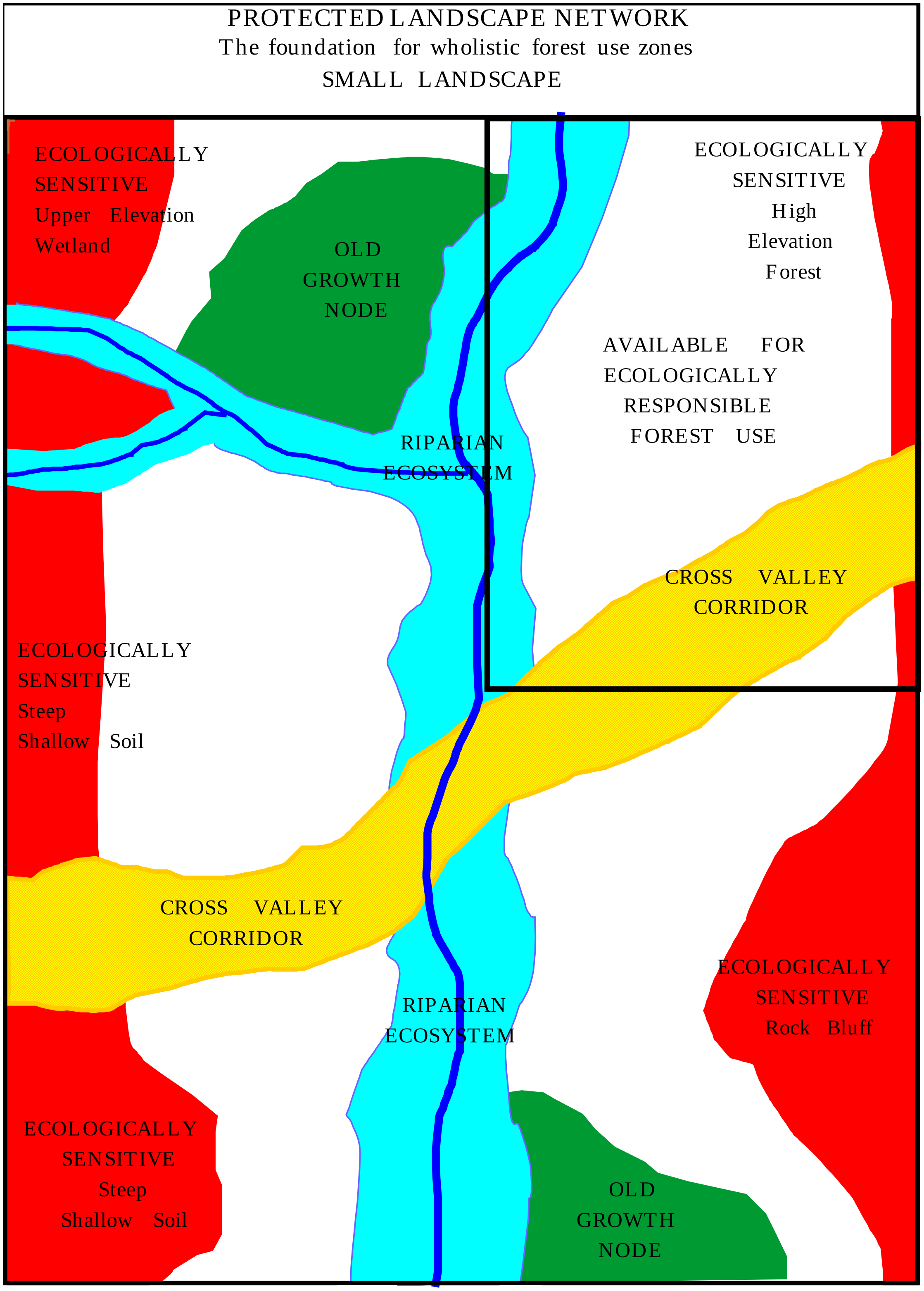

Figure 2: Protected Landscape Network in Small Landscape

"Human use" is an important variable - the ecology of the world would be in excellent shape without ecologically irresponsible human intervention. Still, humans are a part of the total planetary ecosystem; understanding and respecting the principles of landscape ecology and ecosystem-based landscape planning provide our current best hope of living within the ecological limits imposed by the planetary ecosystem.

Wholistic Forest Use Zoning identifies the various forest uses which are ecologically and socially appropriate for a forest area, and then establishes land reserves, or zones, within which those uses can be carried out. Wholistic forest use within each zone is ecologically responsible, ensuring that all forest uses protect the forest, and that no forest use damages other uses. The objectives are to integrate various land uses in the area in order to ensure that each group of forest users has a land base that is suited to its needs, and to protect the needs of all forest users in further planning processes and forest use activities. A primary forest use is determined for each zone. Other forest uses are then integrated, or listed in declining order of importance. The primary users have the first priority at all times and will be given the decision making authority needed to protect their interests. However, constraints and limitations are placed on the primary use(r) in order to protect the other users(human, animal, and plant) of each zone and to maintain fully functioning forests in the zone during and after human use.

Six different wholistic forest zone types are usually identified: Riparian Zones, Culture, Ecologically Sensitive, Fish and Wildlife, Recreation - Tourism - Wilderness and Wholistic Timber. The flow chart in Figure 3 shows the hierarchical process used to delineate the zones. All of the zonal uses are to some degree compatible. For example, a zone with a main land use of culture can also contain secondary uses such as fish and wildlife. Wholistic timber is the most difficult to blend with other land uses. However, wholistic timber activities, if properly carried out, will protect most other forest uses.

Figure 4 is a schematic diagram showing a possible configuration of zones in part of a landscape.

DECISION MAKING PATH FOR WHOLISTIC FOREST USE ZONE TYPING

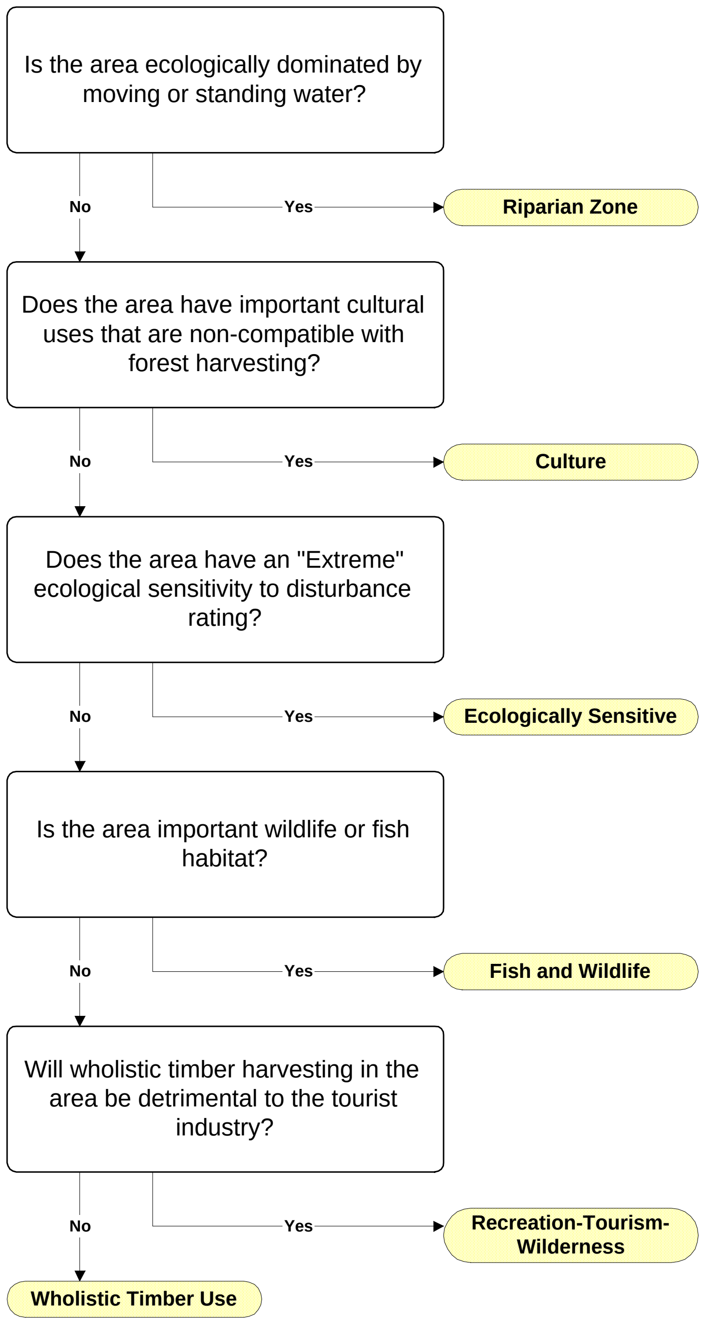

Figure 3: Flow chart of WFUZ decision making process.

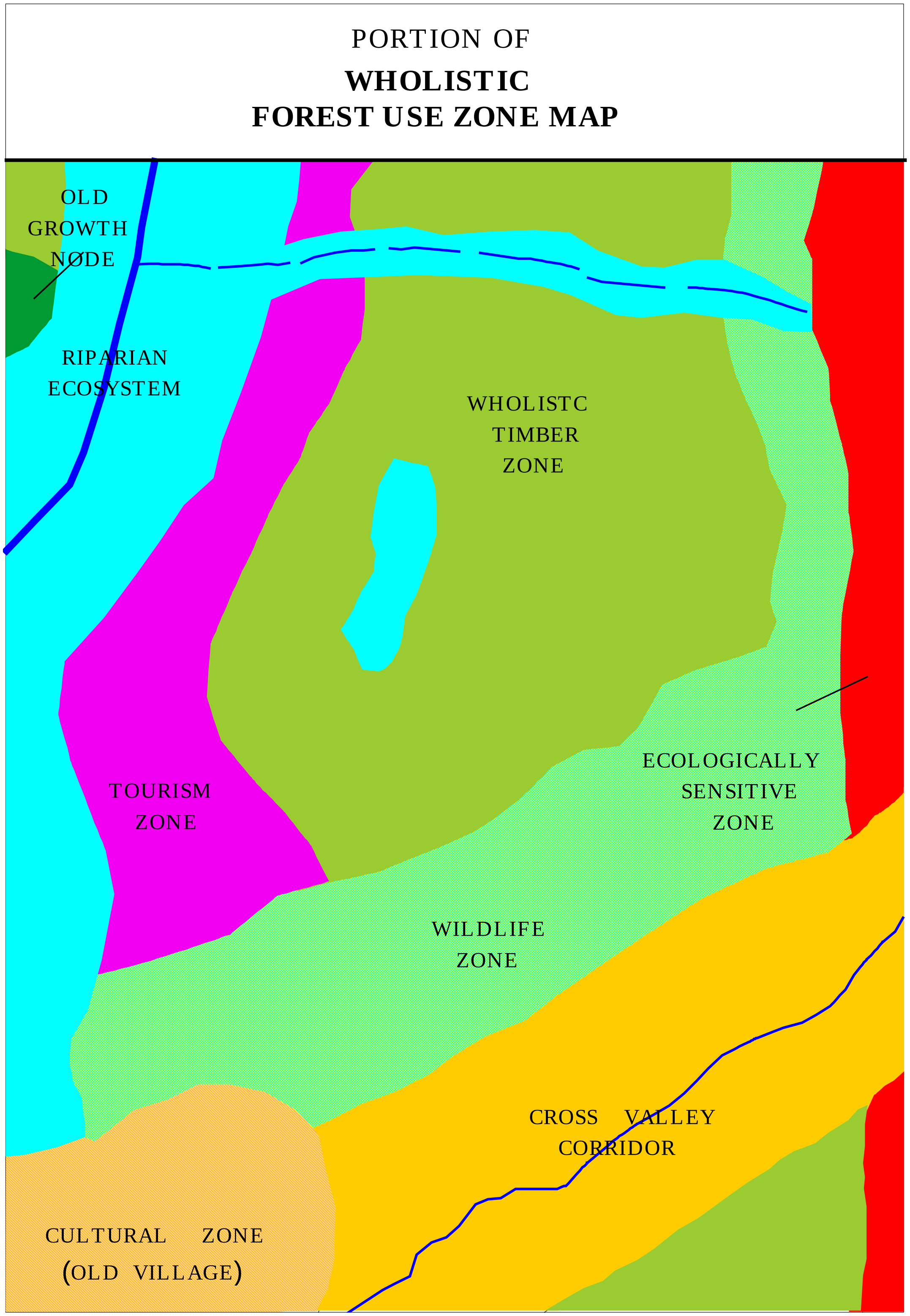

Figure 4: Schematic Diagram of Wholistic Forest Use Zones.

In practical terms, the methods used to carry out these two separate but related forest use zoning processes are very similar. In fact, the riparian zones, or streamside protection zones, are identical in both systems. Landscape analysis and planning attempts to discern the natural pattern of landscape ecosystems in a study area, and plan to retain the structures and functions of these patterns in a managed landscape. Wholistic forest use zoning divides portions of the landscape outside of a protected landscape network into "use zones", based on a combination of ecological limitations and cultural/social/economic goals. These two processes can be carried out hierarchically (one after the other) or relatively independently on parallel tracks, with the results being integrated and compared at the end of the process.

In a hierarchical analysis, a protected landscape network of connecting corridors and various resource patches is delineated first, and wholistic forest use zoning is carried out on the areas left after the protected landscape network has been identified. In a parallel process, each zoning/delineation process is carried out independently on the entire landscape, and the results are compared and integrated at the end of the process. The amount of work involved is slightly greater, but a parallel process has the advantage of enabling an answer to the question "What sort of land, in terms of potential human use, is within the protected landscape network?". An answer to this question is often required.

We prefer to delineate the protected landscape network and to identify wholistic forest use zones relatively independently. Multiple colors of photo marking can be used to differentiate between the two layers of information, or staggered photos can be used (even numbers for WFUZ, odd numbers for LSA). After both processes are complete, the information can be entered into a GIS and analyzed to produce:

1. The protected landscape network.
2. Wholistic forest use zones for the forest areas outside of the network.
3. Information on the forest types contained within the protected landscape network and forest use zones.

For this training exercise, we will use the somewhat more straightforward method of identifying the zones hierarchically.

4.3 Delineate Riparian Ecosystems/Riparian Protection Corridors

The first zones identified are riparian protection corridors which include the riparian zone and the riparian zone of influence. Riparian zones are the forest and wetland areas adjacent to a watercourse. The entire lower valley ecosystem type in which the plant community shows the effects of increased water supply is part of the riparian zone. Drier upland forests immediately adjacent to riparian forests are termed the "riparian zone of influence" and are important buffers that protect the riparian zone.

Forests throughout the landscape are "linked" or connected by riparian ecosystems. For this reason protecting riparian ecosystems is integral to maintaining ecologically viable forest stands and landscapes. Protected riparian ecosystems should include streamside vegetation, the forested valley bottom and the lower slopes adjacent to the watercourse.

These adjacent areas, or the riparian zone of influence, are necessary buffers to protect the riparian ecosystem. Damage to riparian ecosystems breaks connecting links and degrades the health of the entire ecosystem.

Riparian ecosystems are also ecologically sensitive areas. The high soil moisture levels, and the presence of moving water in many locations, make soils fragile and easily degraded. Riparian ecosystems are ecological hot spots, where critical nutrient cycling and biotic control over biogeochemical processes occur. Riparian ecosystem forests also control the critical land/water interface, and maintain healthy and productive forest streams. In order to maintain these varied functions, fully protected riparian ecosystem corridors are necessary along all streams.

The width of the riparian protection corridor will vary with stream size and order. First order streams are the smallest streams with no tributaries, junctions of first order stream segments mark the upstream end of a second order stream segment, the junction of two second order stream segments marks the upstream end of a third order segment, etc. Table 1 shows riparian protection corridor widths per stream order which we have used in the past:

Stream Order	Protection Corridor Width
1st & 2nd order	50 m each side, or 100 m total
3rd order	75 m each side, or 150 m total
4th order	100 m each side, 200 m total
5th order	Generally discernible on forest cover maps or air photos as separate forest type, if not, 200 m each side, 400 m total
6th, 7th, 8th orders	Generally discernible on forest cover maps or air photos as separate forest type, if not, 300 m each side, 600 m total

Table 1: Riparian Protection Corridor Widths by Stream Order

A 50 m per side buffer amounts to 10 ha of buffer per kilometer of stream channel.

These parameters for riparian protection corridors should be considered as general guidelines. Actual riparian zones and riparian zones of influence must be delineated in the field before resource development takes place.

The riparian ecosystems of third, fourth and fifth order streams are identified and marked on the air photos using an Omnichrome photo pencil. We usually we do not delineate the riparian ecosystems of the smaller creeks by hand, but instead use the stream buffering capability of a GIS to create uniform 100 meter buffers on all 1st and 2nd order watercourses. This thin corridor network is combined with the more detailed network delineated on the photos to produce the complete riparian protection network.

The map scale selected for an analysis to a large extent determines the creeks used, and the creeks identified for riparian protection corridors. As map scale increases, smaller creeks become visible. We generally use the Ministry of Forests 1:20,000 forest cover map series to delineate water courses.

Smaller watercourses that are not visible on maps or air photos are protected with riparian corridors during field layout of human uses. Riparian protection is extended to ephemeral (not year round) watercourses.

Riparian protection corridors extend through all forest types. Portions of recent clearcuts which fall within the riparian protection corridor should be included in the protected area because, over the long term, these areas will revegetate and regain much of their former structure and function. Riparian protection corridors remove forest from the timber cutting land base, and reduce the annual allowable cut. We believe that this step is necessary to achieve ecologically responsible forest use and to maintain fully functioning forests in the short and long terms.

4.4 Identify Protected Landscape Network

4.4.1 Introduction

A protected landscape network is a set of ecologically viable habitat areas distributed across the landscape, and connected by defined movement corridors. The first component of the landscape network has already been identified - the protected riparian network. The landscape network components which remain to be added are protected old growth forest areas, protected cross valley movement corridors, and ecologically sensitive areas. This introduction will briefly discuss the importance of these landscape units, and will explain some of the principles of island biogeography. Understanding these concepts will assist the analyst in designing a landscape network.

Old growth forests provide home ranges for specialized species, and are also utilized at critical times by many species thought of as "non-old growth". Deer, for example, often inhabit diverse habitats dominated by young successional vegetation. However, research has shown that old growth forests provide critical winter habitat resources for deer, and may in fact be a limiting factor on deer populations. Old growth forests provide the highest quality water, maintain fish habitat, maintain forest biodiversity and replenish the forest soil. Large old growth trees are unique structures, which support a complex ecology, essentially individual forests with a forest. Ecologists are only now beginning to discover some of the unique and important functions performed by old growth forests, and by undisturbed forest landscapes. A full discussion of the importance and functions of old growth forests is beyond the scope of this paper. Further information can be found on pages 28 to 33 of *Seeing the Forest Among the Trees*, by Herb Hammond[1]. Suffice it to say that a connected network of old growth forest areas is required to maintain forest functioning within the forest landscape.

Cross valley corridors are belts of forest which extend from the riparian ecosystem to the treeline, spanning the entire width of a valley. These corridors provide movement paths for animals which need to traverse multiple valley systems, or which need to move between upper and lower slopes during their life cycle.

Ecologically sensitive areas are ecosystem types that have severe physical and/or biological limitations to most human uses, particularly consumptive human uses. Steep slope gradients, broken or complex terrain, shallow soils (often associated with steep slopes), very wet sites, and very dry sites are common ecologically sensitive areas that are protected from most human uses.

The concept of a protected landscape network was not introduced by Silva. The idea of a network of connected habitats as a means of maintaining ecotypes and species has been developed by a variety of ecologists. The concept is very well synthesized and supported by Larry D. Harris in *The Fragmented Forest* (1984). His review of the literature showed that unique habitat types, specifically old growth forests, become isolated islands if/when they are "preserved" conventionally in managed forest landscapes. These "islands" are likely analogous to real oceanic islands, which were created by rising sea levels after the last ice age. Such islands start with the full complement of continental species, but gradually loose species through local extinctions. Some of the highlights of Harris's study of the ecology of terrestrial habitat islands are:

1. Species richness of a habitat island is directly related to the size of the island. Other factors being equal, larger habitat patches can generally support more species than smaller patches. Increased within patch diversity may also help to maintain species richness.
2. Carnivores and insectivores require larger home ranges per body weight than herbivores or omnivores. Carnivores and insectivores may not be able to reside in areas which are not large enough to meet their food and area needs.
3. The habitat specificity of animals appears to be inversely related to area requirements, and body size. Large animals are wide ranging generalists. Small animals tend to have highly specific habitat requirements and are more sedentary.
4. The degree to which an habitat island is isolated depends upon:
   - the physical distance to the next habitat island,
   - the type of intervening habitat, and
   - the species being considered.

   For example, a 1 km distance is 75 times the normal monthly cruising distance of a mole, but is 1/100th of the normal cruising distance of a cougar. Different species will relate to a landscape in different ways.
5. Isolation may cause local extinctions in the plant and arthropod communities. This could impair habitat values (and ecological functioning) of isolated habitats.

In order to maintain ecosystem functioning and biodiversity, and to mitigate the problems created by habitat fragmentation due to timber extraction, ecologists support the creation of a systematic protected network of connected ecosystems within a landscape. Old growth islands are a critical part of this network, particularly within the managed forest. The size of habitat islands can vary, but a log normal distribution pattern is thought to be appropriate (i.e. a low number of the largest islands, more medium sized islands, many small islands, and a few tiny islands). The very large islands are important, and should occur in valley bottoms which contain the greatest species diversity and biological resources, not in the relatively sterile alpine areas. Smaller islands could occur in upper slope areas, which are close to extensive alpine ecosystems.

There is solid support within the scientific literature for the concept of a dispersed, connected, and protected landscape network, with special attention given to protecting old growth forests. The only "dissent" we are aware of is from parties who caution that a network within the managed forest landbase has not been proven to be a replacement for large, untouched old growth reserves, that reliance on networks may have unforeseen and undesirable consequences on populations, and that a protected network is not a substitute for ecologically responsible use of remaining forests. We agree completely with these cautions.

The methodology described below focuses on identifying protected old growth forests because these are the keys to a protected landscape network. Other components are also described but more briefly. Definition of riparian ecosystems was described in Section 4.3.

4.4.2 Methodology Used

A combination of air photo interpretation and forest cover map analysis are used to identify the components of a protected landscape network. Old growth forest areas show up prominently on air photos, and can generally be immediately identified. Forest cover maps provide species, age, height and stocking information which may be useful. Digital map information and a GIS can provide the opportunity to perform interesting and informative map analyses to rate old growth forest areas in terms of ecological viability.

Detailed analysis and rating may not be required in forest landscapes which have been impacted by human use. Possible large reserve areas, old growth forest nodes and forested movement corridors are often uncommon in such landscapes. In such situations, possible options for protected areas are often very few. Air photo interpretation alone is often sufficient to identify a network of protected areas. In disturbed landscapes, forest restoration often becomes a requirement in establishing a protected landscape network. Since we do not know whether or not time will change a clearcut/tree plantation back into an old growth forest, protecting remaining ecologically viable old growth is critical in a disturbed landscape.

This section of the report contains a simple rating system which evaluates basic ecological parameters of old or old growth forest areas. Where multiple options for protected areas exist, the rating system or the trends expressed in the rating system may be used in conjunction with spatial patterns shown on forest cover maps, satellite images, and other information sources to "rate" old growth patches.

The network can be identified on the air photos, on forest cover maps, or on a combination of both. Once the network has been finalized, mark the protected node boundaries, cross valley corridors, and ecologically sensitive areas on the working areas of the air photos using easily visible photo pencils.

4.4.3 Identify Large Reserve Areas

Very large, intact old growth ecosystems must be fully protected from consumptive human use. These forests should be large enough to:

- maintain fully functioning diverse ecological communities in the face of large natural disturbances.
- ensure the continuation of ecological processes which have co-evolved.
- buffer and withstand (hopefully) the coming assaults from climate change, global pollution and ozone depletion.

Such ecological reserves are needed to provide the gene pool, the species reserve, and the working blueprint needed to maintain forests. Researchers advocate retaining both large reserves and a network of smaller, fully protected old growth forests within the managed forest.

For the purposes of landscape analysis and forest use planning, some large reserves are provided by existing conversation areas (parks and wilderness areas). Additional large reserves are required in many areas, but for political reasons, the designation of large reserves usually falls outside the realm of landscape planning and wholistic forest use zoning. For most "local" landscape analyses, simply knowing where current large reserves are located will usually be sufficient. These reserves should be viewed as part of the landscape network, and connected to the network if at all possible. If large protected reserves do not exist, local landscape planning should attempt to identify watershed areas in the size range of from 5,000 to 50,000+ hectares t recommend for large reserve status.

4.4.4 Identify Protected Old Growth Nodes

A protected landscape network is a set of ecologically viable habitat areas distributed across the landscape, and connected by defined movement corridors. A series of protected old growth forests extending across the managed forest landscape, is the foundation for this network. The individual protected areas within this network can be called "nodes".

The analyst identifies protected old growth nodes, and marks the proposed network on the air photos. This section of the methodology provides information to assist in selecting old growth nodes. Understanding the criteria outlined here will assist the analyst in selecting an area from multiple candidates for inclusion in the protected network. In many locations, very little old growth forest area remains, and the selection of a network will be straightforward.

The protected old growth network should be identified in two stages:

> First, any unique or endangered old growth forest types should be protected regardless of size and location in the landscape. Examples of such forests are old growth remnants in heavily logged areas or naturally rare ecosystem types, such as spruce/hemlock old growth on large river floodplains. Unique old growth can also include stands which are the tallest, or largest in diameter, or which have other unique features. A combination of air photo and map

interpretation, local knowledge and field examination are required to identify such areas.

Second, the primary landscape network should be established. This network should be composed of forest stands of a variety of sizes. The critical questions here are: How many? How frequently? How large? There are, unfortunately, no clear answers to these questions. Old growth ecology and landscape ecology are areas of active research, where the knowledge base and opinions on "best" measures change over time. Many authors call for a network of protected old growth forests, but few have committed themselves to the proportion of the land which should be included in the network. Harris (1984) calls for 5% of the managed or commodity land base to be in a true old growth stage at all times. None of the other sources which we have reviewed quantify the question of "How much". We adopt a conservational philosophy which states: "If in doubt, protect it." You can decide not to cut a forest as often as you like, but you can only decide to log it once.

The ecological viability of an old growth forest area depends on landscape factors. The size, shape, connectivity, and landscape context of any particular old growth forest determines its ecological viability. There are too many landscape and stand specific variables involved to predict the proportion of the managed forest landbase which should be maintained as protected old growth forest in all landscapes. For example, the possibility exists that a poorly designed old growth protection program which included 10% of the managed forest landbase could achieve habitat protection results inferior to a carefully designed network of only 5% of the managed forest landbase. Conversely, 20% of the managed forest landbase may be required to meet minimum habitat objectives for some species in some areas. The type of timber management activities carried out on the commodity forest land base will also greatly affect the size of the nodes required to maintain a viable old growth network. Clearcutting/tree plantation forestry requires larger areas of protection than that required for wholistic timber management.

Debate on "how much and where" may be somewhat esoteric in many forest landscapes which have been heavily impacted by logging. Examination of the landscape may show that there are very few choices remaining, and that any pattern of protected old growth nodes will be somewhat "self defining". In the happy event that many choices for protected old growth forests still exist, the rating system outlined in this report can help to select "best" choices for protection.

We understand that some guidelines are necessary for individuals who are being introduced to this analysis process. Our current concept is that a protected old growth node is required every 2 to 3 km through the landscape. The size of the protected nodes will vary, but nodes less than 50 to 100 ha should only be used if not other choices are available.

Where no old growth forests are available for protection, we advocate protecting the oldest, most suitable stand in the area. These areas will be managed to become (hopefully) old growth forests in the future. Indeed, the entire concept of landscape change over time needs to be considered as a "second step" once basic landscape and stand management plans have been developed. Old growth forests are not permanent - the protected old growth forests of today will succumb to disturbances, natural or human caused, over time. Other areas must then be recruited to continue to provide old growth areas in the landscape. Thus, there is a need for 500 year forest plans as opposed to five year logging development plans. In the present, establishing a protected network of old growth nodes is the first priority.

As mentioned above, there is support for a log normal distribution of area sizes. Figure 4 shows a graph from Harris (1984), which depicts an example of a log normal distribution of areas in a program which planned to set aside 65,000 ha in the Willamette National Forest.

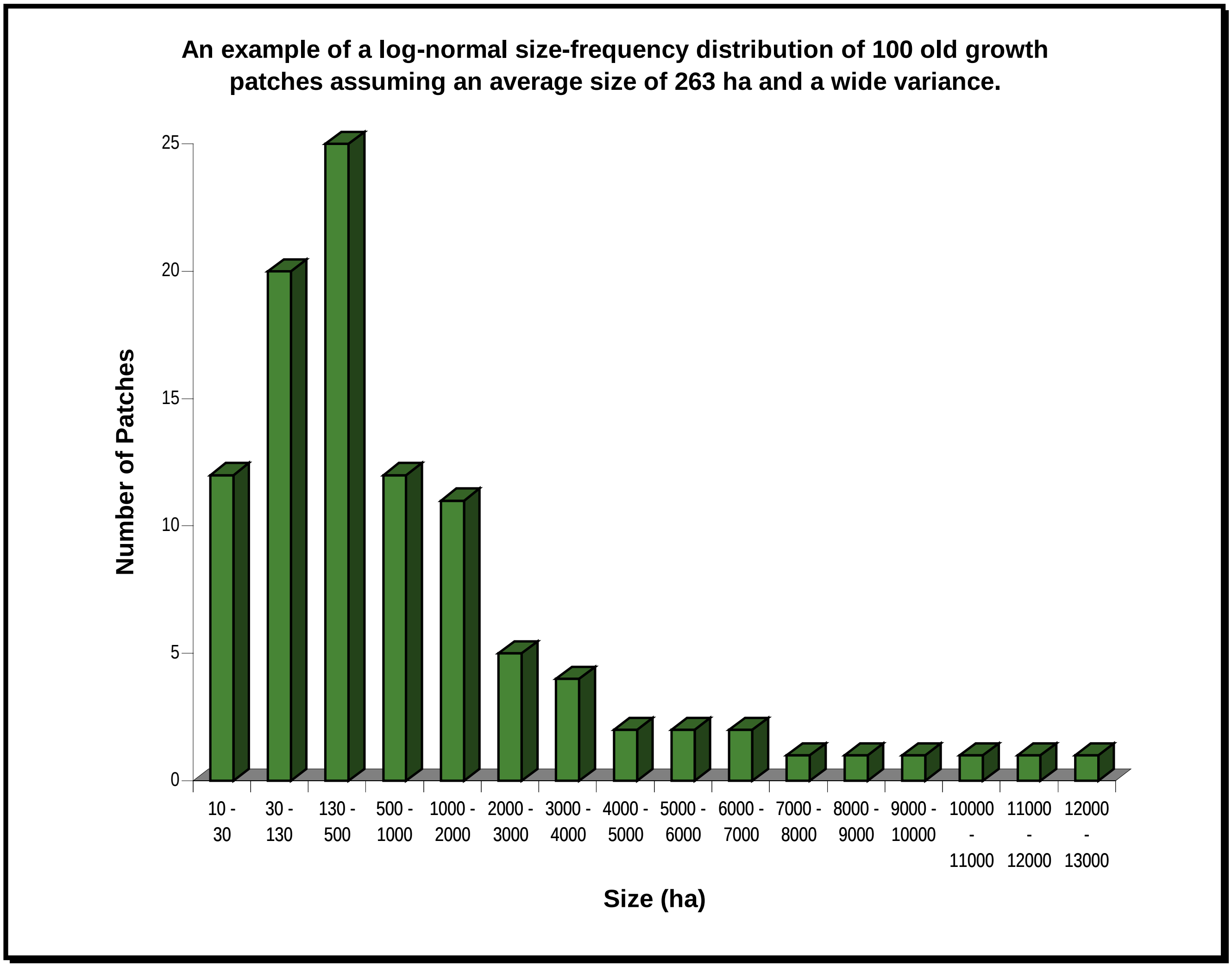

Figure 5: Log Normal Distribution of Protected Areas

A mix of various sizes of protected old growth areas is desirable to provide habitat for various animals and plants. Large carnivores which utilize old growth forests will likely require larger areas than may usually be provided in any network within the managed forest land base. However, the needs of many of these species can hopefully be met through a combination of the large nodes in the network, the dispersed smaller stands in the network, the large reserves, and the travel corridors which permit movement between these landscape elements.

Forest areas or stands are selected for inclusion in the network based on a landscape analysis grading or rating system. The following landscape variables are assessed for each potential old growth forest node:

- stand size
- interior stand area
- landscape context
- human threat
- connectivity

Favorable factors such as large size and established connectivity tend to increase the ability of old growth stands to survive moderate disturbances, and maintain their biological diversity and ecological functions over time. These stands are more ecologically viable than stands with low ratings. Low ratings reflect a landscape ecology which is less favorable to the continued existence of the old growth stand. Isolation, fragmentation and small size all contribute to lower ecological viability, and lower ratings. The total of all the attribute ratings give the overall landscape ecology rating of each old growth type.

A caution: from the standpoint of the ecosystem, no part or stand is any more important or less important than any other part or stand. Therefore, strictly speaking, rating the "ecological viability" of a part or stand is meaningless and gives a misleading sense of security. However, if one assumes that the timber industry will continue to severely modify landscapes with clearcuts and tree plantations, there is an urgent need to protect old growth forests. Since these are the very forest types that the timber industry wants to cut, there is a need to make choices of what old growth to protect and, reluctantly, what to cut. The rating system described below is a tool to help in this difficult, human-centered (as opposed to ecosystem-centered) decision. In proposing this rating system, we are not advocating the continued logging of old growth forests, nor are we suggesting that any particular ecosystem is "better" than another. In the face of ongoing logging across the landscape, we are simply trying to provide conservationists and ecologically responsible foresters and planners with a tool to select old growth forests for inclusion in a protected landscape network to maintain minimum ecosystem functioning across the landscape.

This methodology was developed for use with a GIS system. We are not suggesting that all of these measurements must be performed by hand to carry out a simple landscape analysis. We have included the point rating system to help quantify terms such as "large", "connected" and "interior area". The descriptions and parameters can be used as references when a landscape network is defined by a human interpreter without the benefit of a GIS system.

Research into old growth ecology is ongoing. The variables and parameters presented here are our best interpretation of the scientific literature available in 1990. These interpretations may need to be revised as research proceeds. However, what is already abundantly clear is that old growth forests must remain a part of the forest landscape. We need to protect substantial areas now so that this vital resource and the community, species, and genetic information contained therein, is not lost.

The individual landscape ecology attributes, and the rating system applied to each attribute are discussed below.

4.4.4.1 Stand Age

Old growth forests are, by all definitions, old forests. Most B.C. forest tree species can live to ages greater than 300 years, barring forest fires or other disturbances. The Ministry of Forests provides the age class of each forest cover type polygon mapped in the MoF inventory. The parameters for MoF age classes used are listed in Table 2.

Age Class Limits	Age Class Code
0 - 20	1
21 - 40	2
41 - 60	3
61 - 80	4
81 - 100	5
101 - 120	6
121 - 140	7
141 - 250	8
250+	9

Table 2: Ministry of Forests Forest Cover Age Class Codes

Our field observations indicate that the stands identified on forest cover maps as age class 8 and 9 are generally old growth forests, or are very near the old growth stage. Some Age Class 8 and 9 forests may not have developed all of the distinctive structural attributes of old growth forests, but these stands are likely to become old growth in the near future. In a landscape analysis, we therefore classify all age class 8 and 9 forests with leading species other than lodgepole pine as old growth forest.

Lodgepole pine is a relatively short lived tree species, which matures at a younger age than other B.C. tree species. Structural attributes typical of old growth forests are usually developed much earlier in lodgepole pine forests than in other old growth conifer types. For this reason, we consider age classes 7, 8 and 9 as old growth for all forests where lodgepole pine is the most prevalent tree species. These age parameters are summarized in Table 3.

Although the individual stands selected as possible old growth nodes using stand age as a primary parameter may not be "ideal old growth," the landscape network formed by these old growth and near old growth stands is an acceptable starting point. The initial stand selection is revised based on field examination as necessary.

	Younger Immature	Older Immature	Mature	Old Growth
All Species Except Pl and Decid				
Age Class	1 - 2	3 - 5	6 - 7	8 - 9
Age	1 - 40	41 - 100	101 - 140	141+
Pl and Deciduous				
Age Class	1 - 2	3 - 4	5 - 6	7 - 9
Age	1 - 40	41 - 80	81 - 120	121+

Table 3: Age Class Groups for Old Growth Rating System

4.4.4.2 Forest Area

Total old growth forest area has positive or negative impacts on the landscape ecology of an old growth patch. The forest area variable rates the size of each old growth stand, or group of continuous old growth stands. Forest area affects:

- The integrity of the stand. How susceptible is it to destruction? Can the forest withstand a disturbance and still retain its old growth nature?
- The habitat quality of the stand. Is the forest area large enough to maintain viable wildlife and plant communities? Is there enough area to maintain balanced predator/prey relationships, and biological diversity?

Large stands have a significantly greater ecological viability than small stands, and receive a commensurably higher rating. Large stands (> 1000 ha) will be included in the proposed network periodically, especially when they completely occupy small watersheds, but most of the protected old growth "nodes" in the network will be less than 400 ha in area. This rating system is not intended to apply to the large regional old growth protection areas which will be identified outside of this network rating system. We use the following size class divisions and point ratings.

Area Range	Point Rating
0 to 80 ha	2
81 to 160 ha	5
161 to 400 ha	8
> 400 ha	10

Table 4: Landscape Ecology Rating - Stand/Forest Type Area

Grouping adjoining old growth forests is necessary to rate forest area as a landscape ecology attribute. The forests may be significantly different, but from the viewpoint of landscape ecology, adjacent old growth forests form one old growth landscape unit. Connected old growth stands have a much better chance of retaining old growth characteristics than isolated stands. Thus, the forest area rating given to two adjoining 60 ha old growth stands will be same as that of one 120 ha stand.

4.4.4.3 Interior Stand Area

Interior old growth habitat is the forest area which is protected or buffered from conditions in the ecosystems outside the forest. The interior zone of an old growth forest is different from other locations in the landscape. The surrounding massive old growth trees buffer the climate, reducing wind and temperature extremes, and conserving moisture. Interior old growth forest habitat also provides the seclusion and the stable ecosystem conditions which form the optimum habitat for some wildlife species. Interior habitat is the most unique, and most threatened, form of old growth ecosystem.

Human activities and natural disturbance reduce interior forest area when the forest is divided into islands separated by clearcuts, logging roads, highways, hydro lines, hydro reservoirs etc. The amount of interior forest habitat is reduced not only by the amount of land occupied by the human disturbance, but also by the amount of interior habitat converted to "edge habitat." As a forest becomes divided into smaller pieces, more and more area becomes edge habitat. While the area occupied by human disturbances may rise at an arithmetic rate, the rate at which interior forest habitat is converted to edge habitat rises exponentially. Peter Morrison of the Wilderness Society says in *Old growth in the Pacific Northwest: A Status Report* (1988):

> Continued old growth fragmentation is reaching a critical point. When a 25 acre (10 hectare) clearcut is placed in unfragmented old growth, approximately 35 additional acres (14 hectares) are included in the 400 foot edge surrounding the clearcut and are subjected to deleterious edge effects. Therefore, 60 acres (24 hectares) of old growth (interior area) are destroyed for each new 25 acre clearcut, effectively increasing the impact of each new clearcut in unfragmented landscape by a factor of 2.4. This situation is exacerbated by road construction. For every mile of road built in unfragmented old growth, approximately 97 acres of old growth forest is altered by edge effects.

Fragmentation occurs when a large expanse of old growth habitat is transformed into a number of smaller old growth habitats of smaller total area than the original, isolated from each other by areas of unlike habitats (1988).

Forest fragmentation and the expansion of edge habitat adversely affect the old growth ecosystem. Aggressive site colonizing species of plants and animals will occupy disturbed land outside the old growth forest, and will also invade the edge habitat of the old growth. This process favors the common species of field and clearcut over less common interior forest species. Old growth species are replaced, and the entire old growth stand becomes more vulnerable to disturbance. Old growth interior habitat will disappear from managed landscapes long before old growth forests disappear, if present trends are continued.

Defining the extent of edge habitat into an old growth stand is complicated and there are no definitive guidelines. The extent of the "edge" zone depends on the vegetation cover type outside the old growth forest, and on the structure and composition of the old growth forest itself. There is very little edge habitat at the boundary between an old growth forest and a mature forest. However, an extensive "edge" zone extends into an old growth forests along a boundary with a fresh clearcut. In order to reflect this range, we vary edge zone width with bordering vegetation type. Table 5 shows edge zone width in old growth forests bordered by some basic landscape unit types:

Edge Zone Width	Vegetation Type
400 m	Highway, high human use area
200 m	Clearcut, < 25 years old
200 m	Logging roads, natural opening
100 m	Immature Stand >25 years old
0 m	Mature Stand, other Old Growth

Table 5: Edge Zone Width by Bordering Vegetation Type

Each old growth forest area is rated for <u>total interior area</u>, which is the <u>total stand area less edge habitat</u> (determined using the buffer distances above). As with forest area, assessments and ratings for interior habitat are derived for contiguous old growth stands. The total interior habitat rating for all connected stands is assigned to each individual stand. The interior habitat formed by the sum of the grouped stands determines the landscape value of an old growth area.

The point rating system used for interior stand area is shown in Table 6. Larger areas of interior habitat have greater landscape value than small areas, and thus receive higher ratings. Old growth forests with interior areas less than 20 ha contain very little if any real interior old growth habitat, and are given a zero rating. Some undisturbed old growth stands are naturally low in interior area due to their sinuous shape and landscape context. These stands are also given a low rating.

Area Range	Point Rating
0 to 20 ha	0
21 to 40 ha	2
41 to 100 ha	5

101 to 400 ha	8
> 400 ha	10

Table 6: Landscape Ecology Rating - Interior Stand Area/Habitat

4.4.4.4 Landscape Context

An assessment of landscape context is required to assess the ecological viability of any old growth area. Landscape context means the nature of the surrounding landscape, and the patterns and conditions therein. Is the landscape composed of clearcuts and plantations, or mature and near mature forest types? Does the surrounding landscape improve or decrease the likelihood that this particular old growth forest area will continue to survive? How does the landscape affect the type and number of plant and animal species within the old growth forest? Factors such as these determine, to a great extent, the characteristics and viability of the biotic community found in each old growth area, especially in smaller old growth stands.

In order to assess landscape context, we analyze the land use/forest cover types in a buffer zone extending 1 km from the edges of each old growth patch being evaluated. Grouping old growth stands is not necessary for this analysis function. In the two previous attributes assessed, forest area and interior stand area, absolute size was used as the rating criteria. Landscape context, however, is rated on a proportional basis. The percentage of the surrounding landscape which is occupied by each identified landscape stratum determines the rating given to each old growth forest area. This method has two advantages:

1) The landscape area assessed is directly proportional to the individual old growth forest area being assessed. The areas assessed for a small old growth stand will be small, while the area assessed for a large old growth forest will be proportionally large.

2) This method enables the comparison of landscape context regardless of stand size. The landscape context of a 25 ha stand and a 250 ha stand can be graded using the same system.

The land use/forest cover classes used to rate the surrounding landscape are:

1) old growth forest
2) mature forest
3) older immature forest
4) younger immature forest
5) recent disturbance (<25 years old) disturbance, logging or fire.
6) water, alpine areas, alder slides, wetlands, riparian zones and sub-alpine forests

Age classes for items 1 to 4 are per Table 3.

Water, alpine areas, alder slides, wetlands, riparian zones, and sub-alpine forests need special consideration. These ecosystem types form natural boundaries to old growth forests, and should not be discriminated against in evaluating landscape ecology. When undisturbed by human activities these ecosystems are part of a fully functioning landscape ecology. Old growth forests have developed in conjunction with these natural openings, as part of the natural landscape ecology. Thus, we give old growth forests bordered by these cover types the same landscape context rating as old growth forests.

The rating process outlined in Table 7 is used to determine the "landscape context" rating for each old growth forest type. The formula results in a weighted average rating proportional to the area of each type of landscape surrounding the stand in question, and the point values assigned to each landscape type.

Table 7: Landscape Ecology Rating - Landscape Context

i) Determine the percent of old growth stand perimeter that is occupied by:
- old growth forest
- mature forest
- older immature forest
- younger immature forest
  - recent (within last 25 years) disturbance, logging or fire
  - high value ecosystem features: water, alpine areas, alder slides, wetlands, riparian zones, sub-alpine forests

(Note: Forest age classifications used above are defined in Table 6.)

ii) Determine the old growth landscape context rating for each old growth stand. The following formula calculates a weighted point rating based on the types of ecosystems bordering the stand:

[(% Old Growth + % High Value Ecosystem Features) x 12)] + (% Mature x 8) + (% Older Immature x 5) + (% Younger Immature x 1) + (% Recent Disturbance x 0)

iii) Landscape Context Rating ...Definition:

Points	Rating
9 - 12	Old Growth Landscape
7 - 8	Mature Forest Landscape
5 - 6	Mixed Forest Landscape
3 - 4	Immature Forest Landscape
0 - 2	Disturbed Forest Landscape

4.4.4.5 Human Threat

Old growth forests and the habitats they contain are threatened by human activities. Logging, roads, human-caused fire, firewood cutting, the import of "weed" species, hunting, animal harassment, noise and frequent disturbance all threaten old growth plant and animal species, and old growth structure and composition. "Remoteness" equates to safety for old growth forests, even though safety may be only temporary as human development continues.

The assessment of human threat in this rating system is carried out by evaluating a large landscape unit around each individual old growth forest type. Two features of the surrounding landscape are considered: roads and logging activity. Point ratings based on the proximity of human activity to each old growth stand are shown in Table 8.

Class	Distance to Road or Logging	Point Rating
Remote	> 10 km	10
Moderate	2 - 10 km	5
Threatened	< 2 km	2

Table 8: Landscape Ecology Rating - Human Threat

4.4.4.6 Connectivity/Riparian Ecosystems

Riparian ecosystems have been discussed in Section 4.3 above. The riparian network has an effect on the landscape ecology attributes of surrounding forest areas. Protected riparian ecosystems increase the landscape value of old growth forests which are part of, are adjacent to, or are connected by a protected riparian corridor. Potential old growth habitat value is increased when connected to a riparian ecosystem, and species diversity is more assured because animals have a conduit to move into or out of old growth forests. All other factors being equal, old growth stands which are connected by an intact riparian network are more ecologically viable than old growth stands which are not connected.

The rating system shown in Table 9 reflects the increased ecological value of riparian connections. The rating system is used with grouped forest areas, formed by amalgamating contiguous old growth types. The grouped types are used because an old growth forest type which does not directly contact a riparian ecosystem, but which is connected to another undisturbed old growth forest area which does contact a riparian ecosystem, should be rated as being connected to the riparian network. The rating is calculated for the grouped stands, but is recorded for each individual stand.

Distance to Protected Riparian Ecosystem	Rating
0 - 50 m	8
51 - 200 m	4
200 m	2

Table 9: Landscape Ecology Rating - Riparian Connectivity

4.4.4.7 Summary Of Ratings

Table 10 summarizes the Ecological Viability Rating system.

Stand/Forest Type Area	
0 to 80 ha	2
81 to 160 ha	5
161 to 400 ha	8
> 400 ha	10
Interior Stand Area/Habitat	
0 to 20 ha	0
21 to 40 ha	2
41 to 100 ha	5
101 to 400 ha	8
> 400 ha	10
Landscape Context	
Old Growth Landscape	9-12
Mature Forest Landscape	7-8
Mixed Forest Landscape	5-6
Immature Forest Landscape	3-4
Disturbed Forest Landscape	0-2
Human Threat	
Threatened	2
Moderate	5
Remote	10
Riparian Connectivity	
Distance to Protected Riparian Ecosystem	
> 200 m	2
51 to 200 m	4
< 50 m	8

Table 10: Ecological Viability Rating

Each of the individual landscape ecology attribute ratings shown in Table 10 is expressed in a range from high (most favorable) to low (least favorable). Favorable factors such as large size and connectivity tend to increase the ability of old growth forests to survive moderate disturbances, and to maintain their biological diversity over time. Such stands are more ecologically viable than stands with low ratings. Landscape ecology conditions which are less favorable to the continued existence of the old growth stand are expressed in low ratings. Isolation, fragmentation, and small size all contribute to lower ecological viability, and lower ratings.

This system effectively integrates landscape ecology concerns with the practical problem of selecting a protected landscape network of old growth forests. Old growth forest types with the highest landscape rating are selected wherever possible for use in the landscape network. This helps to ensure that the selected network is ecologically viable, and is able to maintain old growth forests as a part of the managed forest landscape.

4.4.5 Identify Cross Valley Corridors

Cross valley corridors extend across valleys from alpine area to alpine area in order to provide movement paths for species which need to move across the landscape perpendicular to riparian ecosystems. We currently use 300 to 500 meter wide corridors, located at 1 to 2 km intervals along mid sized valleys. The corridors are located to include natural riparian ecosystems, old growth forest patches and moderate slopes wherever possible. Corridors should not include barriers to animal movement, such as rock bluffs or cliffs. Corridors should join other protected habitat areas if at all possible, and/or should join upper elevation habitats such as broad alpine valleys to lower elevation habitats. Including desirable habitat and terrain types in the cross valley corridors is much more important than rigidly adhering to the suggested spacing.

4.4.6 Identify Ecologically Sensitive Areas

Ecologically sensitive areas have physical and/or biological limitations to human use, particularly consumptive human use. Any areas classed as Environmentally Sensitive on Ministry of Forests forest cover maps are defined as ecologically sensitive areas in our system. In addition, ecologically sensitive areas are defined using the system described in Section 4.5.2. Identifying ecologically sensitive areas is a continuous process of refinement or improved resolution as planning moves from large landscapes to small landscapes.

4.5 Perform Wholistic Forest Use Zoning

After identifying the protected landscape network, divide the remaining land base into wholistic forest use zones to regulate human uses of the forest. The wholistic forest use zones are identified within the areas outside of the riparian network, the protected old growth nodes, the cross valley corridors, and the ecologically sensitive areas. The zones are identified in a specific hierarchical order. Forest areas or forest uses which need protection from resource extraction activities are identified first, with the land base remaining at the end of the process being allocated for wholistic timber management.

4.5.1 Identify Cultural Use Areas

This zone type protects areas which are culturally important to the local people from the impacts of timber cutting, tourism, and other resource use. Areas important to local history and culture are considered, as well as areas which provide useful forest resources to the community, such as grazing, hunting and trapping. This category needs to be carefully reviewed by Elders and others with knowledge of the history and culture of the area in question.

Culture zones take precedence over other forest use zones, and may include areas which are ecologically sensitive, or which are important wildlife habitat. Culture zones are delineated at the start of the zoning process so that they are clearly shown on the map, and not obscured by other land use designations.

4.5.2 Identify Ecologically Sensitive Areas

Ecologically Sensitive zones have been first identified in establishing the protected landscape network. At the WFUZ level, further ecologically sensitive areas are identified and protected from aggressive human use.

Ecologically Sensitive zones include any area which has an ecological sensitivity to disturbance rating of `extreme' in the Silva ecological sensitivity to disturbance rating system. (See the paper entitled Ecological Sensitivity to Disturbance Rating for more information.) Thin soils, very dry or very wet areas, steep terrain, broken terrain, wetlands, and river corridors are primary examples of ecologically sensitive areas.

This zone type includes areas which do not meet the sensitivity requirements, but which are not accessible for timber cutting because they are surrounded by ES types.

Riparian ecosystems are important ecologically sensitive areas, due to moist or wet soils and frequent flooding. Most of these areas have already been protected in the riparian network previously identified. However, small streams and wetlands (including ephemeral streams) are protected at this stage of planning.

ES types are delineated on the photos, and each type is given a descriptive label indicating the reasons for the ES call. These are marked directly on the photo, and are later transferred to the analysis map and entered in the GIS or other data base. Type descriptors and parameters which Silva has used are detailed below:

> **ES1 - Riparian Ecosystems** - see description in Section 4.3 Includes ephemeral systems.
>
> **ES2 - Steep Terrain** - Sites with a continuous slope gradient of more than 60% are classed as steep terrain. Development, especially timber extraction, on these sites results in excessive soil and site degradation.
>
> **ES3 - Avalanche Chute** - Linear patches of alder and other deciduous species which occupy avalanche tracks and run out areas. In steep upper slope areas, alder slides from avalanche chutes may form a nearly continuous carpet across the slope. Small patches of sensitive, high elevation forests are often contained in, between, or adjacent to the avalanche chute areas. These forests are not suited for timber management. The snow avalanches prevent most trees from reaching commercial size and form. Heavy snow loads and soil which is frequently saturated with water runoff for much of the growing season also make these areas inhospitable for tree growth. Avalanche chutes and associated forested areas frequently constitute important wildlife habitat.

ES4 - Complex Terrain - Broken, gullied terrain, which is often dissected by year round or seasonal small creeks (i.e. riparian zones). Complex terrain frequently includes areas of steep slopes or rock bluffs arranged in such a way that designing and accessing ecologically responsible timber cutting units between the steep areas is not possible.

ES5 - Shallow Soil - Sites with less than 50 cm of soil over either bedrock, large broken rock, or an impermeable layer. Shallow soil sites cannot withstand the impacts of timber management activities without severe soil degradation and associated ecological damage.

ES6 - Very Dry - Sites where topography and/or soil structure severely limit the availability of water for plant growth. Very dry sites include ridge crests, deep gravel soils, very shallow soils, etc. Such ecosystems are very fragile and easily damaged by any activity. Site rehabilitation after impact is often impossible in a human time frame.

ES7 - Wetlands - Sites with exposed water (i.e. ponds and bogs), and where to water table is within 1 m of the surface throughout the site for all or a substantial part of the year. The high soil water levels decrease the stability of the soil. Timber cutting is likely to cause extensive and permanent soil damage and site degradation on wetlands. Because of high water tables, which frequently rise following timber extraction, these sites are difficult to regenerate to coniferous tree species after logging.

ES8 - Alpine - Includes areas of alpine forest, alpine meadow, alpine tundra, snow, and glaciers. Areas of extensive avalanche chutes, small pockets of trees between slide chutes and rock outcrops, and occasional isolated forest areas in upper elevation basins are also often included in the alpine zone. Small, isolated areas of forest are often included in the alpine zone.

ES9 - Transition Zones - Forested areas at the edge of sensitive, nonforested vegetation zones, such as wetlands or alpine, which would be difficult or impossible to regenerate if logged. Removing the trees in these areas would likely alter the local ecology such that the site would not be capable of growing a forest again. Transition zones often contain very fragile soils, and constitute valuable wildlife habitat.

Ecologically sensitive areas are marked on the air photos, with the various zone types listed in approximate order of importance. Thus, a zone listed as ES2,4,5, has steep, gullied terrain with shallow soils, and some inclusions of riparian ecosystems. A zone listed as ES4 would be a riparian ecosystem associated with several gullies. These designations provide a short explanation of why a particular area was judged to be ecologically sensitive by the analyst.

4.5.3 Identify Fish And Wildlife Zones

This zone identifies and protects areas of sensitive, important and/or critical habitat for wildlife. Typical examples of important wildlife habitat include winter range, and forests used for hiding cover adjacent to forage areas. Riparian zones of influence are a type of fish and wildlife zone, as are many areas which were classified above as ecologically sensitive. The fish and wildlife zones delineated in this step are an addition to these previously protected areas, and are used to protect areas of habitat which are not ecologically sensitive but which are required for wildlife habitat. Areas to be protected can be identified from inventory results and/or from local knowledge. **In our interpretation, suitable habitat must be maintained for all species, not just for large game animals and commercially important fish.**

Significant areas of fish and wildlife habitat have already been protected in the riparian ecosystem network and in the protected old growth forest nodes. The fish and wildlife habitat identified in this zoning stage is habitat which is required in addition to these other landscape units. Winter range for ungulates, or spring range for grizzly bears, are examples of the sorts of habitat identified by this zone type.

4.5.4 Identify Recreation - Tourism - Wilderness Zones

This zone identifies and protects a viable forest land base for forest or wilderness dependent public recreation and tourism. Much of the forest in the RTW zone may be suitable for wholistic timber use. However, to achieve balanced forest use, some areas are zoned RTW, ensuring a fair land base for public recreation and the tourism industry. RTW is a non-consumptive, readily sustainable forest use which, if conducted in ecologically responsible ways, will provide adequate protection for the forest.

RTW zones are identified after Fish and Wildlife zones because this human use and activity may not be compatible with wildlife, depending on the species and type of human use.

A preliminary tourism plan is required in order to identify RTW zones satisfactorily. This plan does not have to be detailed, but basic information such as facility type, facility siting, location of high use areas and visual management zones will greatly assist in the delineation and explanation of tourism use zones. The plan can come from an outside source, or can be developed in conjunction with this analysis.

Before identifying Wholistic Timber Zones, other human use zones specific to a particular landscape may also be established. Two examples are agroforestry and ranching zones.

4.5.5 Identify Wholistic Timber Use Zones

The landbase which remains after sensitive ecosystems have been protected, and after other forest uses have been established and protected, is available and suitable for wholistic timber management. Wholistic forest use zoning identifies timber management areas last because timber extraction is an extremely aggressive land use, which is not compatible with most other land uses.

4.6 Check, Revise, Review

After completing a zoning exercise, return to the first photo zoned and review your work. In all likelihood, you will quickly find areas which you now believe should be re-classified. Small but significant changes in analysis criteria and in the analyst's opinion on classification over the course of the photo interpretation work is not unusual. Review the entire area as many times as is required, striving to achieve a standardized approach to zoning and assessment.

4.7 Transfer To Maps

All of the analysis work thus far has been carried out on air photos. After the zone boundaries have been finalized on the air photos, they must be transferred to a planimetrically reliable base on which zone areas can be measured. Rugged topography causes distortion in air photos, which are taken at relatively low elevations. The side of a mountain facing towards the airplane appears larger than it really is on ground, while the mountainside facing partially away looks much smaller than it really is. This distortion makes accurate area measurement directly from air photographs impossible.

Several methods exist to transfer type lines from air photos to a maps. Consultants with digital image processing equipment can perform this task, but are expensive. Transferring the information "by eye" from the typed air photos to forest cover or topographic maps is possible, but difficult. We have found this method to be time consuming and inaccurate - the level of detail on the target map is often insufficient and long expanses of line must be visually estimated.

Our preferred method is to transferred the type lines by hand to a clear film overlay on an ortho photo or Landsat satellite image color print[2]. The Landsat image is obtained from a satellite in space; the greater altitude of the satellite "photography" largely eliminates the scale distortion problem common to air photos. We have found that areas measured by hand, or lines digitized into a GIS, from a satellite print provide acceptably accurate maps.

The zone boundaries from the air photos can be transferred to the satellite image by using a simple "relation to visible landforms" method. Many terrain features which are visible on the air photos are also visible on a Landsat image. Exposed rock, alder slides, forest type boundaries, stream beds, brushy areas and cut blocks are readily visible on the satellite print. The zone boundaries on the air photos are transferred to the satellite image based on their distance from or congruence with biophysical features common to both images. For example, a zone boundary which extends around the top of an alder slide, through a forested area to a small rock opening, then to the bend in a creek draw on the air photo would be drawn through the same set of points on the Landsat overlay. Using air photos and a satellite image with similar scales makes this process much more efficient.

If a satellite image is not available, the zone types must be hand drawn onto a map for analysis.

Each zone should be color coded by zone type and assigned a unique polygon number as they are transferred to the or satellite image. The unique polygon number is required to identify the zone in the computer data entry, editing, and analysis process.

Final identification of zone boundaries occurs on the ground during planning and implementation of various human activities.

4.8 Summarize And Integrate

The final step in an analysis is to prepare a report on the results of the analysis.

Important questions to be answered include:

1. What is the area of each zone type in the landscape?
2. What proportion of the conventional timber landbase, as defined by the Ministry of Forests, is within the protected landbase? Within wholistic timber zones?
3. What types of land (ecologically sensitive, riparian ecosystems, wholistic timber zones, etc.) are included within the protected landscape network?
4. What is the impact on various forest users, including the timber industry, of establishing these protected areas?
5. Are there viable alternatives? If several alternatives exist, they should be identified, and put forth in an options report.

Completing a landscape planning process in the office is only a first step towards establishing ecologically responsible forest use in a landscape. The plan must be reviewed by all affected parties, disputes must be resolved, and improvements and amendments incorporated. Landscape planning is only a part of a larger community based planning process advocated by Silva, but it is a critical, fundamental part of the process. Landscape planning aims to protect, maintain, and restore (where necessary) fully functioning forest ecosystems during and after human use of the forest. Only if we protect the ecosystem can we achieve sustainable forest use. Plans based on lesser standards at best provide the illusion of short-term sustainability and are, over the long term, likely non-sustainable.

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[1] Further information on Old Growth Forest Ecology can also be obtained in the *Old Growth Literature Review* which can be downloaded from the Silva Forest Foundation Web site

[2] May 1996: Since this document was written, the price of satellite images in Canada has increased by 300% or more. Transfer to maps by hand, or paying a geomatics consultant to transfer the information, may be a more cost effective option.