# Natural Heritage Gap Analysis Methodologies Used by the Ontario Ministry of Natural Resources*

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## Preamble:

The following draft of a paper dealing with gap analysis methodologies used by the Ontario Ministry of Natural Resources for life science and earth science features was the version of this paper available to authors of other papers in this volume (e.g., Nudds et al., Riley). For the sake of context and reference, it was felt by the editors that this version of the gap analysis paper should be published in these proceedings. It should be noted that it is the intent of OMNR to publish a more complete and revised version of this paper as a technical bulletin in the near future. The methodologies will remain relatively unchanged, since these were the methodologies used to identify core representative areas in the "Lands for Life" planning project, but the sections on limitations and assumptions will be greatly enhanced. [December 2, 1998]

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## Intoduction

The goal of the Natural Heritage Areas Program is *"to establish a system of protected natural heritage areas, representing the full spectrum of the province's natural features and ecosystems"* (OMNR, 1997). For life science features, this is accomplished on a Site District basis, through an assessment of the landform/vegetation complexes in that Site District, and the selection of the set of areas that best meets a set of five selection criteria. For earth science features, the goal is accomplished through the development of environmental themes identified by the record of Earth history in the rocks, landforms and geological processes, both past and present, of Ontario. The best representatives of the life science and earth science features are denoted as provincially significant. Protective zoning designations in Provincial Parks (Wilderness, Nature Reserve, and Natural Environment zones), Conservation Reserves, and Areas of Natural and Scientific Interest (ANSIs), taken together, provide the mechanisms by which the natural heritage features of each Site District or earth science theme are represented and protected. The focus in site selection is on the best representation of the natural diversity of the Site District or earth science theme. In the case of life science values, both living and non-living components must be assessed; hence, the setting of representation targets is based on combinations of landforms and vegetation.

Gap analysis, in the conservation biology context, refers to an approach (or a set of methodologies) for setting and filling natural heritage targets. It facilitates the identification of features that are un-represented or under-represented within a natural heritage areas system. Different approaches have been used in different jurisdictions, but the underlying premise is common to all approaches: natural

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heritage features are assessed to determine whether or not some of those features require conservation.

The primary objective of life science gap analysis is the identification of the best representative areas that together contain the full array of natural landform/vegetation associations of a Site District. The selection of the representative areas must be conducted using as rigorous and objective an approach as is possible with qualitative or semi-quantitative site selection criteria. The purpose of this document is to outline the current gap analysis methodologies employed in Ontario, and to outline the application of the five site selection criteria.

While being cognizant of the current debates in the conservation biology community with regard to biological integrity, the selection of areas must be accomplished within the scope of existing policies and principles. The methodologies described here serve to identify core representative areas only, in as efficient a manner as possible. Resource management activities on the intervening lands must be conducted in a manner that does not compromise the values of these core areas, thereby contributing to the ecological sustainability of these core areas as well as of the landbase as a whole.

The objective of selecting the best representative sites carries with it the need to identify parts of the landscape that have been subject to limited recent human disturbance. The objective of identifying the best remaining examples of each landform/vegetation complex in a Site District means that, on occasion, relatively small remnants will be identified, although in other cases, large aggregations or assemblages of features will occur together. No assumptions about minimum size requirements have been applied *a priori.* Rather, the methodologies focus on the identification of the best examples of what exists. Restoration of areas, and other conservation biology objectives, potentially could be added to the system at some later date, if deemed necessary, but to avoid arbitrariness in site selection, the search for sites begins with the undisturbed and least disturbed areas.

## Life Science Gap Analysis

Most gap analysis projects that have been conducted in various parts of the world have focused on life science features, and in particular, species and habitat representation. Almost all jurisdictions applying gap analysis have used a broad landform template, and some have superimposed habitat or vegetation onto the landform template. Most of the variation in approach occurs in the template on which natural heritage features will be assessed (landforms, soils, vegetation types, species, geographic units, etc.), in the resolution of the targets, and in the determination of adequacy of present conservation of the natural heritage values. The approach used by the OMNR is outlined below. Basically, the life science gap analysis method consists of four steps:

1. Coarse filter - landform units (enduring features)
2. Fine filter - vegetation response to landform
3. Assessment of existing representation
4. Identification of areas to fill the gaps.

### *General Approach for Life Science Gap Analysis*

OMNR's gap analysis method consists of four steps:

- Identifying landform features
- Identifying vegetation features on each landform unit
- Assessing existing representation
- Identifying the gaps

*Step 1*: *Coarse filter - landform units (enduring features)*
For the ecological district being studied (in Ontario, the Site District is the unit of study), available landform maps are examined. Surficial geology, bedrock geology, and combinations of these themes, can be used to delineate the landform patterns of the district. Mapping at a scale of 1:250000 is suitable for analysis at the Site District scale. Sources such as the biophysiographic mapping produced by Noble (e.g., 1982, 1983) have been used in central Ontario. They were produced through interpretation of surficial geology, the biophysiographic units essentially consisting of aggregations and/or refinements of Ontario Land Inventory (OLI) units, taking account of mode of deposition, major and minor overburden, and raggedness or irregularity of the terrain. These maps are similar conceptually to the physiographic mapping produced by Chapman and Putnam for southern Ontario (1984), although produced at a somewhat finer scale.

All landform units within the Site District are tabulated in this first step of the method. The finest level of resolution in Noble's biophysiographic unit classification system is used (i.e., Ia-1 and la-4 are considered to be different biophysiographic (landform units).

OLI units may also be suitable for use at this stage of the analysis, but may require some preliminary aggregation of units, to make them comparable to Noble's units. All landform units recognizable at 1:250000 scale within the study area are tabulated and mapped in this step. Other alternative landform systems could include Chapman and Putnam's system for the south, a combination of the bedrock geology and surficial geology coverages produced by the Ontario Geological Survey, or the Northern Ontario Engineering Geology Terrain Study (NOEGTS) coverage in the north. However, some of these coverages are at a coarser scale than OLI or Noble's coverages, and less preferable.

*Step 2: Fine filter - vegetation response to landform*
Using available databases, reports, and literature, the natural vegetation types known to occur within the Site District are summarized, and are correlated with the landforms examined in Step 1. This may be accomplished by manual overlays of the landform units with vegetation mapping [e.g., Forest Resource Inventory (FRI) maps or classified LANDSAT imagery]. However, ideally, gap analysis should be conducted in a Geographic Information System (GIS) environment, where large data sets can be overlaid, analyzed and summarized much more efficiently. In section 2.5 of this document, a step-wise analytical procedure is described for the completion of gap analysis in a GIS environment.

Overlaying the landforms and vegetation types results in tabular and cartographic outputs for each landform/vegetation unit created within the study area. Summary statistics for each vegetation type and age class on each landform unit will be produced in matrix form.

In all cases involving the use of FRI data as the vegetation coverage, the codes representing rock outcrops, lakes, and wetland types will serve as a coarse classification system for non-forest vegetation types.

*Step 3: Assessing existing representation*
Examination of landform/vegetation complexes in existing protected areas [including protective zones within Provincial Parks (e.g., Wilderness, Nature Reserve, Natural Environment), National Parks, and other land designations (ANSIs, Conservation Reserves, etc.) is undertaken to determine which landform/vegetation features are currently protected. Only those areas regulated specifically for natural heritage protection are factored in to the assessment of existing representation.

The landform/vegetation features occurring within existing protected areas are compared with the landform/vegetation features found in the Site District as a whole (Step 2, above). The comparison of existing and expected vegetation types, for each landform, yields the representation targets, and identifies the gaps that still require representation in the natural heritage areas system. In the GIS version of gap analysis, guidelines are applied to ensure that features contained within inappropriate park classes or zones are not considered to be represented. These guidelines do not address the question of adequacy of representation, but simply provide a means of excluding features from Recreation and Historical Parks that might otherwise be factored into the existing representation calculations. In the manual version of the method, these classes of parks would be ignored when considering existing protection.

*Step 4: Filling the gaps*
Landform/vegetation features that are not yet represented in the natural heritage areas system serve as the focus for the search for new areas to fill those gaps. The focus of the method is to identify suitable sites to fill the representation gaps. Selection criteria for new sites conform to those used in existing MNR natural heritage programs (Parks systems planning, ANSI program). These include: representation (the basis for gap analysis, including broad age-class representation of forest types), diversity (the number of different vegetation or landform/vegetation features within a given area), condition (the degree to which anthropogenic disturbance has occurred), ecological considerations (e.g., local hydrological/watershed functions), and special features (presence of populations of vulnerable, threatened, and endangered species, localized or unusual features). The application of these five selection criteria allows for the assignment of relative significance levels to each example of the un-represented features (e.g., provincial, regional, or local significance), taking into account the surrounding landscape (other adjacent un-represented features, nearby special features, hydrological characteristics, etc.).

FRI or LANDSAT databases and landform maps serve as the background in which the search for un-represented features occurs. Previous disturbance of the landbase by human influences (logging, mining, road-building, hydro development, agriculture, settlement) reduces the value of certain portions of the landbase for the achievement of natural heritage representation targets. Thus, such disturbances are taken into account in the search for areas to represent required features. MNR District/Area Offices should be canvassed for cut-over maps and other information relevant to the determination of impacts on the landbase

The entire Site District is scanned for potential representative areas. On each landform (biophysiographic) unit, each area that is still relatively intact, in the sense that it does not contain extensive cut-overs, road networks, or other developments, is compared with respect to the forest types (working groups) that it contains. An assessment of diversity within a block is made on the basis of the number of working groups, since no other site-specific measures of diversity generally are available. Other parameters relevant to the five selection criteria also are assessed, including juxtaposition with high-quality (relatively undisturbed) blocks of other landforms or existing protected areas, size, and special features. In the case of special features, since very little information is available on these, the criterion often cannot be applied with any rigor, but when information is available, it should be used.

The final result of the gap analysis will be a set of provincially significant areas that, taken together, provide the best representation of the array of landform/vegetation associations known to occur in the Site District. It will also identify additional sites that fulfil all or some of the selection criteria, but that are not deemed to be the best representatives. These sites would be assigned lower levels of significance (regionally or locally significant).

### *Site Selection Criteria*

Five site selection criteria are employed to assist in the determination and delineation of provincially significant sites. These are: 1) representation, 2) condition, 3) diversity, 4) ecological considerations, and 5) special features.

*1) Representation*

The most important selection criterion is representation, since the entire natural heritage areas system is based on the principle that the areas containing the best representatives of each landform/vegetation complex are to be conserved. If an area does not contain a high-quality example of at least one landform/vegetation feature, then it should not be considered further, in this context. However, determination of the best representative examples may require comparisons among several potential alternatives, and this is where the additional selection criteria become necessary.

Ontario's approach to life science gap analysis can be considered to be a 'feature-representation' approach. An alternative view of representation, that of proportional representation of landscape features, is not applied in the OMNR's methodology. Firstly, this concept is inconsistent with the existing systematic approach for identifying natural heritage areas in Ontario. Secondly, the determination of an appropriate percentage of any given feature to be represented in a system is an arbitrary process. Thirdly, a given percentage may prove to be more than adequate for some features, and inadequate for others. Thus, a method that attempts to represent the best examples of all features is more likely to capture the full array of values than the application of a percentage target. The application of a standard percentage ignores the reality that some landscapes are more diverse than others, and that the land use history differs among landscapes or landform units. As Harris (1984, p. 109) notes "... *the* *question of how much is enough can only be fairly addressed in the context of surrounding forest conditions."*

*2) Condition*

In the gap analysis method described above, the landbase under consideration for contribution to representation is screened by considering existing and past land uses (but not proposed future uses), including cut-overs, road networks, mining areas, and other unnatural corridors (hydrolines, railways, etc.). In effect, condition, or the degree of anthropogenic disturbance, has already been used as a selection criterion at this point. Potential sites for consideration as natural heritage areas are screened early in the selection process for their relative condition or quality.

Sites that remain under consideration after this criterion has been applied must then be compared using the remaining three criteria. Because there is often a lack of information about special features (populations of rare, threatened, or endangered species, unusual or localized geological features or habitats, etc.), especially on the Precambrian Shield, the special features criterion is best used as a supplementary or supportive one. Thus, all else being equal with regard to representation and condition, the diversity and ecological considerations criteria can be used to determine which of several sites should be regarded as the best site for a given feature or set of features.

*3) Diversity*

A site is considered to be more diverse than another if it contains more high-quality, representative features. Diversity can be achieved at several scales. However, in a landscape (Site District)-scale gap analysis, assessments of diversity should be made at the landform and vegetation community scales, rather than at the species scale. In most cases, species richness is unknown in these sites anyway. Thus, a site that straddles several landform units will be more diverse than a site that is entirely confined to one unit. If the sites being compared are all situated on a single unit, then, again all else being equal, the site with the greatest range of vegetation types would be preferred. If information sources permit (e.g., FRI data), age-classes within vegetation types also are considered in the assessment of relative diversity. This should be done with broad age-class ranges (young, medium, old), defined for each forest vegetation type (classed as working groups in the FRI database) [see Table 1 ].

Unfortunately, most databases available for use in life science gap analysis in Ontario do not do an adequate job of classifying non-forested vegetation types. Nevertheless, an attempt should also be made to consider rock outcrops, shorelines, non-treed wetlands and other non-forested vegetation types in the assessment of diversity, even if only broad categories and presence/absence can be determined.

*4) Ecological Considerations*

Ecological considerations relate to such attributes as hydrological function, and connectivity (aquatic and terrestrial). An area that provides connections with other nearby significant areas, or an area that contains headwater lakes, ponds, springs, or streams, will fulfil this criterion. Other limiting components of habitat, such as important moose aquatic feeding areas, bat hibernacula, spawning beds, etc., could also fulfil this criterion.

These features are used to refine boundaries where they occur in close proximity to the core representative areas.

*5) Special Features*
Special features include populations of rare, threatened, or endangered species, and unusual or localized geological features or habitats. Some parts of Ontario are extremely rich in such information (e.g., southwestern Ontario). However, in other areas, there is a lack of information. This lack of information may be due to difficulty of access or limited survey effort, rather than an actual absence of these features. Therefore, this criterion is best used in a supplementary or supportive role. Areas should not necessarily be penalized or downgraded if they lack special features, unless areas against which they are being compared do contain known special features.

### *Assumptions*
The life science gap analysis described here requires several assumptions:

- due to limitations of data sets (see sect. 2.4) assumptions about non-forested vegetation types are required (rock outcrops, wetland types, meadows, etc.);
- least disturbed is best;
- disturbed areas generally excluded from site boundaries;
- intervening land management; and,
- intervening land provides ecological functions which reduce 'island' effect.

### *Limitations*
Two data sets have potential applicability for the vegetation component of life science gap analysis. These are classified LANDSAT TM imagery, and the Forest Resource Inventory (FRI). Each has advantages and disadvantages. The current classified LANDSAT data set does not provide adequate resolution of most vegetation types. For example, it is not possible to distinguish between spruces, or between intolerant hardwoods, nor is it possible to distinguish between ecotypes of a particular species (e.g., upland versus lowland Black Spruce). This is possible to some degree with FRI, by examining the stand composition, and understanding the ecological preferences of the species associated with Black Spruce. Both LANDSAT and FRI data sets do not classify non-forested lands adequately. However, the FRI does contain general categories for rock outcrops and various lake and wetland types. Thus, it is necessary to make some assumptions about non-forested vegetation communities that may be included within the sites recommended for protection in gap analyses using these data sources.

Ideally, gap analysis should be conducted with proper spatial analytical tools, such as a Geographic Information System (GIS). Manual analysis of data sets is possible, and has been employed in the absence of the necessary digital data sets, but it is extremely time-consuming and inefficient. However, even with GIS, the size of some of the data sets to be analyzed, especially for the larger Site Districts, can stretch the capabilities of the existing technology.

Up-to-date forest history data (cut-overs, roads, etc.) often exist only in paper (not in digital) form, although some data are available in the LANDSAT and FRI data sets. Often, it is necessary to update disturbance coverages by digitizing the newer information, and by vetting the results of gap analyses with knowledgeable staff from the district and area offices. It may be necessary to revise the boundaries of proposed protected areas in the light of these additional disturbance data.

It is also possible that boundary revisions may be warranted at such time as site-specif'lc inventories are conducted, or as information becomes available, either from staff or from members of the public who may visit these sites.

Since gap analysis is extensive, dealing with large land bases, field inventories likely will be limited. However, the results of gap analyses will always benefit from field visits to the sites, even if these occur at some time after the analyses are completed, for the purposes of confirming the results, providing additional details on the vegetation communities of the sites (particularly with regard to understorey species and non-forested communities), refining boundaries, and acquiring data on special features.

Most of the information on populations of rare, threatened, or endangered species is found in OMNR files, and most of it relates to a few "featured species", such as Bald Eagle. Virtually nothing is known of the botany of large portions of the province.

Additional Limitations:

- roads layer limitations
- parks layer limitations

### *Step-wise Methodology for Life Science Gap Analysis*

This section outlines an algorithm for data analysis which will lead to the identification of the best representative core areas that, taken together, will contain the full set of landform/vegetation features found in a given Site District.

*Part 1: Assessment of unrepresented features, and options for filling gaps:*

- For each Site District, overlay landform and vegetation layers
- Summarize proportions and amounts of each landform unit within the Site District (output = table);
- Summarize proportions and amounts of each FRI Working Group by three broad age classes, as per specifications, on each landform unit (output = table); each Working Group age class equals a vegetation type;
- Overlay existing Protected Areas layer
- Summarize proportions and amounts of landform/vegetation types for existing protected areas (output = table)
- Subtract landform/vegetation types found in protected areas from total set of landform/vegetation types in Site District; produce table of unprotected types

Rules for determining minimum levels of representation in protected areas:

1. At least 50 ha of any landform/vegetation feature must be contained within a protected area in order to be considered represented, at this stage in the analysis
2. At least 1% of each landform/vegetation feature must be represented contained within protected areas in order to be considered represented, at this stage in the analysis

- Overlay disturbance layers for Site District
- Remove disturbed areas from Site District land base
- Identify all areas having unprotected landform/vegetation types (polygons), subject to the minimum adequacy rules applied above
- If there are landform/vegetation types within the Site District that do not occur in undisturbed areas, re-examine the disturbed landbase for those types; examination of the disturbed areas may occur in a step-wise manner until suitable polygons are found
- Delineate clusters of contiguous unprotected landform/vegetation polygons, including single polygons
- Tabulate and sum the number of polygon types in each cluster; produce a table summarizing the numbers, types and sizes of polygons for each cluster
- Overlay Special Features data, where available, for the Site District
- Produce a map of clusters, using the above layers, including labels in hard copy and digital formats, and categorize the clusters on the map according to the number of un-represented features contained in them - the digital file will be the plot file used to create the hard copy map

*Part 2: Identification of "best" representative areas*

Using an iterative approach, identify those clusters that, together, best represent the features not yet represented in protected areas within the Site District. This will be accomplished by searching for the clusters that contain the most un-represented landform/ vegetation features, subject to the minimum representation rules noted above.

- Select the cluster identified in Part 1 that contains the most un-represented landform/ vegetation features, subject to the minimum representation rules used above (50 ha and 1%);
- subtract the features contained therein from the list of un-represented features in the Site District;
- Select the next cluster identified in Part 1 that contains the most un-represented landform/ vegetation features from the revised list, subject to the minimum representation rules used above (50 ha and 1 %);
- subtract the features contained therein from the revised list of un-represented features in the Site District;
- Continue this iterative analysis until all landform/ vegetation features are represented in a set of areas.
- Re-do the above iterative analysis, using the clusters that contain the second largest set of un-represented features, assuming that the sites containing the most un-represented features cannot be protected (development of planning scenarios)
- Re-do the above analysis, using the clusters that contain the third largest set of un-represented features (these three levels of diversity would correspond roughly to Provincially, Regionally, and Locally significant sites).

# Earth Science Gap Analysis

### *Introduction*

The earth sciences encompass a range of interconnected but quite distinct subdisciplines which together help to explain how the Earth formed and changed through time, at depth and at the surface. Earth heritage conservation is concerned with the maintenance of landforms, natural and artificial exposures of rocks, and sites where geological processes can be seen in action today.

The primary objective of the earth science gap analysis process is the identification of the representative features of the province's physical landscape that best define its past and present environments. These environments are interpreted through scientific study of the rock record, the surface morphology of the province, and geologic processes active in the province today.

Geological history as interpreted from observations from rocks, unconsolidated sediments and landforms consists of three fundamental components: time, stratigraphy and environment. Earth science representation thus attempts not only to identify an example of all the known geological features in the province (bedrock units, landforms and geological processes), but to identify the march of time as defined by these geological features (lithostratigraphy, biostratigraphy, morphostratigraphy). *Thus earth science representation requires protection of the elements of the physical makeup of the province, as well as geologic time as defined by complexes of the physical features of the province.*

In the bedrock record, this means finding one best representative example of each lithological unit through the full range of lithological units that we know to occur in the rock record (this is classification by physical feature). It also means identifying examples of each lithological unit as it represents a particular time event or environment within the sequence of events in the geologic time scale (this is classification by time). A similar approach is required for the representation of landforms, which, in Ontario, are predominantly glacial in origin. Representation targets will consist of the identification of the best examples of each landform (and its derivatives) as individual features (i.e., esker, moraine, drumlin, kame, et cetera), as representatives of a process of formation (beneath the glacier, at the ice front, at the edge of a lake, et cetera), and in their significance to the glacial history of the province.

Also required is feature representation tied to geologic events in time within each environmental theme. Representation of the best examples of the major elements of each theme will therefore ensure representation of examples of each type of landform feature, as well as representation of the formation of the landscape through time. This inevitably results in feature duplication.

What constitutes "best", as in the "best example" of a geological feature? By virtue of its location, history, et cetera, each outcrop and landform may be considered unique. Depending on the level of research and study of the geology of a specific region, each unit or feature may have several known, and some or many unknown, exposures or occurrences. Thus the "best example" of a geological element is chosen first from one that is known to occur, and second, one which adequately displays a range of typical characteristics by which the element is recognized. Such a best example is often chosen by the concensus of many geoscientists, as reflected by its use in the literature, in field trip guidebooks and by the academic community. Other best examples will be determined through a literature search and field work by an individual earth science surveyor after he/she has been directed to sites by the above sources.

The geologic record in Ontario has been classified into 43 environmental themes, each of which represents a particular and discrete environment of formation. The elements of each of these themes, that is, the features which serve to characterize the environment which identifies each theme, make up the representational targets of the gap analysis process.

### *The Gap Analysis Process*

Earth science (geological) conservation concerns the protection of selected, representative features of the geological history and its physical expression in a system of protected areas, and the monitoring of the remainder of the physical land base to provide alternate sites for scientific and educational opportunities.

In order to determine what is important to be set aside it is necessary to describe the earth science diversity of the land base and to determine the minimum portion of that diversity that has to be set aside for representation purposes.

The classification of earth science diversity is based on concepts of time, geomorphic form and process. It is essential to represent at least one best example of each geological feature in the province, be it a rock type, fossil locality, landform or geologic process. It is equally essential to represent the changing environments that occurred in the province through geologic time by representing a sample of each individual event exhibited in the rock record or by landforms.

For the purposes of representation, earth science diversity in Ontario is classified into 43 *environmental themes.* Each environmental theme contains the evidence for an event, a sequence of events or a geological process. The features which make up this evidence are referred to as the elements of a theme. Elements might consist of rock types (lithostratigraphy), organic remains (fossil record), rock-time units (formations, members), landforms, landform associations or particular geological processes (active or ancient). The basis of the environmental themes as used in Ontario are broadly defined and described in the *Earth Science Framework* (Davidson 1981).

The scale of representation of the elements of an environmental theme varies considerably. Individual bedrock outcrops may need to be only very small, less than 1 hectare in size. Individual landforms and some process themes need only be a few 10s of hectares in size. Large associations of landforms may require many 100s of hectares to adequately represent the features within them. The representation of active geological processes often encompass large areas, sometimes including the management of areas beyond the process area in order to assure the continued natural functioning of that process.

Earth science classification is not comparable to life science classification systems. However, the cornerstone of biodiversity conservation is the identification and classification of the physical substrate of the land base. With complete representation of the physical diversity of an area comes significant completion of biodiversity targets. In this way, earth science and life science goals are connected.

The methodology of determining the best candidate area for representing the diversity within an environmental theme is called "gap analysis" because it determines what is already represented in a system of protected areas, and the "gaps" that exist in representation of that diversity. The process is normally carried out in two phases: a broad analysis of the possible representational targets of a theme (steps 1-4), and a subsequent detailed inventory of specific features and locales required to complete representation (step 5). These steps are summarized:

- Step 1: Identification of significant elements of a theme;
- Step 2: Distribution mapping of the significant elements;
- Step 3: Existing representation within protected areas;
- Step 4: Identification of gaps of features not in protected areas;
- Step 5: Comparison of selected sites required to fill the gaps.

*Step 1: Identification of significant elements of a theme–Representation targets*
For the selected environmental theme, this step identifies the significant elements that make up the theme. Included in this step is the identification of the complexity of the theme, including the variations that may exist in the significant features. This is done through literature review, discussion with experts and original field work. The suite of elements identified in this step constitute the representation targets of the theme.

*Step 2: Distribution mapping of the significant elements*
The second step requires spatial mapping of all elements of the selected theme. This is done from geology maps, literature review and discussion with experts. The scale and complexity of features that make up each theme is dependant on the state of knowledge about its component geology and distribution. Some environmental themes consist of only a few known occurrences of features, whereas others encompass a large portion of the province and constitute many features.

*Step 3: Existing representation within protected areas:*
The next step is the identification of the elements of the theme that already occur in protected areas (provincial parks, conservation reserves, ANS1s). For an element to be considered represented, it must be provincially significant, and it must be protected by appropriate park class or zoning, or have relative protection outside parks through landowner agreements or the relative stability of non-destructive present land uses. This step involves literature review (especially of earth science inventories of parks and checklists of all other sites), original field work and discussion with experts.

*Step 4: Identification of gaps of features not in protected areas*
Elements of the environmental theme that are not considered already protected constitute the gaps in representation that require filling. In this step, the identification of potential candidate sites where the un-represented elements of the theme are found is conducted. This is done through literature review, discussion with experts and, to some extent, original field work. A gross filtering occurs at this stage to remove sites that have a history of disturbance (primarily

for the glacial, landform and process themes). Disturbance consists of any activity which has altered or removed a feature from its natural state. This stage does not generally apply to bedrock features, which are commonly best displayed in highly altered sites such as road cuts and quarries.

*Step 5: Comparison of selected sites required to fill the gaps:*
A comparison of like elements from the list produced in Step 4 is the next step in the process. The list of priority sites for protection is achieved with the application of a set of six primary criteria which are applied to each site. These criteria are: representation, type sections (including reference sections, type morphologies, type localities), diversity, integrity (condition), life science values and special values. These are described in more detail in the following section of the report. The comparison stage is accomplished through original field work in order that the most up-to-date site conditions (quality, integrity, condition) are recorded.

The end result of the gap analysis process is the selection of a suite of sites that best complete the representation of the selected environmental theme. These are ranked provincially significant within the context of the theme.

The minimum requirement of a system of protected earth science features is to represent the complete suite of elements that define each of the 43 environmental themes in Ontario. This "one of-each" approach represents the minimum "line" required to achieve complete representation. This approach is not ideal in that it fails to provide for unforeseen events which may negatively impact this minimum. It also fails to provide the flexibility needed in a fluid science in which concepts and associated significant sites can change with time. In a large province like Ontario, there is also a need to provide for the protection of sites of regional and local significance for the benefit of scientific study and educational opportunities. These sites also serve as a back-up to the provincially significant sites in case of mishaps. As such, in addition to the provincially significant sites, a suite of regionally and locally significant sites should be identified and protected.

The attached flow chart summarizes the steps discussed in this report.

### *Selection Criteria for Choosing Significant Sites*
The following site selection criteria may be used to assist in the determination and ranking of earth science features. Due to the nature of very different types of earth science features, the application of the criteria will vary on a per site basis.

*Representation*: The primary criterion for choosing earth science features is representation. Representation refers to a feature that best displays its make-up and its condition(s) of formation. A representative feature of the geological record can be thought of as one that is typical, or normal, or one that shows "classical" elements of the feature. In the context of features exposed in bedrock outcrop, representation refers to the best available (or known) examples of each type of lithological unit (rock type) that occurs in a given area, as well as examples of each geological time unit as exhibited in the rock record (chronostratigraphy). In order to achieve chronostratigraphic representation the best example of some units may be less-than-ideal because the only known examples are of poor quality or have been disturbed. In these cases, representation will still be sought in order to satisfy the representation of geologic time in the physical record.

In the landscape perspective, representation is also applied to both the physical form of a selected feature, and the morphostratigraphy (change with time) of a theme. Representation of the physical form of a feature should best display an "ideal" morphology or the best example of the deviation from the "ideal" form. Morphostratigraphy refers to representation of like features as they relate to events and time through the geologic record (e.g., an ice retreat phase of a glacial theme will produce similar features at several stages in its history; all of these may require representation).

Representation also refers to the range of features that identifies a geologic event or process, both active today and in the rock and landform record through time. It seeks to identify the best example of each element of the 8 landform/process themes that are considered essential to its identification.

*Type Sections:* Type sections provide standard definitions for all representative lithostratigraphic and biostratigraphic units. In simple terms, type sections represent the sites where rock units were first identified, described and formally named. They are the localities against which all other occurrences of the unit are generally compared. Type sections are generally of the highest scientific value, and may also have historical value as locations where the geology of a region was first described and ranked. In Ontario, type sections are only applied to stratified rocks with sedimentary and volcanic layers which have been only slightly altered by metamorphism.

Related features such as reference sections and type localities represent units for which a type section has yet to be defined. This situation is common in central Ontario, where type sections have not been formalized for most of the Paleozoic stratigraphy of Manitoulin Island (most correlative units have type sections described on the Ontario mainland), or for the sedimentary units of the Huronian Supergroup. Reference sections may also be identified to supplement the type section by representing some variation or additional feature(s) of the original.

The primary elements of the surficial geology of a region are defined by its stratigraphic makeup (morphostratigraphy) and type and pattern of landforms (type morphology). These have not been used in either a formal or consistent manner. In Ontario, and particularly in central Ontario, these classifications are not well developed, and are not used to define representational values.

*Diversity*: A feature or site that incorporates more than one element of the identified geologic unit (i.e., an outcrop of a unit formation that exhibits its range of lithologies and its contact relations with adjacent units), or incorporates an association of features (such as a glacial landscape of drumlins, eskers and meltwater channels), usually in an area more compact than several separate areas, will be ranked more favourably than a collection of individual sites.

*Integrity*: Integrity refers to the wholeness or completeness of a geological feature, and the lack of significant external impacts or alteration by natural or man-induced activities on its form. This applies particularly to landforms, where morphological completeness may be required for their adequate definition. Examples of landforms for which complete morphological representation is desirable are usually relatively small and discrete (e.g., drumlins, perched deltas, aeolian dunes, landslides and their ancient scars, et cetera).

Very large landform features require a different approach. Their size generally prohibits representation of a complete feature or association of features. This applies to features with extensive linear elements and those with broad areal extent. Examples of linear geological features include bedrock faults and shear zones, glacial features such as meltwater channels, end moraines, eskers and raised shorelines, and geomorphological elements such as bedrock escarpments and riverine environments. Features with a broad areal extent include bedrock domes, glacial features such as ancient lake plains, dune fields, and outwash plains, and topographic forms such as ancient meteorite impact craters.

The approach taken to representation focuses on the identification of the major elements which make up the large feature, and seeking representation of the best examples of each of these elements. For example, the Cartier Moraine belt across the north shore of Lake Huron consists of a series of mounds and ridges of ice-contact sediment, anchored to bedrock knolls, and associated with shoreline elements of glacial Lake Algonquin, such as now-abandoned (raised) beach terraces on perched deltas. Representation of this complex of features focuses on the identification of the best examples of each of these elements: an irregular mound element of ice-contact debris; a ridge element of ice-contact debris, preferably intact (i.e., identified by topography along natural boundaries); the bedrock component integral to the story of formation of the moraine; and, a perched delta with its associated beach elements. Where several elements occur together, and their form adequately display the mode of formation of the features and their link to the ice stand position marked by the moraine, an area boundary encompassing this association of elements is desirable. Such feature associations are preferred because they exhibit the inter-relationships within a diverse morphology.

The selection of sites with multiple values also has a practical reason. Such sites limit the size of protected area identified, therefore minimizing impacts on competing land uses. This does not constitute a scientific method for determining site quality or significance, but given the political realities of the day, where these associations can be grouped together, a compact site with multiple representation is preferable.

Site integrity is not as important a factor in the representation of bedrock sites. Adequate representation of a particular lithological (bedrock) unit requires a clear face or surface which exhibits all the elements used to define the unit. These may occur in a natural setting, such as on bare bedrock surfaces (the French River mouth area is an excellent example of this) or in cliff face exposures (the Niagara Escarpment is the best example of this). Here, site integrity may be excellent due to the extent of exposure (vertically and horizontally), and constitutes an aesthetic component due to the natural setting.

In many cases, however, bedrock representation occurs in man-made exposures such as highway or road cuts and pits and quarries, where aesthetic qualities are very low, but representational values are high because of the freshness and quality of exposure. In such cases, site integrity is not a consideration of representational rank. Site integrity may in some cases be enhanced by one-time or occasional re-exposure or "freshening" of exposures.

*Life Science Values:* When comparing sites where earth science values are similar, overlapping life science values may be used to choose a site. This approach is generally only relevant to landscape sites (landforms, landform associations and/or process features) which are large enough to support significant vegetative stands or communities. Small sites (outcrop or some landform scale features) generally do not constitute a large enough area to protect most life science values. Smaller geological features can however, form a component of a larger life science site, and would constitute a preferable site choice given equal values elsewhere. The evaluation of overlapping life science values depends on the level of existing life science information or the availability of life science input to site selection.

*Special Features:* Where two or more sites have similar geological values, the presence of special features may determine site selection. Special features may be geological, such as the inclusion of unusual or unique elements of a theme not represented elsewhere. Special features may also constitute less scientific values such as the quality of a feature's setting or the aesthetic values of a site.

Geology, and particularly geomorphology, often determines the overall effect of the landscape on the culture that inhabits it. It may be integral to that culture, be it local, regional or national, and any change in its integrity might have detrimental effects. Where the scientific values are equal, a choice between two or more sites may thus be determined by a natural setting or degree of impact by external forces.

In some cases, the sensitivity of a particular feature(s) to change, from either natural or man-made impacts, may also influence site selection, more sensitive features presenting a higher priority. In addition, features that are more immediately threatened with natural or man-made impacts may also be a higher priority for selection.

*Other Considerations:* Where known occurrences of a particular unit are already included in the system of protected areas, the selection of discrete bedrock and unconsolidated sediment sites (e.g., road-side outcrops, quarries, aggregate pits, et cetera) popular with the geoscience community (i.e., documented in field trip guidebooks), *in addition to the sites identified in protected areas,* may be of importance because they are accessible, known to geologists. and serve to protect significant occurrences for further research and educational values. This duplication has many values, as described earlier.

### *Comparisons with Life Science Representation*

There continues to be confusion about the relationship and differentiation between earth science representation targets and life science representation targets. How does earth science representation compare to life science representation?

Earth science classification systems, based on physical features and, importantly, on time, cannot generally be correlated with the life science classification system, which is based on macroclimate, landforms, microclimate, moisture regime, and substrate (Angus Hills' division of the province into Site Regions and Site Districts, with classification of site conditions within each Site District). Earth science classification is not related at all to present patterns of climate and moisture. This is particularly true of the bedrock geology component of the province.

For example, Precambrian Grenville Province rock types and environments are associated in time and event geologically to a specific area of exposure, in south-central Ontario. The diversity of features which reflect the history of evolution of the Grenville Province can only be found within this specific area of exposure. The geological diversity within the area of exposure of the Grenville Province, and its significance, is not affected at all by the vegetation patterns which occur on its surface, or by the classification schemes devised to arrange that vegetation diversity. Therefore, the distribution of significant earth science sites to represent the Grenville Province geological theme is not affected by life science values. However, the type and aspect of the bedrock substrate may have a significant influence on the composition of the vegetation communities and species that grow on that substrate. Obvious examples are the different effects of carbonate versus granitic substrates on the vegetation communities growing on them.

Although earth science and life science classification schemes are not compatible, there is an interconnectedness between the two disciplines at the landform level. The diversity of earth science features at the Site District level will determine the diversity of life science representation targets for vegetation communities and species. Earth science diversity in a Site District presents the biological environment with a range of temperature, exposure, aspect, moisture regime, substrate types and habitat on which vegetation develops. The land base of an area determines the diversity of the life forms that occupy and characterize that area.

Where all other factors are equal however, it is a goal of the earth science system plan in most cases to combine earth science and life science values in order to achieve biodiversity in which a number of natural values are protected.

A comparison of the gap analysis process and the site selection criteria for earth science representation and life science representation shows that these are very similar in approach.

***Assumptions***

- we know everything geologically about a region
- geological interpretations and definition of significant sites only reflect the current state of knowledge and/or follow current understanding and theories of concepts

***Limitations***

As already mentioned, geological mapping scales and coverage vary wildly across the province. We therefore know a lot about the geology of selected regions and/or geological environments, and hence selected environmental themes, and very little about others. The effect this has on representation targets is that the environmental themes with a good base of knowledge may have a great number of representational targets, whereas those environmental themes about which relatively little is known will have fewer representational targets. It must be understood that as the knowledge base in these under-represented themes improves, with new, more detailed mapping of a region, new representational targets will present themselves, and the number of candidate sites may increase.

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