GapTool: An Analytical Tool for Ecological Monitoring and Conservation Planning

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Abstract

GapTool is an analytical tool that is used to prepare information on ecological representation. It is based on a framework for terrestrial life science representation developed by the Ontario Ministry of Natural Resources (OMNR). This framework helps to ensure that the full range of Ontario's natural diversity is systematically identified and protected. OMNR has chosen to use naturally occurring landform/vegetation associations as surrogates to represent the range of biodiversity in terrestrial ecosystems. Landform/vegetation associations that are not adequately represented within protected areas in an ecodistrict are known as gaps in representation. Ontario Parks has improved the provincial GIS data sets used to assess ecological representation; these include ecodistricts, protected areas, and landform/vegetation associations. GapTool enhances monitoring and reporting by helping to produce up-to-date tabular reports and maps on ecological representation for all of Ontario's 71 ecodistricts and over 600 protected areas. GapTool also serves as a decision support tool for assessing candidate protected areas during systematic conservation planning.

Ecological representation and gap analysis

The concept of ecological representation has developed worldwide over the past quarter century as a method to help conserve biological diversity. Ecological representation is based on the principle that the full range of a region's natural diversity should be systematically identified and protected.

Fundamentally, protected area systems should include representative examples of the known biodiversity within ecologically defined regions. Examples of biodiversity that are not adequately represented within protected areas are known as gaps in representation.

Gap analyses are efforts to identify features that are not sufficiently represented within protected areas. Gap analyses are used to evaluate the degree of protection already in place for aspects of biodiversity, so that conservation efforts can be focused on species or communities with the greatest need.

Elements of biodiversity with lower levels of existing protection generally merit higher priority for conservation efforts.

Varying approaches to gap analysis have been used in different jurisdictions, but the underlying premise is common to all approaches: natural heritage features are assessed to determine whether or not some of those features require conservation.

GapTool is an analytical tool to help prepare information on ecological representation, including gaps in representation. It is based on a framework for terrestrial life science representation developed by the Ontario Ministry of Natural Resources (OMNR).

Criteria for Selecting and Designing Protected Areas

As outlined in *Nature's Best* (OMNR, 1997), it is an MNR natural heritage objective "to identify, evaluate and select areas that embody the provincially significant geological, aquatic and terrestrial diversity of the Province." OMNR seeks to include the "best" examples that represent the diversity of its natural and cultural features within its system of protected areas.

For more than 30 years, OMNR has used these five criteria to identify, select, design, and assess proposed protected areas:

1. Representation of terrestrial life science, aquatic life science, and earth science features;
2. Condition, in terms of freedom from anthropogenic modifications;
3. Diversity, or heterogeneity of landscape components and species within a proposed site. Sites with greater variety of physical habitats tend to support a wider array of biodiversity because of the range of habitat conditions they provide;
4. Ecological functions, in regard to the ecological role of a proposed site within the broader context of the surrounding landscape and watershed. This is assessed primarily in terms of hydrological functions, size, shape, connectivity with other protected areas, ecologically defined boundaries, limiting habitat components for species not at risk, and successional processes as indicated through features such as old growth forest; and,
5. Special features, primarily populations of species and vegetation communities known to be rare in Ontario, and localized features important to their persistence.

The first criterion, representation, is the backbone of the approach. The other four criteria are used to help identify the "best" examples of representative features, and help design functional protected area systems that promote the persistence of biodiversity (such as through well designed protected area boundaries). The best examples of representative natural features in Ontario are considered to be provincially significant, and many are also nationally or internationally significant (OMNR, 1997). The next best examples are

considered to be regionally significant.

These five selection criteria were developed for the purposes of protected area systems planning in the 1970s. They were applied in the preparation of Site District Reports, in which many of Ontario's Areas of Natural and Scientific Interest (ANSIs) were identified. They were also used in establishing priority areas for protection in District Land Use Guidelines. During the 1980s and 1990s, the approach was used in identifying protection priorities for old growth red and white pine forest, and in the Megisan Lake Environmental Assessment. In the 1990s, the selection criteria were used in Lands for Life, a major Crown land use planning initiative that included the identification of 379 protected areas encompassing some 2.4 million hectares across much of central and northern Ontario. Most of these sites have since been regulated as provincial parks and conservation reserves.

Although the five selection criteria are long established, their application is quite flexible and has continually evolved to reflect changes in available information and technologies.

Ontario's Approach to Ecological Representation

As noted, representation is foremost among the five selection criteria used to identify possible additions to Ontario's system of protected areas.

OMNR has prepared individual frameworks to help identify representative examples of earth science, life science, and cultural heritage features. Each of these frameworks forms a distinct, but complementary stream with unique representation requirements. They do not necessarily capture the same features (Davis and McCalden, 2004).

Geological (earth science) representation provides the basis for protecting selected examples of Ontario's geological history and its physical expression on the landscape. Cultural heritage representation provides the basis for evaluating and protecting archaeological and historical features of Ontario's human history. Ecological (life science) representation provides the basis for protecting a range of examples of Ontario's biological diversity.

These frameworks have been developed through the provincial parks program, and are also applied to conservation reserves. Like national and provincial parks, some conservation reserves contain natural heritage values that are of provincial, national, and international significance.

Since no jurisdiction has completely catalogued its biological diversity, various surrogates are used to represent the range of biodiversity. Depending on the purpose of the analysis, the jurisdiction involved, and the information available, these surrogates can include: physiographic features such as waterbodies, soil types and landforms; biotic features such as vegetation communities and rare species occurrences; or some combination. Some approaches also incorporate

protected area design considerations such as size and connectivity.

Prior to the 1990s, OMNR used landforms as broad surrogates for biodiversity. In the 1990s, OMNR expanded the concept by incorporating vegetation variability on landforms as a more complete basis for assessing terrestrial diversity on the landscape (OMNR, 1997). Thus naturally occurring landform/vegetation associations serve as surrogates to represent the range of biodiversity in terrestrial ecosystems. This concept incorporates surficial geology landforms as coarse elements of the physical environment, local biotic elements (vegetation associations) as finer filters.

OMNR's minimum requirements are to represent at least 1% or 50 hectares of each naturally-occurring landform/vegetation association within each of Ontario's 71 ecodistricts. These are minimum requirements, and do not imply adequacy of representation (Crins and Kor, 2000). Landform/vegetation (L/V) associations that are not protected to these minimum requirements are considered representation gaps.

The GIS process used to identify life science representation gaps and assess potential new protected areas has been automated with the development of an application called *GapTool*.

The *GapTool* application

Prior to the mid 1990s, OMNR conducted life science gap analysis using hard copy maps, reports, and aerial photographs. With the advent of geographic information systems (GIS) and the landform/vegetation approach, MNR began using GIS functions and digital data sets to assess ecological representation. Even with GIS tools, however, the process of preparing suitable data sets and conducting a gap analysis was a time-consuming procedure. An analysis for a single ecodistrict could easily take a week to complete, and consistency of approach was often an issue.

The need for timely gap analyses continued to increase, primarily to support land use planning initiatives that involve potential protected areas, and to assess Ontario Parks' progress in establishing protected areas to help represent and conserve biodiversity. In 2004, Ontario Parks decided to develop tools to help automate the procedure.

A needs analysis was conducted to define what users would require in an analytical gap analysis tool, and identify technical options to building such a tool. Based on this needs analysis, the tool was developed during 2005.

From a technical perspective, *GapTool* is an ArcGIS extension programmed in *ArcObjects* and *Visual Basic*. The application is launched from a button within *ArcMap*, and has a graphical user interface with dialogue boxes that help guide users through a gap analysis. A users guide has been prepared (Davis, 2006) and training workshops are sometimes provided.

GapTool produces formatted tabular reports and maps at two levels: the ecodistrict level, and the individual protected area level. The maps are produced in PDF and GIS shapefile format.

Three representation maps are produced at the ecodistrict level. All three of these maps show the locations of L/V associations for which the minimum representation requirements have not been met, whether they occur within or outside of protected areas. The three maps differ in one respect: the shading of these under-represented L/V associations.

The landform/vegetation representation map is the simplest "gap map". Figure 1 provides an example. This map shows the locations of under-represented landform/vegetation features (representation gaps) for Ecodistrict 3W-2 (Savanne) in Northwestern Ontario.

The other two ecodistrict-level maps highlight the same under-represented features, but colour them according to certain criteria. In the "achievement" map, under-represented L/V associations are shaded to signify the degree to which the minimum representation requirements are met for that feature. In the "rarity" map, under-represented L/V associations are shaded to signify the relative rarity of that feature within the ecodistrict. These two maps are useful in focusing conservation efforts. For example, under-represented features that are relatively rare and are poorly represented in protected areas should generally be a focus of conservation planning efforts if opportunities arise.

When viewing a representation map, it is important to recognize that only a portion of the under-represented L/V associations need to be protected in order to meet the minimum representation requirements. Under-represented natural features may be used as building blocks to guide the placement of any potential new protected areas.

Associated data sets

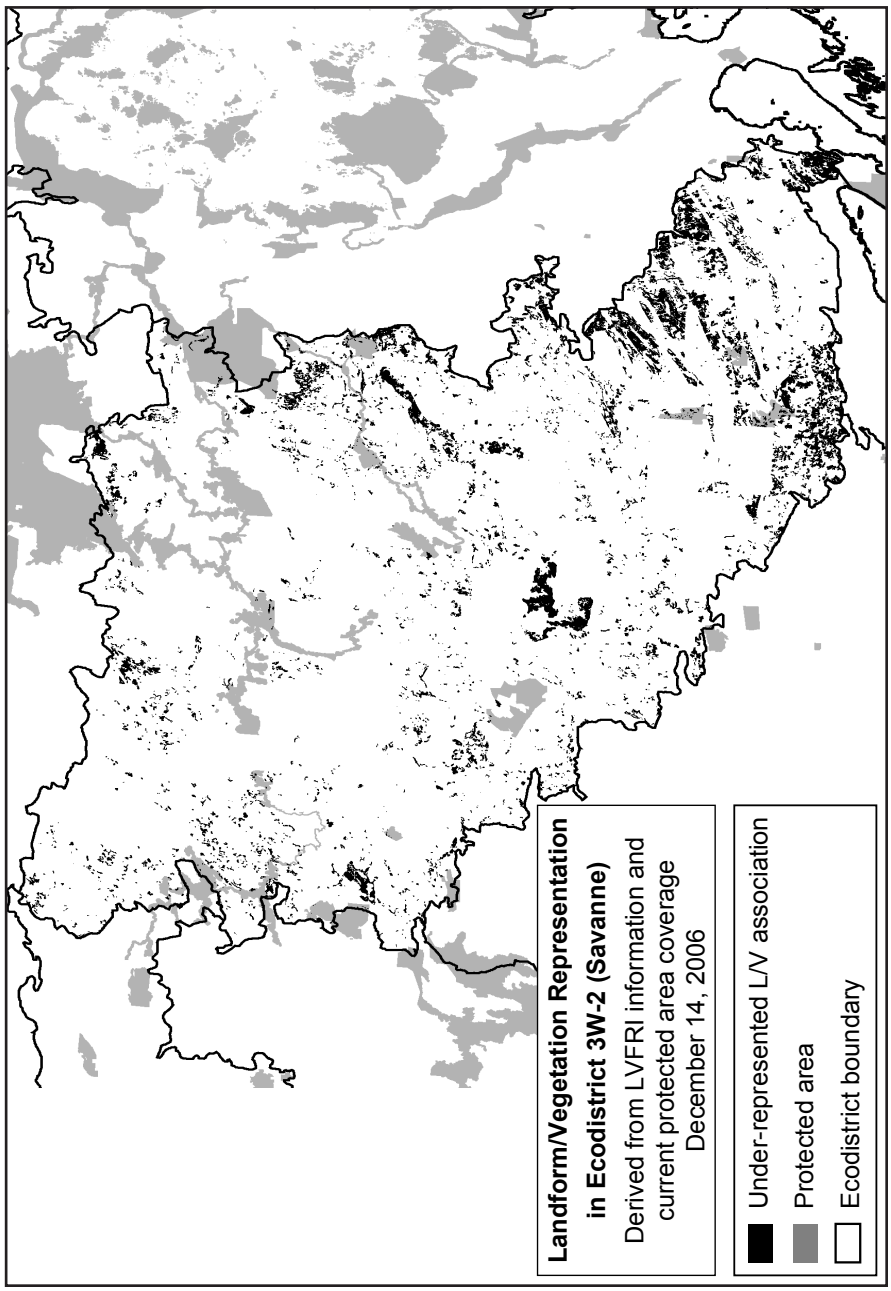
GapTool relies upon several GIS data sets to assess ecological representation; these include ecodistricts, protected areas, and landform/vegetation associations. Ontario Parks has centralized and improved the quality assurance of these provincial data sets, thus making gap analyses more reliable.

In 2005 and 2006, OMNR prepared improved provincial data sets of landform/vegetation associations. These composite data sets incorporate the best information in various regions of Ontario.

Landforms are based on the best available surficial geology data sets in various regions of Ontario: NOEGTS (Northern Ontario Engineering Geology Terrain Study), Ontario Geological Survey maps of Quaternary geology, and Surficial Geology for Southern Ontario. Ontario Parks geologists and ecologists developed a consistent provincial legend of 20 landforms. Using GIS queries, these three data sets were reclassified into this consistent provincial legend.

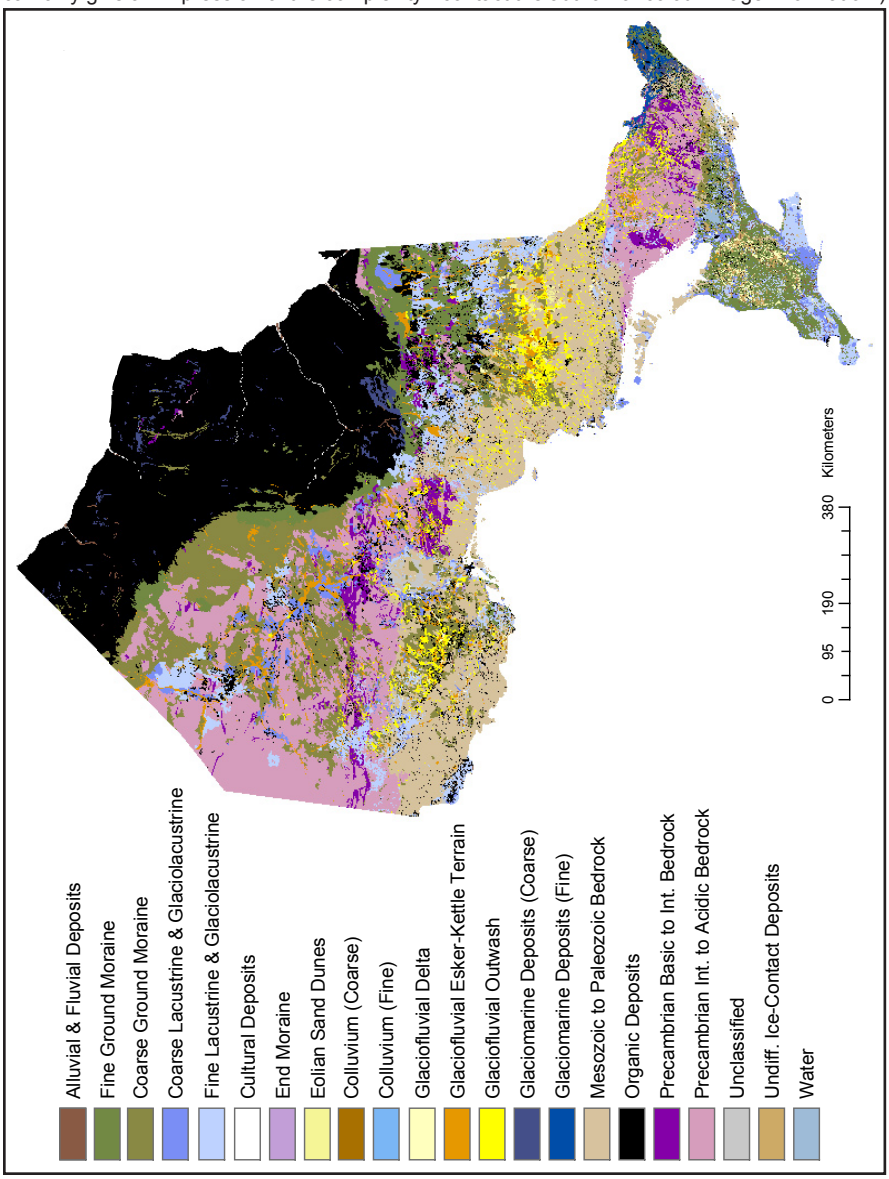
Figure 2 shows the resulting landform data, which is incorporated in the provincial L/V data sets. Three of these landforms – cultural deposits, water, and unclassified – are usually omitted from gap analyses.

Figure 1. Under-represented landform/vegetation associations in Ecodistrict 3W-2 (Savanne)



Vegetation information is derived from Forest Resources Inventory (FRI) mapping where it is available – about 24 of Ontario's 71 ecodistricts. A legend of vegetation classes was developed based primarily on the tree species composition of forest stands. Ecologists used a statistical technique known as hierarchical cluster analysis (Ward's agglomeration method) to identify clusters

Figure 2. Map of Ontario illustrating the complexity of landforms incorporated in provincial landform/vegetation data sets (This greyscale image can only give an impression of the complexity - contact the author for colour image/information.)



of stands with similar tree species composition. Non-forested areas were retained as classified in the FRI. Of the resulting 48 classes, three – open water, developed agricultural land, unclassified, and recent cutovers – are usually omitted from gap analyses.

Since FRI mapping is not available for all of Ontario, OMNR prepared a second data set with vegetation based on the best available land cover information prepared from remote sensing imagery. For all of Ontario except southern Ontario (Ecoregions 6E and 7E), the best available information is called Land Cover 2000. For southern Ontario, the data set incorporates Greenbelt remote sensing imagery where it is available, and an older data set called Land Cover 28 elsewhere. The legends used in each of these original data sets were left unchanged. Several land cover classes – pasture, cropland, open water, unclassified, plantations, and recent cutovers – are usually omitted from gap analyses. Figure 3 shows the resulting vegetation data.

By default, *GapTool* is configured to include these types of protected areas in its analyses: national parks, provincial parks, conservation reserves, wilderness areas, and recommended provincial parks and conservation reserves. The boundaries of protected areas change from time to time as sites are recommended, regulated, and revised. Ontario Parks maintains the most recent boundary information on provincial protected areas.

Other protected areas can also be included in gap analyses, provided their boundaries are stored in appropriate GIS format. These capabilities provide considerable flexibility. For example, *GapTool* can be used to:

- include other types of protected areas, such as Areas of Natural and Scientific Interest (ANSIs) or privately owned conservation easements within a gap analysis;
- assess how candidate protected areas would help to meet minimum representation requirements within an ecodistrict; or,
- conduct "what if" analyses based on various suites of potential new protected areas.

The latter type of analysis can be very helpful in informing land use planning decisions.

Reporting on current representation

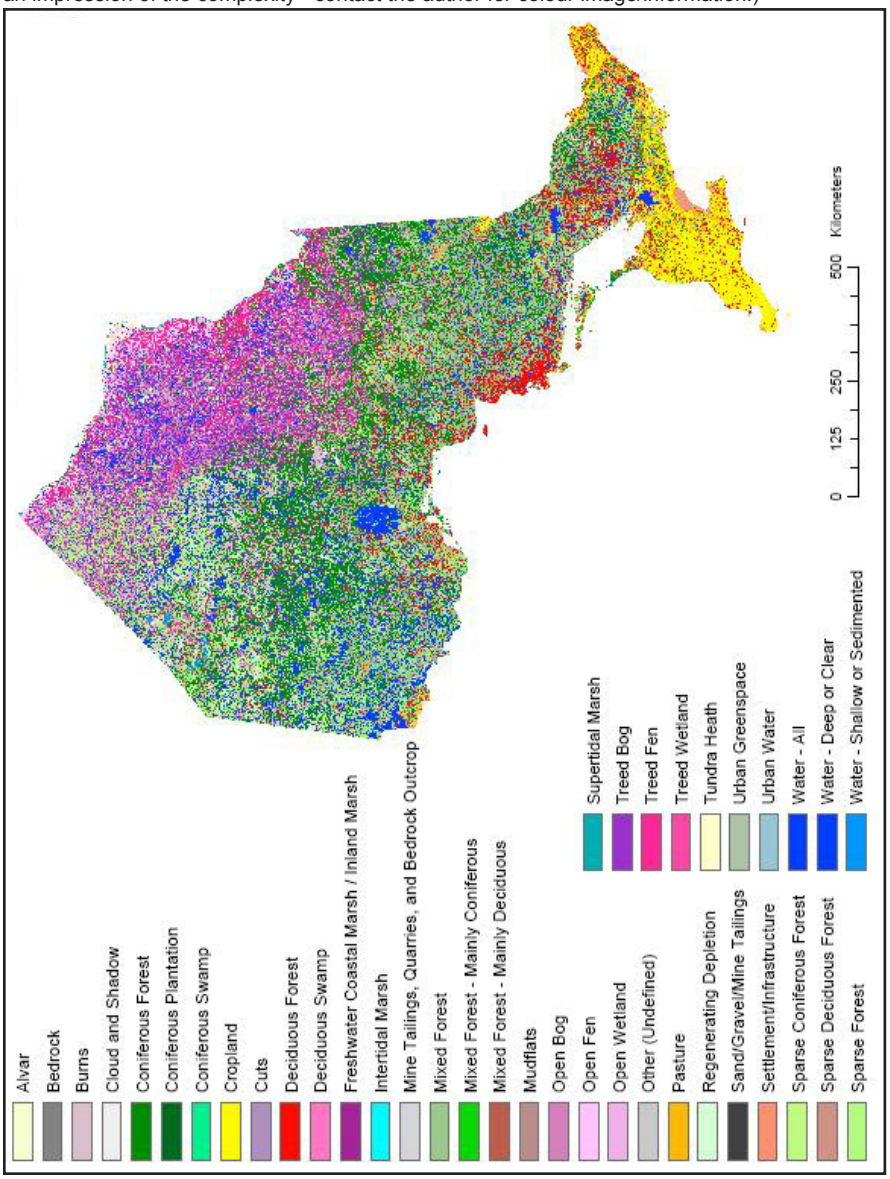
GapTool is now in regular use in Ontario Parks and elsewhere in the MNR, primarily in regional planning units. Its use greatly reduces the time required to complete gap analyses, ensures more consistent results, and allows information to be more readily kept up to date.

One of its primary uses is in producing reports and maps on current ecological representation. This information allows Ontario Parks to report on how well it is achieving its program objectives of protecting representative ecosystems. Under-represented features are also considered during the

preparation of park management plans. This "base case" information is also used to support initiatives that may involve potential new protected areas, including Crown land use planning and securement of private properties.

To reduce duplication in effort and to make these reports more widely available, thePlanning and Research Section of Ontario Parks has produced

Figure 3. Map of Ontario illustrating the complexity of vegetation incorporated in one provincial landform/vegetation data set (This greyscale image can only give an impression of the complexity - contact the author for colour image/information.)



standard *GapTool* tabular reports and maps for all of Ontario's 71 ecodistricts and over 600 regulated protected areas. The reports can be accessed by OMNR staff and is kept up to date. They are updated upon:

- interim protection for recommended new protected areas;
- regulation of new protected areas, which is normally accompanied by detailed mapping;
- changes to protected area boundaries; or
- preparation of new landform and/or vegetation data.

For inclusion in the *2006 State of the Forest Report*, OMNR prepared a map that shows under-represented L/V associations (representation gaps) for all of Ontario as of December 31, 2005 (Figure 4). This map was prepared by merging representation achievement information prepared with *GapTool* for all of Ontario's 71 ecodistricts. This is the first complete provincial map of landform/vegetation representation gaps ever produced.

The provincial map in Figure 4 provides a broad perspective on regions in which current protected area systems largely meet the minimum representation requirements, and regions in which representative protected area systems have yet to be established. The latter includes large regions of the Hudson Bay Lowlands. Natural features in much of southern Ontario (Ecoregions 6E and 7E) are also under-represented. This is not as obvious on the map because many of the features in southern Ontario, such as agricultural land, are omitted from the gap analysis. Most remaining natural features in southern Ontario do appear as representation gaps.

Conservation Planning Context

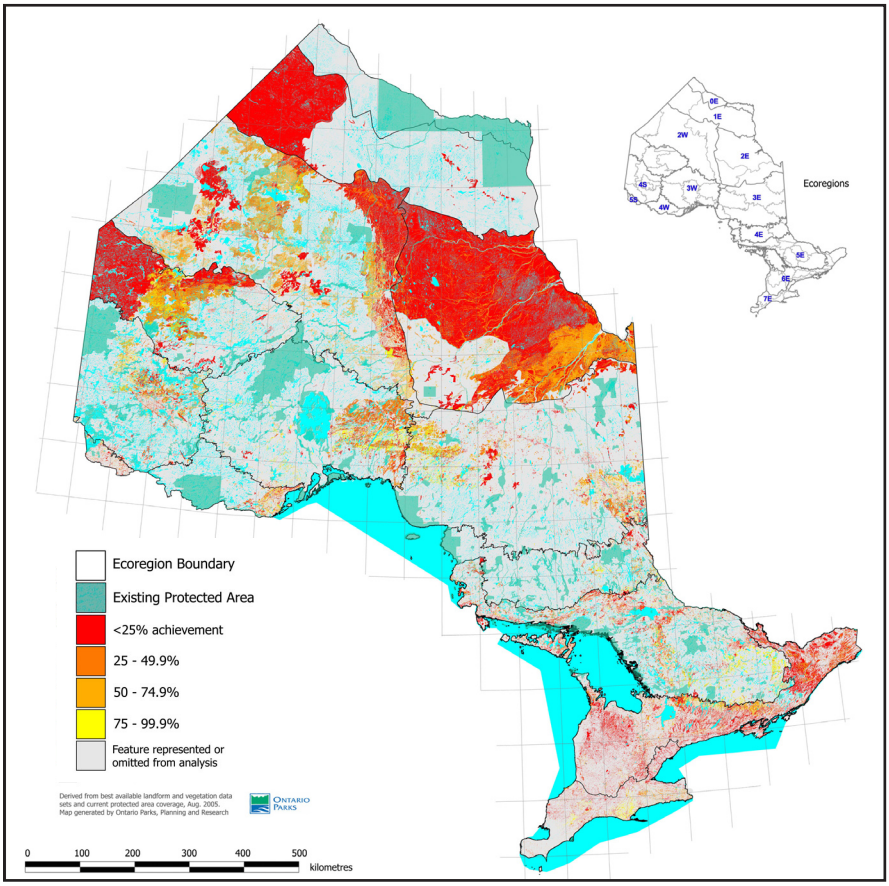
Gap analysis is one tool that can be used within a broader approach called systematic conservation planning (Margules and Pressey, 2000). In systematic conservation planning, protected area systems are designed to represent various elements of biodiversity and help ensure their persistence through time, at relatively low cost to other values such as resource extraction or development.

In conservation planning activities, OMNR often begins by identifying under-represented elements of biodiversity through gap analyses. The reports on current ecological representation prepared with *GapTool* have proven to be very helpful in this regard. Following this initial identification of under-represented features, OMNR tries to identify the "best" examples of representative features, and to design functional protected area systems, through applying the other four selection criteria described earlier – condition, diversity, ecological functions, and special features. A variety of maps, reports, and specialized conservation planning tools such as *C-Plan* (Ferrier *et al*., 2000) and *MARXAN* (Possingham *et al.*, 2000) may also be used to help design potential protected areas.

Conservation planning often involves identifying various suites of potential protected areas, only some of which may be brought forth for further

consideration. People involved in conservation planning often need to know how these alternative suites of protected areas would contribute to representing under-represented features. *GapTool* is well suited to this sort of "what-if" analysis.

Figure 4. Landform/vegetation features under-represented across Ontario



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