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Interpretation guide of natural geographic features from ETM+ Landsat imagery and aerial photography: Tundra ponds

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Introduction

The purpose of this project is to create a visual interpretative guide to the natural geographical entities in the geospatial database (GDB) using Landsat7 ETM+ imagery and aerial photography. The methodology and information fact sheet were developed by Provencher and Dubois (2004a), and the application of this procedure to a test case has already garnered a consensus among the staff of CTI at Sherbrooke (Provencher and Dubois (2004b). The meanings of the sections of the fact sheets are explained in the appendix.

The eight natural entities in the GDB (Centre for Topographic Information, 2004) fall under eight themes that are grouped into three domains: hydrography, landforms, and vegetation (Table 1). In practice, for interpretive purposes they are often subdivided further and represented by 17 fact sheets.

N.B.: Elaboration of the illustrative examples and potential elements of confusion was constrained by the limited time allocated to this guide. It is recommended that they be supplemented as other cases are documented, especially from Landsat ETM+ imagery.

Table 1: Hierarchy of natural geographical entities

Domain	**Theme**	**Sub-theme**	**GDB entity**	**Fact sheet**
Hydrography	Watercourse	Perennial watercourse	Permanent water	Permanent water
		Alluvium	Intermittent water	Intermittent water
		Waterfall	Water disturbance	Waterfalls and rapids
		Rapids	Water disturbance	Waterfalls and rapids
	Waterbody	Perennial freshwater body	Permanent water	Permanent water
		Alluvium, rocky surface	Intermittent water	Intermittent water
		Saltwater	Permanent water	Permanent water
		Alluvium, rocky surface (tidal flat)	Intermittent water	Intermittent water
		Reef	Water disturbance	Reef
	Wetland	Tundra pond	Saturated soil	Tundra ponds
		Palsa bog	Saturated soil	Palsa bog
		Marsh, swamp, and uniform peat bog (wetland)	Saturated soil	Wetlands (marshes and swamps, peat bogs
		String bog	Saturated soil	Wetlands (string bog)
Landforms	Glacial landform	Glacial debris	Landform	Glacial debris
		Esker	Landform	Esker
		Moraine	Landform	Moraine
		Glacier, glacial ice cap, and ice shelf	Permanent snow and ice	Permanent snow and ice
	Periglacial landform	Polygonal soil	Landform	Tundra polygon
		Pingo	Landform	Pingo
	Littoral landform	Barrier beach and spit	Landform (sand)	Barrier beach and spit
	Eolian landform	Dunes	Landform (sand)	Dunes
Vegetation	Wooded region		Wooded region	Wooded region

1- Name of entity

Tundra pond

2- Hierarchy

Hydrography – saturated soil – tundra ponds

3- Definition

A zone within permafrost in which lakes are sufficiently numerous to impede movement, except when they are frozen (CTI, 2004).

4- Summary table of elements of identification

Table 2: Summary of identifying elements of tundra ponds

Shape	View from top: - tundra ponds are circular or egg-shaped - the shape of tundra pond fields is variable View from side: - flat surface
Dimensions	Tundra pond: several decametres Tundra pond field: kilometres
Topographic position	Flat interfluvial regions
Drainage	Poor
Vegetation	Absent
Emplacement process	Thaw in permafrost environment
State	Active
Spatio-temporal variations	Seasonal variations in water levels Decadal variations in the shapes of the ponds
Environment	Permafrost environment in Canada's north
Identification on imagery	Water: band 4 Water/sediment mixture: band 5
Identification with B/W aerial photography	Many points of water juxtaposed with much larger waterbodies
Elements of confusion	String bogs

5- Characteristics

5.1- Specific to the entity

5.1.1- Shape

Individually, the shape of tundra ponds is generally round or egg-shaped. In some regions they may even assume a rectangular form. The regions within which tundra ponds develop have highly variable shapes.

5.1.2- Dimensions

Diameter: a few decametres for tundra ponds
Height: flat
Area: kilometres for tundra pond fields

5.1.3- Topographic position

Tundra ponds are found in flat, interfluvial zones.

5.1.4- Drainage

The drainage of tundra pond zones is very poor.

5.1.5- Vegetation

Vegetation is generally absent from tundra pond areas.

5.2- Relative to the entity's dynamics

5.2.1- Emplacement process

Tundra ponds result from the local and superficial melting of frozen fine sediments (silt and clay) and ground ice. This thawing is caused by direct sunlight, warm summer temperatures, fire, and fluvial or coastal erosion (Boivin, 2005). Tundra pond fields comprise a myriad of points of water with no defined structure, along with shallow lakes that are much larger.

5.2.2- State

Tundra ponds are relatively stable in the human timeframe. They are, however, dependent on local and regional climatic conditions that govern permafrost. Consequently, it is possible to observe rapid changes at the level of the individual pond. Nonetheless, tundra pond regions are unlikely to be affected by these climatic changes.

5.2.3- Spatio-temporal variations

Tundra ponds undergo seasonal variations in water depth that are functions of rainfall and the extent of thawing. Their shape may also vary with the intensity of the seasonal freeze/thaw cycle.

5.3- Relative to the environment

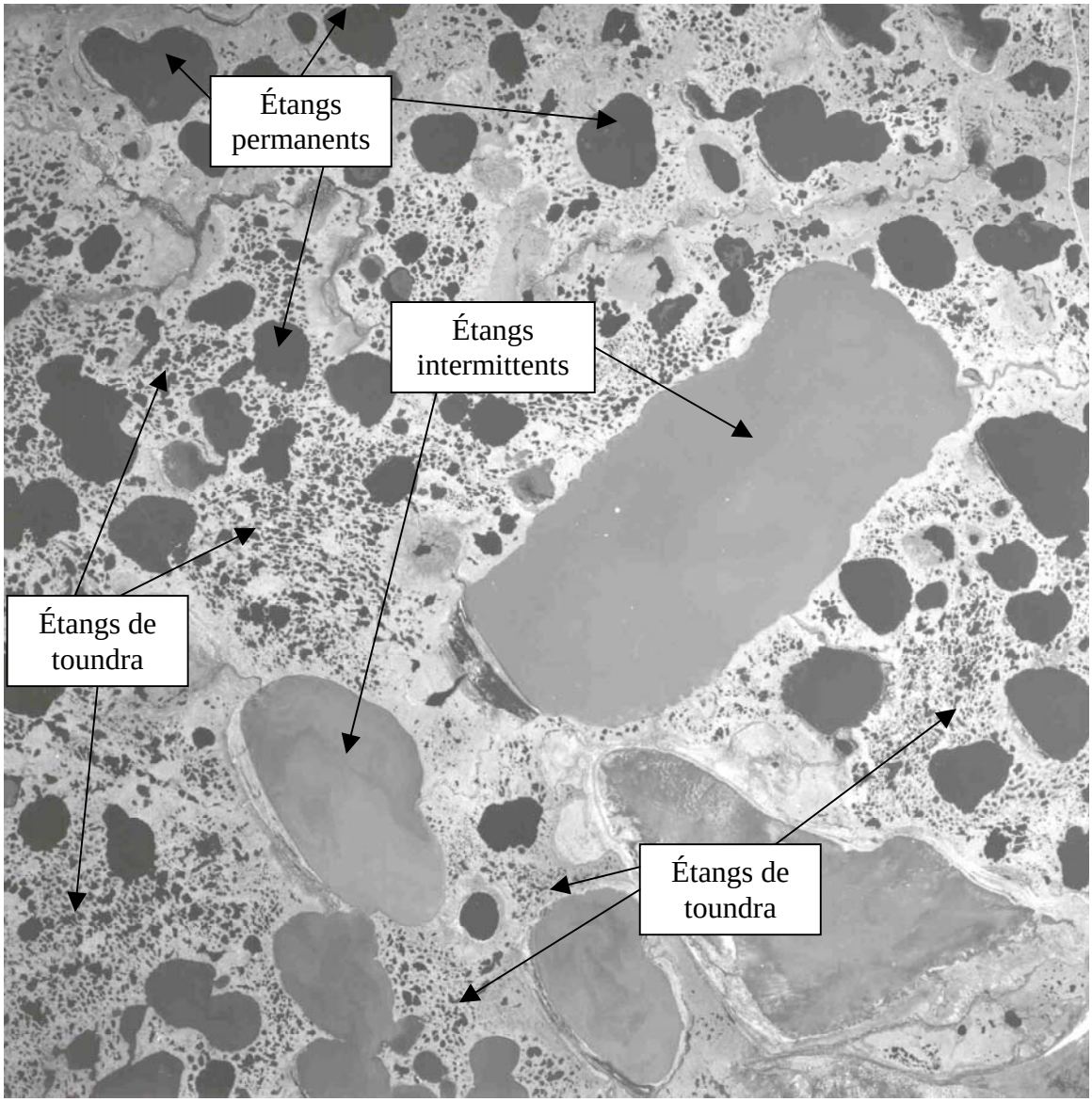
Tundra ponds are found in northern regions of permafrost.

6- Optimal conditions for identification on satellite imagery

On aerial photographs, tundra pond fields are easy to recognize by their constellation of small points of water covering nearly the entire surface. They frequently contrast with lakes that are variable in size, but much larger, in the same areas (Figure 1).

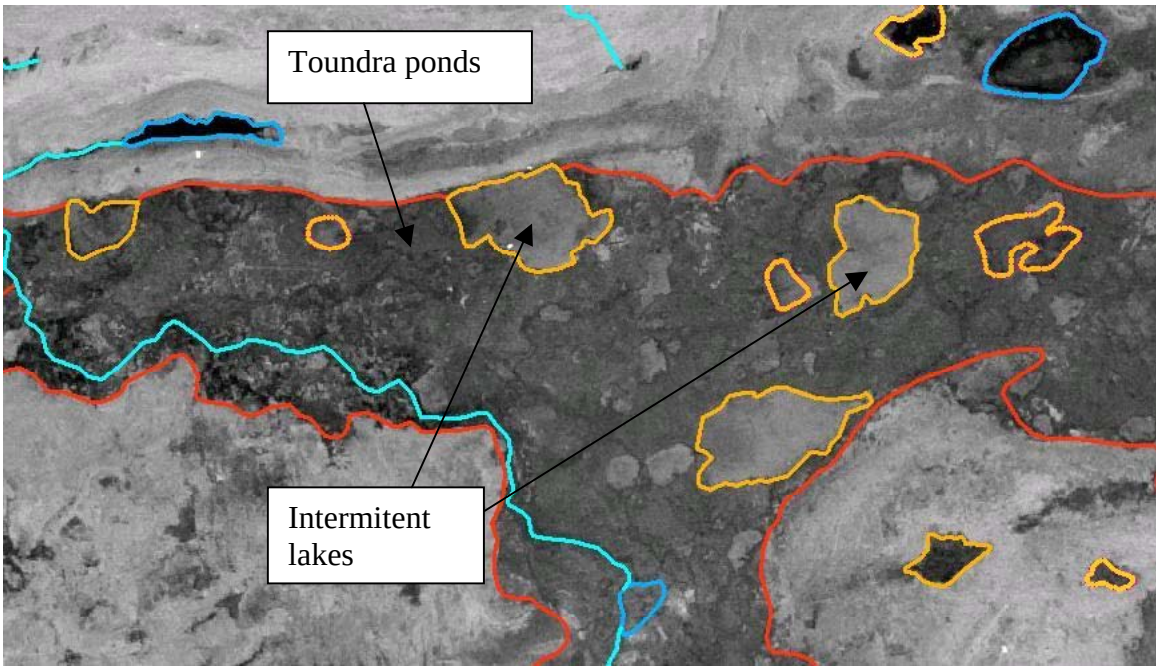
ETM+ imagery is unlikely to capture tundra ponds, owing to their small size relative to the spatial resolution of the images. Only the lakes are visible on band 4 (Figure 2). It is likely that the contrast between bands 4 and 5 will allow tundra pond fields to be distinguished from dry regions, which are identified by the combination of bands 4-3-2.

7- Examples

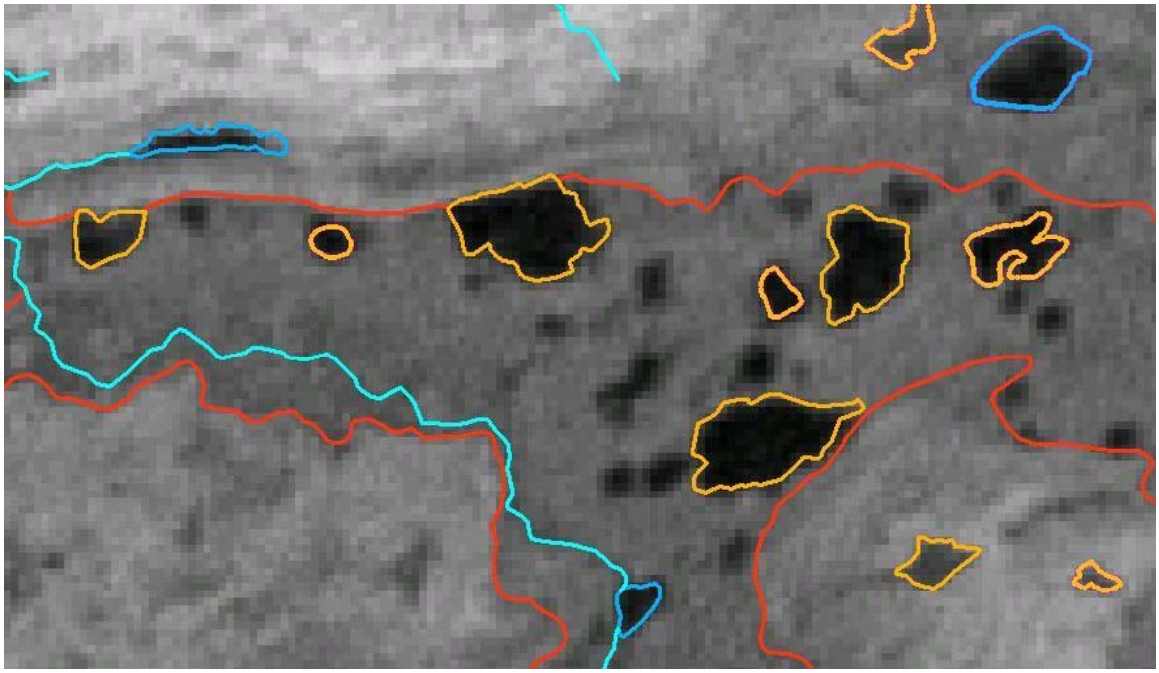


Source : photo A14126 (118), T.S.C.A.P. no 61, Original scale 1 : 60 000, Map54 L/01, 58°10' N – 94°10' O, **Churchill** Area (Manitoba)

Figure 1 : Example of a tundra pond and thermokarst lakes



A) Aerial photography



B) ETM+ Landsat (band 4) Imagery

Figure 2 : Example of a tundra pond area with intermittent lakes. On the ETM+ image, the water level is higher than in the aerial photography

8- Interpretation

8.1- Critical path

The critical path encompasses two phases: distinguishing and delimiting the form, and identifying it.

8.1.1- Distinction and delimitation

On aerial photography, tundra pond zones are easy to distinguish by the many points of water that contrast with much larger waterbodies sharing the same territory.

On ETM+ imagery, the surfaces of tundra ponds are liable to appear as hydromorphic zones (band 5) in areas where ponds are too small for the spatial resolution.

8.1.2- Identification

The identification process for tundra ponds requires that the analyst address the various elements of confusion and recognition (Table 3). The greater the analyst's knowledge and experience, the more accurate the outcome of this labour of discrimination will be.

8.2- Cross-checking with complementary sources of information

Consult the *Atlas of Canada* (http://atlas.gc.ca) for the distribution of discontinuous permafrost zones. In this context, works such as Smith and Burgess (2004), Kettles et al. (1997), and French (1976), may prove useful.

9- Elements of confusion

Table 3: Elements of confusion and recognition between tundra ponds and other entities or forms

Entity or form	Elements of confusion	Elements of recognition	Examples
String bog	- Land/water alternation on ETM+ imagery	- Circular or ovoid shape - Presence of large waterbodies	

10- Bibliography

Boivin, A. (2005) Les principales formes périglaciaires : essai de classification et de synthétisation, Département de Géographie et télédétection, Université de Sherbrooke, Sherbrooke, 81 p.

French, H.M. (1976) The periglacial environment. Longman, London, 309 p.

Kettles, I.M., Tarnocai, C. and Bauke, S.D. (1997) Predicted permafrost distribution in Canada in a climate warming scenario., *in* Current Redearch 1997-E, Geological Survey of Canada, p. 109-115.

Smith, S.L. and Burgess M.M. (2004) Sensitivity of permafrost to climate werming in Canada., Geological Survey of Canada, Bulletin 579, 24 p.

Appendix: the meanings of the sections

1. Name of entity

The name of the entity as it appears in the GDB and in Topolan7.

2. Position in hierarchy

The position of the entity in the hierarchical structure of entities in the GDB.

3. Definition

A brief description based on the entity's principal characteristics and allowing it to be distinguished from any other natural or manmade entity in the GDB.

Only the core features are part of the definition. A detailed description of the characteristics necessary for identification is given in Section 4.

4. Summary table of elements of identification

Presentation of a table summarizing the entity's characteristics (Section 5), of the optimal conditions for identification on ETM+ imagery and black and white (B/W) aerial photography (Section 6), and of the elements of confusion (Section 9).

5. Characteristics

Categorization and description of the characteristics useful for visual identification of the entity.

5.1. Specific to the entity

Characteristics unique to the entity that allow all aspects useful for its identification to be grasped.

5.1.1. Shape

Distinction between linear, point, and areal shapes, three-dimensional pattern of the entity.

5.1.2. Dimensions

Expanse (length, width, diameter) and height of the entity: minima, maxima, and means.

5.1.3. Topographic position

Location of the entity relative to major landforms: drainage basin, mountain, plateau, plain, valley, slope, etc.

5.1.4. Drainage

Surface moisture, outside of saturated zones, in connection with the texture of the materials in the entity.

5.1.5. Vegetation

Presence of vegetation typical of the entity or patterns of plant associations making it possible to distinguish the entity.

5.2. Relative to the entity's dynamics

Characteristics pertaining to the origin and the state of the entity.

5.2.1. Emplacement process

The agent or set of agents responsible for the entity's emplacement and evolution.

5.2.2. State

Dynamic state of the entity: inherited or current. In the case of inherited features, we speak of paleolandforms; in the case of current landforms, we speak of their ongoing formation.

5.2.3. Spatio-temporal variations

Variations in the entity or its appearance that are functions of cyclical conditions (seasonal, multi-year, etc.) or event driven.

5.3. Relative to the environment

Characteristic of the conditions in the entity's milieu and its relationship with other entities or forms present in this milieu.

6. Optimal conditions for identification

Drawing on documentary sources and the experience of the participants, establishment of the optimal conditions for visual identification of the entity. Using satellite imagery, determine the capability of Landset7 ETM+ to capture the characteristics of the entity and identify the band or combination of bands best for visually distinguishing and identifying the entity. Using B/W aerial photography, identify the hues and textures that are most representative of the entity. In cases in which the relief may be significant, recommend the use of stereoscopy.

7. Examples

Illustrating the entity with examples reflecting several of its aspects:

7.3. Land-based photography

Photographs of the landscape that present one or several examples of the entity's aspects, as they might be seen from the ground.

7.3. Aerial photography

Oblique or vertical aerial photographs that present on or several examples of the entity's aspects, as they might be seen from the air.

7.3. Satellite imagery

Satellite images (from Landsat7 ETM+) that present one or several examples of the entity's aspects, as they might be seen from space.

8. Interpretation

Identification of the entity proceeds from interpreting the information in the imagery or aerial photography and complementary sources of information. The quality of the outcome of this interpretive activity will depend upon the knowledge and the experience of the analyst.

8.1. Critical path

Establishing a unique critical path of interpretation for each entity from the imagery or aerial photography on the basis of its characteristics.

8.1.1. Distinction and delimitation

The possibility of distinguishing and delimiting the shape on the image or aerial photograph has been established and the criteria for success have been described.

8.1.2. Identification

Contrasting the various elements of confusion and recognition with other entities or forms for purposes of identification.

8.2. Use of complementary sources of information

Complementing or cross-checking the interpretation with additional sources of information that are easily accessible, such as those on known Internet sites.

9. Elements of confusion

Identifying the entities and forms with which the entity in question can be confused in a table, along with the differentiating features.

10. Bibliography

A list of useful documents quoted in the previous sections.