CanImage
(Landsat 7 Orthoimages at the 1:50 000 Scale)

Standards and Specifications
Edition 1.0

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Canada

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1. Introduction

With the support of GeoConnections, CTIS signed agreements in principle with the main stakeholders in the field of geomatics in Canada (federal, provincial, and territorial levels) to produce Landsat 7 orthoimage coverage of the entire Canadian landmass. Production of the orthoimages, which began in fall 2000, will span a period of three to five years.

The orthoimages comprise seven spectral bands: a panchromatic band with a pixel size of 15 m and six multispectral bands with a pixel size of 30 m. They have been produced in accordance with NAD83 (North American Datum) using the universal transverse Mercator (UTM) projection.

CanImage is a raster image containing information from Landsat 7 orthoimages that have been resampled and based on the National Topographic System (NTS) at the 1:50 000 scale. The product is distributed in files in GeoTIFF format. It offers users a variety of options, including selection of three spectral bands, enhancement, and orthoimage projection.

CanImage files are generated automatically, with no manual intervention. Since the satellite scenes for the images were taken on different dates, image contents may not fully reflect ground truth today. For example, roads built after the indicated scene date will not be in the image.

The quality of the results may vary depending on the date the satellite image was taken. Indeed, the information (contrast between features and color) on an image taken in the spring differs from one taken in the fall. The quality of results also depends on the geographic location of the processed data (north, south, etc.) and its contents (mountains, waterbodies, vegetation, cultivated fields, urban areas, and the like).

Since the product is based on the NTS, the enhancement must bring out the best contrast possible. There may not be consistency between CanImage orthoimages since enhancement proceeded according to NTS data set. Consequently, the appearance varies for every data set for Canada.

The coverage of certain NTS data sets along the edges of satellite scenes is incomplete. In such cases, a mosaic containing several satellite scenes (up to four in all) must be created in order to completely cover an NTS data set at the 1:50 000 scale. Since the data set (NTS) comprises several satellite scenes taken at different dates, quality (consistency) within the data set may be affected. This very particular case, however, represents less than 5% of all data sets.

CanImage GeoTIFF files can be opened in different applications in response to specific needs: geographic information systems (GISs) for land-management applications; mapping software to visually represent a region; remote sensing / digital image processing software and their algorithms (classification and others) to detect topographic entities (vegetation, hydrography, roads, vegetation-free surfaces, etc.), different types of crops and vegetation species, and so on.

2. Data Source

2.1. Geometric Correction of Landsat 7 Images

The primary data source for the product is geometrically corrected (orthorectified) Landsat 7 ETM+ (*Enhanced Thematic Mapper*) images. PCI Geomatics' SRIT (rectification system for remote-sensing imagery) mathematical model is applied in correcting Landsat 7 images. This rigorous method of geometric correction takes into account all global system distortions (satellite, sensor, earth).

2.2. Planimetric Accuracy of Landsat 7 Orthoimages

The planimetric accuracy of the orthoimages depends on control data, the digital elevation model (DEM), and the methodology used to extract the positions of the control points on the image. The best sources of control data currently available **in Canada** were used to generate the orthoimages. A number of control sources were used to correct the Landsat 7 images, namely provincial vector data, roads resulting from the global positioning system (GPS), data from the National Topographic Data Base (NTBD), and geometrically corrected aerial photography (orthophotos). The control points extracted from the sources generally represent road intersections and centres of mass of lakes or islands. Different DEMs also served in generating these orthoimages: provincial DEMs and Canadian Digital Elevation Data (CDED) at the 1:50 000 and the 1:250 000 scales. Planimetric accuracy is obtained by analyzing the parameters of the geometric correction model (SRIT), the accuracy of the source data used to correct the image, and DEM accuracy.

The following formula was used:

$$(((\text{Model\_EMQX}^2 + (\tan(7) \times \text{DEM\_accuracy})^2) + \text{Model\_EMQY}^2)^{1/2}) \times 1.5174$$

Where:

Model_EMQX:	Mean square error of the model along the x-axis.
tan (7):	Impact on the x-axis of the elevation when the viewing angle is at its maximum.
DEM_accuracy:	Accuracy of the least accurate DEM used for geometric correction (slope < 40%).
Model_EMQY:	Mean square error of the model along the y-axis.
1.5174:	Factor for a circular standard error with 90% of probability.

The planimetric accuracy for the orthoimages in Southern Canada is about 20 m, compared to about 30 m in the northern part of the country. It should be noted that only control data within Canada was used. The planimetric accuracy of the part of the image located outside of Canada may therefore be lower. Each orthoimage has a different planimetric accuracy.

2.3. Resampling of Landsat 7 Orthoimages

All spectral bands available for CanImage have a pixel size of 15 m. In fact, the high-resolution panchromatic band (15 m) can be merged with Landsat 7's 6 multispectral bands (originally 30 m). As the result of the resampling integrated into PCI Geomatics software, the resolution for spectral bands 1, 2, 3, 4, 5, and 7 has changed from 30 m to 15 m. This technique makes it possible to enhance image details when viewing with no or little modification of the spectral characteristics of each band. It is therefore still possible to carry out a detailed analysis (classification) after transformation. The technique is applied to all the bands for each orthoimage (complete satellite scene). These resampled orthoimages serve as the sources for generating the CanImage product.

3. Product Specifications

3.1. Spectral Bands

The CanImage product offers 7 spectral bands, that is, 1 panchromatic band and 6 multispectral bands:

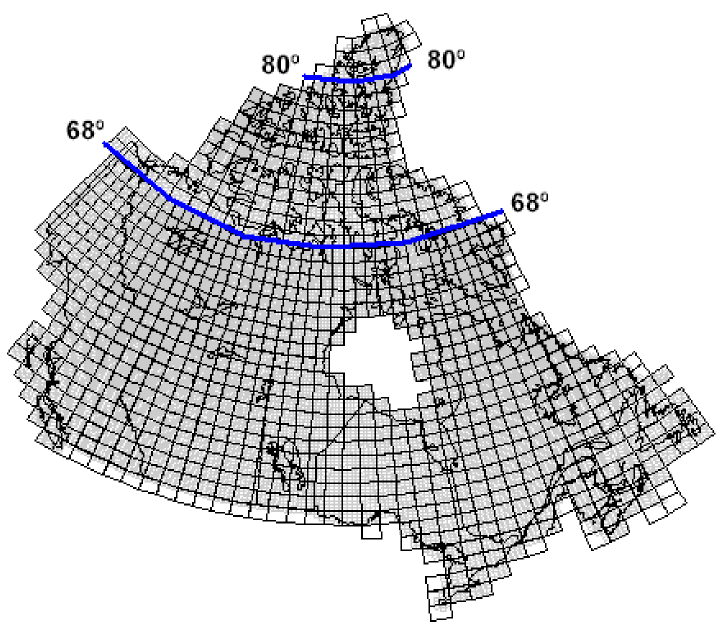
Landsat 7 Band No.	Spectral Location	Wavelength (in µm)
1	Blue-green	0.450 – 0.515
2	Green	0.525 – 0.605
3	Red	0.630 – 0.690
4	Infrared (IR)	0.750 – 0.900
5	Mid infrared I (MIR 1)	1.550 – 1.750
7	Mid infrared II (MIR II)	2.090 – 2.350
8	Panchromatic	0.520 – 0.900

Each band has 8-bit radiometry (values from 0 to 255). The customer can choose combinations of three bands from those listed.

3.2. Coverage (NTS Divisions at the 1:50 000 Scale)

The CanImage product is based on divisions of the National Topographic System (NTS)[1] at the 1:50 000 scale (see Figure 1). Data-set coverage varies depending on geographical location within Canada.

Figure 1
Data-set coverage based on NTS divisions at the 1:50 000 scale



[1] For more details on the NTS, visit: http://cartes.RNCan.gc.ca/maps101/nts.html.

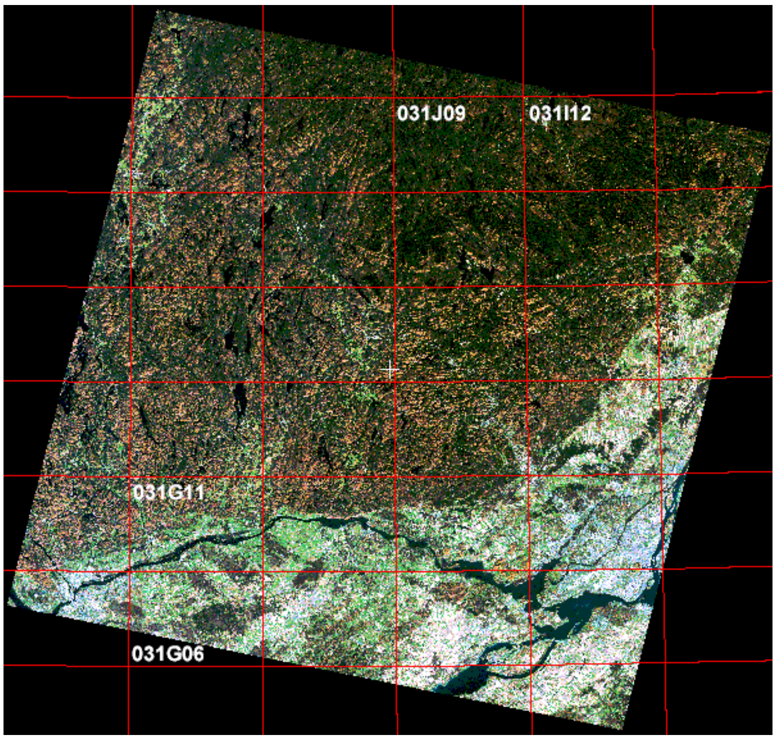
Under the system at the 1:50 000, Canada is divided into primary quadrants measuring 15´ of latitude by 30´ of longitude south of the 68° parallel of latitude, 15´ of latitude by 1° of longitude between the 68° and the 80° parallel, and 15´ of latitude by 2° of longitude north of the 80° parallel of latitude. The coverage of CanImage data sets is provided in the table below.

LOCATION (Latitude)	**COVERAGE** (Latitude X longitude)	**AVERAGE CanImage DATA SET SIZE** UTM projection (in metres) (No. lines X No. columns)	In geographic coordinates (No. lines X No. columns)
40° to 68°	15' X 30'	1 940 X 2 265	1 855 X 3 710
68° to 80°	15' X 1°	1 910 X 2 080	1 855 X 7 420
80° to 90°	15' X 2°	1 930 X 2 165	1 855 X 14 840

The first example illustrates the distribution of NTS data sets on a Landsat 7 orthoimage. Certain NTS sheets are completely covered by the orthoimage (e.g. 031J09), while others have only partial coverage (see 031G06). In instances such as the latter case, a mosaic must be created using adjacent orthoimages.

Example 1

Distribution of NTS data sets on a Landsat 7 orthoimage



LEGEND Theoretical neatline of an NTS data set

Source: Spectral bands: 1, 2, and 3; linear enhancement; UTM projection; Area 18.
Landsat 7 orthoimage => track: 015; frame: 028; scene date: 1999-11-01.

Lastly, because of end lap (7.3% at the equator and about 80% at 80° of latitude) and side lap between Landsat 7 satellite scenes, a single NTS data set may be present in several orthoimages. As a result, there are different editions of CanImage for the same NTS data set.

3.3. Horizontal and Vertical Reference Systems

The North American Datum of 1983 (NAD83) was used to create the Landsat 7 orthoimages.

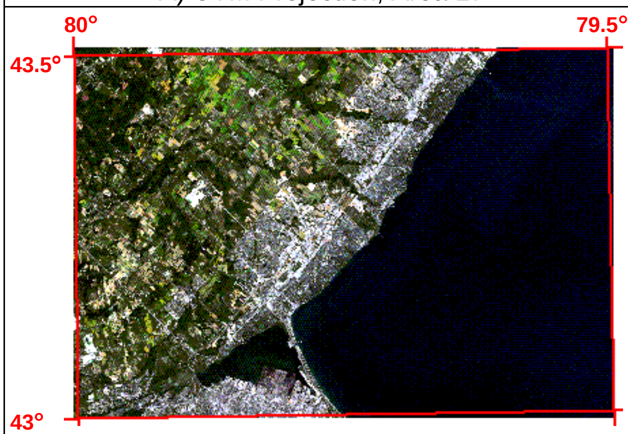
3.4. Coordinate System

CanImage is generated using the universal transverse Mercator (UTM) projection[2] (spatial reference in metres) or in the geographic-coordinate system (latitude/longitude). The original orthoimage (complete satellite scene) is generated using the UTM projection.

Generating the CanImage product using the UTM projection (see Example 2 A) consists in simply dividing the orthoimage according to NTS data sets at the 1:50 000 scale. The resultant image has a pixel size of 15 m and is not subject to radiometric degradation (except when creating mosaics).

When generating the CanImage product based on geographic coordinates (spatial reference in degrees), cubic-convolution resampling was carried out on the pixels, which causes minor radiometric degradation (see Example 2 B), so that some image details may be blurred somewhat. Moreover, since the spatial reference is in degrees, the distances between features and their blurred shapes in the images do not necessarily reflect ground truth. A calculation was carried out to obtain approximately 15 m of spatial resolution (pixel size) in the north-south direction of the image. The CanImage product always has a square-shaped pixel, which means that the data are distorted in the east-west direction. However, since geographic coordinates are used, the size in metres tends to vary according to latitude; image pixel size will be constant in degrees but vary in metres depending on latitude.

Example 2
CanImage Data Set 030M05

<table>
<tr><td>A) UTM Projection, Area 17</td><td>B) Geographic Coordinates</td></tr>
<tr><td>
</td><td>
</td></tr>
<tr><td>1 892 lines X 2 729 columns</td><td>1 855 lines X 3 710 columns</td></tr>
<tr><td colspan="2">LEGEND Theoretical neatline of the NTS data set</td></tr>
</table>

Source: NTS = 030M05 (Hamilton-Burlington, Ontario, Canada), spectral bands: 1, 2, and 3; linear enhancement.
Landsat 7 orthoimage => track: 018; frame: 030; scene date: 1999-09-03.

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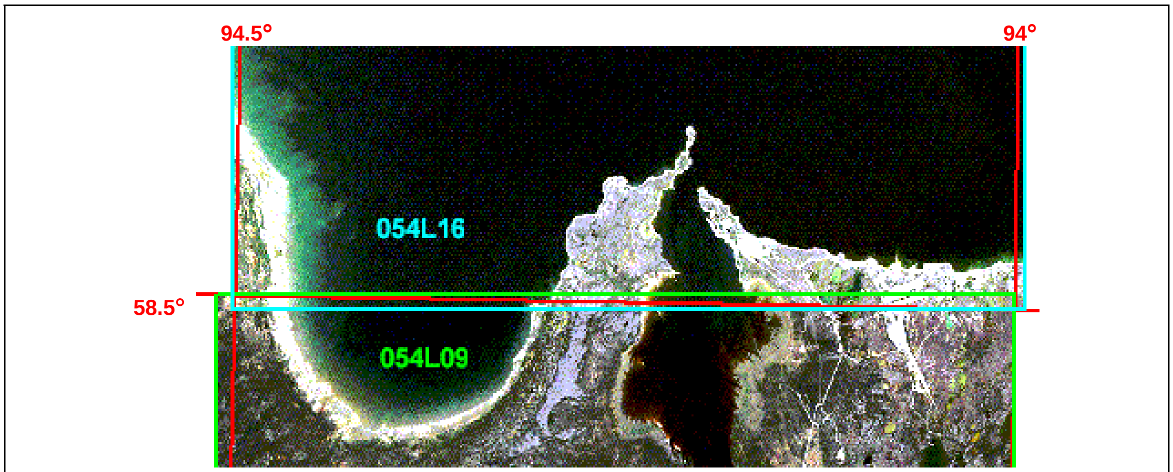
[2] A description of the UTM projection can be found at http://cartes.RNCan.gc.ca/maps101/nts.html.

3.5. Overlapping of Data in the UTM projection

The product is delimited based on NTS divisions at the 1:50 000 scale according to the UTM projection using the following coordinate pair: minimum X metres, maximum Y metres and maximum X metres, minimum Y metres. These coordinates come from the corners (neatline ends) of the NTS tiles. The coverage of a CanImage data set is somewhat larger than the corresponding NTS data set (see Example 2 A). This approach generates an area of overlap between adjacent CanImage files along all four sides of the data set.

Example 3 illustrates overlap in the north-south direction. There are exactly 37 lines in the overlap area for the two CanImage files (054L06 and 054L09). The total common overlap height is 555 metres (37 lines X 15 metres of pixel spatial resolution).

Example 3
North-south overlap between CanImage data sets 054L16 and 054L09



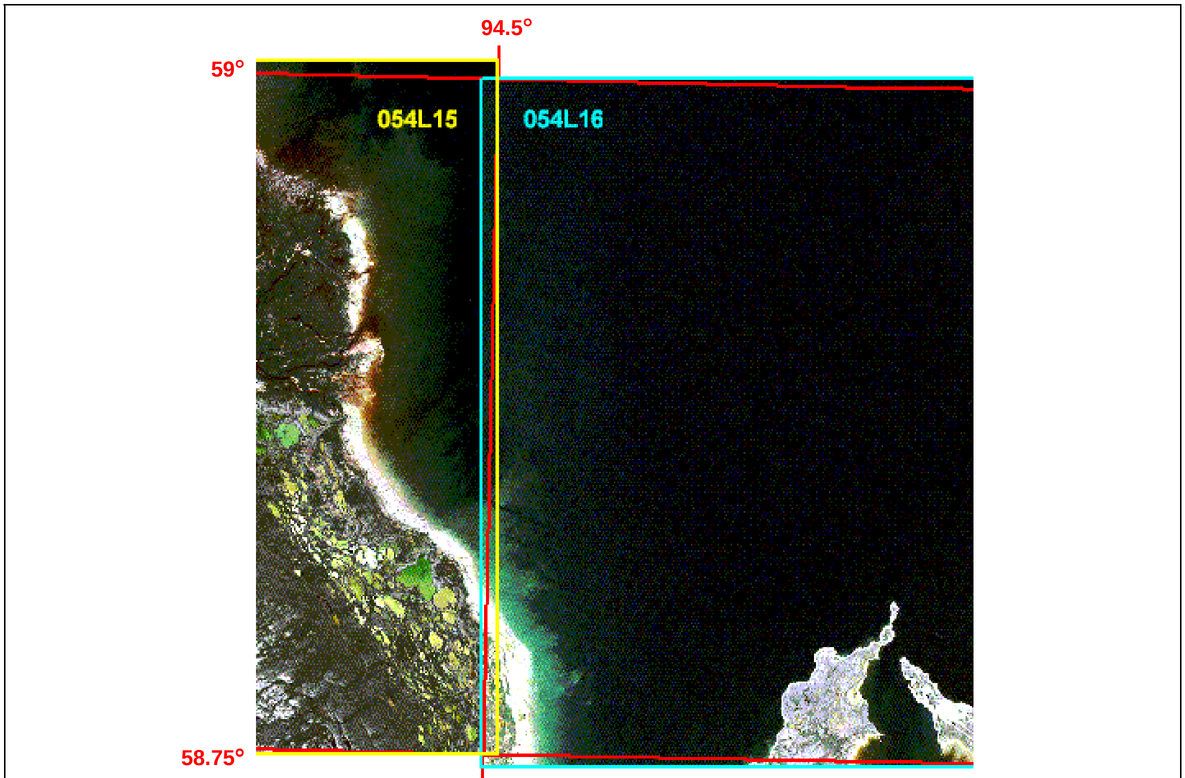
LEGEND: Boundary of CanImage NTS 054L16 — Boundary of CanImage NTS 054L09
Theoretical neatline of the NTS data set — Area of north-south overlap*

* In the overlap area, CanImage NTS 054L16 appears over NTS 054L09.

Source: NTS NORTH = 054L16 (Churchill, Manitoba, Canada), NTS SOUTH = 054L09 (Button Bay, Manitoba Canada).
Source: Spectral bands: 1, 2, and 3; linear enhancement; UTM projection; Area 15.
Landsat 7 orthoimage => track: 032; frame: 019; scene date: 2000-08-06.

The area of overlap in the east-west direction is illustrated in Example 4. A total of 43 columns are common to both CanImage files (054L16 and 054L15). The width of the area of overlap at this position is therefore 645 m.

Example 4
East-west overlap between CanImage data sets 054L16 and 054L15



LEGEND: Boundary of CanImage NTS 054L15 — Boundary of CanImage NTS 054L16 — Theoretical neatline of NTS tiles — Area of east-west overlap*

* In the overlap area, CanImage NTS 054L16 appears over NTS 054L15.

Source: NTS EAST = 054L16 (Churchill, Manitoba, Canada), NTS WEST = 054L15 (Knife Delta, Manitoba Canada).
Source: Spectral bands: 1, 2, and 3; linear enhancement; UTM projection; Area 15.
Landsat 7 orthoimage => track: 032; frame: 019; scene date: 2000-08-06.

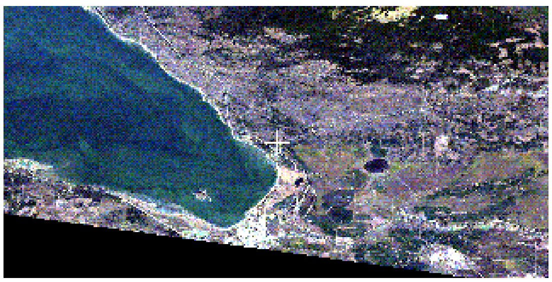
The overlap size between the two adjacent CanImage data sets expressed according to the UTM projection varies depending on its location in the NTS. Firstly, it depends on the position of the data set with respect to the central meridian of the UTM area covered: the further the data are from the central meridian, the greater the distortion of the grid delimiting its limits (not rectangular). Secondly, the extent (number of lines X number of columns) in the areas of overlap increase significantly from the south to the north of the country.

3.6. Mosaic

In certain cases along the edge of Landsat 7 orthoimages, it is not possible to completely cover the full extent of the NTS data set. This entails the creation of a mosaic based on adjacent orthoimages (up to 4 in all). The mosaic is created only when the combination of orthoimages needed is available.

When a mosaic is being produced (see Example 5), the orthoimage covering the major portion of the data set is delimited directly (without resampling). The remainder of the data set from the adjacent orthoimages is adjusted to the frequency histogram of the largest portion covered by the data set and is resampled to the contents of the mosaic. Cubic-convolution resampling of the pixels, however, produces slight radiometric deterioration in the smallest section of the CanImage file.

Example 5
Creation of the mosaic from CanImage data set 083O07

Extraction of orthoimage 043022*	Extraction of orthoimage 043021*
	

Delimitation

Delimitation + adjustment of the frequency histogram with respect to the preceding image (043022)+ resampling

Mosaic 083O07*

LEGEND: Delimiting the mosaic between the two source orthoimages — Theoretical neatline of the NTS tile

* The images were enhanced for presentation purposes. The enhancement is applied only when the mosaic has been completed.

Source: NTS = 083O07 (Slave Lake, Alberta, Canada).
Spectral bands: 1, 2, and 3; linear enhancement; geographic coordinates.
Landsat 7 orthoimage => track: 043; frame: 021; scene date: 2000-10-06.
Landsat 7 orthoimage => track: 043; frame: 022; scene date: 2000-05-31.

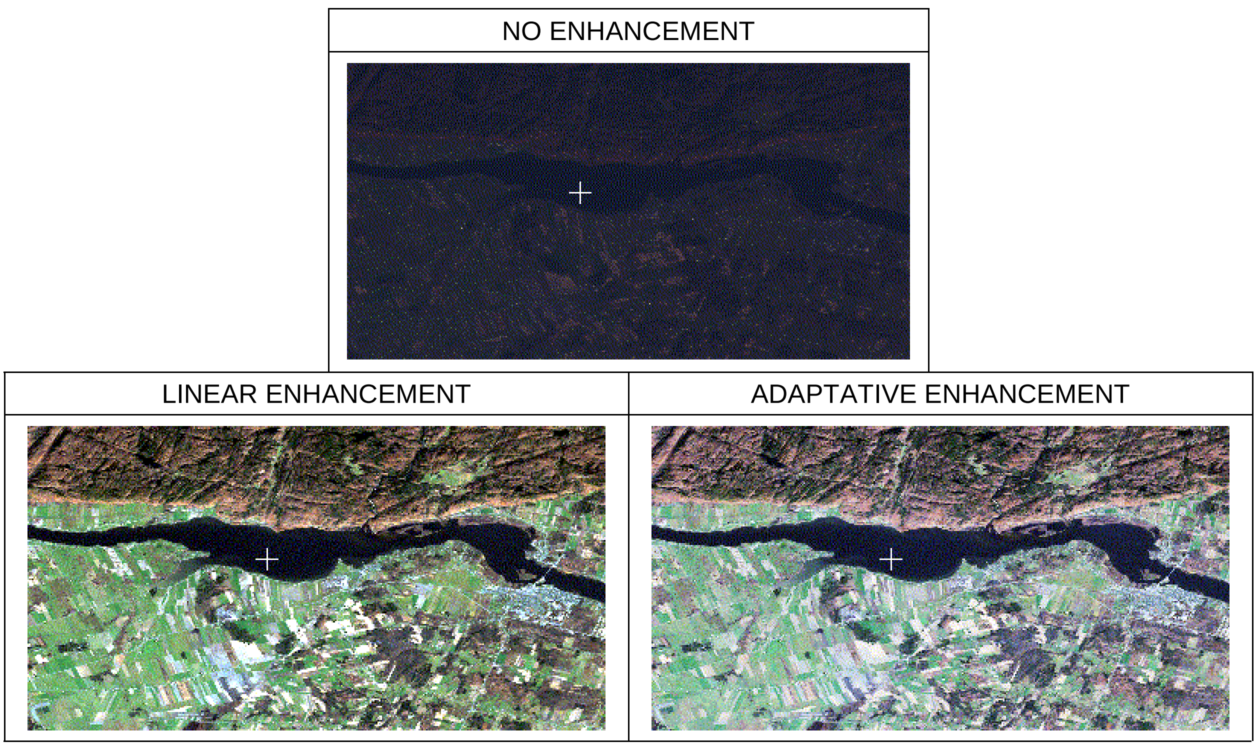
3.7. Data Enhancement (contrast improvement)

The CanImage product is available with and without image enhancement. Image enhancement improves data contrast (radiometric values) to facilitate interpretation. There is a broad track of contrast enhancement algorithms available on the market.

Two types of enhancement are available for the CanImage product: stretching and adaptative enhancement in constant grouping (isopopulation classes) based on the median value of the frequency histogram). The various commands in PCI Geomatics software are used to perform the enhancement. During enhancement (linear or adaptative), the first and last 2% of the image's pixels are put aside. This is a standard contrast enhancement approach used in remote sensing / digital image processing for eliminating edge effect.

Applying the different image enhancement algorithms yields varied results (see Example 6). The data user therefore must decide which enhancement to use, which is usually based on the interpretation elements sought.

Example 6
Enhancement of the visible spectral bands (1, 2, and 3)
Extract from CanImage file 031G10



Source: NTS = 031G10 (Hawkesbury, Ontario, Canada); spectral bands: 1, 2, and 3; geographic coordinates.
Landsat 7 orthoimage => track: 015; frame: 028; scene date: 1999-11-01.

3.8. 24-bit Color Composition

The product contains the three spectral bands selected by the customer. Certain combinations correspond to specific fields of application or standard solutions, as illustrated below.

	Spectral bands	No. of Bands	Description (visualisation elements)
A	red, green, blue	3, 2, 1	True colors that bring out visible details, in particular, infrastructure.
B	infrared, red, green	4, 3, 2	Visualization of forests, hydrography, and vegetation-free surfaces.
C	mid infrared, panchromatic, red	5, 8, 3	This combination is complementary to that in A.

Each band represents 8-bit radiometry (values from 0 to 255). The combination of the three bands yields 24-bit RGB (or red, green, blue) color composition.

3.9. Data Quality

Product quality may vary depending on the date the satellite scene was taken. It depends on the geographic location of the processed data (north, south, etc.) and its contents (mountains, waterbodies, vegetation, cultivated fields, urban areas, and the like). Unwanted natural phenomena, such as snow, ice, and cloud cover, also affect product quality. Waterbodies covering most of a data set can impact product quality due to depth variation along the shoreline and the presence of sediment or waves. Consequently, the product's appearance varies for every NTS data set for Canada.

3.10. CanImage File in GeoTIFF

The output file format of the product is GeoTIFF[3] (*Type R Georeference Tagged Image File Format* (.tif) (RGB or red, green, blue). Using GeoTIFF makes it possible to store different spatially referenced spectral bands in a single file. In the case of the CanImage product, three spectral bands are stored in the RGB display channels (red, green, blue). As a result, users who do not have specialized software for digitally processing images can still view the product in most drawing and all geomatics software.

The CanImage file name corresponds to the NTS file covered at the 1:50 000 scale. For example, the GeoTIFF name for data set 031G08 would be 031g08_<stamp>.tif.

GeoTIFF files containing a combination of three spectral bands track in size from 15 to 20 Mb. Compressing the image file (.zip) reduces its size by about 30 to 50%.

[3] Visit this Web site for more information about the GeoTIFF format: http://www.remotesensing.org/geotiff/geotiff.html.