Heritage Resources Centre
Centre des ressources du patrimoine

Analysis of Land Use/Land Cover Change of the Long Point Region from 1974 to 1984 Using Landsat MSS Images

Long Point Environmental Folio

Long Point Environmental Folio
Publication Series

Technical Note 1

Long Point Environmental Folio Publication Series
Managing Editors: J. Gordon Nelson and Patrick L. Lawrence

A study team at the Heritage Resources Centre is developing an Environmental Folio for the Long Point Biosphere to assist management agencies and local citizens in understanding the human and natural components of the ecosystem. The folio will consist of a series of maps and text that would outline current major management issues and areas of concern. A series of project publications is being prepared to accompany the folio. These reports will consist of supplementary information collected during the study. This project is supported by the Royal Canadian Geographic Society and the Social Sciences and Humanities Research Council of Canada.

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Chi Ling Yeung

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Heritage Resources Centre
University of Waterloo

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Introduction

Studies are underway in the Long Point region and in the Inner Bay as part of a project to prepare an environmental folio for the Long Point Biosphere Reserve. A major goal of this work is to better understand and assess land use changes in the area and implications for environmental and other planning for sustainable development (Nelson et al., 1993) . One source of information for this project is the analysis and interpretation of images recorded by satellites produced by global remote sensing programs. This report presents some preliminary results of an attempt to use this approach in the Long Point study.

Two Landsat Multispectral Scanner (MSS) Images, June 21, 1974 and July 7, 1984[1], were compared to investigate the regional picture of land use change of the Long Point Region. Since the images were taken at the same season with less than a month difference, they are assumed to be phenologically comparable. The images cover a rectangular area comprising mainly the Regional Municipality of Haldimand-Norfolk, bounded in the east and west by Port Burwell and Dunnville, north and south by the Six Nation Indian Reserve and Lake Erie (Figure 1) [2].

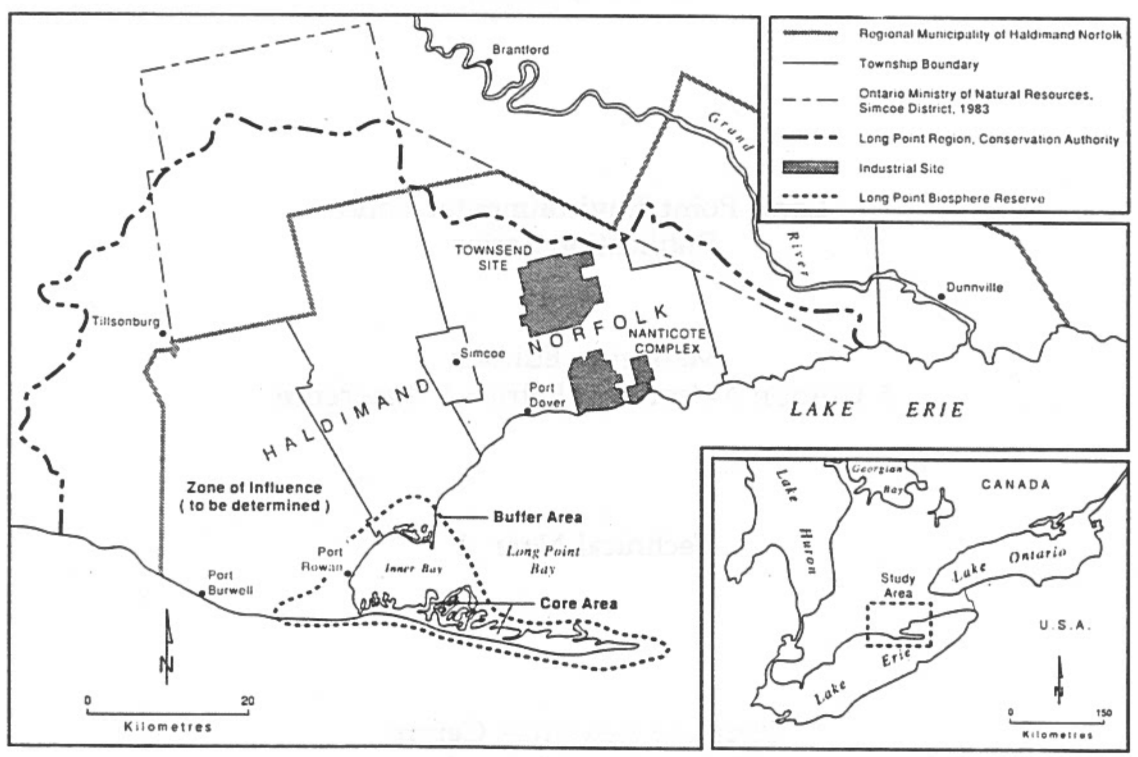

Figure 1. Study Area: Long Point Biosphere Reserve and Region

1 A 1991 Landsat Thematic Mapper (TM) image is also available for comparison. But due to technical problems with comparing images with different spatial resolution, such comparison will be provided in later reports.

2 The actual images for printing and display have been reduced to include an area from Long Point to Turkey Point and north to Simoce.

The MSS images have a spatial resolution of 79 x 58 metres per pixel, which is the size of the smallest distinguishable feature. However, smaller features with sharply defined boundaries (e.g. roads through forested area) are often visible on the images because the signal may saturate the pixel. The Landsat MSS records ground reflectance in four bands, i.e. band 4 (green; 0.5-0.6 mm), band 5 (red; 0.6-0.7 mm), band 6 (near-infrared; 0.7-0.8 mm) and band 7 (near-infrared; 0.8-1.1 mm). Different bands offer different potential for distinguishing ground features. Usually, band 6 and 7 detect water bodies the best while bands 4 and 5 are good for cultural features. A false colour composite is usually produced for visible interpretation by assigning a red colour to band 7, green to band 5 and blue to band 4. This will show vegetation in different intensities of red, cultural features and bare surfaces in light colours and water bodies in very dark colours. False colour composites for the two images have been produced for visual comparison.

Change Detection Strategy

The Segara Anakan, Indonesia Study (Nelson et al., 1992) has developed an effective protocol for detecting land use change which is relatively simple and reproducible. In essence, it involves overlaying two images of different dates to delineate areas that register changes in reflectance values. Ground checks are conducted to determine the nature of the changes. They are then classified to show the pattern of land use change.

However this method is not applicable to the Long Point Region. The region is dominantly agricultural with tobacco and corn as the main corps. A great variety of other crops are also grown, including peanuts, beans, hay, alfalfa, in a three or four year crop rotation cycle which usually includes a one year fallow. If two images are simply overlaid one another, much of the significant differences will simply be regular changes in cropping pattern instead of permanent land use changes that concern us in this study. Moreover, the Long Point peninsula, and the wetland complex associated with it are highly dynamic. Their configuration and extent depend to a large degree on such factors as the lake water level, sediment supply and climatic conditions which are highly variable from year to year. The overlying of multidate images is likely to pick up changes that are transient in nature.

It is for these reasons that a more conventional land use classification approach was adopted for detecting change in this study . The two images are subjected to a supervised classification which would allow visual comparison of land use change. In addition, the overlaying of the two classified images will show where changes have actually occurred.

Classification Scheme

In devising the classification system, the following guiding principles are employed:

1. It should be simple enough to allow visual interpretation. That means the number of classes should be limited to make the general pattern easily discernible and interpretable.

2. It should be non-technical so that it can be easily communicated to laymen. This is in keeping with the objective of the Long Point study which aims at a wide audience.

3. As the classification involves multidate images, classes should be general enough to allow for the emergence and disappearance of minor land cover types over years. For example, the appearance of a new crop should not result in too much misclassification.

4. It should be compatible with the more detailed land cover classification scheme that the study group has developed for use with aerial photography. Classes developed for the Landsat imagery can be considered general with more specific subclasses within the aerial photography analysis.

5. It should provide a meaningful, albeit simple picture of the changing human ecology of the area.

6. It should be reasonable in the sense that the classes are spatially and spectrally separable.

Eventually, a simple classification scheme with six land cover/land use classes was developed. They are:

1. Agricultural Area - Land under crops, pasture, grass and low shrub and herb, as well as area laid fallow (bare soil with some grasses). Abandoned fields and golf courses are also included in this category.

2. Deciduous Woodland - Land under deciduous trees, both planted or natural. Riparian forest as well as swamp are included.

3. Coniferous Woodland - Land under coniferous tress, both planted or natural.

4. Marsh - Inland and coastal marsh with low lying vegetation partly submerged.

5. Built-up Area - Land under concrete or a mixture of concrete and vegetation[3].

6. Open Water - Any water body.

Classification Method

The image analysis was done on the Dipex Image Analysis System. The two images were first co-registered to each other so that they have the same dimensions and the same coordinates. This was done by identifying features in the 1984 image as control points. The coordinates of the same features on the 1974 image were recorded by the system. A polynomial transformation function was calculated and the image resampled to make it coincide with the 1984 image.

A supervised classification was then applied to the 1984 image (Figure 2). Training areas were drawn from which signature statistics for individual land cover classes were calculated. Since the Agricultural and Built-up Areas involve many different types of surface, care was taken to include all the different varieties in approximately the right proportion. Ground-truth information is obtained from field visits, 1990 air photos and 1984 topographic maps. A maximum likelihood classification was then applied to the image. Generally, all four bands are used in the classification. However, in the case of Open Water, the large sediment load in estuaries, near the marsh and around the Long Point peninsula made classification with all four bands unsatisfactory (i.e. silty water comes out largely unclassified). As the infrared band (7) has been shown to produce the best distinction between land and water, only band 7 was used to classify Open Water. Moreover, since the Built-up Area and Agricultural Area have very similar signatures with high variance, a larger *a prior* probability was assigned to Agricultural Area to make them more separable and reflects the dominant agricultural character of the region.

The same approach and set of training areas was then applied to the 1974 image. However, the land cover of a particular training area might have changed during the 10 years interval. The training areas were therefore inspected one by one to ensure that they represented the same land cover class as in

3 Beaches, sand dunes and some extensive bare ground are often included in this class. Their high reflectance in all bands make them very difficult to separate them from Built-up Area. For beaches and sand dunes, they are usually too small for the MSS resolution to be separately classified.

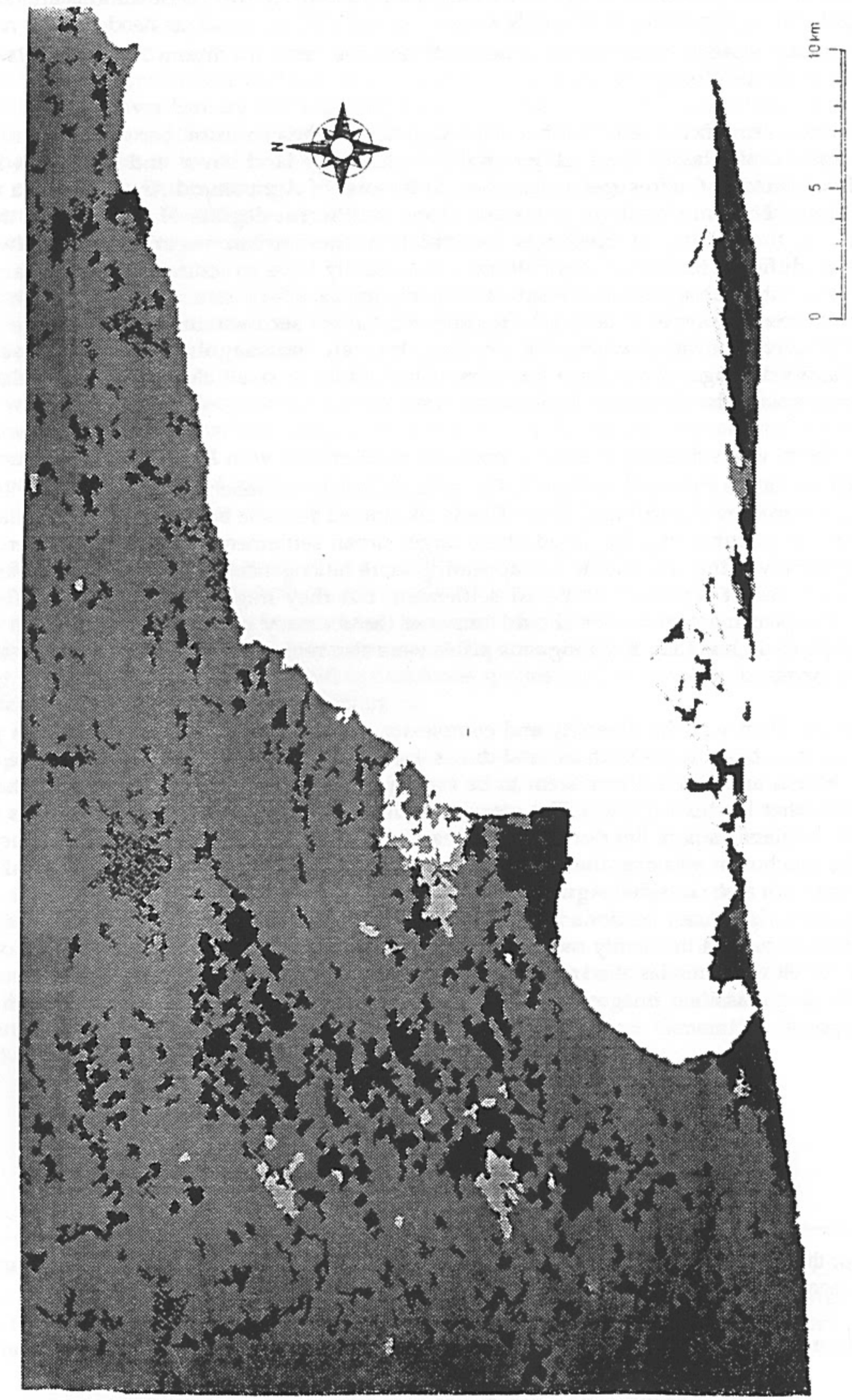

Figure 2 1984 Landsat MSS Classified Image the 1984 image. Minor boundary change was necessary for some training areas while a shift to adjacent areas was needed for some others. In any case, the guiding principle is that there should be minimal change in the location and areal extent of training areas so that the two classifications are comparable to the largest extent. It turned out that only 6 out of about 100 training areas needed to be changed or shifted. Signature statistics were again generated[4] and the same maximum likelihood classification was applied to the 1974 image.

A major problem encountered in this classification was the confusion between Agricultural and Built-up Areas. Both classes are highly variable in terms of land cover and they both involve a mixture of vegetated and non-vegetated surface. In the case of Agricultural Area, there is a mixing of fields in fallow, different density of crops and crops in different degrees of maturity. In the case of Built-up Area, the mixing of buildings, construction sites, urban vegetation and lawn makes interpretation difficult. Moreover, Agricultural areas usually have structures like barns, farm houses and kilns (for tobacco) which show similar reflectance as urban structures. Although the peak reflectance of these two types of land use are different, the variance within them is so large that there exists a large area of overlap where the two land uses are indistinguishable. For this reason, the resulting classified images show large numbers of individual or small clusters of pixels classified as Built-up Area amidst the dominant Agricultural Area.

This problem was solved by replacing pixels or pixel groups with less than 15 contiguous pixels with land cover classes surrounding them[5]. This resulted in large number of pixels classified as Built-up Area being replaced by Agricultural Area. This is considered realistic because of the fact that most of the region is agricultural anyway. In addition, larger urban settlements which are of interest to our study are generally being consolidated or appearing more homogeneous after this replacement. Those replaced pixels might represent scattered settlement, but they might also be misclassified mixed pixels. Their replacement, however should improve the accuracy of the classification. In addition, unclassified pixels in less than 15 contiguous pixels were also replaced, resulted in a smaller amount of unclassified pixels.

Another problem was the diversity and complexity of the Long Point peninsula which possesses some distinct land cover types such as sand dunes and oak savanna, yet are too small to be classified separately. Marsh and Open Water seem to be classified accurately. Some interpretation however is necessary for other land cover types. The cottage community at the base of the peninsula is generally visible from the classification. But due to the large amount of vegetated surface (lawn and trees) among the cottages, much of it was classified as Agricultural. Similarly, the sparsely vegetated oak savanna and low shrubs are also classified Agricultural. Non-vegetated sand dunes and beaches were classified as Built-up Area. Little can be done to correct this misclassification. A classification aiming at the regional land use pattern inevitably sacrifices some unique local details. Finally, cloud shadows in the 1984 image which were misclassified as marsh were manually masked off and were left as unclassified. Both the raw and classified images were then transferred to the Macintosh system for printing and display purposes.

4 Since the two images are not corrected for atmospheric effect and differences in sun angle, signatures of the 1984 image cannot be used directly on the 1974 classification.

5 Diagonally connected pixels are not replaced since they might represent a particular land use pattern of interest.

Interpretation

In general, no dramatic change in regional land use pattern can be discerned in the 10 year study period from June 21, 1974 to July 7, 1984 . The area remains dominantly agricultural with abundant woodlots among the fields, riparian forest along streams and plantations near the St.William Forestry Station and Turkey Point Provincial Park. Marshes are found in the Big Creek Estuary, Long Point, Turkey Point, Grand River Estuary and scattered about inland lakes. Established urban centres such as Port Dover and Simcoe are clearly visible, as well as the Nanticoke Industrial Complex. However, the coarse spatial resolution of the MSS image and the simple classification scheme cannot bring out the complexity of the Long Point peninsula. Beaches were often classified as Built-up Areas and the oak savanna commonly were classified as Agricultural. However, bearing these misclassification in mind, the images still present a meaningful picture of regional land use change.

Close examination of the two classified images shown in Table 1 and 2 reveals some subtle changes during the 10 years period. At a regional scale, the percentage of Agricultural Area remains more or less the same (Table 1). However, it increases in the Long Point Area (from 47% to 57%), even when the confusion with Built-up Area is taken into account (Table 2). This increase seems to be at the expense of the Marsh which registers a decrease from more than 34% to less than 30% locally and from 2.2% to 1.9% regionally. In the classified images, Marsh can still be found around the Inner Bay in discontinuous patches in 1974. But in the 1984 classified image, it is not visible. Although some remaining patches can be found from field survey, they are generally too small to be classified. The reasons for this are not well understood and could involve fluctuations in Lake Erie water levels.

There has been some increase in deciduous woodland, from 10.8% to 12.1% regionally and 7.1% to 9.3% locally. No further fragmentation of the woodland is apparent. Instead, reforestation program and the gradual maturity of the forests have increased the overall forest cover of the region[6]. However, there has been a decrease in coniferous woodland from 0.7% to 0.5% regionally and 4.8% to 3.3% locally. This may be the result of a shift to deciduous species used in reforestation program as most of the coniferous woodland is in forestry plantations.

Built-up Area which is a measure of the level of urbanization of the region is very difficult to interpret because of its confusion with Agricultural Area. It also includes a lot of area of high reflectance such as beaches and bare sand dunes. The estimated decrease in Built-up Area from 1.8% to 1.1% regionally during the 10 year period is unlikely in view of the gradual expansion of towns like of Simcoe and Port Dover, and the proliferation of cottage development during the same period (decrease from 6.6% to 0.9% locally is evenly more unlikely!). A likely explanation is that newly developed residential areas of the 1970's had become better vegetated in the 1980's, resulting in more of those areas being misclassified as Agricultural. As indicated by the two classified images, all major urban centres (Simcoe, Port Dover, Delhi, Tillsonberg) grew modestly in area from 1974-1984. The biggest change in Built-up Area occurs at the Nanticoke Industrial Complex with the addition of the Texaco Refinery and the Stelco Lake Erie Plant in the 1980's to the Thermal Generating Station already visible in the 1974 image.

6 However, the qualitative aspect of forest cover cannot be detected in this analysis. For instance, the classification is not sensitive to the replacement of indigenous forest by planted woodland. Similarly, Agricultural Areas which have been inactive or abandoned may still be classified as Agricultural since a grassy surface is still dominant in such areas.

Table 1 **Percentage Change in Land Cover/Land Use for the Haldimand-Norfolk Region 1974-1984**[7]

Land Cover/Land Use Type	1974	1984
Agricultural Area	84.5	84.3
Deciduous Woodland	10.8	12.1
Marsh	2.2	1.9
Built-up Area	1.8	1.1
Coniferous Woodland	0.7	0.5
Unclassified	0.0	0.2

Table 2 **Percentage Change in Land Cover/Land Use for the Long Point Area 1974-1984**[8]

Land Cover/Land Use Type	1974	1984
Agricultural Area	47.2	56.7
Marsh	34.3	29.9
Deciduous Woodland	7.1	9.3
Coniferous Woodland	4.8	3.3
Built-up Area	6.6	0.9

Conclusion

The use of multidate MSS images can produce a useful clear picture of the change in regional landscape structure. The use of a simple classification scheme yields classified images of such map-like clarity that they should be easily interpreted by professionals and laymen alike. However, this clarity is at the expense of local details, resulted in the Long Point peninsula being less susceptible to reasonably accurate interpretation. Moreover, the confusion between Built-up Area and various land cover types makes it difficult to assess the precise extent and impact of urbanization on the region. Actually, built-up areas (urban or cottages) can be discernible relatively easily by visual inspection of the false colour composite due to their textural difference from the surrounding landscape (usually a coarse texture mixture of gray and red). A textural analysis should greatly improve the separation of Built-up Areas from other land uses. Visual interpretation of the enanced false colour images could be done to more confidently assess the nature of change in support of the classification.

The Long Point Region remains dominantly agricultural in nature although some modest expansion of bulit-up areas is apparent. Woodland has increased. Although no further fragmentation is evidenced during the 10 years period, there is at the same time no significant improvement. More importantly, the decline of the marsh, which contributes much to the environmental quality and character of the region, seems to be continuing. This is especially so in the Long Point coastal area where the marsh is of the highest quality. Overall then, even though the area has acquired a more mature character with more woodland cover and better vegetated urban areas, the loss of valuable marshes may represent a net deterioration of environmental quality.

7 The Region refers to area covers by the whole image which includes essentially the Regional Municipality of Haldimond-Norfolk.

Open Water is not included as the primary interest is terrestrial land use change.

8 The Long Point Area refers to a coastal strip of land from the Big Creek Marsh to Turkey Point which comprises the major study area of the project.

The change detection methodology described above is a first attempt in devising a method that suits the purpose of the study and the special character of the region. Further refinement is necessary to improve separability of land cover/land use types. Ways should also be devised to achieve a better balance between getting a simple regional picture and detecting details of the Long Point peninsula. Moreover, accuracy assessment should be attempted to improve the credibility of the study[9]. The use of higher resolution TM image and their compatibility with MSS image will present both a promise and challenge in the next phase of the study.

Acknowledgements

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References

Nelson, J.G., LeDrew, E., Dulbahri, Harris, J. and Olive, C. (1992) *Land Use Change and Sustainable Development in the Segara Anakan Area of Java, Indonesia: Relevant Information from Remote Sensing, On Ground Survey and the ABC Method* Technical Paper 7, Heritage Resources Centre, University of Waterloo.

Nelson, J.G., Patrick L. Lawrence, Karen Beazley, Ron Stenson, Andy Skibicki, Chi Ling Yeung, and Kerrie Pauls (1993) *Preparing an Environmental Folio for the Long Point Biosphere Reserve and Region* Long Point Environmental Folio Publication Series, Working Note 1, Heritage Resources Centre, University of Waterloo.

9 It was not attempted due to limited time and technical support although information for such assessment is not lacking.

Technical Notes

1. **Directory**

Disk: **IMG1** Directory: **YEUN** Watimp Directory: **DUC1:[ARIES]**

2. **File Name**

Full Scene Area Name:	**J47**	June 21, 1974 Image
	J48	July 6, 1984 Image

Dimension:	Start Line: 1340	End Line: 2060
	Start Pixel: 950	End Pixel: 2710

Local Scene Area Name:	**JJ7**	June 21, 1974 Image
	JJ8	July 6,1984 Image

Dimension:	Start Line: 1510	End Line: 2000
	Start Pixel: 1350	End Pixel: 2200

File Identifier:

Feature File (FF)	**MSS4**	Band 4
	MSS5	Band 5
	MSS6	Band 6
	MSS7	Band 6
	MAP0	Map file for 1984, pixel groups >15
	MAP5	Map file for 1974, pixel groups >15
Theme File (TT)	**84M4**	1984 raw classified image
	74M2	1974 raw classified image
	CUA3	1984 smoothed classified image
	CUA5	1974 smoothed classified image
Training Area (TA) & Signature (MS)	**WATE**	Open Water
	WOOD	Deciduous Woodland
	AGRI	Agricultural Area
	PLAN	Coniferous Woodland
	WTLD	Marsh
	BUIL	Built-up Area
	WATR	Open Water (Band 7 only)
	STAR	Study Area

(These files have an Area Name of **J74** or **J84** because they were produced from a larger orginal scene)

Others:	**J48CTSCA2**	Classification summary from J48TTCUA3
	J47CTSCA3	Classification summary from J47TTCUA5
	J48CTSCA4	Classification summary from J74TASTAR
	J47CTSCA5	Classification summary from J74TASTAR

J74PTJ840 Control Point File
J74CCJ840 Polynomial Transformation File
(The co-registration was done with **J84** as Master Image and **J74** as Slave Image)

3. **Classification Details**

Training Statistics: see attached

A prior Probability	Open Water	1.00
	Deciduous Woodland	1.00
	Agricultural Area	0.90
	Coniferous Woodland	1.00
	Marsh	1.00
	Built-up Area	0.60

Training Index & Colour Assignment:	Built-up Area	1	Red
	Deciduous Woodland	2	Green
	Open Water	3	Blue
	Marsh	5	Magenta
	Agricultural Area	7	Orange
	Coniferous Woodland	8	Grey

Procedure: Classified using **WATR** only first, and Merged classified image with classification using all four bands.

Smoothing: Replaced pixels and pixel groups in less than 15 contiguous pixels; diagonally connected pixels excepted.

Raw Classification Result from **J74** and **J84**:

		J74		J84	
Signature	Probability	Pixels	% Total	Pixels	% Total
WATE	1.00	615981	39.10	668378	42.43
WOOD	1.00	104449	6.68	127173	8.07
AGRI	0.90	621635	39.46	618204	39.25
PLAN	1.00	5787	0.37	5072	0.32
WTLD	1.00	16080	1.02	34243	2.17
BUIL	0.60	69608	4.42	53314	3.38

Raw Classification Summary of **J47** and **J48**: see attached

4. Manuel Manipulation

Task EI on Dipex. Produced mask on themes by writing annotation on VMA with polygon fill. Cloud cover identified by inspecting false colour composite with the aid of classified images.

5. File Transfer

Task DA on Dipex. File transferred in binary. **JJ7** and **JJ8** were used. In Mactinosh, files are saved in pict file format. Raw files have dimension as **JJ7** and **JJ8** with header bit at 1360.

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Working Note 1.	Preparing an Environmental Folio for the Long Point Biosphere Reserve and Region by J. Gordon Nelson, Patrick L. Lawrence, Karen Beazley, Ron Stenson, Andy Skibicki, Chi Ling Yeung, and Kerrie Pauls
Technical Note 1.	Analysis of Land Use/Land Cover Change of the Long Point Region from 1974 to 1984 Using Landsat MSS Images by Chi Ling Yeung
Working Paper 1	The Historical Economies of the Long Point Area by Steven Wilcox