AUTOMATED STREAM PLANFORM MAPPING: A TEST STUDY

Dennis Paradine[1], Donald G. Leckie[2] and Cara Jay[1]

[1] MacMillan Bloedel Ltd.
65 Front Street, Nanaimo, B.C. V9R 5H9

[2] Canadian Forest Service, Pacific Forestry Centre
506 West Burnside Road, Victoria, B.C. V8Z 1M5

ABSTRACT

The nature of streams and their fish habitat is now a critical parameter to forest management. Mapping of the main features of stream courses is valuable baseline information for channel assessment and fisheries surveys, determining stream classes for prescribing logging setbacks and monitoring changes over time due to natural events or logging activity.

Eighty centimeter casi imagery was acquired over Tofino Creek on the west coast of Vancouver Island, British Columbia. Using a spectral angle mapping algorithm, seven surface types were classified (deep water, shallow water, sand, gravel and cobble, woody debris (e.g., logs), conifer and deciduous). Comparison with ground truth taken within days of the imagery indicates general agreement of surface types and accuracy estimations greater than 80 percent for most classes. Individual logs and piles of woody debris were consistently detected. Problems do arise within shadowed areas, boundaries of stream features and forest and with some zones of sand, gravel and cobble.

Keywords: remote sensing, stream, multispectral imagery, casi, high resolution.

RÉSUMÉ

CARTOGRAPHIE AUTOMATISÉE DE LA MORPHOLOGIE DES COURS D'EAU: UNE ÉTUDE EXPÉRIMENTALE

La nature même des cours d'eau et les habitats qu'ils constituent pour le poisson sont désormais des paramètres dont il faut tenir compte dans l'aménagement des forêts. La cartographie des principales caractéristiques des cours d'eau fournit des informations de base utiles pour l'évaluation des chenaux, pour la réalisation d'études sur les pêches de même que pour la classification des cours d'eau aux fins de la prescription des limites de coupe et la surveillance des changements temporels dus aux phénomènes naturels associés à l'exploitation forestière.

Une imagerie de 80 cm du ruisseau Tofino, sur la côte ouest de l'île de Vancouver, en Colombie-Britannique, a été acquise au moyen d'un spectromètre imageur aéroporté compact (CASI). À l'aide d'un algorithme de cartographie angulaire spectrale, on a procédé à la classification de sept types de surfaces (eaux profondes, eaux peu profondes, sable, gravier et galet, débris de nature ligneuse (p. ex., grumes, conifères et feuillus). La comparaison des images et des données de vérité-sol, recueillies quelques jours après l'acquisition des images, révèle une correspondance globale des types de surfaces ainsi qu'une précision d'évaluation

Automated Interpretation of High Spatial Resolution Digital Imagery for Forestry. Victoria, British Columbia, Canada, February 10-12, 1998. D.A. Hill and D.G. Leckie, editors. Natural Resources Canada, Canadian Forest Service, Pacific Forestry Centre, Victoria, British Columbia. pp. 387-394.

supérieure à 80 % pour la plupart des classes. Les grumes et les amas de débris ligneux sont systématiquement détectés. Cependant, les zones ombragées, les limites cours d'eau-forêt et certaines zones de sable, de gravier et de galets posent des problèmes.

INTRODUCTION

Consideration of streams in forest management is now mandatory and a sensitive environmental issue. Their presence, location, nature, and fisheries habitat are key. A number of important considerations lead the need for information regarding streams:

a) In many jurisdictions there are requirements to map the stream course and its nature. For example, in coastal British Columbia, the location of this study, detailed requirements and procedures regarding stream channel assessment are set forth by the Forest Practice Code Act, Channel Assessment Procedure Field Guidebook (1996). Channel morphology and disturbance level are described with water depth, riffles, bars, pools, sediment or substrate material, bank morphology and nature of woody debris being important diagnostic keys. The mapping and assessment is done both from aerial photography and the ground. Where riparian vegetation or shadow obscures the stream channel on the air photos, assessments are by necessity conducted on the ground.

b) The sediment available for transport is important environmentally and from an engineering point of view. Here the volumes of sediment are important.

c) Debris obstructions and debris available for transport is another important consideration. The main concern is large woody debris either as piles or individual pieces. Potential for serious blockage of stream channels or sudden release of large quantities of debris is a major factor.

d) Riparian zone management requires information on streams. For example, in British Columbia the width of the logging reserve zone around streams is partially dependent on the presence or absence of fish and channel width.

e) Fisheries management is closely allied with forest management. Fisheries surveys need to determine quantities of different habitat and to define and sample for fish within reaches. Gradients and obstructions to passage of fish are key.

f) Perhaps one of the most important considerations in stream management is monitoring of changes in the stream due to various causes. Stream channels change seasonally, gradually over time and suddenly due to flood and high flow conditions. Channel changes, bank erosion, debris accumulation and channel obstructions are the changes of most interest. Knowledge of typical changes in stream condition is useful, but surveys of streams after catastrophic events like flooding would be more urgent. Here a quick method to classify and map changes would be effective. A potentially important issue is in monitoring the effects or lack of changes due to logging operations. Knowledge of typical changes, conditions before logging, and those during and after logging are of interest to both forestry companies, government agencies and environmental interests to determine if indeed logging operations are having or did have any effect.

The above applications areas have important common elements and lead to certain requirements for any method developed to map stream characteristics. Gradient is a critical element. This requires a stereo sensor or extraction of gradient from other sources such as topographic maps or laser altimetry. Defining and then describing stream characteristics within a stream reach is a standard survey technique. There is a common set of surface classes and stream parameters which recurs for many of the applications. Water depth and flow are important with pools, riffles and runs being defined and deep and shallow water identified. Sometimes actual depths are required. Substrate material is classified often as: fines (clay, silt, sand), gravel (small and large), cobble (small and large), boulder or bedrock. Other features such as in-stream and over-stream vegetation and large organic or woody debris are factors. Stream width in terms of bank full width, average width, wetted width is a common measured feature.

The applications and requirements lead to a need for high spatial resolution in any aerial survey technique to help the mapping of the surface characteristics of streams (stream planform mapping). Aerial photography is often used as a base for mapping. Digital imagery such as airborne video and digital frame cameras are beginning to be investigated and used, but mainly for visual interpretation as is done with aerial photography. This study, through a test study, explores the merit of high spatial resolution multispectral imagers for this application and whether automated classifications/interpretations can make the process more useful. For example, for some monitoring quick analysis and turn around might be important and automated image mosaicing, geocoding and classification would be advantageous.

STUDY SITE, IMAGERY AND GROUND DATA

STUDY SITE

The study site is Tofino Creek, British Columbia, Canada (49^{o} 12' N; 125 ^{o} 36' W), a typical west coast mountain stream in the Clayoquot Sound area of Vancouver Island. The study area consists of a 5 km length from tidewater to the start of an upper more mountainous stream portion. The rise is 250 m and channel widths range from 10 to 40 m. The stream has some straight reaches but generally follows a sinuous course. Mountains rise fairly steeply on both sides of the stream valley. Substrate material varies from sand, through cobble and some boulder and bedrock. Stream edges are usually surrounded by mature coniferous trees (e.g., western hemlock (*Tsuga heterophylla*); amabilis fir (*Abies amabilis*); Sitka spruce (*Picea stichensis*); western redcedar (*Thuja plicata*)) and some deciduous trees and shrubs with some regenerating areas nearby.

IMAGE DATA

The imagery was acquired by the casi airborne imager on September 25, 1996. The casi sensor is a versatile imaging spectrometer (Anger et al., 1994) which in this case recorded imagery at 80 cm resolution in eight spectral bands (438 nm, 489 nm, 550 nm, 601 nm, 656 nm, 707 nm 782 nm and 847 nm with spectral bandwidths of approximately +/- 25 nm). The imagery was not obtained at higher resolutions due to flight safety considerations in the mountainous terrain. Four adjacent and overlapping flight lines were flown to acquire coverage of the stream course. The imagery was geometrically corrected to an orthoimage using differential GPS, aircraft attitude data and existing British Columbia 1:20 000 topographic map (TRIM) data. Data acquisition and geometric correction was done by Itres Research Ltd., a partner in the project. The imagery was then mosaiced together. The data used in the analysis of this paper was from a section of the stream which was covered mainly by data from one flight line (Figure 1).

GROUND DATA

Ground data was collected September 26 and 27, one and two days after the casi overflights. Over 70 locations were visited along the stream course. At each location 35 mm colour photographs were taken of the channel features. As well several detailed plots were gridded and mapped for surface type. From this information surface conditions were determined for selected areas on the imagery. Water depth (deep, shallow, riffle), substrate material (sand, gravel, cobble, boulder or bedrock) and woody debris (large or small scattered), and surrounding forest condition were assessed. Some finer differentiation of gravel and cobble sizes was done.

METHODS

Automated classification was accomplished in a multiple step process. First the water of the stream was classified with PCI EASI/PACE software and a 30 m buffer from the stream edge created. This created a strip of data for subsequent stream analysis which incorporated only the area around the stream channel. Next, a hierarchical supervised multispectral classification was conducted to extract seven surface types (deep water, shallow water, cobble and gravel, sand, logs and debris, conifer and deciduous). A spectral angle mapper approach (Kruse et al., 1993) using six spectral bands was utilized and implemented with ENVI software. Pixels and groups of pixels of each class distributed throughout the study area were chosen to generate the reference spectra for each class. Threshold spectral angles around each class were determined through an iterative trial and error process. The classification results were reviewed and areas of confusion between classes were then separated into additional classes. For example, areas of cobble, sand or water under the shadow of trees were initially misclassified, but new classes and reference spectra were created (e.g., shadowed cobble). Through this hierarchical approach a reasonable automated classification was produced.

Classification results were assessed both quantitatively and qualitatively. Fifty sites were selected from the ground photo locations and gridded plots. These sites were of the five stream classes (deep water, shallow water, cobble and gravel, sand, logs and debris). The surface type as determined from the field photos and notes was compared to that of the classification. Classification results from this preliminary analysis were compiled. In addition the classification was visually inspected for errors. Particular attention was paid to classification performance in shadowed, boundary or transition zones.

RESULTS AND DISCUSSION

Classification results (Figure 2) were generally good. Quantitative results on the limited and preliminary set of test sites indicates accuracies generally in the 80 percentile range with an 84% average class accuracy over the five stream classes. Shallow and deep water were classified at 80% and 88% respectively. The log and debris areas were classified at 87% accuracy. The sand test areas were classified correctly but there was commission error with some test sites of cobble/gravel and debris being classified as sand. Commission errors were not a problem with the cobble/gravel class, but only 64% of the cobble/gravel test areas were classified correctly. Errors were with sand, debris, deep and shallow water classes. However, some of this error were areas within the shadow of trees.

Visual inspection also indicates good results. The shallow and deep water classes seem solid. The sand to gravel boundary is gradational and some overlap in the classifications is expected, but nevertheless the classification of the sand and cobble/gravel classes is good. The logs and debris class detected the logs well and even zones of scattered small woody debris. However, it was observed that some zones at the boundary between the stream channel and shrub vegetation at the stream edge were incorrectly classified as debris. The hierarchical classification system seemed to have classified reasonably well in shadowed areas, but as noted in the quantitative results, there were misclassifications within shadows.

Results are good both from a quantitative and qualitative point of view. Finer classes need to be tested, especially within the gradation in grain size from sand, through gravel and cobble. More test sites need to be utilized and results tested over a wider segment of the study area and over more than one flight line of data. Procedures and errors within shadow and boundary zones need more investigation. Preliminary tests of the procedure with similar casi imagery over a selection of other streams on Vancouver Island seems to indicate that methods are transferable, but again further testing is needed.

CONCLUSION

A useful mapping of stream surface types was accomplished with automated classification of high resolution casi imagery. It remains to be seen if finer surface classes can be differentiated and how reliable and widely applicable the techniques are. Important gradient information could be obtained digitally through the use of airborne laser altimetry. It is hoped that automated stream planform mapping with casi or other high resolution multispectral imagers will become a tool available to be utilized by those interested in mapping as they see fit to meet their specific needs.

ACKNOWLEDGEMENTS

The study is part of a cooperative project of Macmillan Bloedel Ltd., Itres Research Ltd. and the Canadian Forest Service (Pacific Forestry Centre) entitled "Development of Certified Forestry Applications Using Compact Spectrographic Imager (casi) Data". The project is sponsored and funded by Forest Renewal British Columbia. The authors thank Katrina Roger for assisting with the field work and Shelley Higman of Macmillan Bloedel Ltd. for reviewing the manuscript. Itres Research Ltd. acquired and geometrically corrected the imagery and Doug Davison of Itres, in particular, is thanked for assisting in initiating the study.

REFERENCES

Anger, C.D., S. Mah, and S.K. Babey. 1994. Technological enhancements to the compact airborne spectrographic imager (casi). *Poc. 1st Int'l Airborne Remote Sensing Conference and Exhibition*. September, Strasbourg, France. Vol. II, pp. 205-213.

Channel Assessment Procedures Field Guidebook. 1996. Forest Practices Code of British Columbia. 95 p.

Kruse, F.A., A.B. Lefkoff, J.W. Boardman, K.B. Heidebrecht, A.T. Shapiro, P.J. Barloon, and A.F.H. Goetz. 1993. The Spectral Image Processing System (SIPS) - interactive visualization and analysis of imaging spectrometer data. *Remote Sensing of Environment* 44:145-163.

Figure 1. 550 nm image of test subsection of the study site. Letters indicate locations of the ground photographs of Figure 3.

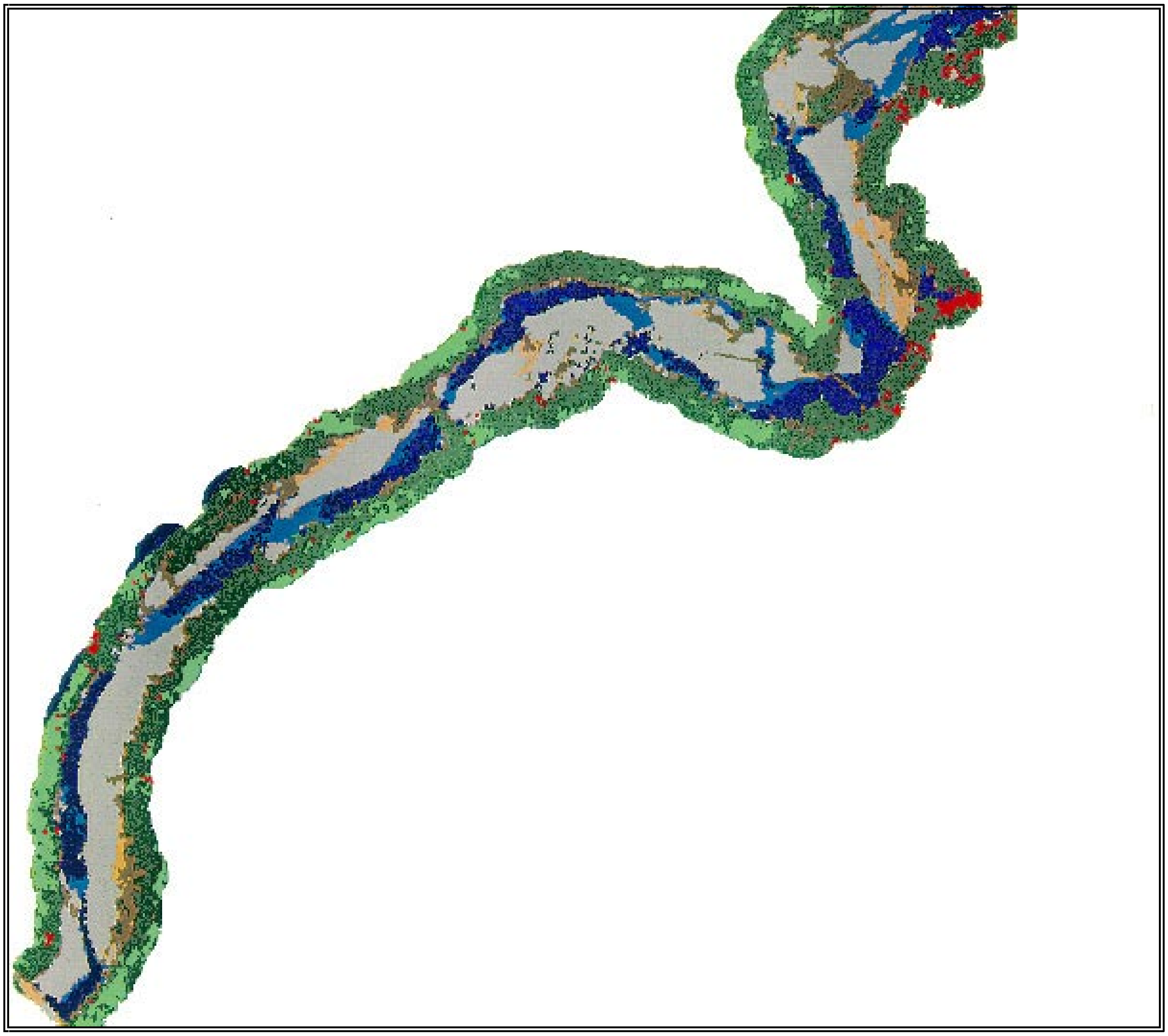

Figure 2. Classification product (deep water = dark blue; shallow water = light blue; cobble and gravel = gray; sand = light brown; logs and woody debris = dark brown; coniferous = dark green; deciduous = light green).

a)

b)

c)

Figure 3. Photos of different substrate material along Tofino Creek; a) sand, gravel and small woody debris; b) cobble, shallow and deep water, woody debris; and c) gravel, woody debris and shallow and deep water. See Figure 1 for the location of these photographs.