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Project Summary

Watershed Characterization Using Landsat Thematic Mapper (TM) Satellite Imagery: Blackfoot River, Montana

K. H. Lee

This report describes a portion of a large regional project undertaken by the Environmental Protection Agency (EPA) and water-quality authorities in the States of Montana, Idaho, and Washington to identify and analyze factors which are affecting water quality in an interconnecting hydrologic system. To achieve this directive in Montana, a spatial database is being constructed which will contain satellite derived land cover, photo-interpreted macrophyte locations, climate data, topography, hydrography, and soils. The database will be used by EPA Environmental Monitoring Systems Laboratory (EMSL) to demonstrate the utility of a watershed scale information management system. This information management system is geared toward nonpoint pollution modeling and will evolve into a decision support mechanism capable of assessing the suitability and feasibility of various alternate management scenarios. The data layers focus on elements required for nonpoint source pollution modeling in which derivation of factors for soil erodibility, rainfall, topographic slope-length, and vegetation management are generated for the watershed. A Geographic Information System (GIS) in which to model alternative land management scenarios such as road building, logging, and fire/burn management. The vegetation management factor will be partially based on land cover derived from Landsat Thematic Mapper satellite imagery. Vegetative management factors combine vegetative cover and soil surface conditions into one numerical factor. This report will address only the generation of land cover maps for the Blackfoot River Watershed through quantitative remote sensing techniques.

This Project Summary was developed by EPA's Environmental Monitoring Systems Laboratory, Las Vegas, NV, to announce key findings of the research project that is fully documented in a separate report of the same title. (See Project Report ordering information at back).

Introduction

This report covers the western third of the Blackfoot River Watershed, which is part of the greater Lake Pend Oreille Watershed. This study is a joint cooperative effort between the U.S. EPA and the States of Montana, Idaho, and Washington to understand the water quality issues of the Lake Pend Oreille watershed. This part of the project deals with several subwatersheds in the western third of the Blackfoot River Watershed, and is based in large part upon the interpretation of satellite imagery.

The entire Blackfoot River Watershed contains approximately 6,022 square kilometers (2325 sq. mi.). Because of budget restrictions, only the western third of the area, 2,185 square kilometers (844 sq. mi.), was classified for land cover.

Figure 1 shows the area covered by this part of the project.

The Blackfoot River flows 132 miles from its source near the Continental Divide westward to its junction with the Clark

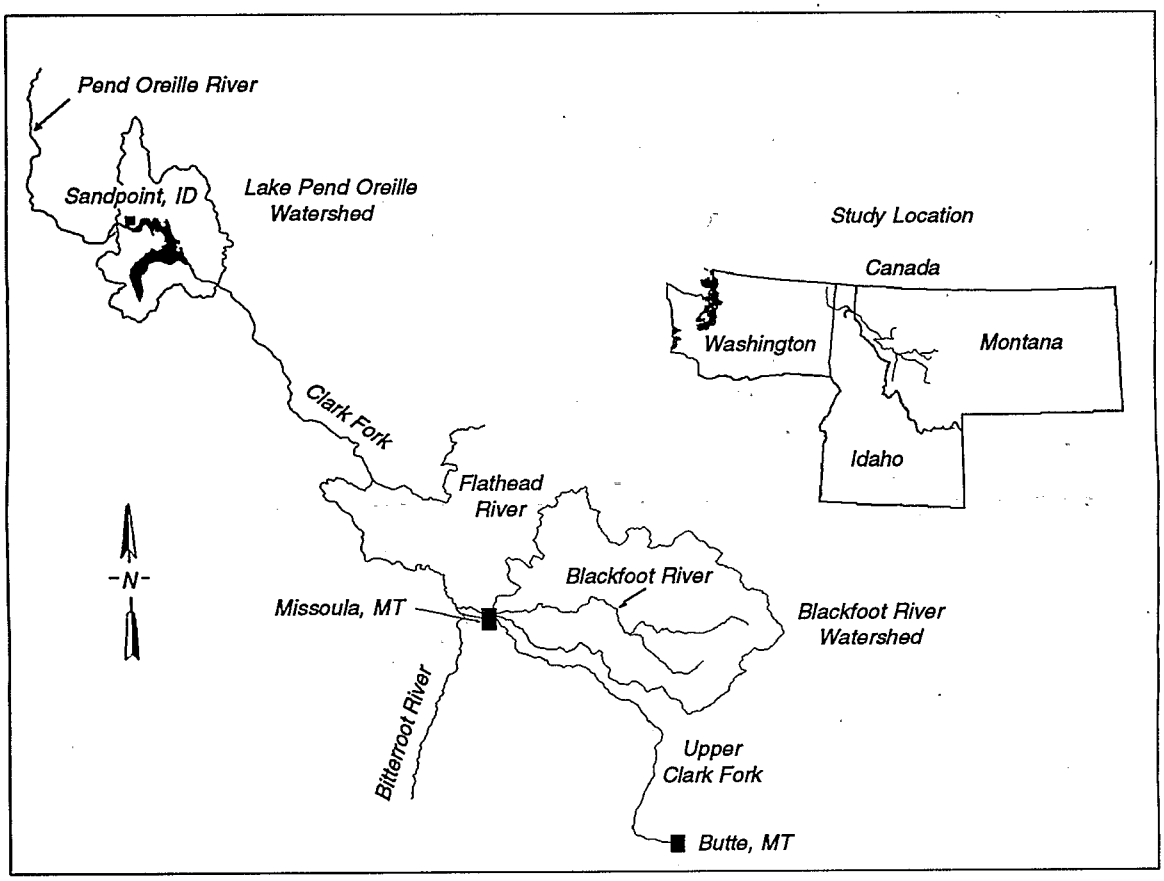

Figure 1. *Remote Sensing/GIS Support for Section 525 of the Water Quality Act of 1987.*

Fork at Bonner, Montana. Factors which affect the water quality are the logging and mining activities, road building, fires, agriculture, unstable river banks, municipal sewage effluent, and pulp mill waste. In Idaho, Lake Pend Oreille receives all the Clark Fork discharge; eutrophication has been associated with the degraded water quality of the Clark Fork.

Procedures

Digital Image Processing

A Landsat-5 Thematic Mapper (TM) digital image acquired on 20 July, 1988 was analyzed to create a general land-cover map for the Blackfoot River Watershed. The Landsat-5 TM satellite sensors record the amount of electromagnetic energy in seven spectral bands: blue, green, and red (visible spectrum); three reflected infrared (IR) bands; and one thermal IR band. Each pixel (or cell) covers about 30 meters by 30 meters, except for the thermal (IR) band which is 120 meters.

The steps taken in the analysis of Blackfoot River satellite data for land-cover characterization were: image rectification; optimum band selection; unsupervised classification; and accuracy assessment of the final classified image.

The Optimum Index Factor (OIF) indicated that a four-band combination of TM bands 3 (red), 4, 5, and 7 reflected (IR) be used to minimize redundancy in the 7-band data set.

Ground Control points (GCPs) taken from topographic maps were used to realign the satellite data, correcting for distortions in the image. The Universal Transverse Mercator (UTM) coordinate system was used for map control.

The TM data set was rectified using 249 ground control points which yielded an overall average locational error of 23.4 meters.

Classification System

Classification units can be selected in two distinct ways: (1) by image interpretation based on previous general knowledge and experience and specific knowledge of the area by the interpreter, or by (2) unsupervised "clustering" of similar pixels by the computer. Spectral characteristics of surface materials, such as soil or vegetation, are likely to vary from place to place. Therefore these clusters must be checked to consolidate some of them having only minor differences in spectral characteristics, but which are part of the same soil or vegetation unit. This was done, and resulted in a total of seven major categories, with the three subcategories, shown below.

Digital classification of multispectral imagery generally produces a salt-and-pepper appearing map. This can arise from a nonuniform response of the sensor, processing errors, the pixel size or mapping unit, or the classification algorithm. In smoothing, every pixel is spatially analyzed in conjunction with the pixels that surround it. Smoothing is used when the final land-cover classification is to have a

Table 1. *Error Matrix: Blackfoot River Watershed Subset*

		Reference					
		Forest-d	Forest-s	Ag	Range	Barren	Wetland	Water
C	Forest-s	15102	1020	157	263	38	313	0
L	Forest-s	71	2001	43	646	128	69	0
A	Ag	0	26	9141	0	62	63	0
S	Range	21	2337	703	1638	159	329	0
S	Barren	4	41	4	191	26	1	0
E	Wetland	0	0	0	0	0	121	0
D	Water	0	85	1	575	0	11	2358

Overall Accuracy = 80.5%

Commission
User's Accuracy

Forest-d = 89%
Forest-s = 68%
Ag = 98%
Range = 32%
Barren = 10%
Wetland = 100%
Water = 78%

Omission
Producer's Accuracy

Forest-d = 99%
Forest-s = 36%
Ag = 91%
Range = 50%
Barren = 6%
Wetland = 13%
Water = 100%

minimum mapping unit such as an acre or hectare.

The problems of converting raster data (having a stair-case appearance) and vector data (shown as a smooth line, arcuate or straight) are presently solved by an intermediate file structure called SVF. The problems of this conversion are expected to be solved in the near future by the utilization of raster data in a grid format in the vector GIS.

The following classification of land-cover features resulted from unsupervised classification combined with adequate reference information from the area.

1. Agricultural lands: cropland and pasture, found in areas of low relief.
2. Barren land: bare, exposed rock.
3. Barren land (roads): including railways.
4. Forest land: having a tree crown areal density of at least 10 percent.
   A) Dense coniferous forest cover (greater than 40%).
   B) Dense deciduous forest cover (more than 40%).
   C) Old timber/thinned sites/sparse cover (cover less than 40%; more than 10%).
5. Rangeland: grasses and shrubs.
6. Wetland: was difficult to distinguish between forest and agriculture. Only several small areas were identified.
7. Water: includes the Blackfoot River and tributaries, lakes, and reservoirs.

Accuracy Assessment

Evaluation of the accuracy of the land-cover classification requires comparison between the classification results and reference data for the area. These reference data are taken from various sources. Site-specific comparisons are made by calculating the frequency of coincident classes, point by point, and reporting these values in an error matrix (confusion matrix or contingency table).

Detailed statements of accuracy are derived from the error matrix in the form of overall and individual land-cover category accuracies. For each class the percent commission and percent omission errors are calculated from the error matrix (confusion matrix or contingency table).

The reference data used to evaluate the final, classified image of the Blackfoot River Watershed subset were taken from photo-interpreted color airphotos (1988) flown for a macrophyte survey, NHAP CIR photography (1984), and soil survey orthophoto maps (1982).

Research indicates that reference data from at least 1 percent of any area should be enough for a valid evaluation of the accuracy of the interpretation. In the case of the Blackfoot River Watershed, the reference data used covered 1 percent of the area.

Table 1 shows the error matrix of the study area having an overall map accuracy of 80.5%. However, this does not consider the accuracies of individual categories. Producer's accuracy (omission error) and user's accuracy (commission error) are important in assessing the reliability of a classified image.

Commission errors are the percentages indicating the ratio of those pixels in any category which are correctly classified. Omission errors are given a percentage to indicate the probability that a reference sample will be correctly classified.

Unsupervised classifications were obtained for the eastern two-thirds of the entire Blackfoot River Watershed. However, not enough reference data were available (i.e., air-photos, maps, and ground verification) for an accuracy assessment to be performed for this area.

Results and Discussion

The selection of a four-band data set containing 61 megabytes instead of the six-band sub-scene of 91 megabytes for the western third of the watershed resulted in the elimination of 30 megabytes from computer computation for the rectified area of 100 km x 100 km.

It is projected that the overall accuracy of 80.5 percent would not be a limiting factor in the calculation of vegetation management factors for the Blackfoot River Watershed. The resolution of the TM imagery (30 meters) will probably have greater impact on nonpoint pollution-modeling as the level of detail required for land cover can become quite specific, even to the point of whether the ground cover is grass or weeds. The forest class was divided into dense and thinned cover arbitrarily; this estimated amount of cover should be useful in the development of vegetation management factors.

The Blackfoot GIS contains other thematic layers which are commonly available (i.e., hydrography, elevation, soils, etc.); these combined with recent land cover estimates will provide the EPA Regions and State agencies with the building blocks on which further analyses surely will develop. The GIS database, as constructed for this modeling effort, is an attempt to work on a third-order watershed where the level of detail required may not need to be so specific. Updates are much easier in the GIS environment as this technology facilitates the incorporation of higher accuracy or resolution information after baseline development. A tentative list of management issues in the Blackfoot River Watershed includes investigations of water quality for fisheries management, comparisons of silvicultural prescriptions for sediment yield reduction, and environmental assessment of potential impacts of proposed mining activities.

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K. H. Lee is with Lockheed Engineering and Sciences Company, Las Vegas, NV 89119
Ross S. Lunetta is the EPA Project Officer (see below).
The complete report, entitled "Watershed Characterization Using Landsat Thematic Mapper (TM) Satellite Imagery: Blackfoot River, Montana," (Order No. PB92- 115 237/AS; Cost: $17.00, subject to change) will be available only from:
National Technical Information Service
5285 Port Royal Road
Springfield, VA 22161
Telephone: 703-487-4650
The EPA Project Officer can be contacted at:
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U.S. Environmental Protection Agency
Las Vegas, NV 89193-3478

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