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APPLICABILITY OF LANDSAT DATA
TO WATER MANAGEMENT AND CONTROL NEEDS

J. W. Jarman

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When the Landsat satellite was launched in June 1972, the Corps of Engineers undertook several experiments related to the use in water resources development programs of automatic classification of the digital data gathered by the satellite. In one application, the U. S. Army Engineer Waterways Experiment Station in Vicksburg, Mississippi, developed techniques for analyzing the multi-spectral data to determine surface concentrations of pollutants in the Chesapeake Bay and several tributary rivers. Our San Francisco District, with contract support from North American Rockwell, used automatic classification of multi-spectral data to delineate flow patterns and sediment movement in the San Francisco Bay and California coast areas. These experiments established the feasibility of automatic classification for Corps of Engineers applications.

On February 26, 1972, 150 million gallons of sludge-filled water cascaded down a 17-mile West Virginia valley after a dam embankment created of mine refuse failed. The Buffalo Creek Disaster took the lives of more than 100 people, injured hundreds, and left more than 1,000 homeless.

In August 1972, Congress authorized the Corps of Engineers to inventory impoundments in the United States and to develop recommendations for a comprehensive national dam safety program.

As so often happens, the time-frame for developing the inventory precluded the general use of the Landsat imagery. Since the classification techniques required further development, they were used in selected areas. However, our success in those areas has convinced us that automatic classification techniques do provide less expensive and more accurate surveys than the manual methods used. If Congress passes a continuing requirement to maintain an inventory of impoundments, we expect that digital data from satellites will be a principal source of information.

Following the completion of these experiments and operational tests, the Corps New Orleans District approached the National Aeronautics and Space Administration's Mississippi Test Facility with a problem related to environmental inventories.

(Environmental inventories are atlases or other compilations of known environmental information regarding water and land resources. The information establishes landuse patterns, water quality, wildlife habitats, and other environmental conditions that could be affected by a Corps project.)

The New Orleans District has manually prepared an "Inventory of Basic Environmental Data, South Louisiana." The problems related to updating this inventory and to extending its coverage required the consideration of alternative methods of data collection.

The New Orleans District and the Earth Resources Laboratory of the National Aeronautics and Space Administration initiated a joint project to develop and demonstrate an automated system based on remotely sensed data. One purpose of the project was to demonstrate the suitability of satellite data in producing updated maps of surface classifications useful in assessing and monitoring the environment. Other project goals were to specify and document an operational system, including hardware and software, and to provide sufficient training in its use to effect a complete transfer of technology to a user.

Twenty atlas categories were carefully compared with the remote sensing capability developed by the Earth Resources Laboratory. Three general categories were considered amenable to identification and updating by remote sensing. These were Generalized Land Use, Ecological Zones, and Vegetation.

Table I lists the classifications used for the demonstration maps prepared with the aid of remote sensing techniques. The correlation between the categories of the three atlas classifications can be determined from the three maps. As can be seen from the table, the classification derived from remote sensing, with some minor exceptions, covers all of the items of the three atlas categories.

The accuracy of the classification was checked by comparing the computer classification with a classification made by an experienced photo interpreter from the 60,000-foot color infra-red aerial

photograph used as "ground truth" in the study. Table II shows this comparison.

In view of our success in testing automatic classification procedures, the Corps is moving toward the general implementation of these techniques in the execution of our routine activities. To accomplish this, we are focusing on one of our primary operational areas, hydrology.

The Corps basic mission relates to the avoidance of damages resulting from floods and to the development of water resources for such purposes as navigation, recreation, and hydropower generation. Much of our planning is dependent upon generalized models which provide the capability of performing analyses over a very broad range of detail. For instance, we might need a general assessment of an entire river basin for an alternative land use pattern, or a specific assessment of an area of a small tributary where a 300-acre shopping center with attendant channel lining and detention storage are proposed. These two extreme levels of detail must be accommodated by providing the capability of automated analysis that can be interrupted at various stages of computation. Figure 1 is a schematic of the conceptual framework for the analysis.

The geographic data files consist of numeric records that legend location and characteristics of landscape features with spatial variation. An example would be a computer file of the (X,Y) coordinates of the boundaries of each of the selected land use types for the river basin. All the area within a boundary then represents the specific land use and could be subdivided into a grid for use in further processing.

Type of land use affects the hydrology of an area. Generally speaking, the greater the development -- or paved area -- the more run-off there will be. In these analyses, we study the impact on future watershed conditions of extending land use. Therefore, land use will be used as the key indicator of the existing and alternative watershed conditions. The analysis methods interpret the consequences of specific land use and other physical characteristics of the watershed in hydrologic, economic, and environmental terms.

The land use categories are a compromise of the requirements needed for hydrologic, economic and environmental analysis. From the hydrologic viewpoint, the concern is with moisture retention/precipitation excess and basic response characteristics which are related to impervious cover. From the economic viewpoint, the damage potential and disruption of community activities is a function of the size, density, and type of structures and contents. From the environmental viewpoint, the concern is mostly with the intensity of development and the potential for adverse impacts such as pollution.

The categories tentatively adopted to meet these analysis needs are:

Pasture -- livestock grazing areas, ranges, meadows, agricultural open areas, abandoned crop land;

Crops -- cultivated land, row crops, small grain, etc.;

Natural vegetation -- heavy weeds, brush, scrub areas, forest, woods;

Developed open space -- lawns, parks, golf courses, cemeteries;

Water bodies -- lakes, large ponds, major streams, rivers;

Low density residential -- single family, 1 unit per 1/2 to 3 acres, large residential lots; (averages 1 unit per 1-1/2 acres);

Medium density residential -- single family, 1 unit per 1/6 to 1-1/2 acres, typical subdivision lots; (averages 1 unit per 2/3 acre);

High density residential -- multi-family row houses on less than 1/6 acre lots, apartments, townhouses, etc. (averages 1 unit per 1/8 acre);

Commercial -- pavement and roofs, buildings, shopping centers, parking lots, etc.; and

Industrial -- industrial complexes, roofs and pavements, possible some grass areas.

If remote sensing can make a significant contribution to the input for watershed model performance and application, it will be of significant benefit to the Corps.

The type of watershed models to be considered first are those which are applied in predicting flood hydrographs. We are particularly interested in those that can provide estimates of runoff stage and volume that can be used in planning and designing flood control structures and setting guidelines for uses of the land surrounding stream channels. Burgy and Algazi (1974)⁵ noted that potential existed in Landsat data for providing input to such watershed models and, in particular, those employed by the Corps of Engineers. This analysis has been corroborated by work done by researchers at the University of Maryland. Their results (Ragan and Jackson, 1975)⁶ indicate that Landsat data extraction is faster and more economical than conventional techniques and compares favorably to conventional results.

Because of the implications of these potential uses, NASA and the Corps of Engineers have entered into a joint venture to further verify the applications. The objective is to define the utility of remotely-sensed data from Landsat and high altitude aircraft in the calibration and application of a practical, widely-used hydrologic model. The basic focus for this emphasis will be an operational model prepared by the Corps of Engineers Hydrologic Engineering Center (HEC) entitled the "HEC-1 Flood Hydrograph Package." The Hydrologic Engineering

Center, located in Davis, California, provides Corps-wide technological services in hydrologic engineering through computer research in water phenomena.

The first year, largely falling in Fiscal Year 1976, will involve definition of the project and preliminary or test projects documenting the feasibility of embarking on the total project.

There are two major elements of this definition phase. The first element will involve a thorough review of the HEC-1 Flood Hydrograph Package and the Surface Treatment, Overflow and Runoff Model (STORM), including the general applications, input data required, parameters within the model to be specified, and the output requirements. This analysis will seek particularly to confirm and refine previous indications of where remote sensing can be applied for delineating and specifying land use, associated degrees of imperviousness of the soil, ground cover conditions such as the extent and condition of bare soil, and broad measures of vegetation type and density.

A second element to be accomplished in conjunction with the analysis and application of the HEC-1 model will be the processing of Landsat data and possibly high-altitude aircraft photography over two watersheds well-known to HEC personnel. The purpose of this is to corroborate previous research findings and to develop and define the remote-sensing data processing procedures to be used in the full-scale evaluation. A specific objective will be to verify, in the form of specific output, that land use data meeting the requirements for model input specified by the Corps can be derived from Landsat data.

The first watersheds to be studied for feasibility are the Castro Valley watershed on the eastern side of the San Francisco Bay and south of Oakland, California, and the Trail Creek watershed near Athens, Georgia.

By January 1977, at the end of the definition phase, we will decide if the full-scale evaluation phase is to be performed. This decision will be made by Corps personnel assisted by NASA and contractor (University of California, Davis) personnel.

The evaluation phase of the project, scheduled to last approximately one year, will consist of processing and utilizing remotely-sensed data in the HEC-1 and/or STORM models and comparing the timeliness, representativeness, costs, manpower, and labor-saving aspects with conventional means of acquiring model input data. In order to properly test the utility of remotely-sensed data, the HEC-1 package and procedures will need to be applied on several watersheds of different sizes and in different environments. Selection will be made of 3 to 5 more watersheds across the United States that provide as wide a variety of conditions as possible. The selection of these watersheds will again be largely at the discretion of Corps personnel and will undoubtedly involve watersheds with which they are familiar through work with the HEC-1 package.

Candidates for this phase of the study include: Alameda Creek in California, Chester Creek in Pennsylvania, North Branch of the Chicago River, Saline Creek near St. Louis, Missouri, the Merrimack River in New England, and a watershed in the Great Basin - Rocky Mountains area.

Care will be exercised during the evaluation phase to collect data and document all procedures so that a well-founded comparison can be obtained between remote sensing and conventional procedures. This is particularly true in the case of cost effectiveness or, possibly, cost benefit results that must be obtained upon conclusion of the project. Many results will be needed in order to decide whether or not to enter the implementation phase.

At the end of the evaluation phase it will be necessary to take the successful portions (hopefully this will be a large portion) of the total effort and make the associated data processing procedures compatible with the HEC-1 model and Corps computational facilities at HEC as well as at Corps District Offices throughout the country. Training sessions will be the primary means of transferring the techniques to the operating elements of the Corps.

To recapitulate, this project will assess the feasibility of using remote sensing and digital techniques for hydrologic model input to basin-wide surveys. We expect to:

- Demonstrate the utility of Landsat hydrologic land-use data in hydrologic engineering models for flood control/waterworks design;
- Accomplish the transfer of successful models to the operating elements;
- Document any achieved cost-effectiveness, accuracy, timeliness, and speed aspects of utilizing Landsat data; and
- Document any successful techniques and procedures developed so that other user agencies can employ them.

That ends my formal presentation. I will be happy to answer any questions.

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TABLE I. Comparison of Categories for Remote Sensor Classification and Generalized Land Use, Ecological Zones, and Vegetation Maps.

REMOTE	GENERALIZED LAND USE	ECOLOGICAL ZONES	VEGETATION
1. Agricultural	1. Agricultural	1. Cleared Land	1. Crops & Pasture
2. Urban/Built-Up	2. Urban/Built-Up	2. Cleared Land	2. Other
3. Forest	3. Forest Land	3. Woodland	3. Forest
a. Deciduous		a. Bottomland	a. Deciduous
b. Evergreen		b. Upland	b. Evergreen
c. Mixed		c. Upland	c. Mixed
4. Forested Wetland	4. Forest Land	4. Bottomland	
5. Nonforested Wetland	5. Nonforested Wetlands	5. Marshland	5. Nonforested Wetlands
a. Saline		a. Saline	a. Saline
b. Brackish & Intermediate		b. Brackish	b. Brackish
c. Water Hyacinth		c. Intermediate	c. Intermediate
d. Fresh		d. Fresh	d. Fresh
6. Barren	6. Barren	6. Cleared Land	6. Other
7. Water	7. Water	7. Water	7. Water

TABLE II - CLASSIFICATION ACCURACY VERIFICATION

PHOTO INTERPRETATION CLASSIFICATION	COMPUTER CLASSIFICATION								TOTAL POINTS	
	URBAN	AGRICULTURE	FOREST	SWAMP	WATER	MARSH	BARREN	UNCLASSIFIED		
URBAN	12	5	2					1	20	
	.60	.25	.10					.05		
AGRICULTURE	1	182	7			2			192	
	.005	.94	.03			.01				
FOREST	1	18	245	10	4				278	
	.003	.06	.88	.03	.01					
SWAMP		1	9	10					20	
		.05	.45	.50						
WATER		1	1		219				221	
		.004	.004		.99					
MARSH	3	1	3	3	1	123	2		141	
	.02	.007	.02	.02	.007	.99	.01			
BARREN			1						1	
			.100							
Total points									874	Percent agreement
									91	

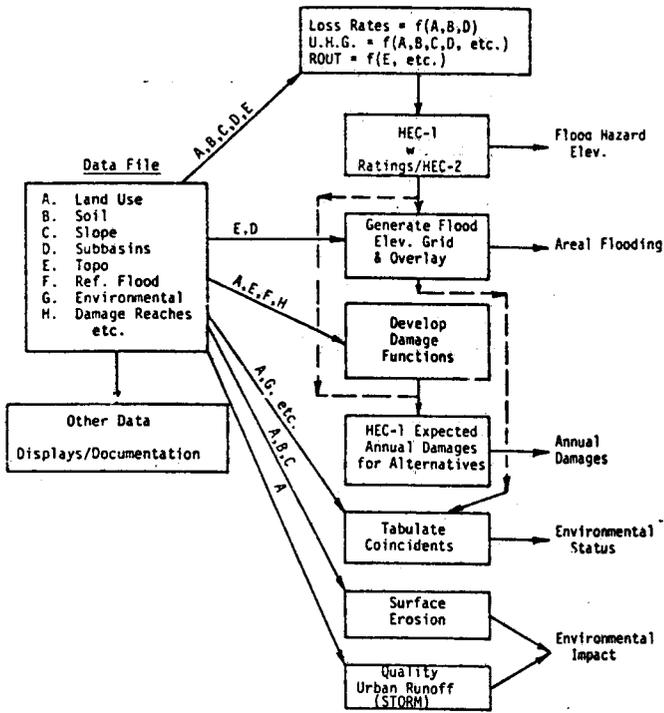


Figure 1
 General Data Management -
 Modeling Scheme