APPLICATION OF REMOTE SENSING IN

FLOODWAY DELINEATION

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INTRODUCTION

Population pressures upon the land resources of Arizona have resulted in the sale and development of areas subject to inundation by floodwaters. These problems are magnified in the predominantly rural areas of Arizona where the availability of relatively low-priced agricultural land combined with the inadequacy of land use controls opens the area to various land speculation schemes and unplanned subdivision growth.

PROJECT CONCEPT

In response to this problem of floodplain development the Arizona legislature passed House Bill 2010 on 3 May 1973. This bill directed local government agencies to outline up to the 100-year floodplains in areas of ongoing land development and to construct a set of ordinances for land use management in these areas. House Bill 2010, and its supporting documentation from the Arizona Water Commission, outlined a set of general procedures for the delineation of flood-prone areas, but was difficult to implement at the county level because of limited financial and personnel resources and a nine-month time-frame for initial compliance.

This report describes the floodplain delineation project conducted by the author for the Planning Department of Cochise County, Arizona. Imagery acquired by the National Aeronautics and Space Administration's (NASA) Earth Resources Technology Satellite (ERTS-1) and by high-altitude aircraft was employed in the project.

If a planning staff is to manage land use within a county-sized jurisdiction, it must have access to a data base which can be updated to monitor changes in land use, and which presents data in a form which requires a minimum of interpretive time after analytic techniques have been developed. The output of the ERTS-1 program meets these specifications for the formulation of a data base for local planning efforts. This remotely-sensed data can effectively be used with existing available county maps, such as the soil survey, geological and topographic maps, and natural resource and land-use maps available from state and federal agencies.

The Cochise County Planning Department initiated the floodplain delineation project in June 1973. It is the intention of this report to demonstrate that a project such as that stimulated by House Bill 2010 can be conducted in-house by a local planning agency within the constraints of available funds and personnel. A county planning staff can, with data acquired by aerial sensors, and with equipment support from university research facilities, meet much of the data requirement for rational planning decision.

EQUIPMENT AND METHODS

Table 1 lists the equipment used on this project.

Table 1

Cochise County Planning Department, Bisbee
- Light table
- Kail K-10 mirror stereoscope
- Overhead projector and screen
- 3x and 6x magnifiers

Office of Arid Lands Studies, University of Arizona
- I^2S color additive viewer
- Light table with variable intensity capability
- Density slicer system

The nine-month time-frame determined by the legislature necessitated the selection of "critical need" areas within the county. Two parameters were analyzed to select areas for floodplain delineation study: first, areas of imminent or ongoing development; and second, portions of the county known to be subject to inundation by storm runoff. The intersect between "development areas" and "flood areas" formed a basis upon which study areas were selected. Several reconnaissance trips, and consultation with planning and engineering staff resulted in selection of the following areas: Willcox, Turkey Creek, Douglas, and Sierra Vista-Fort Huachuca (see Figure 1). "Area" in this context is defined as the two adjoining 15 minutes U.S.G.S. topographic quadrangles containing the above-named locations and significant portions of the watersheds which contribute runoff into these locations.

Parameters of the analysis procedure were soils and geomorphology, vegetation, hydrologic calculations, and historical data. Reckendorf (1968) has reported that this "combination method" is an effective means of delineating areas subject to periodic flooding.

It was found upon attempting to assemble basic data on watershed characteristics and streamflow that little was available; and available

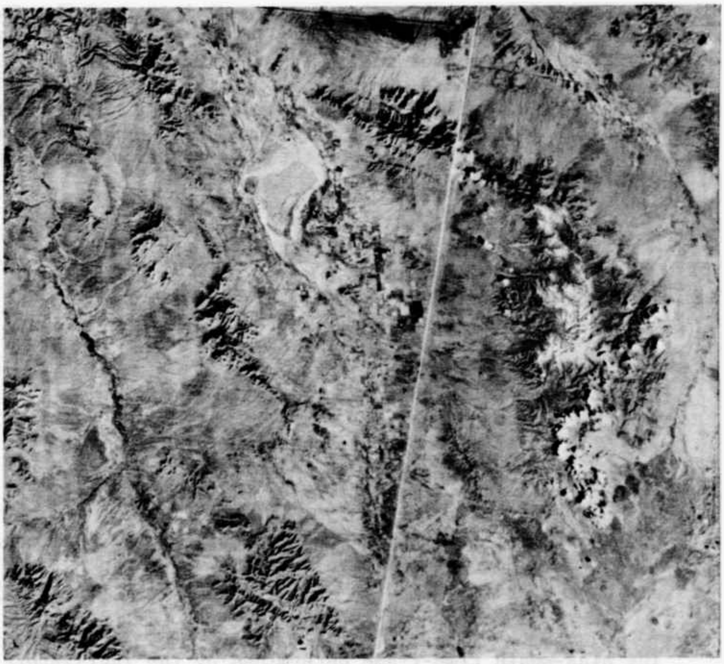

Figure 1. Cochise County, AZ on ERTS 1 Multispectral Scanner Band 7, 1 inch equals 16 miles.

data from various sources were not in agreement as to boundaries and figures. As an example, watershed configuration maps from federal government sources contained a combination of actual watershed boundaries and administratively-determined boundaries which made the product unusable for generating areas of the necessary scale.

Analysis of watershed configurations and drainage patterns was conducted using a step-down procedure from preliminary, synoptic views on ERTS imagery at scale of 1:1,000,000, 1:500,000, and 1:250,000, to color infrared photographs at 1:125,000. Drainage pattern analysis is a function of soil reflectance and vegetation. All interpretations were ground-checked to confirm accuracy of location of patterns. Ground-checks became fewer as interpretive confidence was developed.

Table 2

ERTS-1 imagery used in project:

Image ID	Date
E 1101-17215-4/5/7	01 Nov 72
E 1101-17221-4/5/7	01 Nov 72
E 1102-17274-4/5/7	02 Nov 72
E 1102-17280-4/5/7	02 Nov 72

Product of ERTS-1 Multispectral Scanner (MSS):

MSS Band	Spectral Range (micrometers)
4	5.0 - 6.0 μm
5	6.0 - 7.0 μm
6	7.0 - 8.0 μm
7	8.0 - 1.10 μm

SOILS AND GEOMORPHOLOGY

A detailed soils map should be of considerable use in floodplain delineation because soils associated with flood areas are characteristically young and development has been minimal. Floodplain soils lack developed B horizons, as compared to older, more mature soils not subject to flooding. A "B horizon" is an area of illuviation of clays and typically blocky structure.

The soils map of Cochise County (SCS 1971) showed an area of Whitehouse-Forrest-Tubac soil association northeast of Willcox. This association contains developed soils, and no flooding hazard is normally connected with these soils. Field study resulting from interpretation of high reflectance of this soil area on the imagery clearly revealed that large portions of the association were definitely floodprone and had been inundated recently. Examination of soil profiles showed a shallow (8-15 cm.) overburden of recent alluvium. Further study of the contributing watershed area revealed an extreme overgrazed condition which has caused increased water yield and extensive gullying. This condition could be detected quite clearly as high reflectance on the high altitude color infrared photography.

General soils maps can be used only as guidelines. If a detailed soil survey is available for an area under study, it can add significantly to the accuracy of image interpretation, and few groundchecks need be made. Consultation with Soil Conservation Service staff is strongly urged during the interpretive process.

A problem common to semi-arid environments is the lack of consistent channel geometry. The mode of flow in areas of less than two to three percent slope is a sheet configuration after the capacity of minor drainage channels has been exceeded. When these flows coalesce, they may form a nearly continuous sheet several hundred meters wide and ten to twenty centimeters deep in areas of relatively flat topography. The scour regions of this type of flow can be seen quite readily on bands 5 and 7 of the ERTS imagery and on the color infrared photographs. Scours appear as very highly reflective areas occurring on the lower slopes of alluvial fans.

The sheet-flow drainage becomes a problem when it is affected by, and consequently affects, human activities and uses of land. An example of this interaction that is easily detectable on remotely-sensed data is overgrazing, which accelerates runoff and erosion. The effects of this are severe enough on the upslope rangelands in terms of soil loss; however, the subdivision of lands in the discharge area of ephemeral streams makes necessary careful monitoring of construction as a means for implementation of floodplain land-use management regulations. The necessary monitoring is most efficiently carried out by an ongoing program, gathering data over time.

The ERTS-1 product, in bands MSS 4, 5, and 7, was used to compile a watershed area map of the entire county, and several runoff-contributing areas outside the county's boundaries. This imagery was used in the form of 70 mm. chips for enhancement in the color additive viewer and in all available enlargement modes. By viewing these transparencies in color enhancement and on the light table, a map of apparent watershed configurations was assembled and plotted at 1:62,500. By adjusting the intensity of the light table through the lower end of the range, light-shadow relationships can be used to best advantage for the delineation of erosional features. Ground checks of the watershed delineation map revealed that subtleties of drainage patterns and erosional features interpreted from ERTS imagery at 1:250,000 was nearly equal to the output of a similar analysis of the high-altitude color infrared transparencies. Color infrared is an ideal backup system for geomorphic interpretation if analysis at the individual subdivision level is desired as a component of the regulation function of a local planning department.

VEGETATION

Vegetation data, both interpreted from remote-sensor sources and observed in detail on the ground, is useful for delineation of floodways in a semi-arid climatic zone. The dominant vegetation types for a given area is consistently associated with soils and mositure regime, as well as with climatological factors.

Primary delineations of riparian (Prosopis dominated) vegetation was conducted using ERTS enlargements in bands MSS 4 and 7. High altitude color infrared photographs were found necessary for detailed delineations in smaller channels (<50 feet in width). Erosion-affected soil tones in areas adjacent to active channels proved beneficial in that the heightened contrast served to enhance resolution of vegetation-type boundaries. Ground-checked interpretation confirmed a significant agreement between areas designated flood hazard zones on the basis of vegetation analysis and those generated by hydrologic calculation.

While photointerpretive techniques based on vegetation analysis are highly useful for floodplain mapping in semi-arid situation, ground observation or low-altitude oblique views are important for refinement of data. Assessment of tree condition in and near channels has potential as a data source. Examination of riparian growth by infrared-sensitive photographic method in a low-altitude oblique mode offers the possibility of partial elimination of ground checks and the capability of coverage of large areas within a relatively short time.

An additional vegetation-related factor which is worthy of inclusion in the analytical process is flood-deposited debris. This means of establishing high-water limits is obviously limited to ground-check observation, unless the debris is of considerable magnitude. This part of the vegetation-based method overlaps to some extent the historic data method at the recent end of the scale.

HYDROLOGIC CALCULATIONS

The procedures used in making the hydrologic calculations were basically those of the U. S. Department of Agriculture Soil Conservation Service (SCS), National Engineering Handbook, Section 4 Hydrology. A detailed, step-by-step process is presented in the SCS publication. All graphic and tabular data generated by this method are on file in the Cochise County Planning Department office in Bisbee, Arizona.

Hydrologic calculations were done based on valley cross-sections surveyed at two-to-three mile intervals, and on the parameters included in the SCS discharge equation:

$$Q_p = \frac{484\ AQ}{(\frac{D}{2}) + .6\ T_c}$$

where: Q_p = peak discharge in cfs
A = Drainage area in mi^2
Q = storm runoff in inches
D = storm duration in hours
T_c = time of concentration in hours
484 is a constant for units used

Values for variables in the above equation were determined using curves in the SCS Handbook. Data used to enter the curves were determined by analysis of remotely-sensed imagery with ground-check coordination. One of the variables which is of obvious significance is drainage area; as stated previously, this data was not available for most of the county. The watershed map, which was one of the early products of this study, provided figures for drainage area. Time of concentration, which is the time required for water falling on the most hydrologically remote portion of a watershed to reach the point of concentration or discharge, was also obtained during the delineation of drainage patterns. Two additional factors which are necessary in order to obtain values for the component variables in the SCS equation are "curve number" and "soil hydrologic group". These values are the product of a complex of relationships between four basic factors: (1) climate, mainly rainfall and temperature; (2) soil, its resistance to erosion and rate of water intake; (3) topography, length and incline of slope; (4) vegetation, the per cent areal coverage of soil surface by vegetative canopy. Soil hydrologic groups, as defined by the Soil Conservation Service, are based upon the capacity of a soil to transmit water when the soil is in a saturated condition. A high rate of water transmission is associated with low runoff potential.

Soil hydrologic groups and curve numbers were evaluated using ERTS 70 mm. chips in color infrared enhancement, and high-altitude color infrared photographs in stereo-vision mode at 3x magnification. The bases for this set of interpretations were general slope class, soil reflectance as an erosion indicator, and apparent density and condition of vegetation cover. Estimates of hydrologic group were found to be in agreement with soil type-hydrologic group placement determined by SCS in most (approximately 85 per cent) of the areas observed. Operator experience with this type of interpretation could raise the accuracy to approach one hundred per cent.

Floodplain lines generated by hydrologic techniques were assumed to be correct, and delineations made based upon the various photointerpretive methods were measured against these lines. Although statistical controls were not a part of this project, the confidence level with which one could interpret floodways on the remotely-sensed imagery reached approximately ninety per cent; i.e., in a one-mile reach of well-defined channel the floodplain area generated from analysis of all imagery covered approximately ninety per cent of the area of inundation derived by hydrologic methods. In areas without well-defined channels, or in areas under cultivation, remote-sensor techniques far surpassed hydrologic methods in delineating areas known to be subject to flooding.

HISTORIC DATA

The historic data input into the system of floodplain delineations is dependent upon two components: (1) location of high-water marks, and (2) obtaining a record of the amount of rainfall which resulted in the given high-water mark. This was the least reliable of the methods in this floodplain delineation scheme. Degree of availability of data constitutes a significant constraint on this method. Precipitation records in the county are inadequate, and streamflow gauge records are virtually non-existent except on the San Pedro River. Photographic evidence can be obtained from local newspapers, as aerial photos, in low altitude oblique mode, are often taken by journalists to record floods of significant proportions. Ground photos from newspaper sources can be used to determine water levels relative to structures. Interpretations made from other methods can be field-checked by interview with local residents, and with employees of town government agencies, who often are directly involved during a flooding event.

SUMMARY OF SIGNIFICANT RESULTS AND ONGOING RESEARCH

The successful application of the ERTS-1 program in a problem area of concern to local planning agencies is a major product of this study. The delineation of areas subject to inundation by means of remotely-sensed data acquisition represents a considerable saving in personnel time. Repeated input from aerial sensor sources provides the planner at the county or town level a potent tool for the formation of a data base and for the monitoring of land use patterns over time.

The primary output of this project was a set of base map overlays at a scale of 1:62,500 delineating areas which require special regulation, under state law, when proposed for land use involving human habitation or certain classes of storage, as outlined in House Bill 2010. These overlays were presented to the Board of Supervisors of Cochise County for implementation into their subdivision regulation structure as of 4 February 1974.

Some of the secondary products of the study were county-wide maps of watershed configurations and of soil hydrologic groups. Further research is anticipated to extend the mapping of watershed areas outside the political boundaries of Cochise County, which will provide data for subsequent rainfall-runoff relationship studies in the area.

All of the data provided from this project will be incorporated into the Cochise County composite computer mapping project now operational under partial funding from the County Supervisors. Land use planning decisions are only as good as the basic data, and results of this project have improved the pool of information available to the planning staff of Cochise County.

ACKNOWLEDGEMENTS

Much of the credit for the execution of a project based upon remotely-sensed data is necessarily diverse. I am limited in this instance to expression of appreciation to an identifiable few. First among these is my employer during the course of the project, James Altenstadter, Cochise County Planning Director. Acknowledgement is certainly due the National Aeronautics and Space Administration and their state advisory committee in Arizona for providing not only a source of remote-sensor data, but support funds for a portion of the project. I am particularly appreciative of the technical assistance willingly given by Kennith Foster, Larry Lepley, and Mervyn Tano of the Office of Arid Lands Studies. Donald Post of the Soils, Water and Engineering Department provided support in interpretation of soils data and patient review of the text.

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