**REMOTE SENSING AND HYDROLOGIC MODELING
OF ARID WATERSHEDS: A SCALE ANALYSIS**

Thomas W. Gardner
Department of Geosciences
College of Earth and Mineral Sciences

Gary W. Petersen
Department of Agronomy
College of Agriculture

Final Report
for Period July 15, 1986-August 31, 1990

Prepared for

Ecological Research Division
Office of Health and Environmental Research
the U.S. Department of Energy
Agreement No. DE-FG02-86ER60472

August 1990

DISCLAIMER

This report was prepared as an account of work sponsored by an agency of the United States Government. Neither the United States Government nor any agency thereof, nor any of their employees, makes any warranty, express or implied, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights. Reference herein to any specific commercial product, process, or service by trade name, trademark, manufacturer, or otherwise does not necessarily constitute or imply its endorsement, recommendation, or favoring by the United States Government or any agency thereof. The views and opinions of authors expressed herein do not necessarily state or reflect those of the United States Government or any agency thereof.

MASTER *cb*

DISTRIBUTION OF THIS DOCUMENT IS UNLIMITED

TABLE OF CONTENTS

	<u>Page</u>
Table of Contents.....	i
List of Figures.....	ii
List of Tables.....	iii
Abstract.....	iv
Grant Summary.....	1
Reflex Background.....	1
Research Objectives.....	3
Summary of Primary Results.....	7
List of Publications.....	7
Appendix A - Research Publications.....	9

LIST OF FIGURES

Figure	<u>Page</u>
1. Universal Watershed.....	2
2. Existing and Proposed REFLEX sites.....	4
3. Location Map of the two study basins.....	6

LIST OF TABLES

Table	<u>Page</u>
1. Breakdown of Agreement No. DE-FG02-86ER60472.....	1
2. Description of Existing and Proposed REFLEX Sites.....	5

Abstract

The increasing availability of digital elevation data (DED) created from remotely sensed data has promoted the development of computer algorithms for the calculation of geomorphometric properties of the land surface. These include parameters that are tedious or impossible to do by hand, for example, stream properties by order and flow path mapping for every location within the drainage basin. Flow paths especially are critical for water routing in hydrologic models. These algorithms can be used to explore spatial trends in landscape properties as a function of rock type, climate or neotectonic environment.

The DED can be readily linked with a geographic information system (GIS) which is used to parameterize a quasi-physically based surface runoff model. Various representations (Shreve orders) of the watershed are created by simplifying a stream network delineated from the DED. Different Shreve orders produce significantly different geomorphometrics that affect simulated runoff volumes.

At one of the study sites, the DED are not of sufficient detail to allow stream network extraction. Therefore, classification of SPOT panchromatic data was used to delineate ephemeral, fluvial networks on this low-relief, arid basin. A one pixel proximity search classified correctly over 80 percent of the channelized flow.

GRANT SUMMARY

This final report describes research conducted under Department of Energy Agreement No. DE-FG02-86ER60472 (including Amendments A001-A005) for the project period July 15, 1986 to August 31, 1990. Specifics of the agreement are summarized in Table 1.

Table 1. Breakdown of Agreement No. DE-FG02-86ER60472

Grant No.	Award Amount	Budget Period
86-ER60472	\$80,000.00	7/15/86-7/14/87
86-ER60472.A001	\$50,000.00	7/15/87-7/14/88
86-ER60472.A002, 3, 4, 5	\$69,990.00	7/15/88-8/31/90
Award Total	\$199,990.00	

REFLEX BACKGROUND

Research was initiated within and conducted under the auspices of the Remote Fluvial Experimental (REFLEX) Series Program in the Office of Energy Research, Office of Health and Environmental Research, Ecological Research Division of the department of Energy. As stated in the REFLEX Program dated October 1986, the goals of REFLEX are to:

- apply new and developing aerial and satellite remote sensing technologies--including both advanced sensor systems and digital/optical processing--to interdisciplinary scientific experiments in hydrology and to hydrologic/ecologic interactions;
- develop new concepts for processing and analyzing remote sensing data for general scientific application;
- demonstrate innovative analytical technologies that advance the state of the art in applying information from remote sensing systems, for example, supercomputer processing and analysis.

The REFLEX program was organized around the concept of the universal watershed (Figure 1) with priority given to interdisciplinary research on the hydrologic cycle. Experiments were conducted to evaluate hydrologic interactions in terrestrial landscapes and ecosystems for which historical information bases already exist or where research is in progress.

"The need for information on terrestrial systems to meet environmental health and safety requirements is increasing each year. Information concerning contaminant transport along surface and

Figure 1 Universal Watershed with Principal Processes and Hydrologic-Ecologic Interactions (from REFLEX Program Document, October 1986).

groundwater pathways is essential to anticipating and to mitigating effects on terrestrial ecosystems and on humans. The advanced technologies of REFLEX can potentially help solve environmental safety problems faced by DOE" (REFLEX Program Document, 1986). The underlying REFLEX strategy was to study uncertain or unproven scientific concepts using advanced remote sensing technologies.

To achieve the REFLEX goals, experiments were conducted under phase I of the REFLEX program. Phase I (1984-1990) which encompasses the project period of this grant emphasizes identification, exploration, and hypothesis testing of scientific questions related to the hydrologic cycle and to hydrologic/ecologic interactions. Clearly, perturbations caused by energy development or waste disposal in the long term are a general motivation for this research. In addition, the REFLEX experiments are being conducted within different climatic/ecological zones (Figure 2, Table 2) in an effort to explore the limits and benefits of advanced remote sensing technologies and analyses.

To achieve these REFLEX goals, Phase I research activity for this project was initiated in an arid and semiarid climatic zone. The arid zone site, at the Nevada Test Site in Nevada (Figure 3 and Table 2), was selected because of the potential for radionuclide contamination by surface transport. The semi arid site, at Walnut Gulch in Arizona, (Figure 3 and Table 2) was selected because of the extensive data base on surface hydrology provided by the U.S. Department of Agriculture.

RESEARCH OBJECTIVES

The ultimate goal of this research effort was to model long-term (10^2 - 10^4 yrs), cut and fill cycles in arid region fluvial systems (arroyos). Historic and geologic (late Quaternary) data bases indicate that arid region fluvial systems have oscillated between periods of pronounced aggradation and degradation. This cyclic behavior has affected both water and sediment discharge from arid watersheds as well as ecosystem habitats along hillslopes and valley bottoms. One of the primary causes that has been proposed for this cyclic activity is climatic change for gradual (glacial-interglacial) and catastrophic (volcanic eruptions, el Nino) rates of climatic change on a global scale.

Climatic change acting through temperature changes and in amount, type and distribution of both rainfall and vegetation control the supply of water and sediment to and through a watershed. These variables, in turn, control the arroyo processes and the cut and fill cycles in arid watersheds. Prediction of arid watershed response to climatic change over both short and longer (geologic) time scales is important for DOE waste repository sites.

This research effort required a watershed scale approach which necessarily included large multilayered, digital, data sets that contained parameters for input to a watershed scale hydrologic model. It was amenable to a GIS approach which we have employed in our past research effort. The research conducted for this agreement has focused on specifically evaluating hydrologic modeling (SPUR) of observed runoff

Figure 2 Existing and Proposed REFLEX Site Locations. See Table 2 for Site Descriptions.

Table 2. Descriptions of Existing and Proposed REFLEX Sites

Sites	Nevada	Arizona	Alaska	Washington	Pennsylvania	Tennessee	Puerto Rico
Location	Plutonium Valley	Walnut Gulch	Toolik Lake	Hanford Site- NERP	Central Pennsylvania	Oak Ridge Reservation	"
Physiographic Province	Basin and Range	Basin and Range	Arctic Lowland and Brooks Range	Columbia Plateau	Allegheny Plateau	Ridge and Valley	"
Elevation	1225-1690 m	1290-1785 m	750-1000 m	120-1100 m	300-520 m	"	"
Lithologies	basalt, limestone, dolomite, alluvium, densely welded to nonwelded tuffs, and quartzite	clay to conglomeratic alluvium, conglomerate, granodiorite, limestone, granite, rhyolite, basalt tuff, andesite, quartz monzonite	glacial till	basalt, alluvial and eolian material	shales, siltstone, sandstone, conglomerate, limestone, clay, and coal	"	limestone
Climate	semiarid	semiarid	tundra	arid	humid temperature	humid temperature	tropical to semihumid
Vegetation	low and high desert shrub	rangeland grasses and shrub	tussock tundra shrubs, forbs, sedges, and mosses	shrub-steppe	mixed coniferous-deciduous forest to barren on disturbed lands	"	deciduous
Areal Extent	33 km ²	150 km ²	18 km ²	600 km ²	500 km ²	"	"

" Data not available as of January 31, 1988.

PLUTONIUM VALLEY
EXPERIMENTAL
WATERSHED

• BLAST CENTERS

Scale in miles

WALNUT GULCH
EXPERIMENTAL
WATERSHED

WALNUT GULCH

TOMBSTONE

Scale in miles

FLUME LOCATION

Figure 3 Location map of two study basins.

events and general geographic information systems techniques for manipulation of remotely sensed and field-derived data sets for appropriate watersheds at Walnut Gulch, Arizona (USDA) and Plutonium Valley (Nevada Test Site, DOE).

SUMMARY OF PRIMARY RESULTS

Significant scientific milestones accomplished during the research period are summarized below. Publications that elaborate upon these fundamental accomplishments are itemized in the next section, "List of Publication." This list includes journal publications and abstracts of papers given at professional meetings. All relevant journal publications are included in an appendix to allow the reader to explore and expand upon the scientific milestone outlined below.

- Development of algorithms for extraction of topographic and channel network parameters from digital elevation models for input to hydrologic models.
- Development of algorithms for extraction of channel networks from high resolution SPOT panchromatic data on low relief alluvial fan surfaces at the Nevada Test Site.
- Development of grid-cell GIS techniques for parameterization of SPUR and sensitivity analysis to watershed discretization at Walnut Gulch, Arizona.

LIST OF PUBLICATIONS

Research publication and abstracts partially or completely funded by agreement No. DE-FG02-8GER60472.

Papers:

Gardner, Thomas W., K.F. Connors, and Haujan Hu, 1989, Extraction of fluvial networks from SPOT panchromatic data in a low relief and basin, International Journal of Remote Sensing, v. 10, pp. 1789-1801.

Connors, Kathryn F., T.W. Gardner, and R.L. Day, (1989), Deriving stream parameters for hydrologic modeling from digital elevation data, in Surface Water Modeling - New Directions for Hydrologic Predictions, IAHS Publ. No. 181, pp. 397-406.

Gardner, T.W., K.C. Sasowsky, and R.L. Day (in press), Automated extraction of geomorphometric properties from digital elevation models, Zeitschrift fur Geomorphologie.

Sasowsky, Kathryn C. and Thomas W. Gardner, Watershed discretization, geographic information systems and SPUR hydrology model simulations (submitted to Water Resources Bulletin, August 1990).

*reprints & preprints
removed,
ds*

Abstracts:

Petersen, G.W., T.W. Gardner, K.G. Connors, and D. Miller, 1988, Remote Sensing in Hydrology and Ecology (Abs), Frontiers in Physical Sciences, American Association for Advancement of Sciences, Boston, p. 1.

Connors, K.F. and T.W. Gardner, 1988, Digital Elevation Data Resolution Effects on Slope Lengths and Gradients, Agronomy Abstracts, Annual Meetings of the American Society of Agronomy, p. 273.

Day R.L., G.W. Petersen, T.W. Gardner, and K.F. Connors, 1988, Three-Dimensional Characterization of Drainage Basins, Using Digital Elevation Models, Agronomy Abstracts, Annual Meeting of the American Society of Agronomy, p. 255.

Gardner, T.W., R.L. Day, and K.F. Connors, 1989, Uniformly Gridded Digital Elevation Data as Input to Distributed-Type Hydrologic Models, American Geophysical Union, EOS, v. 70, p. 1091. (Invited).

Gardner, T.W., R.L. Day, and K.F. Connors, 1989, Automated Characterization of Watershed Parameters from Digital Terrain Data Sets, 2nd International Conference on Geomorphology, Geosko, v. 1, p. 101.

END

DATE FILMED

01 / 18 / 91