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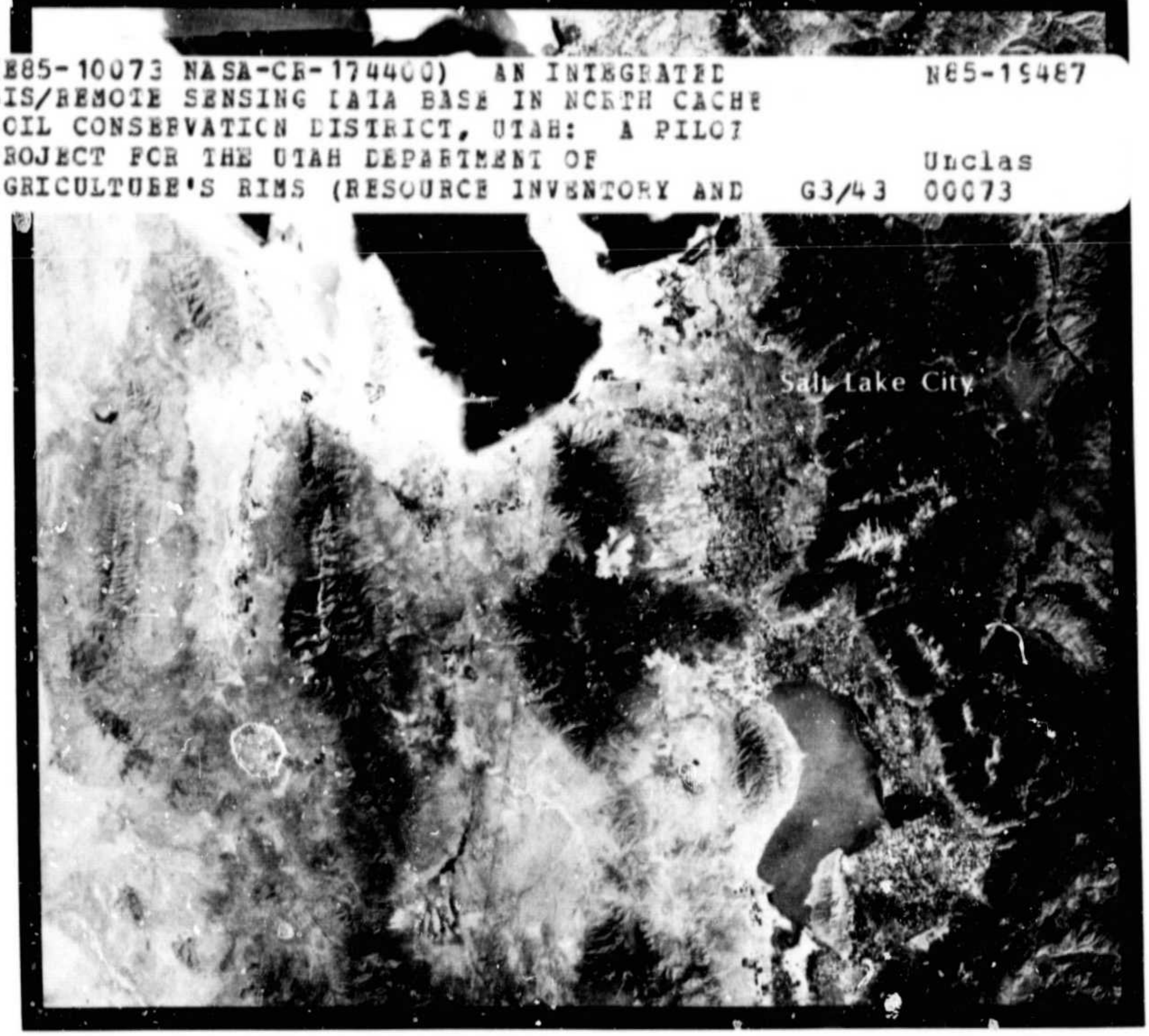

UNIVERSITY OF UTAH RESEARCH INSTITUTE

Salt Lake City

An Integrated GIS/Remote Sensing Data Base in North Cache Soil Conservation District, Utah:

A Pilot Project for the Utah Dept. of Agriculture's RIMS (Resource Inventory and Monitoring System)

CRSC Report 84-8

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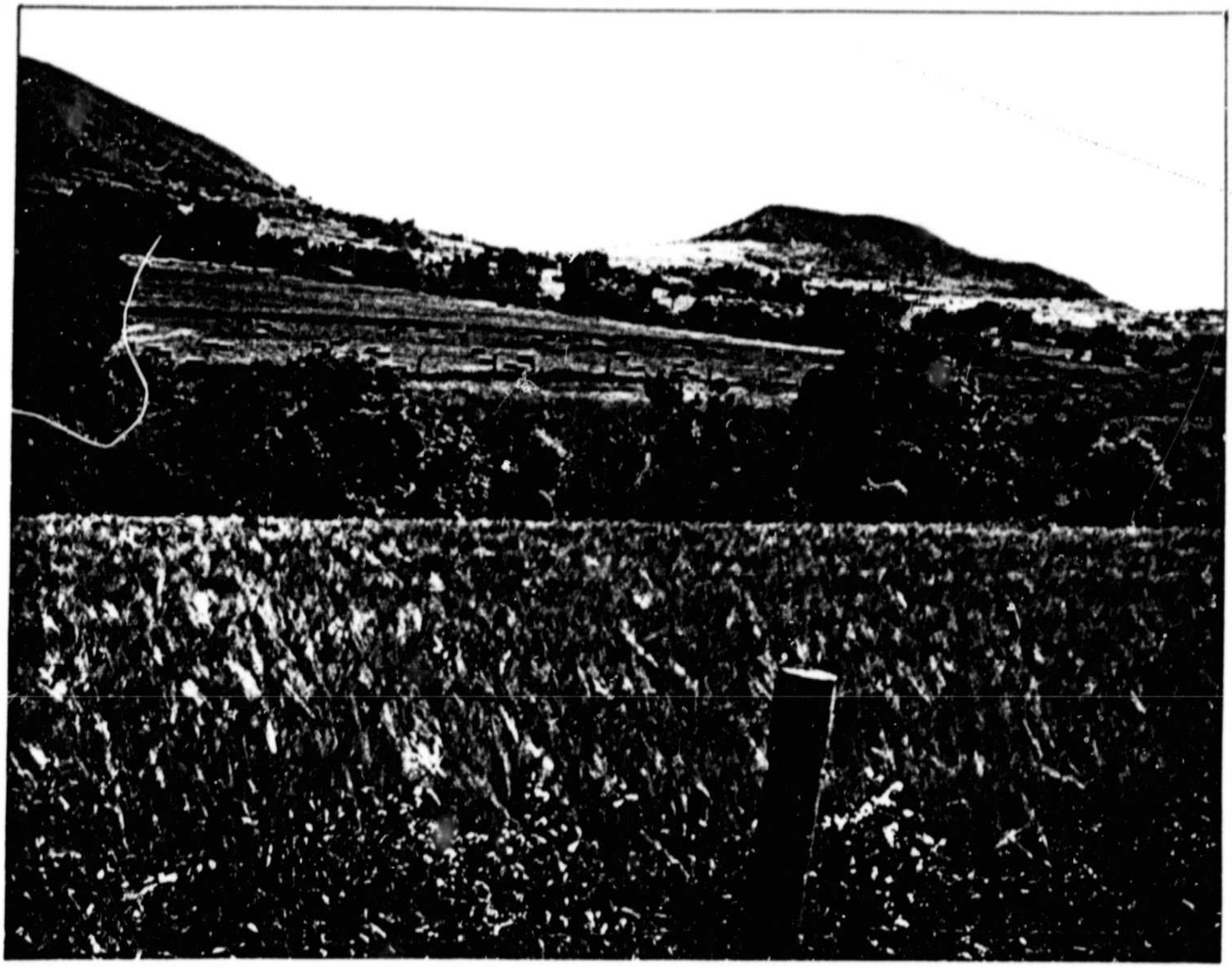

Land use in northern Cache County is closely aligned to terrain conditions from mountains, to high beach, low beach, and lake bottom soils.

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INTRODUCTION

Dam siting, hazardous waste disposal, urban expansion, loss of prime farmland, environmental hazard mapping, flood control, soil conservation, grazing management, timber harvest, wildlife habitat protection.

There are many resource management issues facing Utah. Continuing problems include construction in high-risk zones and covering over, removing, or over-allocating critical resources. These issues are made more accute with a rapidly increasing population and growing capital investment on the land. Nature has a way of reminding us, from time to time, of our need to plan and develop with a full understanding of the ecological system and an accurate inventory of the resource base.

Resource managers have always struggled with two basic questions: (1) How can I get updated inventories and maps of the resource base?; and (2) How can I handle all of the resource maps and data to make the best decisions? Modern satellite and aircraft remote sensing technology helps to answer the first question, while high-speed computers and digital mapping routines help solve the second. This study employs both: exploring the most efficient and accurate ways of obtaining up-to-date inventory maps; and integrating the maps in a computer system to answer specific resource management questions.

This report represents a pilot project in the development of a digital data base related to agriculture and natural resource management. It is designed as a basic working model for the Resource Inventory and Monitoring System (RIMS) of the Utah Department of Agriculture.

The RIMS program is designed "To provide SCD (Soil Conservation District) supervisors with adequate data about agriculture and related natural resources of their district and to use this data for ... district responsibilities" (Utah Department of Agriculture 1984). The department's guidelines for RIMS go on to describe SCD responsibilities for: short and long-term conservation; inputs into various state resource plans; giving direction to Agriculture Resource Development Loan fund programs; and giving direction to SCD programs. The guidelines emphasize the established institutional role of the SCD as a local body to deal with local resource issues in the context of a regional setting. The point is emphasized that the SCD is a legislatively created and recognized entity that integrates state, local, and federal agencies and interests. The RIMS guidelines also provide a sample list of the "Data Required to Meet Purpose" under the heading of soil, water, agricultural land, climate, livestock, and socio-economic base.

The North Cache SCD was selected as the target for this pilot study jointly by the Utah Department of Agriculture and the Panel on Scientific Inputs into Resource Management and Planning, a body appointed by the State

Advisory Council on Science and Technology. It was felt that the North Cache area is representative of many resource issues and would provide a good evaluation of "high technology" approaches to resource analysis and data base management.

The North Cache SCD contains about 324,000 acres, northward from Logan to the Utah-Idaho border (Figure 1). The district stretches from the county boundary at the crest of the mountains on the west, across Cache Valley to the county boundary at the drainage divide on the east. It includes all or parts of 17 USGS 1:24,000 scale quadrangles. The pilot study area provides a good variety of terrain types and land use features, with a representative mix of mountain and valley resource issues, including multiple-use forest lands, proposed reservoir sites, soil erosion problems, urban expansion pressures, wetland management issues, and other problems. The variety of conditions and patterns also provide a sound evaluation of data gathering (remote sensing) techniques, including satellite technology, high-altitude color infrared aerial photography, conventional black and white photography, and low-altitude 35mm photography flown specifically for the purpose of the project. It was felt that this variety of inputs from varied landscape problems would be a good test case for digital data base management techniques.

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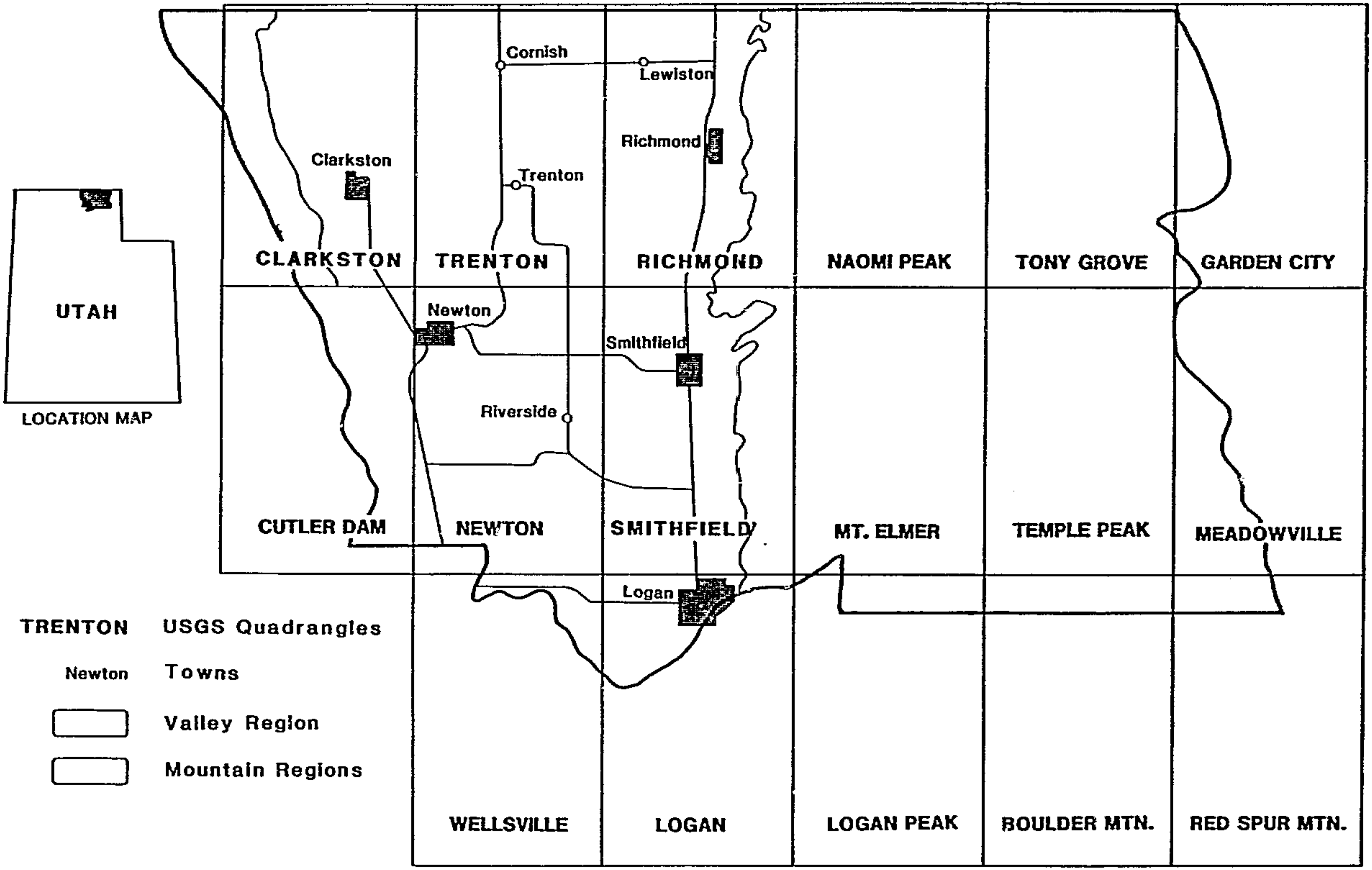

Figure 1. North Cache Soil Conservation District (SCD) showing USGS 1:24,000 scale quadrangle coverage.

Another reason for the selection of Cache County is that a very active local group is already underway, defining local user needs and developing an information system to deal with resource problems at the grass roots level. This group (Bear River Resource Conservation and Development Committee) is well established in integrating the various agency interests in cooperation with local landowners and special interest groups. This pilot project is designed to interface with the progressive activities and objectives of that committee.

It should be emphasized also that this project is also intended to be consistent with the purposes of the state's Automatic Geographic Reference (AGR) system. AGR is established as the central agency within state government to serve as the integrating center for all digital spatial data sets in the state's interest. Through an objective evaluation of available geographic information systems (GIS), the state has made a sound investment in a first-rate hardware/software system (PRIME computer and ARC-INFO software) and supporting equipment, along with developing an experienced professional staff. The present pilot project recognizes the central role of the AGR operation. Data obtained and processed through this project are made available to AGR for their continuing archive of resource data.

GOAL AND OBJECTIVES

The overall goal of this project is to build a basic GIS for the North Cache SCD and to apply the system to selected resource problems. Since the resource management issues in the North Cache SCD are very complex, it is not feasible in the initial phase to generate all the physical, socioeconomic, and political baseline data needed for resolving all management issues. A selection of critical variables becomes essential. Thus, there are four specific objectives of the project:

1. Assess resource management needs and determine which resource factors are most fundamental for building a beginning data base,
2. Evaluate the variety of data gathering and analysis techniques for the resource factors selected,
3. Incorporate the resulting data into a useful and efficient digital data base,
4. Demonstrate the application of the data base to selected real-world resource management issues.

The first objective involves a cooperative communication effort between local and state officials in order to define and articulate "grass roots" resource management needs. The various administrative agencies concerned with resources and planning in Cache county have developed a system of communication and interviews with local users for the purpose of determining fundamental data needs.

Four elemental data planes were selected for the test GIS in North Cache SCD. All four involve different aspects of remote sensing technology. These layers of geographically referenced data include:

1. Land use/land cover information for the valley floor using 1983 as a base year. Data are obtained from natural color (NC) 35mm slides flown at 5,000 feet, large-scale NC aerial photography, high-altitude color infrared (CIR) photography, and extensive field observations.
2. Vegetation/land cover in the mountains and foothills, using a classification of Landsat digital MSS (multispectral scanner) data.
3. Geomorphic terrain units of the benchlands and basins, using conventional black and white (B/W) photography, soil engineering properties, and field work.
4. Digital terrian mapping of the study area using Defense Mapping Agency (DMA) digital data to derive elevation, slope, aspect, and slope length categories.

Each of these data planes were then merged into a geographically referenced data base using the PRIME/ELAS system at CRSC. This was accomplished by digitizing the land use and geomorphic terrian units mapped from aerial photography, and combining them with the Landsat vegetation and digital terrain elements that were already in digital format.

It should be acknowledged that both remote sensing and GIS technologies are evolving rapidly. The experience base in both areas is completely interwoven with advancing computer hardware and software systems. Any project that employs the use of these strategies is engaging the technological frontier of resource management. It should be noted that these remote sensing and data management systems are "operational" in several states, and have been proven useful; yet there is still a considerable need for experimentation to draw these technologies together as a productive resource management tool.

The Agriculture Department realizes that there are many resource problems that call for a solution. The key is to utilize a georeferenced data base as a tool to better define and answer resource management questions; not as a detached and isolated demonstration project, but as an intergral part of the on-going inter-institutional multiple resource management procedure.

It is expected that the North Cache GIS will serve as a working model to be fully integrated into the state's Automatic Geographic Referencing (AGR) system. In this way, experience may be gained at the state level in defining user needs, scientific and technologically sound data aquisition methods, and integration into a computer-based GIS format. As experience with these methods increase, more complete and sophisticated data structures can be built, based upon local resource issues and needs.

METHODOLOGY

The conversion of remotely sensed data into a geographic information base involves many different methodologies, depending upon the format of orginal data. An effort was made in this project to use the most cost-effective means of handling data in order to achieve the desired results. Figure 2 is a flow diagram representing the various steps in processing the four elemental data planes and the final products that are stored in the North Cache RIMS data base. A detailed description of these methods is presented in this section.

Land Use for Valley Basin

The first materials obtained for the North Cache Study area were orthophotoquads to be used as a mapping base. Unfortunately, there were three quadrangles in the study area that did not have orthophotoquads (Clarkston, Trenton, and Newton). It was necessary to use topographic quadrangles and existing photography as a mapping base for these locations.

The ASCS office in Tremonton photographed Cache County in July and August of 1983 using 35mm natural color ektachrome slide film from a mean altitude of 5,000 feet above ground level. The a[illegible]ility of this excellent photography allowed CRSC to use 1983 as a base year for land

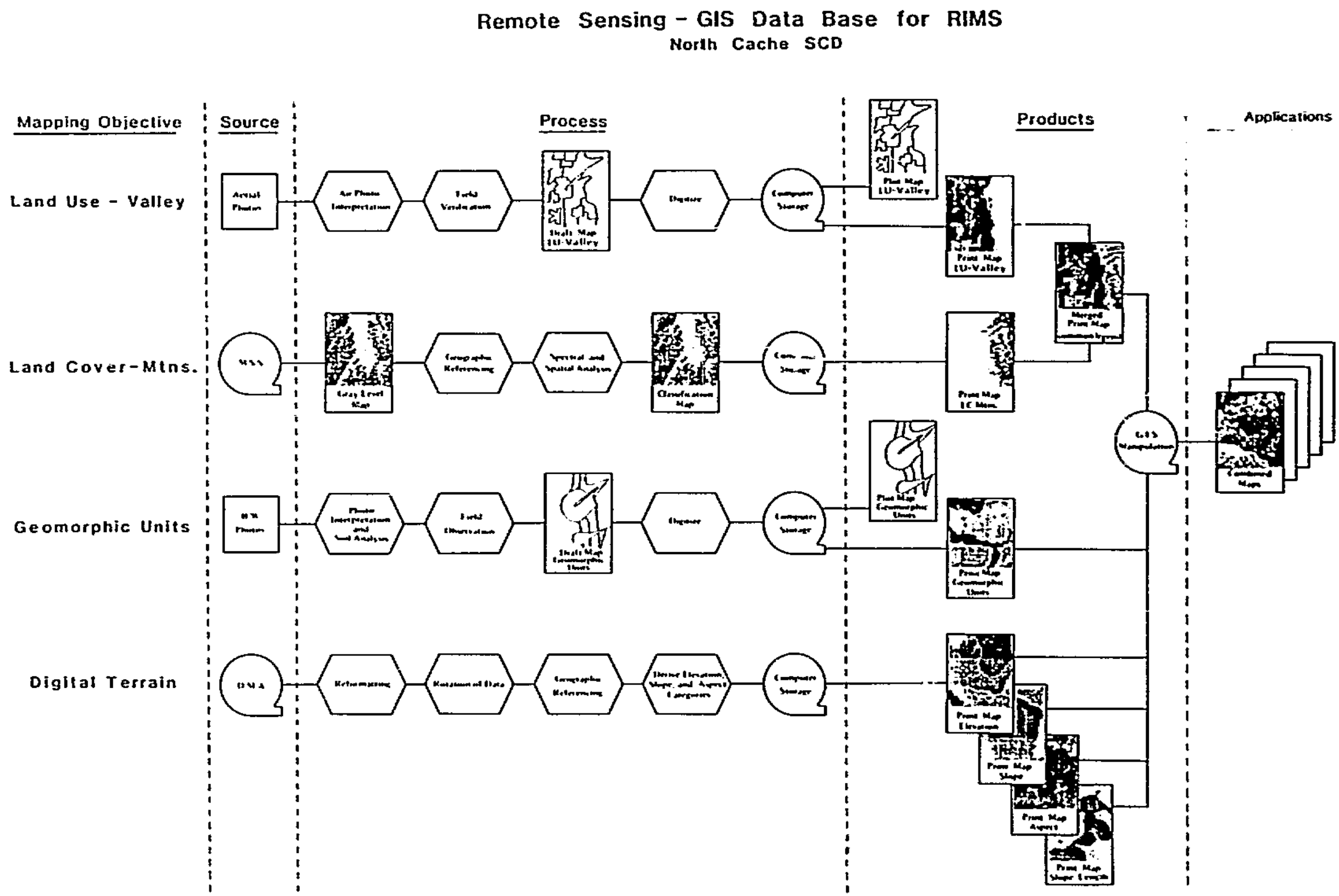

Figure 2. Flow diagram of procedures used in developing Utah Department of Agriculture's North Cache RIMS (Resource Inventory and Monitoring System).

use. The Cache County planning office also loaned the CRSC large-scale (1:9,600) natural color aerial photography for 1981, covering the study area. The CRSC already had high-altitude CIR photography from 1979 that covered Cache County at scales of 1:30,000 and 1:58,000.

The 5,200 foot contour line was determined to be the best threshold between land cover delineations from aerial photography in the valley basin and Landsat coverage in the mountain areas. There are a few agricultural areas above 5,200 feet, but no urbanized areas. For this reason the land use portion of this project includes areas of the basin up to approximately 5,200 feet elevation along the mountain front. Vegetation and land cover above 5,200 feet was determined by classification of Landsat digital data. The few farm fields that do lie above this line were delineated from photography and digitized as polygons for integration into the Landsat data set.

One of the critical issues in a land use/land cover inventory is deciding which categories of information are the most useful to identify. This entails looking at the needs and purposes of the project and determining the detail level that is feasible from the particular medium of observation being used (satellite, aerial photography, ground survey, etc.) For the specific purposes of this project, an extremely detailed land cover classification would not be functional as a data plane for resource management. Categories must be somewhat generalized or they are outdated from year to year and cost too much time and money to update.

For a resource management information system there definitely needs to be a distinction between agricultural land and urbanized land uses in order to monitor the spreading of urban influence. A separation between irrigated agriculture and wetland environments is also needed to determine flooding potential and areas of natural subirrigation. Federal legislation governing wetland management also demands there be current maps of their distribution. Often land use categories are easily determined through observation of aerial phototgraphy.

In the North Cache SCD, it was shown that delineating specific crop types was not the most functional classification approach due to the temporal changeability of cropping practices. It was decided that distinguishing between actively irrigated land and idle irrigated land in 1983 would be much more useful and manageable data for making decisions in subsequent years. Differentiating between irrigated fields and dry farm areas was also important, though often a difficult process due to the common practice of using pumps and mobile irrigation piping systems in some dry farm areas. Many fields with irregular or steep terrain, not conducive to conventional gravity flow flood irrigation methods, are now sprinkler irrigated by mobile units. Knowing the time of year the photography was taken, along with field observations and interviews with farmers, were helpful in distinguishing these areas.

For the upland areas of the benches, knolls, or mountains, this study distinguished rangeland cover types such as grassland, shrub, deciduous, and coniferous habitats. The cover types interpreted from photography, however, were not as definitive in terms of cover density as the Landsat classification. This was due to the more subjective nature of manual interpretation techniques.

Although there are few truly urban areas in the North Cache study area, there are several rural farming communities where homes and services are grouped. For the purpose of this study, all concentrated and contiguous clusters of residential, commercial, and public facilities were classed as urban centers. In this way, the expansion of population growth in these communities may be more easily monitored. The isolated human-constructed facilities that are not clustered in an "urban" class were considered to be in the "built-up" category. This includes farmhouses, barnyards, corrals, commercial establishments, isolated cemeteries, etc.

Table 1(a) identifies the legend categories that were used for land use/land cover in the valley portion of the study area. This is followed by a brief characterization of these categories.

TABLE 1

1.a. Land Use/Land Cover Categories in the Valley (Plotter Maps).

AGRICULTURAL LAND	UPLAND/RANGELAND	OTHER
A - Irrigated agriculture	Ug - Grass and sage	U - Urban communities
Ai - Idle irrigated land	Ur - Deciduous riparian shrub	B - Built-up areas
Ap - Plowed or disked land	Um - Mixed mountain shrub and grass	X - Excavated land
D - Dry farm	Ud - Deciduous forest	W - Wetland environments
P - Nonirrigated pasture (dry)	Uc - Conifer forest	R - Reservoirs
WP - Nonirrigated pasture (wet)		O - Open water

1.b. Merged Land Use/Vegetation/Land Cover Legend for Print Maps.

AGRICULTURAL LAND		UPLAND/RANGELAND		OTHER	
A	Irrigated agriculture		Barren ground	+	Urban communities
I	Idle irrigated land	.	Grass/sage	*	Built-up areas
-	Plowed or disked land	M	Mixed shrub/grass (light)	X	Excavated land
D	Dry farm	M	Mixed shrub/grass (medium)	:	Wetland environments
P	Nonirrigated pasture (dry)	M	Mixed shrub/grass (dense)	B	Reservoirs
W	Nonirrigated pasture (wet)	D	Deciduous trees (sparse)	Ø	Open water
		B	Deciduous trees (dense)		
		E	Conifer		
		S	Deciduous riparian shrub (dense)		

A - Irrigated Agriculture. Fields actively cropped in 1983. Principal crops are alfalfa, small grain, sugar beets, corn, and improved pasture. Minor irrigated crops include peas, potatoes, green beans, and orchard fruits.

AI- Idle irrigated land. Areas below canal lines or with irrigation delivery systems that are not irrigated during 1983. Some areas may not have been actively irrigated for many years but still have the potential.

Ap- Plowed or fallow land. Irrigated areas that are presently plowed. Fields might have been cropped earlier in the year, or have been disked for preparing a seed base.

D - Dry farm. Actively dry farmed in 1983 or in fallow. Some fields alternate between dry farm and pump/sprinkler irrigation depending on water availability conditions. Principal crops are small grains, alfalfa, or grasses.

P - Nonirrigated pasture (dry). Permanent pasture enclosures, usually in foothills, usually containing bluebunch wheatgrass and other grasses. Some portions of pasture are occasionally cut for fodder.

Wp- Nonirrigated pasture (wet). Permanent pasture enclosures with subirrigation from high water table. Principal vegetation are sedges, tufted hairgrass, wheatgrass, or alkali grasses. Some grasses are cut for meadow hay.

Ug- Grass and sage. Mostly native grasses and forbs, with varying amounts of sage, found in foothill and mountain range sites.

Ur- Deciduous riparian shrub. Very dense, healthy phreatophytic shrubs and trees found in shallow upland depressions or along streambeds.

Um- Mixed mountain shrub and grass. Combinations of juniper, maple, aspen, mahogany, sage, and natural grasses in varying densities.

Ud- Deciduous forest. Primarily aspen forests, with either sparse or dense stands.

Uc- Conifer forest. Pine, fir, spruce, with some heavy aspen/conifer mixed forest.

U - Urban communities. Contiguous residential, commercial, or service oriented land uses that are clustered into specific communities.

B - Built-up areas. Developed land not clustered into communities. Includes farmhouses, barnyards, corrals, commercial establishements, isolated cemeteries, etc.

X - Excavated land. Mostly sand and gravel pits for commercial extraction.

W- Wetland environments. Seasonally innundated river floodplains or lake bottom areas. Contains undifferentiated vegetation communities of trees, shrubs, herbs, and grasses. Mud deposits and stream courses are also included within this class.

R - Reservoirs. Diked water impoundments ranging in size from Cutler Reservoir to small irrigation holding ponds.

• - Open Water. Oxbow lakes, sloughs, or shallow ponds found in river floodplain areas. Contains six inches to over 10 feet of standing water throughout the entire year.

These land use categories were interpreted from the 1983 35mm photography and drawn onto an orthophotoquad or topographic map base. The other photography was mostly used for checking detail or viewing temporal changes in land use patterns. Several days were also spent in the field to verify land use/land cover types and to talk with local landowners about farming practices in Cache Valley. The verified land use map was then digitized into a geographic data base using a Prime 400 computer and ELAS software (developed by NASA Earth Resources Laboratory). To do this, each line segment was assigned a unique number. All individual polygons not bordering other line segments were also identified and numbered. Each line segment was then traced on a Tektronix 4954 digitizing tablet. The software created polygonal units from these segments by connecting series of nodes (points where three or more line segments join). After editing the land use polygons in the data file and assigning labels to each polygon, the land use map for the valley was output on a Zeta 3653sx plotter. (See "products" in figure 2 flow diagram.)

Another ELAS module will convert polygonal land use data into a raster format for easier storage and GIS manipulation. The raster file allows the analyst the opportunity to select print symbols for printmap categories or to key classes according to certain color schemes on an image display device. Figure 3 illustrates reduced-scale examples of a plot map (a) and a raster printmap (b) from the Smithfield quadrangle.

An acreage calculation is made automatically by multiplying the number of print characters representating a class by a constant. Table 2 shows a printout of the areal measurements from the entire Smithfield quadrangle as an example. Although acreages are presented to hundreths of an acre, they should only be considered as general estimates, not definitive terms. This is due to the selection process used when converting polygons to raster format. The assignment of cells (print character spaces) tends to slightly overrepresent small polygons and underrepresent larger polygons. The acreage counts, however, are very

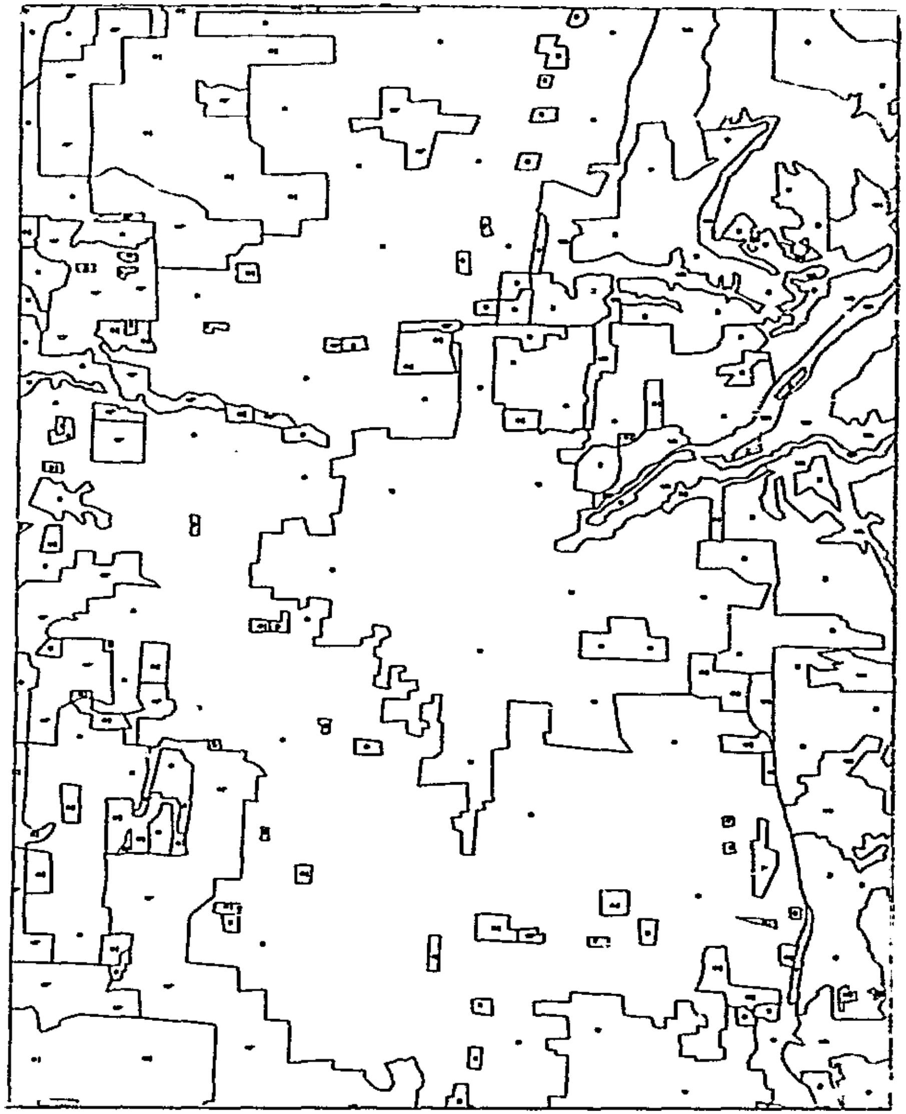

Figure 3a. Reduced scale samples of computer-generated plot map of a portion of the Smithfield quadrangle.

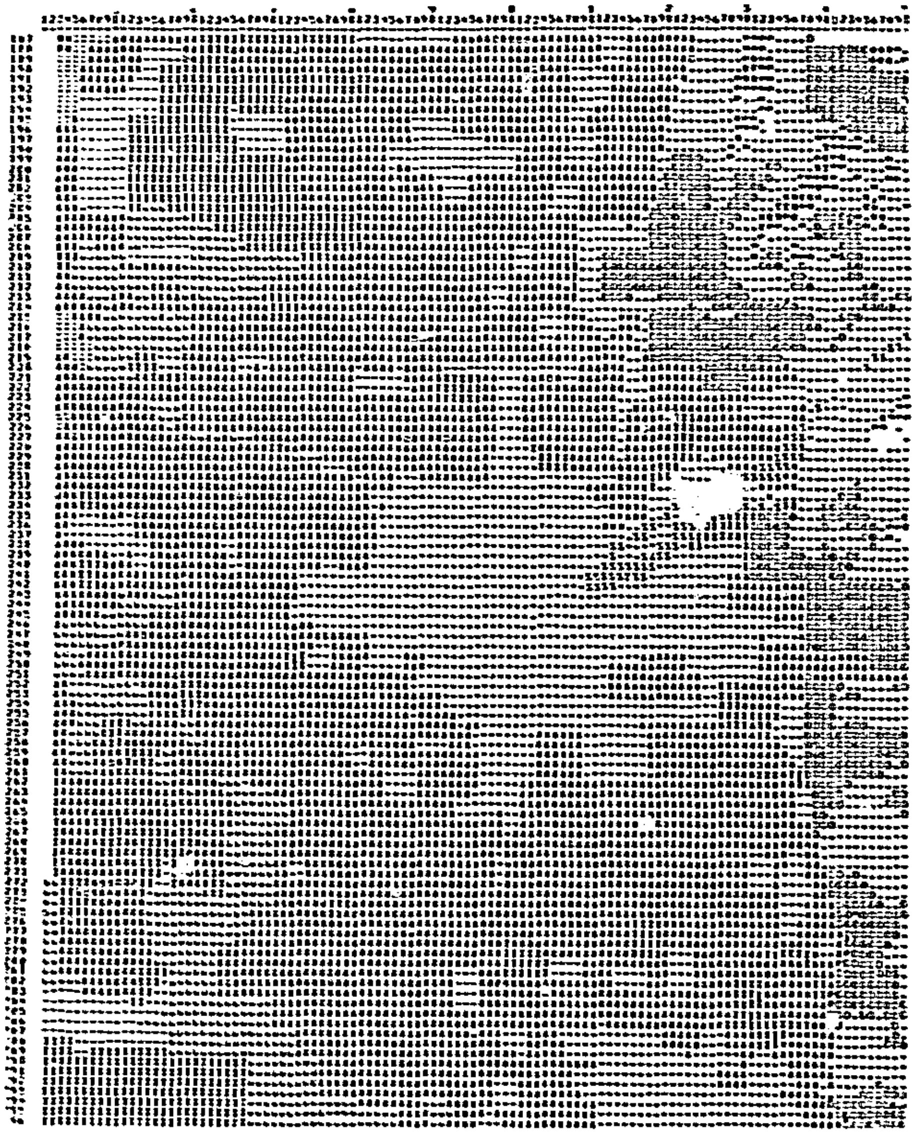

Figure 3b. Reduced scale sample of a raster format printmap of the same area as in Figure 3a.

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TABLE 2

AREAL MEASUREMENT OF LAND USE CLASSES, SMITHFIELD QUADRANGLE
(Derived automatically from PLYA routine).

		FREQ	PCT.	CUM.PCT.	ACRES	SQ MI	HECTARES
	0	805	2.515	2.515	925.20	1.45	374.42
A	1	9955	31.105	33.620	11441.39	17.88	4630.27
I	2	1228	3.837	37.457	1411.35	2.21	571.17
-	3	392	1.225	38.681	450.53	0.70	182.33
D	4	2458	7.680	46.361	2825.01	4.41	1143.26
P	5	6	0.019	46.380	6.90	0.01	2.79
+	6	2478	7.743	54.123	2847.99	4.45	1152.57
*	7	1476	4.612	58.735	1696.38	2.65	686.52
X	8	179	0.559	59.294	205.73	0.32	83.26
:	9	48	0.150	59.444	55.17	0.09	22.33
R	11	4	0.012	59.456	4.60	0.01	1.86
.	12	3960	12.373	71.829	4551.27	7.11	1841.87
S	13	87	0.272	72.101	99.99	0.16	40.47
M	14	3024	9.449	81.550	3475.52	5.43	1406.52
B	15	350	1.094	82.643	402.26	0.63	162.79
R	16	690	2.156	84.799	793.02	1.24	320.93
W	17	2414	7.543	92.342	2774.44	4.34	1122.80
B	18	97	0.303	92.645	111.48	0.17	45.12
M	19	233	0.728	93.373	267.79	0.42	108.37
M	20	1568	4.899	98.272	1802.12	2.82	729.31
( )	21	550	1.718	99.990	632.12	0.99	255.82
S	22	3	0.009	100.000	3.45	0.01	1.40
TOTAL		32005			36783.70	57.47	14886.16

useful for quick assessment of resources, impact statements, or development and management scenarios.

Landsat Vegetation/Land Cover Classification in Mountains

In several studies made in Utah, Landsat digital spectral data has been demonstrated as a successful means of classifying and mapping large tracts of forest and rangeland (Jaynes 1982; Merola, Jaynes, and Harniss 1983; Price et.al 1984). Although Landsat may not be as specific or accurate a classifier as large scale aerial photography for mapping highly detailed areas, its utility is shown as an economical alternative when mapping extensive areas over several quadrangles. For this reason, as well as the opportunity to experiment with its interface capabilities as a data plane for resource management, Landsat digital data has been utilized in the North Cache data base.

Landsat MSS data from July 2, 1979 was used to classify range and forest types in the foothills and mountains (over 5,200 feet in elevation) in the 12 quadrangles of the eastern part of the study area, as well as one strip of mountainland west of Clarkston. The first step in processing of the raw MSS data involved reformatting the data to make it compatible with the processing hardware. Next, the digital data was geographically corrected to remove the effects of earth curvature, rotation, etc., and to rescale the data to fit 1:24,000 USGS quadrangles. A program called "SRCH" was then utilized to generate statistics which characterize pixel groups having similar spectral features across the four Landsat MSS bands. SRCH is a routine in ELAS used to provide training statistics for a program named MAXL, which classifies individual pixels into groups based upon each pixels highest statistical probability of belonging to a given group.

In this study, the SRCH program produced 67 separate signature patterns. Further efforts were directed towards finding those signatures which would most likely represent different types of range and forest habitat. The spectral signature shape and magnitude of reflectance are diagnostic of land cover types. In general terms, similarly shaped signature curves usually indicate similar cover types while upward or downward shifts of similar curves will often indicate differences in topography or amount of ground cover.

The 67 spectral signatures were studied statistically to detect similarities and differences. First, a principal components analysis of the mean values for each signature's four MSS bands reduced the data to factor scores for two components. MSS bands 4 and 5 were combined into one component ("visible" light), and bands 6 and 7 were combined to form the second component ("infrared" light). Next, the factor scores were used in a cluster analysis which grouped spectral signatures according to a similarity index. Finally, the factor scores and group clusters were used in a discriminant analysis of the signatures.

The two-dimensional scatter plot produced in the discriminant analysis allowed the CRSC to graphically view signature relationships. Figure 4 represents a working copy of the scatter plot and the groups of signatures. The discriminant analysis scatter plot (with two axes -- representing the visible and infrared light components) were then divided into groups of signatures that correspond to similar ground cover types. This process served a vital link in allowing an unmanageable number of signatures to be combined into groups of similar signatures. This procedure allowed the CRSC a great deal of flexibility in performing Landsat digital analysis for the North Cache study area. By making a large number of signatures available, the CRSC analysts were able to concentrate on the signatures of particular interest, while signatures of lesser interest were grouped together. For this study, signatures were grouped according to general vegetative cover types of interest in wildland management. Figure 4 indicates the cover type groups selected for this project.

After the classification map was verified from field observations and aerial photography, the data set was included in the North Cache RIMS. The vegetation/land cover map classified from MSS data was merged with the raster file of valley land use map. Those areas above 5,200 feet in

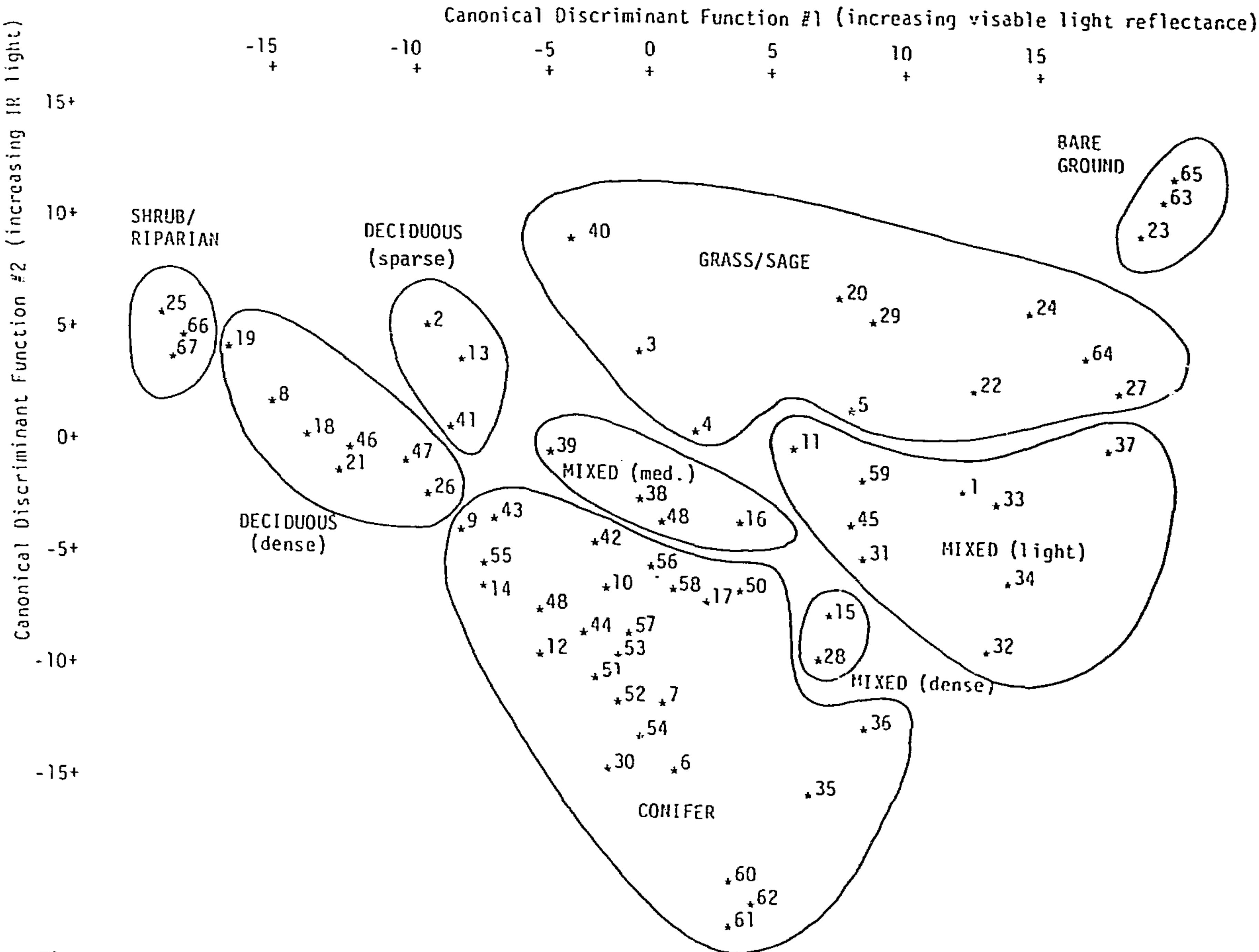


Figure 4. Scatter plot of discriminant scores from 67 MSS signatures.

elevation were classified by Landsat and areas below 5,200 feet were delineated from photography. An example of the common land use/land cover legend of this merged map is shown in Table I.b. on page 15.

Geomorphic Terrain Units

The main purpose of this data plane is to establish a terrain frame of reference on which to imply general geologic, hydrologic, and engineering characteristics of the landscape. The basic premise is that geomorphic terrain units exhibit all the natural processes that have interacted at the earth's surface to create the unit. Geologic, hydrologic, biologic, pedogenic, and climatic factors, interacting through time, have created a particular land unit with distinctive characteristics. To decipher and map such units is to reveal the on-going dynamic nature of the landscape. Man may alter some of those forces or their effects, but to do so unwittingly is to yield to risks that may not be welcome.

There are two basic approaches to terrain classification. The first looks for geomorphic origin and dynamics. It presumes that processes at work in the recent past and present will continue to operate in the future. The second approach is to stratify terrain units according to their specific properties (e.g. texture, soil strength, infiltration rate, etc.)

For the purpose of this study, it was determined that a combination of these approaches would yield the most useful categorization of terrain units. The fact that these geomorphic units are process oriented is evident from their names (beach, river floodplain, alluvial fan, etc.), yet these features were delineated after a careful investigation of soil texture and moisture properties. By using soil properties as identifiers in terrain unit interpretation, it was possible to be more precise in depicting boundaries and makes it possible to use terrain units as surrogates for various other soil engineering properties (permeability, water capacity, strength, shrink-swell potential, etc.) in the future.

The initial means of delineating geomorphic terrain units was through stereographic interpretation of B/W and CIR aerial photography. One of the chief objectives in geomorphic mapping is to identify natural hazard areas relative to flooding, landsliding, faulting, and ground shaking through seismicity, and other instabilities. Aerial photos are excellent tools for identifying and delineating such risk features. By depicting these dynamic features of past (and current) events, we can draw inferences about the future behavior of land units.

Extensive field observation led to further refinement of geomorphic categories and map units. The final refinement came through comparing geomorphic delineations with two other documents: the SCS Soil Survey of Cache Valley Area (1974), and Woodward-Lundgren and Associates' Investigation and Evaluation of the Northern Wasatch and Cache Valley

Faults (1974). Of particular interest in the Soil Survey were the soil engineering properties, which may be used as a general guide to suitability for building permanent structures. Further, soil texture and moisture holding properties may be used to infer certain conditions of agricultural suitability. From the Woodward-Lundgren study, faultlines and landslides were checked against photo and field observations. Thus, geomorphic unit mapping provides a foundation for the following concerns in the North Cache SCD:

1. Natural hazards
2. Construction of various structures
3. Suitability for agriculture

The characteristics of these geomorphic/soil units are presented in a series of three tables. Table 3 gives a brief description of the geomorphic terrain categories mapped for the North Cache SCD. The same terrain categories apply to all quadrangles in the study area. Table 4 identifies the dominant soil types per geomorphic unit and indicates the most significant properties. These properties are selected for their relevancy to agricultural production and engineering considerations. There is a good correlation between soil properties and geomorphic units. Table 5 is a brief summary of management implications for each geomorphic unit and the dominant soil types.

TABLE 3. GEOMORPHIC TERRAIN UNITS

Map Symbol	Geomorphic Character	Description
M	Montane	Bedrock controlled slopes; thin residual soil; steep slopes
B1	Upper beach (essentially Bonneville stage)	Steep to moderate slopes; coarse to fine beach sediments; some colluvium above Bonneville level
B2	Lower beach (essentially Provo stage)	Moderate to gentle slopes; medium to very fine beach sediments; some colluvium above Provo level
B2T	Bonneville terrace	Lake bottom material at Bonneville stage; fine deep water sediment which are now dissected by streams
L	Lake bottom	Nearly level lake bottom; fine to very fine deep water sediments; some "fat" clays with high plasticity
LS	Landslide area	Hummocky debris from recent or ancient landslides
F1	Old alluvium 1 (pre-Bonneville)	Alluvial fan or valley fill above Bonneville beach; some old landslide deposits
F2	Old alluvium 2 (pre- and post-Bonneville)	Alluvial fan or valley fill in canyon valleys; modified by wave action below Bonneville level
F3	Present floodplain	Low areas near perennial streams subject to flooding; gravelly deposits
RF3	Stream course and floodplain	Combination stream course and floodplain, hydrologically dynamic zone
G	Deep gullies	Deeply entrenched stream channels in beaches or terrace
P	Pediment	Gently sloping rock-floored surface above Bonneville level; thin residual soil

TABLE 4. DOMINANT SOIL TYPES PER GEOMORPHIC UNIT AND CHARACTERISTIC PROPERTIES [(a)]

Geomorphic Unit	Dominant Soil Series	Soil Map Code (b)	Slope (%)	Soil Texture	Unified Soil Classification	Permeability (in./hr.)	Shrink-Swell Potential	Plasticity (c)
M	Richmond	RCG2	30-70	v. stony loam	GM, ML	2.00-6.30	low	non-plastic
	Yeates	YLE2	3-30	ext. stony loam	SM, ML	0.63-2.00	low	non-plastic
P	Hendricks	HdC	6-10	silt loam	CL, ML	0.63-2.00	mod	low-medium
	Nebeker	NbC	6-10	silt loam	ML, CL	0.63-2.00	mod	low-medium
B1	Mendon	MeB, C	3-10	silt loam	CL, ML	0.20-0.63	mod	low-medium
	Avon-Collinston	AsC	6-10	silty clay loam	ML, CL	0.63-2.00	mod	slight
	Hillfield	HgE2	20-30	silt loam	ML, SM	0.63-2.00	low	slight
	Leatham	LMG2	30-70	silt loam	ML, CL	0.63-2.00	mod	slight
B2	Mendon	MeA, B	0- 6	silt loam	CL, ML	0.20-0.63	mod	low-medium
	Hendricks	HdA	1- 3	silt loam	CL, ML	0.63-2.00	mod	low-medium
	Blackrock	BnD	10-20	ext. stony loam	SM, ML	0.63-2.00	low	non-plastic
B2T	Mendon	MeA	0- 3	silt loam	CL, ML	0.20-0.63	mod	low-medium
	Greenson	GsA	0- 3	silt loam	ML	0.63-2.00	mod	slight
	Crookston	CoA	0- 3	fine sandy loam	CL, ML	0.63-2.00	low	slight
	Collinston	ClA	0- 3	loamy fine sand	ML	0.63-2.00	low	slight
L	Battle Creek	BcA	0- 2	silty clay loam	CL, CH	0.06-0.20	high	low-medium
	Greenson	GsA, GuA	0- 3	loam over clay	ML	0.63-2.00	mod	slight
	Collett	Ck	0- 3	silty clay loam	CL	0.06-0.20	high	low-medium
	Nibley	NcA	0- 3	silty clay loam	CH, CL	0.06-0.20	high	high
	Timpanogos	TmA	0- 3	silt loam	ML	0.63-2.00	mod	slight
F1	Yeates	YLE2	3-30	ext. stony loam	SM, ML	0.63-2.00	low	non-plastic
	Nebeker	NbE	10-25	silt loam	ML, CL	0.63-2.00	mod	low-medium
F2	Hendricks	HdC	6-10	silt loam	CL, ML	0.63-2.00	mod	low-medium
F3	Steed	SvC	6-10	gravelly loam	ML, GM	2.00-6.30	low	slight

(a) Per Soil Conservation Service, Soil Survey of Cache Valley Area, Utah, 1974. Channel and stream course soils not displayed: narrow and highly variable.

(b) Third character A: 0-3% slope; B: 3-6% slope; C: 6-10% slope; D: 10-20% slope

(c) Per Bureau of Reclamation, Unified Soil Classification System, 1963

(d) Occur as alluvial fans at base of streams

TABLE 5. MANAGEMENT IMPLICATIONS OF GEOMORPHIC-SOIL UNITS

Geomorphic Unit	Soil Series	Soil map code	Agricultural Potential	Engineering Considerations: Foundation limitations	Septic tank limitations	Source of aggregate	Seismic risk (b)
M	Richmond	RCG2	Grazing	Moderate: shallow	Severe	Fair	Slight
P	Hendricks	HdC	Priority II for dry farm	Moderate: shrink-swell	Mod-severe	Poor	Slight
	Nebeker	NbC		Severe: shrink-swell	Severe	Poor	Slight
B1	Mendon	MeB, C	Priority I for dry farm	Moderate: shrink-swell	Severe	Poor	Slight
	Avon-C.	AsC	Dry farm, irrigation	Severe: shrink-swell	Severe	Poor	Slight
	Hillfield	HgE2	Grazing	Moderate: steep slopes	Severe	Poor	Slight
	Leatham	LMG2	Grazing	Severe: steep slopes	Severe	Poor	Slight
B2	Mendon	MeA, B	Priority I for dry farm	Moderate: shrink-swell	Severe	Poor	Slight
	Hendricks	HdA	Priority II for irrigation	Moderate: shrink-swell	Mod-severe	Poor	Slight
	Blackrock	BnD	Pasture	Moderate: slopes	Slight-severe	Poor	Slight
B2T	Mendon	MeA	Priority I for dry farm	Moderate: shrink-swell	Severe	Poor	Slight
	Greenson	GsA	Priority II for irrigation	Moderate: water table, S-S	Severe	None	Slight
	Crookston	CoA	Priority I for dry farm	Slight	Mod-severe	None	Slight
	Collingston	ClA	Priority I for dry farm	Slight	Mod-severe	None	Slight
L	Battle Creek	BcA	Priority III for irrigation	Severe: shrink-swell	Severe	None	Mod
	Greenson	GsA, GuA	Priority II for irrigation	Moderate: water table, S-S	Severe	None	Mod
	Collett	Ck	Irrigated agr.	Severe: water table, S-S	Severe	None	Mod
	Nibley	NcA	Irrigation agr.	Severe: water table, S-S	Severe	None	High
	Timpanogos	TmA	Priority I for irrigation	Severe: water table, S-S	Mod-severe	None	Mod
	Steed	SVA	Irrigation agr.	Slight	Slight-mod	Fair	Slight
	Hendricks	HdA	Priority II for irrigation	Moderate: shrink-swell	Mod-severe	Poor	Mod
F1	Yeates	YLE2	Dry farm, pasture	Moderate: shrink-swell	Severe	Poor	Slight
F2	Hendricks	HdC	Dry farm, irrigation	Moderate: shrink-swell	Mid-severe	Poor	Slight
F3	Steed	SvC	Pasture	Slight	Slight-mod	Good	Slight

There is a close correlation between these geomorphic/soil units and current management issues. The geomorphic units quite nicely stratify the agricultural potential and the engineering considerations. In most cases in the North Cache SCD, as the agricultural values increase by moving from mountainland to lowland, the engineering problems also increase. A standard problem affecting the Wasatch Front is urban growth competing with the prime farmland. The two seem to be quite neatly separated in the Richmond-Smithfield area as the lowland (the best farmland) exhibits more potential seismic instability and foundation problems due to high clay content, while the less productive slopes are quite stable for structures. One reason for this is the fact that there are no major fault scarps along the North Cache foothill area, unlike many other foothill zones. The opportunity to preserve prime farmland in the North Cache SCD may be unusually high when compared to other parts of the state.

After field verification, the geomorphic terrain map was digitized into the North Cache RIMS in the same manner as the land use delineations for the valley, using ELAS software. Both plotter maps and raster-style printmaps of terrain units were produced, scaled to overlay each 1:24,000 USGS topographic quadrangles in the study area.

Digital Terrain Information

The purpose behind the digital terrain element of the North Cache GIS was to enable resource managers to utilize elevation, slope, aspect, and various other topographic factors in their decision-making process without having to repetitively digitize factor maps. Computer tapes containing digital elevation data for ground positions at regular spaced intervals, are available from the National Cartographic Information Center (NCIC).

There are two basic formats of digital terrain data. The USGS produces digital elevation model (DEM) data corresponding to 7.5-minute topographic quadrangles. The data are digitized from contour plates or high-altitude photographs at a 30-meter ground sampling interval. The Defense Mapping Agency (DMA) also digitizes elevation data from contour plates, but at a much coarser frequency. DMA digital data is sampled at a latitude/longitude intervals of three arc-seconds (approximately 80 meters). The elevational accuracy of the data is consistent with the accuracy of contours on the 1:24,000 or 1:250,000-scale topographic maps used to produce the respective data. The root mean square error for the DEM data is 7 to 15 meters.

The USGS DEM data is not yet available for 7.5-minute quadrangles within the North Cache SCD. For this reason. DMA terrain data were obtained covering the western half of the Ogden 1:250,000 quadrangle and the eastern half of the Brigham City quadrangle.

The DMA digital tapes were processed at CRSC using the TOPO modules in ELAS software. Basically, these modules reformat the DMA data from the computer tapes into the ELAS data file format; rotate the data 90° to a north-south orientation; compute mapping coefficients that transpose plate coordinates to UTM coordinates; resample the 16-bit data to a geographically referenced UTM grid file; and use this file to compute slope, aspect, and slope length (Graham, et al. 1984). These categories of slope, aspect, and slope length were computed by sliding a 3x3 pixel window over the elevation data. The cell adjacent to the center cell with the maximum gradient was used to compute these factors.

One of the advantages of using digital topographic information is the capacity to quickly change category boundaries to suit the particular purposes of a resource management question. The computer can generate a new topographic factor map in a fraction of the time required for manually delineating elevation, slope, aspect, or slope length categories from topographic maps, and with greater accuracy. This makes it possible to generate quick scenarios without the need for digitizing new information or being limited by preselected topographic categories.

APPLICATIONS FOR NORTH CACHE RIMS

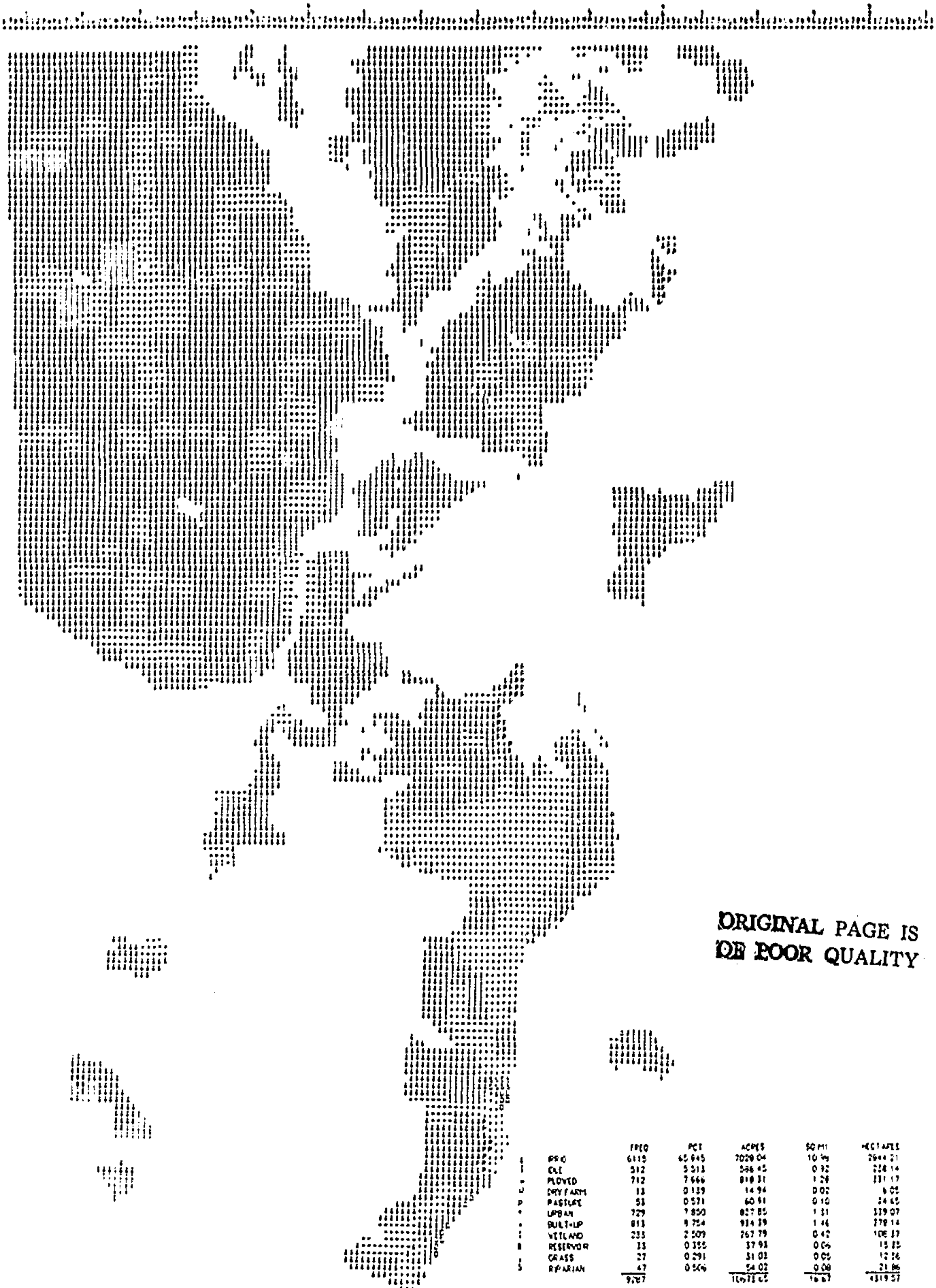
The true evaluation of a resource-oriented GIS comes from testing its utility in making resource management decisions. Queries to the system must be driven by issues and concerns of managers at the local level. Department of Agriculture and North Cache SCD personnel formulated a series of questions related to local needs in order to evaluate the utility of the GIS. These questions include:

1. What land use categories (with acreages) are most susceptible to flood damage from rising waters on the Bear and Cub Rivers?
2. What is the prime farmland in North Cache SCD being used for; where, and what percentage is it being taken over by urban usage?
3. What steep slopes that are presently dry farmed, should be sown in perennial grasses in order to reduce severe soil erosion?
4. Where are the prime deer winter range sites located and how many acres are available?
5. With the installation of the proposed Barrens or Smithfield Reservoirs in Cache County, what land use types would be inundated; what is the land use in a one-mile buffer zone surrounding these reservoir sites?

These questions typify the myriads of resource management issues that may be addressed by utilizing an interactive geographic data base. A strategy was quickly set up to merge data sets in a manner to obtain each of the desired answers, within the limitations of the system's parameters.

To assess which land uses are most susceptible to flooding from the major rivers in Cache Valley, the land use map was merged within the computer with the geomorphic units file. All of the land uses found within the active river floodplain terrain unit (RF3) were printed out in a raster print map and acreages were automatically tabulated. Using the Trenton quadrangle as an example, 87 percent (3,210 acres) of the river floodplain was listed as wetland or open water, nine percent (326 acres) was in irrigated cropland, and only one percent of the area contained man-made structures.

To evaluate the land use activity upon prime farmland a Soil Conservation Service map showing prime farmland and land of statewide importance was digitized into the North Cache RIMS, using the Richmond quadrangle as an example. Figure 5 shows the printmap of land use types and a list of automatically derived acreages. In the Richmond quadrangle, 7,028 acres (66 percent) of the prime farmland was being used for irrigated agriculture in 1983; 17 percent (1,772 acres) was listed as



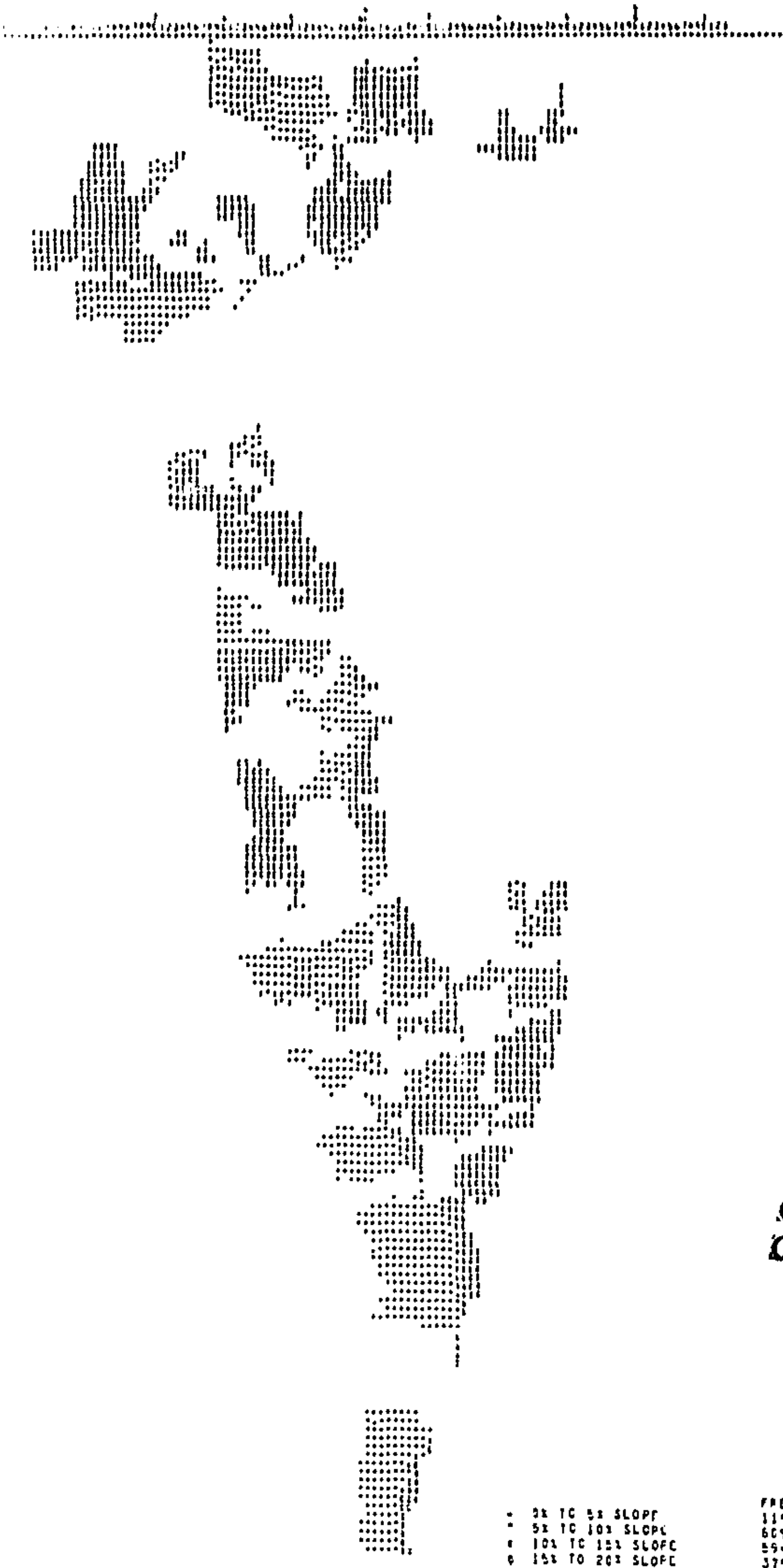
		FREQ	PCT	ACRES	SQ MI	HECTARES
I	IRRIG	6115	65.845	7028.04	10.98	2844.21
I	IDLE	512	5.513	586.45	0.92	228.14
-	PLOWED	712	7.666	818.31	1.28	331.17
U	DRY FARM	13	0.139	14.94	0.02	6.05
P	PASTURE	53	0.571	60.91	0.10	24.65
•	URBAN	729	7.850	837.85	1.31	339.07
.	BUILT-UP	813	8.754	934.39	1.46	378.14
:	WETLAND	233	2.509	267.79	0.42	108.37
B	RESERVOIR	33	0.355	37.93	0.06	15.35
!	GRASS	27	0.291	31.03	0.05	12.56
$	RIPARIAN	47	0.506	54.02	0.08	21.86
		9287		10673.65	16.67	4319.57

Figure 5. Reduced printmap of land use in prime farmland of the Richmond quadrangle.

urban or built-up; eight percent (712 acres) was plowed, but not presently in crop; and five percent (512 acres) was idle agricultural land. In lands considered by the SCS to be of statewide importance, 59 percent (1,022 acres) was irrigated in 1983 and 14 percent (248 acres) was developed or excavated. The only other significant classes were plowed land (9 percent); idle agricultural land (6 percent); upland grass and sage (4 percent); and nonirrigated pasture (3 percent).

Severe soil erosion from dry farm areas on steep slopes have been a great concern to soil conservationists in the North Cache SCD. All plowed slopes over 20 percent, and in many cases over 15 percent, should be sown with perennial grasses to reduce the potential of erosion. A demonstration using the Smithfield quadrangle displayed all slope categories (from DMA-derived slope map) found within dry farm areas (from valley land use file). Figure 6 displays the computer map merging the two files, along with acreage counts. The results show 640 acres of dry farmed land with greater than 20 percent slope. It should be kept in mind, though, that much of this land was in production only once or twice during the past decade. There were 436 acres of dry farm on 15-20 percent slopes.

The deer winter range inventory involved several data planes: the DMA aspect map file; DMA elevation file; and the combined land use/land cover/ vegetation map file. For this particular example, it was



	FREQ	PCT.	ACRES	SQ.MI.	HECTARES
0% TO 5% SLOPE	119	.372	136.77	.21	55.35
5% TO 10% SLOPE	609	2.528	926.79	1.45	375.27
10% TO 15% SLOPE	594	1.856	682.64	1.07	276.26
15% TO 20% SLOPE	379	1.184	435.59	.68	176.28
GREATER THAN 20% SLOPE	557	1.740	646.17	1.00	[illegible]

Figure 6. Reduced printmap of slope categories of the dry farm areas in the Smithfield quadrangle, showing acres by slope category.

determined that prime winter habitat in Cache Valley encompassed areas on south to west facing slopes, below 5,500 feet in elevation, and with riparian or mixed shrub vegetation types. Sage and grass sites were considered secondary habitats. It was noted that most of the prime deer winter range in Cache County has been impacted by development.

The fifth resource management question, which uses the North Cache GIS to evaluate proposed reservoir sites, is typical of many growth management issues. For this reason we will expand a little more on the methods used in obtaining answers to those queries. The two reservoirs proposed in the North Cache SCD include Barrens Reservoir, to be sited in the marshy area south of Trenton and northeast of Newton; and the Smithfield Reservoir, which inundates the Bear River floodplain from a proposed dam near Amalga to the Idaho border, and the Cub River floodplain to a point north of Richmond

For this evaluation, the perimeters of these proposed reservoirs were digitized as additional data files to be used in the GIS. To determine the land uses that would be innundated by the proposed reservoirs, printmaps were made which accessed the land use map file within the limits of the newly digitized reservoir boundary files. An example of the printmap for Barrens Reservoir land use is shown in Figure 7.a. The land use of the proposed Smithfield Reservoir is shown in Figure 8. This map is derived

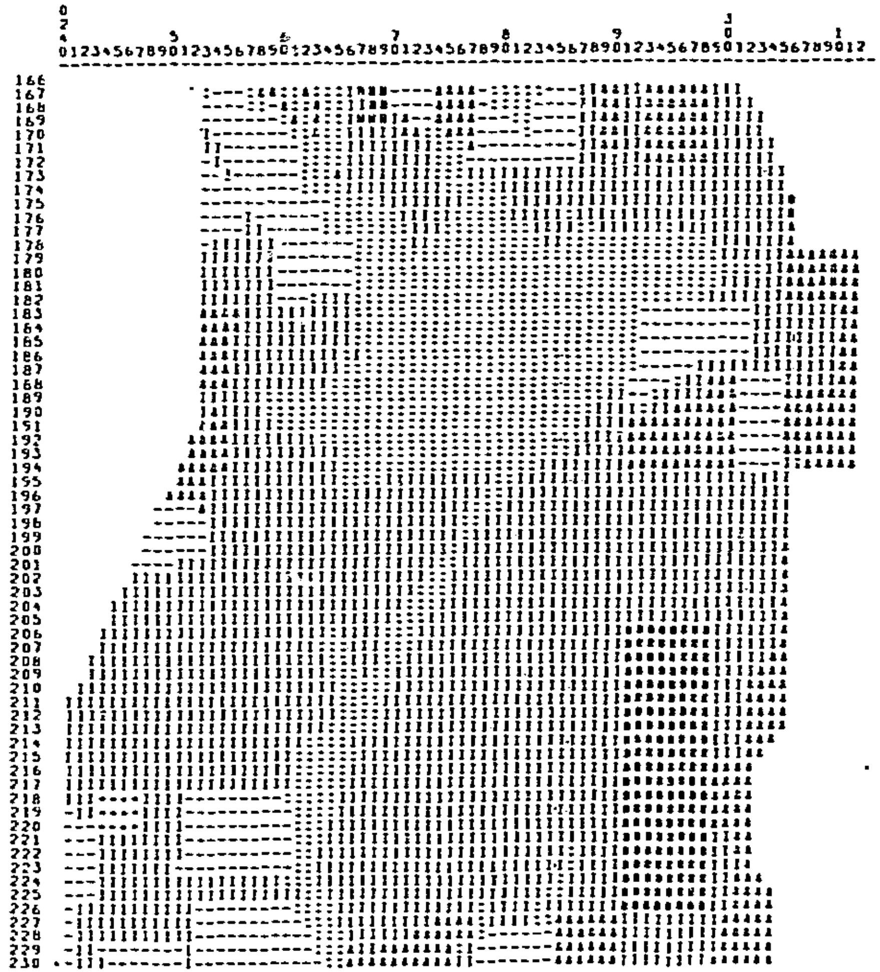


Figure 7a. Reduced printmap of land use classification of proposed Barrens Reservoir site.

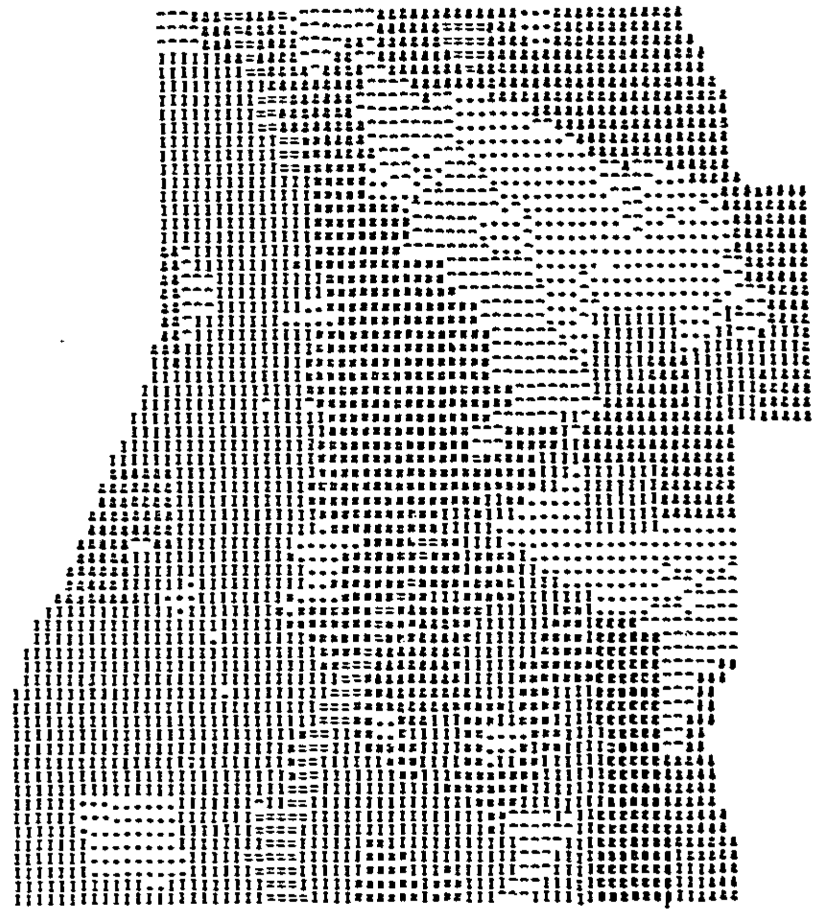


Figure 7b. Reduced printmap of land use, with emphasis on wetland environments interpreted from 1979 CIR photography.

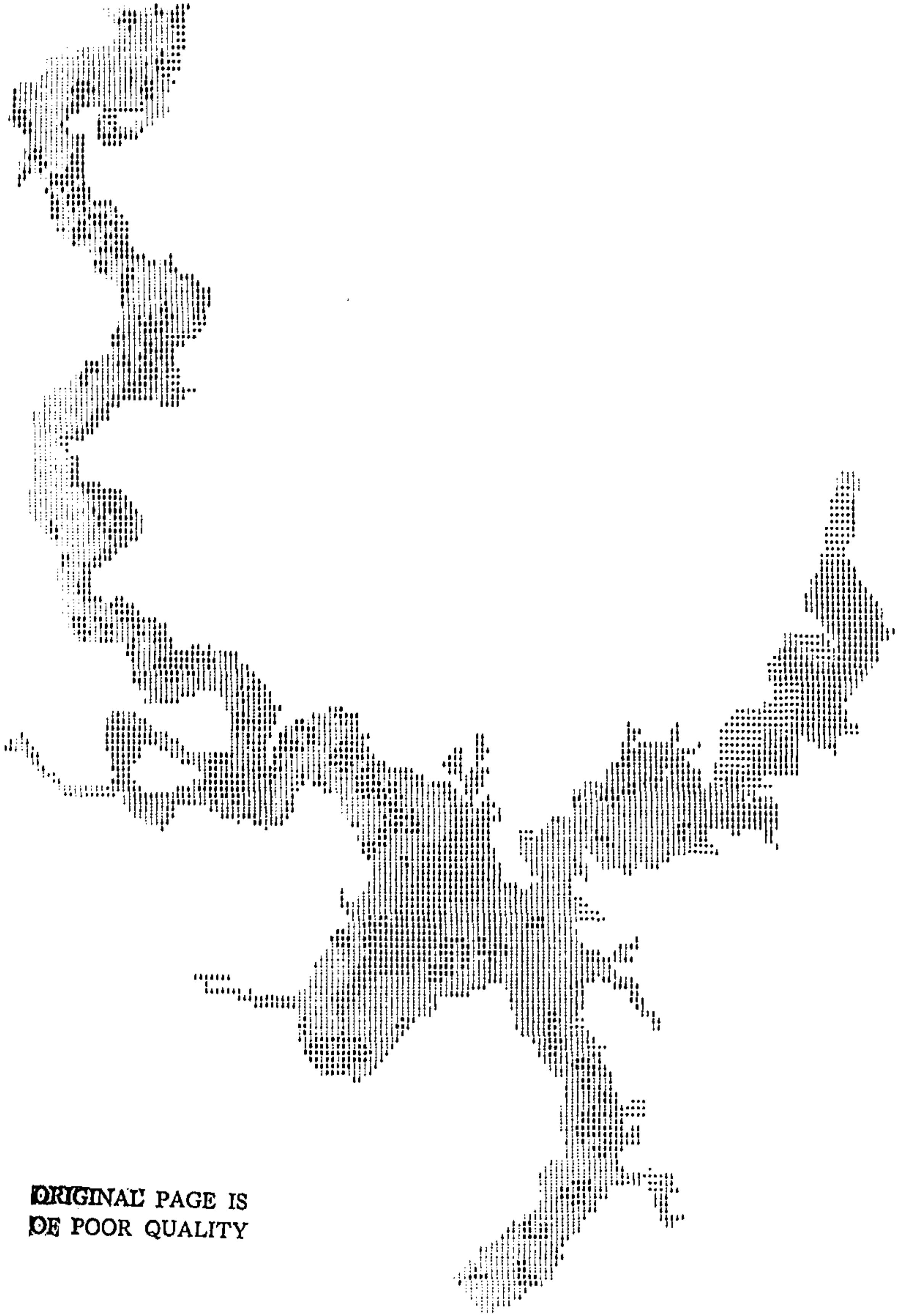


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Figure 8. Reduced printmap of land use classification of proposed Smithfield Reservoir site.

from the land use files on four quadrangles (Trenton, Newton, Smithfield, and Richmond). Table 6, tabulated automatically, shows the comparative acreage by land use to be inundated by the respective proposals.

If a particular management problem requires finer detail than the maps presently contained in the North Cache RIMS there is no reason why specific location maps cannot be entered in the data base as separate resource files. To demonstrate this case, James Christensen, of the Dept. of Agriculture, derived a more detailed categorization of wetland habitats in the Barren site from aerial photography. These delineations (shown in Figure 7.b) were digitized as a separate data plane that is available for use in further resource manangement decisions regarding that area. It is expected that information mapped by a variety of state or local agencies will be integrated into the North Cache RIMS or be available through AGR.

Land contained within the proposed areas of the reservoirs is not the only area to be impacted. Once perimeters are digitized it is possible to determine zones outside of reservoir boundaries that may be affected by seepage, water table fluctations, or further development. Figure 9 displays the land use within a one mile buffer zone surrounding the Barrens Reservoir site. An algorithm may be used to show distance from any type of polygon in the data base. Figure 10 demonstrates this distancing algorithm in the Barrens Reservoir site by showing 0.1 mile

TABLE 6

6.a. Acreage counts of land use to be inundated by the proposed Barrens Reservoir

		Freq	Pct.	Acres	Sq. Mi.	Hectares
:A	Irrig	396	10.286	455.13	0.71	184.19
I	Idle	2,097	54.468	2,410.11	3.77	975.36
-	Plowed	446	11.584	512.59	0.80	207.44
*	Built-up	13	0.338	14.94	0.02	6.05
:	Wetland	720	18.701	827.50	1.29	334.89
UR:	Reservoir	170	4.416	195.38	0.31	79.07
OXM	Water	8	0.208	9.19	0.01	3.72
		3,850		4,424.84	6.91	1,790.72

6.b. Land use to be inundated by the proposed Smithfield Reservoir

		Freq.	Pct.	Acres	Sq. Mi.	Hectares
:A	Irrig	1,386	24.492	1,592.95	2.49	644.66
I	Idle	153	2.704	175.84	0.27	71.16
-	Plowed	305	5.390	350.54	0.55	141.86
+	Urban	9	0.159	10.34	0.02	4.19
*	Built-up	26	0.459	29.88	0.05	12.09
:	Wetland	2,882	50.928	3,312.31	5.18	1,340.48
UR:	Reservoir	19	0.336	21.84	0.03	8.84
OXM	Water	817	14.437	938.99	1.47	380.00
S	Riparian	3	0.053	3.45	0.01	1.40
W	Pasture	2	0.035	2.30	0.00	0.93
		5,602		6,438.44	10.07	2,605.61

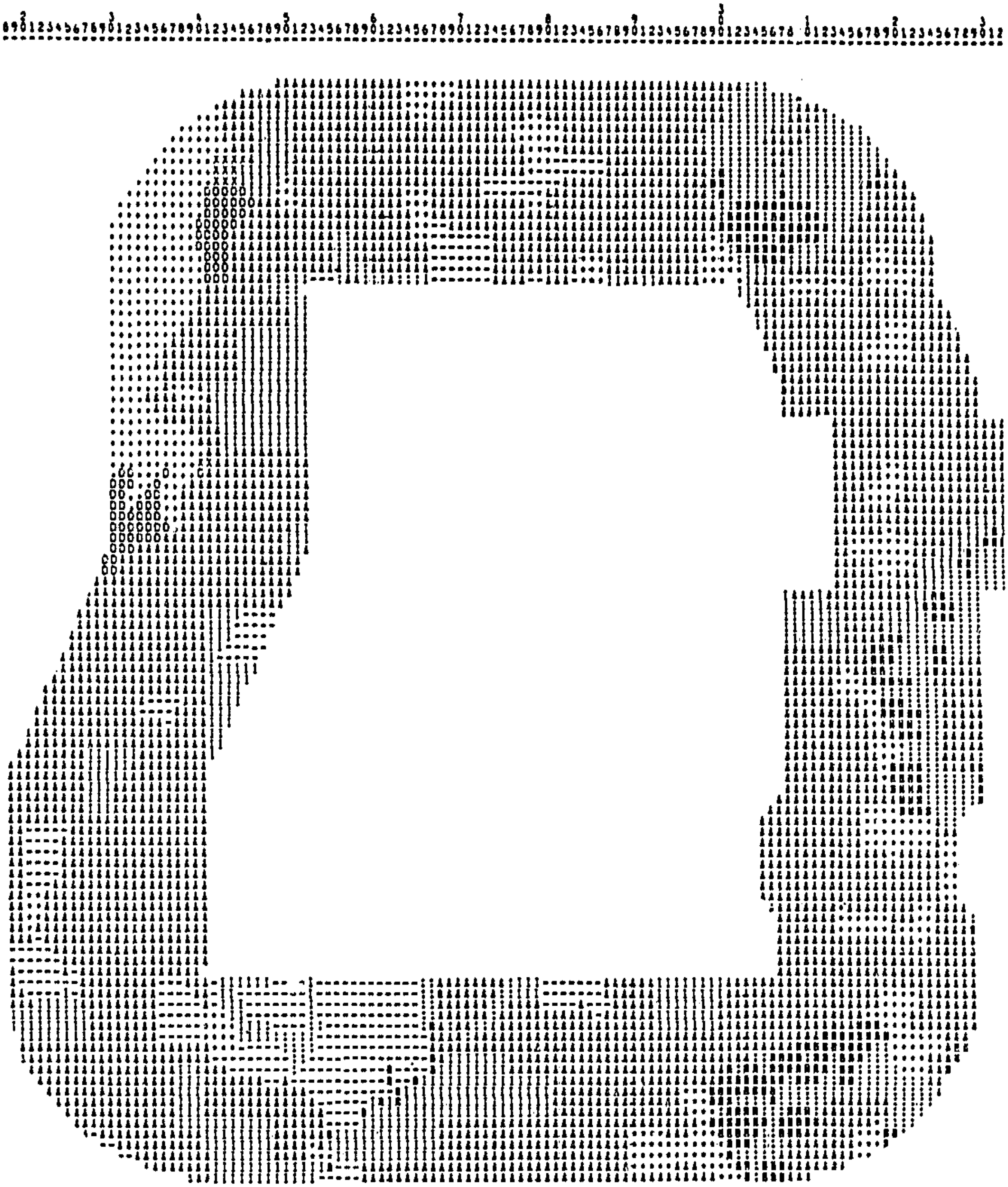

Figure 9. Land use within one-mile buffer zone surrounding proposed Barrens Reservoir site.

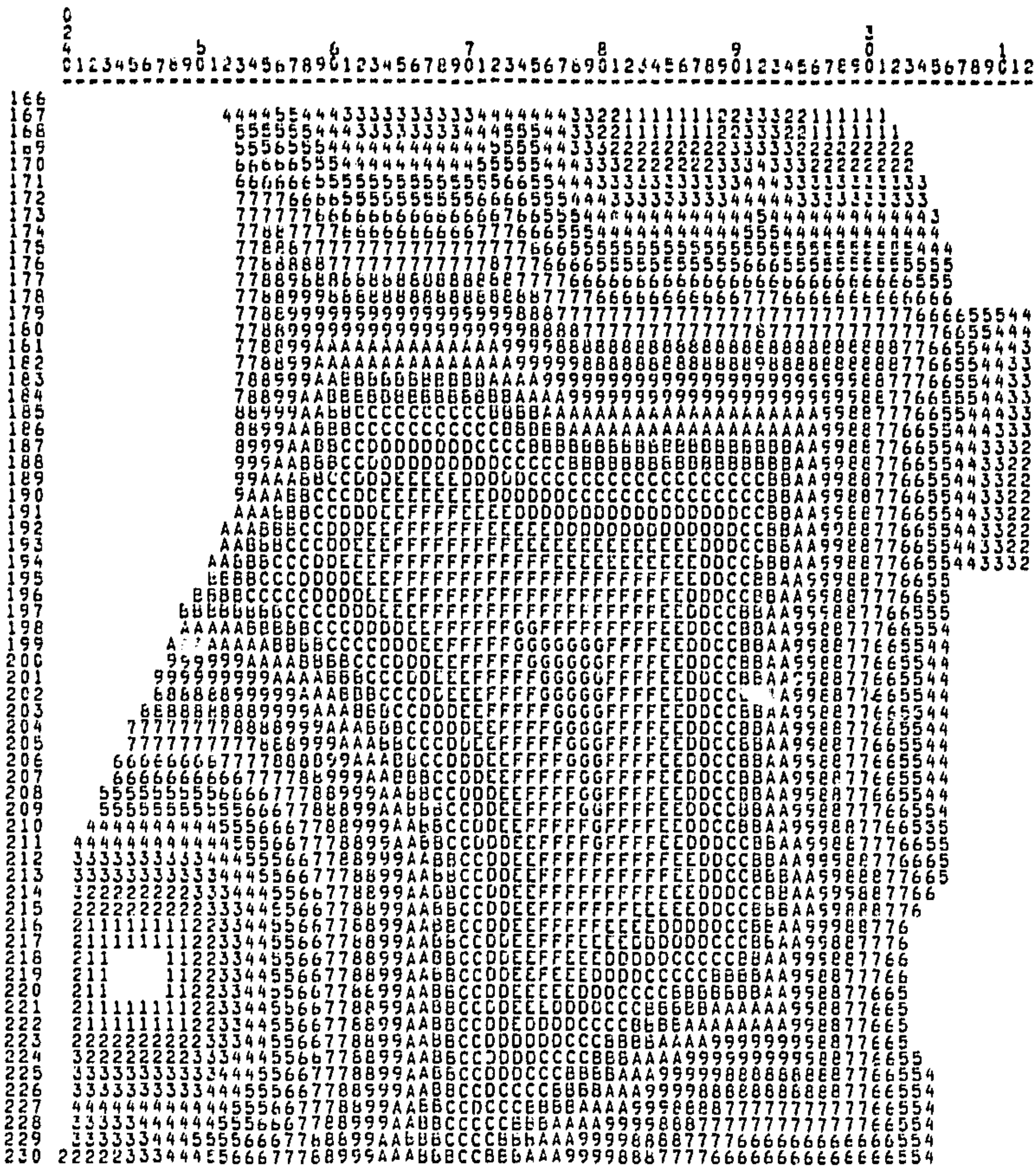

Figure 10. Printmap of distance algorithm showing one-tenth mile increments of distance from built-up areas in and near proposed Barrens Reservoir site.

intervals from built-up areas in the land use file. It should be noted in this example that built-up areas outside of this particular field of view (upper right corner) are still being acknowledged, as evidenced by the numbers 1 and 2, etc. depicting distances of 0.1 and 0.2 miles, respectively, from the built-up area.

CONCLUSIONS

The applications demonstrated in this section are by no means exhaustive. They were described to give a sample of the system capabilities and to stimulate resource managers into developing queries of their own based on resource needs. With a knowledge of local issues and a little creativity, most resource and growth management decisions can be aided by information derived from the North Cache RIMS.

Any number of new data files can be added to the four sets of data created in this project. For example, National Forest, BLM, State, and private land status could easily be digitized, as well as boundaries of incorporated areas. All of the files in the system could then be automatically accessed and printed out (acreage by land use, slope, elevation, aspect, geomorphic type, soil group, cover type, etc.). Even private land parcels could be digitized into the RIMS, allowing access to the same geo-based information.

Once the data files have been entered, they may be easily updated as changes occur. This is another great advantage of a digital data base management system. As more is learned of the conditions or characteristics of a land unit or geomorphic unit, the new information can be entered into growing data files of "attributes" of the land units. The system is open to the continuous updating of spatial and attribute information.

As data bases such as North Cache RIMS are created for various resource management areas across the state, a growing, interactive data file can be built for ready access. With a growing data base, increasing numbers of resource management issues can be addressed automatically by the system.

Finally, to make the use of this growing body of data more widespread and effective, all files need to be entered into the state's AGR (Automatic Geographic Reference) GIS system. A central clearinghouse, repository, and management system becomes an advantage to all resource and planning agencies -- state, local, and federal. The sooner all digital map files and remote sensing classification data can be entered into the AGR system for access by all agencies, the more efficiently all resource managers and planners can perform their roles.

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