AGRICULTURAL LAND-USE CLASSIFICATION USING LANDSAT IMAGERY DATA, AND ESTIMATES OF IRRIGATION WATER USE IN GOODING, JEROME, LINCOLN, AND MINIDOKA COUNTIES, 1992 WATER YEAR, UPPER SNAKE RIVER BASIN, IDAHO AND WESTERN WYOMING

By Molly A. Maupin

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http://wwwrvares.er.usgs.gov/nawqa/nawqa_home.html

or

http://wwwidaho.wr.usgs.gov/nawqa/usnk_home.html

FOREWORD

The mission of the U.S. Geological Survey (USGS) is to assess the quantity and quality of the earth resources of the Nation and to provide information that will assist resource managers and peacemakers at Federal, State, and local levels in making sound decisions. Assessment of water-quality conditions and trends is an important part of this overall mission.

One of the greatest challenges faced by water-resources scientists is acquiring reliable information that will guide the use and protection of the Nation's water resources. That challenge is being addressed by Federal, State, interstate, and local water-resource agencies and by many academic institutions. These organizations are collecting water-quality data for a host of purposes that include: compliance with permits and water-supply standards; development of remediation plans for a specific contamination problem; operational decisions on industrial, wastewater, or water-supply facilities; and research on factors that affect water quality. An additional need for water-quality information is to provide a basis on which regional and national-level policy decisions can be based. Wise decisions must be based on sound information. As a society we need to know whether certain types of water-quality problems are isolated or ubiquitous, whether there are significant differences in conditions among regions, whether the conditions are changing over time, and why these conditions change from place to place and over time. The information can be used to help determine the efficacy of existing water-quality policies and to help analysts determine the need for and likely consequence of new policies.

To address these needs, the Congress appropriated funds in 1986 for the USGS to begin a pilot program in seven project areas to develop and refine the National Water-Quality Assessment (NAWQA) Program. In 1991, the USGS began full implementation of the program. The NAWQA Program builds upon an existing base of water-quality studies of the USGS, as well as those of other Federal, State, and local agencies. The objectives of the NAWQA Program are to:

Describe current water-quality conditions for a large part of the Nation's freshwater streams, rivers, and aquifers.

•Describe how water quality is changing over time.

•Improve understanding of the primary natural and human factors that affect water-quality conditions.

This information will help support the development and evaluation of management, regulatory, and monitoring decisions by other Federal, State, and local agencies to protect, use, and enhance water resources.

The goals of the NAWQA Program are being achieved through ongoing and proposed investigations of 60 of the Nation's most important river basins and aquifer systems, which are referred to as study units. These study units are distributed throughout the Nation and cover a diversity of hydrogeologic settings. More than two-thirds of the Nation's freshwater use occurs within the 60 study units and more than two-thirds of the people served by public water-supply systems live within their boundaries.

National synthesis of data analysis, based on aggregation of comparable information obtained from the study units, is a major component of the program. This effort focuses on selected water-quality topics using nationally consistent information. Comparative studies will explain differences and similarities in observed water-quality conditions among study areas and will identify changes and trends and their causes. The first topics addressed by the national synthesis are pesticides, nutrients, volatile organic compounds, and aquatic biology. Discussions on these and other water-quality topics will be published in periodic summaries of the quality of the Nation's ground and surface water as the information becomes available.

This report is an element of the comprehensive body of information developed as part of the NAWQA Program. The program depends heavily on the advice, cooperation, and information from many Federal, State, interstate, Tribal, and local agencies and the public. The assistance and suggestions of all are greatly appreciated.

Robert M. Hirsch
Chief Hydrologist

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FIGURES

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CONVERSION FACTORS AND VERTICAL DATUM

Multiply	By	To obtain
acre	4,047	square meter
acre-foot (acre-ft)	1,233	cubic meter
cubic foot per second (ft^3/s)	0.02832	cubic meter per second
foot (ft)	0.3048	meter
inch (in.)	2.54	centimeter
mile (mi)	1.609	kilometer
square foot (ft^2)	0.09290	square meter
square mile (mi^2)	2.590	square kilometer

Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as follows:

$$°C = (°F - 32) / 1.8$$

Sea level: In this report, "sea level" refers to the National Geodetic Vertical Datum of 1929 (NGVD of 1929)—a geodetic datum derived from a general adjustment of the first-order level nets of both the United States and Canada, formerly called Sea Level Datum of 1929.

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By Molly A. Maupin

ABSTRACT

As part of the U.S. Geological Survey's National Water-Quality Assessment Program in the upper Snake River Basin study unit, land- and water-use data were used to describe activities that have potential effects on water quality, including biological conditions, in the basin. Land-use maps and estimates of water use by irrigated agriculture were needed for Gooding, Jerome, Lincoln, and Minidoka Counties (south-central Idaho), four of the most intensively irrigated counties in the study unit. Land use in the four counties was mapped from Landsat Thematic Mapper imagery data for the 1992 water year using the SPECTRUM computer program. Land-use data were field verified in 108 randomly selected sections (640 acres each); results compared favorably with land-use maps from other sources. Water used for irrigation during the 1992 water year was estimated using land-use and ancillary data. In 1992, a drought year, estimated irrigation withdrawals in the four counties were about 2.9 million acre-feet of water. Of the 2.9 million acre-feet, an estimated 2.12 million acre-feet of water was withdrawn from surface water, mainly the Snake River, and nearly 776,000 acre-feet was withdrawn from ground water. One-half of the 2.9 million acre-feet of water withdrawn for irrigation was considered to be lost during conveyance or was returned to the Snake River; the remainder was consumptively used by crops during the growing season.

INTRODUCTION

In 1991, the upper Snake River Basin (USNK) was selected as one of the first 20 National Water-Quality Assessment (NAWQA) study units. Land- and water-use data were used to describe activities that could potentially affect water quality, including biological conditions, in the basin. Data were used to describe water quality and biological conditions in (1) drainages upstream from surface-water-quality sample sites, (2) areas of ground-water-quality land-use studies, and (3) stream habitats (Clark, 1994; Rupert, 1994; Maret, 1995; Maupin, 1995).

Descriptive and comprehensive land- and water-use data were acquired and summarized during the first 2 years of the USNK NAWQA study. Land-use data acquired from the Geographic Information Retrieval and Analysis System (GIRAS) represent conditions in the mid-1970's (U.S. Geological Survey, 1986) and were the only available land-use data that included the whole study unit. However, GIRAS data have land-use classification errors. Water-use data for 1990 were available from the U.S. Geological Survey (USGS) National Water Information System (NWIS). Important data from this source were ground- and surface-water

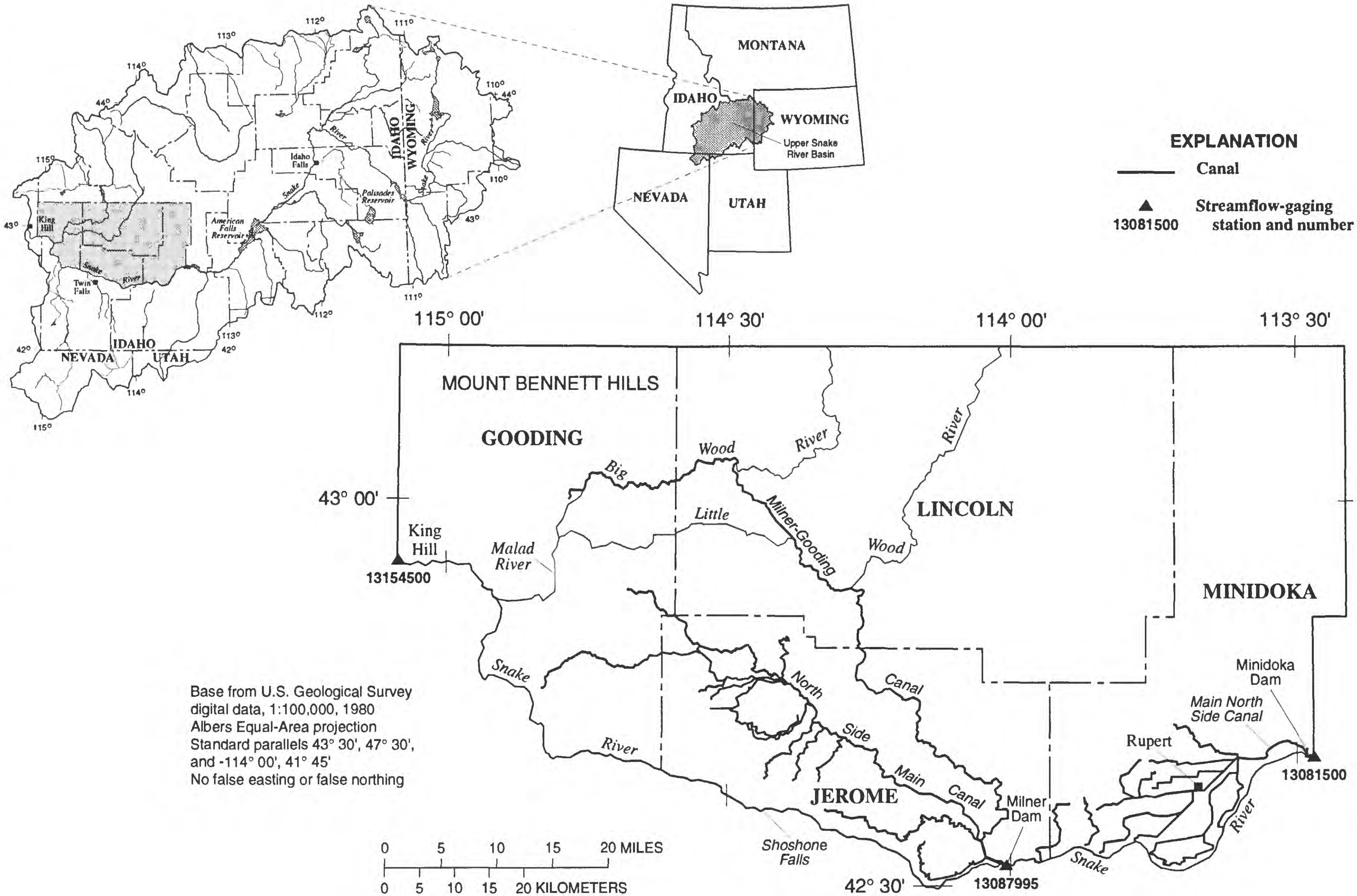

Figure 1. Location of upper Snake River Basin study unit for the National Water-Quality Assessment Program and study area of this report.

withdrawals for irrigated agriculture, conveyance losses, and consumptive uses.

The NAWQA Program required updated delineations of irrigated agricultural land, the most dynamic land use in most study units. As part of the NAWQA Program, the USGS participated with several other agencies to form the Multi-Resolution Land Characteristics (MRLC) Consortium. The Consortium formed a partnership that enabled the acquisition of Landsat Thematic Mapper (TM) imagery data from the Earth Observation Satellite (EOSAT) Company. TM data were used with a computer program called SPECTRUM, a tool developed by Khoral Research, Inc., to classify land use. Land-use maps from the SPECTRUM program were constructed and verified for the most intensively irrigated counties in the USNK study unit—Gooding, Jerome, Lincoln, and Minidoka Counties in south-central Idaho. The data also were used to help derive water-use estimates for irrigated agriculture.

Irrigated agriculture is the largest consumptive use of water in Gooding, Jerome, Lincoln, and Minidoka Counties (fig. 1). Withdrawal estimates were derived using data for land use, crop irrigation requirements, irrigation-system efficiencies, and crop distribution. Irrigation-withdrawal estimates were used in assessing ground- and surface-water-quality conditions and in defining temporal changes.

Study Area

Gooding, Jerome, Lincoln, and Minidoka Counties are located in the southwestern part of the USNK (fig. 1). The counties cover almost 3,300 mi^2 (Idaho Department of Commerce, 1996). About 1,054 mi^2 is classified as irrigated cropland and pasture (U.S. Geological Survey, 1986). In 1990, almost 14 percent of the total irrigation withdrawals in the USNK occurred in these four counties. A typical growing season in the vicinity of Rupert and Twin Falls is about 130 days, which begins in early March and extends to mid- or late October (Doug Doctor, Bureau of Reclamation, oral commun., 1996).

The study area is from 2,600 to slightly less than 6,400 ft above sea level (fig. 2). The highest part, Mount Bennett Hills, is composed of volcanic and sedimentary rocks. The Snake River defines the southern boundary of the study area, and between Shoshone Falls and King Hill, the river is entrenched in a canyon as much as 700 ft deep. Generally flat lands, used mostly for agriculture, compose the central and eastern parts of the study area; large basalt flows, with little or no vegetation, are located in northern Minidoka County.

Annual temperatures average about 50°F (Bureau of Reclamation, 1994) throughout the study area, and mean annual precipitation ranges from less than 10 to 20 in. (Molnau, 1995) (fig. 3).

Purpose and Scope

The purpose of the report is to describe methods used to map agricultural lands from Landsat TM imagery data using SPECTRUM, a computer program that relates imagery data to a land-use classification scheme. Methods used to select sample sites and conduct field verification of the land-use maps are presented, and the maps are evaluated for application to the water-use estimation process. Finally, estimates for consumptive use, irrigation withdrawals, and conveyance losses are presented.

Consumptive-use estimates were derived from irrigated acreages and crop irrigation requirements. Irrigation withdrawals were derived from consumptive-use estimates and irrigation-system efficiencies for ground- and surface-water-irrigated areas. Conveyance losses were estimated from irrigation withdrawals and irrigation-system efficiencies.

Multi-Resolution Land Characteristics Consortium

The MRLC Consortium was formed from five Federal environmental monitoring programs to develop and generate new land-use data for the contiguous 48 United States. Land-use data developed by the Consortium reflect the diverse needs of each program. Figure 4 depicts the organizational structure of the Consortium. Jennings (1996) explains the Consortium organization, activities, products, and timelines. The programs and their agencies are:

- NAWQA Program, USGS, Water Resources Division
- Environmental Monitoring and Assessment Program (EMAP), U.S. Environmental Protection Agency (USEPA)
- Gap Analysis Program (GAP), USGS, Biological Resources Division

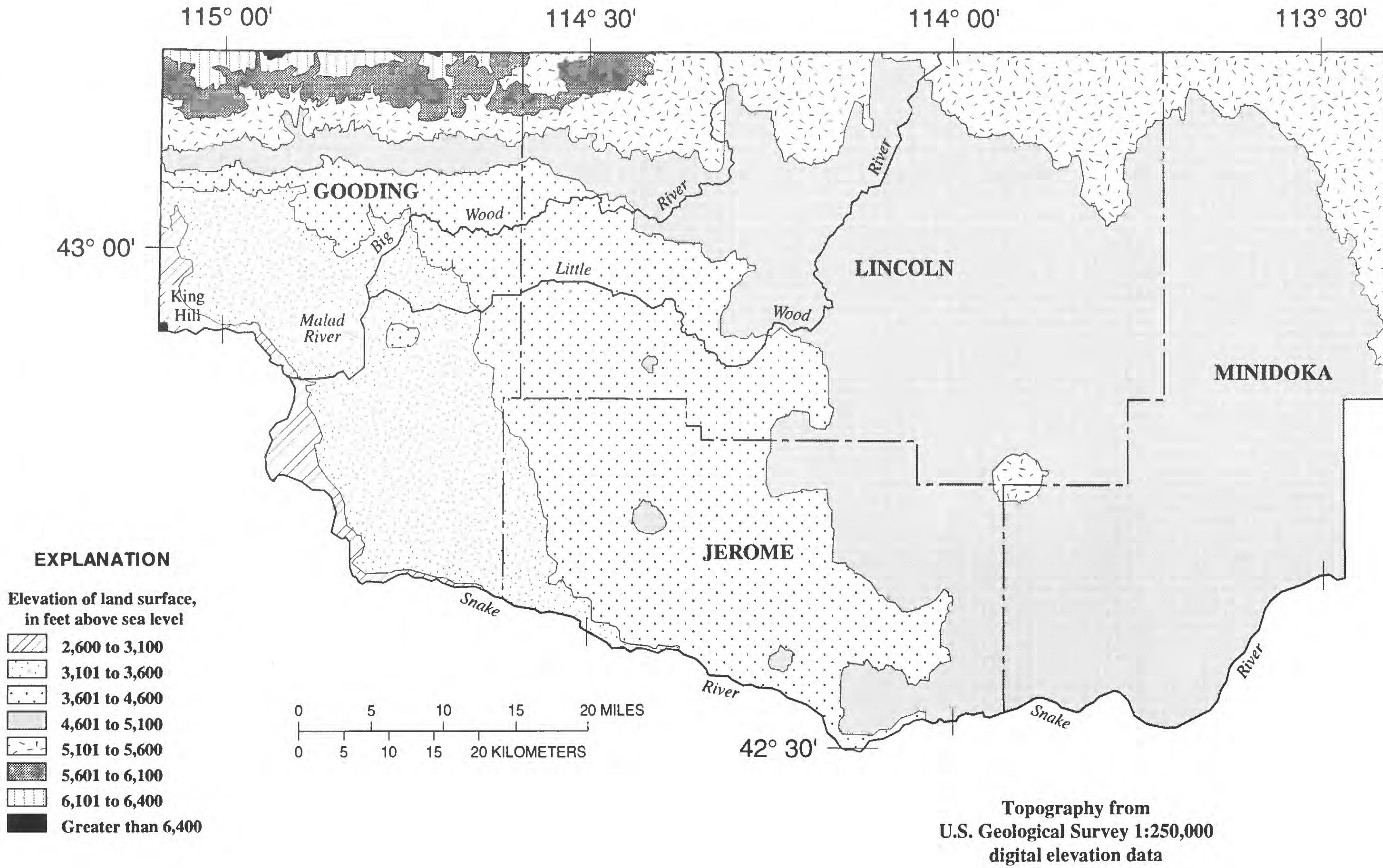

Figure 2. Topography of Gooding, Jerome, Lincoln, and Minidoka Counties, south-central Idaho.

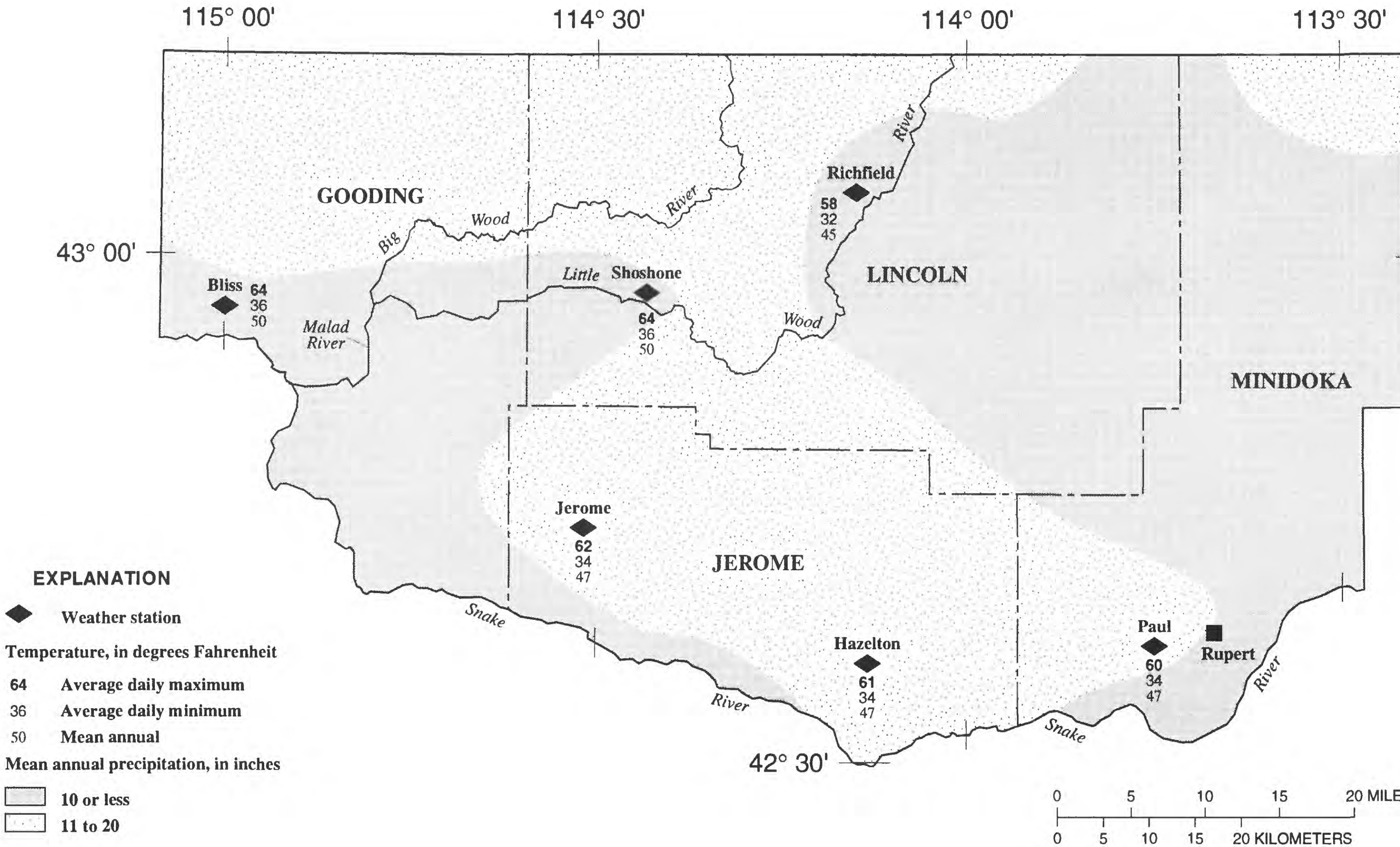

Figure 3. Average daily maximum and minimum, and mean annual temperatures at selected weather stations and mean annual precipitation in Gooding, Jerome, Lincoln, and Minidoka Counties, 1961–90. (Temperature data from Bureau of Reclamation, 1994; precipitation data from Molnau, 1995)

- CoastWatch Change Analysis Program (C-CAP), National Oceanic and Atmospheric Administration (NOAA)
- North American Landscape Characterization Project (NALC), USEPA and USGS

A more complete listing and information about each participating agency may be obtained from the Internet site < http://www.epa.gov/grd/mrlc/mrlc.html >

The MRLC Consortium oversees a cooperative agreement between member agencies and the USGS EROS (Earth Resources Observation Systems) Data Center (EDC) in Sioux Falls, South Dakota. EDC supplied the resources for preprocessing, spectral clustering (see Landsat Imagery Data section), ancillary data acquisition, data distribution, and archival of the massive collection of TM data. The preprocessed data are copyrighted by the EOSAT Company and are to be used only by MRLC Consortium agencies in their respective programs. No distribution of these data is allowed. However, clustered and formatted data (see Clustering and Formatting section) are public domain and may be freely distributed for only the cost of reproduction and handling. The clustered and formatted data are designed to be used with SPECTRUM software.

The NAWQA Program provided information to the MRLC Consortium to guide the acquisition of TM data that would be best suited for land-use classification of agricultural lands. TM data were acquired for the 1991–93 growing seasons to enable discrimination of agricultural land from other land uses; the 1992 growing season was given highest priority. If available, multitemporal data were acquired within the same growing season. These data provided more descriptive information for crop identification.

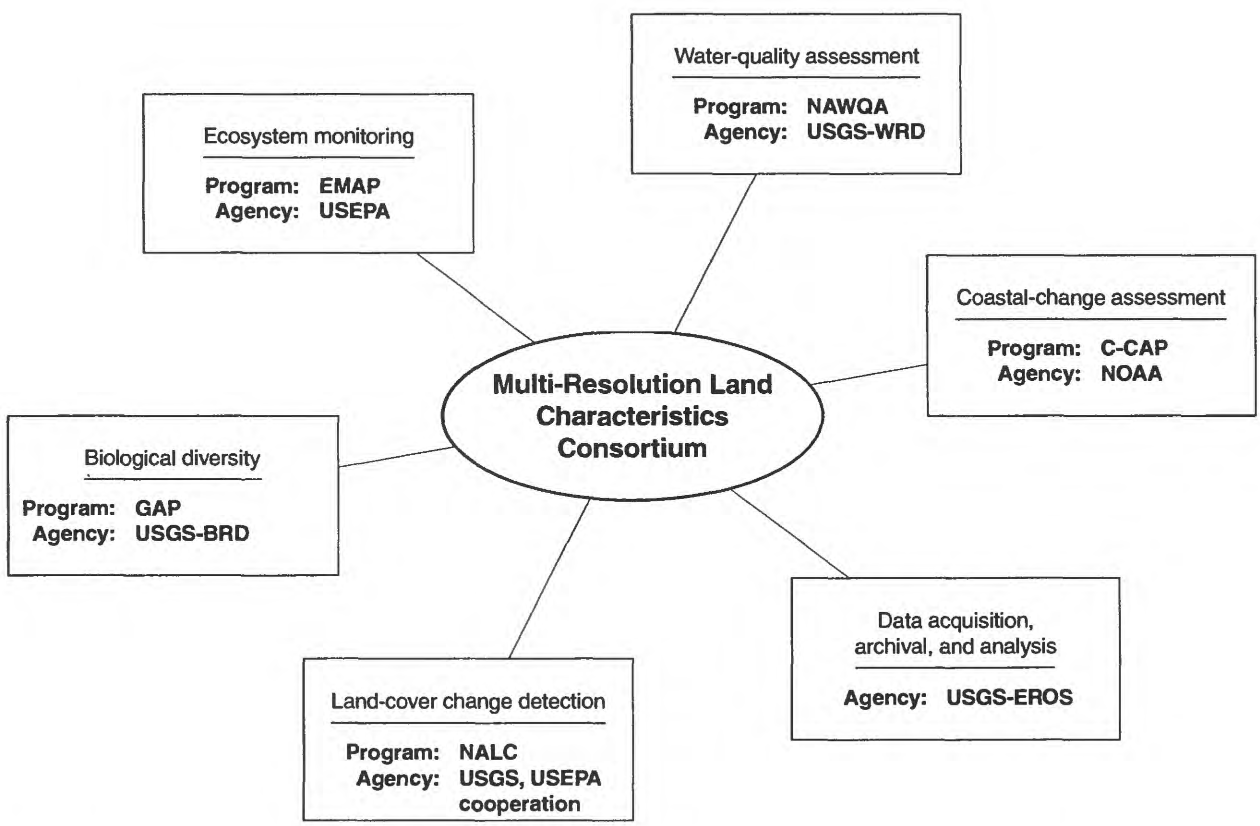

Figure 4. Programs and agencies of the Multi-Resolution Land Characteristics Consortium. (NAWQA, National Water-Quality Assessment Program; USGS, U.S. Geological Survey; WRD, Water Resources Division; C-CAP, CoastWatch Change Analysis Program; NOAA, National Oceanic and Atmospheric Administration; EROS, Earth Resources Observation Systems; NALC, North American Landscape Characterization Project; USEPA, U.S. Environmental Protection Agency; GAP, Gap Analysis Program; BRD, Biological Resources Division; EMAP, Environmental Monitoring and Assessment Program)

Through the MRLC Consortium, the NAWQA Program supplied each study unit with TM data, software, and assistance in classifying land uses. TM data were provided to the study units with Digital Elevation Model (DEM) data. Typically, DEM data are organized by areas shown on 1:250,000-scale quadrangle maps (U.S. Geological Survey, 1987); EDR combined into one file all the DEM data associated with a TM scene.

LANDSAT IMAGERY DATA

Landsat sensors measure reflective and emitted energy from the Earth's surface as visible, near-infrared, middle-infrared, and thermal-infrared ranges of the electromagnetic spectrum. Landsat TM bands 1 through 7 are associated with different wavelengths in the spectrum (fig. 5), and satellite sensors measure and record each band in a TM scene. A TM scene covers approximately 71 x 69 mi. Data for all bands, except band 6 (not used in this study), are collected at a spatial resolution of about 98 x 98 ft and are called pixels, or picture elements.

The USNK NAWQA study unit received 11 preprocessed TM scenes from EDC; all but one were single-date scenes. The scene that covers the four-county study area (fig. 6) was recorded in July 1992 and, therefore, depicted crops that were emergent and fairly well established. Preprocessing at EDC included the removal of errors from the scene; mostly missing data were interpreted and terrain corrections were made. Standardized procedures were used to correct errors (Jensen, 1986, p. 95). Terrain correction, using DEM data, and geometric corrections, using 1:100,000-scale Digital Line Graph (DLG) data (U.S. Geological Survey, 1989) were done by EDC.

Clustering

EDC grouped the TM data into 240 clusters (groups of data based on similar spectral response) using a program developed at Los Alamos National Laboratory, New Mexico (Kelly and White, written commun., 1994). The program randomly selected pixels in a systematic manner and grouped them using the k-means clustering algorithm. During each iteration, an increasing number of pixels were selected from the TM data, and the mean value for each of the six bands was computed. As more pixels were added, a clearer representation of the clusters was defined. When the process was finished, 240 clusters were defined, and a mean value was calculated for each band in each cluster. Finally, each pixel from the original TM data was assigned to the cluster for which band values were most similar. When the clustering process was finished, the size of the file used in the SPECTRUM computer program was about one-seventh the size of the original TM data set. The data set was then written to a file that was specially formatted to be read by the SPECTRUM computer program.

Analysis Using SPECTRUM Computer Program

The SPECTRUM computer program is an image-classification system that associates clustered TM data to a land-use classification scheme through interactive

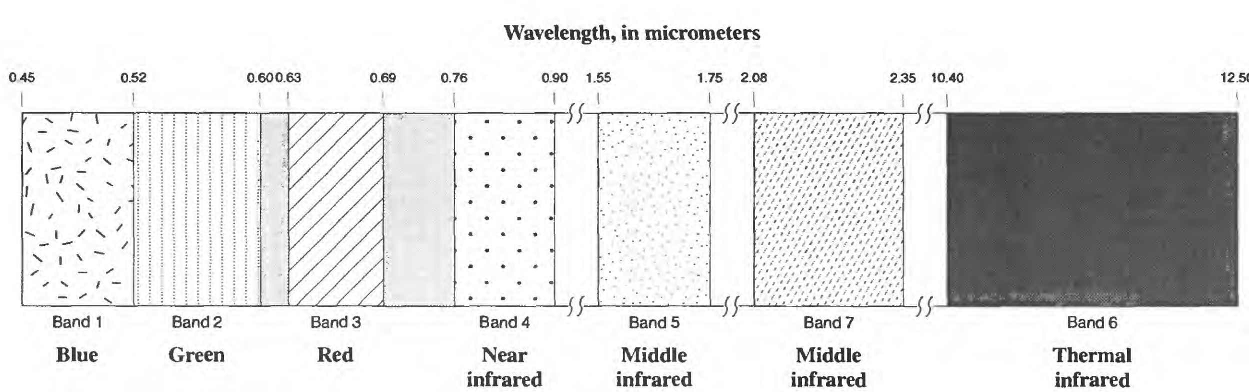

Figure 5. A portion of the electromagnetic spectrum and the relation to Landsat Thematic Mapper bands 1–7.

processes in a menu-driven environment. The SPECTRUM program will read the clustered and formatted TM data and display them with an associated, predetermined land-use classification list. Pixels may be selected in a display window and assigned to land-use categories that best describe the area. The clustered nature of the TM data allows land-use categories to be assigned systematically throughout the whole TM scene. For example, when a pixel is selected and defined as a certain land-use category, all other pixels that belong to that cluster automatically are chosen and defined as well. Many clusters (and therefore, pixels) may belong to one land-use category, and clusters may be redefined from one category to another.

Specific crop types could not be differentiated by the SPECTRUM program because the single-date TM scene did not provide enough information to distinguish crops at different stages of growth. Specific crop types

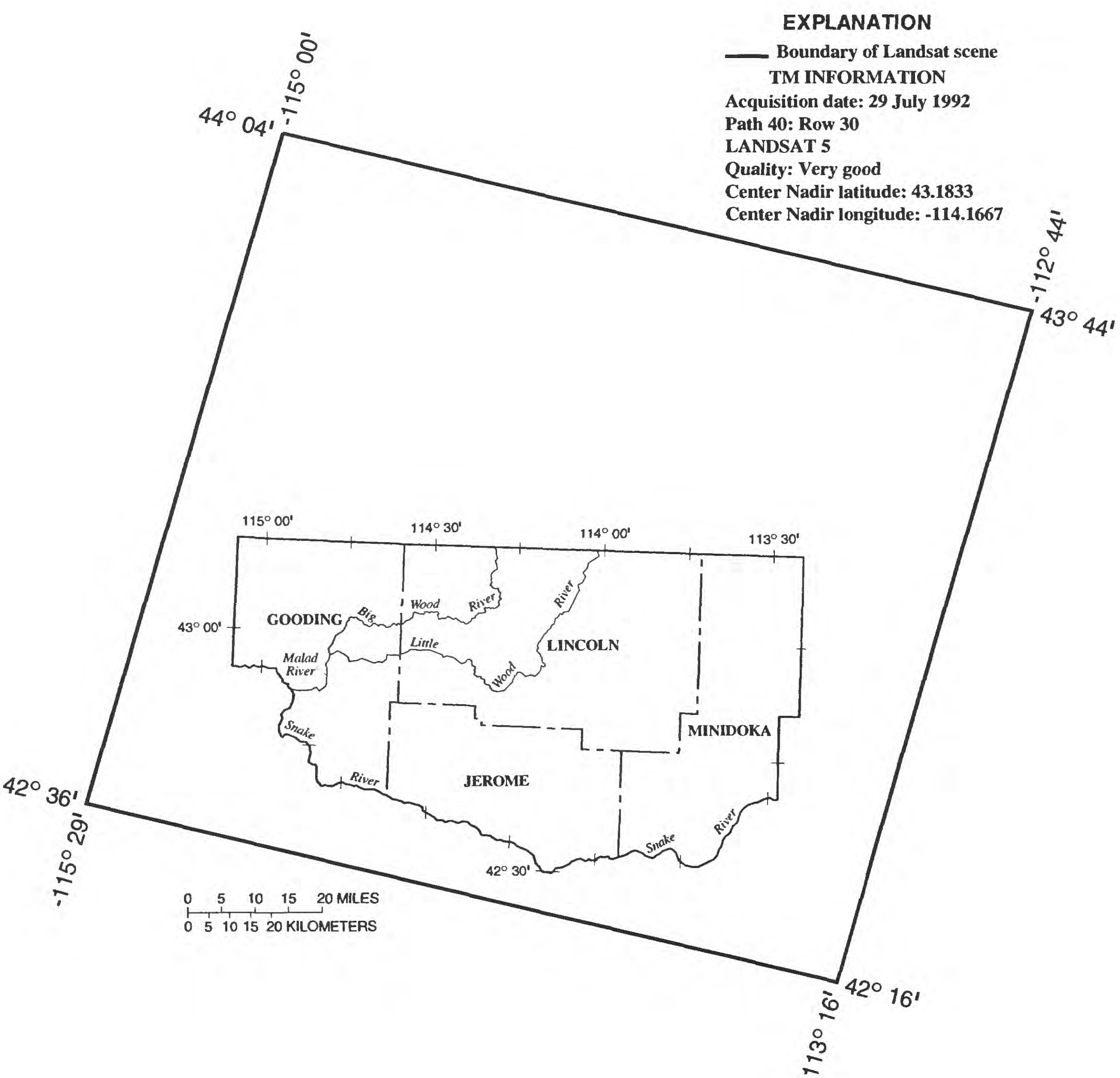

Figure 6. Location of Landsat Thematic Mapper (TM) scene that includes Gooding, Jerome, Lincoln, and Minidoka Counties.

may be classified using the information that is available in multitemporal TM scenes. The SPECTRUM program was able to map only agricultural, forest, range, and urban lands; rock; and water. The SPECTRUM program was able to divide agricultural lands into two categories—center pivot and other irrigated lands—because center-pivot irrigation systems were easily recognizable.

After the SPECTRUM program classified the TM scene, a file was written that explained the association between the land-use categories and the 240 clusters. The file was read into a geographic information system (GIS) to further refine the land-use classifications, plot field-verification maps, and display the final products. The Public Land Survey System (PLSS) data (U.S. Geological Survey, 1989) contain the township, range, and section numbers for each county and were used to help determine areas where field verification would be conducted.

Field Verification

A computer program designed by Scott (1990) was used to randomly select, for field verification, a sample of 10 percent of the sections (1 mi x 1 mi, or 640 acres) in which part or all of the section was classified by the SPECTRUM program as agricultural land. A random sample of only sections with agricultural land was necessary to determine the effectiveness of the SPECTRUM program and to later estimate irrigation water use. Field verification included a drive-by survey and photographic documentation of land and water use in 108 sections in the four counties (fig. 7). Field verification occurred during a 2-week period in late May and early June 1996.

A standardized form (fig. 8), USGS 7.5-minute orthophoto quadrangle maps, and methods similar to those used by Zelt and others (1995) were used to (1) verify land-use classifications from the SPECTRUM program, (2) determine type of irrigation systems, and (3) identify specific crops in each section. Orthophoto maps were used because crop boundaries and landmark features are easily discernible. No efforts were made to compensate for orthophoto maps that were older than the TM data (1992); however, most orthophoto maps were more recent than 1987.

Land-use boundaries and codes were plotted and labeled on transparent film and registered to the orthophoto maps. Section boundaries were outlined on the transparent film to help the surveyors locate sections to be field verified. In the field, surveyors documented the correctness and accuracy of the land-use classifications by making any changes to the boundaries plotted on the transparent film and, if necessary, recoding land uses with codes listed on the standardized form (fig. 8). Accuracy of the land-use classifications was determined using a transparent grid overlay (100 squares per section). For each section, the surveyor determined the percentage of land correctly classified and gave it a ranking of "very good," "moderate," "fair," "poor," or "terrible" (fig. 8). Additionally, the surveyor noted irrigation-system types and tabulated the percentage of land serviced by each type. If crops were planted and emergent, crop types were noted and mapped. At least two photographs were taken at each section using 35-mm (millimeter) color film to document crops, irrigation systems, and any unusual water-conveyance techniques. Additional comments and notes were recorded in the "NOTES/COMMENTS" section on the form.

AGRICULTURAL LAND-USE CLASSIFICATION

About 691,000 acres was classified as agricultural land using SPECTRUM, about 33 percent of the total land area in the four counties (fig. 9). The total amount of agricultural lands mapped using SPECTRUM was within 95 percent of the total agricultural lands mapped by the Bureau of Reclamation (BOR) (Idaho Department of Water Resources, 1996) and within about 89 percent of 1992 Census of Agriculture enumerations (Idaho Department of Commerce, 1996). All lands classified as agricultural were presumed to be irrigated, but not all of the agricultural lands were irrigated cropland. For instance, pasturelands were not considered irrigated cropland but were irrigated and, therefore, were included in the agricultural classification.

Summary statistics from field-verified sections produced a mean accuracy rating of "moderate"; on average, 76 to 90 percent of each field-verified section was classified correctly. A comparison between the acreages of agricultural lands from SPECTRUM, GIRAS, and BOR maps indicated that the methods and results were reasonable.

About 10 percent of land classified as agricultural was different between GIRAS and BOR maps and the SPECTRUM map. Shaded areas in figure 10 indicate where agricultural lands were classified differently.

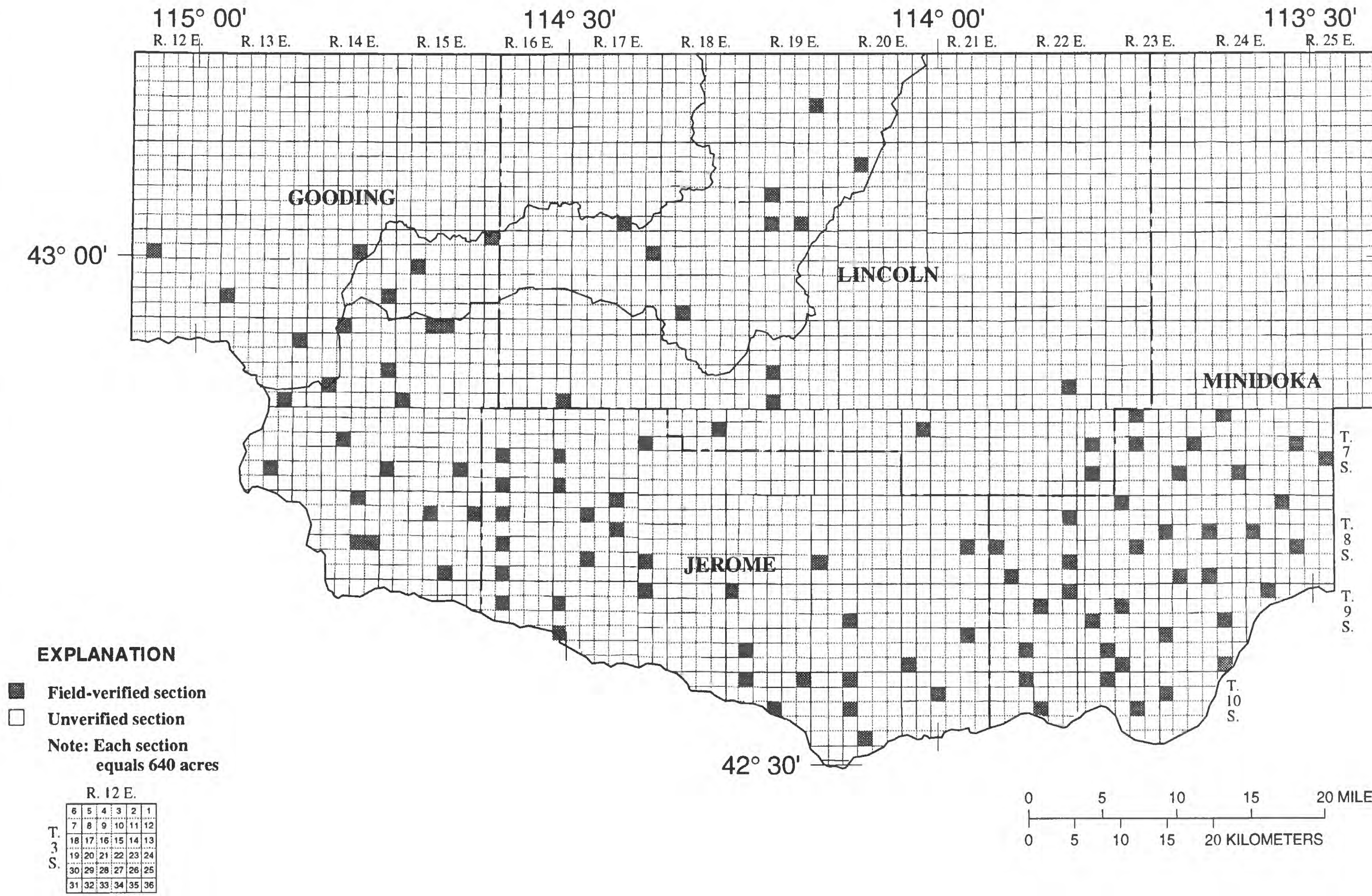

Figure 7. Distribution of randomly selected field-verified sections classified by SPECTRUM program as agricultural land, Gooding, Jerome, Lincoln, and Minidoka Counties.

Land-Use Field-Verification Form

SITE LOCATION:

Site number:______________County:_______________Public land survey system: Township_____S, Range___E, Section ____

Topo map name:____ Scale 1:24,000

SURVEY INFORMATION:

Recorded by:_________________________ Date:______________ Time:________Weather conditions:________________

Photo documentation: Roll #___________ Photo #(s)________________________

ACCESS:

Do public roads provide an adequate view of entire site? YES________NO________

Owners name:_______________________________Permission to enter private lands given by:______________Date:________

Permission to re-enter: YES____NO____CALL____STOP BY____ OK IF NOT THERE___

LAND USE:

How well was land-use classified using SPECTRUM software:

[(91-100%) (76-90%)(51-75%) (26-50%)(< 25%)]

VERY GOOD ________MODERATE________ FAIR________POOR________TERRIBLE________

IRRIGATION SYSTEMS:

Irrigation system	Percentage of land	Source of water
Center Pivot: impact heads		
Center Pivot: low flow heads		
Side roll wheel line		
Solid set		
Hand move		
Flood (from ditches)		
Open ditch		
Gated solid pipe direct from source (surge, etc.)		
Other		

Check the types of irrigation systems being used in the section. If there are more than one type, estimate the percentage of land that each type serves. If possible, determine the source of the water, either ground water (G) or surface water (S), or a mix of both (M).

NOTES/COMMENTS: Include any observations, photos, or sketches here. Include any information about neighboring stockyards, industrial facilities, or urban settings that are important to changing land uses.

Figure 8. Example of land-use field-verification form

LAND USE:

Using the CODES listed below and the orthophoto quadrangle maps, delineate the approximate boundaries between different land uses. Also, estimate the percentages of crop types if you can. Make special note of irrigation systems and note the percentages and locations of each type that you see. Use the comments section to clarify any land uses that need further explanation.

CODE	Land use	Percentage of section	Percentage irrigated
R	Rangeland		
Rf	Rangeland fenced		
Ru	Rangeland unfenced		
Pi	Pasture, irrigated		
Pn	Pasture, nonirrigated		
A	Agricultural lands (farmyards, barns, etc.)		
Ai	Agricultural lands, irrigated cropland		
Ad	Agricultural lands, nonirrigated (dryland)		
Af	Agricultural lands, fallow cropland		
U	Urban or built up		
Ow	Open water (ponds, canals, streams)		
B	Barren land (< 50% vegetated)		
F	Forest or woodlands (>50% tree closure)		
Ca	Confined animals, stockyards, corrals		
Ot	Other land use: ______________________		
	CROP TYPES	Percentage of section	
P	Potatoes		
S	Sugarbeets		
B	Beans		
C	Corn		
Alf	Alfalfa, hay		
W(s,w)	Wheat, spring or winter		
G	Grains, oats, barley		
O	Onions		
Ot	Other? Specify		

Figure 8. Example of land-use field-verification form—Continued

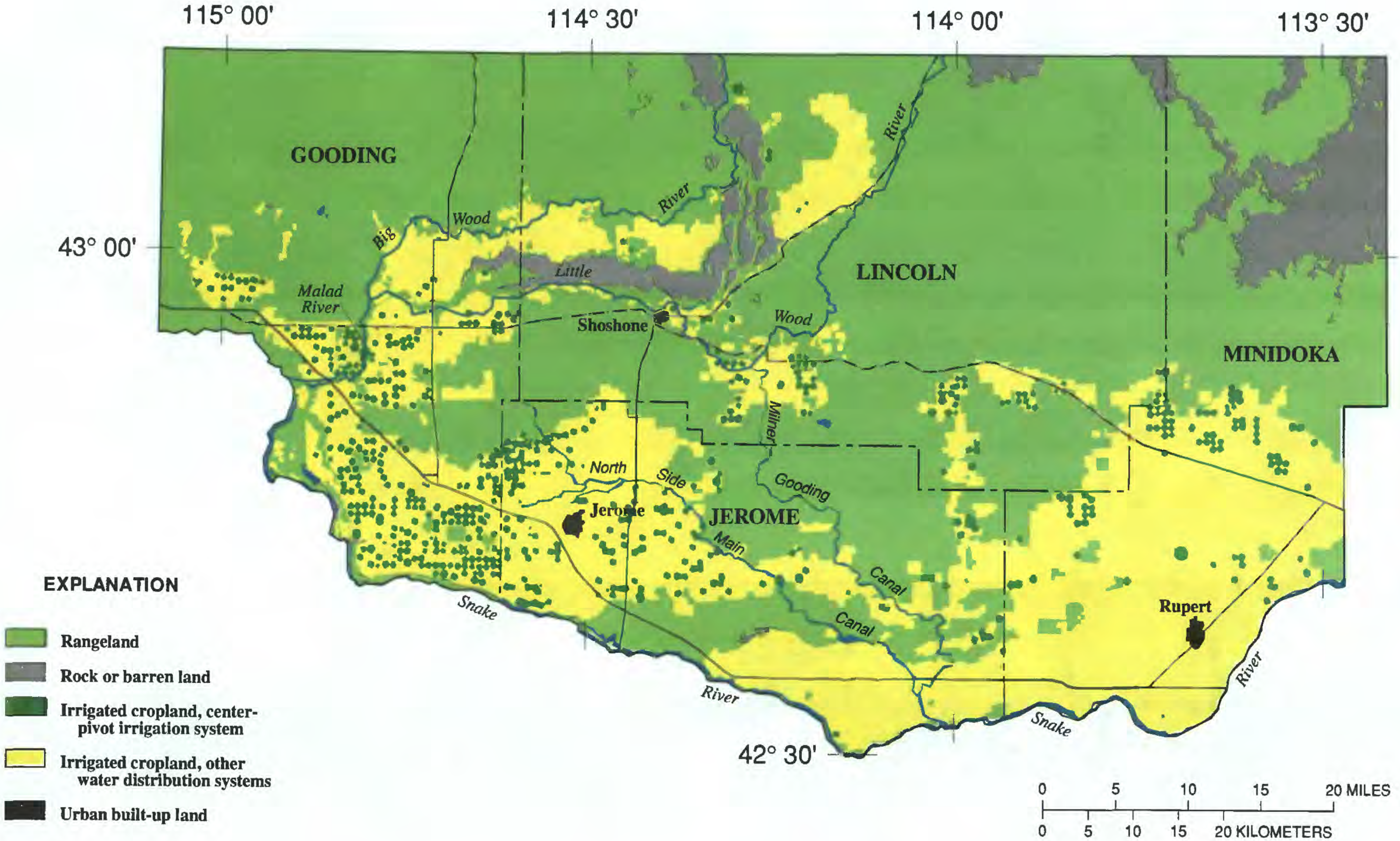

Figure 9. Land use in Gooding, Jerome, Lincoln, and Minidoka Counties classified using SPECTRUM software.

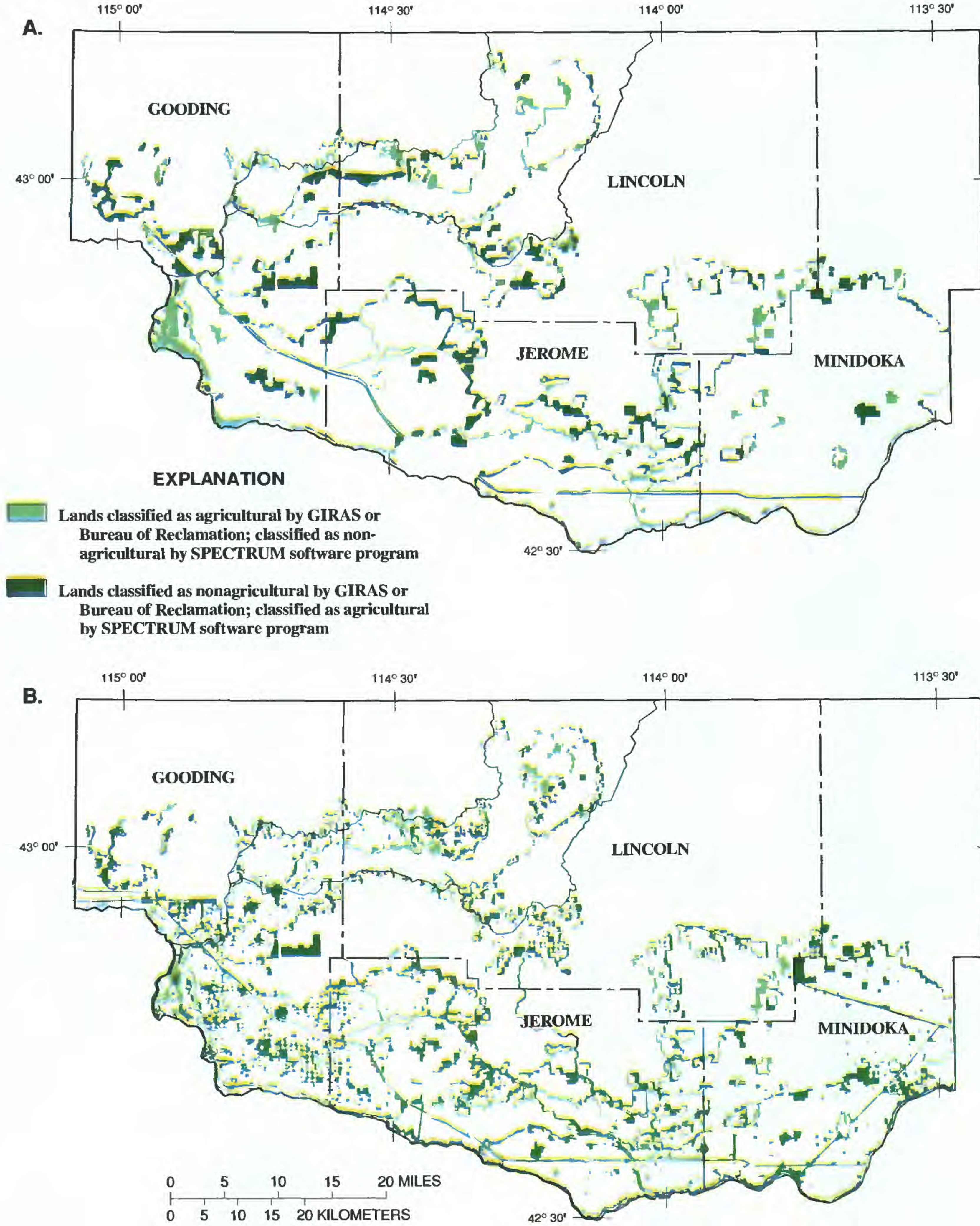

Figure 10. Comparison between land-use classifications made by (A) GIRAS and SPECTRUM software program and (B) Bureau of Reclamation and SPECTRUM software program, Gooding, Jerome, Lincoln, and Minidoka Counties. [GIRAS, Geographic Information Retrieval and Analysis System (U.S. Geological Survey, 1986); Bureau of Reclamation map published by Idaho Department of Water Resources (1996)]

Most land-use differences between GIRAS and SPECTRUM maps were along the fringes of agricultural lands.

More agricultural land was mapped in all four counties by SPECTRUM than by GIRAS; 17 percent more in Gooding County, 7 percent more in Lincoln County, and 10 percent more in Jerome and Minidoka Counties. Some of the differences can be attributed to an increase in agricultural land between the 1970's, represented by the GIRAS map, and 1992, represented by the SPECTRUM map.

Likewise, more agricultural land was mapped in all four counties by SPECTRUM than by BOR; 15 percent more in Gooding County, 12 percent more in Lincoln County, and about 10 percent more in Jerome and Minidoka Counties. The BOR map was derived using 1987 aerial photography (1:40,000-scale) and 7.5-minute quadrangle maps that were photoreduced to a scale of 1:40,000. Agricultural land uses were delineated from the photography onto the quadrangle maps; randomly selected sample areas were field checked in 1992 and revised in 1996. Therefore, differences in percentage of agricultural land can be attributed mostly to different data collection methods and, to a lesser degree, different source data.

Although land-use changes were small in most sections that were field verified, land use changed more than 80 percent in others. For example, field verification revealed freshly plowed fields and a newly installed center-pivot sprinkler system in one section in Jerome County (J092016, Appendix A). The land-use change doubled the agricultural acres for the section and, accordingly, reduced the rangeland acreage. Land use in field-verified sections is listed in Appendix A. The comparison among percentages of rangeland, agricultural land, and other land-use acreages determined using SPECTRUM and results from field-verified sections are shown in table 1.

More agricultural land consistently was classified with SPECTRUM than was recorded in the field verification because some fenced and grazed rangeland appeared similar to certain types of agricultural land in the SPECTRUM classification process. Also, multitemporal TM data were not available, which would have allowed for distinction between certain crops and rangeland. Comparisons among SPECTRUM maps, field-verification data, and BOR maps have been useful in correcting misclassified areas.

Classifications using SPECTRUM correlated best with field-verification sections in Gooding County, where total acreages of agricultural land corresponded with more than 95 percent of acreages determined with SPECTRUM. In Minidoka County, rangeland acreage determined with SPECTRUM was only one-half that in field-verified sections; consequently, agricultural-land acreages were overclassified. Areas classified as agricultural land in all counties may include small tracts of rangeland, and agricultural lands were favored in the SPECTRUM classification process.

Table 1. Percentages of land-use acreages determined using SPECTRUM software program and results from field-verified sections in Gooding, Jerome, Lincoln, and Minidoka Counties

[Values are normalized to total sampled acreages in each county and are not total county acreages. Other land use includes urban, farmsteads, pastures, dairies and feedlots, open-water bodies, and barren lands. <, less than]

	Land use (percentage of total)					
	SPECTRUM			Field verified		
County	Range-land	Agri-cultural land	Other	Range-land	Agri-cultural land	Other
Gooding	20	78	2	21	76	3
Jerome	10	87	3	12	81	7
Lincoln	36	64	<1	43	57	<1
Minidoka	7	92	1	14	82	4

In parts of some counties, especially Gooding and parts of Jerome Counties, fields with crops were small and often were interspersed with homesteads and pastures. SPECTRUM was unable to distinguish pastureland from cropland where land use was patchy. However, differentiation of irrigated pasture from cropland was necessary to best estimate water use in each county. Therefore, the homestead and pasture categories (Pi and A, respectively) were added to the field form (fig. 8) to determine the percentage of pasture and homestead land uses in each section.

Field-verification measurements for these two categories provided a means to differentiate irrigated land in pastures and yards from major agricultural crops. Homesteads were interpreted in the field as areas occupied by farmhouses, yards and gardens, barns and surrounding equipment yards, and small corrals and stock pens. Typically, less than 5 percent of each field-verified section was occupied by homesteads. The percentage of pastureland varied by county and ranged from 19 percent in Lincoln County to 7 percent in Minidoka County. In final tabulations, land used for pasture and agriculture was combined to obtain total irrigated acres.

The anticipated application of the maps from SPECTRUM was limited because multitemporal TM data were not provided. Multitemporal data are two TM scenes, taken at different times during the growing season. Different stages of crop development are more accurately depicted from multitemporal TM data and, therefore, crop-type distinctions are possible. For this study area, SPECTRUM was unable to differentiate specific crop types because the single-date TM scene was basically a "snapshot" of the growing season. The only determination that was possible was one that distinguished between any type of agricultural land (pasture, crop, homesteads) and rock, water, rangeland, or urban lands. If multitemporal TM data had been provided, crop types could have been determined and more accurate land-use maps developed. Similarly, the single-date TM data limited the use of the maps for water-use estimations.

Table 2. Consumptive irrigation requirements (CIR) for selected crops grown in Gooding, Jerome, Lincoln, and Minidoka Counties, 1992 growing season

[Data are from AgriMet stations, maintained by Bureau of Reclamation, Boise, Idaho]

Crop	CIR (inches of water)	
	Rupert	Twin Falls
Alfalfa	40.9	40.7
Barley	25.1	25.1
Beans	19.6	19.2
Corn	26.7	26.9
Oats	25.1	25.1
Pasture	32.2	32.0
Potatoes	25.5	27.0
Sugar beets	30.9	32.0
Wheat	25.3	25.2

ESTIMATES OF IRRIGATION WATER USE

Consumptive use (CU), surface- and ground-water withdrawals (W), and conveyance losses (CL) for irrigated agricultural lands were estimated for water year 1992 in Gooding, Jerome, Lincoln, and Minidoka Counties. Consumptive-use estimates were based on acreages and crop consumptive irrigation requirement (CIR) values. The U.S. Department of Agriculture (USDA), Agricultural Statistics Service (ASS), provided specific crop acreages; pasture acres were derived from the National Resources Inventory (NRI) data base (U.S. Soil Conservation Service, 1994). Land-use acreages from SPECTRUM were not used because SPECTRUM was unable to differentiate specific crop types. The following sections describe the methods used to make estimates of irrigation water use.

Consumptive Use

Consumptive use is the amount of water (in inches) that a healthy, well-watered crop evapotranspires (ET) during the growing season. Summer months in the USNK are hot and dry, and during the 1992 growing season, very little precipitation was available for plant use. Therefore, CIR were assumed to equal the amount of water needed for crop ET. CIR values from the BOR Agricultural Meteorological (AgriMet) stations (McVay, 1992; Gardiner, 1994) were used with crop and pasture acreages to estimate total CU in acre-feet for each county.

AgriMet weather stations in and near the study area are located at Rupert and Twin Falls, Idaho (fig. 1). The stations are equipped with sensors that automatically monitor and relay information such as air temperature, wind speed, relative humidity, solar radiation, and precipitation. Data are transmitted digitally via a satellite relay to the BOR regional office in Boise, Idaho, and are used in the 1982 Wright-modified Penman equation to calculate CIR for different crops (Powers, 1992). CIR values from the Twin Falls station were used for Gooding and Jerome Counties; values from the Rupert station were used for Lincoln and Minidoka Counties (table 2).

The eight largest crops (pasture is not considered a crop) in the study area in 1992 were, in descending order: wheat, alfalfa, barley, sugar beets, potatoes, beans, corn, and oats (table 3). Three-fourths of the wheat in the study area was grown in Jerome and Minidoka Counties, and almost two-thirds of the alfalfa was grown in Gooding and Jerome Counties. Barley, sugar beets, and potatoes were large crops in Minidoka County. Almost half of Lincoln County crop acreages were planted with wheat and alfalfa.

Total consumptive use for the crops in 1992 was about 1.43 million acre-ft of water. In all counties except Minidoka, alfalfa, pasture, and wheat accounted for the three largest consumptive-use estimates. The three largest consumptive-use estimates in Minidoka County were for wheat, sugar beets, and barley (table 4).

Table 3. Selected irrigated crop acreages in Gooding, Jerome, Lincoln, and Minidoka Counties, 1992 growing season

[Crop acreages from the Idaho Agricultural Statistics Service, 1993; pastureland acreages are from the U.S. Soil Conservation Service, 1994]

County	Irrigated cropland and pastureland (acres)									
	Wheat	Alfalfa	Barley	Sugar beets	Potatoes	Beans	Corn	Oats	Pasture	Total
Gooding	15,000	35,000	4,500	4,300	12,000	6,100	11,200	3,300	19,700	107,800
Jerome	46,400	28,400	20,000	13,200	19,000	30,000	12,200	1,000	19,500	188,700
Lincoln	16,900	17,900	8,000	7,400	5,100	1,000	4,000	6,900	14,500	74,800
Minidoka	60,800	17,000	37,000	43,100	23,000	13,900	1,300	800	15,600	211,700
Total	139,100	98,300	69,500	68,000	59,100	51,000	28,700	12,000	69,300	583,000

Surface- and Ground-Water Withdrawals

Most irrigation water is withdrawn from the Snake River near Minidoka Dam and at Milner Dam (fig. 1). Surface-water diversions for irrigation usually begin in mid-March or early April and end in early to mid-October (Idaho Department of Water Resources, 1992, Appendix F). Streamflow records for the Snake River near Minidoka show an increase in flow in mid-March when irrigation withdrawals for Minidoka County begin; concurrently, streamflow at Milner Dam decreases substantially when diversions to the north and south reduce the flow to nearly zero (fig. 11). Streamflow at King Hill shows the effects of recharge from springs along the north canyon wall, between Milner Dam and King Hill, irrigation-return flows from north- and south-side irrigated lands, and flow from the Malad River.

The 1992 water year (October 1, 1991, to September 30, 1992) was one of the lowest on record in terms of streamflow. Below-normal precipitation the previous 4 years resulted in depleted water reserves in the reservoir system and diminished flows in the Snake, Big Wood, and Little Wood Rivers. Diversions for irrigation were below normal, and some irrigation needs were not met. Surface-water diversions northward from the Snake River were measured and reported by the Idaho Department of Water Resources (1992) and totaled 1.7 million acre-ft (table 5), whereas in previous years, diversions were closer to 2.0 million acre-ft. Part of the diversions southward from the Snake River are reported with the Minidoka Irrigation District diversion; only quantities of water diverted to the north, however, are included in table 5. Surface-water diversions from the Big Wood and Little Wood Rivers, which supply water to northern parts of Gooding and Lincoln Counties, were measured in 1992 at 340,000 acre-ft (R. Lutz, Idaho Department of Water Resources, written commun., 1996). Therefore, total surface-water diversions in the study area were about 2.08 million acre-ft during the 1992 water year.

Measured surface-water diversions are most desirable for determining the surface-water irrigation water use. Estimated surface-water withdrawals from this report were compared to the aforementioned measured withdrawals to determine the accuracy of estimation methods. However, there were no available ground-water measurements with which to compare estimated ground-water withdrawals. Withdrawals for ground- and surface-water irrigation in the study area were estimated using the following equation:

Table 4. Estimated consumptive use in Gooding, Jerome, Lincoln, and Minidoka Counties, 1992 growing season

County	Consumptive use (acre-feet)									
	Wheat	Alfalfa	Barley	Sugar beets	Potatoes	Beans	Corn	Oats	Pasture	Total
Gooding	31,500	118,700	9,400	11,500	27,000	9,800	25,100	6,900	52,500	292,400
Jerome	97,400	96,300	41,800	35,200	42,800	48,000	27,300	2,100	52,000	442,900
Lincoln	35,600	61,000	16,700	19,100	10,800	1,600	8,900	14,400	38,900	207,000
Minidoka	127,900	57,900	77,400	111,200	48,900	22,700	2,900	1,700	41,900	492,500
Total	292,400	333,900	145,300	177,000	129,500	82,100	64,200	25,100	185,300	1,434,800

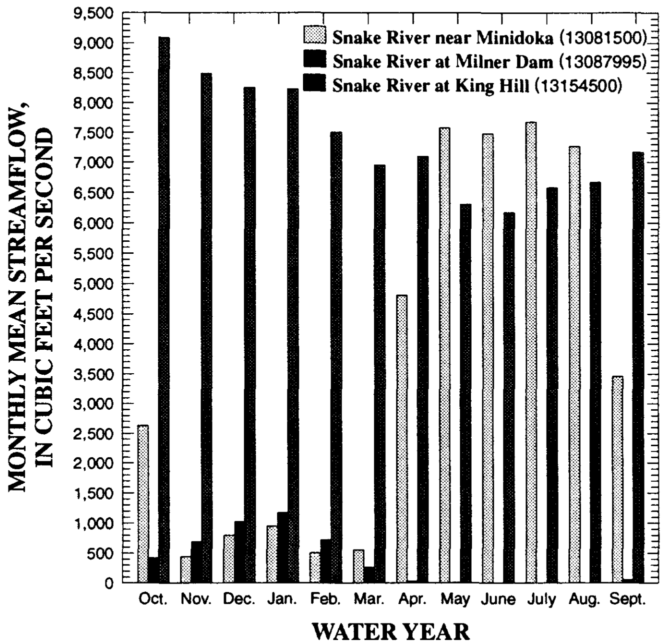

Figure 11. Streamflow at selected gaging stations, 1992 water year. (Location of gaging stations shown in figure 1)

$$W = [(CIR \times A / 12) \times S] / L, \qquad (1)$$

where

W = total irrigation water withdrawal for a county, in acre-feet;

CIR = consumptive irrigation requirement for a particular crop, in inches;

A = acres of a particular crop in a county;

S = ground- or surface-water-irrigated lands, as a percentage of total irrigated acres in a county; and

L = irrigation-system efficiency for ground- or surface-water-irrigated lands, based on the type of irrigation systems in a county, expressed as a decimal percentage.

CU = $CIR \times A / 12$, in acre-feet, and

CL = $W - CU$.

Withdrawals were estimated separately for surface- and ground-water-irrigated agricultural land because irrigation-system efficiencies differ for each. Percentages of surface- and ground-water-irrigated agricultural land (table 6) were derived from the National Resources Inventory data base (U.S. Soil Conservation Service, 1994) collected at statistically sampled locations in 1992. An example of the equation to estimate irrigation water use for Gooding County is given in Appendix B.

Total estimated surface- and ground-water-irrigation withdrawals in 1992, using equation 1, were about 2.9 million acre-ft (table 7). Surface-water withdrawals were estimated to be about 2.12 million acre-ft, mostly diverted from the Snake River; ground-water withdrawals were estimated to be nearly 776,000 acre-ft, mostly pumped in Minidoka County. Estimated surface-water withdrawals exceeded measured withdrawals by about 40,000 acre-ft.

Table 5. Surface-water diversions northward from the Snake River as measured in the 1992 water year

[Idaho Department of Water Resources, 1992, p. 50]

Canal	Diversions (acre-feet)
Minidoka Irrigation District	332,700
A & B Irrigation District	62,200
Reservoir District #2	377,900
North Side Canal Co.	971,200
Total	1,744,000

Conveyance Losses

The efficiency of an irrigation system reflects its ability to effectively transport water from the point of diversion to the place of use. Conveyance losses include leakage through the bottoms and sides of canals, irriga-

Table 6. Sources of irrigation water estimated as a percentage of total irrigated agricultural land in Gooding, Jerome, Lincoln, and Minidoka Counties, 1992

[National Resources Inventory, U.S. Soil Conservation Service, 1994]

County	Source of irrigation water (percent)	
	Surface water	Ground water
Gooding	70	30
Jerome	75	25
Lincoln	62	38
Minidoka	46	54

Table 7. Estimated irrigation water withdrawals in Gooding, Jerome, Lincoln, and Minidoka Counties, 1992 water year

[Values rounded to the nearest tenth]

County	Irrigation withdrawals (acre-feet)		
	Surface water	Ground water	Total
Gooding	487,320	125,310	612,630
Jerome	790,900	158,180	949,080
Lincoln	305,570	112,370	417,940
Minidoka	539,400	379,930	919,330
Total	2,123,190	775,790	2,898,980

tion-return flows, water use by phreatophytes along canal banks, and deep percolation; specific values for the different types of conveyance losses were not estimated in this study. Most irrigation water was diverted from surface-water sources, conveyed in canals, and distributed by sprinkler systems. Irrigation water from ground-water sources was usually transported through closed pipes and sprinkled directly on crops. Irrigation systems that use surface water were estimated to have an irrigation-system efficiency of 42 percent (Brockway and Claiborn, 1975, p. 32). Irrigation systems that use ground water were estimated to have an irrigation-system efficiency of 70 percent (Frenzel, 1985, p. 224).

Irrigation systems have become more efficient since these studies were published; therefore, efficiency values used to estimate irrigation water use in this report may be smaller than actual efficiency values.

Conveyance losses (equation 1) were estimated to be 1.46 million acre-ft, or just over one-half of the total estimated withdrawals in the study area. Surface-water-irrigated land in Minidoka County is localized in the southern part of the county, and water diverted from the Snake River at Minidoka Dam travels through a relatively compact network of canals. Ground-water-irrigated land in Minidoka County is north of the surface-water-irrigated land, and conveyance losses are minimal (Brockway and Claiborn, 1975; Allen and Brockway, 1979; Jeff Bohr, A & B Irrigation District, written commun., 1992). In contrast, irrigated lands in Jerome County are more dispersed, and water travels greater distances between points of diversion and irrigated fields. Surface water diverted at Milner Dam can travel as far as 50 mi in the mostly unlined North Side Main Canal, allowing for conveyance losses along the way. Much of the irrigated land in Gooding County receives Snake River water from the Milner-Gooding Canal, which stretches more than 100 mi from Milner Dam across the open expanses of rangeland and basalt flows of the Snake River Plain.

SUMMARY

Land- and water-use information was used to estimate irrigation withdrawals in the upper Snake River Basin NAWQA study unit. As part of the NAWQA Program, new land-use data were obtained using Thematic Mapper satellite imagery and the SPECTRUM computer program. Four intensively irrigated counties (Gooding, Jerome, Lincoln, and Minidoka in south-central Idaho) that coincide with other NAWQA surface- and ground-water and biological study areas were mapped. Rangeland, agricultural land, and other land uses were mapped and compared with land-use data from other sources using GIS techniques. During the summer of 1996, the land-use data were verified in the field for 108 randomly selected sections of 640 acres each in the four-county area. Results of land-use mapping and field verification were favorable in comparison with land-use data from other sources but proved to be less than adequate for water-use estimations because of SPECTRUM's inability to identify specific crop types. Other data eventually were used to estimate irrigation water use for the largest crops and pasturelands in the four counties.

Water-use estimates for consumptive uses, irrigation withdrawals, and conveyance losses were derived from acreages, crop irrigation requirements, and irrigation-system efficiencies. During the 1992 water year, an estimated 2.9 million acre-ft of water was needed to meet consumptive use and conveyance losses. However, the 1992 water year was the peak of a drought that left some farmers with a less-than-adequate water supply. Estimated surface-water withdrawals for irrigation (2.12 million acre-ft) exceeded measured withdrawals (2.08 million acre-ft). Surface-water withdrawals in previous normal water years ranged from 1.7 to 2.0 million acre-ft. Of the estimated 2.9 million acre-ft withdrawn for irrigation (surface and ground water), nearly one-half was lost in conveyance (mostly canal leakage and irrigation-return flow), and the remainder was consumptively used by crops during the growing season.

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APPENDICES

Appendix A—Land use in field-verified sections, Gooding, Jerome, Lincoln, and Minidoka Counties

[No., number; site numbers are a sequence of township, range, and section numbers with leading letters that denote the first letter of each county (G051208 is Gooding County, township 5 south, range 12 east, section 8). Map names divided by a "/" mean that the section was located on both maps. SE, southeast; SW, southwest; NW, northwest; NE, northeast. R, rangeland; Rf, rangeland fenced; Ru, rangeland unfenced; Pi, Pasture, irrigated; Pn, Pasture, nonirrigated; A, agricultural lands (farmyards, barns, etc.); Ai, agricultural lands, irrigated cropland; Ad, agricultural lands, nonirrigated (dryland); Af, agricultural lands, fallow cropland; U, urban or built up; Ow, open water (ponds, canals, streams); B, barren land (less than 50 percent vegetated); F, forest or woodlands (greater than 50 percent tree closure); Ca, confined animals, stockyards, corrals; Ot, other land use]

Site No. (fig. 7)	Orthophoto map name	Land-use categories (see fig. 8), in percentage of section														
		R	Rf	Ru	Pi	Pn	A	Ai	Ad	Af	U	Ow	B	F	Ca	Ot
							Gooding County									
G051208	Hog Creek	0	70	0	0	10	2	18	0	0	0	0	0	0	0	0
G051330	Bliss	6	0	0	12	0	7	73	0	0	0	0	0	0	2	0
G051410	McKinney Butte	0	40	0	10	0	2	48	0	0	0	0	0	0	0	0
G051425	Gooding	14	0	0	9	0	0	73	0	0	0	0	0	0	4	0
G051517	Gooding	0	0	0	9	0	0	90	0	0	0	0	0	0	1	0
G051606	Thorn Creek SE	0	9	0	69	0	5	17	0	0	0	0	0	0	0	0
G061312	Gooding Butte	0	23	0	5	20	2	50	0	0	0	0	0	0	0	0
G061335	Hagerman	70	0	0	0	27	0	3	0	0	0	0	0	0	0	0
G061404	Gooding Butte	45	0	0	0	13	0	40	0	0	2	0	0	0	0	0
G061424	Gooding	0	34	0	13	0	0	53	0	0	0	0	0	0	0	0
G061429	Tuttle	50	0	0	0	0	0	47	0	0	0	3	0	0	0	0
G061503	Gooding	0	0	0	10	0	0	90	0	0	0	0	0	0	0	0
G061504	Gooding	0	0	0	24	0	0	75	0	0	0	0	0	0	1	0
G061531	Wendell	10	0	0	4	0	0	86	0	0	0	0	0	0	0	0
G071326	Hagerman	0	55	0	21	0	0	21	0	0	0	2	0	0	0	1
G071415	Tuttle	0	69	0	0	0	0	31	0	0	0	0	0	0	0	0
G071525	Wendell	0	0	0	95	0	0	0	0	5	0	0	0	0	0	0
G071530	Wendell	0	0	0	10	0	0	80	0	0	10	0	0	0	0	0
G081402	Tuttle	10	0	0	10	0	0	80	0	0	0	0	0	0	0	0
G081423	Thousand Springs	0	0	0	40	0	5	55	0	0	0	0	0	0	0	0
G081424	Thousand Springs	0	0	0	2	0	1	93	0	0	0	0	3	0	1	0
G081510	Niagara Springs	0	0	0	2	0	0	83	0	0	0	0	0	0	15	0
G081535	Niagara Springs	0	0	0	1	0	1	93	0	0	0	0	0	0	5	0
G081607	Niagara Springs	0	0	0	16	0	0	59	0	0	10	0	0	0	15	0
							Jerome County									
J071621	Gooding SE	12	0	0	0	0	0	87	0	0	1	0	0	0	0	0
J071633	Gooding SE	10	0	0	0	28	4	58	0	0	0	0	0	0	0	0
J071719	Gooding SE	0	0	0	0	2	3	95	0	0	0	0	0	0	0	0
J071731	Gooding SE	1	0	0	20	0	3	75	0	0	0	1	0	0	0	0
J071818	Shoshone SW	0	30	0	0	0	1	68	0	0	0	0	0	1	0	0
J081609	Jerome/Gooding SE	0	11	0	0	40	5	44	0	0	0	0	0	0	0	0
J081621	Jerome	0	0	0	23	0	0	61	0	9	0	0	0	0	7	0
J081633	Jerome	0	0	0	27	0	5	37	0	0	0	0	0	0	31	0
J081702	Shoshone SW	2	0	0	0	0	2	96	0	0	0	0	0	0	0	0
J081709	Shoshone SW	0	0	0	2	0	1	95	0	0	0	0	0	0	2	0
J081714	Falls City	30	0	0	0	0	1	52	0	0	8	0	0	0	0	9
J081728	Falls City	0	0	0	3	0	6	91	0	0	0	0	0	0	0	0
J081830	Falls City	0	24	0	2	0	3	71	0	0	0	0	0	0	0	0
J082030	Hunt	50	0	0	0	0	0	33	0	10	0	7	0	0	0	0
J082123	Burley NW	60	0	0	0	0	0	40	0	0	0	0	0	0	0	0

Appendix A—Land use in field-verified sections, Gooding, Jerome, Lincoln, and Minidoka Counties—Continued

Site No. (fig. 7)	Orthophoto map name	Land-use categories (see fig. 8), in percentage of section														
		R	Rf	Ru	Pi	Pn	A	Ai	Ad	Af	U	Ow	B	F	Ca	Ot
							Jerome County—Continued									
J091609	Jerome	0	0	0	12	0	5	75	0	0	0	0	0	0	8	0
J091707	Jerome	0	0	0	11	0	2	72	0	0	10	0	0	0	5	0
J091719	Jerome	18	0	0	0	0	0	0	0	0	45	0	12	0	0	25
J091806	Falls City	0	0	0	0	0	3	97	0	0	0	0	0	0	0	0
J091906	Twin Falls NE	33	0	0	67	0	0	0	0	0	0	0	0	0	0	0
J091929	Kimberly	10	0	0	0	0	0	85	0	0	0	0	0	0	5	0
J092016	Eden NE	5	0	0	0	0	0	95	0	0	0	0	0	0	0	0
J092123	Burley NW/ Burley SW	28	0	0	0	0	0	72	0	0	0	0	0	0	0	0
J092131	Milner	32	0	0	4	0	0	61	0	0	0	0	0	0	3	0
J101901	Eden	0	0	0	4	0	0	96	0	0	0	0	0	0	0	0
J101905	Kimberly	0	0	0	2	0	0	97	0	1	0	0	0	0	0	0
J101915	Eden	9	0	0	91	0	0	0	0	0	0	0	0	0	0	0
J102004	Milner	0	0	0	2	0	0	97	0	0	0	1	0	0	0	0
J102016	Milner	0	0	0	0	0	0	100	0	0	0	0	0	0	0	0
J102027	Milner	0	0	0	1	0	0	99	0	0	0	0	0	0	0	0
J102109	Burley SW	0	0	0	2	0	2	96	0	0	0	0	0	0	0	0
							Lincoln County									
L031923	Tapper Lake	0	7	0	31	0	2	51	0	9	0	0	0	0	0	0
L041734	Mammoth Cave	0	83	0	0	0	1	16	0	0	0	0	0	0	0	0
L041920	Richfield	0	30	0	0	0	5	55	10	0	0	0	0	0	0	0
L041932	Richfield	0	13	0	0	14	0	50	20	0	3	0	0	0	0	0
L041934	Richfield	0	55	0	25	0	5	15	0	0	0	0	0	0	0	0
L042008	Pagari	0	100	0	0	0	0	0	0	0	0	0	0	0	0	0
L051712	Mammoth Cave	0	3	0	59	0	3	35	0	0	0	0	0	0	0	0
L051832	Dietrich	60	0	0	5	0	0	35	0	0	0	0	0	0	0	0
L061636	Shoshone SW	90	0	0	0	0	0	5	0	5	0	0	0	0	0	0
L061920	Dietrich Butte	0	2	0	0	0	1	97	0	0	0	0	0	0	0	0
L061932	Star Lake	25	0	0	0	0	0	75	0	0	0	0	0	0	0	0
L062227	Kimama/Shale Butte	50	0	0	0	0	0	50	0	0	0	0	0	0	0	0
L071812	Shoshone SE	50	25	0	0	0	0	25	0	0	0	0	0	0	0	0
L072108	Owinza Butte	0	6	10	0	0	0	15	0	69	0	0	0	0	0	0
L072317	Kimama	0	0	50	0	0	0	50	0	0	0	0	0	0	0	0
L072329	Kimama	0	7	23	0	0	2	68	0	0	0	0	0	0	0	0
							Minidoka County									
M072302	Norland	0	0	0	50	0	0	50	0	0	0	0	0	0	0	0
M072314	Norland	0	0	0	0	15	1	69	0	0	0	0	0	0	15	0
M072402	Max	0	0	30	0	0	0	51	0	19	0	0	0	0	0	0
M072416	Norland	0	0	0	0	0	1	99	0	0	0	0	0	0	0	0
M072425	Max	0	0	0	0	0	0	100	0	0	0	0	0	0	0	0
M072429	Norland	0	0	0	0	1	1	98	0	0	0	0	0	0	0	0
M072515	Max	0	0	11	0	0	0	89	0	0	0	0	0	0	0	0
M072524	Minidoka	0	0	89	0	0	0	11	0	0	0	0	0	0	0	0
M082212	Burley NE	0	0	0	2	0	0	98	0	0	0	0	0	0	0	0
M082219	Burley NW	57	0	0	0	0	0	43	0	0	0	0	0	0	0	0

Appendix A—Land use in field-verified sections, Gooding, Jerome, Lincoln, and Minidoka Counties—Continued

Site No. (fig. 7)	Orthophoto map name	Land-use categories (see fig. 8), in percentage of section														
		R	Rf	Ru	Pi	Pn	A	Ai	Ad	Af	U	Ow	B	F	Ca	Ot
							Minidoka County—Continued									
M082225	Burley NE	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0
M082232	Burley NW	0	0	0	0	0	0	100	0	0	0	0	0	0	0	0
M082303	Kimama/Norland	0	0	1	0	0	0	95	0	0	0	1	0	0	3	0
M082323	Rupert NW	0	0	1	0	0	1	93	0	5	0	0	0	0	0	0
M082415	Rupert NW	0	0	0	0	0	1	97	0	0	0	0	0	0	2	0
M082418	Rupert NW	0	0	0	0	1	1	98	0	0	0	0	0	0	0	0
M082432	Rupert NW	0	0	29	2	7	2	60	0	0	0	0	0	0	0	0
M082434	Rupert NW	14	47	0	12	0	0	0	0	0	0	26	0	0	1	0
M082504	Max	0	0	0	0	0	1	99	0	0	0	0	0	0	0	0
M082518	Acequia	0	0	0	0	1	1	98	0	0	0	0	0	0	0	0
M082522	Acequia	0	0	0	1	0	5	91	1	1	0	0	0	0	1	0
M092201	Burley NE	9	0	0	90	0	1	0	0	0	0	0	0	0	0	0
M092210	Burley NE/ Burley NW	0	0	0	99	0	1	0	0	0	0	0	0	0	0	0
M092228	Burley SW	0	0	0	12	0	0	79	0	0	5	2	0	0	2	0
M092310	Burley NE/ Rupert NW	0	43	0	1	0	0	52	0	0	0	2	0	0	0	2
M092317	Burley NE	0	0	0	4	0	0	94	0	0	0	1	0	0	1	0
M092328	Burley	0	0	0	22	0	0	41	0	0	33	1	0	0	3	0
M092334	Burley/Rupert	0	0	0	6	0	0	87	0	0	7	0	0	0	0	0
M092414	Acequia	0	0	0	0	0	2	94	0	3	1	0	0	0	0	0
M092419	Rupert NW	0	0	0	0	0	4	92	0	0	4	0	0	0	0	0
M092435	Rupert SE	0	0	0	8	0	0	76	0	0	0	15	0	0	1	0
M092505	Acequia	0	20	50	6	5	1	12	0	2	0	0	0	0	1	0
M102204	Burley SW	7	0	0	0	0	0	88	0	0	5	0	0	0	0	0
M102215	Burley	20	0	0	5	0	0	75	0	0	0	0	0	0	0	0
M102304	Burley	0	0	0	5	0	4	82	0	0	0	0	0	0	9	0
M102314	Rupert	0	0	0	30	0	0	70	0	0	0	0	0	0	0	0
M102407	Rupert	0	0	0	35	0	0	62	0	0	2	0	0	0	1	0

Appendix B—Estimated irrigation water use for Gooding County using equation 1

Equation 1: $W = [(CIR \times A / 12) \times S] / L$ where $(CIR \times A) / 12 = CU$

CONSUMPTIVE USE (CU) FOR:

Wheat	(25.2 inches x 15,000 acres) / 12 =	31,500 acre-feet
Alfalfa	(40.7 inches x 35,000 acres) / 12 =	118,708 acre-feet
Pasture	(32.0 inches x 19,700 acres) / 12 =	52,533 acre-feet
Barley	(25.1 inches x 4,500 acres) / 12 =	9,413 acre-feet
Sugar beets	(32.0 inches x 4,300 acres) / 12 =	11,467 acre-feet
Potatoes	(27.0 inches x 12,000 acres) / 12 =	27,000 acre-feet
Beans	(19.2 inches x 6,100 acres) / 12 =	9,760 acre-feet
Corn	(26.9 inches x 11,200 acres) / 12 =	25,107 acre-feet
Oats	(25.1 inches x 3,300 acres) / 12 =	6,902 acre-feet
	Total consumptive use	292,390 acre-feet

SURFACE-WATER AND GROUND-WATER WITHDRAWALS (W): $W = (CU \times S) / L$

Surface-water-irrigated lands = 70 percent
Irrigation efficiency for surface-water withdrawals = 42 percent

292,390 acre-feet x 0.70 / 0.42 = 487,317 acre-feet

Ground-water-irrigated lands = 30 percent
Irrigation efficiency for ground-water withdrawals = 70 percent

292,390 acre-feet x 0.30 / 0.70 = 125,310 acre-feet

TOTAL WITHDRAWALS = Surface water + Ground water

487,317 + 125,310 = 612,627 acre-feet

CONVEYANCE LOSSES (CL): $CL = W - CU$

612,627 - 292,390 = 320,237 acre-feet

GLOSSARY

As used by U.S. Soil Conservation Service (1967) and Solley and others (1993).

acre-foot (acre-ft)—the volume of water required to cover 1 acre of land (43,560 square feet) to a depth of 1 foot.

consumptive irrigation requirement—the amount of water that is evaporated, transpired, or incorporated into crop material, usually measured in inches. Also referred to as consumptive use or crop consumptive use.

conveyance loss—water that is lost in transit from a pipe, canal, conduit, or ditch by leakage or evaporation. Generally, the water is not available for further use; however, leakage from an irrigation ditch, for example, may percolate to a ground-water source and be available for further use.

evaporation—process by which water is changed from the liquid into the vapor state. *See also* evapotranspiration and transpiration.

evapotranspiration—a collective term that includes water discharged to the atmosphere as a result of evaporation from the soil and surface-water bodies and as a result of plant transpiration. *See also* evaporation and transpiration.

ground water—generally all subsurface water as distinct from surface water; specifically, that part of the subsurface water in the saturated zone (a zone in which all voids are filled with water) where the water is under pressure greater than atmospheric.

irrigation district—in the United States, a cooperative, self-governing public corporation set up as a subdivision of the State government, with definite geographic boundaries, organized and having taxing power to obtain and distribute water for irrigation of lands within the district; created under the authority of a State legislature with the consent of a designated fraction of the landowners or citizens.

irrigation efficiency—the percentage of applied irrigation water that is available in the soil and may be consumptively used by the crop.

irrigation-return flow—part of irrigation water that is not consumed by evapotranspiration and that migrates to an aquifer or surface-water body. *See also* return flow.

irrigation water requirement—the depth of irrigation water needed for consumptive irrigation requirements, exclusive of precipitation, soil moisture, and available ground water, divided by irrigation efficiency.

irrigation water use—artificial application of water on lands to assist in the growing of crops and pastures.

land use—describes both the vegetation or other kind of material that covers the land surface, and any human activity on the land.

return flow—the water that reaches a ground- or surface-water source after release from the point of use and thus becomes available for further use.

surface water—an open body of water, such as a stream or a lake.

transpiration—the process by which water is absorbed by plants, usually through the roots, and evaporated into the atmosphere from the plant surface. *See also* evaporation and evapotranspiration.

water use—(1) in a restrictive sense, the term refers to water that is actually used for a specific purpose, such as for domestic use, irrigation, or industrial processing. (2) More broadly, water use pertains to human interaction with and influence on the hydrologic cycle, and includes elements such as water withdrawal, delivery, consumptive use, wastewater release, reclaimed wastewater, return flow, and instream use.

water year—a 12-month period beginning October 1 and ending September 30. The water year is designated by the calendar year in which it ends. For example, the period from October 1, 1991, through September 30, 1992, is called the 1992 water year.

withdrawal—water removed from the ground or diverted from a surface-water source for use.

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