STATISTICAL COMMISSION and ECONOMIC COMMISSION FOR EUROPE

COMMISSION OF THE EUROPEAN COMMUNITIES

CONFERENCE OF EUROPEAN STATISTICIANS

EUROSTAT

Joint ECE/Eurostat Work Session on Methodological Issues of Environment Statistics
(Jerusalem, Israel, 11-14 October 1999)

Working paper No.4

THE 1998 FARM AND RANCH IRRIGATION SURVEY (FRIS), A MEASUREMENT OF U.S. AGRICULTURE WATER USE AND MANAGEMENT

Paper submitted by the U.S. National Agricultural Service1

Abstract

This report presents the survey design and methodology for the 1998 Farm and Ranch Irrigation Survey (FRIS) conducted in the United States by the U.S. Department of Agriculture, National Agricultural Statistics Service (NASS) during the spring of 1999. This was a special follow-on sample survey to the 1997 Census of Agriculture which collected basic irrigation data from farm and ranch operators. The FRIS will provide detailed information on irrigation in all 50 States of the United States including acres irrigated by land use, acres and yield of irrigated and non-irrigated crops, quantity of water applied and method of application to selected crops, acres irrigated and quantity of water used by source, acres irrigated by type of water distribution systems, the number of irrigation wells and pumps, and other related information on expenditures and energy sources used in water management practices. This is the fifth FRIS with 1994 and earlier surveys conducted by the U.S. Department of Commerce. The sample size in the 1994 FRIS covered 48 States but permitted publishing of only the 27 leading irrigation States. Presentation of 1998 FRIS data is not possible in this paper as official results will be published in November 1999. Selected findings from the 1997 Census of Agriculture and 1994 FRIS are presented.

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I. INTRODUCTION

1. Water is the most common substance on earth. It covers over 70 percent of the earth's surface and without it there is no life. All living things consist mostly of water. As examples, the human being is about 65 percent water and the potato about 80 percent water. Water, through history, has been people's slave as well as their master. Great civilizations have risen when water sources were abundant and have fallen when these sources failed. As the world population increases, the demand for fresh water and the competition for limited water supplies increases.

2. There are about 326 million cubic miles of water on earth, but only about 3 percent is fresh water and nearly three-fourths of it is frozen in glaciers and icecaps in Antarctica and Greenland [1]. This leaves less than 1 percent as surface and underground fresh water.

3. Although the world as a whole has adequate fresh water, some regions have a water shortage. These dry areas account for about half of the earth's land which includes most of Asia, central Australia, most of northern Africa, and the Middle East. The United States is fortunate, however, to be a part of the world which generally receives adequate rain. Water problems in the United States are sometimes self-inflicted because of careless and wasteful practices or a local/regional distribution problem. The severe drought in the 1930's in the Southwest was an exception.

4. The United States has plenty of water, in contrast to the conference host country Israel. The United States averages about 30 inches (76 centimeters) of rain annually. This total is large, but it is unevenly distributed. Most States east of the Mississippi get 30 to 50 inches (76 to 130 centimeters) of precipitation a year. But large regions in the western States get less than 10 inches (25 centimeters). In Israel, rainfall ranges from an average of 1 inch (25 millimeters) in the driest areas to over 42 inches (105 centimeters) in the wettest area of the hilly parts of Upper Galilee. In both countries, the annual renewable water being unevenly distributed is a problem which requires significant dollars to re-allocate and manage. Data sources, such as the Census of Agriculture and the Farm and Ranch Irrigation Survey (FRIS), provide crucial water statistics to facilitate this decision-making and policy determination.

5. The paper presents initially the history and an overview of the FRIS. A discussion follows of the survey purpose, its uses and users, and its importance for water policy and water management considerations. Alternative water data sources are identified. The FRIS survey design and survey methodology are then presented. Finally, selected irrigation data from the 1994 FRIS and 1997 Census of Agriculture are illustrated. FRIS irrigation data to be published by the U.S. Department of Agriculture (USDA), National Agricultural Statistics Service (NASS) for the first time will be highlighted. The 1998 FRIS data will be officially released by NASS in November 1999.

II. SURVEY HISTORY AND OVERVIEW

6. The agriculture census initially collected limited data about on-farm irrigation in 1890. In 1900, the United States Congress authorized a census of farms using irrigation. The Department of Commerce, Bureau of the Census,

conducted censuses of irrigation (and later drainage) as part of the decennial censuses through 1950, and a survey of on-farm irrigation in selected States was added to the 1954 and 1959 agriculture censuses [2]. The FRIS on-farm irrigation surveys [3], which use a sample of respondents reporting water usage from the agriculture census, have been completed following the 1978, 1982, 1987, 1992, and the 1997 Censuses of Agriculture. Similar survey design and methodology and data collection and processing have existed generally for each FRIS. Questionnaire content has been updated to capture new technologies and management practices.

7. Beginning in 1997, the United States Congress transferred the authority for conducting the agriculture census to the United States Department of Agriculture, National Agricultural Statistics Service (NASS). This historic event consolidated all U.S. agricultural statistics survey activity into one statistical organization. NASS published the 1997 Census of Agriculture, Volume 1 for all States and the United States in February 1999 [4], approximately one year from the initial mailing date to respondents and 10 months earlier than past censuses of agriculture.

8. The authority for the Secretary of Agriculture to collect the 1997 Census of Agriculture and other special follow-on studies including the FRIS is granted by Congress in U.S. Code, Title 7. It also ensures the confidentiality of these data. Reported data can only be used to prepare statistical summaries that will not reveal individual information. The legal mandate, in the Census of Agriculture Act of 1997, Public Law 105-113, requires a census of agriculture in 1997 and every fifth year following 1997. Previous agriculture censuses were conducted by the Department of Commerce under the provisions of Title 13, Section 182 of the United States Code.

9. The FRIS is an integral part of the 1997 Census of Agriculture. This survey was conducted to supplement the basic irrigation data collected by law from all farm and ranch operators in the general agriculture census. The survey specifically targeted operations meeting the farm definition that irrigate crops and provided information relating to on-farm irrigation practices. A farm, since 1974, is defined as any place from which $1,000 or more of agricultural products were produced and sold, or normally would have been sold, during the census year. For the past two decades, FRIS has been the only source of detailed, nationally consistent data on water uses and water management practices in American agriculture. FRIS provides comprehensive data for analysis of irrigation, production, and operator information.

III. FRIS DATA USES AND PROGRAM IMPORTANCE/RELEVANCE

10. A primary purpose of FRIS is to provide detailed data relating to on-farm irrigation activities for use in preparing a wide variety of water-related programs, economic models, legislative initiatives, market analyses, and feasibility studies. The farm and ranch irrigation surveys are the only data that are complete, consistent, and accurate enough to be used for bench marking on-farm irrigation measures over time.

11. The Nation recognizes that high quality data on agricultural water use to help public and private sector officials understand and manage this important national resource. Water policy must address the issues of adequacy of surface

water supplies, competition for available water supplies, overuse of ground water, and water quality. This is particularly critical with agriculture irrigation the largest single user of available U.S. water supplies, accounting for more than two-thirds of all ground water withdrawals and more than 80 percent of all consumptive uses [5].

12. FRIS data are used by numerous government agencies, research organizations, irrigation industries, and farm operators/managers. There is also extensive use of the irrigation data by the international community. Several examples of the relevance of the data for research and policy are presented below.

13. The USDA, Economic Research Service, relies on FRIS data for water use and pricing and water management practices. Their analysis and economic models provide essential data to evaluate the impact of alternative farm policies on the irrigated sector. The selection of research papers that follow illustrates the diversity of analytical uses of the FRIS data. Based on FRIS data, an economic analysis of water policy alternatives in the Pacific Northwest showed less water could be used with minimal impact on agricultural economic returns [6]. Applying a model of the multi-output firm, econometric results were reported for irrigated production in four multi-State regions of the West using cross-sectional micro data from FRIS [7]. A stochastic production frontier model of irrigation used FRIS data to analyze sources of economic inefficiency in irrigation practices [8]. Finally, FRIS data were used in an irrigation technology study, referred to as chemigation, to improve timing and flexibility of chemical applications [9].

14. The USDA, Natural Resource Conservation Service (NRCS), uses the general agriculture census and FRIS data to appraise the status and condition of water and to appraise water-use trends on non-federal lands. The NRCS uses these data to plan and evaluate a national water-conservation plan.

15. The United States Geological Survey (USGS) uses these data for preparing national water inventory summaries provided to the Environmental Protection Agency (EPA), the Army Corps of Engineers, and other agencies developing water related programs. The water inventory data are important to address water quality issues that are linked to the EPA’s 1995 Water Quality Inventory which judged agriculture as a leading source of impairment to healthy year around use of the Nation’s rivers, lakes, estuaries, and wetlands [10].

16. Other major links to water use are EPA’s regulatory enforcement of the 1972 Clean Water Act. Animal waste discharges from large confined livestock operations are regulated under this law. In 1990, USDA established the Water Quality Program with a commitment to protect the Nation’s waters from contamination by agricultural chemicals and waste products. Another major program was implemented in 1996 by USDA, called the Environmental Quality Incentives Program (EQIP). The objective of EQIP was to encourage farmers and ranchers to adopt practices that reduce environmental and resource problems. Participation in these and other government cost-sharing programs for irrigation and drainage improvements are reported by the 1998 FRIS.

17. The United States Department of Interior, Bureau of Reclamation, uses FRIS data to conduct feasibility studies of irrigation projects.The United States Congress and State legislative bodies use the data to formulate policy and assess natural resource legislation.

18. State water resource agencies use these data to develop programs and prepare descriptive information. Planning agencies use information regarding water supplies and water use by State and water resource area to evaluate ground water withdrawals, especially the depletion of ground water reserves in major irrigation areas.

19. Private businesses and irrigation system manufacturers use FRIS data to monitor trends in irrigation equipment use, irrigation trends, and other production-related activities.

20. Land Grant Universities and other research organizations use these data to study irrigation technology development and adoption in agricultural production.

21. Farmers and ranchers use the FRIS data to determine the economic feasibility of investing in irrigation systems and changing water management practices. Economic data on input costs and expected output returns are possible using key survey data reported, such as irrigation equipment capital investment requirements, maintenance costs, land improvement costs, and average yields of irrigated and non-irrigated crops.

22. Alternative data sources exist for water statistics but there is no replacement for the FRIS. A limited number of States, in cooperation with NASS, prepare irrigated and non-irrigated cropping practice estimates for selected crops. About 40 percent of the State offices published State or county level irrigated cropland data in 1997. These data are not available at the national level and are not in the detail provided by the FRIS.

23. Annual irrigation data are published in The Irrigation Journal by Gold Trade Publications, Inc. from Cathedral City, California. However, irrigated acres and irrigation system estimates are not statistically reliable and are often significantly different from census data. These data are comprised of opinions and educated estimates from State water agencies and cooperative extension agents.

24. The USGS conducts annual surveys as mandated by the U.S. Congress to collect and publish water use data. Data compare usage across sectors of the U.S. economy based on a hydrologic definition. Published data are by watershed and major drainage areas.

IV. FRIS SURVEY DESIGN

25. The Farm and Ranch Irrigation Survey supplemented the basic irrigation data collected from farms and ranches in the 1997 Census of Agriculture. The agriculture census limited its questions to acres irrigated by crop and land use and irrigated cropland production. The FRIS was conducted in the year following the general agriculture census with a reference year of 1998. This same data collection pattern, with the survey reference period one year after the census, was followed for the 1978, 1982, and 1987 FRIS. The 1994 FRIS conducted by the Department of Commerce occurred two years following the agriculture census because budget restrictions required a general “stretching out” of the census operation to save cost.

26. The five year rotation for FRIS as a special follow-on survey to the agriculture census was reviewed in 1983 by the Executive Branch, Office of Management and Budget (OMB). Their evaluation determined a less frequent rotation would hinder Federal agencies' ability to monitor current farm programs and environmental regulations affecting the agriculture sector of the U.S. economy.

27. A major change in the 1998 FRIS was the expansion of the survey universe to include all 50 States. The FRIS survey design and questionnaire content were similar to earlier irrigation surveys, partially to ensure data comparability for trend analysis. Because NASS conducted the FRIS for the first time, some data collection and processing steps differed from earlier Department of Commerce procedures. Specific details will be discussed later in this section.

28. The FRIS sample design was a stratified systematic sample of farm and ranch operations selected from the 1997 Census of Agriculture who reported irrigated cropland or pastureland. The sample was designed to provide reliable estimates of irrigation practices for the 50 States and the 20 Water Resource Areas (WRAs). The target population included approximately 248,000 farms in the 50 States. Omitted from the universe were all horticultural operations reporting on the 1997 Census of Agriculture which accounted for approximately 31,000 farms. These firms were omitted to reduce respondent burden since they were required by law to complete a Census of Horticulture which also asked some irrigation-related questions. Also omitted from the population were abnormal operations such as research experiment farms. Indian reservations were included in the 1998 FRIS.

29. The WRA boundaries are unchanged from previous censuses as defined by the Water Resources Council. WRAs are geographic areas which use the county boundaries to identify major drainage areas. The water resource areas approximate the actual drainage-basin boundaries but are not the exact topographic drainage characteristic boundaries. As shown in Appendix A, WRAs may intersect State boundaries but do not intersect county boundaries.

30. Acres irrigated is defined as the acres of agricultural land to which water was artificially applied by controlled means including pre-plant, partial, supplemental, and semi-irrigation. Land flooded during high water periods was included as irrigation if the water was diverted to agricultural land by dams, canals, or other means.

31. The FRIS sampling frame was stratified by the variable irrigated acres. There were 10 defined strata. Stratum 0 was a certainty stratum where the largest irrigated farms in each State were completely enumerated. Each State's sample design used some combinations of the 10 strata which are documented. FRIS Administrative Manual [11]. The strata were:

Stratum Code	Acres Irrigated
0	Exceeds Certainty Level
1	1,000 to Certainty Level
2	500 to Certainty Level
3	500-999
4	200-499
5	100-199
6	50-99
7	10-49
8	1-49
9	1-9

32. The 1998 FRIS sample size was about 23,600 operations, representing about 8 percent of the farms and ranches reporting irrigation on the agriculture census. The sample size for each State ranges from 37 in Rhode Island to 930 in Texas; reference Appendix B. A certainty sample of about 1,600 farms was pre-selected for enumeration with the balance of the sample independently drawn.

33. To illustrate, the Texas sample design consisted of 7 strata using the 1997 Census of Agriculture reported total acres irrigated as the stratification variable. The first stratum, labeled 0, was the certainty stratum and contained the largest irrigators in the State. Its stratum boundary was set at 3000 or greater acres irrigated. The other FRIS strata were stratum code 1 with 1000 to 2999 irrigated acres; stratum code 3 with 500 to 999 irrigated acres; stratum code 4 with 200 to 499 irrigated acres, stratum code 5 with 100 to 199 irrigated acres; stratum code 6 with 50 to 99 irrigated acres; and stratum code 8 with 1 to 49 irrigated acres.

34. The FRIS sample size in each State was based on the variability in total irrigated acres from the 1997 Census of Agriculture. The survey design coefficient of variation target level was 5 percent in 42 States and slightly higher in the remaining smaller States. Response rates from the 1994 FRIS were factored into the final States sample size. The final survey response rate is expected to exceed the overall 74 percent rate in the 1994 FRIS by about 10 percent. Also considered in the allocation were the size of the universe and distribution of farms across the States.

35. The sample was designed to provide reliable estimates for total irrigated acres with an average coefficient of variation of 5 percent for 42 States, 10 percent for 7 States, and 15 percent for 1 State. This strategy was used to avoid a complete census enumeration in some of the smaller States of the New England region. An average coefficient of variation was targeted at less than 5 percent for each of the Water Resource Areas and at the U.S. level. In short, estimates for the survey will be computed by weighting the data for each respondent by an expansion factor equal to the initial sampling interval adjusted for whole farm non-response.

V. FRIS SURVEY PROCESS

36. Planning and development of the 1998 FRIS began about one year before data collection was scheduled. Significant events included a review of the 1994 survey conducted by the Department of Commerce, soliciting input from data

users, and finalizing current survey specifications. A part of this activity included submission and approval from OMB to conduct this data collection activity as a mandatory survey. A Federal Register Notice solicited public comments on the survey.

37. Early in the planning of the 1998 FRIS, information was compiled from a number of sources. A letter requesting comments and recommendations was sent to 150 data users. Responses from about one-third were returned with suggestions. Organizations responding included government agencies, universities, research laboratories, irrigation publishers, and private hydrologists. The Advisory Committee on Agriculture Statistics, a committee comprised of 24 private industry and government agency representatives, reviewed content and offered comments at their annual meeting. The irrigation industry and other industry experts contributed comments.

38. The 1998 FRIS questionnaire was a 12-page report form using standard 8 2" x 11" paper. The expected response time to complete the report will average about 45 minutes. Major sections of the questionnaire covered the following 18 topics related to irrigation: acreage; land use; whether any land was irrigated; method of water distribution; acres irrigated and estimated quantity of water used by source; acres harvested and crop yields; irrigation frequency, method of water distribution, and use of commercial fertilizers and pesticides in irrigation water by selected crops; number of irrigation wells, well depth and pumping capacity; pumps other than well pumps; energy used for pumping irrigation water by power source; maintenance and repair costs for irrigation equipment and facilities; expenditures for irrigation facilities; irrigation practices; other uses of irrigation water; participation in Federal Government programs; improvements to irrigation systems to reduce energy and/or conserve water used in irrigation; sources of irrigation information; and irrigated land in 1997, and (if no irrigation in 1998) reasons for discontinuing irrigating.

39. The 1998 FRIS questionnaire was very similar to the previous survey instrument used in 1994. No formal pre-test was employed because of the limited changes. Information from the above mentioned sources formed the basis for refining the 1998 FRIS questionnaire wording and content.

40. New questions added to the 1998 FRIS in response to data requests were:

41. rent or lease of water to municipal or industrial users (yes/no),
    2) increase of well depth to water in last 5 years (yes/no),
    3) land disposal of liquid livestock waste (acres impacted),
    4) mechanical-move irrigation by nozzle pressure (acres irrigated),
    5) costs for irrigation system computers and software (dollars), and
    6) use of water-soluble polyacrylamide (acres),
    7) participation in government cost-sharing programs (yes/no), and
    8) lined and unlined open surface gravity ditch irrigation (acres irrigated).

42. One question from the 1994 FRIS was dropped which asked have you made any special provisions on your farm for wildlife habitat (yes/no).

43. The approximate 1998 FRIS time table for major events were:

Event	Start	Finish
Industry & Data User Feedback	2/97	3/98
Questionnaire Design	12/97	7/98
System Development	1/98	12/98
Sample Selection	10/98	11/98
Initial Mailing	2/99	2/99
Follow-up Mailing (letter & form)		3/99
State Follow-up (interviews)	4/99	5/99
Process and Tabulate		8/99
Data Review and Analysis		8/99
Disclosure and Publication Review		9/99
Publication		11/99

44. Data collection for the 1998 FRIS had a primary goal to maximize response rates and to minimize the non-response adjustment. NASS used its infrastructure of 45 field offices that support the 50 States to support the survey conducted primarily by mail. There were two mailings. Selected operations were contacted by telephone and a limited number by face-to-face interview. All States were required to meet a minimum 60 percent response rate. Weekly check-in reports generated at the central processing center in Kentucky provided a status to monitor progress. Follow-up interviews were made by the field offices which included non-respondents who were large irrigation operations in the 1997 Census of Agriculture.

45. The initial and second mailing of the 1998 FRIS occurred from the North Carolina field office mail center. The follow-up mailing to non-respondents occurred about two weeks after the initial mailing. A cover letter accompanied the second questionnaire mailing to emphasize the need to respond. Each field office, prior to the mailing, could “mark” farms and ranches that would not be sent from the mail center. These “marked” operations then became the responsibility of the respective field office to collect the FRIS data. Large operations and special handled cases typically fit this situation. Each field office was also responsible for monitoring data collection response rates. Telephone and face-to-face interviews were conducted by trained enumerators through the field offices.

46. Mail receipt, record check-in, and data editing of the FRIS was the responsibility of the Kentucky field office. This ensured consistent editing and processing of data for all States. Data keying also occurred in the same office. Questionnaires were reviewed by statisticians prior to data keying to identify inconsistencies and other data reporting problems. Computer edits further checked and validated the FRIS data.

47. After the edit phase, each field office received from NASS Headquarters a summary of their State FRIS data for analysis and review. A listing of potential outliers or atypical operations accompanied the summary to facilitate the review. Each field office then identified any records with potential data errors that required another review by statisticians in the Kentucky field office. These problem cases were documented and forwarded to Kentucky for resolution.

48. All FRIS main frame processing was done at the National Information Technology Center in Kansas City, Missouri. The edit and summary were written as SAS code.

49. Sample level data were expanded using a re-weighted direct expansion estimator [12]. The reported survey data were simply expanded by the inverse of the probability of the sampling fraction which was then multiplied by the non-response rate. The expansion factor for each record was at the strata level. Both State and WRA summary totals were calculated.

VI. WATER USE DATA FINDINGS AND TABULATIONS

50. The 1998 Farm and Ranch Irrigation Survey publication to be released in November 1999 will contain approximately 200 pages. It will consist of an introduction, approximately 35 tables, a summary, an appendix with a copy of the questionnaire, and a water resource area map. Data will be published for the 50 States and the 20 water resource areas. This expands the previous publication detail from 27 leading irrigation States and 18 WRAs in the 1994 FRIS. The 1998 FRIS excludes horticulture farms and abnormal farms, except Indian reservations. The publication will include estimates and the relative standard errors for the estimates for selected characteristics by State and region.

51. The discussion that follows presents currently available information from three primary data sources for water and irrigation statistics in the United States. The 1997 Census of Agriculture provides information on the number of farms irrigated, irrigated acres by crop, and associated crop yields. The 1994 FRIS data will highlight water use in agriculture for irrigation, sources of irrigation water, and methods of irrigation. Data from these sources are available using the World Wide Web address of http://www.nass.usda.gov. Additional data on 1995 water consumption and withdrawals for agriculture and other users in the United States are reported by the United States Geological Survey (USGS). Their web site is http://h2o.usgs.gov/watuse. Another good source for information on water use and management is the USDA, Economic Research Service's briefing room for water use. The web site address is: http://www.econ.gov/briefing.

52. The 1997 Census of Agriculture reported that irrigated agricultural land was found in every State and accounts for over 55 million acres on over 279 thousand U.S. farms. The proportion of all farms that were irrigated was 14.6 percent. The average irrigated farm size was 197 acres. Appendix C shows the distribution of irrigated land by State. Irrigated cropland ranged from nearly 8 million acres in California to less than 3 thousand acres in States like Alaska, New Hampshire, and Vermont. Harvested cropland accounted for 90.8 percent of the irrigated farm acres while pastureland and other uses totaled 9.2 percent. Table 1 provides additional information and a comparison with earlier censuses.

Table 1: United States Farms
Census of Agriculture Data Compared

Characteristics	Unit	1997	1992	1987
All farms	number	1,911,859	1,925,300	2,087,759
Land in farms	acres	931,795,255	945,531,506	964,470,625
Ave. farm size	acres	487	491	462
Irrigated farms	**farms**	**279,442**	**279,357**	**291,628**
	acres	**55,058,128**	**49,404,030**	**46,386,201**
Percent of total	percent	14.6	14.5	14.0
Ave. per farm	acres	197	177	159
Harv. Cropland	percent	90.8	91.6	90.0
Pastureland/other	percent	9.2	8.4	10.0

53. Since 1992, there has been a net increase of over 5.6 million acres of irrigated land in the United States based on the 1997 agriculture census. Four States accounted for nearly 60 percent of the expansion. The States, listed in order of largest change, were the eastern State of Arkansas followed by three western States of California, Nebraska, and Texas. Irrigated cropland acres in Arkansas expanded during the 5 years by 1 million acres, a 37 percent increase. Most of this irrigated land is located in the eastern part of the State where rice, soybeans, wheat, and cotton were produced. Irrigation on California cropland increased 15 percent with an additional 1.1 million acres watered. Both Nebraska and Texas cropland irrigated acres increased 10 percent. The U.S. dot map, shown in Appendix C, illustrates these shifts in agricultural irrigation from 1992 to 1997.

54. From the 1997 Census of Agriculture, the only U.S. crop with 100 percent of acres irrigated was rice. Over 80 percent of the cropland in orchards was irrigated and nearly 80 percent of the cropland producing potatoes was irrigated. About 70 percent of the vegetable acreage was irrigated. Approximately 50 percent of the U.S. cropland in sugarcane production was irrigated. Other major crops grown on irrigated lands were popcorn, cotton, and dry beans with between 35 and 40 percent of the acreage watered. Acres irrigated for hay and corn accounted for about 15 percent of the cropland for each commodity. Irrigation of corn is concentrated in the Central Plains States, particularly Kansas, Nebraska, and Texas.

55. The correlation between irrigated cropland and livestock production in the Western United States is quite high. Irrigated acres for corn and alfalfa provide significant feedstuffs for the livestock industry. Feedlots and confinement facilities in the West are highly dependent on irrigated forage and feed grain production. It is not unexpected that Kansas, Nebraska, and Texas are major States for cattle-on-feed in confined lots.

56. Data on the methods of irrigation were last published in the 1994 FRIS. These data will be updated in November 1999 with the publication of the1998 FRIS. There were 46.4 million acres irrigated by different water distribution systems at that time. Approximately 2.2 million acres were irrigated by more than 1 of the 13 distribution systems listed on the FRIS report form. Of the total acres irrigated by all types of distribution systems, 25.1 million acres were irrigated by gravity flow systems and 21.5 million acres by sprinkler systems. Gravity flow systems were used on 54 percent of the land irrigated in

1994, compared to significantly higher percentages in earlier years. Sprinkler systems were used to irrigate 46 percent of the total land irrigated in 1994 compared with 40 percent in 1988. Of the 21.5 million acres irrigated by sprinkler systems, center pivot medium pressure systems (30 to 59 pounds per square inch (psi)) were used to irrigate 5.9 million acres and center pivot low pressure systems (under 30 psi) were used to irrigate 5.7 million acres. Next were center pivot high pressure systems (60 psi or greater) with 3.2 million acres, and linear and wheel move systems with 3.0 million acres. Hand move sprinklers and solid set and permanent sprinklers were used on 1.9 and 1.0 million irrigated acres, respectively. Drip, trickle, and micro irrigation systems were used on 1.8 million acres based on the 1994 FRIS. Sub-irrigation was reported on about 361 thousand acres.

57. The increased use of more efficient irrigation practices is expected to continue when data from the 1998 FRIS are published. Gravity flow systems, especially prominent in the West, reflecting early irrigation projects are being upgraded or replaced with more efficient systems and improved land and water management. Pressurized systems which include sprinkler and low-flow systems are gaining in use. Although more capital intensive and almost always requiring an energy source, the long term benefits of highly efficient water application technologies coupled with labor savings have encouraged adoption of these new technologies of drip, trickle, and micro sprinklers. Cropland in vegetables and perennials like orchards and vineyards is the first to use these improved water management practices.

58. Water use data for irrigation are available from two primary sources, the FRIS and USGS. The 1994 FRIS, until updated with the 1998 FRIS, reported irrigators estimating a total of 79.6 million acre-feet (MAF) applied to 46.4 million acres irrigated in 1994. This converts to an average of 1.7 acre-feet per acre of U.S. agricultural land irrigated. For comparison, the average acre-feet of water applied per irrigated acre in the 1988 FRIS was 1.82 in contrast to the 1969 Census of Agriculture reported 2.11 acre-feet. The 1994 FRIS data were for the conterminous (48 States) United States and excluded horticulture farms and abnormal farms.

59. Freshwater withdrawals for irrigation was estimated by the USGS survey in 1995 at 150 MAF. This accounts for nearly 40 percent of the U.S. total freshwater withdrawals. Keep in mind this USGS estimate is a broader based survey than FRIS and included significant irrigation uses for golf courses and parks. Withdrawal is defined as total water diverted from both surface water sources and removed from ground water aquifers. The 1995 USGS survey data showed 91 MAF consumptive use for irrigation where it is consumed and does not immediately return to a water source for reused.

60. The 1994 FRIS reported the largest source of irrigation water, from the estimated 79.6 MAF used, as wells located on-farms. Water pumped from over 329,000 wells in 1994 totaled 39.4 MAF or 49 percent of the total used. Farms with wells used in 1994 averaged 3.1 wells per farm. Off-farm water suppliers provided 31.6 MAF (40 percent) and on-farm surface sources provided 8.6 MAF (11 percent).

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VII. APPENDICES

A: Water Resource Areas Map (will be provided at meeting)

B: 1998 Farm and Ranch Irrigation Survey Sample

C: 1997 Irrigated Land in Farms
Irrigated Land-Change in Acreage 1992-1997 (will be provided at meeting)

APPENDIX B

1998 Farm and Ranch Irrigation Survey Sample
Sample Size by State

State	Certainty Samples	Other Samples	Total Samples
Alabama	5	505	510
Alaska	8	37	45
Arkansas	27	477	504
Arizona	83	612	695
California	101	768	869
Colorado	67	464	531
Connecticut	5	98	103
Delaware	11	195	206
Florida	71	522	593
Georgia	18	758	776
Hawaii	16	386	402
Idaho	94	612	706
Indiana	15	565	580
Illinois	21	550	571
Iowa	13	448	461
Kansas	64	469	533
Kentucky	3	643	646
Louisiana	64	858	922
Maine	8	97	105
Maryland	7	298	305
Massachusetts	11	114	125
Michigan	11	573	584
Minnesota	32	633	665

State	Certainty Samples	Other Samples	Total Samples
Nevada	19	383	402
New Hampshire	3	96	99
New Jersey	21	363	384
New Mexico	60	520	580
New York	9	396	405
North Carolina	8	437	445
North Dakota	12	339	351
Ohio	6	308	314
Oklahoma	20	553	573
Oregon	76	621	697
Pennsylvania	4	462	466
Rhode Island	1	36	37
South Carolina	9	275	284
South Dakota	18	388	406
Tennessee	16	395	411
Texas	101	829	930
Utah	52	476	528
Vermont	10	87	97
Virginia	3	411	414
Washington	58	613	671
West Virginia	4	79	83
Wisconsin	46	467	513
Wyoming	58	379	437
Total	**1,579**	**21,988**	**23,567**