AGRICULTURAL RESEARCH SERVICE INITIATES SOIL AND WATER STUDY AT OAKES

R. F. Follett, E. J. Doering, G. A. Reichman, and L. C. Benz

INTRODUCTION

Delivery of water for irrigation to the Oakes Area-West Side in North Dakota is scheduled within five years. Delivery to other areas in the 250,000-acre Garrison Diversion Unit-Initial Stage is to follow soon thereafter. As in any newly irrigated area, there will be problems as irrigators learn to manage both water and fertility.

Garrison Diversion is different from any other irrigation project in the United States because of its northern Great Plains climate and the glacial -lake, -outwash, and -till origins of its soils (10). Research must determine the optimum water and fertility management practices for crops on the soils to be irrigated under the climatic conditions of the northern Great Plains. Studies initiated by the Agricultural Research Service to obtain this information are described in this paper.

Follett and Reichman are soil scientists, Doering and Benz are agricultural engineers, Northern Plains Branch, Soil and Water Conservation Research Division, Agricultural Research Service, USDA, Mandan, North Dakota.

Based upon the approximate boundaries of the Garrison Diversion Unit-Initial State (13) and county general soil maps (11), we have estimated that over one-half of the soils in the Initial Stage are mainly coarse-textured soils that are affected by shallow water tables. The parentage of these soils is glacial lake sediments and glacial outwash deposits. The percentage of coarse-textured soils on irrigated acreages will be higher if sprinkler irrigation is chosen in the Initial Stage.

Present research at the Carrington Irrigation Branch Station in North Dakota is providing information on soils formed from medium-textured glacial tills, and work at the Redfield Development Farm in South Dakota is providing information on soils formed from medium-textured lacustrine sediments. Except for research previously conducted near Upham, North Dakota (2, 3, 4, 7, 8) there is a serious lack of research knowledge about irrigation and fertility management on soils formed from coarse and moderately coarse textured glacial lake sediments and glacial outwash deposits in the northern Great Plains. Of the coarse and moderately coarse textured soils in the initial stage, over one-third are in the Hecla-Hamar and Hecla-Ulen associations. Our research at Oakes will be on these soils.

Little research information is available relative to "crop drainage requirements" of soils in the northern Great Plains. The term "crop drainage requirement" refers to the degree of drainage that must be maintained in the root zone to provide optimum growing conditions for a crop. Different crops respond differently to a specific root environment and therefore have different drainage requirements. For example, work in Holland (6) showed that optimum water table depth for grass was approximately 24 inches; yields were appreciably reduced if the water table was deeper. In North Carolina, the optimum water table depth was 30-34 inches for corn and 18-24 inches for soybeans (14). In Nevada the optimum water table depth for alfalfa was 24 inches. The alfalfa root system progressively deteriorated and yields decreased when the water table was periodically raised to the soil surface for intervals exceeding four days (12). Water tables maintained at shallower than optimum depths also cause reduced yields. However, for grain crops and grasses, it has been shown that fertilization will reduce the adverse effects of waterlogging (15).

Because specific crop drainage requirements have not been determined for the conditions and crops to be grown in the Garrison Diversion Unit, drainage design presently calls for sufficient drainage to insure that the water table does not rise higher than four feet below the surface. This four-foot minimum depth insures adequate root-zone aeration and trafficability for machines; it also provides ample water storage capacity for rainfall, for some over-irrigation, and for leaching and salinity control. To control the water table at four feet, drains customarily are placed approximately eight feet deep. With drains at that depth, the water table will probably fall to near the eight-foot depth by late fall or winter.

Since deep drainage systems are generally more costly to build and maintain than shallow drainage systems, the most economical system may be the one that lowers the water table the least but still satisfies the crop drainage requirement. Even though different crops have different drainage requirements, one drainage regime may provide drainage that is nearly optimum for several different crops, especially if irrigation is applied properly.

RESEARCH SITE

During the summer of 1969 an 80-acre research site was leased. The site has a high water table resulting from a shallow water table aquifer. The aquifer will be used to provide irrigation water and the desired water table depth for research on crop drainage requirements. The location of the research site is shown in Fig. 1; it is outside of the service area of the Oakes Area-West Side and will not be affected by or interfere with irrigation development within the service area.

A 100-foot grid-coordinate system has been established on the 80 acres for on-site measurements. The grid system has been used for topographic mapping, locating deep borings, and soil mapping.

A deep boring study was conducted in 1969, with assistance from the U.S. Bureau of Reclamation, to determine the types of material in the aquifer and to locate clay lenses or aquifer obstructions.

Soil cores to five feet have been obtained on

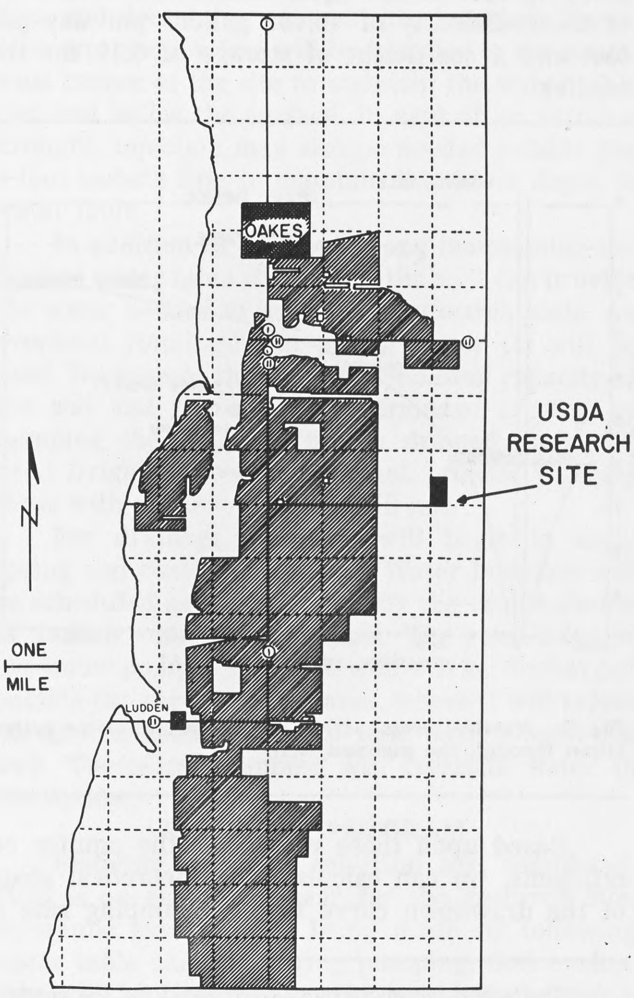

Fig. 1. Map of the Oakes Area-West Side showing the location of the USDA Research Site.

the 100-foot grid-coordinates for profile description and laboratory analysis. Samples for laboratory analyses were obtained by soil horizon. This work was done cooperatively by the NDSU Soils Department and the Agricultural Research Service. Ten soil series exist on the 80-acre site; the major series are also major soils of Garrison Diversion Unit-Initial Stage.

DRAINAGE AND IRRIGATION

To evaluate drainage requirements for crops, a range of water table depths must be provided. We chose to use a pumped well to provide the needed drainage depths at our site.

The well was constructed in the fall of 1969. It consists of a 16-inch diameter (25-foot long) Johnson Irrigator Screen* installed in a 38-inch diameter bored hole with a graded gravel pack. It is 53 feet deep and penetrates an aquifer having an average saturated thickness of 48 feet. Results of a 24-hour pump test conducted in November, 1969, at a pumping rate of 270 gpm, indicated a coefficient of transmissibility of 46,400 gallons per day per foot and a coefficient of storage of 0.19 for the aquifer.

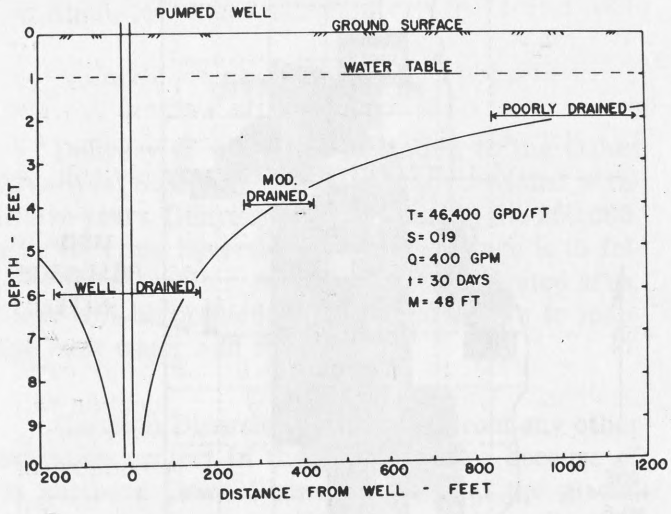

Fig. 2. Vertical cross-section of the ground water system taken through the pumped well.

Based upon these values for the aquifer coefficients, we can calculate the theoretical shape of the drawdown curve for any pumping rate at

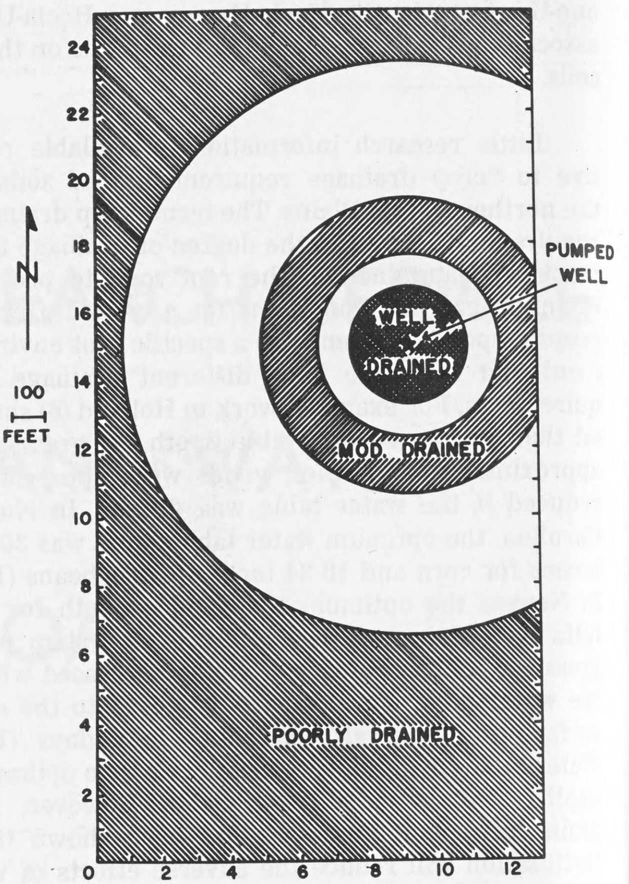

Fig. 3. Plan view of an 80-acre site showing areas having various degrees of drainage produced by a pumped well if the soil surface is level.

any time after pumping begins. The hydraulics of the system are described by Figs. 2 and 3. Fig. 2 is a vertical cross section of the system through the pumped well. Both the original water table and the surface of the projected cone of depression after 30 days of pumping at 400 gpm are shown. Pumping must be continuous to maintain the desired drawdown conditions; the required rate of pumping will decrease with time. The regions of good drainage, moderate drainage, and poor drainage also are shown in relation to the well. The terms "good," "moderate," and "poor" drainage are relative terms arbitrarily associated with water table depths of 6, 4, and 2 feet below the soil surface, respectively.

Fig. 3 represents a theoretical plan view of an 80-acre area beneath which pumping has produced a cone of depression. Because the soil surface is assumed to be level, the lines connecting points of equal distance from the soil surface to the water table (called isobath lines) are concentric circles around the well. Actually, the soil surface at the research site has many surface depressions and irregularities; therefore, lines connecting equal distances from surface to water table are also ir-

*Trade and company names are given for the readers' benefit and do not imply endorsement or preferential treatment of any product by the U. S. Department of Agriculture.

regular in shape, as shown in Fig. 4. This isobath map for the research site represents water table

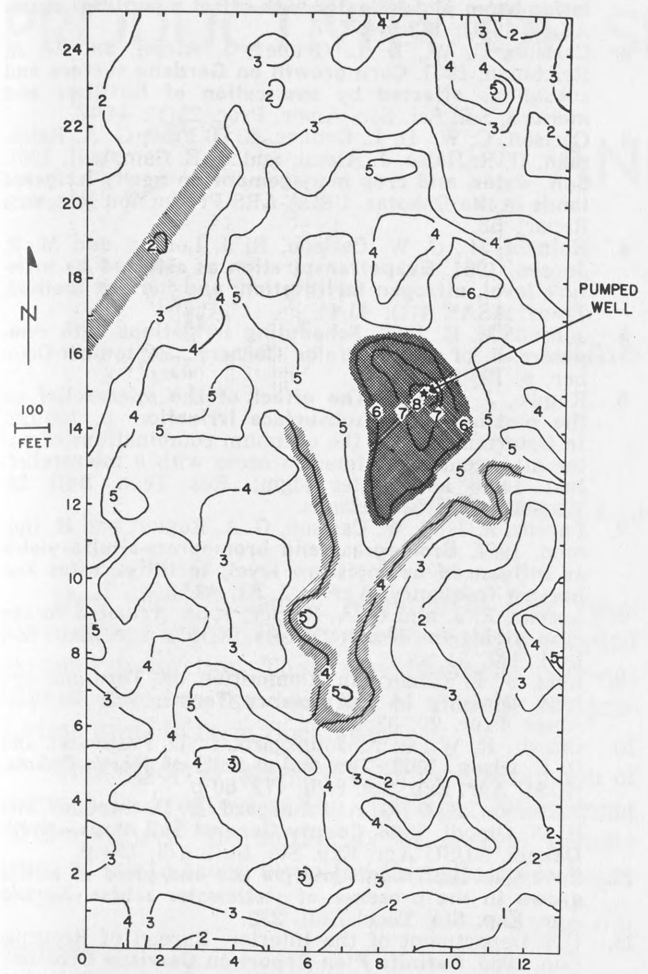

Fig. 4. Isobath map for the USDA Reseach Site based on calculated drawdown after 30 days of pumping at 400 gpm. Shaded areas are tentative locations of research plots.

conditions that we expect will exist after 30 days of pumping at 400 gpm; these are the conditions desired for the entire growing season.

The development of and ability to maintain the cone of depression was carefully observed during 1970. Research plots established in 1971 will be located on the 2-, 4-, and 6-foot isobath lines. The tentative research plot locations are shown as shaded areas in Fig. 4.

The natural seasonal fluctuations of the water table in this area for the past few years are shown in Fig. 5. This information was obtained from the U. S. Bureau of Reclamation. The spring rise of the water table is associated with the spring thaw and spring precipitation. Thus, during the spring the natural water table may be above the soil surface on part of the research site, in many of the interconnected surface depressions, and on land adjacent to the experimental site. The pumped well is capable of lowering the water table in the research site if surface water from adjacent land is kept out. Therefore, dikes across appropriate interconnected surface depressions were constructed in November, 1969.

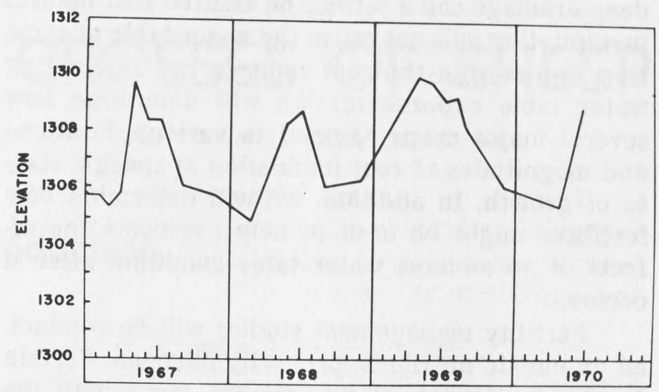

Fig. 5. The natural fluctuation of the water table as a function of time at the SW corner of the USDA Research Site.

The low water table in late summer and fall (Fig. 5) is associated with a natural discharge or leakage from the area, continued evapotranspiration, and decreasing seasonal precipitation. Therefore, an injection line will be installed in the northwest corner of the site to maintain the water table two feet below the surface. In case of an extreme drought, injection may also be needed outside the 4-foot isobath line to maintain the 4-foot depth to water table.

In addition to developing and maintaining the desired water table conditions, the well can provide the water needed to irrigate the research plots. An overhead rotating-boom plot irrigator (1) will be used. Because of the low water-holding capacity of the soil and the degree of drainage created by pumping the well, the deeply drained plots will need irrigation to support plant growth, whereas those with shallow drainage will not.

For drainage, pumping will begin in early spring and continue until fall. Water injection will be scheduled as needed to satisfy the requirements of various research objectives. The remainder of the water pumped from the well will be discharged outside the experimental area, where it will rejoin the groundwater system to flow back toward the well. Therefore, pumping will circulate water in the aquifer.

RESEARCH PROGRAM

Planning and site selection are completed. 1970 is an evaluation year for the research site. Hydraulic evaluation is being made by following water table changes during pumping. Soil evaluation will be based upon results obtained from a field-wide crop of corn grown during 1970.

Various plant species respond differently to water tables at different depths; they also respond differently to fluctuating water tables. How each species responds also depends on timing and duration of root inundation. Only by costly deep drainage can a farmer be assured that natural precipitation will not cause the water table at some time to rise into the root zone. In our fluctuating water table experiments we will determine how several major crops respond to various durations and magnitudes of root inundation at specific stages of growth. In addition, we will determine how fertilizer might be used to help overcome the effects of an adverse water table condition after it occurs.

Fertility management studies will be conducted on mobile nutrients, primarily nitrogen. Certain forms of nitrogen, mainly nitrate, move with the flow of water through the soil. If water percolates downward past the bottom of the root zone, nitrates are carried with it and become inaccessible to plant roots. This nitrogen loss results in reduced efficiency of fertilizer use and lower crop yields.

Water management studies are being designed to determine the drainage requirements for various crops, the relationship between actual evapotranspiration and water needs calculated from meteorological measurements (5), and how water table depth affects irrigation requirement. Non-weighing lysimeters (9) will be used to separate the quantities of water used by crops into components of applied water, precipitation, and water moving upward from the water table. These relationships will serve as a basis for using meteorological data and a knowledge of the properties of the soil-water system to schedule irrigations in the Garrison Diversion.

Information obtained in water table studies, fertility studies, and lysimeter studies will be used to evaluate the combined interactions of water management, fertility management, and water table depth (drainage) on crop growth. By studying the soil environment in which the root grows, we hope to determine the factors that affect root growth and the factors that cause certain crop species to have certain drainage requirements. The data obtained in these studies will provide much of the information an irrigation farmer in the Garrison Diversion will need in making his water and fertilizer management decisions.

ACKNOWLEDGMENTS

The authors gratefully acknowledge assistance by the U. S. Bureau of Reclamation and the Soils Department, North Dakota State University, in planning and in research site selection.

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From The Director . . . . **Continued from Page 2**

world. By North Dakota standards, the grain is not of high quality; they are not fine bread wheats. But these wheats are filling empty stomachs where previously hunger and starvation were constant companions.

One of NDSU's own wheats, not considered for release in North Dakota because of quality defects, recently was named Dakuru and is being produced in Uruguay as part of the "Green Revolution."

NDSU is proud to join the world in its salute to Dr. Borlaug, the first agricultural scientist since the inception of the Nobel prizes in 1901 to be so honored.