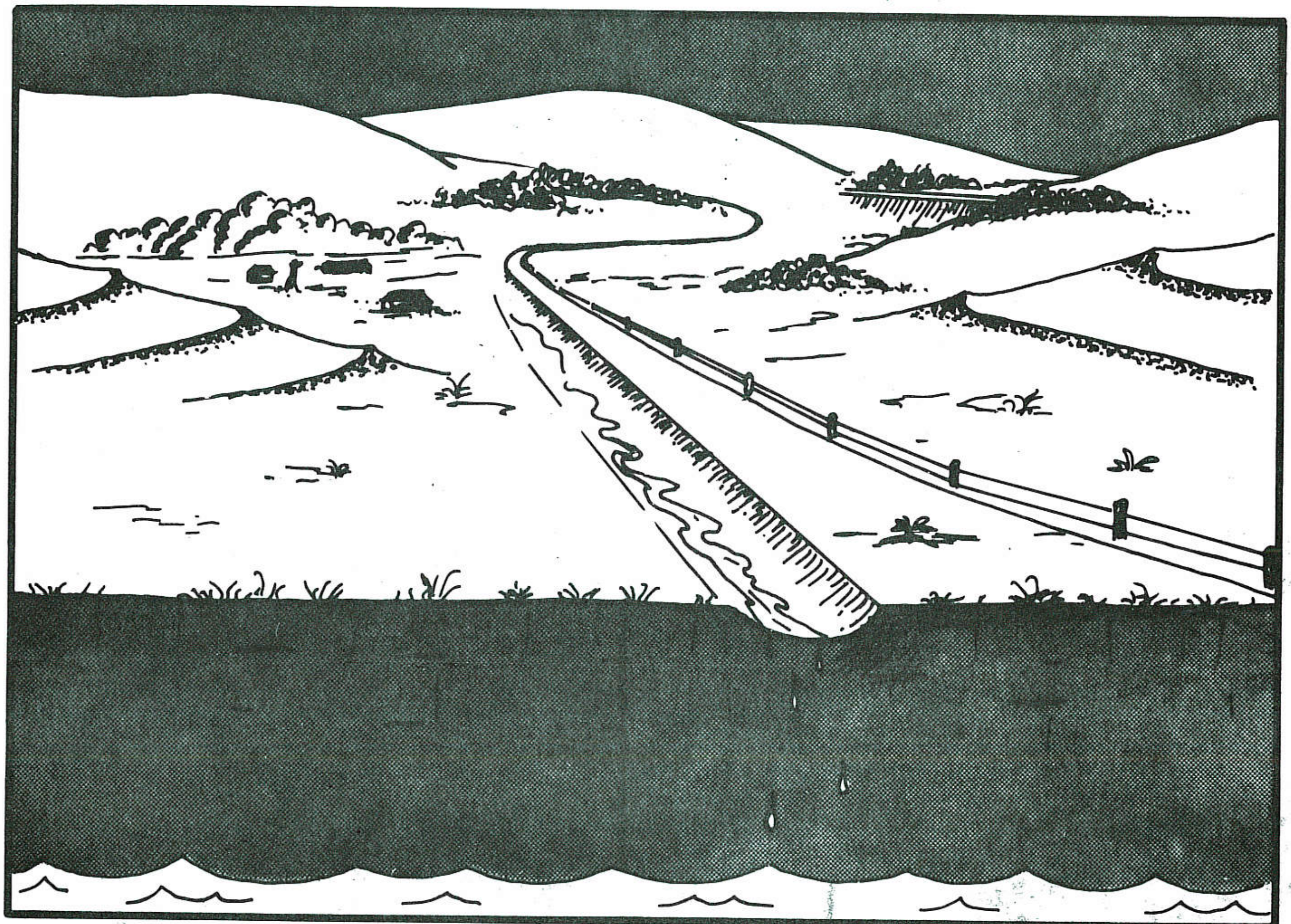
LEWIS & CLARK
NATURAL RESOURCES DISTRICT



Groundwater Management Plan

1986

LEWIS AND CLARK NATURAL RESOURCES DISTRICT
NATURAL RESOURCES DISTRICT
GROUNDWATER MANAGMENT PLAN

JANUARY 1986

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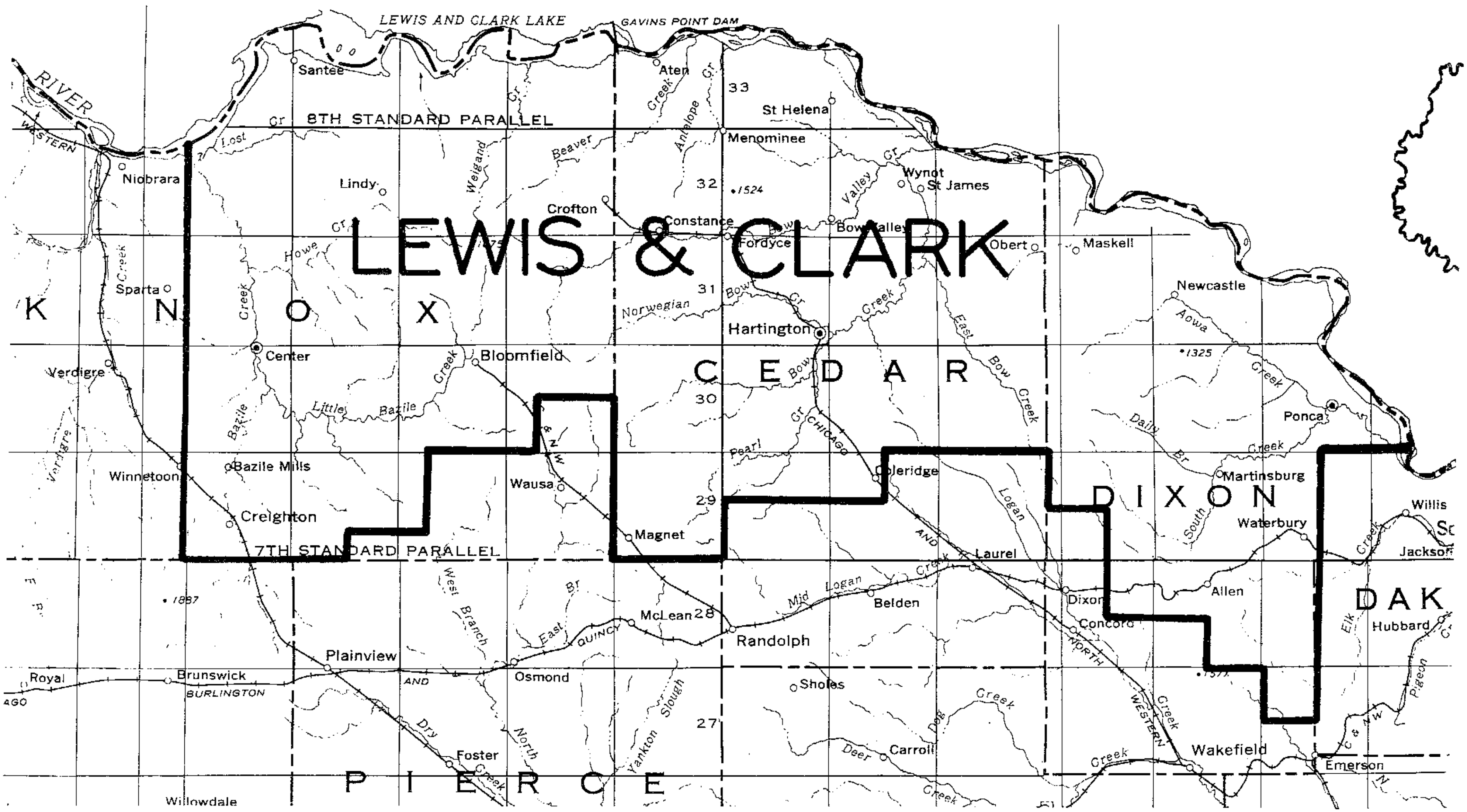
LEWIS AND CLARK LAKE
GAVINS POINT DAM
RIVER
WESTERN
8TH STANDARD PARALLEL
7TH STANDARD PARALLEL
LEWIS & CLARK
KNOX
CEDAR
DIXON
PIERCE
DAK
Santee
Aten
St Helena
Menominee
Niobrara
Lindy
Crofton
Constance
Fordyce
Wynot
St James
Bow Valley
Obert
Maskell
Newcastle
Sparta
Hartington
Center
Bloomfield
Verdigre
Ponca
Bazile Mills
Winnetoon
Wausa
Coleridge
Martinsburg
Creighton
Magnet
Laurel
Waterbury
Willis
Jackson
Dixon
Allen
Belden
Concord
McLean
Randolph
Hubbard
Plainview
Royal
Brunswick
Osmond
Sholes
Foster
Carroll
Wakefield
Emerson
Willowdale
Lost Cr
Weigand Cr
Beaver
Antelope Cr
Creek
Valley Cr
Howe Cr
Norwegian
Bow Cr
East Bow Creek
Aowa Creek
Daily Br
South Creek
Bazile Creek
Little Bazile
Pearl Cr
Logan
Mid Logan Creek
West Branch
East Br
Dry Creek
North
Yankton Slough
Deer
Dog Creek
Elk
Pigeon
Verdigre
CHICAGO
AND
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WESTERN
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BURLINGTON
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INTRODUCTION

As required by Nebraska Revised Statute #46-673.01 (Cum. Supp., 1984), the Lewis and Clark Natural Resources District has prepared this groundwater management plan based on the best currently available information.

The format for this plan follows the "Handbook on Preparation of Groundwater Management Plan" distributed by the University of Nebraska Lincoln, Conservation and Survey Division, November 19, 1984. The District has attempted to assemble technical information specific to its area in accordance with statute requirements. Based on that data, the directors have determined policy relating to future management actions for the groundwater goals and objectives of the District. Public input was sought throughout the process by media publicity, task force committee meetings, discussion at NRD Board meetings, and an advertised public meeting on the Groundwater Plan.

By the general nature of the information available, this report is not intended as a specific reference for individual situations occuring within the District. Rather it is intended as a concise basic document indicating the status of groundwater in the area and stating in general terms what policy goals and objectives should be considered in managing that resource.

This information was compiled by NRD Manager Tom Moser and prepared by Administrative Secretary Marilyn Schumacher. Following is a list of the Board of Directors.

LEWIS AND CLARK NRD DIRECTORS

Eugene Schroeder
James Wortmann
Allen Heine
Don Hart
Ray Dykeman
Randall Patefield
Lou E. Benscoter
Dale Jackson
Roman Kramer
William Walton
Lawrence Zavadil
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Mark Fehringer
John Fleming
Milo Johnson
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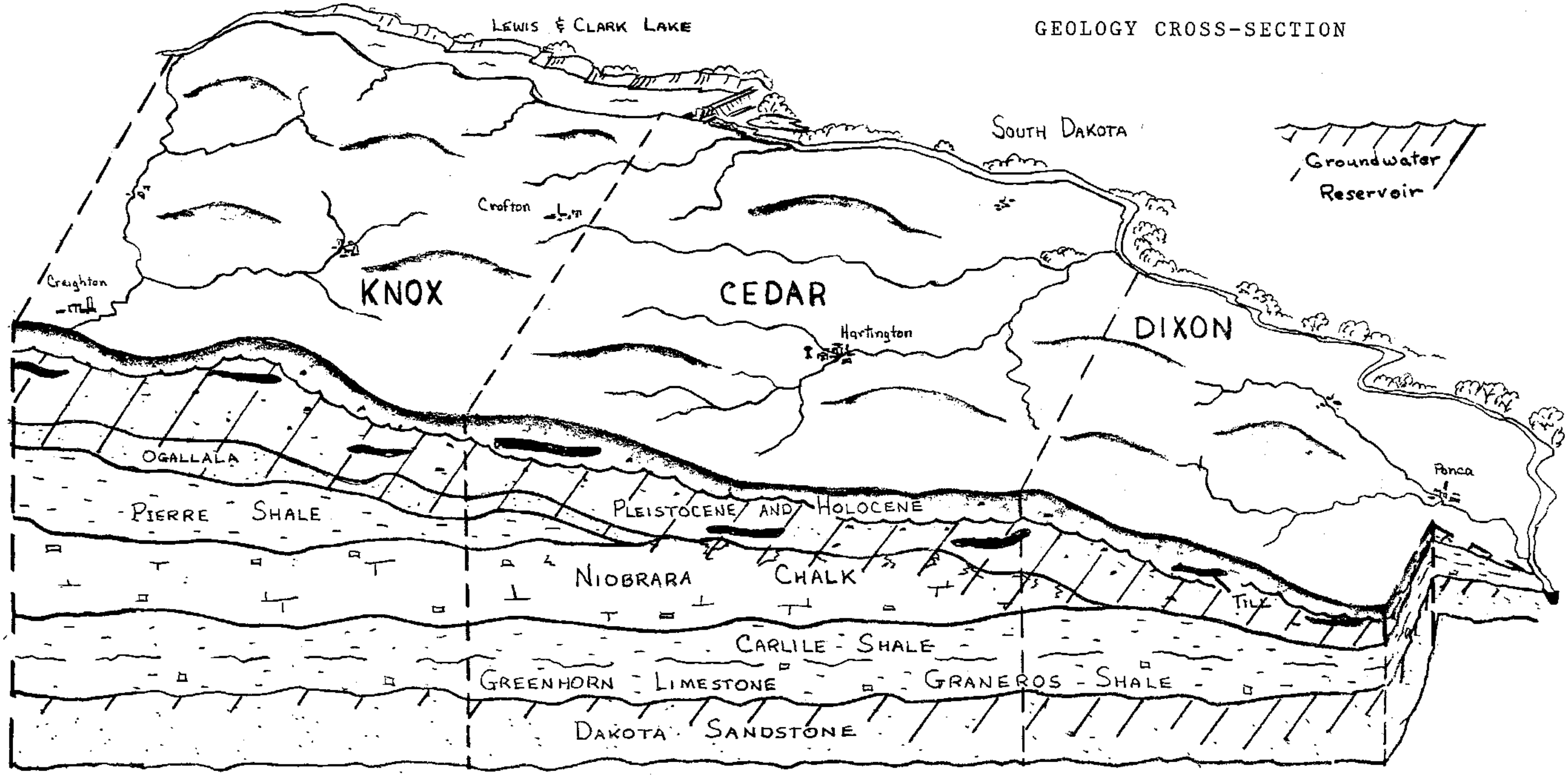
LEWIS AND CLARK NRD

GEOLOGY CROSS-SECTION



Map #1 Representative Illustration of Water Bearing Aquifers
(not to scale)

TECHNICAL ASPECTS OF GROUNDWATER
IN THE LEWIS AND CLARK NATURAL RESOURCES DISTRICT

This section of the plan includes a review of known facts and circumstances relating to groundwater resources of the Lewis and Clark NRD. Following are descriptions of the groundwater reservoir, other water in the management area and water uses. Certain references will be given throughout the document and further information can be obtained by consulting those publications. This information has been condensed to pertain specifically to the Lewis and Clark NRD.

DESCRIPTION OF GROUNDWATER RESERVOIR I. Geographic and Stratigraphic Dimensions

A groundwater reservoir is an aquifer or combination of aquifers being used as a source of water. An aquifer is defined as a water-bearing layer of rock or sediment capable of yielding supplies of water. Groundwater reservoirs need to be described geographically to define the extent of surface area covering a reservoir and stratigraphically to give a vertical indication of thickness and composition of the unit.

In order to give an accurate picture of geology for the District (Knox, Cedar, and Dixon Counties), the history of the area needs to be reviewed from the depths up to the surface material. (ref IANR Educational Circular #6) The oldest subsurface rock in the region is Pre-Cambrian age found at the shallowest depth at about 900 feet below land surface in northeastern Dixon County. Since it last saw the light of day 600 million years ago, the Pre-Cambrian rock of the midcontinent of North America has been covered by sea many times. Left behind are the marine and stream deposited formations that make up the bedrock part of our complex aquifer system. (Map 1: "Illustrated Geology Cross Section" and Table 1: USGS #81-58).

Of these marine and stream deposits laid down in Paleozoic and Mesozoic times, only the upper water bearing Cretaceous formations are sufficiently water-rich and near the ground surface to be of concern and interest as aquifers of the Lewis and Clark Natural Resources District. The lowest formation penetrated by wells is the Dakota Group Sandstone, which was deposited in a shallow sea and adjacent coastal plain that connected the Gulf of Mexico to the Arctic Ocean and separated the continent. Above it is the Graneros Shale, a succession of mud layers carried by wind and streams draining from the continent to the east, and then the Greenhorn Limestone which contains more Calcareous deposits derived from algae and shell structures from marine organisms. Above this is the Carlile Shale which thins out from west to east in the District and ends in Dixon County. None of these formations is considered an important source of water for the District with the exception of the Dakota formation.

The next formation deposited was the Niobrara Formation, a chalky marine shale which outcrops along Lewis and Clark Lake and extends eastward throughout most of Cedar County and into Dixon County. Above the Niobrara Formation is the Pierre Shale (not a source of supply for wells) which extends under most of Knox County into parts of Cedar County. These bedrock formations were exposed to weathering and erosion in Tertiary time, 70 million years ago, when the Missouri River flowed north east across North Dakota to Hudson Bay and before the glaciers invaded the midwest. At present The Niobrara and Pierre formations are exposed to some extent in the Missouri

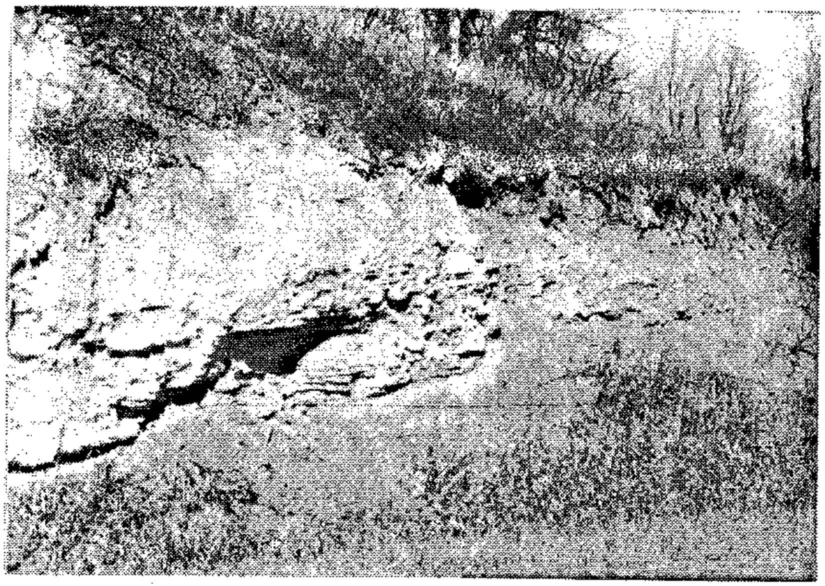
TABLE I

Table 1.--Generalized section of geologic formations and their water-bearing properties
(Modified from Simpson, 1960)

Erathem	System	Series	Formation	Lithology	Water Supply
Cenozoic	Quaternary	Holocene		Alluvial deposits	Principal source of water supply to wells, reported yields range from 550 to 1,500 gal/min; also transmits water to recharge other aquifers.
		Pleistocene		Sand and gravel deposits interbedded with clayey till.	
	Tertiary	Miocene	Ogallala Formation	Sand, silty clay, interbedded with a little volcanic ash and orthoquartzite.	Not a known source of water supply; may yield water to some domestic wells.
Mesozoic	Cretaceous	Upper Cretaceous	Pierre Shale	Shale and claystone, interbedded with thin bentonite layers, marl and sand; fissile to thin bedded, soft, weak.	Not a source of water supply to wells.
			Niobrara Formation	Argillaceous limestone, chalky, medium bluish-gray weathering to dark yellowish-orange; soft, sub-firm, highly fractured in places.	Significant source of water supply to wells through secondary porosity. Reported yields range from 360 to 900 gal/min.
			Carlile Shale	Moderate gray calcareous shale, fissile, soft, weak; interbedded with clayey siltstone.	Not a source of water supply to wells.
			Greenhorn Limestone	Light to medium dark gray limestone, interbedded with argillaceous limestone, marl, calcareous shale, and two very thin layers of bentonite.	Do.
			Graneros Shale	Medium to dark gray shale, fissile, soft, weak; interbedded with thin layers of silt and sand in lower part. Few scattered thin layers of bentonite material.	Do.
		Lower Cretaceous	Dakota Formation	Sandstone, yellowish white in color, cemented in part by calcium carbonate interbedded with medium to dark gray claystone and shale; numerous thin layers of black carbonaceous material.	Significant source of water supply to domestic and stock wells. Irrigation wells possible. Potential yields may be as much as 600 gal/min.
Paleozoic, undifferentiated				Predominantly limestones and dolomites, but some thin sandstone and shale beds.	Not used as a source of water in study area.
Precambrian			Sioux Quartzite	Orthoquartzite, grayish-orange pink, fine to coarse-grained.	Not a source of water supply to wells.

Source--USGS #81-58

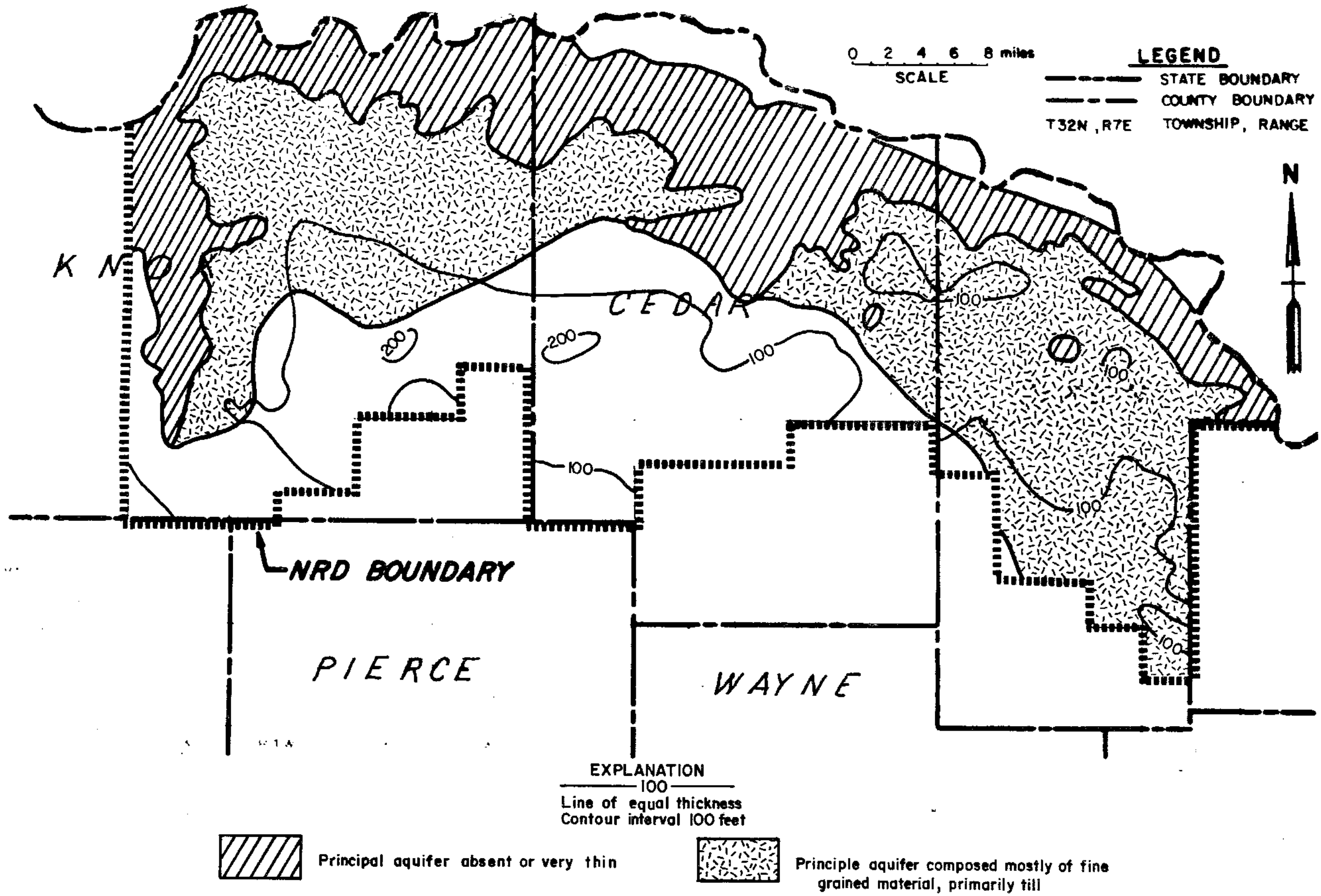
River Bluffs area from east to west across the NRD. Where the Pierre shale is close to the surface in areas of northern Knox County, springs appear and large slumps have occurred causing massive land slides and sometimes moving trees and roads. Besides being visible on the Lake shores, the Niobrara chalk can also be seen in tilled fields in northern Cedar County where it shows through as a yellowish chalky subsoil when erosion has taken topsoil away. Further east in Dixon County, the Carlile Shale and Greenhorn limestone can be seen at the Missouri River landing as Ponca State Park.



Above these formations of bedrock lie the principal aquifers of the District which came in with the Ice Age and are defined geologically as the "Pleistocene or Holocene deposits". They consist of sand, gravel, till (powderized rock), and younger stream and wind deposits, and constitute the principal source of water supply to wells. They were deposited by the glaciers and consisted of great loads of unstratified debris made up of particles of clay, silt, sand, gravel, and boulders. As the Wisconsin ice sheet melted, sand and gravels were deposited on and around the till and much of it was covered by wind deposited loess blown off of bare uplands and intermittent stream bottoms. Near the mouth of the Niobrara River, the Missouri River was shifted to its present course, forming a well developed pattern of drywash tributaries and streams draining the bluffs and leaving eventually the surface of this present age.

The groundwater areas in the District can broadly be described as primarily within the Northeast Nebraska glacial drift groundwater region but extending into the Missouri Valley lowlands. The primary aquifers supplying water are the sand and gravel deposits of the Pleistocene and Holocene age and the Dakota and Niobrara sedimentary formations of Cretaceous Age. While the sand and gravel deposits, when thick, hold water of variable quantity and quality for all uses, that in the Niobrara is even less reliable because it is generally less permeable unless in a fractured state. The Dakota is mostly higher in salinity and would require more careful management by users, but is used commonly, near the Missouri River as a source for artesian "flowing" wells.

The base of the principal aquifer in the District is defined as the top of the consolidated cretaceous bedrock discussed previously and the lower limit of those water holding materials which comprise the major groundwater reservoir. In this District the principal or major aquifer consists of the unconsolidated materials of Plestocene (found throughout the NRD) and Holocene Age (found usually along streams). The water saturated layer includes till, silt, and clay which are non water-yielding and sand and gravel which are water yielding. The Ogallala formation is only present in thin and eroded areas that disappear eastward across the NRD in parts of



MAP # 2 - Thickness of Aquifer of the Lewis & Clark NRD

Knox and Cedar County and is in hydrologic connection with the Pleistocene. For purposes of this report, Ogallala sediments will be included with the principal aquifer. The Niobrara chalky shale is of secondary importance because it is a good supply only in the upper layers where fractures allow permeability and where it is near the surface (northern Cedar County). It is not found extensively in Dixon County and is blocked from recharge in Knox County by the Pierre Shale. The Dakota can best be described as the aquifer of last resort, but in northeastern Dixon County is the only source available when shallower aquifers are lacking.

II. Transmissivity and Saturated Thickness

By comparing configurations of the aquifer base with average water tables (1979) we can arrive at a map showing thickness of the principal Pleistocene-Holocene aquifer (map #2). Although the map shows the thickness in contour intervals of 100 feet, there is enough information to generalize on depth of the aquifer. It is interesting to note that the entire Missouri bluff area running the full length of the district has an aquifer that has little or no saturated thickness. This area extends southward along the Bazile Creek drainage and the lower Bow Creek drainage nearly to Hartington. Much of the area beyond that is additionally restricted as an aquifer because of the presence of fine grained material, primarily till; but the rest of the District has good potentially saturated thickness.

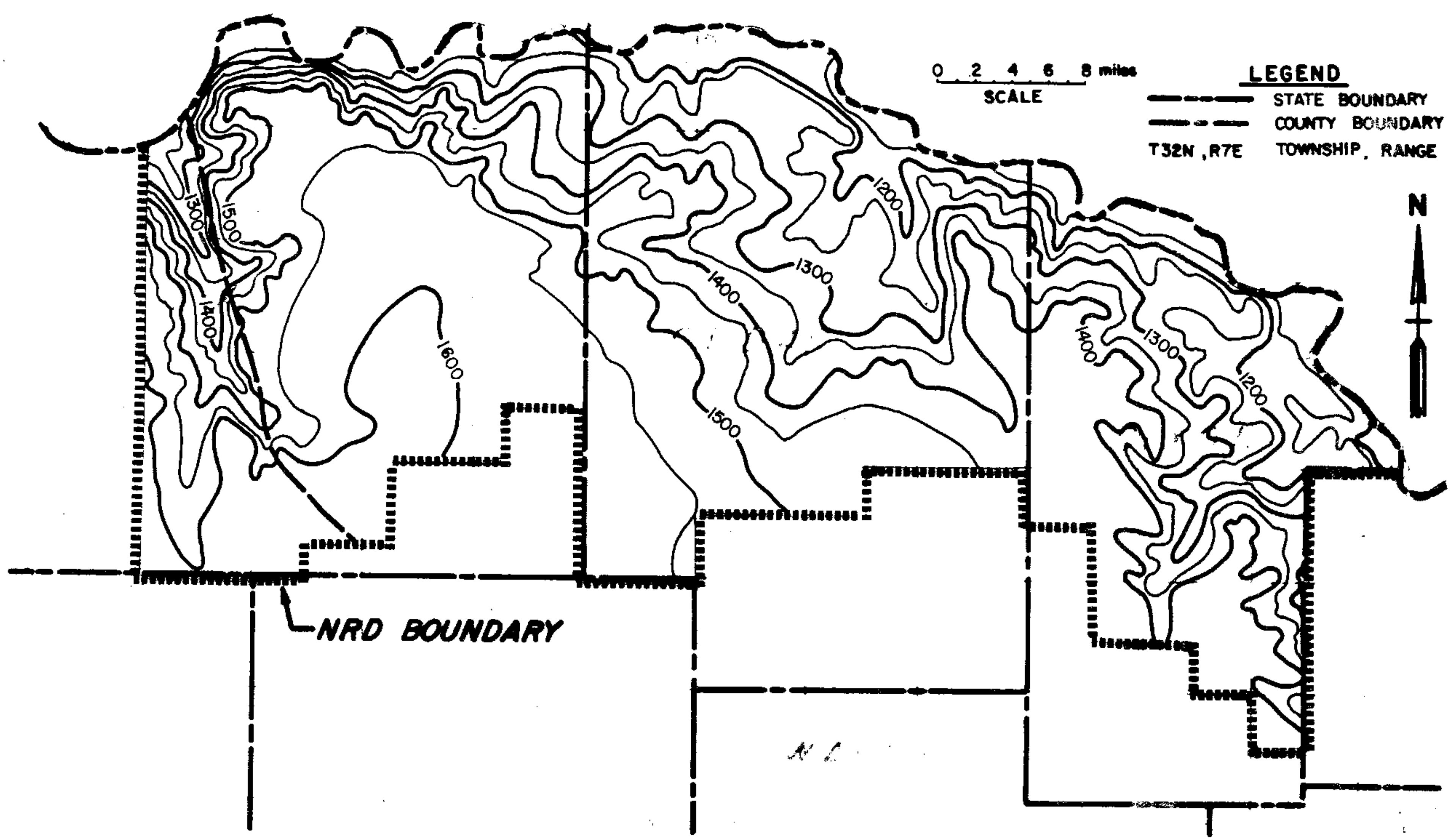
The majority of the principal aquifer is generally composed of both coarse grained material, primarily sand and gravel, and fine grained material (till, silt, and clay) and is up to 100 feet thick. Isolated spots over 100 feet deep are found in Dixon County and the entire area roughly south of a line from Bloomfield to Hartington where the District has the most groundwater use and development at present. A spot near Bloomfield and one near Pleasant Valley show a thickness over 200 feet deep. All these areas have variable thickness of porous material within the aquifer, and are not necessarily the areas of greatest availability of water. In northeast Nebraska, considerable portions of surface soils and the principal aquifer are fine grained material that yield water slowly and impede the migrations of groundwater.

The aquifer material and water table slope affect the low transmissivity or rate at which water is able to move through an aquifer. Movement of groundwater along a flow line probably is no more than 3 to 4 feet per day and in total volume has changed little from 100 years ago. Transmissivity values express the aquifers total permeability in relation to the saturated thickness and can be used to make estimates of well yield, which are generally low in this particular area. Groundwater level contours show that groundwater movement in the district runs generally east or northeast toward the Missouri River (see Map #3).

The transmissivity map (Map #4) for the District shows a large area having less than 20,000 gallons per day per foot transmissivity with the remainder showing 20,000 to 100,000. Generally those areas with values less than 20,000 gallons per day per foot are incapable of well yields sufficient for irrigation. In such areas aquifer transmissivity would seem to limit groundwater irrigation development potential. Irrigation well development has substantiated this (Registered Wells Map #5) so that a comparison of transmissivity with well development shows the limited area with potential for irrigation from the principal aquifer.

III. Depth to Groundwater Level

The distance from the ground surface to the water level is the depth to groundwater. This distance varies with season and location across the



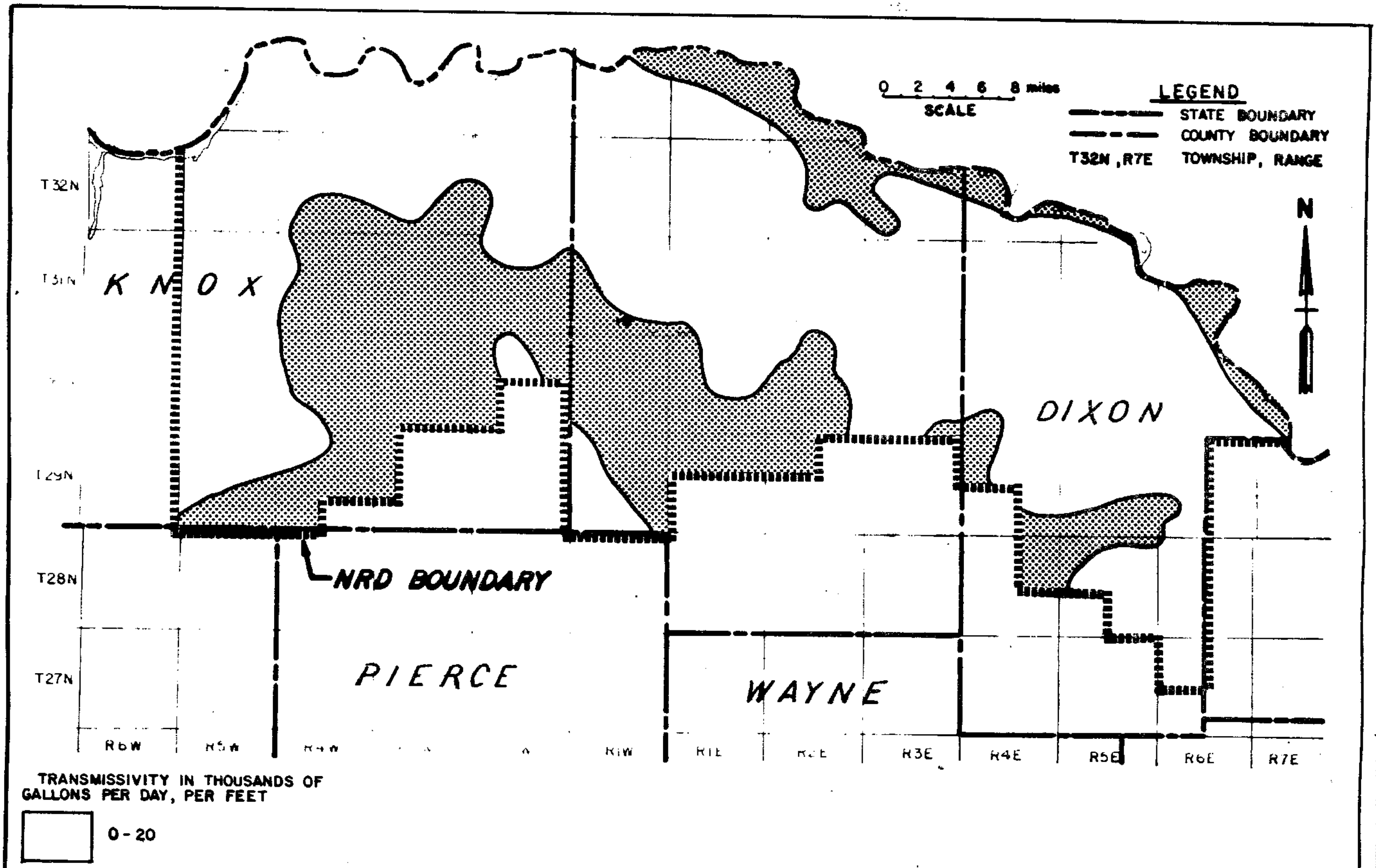
Explanation

1700

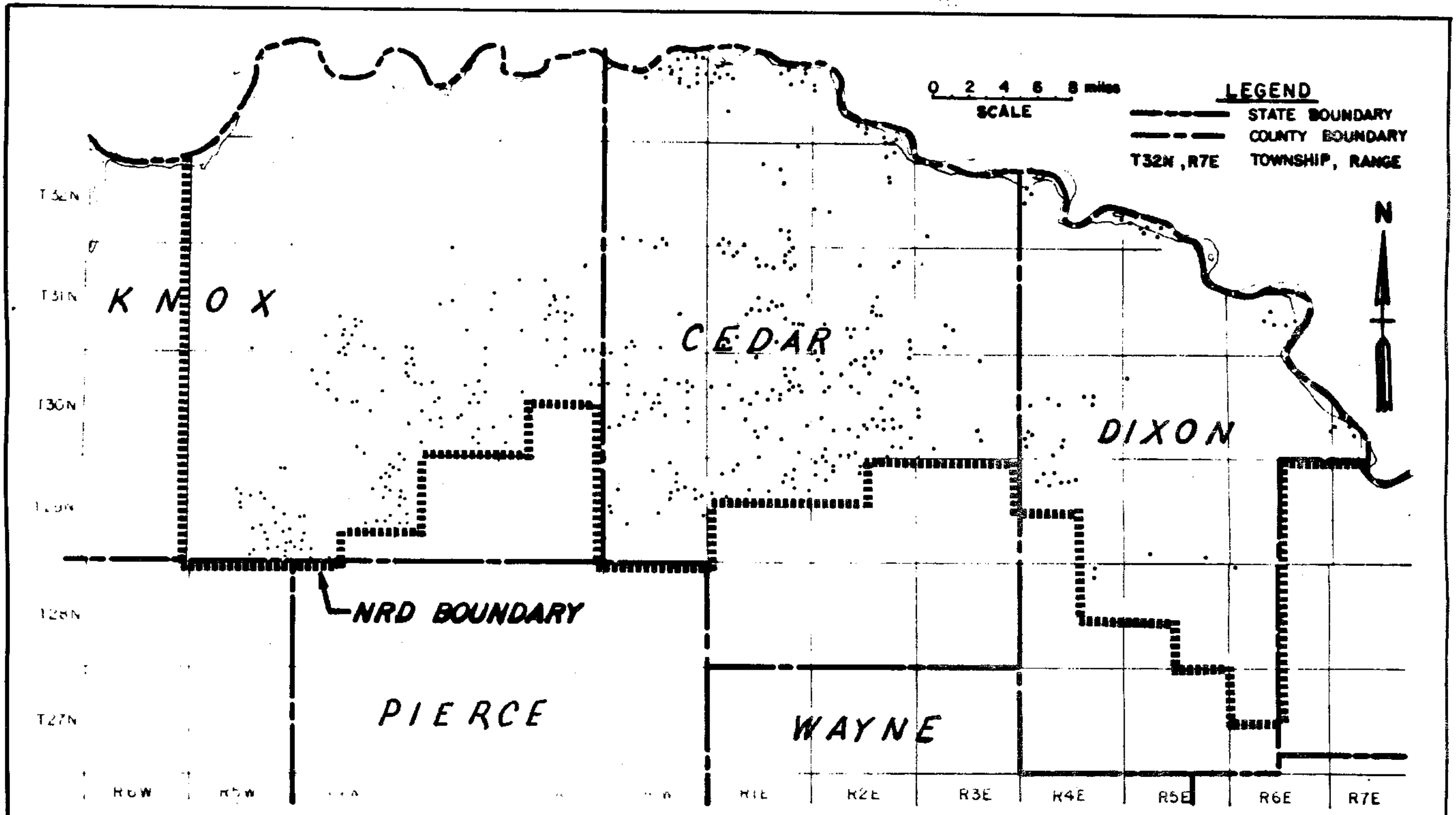
Water-table contours

Contour interval is 50 feet. Datum is mean sea level. Contours east of the dashed line represent only the level of water that might be found in shallow wells.

MAP #3 WATER TABLE CONFIGURATION OF LEWIS & CLARK NRD



MAP # 4 – Transmissivity of the Principle Aquifer in the Lewis & Clark NRD – A function of aquifer thickness and permeability, transmissivity estimates provide an indication of the productivity of an aquifer.



MAP # 5 Registered Irrigation Wells thru 12/31/84 in the Lewis & Clark NRD

District. A depth to water map by necessity must be very general (Map #6), but we can determine that in parts of northeastern Knox County and northern Cedar County we should be able to locate water at less than 50 foot depth in the Niobrara formation or Holocene sand and gravel deposits along the major streams and tributaries. Otherwise most water tables are found in the Pleistocene over a range of 50 to 200 feet deep. An area starting in the Lindy area and running southeast toward Wausa and into Cedar County has water tables of over 200 feet below the ground surface (ref Nebraska Groundwater Atlas, 1981). Throughout eastern Nebraska shallow "perched water tables" are common because of less permeable glacial till and these "pockets" of water can cause some shallower wells to have unexpectedly high water levels.

In describing the depth to groundwater for the aquifers of the District we refer to information from the Crofton Unit Geohydrologic Study, USGS, 1981. "The Pleistocene and Holocene sand and gravel deposits are thin or absent in much of the northern parts of the area, but are the source of water from wells along streams or the Missouri River and also in the area south of Hartington in Cedar County. Average water levels in the Pleistocene during 1978 ranged from 6 feet to 165 feet while saturated thickness was about 77 feet. Yields from irrigation wells ranged from 550 to 1500 gallons per minute".

The Niobrara formation underlies much of the District, and is characterized by a medium bluish-gray chalk or chalky shale that weathers to dark orange-yellowish. Many of the local people refer to it as "shale" because of its color. This formation sometimes yields sufficient good quality water for irrigation wells especially in Northern Cedar County, because solution openings and fractures store and transmit groundwater. Depths to water in the Niobrara wells range from 2 feet to 45 feet in 1978, in the area covered by the USGS study.

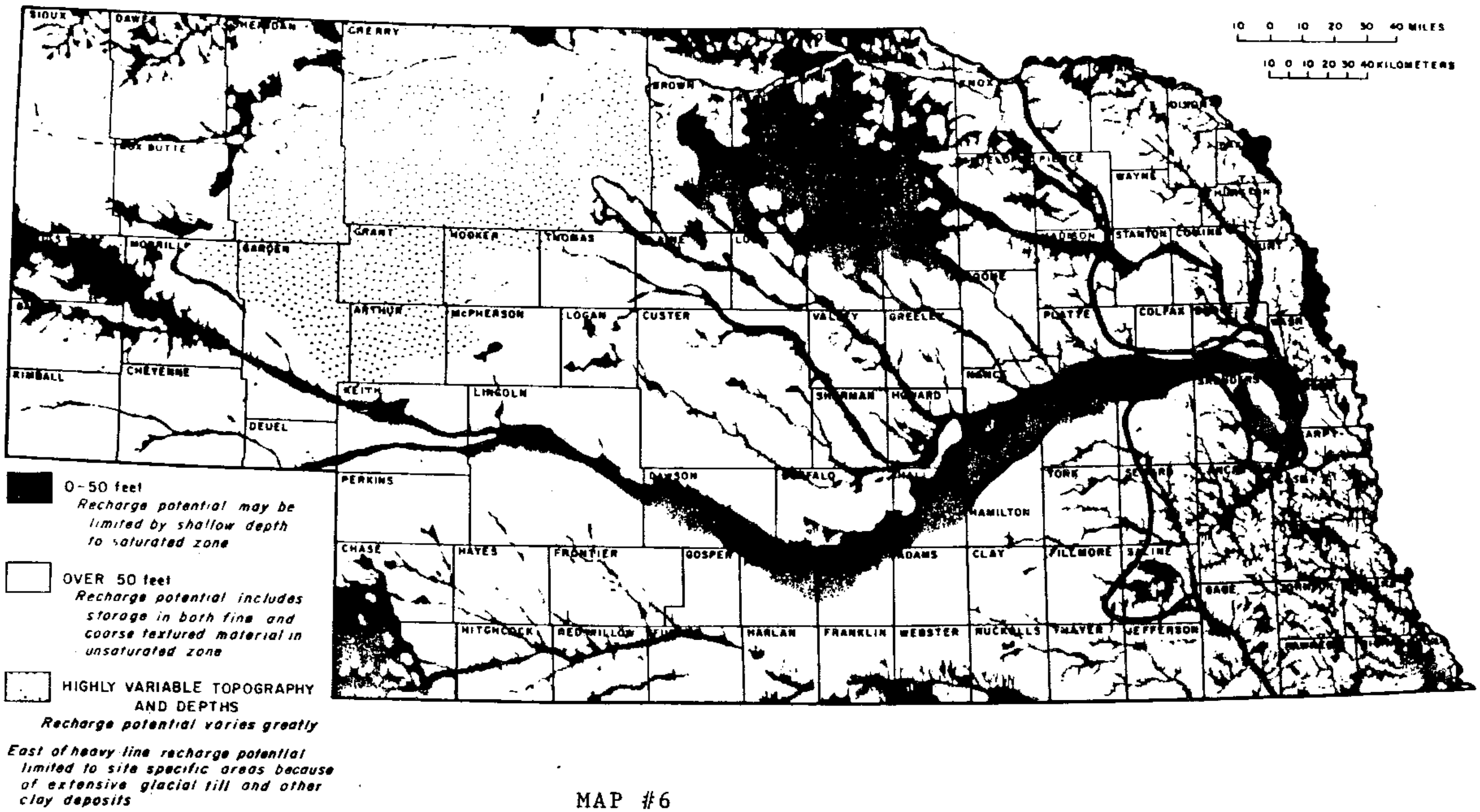
The Dakota formation underlies the shale of the Carlile, Greenhorn, and Granerous formations. It is composed mostly of fine to coarse grained yellowish white sandstone with some gray claystone and shale. It has been developed in scattered locations for domestic and livestock use and wells are generally very deep. Because of the formations confining pressure however, water rises to within less than 260 feet of the ground surface and vary to some free-flowing artesian wells.

The NRD monitor program measures static water levels twice a year at 30 sites throughout the NRD. Water levels vary from 4 feet to 290 feet in wells measured across the NRD and average 90 feet. Records kept since 1975 indicate water tables have remained fairly constant in the District. These measurements are part of a state-wide observation well data collection system as part of a cooperative program with United States Geological Survey and the Conservation and Survey Division. (ref. Groundwater Levels in Nebr., 1984). Selected examples of the well monitor hydrographs provided by U.S. Geological Survey show water level trends in some wells on Table II.

As stated earlier in this plan, site specific estimation of localized depth to Groundwater is unreliable due to the presence of local perched water tables. This plan can only present generalized information about the range of depths in the District.

IV. Recharge Characteristics and Rates

Aquifers are recharged by precipitation, runoff, and surface water



MAP #6

Generalized Depth to Water - This map was developed from a depth to water map which was produced by CSD for the NRC policy issue study on groundwater reservoir management (1982).

infiltration. The factors affecting recharge are depth to groundwater, precipitation amounts, land slope, soil types, permeability of the subsoil and storage potential.

Natural recharge takes place through precipitation falling on the land or percolating through porous soils and valley streambeds, following concentrated runoff. Well monitor levels indicate that essentially no recharge results from the Missouri River and likewise, Lewis and Clark Lake does not contribute to the natural recharge of the District because groundwater levels slope downhill towards the River.

The Pleistocene and Holocene deposits receive their recharge from precipitation. Recharge to the Niobrara formation likewise is by percolation through the overlying permeable material. The glacial till in this part of Nebraska is of low permeability and in places causes perched water tables by intercepting some recharge.

On the average, a predictable percentage of annual precipitation becomes groundwater recharge. Two important variables affecting groundwater recharge are soil and topography. By comparing the average annual precipitation (24" to 26") with typical topographic regions, an estimate of recharge can be calculated for the District. The topographic region best classifying this district is the "rolling hills" which has a recharge percentage of 1 to 5%. This would indicate that under average conditions .25 to 1.3 inches or about an inch or our annual fainfall acts as recharge in the District. Along the Missouri River Valley, the annual recharge activity would be higher because of the difference in topography. (reference Groundwater Management Plan Handbook)

The potential for accepting more water into the aquifer is moderate to excellent with some limits due to underlying glacial till. Although adequate storage potential is sometimes limited and land slope increases runoff losses, the soil structures and especially sand and gravel materials, provide generally good permeability for water absorption ranging from 1 inch per hour in clay soils to 10 inches per hour in loamy sands (ref. USGS paper #2245)

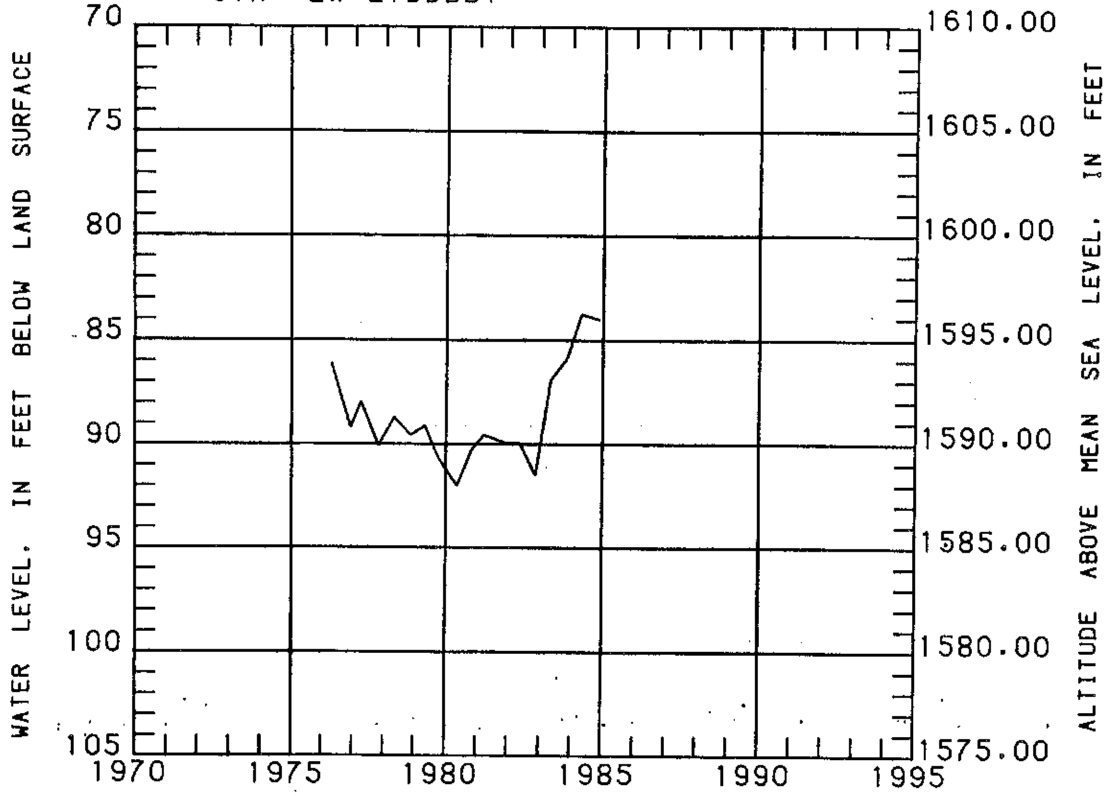
Because of the soil associations of particular parts of the NRD, recharge potential would be greater in areas where surface and subsurface soil is more coarse or sandy. From USGS paper #2222, (Hydrology Characteristics); those highly permeable soil associations would include: Bazile-Paka Thurman, Moody-Thurman, O'Neil-Meadin-Jansen, Simeon-Meadin-Betts, and Thurman-Boelur-Nora (Map #9). Properties of individual soil types are described in detail in local county soil surveys. These areas bear watching because they have excessive drainage capability allowing permeability from 5 to 14 inches per hour and have a high potential for groundwater pollution by agrichemicals or other contaminents. Other areas that might be likewise affected are soils developed over weathered Niobrara formation.

Consideration on Artificial recharge has been discussed in the District as part of the Crofton Unit Appraisal Report (Bureau of Reclamation 1979). Recharge from construction of such a project from Lewis and Clark Lake was estimated at 1,000 acre feet per month, should the project ever be built.

TABLE II

KNOX COUNTY

31N 2W 21DDBB1



CEDAR COUNTY

30N 1W 30ADBB1

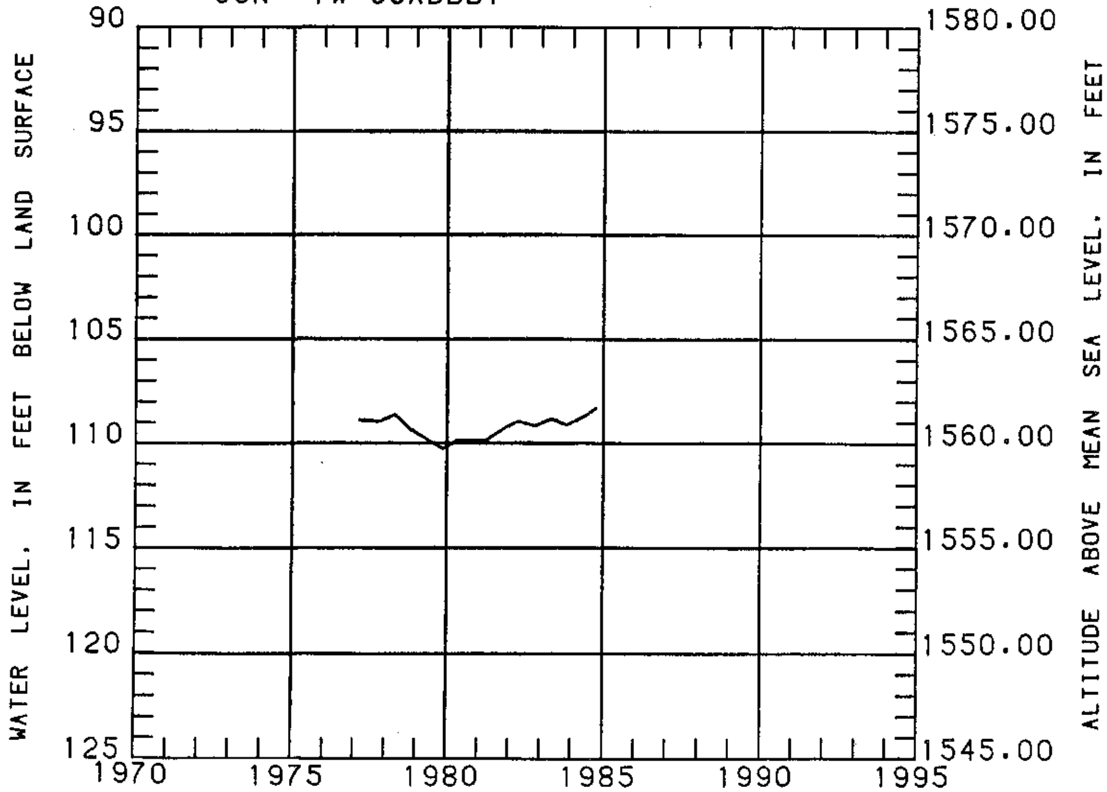
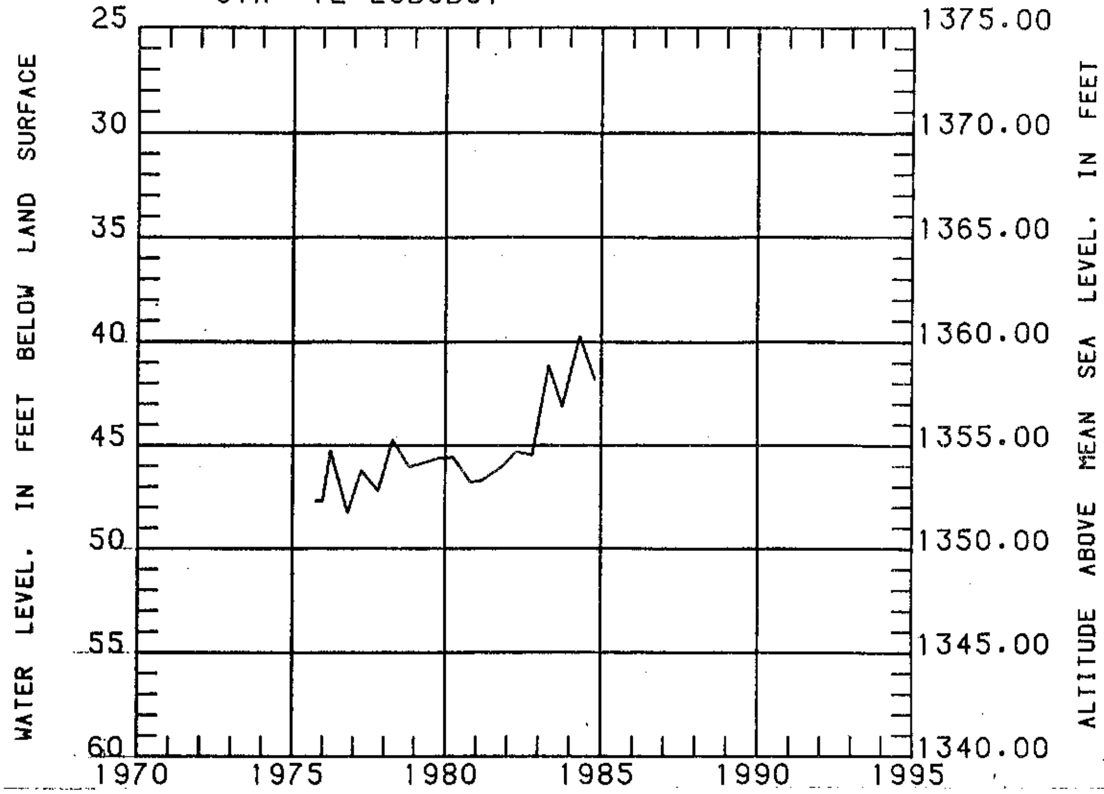


TABLE II

CEDAR COUNTY

31N 1E 25BCBC1



DIXON COUNTY

29N 4E 8ACBA1

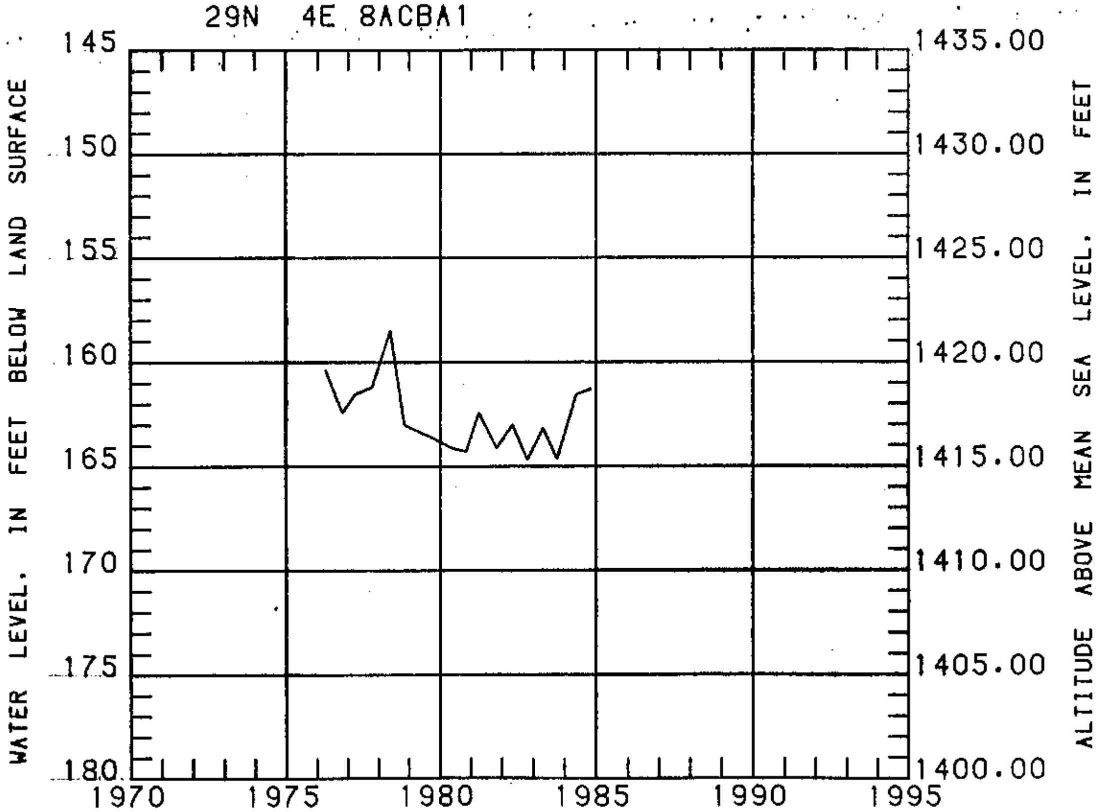


TABLE III

CHEMICALS OF DISTRICT CONCERN

CHEMICAL	STANDARD OR LIMIT (mg. per liter)	SIGNIFICANCE
Calcium		Imparts hardness to water, desirable with sodium in irrigation
Magnesium		Significantly affects hardness, desirable with sodium in irrigation
Sodium		May be harmful if on low sodium diet can be undesirable in irrigation eventually causes soil swelling and reduces tillability
Potassium		Essential in animal nutrition, may or may not be soluble
Alkalinity		Bicarbonate, has capacity to neutralize acidity
Sulfate	250	Contributes to salinity in irrigation, may have laxative affect
Chloride	250	Contributes to salinity in irrigation, causes salty taste in water
Silica		Found in sand aquifers, plant nutrients, contributes to boiler scale
Nitrate-Nitrogen	10	Health hazard for infants, common human pollution result
Iron	.3	Stains laundry and fixtures, causes discoloration and taste
Manganese	.05	stains laundry and fixtures, causes discoloration and taste
Selenium	.01	micronutrient, but toxic in higher concentrations
Phosphorus		essential nutrient, not likely toxic
Fluroide	1.7	beneficial to teeth in amounts of

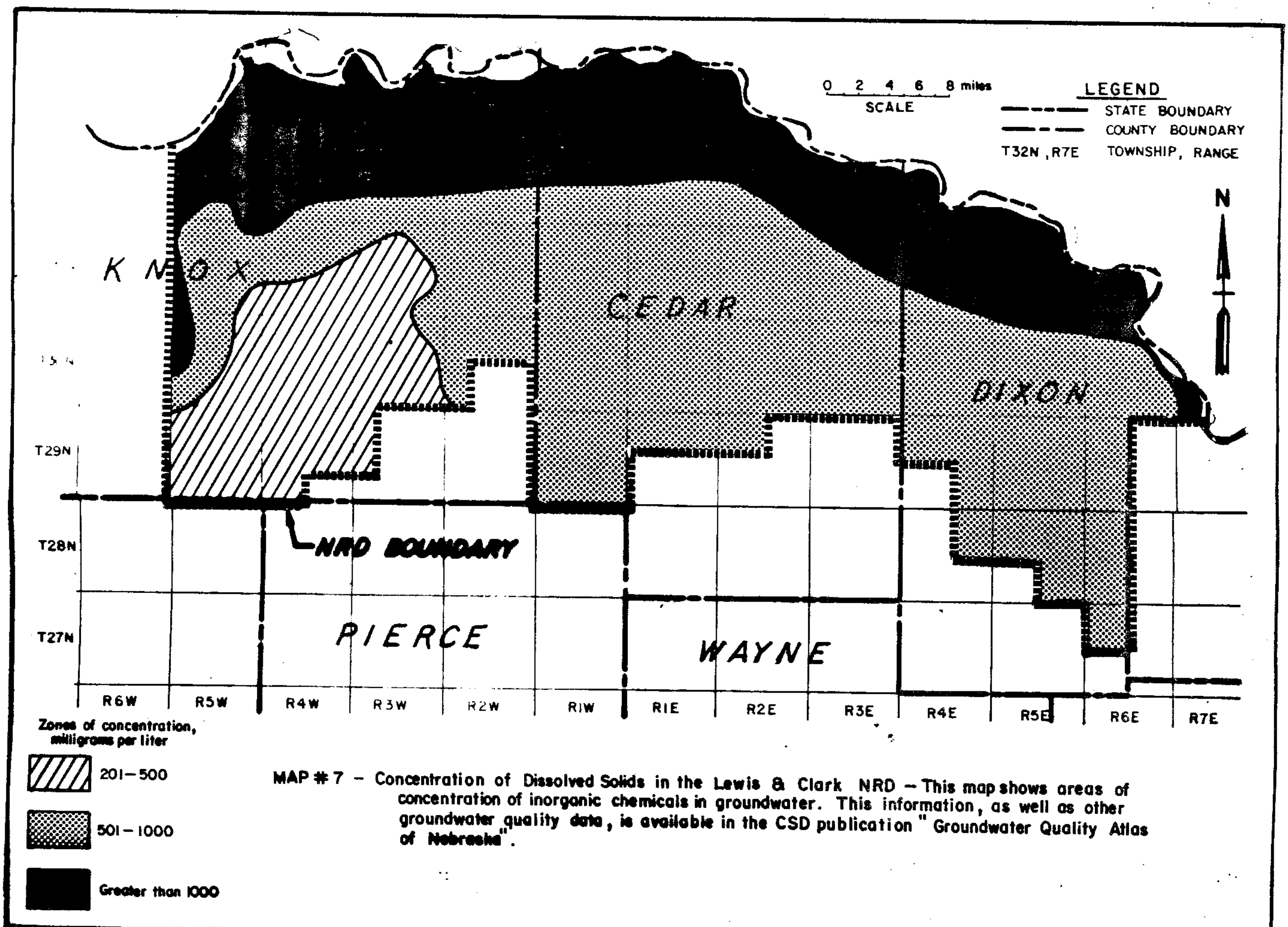
V. Groundwater Quality

The Lewis and Clark NRD considers the quality of our groundwater its most serious concern. Water quality "standards" are recommended safe limits for some chemical constituents and desirable limits for others. Standards for some constituents differ depending on intended use. Precipitation as it runs off or percolates into the ground is altered by reaction with mineral and organic substances in the soil and vegetation to form different characteristics affecting water quality. The more permeable the soil, the less the opportunity for chemical reaction and the better the quality of the infiltrated water. This report will review the major chemicals found in the groundwater reservoir, safe levels and significance for each, and indicate the concerns that need be addressed.

Most groundwater in the principal aquifer is of good to excellent quality. Generally, water low in chemical content or "total dissolved solids" is suitable for most uses, while very mineralized water is considered unsuitable for many uses. Amounts of total dissolved solids in this District run higher than most areas of the state, ranging from 200 to over 1,000 mg/l (see Map #7). The higher concentrations of greater than 1,000 are mostly found north of Highway #12. High concentartions of over 500 mg/l can create salinity problems harmful to irrigated crops.

The major dissolved solids are calcium, magnesium, sodium, potassium, bicarbonite or alkalinity, sulfate, chloride, and silica. This plan will also include nitrate, boron, iron, manganese, selenium, phosphorus, and fluoride.

Table III is a list of chemical properties of concern in the District (ref. USGS #2245).



MAP # 7 – Concentration of Dissolved Solids in the Lewis & Clark NRD – This map shows areas of concentration of inorganic chemicals in groundwater. This information, as well as other groundwater quality data, is available in the CSD publication "Groundwater Quality Atlas of Nebraska".

The chemicals of chief concern to the NRD and found regularly (ref. Groundwater Quality Atlas, 1978) are: calcium and magnesium, which affect hardness, and are generally greater than 360 mg/l throughout most of the District; sodium plus potassium, which are found in concentartions of over 50 mg/l around Wausa and along the Missouri River Bluff areas; and iron and manganese, usually found concurrently and considered nontoxic but objectionable.

Within the District, known isolated point source pollution problems have arisen near Center (hydrocarbons) and near Hartington (chloride) (ref. Nebraska Water Quality Strategy, 1985).

The sodium hazard of irrigation waters is indicated by the Sodium Absorption Ratio (SAR). The SAR indicates the extent to which irrigation water will replace absorbed calcium and magnesium on soil and clay particles with sodium. Sodium absorption causes soil swelling and reduces tillability, eventually rendering soils unfit for crop production. Water with an SAR of less than 10 units is classified as low sodium hazard. Such water is suitable for irrigation on almost all soils and crops except very sodium-sensitive ones. For all groundwater in the central NRD, the sodium hazard is minimal. (ref. USGS 81-58).

Also of growing serious concern is groundwater contaminated with nitrate-nitrogen occuring at scattered locations throughout the District. Because of the hazardous side effects of methemoglobinemia, a blood disorder in infants, water having more than 10 mg/l of nitrate-nitrogen is considered a serious threat to rural and municipal supplies. The effects of nitrate-nitrogen on livestock is also of concern, although water containing less than 100 parts per million is normally safe (ref. Crowley Research Paper #80-2026). Contamination of groundwater is usually the result of the leaching of livestock or human wastes, fertilizer, or other agriculture chemicals.

To complicate this problem, records of testing done by the Department of Health to show the exact location where nitrate problems have occurred in the District are not publicly available, for reasons of privacy, to the individual well owners tested. General results from the testing does indicate nitrate presence, however. 1984 saw 63 samples tested in Cedar County with 28 having concentrations over 10 mg/l, Knox County had 89 samples tested with 38 having high concentrations, and Dixon County had 10 samples out of 19 that showed high nitrate. This data is inconclusive because it merly indicates sample results and cannot be separated out for the NRD, for types of wells or number of samples from the same well. Unverified reports of individual problems, are mostly found where the aquifer is being more utilized for irrigation and groundwater development in southern Cedar County and southeast Knox County. Reports have also come however, from the Lindy area and isolated farm wells at various locations.

Water tables have risen in past years in many places, causing a mixing of groundwater with contaminated recharge water that has affected shallower wells. Because concentrations vary widely with several factors, the present data does not allow us to portray zones of nitrate in groundwater. Attention needs to be given to prevention measures and better identification of existing problem areas, because methods to get rid of nitrates involve expensive and sometimes ineffective treatment or locating an alternate supply source. Results of the Hall County Report on Nitrates and Irrigation Managment show that with intensive irrigation

TABLE IV

--Chemical quality of ground water, 1978

[umhos = micromhos per centimeter at 25 degrees Celsius; mg/L - milligrams per liter; Mg/L = micrograms per liter]

Well number	Date of sample	Total depth of well (feet)	Specific conductance (umhos)	pH (units)	Hardness (mg/L as $CaCO_3$)	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Sodium adsorption ratio	Potassium, dissolved (mg/L as K)	Bicarbonate (mg/L as HCO_3)	Sulfate, dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)	Solids, residue at 180° C., dissolved (mg/L)	Nitrogen, NO_2+NO_3, dissolved (mg/L as N)	Boron, dissolved (ug/L as B)
Water from the Dakota Formation																
31N-1E-13DDB1	78-08-09	820	1,760	7.3	770	240	41	130	2.0	24	266	750	58	1,330	0.00	410
32N-2E-12CBC1	78-08-22	520	1,610	7.3	770	240	42	51	.8	18	83	730	55	1,320	.01	110
32N-2E-24BC1	78-07-27	288	1,510	7.5	770	240	42	42	.7	19	180	650	43	1,210	.57	160
32N-2W-15DC1	78-08-09	746	1,560	7.4	820	260	41	59	.9	17	211	690	54	1,230	.01	140
33N-2E-30BD2	78-07-27	515	1,560	7.3	830	260	44	44	.7	17	196	690	48	1,250	.13	140
33N-2W-27DAC1	78-08-09	900	1,420	7.3	780	240	44	60	.9	21	220	630	61	1,140	.36	360
Water from the Niobrara Formation																
30N-1E-14BCB1	78-08-02	105	644	7.3	330	93	23	18	.4	8.3	378	57	4.5	359	.29	80
31N-2E-22BCDD1	78-08-02	87	879	7.0	480	160	19	19	.4	6.0	474	120	8.7	592	.17	100
31N-2E-30ADA1	78-08-03	77	740	7.2	390	140	10	6.3	.1	4.5	368	100	2.8	447	.15	50
31N-1E-21CAA1	78-08-02	100	619	7.3	310	90	21	14	.3	7.5	344	61	2.8	347	.42	70
31N-1E-25BCB1	78-08-01	100	637	7.2	320	94	21	18	.4	5.4	343	75	5.3	307	.06	80
31N-1E-36BB1	78-07-26	84	739	7.5	350	100	25	21	.5	7.5	345	92	20	470	.20	60
31N-1W-4ABAD1	78-07-26	98	695	6.9	330	95	23	21	.5	10	294	140	2.1	452	.06	120
Water from both the Niobrara Formation and Pleistocene deposits																
31N-1E-4DDB1	78-08-08	104	1,650	6.7	1,000	380	19	18	.2	4.9	502	630	2.7	1,100	.27	80
32N-1E-1BBD1	78-08-08	100	1,970	6.9	1,300	420	49	29	.4	12	376	970	5.2	1,710	.70	260
32N-1E-22DCCC1	78-07-27	100	2,040	6.6	1,300	480	26	28	.3	10	642	810	6.2	1,760	.11	190
32N-1E-32CCD1	78-08-07	105	1,310	7.0	590	190	29	22	.4	9.5	445	270	5.0	640	.25	120
33N-1E-30DDD1	78-08-09	85	1,840	6.8	1,100	370	42	29	.4	12	520	680	26	1,270	.85	180

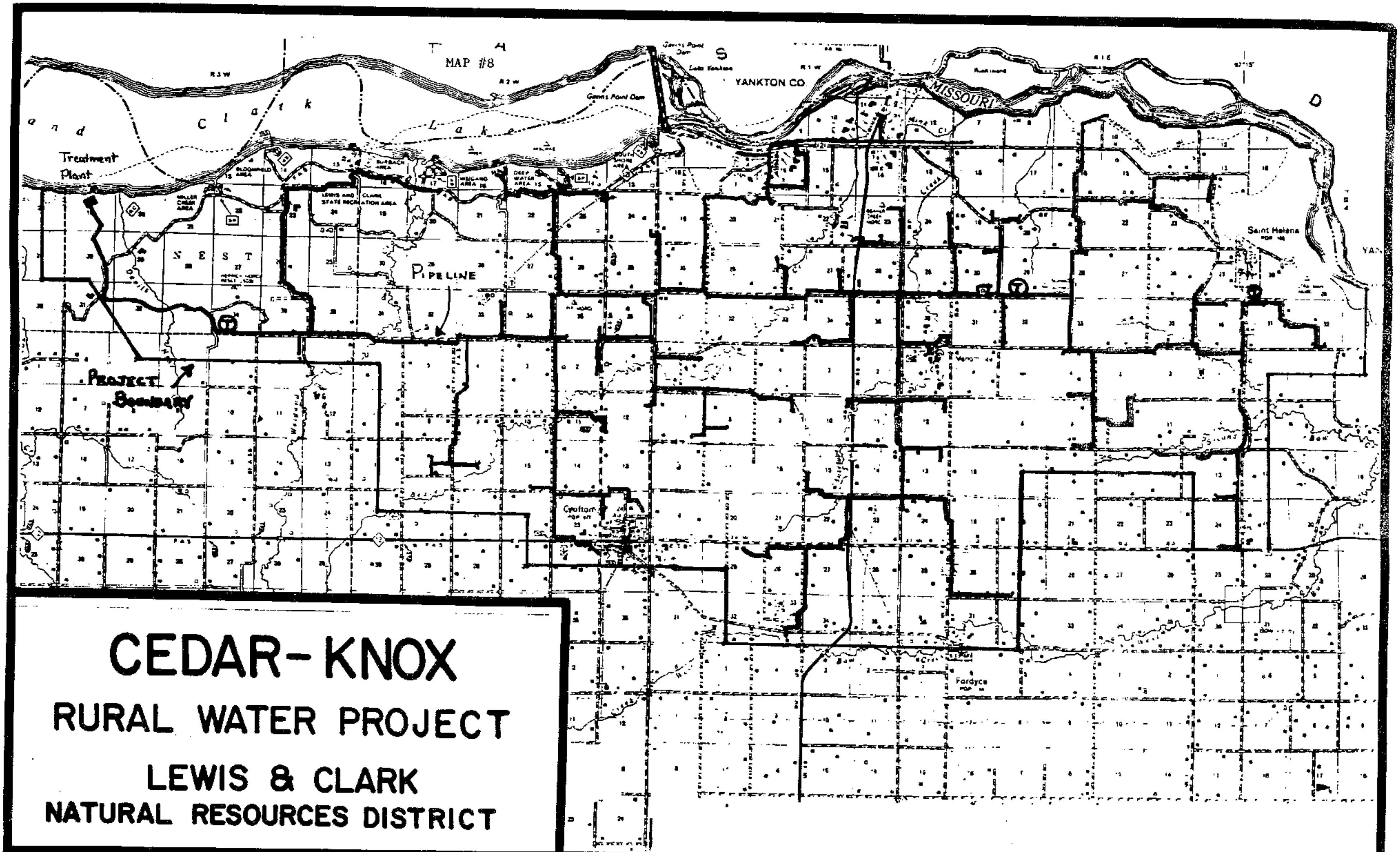
Source--USGS #81-58

TABLE IV - continued

Table 4.--Chemical quality of ground water, 1978--Continued

Well number	Date of sample	Total depth of well (feet)	Specific conductance (umhos)	pH (units)	Hardness (mg/L as $CaCO_3$)	Calcium, dissolved (mg/L as Ca)	Magnesium, dissolved (mg/L as Mg)	Sodium, dissolved (mg/L as Na)	Sodium adsorption ratio	Potassium, dissolved (mg/L as K)	Bicarbonate (mg/L as HCO_3)	Sulfate, dissolved (mg/L as SO_4)	Chloride, dissolved (mg/L as Cl)	Solids, residue at 180° C., dissolved (mg/L)	Nitrogen, NO_2+NO_3, dissolved (mg/L as N)	Boron, dissolved (ug/L as B)
Water from Pleistocene or Holocene deposits																
29N-2E-3CCCC1	78-07-26	195	755	7.2	380	110	26	18	0.4	6.0	351	110	4.8	486	5.4	60
30N-3E-31ADD1	78-08-07	169	979	7.3	340	96	24	26	.6	4.8	220	41	2.2	529	49	80
30N-2E-3BBD1	78-08-22	150	589	7.3	280	81	18	15	.4	6.0	261	75	2.4	393	5.9	40
30N-2E-8CCCD1	78-08-01	117	659	7.2	340	96	25	19	.4	5.6	320	110	2.8	445	2.9	70
30N-2E-12ACC1	78-08-03	147	863	7.2	350	100	25	19	.4	4.8	221	110	3.0	512	28	60
30N-2E-27AAA1	78-07-26	188	622	7.1	300	84	21	19	.5	4.9	316	66	2.5	386	3.5	60
30N-1E-7CCD1	78-08-01	147	701	7.4	350	95	27	16	.4	15	350	100	3.8	430	1.6	100
31N-2E-1CCC1	78-08-22	60	1,390	7.1	680	210	38	18	.3	17	421	370	7.1	979	.17	140
31N-2E-2DDC1	78-08-22	35	1,165	7.2	630	200	32	22	.4	17	497	270	4.3	722	1.5	140
31N-1W-13DDD1	78-07-26	80	667	7.8	320	92	22	20	.5	5.4	347	59	6.3	435	4.4	40
31N-2W-13BCB1	78-08-09	120	1,190	7.0	610	170	46	38	.7	10	419	330	7.3	880	3.2	90
32N-2E-29BDB1	78-08-08	55	1,650	6.8	1,000	360	27	24	.3	8.1	421	670	15	1,230	2.3	130
32N-2E-32DAC1	78-08-01	65	1,910	6.7	1,200	380	67	26	.3	33	704	710	4.3	1,440	.13	680
32N-2E-32DAC2	78-08-01	100	2,620	6.7	1,700	560	70	37	.4	17	627	1,100	67	2,370	9.4	300
32N-1E-8CCD1	78-08-08	100	509	7.3	250	78	13	12	.3	2.1	262	24	2.7	314	9.3	20
32N-1E-14BAB1	78-08-22	23	1,070	7.2	580	200	20	17	.3	7.8	314	310	14	792	7.9	60
32N-1W-4BCC1	78-08-23	35	1,470	6.7	800	290	18	17	.3	9.8	456	450	3.1	986	.08	190
32N-1W-20ACBB1	78-07-26	22	894	7.4	400	120	25	23	.5	4.6	244	41	26	705	50	30
32N-2W-18ACA1	78-08-09	65	970	7.1	520	89	72	38	.7	9.8	437	120	34	645	23	110
33N-2E-34CBC1	78-08-08	65	1,220	7.3	660	170	56	72	1.2	9.4	508	370	10	777	2.1	170
33N-1E-11DCA1	78-08-08	73	1,358	7.4	630	170	49	83	1.4	12	532	340	12	901	4.1	190
33N-1E-17BBD1	78-07-27	55	1,170	7.3	610	180	39	23	.4	8.3	465	270	5.6	782	.09	120
33N-1W-10CCB1	78-08-09	54	1,146	7.1	630	200	32	27	.5	9.0	444	310	4.0	720	2.5	110

Source--USGA #81-58



MAP #8
YANKTON CO.
MISSOURI
Lewis and Clark Lake
Treatment Plant
Pipeline
Project Boundary
Gavins Point Dam
Saint Helena
Crofton
Fordyce
CEDAR-KNOX
RURAL WATER PROJECT
LEWIS & CLARK
NATURAL RESOURCES DISTRICT

MAP # 8

(ref. MP-42). However, probability of receiving a trace or less every two weeks during that same growing season period ranges from 5% May 1st, to 0% around June 1st, up to 29% in mid September (MP-10). These variations tell us that groundwater used for agriculture will be in most demand during the months of July, August, and September and that rainfall probability decreases steadily after June 1st.

VII. Surface Water

Because surface water is a possible source of supply to supplement groundwater, it must be considered in the management plan. The major surface water source in the District is the Missouri River. The Department of Water Resources has gaging stations on the river as well as the two main tributary streams in the District, the Bazile Creek in Knox County and Bow Creek in Cedar County (Ref. Water Resources Data, Nebraska).

Because the Gavins Point Dam makes annual adjustments based on flood control and navigation needs, discharge amounts vary. Average river flow taken downstream at the station on the Meridian Bridge was 25,000 cfs for calendar year 1981. Average flow in the same period for Bazile Creek taken at the station on Highway #12 was 36.5 cfs per year. While Bow Creek records indicate 26.4 cfs per year was at the station on Highway #12, which would probably be insignificant for supplementing groundwater supplies.

The Lewis and Clark Lake above Gavins Point Dam is the largest source of surface supply in, or adjoining, the state of Nebraska. In the Crofton Unit Appraisal Report, 1979, the Bureau of Reclamation stated that average annual flow through the Lake was 26,000 cfs over the last 40 years or about 18.9 million acre-feet per year. An irrigation project from the lake would be feasible and economically justified, according to the reference. The lake itself covers 32,000 acres. Quality of the water is good to excellent and the District presently uses this source as a supply for the Cedar-Knox Rural Water Project. Annual project consumption since its start in 1981 has run about 55 to 60 million gallons per year, with expansion treatment capability in place for providing up to 140 million gallons per year. Although ample supply is available, financial limits of potential users may prevent further expansion of service. (see rural water district map #8)

VIII. Supplemental Sources

Supplemental sources of water are amounts added to the existing supply to make up for insufficient quantities. Examples would be surface water, which was covered in the previous Section VII or water brought from a distant or deeper aquifer.

In the Natural Resources Commission's Supplemental Water Supplies Policy Issues Study, mention is made of the off stream storage capabilities that were components of the Crofton Unit Report. Structures for storing 74,300 acre feet in West Bow Creek and 78,500 acre feet on Pearl Creek were considered in one alternative of that plan by the Bureau of Reclamation. The study also mentions the Bazile Creek again, indicating an annual supply available of 48,690 acre feet, but adds that the stream had gone dry near the mouth during drought years, an occurence affecting nearly all streams in the District.

Both the Natural Resources Commission and the Bureau of Reclamation indicated that capacity for increasing irrigation development is present in the District by making use of supplemental water supplies. However, economic factors at present have put constraints on such development, although future considerations may differ. The Missouri River really is the only major source of supplemental supply since the District has only streams and no rivers to utilize. Locally, this fact was recognized in the Cedar County Comprehensive Water and Sewer Plan, 1969, which suggested county wide rural water systems for farm and community domestic use because of the difficulty finding good supplies of groundwater for all purposes.

IX. Existing Groundwater Uses

An inventory of existing use needs to be reviewed to determine what the present demand is on groundwater.

The Natural Resources Commission in Groundwater Reservoir Management, 1982, has some positive things to say on that subject; "the principal aquifer in portions of Nebraska has quantities of groundwater in storage that appear to exceed use-demands over any forseeable period." In this portion of Nebraska, most of the District in 1979 showed that annual recharge from precipitation exceeded the level of irrigation usage. Under realistic projections of development, there is a high potential for utilization without a major impact on the aquifer. Even partial depletion, if anticipated, need not have a significant impact over more than a local area.

Groundwater stored in the principal aquifer is part of an active hydrologic system. Subsurface flow within the aquifer is usually too slow to move into withdrawal areas so that recharge is by precipitation. Under natural conditions the recharge and discharge balance. Withdrawal by pumping results in a combination of decrease in storage, increase in recharge, and decrease in discharge. This means the acutal amount withdrawn will not usually result in a corresponding loss in volume of the amount in storage. In other words, unless use develops to an unforseeable high amount, recharge from precipitation should balance withdrawals and discharge over most of the district over the long term.

By far the greatest use of groundwater in the District is for irrigation. In 1985, there were 479 irrigation wells registered, 26 municipal, and 4 industry in the Lewis and Clark NRD. Land suitability for irrigation is high in most areas, but much of the aquifer is fine grained and provides only low yields of groundwater so that irrigation is not extensive and confined to areas where groundwater is more available and can be found in quantity. Most irrigation in the District is utilized through center pivot systems. In 1984, there were 330 pivots in the Lewis and Clark NRD.

The SCS prepared Multi-Year Plan provides an indication of potential irrigation development. Their figures show over 58,000 acres irrigated in 1985 or 6% of the total cropland acres. That has the potential to increase to 126,000 acres (14%) in 20 years or a maximum of 286,916 acres (31%) that could be irrigated. Other factors such as economics and water availability will affect whether such development takes place.

The available amounts of groundwater as discussed earlier is variable in the District. In "Availability and Use of Water, 1975", Conservation and Survey #48, mention is made that in subregion #3, which includes the Lewis and Clark NRD as well as the other Missouri Tributaries region, there is about 13,000,000 acre feet in storage which if averaged out for depth, would equal about 6.91 feet of water. In this district, however, (49% of sub #3) the amount of acre feet present in the aquifer is estimated to be about 6,300,000 and the depth in feet ranges from less than 4 feet along the Missouri Bluffs area to 20 to 40 feet in parts of south central Knox County and south western Cedar County. Since some measure of groundwater use is required for this plan, some of the information from this reference will be interpolated to provide an estimate of use.

The same source listed above described 1975 usage at 54,300 acre feet for subregion #3 (Missouri Tributary subregion) which is about 9 times greater than the amount of surface water used for irrigation. There were 215 irrigation wells drilled in Lewis and Clark NRD through 1975, most used on center pivot systems. From percentage calculations for the NRD, we can estimate in 1975 that about 70,000 to 80,000 acre feet (1.2%) left the District through natural discharge to evapotransportation and streams, and an estimated 35,000 (.5%) acre feet was actually used for irrigation, public supplies, livestock, and rural domestic use for a total use or loss of about 110,000 acre feet. Again estimating the figure of 6,300,000 acre feet (approx.) as the total storage, there was only about 1.7% that was used or lost annually. Comparing this use to the recharge rate discussed earlier of 1" per year over the 933,660 acres of the District would give us an average recharge per year of 75,000 acre feet (1.2%), or twice more than the amount used under average conditions, and about equal to the total amount lost to use and natural discharge. Based on this estimation, this would tell us that in 1975 recharge and discharge were about equal and only about .5% of the aquifer was used. It is interesting to note here that we effectively use each year something less than half of what is lost through natural discharge.

Water use has likely increased since 1975, however, a comparison of municipal water use alone in the District from 1979 to 1980 showed an increase from 673 million gallons to 784 million. Even the irrigation wells have more than doubled since 1975. Well monitor records kept by the NRD however, do not indicate that increase has depleted any of the supply.

In determining where water gets used in the District, a breakdown of the 35,000 acre feet per year shows that irrigation uses about 26,800 acre feet (77%), rural domestic and livestock, 6,400 acre feet (18%), and public supplies 1,800 acre feet (5%). This give us an indication of the types of use, the magnitude, and amount (ref: Conservation and Survey #48). The only coordinated use from a different source is the Cedar Knox Rural Water project which supplies treated surface water for rural domestic, livestock, and public use and provides supplemental amounts of 17 acre feet per year.

X. Subirrigation

Subirrigation is the process by which growing plants obtain water from saturated subsoils, resulting from high water tables. In reviewing U.S. Corps of Engineers Wetland Atlas, there are small areas of marsh and riparian wetlands, usually adjoining the Missouri River or its tributary streams, but there are essentially no significant subirrigated areas in the District to merit consideration for this plan.

TABLE VI

AVERAGE EXPECTED CROP WATER USES IN NORTHEAST NEBRASKA

(CROP USE VALUES IN INCHES/WEEK)

WEEK	DATE	ALFALFA	CORN	SOYBEANS
1	4/1 - 7	0.65	–	–
2	4/8 - 14	0.85	–	–
3	4/15 - 22	1.00	–	–
4	4/23 - 28	1.00	–	–
5	4/29 - 5/5	1.05	–	–
6	5/6 - 12	1.10	–	–
7	5/13 - 19	1.30	0.80	–
8	5/20 - 26	1.35	0.90	–
9	5/27 - 6/2	1.40	1.05	0.30
10	6/3 - 9	1.50	1.55	0.35
11	6/10 - 16	1.55	1.55	0.45
12	6/17 - 23	1.60	1.60	0.65
13	6/24 - 30	1.65	1.85	1.00
14	7/1 - 7	1.70	1.90	1.40
15	7/8 - 14	1.75	2.00	1.85
16	7/15 - 21	1.70	1.85	1.75
17	7/22 - 28	1.65	1.70	1.70
18	7/29 - 8/4	1.50	1.40	1.25
19	8/5 - 11	1.45	1.40	1.20
20	8/12 - 18	1.50	1.45	1.25
21	8/19 - 25	1.45	1.40	1.05
22	8/26 - 9/1	1.40	1.10	0.60
23	9/2 - 8	1.20	0.75	0.40
24	9/9 - 15	1.15	0.60	0.20
25	9/16 - 22	1.05	0.35	–
26	9/23 - 29	1.00	0.25	–
27	9/30 - 10/6	0.80	–	–
28	10/7 - 13	0.75	–	–

Note: A killing frost will effectively stop crop water use for the season.

These figures represent averages, their accuracy for a particular week are not guaranteed, these are guide lines (see scheduling method). Crop water use can vary by variety, plant population, and weather. Soil moisture monitoring of some kind is recommended.

Allow for some losses in irrigation efficiency.

Source — University of Nebraska

XI. Crop Water Needs

In attempting to analyze the groundwater needed by crops, many variables enter in the determination. The average length of the frost free period is 162 days (April 29 - October 8). Besides climate discussed earlier, "growing degree days" provide information pertaining to how temperature affects the ability of crops to grow and consequently the water needed.

Growing Degree Days is another way to say that "a certain number of days" over 50 degrees Fahrenheit temperature (40 degrees F for oats) are needed to grow most crops. The number of days plus the number of degrees over 50 degrees each day accounts for that number; which for 90 day corn is 2200 GDD and for 120 day corn is 2800 GDD in Cedar County. The number of GDD for this district between average dates of 32 degree days in spring and fall ranges from 2700 in central Knox County to 3000 in eastern Dixon County. This tells us that the temperature is cooler and growth rates slightly slower from east to west in the District and Nebraska as well. In other words the crop water need is "slightly less as one goes west", and the resulting need for groundwater is greater in eastern areas of the District.

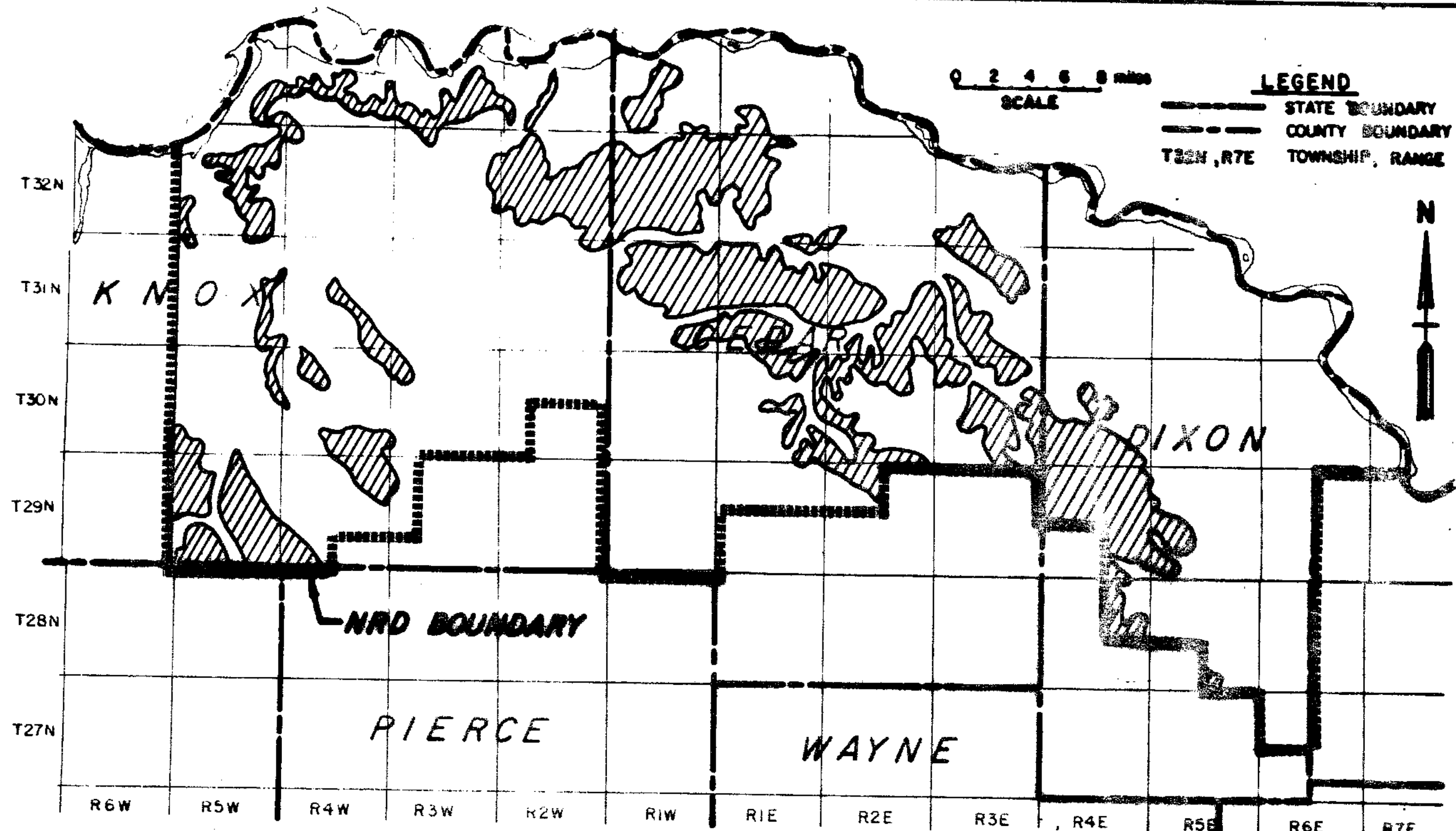
Other methods were used to determine crop water needs. The Nebraska Irrigation Guide, SCS, indicates the net irrigation needed to raise corn and sorghum 10 out of 20 years. In the Lewis and Clark NRD 10 to 11 inches were necessary for a maximum corn crop in that time period while sorghum took about 9 inches. A Water Requirement Study of the North Loup Division also gave some indications on crop irrigation requirements or amounts above precipitation needed for a full crop. Crop water use does vary with the crop and soil type. Sandy soils for instance require more water than heavier soils. The average water extraction depths for different crops are alfalfa, 8 feet; corn, 6 feet; and small grains, 4 feet. Table VI gives an interesting average of cropwater use in inches per week.

Because irrigation use is not extensive in the District, crop water use is not a subject that carries much significance to this plan.

XII. Economic Value of Existing Groundwater Uses

The Groundwater Management Plan Act requires a determination of the economic value for uses of groundwater, but there is little information to base that determination on. As discussed earlier, existing uses include irrigation 77%, rural domestic and livestock, 18%, and municipal, 5%.

Since irrigation comprises a major portion of the groundwater use, it needs to be considered for its economic value. The Crofton Unit Appraisal 1979, researched this in its economic analysis based on local farm budgets and their net income. Comparisons were made on variations with and without irrigation to calculate benefits, and projections made to the year 2020. Since corn is the principal irrigated crop, the report figures showed 1971 variations in yield for Cedar County from dryland at 47 bushels per acre to irrigated at 98 bushels per acre. The year 2020 showed variations in yield for Cedar County from dryland at 70 bushels per acre to irrigated at 175 bushels per acre. Without going into the details here on prices paid and received as well as production costs, the report indicated an irrigation benefit of $164 per acre on irrigated compared to



Soil Associations having excessive drainage and more likely to show contamination from surface leaching.

Soil Associations less likely to show contamination from surface leaching.

MAP # 9 SOIL ASSOCIATIONS

dryland.

For irrigation use, other comparisons can be inferred from the Estimated Crop and Livestock Production Costs EC 84-872. The availability of groundwater that could be utilized for irrigating corn made possible expected yields in Northeast Nebraska of 130 bushels per acre, compared to similar tests on dry land with expected yields of 75 bushels per acre. A similar comparison for irrigated soybeans at 45 bushels per acre with dryland at 30 bushels per acre. These results indicate that irrigation has a significant impact on yields in Northeast Nebraska. Of course, production costs need to be considered on this but generally speaking the use of irrigation results in a higher economic value for groundwater than dryland agriculture. The price of land is also enhanced by the availability of irrigation.

Assigning values to rural domestic, livestock, and municipal uses of water is more difficult. Comparisons from the District's Rural Water Project shows what treated surface water is worth to users of the project who desire rural water pipeline services where available, to avoid the use of groundwater in the areas where quality sources are a problem. 1985 rate shcedules have minimums of $20.00 for the first 1000 gallons charged monthly and bulk rates are $1.25 per 1000 gallons. The average user of 11,500 gallons per month pays $44.00 ($530/year). This would indicate the economic value of quality water over non-quality water if comparisons could be made with private well installation and maintenance costs.

Published information is of little use in calculating economic values for most uses of groundwater in the District because there are so many circumstances affecting each user. It is very difficult to place a dollar value on water when a municipality, for example, finds a quality problem in its source. Different alternatives must be examined for each situation to determine a course of action. Generally stated aquifer limits on water availability restrict any exonomic value for development of groundwater in the NRD.

XIII. Coordinated Uses from Different Supply Sources

The Cedar Knox Rural Water Project is one example of the use of treated surface water to supplement poor quality groundwater. Users on the system in many cases combine the supplies to improve their overall quality to the economic degree they can best afford. The town of Crofton uses treated surface water as it can afford in conjunctive use with its minicipal wells. Farmers use treated water for household use and well water for livestock in many cases. The project although insignificant in quantity impact on the groundwater use of the District, nevertheless illustrates the fact that where there is a need and a financial interest, coordinated uses can be developed to the benefit of the District when dedicated efforts are put forth.

The Crofton Unit Appraisal Report in 1979 represented an effort to consider irrigation possibilities from Lewis and Clark Lake into Knox and Cedar Counties. The report resulted from successive dry years that sparked a demand for a study by the Bureau of Reclamation; but by the time the positive results were presented, proponent interest had dwindled and opposition rose, giving little support for the project. It is generally recognized in the District that conjunctive use of surface water for irrigation will not be a viable need until economic factors show commodity prices will off set the expenses.

No other integrated uses of surface water with groundwater has been contemplated to the knowledge of the District. The importance here is to note that quality groundwater is a prime commodity, and that in its absence where interest is sincere and local involvement active, coordinated use can be very effective and beneficial.

XIV. Conservation of Groundwater

Because of the topography of the area, the NRD is convinced that conservation practices play a major role in reducing groundwater application needs and reduction of surface erosion problems resulting from groundwater runoff. It continues to provide a number of programs available to help landowners make more practical use of groundwater by means of reduced run off, management alternatives, increased precipitation recharge, and erosion control measures. With the technical assistance of SCS, the NRD offers the Habitat Program, Cost Share payments on terraces and dams through Nebraska Soil and Water Conservation Program and local funds, tree planting and grass drill services, conservation tillage test plots, and watershed erosion and flood control dams. Although estimates of the magnitude of groundwater saved would not be possible, the amount could significantly affect the resources.

When discussing conservation of groundwater, the main concern is to use best managment practices on the land so as to minimize the amount of groundwater required for irrigation or make the best use of water on the soil surface to reduce quality problems from leaching. Best management practices are solutions used to accomplish these means. They include: conservation tillage which utilizes different tillage means to keep at least 20 to 30% crop residue on the soil surface after planting to conserve moisture and reduce soil erosion from rainfall; contour farming decreases runoff by creating furrows around rather than up and down hills crop rotation and strip cropping with small grain or cover crops create diversity in the ground cover and act as vegetative filters to remove sediment and slow runoff; terraces reduce erosion by breaking up the long slopes into several short sections to reduce the speed and amount of runoff, while grass waterways provide for controlled release of that water along natural drainage ways; ponds and dams actually stop and release the flow of water and can act as a major source of groundwater recharge for an immediate area. These practices used alone or in some combination are considered the most practical and effective methods to maintain water quality and conserve our groundwater resource (ref. Neb. Guide #G82-586). Along with them, such practices as irrigation scheduling, soil testing, and proper storage and handling of fertilizer contribute to improved conditions to preserve groundwater quality.

SUMMARY: A REVIEW OF ASSETS

The Lewis and Clark NRD has a complex groundwater reservoir that forces the technical focus of this plan to be very general. Any specific descriptions would require new studies and investigations. Generally speaking the NRD has a variable groundwater resource, limited by geologic factors as well as some quality factors, but with an estimated storage of 6,300,000 acre feet which should still provide a dependable source in most areas. Because the aquifer is absent or very thin and transimissivity is limited, groundwater stored is not easily located or withdrawn, resulting in wells with low yields.

To begin with the reservoir itself, the principal aquifer is the Pleistocene and Holocene deposits which are found across the District. Of secondary concern because of limited availability is the Niobrara formation; and because of depth and water quality the Dakota formation. Information on depth of the primary aquifer shows that it ranges from 0-200 feet. Transmissivity or flow rate limits irrigation development (groundwater movement tends to move east-northeast toward the Missouri River). Depth to groundwater itself is usually in the range of 50 to 200 feet with exceptions both ways. Static levels have remained constant indicating no immediate threat to groundwater quantities. Recharge comes through precipitation and based on average estimates, amounts to an inch or less per year, even though soil structures could usually handle more.

Groundwater quality is the Districts most serious concern. Most of it is good to excellent, but not always low in total dissolved solids. Calcium and magnesium along with iron and manganese are found often and associated with hardness but are considered more a nuisance than a health hazard. Likewise, sodium can cause some irrigation management problems and diet concerns. Of a more serious nature is nitrate-nitrogen which usually results from leaching into water tables affecting primarily domestic wells. Prevention is emphasized to avoid expensive relocation or treatment of existing contaminated supplies. Drilling deeper wells to avoid nitrate contamination is not always a practical solution. As is apparently the case in the Creighton area, isolated cases of groundwater pollution are increasing. Generally, areas in the northern part of the District appear to be more susceptable to point-source problems and the southern part to non-point source problems because of the aquifer characteristics.

A review of other water resources in the area show that rainfall probabilities during the growing season of crops decreases steadily after June 1st. Surface water supplies exist in insignificant amounts from Bazile Creek and Bow Creek but in major amounts from the Missouri River and Lewis and Clark Lake. the Cedar Knox Rural Water Project makes use of this source for a domestic supply system using 17 acre feet per year. The Crofton Unit Appraisal Report (Bur. of Reclamation, 1979) considered irrigation a feasible and economic possibility that could also be used for artificial recharge or a supplemental source. Utilization of the Lewis and Clark Lake will not be a viable need until economic factors and local interests support it.

Groundwater use as determined by Conservation and Survey Paper #48, 1975, shows that on an annual average we use .5% (35,000 acre feet) and lose to natural discharge about 1.2% (70-80,000 acre feet) of our total groundwater in storage. During the same time it gets recharged about 1.2% (75,000) acre feet. Groundwater monitor records however, indicated no apparent reduction in water tables since 1975, so that the average loss figure qualifies as insignificant because recharge and discharge usually balance each other out in this area. Most of the groundwater used goes to irrigation use (77%) with rural and livestock next (18%) and municipal last (5%). Subirrigation is not a factor and little information is available on crop water needs. Economic values of existing users are highly variable and not available in terms of making substantial statements here. Conservation of groundwater has been and remains a serious effort of the NRD which makes available various programs to encourage practical use and management alternatives.

Collectively speaking then, the Lewis and Clark NRD has geologically limited groundwater quantities available. Irrigation growth where practical has presently peaked and well measurements indicate water levels are not dropping. While rainfall still limits crop production from year to year, economic justification for bringing in supplemental supplies does not appear to merit doing so. The information available indicates that groundwater quantity is generally stable, that future development of the supply will require a significant economic need, and that maintenance of groundwater quantities can be accomplished by continued static-level monitoring of the resource.

Groundwater quality does appear to be a growing problem however. Most groundwater sources are naturally high in total dissolved solids and hardness. Because it would be difficult to enforce more strict standards, the District needs to follow Federal or State acceptable limits on chemicals of concern. At present the most serious inorganic chemical threatening groundwater users in the District is Nitrate-Nitrogen. More information is necessary to determine the frequency and scope of its presence, while still keeping in mind the financial and staffing limitations of the District.

POLICY CONSIDERATIONS ON GROUNDWATER

RESERVOIR LIFE GOALS

NRD policy needs to be reviewed and considered to decide on a future course of action for the management of groundwater in the District. Those decisions shall be based on the technical information available and need to identify specific groundwater management policies. Among those policy requirements are developing objectives, including a groundwater reservoir life goal, and setting management area boundaries. In addition, proposed controls or program options along with their impacts need to be considered.

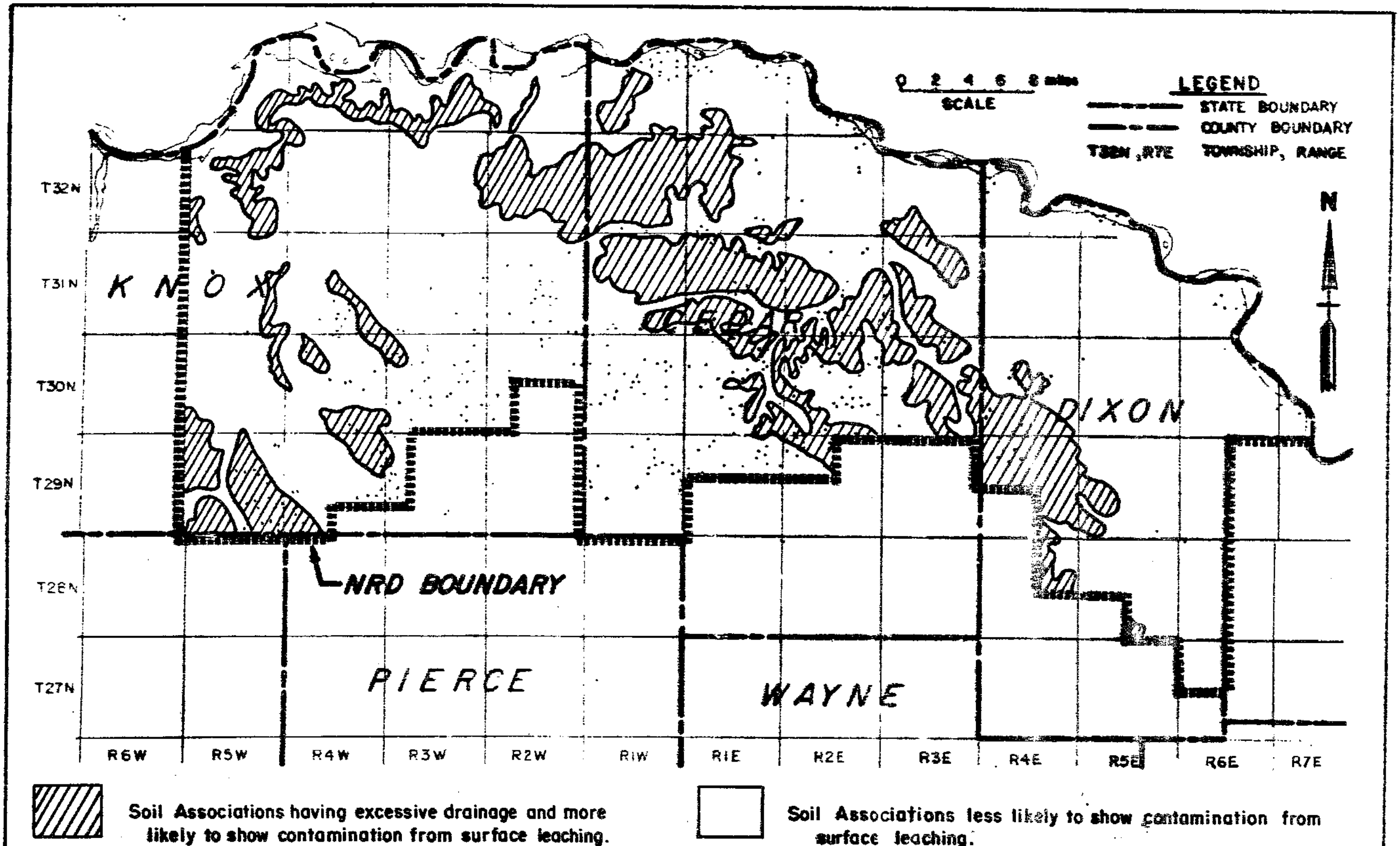
Since the statutes require a groundwater reservoir life goal for maintenance of the supply of water, the NRD must set a period of time that it hopes to be able to obtain water from the reservoir. Because specific data for the District is unavailable to set a specific time, that goal must be generalized as follows: To preserve and maintain the natural quality and quantity of groundwater an indefinite period of time for the sustained use of the resource. In other words the NRD would expect to be able to obtain water from the reservoir consecutively for indefinite years. Technical information from this report reflects this status and no dramatic changes are foreseen.

A review of that information indicates that the District does not have an immediate problem in the future on water quantity although maintenance by static level well monitoring shall continue. The quality however, does merit attention and cause for increased planning efforts. The areas of concern from a possible management area basis for consideration, is where soil associations with excessive drainage coincide with concentrated irrigation use and the aquifer is being more utilized. Potential management areas as shown on Map 10 can be roughly described as areas which have the most potential for water quality problems in the present and future because of possible leaching of groundwater contaminents. Outside of the area quality problems are generally thought to be less likely and limited to isolated locations or individual source contaminations.

Having set a goal for the reservoir, management objectives need to be developed to sustain that goal. Objectives are specific statements about the methods to maintain or improve the reservoir situation. They can take the form of data collection processes, program options, or controls. Examples of the types of objectives considered to meet the goal are: monitoring of quality and quantity, water conservation programs, conjunctive use management, and groundwater management and control areas. Along with the objectives, the impacts and affected results on the goal need to be considered. Social, economic, physical, financial, institutional, or environmental factors all play a role in determining the best method in achieving the goal.

REVIEW OF POTENTIAL OBJECTIVES

Several references were consulted for recommendations on management objectives. Recognizing future problems in water quality for this NRD that may develop, aspects need to be considered to evaluate which objectives would be most effective in meeting the need. Following are several of those possible solutions:



MAP #10: ILLUSTRATION OF POTENTIAL MANAGEMENT AREAS FOR WATER QUALITY

MAP # 5 Registered Irrigation Wells thru 12/31/84 in the Lewis & Clark NRD
Overlying **MAP # 9 SOIL ASSOCIATIONS**

I. The Hall County Water Quality Report, 1984, reviews a response to a groundwater quality problem of the accumulation of nitrate-nitrogen. To confront that problem the Hall County project set the following objectives:

1. Impede the leaching of nitrates from fertilizer into the aquifer.

2. Remove existing nitrates through irrigation.

3. Demonstrate efficient management of nitrogen with irrigation.

4. Develop practices for application elsewhere in Nebraska.

The effort to implement these objectives was accomplished through cost-share incentives, individual consultation, group educational meetings, newsletters, field demonstrations, and yield checks. The lead agency in this case was Agricultural Stabilization and Conservation Service. Two full time specialists and seasonal employees were hired over apparently a four year period to work on the project which showed positive results. It demonstrated that irrigation scheduling and water measurement are useful tools for improving irrigation management without loss of yields, and limiting leaching of nitrates into the groundwater. The Central Platte NRD is carrying out education on these procedures in its District by using demonstration areas.

II. Nebraska EC 81-2400 "Living with Nitrates" explains in common terms, the nitrogen cycle, leaching hazards, and the affects on ffod, livestock, and domestic supplies. It indicates nitrate contamination most often occurs from leaching and that on irrigated soils the control of excess fertilizer or excess water will reduce the amount of nitrate contamination. Once present in a water system, nitrate can be partially removed by three methods; Distillation (boiling of water and collecting the steam), Reverse Osmosis (pressurized filter process to remove impurities), and Deionization (electronically charged removal). All of these methods are expensive in one form or another and involve a certain degree of technical capability. The need should be definitely established by checking with professional consultants. Other alternatives to nitrate removal are relocation or deepening of wells, or using pure bottled water.

III. A review of the Policy Issue Study on Groundwater Reservoir Management, 1982, indicates that the NRDs principal aquifer can provide moderately large supplies of water but usually of limited areal extent. Small areas of decline can be expected, however, many are seasonal and could respond quickly to variations in amount of withdrawal. This indicates best management objective by analysis of local conditions.

The Policy Issue Study provides an excellent review of potential techniques for groundwater management. It explains that a variety of objectives could be utilized to achieve our goal, but to be effective the techniques must function within the capabilities of the resource and consider the stress or impact resulting from development.

If potential restriction of groundwater development is thought a necessary objective to maintain or extend aquifer life, the following management actions could be taken:

1. Reduce irrigation water need by improving efficiency.

2. Reduce irrigation water need by improving crop water use efficiency.

3. Reduce irrigation water need through improved conservation practices.

4. Reduce groundwater development based on water supply criteria.

5. Reduce groundwater development based on geographic and environmental criteria.

6. Reduce groundwater withdrawals to prolong supplies and reduce environmental impacts.

All of the above actions can be elaborated on by methods to encourage or require irrigators to adopt practices that will help the situation or to not develop wells that will cause problems. Research, demonstration, financial incentives or disincentives, and legislation or administrative action are tools that could be used to accomplish these management actions.

IV. Another Policy Issue Study on Municipal Water Needs, 1983, suggests several alternatives for problems relating to municipal water systems. Most of the recommendations involved legislative statutory changes or state wide alternatives. Although some might be encouraged by the NRD, they are not being considered as local objectives.

V. A research paper entitled "Nitrate Pollution of Groundwater in Nebraska and Policy Options to Address It" by Linda Willman, 1984, was reviewed for possible recommendations for water quality maintenance. Among the major points made in the study were the following:

1. Irrigation and fertilizer management are interdependent and should be mutually cooperative efforts...including an accounting for all sources of nitrogen available to the crop.

2. Factors affecting nitrate leaching include; depth to water table, soil permeability, seasonal rainfall, organic matter, microbial activity, fertilizer and irrigation practices, and crop uptake of nutrients.

3. The potential for nitrate leaching below the plant root zone is especially high in spring and fall precipitation periods...(more so too on sandy soils)

4. Soil testing and utilizing residual soil nitrogen is a key factor in effective nitrogen management.

5. Point source pollution has generally been related to septic tanks, feedlot runoff, and fertilizer spillage.

6. Proper well location and construction are critical in reducing the risk of nitrate contamination.

7. As groundwater nitrate contamination is documented with regard to point or non-point sources, feasible efforts to control leaching will need to be employed.

8. As the use of nitrogen fertilizer has increased, the practice of

rotating crops with legumes has decreased, which generally contributes to nitrogen contamination of our drinking water.

9. NRD's across the state must consider regional supply systems or cooperatives as alternatives for communities with contaminated supplies.

10. Best management practices should be used with fertilizer and irrigation application methods.

VI. Other NRD's in the state are working on programs that provide more information on water quality to document where and what their problems are. The Middle Missouri NRD (Walthill) is working on an extensive quality measurement program primarily through the efforts of their County Extension Service personnel. The Lower Loup NRD (Ord) publishes an annual report on water quality samples taken, one per township, across the bulk of their District. Their tests include the date, conductivity, pH, nitrate-nitrogen, alkalinity, chloride, sulfate, and iron. The tests are apparently taken annually at domestic wells with the results analyzed and provided by the NRD with their own lab equipment.

Other Districts as well do similar testing and special studies to evaluate groundwater quality information. Concern over liability on testing results however, makes professional testing more advantageous to utilize.

VII. In Overview of Nitrates in Groundwater, NRC, 1983, Remedial Action for Nitrate Problems are discussed. Three options considered in the publication are: using different sources, removing nitrates from the water supply, and reducing the amount of nitrates entering the groundwater. The report says that most contamination problems in the eastern part of Nebraska are localized problems as opposed to a widespread area contamination. In those local areas contamination usually results from activity around the wells in the form of poor well construction or point sources of pollution.

Standards for measurement of nitrate amounts is important and minimum procedures are suggested. "Hach Kits" used presently by some NRD's including Lewis and Clark NRD should not be considered for a high degree of accuracy and reliability. Remedies in this publication discuss different means of working with the problem, all of which have been discussed previously in this plan.

VIII. The Nebraska Groundwater Quality Protection Strategy addresses the aspect that the state has not been aggressive in protecting its water quality. As a result, considerable legislation may be required in the future to protect groundwater supplies from pollution; from chemical and fuel storage, agriculture chemicals, waste treatment and disposal areas, improper design, installed or abandoned wells, industrial facilities, and accidental spills or leaks.

They suggest local Special Project Areas could be designated to regulate sources of potential contamination and that NRD's could work with them to develop and implement protection measures.

Their strategy for dealing with future Nitrate contamination issues includes further reviewing the harmful effects, developing legislation, regulating fertilizer applicators, registering chemigators, establishing best management practices and developing monitoring programs.

IMPLEMENTATION OF OBJECTIVES

While several alternatives can be considered for a course of action, the NRD must consider which objectives apply to the local area and what impacts they might have. Since most of the present groundwater problems are centered on quality concerns, it is important to establish and support, with adequate base data, what and where existing quality concerns are before decisions are made on the proper objectives. The Department of Health can not provide specific locations of their past testing experiences so the District shall consider a monitoring system of its own. Once data is available, education and demonstration programs to encourage conservation and best management practices should logically follow. The chart on Table VII gives a progressive indication of the alternatives considered workable by the District and what their respective impacts might be. It also outlines the implementation schedule for how those alternatives shall be utilized and their order of consideration.

The Lewis and Clark NRD has limited capability for implementing major program changes specifically for groundwater alone. With a valuation among the smallest in the state and utilizing close to its full levy, the District cannot expand readily to absorb added program components and costs. As situations arise a determination needs to be made by the Board of Directors on the balance necessary to create a program to meet serious groundwater needs as compared with the costs in tax dollars to protect the resource. In other words, criteria needs to be set to help directors decide on how severe a groundwater problem needs to be present before more expensive objectives are utilized to deal with it. The following policy shall be utilized for that purpose, according to the objectives considered:

1. <u>Conflict Resolutions</u> - On-going program, District will attempt to resolve issues between parties without advocating one cause over the other. Groundwater is public property, its use should be shared for the mutual benefits of all concerned. If applicable, rules and regulations of the Nebraska Groundwater Management Act on improper irrigation runoff or illegal wells will be used.

2. <u>Legislative Support</u> - On-going program, District will support legislation that provides local control with the groundwater management tools necessary to preserve and maintain the resource and oppose those which it feels harms that authority.

3. <u>Expand Monitor Program</u> - Already active in quantity monitoring program, the District will seek to expand that effort to obtain base data on quality problems. Domestic well information would support issues of public concern and irrigation well monitoring would more accurately indicate area-wide aquifer problems. Location shall be selected based on potential quality problems and prompt respectable testing will be necessary to make accurate determinations.

4. Education and Demonstration - On-going program, District will continue conservation practice emphasis and as specific quality problems are determined, broaden that effort to educate the public on contamination concerns, fertilizer management, nitrate utilization, or other issues.

5. Supplemental Supplies - On-going Program, District administers the Cedar Knox Rural Water System and can expand off that base to serve others in the District. Criteria necessary to consider a supply system should be: lack of alternate quality sources to numerous users, consideration of treatment expenses for using present sources, economic potential for financing a project and availability of interested and dedicated local participants.

6. Groundwater Management Area - If objectives mentioned previously prove ineffective or seem unworkable the District will propose a management area to address irrigation or non-point pollution problems. Since present laws provide limited capabilities in quality situations, criteria for this objective will require that problems be shown to affect the aquifer for more than just a few isolated users, and there exists a serious pollution problem that can be corrected with irrigation regulation or fertilizer management.

7. Groundwater Control Area - If a management area does not appear to address groundwater use problems related to irrigation, then a control area might. Serious non-point pollution occurrences or irrigation development expanding beyond isolated cases that cause economic hardship and affect the aquifer in general, are necessary before initiating a control area. Approval must be made by the Department of Water Resources.

In summary, the Lewis and Clark NRD believes that the technical information presently available indicates that the District in general does not have serious groundwater quantity problems. Quality, however, particularly nitrate-nitrogen is a growing concern and merits increased monitoring efforts. Hard water is common to the area, but contamination events appear to be increasing.

The policy of the NRD will be to continue on-going programs to achieve our goal to preserve and maintain the natural quality and quantity of our groundwater resource. In addition, the District intends to expand its monitor efforts in groundwater quality and to establish an adequate data base to provide a basis for future decision on the need for management or control area objectives to achieve our goal. Lastly, the District will actively strive to address those groundwater problems that arise in the future by using the tools available to locally administer the programs necessary to protect our valuable resources.

TABLE VII — IMPLEMENTATION SCHEDULE

PROGRAM OBJECTIVES	METHODS	IMPACTS
1. Groundwater Conflict Resolution	1. Negotiate without taking sides to seek a mutually acceptable solution. Emphasize groundwater is public property. Utilize 1975 Groundwater Management Act.	1. Staff time, expert assistance necessary but less likely to involve lawsuits under present laws.
2. Support Legislative Action	2. Case by case analysis and contribution to support local control authority	2. Variable, wide range of impacts possible
3. Insitute Monitor Program on Water Quality	3. Work with Extension & Conservation & Survey on procedures & testing to obtain results from domestic and irrigation wells	3. Technical requirement, time involved in set-up coordinating samples--low impact economically, socially, or legally. Teting lab respectability is a concern.
4. Education & Demonstration Programs	4. Coordinate with Extension, Dept. of Health, & Dept of Environmental Control on public information meetings	4. Minimum costs and time involved on small scale programs. Additional staff necessary if area wide project started (ref. Hall Co. report)
	A. Demonstration on Conservation Practices	A. On-going programs
5. Conjunctive Use & Supply Augmentation	5. Utilize water from Missouri River for Domestic supply alternative	5. On-going program. limited for economic reasons to northern Cedar-Knox Counties.
	A. utilize other sources for development of rural water systems	A. Requires considerable time of staff and dedicated volunteers, suitable sources, financing & sincere need.
6. Establish Groundwater Management Area	6. NRD holds public hearing, defines area, works with DEC, adopts controls and sets limits on use by allocation, rotation, well spacing or irrigation scheduling & fertilizer management.	6. High administrative requirement, economically expensive, social acceptance variable
Management Options	A. Reduce irrigation need by improving effeciency	A. Incentive needed--new legislation helpful
	B. Reduce irrigation need by improved crop water use	B. Educational requirements, violation needs
	C. Reduce irrigation need by improved conservation	C. Cost-sharing funding needs to be available
	D. Reduce development based on water supply	D. Set limits on amounts used for irrigation
	E. Reduce development based on environmental criteria	E. Set limits on amounts used for irrigaiton
	F. Reduce development to prolong supplies	F. Reduce withdrawals by education &Rregulation
7. Establish Groundwater Control Area	7. NRD holds public hearing, defines area, works with Dept of Water Resources, adopts controls & regulations reports, investigations, rotation, well spacing, meters, allocation, or cease and desist orders on new well drilling	7. High administrative requirement, economically expensive, socially difficult. Well permits required regulated use of irrigation can restrict development.

PUBLIC INVOLVEMENT ACTIVITY

As part of the planning process, Natural Resource Districts are required to actively solicit public comment and opinion during the preparation of a groundwater management plan.

The Lewis and Clark NRD did this by regular newspaper articles across the district before and during the planning process to invite comment at regular monthly meetings where the issue was on the agenda from February through November, 1985. An advisory task force of locally concerned citizens was appointed, and met twice during the year to provide direction. A publicly advertized meeting concerning the groundwater management plan was held on August 1, 1985 following newspaper publication and radio announcements discussing agenda items.

The task force committee was appointed by the NRD Board of Directors and consisted of: Lyle Vawser-Cedar County Extension Agent, Jerry Langhorst - Creighton Mayor, Terry Gompert - Knox County Extension Agent, Brad Jones - Small Farm Resources Project: Water Policy Specialist, Bruce Hanson - Conservation and Survey Division, Bill Christiensen - well driller, Jim Wortmann - farmer, NRD Director, Dan Pierce - SCS, District Conservationist, Lou E. Benscoter - farmer, NRD Director, Bill Pick - irrigator, farmer, and Jess Wolfe - science teacher. They met initially on March 12, 1985 to review technical data and direction, and again on September 20, 1985 to review comments received and provide recommendations on goals, objectives, and policies. Their input was approved entirely by the NRD planning committee on September 19, 1985 and incorporated into the plan.

Comments received from the task force as well as the public meeting August 1st (which had a total attendance of thirteen) were for the most part worked into the plan. Following review by Department of Water Resources and the Conservation and Survey Division, their comments were added as well. The final Groundwater Management Plan was reviewed and adopted at the November 21, 1985 meeting of the Lewis and Clark NRD Board of Directors.

Update of the plan will be considered as the need requires it or when the District reviews its official Master Plan.

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