WATER RESOURCES MANAGEMENT OF THE OGALLALA AQUIFER

Technical Report
E-036

Submitted to
The University Center for Water Research
Oklahoma State University

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April 1985

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of

THE OGALLALA AQUIFER

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April 1985

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ABSTRACT

This Report presents a review of recently completed studies by various state and federal agencies on the Ogallala Aquifer in Oklahoma. These investigations have been compared, and gaps in the studies are noted. The concept of conjunctive use of surface and ground waters is introduced for better planning of the Ogallala. Advanced treatment and use of sewage wastewater is suggested as an additional source of water. This water can be supplemented with imported surface water for recharge through spreading basins or recharge wells. A management model, together with numerical models for water levels and water quality, is recommended for water management in the Ogallala without impairing the quality of native fresh water.

WATER RESOURCES MANAGEMENT OF THE OGALLALA AQUIFER

I. INTRODUCTION

Congress authorized a study by Public Law 94-587, Sec. 193, in October 1976 because of concern over declining water levels in the Ogallala aquifer, decreasing oil and gas resources, and the potential effects on state, regional, and national economies and on national food supplies. Six million dollars were authorized and subsequently appropriated for the study.

The U.S. Department of Commerce, Economic Development Administration (EDA), was the responsible federal agency. The study was directed by the High Plains Study Council, which consisted of the Nebraska, Kansas, Colorado, New Mexico, Oklahoma, and Texas governors, three interested citizens selected by each governor, and a representative of EDA. The council was formed in 1977 at the insistence of the states after a federally-oriented initial plan of study had been formulated by Resources for the Future under a contract with EDA. The council then developed a plan of study which resulted in conclusions and recommendations that were submitted to the Secretary of Commerce and to Congress.

The regional study was conducted for EDA under a contract executed in September 1978, by High Plains Associates, the general contractor, which was composed of Camp, Dresser, & McKee (CDM), the prime contractor, Arthur D. Little, Inc. (ADL), and Black and Veatch (B & V). The study considered the conservation, water resources, environmental and legal/institutional, agricultural, economic, social and energy studies in the Ogallala aquifer (High Plains Associates, 1982).

The U.S. Army Corps of Engineers, under a separate contract with EDA, studied the possibilities of importing water--sources, points of diversion, amounts, conveyance routings, storage and costs--from adjacent areas, particularly the Missouri River, the Arkansas River, and other streams in Arkansas (Corps of Engineers, 1982). The U.S. Geological Survey recently completed a Regional Aquifer Systems Analysis (RASA) study of Ogallala Aquifer. In addition, the U.S. Bureau of Reclamation, U.S. Department of Agriculture, U.S. Fish and Wildlike Service, and other federal agencies cooperated in the study.

II. HIGH PLAINS REGION

The region encompassed by the six-state High Plains-Ogallala Aquifer Regional Resources Study, as shown in FIGURE 1, comprises some 180 counties, an area of about 220,000 sq. miles, wholly or partly overlying the Ogallala aquifer, which is the principal source of water supply for irrigation and other uses. The aquifer extends from the High Plains area of west Texas and eastern New Mexico, northward under the Panhandle area of Oklahoma, western Kansas and eastern Colorado, and the central and western parts of Nebraska. The region is one of the most heavily irrigated areas in the United States, comprising about 20 percent of the national total. About 40 percent of the fed beef are fattened within the region from the grain grown there.

Rapid expansion of irrigation began after World War II and will expand further in those areas where groundwater continues to remain available within economic pumping limits. About 16 million acres are currently under irrigation out of a total of 35-40 million potentially irrigable acres. The region is an important source of oil and gas and is a significant sector of the regional economy. The Ogallala aquifer is one of the most extensive and important interstate aquifers in the country. It varies widely

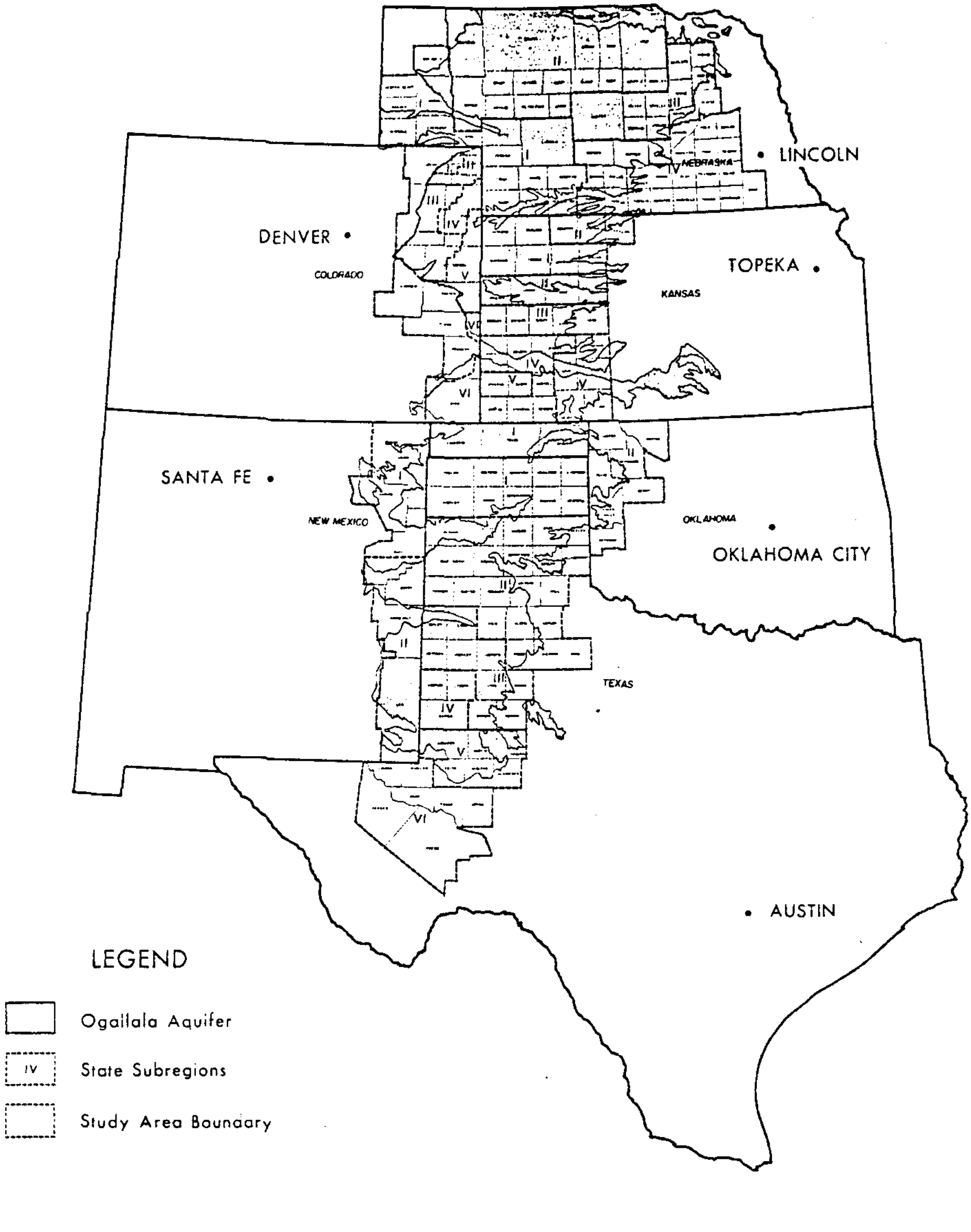


FIGURE 1. LOCATION OF OGALLALA AQUIFER

in hydrologic and hydraulic characteristics, in amount of recharge, in lateral extent and depth, and in remaining saturated thickness. It is severely overdrawn. The overdraft is increasing as irrigation expands. The aquifer is now subject to plan management only to a limited degree.

III. OGALLALA AQUIFER IN OKLAHOMA

The Oklahoma Water Resources Board (OWRB) has prepared the Oklahoma Comprehensive Water Plan (1980). Major features of the plan were two extensive intrastate interbasic water conveyance systems. The Northern Water Conveyance System would divert surplus flows at Lake Eufaula on the Canadian River and at Kerr reservoir on the Arkansas River, both in eastern Oklahoma, and convey the water for multiple uses in the western region. The Southern Water Conveyance System would divert surplus yields from existing and authorized reservoirs in southeastern Oklahoma for uses in southwestern Oklahoma.

Under the High Plains Study, the Oklahoma Water Resources Board modified the Northern Water Conveyance System. This system would deliver about 850-1000 acre-feet per year in Oklahoma at a cost of 5.3 billion dollars in terms of 1978 dollars, over a 30-year construction period. Irrigation water use under Management Strategy Four in this study would be 1.5 million acre-feet in the year 2000 and 1.4 million acre-feet in 2020 compared to 1978. Correspondingly, irrigated acres would increase significantly, 77 percent by the year 2000 and 74 percent by 2020, compared to the baseline, with dry land acres decreasing by about the same amounts so that the total harvested acres remain nearly constant.

FIGURE 2 shows Oklahoma portion of the Ogallala Aquifer, which is about 6,300 square miles. In FIGURE 3, ten counties are shown to contain

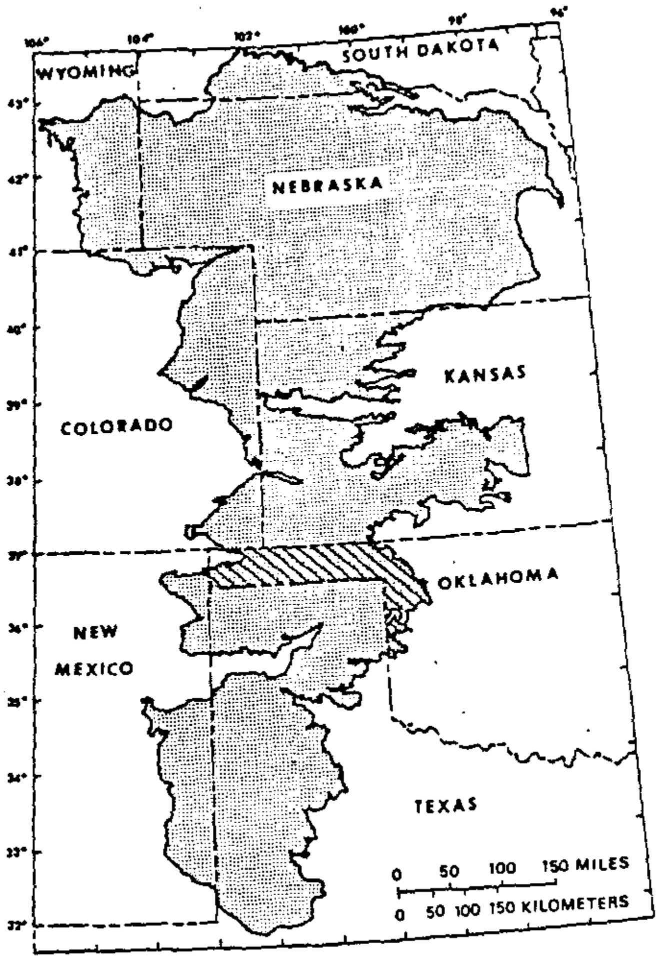


FIGURE 2.

LOCATION
OF
OGALLALA AQUIFER IN OKLAHOMA

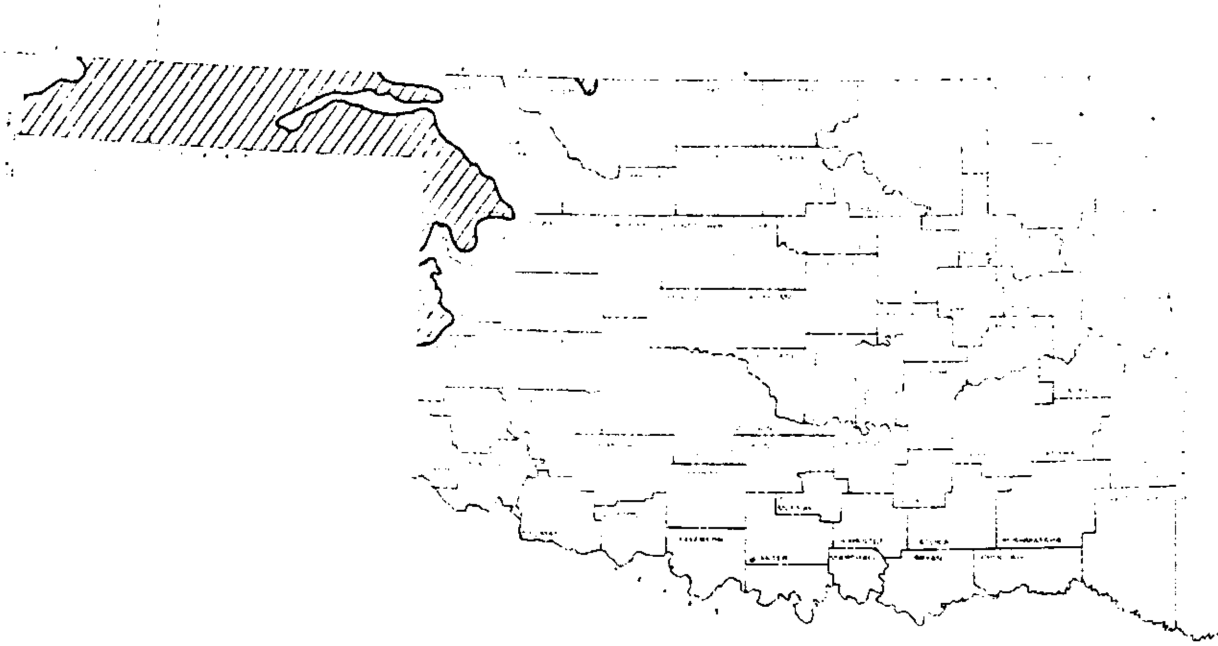


FIGURE 3.

OGALLALA AQUIFER
IN
NINE COUNTIES,
NORTHWESTERN OKLAHOMA

the Ogallala. OWRB (1983) divided the Ogallala in two subregions. Subregion 1 consists of Beaver, Texas, and Cimarron counties, whereas Subregion 2 includes Woodward, Ellis, Dewey, Roger Mills, Beckham, Woods, and Harper counties (see FIGURE 4). The two subregions are based on area covered by and saturated thickness of the Ogallala.

Subregion 1 has a high dependency on groundwater irrigation for growing wheat, sorghum, corn, and alfalfa. This region having 385,900 acres of irrigated land in 1977, about 43 percent of the state's total irrigated area, has experienced the greatest groundwater pumpage of the subregions.

In 1960, there were approximately 400 wells in Subregion 1 with the number more than doubling to 975 wells in 1965, then increasing to some 2,227 wells by 1980. Most of the wells yield from 500 to 1000 gallons per minute, averaging approximately 750 gallons per minute. The primary source of recharge to ground water basins in the Panhandle is through rainfall. With a semi-arid climate averaging about 16 inches of precipitation annually, recharge from precipitaion is estimated at 0.25 to 0.5 inches per year. In addtion to recharge from precipitation, recharge provided by return flow from irrigation water is estimated at about 20 percent of the applied water.

Subregion 2 consists of the remaining seven counties either wholly or partially underlain by the Ogallala. The subregion has a dry, subhumid climate with average annual precipitation of about 21 inches. Compared to Subregion 1, this subregion has experienced relatively less aquifer development and substantially less scientific research on the underlying Ogallala formation. Though the area in predominantly agricultural, irrigation is not as extensive in the subregion, with only about 69,628 acres reported to be irrigated in 1977 -- about 8 percent of the state's total irrigated acres for the same year. It is estimated that there are about

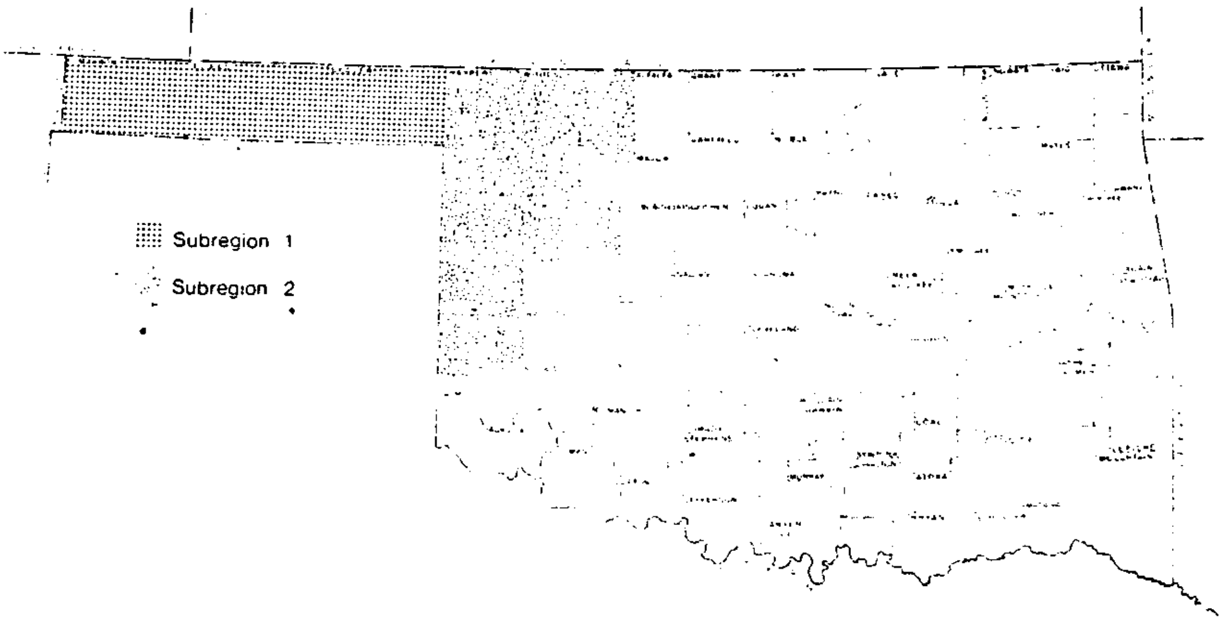


FIGURE 4.

TWO SUBREGIONS IN OGALLALA AQUIFER
BASED ON WATER STORAGE

225 high-capacity wells tapping the Ogallala in Subregion 2, with areas where the saturated thickness is 100 feet or more remaining as prospects for future development.

IV. CORPS OF ENGINEERS WATER TRANSFER STUDY IN OKLAHOMA

The Corps of Engineers investigated only the transfer of surface water to Oklahoma from Arkansas River. FIGURE 5 shows water transfer Routes A, B, C, and D for Nebraska, Kansas, Oklahoma, and Texas. The alignment of Route C is used to estimate the cost of diverting surface water to the Pahhandle (see FIGURE 6).

Six water sources were considered to be available to supply Route C. Since a range of water transfer amounts was to be considered for Route C, and opportunity was available to minimize cost through elimination of some of the sources or even one of the legs of the potential route. In fact, the minimum quantity considered for transfer could be supplied by a single source. Each combination was evaluated based on a maximum and minimum base flow at the surce locations. The maximum base flows which result in the minimum yield from the source are estimated to be consistent with HPSC Resolution 6.

The mimimum base flows are estimates based on previous studies and are believed to represent the quantity of water necessary to meet current requirements and future needs from the particular stream. The mimimum and maximum baseflows for each source were shown earlier on Table 1. The minimum quantity of water considered for transfer was 1.26 Million Acre-Feet Annually (MAFA). That quantity is slightly more than the 1.16 MAFA needed to restore and maintain irrigated lands in New Mexico, Oklahoma, and Texas. The needs identified by those individual states are shown below:

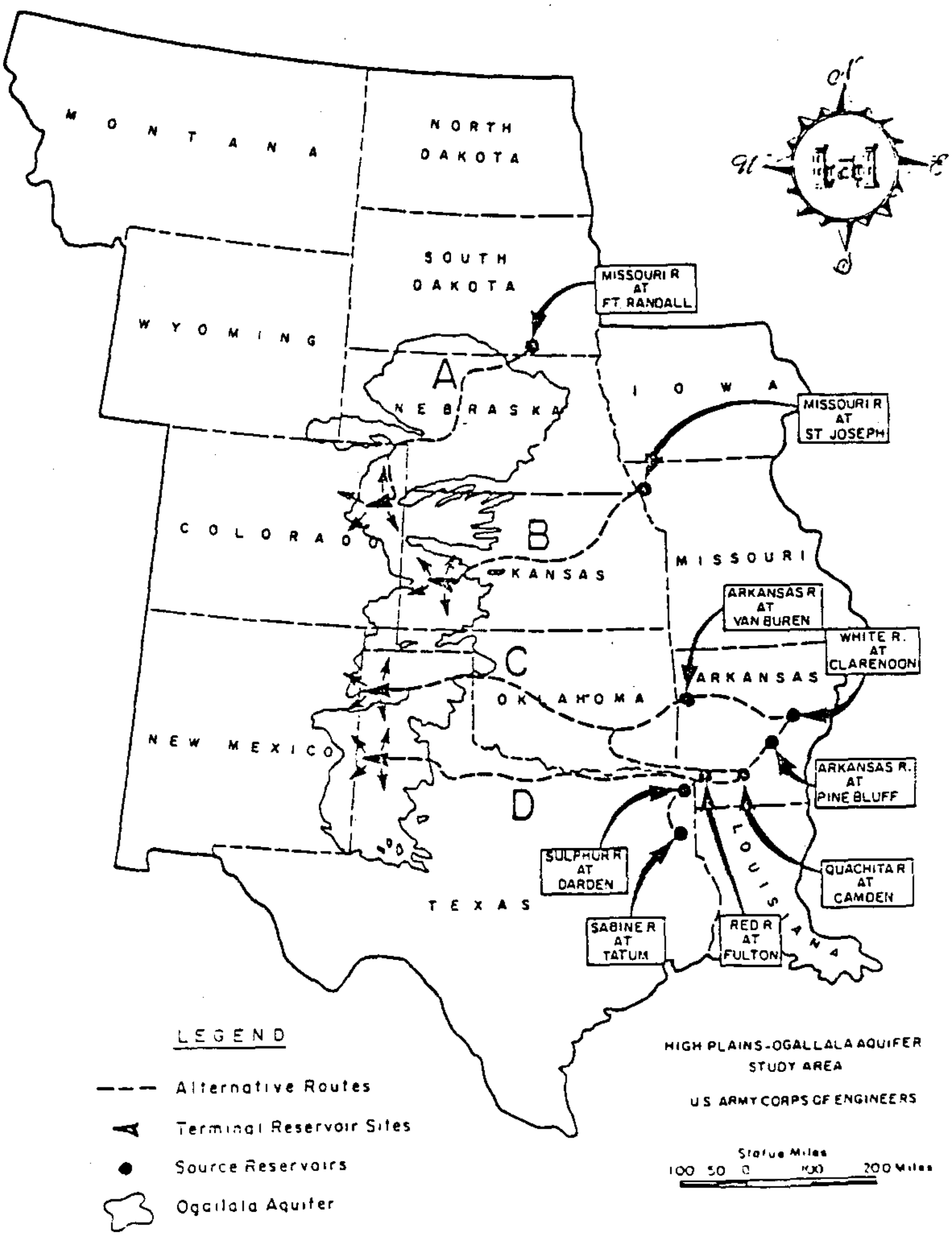


FIGURE 5.

INTERBASIN WATER TRANSFER TOUTES ASSESSED
BY THE CORPS OF ENGINEERS

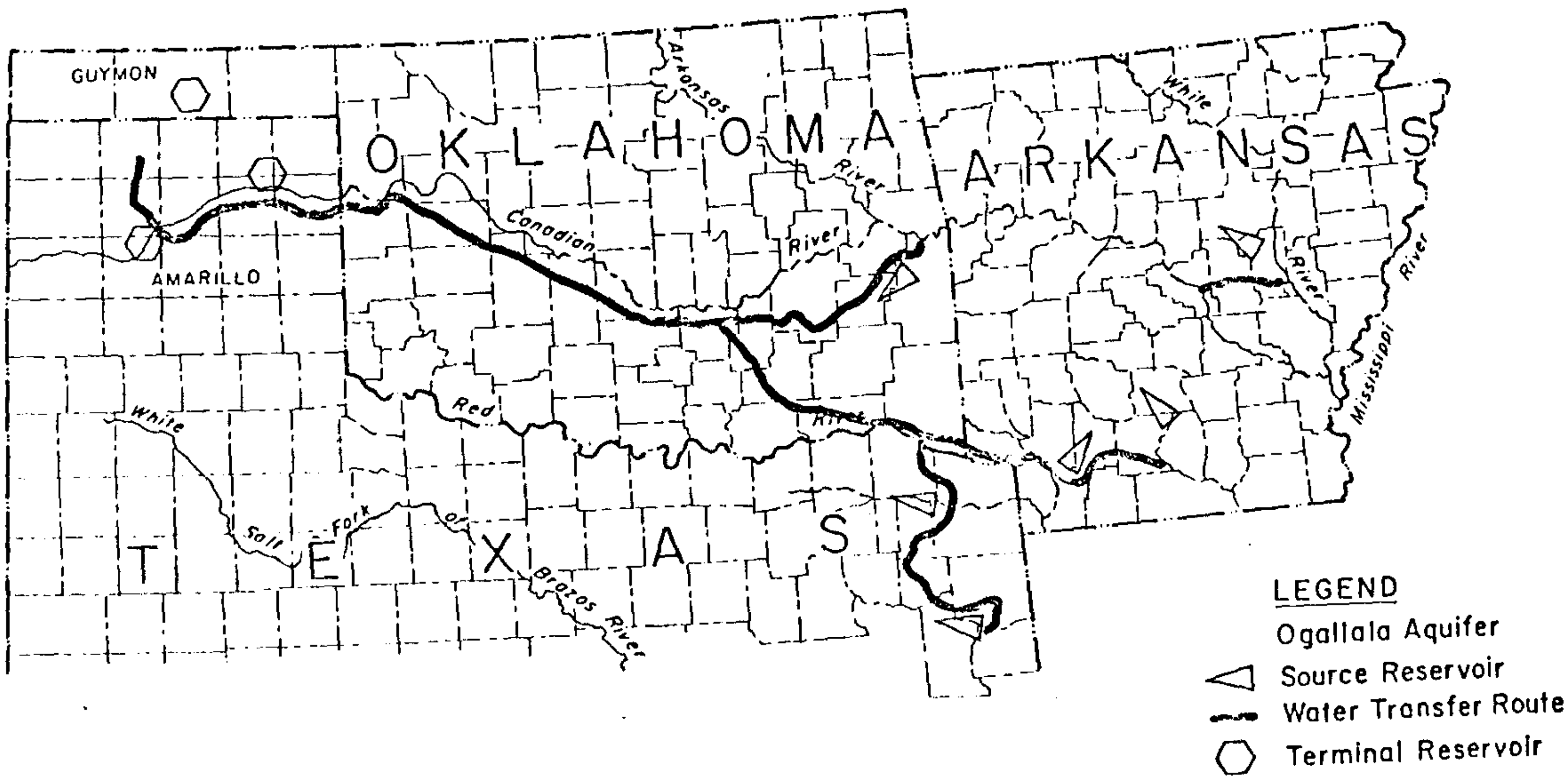


FIGURE 6.

WATER TRANSFER BY ROUTE C IN OKLAHOMA AND TEXAS

TABLE I

ALTERNATIVE BASE FLOWS FOR ROUTE C

IN OKLAHOMA

Source	Corps Estimated Base Flow (cfs)		Tentative Fish and Wildlife Service-Base Flow (cfs)	
	Low	High	Median	Mean
White River At Clarendon, AR	5,000	20,000	20,000	28,800
Arkansas River at Van Buren, AR	10,000	20,000	21,000	31,300
Ouachita River at Camden, AR	3,000	10,000	4,600	7,300
Red River at Fulton, AR	5,000	20,000	7,500	17,500
Sabine River at tatum, TX	1,000	--	680	2,300
Sulphur River at Darden, TX	1,000	--	60	1,400

New Mexico	0.302 MAFA
Oklahoma	0.334 MAFA
Texas	0.525 MAFA

The state of Texas has maintained that the 0.525 MAFA is an absolute minimum requirement since there is no real guarantee that voluntary conservation measures will be adopted. Texas officials can see the possibility that up to 2.5 MAFA could be needed to restore and maintain lands that were under irrigation in 1977. The range of flows considered for Route C is broad enough to cover even the potentially much larger need suggested by Texas. The largest quantity for which costs were evaluated for Route C involves delivery of 7.510 MAFA and utilizes all 6 potential sources and assumes the minimum baseflow at each source location.

The most economical way to meet the low end of the range is by using as a source the Arkansas River at Van Buren. The system would begin at a pumping plant on the Arkansas River near W. D. Mayo Lock and Dam, Oklahoma. The canal would extend southwest along the south divide of the Canadian River to near Ada, Oklahoma. From the Ada junction the canal would be constructed toward the northwest still along the South divide of the Canadian River to the main terminal area at Lake Meredith. To provide adequate terminal storage the existing Optima Lake, Oklahoma would be utilized. A pumping plant at Lake Meredith would supply water to a canal flowing northward for about 50 miles where the water would empty in Coldwater Creek and flow northeast into Lake Optima. This system could deliver up to 1.26 MAFA.

A system to provide up to 4.07 MAFA could be developed by adding the White River at Clarendon as a source and utilizing the Arkansas River Navigation Channel. The system would extend from the White River near

Clarendon, Arkansas about 52 miles to David D. Terry Lock and Dam on the Arkansas River. The water would then be transported up the Arkansas River Navigation Channel using one pumping plant at each existing lock and dam to connect with the previously discussed system at Mayo Lock and Dam. Expansion of this system to provide more than 1.85 MAFA and up to 4.07 MAFA would require the construction of a terminal storage site on the Canadian River downstream of Lake Meredith. If additional quantities were needed the southern leg tapping the Red River at Fulton and the Ouachita River at Camden could be added to deliver a total of up to 6.04 MAFA. The southern leg originates near Camden, Arkansas, crosses the Red River divide and empties into the upper end of potential Red River source storage, Bodcau Lake. Water is withdrawn from Bodcau Lake near the dam site and follows the canal alignment along the north divide of the Red River and the west divide of Muddy Boggy Creek to the junction with the north leg near Ada, Oklahoma.

An optional final increment to Route C adds the Sabine (Carthage site) and the Sulphur (Naples site) sources in Texas. The addition of those sources under the minimum base flow assumptions would also allow delivery of an additional 1.47 MAFA by the total system. These two additional potential sources constitute an intrastate option which is not truly appropriate to management strategy 5. As in all of the sources no official state approval should be implied by their inclusion.

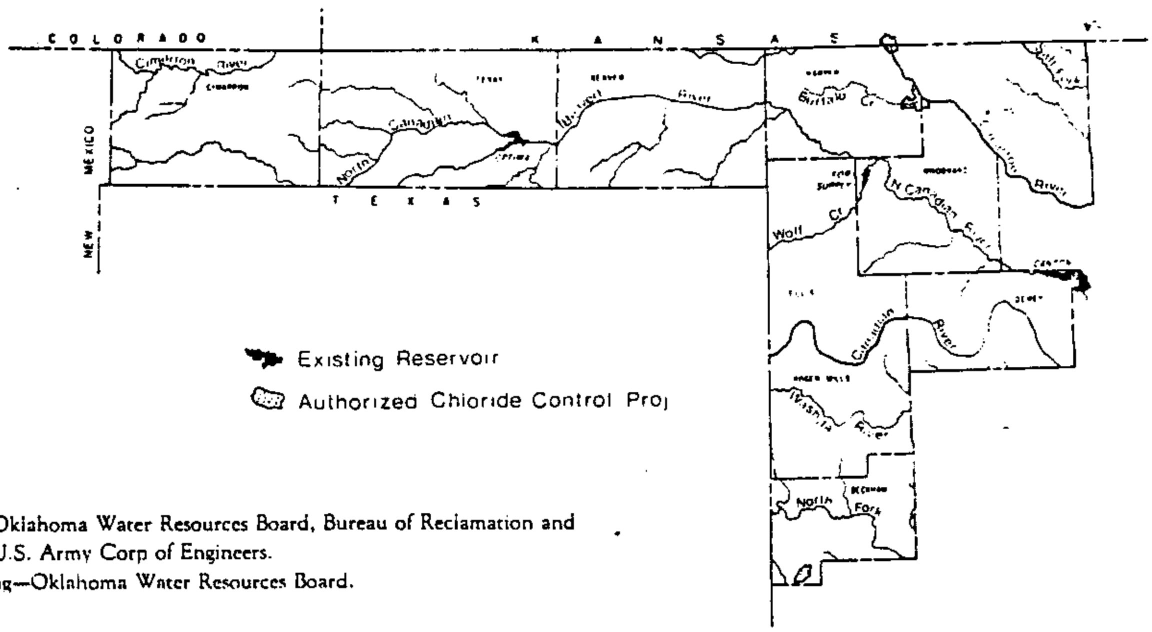
Canal capacities vary considerably because of the sequential addition of the various sources. Under the minimum baseflow assumption capacities increase from 5640 cfs at the White River source to 8460 cfs before joining the southern route. Comparable capacities for the maximum baseflow condition are 470 and 1760 cfs. The southern leg canals increase in capacity from 1940 cfs (minimum baseflow) and 1180 cfs (maximum baseflow) to 3940 cfs and 2240 cfs just prior to joining the northern route near Ada, Oklahoma. The canal connecting the Sulphur and Sabine sources increases from a capacity of 700 cfs to 2940 cfs near the junction with the southern leg.

V. Surface Water Limitaions in Panhandle Area

The project area is drained by two major rivers -- the Arkansas River and the Red River. As shown in FIGURE 7, major streams in the region are the Salt Fork, Cimarron, Canadian and Forth Canadian Rivers, all tributaries of the Arkansas River, and the North Fork and Washita Rivers, both tributaries of the Red River. Beneficial use of these streams, except for the North Canadian, Washita and North Fork, is restricted by poor water quality that is attributed to excessive amounts of naturally occurring salts and other dissolved minerals brought into solution as the water moves through the region. In addition to quality problems, most surface streams in the High Plains exhibit intermittent flows due to adverse topography and climate.

Majority of stream water resources containing water of acceptable quality have been fully appropriated. A relatively small amount of fair-quality unappropriated water does exist in that part of the North Canadian River Basin between Optima Lake and Canton Dam.

Poor water quality and adverse climatological conditions have also limited reservoir development in the region. Of the three major reservoirs in the study area, Canton and Fort Supply are currently supplying water for municipal and industrial uses, while Optima, though final impoundment was completed in 1978, is still in the early filling stage. However, it should be noted that pending application on file at the Oklahoma Water Resources Board already far exceed Optima's anticipated dependable yield.



Data—Oklahoma Water Resources Board, Bureau of Reclamation and U.S. Army Corp of Engineers.
Mapping—Oklahoma Water Resources Board.

FIGURE 7.

MAJOR STREAMS IN THE OGALLA AREA

Playa lakes occur in Texas County and extend into both Beaver and Cimarron counties. Although the size of a lake may be as large as two square miles and as deep as 25 feet, the rainfall that fills them is both erratic and scarce, thereby restricting dependence on playa lakes and an alternative to the Ogallala.

The Llano Estacado Playa Lake Water Resources Study, a special investigation completed by the Bureau of Reclamation's Southwest Regional Office, presents further information demonstrating the constraints of utilizing playa lakes in the states for large-scale water projects. One major point stressed in the report is that because peak rainfall in the study area does not coincide with major irrigation periods, playa lakes would have to be capable of providing carryover storage to be useful as a supplemental water supply. The modifications needed to insure such storage would have to allow for the high evaporation rates in the area, which normally exceed the rainfall. However, the report does recommend further assessment to determine the feasibility of developing the lakes as small-scale local water projects to supplement existing supplies, primarily for agricultural purposes.

VI. Water Supply and Demand in Panhandle Area

It is estimated that the potential 1977 yield of the Ogallala auifer in the State of Oklahoma was 60.6 million acre-feet of water -- 49 million acre-feet in Subregion 1 and 11.6 million acre-feet in Subregion 2. These yield figures consider that 70 percent of the water in storage can be economically recovered. It is estimated that Soil Conservation Service Projects in these two subregions provided approximately 8,600 acre-feet of additional water in 1977, with that amount predicted to increase to 27,200 acre-feet by the year 2020.

The 1977 demand on the Ogallala water of 674,600 acre-feet for irrigation , municipal and industrial requirements is projected to increase to 850,700 acre-feet by the year 2020. This estimated demand, taking into account both target years and interim years, will decrease the available water in the Oklahoma High Plains area by 31.7 million acre-feet over the next 40 years. The resulting 52 percent reduction in supply is predicted to leave approximately 19.9 million acre-feet in Subregion 1 and 9.0 million acre-feet in Subregion 2 by the year 2020.

VII. Geohydrology of the Ogallala in Oklahoma

Extensive hydrogeologic data on aquifer tests and well logs are available from OWRB (1983) and USGS (Gutentag and Weeks, 1980; Havens, 1982; Luckey et al., 1981; Marton and Goemaat, 1973; Sabik and Goemaat, 1973).

The Ogallala formation of Oklahoma's High Plains area consists of interbedded sand, siltstone, clay, lenses of gravel, thin limestone and caliche. The various rock types generally occur as lenses and poorly sorted beds of loosely cemented material. Due to the irregular surface on which the Ogallala was deposited, total thickness of the deposit ranges from zero to more than 700 feet.

The volume of water stored in the Ogallala aquifer was estimated from the average saturated thickness, specific yield and areal extent of the aquifer as shown in Table 2. The total land area in each instance represents the area overlying the Ogallala deposits having 15 feet or more of saturated thickness in 1973. The .15 storage value is considered representative of most of the Ogallala deposits in Oklahoma's Panhandle. An average storage coefficient of .10 was used for the Ogallala aquifer outside Oklahoma's Panhandle as the aquifer is thinner in this subregion.

TABLE 2.

GROUNDWATER IN STORAGE IN OKLAHOMA PORTION OF OGALLALA AQUIFER

Subregion County	Areal Extent of Ogallala (acres)	Average Saturated Thickness (feet)	Specific Yield	Total Water in Storage (acre-feet)
Subregion I				
Cimarron	650,000	70	0.15	6,825,000
Texas	1,255,600	240	0.15	39,700,000[1]
Beaver	950,000	165	0.15	23,513,000
Subtotal	2,855,600			70,038,000
Subregion 2[2]				
Woodward	204,800	180	0.10	3,686,000
Ellis & Dewey	555,520	180	0.10	9,999,000
Roger Mills & Beckham	151,040	75	0.10	1,133,000
Harper	177,280	100	0.10	1,773,000
Subtotal	1,088,640			16,591,000
Total	3,944,240			86,629,000

[1]Calculations from U.S. Geological report "Digital-Model Projection of Saturated Thickness and Recoverable Water in the Ogallala Aquifer, Texas County, Oklahoma."

[2]Insufficient data available to make estimation for Woods County.

The ten percent coefficient utilized is considered by the U.S. Geological Survey as a reasonable figure, based on aquifer tests made in the Ogallala formation in Woodward County.

A survey of chemical quality of water in the Ogallala is generally acceptable for most uses except in extreme eastern and southeastern Texas County, where wells tapping water from the lower part of the Ogallala may contain excessive amounts of dissolved solids. The most likely source of this lesser quality water in infiltration from Permian rocks below and adjacent ot the Ogallala formation. The quantity of dissolved solids ranges from 140 to 3,450 mg/l, but is generally les than 500 mg/l except in the area noted above.

Considering present technological constraints, it is estimated that about 70 percent of the water in storage can be economically recovered. As shown in FIGURE 8, recoverable water in storage is predicted to decline approximately 31 million acre-feet from the period 1977 through 2020, representing a 52 percent depletion rate for the 43-year study period.

VIII. Groundwater Management of the Ogallala in Oklahoma

Guhl (1972), Marton (1980), and Havens and Shristenson (1984) have completed studies identifying hydrologic parameters for the Ogallala aquifer in Oklahoma, using a two-dimensional numerical model. In recent years personal communication with hydrologists in OWRB, USGS, and USBR indicate that artificial recharge must be considered to restore the water levels in the Ogallala. None of the studies completed so far have considered artificial recharge as a viable alternative.

We suggest that a conjunctive use approach of surface water and groundwater must be adopted in managing the Ogallala, not only in Oklahoma but

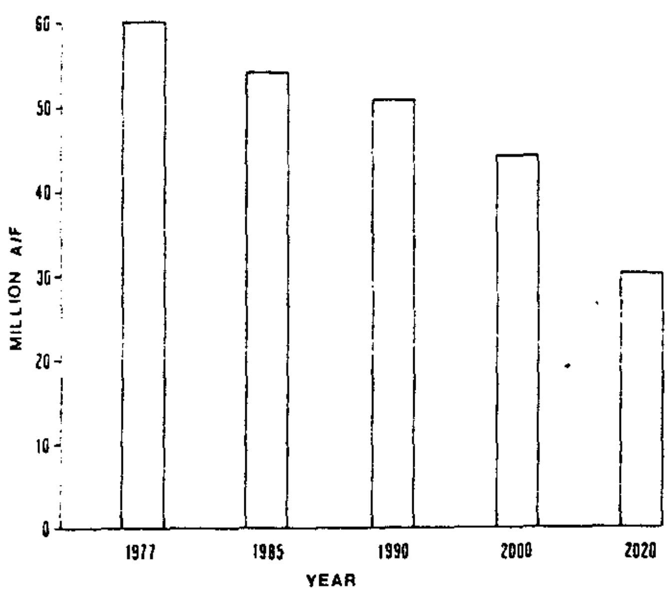


FIGURE 8.

ECONOMICALLY RECOVERABLE GROUNDWATER
STORED IN OGALLALA, OKLAHOMA

also in other states. Studies done by the Corps of Engineers (1982), High Plains Study Council (1982), and Oklahoma Water Resources Board (1983) lack this approach.

Studies must be conducted to economically evaluate the feasibility of spreading basins and recharge wells. The use of treated-sewage wastewater as a source of water must be considered, rather than waste it to evaporation or disharge in streams. Enough wastewater technology exists to further treat this water so that nutrients may largely be removed. This treated water can then be used for recharge purpose without causing bacteria buildup and clogging in the well casing (Lamirand, 1970).

Once the imported water is recharged to the Ogallala, its impact on waterlevels must be studied. It takes sometime before this recharged water actually joins the water table and increases water levels in the Ogallala. This involves the study of water flow and water quality through unsaturated and then saturated zones of the Ogallala aquifer if spreading basins are used; otherwise, only saturated zone be considered in recharge wells (Tee and Tyagi,1983; Yuan and Tyagi, 1985). An optional water quantity can be determined if an increase in water levels in the Ogallala is specified and development schedule of future irrigation needs is provided. Then, based on the currently completed studies by federal agencies, one can determine the mix of available treated sewage and imported water.

IX. CONCLUSION

The following conclusions may be drawn based on the review of available literature:

1. Studies completed by various agencies have not considered conjuctive use of surface water and groundwater in the management plan of the Ogallala aquifer.
2. Treated sewage wastewater may be used for artificial recharge, using advanced wastewater treatment technology in order to avoid bacteria buildup and clogging of screens in recharge wells.
3. Impact of recharge of imported and treated sewage may be determined using a model to predict the recovery of water levels in space and time in the Ogallala. For accurate determination, both unsaturated and saturated zones must be considered in spreading basins and only saturated zone in recharge wells.
4. Because the water quality of imported and treated sewage water may be different than that of the Ogallala aquifer, water quality determination in space and time must be made using a numerical model to avoid an adverse effect on existing groundwater in the Ogallala.
5. Finally, a management model must be developed to effectively manage the Ogallala in Oklahoma, encompassing the water flow and quality models, the recovery schedule of the aquifer, and pumpage schedule of wells in differnet counties.

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