HIGH PLAINS - OGALLALA AQUIFER STUDY
WATER TRANSFER ELEMENT

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1. Introduction

This paper presents findings on the four water transfer alternatives authorized by the High Plains Study Council (HPSC) for further study by HPSC Resolution 8. Figure 1 indicates the four alignments studied. The routes have been sized to provide costs on a range of flows to restore and maintain the maximum amount of irrigated lands projected to go out of production between 1977 and 2020 under Management Strategy One, voluntary conservation.

The total first costs shown in Table 1 (p. 149), including interest during construction, are based on 1977 prices, a nine-year authorization and design period, a fifteen-year construction period with equal investments each year and compounded using the FY 81 federal interest rate of 7 3/8 percent. The unit costs of water were computed using the quantity of water estimated to be deliverable to the farmlands. These costs include the cost of the energy necessary to pump the water from the source. The cost of energy in 1977 dollars interpolated from projections of future energy prices and other project data are shown in Table 2 (p. 150).

The Fish and Wildlife Service prepared reconnaissance-level evaluations of the potential adverse and beneficial impacts along the route corridors that might be associated with construction of the potential water transfer plans. These impacts will be discussed later in the paper.

2. Study Authority and Organization

The Corps of Engineers is charged by Section 193 of Public Law 94-587 with studying the engineering feasibility of transferring surplus water into the High Plains region from adjacent areas. In addition to determining the costs, the corps is to consider the environmental impacts

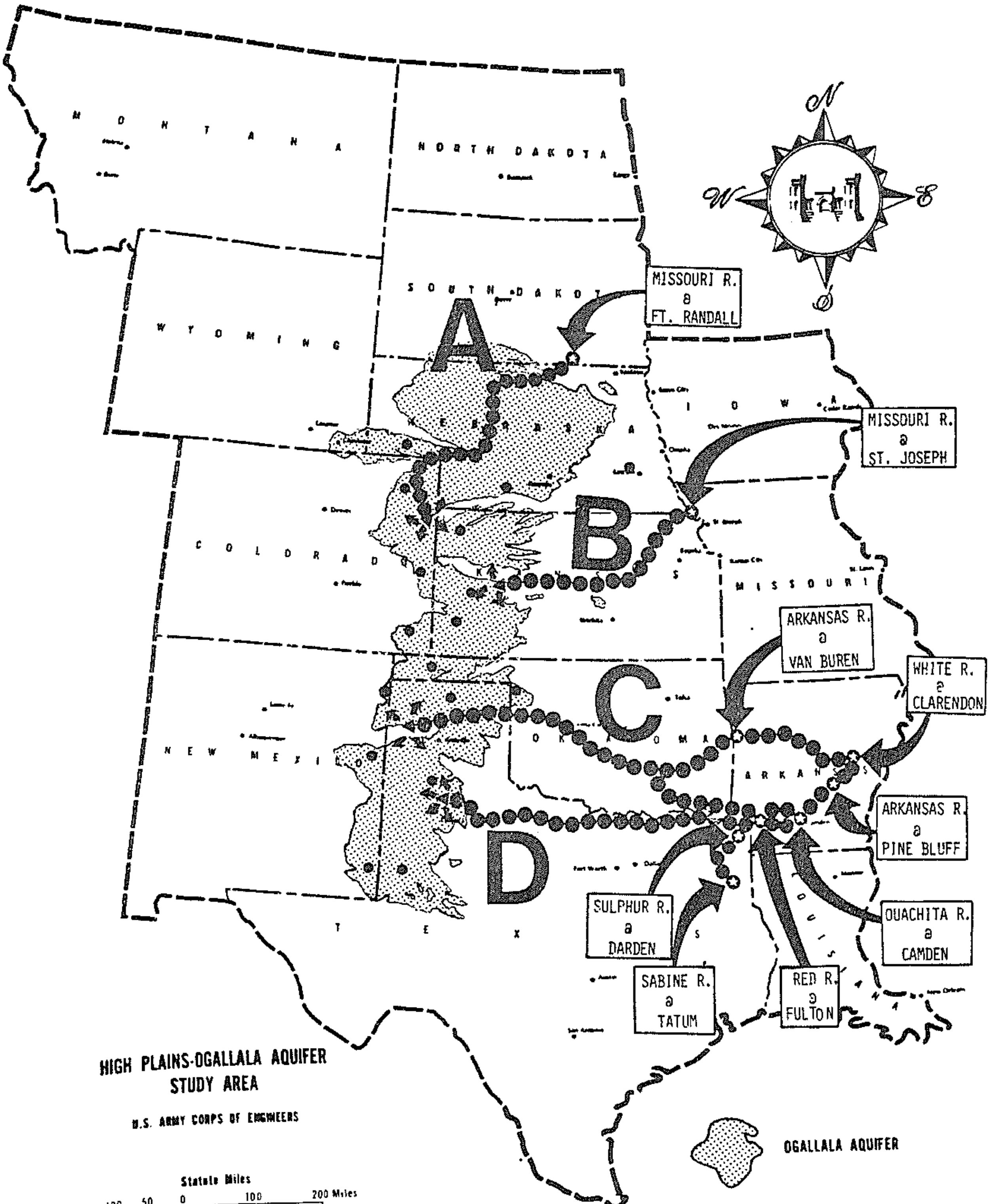
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Figure 1

of those alternative plans along corridor routes. This work has been closely coordinated with other elements of the High Plains-Ogallala Aquifer Study being undertaken by the states and the general study contractor for the Department of Commerce.

Results of the corps studies have been furnished to the general contractor who has determined the benefits of water transfer and has made estimates as to the economic impacts of water transfer to the High Plains region.

The firm of Camp Dresser & McKee Inc., heads a consulting consortium selected by the Department of Commerce to serve as general contractor for the overall study. The consortium includes the firms of Black & Veatch, Consulting Engineers and Arthur D. Little, Inc., and maintains a study office in Austin, Texas. Their work, as well as the corps', is overseen by the High Plains Study Council which is made up of the six states involved and the Department of Commerce.

To support the grassroots management philosophy of the overall study, the commander of the Army Corps of Engineers assigned management responsibility for corps involvement to the Southwestern Division located in Dallas, Texas. The Southwestern Division is being assisted by the Missouri River Division, located in Omaha, Neb., on those transfer options falling within the Missouri River Division boundaries. The Southwestern Division represents the corps on all coordinating and technical committees such as the High Plains Study Council and its Liaison Committee and the Department of Commerce's (EDA) Technical Advisory Group.

3. The Study

The initial phases of the corps' effort involved review of previous reports and identification and screening of alternatives. Those phases were begun during the Plan of Study stage and culminated in recommendations to the HPSC in April 1980. The recommendations were that the number of alternative transfer routes to be carried forward in the study be reduced to four. Those recommended routes were:

a. Alternative 2 (now called route A); source, Missouri River at Fort Randall, S.D.; route, southwest through Nebraska to terminal storage at Bonny Reservoir, Colo.

b. Alternative 3 (now called route D); sources, White River at Clarendon, Ark.; Arkansas River at Pine Bluff, Ark.; Ouachita River at Camden, Ark.; Red River at Fulton, Ark.; Sulphur River at Darden, Texas; and Sabine River at Tatum, Texas; route, west through Texas to terminal storage at Bull Lake, near Littlefield, Texas (subsequently replaced by Blanco Canyon near Crosbyton, Texas).

c. Alternative 4 (now called route B); source, Missouri River near St. Joseph, Mo.; route, southwest through Kansas to terminal storage on the Arkansas River near Dodge City, Kan.

d. Alternative 5 (now called route C); sources, White River at Clarendon, Ark.; Arkansas River at Van Buren, Ark.; Ouachita River at Camden, Ark.; Red River at Fulton, Ark.; Sulphur River at Darden, Texas; and Sabine River at Tatum, Texas; route, west and northwest across Oklahoma into the panhandle of Texas to terminal storage on the Canadian River near Canadian, Texas.

As a result of that recommendation, the High Plains Study Council passed Resolution 8 on April 17, 1980, authorizing continued study of the recommended four routes.

In February 1981 the corps provided an initial set of estimated costs to the High Plains Study Council for the four alternative transfer routes. The costs per acre-foot of water delivered ranged from $278 to $880 per acre-foot. Those costs were based on quantities of water from 2.0 to 7.2 million acre-feet per year. As a result of that exercise, it was determined that there were several opportunities to improve the consistency and breadth of approach used in the cost estimates. The current estimates, adopting those improvements, are based on a 15-year construction period with information also shown on 10- and 20-year periods; the current federal interest rate of 7 3/8 percent; 1977 construction costs; 1981 "off peak" energy costs in 1977 dollar values (interpolated from 1980 and 1985 values provided by Black & Veatch); 10 percent loss between source and terminal storage; 10 percent loss between terminal storage and farm site; 85 percent utilization of the system's annual capacity; and appropriate evaporation losses in the terminal reservoirs.

4. Water Requirements

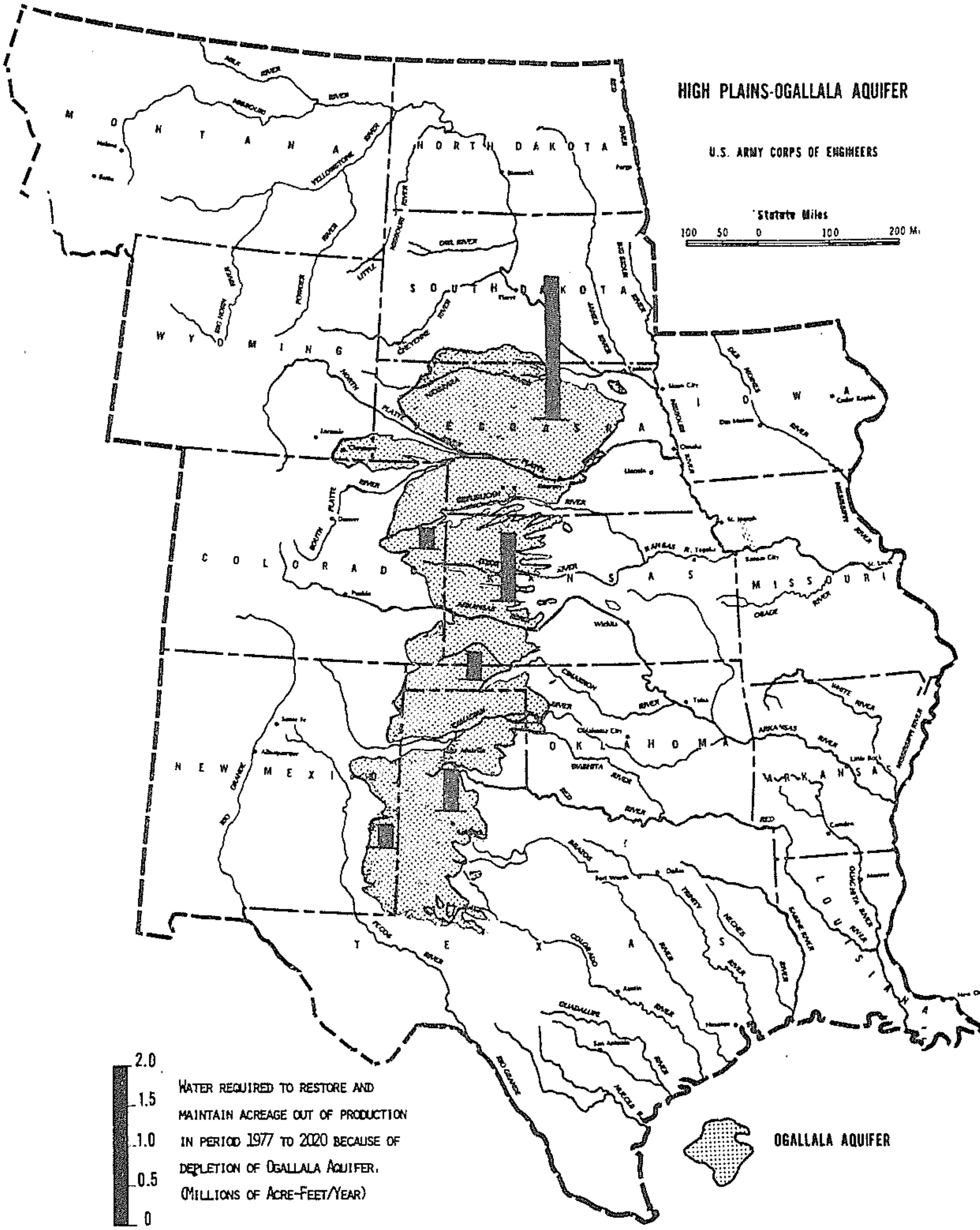
As described earlier, the corps has determined costs to transfer a range of quantities of water for each route. One end of the range has been defined by information generated by the states and provided to the corps by the general contractor. That information defined the quantities of water required to restore and maintain irrigated lands in the High Plains Study area that might otherwise go out of production between 1977 and 2020. One basic assumption behind those estimates is that Management Strategy One, voluntary conservation, is in effect. The quantities of water needed are tabulated below and shown graphically in Figure 2.

State	Water Requirements (acre-foot)
Colorado	250,000
Kansas	862,000
Nebraska	1,783,000
New Mexico	302,000
Oklahoma	334,000
Texas	525,000

The other end of the range of flows for which costs were prepared was to be defined by the requirements of Resolution 6. Preliminary guidance on base flows that would meet the intent of HPSC Resolution 6 was provided by the general contractor in October 1980. Subsequent discussions between the corps and the general contractor resulted in a letter of May 11, 1981, which provided a general outline of references to be used in complying with Resolution 6. In the absence of specific base flows, the Fort Worth and Tulsa study managers evaluated the guidance in the May 11 letter and decided on a set of base flows which appeared to meet present and future in-basin needs. Those base flows are tabulated below. The assumed base flows were provided to the general contractor for review prior to their use in this phase of the study.

Source	Average Annual Flow (cfs)	Assumed Base Flow (cfs)
Sulphur River at Darden, Texas	2,500	1,000
Sabine River at Tatum, Texas	2,300	1,000
Arkansas River at Pine Bluff, Ark.	41,500	10,000
Arkansas River at Van Buren, Ark.	30,150	10,000
Oucahita River at Camden, Ark.	7,600	3,000
Red River at Fulton, Ark.	17,400	5,000
White River at Clarendon, Ark.	29,200	5,000

Base flows for the Missouri River at Fort Randall, S.D., and St. Joseph, Mo., are to reflect current needs as defined by present operating procedures of the Missouri River Navigation System and future needs projected by the Bureau of Reclamation for the Missouri River Basin. The Missouri River Division Office of the Corps of Engineers has evaluated the base flows necessary to meet present and future requirements and the impact of various potential diversions on those base flows. Transfer alternatives A and B, through Nebraska and Kansas, have been designed to deliver an assumed minimum quantity of water per year to define the lower end of the range. In the case of route A, the studies have shown that diversion of any significant amounts of water from the Missouri River at Fort Randall Dam, S.D., would reduce the dependability of full service navigation as currently defined. Therefore, for purposes of cost estimation, a system was designed to meet the year 2020 needs of Nebraska plus one-half the needs of Colorado, or about 1.9 million acre-feet per year. The assumed source for route B, the Missouri River near St. Joseph, was projected to have about 2.1 million acre-feet of water surplus to the projected needs. Costs were analyzed for a system to divert 2.1 million acre-feet which after losses equates to 1.6 million acre-feet deliverable to agricultural land in the High Plains. The maximum quantity for which those routes were designed provides sufficient water to restore and maintain lands in Nebraska, Colorado, Kansas, Oklahoma and a portion of Texas, or about 3.4 million acre-feet per year.



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U.S. ARMY CORPS OF ENGINEERS
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WATER REQUIRED TO RESTORE AND MAINTAIN ACREAGE OUT OF PRODUCTION IN PERIOD 1977 TO 2020 BECAUSE OF DEPLETION OF OGALLALA AQUIFER. (MILLIONS OF ACRE-FEET/YEAR)
OGALLALA AQUIFER

Figure 2

Routes C and D through Oklahoma and Texas were designed to deliver a range of flows, defined at a mimimum by the quantities necessary to restore and maintain lands in Texas, Oklahoma and New Mexico, and at a maximum by the quantities available for diversion above the base flow requirements of the sources.

The range of needs assumed for the various routes does not in any way imply that those quantities are available for transfer. Judgements of that type can only be made by the affected parties after detailed studies. The range was established for the purpose of defining costs.

5. Sources

Availability of water from the designated sources is a question of the allocation of the residual resource after existing and potential in-basin uses have been satisfied. The policy for inter-basin transfer has been set by the High Plains Study Council in their Resolution 6. That policy prescribes that states in the basins of origin, both upstream and downstream of diversion points, must have prior rights in perpetuity for beneficial use of the source streams. Only water surplus to in-basin needs over time would be considered for export. Any decision on implementation of a water transfer plan would be made by the exporting and importing states in cooperation with the U.S. Congress. This paper does not attempt to report on the institutional availability of water from source states, but only to evaluate the apparent physical availability of water for transfer and the engineering feasibility of the four alternative transfer routes.

In order to represent the present and future in-basin needs which must be met before export could take place, a hypothetical base flow has been assumed for each diversion point. The base flow is planned to be sufficiently large to meet both existing and future needs. Withdrawals from the source stream would not be taken when the stream flow was less than the base amount. Amounts exceeding the base flow would be skimmed and stored in nearby source storage to be transferred to the High Plains at a steady rate. On the Missouri River it was assumed that Fort Randall Dam would act as the source storage for the diversion across Nebraska and that an off-stream reservoir would be constructed near St. Joseph, Mo., for the route through Kansas. In all cases the base flow concept has been used.

The Water Management Branch for the Corps of Engineers in Dallas analyzed the individual source points using historical flow data and determined relationships between base flow, quantity of source storage, diversion pumping rate and dependable yield. The individual study groups then utilized those relationships to select the components of their source arrangement. The final report will include plots of the data for each source location.

The use of the largest available source storage allows the maximum yield from the source river. It is also important from a cost standpoint to have the source storage located as close to the source river as possible. This is necessary because the pumps and pipelines which remove and carry the water when available from the source stream to the source reservoir are much larger than the capacity of the canal system which is designed to remove the water from the source reservoir at a constant rate. The source reservoirs as presently conceived would be single purpose and could experience wide fluctuations in water levels. Because of the size, location and operating requirements, the source storage reservoirs would cause major environmental impacts. Those impacts will be addressed in the final report.

6. Transfer Facilities

The primary means of transferring the water would be by an open, trapezoidal, concrete-lined canal. Routes were selected based on the concept of a series of ridgeline canals connected by pumping plants. The pumping plants are needed to lift the water several thousand feet to the terminal points. The individual routes, their respective elevation differences and the number of pumping plants required are shown in the following table.

Route	Total Elevation Difference (ft)	Maximum Number of Pumping Plants
A (Nebraska)	2,400	18
B (Kansas) South/North	1,745/1,965	16/29
C (Oklahoma)	3,600	49
D (Texas)	2,725	30

Gravity flow would transfer the water between pumping plants with siphons used to cross major streams, some highways and railroads. Other roads and railroads would be relocated to cross the canal by bridge. Tunnels would be used to cross some ridges or series of ridges. The pumping plants would utilize up to 10 turbine-type centrifugal pumps driven by electrical motors. The pumps would discharge into prestressed, precast concrete pipe for delivery to higher elevations where it would again flow by gravity to the next pump station. The canals would be designed for flow velocities of less than five feet per second with three to six feet of freeboard and check gates at approximately four-mile intervals. The maximum length of the canals for each route is shown in the following table.

Route	Length of Canal (miles)
A	620
B (south)	375
C	1,135
D	850

Route C utilizes the Arkansas River Navigation System Channel to transfer the water 209 miles from near Little Rock, Ark., to W.D. Mayo Lock and Dam on the Oklahoma/Arkansas border. Pumping plants would be constructed at each of the existing six locks and dams. Movement of the quantities of water contemplated in this study could probably be accomplished without increasing the dimensions of the navigation channel.

Canal dimensions are defined in the Cost and Design Manual prepared by the Corps of Engineers for this study. Figure 3 shows a cross-section of a 10,000 cubic feet per second canal which is close to the largest that might be required for the quantities under consideration.

The canal system is designed to operate at a constant discharge. For design purposes it was assumed that breakdowns, weather, etc., would limit the system to 85 percent of capacity. The canals, therefore, are oversized to provide a flow capacity of 1.18 times the design flow. Losses of water in transit because of evaporation, seepage, etc., were assumed to be 10 percent of the flow.

The tentative alignment of the canals is shown in Figure 1. Although the alignments have been selected to follow ridge lines, avoid rough terrain and environmentally sensitive areas, and minimize pumping plants and siphons, they remain tentative and should not be assumed to be the "best" routes without much more detailed studies.

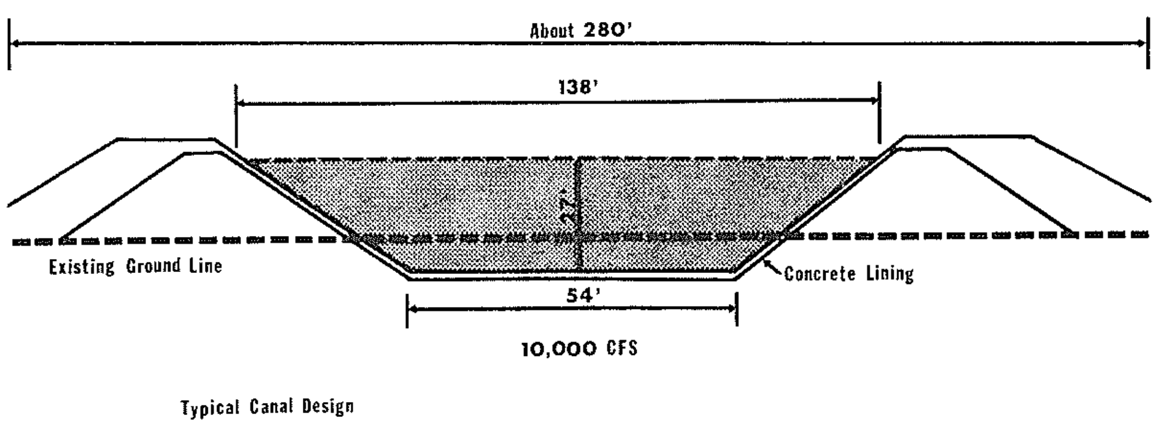

Figure 3

7. Terminal Storage

Since agricultural water needs in the High Plains area are not divided equally throughout the months of the year, it is necessary to provide storage at the terminal end to be able to distribute the water when needed. The general contractor has provided a tabulation of seasonal irrigation water needs typical of the northern and southern portions of the High Plains. That information is shown below.

Month	Percent of total year water demand	
	North	South
January	0.5	1.0
February	1.0	3.0
March	5.0	6.0
April	10.0	19.0
May	18.0	8.0
June	12.0	11.0
July	19.0	24.0
August	25.0	19.0
September	7.0	7.0
October	1.0	1.0
November	1.0	0.5
December	0.5	0.5

Terminal storage facilities were developed for each route and were designed to be of sufficient size to meet the above monthly needs while receiving a constant inflow. Evaporation consistent with the location of the particular terminal reservoir was accounted for along with an assumed loss of 10 percent between the terminal reservoir and the farm site. Route C assumed the use of existing reservoirs for terminal storage, while routes A, B and D used sites which are presently undeveloped. A tabulation of the routes and their terminal storage sites is shown below.

Route	Terminal Storage Site	Storage Required (acre-feet)
A (Nebraska)	Seven sites in Nebraska and one in Colorado	1,330,000
B (Kansas) (South)	Utica Site, Kan.	1,820,000
C (Oklahoma)	Existing Meredith & Optima lakes, Canadian Site	2,630,000
D (Texas)	Blanco Canyon Site, Texas	3,800,000

8. Multipurpose Opportunities

This reconnaissance-level study only considers costs to transfer water from specific sources to specific terminal points. However, opportunities exist throughout the system to develop related benefits which could help justify the system's costs. For example, flood control could be included in conjunction with the source and terminal reservoirs, and recreation and fish and wildlife benefits could be considered at the reservoirs and along the canals themselves. In addition, municipal and industrial water supply, as well as supplemental wildlife water supplies, are very probable multipurpose opportunities along the transfer routes. Although it was evident that additional project-related opportunities existed with each of the transfer plans evaluated, an in-depth study of them was considered to be beyond the scope of this reconnaissance-level planning effort.

9. Environmental Studies

To supplement its engineering feasibility studies, the Corps of Engineers conducted, in cooperation with the U.S. Fish and Wildlife Service, broad-based assessments of the potential environmental impacts that could be expected along each of the corridor routes studied. These studies included identification and mapping of sensitive environmental and cultural areas to assist in corridor layout that would avoid adverse impacts on state, federal and private wildlife refuges; Indian reservations; military reservations; ethnic settlements; management areas; natural areas; parks; recreation areas; archeological and historic sites; wetlands; and national or state forests. The general importance of wildlife habitat, aquatic systems, land use, physiographic features, aesthetics and environmental quality adversely affected along the study routes was assessed using known base resource data for the regions involved. General conclusions reached separately by the four Corps of Engineers' districts are summarized as follows. The actual assessments conducted are quite extensive and are currently under review in the Southwestern Division Office.

Route A (Nebraska). Looking at the entire project, it appears that most of the fish and wildlife impacts would occur in the northern half of the study area. This is due to aquatic habitat losses in Lake Francis Case and the Missouri River below Fort Randall Dam; woodland habitat losses due to construction of Eagle Creek Reservoir; and wetland, woodland, and native prairie losses due to canal construction in the Niobrara Valley and the sandhills in Nebraska.

Most of the fish and wildlife benefits would occur in the southern half of the project area (assuming that woodland habitat losses are adequately compensated for). This is due to the reservoirs providing increased public fishing and hunting opportunities, flow increases in the North Platte and Platte rivers, and the possibility of flow increases in other streams in Nebraska and eastern Colorado. Also, the construction of additional open water north and south of the Rainwater Basin area could help distribute crowded waterfowl populations over a larger area, thus reducing disease problems during spring migration.

Endangered and threatened species losses will probably be insignificant over most of the project area, except for those aquatic species associated with the Missouri River. The bald eagle, whooping crane and interior least tern could benefit from various aspects of the project.

To achieve the full compensation goal of no net loss of in-kind habitat, an estimated 10,000-25,000 acres of land would be required to compensate for anticipated woodland and wetland losses.

Route B (Kansas). Although no federal or state designated fish and wildlife area, refuge, or public hunting area would be directly affected, the construction and operation of an intake structure in the Missouri River at St. Joseph, Mo., may result in some entrainment and impingement of fish as a result of high intake velocities. Also, significant environmental effects would result from construction of the intake storage facility that would require approximately 19,000 acres of land in northeast Doniphan County near White Cloud, Kan. Construction of this reservoir would inundate an area containing scenic high loess bluffs and heavily dissected drainage valleys mantled with an oak-hickory forest containing significant terrestrial wildlife habitat.

Although 13,000 acres of terrestrial habitat would be eliminated, these acres would be supplanted by an equivalent number of aquatic acres. This ecosystem change would result in a large reduction of faunal and floral diversity.

In a region of western Kansas where terrestrial wildlife habitat is at a premium, and primarily relegated to the narrow stream borders, removal of between 15,800 and 33,000 acres of habitat for terminal storage reservoirs would have a major negative impact on terrestrial wildlife species, such as mule and white-tailed deer. However, the negative impacts of the western storage reservoirs could be ameliorated by development and management of wildlife areas adjacent to the lake shore. Management of the upper reaches of most Kansas impoundments has provided excellent wildlife cover, increasing the carrying capacity of many wildlife species in the drainage when compared to preproject conditions.

Considering the impacts along the canal corridors themselves, an adverse environmental impact on mammal movements in the area would occur. The fenced canal effectively would be an impregnable barrier along its entire length, the exceptions being small areas adjacent to the canal's siphons and lift pumps. Random population movements of such mammals as furbearers (raccoon, coyote); small game (rabbits, squirrels); and big game (mule and white-tailed deer) would be restricted once the canal was constructed.

Any water transfer route through Kansas, with the inclusion of the storage lakes, would impact on agriculture throughout its entire length. A southern route, 376 miles long, would remove between 26,300 and 37,600 acres of private land from production, depending upon the channel size selected. The northern route studies, 337 miles long, would remove between 23,600 and 33,700 acres from agricultural production.

Route C (Oklahoma). The route C water transfer system would involve the construction of more than 1,000 miles of concrete canals and associated pumping facilities, and periodic or permanent inundation of more than 300,000 acres of land for storage reservoirs. The major loss of land and associated wildlife habitat would most likely have extensive and significantly long-term environmental impacts. Each of the seven storage reservoirs would involve environmental, social and cultural resource impacts equivalent to a large multiple-purpose water resource project. The severity of environmental impacts associated with the loss of valuable wetland and flood plain habitat inundated for storage reservoirs would greatly exceed the losses from construction of the canals and pumping facilities. Also, the beneficial aspects of a lake fishery and recreation resources normally associated with most water resource projects would be limited by the single-purpose nature of the storage reservoirs due to widely fluctuating water levels.

In addition to the probable loss of aquatic organisms and flood plain habitat downstream from the diversion intakes affected by reduced flow -- including the indirect impacts on coastal regions and the possible impacts on several federal-listed threatened and endangered species -- the loss of critical habitat along the canal route itself needs to be considered and evaluated in more detailed studies.

Although not evaluated in great detail in this study, the impact of transporting water from sources of better quality than the water presently stored in Lake Meredith should be considered. Transporting softer, more acidic water to hard and basic water regions needs to be considered if further, more detailed studies are pursued. Also, future studies should determine if the transportation of water and microscopic organisms to different drainage basins would impact endemic species in the High Plains region.

Route D (Texas). Construction of more than 900 miles of concrete canals and associated pumping facilities, and periodic or permanent inundation of as much as 437,000 acres of land for storage reservoirs, would have a significant long-term environmental impact. Each of the seven storage reservoirs included in the alternative route D plan would involve environmental, social and cultural resource impacts equivalent to a large multiple-purpose water resource project. Also, the beneficial aspects of lake fishery, recreation and aesthetic value normally associated with a water resource project would be constrained in these single-purpose water transport storage reservoirs, as presently planned, due to fluctuating water levels.

It is believed that environmental quality problems relating to air and water pollution could be reduced to tolerable levels during construction. Environmental design, landscaping and reclamation of disposal sites and exposed areas also could limit impact on aesthetic values. Social impacts related to land acquisition and relocation of homes and people would also be minimized in accordance with existing laws, policies and regulations relating to economic compensation to affected landowners and tenants. Cultural resources largely could be avoided, incorporated into interpretive facilities, or mitigated through relocation or data salvage. Costs for cultural resources mitigation have been included in the water transfer facility cost estimates.

Extensive adverse impacts on wildlife habitat would be expected with construction of water transfer facilities and storage reservoirs. Potentially significant impacts on stream fisheries and indirect impacts on coastal fish and wildlife resources also are possible as a result of withdrawals of source water and construction of holding reservoirs. There are a number of ways to reduce and minimize adverse impacts on these resources through design of facilities and detailed mitigation planning. There is also a number of opportunities relating to development of fish and wildlife resources on lands acquired for right-of-way for canals and storage reservoirs and on lands which could be acquired and managed specifically to replace wildlife productivity lost to construction. Costs for wildlife mitigation also have been included in the overall cost estimates.

Severely fluctuating water levels at storage reservoirs would generally constrain development of a traditional lake fishery. However, management of water levels in a system operation, and dedication of quantities of water for fish and wildlife purposes, could result in some innovative approaches to both lake fishery development and management and downstream flow enhancement to affected streams. The canal, being a uniform concrete bottom structure, would also be a significant constraint to development of an aquatic ecosystem of beneficial use to man. The lack of bottom substrate, bank vegetation and cover, temperature fluctuation, and general lack of a supporting primary/secondary productivity ecosystem would severely limit diversity and general health of a fishery in the canal. Velocity, fluctuations in discharge, and entrainment of larvae or juveniles in pumping facilities would also constrain development of a fishery. However, the potential is there for designing an appropriate bottom structure, shelter areas, and protection devices on pumping facilities in order to create an ecosystem functional for at least a few native fish species or potential exotic introductions.

Natural heritage areas along or near the affected corridor and storage reservoirs could be considered for acquisition and incorporation into mitigation planning of the water transfer system. Opportunities to preserve some of these unique areas, and make them available to the public, would be present in detailed planning.

Due to expected water fluctuations in storage reservoirs and limited aesthetic value of concrete lined channels, recreation potential of these facilities would be limited, particularly in northeast Texas and Arkansas where natural or manmade water resources are abundant. However, in portions of north-central and west Texas, the canal and terminal storage at Blanco Canyon may provide a focal point for satisfaction of identified water resources-related recreation demand. Off channel recreation lakes utilizing a portion of the water transferred, or localized hiking, biking, or other recreational outlets along the canal itself, may be included in more detailed planning.

10. Cost Estimates and Route Comparisons

The total investment cost of each route is composed of the total first cost combined with the cost of interest during construction. The total first cost includes the estimated construction cost, plus the engineering and design, plus supervision and administration of the actual construction. Interest during construction represents the return foregone on the funds invested in the construction before the project begins to generate benefits. Because of the length and size of the routes and the resulting lengthy construction period, the interest-during-construction cost is a sizable portion of the total investment cost. The total investment cost is very sensitive to the assumed length of the construction period.

To display the costs in a more understandable way, the total investments costs were converted into an average annual cost. The average annual cost is the amount that would have to be recovered each year to repay the original investment over a specific period of time at a specific rate of interest. For this study, the interest rate used was the FY 81 Federal Water Resources Council rate of 7 3/8 percent and the period of analysis was 100 years. The average annual cost is then combined with an estimated annual operation, maintenance and replacement cost and an estimated cost of energy to arrive at a total average annual cost of the project.

In order to bring the cost data to an even more practical level, the total average annual cost was divided by the quantity of water assumed to be delivered to the farm site. This procedure results in an average cost of water in dollars per acre-foot per year. This value could be described as the cost of an acre-foot of water in storage at the terminal reservoir. It does not reflect the cost of distribution of the water from the terminal reservoir to the farm site. Table 1 shows the average cost of water per acre-foot per year. The table also shows the energy component of that total cost of water.

Electrical power costs used in the study were furnished by Black & Veatch, Consulting Engineers. They were based on 1977 price levels and projected through the year 2020. Projected completion of the water transfer project is in year 2005, so full use of electrical power would not begin until that year. Power costs beyond year 2020 were projected by linearly extrapolating Black & Veatch's projected 2000 and 2020 values. These costs are specific to each route and are generally higher for routes C and D as shown in Table 1.

11. Conclusions

Although the report is still under review and final conclusions have not been reached, the study results indicate:

a. Construction of canal systems capable of transporting up to 9 million acre-feet of water from adjacent areas is feasible from an engineering standpoint.

b. The first cost of such systems ranges from $3.6 billion for a system to deliver 1.6 million acre-feet per year to western Kansas to $22.6 billion to deliver 6 million acre-feet per year to the northern panhandle of Texas and the panhandle of Oklahoma. The costs are in 1977 dollars, and the construction period is assumed to be 15 years.

c. The annual cost for such systems ranges from $413 million per year for the Kansas route to $3.8 billion per year to transfer 8.7 million acre-feet to near Lubbock, Texas, along route D. Those annual costs include energy at current prices in 1977 dollars.

d. The costs in this report do not include a distribution system beyond the terminal reservoirs. The quantities of water have been reduced by a factor of 10 percent to account for losses in distribution.

e. The unit cost of water delivered to terminal storage in the High Plains-Ogallala area ranges from $226 per acre-foot to $569 per acre-foot in 1977 dollars.

f. The construction of any of these systems would require from 10 to 20 years, with 15 years considered a reasonable period. Reducing or increasing the construction period by 5 years can alter the investment cost by as much as 25 percent.

g. Large amounts of energy would be required to operate any of the systems. From 4 to nearly 50 billion kilowatt hours per year of electrical energy would be required to operate any one system. The annual cost of that energy in 1977 dollars would range from $140 million to $1.1 billion.

h. If increases in energy costs occur as projected, the unit cost of water will range from $320 to $880 per acre-foot in year 2105.

i. Water sources exist in areas adjacent to the High Plains with sufficient flow to provide up to 8.7 million acre-feet per year of water for transfer to the High Plains. None of that water has been identified as surplus to the needs of the basin of origin.

j. Construction of any of the routes would result in major environmental impacts. These impacts would include altered flow regime on the source streams, inundation of large areas for source and terminal storage, conversion of large amounts of agricultural land to other purposes, disruption of wildlife patterns, and transfer of organisms to new areas. Any future studies considering implementation should include comprehensive environmental studies.

TABLE 1

Unit Cost of Transferred Water[1]

Route	Quantity Transferred (mafa)[3]	Energy Cost[2] ($/acre-foot)	Unit Cost of Water[4] ($/acre-foot)
A	1,980	80	292
	4,135	99	292
B (North)	1,615	108	335
	3,878	104	302
B (South)	1,615	87	255
	3,878	82	226
C	1,260	154	569
	6,040	154	434
D	1,550	112	490
	8,700	130	441

[1]15-year construction period, first cost amortized at 7 3/8 percent interest for 100 years, energy and construction in 1977 dollars.

[2]Energy cost based on 1981 energy price in 1977 dollars.

[3]Million acre-feet annually.

[4]Includes energy cost.

TABLE 2

Project Data

Route	Total Static Lift (ft)	No. of Pumping Plants	Length of Project (Miles)	Quantity Transferred (maf)	Investment Cost[1] ($billion)	Energy to Operate (kwh/yr)
A (Neb.)	2,400	18	620	4.1	10.6	18,000
B (Kan.)	1,745	16	375	3.88	7.4	14,200
C (Okla.)	3,600	49	1,135	6.04	22.6	42,700
D (Texas)	2,725	30	850	8.7	20.6	50,000

[1]1977 prices.

TABLE 3

Summary of Energy Costs

Transfer Route	Range of Quantities (million acre-feet delivered per year)	Energy Requirement (billion kilowatt-hours per year)	Energy Cost (1977 price level)	
			$/acre-foot	mil $/year
A	2.0	7.0	80	158
	4.10	18.0	99	409
B	1.62	6.2	88	142
	3.88	14.1	82	320
C	1.26	8.4	154	194
	6.04	42.7	154	930
D	1.55	7.5	112	174
	8.71	50.	130	1,134