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Interbasin Transfer Economics: The High Plains Region

Allen Kneese

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Citation Information

Kneese, Allen, "Interbasin Transfer Economics: The High Plains Region" (1982). *New Sources of Water for Energy Development and Growth: Interbasin Transfers: A Short Course (Summer Conference, June 7-10)*. <https://scholar.law.colorado.edu/new-sources-of-water-for-energy-development-and-growth-interbasin-transfers/7>

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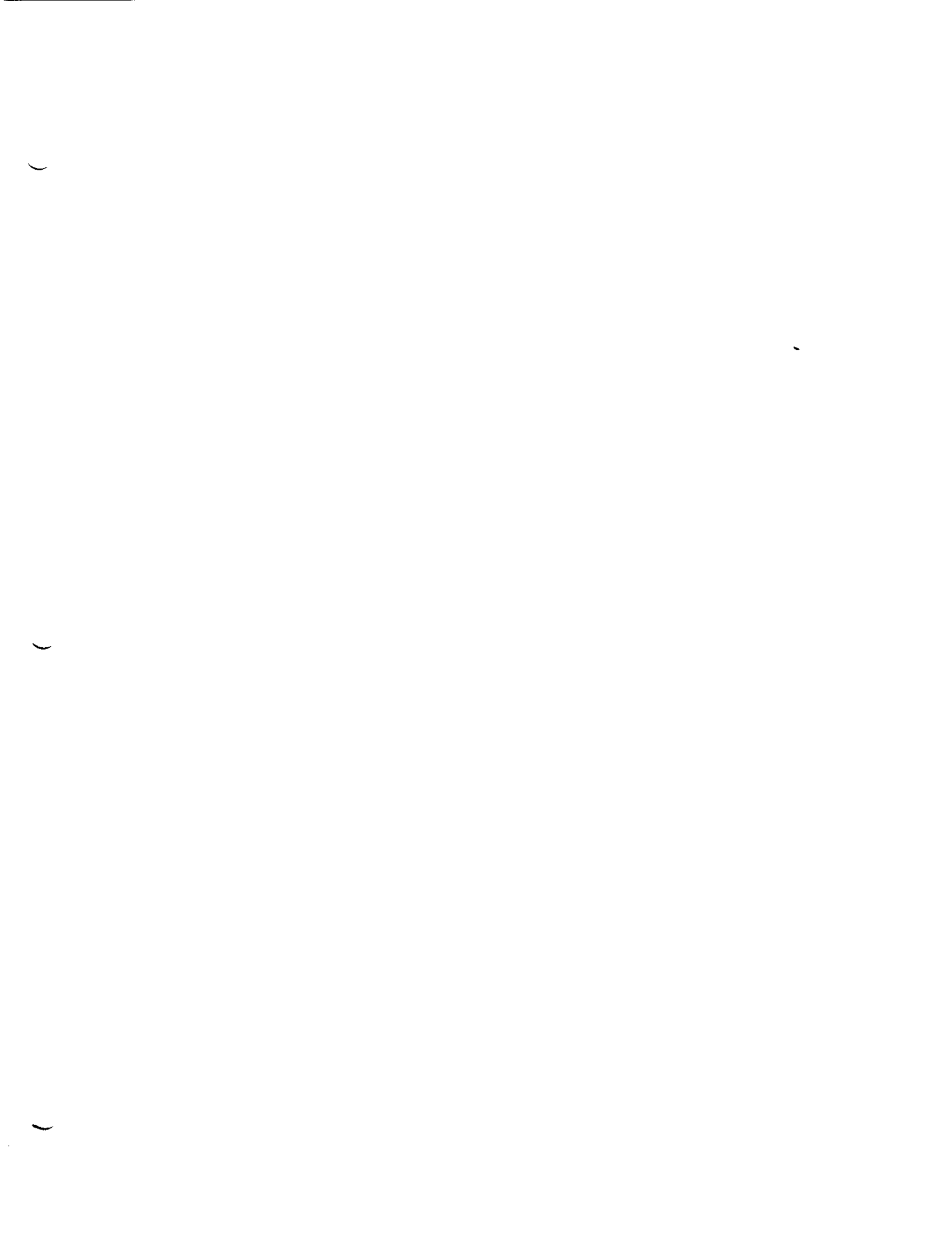
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INTERBASIN TRANSFER ECONOMICS:
THE HIGH PLAINS REGION

Allen Kneese
Resources for the Future, Washington, D.C.

New Sources of Water for Energy
Development and Growth: Interbasin Transfers

a short course sponsored by the
Natural Resources Law Center
University of Colorado School of Law
June 7-10, 1982



Outline for "New Sources of Water for Energy Development
and Growth: Interbasin Transfers"

University of Colorado School of Law
June 7, 1982

1. A brief history of High Plains development leading to irrigation of 15 million acres.
2. A brief history of proposed interbasin transfers in Texas and other High Plains states.
3. The water depletion problem in the Ogallala Aquifer.
4. Adaptations of farmers to declining water supplies and increased energy costs.
5. Section 193, Public Law 94-587 and the Six State High Plains-Ogallala Aquifer Regional Resources Study.
6. The organization and structure of the study.
7. The Corps of Engineers study of transbasin diversions.
8. Monetary and other costs of transbasin diversions to the High Plains.
9. Benefits of diversions to the High Plains.
10. Indirect benefits and costs associated with diversions to the High Plains.

SIX-STATE HIGH PLAINS-
OGALLALA AQUIFER
REGIONAL RESOURCES STUDY

A Report to the U. S. Department of Commerce
and the
High Plains Study Council

March 1982

High Plains Associates:

Camp Dresser & McKee Inc.
Black & Veatch
Arthur D. Little, Inc.

EXECUTIVE SUMMARY

SIX-STATE HIGH PLAINS-OGALLALA AQUIFER REGIONAL RESOURCES STUDY

INTRODUCTION

The problem of depleting Ogallala Aquifer water supplies to support 15 million acres of irrigation crop farming in the High Plains was addressed by the U.S. Congress in Section 193, Public Law 94-587. The Congressional intent was clear and concise in directing the Secretary of Commerce ". . . to examine the feasibility of various alternatives to provide adequate water supplies" for the High Plains Region, and ". . . to assure the continued economic growth and vitality of the region." The High Plains Study Council, made up of the governors of the six states and three representatives of each state appointed by the Governor and a representative of the Department of Commerce, was also clear and concise in stating overall study objectives: "(i) to determine potential development alternatives for the High Plains, (ii) to identify and describe the policies and actions required to carry out promising development strategies, and (iii) to evaluate the local, state, and national implications of these alternative strategies or the absence of these strategies."

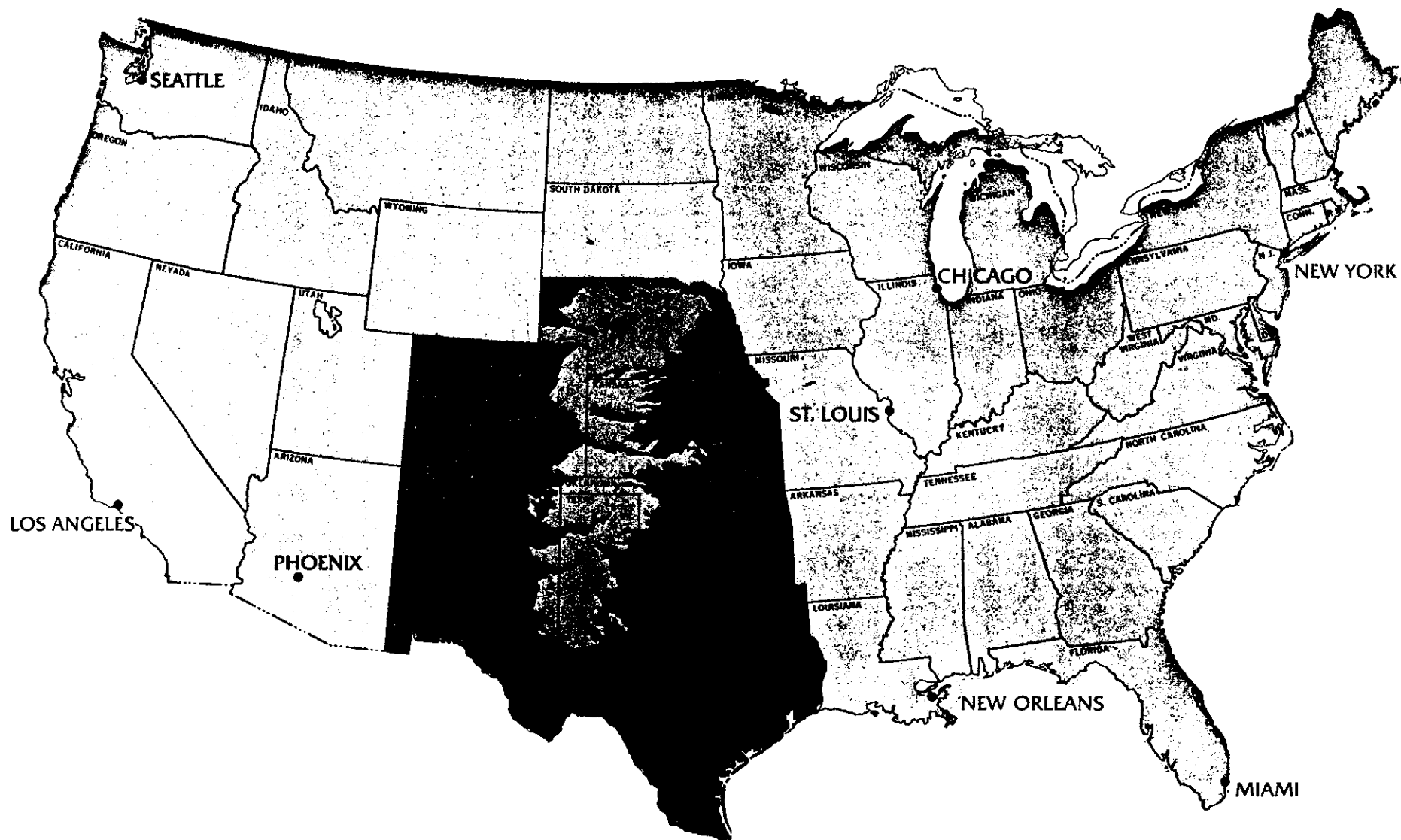
GEOGRAPHIC AREA

The High Plains area extends over parts of Colorado, Kansas, Nebraska, New Mexico, Oklahoma and Texas in the Great Plains land resource region of mid-continental America. Much of the High Plains is underlain by the Ogallala Formation, a major aquifer supplying most of the water needs of the area's large agricultural economy.*

The Ogallala Formation, of Tertiary age, is an unconsolidated remnant of vast deposits of gravel, sand, and silt eroded from the ancestral Rockies. Erosion has reduced the area of the extensive deposits that once covered all of the Great Plains region, leaving the Ogallala as the principal geologic unit associated with the High Plains today.

* See Figure 1

FIGURE - 1: THE HIGH PLAINS REGION—OGALLALA AQUIFER



The area encompassed by this Study includes 180 counties in the Region underlain in whole or in part by the Ogallala Formation or Aquifer, an area of about 220 thousand square miles.

STATEMENT OF PROBLEM

The High Plains Study Region offered large quantities of good quality water, abundant low cost energy, deep soils, level terrain, and a climate favorable to agricultural enterprises. Development of irrigated agriculture, largely supplied by water from the Ogallala Aquifer, expanded rapidly following World War II. Total irrigated acreage in the Study area expanded from about 3.5 million acres, mostly in Texas and Nebraska in 1950, to more than 15 million acres in 1980.

As irrigated acreage expanded, water requirements grew. Less than 7 million acre-feet of water were withdrawn from the Ogallala in 1950. By 1980, more than 21 million acre-feet were pumped annually even though over the same period improved irrigation efficiencies had reduced per acre application of water by about 30 percent from 2 acre-feet per acre to about 1.4 acre-feet per acre.

Feed grain crop production grew from 150 million bushels in 1950 to 1.25 billion bushels in 1980. The Region marketed about 38 percent of the fed beef cattle production in the Nation by 1980.

A complex infrastructure of agricultural business supply developed-- fertilizers, farm equipment, and capital investments.

Energy production from the oil and gas reserves became an important sector in the regional and subregional economies. Over the long term, these reserves will be seriously depleted.

With this progressively expanding agricultural economy came larger demands for water from the Ogallala, coupled with simultaneous and complex changes in the availability of low cost natural gas. As a result, this Study was undertaken to project the probable consequences of various water resource

management alternatives for the High Plains Region and depletion of the energy resources. These consequences will have local, state, regional, and national impacts. The measure of the extent and timing of those impacts were the key problems resulting in authorization of the Study.

STUDY AND REPORT ORGANIZATION

Responsibility for administrative direction of the Study, and for final recommendations to the Congress, was assigned by the authorizing legislation to the Secretary of Commerce acting through the Economic Development Administration (EDA). The states and EDA formed the High Plains Study Council to assure policy guidance for the Study, and to submit its conclusions and recommendations to the Secretary and the Congress. Key federal agencies were represented on a Technical Advisory Group formed by EDA to provide technical review support.

Technical direction of the Study was provided by the High Plains Associates (General Contractor) made up of the consulting firm of Camp Dresser & McKee Inc., as prime contractor, in association with Black & Veatch as joint venturer, and Arthur D. Little, Inc., as subcontractor. Vital research was carried out by the states. Concurrent studies by federal agencies contributed directly to Study results.

The full \$6 million authorized for the Study was appropriated by Congress. Two million was allocated to the states for state level research basic to the Study under subcontracts with the General Contractor, and \$775,000 to the U.S. Army Corps of Engineers for studies of interbasin transfers under a contract with EDA.

The High Plains Associates entered into a contract with the Department of Commerce in September 1978, and negotiated subcontracts in the spring and summer of 1979 with each of the six states for performance of state and farm-level work elements. These state subcontracts involved work tasks by state agencies, universities, and private consultants.

The Plan of Study outlined three research elements which were conducted by the states:

- State and farm-level research
- Energy production impacts
- State water resources evaluations and economic and other impacts

Regional assessments were performed by the High Plains Associates of important Study elements (division of responsibilities among the three members of the team shown in parentheses):

- Interbasin transfer assessment (CDM)
- National and regional impact assessment (ADL)
- Agriculture and water technology assessment (CDM)
- Preliminary environmental assessment (CDM)
- Unconventional water supply assessment (CDM)
- Institutional assessment (CDM)
- Crop prices assessment (ADL)
- Energy price and technology assessment (B&V)
- Dryland farming assessment (ADL)
- Nonagricultural development potential assessment (ADL)
- Alternative development strategy assessments (ADL)
(via a regional input/output model)

This Report, together with separate documents presenting the special Regional Assessments, the state reports on research conducted by each of the six states, and the U.S. Army Corps of Engineers report on interbasin transfers describe how broad Study objectives have been met. Chapter One provides background information which led to the Study, and Chapter Two provides information on the Region under study and its diminishing water and energy resources. Chapter Three defines the alternative water management strategies selected for analysis. Chapter Four defines the Study's methods of analysis, starting with 1977 as the base year with monetary results expressed in terms of 1977 dollars. Chapter Five describes impacts of projected "Baseline" conditions reflecting a continuation of present trends to 2020 without a new purposeful public policy and action program to alter the trends, and Chapter Six describes impacts of strategies designed to alter trends in water availability and use in the future to 2020. In Appendix A, the brief discussion of methodology included in Chapter Four is expanded, and

the models used in the Study's analytical framework are described in detail. Appendix B presents detailed tables showing Study results. Appendix C provides task detail on the Study organization and identifies source agencies and entities which can be contacted with respect to the Study.

In this Executive Summary, the results of the several analyses are synthesized and presented. This is accomplished by inter-strategy comparisons highlighting significant quantitative differences in impacts among water management strategies, and by summarizing those results of the separate regional assessments that significantly relate to the quantitative strategy analyses. The methods of analysis chosen were those appropriate to the objectives of the Study as defined in the authorizing legislation. Analyses of benefit and cost comparisons would only be made for specific projects or actions undertaken as a part of implementing Study results.

In arraying results, the intent is to provide information about projected outcomes as an aid in making major policy choices, and for choosing among mechanisms for translating policy into program administration. Thus, the results of the High Plains-Ogallala Aquifer Regional Resources Study are portrayed to facilitate an effective response by the Council and the Secretary of Commerce to the Congressional intent. /

ALTERNATIVE STRATEGIES AND INTER-STRATEGY COMPARISONS

To carry out the Congressional directives and to fulfill the High Plains Study Council objectives, two incremental management strategies to reduce water demands in the Region and three strategies to increase regional or subregional water supplies were formulated. These water demand and supply management strategies were evaluated in comparison to projected "Baseline" conditions, i.e., the continuation of present trends in use of Ogallala Aquifer water with no new public policies or programs to effect greater water conservation or to increase supplies. The probable future of the energy sector and the effect on the High Plains regional and subregional economies was analyzed including projections of future energy prices. The potential for future nonagricultural development in sustaining the regional economy was assessed.

The Framework for Impact Assessment

The water management strategies analyzed in the Study are:

- A "Baseline" trend projection of currently available water conservation and use technology and practices already in use to some extent, with no new purposeful public policy to intervene with action programs for altering the course of irrigation water consumption. (the Baseline)
- A strategy which would stimulate voluntary action to reduce water demands through research, education, demonstration programs and incentives, using technology and practices either not considered in the Baseline analysis or reflected at rates which would be purposefully accelerated. (Management Strategy One)
- A strategy which assumes Strategy One policies and programs, and in addition projects further water demand reduction by mandatory programs of a regulatory nature to control water use. (Management Strategy Two)
- A strategy to add local water supply augmentation actions to demand reduction efforts. These actions could include local practices such as cloud-seeding, local storage, ground water recharge, desalination, and snowpack and vegetation management. (Management Strategy Three)
- A strategy of intra-state surface water interbasin transfers, importing water into the High Plains Region in accordance with State Water Plans of the six High Plains states. (Management Strategy Four)
- A strategy of interstate surface water transfers, importing water from sources in areas adjacent to the Ogallala Region by means of large-scale federal-state or federal projects to

restore and maintain irrigation of the acreage that would have reverted to dryland farming by 2020 under Strategy One or Two. (Management Strategy Five)

For each water management strategy, state-level linear programming (LP) models were used to project crop production, irrigated and dryland crop acreages, value of agricultural production, returns to land and management (plus returns to imported water for Strategy Five), and ground water use, each for 1985, 1990, 2000 and 2020. State and regional input/output (I/O) models were then used to project industry sector activities, sector employment, total value added, total household income, and state and local tax revenues, each related to the LP projections for the future years.

A special feature of the regional I/O model was its division of outputs by northern (Nebraska, Kansas and Colorado) and southern (Oklahoma, New Mexico and Texas) subregions so as to highlight the probable difference in conditions in the future for these parts of the Study region. Projections of energy production, economic effects and prices were incorporated into the LP and the I/O models.

Projected trends in energy production and availability are important factors in the regional economy. These projections, however, do not indicate significant differences among the effects of the several water management strategies although a major interstate water diversion project under Strategy Five would impose unique energy production and use requirements. Over the Study period to 2020, the decline in crude oil and marketed natural gas production is projected to continue. By 2020, these production levels are projected to be approximately 1/10 the levels at the beginning of the Study period. Electricity production, however, is projected to increase, both in installed generating capacity and electric energy production, by approximately threefold over the Study period. Some increase is projected in water consumption associated with energy production.

Comparison of Economic Indicators Among Strategies

Table 1 shows some key economic indicators of projected strategy effects, by northern and southern subregions and the Region for the Baseline,

Table 1: INTER-STRATEGY COMPARISONS OF KEY REGIONAL ECONOMIC INDICATORS

Base Year 1977*

| | Irr. Acres (1000's) | Dry. Acres (1000's) | Total Value of Agr. Prod.** (Million 1977 \$) | Returns to Land & Management (Million 1977 \$) | Water Remaining in Storage (Million Ac-Ft) | Total Value Added All Sectors*** (Million 1977 \$) | Employ- ment (1000's) |
|---------------|---------------------------|---------------------------|---|--|--|--|-----------------------------|
| NORTH | | | | | | | |
| Baseline | 7,480 | 11,595 | 2,610 | 850 | 2,659.4 | 7,047 | 444.2 |
| SOUTH | | | | | | | |
| Baseline | 6,805 | 6,675 | 1,960 | 200 | 367.4 | 14,406 | 563.6 |
| REGION | | | | | | | |
| Baseline | 14,285 | 18,270 | 4,570 | 1,050 | 3,026.8 | 21,453 | 1,007.8 |

* Water Management Strategies MS-1 and MS-2 do not become operative until 1985, MS-5A and MS-5B in 2000.

** Includes product value from dryland as well as irrigated crop production.

*** Includes energy and other sectors as well as agricultural sector.

Table 1: INTER-STRATEGY COMPARISONS OF KEY REGIONAL ECONOMIC INDICATORS (Cont'd)

1990

| | Irrigated Acres | | Dryland Acres | | Total Value of Agr. Prod.** | | Returns to Land & Management | | Water Remaining in Storage | | Total Value Added All Sectors*** | | Employment*** | |
|----------|-----------------|-------|---------------|------|-----------------------------|------|------------------------------|------|----------------------------|-----|----------------------------------|------|---------------|------|
| | 1000's | %Δ* | 1,000's | %Δ* | Million 1977 \$ | %Δ* | Million 1977 \$ | %Δ* | Million Ac-Ft | %Δ* | Million 1977 \$ | %Δ* | 1,000's | %Δ* |
| NORTH | | | | | | | | | | | | | | |
| Baseline | 9,480 | % | 11,605 | - | 4,640 | % | 1,775 | % | 2,501.2 | % | 11,957 | % | 533 | % |
| MS-1 | 9,710 | 2.4 | 11,575 | -0.3 | 4,710 | 1.5 | 1,805 | 1.7 | 2,508.3 | 0.3 | 12,028 | 0.6 | 537 | 0.7 |
| MS-2 | 9,420 | -0.6 | 11,820 | 1.9 | 4,425 | -4.6 | 1,730 | -2.5 | 2,516.3 | 0.6 | 11,699 | -2.2 | 521 | -2.4 |
| SOUTH | | | | | | | | | | | | | | |
| Baseline | 6,355 | | 7,105 | - | 2,770 | | 530 | | 266.8 | | 26,643 | | 703 | |
| MS-1 | 6,400 | 0.7 | 7,070 | -0.5 | 2,785 | 0.5 | 531 | - | 272.0 | 2.0 | 26,662 | 0.1 | 704 | 0.2 |
| MS-2 | 5,635 | -11.4 | 7,765 | 9.3 | 2,565 | -7.4 | 495 | -6.6 | 273.6 | 2.5 | 26,514 | -0.5 | 696 | -1.1 |
| REGION | | | | | | | | | | | | | | |
| Baseline | 15,835 | | 18,710 | - | 7,410 | | 2,305 | | 2,768.0 | | 38,600 | | 1,237 | |
| MS-1 | 16,110 | 1.7 | 18,645 | -0.3 | 7,495 | 1.1 | 2,335 | 1.3 | 2,780.3 | 0.5 | 38,690 | 0.2 | 1,241 | 0.4 |
| MS-2 | 15,055 | -4.9 | 19,585 | 4.7 | 6,990 | -5.7 | 2,225 | -3.5 | 2,789.9 | 0.8 | 38,212 | -1.0 | 1,216 | -1.6 |

* Change from Baseline.

** Includes product value from dryland as well as irrigated crop production.

*** Includes energy and other sectors as well as agricultural sectors.

Table 1: INTER-STRATEGY COMPARISONS OF KEY REGIONAL ECONOMIC INDICATORS (Cont'd)

2020

| | Irrigated Acres | | Dryland Acres | | Total Value of Agr. Prod.** | | Returns to Land & Management | | Water Remaining in Storage**** | | Total Value Added All Sectors*** | | Employment*** | |
|---------------|-----------------|-------|---------------|-------|-----------------------------|-------|------------------------------|------|--------------------------------|------|----------------------------------|------|---------------|------|
| | 1000's | %Δ* | 1,000's | %Δ* | Million 1977 \$ | %Δ* | Million 1977 \$ | %Δ* | Million Ac-Ft | %Δ* | Million 1977 \$ | %Δ* | 1,000's | %Δ* |
| NORTH | | | | | | | | | | | | | | |
| Baseline | 12,410 | % | 11,825 | - | 8,110 | % | 3,990 | % | 2,177.9 | % | 19,636 | % | 555 | % |
| MS-1 | 13,305 | 7.2 | 11,710 | -1.0 | 8,475 | 4.5 | 4,035 | 1.1 | 2,161.1 | -0.8 | 20,048 | 2.1 | 568 | 2.4 |
| MS-2 | 13,280 | 7.0 | 11,410 | -3.5 | 7,550 | -7.0 | 3,670 | -8.0 | 2,264.3 | 4.0 | 18,855 | -4.0 | 531 | -4.3 |
| MS-5A | 16,280 | 31.2 | 9,845 | -16.7 | 9,385 | 15.7 | 4,540** | 13.8 | 2,161.1 | -0.8 | 21,162 | 7.8 | 604 | 8.9 |
| MS-5B | 15,475 | 24.7 | 10,265 | -13.2 | 8,375 | 3.3 | 4,070*** | 2.0 | 2,264.3 | 4.0 | 19,787 | 0.8 | 563 | 1.5 |
| SOUTH | | | | | | | | | | | | | | |
| Baseline | 5,635 | - | 7,725 | - | 3,385 | - | 920 | - | 125.7 | - | 29,540 | - | 778 | - |
| MS-1 | 5,685 | 0.9 | 7,685 | -0.5 | 3,400 | 0.4 | 955 | 3.8 | 139.4 | 10.9 | 29,577 | 0.1 | 780 | 0.2 |
| MS-2 | 4,755 | -15.6 | 8,520 | 10.3 | 3,035 | -10.3 | 880 | -4.3 | 163.0 | 29.7 | 29,270 | -0.9 | 770 | -1.1 |
| MS-5A | 7,320 | 29.9 | 6,160 | -20.3 | 3,815 | 12.7 | 1,100*** | 19.6 | 139.4 | 10.9 | 30,011 | 1.6 | 793 | 1.8 |
| MS-5B | 6,020 | 6.8 | 7,350 | -4.9 | 3,335 | -1.5 | 1,020*** | 10.9 | 163.0 | 29.7 | 29,609 | 0.2 | 780 | 0.2 |
| REGION | | | | | | | | | | | | | | |
| Baseline | 18,045 | - | 19,550 | - | 11,495 | - | 4,910 | - | 2,303.6 | - | 49,176 | - | 1,333 | - |
| MS-1 | 18,990 | 5.2 | 19,395 | -0.8 | 11,875 | 3.3 | 4,985 | 1.5 | 2,300.5 | -0.1 | 49,625 | 0.9 | 1,347 | 1.1 |
| MS-2 | 18,035 | -0.1 | 19,930 | 1.9 | 10,585 | -7.9 | 4,550 | -7.3 | 2,427.3 | 5.4 | 48,125 | -2.1 | 1,301 | -2.4 |
| MS-5A | 23,600 | 30.7 | 16,005 | -18.1 | 13,200 | 14.8 | 5,640*** | 14.9 | 2,300.5 | -0.1 | 51,173 | 4.1 | 1,397 | 4.8 |
| MS-5B | 21,495 | 19.1 | 17,615 | -9.9 | 11,710 | 1.9 | 5,090*** | 3.7 | 2,427.3 | 5.4 | 49,396 | 0.5 | 1,343 | 0.7 |

* Percent change from Baseline.

** Includes product value from dryland as well as irrigated crop production.

*** Includes returns to imported water - no cost charged in farm budgets for imported water.

**** Water remaining in storage is the same for MS-1 and MS-5A, and for MS-2 and MS-5B.

and Strategies One, Two, and Five. Strategy Three, local water supply augmentation, could not be quantified meaningfully, because data were fragmentary and did not support a finding of significant regional potential. Strategy Four was quantified for Nebraska and Oklahoma, reflecting interest by those states in intra-state imports. Strategy Five was analyzed in two ways: an interstate import constrained to water needed to restore irrigation to acreage reverting to dryland farming by 2020 due to aquifer depletion under projections of Strategy One and under Strategy Two; these analyses are described as Strategies Five-A and Five-B, respectively.

It is important to note that in making its studies of interbasin diversion, the Corps of Engineers did not make a determination that there would be surplus water available for such imports from the sources.

Regional Comparisons - North and South

Because Aquifer thickness generally increases from south to north, the volumes of ground water in the Ogallala Aquifer of New Mexico, Oklahoma and Texas have historically been less than that available to the northern Ogallala states. By the base year 1977, the three southern states had only a 12 percent share of Ogallala water remaining in storage for the entire Region. Much of the southern High Plains has been in irrigated production over a longer period of time than the Northern Ogallala and the South's available ground water supply is therefore depleted more extensively.

The effects of the more limited water supply in the southern Ogallala are reflected in the key indicators summarized in Table 1. Most indicators show a very different pattern of projected impacts between north and south, both across the Study period for 1990 and 2020, and among the water management strategies, in comparison to the Baseline.

Under Baseline conditions in 1977, the southern Ogallala has a relative parity with the North in irrigated acres, with about 48 percent of the Regional total, but has only about 36 percent of the dryland acreage. The disparity in total cropland acreage in the South is reflected by lower value of agricultural production and in returns to land and management from agricultural sales. In contrast, the South enjoys a relative advantage over the

North in the key regional economic indicators displayed in Table 1, due primarily to a more vigorous and diversified nonagricultural economy in 1977, particularly in the energy sector. Total value added by all sectors in the South is more than double that of the northern Ogallala. Employment in the South constitutes about 56 percent of total regional employment.

By 1990, the differences between the southern Ogallala states and the northern subregion are even more pronounced for the agricultural sector indicators. These differences are accentuated by the impacts of the alternative water demand (reduction) strategies MS-1 and MS-2. The projected effects of these water demand strategies reflect the impact of further depletion of water remaining in Ogallala storage in the South.

Under the most favorable water use reduction strategy (MS-2) for extending the Ogallala water supply in the South, the southern subregion still declines from a 12 percent share of regional water in storage in 1977 to less than 10 percent in 1990. Irrigated acreage for the southern three states falls to only 40 percent of total regional irrigation (down from 48 percent in 1977) for Baseline. Irrigated acreage under MS-1 and MS-2 are even less as a percent of total regional irrigation, with a projected 11 percent decline in acreage for MS-2 in comparison with Baseline projections for 1990.

The related economic effects of MS-2 in 1990 are consistent by negative for the South, with a 7.4 percent loss in total value of agricultural production and a 6.6 percent loss in returns to land and management in relation to 1990 Baseline projections. Subregional economic indicators--total value added, all sectors, and employment projections show insignificant inter-strategy differences from Baseline for 1990.

The water supply (importation) strategies MS-5A and 5B are projected to be in place by the year 2000 and Table 1 indicates the comparative impacts for 2020 of these strategies, both to Baseline and the water demand reduction strategies MS-1 and MS-2. The 2020 projections indicate a significant further decline in ground water remaining in storage from 1990 for the southern Ogallala states, for all strategies, as well as for the Baseline.

By 2020 the southern Subregion is projected to have only 5.0 percent of remaining Ogallala water in storage under Baseline, and a scant 7.0 percent under the more favorable water supply strategies MS-2 or MS-5B.

Total irrigated acreage for the Southern Ogallala is most favorable for MS-5A, at 7.32 million acres or about 30 percent above Baseline projections for 2020, while the least favorable is MS-2 with only 4.75 million acres remaining in irrigation, down almost 16 percent from Baseline projections. This impact on irrigated acreage is reflected in similar patterns of favorable increases in total value of agricultural production (up about 13 percent) and returns to land and management (up by almost 20 percent for MS-5A, and corresponding negative impacts from MS-2.

Many other interregional and interstrategy comparisons can be derived from the key indicators summarized in Table 1. Additional indicators and more detailed analyses of these projected impacts can be found in Chapter Five (Baseline) and Six (Alternative Water Management Strategies) of the main Report.

Comparisons of Other Regional Impacts Among Strategies

In addition to the quantitative projections and comparisons of strategy economic impacts discussed above, other impacts shed light on strategy differences within the Region. Six other impacts are described here and in the accompanying matrix. These effects are discussed generally in a region-wide context, although subregional variations are shown between the northern and southern tiers of states within the Region.

Crop Production - Table 2

Four major crops are well-suited to irrigation in the High Plains--corn, wheat, grain sorghums, and cotton, in that order, of 1977 value of production. These four crops, irrigated and dryland together, in 1977 accounted for nearly 94 percent of all principal crop production value in the Region. By 2020, the Baseline projections change this order slightly to move cotton ahead of grain sorghum production. Virtually a one-crop cotton economy in Texas would replace sorghums, while Nebraska corn dominates all crop production in

Table 2: INTER-STRATEGY COMPARISONS - REGIONAL CROP PRODUCTION AND RESOURCE DEPLETION PROJECTIONS

| | | REGIONAL CROP PRODUCTION | | | SOIL AND WATER RESOURCE DEPLETIONS |
|----------|----------|---|--|--|--|
| | | REGIONAL FEED GRAINS | REGIONAL FIBERS AND OILS | NATIONAL FOOD GRAINS | |
| STRATEGY | BASELINE | 1977 corn + sorghum crop 1,162 million bushels for regional beef feedlot/processing industry, 15.8% of U.S. production. 1990 - 1,513 million bushels 2020 - 2,219 million bushels | 1977 cotton crop, 2.96 million bales, processed for yarns, cloth, oil, meal, 24.9% of U.S. production. 1990 - 4.94 million bales 2020 - 5.94 million bales | 1977 wheat crop 327.5 million bushels for national flour/cereal markets, 16.4% of U.S. production. 1990 - 350 million bushels 2020 - 472 million bushels | Remaining storage of 3,027 acre-feet 1977 drops 24% to 2,304 acre-feet 2020; concentrated in the northern area, critically short in South. Soil depletion serious for cotton production. |
| | MS-1 | Production up slightly, to 1,540 million bushels in 1990, 2,325 million bushels in 2020. Percent of U.S. crop up 0.6%. Still excellent base for beef industry. | Little crop production change any year to 2020 as most water demand reduction efforts already projected in Baseline. Still good base for fiber/oil industries. | Production lower by only 0.3% and 0.2% in 1990 and 2020. No adverse national effects; percent of U.S. crop virtually unchanged. | Little change from Baseline storage drawdown. Beneficial effect on cropping but adverse from soil mining in one-crop cotton farming areas. |
| | MS-2 | Production drops for corn 12%, 1990, 15%, 2020, less for sorghum from Baseline. Percent of U.S. crop down 1.8% for corn up 1.5% for sorghum in 2020. | Production down 8.0% in 1990, 10.7% in 2020; 1990 crop - 4,548,000 bales. 2020 crop, 5,307,000 bales or 28.7% share of U.S. crop in 2020. Still good base. | Production rises by 2.4% in 1990, 0.3% 2020. Percent of U.S. crop share is still virtually unchanged. | Some increase in water remaining in storage. Most water savings in voluntary conservaton policies. Soil saving effects probably beneficial. |
| | MS-5A | By 2020, a 22.4% rise in corn crop, but sorghum drops 6.0%. Share of U.S. corn crop up, sorghum down. Large feedlot growth supportable. | With import, crop rises by 19% to 7,103,000 bales, 37.2% of U.S. share, by 2020, relative to Baseline. | Wheat production down 7.5% with water import by 2020; National effects limited. Percent of U.S. crop 0.8% below Baseline. | Little change from Baseline water remaining in storage. Imported water all goes to formerly irrigated lands. More intensive cropping could further deplete soil. |
| | MS-5B | By 2020, a 4.5% drop in corn, 5.0% rise in sorghum. Feed grain base for beef industry expansion assured under any strategy. | Crop rises 4.9% to 6,232,000 bales; dryland production above MS-5A. | Production down 5.7% with water import by 2020. Percent of U.S. down 0.6%. | Slight increase from Baseline water remaining in storage. Rate of drawdown slows, extending Aquifer life. Intensive cropping further depletes soils. |

the northern subregional three states under Baseline projections. Wheat, the Region's "natural" crop, remains important in all states except New Mexico. The feed grains, primarily corn and sorghums or milo, account for over 55 percent of regional production value over the Study period.

Generally, projections for the several strategies do not indicate a marked change in the current mix of crops and the relative sizes of their volume of production to 2020. Corn (almost all in Nebraska) and cotton (almost all in Texas) do indeed expand in the years ahead, but only slightly at the expense of other crops. Also, the strategies would not cause major shifts in the share of each crop in national production. The water demand reduction strategies (Strategy One and Strategy Two) occasion the least departures from the Baseline projections, while the import strategies cause the most, raising the regional share of high-water-using crops such as corn.

Soil and Water Resource Depletions - Table 2 .

The continued sufficiency of basic ingredients for High Plains crop production--its soils and ground water--must be considered. Of most concern is the diminishing ground water supply, with higher pumping lifts and energy costs. Table 1 shows estimates of water remaining in storage by years for Baseline and each strategy. Some of this water in storage cannot be recovered with existing technologies. A second concern in some areas in the High Plains is the possible effect on soil productivity of intensive one-crop farming without crop rotation to restore soil nutrients.

Compared to Baseline, all strategies could by definition be viewed as beneficial to the water depletion problem. The water demand reduction strategies could be considered beneficial with respect to maintenance of soil productivity, because their effect would be to promote wise farming practices to maximize returns by soil-saving methods as efforts at water-saving methods are applied.

Environmental Quality - Table 3

The High Plains is generally flat to gently rolling with vegetation typical of the Plains' moderate to low-rainfall environment. Shallow river

Table 3: INTER-STRATEGY COMPARISONS - ENVIRONMENTAL AND ECONOMIC CONSIDERATIONS

| ENVIRONMENTAL CONSIDERATIONS* | | ECONOMIC ASPECTS | | | |
|-------------------------------|---|---|--|---|---|
| | | REGIONAL | NATIONAL | | |
| | | | CONSUMER PRICES | EXPORTS | |
| G-19 STRATEGY | BASELINE | See Chapter Five for Baseline description. Little direct effect from evaporation reduction or improved efficiency in irrigation systems and management. Reduced runoff into upland wetlands and streams expected, lowering aquatic habitat values. | Value of agricultural production more than doubles, as does the Region's total value added, resulting in a strong economy. | 43-year average annual farm price increase projected at 0.6%, translates to 3.2% increase in food costs. | Agricultural crop exports rise by 150% - \$21 to \$51 billion, 1985-2020, nationally. This demand will keep Region's prices high. |
| | MS-1 | MS-1 and MS-2 show comparatively little change in overall effects on fish and wildlife resources from Baseline conditions projected. Combination of lower corn acreage and reduced tailwater runoff to playas may lower winter carrying capacities for migratory waterfowl. Reduced soil erosion rates and amounts of chemical fertilizers and pesticides residues in runoff waters will benefit wetland and aquatic habitats. Extensive weed suppression would eliminate habitat for upland game and nongame species, partially offset by mulching and fallowing. Modified playa lakes would reduce habitat value to both migratory and resident species. MS-2 effects on somewhat magnified scale over MS-1. | Improvement over Baseline growth is not significant by any economic measure. | Crop production changes so little that crop and food prices remain unaffected. | Volume of exports not expected to change from that projected in the Baseline. |
| | MS-2 | Effects weighted toward negative; reduction of import source stream discharges and those below reservoirs coupled with loss of riparian habitat major concern. Holding reservoirs in Region would inundate areas of riparian and stream habitat valuable for fish and wildlife species. Conveyance facilities could block migration and movement patterns. Animals could be trapped in open canals. Use of some streams to convey water could give local benefits. Terminal reservoir effects same as for holding reservoirs. Also, fluctuating water levels would render management for fish and wildlife largely ineffective. Impacts of diversions from source streams might be felt as far downstream as Louisiana. | Farm production is lower under this water demand reduction strategy and carries economy lower. | Crop production is lower, prices rise. Effect on consumer about \$2.60 per year per person at retail level (marked up). | Volume of exports falls due to higher farm prices; grain and oilseed down 1.4%, cotton 1.7% |
| | MS-5A | Effects weighted toward negative; reduction of import source stream discharges and those below reservoirs coupled with loss of riparian habitat major concern. Holding reservoirs in Region would inundate areas of riparian and stream habitat valuable for fish and wildlife species. Conveyance facilities could block migration and movement patterns. Animals could be trapped in open canals. Use of some streams to convey water could give local benefits. Terminal reservoir effects same as for holding reservoirs. Also, fluctuating water levels would render management for fish and wildlife largely ineffective. Impacts of diversions from source streams might be felt as far downstream as Louisiana. | Crop production up greatly with water import, but regional growth is only 4.1% over Baseline, employment only 4.8% higher. | Production rises, lowering farm commodity and retail food price - by about \$2/person. | Exports expand with lower farm prices; in 2020, grain exports up 100 million bushels, cotton one-half million bales, but total value lower. |
| MS-5B | Effects weighted toward negative; reduction of import source stream discharges and those below reservoirs coupled with loss of riparian habitat major concern. Holding reservoirs in Region would inundate areas of riparian and stream habitat valuable for fish and wildlife species. Conveyance facilities could block migration and movement patterns. Animals could be trapped in open canals. Use of some streams to convey water could give local benefits. Terminal reservoir effects same as for holding reservoirs. Also, fluctuating water levels would render management for fish and wildlife largely ineffective. Impacts of diversions from source streams might be felt as far downstream as Louisiana. | Less favorable to regional economy than MS-5A or MS-1; creates 10,000 more jobs than Baseline. | Production rises over Baseline but much less than in MS-5A; impact on consumers not significant. | Exports expand less than in MS-5A, as price drop is less, but value offsets decline. | |

* Adapted from U.S. Fish and Wildlife Service Report.

and tributary stream valleys crossing the Plains afford residual habitat for wildlife from intensively cropped fields and grasslands. River valleys and sand hills in the northern states and the playa lakes provide vital habitat for waterfowl migrating along the Central Flyway to and from Canadian breeding grounds.

Environmental effects of the various strategies have been examined by the U.S. Fish and Wildlife Service and by the General Contractor. Many of the environmental impacts which are influenced by farming practices and aquifer depletion will occur under the Baseline, but the rate of change would be altered to differing degrees by the different water management strategies. Major factors evaluated were physical, biological and cultural. Under physical factors, soil loss due to wind erosion is probably the most significant consideration. Generally, dryland farming and farm abandonments result in greater soil losses than in irrigated agriculture. Negative effects on water resources result from streamflow reduction and ground water drawdown. Already beginning to occur in some areas, greater reductions in streamflow are expected in parts of the Loup, Niobrara, Elkhorn, Blue, Platte and Republican Rivers in Nebraska; the Republican, Solomon, and Cimarron Rivers in Kansas, and others. Where streamflow is reduced, aquatic habitat, potable supplies, diversions for agriculture and low-flow contributions to reservoirs are negatively affected. Streamflows will be reduced to some extent regardless of the strategy considered.

Two main types of biological impacts occur: the first results from streamflow reduction or direct increased use of surface waters, the second from land use changes caused by water availability variations. In the first, effects on aquatic habitat and associated species include direct loss or reduction of aquatic species and biological productivity and the degradation of habitat for related species such as waterfowl, wading birds and shorebirds. Riparian habitat has already been affected by reductions in surface flows. Species such as birds and small animals will be affected by losses or alterations in riparian habitat, including the invasion of exotics such as saltcedar. Aquatic habitat and fisheries in lakes and reservoirs may be affected by depletion of feeder streams. Modification of playa lakes and drainage of other wetlands may result in scarcity of water with adverse effects on wildlife resources.

Land use changes will affect both aquatic and terrestrial species. In terms of aquatic habitat, the effect is largely negative, in part because of loss of tailwater from improvement in irrigation. Water quality would improve, but turbid water is preferable to no water in this semi-arid Region. Terrestrial species would be more positively affected. Dryland farming and rangeland are less intensively used, and, in general, provide better wildlife habitat. Rangeland or native grasses provide excellent natural habitat. Achieving this benefit, however, would require that a conservation program be initiated to reseed abandoned acreages. Where irrigated agricultural acreage increases, effects may be negative because of siltation and draining of valuable wetlands and loss of cover and terrestrial habitat. Both habitat and wildlife are generally improved by conversion to dryland farming and rangeland. If reseeding is done, effects can be beneficial. Major adverse effect would be development of marginal lands in areas with surface or near surface water such as the sandhills.

The U.S. Fish and Wildlife Service made an environmental assessment of each of the alternative interstate, interbasin transfer routes evaluated by the U.S. Army Corps of Engineers. Adverse impacts on fish, wildlife and other natural resources at and near the points of diversion, at and around the conservation storage provided near the point of diversion, along the conveyance routes and at and around the terminal storage reservoirs were identified and to some extent quantified. A major negative environmental impact would be the large amount of land required for these facilities, much of which would be important habitat. The loss could be mitigated to some extent by acquiring replacement habitat.

No assessments have been made of the impacts downstream of the points of diversion considered by the Corps for interbasin transfers. Some possible impacts can be identified, however. Reductions in downstream discharges could result in changes in stream channel morphology, and could have an adverse impact on aquatic species and productivity, on riparian wildlife habitat, on water quality, on sediment transport, on minimum flows needed for salinity repulsion in the Mississippi River delta, and on freshwater inflows needed for the coastal fisheries in Louisiana.

With proper planning, impacts on cultural resources could be minimized.

Economic and Demographic Aspects

The inter-strategy comparisons considered here include:

- ° an overall or composite appraisal of the general health of the regional economy as expressed in part by such variables as enumerated in Table 1 and evaluated in other Study assessments;
- ° the effect of strategies or policies on national consumer prices; and
- ° their effect on exports to foreign markets.

Economic Effects - Table 3

The composite picture of the Region's general state of economic health under the various water management strategies is implicit in such factors as farm-level production, the value of that production, its profitability, regional value added by economic activities in all sectors off the farm (textiles, meat processing, energy, milling, fabricating, and other pursuits), regional population employment and income, and the state and local government tax revenues generated by these activities.

Between 1985 and 2020 under the Baseline situation, the percentage of per capita disposable income spent on food is projected to decline from 17.5 percent to 17.1 percent. During the same period, the value of major agricultural exports would more than double from under \$21 billion to slightly over \$51 billion (1977 dollars). Farm prices are projected to increase at an average annual real rate of about 0.6 percent. This would increase consumer expenditures on food, assuming current consumption patterns, by \$40 to \$50 per person. The following tabulation presents the projected direct impact on consumers of farm level price increases:

CONSUMER PRICE INCREASES DUE TO FARM COMMODITY PRICE INCREASES
UNDER BASELINE - 1977 to 2020

| Item | Food Expenditure Increases | |
|--------------------------------|----------------------------|--------------------|
| | Per Person | Per Family of Four |
| Wheat and Wheat-Based Products | \$ 2.22 | \$ 8.88 |
| Beef and Veal | 17.48 | 69.92 |
| Pork | 9.80 | 39.20 |
| Boilers | 5.12 | 20.48 |
| Eggs | 3.03 | 12.12 |

When compared to total national production, the Region is projected to produce a declining proportion of national output for several crops under Baseline conditions. Table 5 shows the High Plains as a portion of total national output for four major crops. For example, wheat produced in the High Plains falls from 16.4 percent of the national total in 1977 to 10.4 percent in 2020.

Under Strategy One, projected crop production changes so little that crop price changes were not projected. With the cutback in water use under Strategy Two, regional production is reduced and national crop prices rise. A rough estimate suggests that consumer payments for food will increase about \$1 per person per year at the farm level; perhaps as much as \$2.60 when markups are added. The net increase thus ranges from \$290 million at farm level to \$750 million by 2020. The volume of exports will fall due to higher prices and reduced production with grain and oilseed exports down 1.4 percent and cotton down 1.7 percent in 2020. Total value of exports falls about 0.7 percent for a foreign exchange loss of some \$365 million on those crops which are staples in the High Plains.

Rising production which would accompany Strategy Five-A water imports is projected to have a limited but positive value for the consumers. At the farm level, consumer expenditures for food and fiber should fall about \$2 per person by 2020 due to price decreases associated with increased national production. Increased production and lowered prices expand the volume of exports. In 2020, grain exports rise nearly 100 million bushels (1.0

Table 5: NATIONAL DEPENDENCE HIGH PLAINS PRODUCTION

| <u>Crop</u> | <u>Year</u> | <u>Percent of National Production</u> | | |
|-------------|-------------|---------------------------------------|------------------|----------------|
| | | <u>Total</u> | <u>Irrigated</u> | <u>Dryland</u> |
| Wheat | 1977 | 16.4 | 3.1 | 13.3 |
| | 1985 | 13.4 | 1.6 | 11.8 |
| | 1990 | 12.8 | 1.0 | 11.8 |
| | 2000 | 11.9 | 0.7 | 11.2 |
| | 2020 | 10.4 | 0.4 | 10.0 |
| Corn | 1977 | 13.1 | 12.3 | 0.8 |
| | 1985 | 13.1 | 12.7 | 0.4 |
| | 1990 | 12.6 | 12.4 | 0.2 |
| | 2000 | 13.2 | 13.1 | 0.1 |
| | 2020 | 12.6 | 12.5 | 0.1 |
| Sorghum | 1977 | 39.7 | 22.8 | 16.9 |
| | 1985 | 36.8 | 20.0 | 16.8 |
| | 1990 | 34.5 | 18.4 | 16.1 |
| | 2000 | 33.4 | 18.5 | 14.9 |
| | 2020 | 29.8 | 15.0 | 14.8 |
| Cotton | 1977 | 24.9 | 16.5 | 2.4 |
| | 1985 | 31.2 | 22.6 | 8.6 |
| | 1990 | 33.8 | 25.1 | 8.7 |
| | 2000 | 35.5 | 26.8 | 8.7 |
| | 2020 | 31.9 | 23.0 | 8.9 |

percent) over Baseline and cotton exports rise 0.5 million bales (4.3 percent). However, the decreased price for all exports actually lowers the net value of agricultural exports in 2020 under Strategy Five-A by \$100 million.

Legal/Institutional Aspects - Table 4

The institutional question in considering alternative water management strategies is whether the necessary statutes and institutions are in place and, if not, what is needed to make implementation possible. Institutional structures are summarized in Table 4 together with an appraisal of possible changes that might be required for implementing management strategies.

With respect to Strategy Five, each of the streams considered as a possible source for water transfer to the High Plains is interstate in character. Federal projects on each serve specific purposes--irrigation, municipal and industrial uses, flood control, hydropower, navigation, recreation, and other instream uses. Diversion to the Region could impair existing and future instream and offstream uses downstream from the diversion point. Depletions by future uses upstream of the point of diversion could decrease the amount available for transfer. If existing or authorized uses were impaired, or future upstream depletions limited, the tradeoffs involved would have to be evaluated and negotiated.

Before a specific transfer project could be proposed for authorization, detailed planning would be required to determine needs, projects and programs for development and management of water supplies for the Region, both imported and local, and future water needs within the basins of origin, both upstream and downstream of the point(s) of diversion.

Once a definite plan is formulated, an apportionment of waters of the interstate streams involved among basins of origin and the states of the High Plains would be required, either through congressional action or through an interstate or federal-interstate compact.

Table 4: INTER-STRATEGY COMPARISONS - LEGAL/INSTITUTIONAL CONSIDERATIONS

| | | LEGAL/INSTITUTIONAL ASPECTS | | |
|----------|----------|--|--|---|
| | | LOCAL | STATE | FEDERAL |
| STRATEGY | BASELINE | There is sufficient authority at the local government level in all of the states to carry out many of the voluntary and regulatory water demand reduction and supply augmentation measures now in place or projected for the Baseline. | Each of the six states have water and natural resource agencies to administer programs at state and local levels and provide local assistance to districts and farmers. | Many state resource agencies are now supported to some extent by federal agencies and programs, such as those of the Department of Agriculture and Interior in present ongoing Baseline efforts. |
| | MS-1 | Implementation of MS-1 would require little change or realignment of the institutions in the area at local level. Additional funding and staff required. | Implementation of MS-1 would require little change or realignment of the institutions at state government level. Authorization and funding for selected financial incentives required. Additional funding and staff necessary. | Federal agency authorities to support state and local efforts in water demand reduction would need some extension to carry out certain MS-1 programs. Additional funding and some additional staff needed, particularly for research. |
| | MS-2 | Some local political subdivisions would need added powers to promulgate rules and regulations, and to enforce restrictions on uses of water. Additional funding and staff might be needed. | Nebraska, New Mexico and Oklahoma appear to have adequate statutory authorities to control ground water use although there may be constitutional questions as to power to reduce use under existing permits. Colorado and Kansas statutes may require broadening. State level agencies in Texas have no statutory authority to control ground water use. Additional funding and staff required. | Enforcement of mandatory restrictions on ground water use would not be a federal responsibility. |
| | MS-5A | Local management agencies would be needed with adequate powers to contract for, receive and distribute imported water, to finance, construct, operate and maintain local facilities, and to levy and collect water charges and taxes to pay local costs and to repay allocated reimbursable costs of import project. | State legislation would be needed to provide necessary authorization for local management agencies, to contract with exporting states for water, to participate with the federal government or with the other states and the federal government in a federal-interstate compact management commission to plan, finance, construct, manage, operate and maintain the import project, and to provide necessary funding for cost-sharing and other costs. | Congressional actions needed to authorize and fund planning and feasibility studies, to provide for participation with the states in a federal-interstate compact management commission, and to authorize and fund federal participation in the import project. |
| | MS-5B | Same as MS-5A | Same as MS-5A | Same as MS-5A |

SENSITIVITY OF RESULTS TO VARIABLES

Long-term projections of events and conditions, such as have been made in this High Plains Study, require the qualification of uncertainty. The longer the term, the wider the margin of probable error in projections. This is particularly true of variables influencing and influenced by agricultural production, where the vagaries of weather, plant disease, insects, and the farm managers' skills add to uncertainties of production costs, demands, prices and research outcomes.

Sensitivity analyses can indicate how projections may vary under different assumptions about future trends. A few key assumptions most vulnerable to long-term variability were selected and the sensitivity of projected values to a different assumption for each was tested.

Water Use

Where the saturated thickness of the Aquifer is thin, as in Texas, projections of irrigated acreage towards the end of the Study period are extremely sensitive to the rate at which water use efficiency improves.

Crop Yields

Yields of the major High Plains crops are expected to increase but at a slower rate than historically since 1946 when dramatic productivity improvements began. If yield increases were to fall below projections, a compensating rise in national crop prices could be expected because of the lower production.

To test the sensitivity of Study results to yield assumptions, a national rate of crop productivity increase at 75 percent of the projected High Plains Study annual rate of increase was assumed. The result was an alternative crop price projection (analyzed by use of the NIRAP model) that was 6 to 12 percent higher by 2020 than with higher yield assumptions. Applying these lower yields and higher prices to major crops in Nebraska (a High Plains state with much of the production) in 2020, total value of production per acre falls by only \$10 (1.8 percent) for corn, \$7 (3.7 percent)

for dryland wheat, \$10 (3.8 percent) for irrigated wheat, and \$20 (5.0 percent) for sorghum. The health of the regional farm economy is not highly sensitive to changes in crop yield rates of increase, provided changes in regional and national productivity trends are parallel over the Study period.

Energy Prices

Prices are projected to increase (crude oil at 0.4 percent per year in real dollars) after a period of rapid adjustment during which decontrolled domestic prices rise to world price levels.

A set of high band world oil prices based on oil escalating at 3.0 percent real prices after U.S. prices reach world market levels, rather than 0.4 percent, were used to test the sensitivity of farm production estimates to higher energy prices. These high band prices were incorporated into crop budgets in some states to test sensitivity of LP model results. In general, while higher energy prices caused some crop switching and lower returns, they did not cause farmers to abandon irrigated production while water remained available. Over the long run, lower returns resulting from higher pumping costs would reduce land prices. However, crop prices, total production, and value of farm production remains generally unaffected by higher energy prices within the range analyzed.

This apparent insensitivity conflicts with experience in the 1970's where some farmers were forced into dryland farming before ground water was exhausted by increased energy costs. These short-term effects, however, may not be consistent with the capacity for adaptation by farmers to long-term effects.

Because of dependence of the southern subregion economy on the energy sector, an increase in energy prices that would sustain this economy beyond the expected downturn by 2020 was examined. This analysis accounts for increased oil, gas and electric revenues and the resulting increase in value added in energy conserving sectors. No increase in production is assumed, and the higher energy price produces a net positive effect on the regional economy.

Farm Commodity Export Demand and Crop Prices

Domestic demand for crops is projected to grow at a moderate rate, due to slower population, economic and real per capita income growth than in the past (before 1977). Export demand for crops is projected to show strong growth responding to an expanding world economy, agricultural shortages abroad and U.S. policy encouraging agricultural exports. Export projections used for crop pricing by the NIRAP model in this Study show steady growth through 2020.

To test price sensitivity, export growth was reduced to the 30-year (1950-1979) trend for High Plains crops. The sensitivity analyses showed that by 2020, real crop prices for those crops would fall 19 percent for wheat and cotton, 22 percent for corn and sorghums, and 20 percent for soybeans. The effect on the farmer would vary from subregion to subregion depending upon many other factors, but on balance, decreases in value of production would lower returns to land and management sharply, likely reducing the total irrigated acreage in the Region but increasing ground water remaining in storage.

Drought

The strategy analyses and projections assume average rainfall and the same general climatic conditions that have been experienced in the recent past. To test the sensitivity of projections to drought conditions, a year in which yields fell due to insufficient rainfall was examined. Yield reductions for the worst year in the last ten indicate a loss of 25 percent for dryland wheat, sorghums and cotton compared to Baseline, and decreases in irrigated corn yields of 7 percent, irrigated sorghums of 16 percent and irrigated cotton by 25 percent. As a result, value added by farm production in the northern subregion would fall by 10 percent below Baseline in any year, in the southern subregion by 16 percent to 18 percent and for the Region by 12 percent. These changes do not reflect compensating adjustments in crop prices which might occur if production losses were not offset elsewhere.

While production is cut by drought even when imported irrigation water is available (Strategy Five-A), imports keep farm returns well above Baseline levels. In the northern subregion, in 2020, the improvement from a drought year without water imports totals 27 percent above Baseline value added in the farm sector. In the southern subregion, farm value added in 2020 in a drought is 3 percent less than Baseline, but 18 percent above the levels which would occur in a drought without water imports. For the Region, in 2020, water imports change a drought year loss of 12 percent from Baseline into a gain of more than 10 percent above Baseline.

These drought year gains from water imports work through the economy in a significant way. For example, by 2020, water imports shift a drought year economic loss of 2.8 percent from Baseline into a gain of 2.7 percent, a net saving of 5.5 percent or almost \$2.7 billion. The swing in household income is comparable. The stabilizing effect on employment is even more notable, particularly in the northern area, which is more dependent on agricultural production. For the whole Region, a drought year employment loss of 2.7 percent converts to a 3.8 percent gain with the import strategy.

Increased Imports

In this analysis, the amounts of water to be imported to each state beginning in year 2000 were projected at double the amounts provided under Strategy Five-A, all water to be used for crop irrigation. Cropping patterns would not differ from those assumed in Strategy Five-A. This variation on Strategy Five measures the economic expansion that might occur if irrigation were greatly expanded by increased importation of water. No attempt was made to define the need for such expansion in the states or the relative value of added water. Prices were not recalculated, but would fall further in line with the reduced national crop prices projected under Strategy Five-A.

Results of the analysis show favorable effects carrying throughout the regional economy. The effects shown here, using the regional I/O model, somewhat overstate the net favorable effects because no downward revision in crop prices was made to reflect the continuing increase in national production which would follow from expanded irrigation in the Region. In the

northern subregion, farm production rises \$2.1 million above Strategy Five-A to 43.3 percent of total value added in the economy in 2020. For the Region, farm value added rises \$2.4 billion in 2020 above Strategy Five-A, without compensating adjustments in crop prices, while total value added increases \$3.3 billion above Strategy Five-A and \$3.5 billion above Baseline.

TRANSITION TO DRYLAND FARMING

Surveys in nine Texas South Plains counties and in 14 Southwest Kansas counties were conducted to assess conditions that might be encountered in a transition from a presently mixed irrigation-dryland agricultural economy to a dryland economy. Conditions before the beginning of substantial irrigation development in 1945, trends from 1946 through 1981, and projected conditions in these two areas as water becomes scarcer and more costly were analyzed.

Three probable sets of consequences could be projected as the transition to dryland farming occurs:

1. If the farmer, agri-business, and related economic interests are forced to operate in a nearly dryland farming economy in the near term, say the next three to five years, with stable land prices, high mortgages, rising energy and other production costs, and today's crop prices, resulting economic and social readjustments could be devastating for some.
2. If crop prices and yield relationships of 1975 to 1980 were to hold for the next 40 years, while projected rates of ground water depletion continue, adjustments would be difficult. Declines of 25 percent to 50 percent in gross incomes, depending on area, would occur over an extended time-span, but as an offsetting factor dryland farming involves lower production costs than irrigated farming.
3. If crop prices and yields increase more than farm costs, as projected in the analyses used for this Study, while rates of water depletion continue, the transition would occur within a long-term agricultural setting that could provide opportunities to cushion severe local economic and social disruptions.

NONAGRICULTURAL DEVELOPMENT

In the past 20 years, the High Plains Region's population grew by about five percent, a significantly slower rate than the 26 percent rate for the United States. Regional employment grew by 32 percent, compared to a U.S. increase of 50 percent. In contrast, the areas within the six states not overlying the Ogallala Aquifer experienced a 44 percent growth in population and a 75 percent growth in employment. Agricultural employment declined throughout this period with most of the Region's employment growth the result of a growth in smaller manufacturing and service sectors.

During the 1970s, the Region grew at about the same rate as the rest of the country. The major factors supporting this stronger growth were: oil and gas booms in western Texas and southwestern Kansas due to price increases and decontrol, and oil field equipment, financial and technical services needs of this industry; increasing concentration of feedlots and meat processing plants as more irrigation spurred the cultivation of corn and other feed grains; and, growth in other agricultural processing industries, including food processing, cotton ginning and textiles, and growth of agricultural production-input suppliers.

Manufacturers moved to the area to take advantage of the productive labor force, which has swelled due to increased participation by women, decline in farm employment, and baby-boom children entering the labor force. Most growth in manufacturing occurred in three metropolitan areas--Midland-Odessa, Lubbock and Amarillo--and in the High Plains of central Nebraska. Large increases in agricultural production have been projected for the Region for the next 40 years, and the value of oil and gas production is projected to rise in the near term. This presents opportunities for further increases in industries and services related to agriculture and energy:

- ° Agricultural Processing -- As synthetic fibers lose some of their competitive advantages, natural cotton fibers are likely to enjoy a comeback, and the Region's cotton production could support an expanded textile industry. Concentration of feedlots and meat packing plants have probably not yet run full course, and supporting industries could continue to grow. Other agricultural

processing, such as oil seed mills and grain milling may expand with the expanded farm production.

- ° Agricultural Suppliers and Services -- Although farm production increases will not necessarily mean acreage increases, there will still be needs for additional inputs, such as fertilizers, new equipment and services to support production.
- ° Oil and Gas Suppliers and Services -- A fast growing industry now while new wells and enhanced recovery projects are being developed, but likely to decline as reserves are depleted.

A number of barriers exist to these developments and other development opportunities unrelated to agriculture or energy:

- ° Given the unlikelihood of a major population shift to the Region, the resident labor force cannot support large additional growth. Internal sources of labor force expansion in the 1970s are depleted. Employment rates are high due to high labor force participation.
- ° The effect of rapid growth in oil and gas development on local wage rates, the housing market, and demand for community services and facilities may threaten the ability of other industries to compete or expand and may discourage potential new employers from locating in the High Plains, particularly in the southern portion where manufacturing employment increased sharply in the 1970s.
- ° Distance from major markets and from sources of raw materials, dispersed population patterns, and lack of support industries and services limit the attractiveness of the Region for industries not related to the locally-based agriculture and oil and gas economies. The only areas today with diversified economies are Lubbock and eastern Nebraska.

Given these constraints, an aggressive economic development strategy would be required to sustain the growth rates of the last decade. Despite substantial increases which are projected for regional economic output,

Baseline employment increases for the Study period to 2020 are forecast at about one-fourth the rate that occurred during the last decade, and at about 40 percent of the rate that has occurred since 1960. Three principal thrusts could be pursued regardless of the water management strategy or strategies adopted for the Region.

- ° Build an expanded labor force by keeping existing population, particularly youth, by attracting immigrants, particularly those who will find the environment suitable and will work for competitive wages, and by assuring an adequate supply of housing and recreational/cultural facilities to support an expanded population;
- ° Assist existing and new industry in expanding markets, in applying new technology, and in obtaining labor and raw materials; and
- ° Maintain and improve the infrastructure necessary to support processing industries by continued upgrading of road and rail systems to assure access to markets, by upgrading community facilities needed to support industry in growth centers, and by expanding the industrial and service infrastructure to provide a range of linkages for expanded activities.

ENERGY FUTURE

The Study Region is one of the major crude oil and natural gas producing areas of the United States. Although the Region has only about 1 percent of total U.S. population and 6 percent of the land area, the Region contributed 20 to 25 percent of domestic U.S. crude oil and natural gas production over the last decade.

The decontrol of crude oil and natural gas prices has resulted in a rapid increase in the value of these energy resources and in exploration and reservoir development activities. The direct impact of this increased activity on employment and income for the Region will be significant.

Crude Oil and Marketed Natural Gas Production

Over the Study period, the historical trend of decline in crude oil and marketed natural gas production in the Region is expected to continue. However, crude oil production is expected to increase from 1990 to 2000 due, primarily, to implementation of gas flooding techniques in the Permian Basin area of West Texas and eastern New Mexico. By 2020, both crude oil and natural gas production levels in the Study area are projected to be approximately one-tenth of current levels of production.

Electric Generating Capacity and Electric Energy Production

Electricity production is projected to increase regionally. Over the Study period, both installed electric generation capacity and electric energy production are projected to increase approximately threefold.

Water Consumption Associated with Energy Production and Processing

Water consumption associated with energy production in the Region is projected to increase since most of the projected water consumption will be directly associated with electricity generation. These increases will have some effect on the Ogallala Aquifer; however, much of this water could come from other formations or sources such as treated sewage effluent.

COST COMPARISONS

Effective water demand and supply management programs cannot be achieved without substantial investment in improved water management capabilities. This "no free lunch" truism is applicable to all the alternative water management strategies, including the Baseline scenario.

The alternative water resource management strategies represent a continuum of potential reductions in water demand or increases in water supply for High Plains Region agricultural uses over time, with an accompanying increase in cost of implementation.

Baseline - variety of effective agricultural water management practices have already been implemented extensively, although at varying rates and levels among the states, and these are projected to expand under Baseline assumptions.

Several agricultural water management improvements are presently eligible for cost sharing assistance and/or extension, demonstration, and technical assistance from existing public sector programs. Current (1978) expenditures by U.S.D.A. programs amount to about \$120 million per year. This represents a federal investment of about \$3.50 per irrigated acre. A matching investment by the private sector of about four to one, or \$14 per acre annually, a typical rate from prior years, projects a total annual investment of about \$17.50 per acre in agricultural water management improvements.

An average annual total cost per acre (both public and private investment) of \$17.50 per acre for improved agricultural water management under Baseline assumptions would indicate a total regional cost of about \$280 million in 1985 increasing to about \$315 million by 2020 with the increase largely resulting from projected increases in total irrigated acres.

Management Strategy One (MS-1) - the principal difference between Baseline and MS-1 projections is the assumption of expanded and accelerated voluntary adoption of improved agricultural water management practices and technologies due to new incentives (mainly public sector changes).

The cost of new incentive programs is projected to increase costs per acre by about ten percent over the Baseline, or to an average of \$3.85 per acre for public investment and to an average of \$15.40 per acre for private investments. In total regional cost, this represents a 1985 incremental cost increase of about \$35 million and a 2020 cost of \$41 million over projected Baseline costs.

Management Strategy Two (MS-2) - the added costs are primarily institutional costs required to administer a local/state regulatory program capable

of implementing the projected mandatory reductions in annual water use rates by individual irrigators.

On the basis of projected average annual cost per well of about \$50 for administration of MS-2 requirements, additional regional costs are estimated at about \$6 million in 1985, increasing to \$7 million by 2020. Initial capital costs (equipment) for well gauging and monitoring of pumping rates could be in the range of \$100 to \$150 per well, or a total cost of about \$20 million.

Management Strategy Three - Current levels of agricultural research in High Plains Study states (all sources) of about \$20-\$25 million annually should increase by \$1-\$1.5 million each year until 1990, for an initial cost of \$9 to \$12 million. Determination of priority for funding for the various technologies should be at the discretion of the respective states.

Management Strategies Four and Five (MS-4, MS-5A and MS-5B) - relevant cost estimates and projections for the periods 2000 and 2020 are provided in detail for the water transfer strategies and alternatives in the state and regional (Corps) reports on the various water transfer options. Another cost for MS-4 and MS-5 options is related to increased irrigated acreage of 4.6 million acres by 2020 under MS-5A. The additional 4.6 million acres maintained in irrigation by MS-5A would represent an additional \$90 million investment.

An additional cost associated with the water transfer alternatives relates to water distribution costs from terminal reservoirs to the farm headgates. Distribution system capital costs from the terminal reservoirs to farm headgates are estimated at about \$2,150 per irrigated acre. For the 4.6 million acres that are projected to go out of irrigated production by 2020 under MS-1 assumptions, the total capital cost for the necessary distribution systems could amount to \$9.9 billion.

POLICY ISSUES

During the course of the High Plains-Ogallala Aquifer Regional Resources Study, analyses were made of the resource use alternatives available to the six states and to the Nation in the face of depletion of the Ogallala Aquifer and the decline of oil and gas production and reserves.

The alternatives were considered with the recognition that some constraints might hinder their implementation. For example:

- ° The Ogallala Aquifer has been intensively mined for irrigation since the years following World War II. Some areas such as in the South High Plains of Texas are already either out of water or water levels have dropped below economically feasible pumping lifts.
- ° The waters of the Missouri River System and the other streams being considered by the Corps of Engineers for interstate interbasin transfers to the High Plains are already largely developed, mostly by federal projects, and committed. For these interstate streams available storage has been committed for flood control, hydropower generation, navigation and local consumptive uses even where the water has not yet been fully developed and allocated.
- ° Upstream and downstream states are developing state water plans to meet their potential water needs that will have major long-term impacts on the potential availability of water for diversion to the High Plains Region.

Under these circumstances, certain public policy questions arise that will determine the mix of alternatives, including the option of no-action, to be implemented. These are not new questions -- they have been raised for many years in various contexts with respect to water and related resource management. Through the results of this Study, however, their resolution within the context of the High Plains Region may be possible. Experience in the Region indicates that the questions to be answered cannot be related singularly to an alternative strategy. Rather these questions relate to the

choices to be made that will tailor alternatives and mixes of alternatives to the physical, social, economic, environmental and institutional conditions to local areas in the High Plains. This will shape the future of the High Plains Region.

1. Major changes would occur in production of agricultural commodities (feed grains, food grains, cotton, etc.) as the result of transition in the High Plains from irrigated to dryland farming. Climatic variations make dryland less assured, year to year, than irrigated production. These changes and uncertainties would impact federal policies on agricultural commodity market stability, international trade and balance of payments, inflationary controls, support for agricultural prices and income, and related programs. These impacts would be the basis for considering implementation of all alternative strategies for the Region. Would these impacts justify federal intervention to assure continued levels of agricultural production? How could these impacts be considered quantitatively in analysis of the federal subsidy that probably would be required for interbasin transfers of water? There also would be adverse economic and social impacts on the states. Would state intervention be justified, and if so, in what manner?
2. Should promotion of or a requirement for conservation of water and energy in irrigation enterprises be a major federal objective and program? If so, could and should this be built into programs of the Department of the Interior, Environmental Protection Agency, Department of Agriculture, and Corps of Engineers? Should such promotion include research and development aid to states and local districts, education, incentives such as low interest loans, or a mix of these and others built into existing agency programs? What could be the mechanism for getting it underway? If a federal requirement, in what manner should it be implemented? Should it be a major state objective and program? What actions should the states and state agencies take? Should primary responsibility for enforcement of conservation measures be at the local water resources management agency level? If so, what statutory changes would be necessary including source of funds? This would vary among the states as Strategies One, Two, and Three are considered.
3. The economic study results indicate that mandatory water demand management (Management Strategy Two) through laws and regulations controlling the use of Ogallala water, would significantly extend the duration of availability of such water but would result in decreased annual agricultural production and returns to land and management over the period to 2020. Would it be in the public interest to legally restrict current usage of the ground water with near-term economic detriment in order to prolong the availability of water for far future economic benefit?

4. Should investigation and planning of possible interstate interbasin transfers be continued? Should investigations and planning encompass the basins and states of origin? What institutional mechanism should be established for accomplishment? Should planning for an interstate transfer be integrated with planning for potential intrastate interbasin transfers?
5. Should further study be given to local water supply augmentation measures examined under Strategy Three such as desalting, direct use of brackish and saline waters, water harvesting, water banking, and other innovative approaches to augmentation of local water supplies for the Region? By whom? What actions, if any, should the federal agencies and the states take to encourage augmentation of water supplies from local sources?
6. Although the High Plains Study preliminary results indicate that the overall regional irrigation economy could be maintained into the next century, projections of oil and gas reserves indicate that adverse declines would have occurred by that time unless significant new reserves are found. Depletion of the Ogallala by the end of the Study period to 2020 would already have occurred in several intrastate subregions, with many other subregions going out of irrigation in the following decade or two. Experience with large-scale water diversions demonstrates that a long time period is needed for the necessary engineering, economic, financial, social and environmental planning and feasibility studies, and to achieve the political consensus required to move such projects to fruition. Is there a federal interest in making a participatory commitment now for that time frame in order to maintain the food and fiber production of the Region? Assuming that federal interest, what federal-state mechanism could and should be established to provide continuity of leadership over such an extended time frame?
7. The present Administration has emphasized reliance on the states as the responsible cornerstone for water resources planning and management. It has effectively moved to abolish the Economic Development Act of 1965 Title V Regional Commissions, and the River Basin Commissions. In the case of the six-state High Plains Region, action by an individual state could have little significant effect in implementing actions with regional consequences under any mix of alternative strategies. What would be the federal and state interests in:
 - ° Continuation of a multi-state regional entity such as the High Plains Study Council as a planning and policy body?
 - ° A new federal-state-local institutional mechanism, a compact or commission for example, for multi-state resource planning, development and management for the High Plains Region by itself, or in combination with upstream and downstream states in basins of origin for possible

interstate transfers? Would such a mechanism, including states of origin, be of value in gaining support for both intrastate and interstate developments?

- A federal approach to planning and development for the High Plains Region on a regionalized systems basis? Including basins of origin?
8. In view of the increasing in-basin demands for consumptive and instream uses, and possible out-of-basin needs, for example the High Plains region, and the competition among states and with federal reserved and Indian water rights, for the waters of interstate stream systems, should the Congress establish an institution for continued investigations and planning to advise the Congress, states and others as to the proper allocation and reallocation of interstate waters among states, areas and uses?
 9. The gains resulting from any regional alternative approach, and in some cases even a subregional approach, to solution of water problems of the High Plains, would not be distributed evenly among all those who might achieve some gain. What legal/institutional/financial mechanism(s) might be developed and implemented to achieve equitable distribution of costs and resultant obligation for repayment? Creation of zones of benefit and variable pumping assessments have been used in similar instances elsewhere.
 10. Nonagricultural economic development might alleviate to some extent the adverse impacts on the regional economy of a decline in irrigated agriculture but would some positive actions for implementation. Should the states or local governments develop and carry out programs to stimulate nonagricultural development? Concentration of the labor force in a few centers might make the High Plains more attractive to industry. However, this would provide no relief for small farmtowns where irrigated farming is declining. What tradeoffs are possible and acceptable?
 11. Base flows in interstate and intrastate streams have been significantly reduced in the High Plains Study area as pumping from the Ogallala has lowered ground water levels. Significant examples of this occur in the northern High Plains area in Nebraska and Kansas. This has had and will have increasing adverse impacts on availability of surface water for diversion for irrigation resulting in greater demands on the ground water and increased costs, and on the aquatic and riparian habitats. In the case of interstate streams, is there need for a mechanism for federal or state intervention or both, to prevent further reduction in base flows? Should the states take action and, if so, what?
 12. As water levels in the Ogallala Aquifer continue to decline, and as surface application of pumped water is reduced because of economics, riparian wetland habitat will be increasingly

impacted. The High Plains Study area is a major flyway for migratory birds. Substantial federal law and policy have been established to protect water critical habitat. Is there a federal interest and appropriate role in intervening to minimize adverse impacts? Is there a state interest and appropriate role?