CHAPTER THREE
ALTERNATIVE WATER RESOURCE MANAGEMENT STRATEGIES

INTRODUCTION

The foundation for the analytical framework and structure of the High Plains Study was built from a set of alternative water resource management strategies. These strategies were designed to explore the effects on the Study area, the States and the Nation of implementing various public policy options. Selection of public policy options to be evaluated was in accordance with the objectives of Public Law 94-587 and the Plan of Study developed by the High Plains Study Council.

The Congress in Public Law 94-587 directed the Secretary of Commerce ". . . to examine the feasibility of various alternatives to provide adequate water supplies in the area including, but not limited to, the transfer of water from adjacent areas." The Council set forth its objectives in its early Statement of Work to potential study contractors:

"1. Determine potential development alternatives for the High Plains.

2. Identify and describe the policies and actions required to carry out promising development strategies.

3. Evaluate the local, state, and national implications of these alternative development strategies, or the absence of these strategies."

One of the earliest tasks of the General Contractor, before data could be collected and analyses conducted, was to develop an unambiguous definition of these alternatives about which the Congress and the Council had spoken.

At the outset of the Study, water resource management was defined to avoid any misunderstandings. As used herein, the term "water resource management" encompasses the management continuum of policy selection, adoption, and implementation including legal/institutional arrangements, planning, programming, developing, financing, constructing and operating any necessary facilities, analyzing policy results, and modifying policies as required to adapt to changing conditions. Alternative strategies--and the tactics needed to carry them out--need not in every case be solely developmental or solely conservation oriented because resource management can combine conservation with development. Similarly, program alternatives, i.e., tactics to implement policies, can encompass both conservation and development measures.

Another way of expressing alternative policies or strategies and related programs was useful in the definitional process. Nonstructural or nondevelopmental options such as water conservation and water use efficiency improvements were defined as water demand management strategies or policies. Structural and developmental options were defined as supply management strategies or policies. Water demand management strategies were designed to accomplish reduced demand for ground water withdrawals from the Ogallala Aquifer, while water supply management strategies were designed to provide additional water supplies from sources other than the Ogallala.

Definition of alternative strategies to serve as the framework for the Study's analytical process was a two step effort. The General Contractor defined a preliminary set of alternatives in the Interim Report of January 15, 1979. These were endorsed and adopted by the High Plains Study Council in the early months of the Study by Council acceptance of the Interim Report. Thereafter, the program choices--the tactics to carry out strategies and the analysis of effects of each--were a joint effort between the General Contractor and the researchers in each of the six High Plains states.

The alternative water resource management strategies as originally defined survived a long period of intensive analysis without major alteration in concept. They have undergone careful review by High Plains states through the Council and its Liaison Committee, review by the Technical Advisory Group, the committee of the federal agencies which served in a review capacity to EDA, the General Contractor's Panel of Consultants, and the states' university and agency research groups.

ALTERNATIVE WATER RESOURCE MANAGEMENT STRATEGIES

The General Contractor's Interim Report of January 15, 1979 (three months into the Study effort) defined the strategies as follows:

(0) Baseline - no new public action or deliberate change; continuation of current trends in water and agricultural management in public and private sectors.

(1) Voluntary Water Demand Management - incentives provided for technological change and improved water and agricultural management practices at the farm level.

(2) Alternative (1) above plus Mandatory Water Demand Management - institutional/regulatory change requiring water conservation, improved water and agricultural management practices at farm level, and/or restrictions on new irrigated agriculture developments.

(3) Alternative (2) above plus Local Water Supply Management - water supply augmentation (e.g., precipitation enhancement and management, land use modifications; water harvesting/ water banking techniques; deep percolation and artificial recharge; brackish or saline water uses; and others).

(4) Alternative (3) above plus Minor Subregional Importation Supply Management - generally intrastate if long-term surpluses exist in certain intrastate regions.

(5) Alternative (4) above plus Major Importation Supply Management - major water importation schemes.

The future of the energy sector in the High Plains Region was analyzed as a separate issue. The future cost of energy to the agricultural sector was, of course, of critical significance in evaluating alternative water resource management strategies. The Interim Report, in defining the alternative management strategies, also recognized the importance of the nonagricultural development potential in the Region, and provided for analysis of that potential. All monetary values were to be expressed in constant 1977 dollars, since 1977 was the last full year for which data were readily available at the beginning of the Study.

The planning period was to extend to 2020. The selection of the year 2020 as the ending date for study analysis and projection was based on several considerations. The study period was to be no longer than absolutely necessary, on the basis that the degree of reliability of future projections diminishes over time. A period of time sufficient to analyze projected impacts of all management strategies was considered necessary. The water importation supply management strategies could not realistically be projected to become available in less than 20 years (or before the year 2000), and a suitable period for impact analysis beyond the projected availability of imported water was needed. On the basis of these criteria, and others, the termination date of 2020 was selected, beyond which no further analysis or projections were to be made.

It was recognized that no management strategy could be initiated immediately. It was assumed that no definitive new action or program would be taken before 1985 and that interbasin transfer projects which require extensive physical works, would not be operational until year 2000.

This hierarchical arrangement of alternative strategies established the framework for analysis. A comparison could be made among alternative strategies and with the "no new action" Baseline projections. Criteria considered in formulating the management strategies included, among others: fulfilling the intent of Congress as expressed in the enabling legislation; complying with the objectives of the Council defined in its Statement of Work; insuring that the strategies were realistic and amenable to the quantitative analytical techniques to be used. Strategies were designed to be additive as combinations of strategies were likely to be the preferred options for program implementation.

Comparisons among the alternative management strategies, and with the "no new action" Baseline, were to be in terms of direct farm-level effects such as land use changes (shifts between irrigated and dryland acreage or out of agricultural production), water use rates, total quantities of water used and resultant changes in amount of water remaining in the Ogallala Aquifer, farm commodity prices and production changes, and ultimately, impacts on net returns to land and management (a measure of profitability used to simulate operational decisions by individual farmers). Off-farm or indirect effects were then compared for both agriculturally related economic activities, and in turn by general economic indicators such as employment, income levels, fiscal capacities and other related effects. Evaluations and comparisons were made at the subregional and state level for each of the six states as well as for the Region and the Nation.

Environmental and social impacts of the alternatives, although not amenable to quantitative analyses, were evaluated and compared as well as the economic effects. This procedure permitted development of policies and plans involving combinations of strategies at the state and subregional levels to achieve defined Study objectives.

Operational Definitions and Analytical Procedures

Later clarification and amendments of the alternative strategies, reflecting changes to accommodate analytic, operational or program needs, were presented to and approved by the Council in mid-1979. These modifications and a subsequent Working Paper dated April 4, 1980, titled "Operational Definitions of Alternative Development Strategies", were prepared by the General Contractor to provide consistency among state-level researchers and the regional analyses conducted by the General Contractor. The adopted amendments and the supporting operational clarifications were as follows:

(0) BASELINE: Continuation of current local, state and federal policies and trends; no new state or federal programs (previous reference to "agricultural management" was deleted).

Under the Baseline condition, it was assumed that state and federal governments would make no new efforts to reduce demands on the Aquifer or to augment the supply in the foreseeable future, i.e., nothing purposeful by way of new or additional public actions. Rather, it was assumed that current

(1980) trends in public sector and private sector water demand and supply management would continue. For example, if state or local actions were in progress to alleviate overdrafts on the ground water, their outcomes or impacts would be reflected in the Baseline. Similarly, current trends in crop improvements, crop yields, cropping patterns, and adoption of proven technological improvements in water and agricultural management practices by farmers faced by increased pumping or other costs were reflected in the Baseline projections, as these would be dictated by rational and normal behavior of the individual farmer operating in a relatively free market.

Typical farming operations for each state subregion, cropping system and agricultural/irrigation management systems were defined by the state researchers, to include those conservation practices and water use management practices already in common use, as part of the Baseline assumptions. Each state estimated the rate at which water use efficiency improvements would be adopted by farmers in the state. The General Contractor reviewed estimates of the efficiencies of technologies adopted to provide some consistency among state results. On the basis of these assumptions, the Baseline portrays the projected changes in the High Plains agricultural sector as water availability declines.

While the Baseline projects "no significant change" in program assistance to irrigated agriculture at federal, state, regional or local levels, this was interpreted to permit changes in present conditions where public programs are already available. The effects of public sector initiatives presently authorized and funded that are likely to produce significant changes in water use and agricultural management practices in the future were estimated (quantified) and included in the Baseline projections. An example for the High Plains of Texas is illustrative. In 1978, a cooperative project was undertaken by the High Plains Underground Water Conservation District No. 1 and the Lubbock Area Office of USDA-SCS. The project was titled the "Field Water Conservation Laboratory", and has the objective of providing accelerated and improved assistance to irrigation farmers to achieve more efficient use of the water available from the Ogallala Aquifer. The initial project consisted of operating a mobile field lab with specialized irrigation testing equipment (funded by the HPUWCD#1), and its use for training and demonstration purposes throughout a multi-county area. The concept and approach has proven so popular and effective that the project has been expanded with assistance from the other ground water management districts in the Texas High Plains, the Texas Department of Water Resources, other area SCS offices and others to a full scale program available to irrigation farmers throughout most of the Texas High Plains. The projected efficiencies achievable from this program were included as appropriate by Texas researchers in Baseline projections.

Thus, the Baseline condition was not interpreted as a "do nothing" response on the part of individual farmers or of responsible government agencies. Significant changes currently underway in cropping practices, cultural or tillage methods, water management, irrigation systems and other variables were estimated and included in the states' Baseline projections. As an example, the increase in use of center pivot irrigation systems, and more particularly the improved efficiency-low head systems that are being used for most new installations and conversions, was estimated by each state.

Criteria were suggested by the General Contractor to guide the states in defining their individual Baseline conditions and projections in order to establish a workable level of regional consistency and comparability. Some of these were:

1) No new public actions not already underway or authorized (and presently funded to some degree) to be introduced into Baseline projections. (No limitation on the level of implementation or on future changes in the level of funding for authorized programs, if appropriate rationale or documentation was provided to justify such changes.)

2) No significant change in private sector (farmer) management or conservation practices to be estimated for the Baseline unless already in limited use or of demonstrated applicability in the state.

3) No new nonagricultural competition for available water to be estimated beyond that already identified, with provision for normal growth in those nonagricultural sectors currently in existence.

4) Significant deviation from historical rates of change in variables such as markets, unit water demands, input availability, or other factors used by the states in Baseline projections, were to be supported by appropriate rationale and documentation.

5) No significant <u>new</u> technological advances in agricultural or water management not already proven in a state were to be estimated.

6) A reasonable limit on change (e.g. 15-20 percent) in a production variable over any ten-year period or projection was to be followed, unless currently available documentation could substantiate higher rates of change.

7) Energy availability was not to be imposed as a constraint on the Baseline projections.

Examples of improved irrigation management practices, water conservation and water use efficiency methods considered by one or more of the states as representing Baseline conditions were:

1) Improved water application efficiencies achieved by converting from surface to sprinkler irrigation; from high pressure to low pressure sprinkler systems; and to improved application design and operations.

2) Return flow and runoff (tail water) recovery systems to minimize surface losses.

3) Instrumentation, automation and scientific scheduling of water applications based on soil moisture measurement, climatic conditions, crop growth requirements, etc.

4) Land treatment, tillage and cultivation practices to minimize soil moisture losses, and evapotranspiration losses.

5) Cultural and crop selection practices to reduce irrigation requirements.

(1) <u>VOLUNTARY WATER DEMAND MANAGEMENT STRATEGY (MS-1)</u>:
Encourage users to practice conservation through application of proven technology; provide incentives for the farmer to conserve (proven technology, not potential future technology, was added as criteria).

This first departure from the "no new change" assumptions of the Baseline postulated a set of voluntary measures directed toward greater water demand reduction at the farm level with accelerated and widespread adoption of new techniques by farmers stimulated by publicly provided incentives. These incentives would take the form of vigorous new public supported informational and demonstration programs to encourage water conservation; innovative programs of tax credits, accelerated depreciation, loans, grants or other financial incentives to induce adoption of new technological applications, new water application efficiency measures; and, new crops or cropping systems aimed at slowing the rate of ground water withdrawals. This would be coupled with increased agricultural and irrigation research and demonstration in development of crop strains requiring less water; and improved technology for reducing evapotranspiration losses and other on-farm water saving techniques for possible use during the planning period. The key to the strategy was still voluntary farmer decisions, but it differed from the Baseline by modifying the farmer's economic behavior by the offer of "carrots", but not the use of "sticks."

The most likely methods and extent of increased public sector programs for encouragement of new water conservation and/or water use efficiency practices were estimated and factored into the projection process by each state for Strategy One. Each state identified and adopted that set of programs and methods considered most relevant to its own situation. The assumption was made that the incentives provided by Strategy One would accelerate the rate of adoption of water demand reduction methods by one time period in comparison to Baseline projections.

Difficult aspects of Strategy One were: estimating and projecting the extent and effectiveness of management actions by irrigation farmers in terms of quantities of water conserved and costs related to varying levels of water use reduction, the levels of incentive required to achieve a desired reduction in water application, and types of inducements to be provided and timing. Regional Study elements conducted by the General Contractor and state-level research provided an initial set of management actions to be evaluated as an array of possible changes injected into the system. Results of this work are presented in detail in supplements to this report as Regional Study Elements B-3, B-5, and B-8. Management Strategy One had the overall effect of accelerating the adoption of improved water management practices and therefore reducing water use rates in the early periods of the Study but less significant improvements later (after the year 2000).

Limiting conditions were provided by the General Contractor to be applied by the individual states in their analysis of Strategy One.

1) No projected water savings due to Strategy One were considered as available for increasing irrigated acreage. Water saved was to be considered available to prolong use of the Aquifer.

2) Assumed new programs of incentives were to be judged and constrained on the basis of reasonableness and likely scale of application. New incentives for adoption of practices or technologies were sought within existing institutional arrangements.

3) Agricultural/water management and conservation practices were restricted to those already technically proven and available until after the year 2000.

4) Estimated and projected water use rates for Strategy One were to fluctuate within a reasonable range of reduction in water use per acre (unit water demand) from the Baseline.

5) Extent and rates (timing) of adoption of practices induced through incentives were to be reasonable in relation to past experience and locally informed best estimates.

6) To reflect the effect of these incentives in the analytic model, states were asked to bring forward by one time period the average water use efficiencies projected in the Baseline for each crop, thus, if water use for a crop averaged 1.3 acre-feet in 1990 and 1.1 acre-feet in 2000 in the Baseline, the water use rate of 1.1 acre-feet would be used with the crop in 1990 for Strategy One. In addition, allowances of 3 to 5 percent for improved water use efficiency resulting from new research were to be included in the models in 2020, by which time technical advances could move from the research station into the field.

(2) VOLUNTARY PLUS MANDATORY WATER DEMAND MANAGEMENT STRATEGY (MS-2): Apply all advanced water and agricultural management technology on a broad scale, identifying any necessary constraints (reference to institutional/regulatory changes was eliminated in some documents describing this strategy).

If projected voluntary water conservation measures were found to be inadequate to fulfill regional and subregional social and economic goals, new demand management measures, beyond those reflected in the Baseline and Strategy One, may be considered by federal, state or local governments. Such institutional measures could take the form of some regulatory constraints on rates or total amounts of pumping, seasonal timing of pumping, well spacing, new wells, capacities of new wells, or new irrigated agriculture developments, among others. Thus Strategy Two added the "sticks" to the "carrot" approach of Strategy One. Measurable reductions in unit water demand that would prolong irrigated crop production over Strategy One were added based on the assumption that statutory controls would require farmers to use less water. Full implementation of Strategy Two would represent the most stringent level of public sector water demand management feasible for each state. The simplifying assumption was adopted by the state research groups to reduce water use rates for Strategy Two to 90, 80 and 70 percent of projected Strategy One water application rates by 1985, 1990 and 2000, respectively.

The legal/institutional changes needed to implement Strategy Two would require greater lag-time before full implementation could be achieved than was the case for Strategy One. For example, a new program projected to become operative in 1985 would not result in broad implementation until about 1990. Limiting criteria from the General Contractor that provided some comparability among the states' operational definition of Strategy Two were:

1) A reasonable level of reduced demand from the changes projected for Strategy One was assumed. In order to project farm production impacts, the state reduced total water use for Strategy Two by 10 percent below Strategy One annual water use rates by 1985, by 20 percent in 1990, and by 30 percent below corresponding Strategy One levels by 2000, and thereafter. In the farm production (LP) models, farmers were allowed to "stack" water use within a farm unit, where favorable producton impacts resulted from applying available (restricted) water supplies on fewer acres. The option of reduced water use on the full acreage irrigated under Strategy One was also used.

2) Direct regulatory measures such as controls on pumping rates, well spacing or size, required metering and permits, or other control measures which would result in decreased water withdrawals were to be considered for achieving specific conservation or efficiency goals.

3) Any new regulatory controls or other significant state/local institutional changes assumed for this strategy were to be constrained to those considered to be operationally feasible within the each state.

In effect, Management Strategy Two differs from Strategy One mainly in reduced total water demand, graduated over time, due to regulatory constraints on ground water withdrawals. The reduced water use under Strategy Two was to be constrained to extending the effective life of the Aquifer, and not for expanded irrigated development.

(3) LOCAL WATER SUPPLY MANAGEMENT STRATEGY (MS-3):
Augment water supplies at local level with techniques such as artificial recharge, weather modification, vegetative management, desalting, precipitation management, and others.

The principal assumption underlying Strategy Three was that water demand reduction measures (MS-1 and 2) would not fully meet subregional, regional, or national goals for agricultural production and related economic growth and vitality. Therefore, purposeful water supply augmentation developments at the local level should be investigated. These include weather or precipitation modification (to the extent not already in practice as might be reflected in the Baseline), water banking, water harvesting, vegetative and evaporation management, and other methods on a multi-farm, watershed or subregional scale. This third in the array of water management changes injected into the analysis might take the form of actions by local water management districts, by state agencies, or the federal government, or some combination of public sector programs.

Some local augmentation methods are already being implemented by individual farmers, e.g., conjunctive use of playa waters. Others would require initiatives, participation and/or funding support by local, state or federal agencies. Weather modification and desalinization programs are good examples of the latter. Any of these programs already authorized and available are included in the Baseline projections, particularly those available for adoption by individual farmers at their own discretion. Programs which require regional or subregional publicly sponsored action (e.g. desalination) were treated as new programs for analysis. These included:

Method	Future Applicability
1) Precipitation augmentation and management	
a. Weather modification	All states. Technology is still in developmental stage. Significant legal, institutional and operational problems to be resolved.
b. Snow pack management	Primarily the northern High Plains states--Colorado, Kansas and Nebraska. In years when snow accumulations are heavier than normal it may become feasible to use evaporation suppressants to increase snow melt and improve soil moisture conditions.

c. Water harvesting, catchment areas	High runoff, noncultivated areas of all states. Watershed management to trap local runoff into catchment basins for either supplemental irrigation water or recharge to the aquifer. Water rights issues and institutional changes would need to be resolved.
2) Land treatments and modifications	
a. Noncultivated area treatments such as pitting, chiseling, water spreading, diversions and vegetative management to increase infiltration and reduce runoff. Also playa lake modifications in rangeland areas. Water banking opportunities.	Selected areas with appropriate soil and topographic conditions in all states. Acquisition of water rights and a suitable method for recapturing conserved waters would be necessary.
b. Cultivated area treatments such as deep plowing, clay pan control, terracing, benching, leveling, basin tillage, runoff recovery and soil conditioning.	Appropriate areas in all states selected on the basis of comprehensive farm-level conservation plans.
3) Vegetative management	
a. Noxious, deep rooted woody perennials, phreatophytes	Several million acres in local areas throughout the High Plains Region. Management and control of unproductive species like mesquite, shinnery, chaparrel, salt cedar and others could enhance soil moisture and deep percolation. Both institutional and environmental problems to be resolved.
b. Reestablish native grasslands	Poor condition rangelands or abandoned croplands throughout the Region. To increase soil cover, reduce runoff and increase infiltration/deep percolation. Difficult cost and management problems.
4) Conjunctive Uses	
a. Direct use of brackish or saline waters; blending with Ogallala water; desalination	Opportunities exist in local areas in all six study states. Need expanded research and development of these technologies.

b. Surface waters, playa lakes, reclamation and reuse of wastewaters, successive water uses.	Local opportunities in all states. Incentives, technical assistance and further R&D needed.
c. Artificial recharge of available surface waters.	Where geologically and hydrologically feasible in all states. Further technology development is needed.
5) Evapotranspiration (ET) management and reductions	Opportunities in all states to reduce ET losses from both cultivated and noncultivated areas.

The General Contractor has determined that the potential for significant augmentation of local water supplies within the Study area and within the selected Study period is limited and not quantifiable (see more detailed discussion in Chapter Six). Available data concerning most of the augmentation potentials and their future feasibilities are very limited. Analyses for Strategy Three, therefore, were made by the General Contractor as a separable strategy and examined qualitatively where local physical conditions offer possibilities for subregional augmentation. This strategy was not subjected to the rigorous impact analysis and projection of results as were Strategy One and Strategy Two. The economic effects of possible local water supply augmentation measures were not analyzed quantitatively, but are discussed subjectively in Chapter Six.

(4) SUBREGIONAL INTRASTATE IMPORTATION SUPPLY MANAGEMENT STRATEGY (MS-4): Augment local water supplies with interbasin transfer of surface waters as available (the words "minor" and "long-term" as used in original definition were dropped).

Prior studies and reports indicate that portions of some of the six states, particularly Nebraska and eastern Oklahoma, have surface water resources that may be surplus to their future needs and which might be conserved and transferred for use in deficient areas within the Region.

The assumption for Strategy Four was that all decisions and actions required to implement the water transfer are within the power and authority (existing or amended) of the individual state and would not require interstate agreements. Long-range state water plans provide a basis for defining possible sources, quantities, conveyance routings, costs and inputs. Each state quantified for the Study "existing and potential intrastate sources of water supply--surface, ground, reclaimed--other than the Ogallala Aquifer, for use within the High Plains by subregions".

After preliminary studies by the individual states, only Nebraska and Oklahoma elected to conduct full-scale analyses of intrastate transfer options, based on prior state water plans, under Strategy Four. These state studies were made independently of the analyses for Strategies One and Two but may be compared to projected Baseline conditions. The quantities of water considered available for transfer were not constrained and there were no acreage limitations placed upon their use within a state.

(5) REGIONAL INTERSTATE IMPORTATION SUPPLY MANAGEMENT STRATEGY (MS-5): Augment local water supplies with major interbasin transfers of water possibly providing for expansion of irrigated acreages (conceptually adopts the idea of enhanced or expanded irrigation in contrast with the original definition).*

The legislation authorizing the High Plains Study directed that consideration be given to alternatives for providing ". . .water supplies . . ." including ". . .transfer of water from adjacent areas". The Chief of Engineers was to conduct this portion of the Study to ". . .assure the continued economic growth and vitality of the region."

The studies of interstate, interbasin water transfers were conducted by the U.S. Army Corps of Engineers on behalf of the Chief of Engineers, in cooperation with the General Contractor.

Understandably, the long-range implications of implementing Strategy Five were of interest and concern to those states outside the Study area that could be affected by such water exportations. The High Plains Study Council, working with the General Contractor, was sensitive to these concerns. The Council adopted High Plains Study Council Resolution Number Six on January

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* Later modification of Strategy Five restricted water importation to levels sufficient only to restore lands for which ground water resources had been exhausted in the Study period.

16, 1980, in order to clarify the intent of the studies of MS-5, and to assure neighboring states of the Council's intent to pursue those studies in the context of "friendly and equitable understanding". This Resolution is of such significance to an understanding of the Council, the Study, and Strategy Five that it is quoted here in full.

> "Whereas the legislation authorizing the Six State High Plains - Ogallala Aquifer Region Study (P.L. 94-587), directed the Corps of Engineers to conduct a study of alternatives for transferring water 'from adjacent areas' into the High Plains - Ogallala Aquifer Region: and
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> "Whereas P.L. 94-587 requires that if such water transfer(s) are found to be a part of "a reasonable solution," the "Secretary (of Commerce) . . . shall include a recommended plan for allocating and distributing water in an equitable fashion, taking into account existing water rights and the needs for future growth of all affected areas;" and
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> "Whereas the Corps of Engineers, under separate agreement with EDA, and the General Contractor under Study Element B-1, are now cooperatively pursuing the technical aspects of alternative water interbasin transfer possibilities, both intrastate and interstate;
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> "Now therefore be it resolved that (1) the interbasin transfer study element is of significant importance to the High Plains - Ogallala Aquifer Study both within and without the High Plains - Ogallala Aquifer Region; (2) P.L. 94-587 requires such interbasin transfer study; (3) there is need to provide a friendly and equitable understanding of these studies among the six states involved, those states from which potential transfers might be considered and those through which possible conveyance aqueducts would pass; and that (4) the High Plains Study Council is stating the following diversion concepts and assurances:
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> > (1) The present uses and prospective future needs for beneficial purposes for the foreseeable future in the potential basin(s) of origin of surplus water will be considered as having prior rights to the waters involved. Likewise, present uses from and prospective future demands on the stream(s) outside the basin(s) of origin in accordance with state water plans, will be considered as having prior rights. Only those amounts of water estimated to be surplus to those present uses and future needs will be recognized as being potentially available for exportation to the High Plains - Ogallala Aquifer Region.
> >
> > (2) Existing compacts, water rights, contracts and commitments will be considered to remain in effect in estimating exportable surpluses.

(3) Future upstream depletions and future downstream flow requirements for instream uses will be estimated in calculating potential surpluses. Instream uses to be considered include but are not limited to fish and wildlife, navigation, quality control, hydropower generation, recreation and esthetics.

(4) State water plans for downstream states for development and utilization of the waters of the stream(s) involved will be taken into account.

(5) Needs of potential exporting states for early project development on the stream(s) involved for instate purposes will be examined in discussions with those states, in terms of compatibility and possible integration with a water transfer system. Where feasible, early financing and equitable cost sharing of such projects will be considered as a part of any interbasin transfer plan. The possible integration with existing system(s) will also be investigated.

(6) The possibility of integration with existing and prospective water resource systems within the state(s) through which an interbasin transfer aqueduct would pass, will be explored, including the potential for equitable cost-sharing and for joint financing of future projects.

(7) Where there appear to be potential benefits to be achieved, discussions will be held with states of origin, concerning possible exchanges between and among hydrologic systems. Consideration of such exchange would accord full recognition of water rights in making water available for export.

(8) No interbasin transfer will be recommended for the High Plains-Ogallala Aquifer Region except on the basis of full and frank discussions with potential exporting state(s) and other states directly involved of all relevant issues of water availability, equity, present commitments, mutual benefits and assurances considered necessary by such state(s) for protection.

"Be it further resolved; (1) that these concepts and assurances will provide the framework for the protections required by P.L. 94-587, and will provide the basis for initiation of discussions of diversion alternatives with the states from which water export may be considered and other states that might be involved; and (2) that the Chairman of the High Plains Study Council, in close cooperation with the Secretary of Commerce or Secretary's designee, and the Secretary of the Army or the Secretary's designee, with the counsel, advice and assistance of the General Contractor shall contact affected states and initiate technical discussions of these interstate transfer studies on the basis of the concepts and assurances stated herein."

The Corps of Engineers accepted and has followed this statement of policy in its interbasin transfer studies.

Following adoption of Resolution Number Six, Governor John Carlin of Kansas, Council Chairman for 1980, invited the governors of all states within the Missouri River Basin, and all other states in "adjacent areas" which might be affected by a water transfer, to name a representative who would be authorized to conduct "technical discussions" on behalf of his state. These discussions were conducted at the preliminary technical level on behalf of the Council by the General Contractor.

The General Contractor provided estimates of the cost of distribution systems to convey the imported water from the terminal storages selected by the Corps to the farm headgates. These estimates were based upon projections developed by the U.S. Bureau of Reclamation for the Oklahoma Water Plan.

The High Plains Study Council determined that water import evaluations were to be limited to those quantities of water required to restore irrigation capacity on lands previously irrigated which were projected to exhaust ground water supplies during the Study period. Because of the incremental nature of the analysis, two substrategies were defined and approve by the Liaison Committee:

° Management Strategy Five-A (MS-5A) - imported water constrained to be used to restore lands to irrigation for which ground water supplies were exhausted under MS-1. Management Strategy One production levels and water application rates were to apply to MS-5A.

° Management Strategy Five-B (MS-5B) - imported water constrained to be used to restore lands to irrigation for which ground water supplies were exhausted under MS-2. MS-2 production levels and water application rates were applied to ground water use in MS-5B. MS-1 levels were applied to imported water.

The location of terminal storage sites and the cost of distribution facilities were recognized as limiting the areas that could actually be served by any import alternative and "acre per acre" restoration would not be possible. The Study Council and the respective State Liaison representatives agreed that the "restoration strategies--MS-5A and 5B" provide a reasonable estimate of the changes in regional projections that might be anticipated with the availability of imported water.

CHAPTER FOUR
STUDY PLAN AND METHODOLOGY

INTRODUCTION

The High Plains Study was accomplished through the collective coordinated efforts of state and federal agencies, researchers from universities, the General Contractor and private contractors. The Study included fourteen technical work elements--three performed by the states and their researchers and eleven performed by the General Contractor. Six additional management and administrative work elements were conducted by the General Contractor for purposes of overall Study coordination and management.

The Interim Report submitted by the General Contractor to the EDA in January 1979 detailed the Plan of Study for each of the work elements and established the general framework for interaction among the specific tasks involved in each of the several elements. The state-level research to be performed by the states served as the basis of subcontracts between the General Contractor and each of the Study states. These subcontracts outlined the scope of work each state was to conduct, scheduled work completion, identified key researchers, and established budgets.

The Plan of Study was subsequently supplemented and expanded by the General Contractor through a series of workshops conducted with state researchers and other Study participants, by guidance memoranda issued periodically, and by frequent meetings and discussions among General Contractor team members and state researchers.

PLAN OF STUDY

The technical work elements of the Plan of Study were identified in two series--the A series describing state-level research and the B series describing the regional research by the General Contractor. Full detail on the Plan of Study task outline is presented in the Interim Report, and available as Appendix C to this report. The analytical framework for the Study, procedures followed in pursuing the work and a discussion of the assumptions used by the states in their A series research elements and by the General Contractor in the regional B series research elements are described in the following sections of this chapter. The following summarizes the work involved in each:

State Research A Series

A-1: Agricultural and Farm-Level Research

State farm-level research for each High Plains Study state involved developing an agricultural linear programming (LP) simulation model for that portion of the state supplied mainly from the Ogallala Aquifer and associated aquifers. The LP models were used to project changes over the 43-year study horizon in agricultural resource uses, cropping patterns, production costs, outputs, returns from agricultural production, farm employment and incomes, water demands, and other variables, in response to the alternative strategies assessed. Costs of pumping irrigation water from the Ogallala were a significant input variable; the costs were varied over time in response to declining ground water levels and increases in pumping energy prices. Each subregion in a state was analyzed individually.

A-2: Energy Production Impacts

State energy production impact studies involved projecting time profiles of energy production in each state and royalty payments, employment directly related to energy production, water used for energy production, and other energy related changes. Future prices for pumping energy and other agricultural uses were estimated as part of the regional energy impact studies.

A-3: Water Resources Evaluation and Economic Impacts Research

Assessments of the water resources for each state's area within the High Plains Region and the related economic, social and environmental changes projected in relation to effects of the alternative water resources management strategies, energy uses and other adjustments were the principal requirements of this state Study Element. State water resource assessments identified surface and ground water resources and their characteristics; subregional differences; estimates of ground water remaining in storage; possible intrastate sources of water other than the Ogallala Aquifer; historic water use patterns; planned water developments; projected costs of pumping Ogallala waters; projected water demands over the entire planning horizon; and projections of the effects on the Ogallala Aquifer over time. Economic impact analysis required the development by each state of state and sub-state (High Plains Region) inter-industry input/output (I/O) models to assess the changes among economic sectors that would be brought about by the alternative strategies.

Regional Research B Series

B-1: Interbasin Transfer Assessment

In coordination with the U.S. Army Corps of Engineers, as authorized in P.L. 94-587, and the states, the General Contractor identified the areas of significant water deficiencies in the High Plains Region, and possible water delivery and terminal points for imported waters. The Corps was responsible for identifying potential sources of supplemental water that might be imported to mitigate deficiencies; possible conveyance routes, and on-line and terminal storage possibilities; preparing reconnaissance level designs; and estimating the energy requirements, capital costs and operation and maintenance costs for each diversion, conveyance and storage scheme. The Corps, with the U.S. Fish and Wildlife Service, assessed the environmental impacts of each scheme. The General Contractor estimated the cost of distribution systems from the terminal storage reservoirs to farm headgates.

B-2: National and Regional Impact Assessment

The National-Inter-regional Agricultural Projections (NIRAP) model developed by the U.S. Department of Agriculture was used to make projections by commodity of supply, demand, and price. The General Contractor worked to insure consistency between the assumptions underlying the NIRAP model and the state A-1 agricultural simulation models of farm enterprises. Baseline projections for supply, demand, and price were made for the planning horizon to 2020. Further interactions between the NIRAP model and the state models projected changes in commodity supplies and prices from the Baseline under the alternative water resource management strategies. The changes from Baseline were then translated into the impact on macroeconomic factors such as consumer prices and balance of payments.

B-3: Agricultural and Water Technology Assessment

An array of improved agricultural water management practices and technologies were identified and assessed as to their applicability in improving water conservation and water use efficiency in High Plains irrigation. Practices were assessed for stage of development or use; relative effects upon reduced demands for Ogallala waters; cost effectiveness in terms of increased net returns or decreased production costs; on-farm or off-farm implementation or application; geographic applicability within the High Plains Region; status or availability for general use; anticipated crop yield or commodity production effects; associated requirements or changes in input costs for labor, energy, land, water, capital or other; expected environmental and/or water quality impacts; need for further research, development or demonstration; and the probable need for any incentives or institutional changes to achieve widespread and expeditious adoption and use of those measures with potential for achieving real gains in water conservation.

B-4: Environmental Impact Assessment

A general environmental assessment of the High Plains Region was made, and the probable environmental consequences of implementing the alternative strategies was qualitatively assessed. Possible mitigating measures that might minimize negative environmental impacts were considered.

B-5: Unconventional Water Supply Assessment

State-of-the-art assessments for existing or potential methods/technologies for augmenting local/regional water supplies for agricultural uses from sources other than the Ogallala Aquifer were compiled. Unconventional water resource augmentation options such as precipitation augmentation and management; use of brackish/saline waters for irrigation; desalination of brackish/saline waters; artificial aquifer recharge; land treatments to decrease water losses and increase infiltration and deep percolation of precipitation; water harvesting and banking; natural recharge; reclamation and use of wastewaters or urban storm waters; use of natural sinks (playa lakes) or other water harvesting techniques for trapping and using surface runoff; and other conjunctive water use opportunities were evaluated in relation to applications in the High Plains Region.

B-6: Institutional Assessment

The institutional framework of laws, agencies, interstate compacts and other institutional constraints that influence the use of available resources in the High Plains Region was inventoried. Existing policies, case law, water rights and contractual commitments were reviewed for pertinence to High Plains Study objectives. The institutional/legal needs or opportunities associated with the implementation of the alternative strategies were assessed.

B-7: Crop Prices Assessment

Information was provided state researchers on projections of (1) the costs of farm input supplies, (2) changes in farm productivity (yields per acre), and (3) shifts in the mix of input supplies used in agricultural production. These projections were made for the 43 year planning horizon and were localized, where necessary, to reflect conditions in specific areas under consideration. These data were used by the states in constructing the LP models to simulate farm production in each state to 2020. After initial runs of the LP models, assumptions were modified where necessary for consistency.

B-8: Energy Price and Technology Assessment

Energy price projections, long-term energy contract assessments, advanced technology assessments, and energy regulatory assessments were made. Projections of future primary and end-use energy commodity prices were prepared for use in other Study Elements. Regional projections of energy production and associated water resource and economic impacts were developed using data supplied by the states under Study Element A-2. An assessment was made of the possible effect of long-term contracts on future energy production. Detailed evaluation was prepared of advanced energy technologies, taking into account the variability of renewable energy resources in the High Plains Region. The potential economic impacts of energy shortfalls were also assessed.

B-9: Dryland Farming Assessment

Conditions likely to be encountered in the transition from a presently mixed irrigation-dryland agricultural economy to a dryland economy were assessed. Field surveys were made in two areas--fourteen counties in southwest Kansas and nine counties in the Texas South Plains--to illustrate past, present, and expected conditions in this transition.

B-10: Nonagricultural Development Potential Assessment

Nonagricultural development potentials and the relative effects of such development in the Region were evaluated. Recent trends in nonagricultural development for the Region were examined using state and county level data. Existing projections and forecasts of future nonagricultural development were assembled. The advantages and disadvantages to the Region for various types of nonagricultural development were profiled.

B-11: Assessments of Alternative Strategies

As originally designed, this Study Element compared alternative water resource management strategies in terms of impacts on agricultural production, on selected indicators of economic activity, on U.S. consumers and national commodity exports, and on remaining water supplies. A qualitative assessment of long-term environmental effects and legal and institutional changes was to be included. This material is now included in chapters six and the Executive Summary of this report. A regional input/output model was developed to project net regional economic impacts for each strategy, and is reported in Study Element B-11. Projections of economic activity using this model show the effects of changing water use and agricultural production on the total economy of the Region.

METHODOLOGY

Agricultural and Economic Analyses

The principal interacting models and projections used to evaluate water management strategies are shown in Figure IV-1. These elements are numbered on the diagram and described briefly below. Additional information is available in Appendix A: Forecasting Methodology, and in the various Study Element reports shown in parentheses.

1. A-1 Agricultural Simulation Models (LP models) - developed by each state. (Study Elements A-1 and B-2)

2. Estimate of Water Remaining in Storage in Aquifer - by state hydrologic models. (Study Element A-3)

3. Energy Price Projections - developed by Black & Veatch. (Study Element B-8)

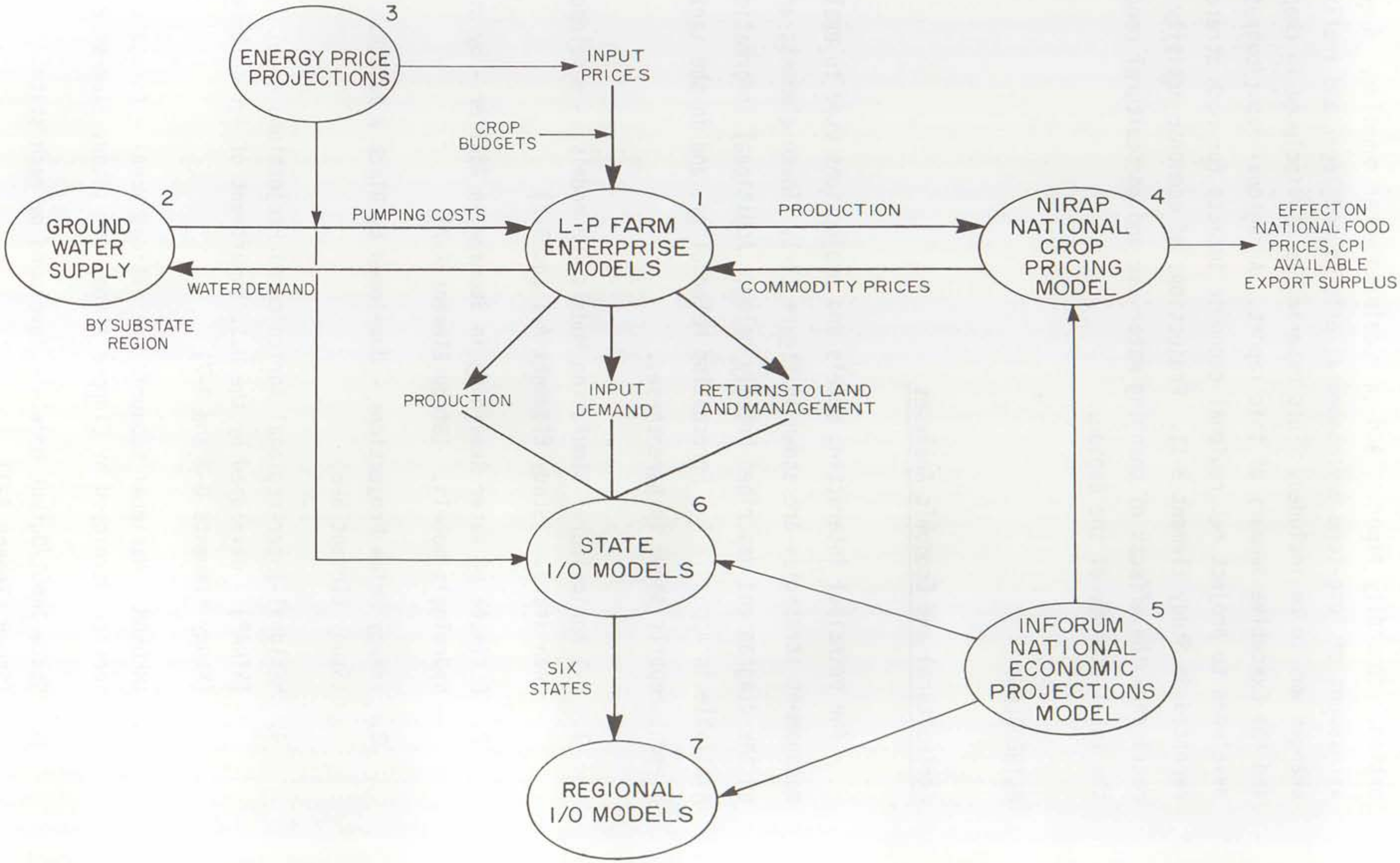
4. National-Inter-regional Agricultural Projections Model (NIRAP) - developed by the U.S. Department of Agriculture. (Study Elements B-2 and B-7)

5. INFORUM - National Economic Projections Model - forecasting service developed by Clopper Almon, Jr. (Study Element B-11)

6. State Input/Output Models - developed by each state. (Study Element A-3)

7. Regional Input/Output (I/O) Model - developed by Arthur D. Little, Inc. (Study Element B-11)

FIGURE IV-1: THE HIGH PLAINS STUDY INTERACTING MODELS AND DATA INPUTS



The principal component of the projection methodology is the state A-1 (LP) model [1]*. Each of the High Plains states developed an LP model to simulate the decisions made by the farmer in selecting and managing his crops. The model identifies a choice among a variety of crop budgets that maximizes an objective function. The objective function, returns to land and management (RLM) (and to imported water for the strategies involving importation), is an indicator of farm profitability and represents the financial return to a freehold farmer after operating costs are deducted from crop sales. For farmers who rent or have a mortgage on their land, actual cash returns would be less. All labor required for actual farm operation (machinery operation, etc.) is included as a labor input cost, even if performed by the farm manager, and is not included in RLM.

Input costs were quantified in constructing crop budgets. Each crop budget represents a different crop, grown in different climatic and soil conditions with different levels and types of irrigation. Projected changes in agricultural and irrigation technology are incorporated into the projections by changes in these budgets over the Study period. Energy costs, an important element in determining the cost of irrigated crop production, are derived from projections developed by the General Contractor** [3]. These projections show U.S. oil prices rising to world levels in the early part of the Study period, with a moderate annual increase in real oil prices thereafter. The real prices of other farm inputs were projected in a cooperative effort by the General Contractor and state researchers. All values were estimated in constant 1977 dollars to avoid the distorting effects of inflation in the presentation of results. Because of the measure of farm profitability used--returns to land and management--prices for farmland were not forecast. If returns to land and management increase, these returns may well be capitalized into the value of the land.

Of equal importance in constructing the crop budgets were future crop prices. Real prices (1977 Dollars) for key crops were projected using the NIRAP model [4].*** This is an econometric/equilibrium model which reflects

* Refers to numbered elements on Figure IV-1.

** Black & Veatch.

*** Because of a U.S. law barring government projection of cotton prices, these were estimated separately by Arthur D. Little, Inc.

past price/ production trends, future demand and production, and the interrelationship of prices of different crops. As projected production in the Region changed under different management strategies, the NIRAP model projected modifications in price projections in response to the resulting changes in total commodity supply. Commodity prices were converted to prices paid in each state of the Region based on historic national/local price relationships and were incorporated into the crop budgets.

The LP model approach was particularly useful for the High Plains Study because researchers were able to maximize returns by choosing among crops in the light of various resource constraints. Arable land was limited as an input constraint in the models, but the most important resource constraint for the Study was the availability of ground water. Estimates of saturated thickness [2]* developed by each state in each subregion were provided the researchers as an input to the LP models. Using these data the models then determined how much water would be used for irrigation each year given crop prices and pumping costs. Depletion of water in storage resulting from that amount of use was factored back into the hydrologic estimates with appropriate adjustments to water remaining in storage and depth to water in the next year. When saturated thickness of the Aquifer fell below state specified minimums, the LP models were constrained from using further ground water for irrigation. These minimums were determined based upon known Aquifer characteristics of transmissivity and specific yield in relation to relative well efficiencies.

Outputs from the LP models projected the significant variables in the agricultural economy of the Region, including:

- amount of irrigation water used
- cropland acreage - irrigated and dryland
- volume produced for each major crop
- value of agricultural production
- returns to land and management (plus returns to imported water for Management Strategy Five)

These projections developed for each sub-state area in the Region were then aggregated for each state and for the entire High Plains Region. In

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* See Figure IV-1.

addition, the models were run for the base year (1977) to determine the value of these indicators if "average 1977" prices and yields (a three year average of 1976-1978 statistics) had prevailed in that year. Actual 1977 conditions varied from the values used in the models and the production levels shown for 1977 from the state models will differ somewhat from production reported by the USDA or state statistics for that year.

The farm economy of the Region is strongly interconnected to the broader regional economy. Purchases by farmers drive a wide range of supply industries, while "downstream" demand industries, from feedlots and meat packing to cotton ginning, depend on regional agricultural production. In a similar manner, the production of oil and gas provides a primary source of demand for other industries in the Region and is a source of raw material for some "downstream" industries such as oil refining and chemical manufacturing. To project the effects of changing farm and energy production on the regional economy, the input/output modeling technique was used. Each state developed an I/O model [6]* showing sales and purchases among industry sectors. Changes in agricultural production and input purchases derived from the A-1 model results were then factored into the I/O models to determine the net effect on primary economic indicators including:

- activity in each industry sector
- total value added in the regional economy (a measure roughly equivalent to Gross National Product at the U.S. level)
- total sales (gross output)

In order to construct an I/O model which would be useful for the full Study period, projections of overall national economic growth and changes in labor productivity were incorporated. Trends at the national level will have a significant effect on the economy of the High Plains Region. Projections of these variables were developed from the INFORUM national forecasting model [5]* and were incorporated into the state I/O models. National economic projections from INFORUM were also used in projecting the domestic demand for food and fiber in the NIRAP crop pricing model [4]*.

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* See Figure IV-1.

The complex relationships among the states and industries precluded the straightforward approach of arithmetically adding the results of state I/O projections to estimate economic variables for the entire High Plains Region. A regional I/O model was used to project the economy of the High Plains Region [7]*. Adjusted state I/O results provided inputs for the regional I/O model, which were then used to project key variables for the North and South subregions and for the entire Region. These variables included:

- activity by industry sector
- total value added
- total household income
- employment by industry sector and total
- state and local government revenues (if current tax structure remains unchanged)

CRITICAL ASSUMPTIONS

The analytic methods described in the previous section on Methodology required the adoption of a number of critical assumptions to guide the interactive analytic process. Assumptions were necessary to simplify very complex relationships, to provide consistency among the separate research groups in the six states, to conform to "best judgment" of local/regional experience where deviations from national or regional norms were indicated, and to permit regional aggregation of state results.

Although many additional assumptions were used at technical levels of model adaptation, only those broadly relevant and more significant assumptions are summarized in this section. This review of critical assumptions follows the general organization of state research elements outlined previously, under the following headings:

° Agricultural and farm-level analysis
° Energy production impact analysis
° Economic impact analysis

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* See Figure IV-1.

Agricultural and Farm-Level Analysis Assumptions

Assumptions directly related to analysis of farm production, as summarized here, are those used by the state research groups in structuring relevant crop budget and LP models. Significant differences among the states (climate, soils, etc.) are reflected as variations in both model structures and underlying assumptions. The purpose here is not to identify those differences, but to set forth the unifying assumptions that provide consistency to the research results and projections.

The basic geographic areas of analysis for each state were sub-state areas combining counties with similar soil, climatic and/or water supply conditions. The sub-state areas were aggregated into a single economic unit for the High Plains Study Region of each state. Twenty-one subareas were identified within the six Study states.

Principal constraints on farm production in each model were the availability of suitable land and water supplies. Land availability and suitability estimates were derived from soil survey inventories while water supply constraints were estimated from climatic and ground water (aquifer) characteristics (mainly saturated thickness, well yields and withdrawal rates). Activities were identified in each LP model for each major crop grown in each state, according to the quantities of resources used (water, fertilizer and labor). Production of each crop was estimated at up to four levels of applied irrigation water, and as dryland where dryland production appeared to be a viable alternative for certain crops. Crop/water production functions for major crops were estimated for local (subregion) conditions and appropriate water application rate effects identified.

The objective function of the state LP models was to maximize the returns to land and management (plus returns to imported water), defined as the net income to a freehold farmer from a "typical" farm enterprise. The "typical" values were used in preference to "average" values for each crop in each subarea to allow common assumptions by state researchers about projected crop yields, input costs, commodity prices, input mixes and other variables, and to avoid unusual price or climatic (production) variations which influence average values.

Costs of inputs were assumed to be constant in real dollars (i.e. increase at a rate equal to the general inflation rate) unless specific exceptions were adopted. Such exceptions were made for the following input costs:

- ° Energy costs
- ° Fertilizer costs (because of correlation to energy costs)
- ° Seed costs
- ° Insecticide and herbicide costs

Detailed explanations of the assumptions associated with these exceptions to constant dollar prices are provided in the regional Study Element on crop price assessments (Element B-7). Further clarification of individual state assumptions used in state level analysis are available from the state A-1 reports. Assumptions relating to quantities of inputs used in "typical" farm enterprise budgets for each crop, area, and time period due to changing technology or other factors are also detailed in the B-7 Report and individual state A-1 reports.

Major assumptions were made about future irrigation technology and water management practices. Current trends toward more efficient and economic application of irrigation water were projected to continue and accelerate over time. Transition from gravity irrigation systems to sprinkler systems was assumed by some states. A significant reduction in operating pressures of sprinkler systems was a common assumption for all states. Specific rates of change vary among the six Study states.

Crop yield projections and commodity price projections were the two most critical assumption variables. Crop yield forecasts were developed by the state researchers, in cooperation with the General Contractor and agronomy experts, based on actual 1977 yields and historical yield trends. A yield projection methodology prepared by the University of Nebraska based upon a 29-year data base was integrated as appropriate by the other Study states into their yield trend procedures.

A set of functional relationships were developed between crop yield projections and associated rates of water application*. Crop yield reductions resulting from reduced amounts of water application (below "full irrigation" requirements) were also developed by Nebraska reseachers and incorporated as appropriate by other states with the concurrence of the General Contractor.

Commodity price projections were derived with the assistance of the USDA - NIRAP system. A set of assumptions mutually acceptable to USDA, the General Contractor, and the states was adopted. A document summarizing those assumptions is incorporated in the Study Element B-7 Report. Appropriate indices were used by each state to convert national commodity price projections to state prices. The NIRAP system was not able to provide price projections for certain crops (e.g. cotton, alfalfa, sunflowers). The General Contractor provided those projections based upon historial relationships between these commodity prices and the crops available from NIRAP projections.

An assumption based upon a historical "percentage of U.S. production" constraint was used to moderate the rate of change in crop production that could occur within a state over time. Other factors that state researchers used to influence the rate of change in crop mixes were relative commodity prices, risk and diversification assumptions, and control limits on the rate of expansion or contraction of crop acreages in a time period.

Another assumption adopted by the states was in relation to the rate of irrigation development. The projection of new irrigation development was estimated by determining the irrigable land in each subarea underlain by quantities of ground water adequate to justify new investment in irrigation development. It was assumed that future irrigation development would occur on these lands at the same rate that has occurred over the past ten years, until all irrigable land with adequate ground water supplies had developed, as long as justified by the projected profitability of irrigation. Some variation in these assumptions was made by individual states to fit the analysis to the conditions in those states.

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* Typical water application rates for crops at levels of water use efficiencies to provide full evapotranspiration requirements of the crops were assumed.

It was assumed that future climatic conditions will not vary significantly from those experienced in recent years, an assumption critically important with respect to the viability of and production from dryland farming. A climatic variability analysis (drought sensitivity) was analyzed separately and is discussed in Chapter Five.

Energy Sector Analysis Assumptions

Significant assumptions in the energy sector analysis fall within the general categories of energy price projections; crude oil, natural gas and electric energy production projections; water consumption projections associated with energy production; and employment and income projections assocciation with energy production. Estimates and projections for each of these indicators were prepared at both the state level of analysis (Study Element A-2) and the regional level (Study Element B-8).

Significant differences in assumptions used to support the energy sector analysis exist among the separate states and are summarized in the Study Element B-8 Report. The purpose here is to focus on those assumptions with regional significance that provide consistency to state and regional projections and conformity to related national projections. Wherever relevant, basic energy sector assumptions were linked with national projections used in other Study elements to ensure compatibility with the other analyses.

Energy Price Projection Assumptions

- Regional primary energy commodity prices (except natural gas) were projected based on long-term annual rate-of-change in constant (1977) dollars per million British thermal units ($/MBtu).

- Near-term, natural gas and natural gas product prices were projected to conform to existing federal law. By 1990 and thereafter natural gas prices at wellhead were assumed to be equivalent on an MBtu basis to crude petroleum.

Water Consumption, Employment and Income Projection Assumptions

- ° Water use projections associated with energy production include both direct consumptive requirements (oil, gas and electricity production) and indirect consumption associated with petroleum refining and natural gas processing.

- ° Water consumption associated with energy production was defined as only the fresh water required by production activities; this could be offset by using treated poorer quality waters in some activities such as refining and electric energy production. Therefore projected water consumption values probably represent the maximum impact on the Ogallala Aquifer from energy production activities.

- ° Employment directly associated with energy production in the Study area is assumed to follow historical oil and gas production investment trends with adjustments for increased labor requirements of enhanced oil recovery.

- ° Employment indirectly associated with energy production is projected based on both local production and local demand for energy.

- ° Projections of earnings are consistent with general productivity increases specified for the regional economic analyses.

- ° Royalty payments to local private leaseholders were estimated assuming the trend of increasing royalty payments to continue until oil production peaks and to decline thereafter to the traditional value of one-eighth.

Economic Impact Analysis Assumptions

The major assumptions adopted to provide consistency within the state and regional economic impact analyses (state and High Plains Region I/O models) were those projecting the rate of growth and structure of the national economy. Projections of productivity growth in each sector determined the growth in real income and demand. The INFORUM projections for these values were incorporated in the state and regional I/O models. The growth rates projected by INFORUM for the national economy drive the demand for regional products. These projections are discussed in detail in the Study Elemenet B-11 Report.

Projections were developed from the Clopper Almon, Jr. INFORUM forecasting service. These projections were used in two ways in the High Plains Study: they were distributed to state economic researchers as a common basis for state I/O model projections, and were used as the guideline for specifying the national economy in the regional economic impact model. The INFORUM projections were also used to project some of the basic economic factors used in the NIRAP model--economic growth, consumer demand, export growth--to keep the basic economic projections consistent for the projection of agricultural prices and the determination of state and regional economic impacts.

Summary of Critical Projections

The following tables summarize the projections of critical parameters used in the simulation models. These tables show projected changes over time in:

- ° Crop yield projections (state averages) - Table IV-1.
- ° National crop prices - Table IV-2.
- ° Energy prices - Table IV-3.

Crop prices vary in the subsequent strategy analyses as water management strategies and crop production vary. Energy prices are unaffected by the alternative management strategies, while projected yields for each crop budget in each year remain fixed. However differences among various crop budgets in different subregions with different soil fertilities as well as differences in irrigation levels may result in changes in state-wide average yields for a given crop in a given year.

Another critical variable which is projected to shift across time during the Study period and from state to state are the assumed levels of water use efficiencies. These vary by method of water application, by crop, by alternative strategy and other factors. Details of water use efficiency, water application rates and crop water requirements can be found in the respective state A-1 Study reports.

Table IV-1: HIGH PLAINS STUDY - PROJECTIONS OF AVERAGE YIELDS FOR FOUR MAJOR CROPS, BY STATE

State	Year	Wheat Dry	Wheat Irr.	Corn Irr.	Sorghum Dry	Sorghum Irr.	Cotton Dry	Cotton Irr.
		bushels per acre					bales per acre	
Colorado	1977	23.7	46.3	129.4	19.8	84.4		
	1985	26.7	-**	141.8	21.8	87.5		
	1990	29.3	-	151.1	22.8	89.5	N/A	
	2000	33.2	-	166.6	25.6	85.7		
	2020	42.7	79.1	187.2	30.4	100.0		
Kansas	1977	29.7	37.3	91.4	39.6	65.8		
	1985	33.3	41.6	110.0	32.4	69.0		
	1990	36.7	45.9	120.8	35.5	76.1	N/A	
	2000	42.5	51.5	129.3	42.0	90.7		
	2020	52.5	61.5	149.2	54.8	-		
Nebraska	1977	33.3	41.6	118.4	62.6	86.0		
	1985	39.6	44.7	144.0	74.4	100.8		
	1990	41.9	55.8	154.1	79.3	112.7	N/A	
	2000	45.4	65.0	169.8	82.0	130.2		
	2020	50.7	81.8	189.9	88.8	159.8		
New Mexico	1977	13.0	45.7	113.9	23.1	79.1	0.5	0.9
	1985	15.8	56.1	140.4	28.1	98.9	0.5	1.0
	1990	19.3	74.9	149.7	30.9	108.5	0.6	1.1
	2000	22.8	89.3	161.9	35.2	118.8	0.6	1.2
	2020	26.3	114.8	174.6	39.4	91.8	0.7	1.3
Oklahoma	1977	20.5	48.3	118.6	33.5	76.7		
	1985	26.0	45.1	139.6	41.2	101.4		
	1990	28.2	46.5	149.9	46.0	112.9	N/A	
	2000	34.0	54.4	166.1	51.5	123.2		
	2020	46.0	70.2	184.1	57.6	137.0		
Texas*	1977	11.6	29.0	115.4	20.8	93.9	0.5	1.1
	1985	12.7	30.5	123.7	22.2	103.0	0.6	1.3
	1990	13.2	29.6	122.6	23.0	110.1	0.6	1.3
	2000	14.0	34.8	126.4	23.8	113.5	0.6	1.3
	2020	15.1	37.8	134.4	25.2	121.7	0.6	1.4

* Planted acre yields. Yields for other five states are on a harvested acre basis.

** Yields are not shown when no production for that crop was projected by LP models for a particular year.

Table IV-2: HIGH PLAINS STUDY - NATIONAL CROP PRICE PROJECTIONS FOR BASELINE

	Wheat* ($/bushel)	Corn* ($/bushel)	Sorghum* ($/bushel)	Cotton** ($/lb)	Soybeans* ($/bushel)
1977***	2.66	2.13	1.95	.58	6.43
1985	3.03	2.54	2.28	.54	6.10
1990	3.05	2.58	2.32	.55	6.14
2000	3.12	2.76	2.48	.56	6.37
2020	3.40	2.89	2.60	.58	7.05

* Projected using the USDA NIRAP model.

** Projected by Arthur D. Little, Inc.

*** Average 1977 prices are a 3-year average in 1977 dollars, i.e. 1976 inflated, 1978 deflated.

Table IV-3: HIGH PLAINS STUDY - PROJECTED REGIONAL PRICES OF PRIMARY AND END-USE ENERGY COMMODITIES (1977 DOLLARS)

	Year 1980	1985	1990	2000	2020
Primary Energy Commodities					
Coal - Mine ($/ton)	11.10	11.80	12.00	14.00	17.40
Crude Petroleum - Wellhead ($/bbl)	19.60	24.40	24.90	25.90	28.10
National Gas - Wellhead ($/mcf)	1.23	2.81	4.39	4.56	4.95
Petroleum and Natural Gas Products					
Residual (No. 6) Oil - Refinery ($/bbl)	23.20	28.42	29.00	30.10	32.40
Diesel (No. 2) Oil - Refinery ($/bbl)	26.30	31.10	31.60	32.60	34.80
Diesel (No. 2) Oil - Pump ($/gal)	0.86	0.97	0.98	1.01	1.06
Gasoline - Refinery ($/bbl)	31.20	35.50	36.00	36.90	38.90
Gasoline - Pump ($/gal)	0.89	0.99	1.00	1.02	1.06
Natural Gas - Commercial Class ($/mcf)	1.73	3.31	4.89	5.06	5.45
Natural Gas Liquids - Plant ($/bbl)	6.81	13.10	19.30	20.00	21.50
Electricity					
Electricity - Average All Classes (mills/kWh)	35.10	41.60	48.10	61.10	67.60
Electricity - Small Commercial (mills/kWh)	39.50	46.80	54.30	68.60	76.50

CHAPTER FIVE
BASELINE IMPACT PROJECTIONS

INTRODUCTION AND SUMMARY RESULTS

Baseline projections for the High Plains Region for the Study period to 2020 portray an economy and resource base that--on an overall regional basis--is prosperous and adequate to maintain a large agricultural production capacity and a strong interactive economy. Some individual subregions indicate serious economic problems resulting from projected resource depletion during the Study period. Water remaining in storage to supply irrigation declines to the point that water levels are below economic pumping limits in those areas, with these declines encroaching on other subregions during and following the Study period. Crude oil and marketed natural gas production are projected to decline sharply for the Region by 2020 to approximately one-tenth of current production levels.

The analyses performed in the Study, described in Chapters Three and Four, constrained Baseline projections to those conditions that could occur with no <u>new</u> purposeful actions by government entities. Authorized and funded policies and programs in place were projected to continue. Significant improvements in farm management practices and applications of <u>proven</u> technology were projected as part of the Baseline by state researchers as a <u>continuation of current trends</u>.

Baseline Study results and projections are organized and presented in three major categories--agricultural sector impacts, energy sector impacts, and regional economic impacts. Agricultural sector impacts are presented at both state and regional levels of detail, with significant subregional differences--a northern subregion of Nebraska, Colorado and Kansas, and a southern Ogallala subregion of Oklahoma, New Mexico and Texas--shown separately for long-term trends that might be obscured by regional aggregation. Energy sector projections are aggregated at the regional level of analysis only, while total regional economic impacts are presented at subregional (northern and southern Ogallala) and regional levels of aggregation.

In brief, the Baseline projections indicate:

1) Continuing gradual increase in regional agricultural production because of:

   - ° improved yields
   - ° higher prices
   - ° expanded irrigation acreage in Nebraska
   - ° increased efficiencies of water use

2) Continuing depletion of ground water, with water remaining in storage below economically recoverable limits in an increasing part of the Region, and with higher pumping costs as water levels decline.

3) Decline in irrigated acreage is limited because of:

   - ° improved water efficiencies
   - ° application of <u>proven</u> new technologies
   - ° changes in cropping patterns

4) 5.1 million acres drop out of irrigated production by 2020 as water levels decline and as Ogallala water remaining in storage is depleted locally to nonrecoverable levels.

5) Shifts in production

   - ° to cotton (low water crop) in South
   - ° declining corn production in Texas and Kansas with substantial increase in Nebraska
   - ° feed grain production adequate for fed cattle industry on a regional basis
   - ° increasing wheat production except in Nebraska and Texas

6) Regional energy production to follow historical trends, with crude oil production to decline sharply after a mid-period (year 2000) recovery due to enhanced recovery techniques; marketed natural gas to decline over the entire projection period; and electric energy production to continue current increasing trends.

7) Water consumption associated with energy production in the Region is projected to increase, mainly because of projected rising electricity production demands.

8) Employment and incomes associated with energy production in the Region are projected to rise to about the year 2000 and decline thereafter.

9) Regional economy is projected to grow:

- ° buoyant energy economy in the South to 2000.
- ° continued industrial growth.
- ° growth of the agricultural sectors as a percentage of the regional economy (gross regional product) from 20 percent in 1977 to 26 percent in 2020 as the result of declining energy production.
- ° decline in growth rate of overall economy of the South as oil and gas reserves decline--the agricultural growth rate is projected to remain relatively stable with a resultant net economic decline in the South.

BASELINE - AGRICULTURAL SECTOR IMPACTS

Figures summarizing the results of the Baseline projection from state farm-level research developed through the LP models are presented at the end of this section. Tabular and graphic displays aggregate these results at state, subregional North-South, and regional levels. Supporting data tables for the Baseline agricultural sector projections are presented in Appendix B as Tables V-1 through V-12.1.

The following resource and economic indicators are projected for each of the Study years:

- ° Water Availability Impacts
- ° Land in Production (Irrigated/Dryland)
- ° Production - Six Significant Crops
- ° Value of Agricultural Production
- ° Returns to Land and Management

<u>Water Use and Availability Impacts</u>

(Figures V-1, 1.1, 2 and 2.1 in this section)
(Tables V-1 and 1.1 in Appendix B)

In all states except Nebraska and Oklahoma, the annual volume of water used declines through the Study period. Initial declines result from rapid expansion of the adoption of more efficient irrigation practices. Subsequent declines in water use occur as water under some lands is exhausted. Water use in Nebraska increases because of a significant increase in the number of acres irrigated.

Projected trends in annual water use for irrigated agriculture in the six Study states by 2020 are as follows:

Colorado	- down 0.5 million acre-feet or 43 percent from 1977 use rates
Kansas	- down 2.5 million acre-feet or 75 percent from 1977 use rates
Nebraska	- up almost 7 million acre-feet, or 89 percent over 1977 use rates

New Mexico - down over 400 thousand acre-feet, or 42 percent, from 1977

Oklahoma - up by 150 thousand acre-feet, or 22 percent over 1977 use rates

Texas - down by 5 million acre-feet, or 61 percent from 1977 use rates

The decline in annual water use projected for Texas by 2020 results from decreased irrigated acreage and improvement in irrigation water management and efficiency of use. Lower water use rates in Colorado and New Mexico are most directly related to reductions in projected acres under irrigation, while Kansas' reduced water use results from improved efficiencies, lower returns from irrigation, and lowered water levels (higher pumping costs). The increased water use rate in Oklahoma results primarily from an increase (55 thousand acres) in irrigated acreage. Nebraska's increased water use is due to new irrigation development.

Northern and southern Ogallala subregional water use trends are projected to move in opposite directions, with the North showing an increase in annual water use of over 4 million acre-feet by 2020, due entirely to increasing irrigated acreage in Nebraska, while the South indicates a decline in annual water use of over 5 million acre-feet by 2020. The two trends nearly compensate for each other when the Region is viewed as a whole. Annual water use in 2020 for the Region is 20.9 million acre-feet, down only 6.0 percent from the 1977 peak of 22.1 million acre-feet.

Projections of water remaining in storage in the Aquifer portray a depletion of more than 50 percent by 2020 for all Study states except Nebraska and Kansas over the Study period. Trends in aquifer depletion for the six states are as follows:

Colorado - about 23 million acre-feet depletion by 2020, or a 25 percent decline from 1977

Kansas - storage down about 62 million acre-feet, or a 25 percent decline from 1977

Nebraska - about 379 million acre-feet of depletion, slightly more than 16 percent

New Mexico - aquifer storage down by about 14 million acre-feet, or 60 percent from 1977

Oklahoma - depletion of nearly 31 million acre-feet, or 52 percent of 1977 storage

Texas - aquifer storage down by almost 200 million acre-feet, 69 percent of 1977 storage

The relationships between beginning (1977) and ending (2020) aquifer storage for the individual states are highly significant. Total ground water withdrawals from storage in Nebraska by 2020 are nearly twice those in Texas (379 million acre-feet vs. 196 million acre-feet) while relative depletion of water in storage is only about 16 percent in Nebraska and nearly 70 percent in Texas. This reflects the fact that beginning storage in Nebraska is more than 800 percent of that in the Texas Ogallala.

Not all water remaining in storage can be economically recovered, so that these figures overstate the amount which is available to High Plains farmers under present technology. Some of this water lies in areas of very thin saturated thickness where well yields fall to a point that irrigation is no longer feasible. Additional quantities of Ogallala water "remaining in storage" lie beneath lands which cannot be developed for irrigation for physical or other reasons. Due to the very slow lateral flow characteristics of the Aquifer, these waters may also be unavailable for irrigation.

<u>Land in Production (Irrigated/Dryland)</u>

(Figures V-3 and 4, this section)
(Table V-2 in Appendix B)

Total land in production (cultivation) in the Region is projected to increase over the Study period by more than 5 million acres--from 32.6 million in 1977 to 37.6 million acres by 2020, or a 15 percent rise. This growth results from net increases in both irrigated (3.8 million acres) and dryland (1.3 million acres) production, with increases in Nebraska and Kansas accounting for most of the net growth. Oklahoma projects a stable base of total cultivated lands while Texas (down 155 thousand acres) and Colorado (down 105 thousand) show net declines by 2020. New Mexico cropland shows an increase of 30,000 acres.

The projected increase in cropland acreage for the Region is attributable mainly to net growth in irrigated acres in Nebraska (up nearly 6.8 million acres or 144 percent by 2020). Shifts among the six Study states in projected cropland acres (irrigated, dryland and total) by 2020 are as follows:

Colorado - irrigated acres down 235,000 (41 percent net); dryland up 130,000 (8 percent); and total cultivation down by 105,000 (5 percent)

Kansas - irrigated acres down 1,600,000 (73 percent); dryland up 2,485,000 (63 percent); total cultivation up by 885,000 (14 percent)

Nebraska* - expanded irrigation of 6.77 million acres (144 percent net); decline of dryland acres by 2.39 million (40 percent); net increase of 4.38 million acres (41 percent) in cultivation by 2020

New Mexico**- shift of 195,000 acres (44 percent) out of irrigation into dryland, and a net increase in cultivated lands of 30,000 acres (3 percent)

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* This excludes surface irrigation. Nebraska has approximately 700,000 acres currently irrigated by surface water supplies. Although there is some linkage between surface and ground water supplies, water for surface irrigation has been assumed to be available independent of fluctuations in the Ogallala Aquifer. Because production on surface irrigated acreage is unaffected by Baseline Aquifer declines or the management strategies, it has been excluded from the results shown in this Study and is treated in the same manner as Nebraska production outside the Study area.

** Includes a small amount of land irrigated with surface water under irrigated acreage and production.

Oklahoma	-	shift of 50,000 dryland acres (4 percent) into irrigation, with a small net increase of 5 thousand acres in cultivation and irrigation
Texas	-	a decline of 1.03 million acres (17 percent) out of irrigation; an increase of 875,000 acres (18 percent) in dryland crops; and a net decrease of 155,000 acres (1 percent) in total cultivation

The net change in cropland acres identified above obscures some very significant projected shifts revealed by the individual state farm sector (LP) models. While a net increase of 3.8 million acres in irrigated land for the entire Region is projected, the state studies project 5.1 million acres going out of irrigated production over the Study period due to aquifer depletion and/or economic exhaustion. These lost irrigated acres are distributed among the states as follows:

Colorado	-	261,000 acres
Kansas	-	1,603,000 acres
Nebraska	-	1,516,000 acres
New Mexico	-	224,000 acres
Oklahoma	-	330,000 acres
Texas	-	1,203,000 acres
Region	-	5,137,000 acres

The apparent conflict in this summary of total loss in irrigated acreage (5.1 million acres) in contrast with a net increase of 3.8 million irrigated acres results because the state models were structured to account for lands going both into and out of irrigated production in each time period, with only the net change showing up in the final results.

Very different trends in cropland acreage characterize the two subregions, due mainly to the projected growth of irrigation in Nebraska. The northern Ogallala states show a projected growth in irrigated acreage of 4.9 million acres (66 percent increase from 1977), a relatively small (2.0 percent) increase in dryland acreage of 230,000 acres, and a 5.2 million acre (27 percent) increase in total cultivation.

The southern three states project a net loss of 1.2 million irrigated acres (a 17 percent decline from 1977), a gain of 1.05 million dryland acres (16 percent), for a net loss of only 0.1 million acres (1.0 percent) in total cultivated acres by 2020.

Production - Six Significant Crops

(Figures V-5 through V-10, this section)
(Table V-2.1 and 2.2, Appendix B)

Shifts in production of the High Plains Region's major field crops - wheat, corn, grain sorghum, soybeans, cotton and alfalfa - are among the most significant projected changes revealed by the Study. With the exception of soybeans (less than four percent of total national production) and alfalfa, for which no national market exists, the major High Plains crops constitute a significant part of total national agricultural production and play an important role in setting national commodity price and international (export) trade levels.

The following tabulation illustrates the relative importance of High Plains regional production of wheat, corn, grain sorghums and cotton as a percentage of the total projected national production of these commodities.

BASELINE - High Plains Projected Crop Production as a Percentage of Total National Production for 1977, 1985, 1990, 2000 and 2020

Crop	1977	1985	1990	2000	2020
Wheat	16.4	13.4	12.8	11.9	10.4
Corn	13.1	13.1	12.6	13.2	12.6
Sorghum	39.7	36.8	34.5	33.4	29.8
Cotton	24.9	31.2	33.8	35.5	31.9

Total regional production of all six major crops is projected to increase significantly over the Study period, with soybeans experiencing more than a 1,000 percent increase in production by 2020. The expanding production of major crops results from several related factors, most important of which are expanding irrigated acreage (mainly in Nebraska) and projected improvements in yields per acre. As shown in Table V-2.2, Appendix B, wheat production is projected to increase by almost 45 percent, grain sorghums by about 60 percent, corn and cotton by slightly more than 100 percent, and soybeans by about 1,060 percent by 2020.

Intraregional shifts in crop production are projected as well. Corn production increases by almost 150 percent in the North due to growth in acreage and production in Nebraska. Both Kansas and Colorado project declining corn production. A decline in corn production in the South of almost 80 percent is attributable to a projected shift out of irrigated corn production in the Texas High Plains. New Mexico remains relatively stable in corn production while Oklahoma projects a substantial increase.

Other shifts in crop production projected by 2020 within the Region are:

- Colorado - increasing wheat production (75 percent); declining corn, sorghum and alfalfa production
- Kansas - increasing sorghum (154 percent) and wheat (94 percent) production to offset declining corn production (-70 percent); a 37 percent increase in alfalfa production and a large (767 percent) relative increase in soybean production from 0.6 to 5.2 million bushels.
- Nebraska - growth in soybean production (up almost 1,800 percent); corn production up by 201 percent; modest growth in sorghum and alfalfa production; and a 24 percent decline in wheat production.
- New Mexico - increases in wheat production (119 percent); alfalfa (102 percent)*; cotton (31 percent); and declining grain sorghum production (-44 percent).
- Oklahoma - growth in corn production (130 percent), grain sorghums (121 percent) and wheat (87 percent), with a 29 percent increase in alfalfa production.
- Texas - growth in cotton production (102 percent), grain sorghums (57 percent), and alfalfa (55 percent) to offset declining corn (93 percent decrease), wheat (31 percent) and soybean (37 percent) production.

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* This heavy water using crop shows large increases because of increasing demand from feedlots, which purchase alfalfa within a relatively small area.

In terms of absolute change, a projected billion bushel increase in annual corn production in Nebraska by 2020 has the greatest implications for the economy of that state, and perhaps the Region as well.

The other most significant change in crop production is the projected growing reliance on cotton in Texas. A projection of almost a three million bale increase in cotton production in Texas by the year 2020 indicates the scale of that change, with implications for intensification of cotton related industries.

Value of Agricultural Production

(Figures V-11 and 11.1, this section)
(Table V-3, Appendix B)

As a measure of the importance of the agricultural sector to the regional economy, the total value of agricultural production is a good indicator of the projected long-term growth of the High Plains regional economy. From a base of about $4.6 billion in 1977, the total value of agricultural production in the High Plains Region is projected to grow steadily to almost $11.5 billion by 2020, a 151 percent increase in real (1977 dollars) terms.

Incorporated within that significant projected regional growth is a very substantial increase in all six states. Led by Nebraska with almost a $5 billion increase in its total value of annual agricultural production, the six Study states project the following growth by 2020:

Colorado	- 44%
Kansas	- 92%
Nebraska	- 284%
New Mexico	- 76%
Oklahoma	- 150%
Texas	- 66%

The high growth in Nebraska is related primarily to the steadily increasing corn production in that state. The overall growth in the Region is attributable to projected improvements in crop yields per acre and long-term real increases in agricultural commodity prices. The relative difference in growth of agricultural production between the northern Ogallala states (211 percent) and the southern three states (73 percent) is shown in Figure V-11.1, and is attributable mostly to the steady growth in value of production in Nebraska.

Returns to Land and Management

(Figures V-12 and 12.1, this section)
(Table V-4, Appendix B)

An indicator of the profitability of farming enterprises in the High Plains Region, returns to land and management was used by the individual state research groups as the objective function for optimizing the state linear programming (LP) models. As a measure of the relative returns to capital investment (land) and the risk-taking of entrepreneurship (management), the expressed values and projections represent an approximation of profitability which assumes no land indebtedness of the farming enterprise--i.e. a measure of direct returns to the freehold farmer.

On a regional level, returns to land and management correlate closely with total agricultural production and value of production projections. Real returns of slightly more than $1 billion to agricultural production in 1977 are projected to increase to almost $5 billion by 2020, about a 370 percent increase. This translates into a 3.7 percent annual growth rate in real terms. However, these returns will not be realized in real dollars if land prices and mortgage costs increase with the increase in projected returns.

On a state-by-state basis, real growth in returns to agriculture are projected for all six Study states as follows:

Colorado	- 78%
Kansas	- 307%
Nebraska	- 436%
New Mexico	- 360%
Oklahoma	- 133%
Texas	- 407%

FIGURE V-1: BASELINE ANNUAL WATER USE RATES, BY STATE (1,000's of Acre-Feet per Year)

Note: A significant difference in vertical (ordinate) scales is necessary for those states with more extensive irrigation (Nebraska, Kansas and Texas) than for Colorado, Oklahoma and New Mexico.

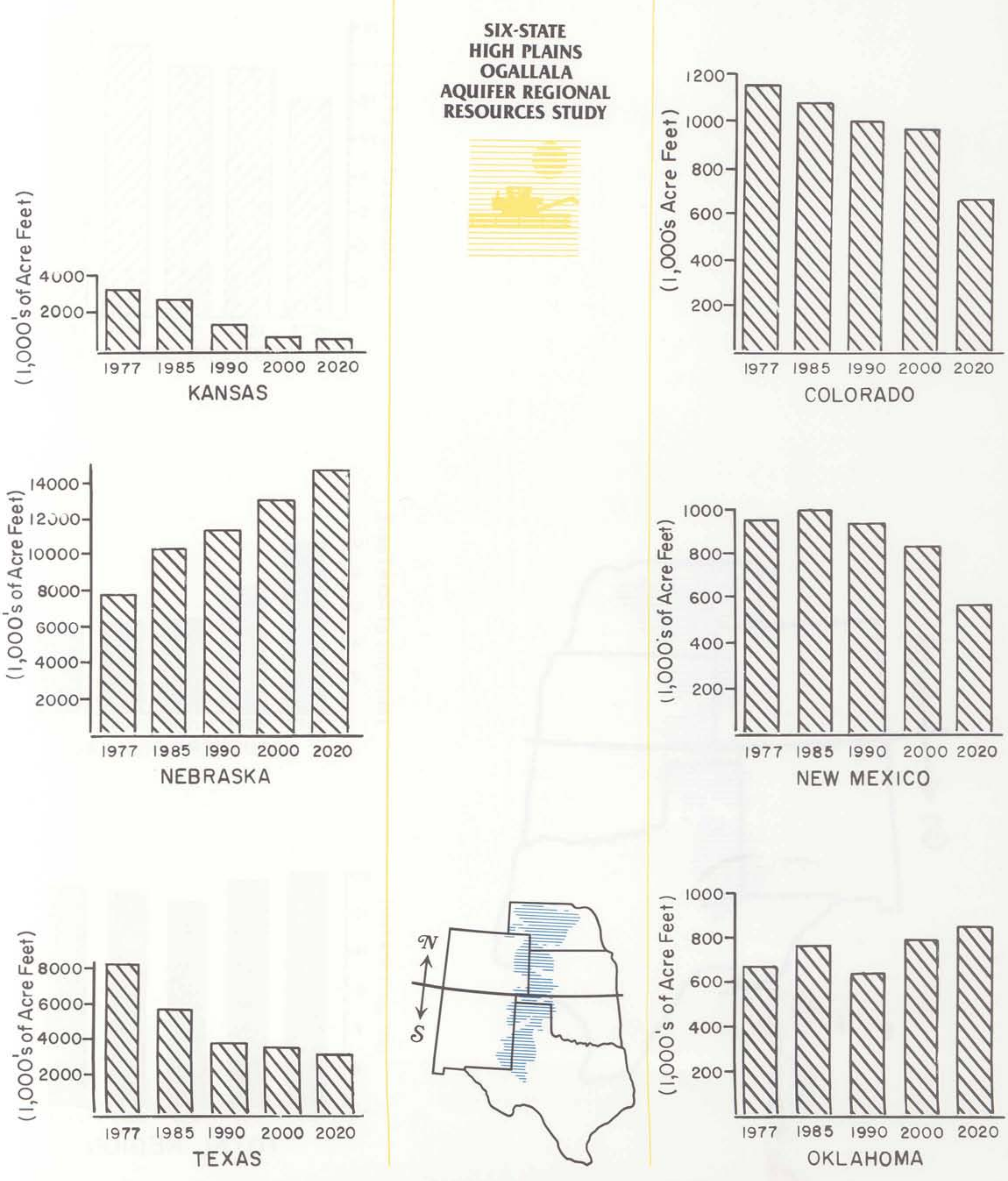
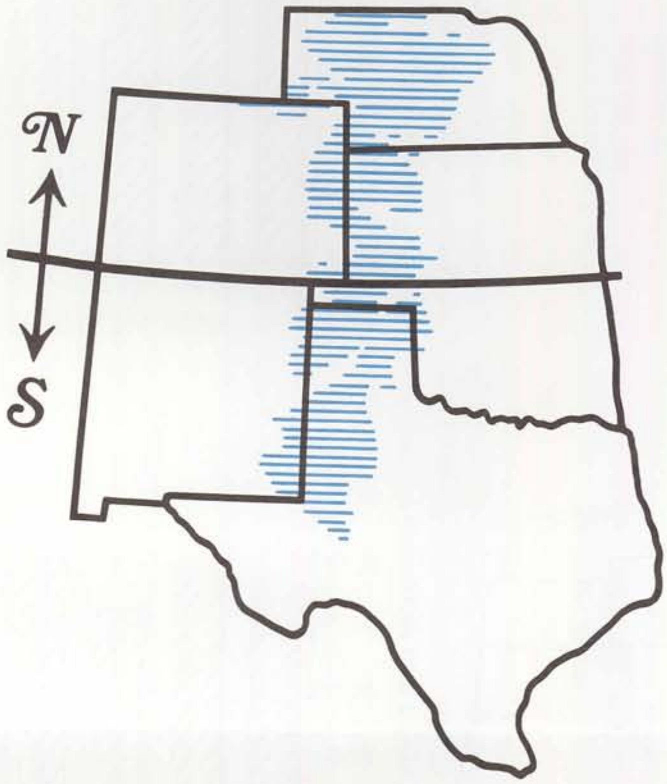
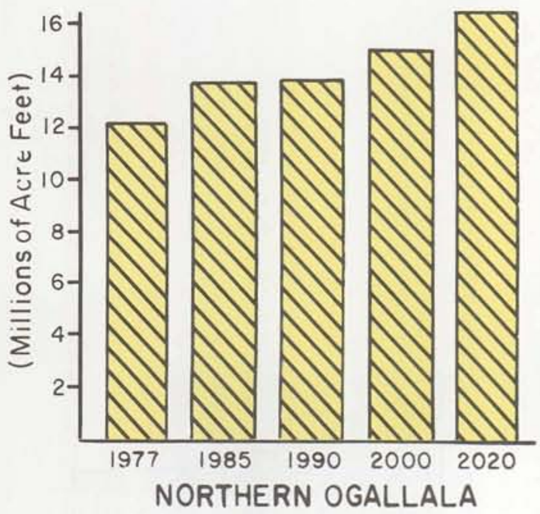
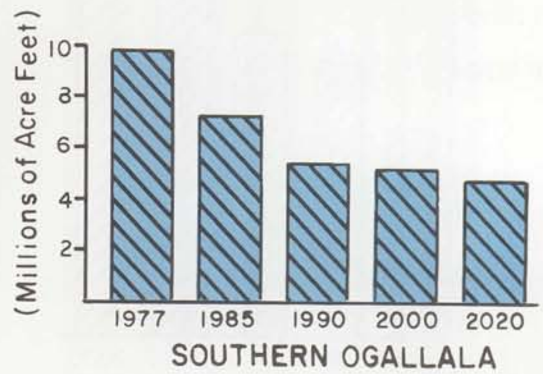


FIGURE V-1.1: BASELINE ANNUAL WATER USE RATES, BY SUBREGION AND REGIONAL TOTALS
(Millions of Acre-Feet)







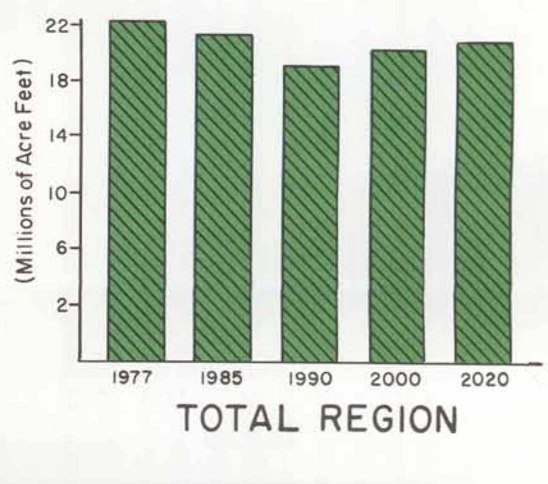


FIGURE V-2: BASELINE OGALLALA WATER REMAINING IN STORAGE, BY STATE
(Millions of Acre-Feet)

Note: A significant difference in vertical (ordinate) scales is necessary for those states with more extensive irrigation (Nebraska, Kansas and Texas) than for Colorado, Oklahoma and New Mexico.

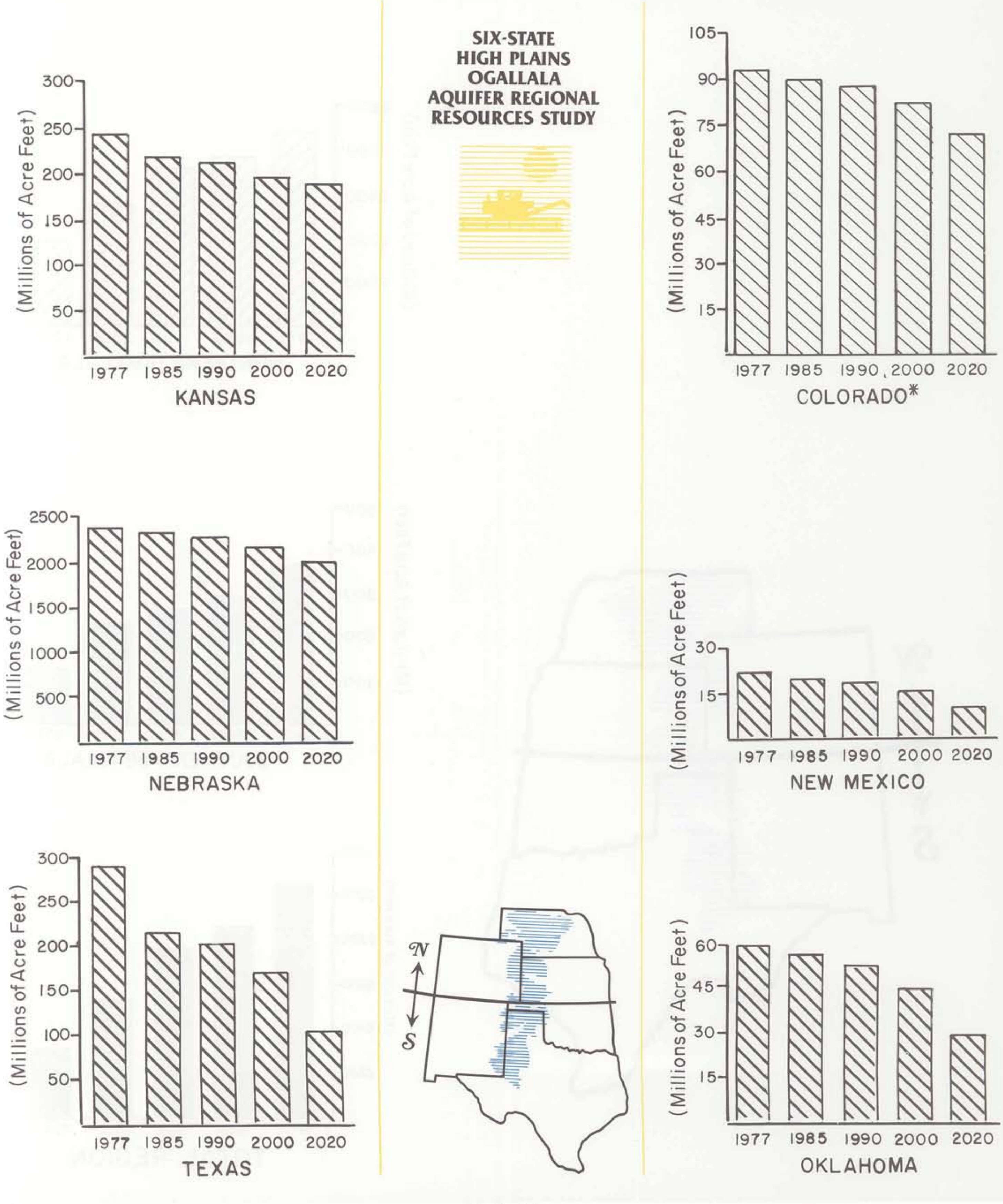


FIGURE V-2.1: BASELINE OGALLALA WATER REMAINING IN STORAGE, BY SUBREGION AND REGIONAL TOTALS (Millions of Acre-Feet)

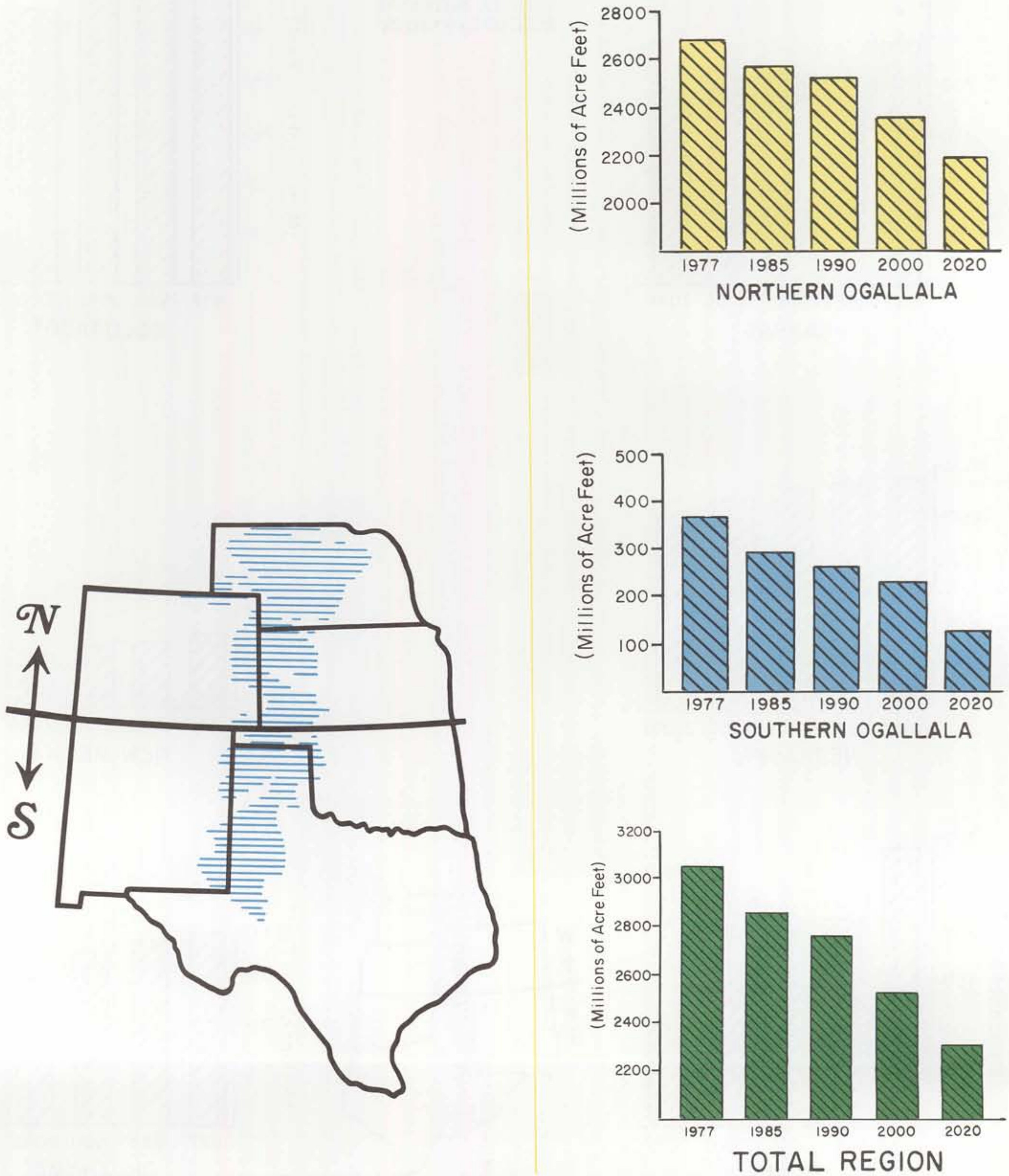


FIGURE V-3: BASELINE CROPLAND ACREAGE—IRRIGATED AND DRYLAND, BY STATE (1,000's of Acres)

Note: A significant difference in vertical (ordinate) scales is necessary for those states with more extensive irrigation (Nebraska, Kansas and Texas) than for Colorado, Oklahoma and New Mexico.

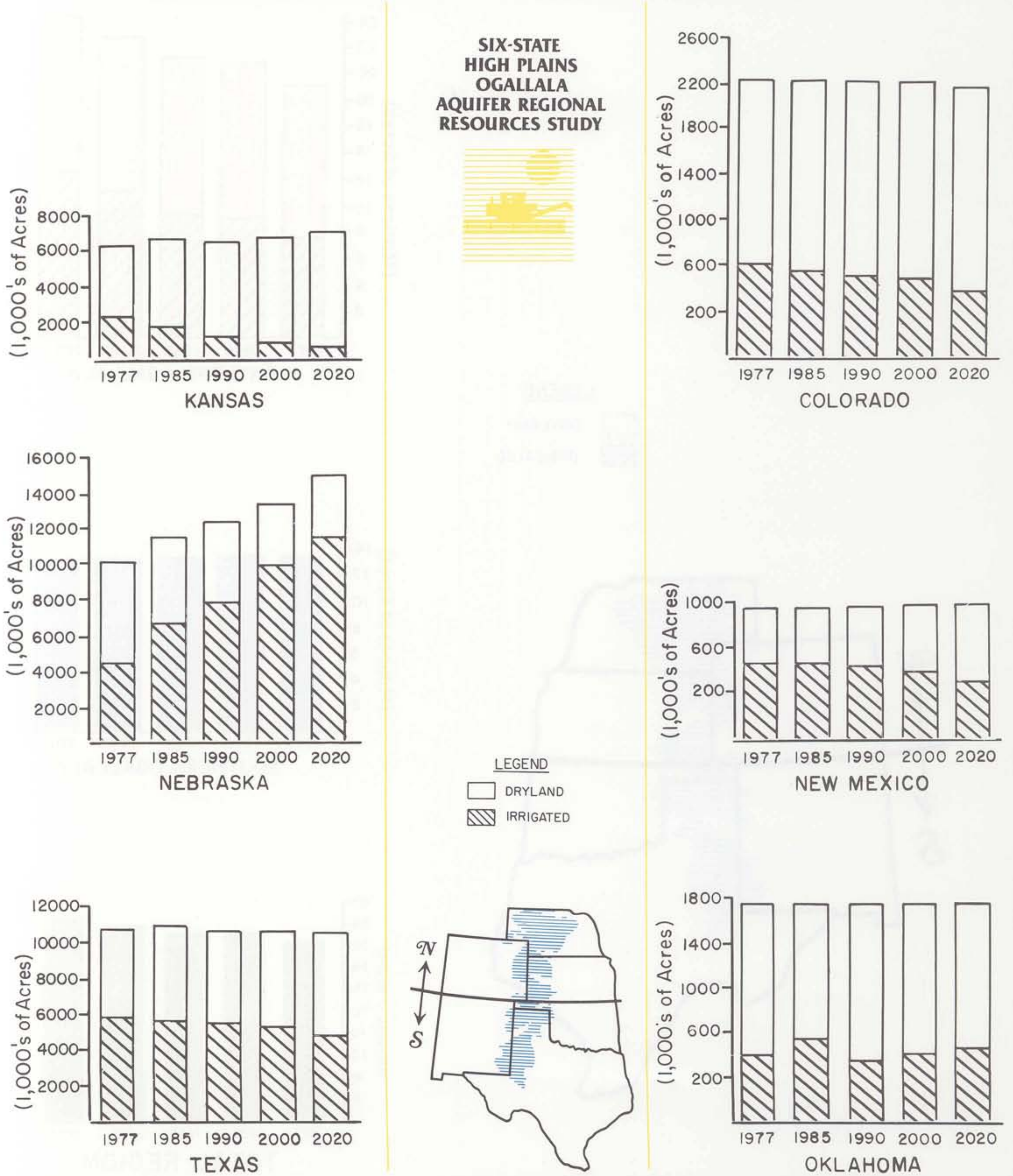


FIGURE V-4: BASELINE CROPLAND ACREAGE, BY SUBREGION AND REGIONAL TOTALS
(Millions of Acres)

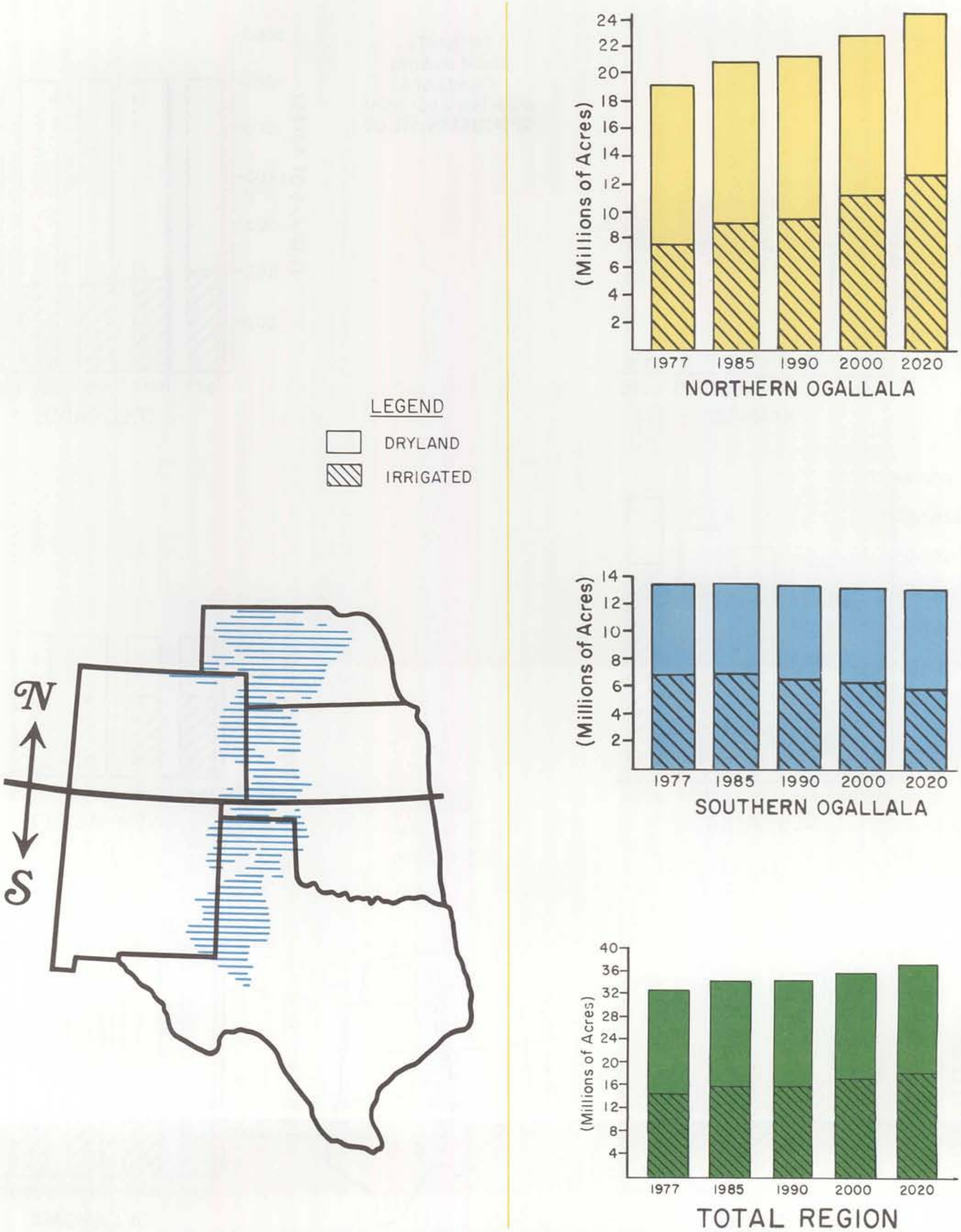


FIGURE V-5: BASELINE WHEAT PRODUCTION, BY STATE (Millions of Bushels)

Note: A significant difference in vertical (ordinate) scales is necessary for those states with more extensive irrigation (Nebraska, Kansas and Texas) than for Colorado, Oklahoma and New Mexico.

SIX-STATE HIGH PLAINS OGALLALA AQUIFER REGIONAL RESOURCES STUDY

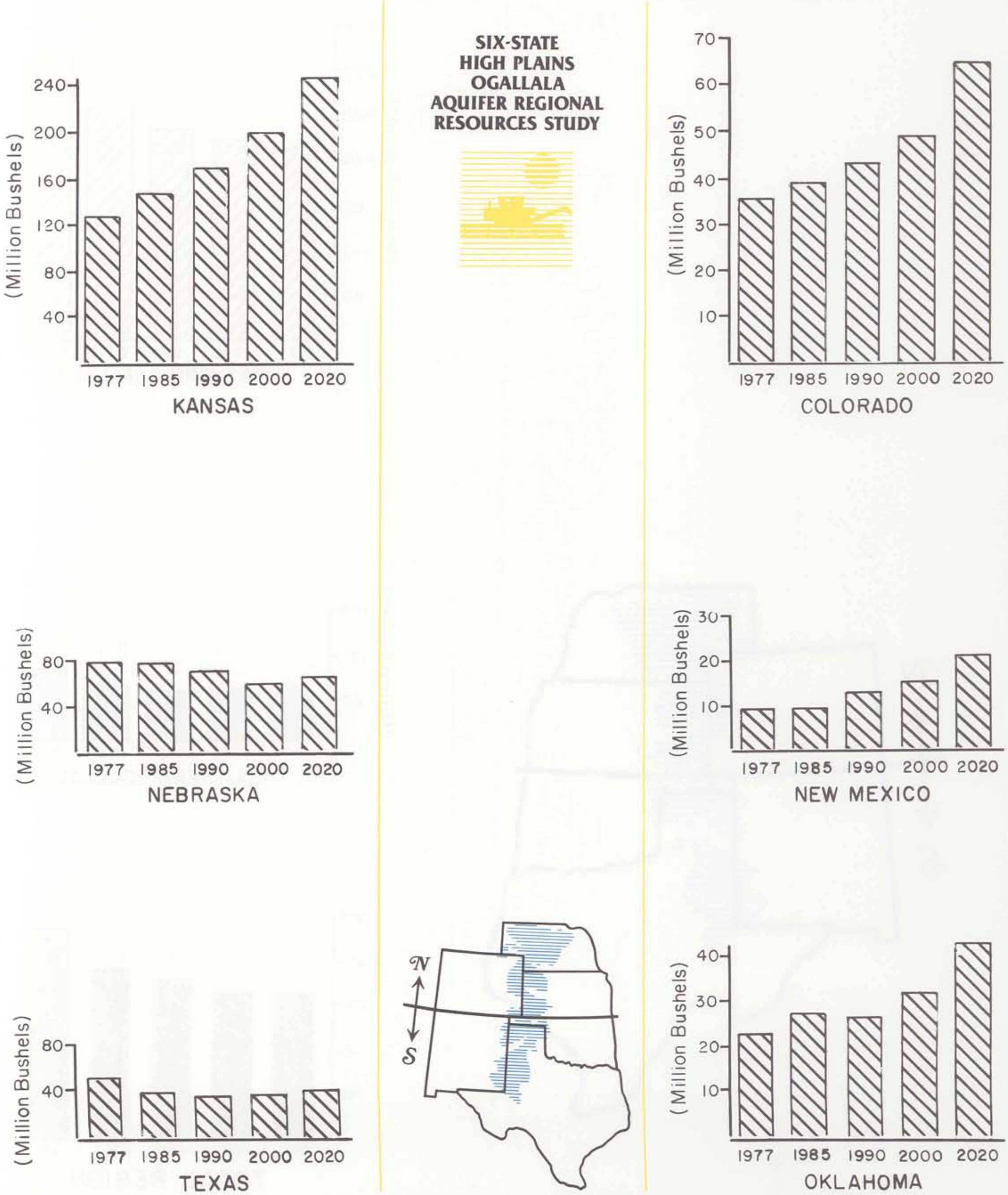


FIGURE V-5.1: BASELINE WHEAT PRODUCTION, BY SUBREGION AND REGIONAL TOTALS
(Millions of Bushels)

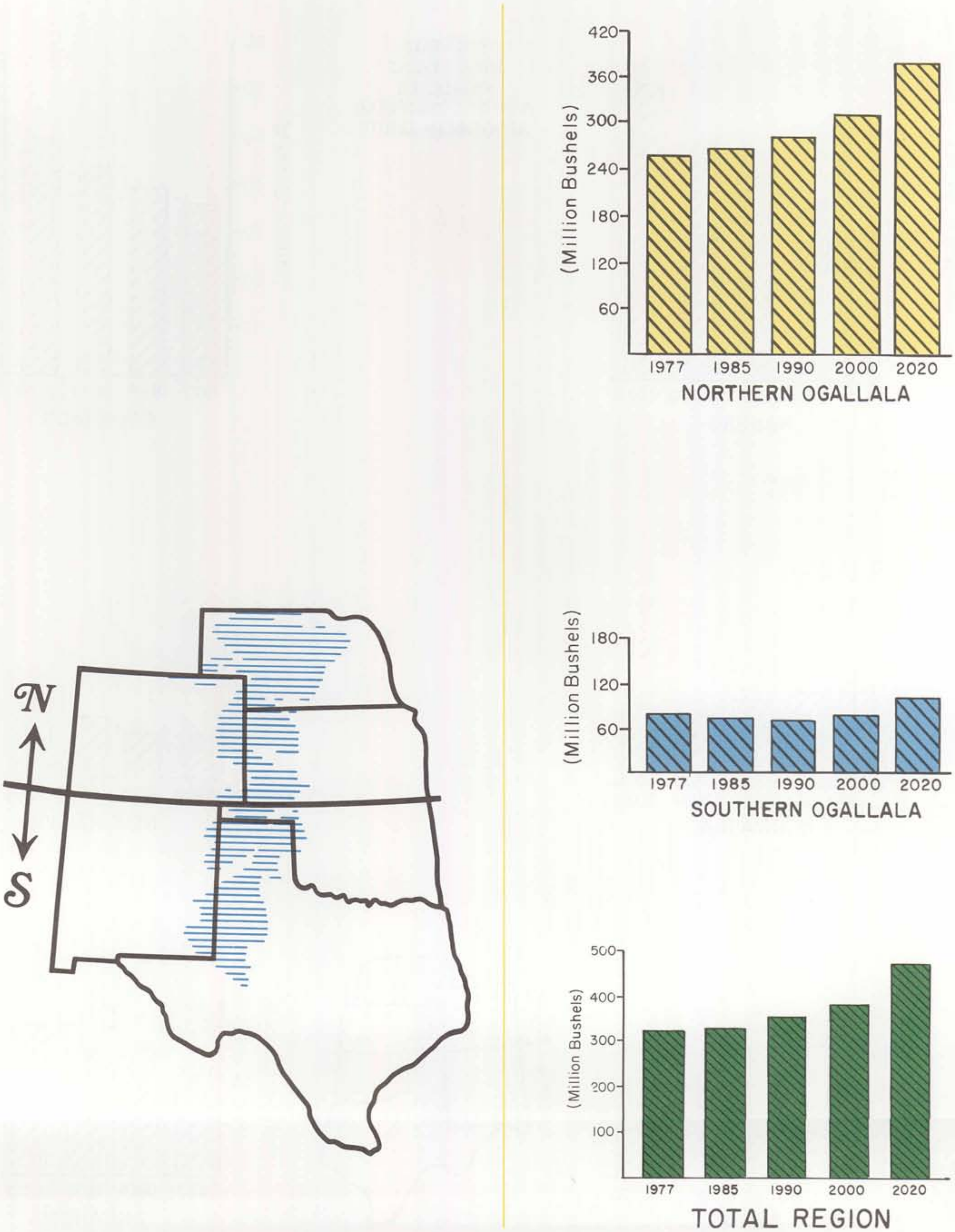
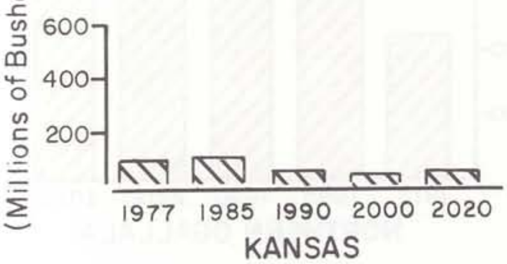
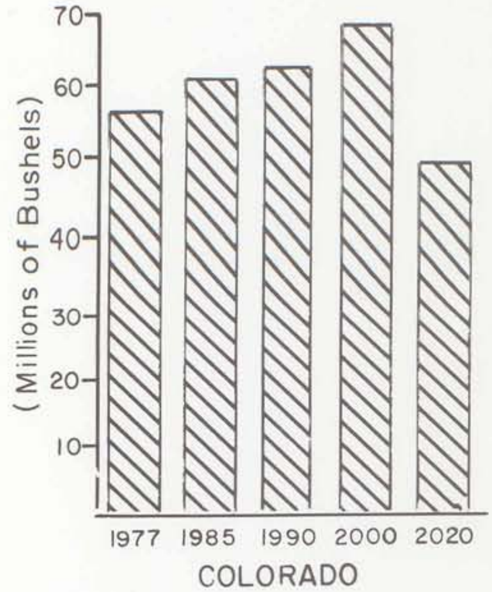


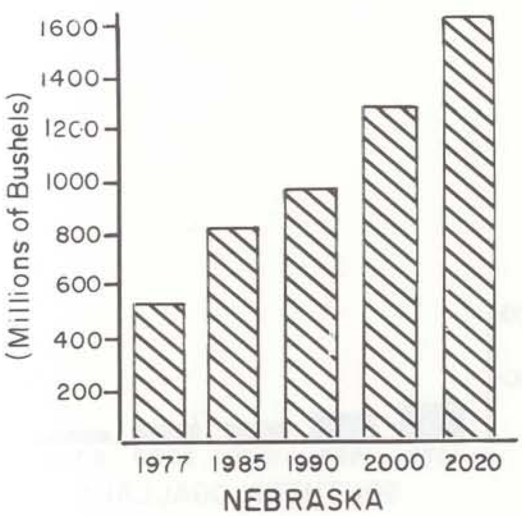
FIGURE V-6: BASELINE CORN PRODUCTION, BY STATE (Millions of Bushels)

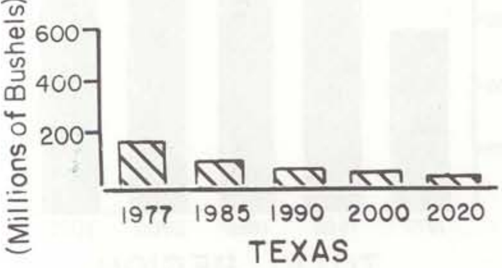
Note: A significant difference in vertical (ordinate) scales is necessary for those states with more extensive irrigation (Nebraska, Kansas and Texas) than for Colorado, Oklahoma and New Mexico.

SIX-STATE HIGH PLAINS OGALLALA AQUIFER REGIONAL RESOURCES STUDY









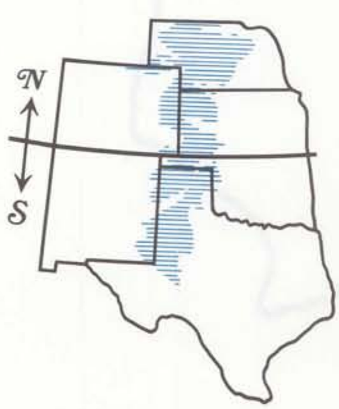
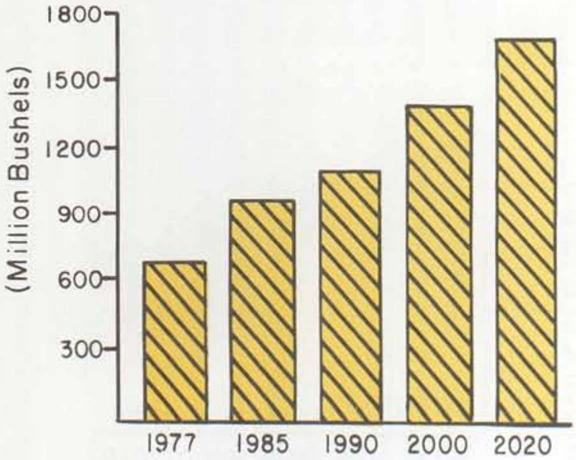
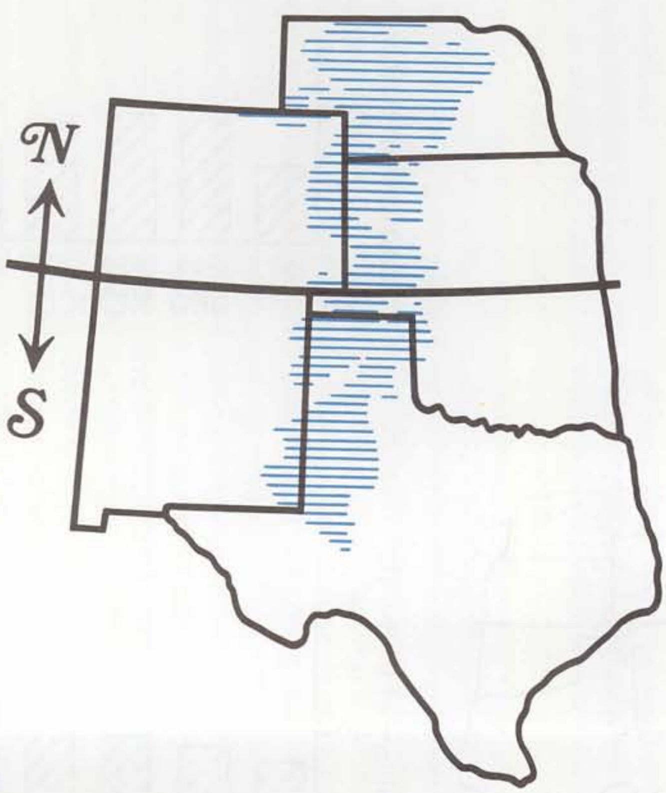
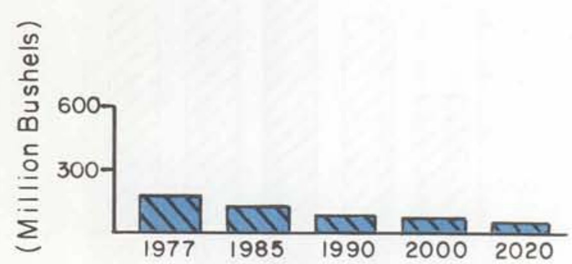


FIGURE V-6.1: BASELINE CORN PRODUCTION, BY SUBREGION AND REGIONAL TOTALS
(Millions of Bushels)







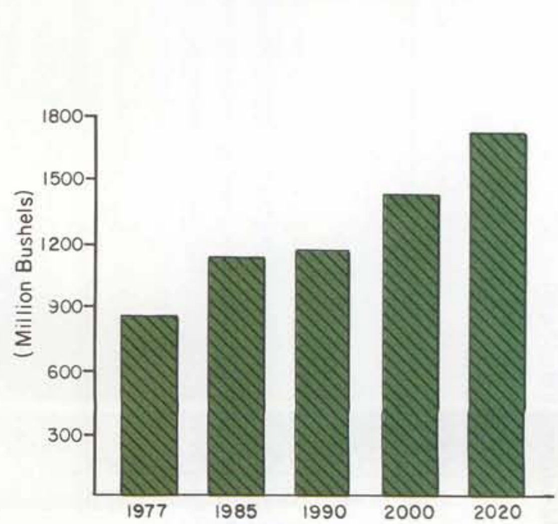


FIGURE V-7: BASELINE GRAIN SORGHUM PRODUCTION, BY STATE (Millions of Bushels)

Note: A significant difference in vertical (ordinate) scales is necessary for those states with more extensive irrigation (Nebraska, Kansas and Texas) than for Colorado, Oklahoma and New Mexico.

SIX-STATE HIGH PLAINS OGALLALA AQUIFER REGIONAL RESOURCES STUDY

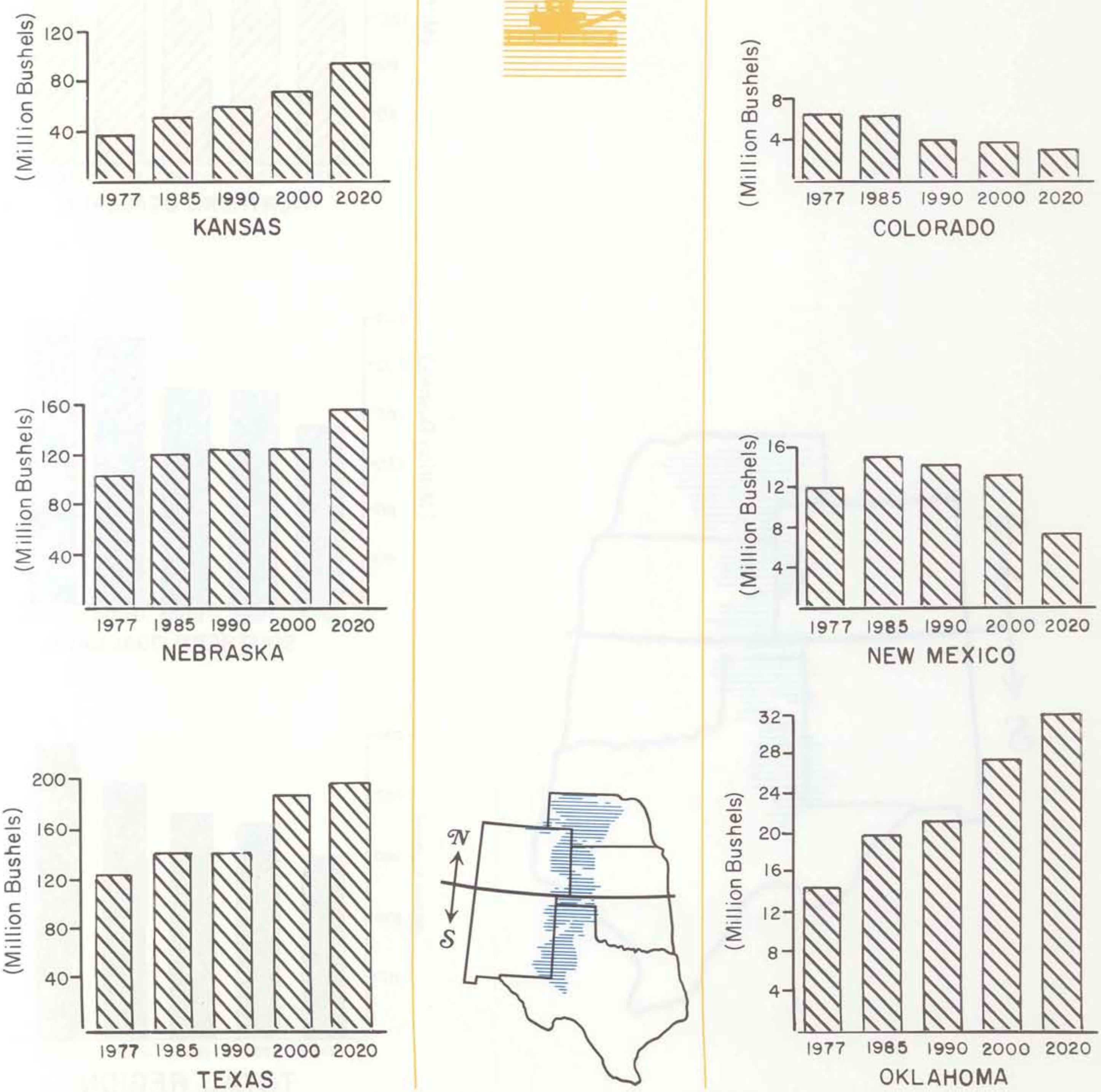
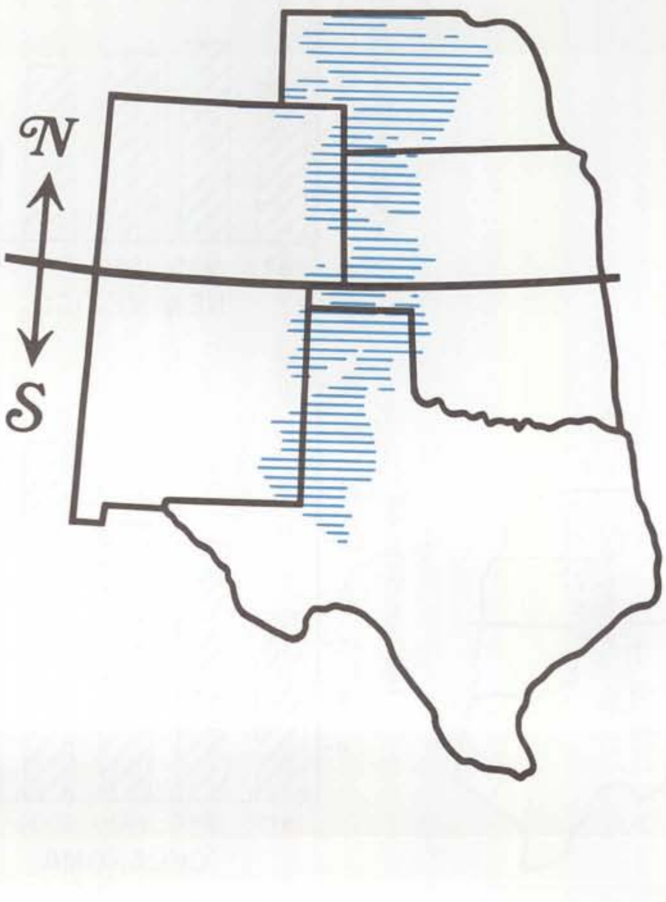
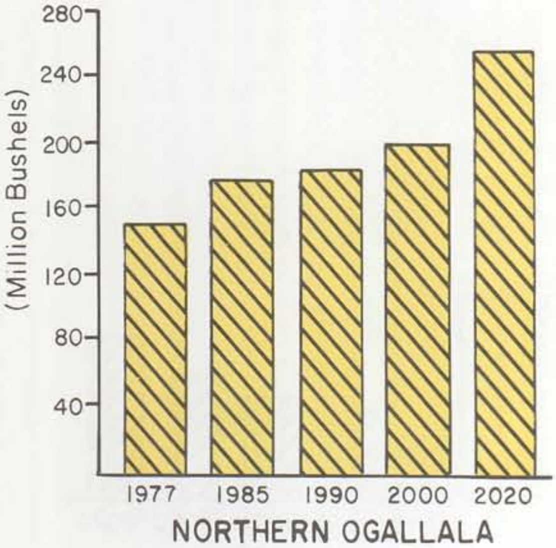
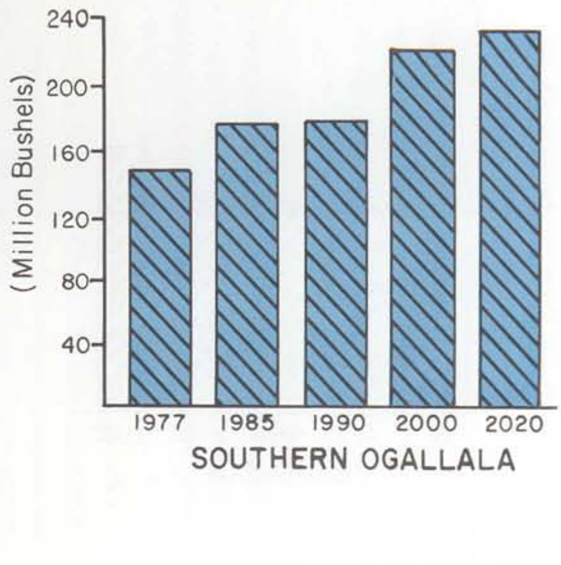


FIGURE V-7.1: BASELINE GRAIN SORGHUM PRODUCTION, BY SUBREGION AND REGIONAL TOTALS (Millions of Bushels)







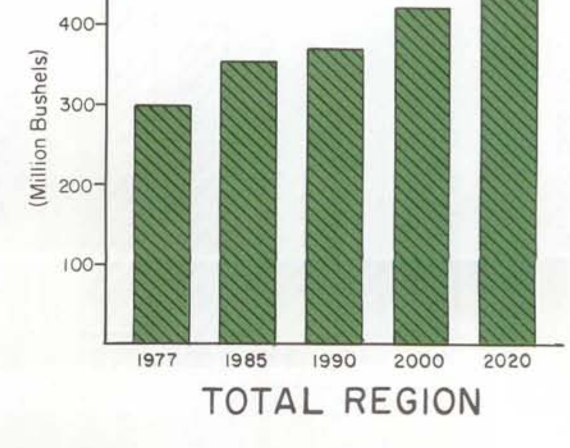
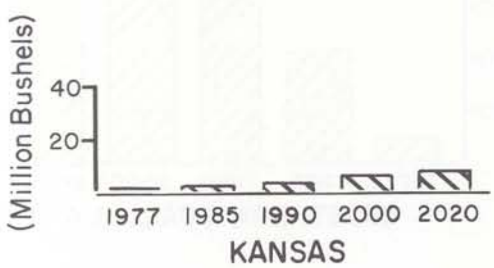
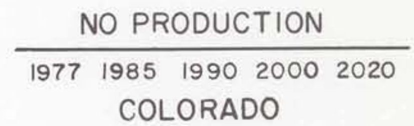


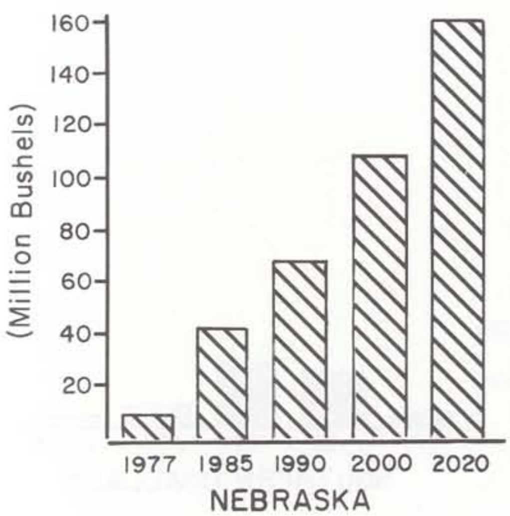
FIGURE V-8: BASELINE SOYBEAN PRODUCTION, BY STATE (Millions of Bushels)

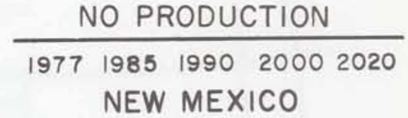
Note: A significant difference in vertical (ordinate) scales is necessary for those states with more extensive irrigation (Nebraska, Kansas and Texas) than for Colorado, Oklahoma and New Mexico.

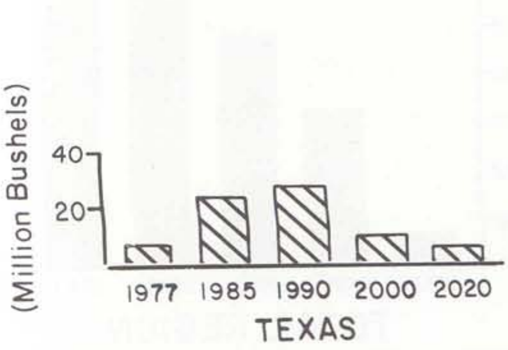
SIX-STATE HIGH PLAINS OGALLALA AQUIFER REGIONAL RESOURCES STUDY

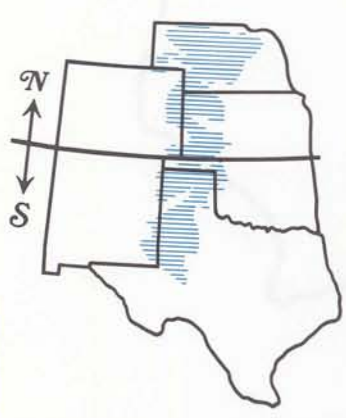












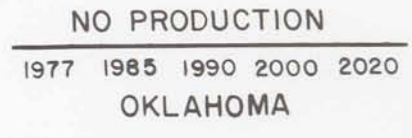
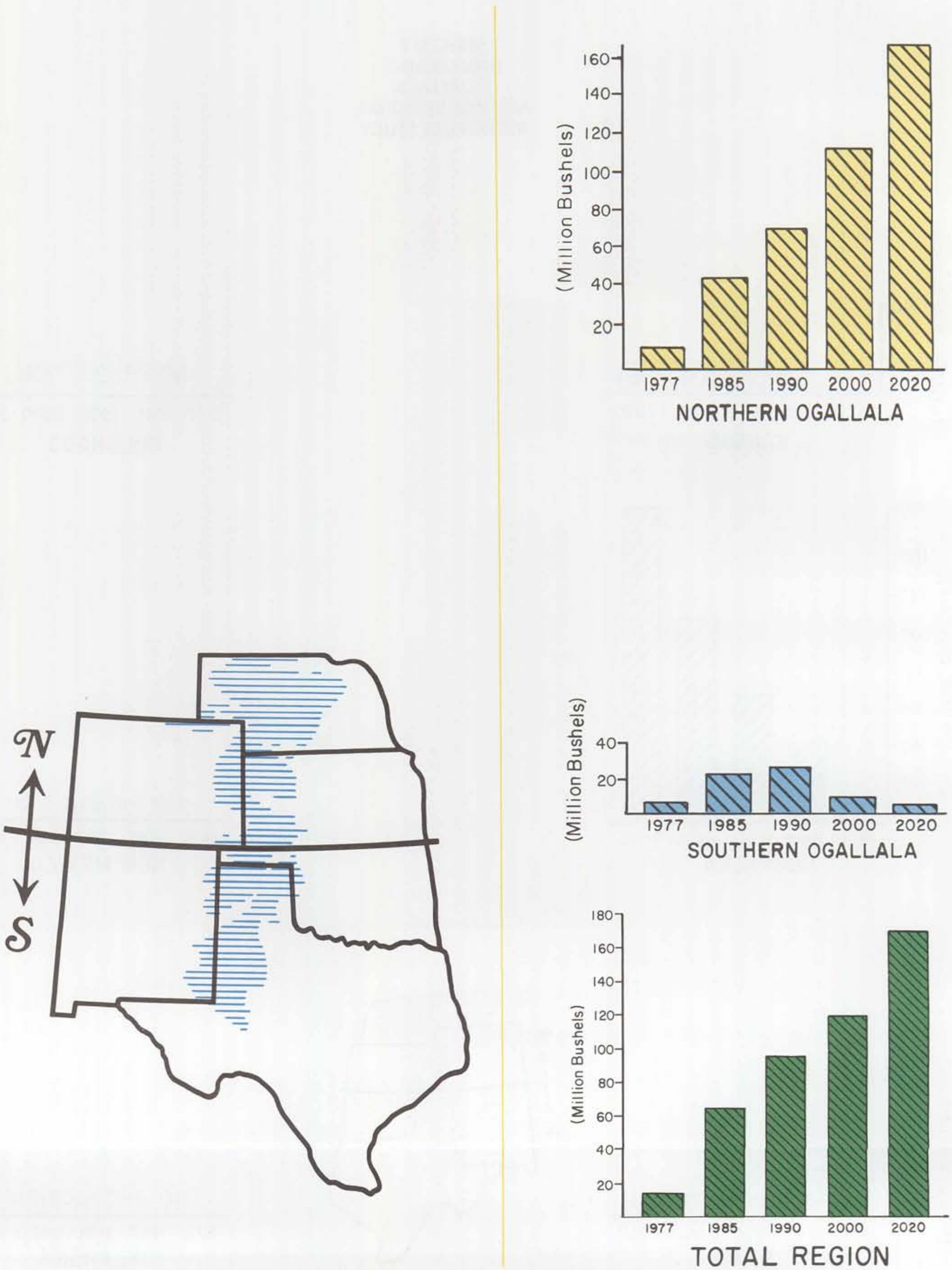


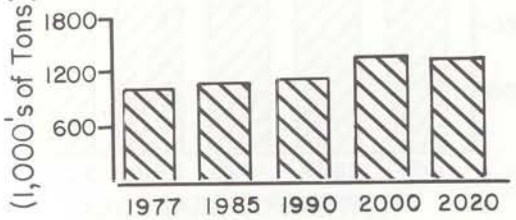
FIGURE V-8.1: BASELINE SOYBEAN PRODUCTION, BY SUBREGION AND REGIONAL TOTALS
(Millions of Bushels)



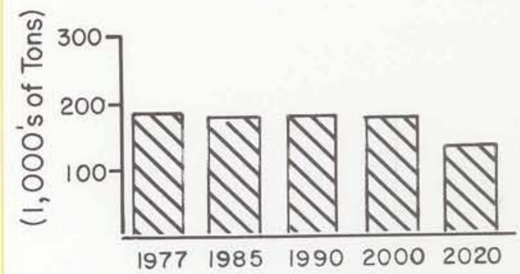
BASELINE ALFALFA PRODUCTION, BY STATE (1,000's of Tons)

Note: A significant difference in vertical (ordinate) scales is necessary for those states with more extensive irrigation (Nebraska, Kansas and Texas) than for Colorado, Oklahoma and New Mexico.

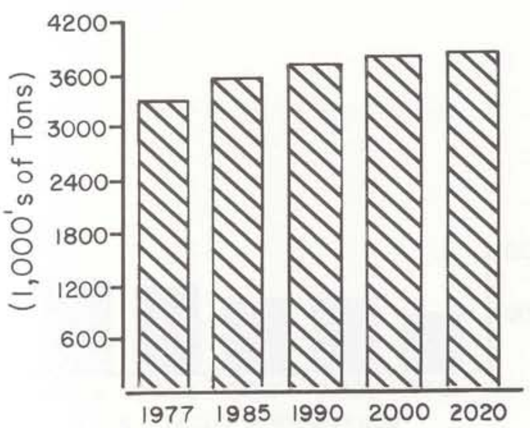
SIX-STATE HIGH PLAINS OGALLALA AQUIFER REGIONAL RESOURCES STUDY



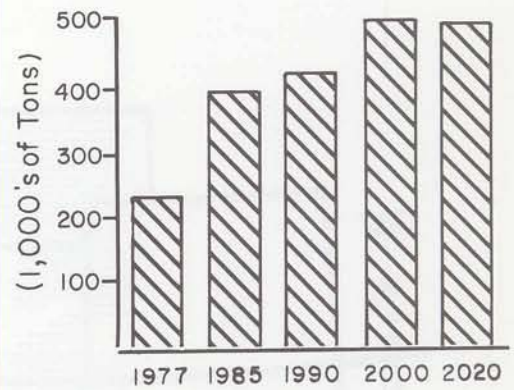
KANSAS



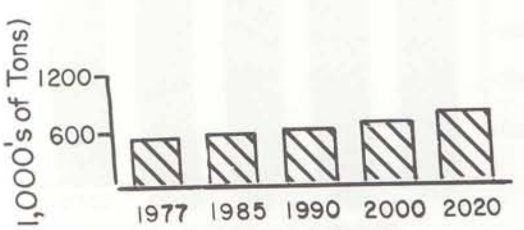
COLORADO



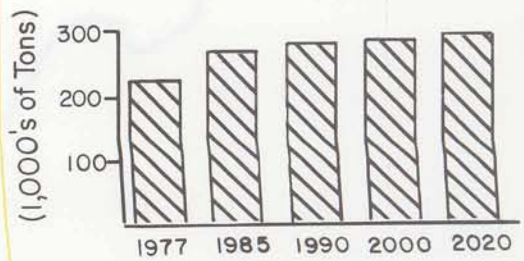
NEBRASKA



NEW MEXICO



TEXAS



OKLAHOMA

FIGURE V-9.1: BASELINE ALFALFA PRODUCTION, BY SUBREGION AND REGIONAL TOTALS
(1,000's of Tons)

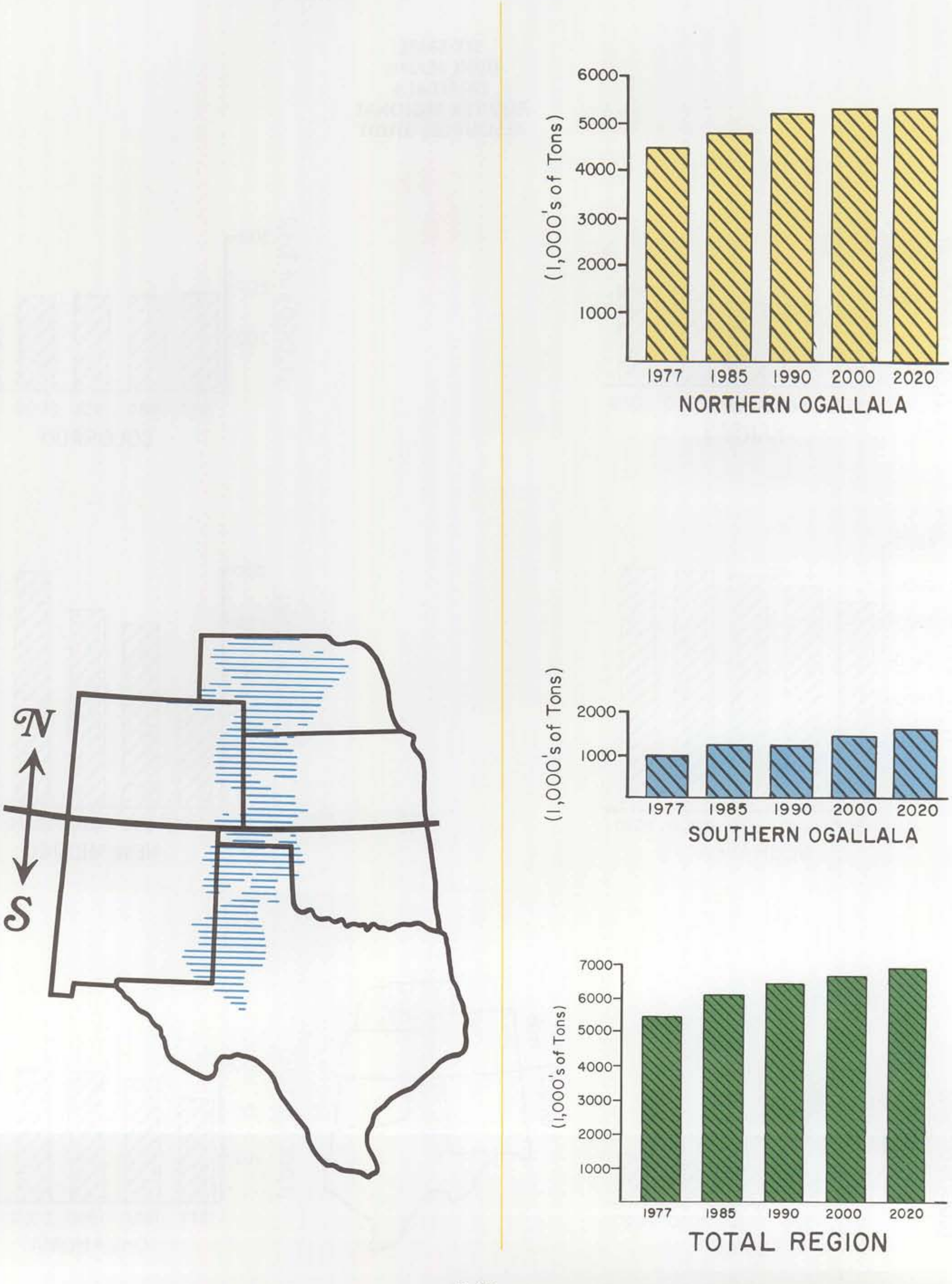
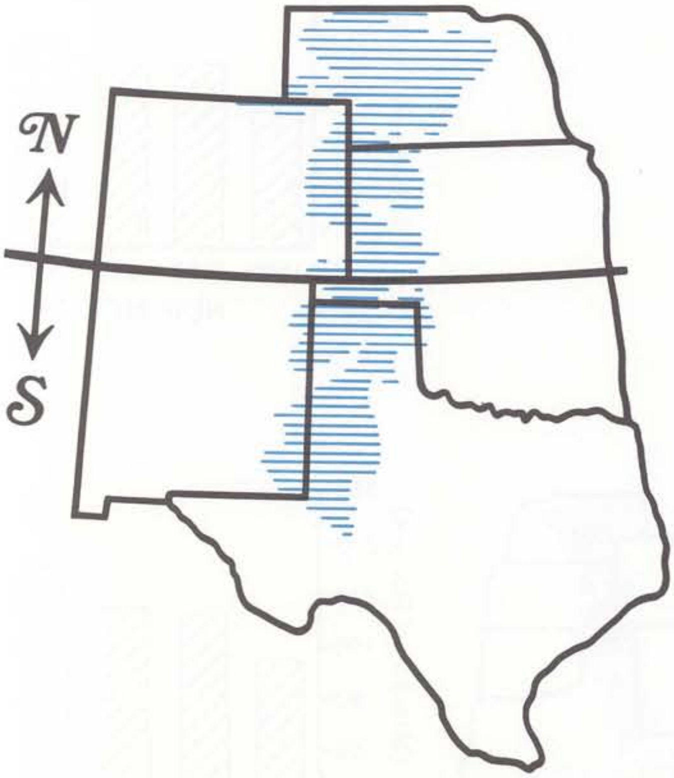
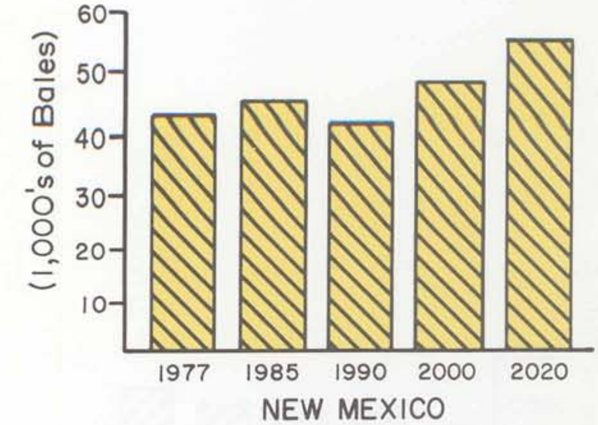
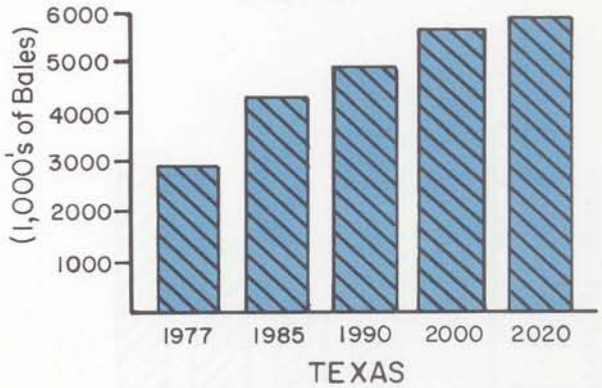


FIGURE V-10: BASELINE COTTON PRODUCTION, BY STATE AND REGION (1,000's of Bales)







COLORADO
KANSAS
NEBRASKA
OKLAHOMA
NO COTTON PRODUCTION

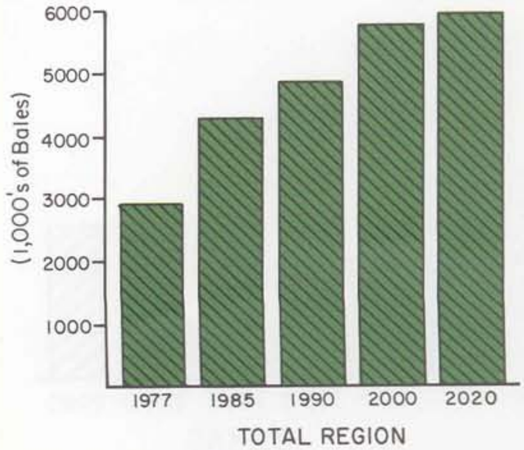
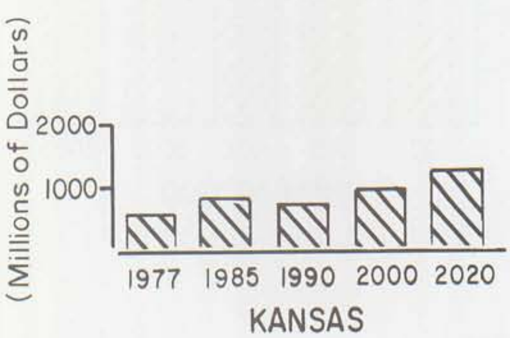
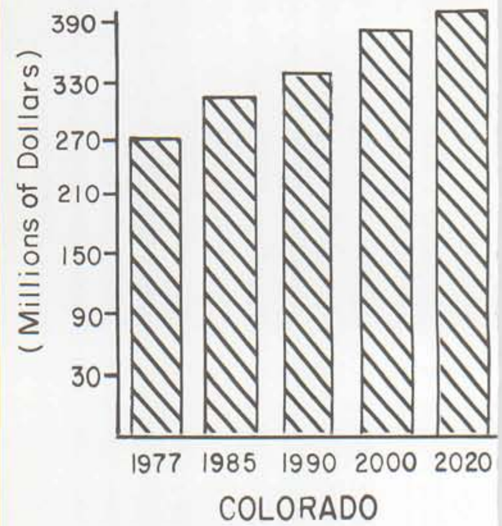


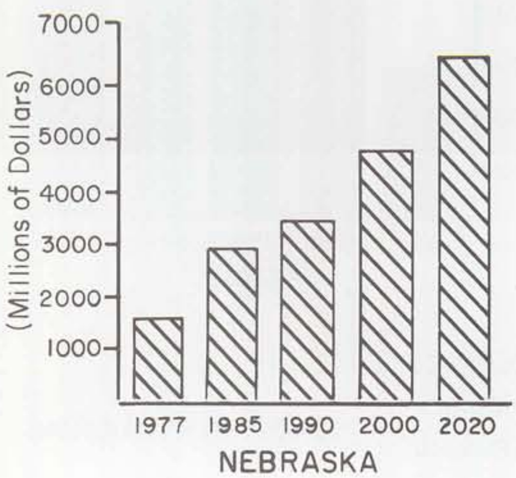
FIGURE V-11: BASELINE VALUES OF AGRICULTURE PRODUCTION, BY STATE
(Millions of 1977 Dollars)

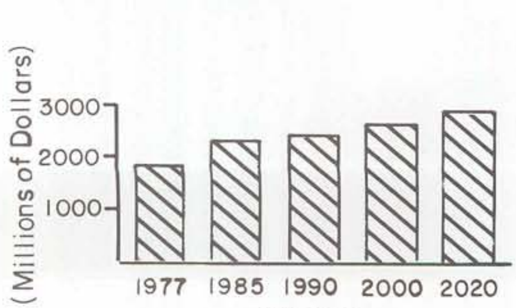
Note: A significant difference in vertical (ordinate) scales is necessary for those states with more extensive irrigation (Nebraska, Kansas and Texas) than for Colorado, Oklahoma and New Mexico.

SIX-STATE HIGH PLAINS OGALLALA AQUIFER REGIONAL RESOURCES STUDY









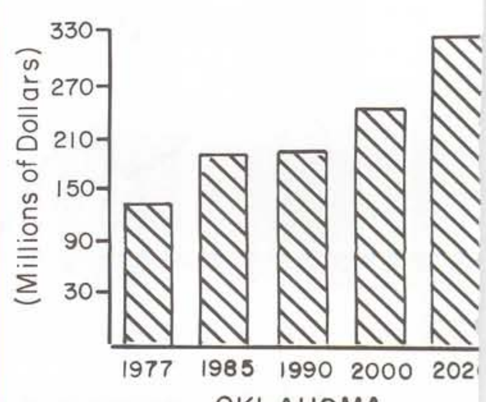


FIGURE V-11.1: BASELINE VALUE OF AGRICULTURAL PRODUCTION, BY SUBREGION AND REGIONAL TOTALS (Millions of 1977 Dollars)

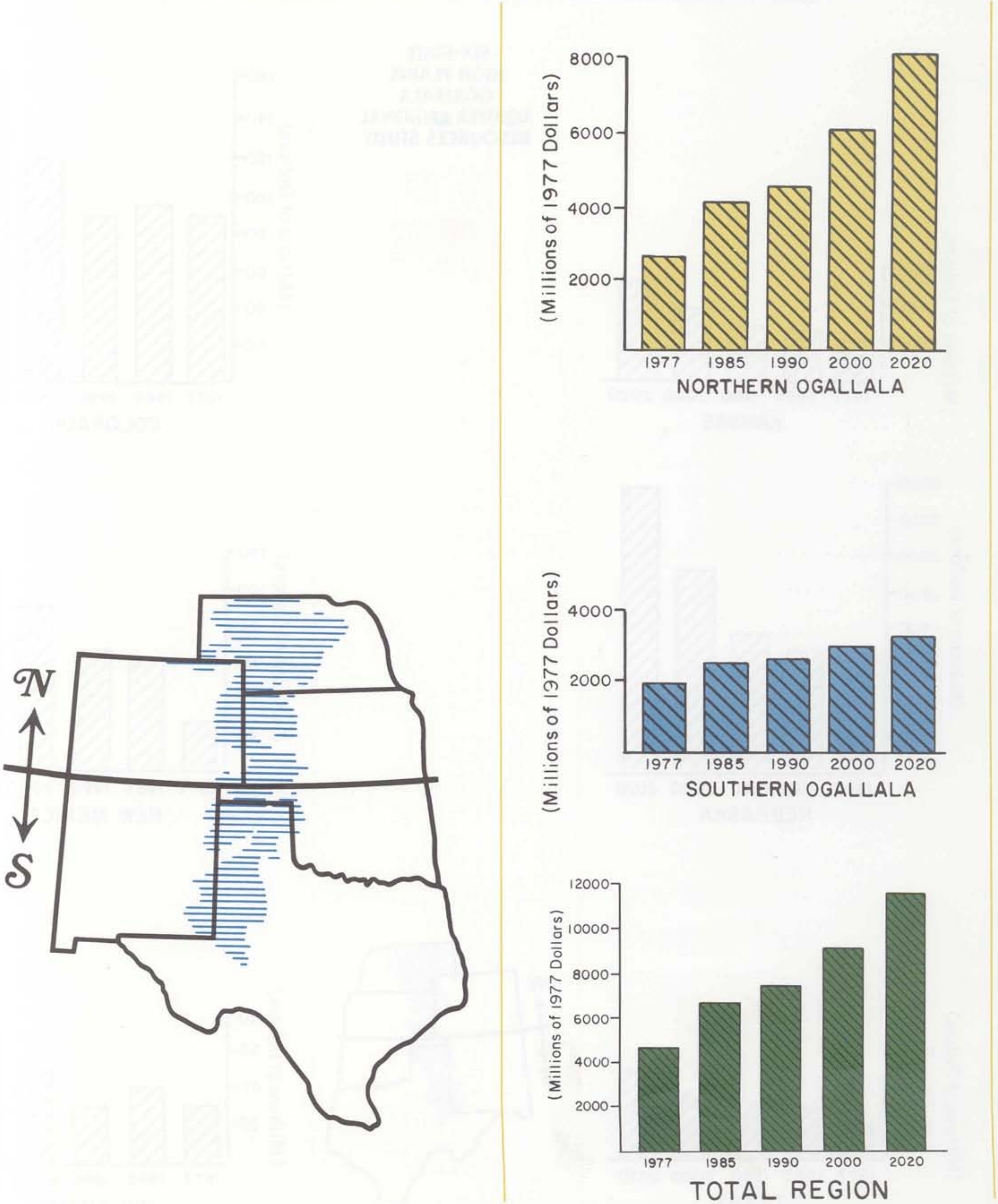
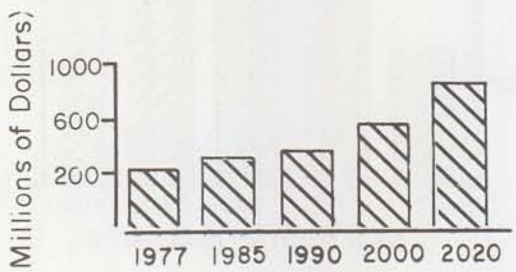


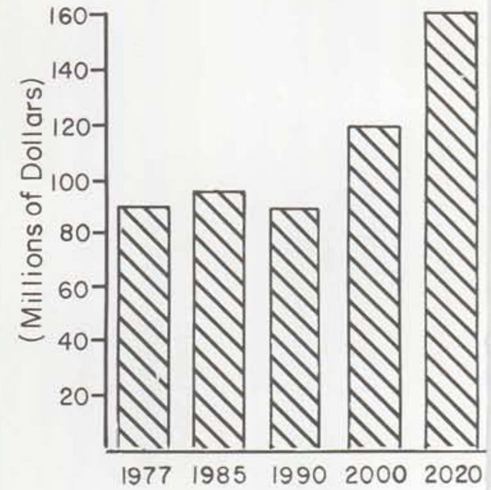
FIGURE V-12: BASELINE RETURNS TO LAND AND MANAGEMENT FOR AGRICULTURAL PRODUCTION, BY STATE (Millions of 1977 Dollars)

Note: A significant difference in vertical (ordinate) scales is necessary for those states with more extensive irrigation (Nebraska, Kansas and Texas) than for Colorado, Oklahoma and New Mexico.

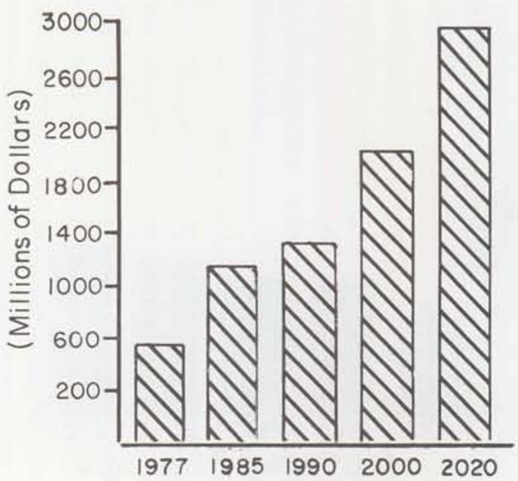
SIX-STATE HIGH PLAINS OGALLALA AQUIFER REGIONAL RESOURCES STUDY



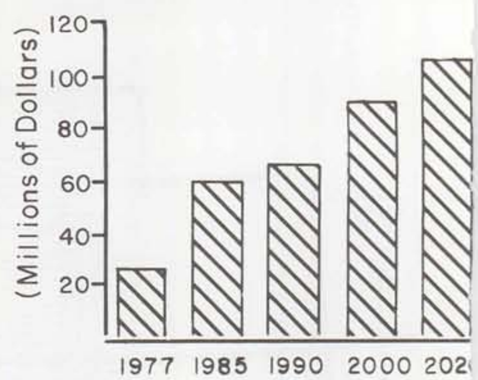
KANSAS



COLORADO

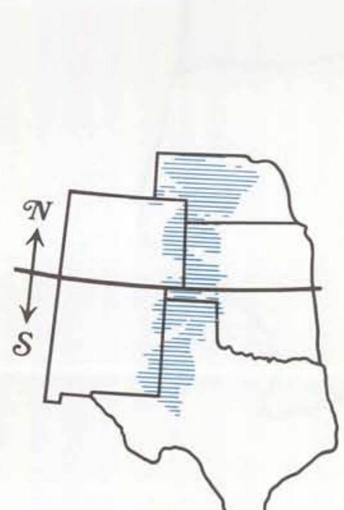


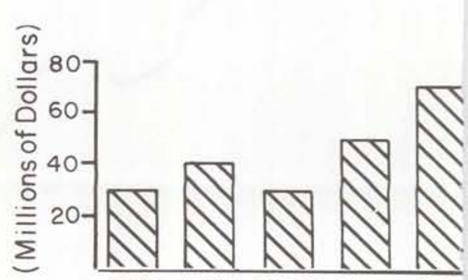
NEBRASKA



NEW MEXICO

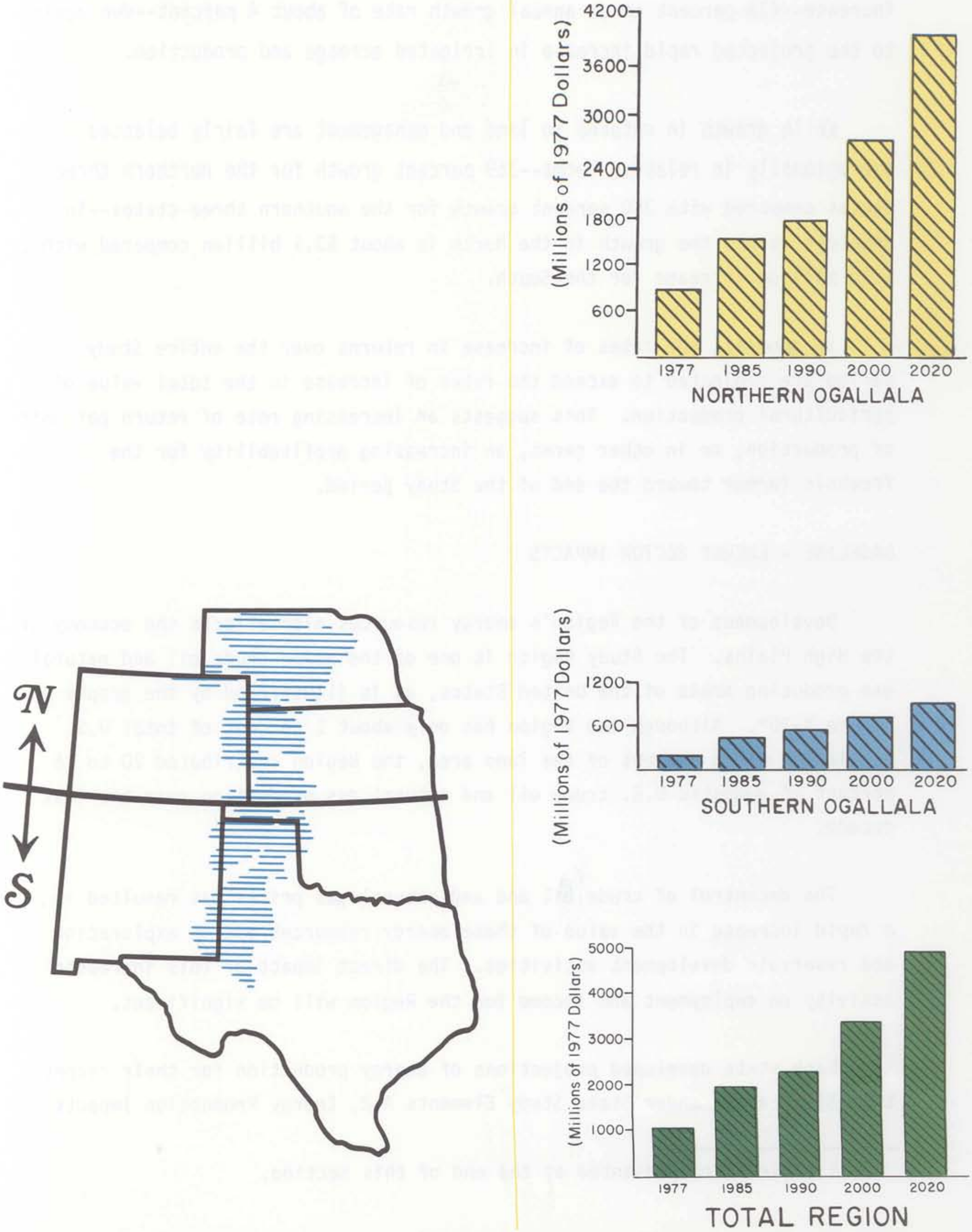
TEXAS





OKLAHOMA

FIGURE V-12.1: BASELINE RETURNS TO LAND AND MANAGEMENT FOR AGRICULTURAL PRODUCTION, BY SUBREGION AND REGIONAL TOTALS (Millions of 1977 Dollars)



Growth in returns to land and management is projected to be steady over the entire Study period to 2020 with the exception of temporary reversals in the 1990 period for Colorado and Oklahoma. Nebraska indicates the greatest increase--436 percent or an annual growth rate of about 4 percent--due again to the projected rapid increase in irrigated acreage and production.

While growth in returns to land and management are fairly balanced subregionally in relative terms--369 percent growth for the northern three states compared with 360 percent growth for the southern three states--in absolute values the growth in the North is about $3.1 billion compared with a $720 million increase for the South.

In general, the rates of increase in returns over the entire Study period are projected to exceed the rates of increase in the total value of agricultural production. This suggests an increasing rate of return per unit of production, or in other terms, an increasing profitability for the freehold farmer toward the end of the Study period.

BASELINE - ENERGY SECTOR IMPACTS

Development of the Region's energy resources also affects the economy of the High Plains. The Study Region is one of the major crude oil and natural gas producing areas of the United States, as is illustrated by the graphs in Figure V-20*. 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 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.

Each state developed projections of energy production for their respective Study areas under State Study Elements A-2, Energy Production Impacts

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* All figures are presented at the end of this section.

Research. Most of the states also prepared projections of associated water use and economic activity for the years 1985, 1990, 2000, and 2020. Low, expected, and high projections series were developed to provide some measure of the range of uncertainty.

Drawing on the work reported by the State A-2 researchers, the General Contractor* developed regional Baseline projections using a consistent set of data and assumptions and, where necessary, engineering analyses. Basic assumptions were linked, wherever possible, with Baseline projections used in the other study elements in order to ensure consistency with other inputs for the regional analysis. Thus, the regional projections are not merely the sum of the state projections. The following paragraphs summarize the resultant regional Baseline energy production projections and the projections of associated water consumption and economic activity which are displayed in the accompanying figures**. Details of these projections as well as the individual state projections are reported in the Regional Study Element B-8 Report.

Projections are presented for each of the Study years of the following resources and economic indicators.

- ° Crude oil and marketed natural gas production
- ° Electric generating capacity and electric energy production
- ° Water consumption associated with energy production and processing
- ° Employment associated with energy production, processing, and transportation
- ° Income associated with energy production, processing, and transportation

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* Black & Veatch

** Associated data tables are presented as Tables V-11 through V-14 in Appendix B.

Crude Oil and Marketed Natural Gas Production

(Figures V-21 and 22, this section)
(Table V-11, Appendix B)

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 techiques in the Permian Basin area of west Texas and eastern New Mexico. The projections of enhanced oil recovery are sensitive to economic and reservoir geology assumptions and, therefore, should be viewed as upper bound projections. 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

(Figure V-23, this section)
(Table V-11, Appendix B)

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. The projections are more than adequate to meet future electric irrigation loads and economic growth as projected by the regional model; should the assumed physical constraints on the expansion of electric pumping not be realized in some of the states these projections may be too low.

Water Consumption Associated with Energy Production and Processing

(Figure V-24, this section)
(Table V-12, Appendix B)

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. The projections represent the probable maximum impact of energy production on the Ogallala Aquifer; it is likely, however, that much of this water could come from other formations or sources such as treated sewage effluent.

Employment Associated with Energy Production, Processing and Transportation

(Figure V-18, this section)
(Table V-13, Appendix B)

Employment directly associated with energy production in the Region is projected to increase through 2000. Beyond 2000, employment is expected to decline in relation to declining crude oil production. Included in the projection is an allowance for the incremental employment required for maintenance, research, and development of enhanced oil recovery projects. Electric energy production employment is that which is required for operating and maintaining the projected installed electric generation capacity.

Employment indirectly related with energy production is projected to follow the trend of directly associated employment increasing through 2000 and then declining. The relative year to year changes are much smaller, however, reflecting the fact that growth in the share of employment in indirect industries is linked to factors other than regional energy production, such as local demand for refined petroleum products and natural gas. The largest portion of indirectly associated employment is in energy transportation, which includes industries involved in pipeline transmission of crude oil and refined petroleum products and transmission and distribution of natural gas and electricity.

Income Associated with Energy Production, Processing and Transportation

(Figure V-19, this section)
(Table V-14, Appendix B)

Income directly associated with energy production in the Region follows the same general trend as employment. Projections of earnings are consistent with productivity increases specified for the regional economic analysis. Royalty payments to local private leaseholders are estimated assuming that

FIGURE V-20: OGALLALA AQUIFER STUDY/UNITED STATES RELATIONSHIPS—CRUDE OIL AND NATURAL GAS PRODUCTION, POPULATION AND LAND AREA

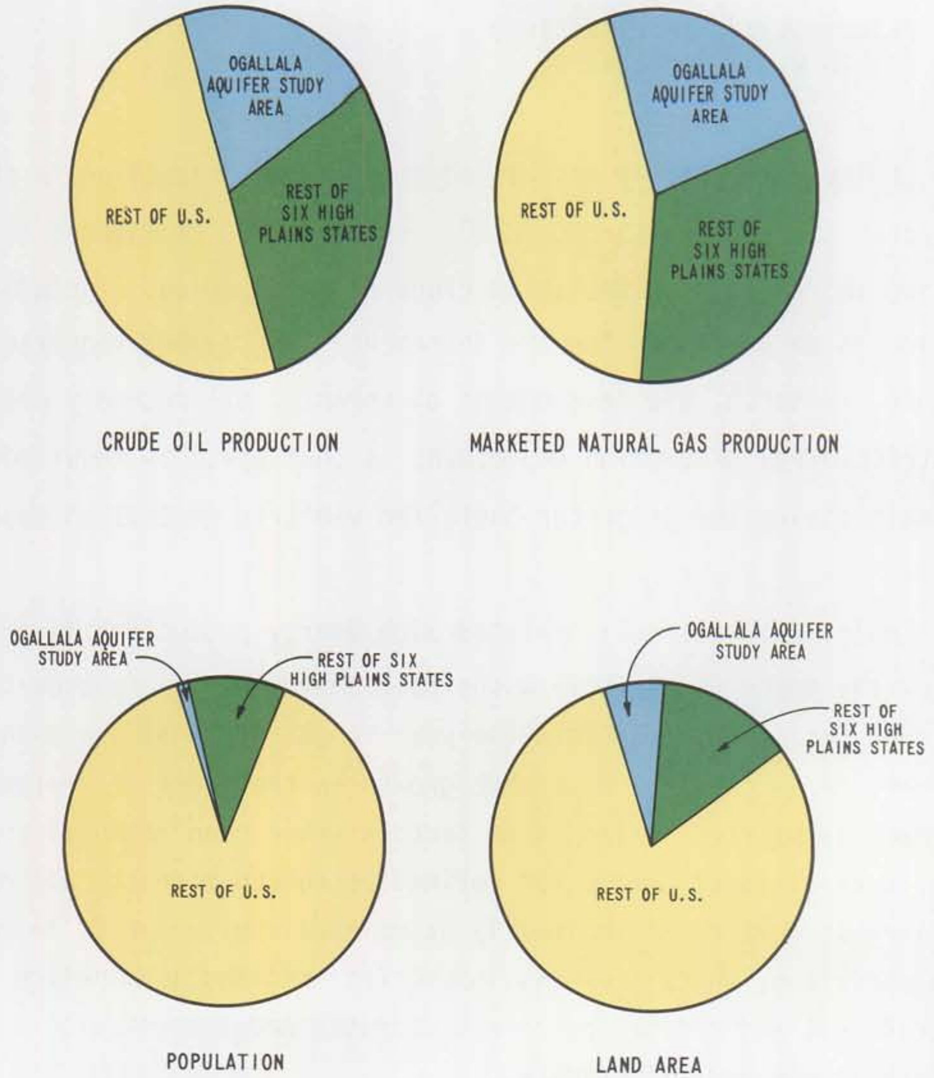
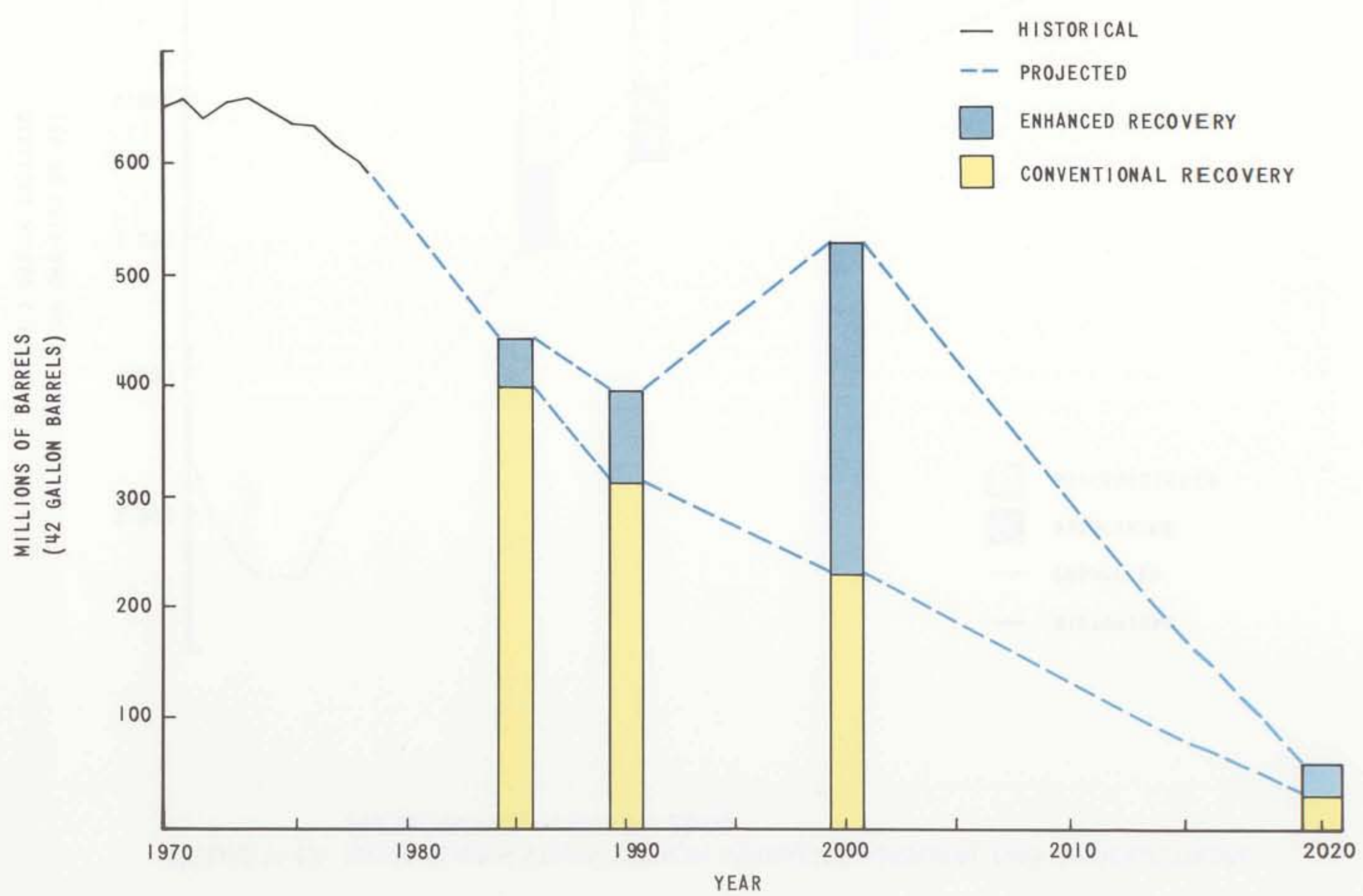


FIGURE V-21: HIGH PLAINS STUDY REGION CRUDE OIL PRODUCTION PROJECTIONS—1985 TO 2020



SIX-STATE
HIGH PLAINS
OGALLALA
AQUIFER REGIONAL
RESOURCES STUDY

FIGURE V-22: HIGH PLAINS STUDY REGION MARKETED NATURAL GAS PRODUCTION PROJECTIONS—1985 TO 2020

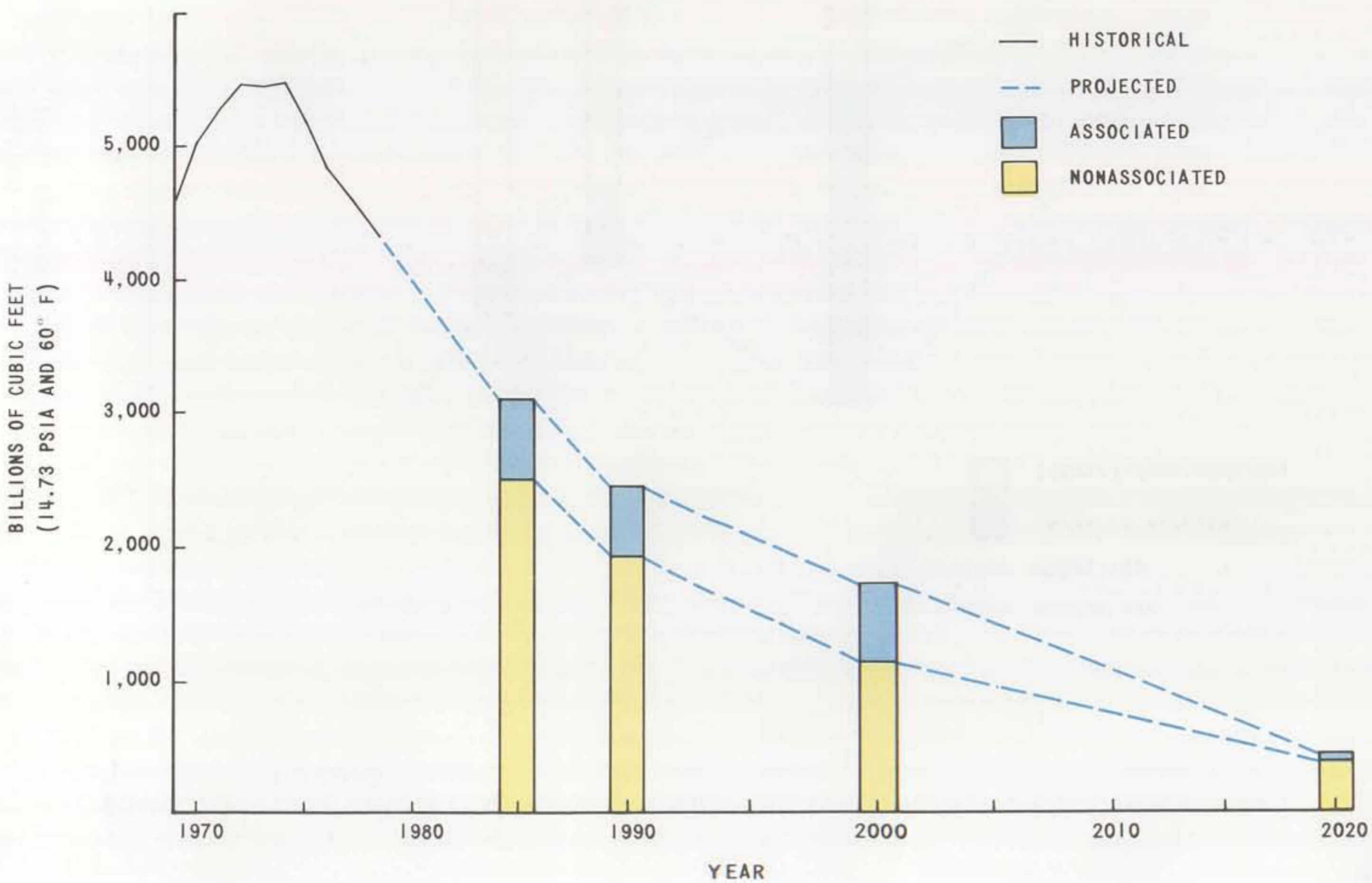


FIGURE V-23: HIGH PLAINS STUDY REGION ELECTRIC GENERATING CAPACITY AND ENERGY PRODUCTION PROJECTIONS—1985 TO 2020

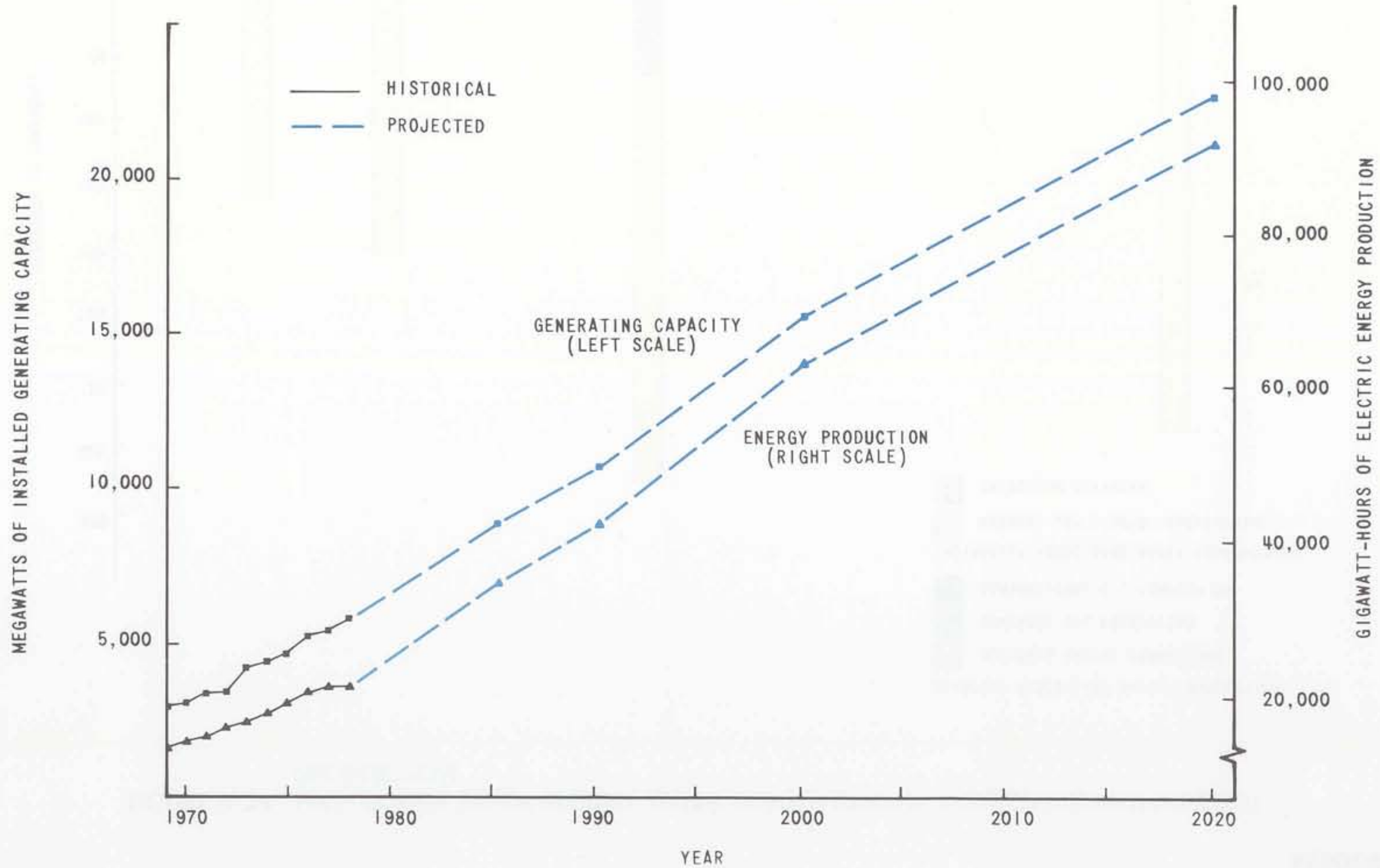


FIGURE V-24: HIGH PLAINS STUDY REGION WATER CONSUMPTIONS ASSOCIATED WITH ENERGY PRODUCTION

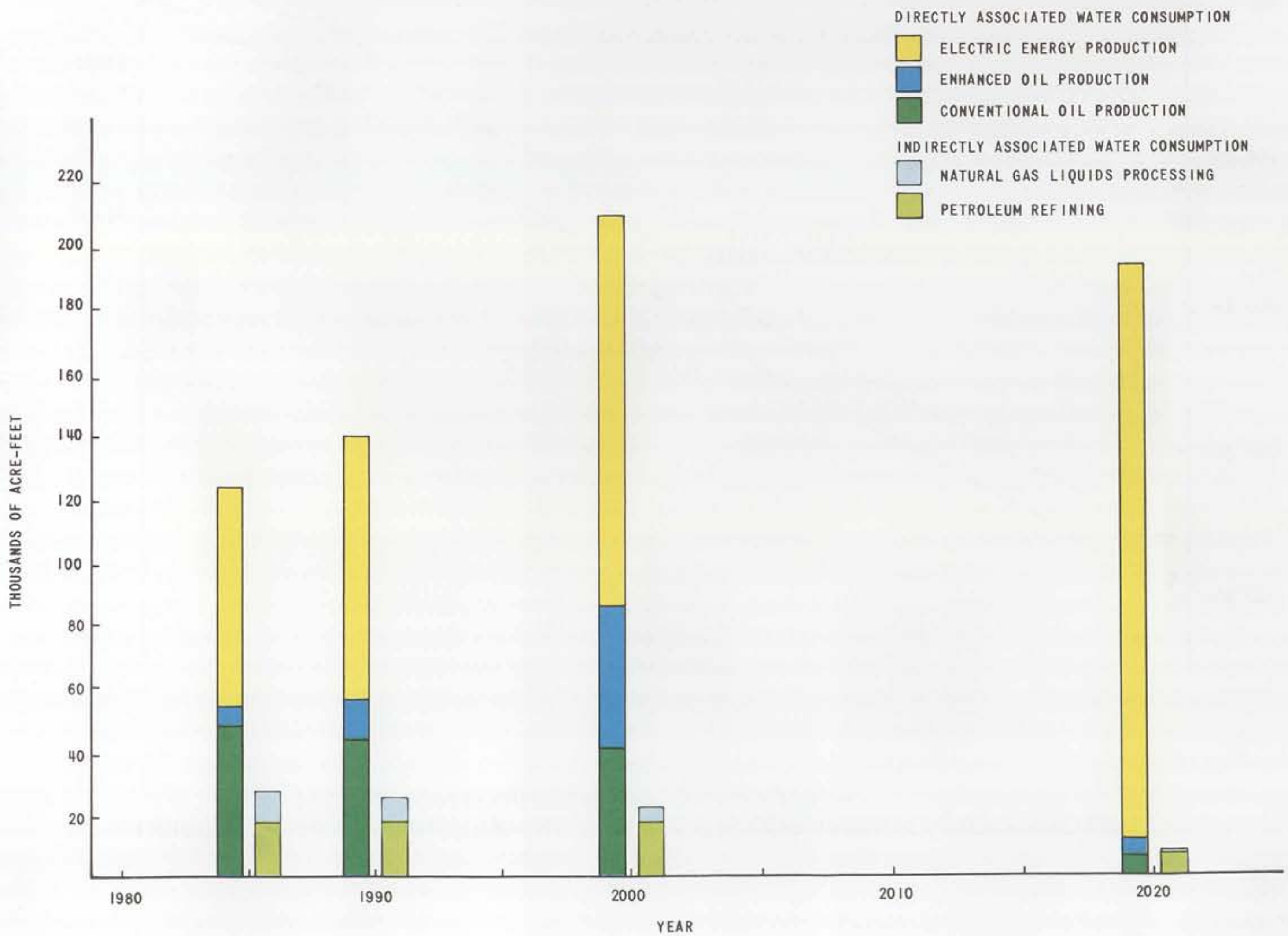


FIGURE V-25: HIGH PLAINS STUDY REGION EMPLOYMENT ASSOCIATED WITH ENERGY PRODUCTION

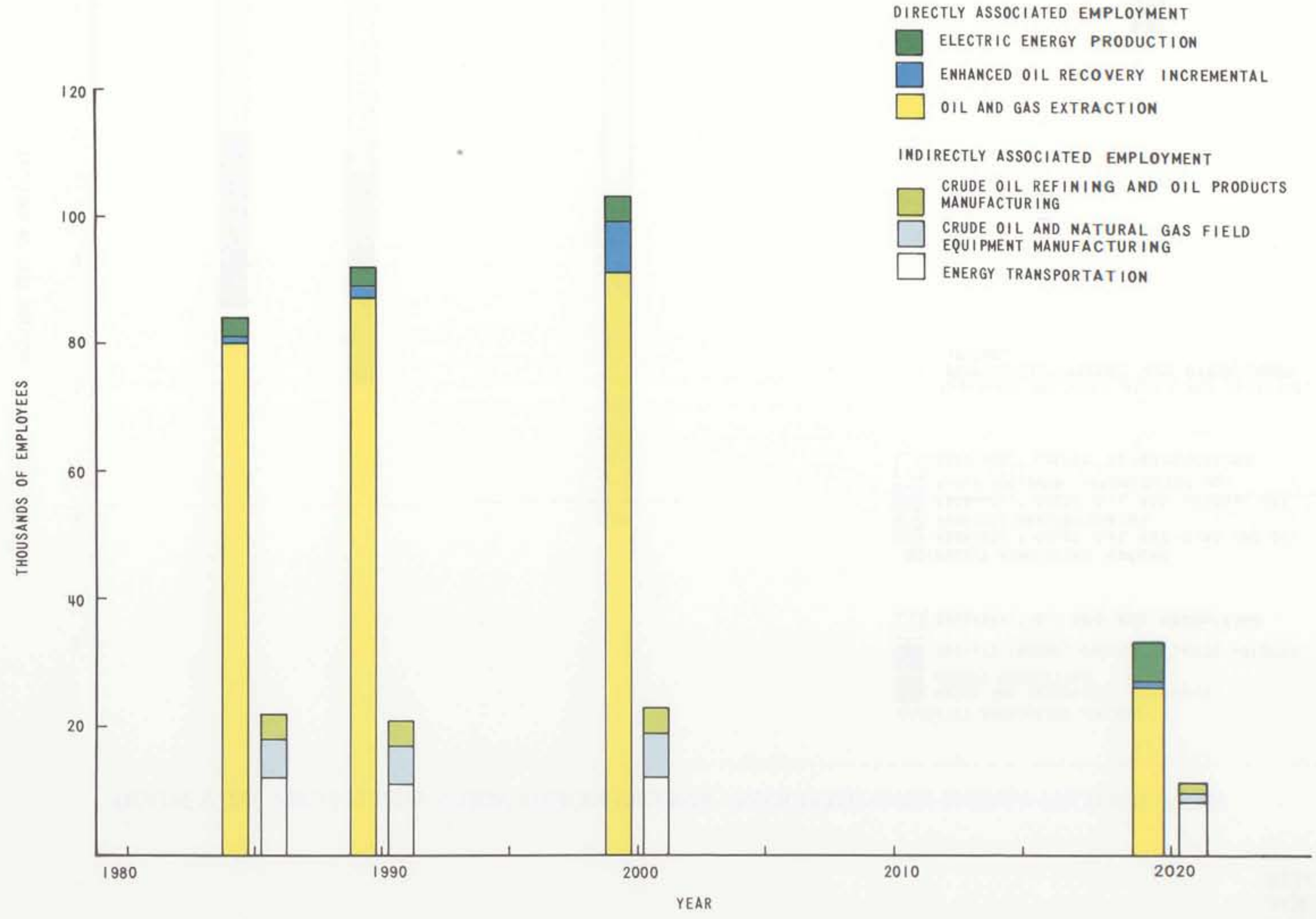
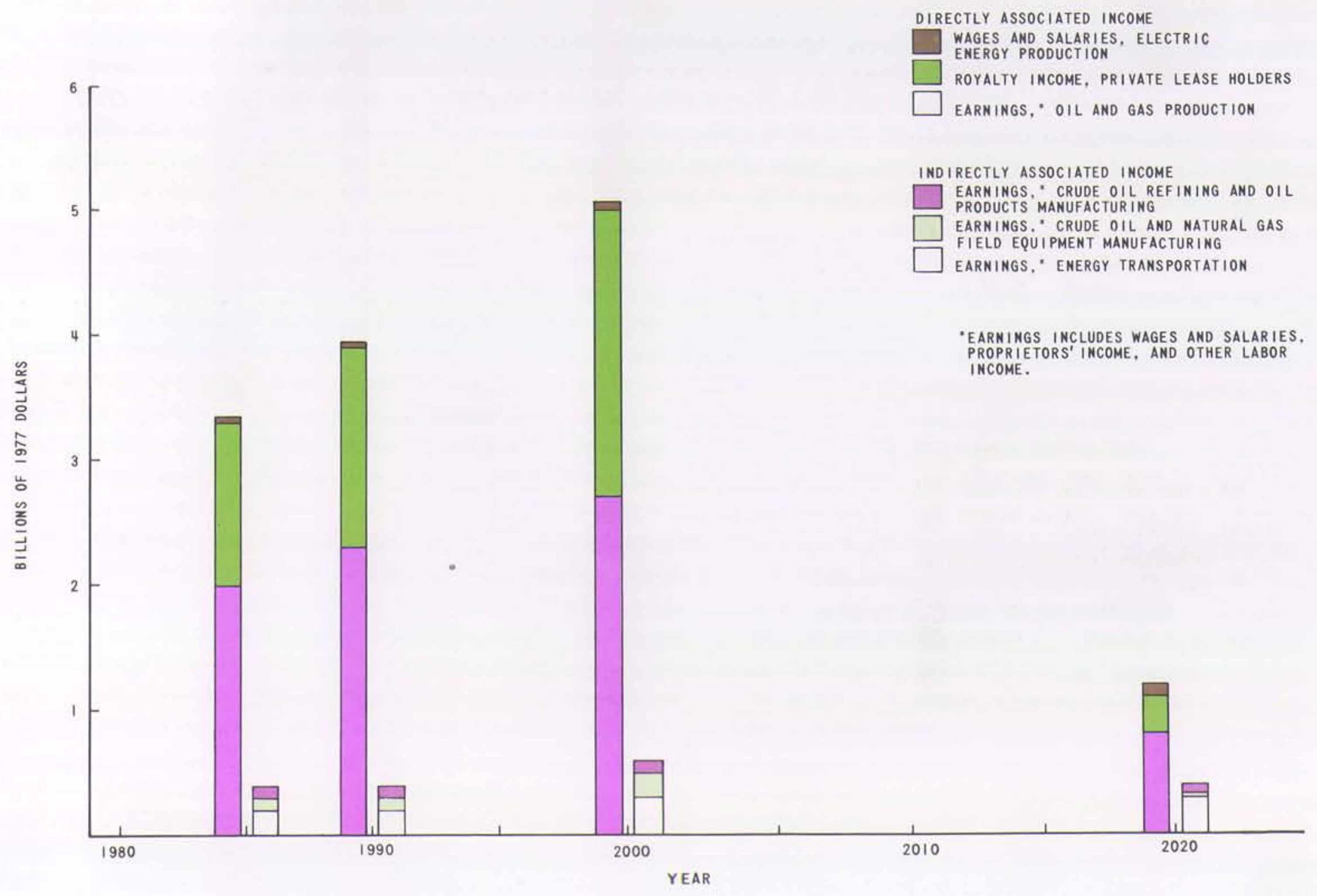


FIGURE V-26: HIGH PLAINS STUDY REGION INCOME ASSOCIATED WITH ENERGY PRODUCTION



the trend of increasing royalty payment shares will continue through 2000; beyond 2000, the royalty payment shares are assumed to decline, reflecting the projected decline in oil and natural gas production in this mature production region.

Income indirectly associated with energy production in the Region follows the same trend as indirect employment. Like the projections of directly associated income, these earnings projections are consistent with projected productivity increases specified for the regional economic analysis.

REGIONAL ECONOMIC IMPACTS

To this point only the more significant projected changes and implications of continuing the existing patterns of the agricultural and energy sectors have been considered. It is equally important to track the consequences of this policy alternative through the entire High Plains regional economy.

Figures presenting regional and subregional economic projections of Baseline indicators to 2020 are at the end of this Section*. These projections were made using the regional I/O model, described in Chapter Four. Input to the regional I/O model was developed from the state I/O models. Indicators presented are:

- Regional Value Added and Value Added by Agricultural Sectors
- Employment and Household Income
- Population
- Per Capita Income
- State and Local Tax Revenues

The economic projections are taken from the regional I/O model, which incorporated growth projections for each sector from the state I/O models.

* Supporting data tables are to be found in Appendix B as Tables V-5 through V-10.

As a result, the energy sectors evaluated in the regional I/O model, and the resulting aggregate economic effect differ somewhat from the energy sector projections developed for the High Plains Study by Black & Veatch. This is because it was not possible for the General Contractor to revise all state I/O models to provide results consistent with the integrated regional energy production projections. As a result, the general economic projections reflect an energy economy which peaks earlier and begins to decline at a date earlier than that shown in the energy projections although both decline to similarly low levels of activity by 2020.

Regional Value Added and Value Added by Agricultural Sectors

(Figures V-13 and 14, this Section)
(Tables V-5 and V-6, Appendix B)

Regional value added is an economic concept similar to gross national product. It indicates the total aggregate value added in the regional economy by all economic activities which use the labor and other resources of the Region. This measure includes savings and payments to households and governments by enterprises within the Region. As an indicator of the economic growth or vigor of the economy, regional value added is projected to increase steadily throughout the High Plains Region for the Study period under Baseline assumptions. Total regional value added is projected to increase from about $21.5 billion in 1977 to about $49.2 billion by 2020, a 129 percent increase.

Agricultural related economic activities in the High Plains regional economy account for only 20 to 26 percent of total regional value added. The projected growth in those sectors, however, tends to drive the growth in the full economy over the long-term. This is due to agriculture's role as a growing primary (natural resource based) industry. The net increase in the value added by agricultural related sectors for the Region of 202 percent by 2020 influences the 129 percent increase in total regional value added for the same period. Value added in the primary production sectors--agriculture and energy--is a relatively large proportion of the total value added in the

Region. The "multiplier" effect of these industries within the Region is lower than might be expected because so many of the inputs required in production are manufactured outside the Region, and much of the downstream processing occurs outside the Region as well.

Strikingly different patterns of regional economic growth characterize the northern (Colorado, Kansas and Nebraska) and southern (Oklahoma, New Mexico and Texas) subregions of the Study area. The northern subregion starts from a smaller base of regional economic activity (about $7 billion subregional value added in 1977, or only 33 percent of total regional value added for that period) but grows more rapidly than the southern Ogallala economy, realizing a projected 179 percent increase by 2020. Agricultural related sectors account for a much greater percent of total subregional economic activity in the North (36 to 45 percent) than in the South (9 to 13 percent). By 2020, the northern subregion has increased its share of the total regional economy from 33 percent to 40 percent.

The southern subregion has an initial (1977) 67 percent share of the total regional economy, with a total value added of $14.4 billion. Agriculturally related sectors contribute only $1.7 billion of that total (or 11.6 percent) and the dominant economic sectors in the southern subregional economy until about the year 2000 are energy related. While the southern economy continues to grow throughout the Study period, it increases less than the northern economy (105 percent growth by 2020, as contrasted with 179 percent growth in the North). By 2020, the southern economy has declined from 67 percent to 60 percent as a portion of the total regional economy.

The southern Ogallala subregion is less dependent on the primary agricultural sectors than is the North. With three metropolitan areas (Amarillo, Lubbock and Midland-Odessa in the Texas High Plains area); about 50 percent larger population; and a significantly larger energy sector than the northern subregion, the South responds less directly to projected changes in the agricultural economy.

Employment and Household Income

(Figures V-15 and 16, this section)
(Table V-7, Appendix B)

Employment and household income projections for the Region and subregions are tied closely to projections of increasing economic activity (as measured by regional value added). Estimates of total employment (all sectors, full time jobs) and household income (all payments to labor or households from all other economic sectors) are derived from the projected levels of regional value added, from past trends and relationships of incomes and employment to levels of economic activity, and from projected future increases in labor productivity. These factors provide a basis for estimating the number of people required to produce the projected volume of economic activity.

Regional employment is projected to increase throughout the Study period from a base of about 1 million jobs in 1977 to 1.3 million by 2020, an increase of 32 percent. The rate of growth in employment is significantly lower than the rate of growth in economic activity (value added) because the primary growth sector (agriculture) has a relatively low labor requirement in relation to other sectors.

Growth in regional employment is strongest during the earlier (pre-2000) periods and stabilizes thereafter. This is related mainly to nonagricultural employment in the southern three states, with manufacturing and energy sector employment leading the way. Employment in the southern Ogallala area increases by 231,000 or 41 percent by the year 2000 but is projected to decline slightly (about 16,000 jobs) in the period after 2000.

The northern three states project an initial growth of about 21 percent for the period 1977 to 1985 but show a decline or very slow growth in employment after 1985. In general, the future employment opportunities for the Region, and more particularly for the northern subregion, are not bright. Any additional growth in employment will have to be triggered by new nonagricultural growth (see Regional Study Element B-10 Report).

Growth in household incomes are considerably more favorable than projected growth in employment. Total household incomes are projected to increase by nearly 200 percent by 2020 under Baseline conditions, with slightly lower growth in the northern subregion (172 percent) than in the South (211 percent).

Projected growth of household income in the northern subregion exceeds that of the South only in the final Study period (2000 to 2020), but in absolute terms (measured in 1977 dollars), the North still trails the South substantially by the end of the Study period - $13.4 billion in the North to $23.6 billion in the South. Overall, income is increasing throughout the 43-year study period in both subregions, but at a declining average annual rate. This indicates a leveling off of income growth for the Region as the economic changes projected previously impact the regional economy.

Population

(Figure V-17, this section)
(Table V-8, Appendix B)

To project population levels that would accompany projected levels of economic activity, it was assumed that populations, in the long run, will migrate to available economic opportunities, with people moving in and out of a region as jobs are created or lost. Thus, the population projections assume an umemployment rate similar to current unemployment in the Region. Projected changes in the labor force participation rate based upon family size, changes in the female work force, and the age structure of the population have been used to determine the number of people who will be supported in the Region at a given level of employment. Therefore, the population projections shown should only be used as a basis for comparing regional growth or contraction under the different resource management strategies.

Regional population projections are closely related to regional employment projections. Total population estimates for the Region in 1977 of about 2.2 million are projected to increase to 2.9 million by 2020. Intraregional distribution of the nearly 750 thousand projected growth in population is skewed in favor of the southern Ogallala states, just as is projected employment.

The southern three states start from an estimated population base of 1.3 million in 1977, about 58 percent of total regional population, and grow to nearly 1.8 million by 2020, a 41 percent increase. By the end of the Study projection period, the southern High Plains states will have increased their share of total regional population to about 61 percent. Population growth projections in the South are expected to differ significantly from the North. After experiencing over 40 percent growth by the year 2000, the South is projected to decline thereafter and lose about 24,000 people between 2000 and 2020.

In contrast, the northern three states of Nebraska, Colorado and Kansas are projected to have almost no population growth in the middle periods (1985 to 2000), showing an actual population decline of about 1.0 percent in the 1985 to 1990 period. The period of limited population change from 1985 to 2000 is related to lack of diversification in the economy and further mechanization decreasing labor requirements in the expanding agricultural sector.

Per Capita Income

(Figure V-18, this section)
(Table V-9, Appendix B)

Projected growth in per capita income for the Region and subregions are derived directly from projections of total household income and population. Per capita income is projected to grow about 120 percent for both subregions and the entire Region. Most of that growth occurs in the pre-2000 period, with a lesser increase from 2000 to 2020. This increase in per capita income is driven by the effect of small but continuous increases in productivity, projected in the INFORUM model at levels somewhat above the stagnant period of the mid to late 1970s. Rising returns to land and management in the farm sector, where strong export demand keeps up farm prices while agricultural productivity continues to rise are also a significant factor in rising incomes.

The southern Ogallala states are projected to have an advantage in per capita income throughout the Study period. The Region has an estimated average per capita income of $5,750 in 1977, increasing to about $12,660 by 2020. The South starts at $5,974 in 1977 and increases to a projected $13,182 by 2020, while the North begins at an estimated $5,436 and increases to $11,840 by 2020.

The disparity between per capita income in the North and South, while increasing slightly from 1977 to 2000, declines by 2020 to about the same proportional relationship that prevailed in 1977.

<u>State and Local Tax Revenues</u>

(Figure V-19, this section)
(Table V-10, Appendix B)

Using the regional input/output model, the future state and local tax revenues in the Region were projected assuming the existing <u>structure</u> of state and local taxes remains unchanged. State and local government revenues will rise more rapidly for the entire Region than population because of growing real incomes and output.

A pattern of constant growth in government revenue is seen in the northern portion of the Ogallala Region. However, a different trend is projected for the South. Taxes paid by the oil and gas industry make up a significant portion of government revenue in the Ogallala portion of the three southern states. After increasing by 73 percent from 1977 to 1990, state and local government revenues are expected to fall by about $430 million (44 percent) <u>in real terms</u> in the South from 1990 to 2020 as the result of the projected decline in the value of oil and gas produced after 1990. This drop is far more precipitous than the projected decline in population and employment and is the opposite of the projected trend in per capita income. Because much of the oil and gas tax revenue goes to the state, and may be spent outside the Region, the effect on government services within the Region may be less than the revenue decrease would indicate. Both patterns of government expenditures and tax structures could be altered to compensate for the projected decline in governmental revenues in the southern subregion.

FIGURE V-13: BASELINE REGIONAL ECONOMY—TOTAL VALUE ADDED; ALL SECTORS, BY SUBREGION AND REGIONAL PROJECTIONS FOR 1977 THROUGH 2020 (Millions of 1977 Dollars)

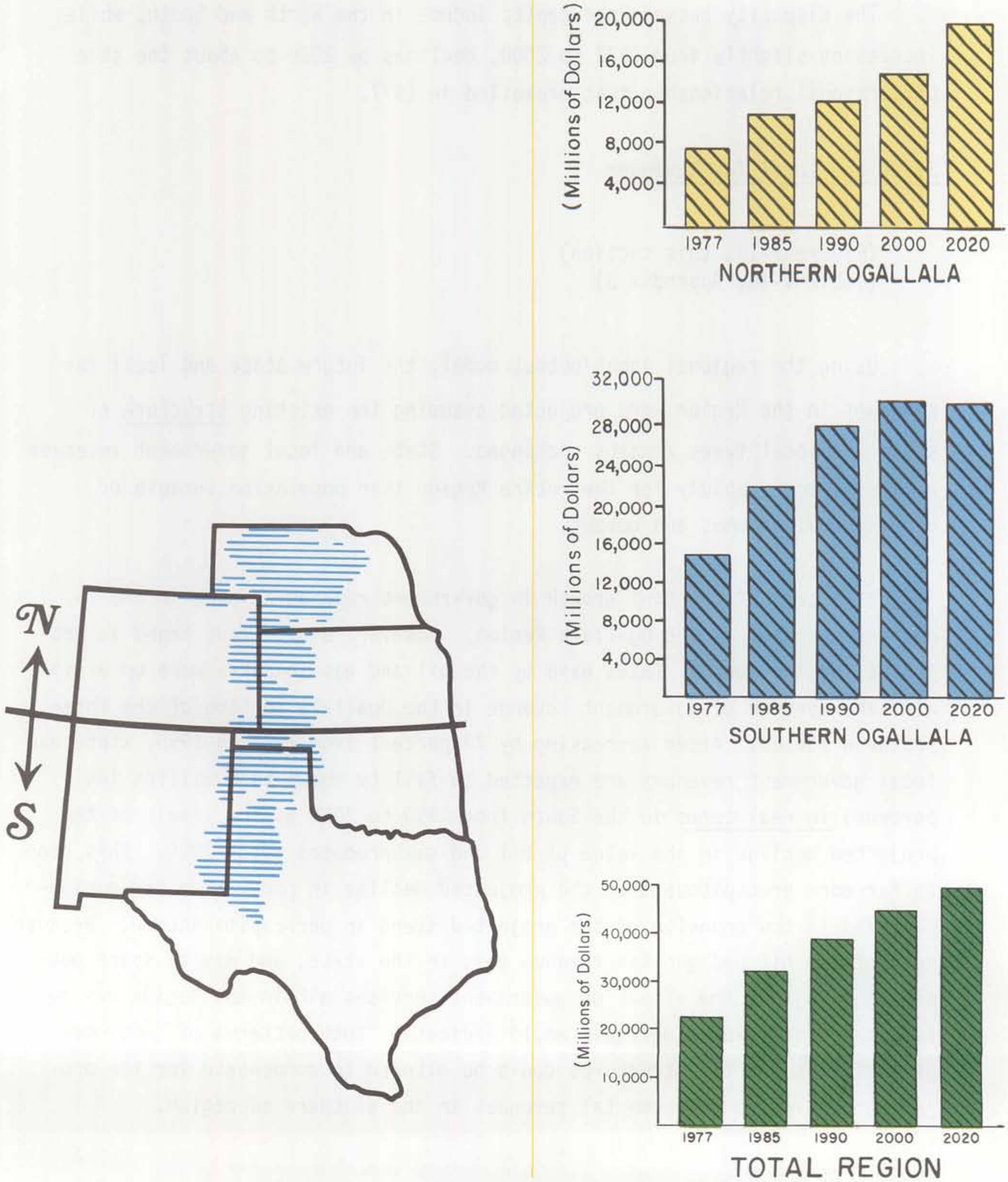


FIGURE V-14: BASELINE REGIONAL ECONOMY—VALUE ADDED BY AGRICULTURAL RELATED SECTORS, BY SUBREGION AND REGIONAL PROJECTIONS FOR 1977 THROUGH 2020
(Millions of 1977 Dollars)

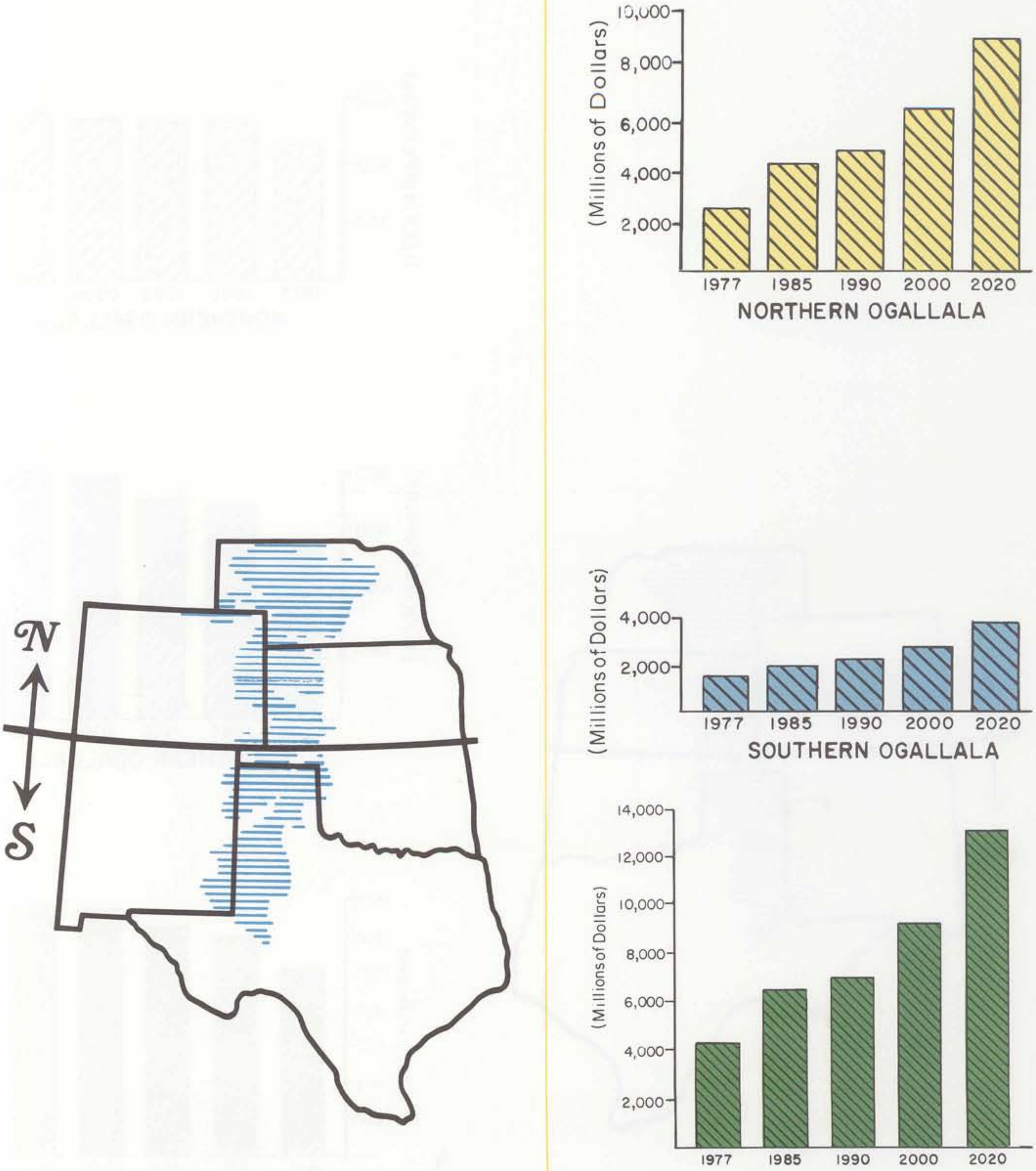
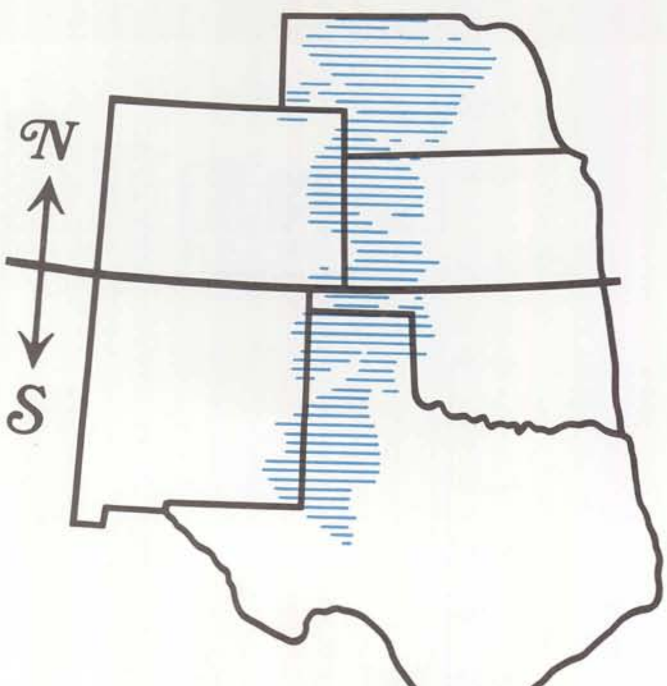
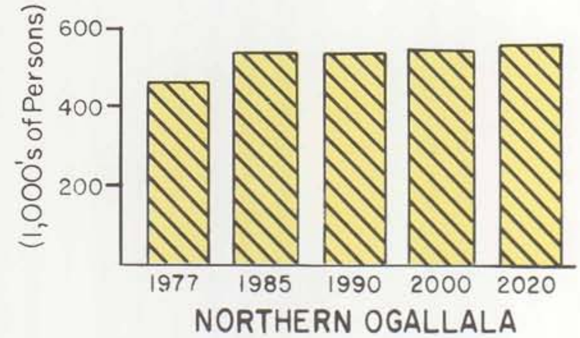
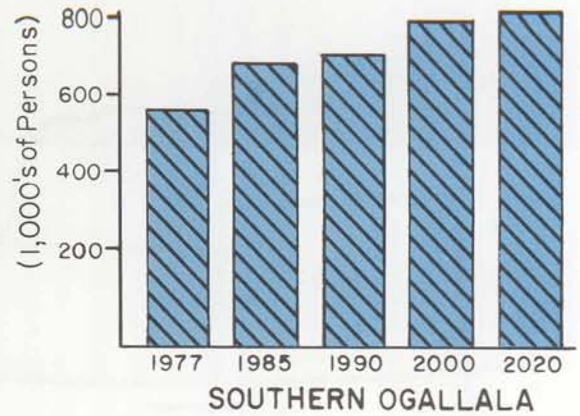


FIGURE V-15: BASELINE REGIONAL ECONOMY—TOTAL EMPLOYMENT; ALL SECTORS, BY SUBREGION AND REGIONAL PROJECTIONS FOR 1977 THROUGH 2020 (1,000's of Jobs)







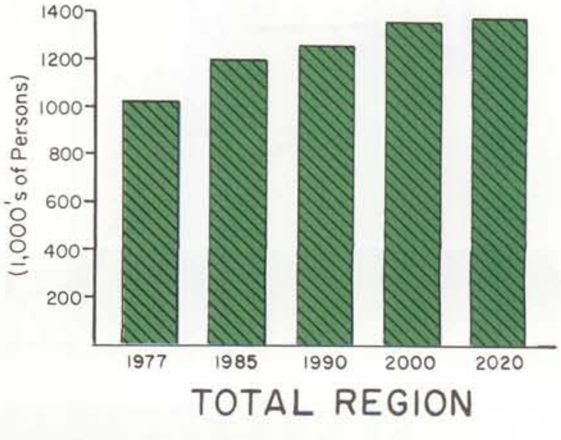


FIGURE V-16: BASELINE REGIONAL ECONOMY—TOTAL HOUSEHOLD INCOME, BY SUBREGION AND REGIONAL PROJECTIONS FOR 1977 THROUGH 2020 (Millions of 1977 Dollars)

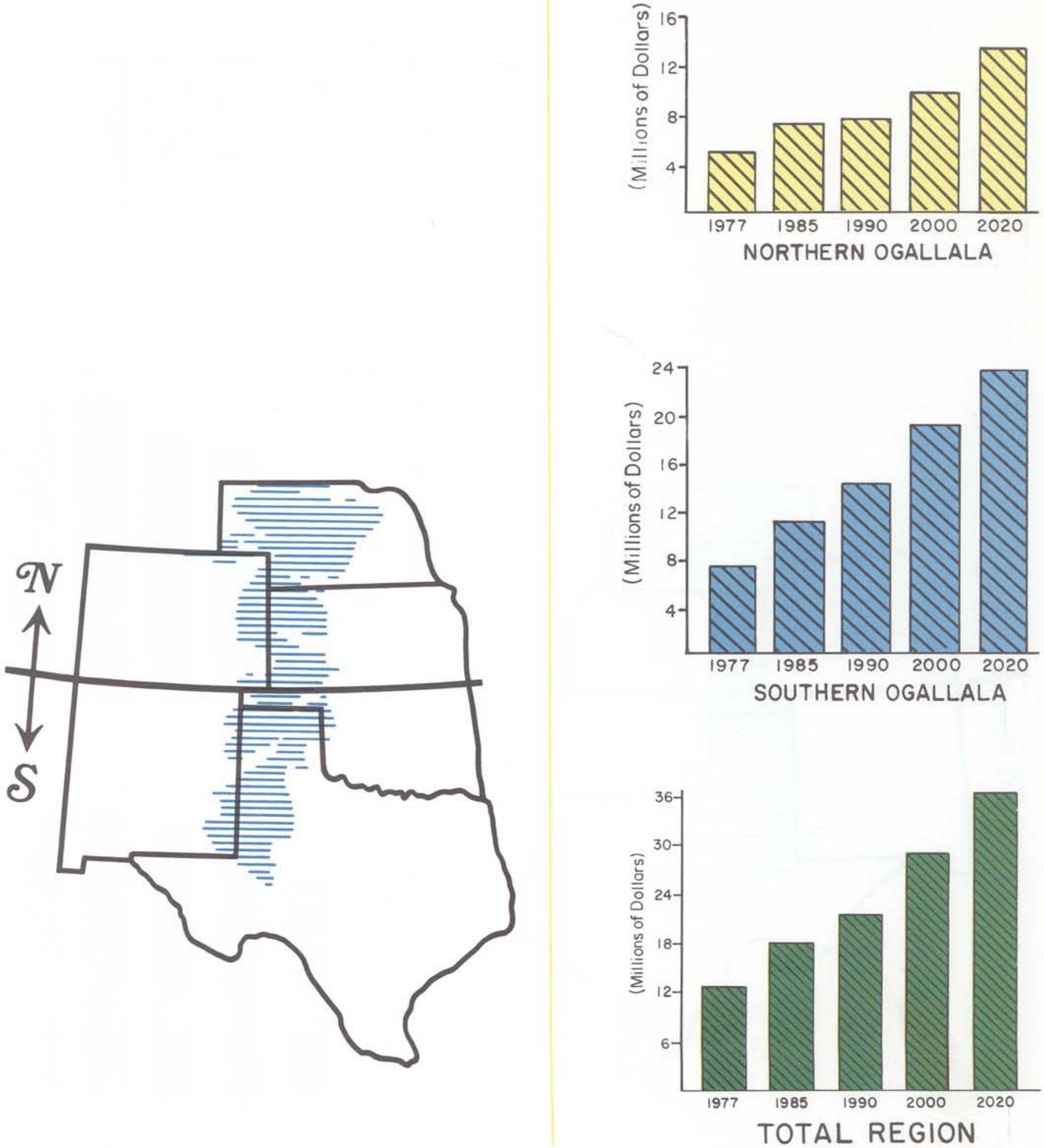
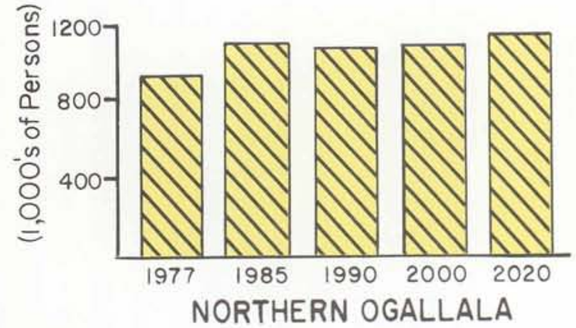
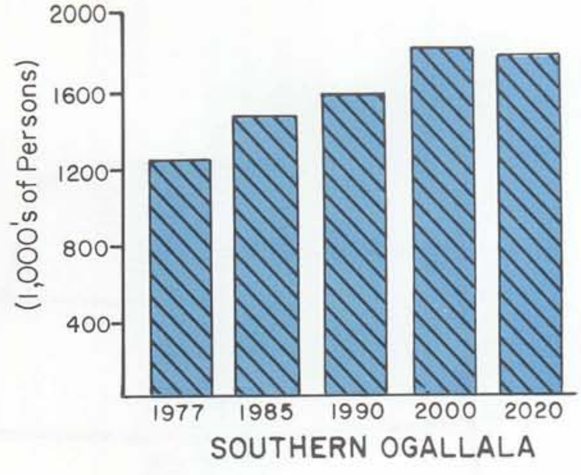
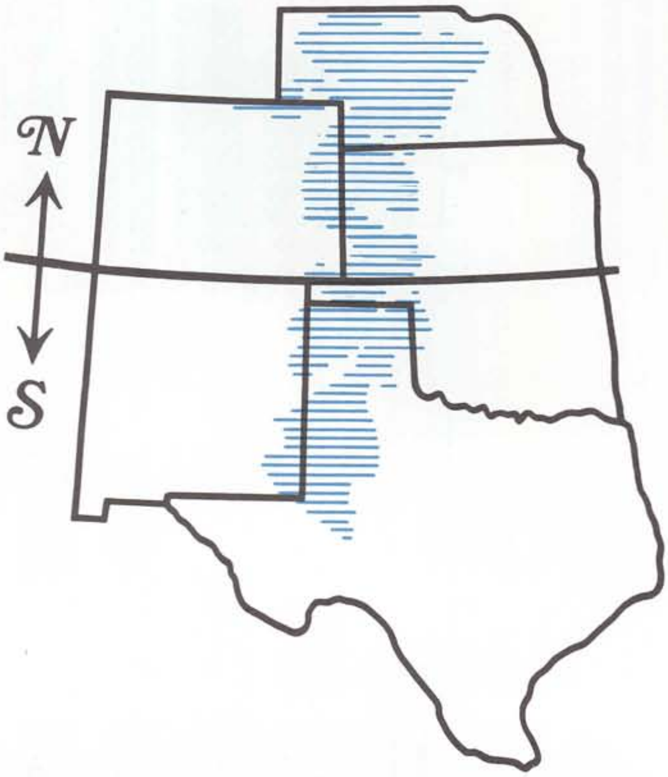


FIGURE V-17: BASELINE REGIONAL ECONOMY—POPULATION PROJECTIONS, BY SUBREGION AND REGIONAL TOTALS (1,000's of Persons)







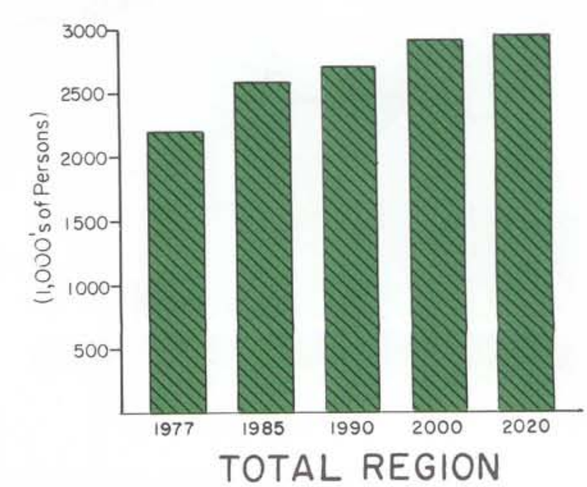
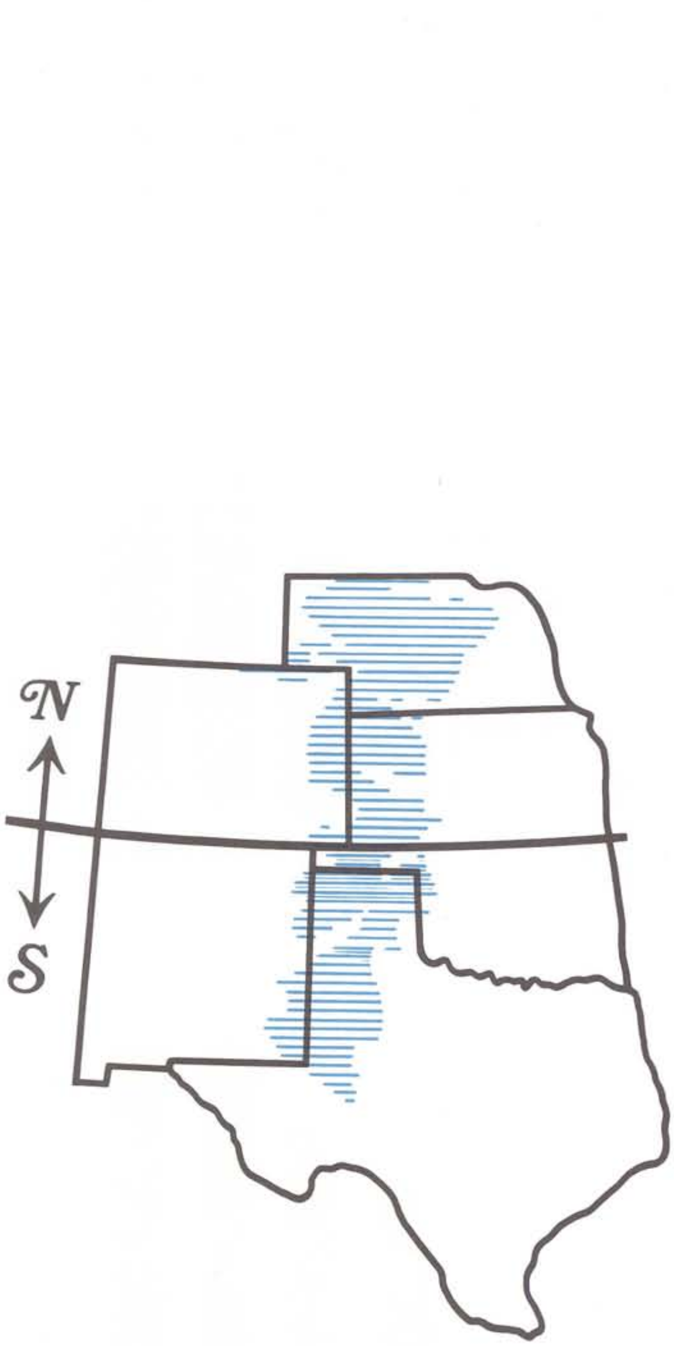
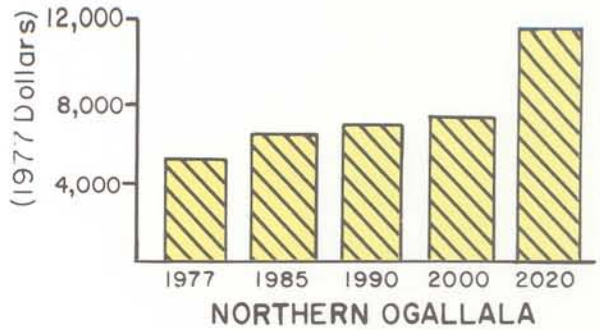
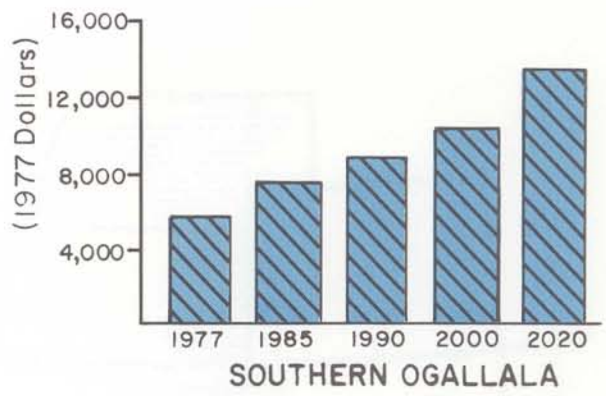


FIGURE V-18: BASELINE REGIONAL ECONOMY—PER CAPITA INCOME, BY SUBREGION AND REGIONAL PROJECTIONS (1977 Dollars)







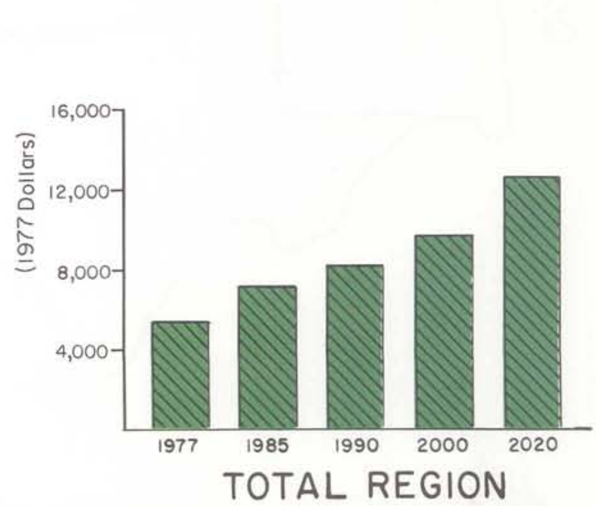
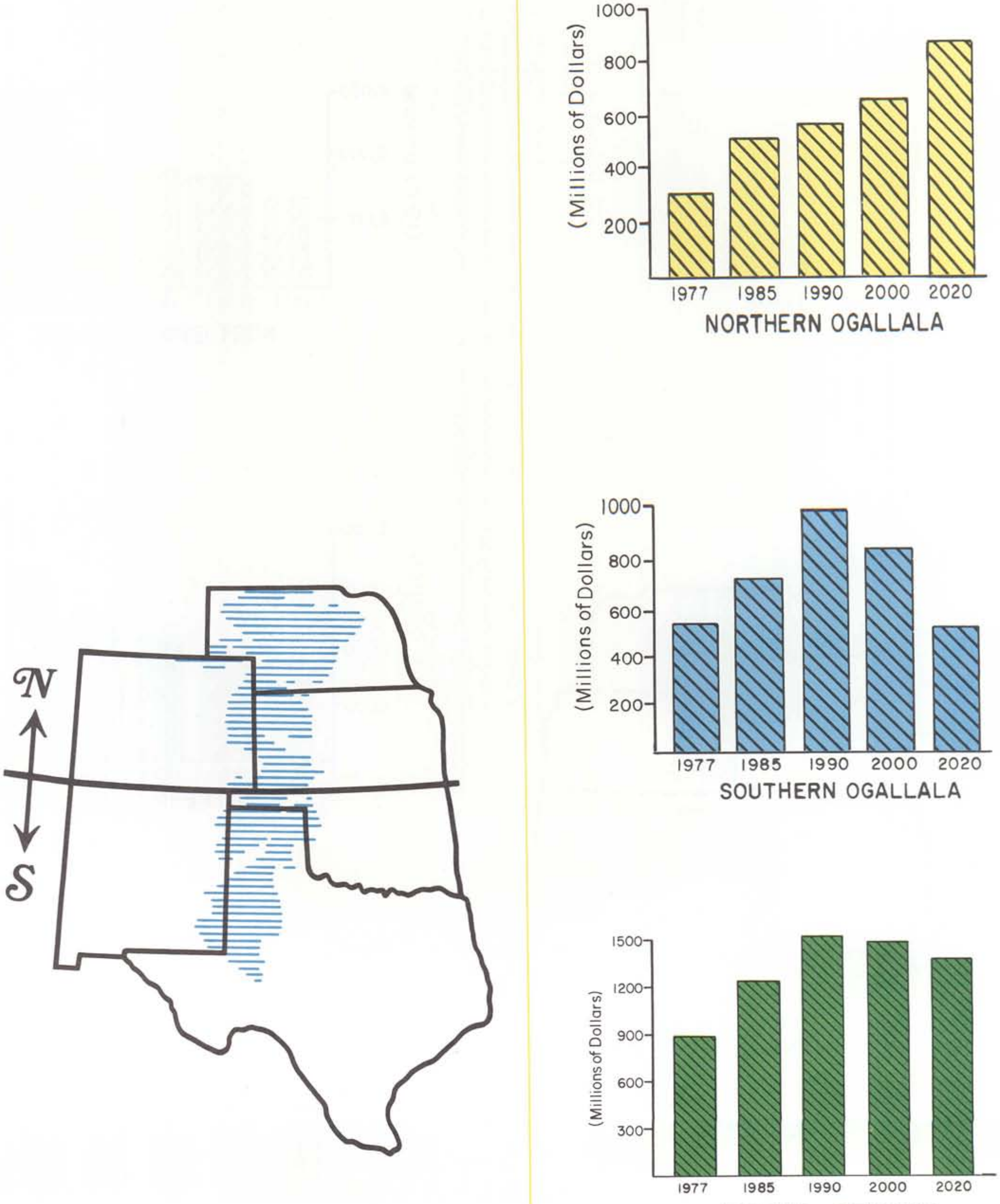


FIGURE V-19: BASELINE REGIONAL ECONOMY—STATE AND LOCAL GOVERNMENT REVENUES PROJECTIONS, BY SUBREGION AND REGIONAL TOTALS (Millions of 1977 Dollars)



OTHER BASELINE IMPACTS

Implementation Costs

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.

The selected set of 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. They also represent a continuum of increasing cost of implementation with the Baseline case as the least costly option and Management Strategy Five (the major water importation strategy) as the most costly option.

Estimated costs of achieving the projected levels of water resource demand reduction--the Baseline projections--are discussed here in broadly defined and relative terms. The estimations are not intended to represent projections of actual future costs of program implementation but rather the relationship of costs for Baseline implementation in comparison to other strategies. Relative costs can be classified as either direct (on-farm) or indirect (public sector) investments in improved water resource management capabilities or facilities.

The Baseline case assumes no substantive change in public sector programs or assistance to the agricultural industry to reduce water demands or increase water availability. This does not imply a "no-change" effect on water demand or supply management, however, as existing public sector programs and private (on-farm) activities to achieve cost effective water conservation, water use efficiencies, and local water supply augmentation are projected by the individual states to continue and expand under Baseline assumptions. A significant level of improved agricultural water management is evident throughout the High Plains Region and this is projected to increase during the Study period based on favorable cost-return relationships for proven water management practices and technologies.

A 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. Such practices as improved irrigation scheduling; adoption of more water efficient application methods; crop and cultural selections for improved water use characteristics; evapotranspiration reduction; precipitation and infiltration management; water runoff recovery methods; and several other water demand reduction or supply augmentation methods are included by one or more of the Study states.

Several of the listed agricultural water management improvements are presently eligible for cost sharing assistance and/or extension, demonstration, and technical assistance from existing public sector programs. A recent report by the U.S. Department of Agriculture* estimates that current (1978) expenditures by U.S.D.A. programs which provide cost sharing, technical assistance and/or loan assistance to irrigated agriculture amount to about $120 million per year. For the water short western states, this represents a federal investment of about $3.50 per irrigated acre in terms of improved agricultural water management. A matching investment by the private sector (individual farm operators) of about four to one, or $14 per acre annually can be assumed, as a typical rate from prior years, for a total annual investment of about $17.50 per acre in agricultural water management improvements.

The projected level of increased agricultural water management improvements under Baseline assumptions do not represent a significant increase in annual costs <u>per acre</u> (in real terms) over the Study period but do indicate a substantial increase in total costs due to the projected changes in total irrigated acres by 2020 in the respective states. 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. The on-farm (private sector) increments of annual costs for improved water management projected for the Baseline are

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* U.S.D.A. Report on Technical Assistance for Water Conservation in Water-Short Areas, December, 1978.

already factored into the cost analyses. The increase in public sector costs would be about $56 million by 1985 and increase to about $63 million by 2020 under these assumptions.

National Consumer Price and Agricultural Export Market Effects - Baseline

Between 1985 and 2020, in the Baseline or no action situation, the percentage of per capita disposal income spent on food is projected by NIRAP to decline from 17.5 percent to 17.1 percent. During the same period, the value of major agricultural exports is expected to more than double from about $21 billion to slightly over $51 billion*. During the 1977-2020 period farm prices are increasing at an average annual real rate of about 0.6 percent. This will increase annual consumer expenditures on food (with current consumption patterns) by $40-50 per person by 2020. The following presents the direct impact on consumers of farm level price increases.

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

Item	Annual Food Expenditure Increase: Per Person	Annual Food Expenditure Increase: 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
Broilers	5.12	20.48
Eggs	3.03	12.12

Assuming a U.S. population in 2020 of 290 million, this would reflect an increase of $11.6-14.5 billion dollars, or 1.2 percent of expected consumer expenditures on food at that time. Although added costs need not occur at each level of the food chain (e.g., processors, handlers, retailers) due to a price increase at the farm level, they often do. If all middle groups increased their margins by the same percent as found at the farm level, then

* 1977 dollars

consumers would pay $29-36 billion more, a 3.2 percent increase in food and beverage expenditures which can be attributed to the increase in farm prices* projected in the Baseline case for the High Plains Study.

Incremental production on the 5.1 million acres on the High Plains which cease irrigation in the Baseline could help to reduce very slightly the increase in food prices to consumer. However, most of the increase is attributable to a general tightening world supply-demand situation for agricultural commodities. The relatively small impact of this loss in irrigated acreage is apparent when it is realized that during the same period grain and oilseed exports have increased nearly 150 percent and the percentage of per capita disposable income spent on food and beverages actually declined slightly between 1985 and 2020 due to rises in real income which exceed the projected rise in food costs.

When compared to total national production, the Region is expected to produce a declining proportion of national output for several crops under Baseline conditions. Wheat produced on the High Plains falls from 16.4 percent of the national total to 10.4 percent in 2020. Sorghum falls from 39.7 percent in 1977 to 29.8 percent in 2020. Corn declines from 13.1 percent of the national total in 1977 to 12.6 percent in 2020. Soybean and cotton proportions increase through the period as water is concentrated on these crops.

Transition to Dryland Farming

To assess conditions that might be encountered in the transition from a presently mixed irrigation-dryland agricultural economy to a dryland economy, field surveys were conducted in two areas of the High Plains Region selected to illustrate past, present and expected conditions throughout the Region. Surveys in nine Texas South Plains counties and in 14 southwest Kansas counties were the basis for assessment. Farming conditions before the beginning of irrigation development in 1945, trends from 1946 through 1981, and expected conditions as future water supplies become scarce and more costly were analyzed.

* 1977 dollars

Before widespread irrigation began, the Region's economy was vulnerable to recurring drought. A seasonal shortage of rainfall coupled with typical high growing season temperatures and high winds often meant crop failures in this drought prone area of the Great Plains. In good years, wheat, cotton and hay crops provided good returns to the farmer and cattleman at reasonable production costs. On the average, crop yields were uncertain, as were prices, and the opportunities for diversification and the assurance of a feed-grain base for the cattle industry were limited.

With the expansion of irrigation by pumping from the Ogallala Aquifer in the years following World War II, crop yields and production increased; corn and grain sorghums and soybeans became major cash crops; and fed cattle and meat processing industries relocated to the High Plains. More recently, farm land prices and money costs have escalated, farm production costs have soared, and costs of pumping water from deeper wells and lower water levels have increased. In the last two to three years, prices received by farmers have declined. In October, 1981, the parity ratio based on historical farm prices received and paid was the lowest since 1933.

Off the farm, agribusinesses also prospered. The irrigation equipment dealers and suppliers of production inputs, as well as cottonseed mill and textile mill owners and laborers, all shared in this growing economy. In the community, the banker, wholesaler, retailer, and many service industries benefited from a growing agricultural economy. More recently, however, these enterprises began to feel the adverse effects of the cost-price squeeze on the farmer due to pervasive, persistent inflation and high water pumping costs. In the Texas South Plains, widespread and significant declines were experienced in the amount of water that could be pumped, whatever the cost. Large areas of West Texas cotton country have already gone through a decade of adjustment back to dryland crop farming. The transition has been relatively smooth because dryland cotton is a profitable crop in the South Plains.

Technical studies and informed professional judgments point to a gradual 40-60 year transition in most areas (except where water is abundant in portions of Kansas and Nebraska) back to the dryland farming economy of 40 years ago, in the absence of an imported water supply priced within the farmers ability to pay. Remaining water in storage and rates of depletion have been measured throughout the Region. With recent improvements in water use technology and application practices, it is now estimated the supplies will last well into the next century--perhaps longer in the southwest Kansas case area than in the Texas South Plains. Farmers are finding that currently adopted conservation measures can save substantially on energy costs, and good returns particularly in cotton and sorghums, are being achieved. Corn, a high water-consuming crop, is no longer a profitable crop in the two areas studied. At agricultural experiment stations, new research emphasis is on dryland crops and practices, and not as intensively on irrigated crops and management.

The projected ongoing transition to dryland farming under Baseline assumptions, with significant implications for localized areas where ground water depletion occurs the earliest, has three probable consequences.

If a near-term (3 to 5 year) transition becomes necessary, the adjustments may be devastating to the more marginal irrigated producer and many will be forced out of farming. Farm consolidations and more long-term adjustments to dryland farming will follow.

If typical cost, price and crop yield relationships of the past decade hold into the next decade, a more gradual transition to dryland farming will be possible. Adjustments would be difficult but manageable for the majority of farmers because the gradual declines in gross incomes would occur over a more extended time and compensating adjustments in farm size and operations could be adopted.

If crop prices and improved dryland yields, as projected under Baseline conditions, increase more than production costs, then the transition can be relatively smooth and long-term adjustments more readily adopted.

Nonagricultural Development

Agricultural employment has continued to decline over the past several decades in the High Plains Region and most of the Region's employment growth has been the result of an increase in the traditionally smaller manufacturing sector and in the service sector.

During the 1970's the Region grew at about the same rate as the rest of the country--in sharp contrast to the population declines and stable employment of the 1960's. The major factors which supported the Region's stronger growth during the 1970's were:

- ° Oil and gas booms in western Texas and southwestern Kansas due to price decontrol and the increased service needs of this industry (e.g. oil field equipment and financial and technical services)

- ° Increasing concentration of feedlots and meat packing plants in the area, as the advent of center-pivot irrigation systems spurred the cultivation of corn and other grains.

- ° Increased growth in other agricultural processing industries including food processing, cotton ginning and textiles, and increased growth of agricultural suppliers including farm equipment and agricultural chemicals.

Manufacturers have 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 a large number of baby boom children entering the labor force. Most of this growth in manufacturing has occurred in the Region's three metropolitan areas (Midland-Odessa, Lubbock and Amarillo) and in the eastern portions of the Nebraska High Plains.

Substantial increases in agricultural production have been forecast for the Region for the next 40 years and the value of oil and gas production is expected to rise in the early years of the Study period. This increasing production of primary products presents a number of opportunities for further increases in industries and services related to agriculture and energy. These include:

° Agricultural Processing

- As synthetic fibers lose some of their competitive advantages, natural fibers, particularly cotton, are likely to enjoy a comeback and the Region's substantial cotton production could support an expanded textile industry.

- The regional concentration of feedlots and meat packing has probably not yet run full course and should not be constrained by a shortage of feed grains in the Region as a whole. Numerous supporting industries could continue to grow to supply this industry.

- Other agricultural processing activities (e.g., oilseed mills, grain milling) are likely to expand with the expanding agricultural production.

° Agricultural Suppliers and Services

- Expanding agricultural production will trigger needs for additional inputs (e.g., fertilizer) and for new equipment and services to support the agricultural production.

° Oil and Gas Suppliers and Services

- This is a fast growing industry and should continue to be through the period in which new wells and secondary and tertiary recovery projects are being developed in the Region (to about the year 2000). However, as reserves are exhausted this sector will decline.

There will be a number of barriers to future development opportunities in the Region. The available resident labor force is not sufficient to support large additional growth. Internal sources of labor force expansion in the 1970's have been depleted, and employment rates in the area are high. The effect of rapid growth in oil and gas development on local wage rates, on the housing market, and on demand for community services and facilities in the "boom" areas may threaten the ability of other industries to compete or to expand and may discourage potential new employers from locating in the High Plains, particularly the southern portion of the Region where manufacturing employment increased sharply in the 1970's. 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 area for industries not related to the locally-based agriculture/oil and gas economy.

Given these potential constraints to achieving nonagricultural development opportunities of the High Plains, an aggressive economic development strategy would probably be needed to sustain anything approaching the growth rates of the last decade. Despite substantial increases which have been forecast for regional economic output, Baseline employment increases for the next forty years have been forecast at about one-fourth the rate that has occurred during the last decade, and at about 40 percent of the growth rate that has occurred since 1960.

Environmental Effects

Detailed information on environmental effects, both beneficial and adverse, is presented in the Report on Regional Research Study Element B-4: Preliminary Environmental Assessment. Following is a summary of probable environmental effects under Baseline conditions with particular emphasis on impacts on fish and wildlife resources.

- ° Riparian habitat declining as the result of increased ground water depletion, development, some phreatophyte control, grazing pressure in riparian areas within rangelands, more intense cultivation of some floodplains.*
- ° Native prairie cover increasing as present level of application of irrigation water decreases.*
- ° Mixed response - both negative and beneficial to terrestrial wildlife species due to changing land use patterns.

* Excerpted from U.S. Fish & Wildlife Service Report, November 1981, pp. 65-70.

° Some stream base flows and wetland areas may decrease due to declining ground water levels with resultant increasing damage to aquatic habitats.

° Conversion of high value habitat (native prairie, riparian wetlands) to low value habitat (irrigated cropland where irrigation is projected to increase).*

° Possible danger to threatened and endangered species and their habitats that are dependent on instream flows and wetlands.*

° Soil erosion - particularly wind erosion - may increase as presently irrigated lands revert to dryland farming or are abandoned.

SENSITIVITY OF BASELINE RESULTS

Projections extending forty years into the future, such as those made for the High Plains Study, are obviously made with the qualification of uncertainty. The effect of changes in all the variables considered may cause wide swings from Study results as the time from known historical values increases. Projections become more uncertain as the Study period progresses. Sensitivity analyses were made of Study results to key uncertainties that may be caused by significant change in projections and assumptions. These sensitivity analyses are reported in the "B" element studies and discussed in more depth in Appendix A.

Sensitivity analyses were performed to examine effects of changes in variables controlling agricultural production--crop yields, efficiency of water use, input costs (especially energy), and measures of domestic and export demand that determine the unit price that will be paid for a particular crop.

Yields

Agricultural productivity is projected to increase, although at a slower rate than the historic increase that has occurred in the Region since World War II.

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*Excerpted from U.S. Fish & Wildlife Service Report, November 1981, pp. 65-70.

If projected yield increases do not materialize, a compensating rise in national crop prices results from lower production. An alternative crop price projection was performed with the USDA-NIRAP model, setting the rate of productivity increase nationally at 75% of the annual increase projected in the High Plains Study. In this analysis, crop prices would be 6-12 percent higher at the end of the Study period. Applying these higher prices and lower yields to major crops in Nebraska* in 2020, the total value of production per acre falls only $10 per acre (1.8 percent) for corn, $7 per acre (3.7%) for dryland wheat, $10 per acre (3.8 percent) for irrigated wheat, and $20 per acre (5.0 percent) for sorghum. The total value of production in the High Plains Region and the health of its farm economy are not highly sensitive to changes in the rate at which farm productivity will increase, provided that changes in High Plains productivity parallel national productivity trends over the Study period. If High Plains productivity increases lag behind national levels, the compensating price effect will not occur, and the profitability of High Plains farming will be affected much more adversely.

Water Use Efficiency

If adoption of more efficient irrigation and agricultural technologies falls behind projected rates, a marginal effect would occur on production costs (higher pumping costs), production and returns to land and management in the early years of the Study. However, where saturated thickness of the Ogallala is already thin, as in much of the Texas High Plains, any reduction in the rate at which increased efficiencies are adopted will hasten the time when irrigation must be abandoned. The State of Texas ran an alternative Baseline analysis in which improvements in water use efficiency were cut approximately in half over the Study period. Under this scenario, the loss of irrigated acreage increases by more than three times. Over four million acres drop out of irrigated production. The analysis is so sensitive to this diminished efficiency that land remaining in irrigation in 2020 in Texas falls from 4.9 million acres to 1.9 million acres. Any allocation of imported water based on a strategy to restore "lost" irrigation capacity would require a commensurate increase.

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*A generally representative state with a high portion of High Plains production and an easily adjusted LP model.

Energy Prices

Prices are expected to increase at a moderate rate (crude oil at 0.4 percent per year in real dollars) after a period of rapid adjustment in which decontrolled domestic prices rise to world price levels. This long-term rate of increase is the long run historical average adjusted for the rapid increases of the 1970's.

A set of high band world oil prices were used to test the sensitivity of farm production estimates to higher energy prices. These high band prices were based on world oil prices escalating at 3.0 percent real, rather than the 0.4 percent used in the High Plains analyses. These prices were incorporated into crop budgets in some states to test the sensitivity of LP model results. In general, higher energy prices produced some crop switching and lower returns to land and management, but did not cause farmers to abandon irrigated production while water remained in the ground. Over the long term, lower returns resulting from higher pumping costs would be expected to reduce land prices. However, crop prices, total farm production and the value of farm production remain generally unaffected by significantly higher energy prices.

The apparent insensitivity of regional agricultural projections to increased energy prices conflicts with recent experience. Energy price increases in the 1970's have forced some farmers into dryland farming before ground water is exhausted, and has severely affected the profits of many irrigators. However, short-term trends may not be consistent with adaptation by farmers to long-term effects. Real energy prices have increased 200-300 percent since the early 1970's. Crop yields increase slowly and cannot compensate in this short period of time. Short-term price fluctuations further exacerbate the energy price squeeze on the farmer. The sensitivity analyses indicate that over the longer term of this Study, gradual energy price increases even at 2.5 to 3.0 percent per year--should be accommodated within the higher amounts received for High Plains crops as a result of rising prices and improved yields. With oil and gas prices rising at this rate, farmers can be expected to switch to electric pumps--which derive their power from coal fired generating stations--and to accelerate the adoption of water efficiency improvements, thus partially offsetting the more rapid increase in oil and gas prices.

Demand

Domestic demand for food and fiber is projected to grow at a moderate rate, as a result of slow population and economic growth and a rate of increase in real per capita income somewhat above the levels observed since 1974, but below the rates of increase observed in the 1950's and 1960's. Corn demand reflects a significant ethanol industry, which seemed plausible at the time of study formulation in 1978-79 but is less likely with prevailing federal policy in 1981.

Export demands are projected to show strong growth as a result of a growing world economy, continued agricultural shortages in several industrialized nations, and a U.S. policy encouraging agricultural exports (no significant embargoes).

Export projections used for crop pricing by the NIRAP model in this Study show steady growth through 2020. For most crops, with the exception of wheat, exports are expected to grow at a rate slower than that experienced in the 1970's, but faster than the trend of the past thirty years. A slight increase in the rate of growth of wheat exports is forecast.

Domestic and export demand combine to affect crop prices. Export demand is drastically affected by shifts in trade policy which cannot be forecast in a deterministic model. Domestic demand is likely to vary only a small amount from that projected.

To test price sensitivity, export growth was reduced to the thirty year (1950-79) trend for High Plains crops. By 2020, real crop prices for those crops would fall 19 percent for wheat and cotton, 22 percent for corn and sorghum, and 20 percent for soybeans. Because there is no offsetting rise in yields, the value of farm production in the High Plains would fall by similar percentages. While the ultimate effect on the farmer will vary from subregion to subregion depending upon soil productivity, depth to water and cost of pumping, and land prices (if the farmer is not a freeholder), the effects realized would be extensive.

The lower price resulting from decreased exports were not cycled back through the state agricultural simulation models. However, the following appear to be reasonable projections:

- ° The regional agricultural economy is more sensitive to export fluctuations than other critical economic indicators used in the Study.
- ° Price of food would be reduced by decreased export demand; a favorable effect for consumers which must be balanced against the loss of foreign exchange.
- ° Decreases in value of production resulting from decreased export demand would cut very significantly into returns to land and management and would likely cause the early abandonment of irrigation in some areas, and perhaps would reduce the total number of irrigated acres in the High Plains Region.
- ° As a result of the decreased demand for exports, commodities and lower price for crops with lower acreage irrigated, the total amount of water left in storage in the Ogallala at the end of the Study period would increase slightly.

CHAPTER SIX

IMPACTS OF MANAGEMENT STRATEGIES AND COMPARISON WITH BASELINE

INTRODUCTION AND SUMMARY

In this chapter, results of analyses of the water management strategies are compared with the estimates and projections derived for the Baseline presented in Chapter Five and with other management strategies. Indicators used for comparison are those used in discussion of the Baseline, with some additions. Most indicators are shown as a percentage difference from the Baseline for each Study year. These differences from the Baseline projections are measures of the effect of implementing each management strategy.

The alternative management strategies are described in detail in Chapter Three. Brief definitions of each strategy and the hierarchical (cumulative) relationships among them follow:

- ° Management Strategy One (MS-1) - voluntary water demand management to achieve improved agricultural water use efficiencies and water conservation at the farm level through early and widespread adoption of available (proven) technologies stimulated by new or expanded incentive programs.

- ° Management Strategy Two (MS-2) - voluntary (MS-1) plus mandatory water demand management practices and programs with the objective of prolonging the availability of water supply from the Ogallala Aquifer while maintaining viable irrigated agriculture through institutional or regulatory measures to induce widespread reduction in water demand at the farm level and the adoption of potential new (advanced) technologies.

- ° Management Strategy Three (MS-3) - all feasible reductions in water use rates achieveable from the water demand management Strategies One and Two plus local water supply management to augment ground water supplies from potential surface water sources.

° Management Strategy Four (MS-4) - maximum potential water demand reductions and local water supply augmentation through Strategies One, Two and Three, plus any opportunities for intrastate (subregional) water transfers to the High Plains Region, if long-term surpluses can be identified within the study states. All states have investigated such opportunities in previous water development studies.

° Management Strategy Five (MS-5) - regional and interstate importation strategy. Assuming all potential water demand reductions and local/state water supply augmentation measures (MS-1,-2,-3 and -4) have been achieved, the regional (interstate or interregional) water supply importation strategy is designed to examine potentials for importing water from streams in adjacent areas to augment High Plains Region water supplies.

Projected impacts of Strategies One, Two and Five are presented at the state and subregional levels and for the total Region. Relevant North - South subregional differences are shown.

Strategy Three is discussed qualitatively, presenting descriptions of the various local water supply augmentation options, discussed in detail in regional Research Report B-5, as applicable in the Study area and assessing their potential for future implementation in the Region. The full range of agricultural production and economic analyses performed for Strategies One and Two were not conducted for Strategy Three because the technologies reviewed did not offer sufficiently significant and dependable sources of additional local water supply for irrigation (other than those already included in Baseline forecasts) to justify the rigorous quantitative level of LP and I/O analysis applied to Strategies One, Two, and Five.

Strategy Four, dealing with intrastate water transfer potentials, was analyzed by state researchers only for Nebraska and Oklahoma. Intrastate transfers to the High Plains Region were not judged by the other four states to be feasible in providing a significant potential for alleviation of long-term water depletion from the Aquifer.

For each management strategy for which a full agricultural production and economic analysis was performed, information is presented on:

- ° changed hydrologic conditions (ground water remaining in storage)
- ° agricultural production
- ° economic activity
- ° costs of implementation
- ° effects on U.S. consumers and exports
- ° environmental effects

An analysis of the energy economy shows that Baseline energy projections will be affected only marginally by the water management strategies, except for operation of the transfer alternatives in Strategy Five, which would involve very large energy requirements. Baseline conditions will generally prevail in the energy sector for all other management strategies.

A brief summary of the results of Strategies One, Two and Five follows, with more detailed results provided in later sections.

<u>Management Strategy One: Voluntary Demand Reduction Initiatives with Incentive for Improved Water Use Efficiency</u>

1) Agricultural production:

   - ° Very small increases in value of farm production in relation to Baseline, with northern subregional gains above southern subregional gains.

   - ° Returns to land and management improve very slightly because of reduced pumping costs.

   - ° Relatively small change in water use in most states by 2020 because farmers are projected to have adopted most water saving technologies voluntarily (Baseline) without added incentive programs but not as rapidly.

2) Remaining ground water supplies and irrigated lands:

° Irrigated acreage by 2020 is up 0.94 million acres (5 percent) over the total amount irrigated under the Baseline. In Kansas, however, increased irrigation made feasible by efficiency improvements increases irrigated acreage more (123 percent) by 2020.

° The problem of increasing losses of irrigated lands after 2020 remains, but is postponed in some areas due to decreasing water use rates.

3) Regional economy

° A positive but relatively small gain in regional economic growth over Baseline because the agricultural sector has a small net favorable change while the energy sector is unchanged.

° Absolute gains from Strategy One in northern subregion are generally several times higher than in southern subregion for most economic indicators by 2020.

° Regional Value Added is up from Baseline projections by:

$364 million (0.8 percent) in 2000
$449 million (0.9 percent) in 2020

° Region gains 14,000 employees by 2020 over Baseline (13,000 in North).

Management Strategy Two: Restrictions on Ground Water Use; for Purposes of Analysis, Each State Cut Pumpage by 10 percent in 1985, by 20 percent in 1990 and by 30 percent in 2000 Below the Levels in Management Strategy One

1) Agricultural production:

° Generally lower because of limitations on water use. Regional wheat production remains relatively stable compared to Baseline, while corn, cotton and soybean production declines.

° Total value of production is down, proportionately less than regional crop production because the reduction in national production forces crop prices up.

° Total returns to land and management for the Region are down relative to Baseline projections, but not as much as decreases in total value of production.

° Production declines greater in South than in North, but returns to land and management decrease more in North.

2) Remaining ground water supplies and irrigated lands:

° The major gain is a considerable increase in the amount of water remaining in storage after 2020--ground water depletion of many areas would be delayed even further than for Strategy One.

° In the early years, irrigated lands are less than in the Baseline, but by 2020, lands under irrigation are 0.1 percent below Baseline levels. Strategy Two falls five percent short of the voluntary conservation strategy (MS-1) in lands remaining in irrigation at 2020.

3) Regional economy:

° Reduced agricultural production results in a significant decline below levels of activity in Baseline.

° Total value added for the Region shows a 2.1 percent decline below Baseline projections--4.0 percent in the North and 0.9 percent in the South.

° Other economic indicators are comparable to value added changes by subregions and regional totals.

Management Strategy Five: Analyses Constrained to the Amount of Import Water Required to Restore Lands to Irrigation Where Water Was Physically Exhausted After 1977--Analysis Assumed Imports Would be Incremental to Strategies One (MS-5A) and Two (MS-5B)

The following paragraphs summarize the results of MS-5A; MS-5B results are generally less than those for MS-5A.

1) Agricultural production:

- ° Significant increase in crop production as water is available for restored lands formerly irrigated.

- ° Wheat, the principal dryland crop, declines by 7.5 percent with the availability of water imports for producing higher-valued crops.

- ° Returns to land, management and imported water increase substantially but increased production results in lowered national prices; the increase in total value of production is proportionately less than the increase in total crop production; a portion of the increased returns would be used for payment for imported water.

2) Remaining ground water supplies and irrigated lands:

- ° 2,410,000 acres restored to irrigated production in 2000; 4,610,000 acres in 2020 (up 25 percent).

- ° 1.7 million acre-feet of imported water used in 2000; 4.1 million acre-feet of imported water used in 2020.

- ° Because ground water is still being used throughout the Study period where it is available, irrigated lands would decrease in years after 2020 unless import volumes are increased.

° Value of imported water is difference between returns to land and management for dryland and returns to land, management, and water when irrigated with imported water. Outside limit on the ability of the farmer to repay costs of import water will be significantly below full cost of the water delivered to the farm headgate.

3) Regional economy:

° Expanded agricultural production produces a stronger regional economy - about 13 percent increase region-wide in value added by agricultural sectors, in comparison to Baseline projections for 2020.

° Net additional economic activity (value added) over Baseline is $2.0 billion in 1977 dollars by 2020.

° Employment gains about 9 percent in the North, nearly 2 percent in the South over the Baseline by 2020.

MANAGEMENT STRATEGY ONE

Tables and figures that portray results of implementing Strategy One were derived from state LP model analyses. These tables and graphic displays present in detail the results of analyses at state, subregional North and South, and High Plains regional levels. Figures showing the percentage change from Baseline for Strategy One and other management strategies are provided at the end of this section. Tables VI-1 through VI-10 in Appendix B present state, subregion and regional data for Strategy One.

MANAGEMENT STRATEGY ONE - AGRICULTURAL SECTOR IMPACTS

Water Availability Impacts

(Figures VI-17 and 18, this section)
(Tables VI-1 & VI-1.1, Appendix B)

For the Region as a whole, total annual water use is less than the projected Baseline amount in the early years of the Study (1985 and 1990) and exceeds the Baseline projections by approximately 2.0 percent at the end of the Study period. This pattern results from accelerated conservation practices--reducing water use in the early years--leaving a larger amount in storage for subsequent years.

The southern Ogallala states of New Mexico, Oklahoma and Texas show a diminished water use rate for all periods with the exception of a small (less than one percent) increase in New Mexico for 2020.

In Kansas and Colorado, the regional trend is reversed, with increased annual water use in all periods, except for a six percent decline for Kansas in 1985. Water use efficiency improvements achieved with Strategy One incentives are sufficient to make irrigated farming once again attractive where it was abandoned for economic reasons in these states under Baseline. Additional acreage remains under irrigation that had gone out under Baseline projections so that total annual water use increases despite the lower per acre use rates. As a result, the amount of water remaining in storage later in the Study period is reduced in Kansas and Colorado, while storage is greater due to Strategy One in all other states. Total annual water use in Kansas is up by more than one million acre-feet in 2000 and by more than 700,000 acre-feet in 2020. Kansas irrigated acreage is up by 109 percent in the year 2000 and by 123 percent by 2020 in comparison to Baseline.

Land in Production (Irrigated/Dryland)

(Figures VI-19 and 20, this section)
(Tables VI-2 and 2.1, Appendix B)

The benefits of voluntary conservation measures analyzed in Strategy One are more apparent in terms of the amount of irrigated land in production than appeared in the impacts on remaining water. Decreases in water use as a result of conservation under Strategy One are projected to provide additional irrigation capability. By 2020, the amount of land remaining in irrigation in the Region as a whole is projected to increase almost one million acres (five percent) over Baseline levels. Only in Oklahoma and Texas is the amount of irrigated acreage in 2020 unchanged in Strategy One. These states forecast an early and rapid decrease in water use as a result of improved irrigation technology in the Baseline, so smaller gains accrue from incentives for voluntary conservation.

Regional dryland acreage is projected to decline (about one percent), but total cropland in the Region increases slightly (two percent) above the Baseline to 38.4 million acres.

The results reported by Kansas researchers show a significant response to this voluntary water demand management strategy. The increased irrigation efficiency in Kansas included in these results permits farmers to continue irrigation where it would have become uneconomic under the Baseline. As a result, although the total amount of land where water in ground water storage is economically depleted increases slightly by 2020, the continuation in irrigation of lands where irrigation was uneconomic under Baseline more than offsets this loss. Kansas shows a net increase in irrigated acreage by 2020 of 715,000 acres, Colorado has an increase of 105,000 acres, and small increases are projected for Nebraska and New Mexico in comparison to Baseline projections for 2020.

<u>Production - Six Significant Crops</u>

(Figures VI-21 through VI-26, this section)
(Tables VI-2.2 and 2.3, Appendix B)

The higher efficiencies in water use prevailing in Strategy One permit slight increases in production of more water-intensive crops with small offsetting decreases in dryland and/or low water demand crops. Regional corn production rises above Baseline by 6.2 percent by 2020. Alfalfa and soybean production also shows an increase while wheat, cotton and sorghum production is down slightly by 2020. The most significant shifts in crop production projected for Strategy One are very large increases in corn production in Kansas in 2000 and 2020; a moderate (35 percent) increase in corn production in Colorado by 2020; a 38 percent increase in sorghum production in New Mexico by 2020; and almost 50 percent increase in soybean production in Kansas by 2020 over Baseline projections.

Value of Agricultural Production

(Figure VI-27, this section)
(Table VI-3, Appendix B)

The total value of agricultural production for the Region is projected to increase in each Study period. This results from projected increases in irrigated acreage and in major crop production increases. In 2020, the total value of production is projected to increase $380 million (3.3 percent) over Baseline levels. This increase is concentrated in the northern part of the High Plains, with nearly 78 percent of the regional increase occurring in Kansas. Only very modest increases over Baseline projections occur among the other five states.

Returns to Land and Management

(Figure VI-28, this section)
(Table VI-4, Appendix B)

Returns to land and management show a mixed pattern when Strategy One is compared to the Baseline. For the Region as a whole, returns to land and management increase by less than two percent in 2020 a net change of $75 million. An increase of 1.1 percent in the North is compared to an increase of 3.8 percent in the South in 2020 over Baseline projections. Colorado and New Mexico show the most significant increase in returns by 2020 in comparison to Baseline results.

MANAGEMENT STRATEGY ONE - REGIONAL ECONOMIC IMPACTS

The regional I/O model was used to analyze the impacts of implementing Strategy One on the regional economy. As in the regional analyses of the Baseline projections, inputs to the model were provided by the states through results derived from their individual LP and I/O analyses. Indicators are those used in the Baseline projections to provide a comparative measure:

- ° Regional Value Added and Value Added by Agricultural Sectors
- ° Employment and Household Income

° Population

° Per Capita Income

° State and Local Tax Revenues

The changes in overall economic activity as measured by regional value added are larger in absolute amounts because of multiplier effects than the changes in farm production or returns to land and management. However, percentage changes in overall economic activity are smaller than changes in agricultural production. Although the Region is heavily dependent upon agriculture, manufacturing and energy production are also significant factors in the economy. National economic trends and local oil and gas production govern these sectors and do not change for each management strategy. As a result, overall economic indicators such as employment, population, and household income show smaller percentage variations between management strategies over the Study period than the principal agricultural production indicators.

Regional Value Added

(Figure VI-29, this section)
(Tables VI-5 and VI-6, Appendix B)

For each Study year after 1977, the regional economy shows a small improvement as a result of Strategy One. By 1990, total value added increases $71 million (0.6 percent) over the Baseline in the North, but changes more gradually, (a $19 million increase, or 0.1 percent) in the South. Both the rate of increase in regional value added and the absolute values increase more rapidly in the North than in the South throughout the Study period.

For the Region as a whole, total value added increases by $364 million over the Baseline in 2000, or approximately one percent. By 2020, the net economic benefit of adopting Strategy One in the entire Region is projected to be $449 million. This greater absolute increase in the later Study period results from the small increase in the number of acres remaining in irrigation because of conservation, plus the declining relative importance to the overall economy of the energy sector. As shown in Table VI-6 Appendix B, the percentage of value added contributed by agriculturally related sectors rises slightly in all years in the North, and also rises in 2020 in the South when Strategy One is compared to the Baseline. By 2020, the value added by agricultural related sectors increases by $402 million in comparison to Baseline, a 3.0 percent increase.

Employment and Household Income

(Figures VI-31 and 32, this section)
(Tables VI-7 and VI-7.1, Appendix B)

Employment and household income show small increases in Strategy One over Baseline in parallel with improvement of the overall economy. By the end of the Study period--2020--an additional 14,200 people over Baseline would be employed under these projections in the High Plains Region if Strategy One were fully implemented. This increase is unequally divided--13,100 in the North and 1,200 in the South. Net payments to households (household income) are projected to increase by $269 million in 1977 dollars in 2020, with 88 percent of this increase occurring in the North.

Population

(Figure VI-33, this section)
(Table VI-8, Appendix B)

The very small projected changes in employment relative to Baseline (1.1 percent of total regional employment in 2020) make it difficult to calculate population effects of Strategy One reliably. A change this small on a regional basis may be caused by changes in unemployment or labor force participation rates, rather than by any positive migration impact. Thus the estimated population increase of 28,000 for the Region in 2020 resulting from the implementation of Strategy One is probably well within the margin of error of the Baseline population estimate. Population increase is projected to be greater in the North (25,000 of the total 28,000 increase) where the larger expansion in the agricultural sector would occur.

Per Capita Income

(Figure VI-34, this section)
(Table VI-9, Appendix B)

Assuming the projected population increase occurs, average personal (per capita) income in the Region is projected to remain nearly stable at about $12,634 per year in 2020 (a small decline of 0.2 percent from Baseline). The northern subregion is projected to experience more of a decrease in per capita income (0.4 percent) than does the southern subregion (a loss of only 0.03 percent). These projections are also within the probable margin of error for Baseline projections.

State and Local Tax Revenues

(Figure VI-35, this section)
(Table VI-10, Appendix B)

While the increased agricultural production resulting from adoption of Strategy One will increase employment and the size of the regional economy, it will do relatively little to stop the erosion of state and local tax revenue which results from declining oil and gas production. Regional tax revenues would increase only $3 million in 1990 and $15 million (1.1 percent) in 2020 relative to the Baseline. These are small compared to revenue declines from the energy sector. In the South, where government revenue loss occurs after 1990, Strategy One provides only an additional $0.7 million in 2020 to offset the $430 million drop in revenue which occurred in the Baseline from 1990 to 2020.

MANAGEMENT STRATEGY ONE - OTHER IMPACTS

Implementation Costs

The principal difference between Baseline and Strategy One 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) for Strategy One. The kinds of positive incentive programs assumed by the states to trigger the increased rate and extent of adoption of agricultural water demand reduction methods include federal, state, and local programs aimed explicitly at irrigated agriculture for expanded education and extension; agricultural/irrigation research and development; direct payments and/or cost sharing assistance; low interest loan programs; and potential tax credit or more favorable depreciation programs for defined water conservation and water use efficiency improvements.

Methods of cost estimation for the added public/private investments necessary to achieve Strategy One projected levels of improved agricultural water management are less well defined than for the Baseline case. A direct relationship between increased cost per acre associated with new incentive programs and the matching private investment triggered by such programs would appear reasonable. An inverse relationship between decreasing unit demand for irrigation water (relative improvements in water use rates per acre) and the increasing cost of implementation of those improvements is suggested.

Applying these relationships, the cost of new incentive programs would increase costs per acre by about ten percent over the corresponding Baseline case, 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 comparison to $3.50 per acre public cost and $14.50 private investment for Baseline). 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.

Commodity Price, Consumer Price or Export Market Effects

Regional production changes from the implementation of Strategy One generally produces changes of less than 1.0 percent in the amount of a crop produced in the Nation as a whole. Because of these small changes, the NIRAP crop pricing model and related estimate of consumer food prices and agricultural exports were not recalculated. Any resultant changes in these indicators would clearly lie within the margin of error in projecting the regional effects of Strategy One.

Effects of Transition to Dryland Farming

In general, the transition to dryland farming will be further eased by voluntary reduction in water demand, particularly where farmers can achieve significant water use efficiency as compared to the Baseline. Because the shift in water use efficiency by 2020 is minor in most states, there is only a small delay in the time when some ground water supplies are exhausted in most states, and the additional transition period will occur after the end point of the Study period (2020) in many places.

Environmental Effects*

Management Strategy One - Comparatively little change in overall effects on fish and wildlife resources from Baseline conditions expected. Examples of improved water conservation and water use efficiency practices under Strategy One and their possible environmental effects are:

- Evaporation Reduction - Little direct effect on fish and wildlife resources.
- Reduction of Surface Runoff and Deep Percolation - Reduced runoff into upland wetlands (esp. playas) and streams, lowering aquatic habitat values.
- Improvement of Efficiency in Irrigation Systems and Irrigation Management - Little direct effect on fish and wildlife resources foreseen, based on available information.
- Cultural Methods and Soil-Plant-Moisture Relationships - Combination of decline in acreages of corn and reduction of tailwater runoff to playas may lower winter carrying capacities for migratory waterfowl populations in southern portion of study area. Reduction in soil erosion rates and amounts of chemical fertilizers and pesticide residues in runoff waters will benefit wetland and aquatic habitats. Extensive weed suppression would eliminate habitat for upland game and nongame species. Mulching and fallowing, however, would partially offset these habitat losses.

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* Excerpted from U.S. Fish & Wildlife Service Report, November 1981, pp. iv and v, Executive Summary.

° Conjunctive Water Uses - Intensive modification of upland wetlands (esp. playa lakes) would reduce their habitat value to both migratory and resident species.

Institutional Implications

Implementation of Strategy One would require very little change or realignment of the institutions in the Study area states but increased levels of staffing and funding would be necessary.

In each of the six states, the State University system and Extension Service are available to conduct needed research and demonstration in irrigation and agricultural management, carry out educational programs, and provide technical assistance and, in some instances, services to farmers. Federal agencies, particularly those of the U.S. Department of Agriculture, are operative in the Region providing research and demonstration, experiment stations, educational materials, technical assistance to state and local agencies and to farmers, and programs of financial assistance to farmers.

Within Colorado, Kansas, Nebraska and Texas, local districts (ground water management districts, natural resource districts and water conservation districts) have adequate authorities to provide necessary technical assistance to water users. In New Mexico and Oklahoma no local ground water-type districts have been organized to provide such services. In these latter states, however, other agencies are in place to assist water users.

In New Mexico, the Natural Resources Department administers a number of agencies whose authorities and responsibilities are natural resource-oriented. The State Engineers Office and Interstate Stream Commission are a part of the Natural Resources Department as is the Soil and Water Conservation Division. The latter Division has local soil conservation districts in place over the entire Ogallala Aquifer area. The State Engineers Office and the Soil and Water Conservation Division could organize for technology transfer through an intra-agency agreement. In this manner farmers could get requisite technical information and assistance through existing soil conservation districts.

In Oklahoma, the Oklahoma Resources Board has a broad mandate that includes both planning and management functions. Planning for present and future development and utilization of Oklahoma's water resources is concentrated in this agency. The Board has responsibility for state-wide, regional and local planning for the use and control of water and has statutory power in the granting of water rights to users.

Each of the other states in the Study area have state and local soil and water conservation agencies and districts which provide research and other assistance to farmers. Strategy One implementation will be enhanced by close cooperation of local ground water or natural resources districts with soil and water organizations, as well as the state water agencies.

Other single purpose agencies exist in the states whose resources should be used when appropriate. Of particular note is the Nebraska Agriculture Development Division of the Department of Agriculture. One of the functions of this Division is to provide incentives and encouragement to young farmers and ranch couples actively involved in agricultural production. The University of Nebraska provides valuable operational information and technical assistance to farmers through its computerized AGNET program.

As noted, increased funding and staffing will be necessary for all these agencies to achieve expeditious implementation of Strategy One. Increased funding for irrigation and agricultural research is essential at both federal and state governmental levels. If new types of financial assistance to farmers are to be instituted to stimulate early and widespread water demand reduction practices, these would need to be authorized and funded, probably by both the Congress and state legislatures.

MANAGEMENT STRATEGY TWO

Analysis and projection of impacts of Strategy One were modified for Strategy Two by addition of restrictions on water use, including possible regulation of well location and pumping rates, as well as other regulatory incentives, in order to reduce water withdrawals for each acre irrigated in Strategy One by:

- 10 percent below MS-1 levels by 1985
- 20 percent below MS-1 by 1990
- 30 percent below MS-1 by 2000 and thereafter

Results of the analyses indicate decreased agricultural production under Strategy Two because of reduced water use. Water remaining in storage, however, increases over Strategy One in 2020, thus delaying the water supply exhaustion in some subregions.

This management strategy has negative impacts when compared with the Baseline and Management Strategy One for most economic indicators. Energy used by the farm sector in pumping water will decrease by approximately 30 percent of Baseline pumping energy demand in most cases by 2020.

MANAGEMENT STRATEGY TWO - AGRICULTURAL SECTOR IMPACTS

Water Availability Impacts

(Figures VI-17 and 18, this section)
(Tables VI-11 and VI-12, Appendix B)

Water use in all states declines significantly below Baseline levels in 1985 and 1990. Kansas water use under Strategy Two increases for 2000 and 2020, while all other states show declines for the entire Study period. For the Region as a whole, the reduction in net water use reflects the assumed reductions in allowable water use outlined above which were used as guidelines in calculating the results of implementing Strategy Two. In 1985, total water use in the Region is over four million acre-feet (19 percent) below Baseline levels. By 2020, water use is reduced by 5.9 million acre-feet (28 percent) from Baseline projections. The increase in the percentage reduction results because in the early years farmers may, in response to restricted water use, adopt more efficient technologies which permit economically marginal irrigation operations to continue. By the year 2000, most farmers are assumed to have adopted the most efficient irrigation practice available, and the 30 percent cut in allowable water withdrawals per acre produces a corresponding decrease in total water withdrawals. Water remaining in storage in the Ogallala Aquifer under Strategy Two is over 128 million acre-feet greater than under Baseline projections. It is possible that the proportion of water withdrawn which returns to the Aquifer by deep percolation may decrease in this strategy with lower application rates, so that this value (128 million acre-feet) slightly overstates the increase in the amount of water remaining in storage.

Land in Production (Irrigated/Dryland)

(Figures VI-19 and 20, this section)
(Tables VI-13 and 13.1, Appendix B)

Implementation of Strategy Two generally results in a decrease in the number of acres irrigated when compared to Baseline or Strategy One. By 2020 the conservation of ground water induced by Strategy Two results in only a minor change in irrigated acreage in comparison to Baseline projections (a 0.1 percent decrease). In 1985, irrigated acreage is 15.4 million acres, 585,000 acres or 4.0 percent below Baseline; in 1990, the difference between Strategy Two and Baseline falls to 780,000 irrigated acres (5.0 percent). The difference between Strategy Two and Baseline for 2000 is 645,000 acres, or about 4.0 percent reduction. The much smaller reduction (10,000 acres) by 2020 comes about as reduced water use permits some land to stay in irrigated production. In comparison to Baseline projections, Strategy Two results in an 870,000 acre increase in irrigated acreage (7.0 percent) in the northern subregion and an 880,000 acre decrease (16.0 percent) in the South, for a net decrease of 10,000 (0.1 percent) for the entire Region.

Production - Six Significant Crops

(Figures VI-21 through VI-26, this section)
(Tables VI-13.2 and 13.3, Appendix B)

Under the restricted water use assumption in this Strategy, production of most crops (except wheat) generally fall below Baseline projections.

Cotton production falls by 11.5 percent below Baseline by 2000 and by almost 11.0 percent in 2020. Regional corn production is down by 15.0 percent by 2020; soybean production is down by 9.0 percent and alfalfa by 5.0 percent. Wheat production increases in the South, with a relatively small Region-wide increase in wheat production over Baseline. Soybean production decreases until 2000 (by up to 13.0 percent) but then recovers for about a 7.0 percent gain by 2020. Significant increases in wheat production in Texas, corn production in Kansas, sorghum production in New Mexico, and soybean production in Kansas are other important effects.

Value of Agricultural Production

(Figure VI-27, this section)
(Table VI-14, Appendix B)

Decreasing irrigated production means higher prices for some crops due to declining total national production. Projected prices for selected crops are tabulated below:

National Unit Crop Price (Baseline & Management Strategy Two)*

	Wheat**		Corn**		Sorghum**		Soybeans**		Cotton***	
	Base	MS-2	Base	MS-2	Base	MS-2	Base	MS-2	Base	MS-2
1985	3.03	3.03	2.54	2.54	2.28	2.29	6.10	6.10	.54	.55
1990	3.05	3.05	2.58	2.60	2.32	2.34	6.14	6.13	.55	.56
2000	3.12	3.11	2.76	2.81	2.48	2.53	6.37	6.36	.56	.58
2020	3.40	3.38	2.89	2.92	2.60	2.63	7.05	7.05	.58	.59

* NIRAP estimates; except cotton estimated by ADL.
** 1977 $ per bushel.
*** 1977 $ per pound.

The combined effect of changes in price and irrigation water availability on the amount of each crop produced is shown in Figure VI-13.2

The value of production under Strategy Two generally falls below projected results for Strategy One and Baseline in the Region in all Study years. Exceptions are projected in results for Kansas for 1990, 2000, and

2020; in Colorado in 2020; and in New Mexico in 2020. In these cases, the projections of more efficient water use with resulting increased supplies of ground water in storage permitted increases in value of production. For the Region as a whole, the loss in value of production increases over the Study period, with a net loss of 7.9 percent below Baseline in 2020.

The results of the Study shown in the figures and tables indicate that mandatory restrictions on water use will not increase the value of farm production during the Study period. The value of production falls below Strategy One despite the fact that national crop prices are projected to increase because of the decline in irrigated production. For the Region as a whole, value of production is consistently below Baseline and Strategy One levels throughout the Study period. Total value of regional production is $175 million (2.6 percent) below the Baseline and $200 million (3.0 percent) below Strategy One in 1985. By 2020, the deficit in the value of production in Strategy Two rises to $910 million (7.9 percent) when compared to the Baseline, and $1.29 billion (11.0 percent) when compared with Strategy One.

Returns to Land and Management

(Figure VI-28, this section)
(Table VI-15, Appendix B)

Returns to land and management under Strategy Two do not decline as precipitously as the total value of production because farmers are saved the costs of pumping the additional water and decreased crop production increases prices somewhat. In 2020, total returns in the Region are $435 million (8.7 percent) below Strategy One and $360 million (7.3 percent) below the Baseline. Nebraska and Texas experience the largest losses in returns under Strategy Two, at about 12.0 and 5.0 percent reductions respectively.

MANAGEMENT STRATEGY TWO - REGIONAL ECONOMIC IMPACTS

Management Strategy Two--produces a more pronounced effect than Strategy One on regional economic variables. This effect is generally negative throughout the Study period to 2020.

Regional Value Added

(Figures VI-29 and 30, this section)
(Tables VI-16 and VI-17, Appendix B)

In all Study years, Strategy Two has a lower regional value added than in either the Baseline or Strategy One. This reduction occurs in both the North and South. For the Region as a whole, declines from Baseline levels of economic activity are as follows:

Decline in Regional Value Added (All Sectors)* Management Strategy Two From Baseline

Year	Decline	Percentage
1985	$ 135	0.4
1990	388	1.0
2000	583	1.3
2020	1,051	2.1

* In million 1977 dollars

Percentage declines in the early years are smaller because the required restrictions on water use are less (10.0 percent less by 1985 and 20.0 percent less by 1990). By 2020, with a concurrent decline in the energy sector, the decrease in farm production has a larger relative regional effect. As would be expected, the contribution of the farm sector falls in Management Strategy Two. By 2020, only 16.8 percent of value added in the Region comes from farm production, as compared to 18.4 percent of value added in Strategy One and 17.9 percent in the Baseline. Within the Study period, the increase in irrigated acreage is too small to offset the decreases in production on the remaining irrigated land. When all agricultural related sectors are combined, the regional contribution of agriculture to total value added increases from about 20.0 percent in 1977 to about 25.0 percent by 2020. This still represents, however, almost a $900 million decline from Baseline projections for 2020.

Employment and Household Income

(Figures VI-31 and 32, this section)
(Tables VI-18 and VI-18.1, Appendix B)

Other significant economic indicators follow the trend in value of production when Strategy Two is compared to the Baseline and Strategy One. In 1990, total regional employment projected under Strategy Two is 20,300 below the Baseline and 25,000 below Strategy One. In 2020, the difference has increased to 32,000 when compared to the Baseline and 46,200 when compared to Strategy One. Most of the regional decline in employment by 2020 (74.0 percent) is concentrated in the northern Ogallala subregion.

Total household income for Strategy Two in 2020 falls by almost $678 million (1.8 percent) when compared to Baseline. The unfavorable difference increases to $947 million (2.5 percent) when Strategy Two is compared to Strategy One for the same year. As with all previous regional economic indicators, the majority of the impact of reduced household income due to Strategy Two (63 percent) occurs in the northern subregion.

Population

(Figure VI-33, this section)
(Table VI-19, Appendix B)

Population projections for Strategy Two decline by 45,000 and 52,000 in the Region when compared to the Baseline and Strategy One respectively, in 1990. By 2020, population in the Region will lag 71,000 and 99,000 behind the levels projected for the Baseline and Strategy One, although total regional population still increases significantly over current (1977) levels. Even under Strategy Two, which has the poorest overall economic results of any strategy analyzed for the Study period, population is expected to increase by 19.0 percent over 1977 levels in the North by 2020, and by 40.0 percent in the South in the same period for a net increase in regional population of 673,000 people (a 31.0 percent rise for the Region).

Per Capita Income

(Figure VI-34, this section)
(Table VI-20, Appendix B)

Due to population and household income effects previously discussed, per capita income projections indicate a mixed effect from Strategy Two, with slightly higher average increases in the North than both Baseline and Strategy One, virtually unchanged relative incomes in the South. Regional average per capita income is up by a slight $78 (0.6 percent) over Baseline projections for 2020, due entirely to a 1.4 percent rise in the northern subregion.

State and Local Tax Revenues

(Figure VI-35, this section)
(Table VI-21, Appendix B)

The relatively poor performance of the regional economy under Strategy Two exacerbates the decline in state and local government revenues projected to accompany the expected declines in oil and gas production. In 2020, revenues will be $3.5 million (0.6 percent) below Baseline levels in the South and $30.4 million (3.6 percent) below Baseline levels in the northern subregion. Despite reduced agricultural production levels, the steady increase in government revenues in the North continues under Strategy Two, but at a lower rate than for Baseline or Strategy One. In the South, the lower level of tax collection from reduced farm production augments the decline in government revenue that occurs after 1990 resulting from oil and gas declines. Although the North is more dependent on agricultural production, which is reduced under Strategy Two, total state and local government tax revenues in the North still exceed collections in the more populous South by 2020 under Strategy Two projections.

MANAGEMENT STRATEGY TWO - OTHER IMPACTS

Implementation Costs

The added costs associated with Strategy Two over and above those entailed by Strategy One are primarily institutional costs required to administer an effective local/state regulatory program capable of implementing the projected mandatory reductions in annual water use rates by individual irrigators. Representative budget analysis for state and/or local water management agencies with regulatory experience was not available and could not be used as proxy for estimating the cost of new regulatory programs.

The existing institutional structure of state and local ground water management agencies, and their capabilities, vary widely among the six study states. The operational/administrative costs of establishing management and regulatory procedures would therefore vary accordingly and would shift over time with the changing number of irrigation operators and numbers of operational irrigation wells projected for each state and local area or district, for each study period.

On the basis of a projected average annual cost per well of about $50 for administration of Strategy Two 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 quantities could be in the range of $100 to $150 per well, or a total cost of about $20 million or more.

Transition to Dryland Farming

Strategy Two will have two very different effects on the transition to dryland farming. If severe regulatory limits are imposed on ground water usage over a short period of time, farmers will experience severe dislocations. Payments for land and equipment based on full irrigation will be hard to meet if irrigation water supply is restricted below the levels used by efficient farmers in the Baseline or Strategy One. The transition might be sharper than would occur with projected Aquifer exhaustion under the Baseline or Strategy One. The trend towards farm consolidation may also be accelerated by these dislocations. On the other hand, the larger amounts of water remaining in storage as the result of Strategy Two water use restrictions could have the effect of delaying the transition to dryland farming.

National Consumer Price and Export Market Effects

With the cutback in water usage under Strategy Two, regional and national crop production will be reduced and prices will rise. A rough projection is that consumer payments for food will increase about $1 per person at the farm level; perhaps as much as $2.60 per year if intermediate markups are included. The total consumer increase thus ranges from $290 million (at the farm level) to $750 million (including markups). The volume of exports will fall due to higher prices and reduced production, with grain and oil seed exports down 1.4 percent and cotton exports down 1.7 percent in 2020. The total value of agricultural exports then falls about 0.7 percent for a foreign exchange loss of some $365 million on those crops which are staples in the High Plains.

Environmental Effects*

Alternative Strategy Two--Water conservation methods identical to Strategy One. Similar effects on fish and wildlife resources expected on a somewhat magnified scale due to more widespread application.

Institutional Implications

For the purposes of this discussion of the legal/institutional requirements to implement Strategy Two, the Strategy is further defined:

- It is assumed that for regulatory purposes, progressive reductions in amounts of water being pumped from the Aquifer could be quantitatively required for a subregion but not necessarily equally for all individual farmers. This would allow the regulatory authority to consider peripheral but relevant factors

* Excerpted from U.S. Fish & Wildlife Service Report, November, 1981.

such as water conservation measures already in place on the farm; water use efficiency on the individual farm; relative availability of water areally and other factors.

° The subregions for regulatory purposes need not necessarily be coterminous with the subregions defined in other parts of this High Plains-Ogallala Aquifer Regional Resources Study Report, but may represent an already existing substate-entity such as a water conservation district, ground water management district, natural resources district or a new entity not presently in place.

° The goal of Strategy Two is assumed to be to achieve quantitative reductions in water use throughout the Region over time to accomplish the management objective of prolonging the duration of economic availability of water from the Aquifer, rather than an arbitrarily-defined across-the-board regional percentage reduction irrespective of localized Aquifer characteristics and economic conditions.

Regulatory Measures

° A permitting system for ground water as well as surface water would be required to implement Strategy Two. All of the states except Texas have some type of ground water appropriative right mechanism in place, although some would have to effect substantive changes in the statutes to implement Strategy Two.

° A state or a political subdivision would need the power to promulgate rules and regulations regarding beneficial use of water, and the criteria governing the amounts of extraction to be allowed, with broad authority to define and prevent waste. In this manner, states could then judiciously regulate individual farmers by requiring certain levels of efficiency of their operation. With this authority, the state would avoid penalizing an efficient farmer, or, conversely, unduly rewarding the farmer who has failed to adopt the most efficient methods.

° A companion authority would be the power to require those conservation techniques, e.g. high pump efficiency, distribution efficiency; farming practices, etc., proposed for voluntary adoption in Strategy One. With this authority, a regulatory body could require less efficient water users to become more efficient.

° All wells, except small domestic wells, would need to be registered.

° The state would need the flexibility to assign different allowable withdrawals within different areas, rather than assigning a single rate throughout the state or even across an entire aquifer, especially the Ogallala Formation because of its lack of homogeneity. The regulatory agency should have the authority to change allowable withdrawals as and when necessary due to changed conditions, particularly as regards hydrologic changes.

° Although not absolutely essential to the implementation of Strategy Two, consideration should be given to the general concept of requiring water use to be appurtenant to the land and the allocation of a water right based on currently owned irrigated acres; but allow the farmer to use the allocated amount of water on less or more acreage if he desires to do so. This would allow the farmer to optimize the diminished quantity of water allowed him in whatever fashion and on the number of acres he desires.

° Measuring devices would be necessary to enforce regulatory measures effectively, with records of extractions submitted at least semiannually. The regulatory authority would have authority to check the accuracy of the measuring devices and the records submitted. Penalties for willful noncompliance would be needed.

° Regulation of crop types and patterns annually has been suggested. However no mechanism exists at the state level to implement such a scheme except in Arizona. It would be very costly to implement. Further this type of control is essentially applied by the limiting of water availability to the farmer. The more restrictive the requirement, generally the less water demanding crops will be planted.

° Disincentives in the form of penalties for failure to adhere to rules and regulations would be needed by the regulatory entity.

° The state or other management entity would need extensive data management capabilities to carry out regulatory functions properly.

° Adequate funding and staffing would be needed for state and local agencies with regulatory authorities and responsibilities.

Legal/Institutional Changes--Changes in legal/institutional structure, or the initiation of new structures, for management of ground water resources would be necessary in each of the six states to effectuate Strategy Two.

Each state would need a policy that the availability of water from the Ogallala Aquifer is to be prolonged as long as economically feasible by:

° Strict conservation in water use to effect reduction in demand below levels under Management Strategy One.

° Restrictions on extractions to the minimum amounts necessary to maintain economically viable irrigated agriculture on presently irrigated lands.

° Limiting development of new lands for irrigated agriculture.

Amendments to existing statutes, or the enactment of new laws, would be necessary to provide for the regulatory measures outlined above, and to grant adequate authority and delegate responsibility to state agencies and local agencies to carry out the policy.

Implementation of the state policy generally could be through local districts acting under overall state policy and direction. Where local districts now exist, their powers and duties would need to be broadened as necessary, new districts created with adequate powers where none now exist. In the case of New Mexico the State Engineer now has extensive authority, although perhaps not fully adequate to implement the above policy to control ground water usage in designated ground water basins.

MANAGEMENT STRATEGY THREE

Introduction

Management Strategy Three was included to provide a structured element for examining the potential for local water supply augmentation. The results of the analyses indicate that while several technologies offer potential benefits in local areas, they do not provide a major breakthrough in meeting long-range regional irrigation water requirements. Most of those that might result in significant augmentation are as yet largely unproven. Much more research and planning will be necessary before the potential could be assessed. Therefore, the technologies studied were not analyzed by the states through their LP and I/O research, except to the extent that presently applied methods of augmentation were included in the Baseline and water demand management strategy analyses. Other potential techniques and methodologies are described in supplemental reports on Region Study Elements B-3 and B-5. High Plains irrigators have long recognized the importance of water management in their farm enterprises. The extent of incorporation of best available practices in the Baseline is a significant measure of that awareness. The methods of local water supply augmentation showing most promise for the area were examined qualitatively by the General Contractor, and are described briefly below. Some of the on-farm practices described are practiced or may be available as measures to achieve enhanced irrigation and land management efficiencies. However, because they also contribute to recharge and/or conservation of runoff, they are included here as local augmentation possibilities.

Potential Local Water Supply Augmentation Methods

1. Precipitation augmentation and management.

   a. Weather modification technologies. This technology is still in the developmental stage. There are significant legal, institutional, attitudinal, economic and operational problems associated with weather modification which make its wide-spread use as a local water augmentation method difficult and uncertain even if techniques are perfected. For these reasons, it is not anticipated that weather modification will become a significant factor for High Plains agriculture for the foreseeable future.

   b. Snowpack management (both mountainous and plains; quantity and water yield). Technology is emerging for large scale applications of evaporation suppressants to heavy snow areas to increase snow melt and soil moisture augmentation. This technology does not appear to hold significant promise for increasing water supplies for the High Plains region.

   c. Water harvesting techniques, water banking. Water harvesting and water banking techniques do represent potential opportunities for local water supply augmentation in much of the High Plains region. Water harvesting involves trapping local runoff waters from adjacent watersheds and using that water for crop production to supplement ground water use. Water banking is a technique for capturing available surface waters in excess of immediate needs and over-watering areas with favorable infiltration rates. Excess waters are "banked" in ground water storage (by deep percolation) for later recapture.

      Because representative projects are not available for assessment and because the legal/institutional mechanisms are not in place for initiating such projects, no projections of potential local water supply augmentation have been included for this technology by any of the six study states.

   d. Artificial recharge. There are extensive areas in most High Plains states where increased recharge to the Ogallala Formation is feasible (e.g. Nebraska Sand Hills, dune areas in eastern New Mexico and western Texas, etc.). Water rights questions and other institutional and operational constraints preclude any water supply projections from this technology at this time.

2. Land treatment and modification. These are on-site methods for improving effective soil moisture storage and deep percolation on both cultivated and noncultivated areas.

   a. Noncultivated areas - over 100 million acres in High Plains Study Region.

      1) Pitting/chiseling. Land treatment practices to capture more precipitation in-place and increase infiltration are possible through pitting, chiseling, water spreading diversions and

other methods. Such practices on extensive areas would require high cost incentives and are not considered economically feasible at this time.

2) Nonproductive soil moisture loss reductions. A variety of methods are available for managing noncultivated areas to reduce nonproductive soil moisture losses. Maintenance of good rangeland condition (effective ground cover) of native climax forage species through proper grazing management is the best and most dependable method for reducing runoff losses, increasing deep percolation, and improving the productivity of available soil moisture. Removal or control of noxious, nonproductive weeds or deep-rooted brush is another effective moisture conservation practice.

3) Playa lake modifications. Playa lakes or other natural depressions occurring on noncultivated areas throughout much of the High Plains Region can be modified to decrease evaporative losses and/or increase water infiltration as a water conservation method. Modifications include diverting playa waters to nearby cultivated areas, construction of pits to provide deeper, less extensive water areas and thus reduce evaporative losses. Such modifications are practiced widely now, particularly in the southern High Plains.

b. Cultivated areas - projections of up to 38 million acres during the Study period to 2020

1) Deep plowing/clay pan controls. On many soils found in the High Plains region, either a naturally occurring or man-made (plow pan) layer of soil occurs at various depths that restrict soil moisture infiltration, limits effective root zone depths, or otherwise constrains favorable plant-soil-moisture relationships. Conservation practices such as deep plowing or chiseling of such cultivated areas will usually improve plant growth, soil moisture conditions and provide other advantages. Soil surveys prepared by the USDA/SCS are used to identify areas needing this kind of treatment.

2) Terracing/benching/leveling/diversions. Terracing, benching, leveling and other treatment methods can be used to effectively improve soil moisture infiltration, prevent runoff, increase deep percolation and decrease irrigation requirements on cultivated areas. These methods are already applied widely in the High Plains Region.

3) Soil conditioning/mulching. Crop rotations, good residue management, and other methods of improving soil tilth and condition can increase the soil's infiltration capacity. Runoff from excessive rates of precipitation or irrigation is reduced significantly and costs of recapturing runoff waters can be minimized.

4) Basin tillage. A relatively recent innovation in water conservation and supply enhancement is called "basin tillage" or "furrow dyking". An added tillage implement is used during planting to erect small dykes or dams at regular intervals in each row (or alternate rows) which serve to trap water where it falls until full infiltration occurs. This is an effective method of reducing runoff, improving soil moisture in the root zone and conserving excess water through deep percolation. This practice also has both water supply augmentation and water demand reduction advantages.

5) Runoff recovery systems. Growing season rainfall in the High Plains area occurs frequently as intensive short-duration thundershowers which result in runoff regardless of mechanical or cultural control practices. Most High Plains irrigated farms can capture such excess surface runoff by establishing runoff recovery systems carefully designed for local conditions. Where slope and soil conditions permit, multiple opportunities may occur on a single farm to install recovery pits and pump-back facilities.

3. Vegetative Management. Treatment of phreatophytes, deep rooted woody perennials or other noxious plants to minimize soil moisture losses to non-productive uses are possible.

   a. Noxious, deep rooted vegetation control. Several million acres of non-productive vegetation infest areas in the High Plains. Where brush and other perennial woody vegetation like mesquite, shinnery, salt cedar or chaparral have invaded areas overlying the Ogallala, effective control programs can reduce water losses significantly and increase deep percolation but may reduce wildlife habitat.

   b. Phreatophyte treatment, management, or control. Salt cedar, willow and other moist site vegetation can be effectively controlled to reduce very high evapotranspiration losses to these plants. Typically found along stream courses with other riparian vegetation, phreatophytes waste large quantities of water but may provide important wildlife habitat.

   c. Reestablishing native grassland. Where native grasslands can be reestablished on lands overlying the Ogallala formation, increased soil cover, infiltration and deep percolation can effectively reduce runoff from such areas by 50 to 70 percent.

4. Evapotranspiration ET management. Most significant water losses on both cultivated and non-cultivated areas are the nonrecoverable losses due to evaporation (from land or water surfaces) and transpiration by plants. Reduction of evapotranspiration losses may significantly increase soil moisture and deep percolation and decrease the amount of irrigation water necessary to apply.

a. Management and cultural advances. To minimize ET losses in High Plains irrigation without sacrificing yields and farm incomes, a variety of methods can be applied. The selection of crop or crop cultivars with relatively low water requirements; conversion to more water efficient application methods (e.g. low pressure sprinkler methods); the use of reduced or minimum tillage techniques; residue management to maintain significant quantities of previous crop residues on or near the soil surface; basin tillage, terracing, or other moisture management/technological improvements each or collectively offer significant reductions in ET losses and therefore less ground water pumping requirements.

b. Artificial ET reductions. Chemical or other artificial materials are currently being tested for feasibility as evaporation suppressing and/or transpiration retarding qualities. None have been shown to be economically feasible for field crop applications.

5. Conjunctive Uses. Many other potentials exist for capturing and using surface waters conjunctively with ground water to reduce the existing overdraft on the Ogallala. Examples are:

a. Brackish/saline water use; desalting; blending of fresh and saline waters.

b. Playa lake water management; modifications; water harvesting.

c. Wastewater reclamation/reuse (only minor opportunities); but already in practice in local situations.

d. Successive water uses.

e. Modernization of water supply storage and distribution facilities.

A number of the techniques for local water supply augmentation described above are already in use to some degree and in some areas of the High Plains Region. Expanded use of these and future use of certain others have already been incorporated in analyses of Management Strategies One and Two. Further research and planning will be necessary before the potential of still other techniques such as transpiration suppression and use of noncultivated lands and the underlying ground water as a source of supply for irrigated areas can be assessed. Research has been initiated very recently in the High Plains area of West Texas on the possibility of capturing the water held by molecular and capillary forces in the interstices above the water table.

MANAGEMENT STRATEGY THREE - OTHER IMPACTS

Cost Estimates

Although a formal economic impact analysis of the local water supply augmentation technologies considered under Strategy Three was not undertaken (see Chapter Three), the potential for several of the technologies to provide future agricultural water supplies is not minimized. A significantly expanded research and development (R&D) effort would appear to be justified on the basis of current progress with such techniques as precipitation enhancement and management; water harvesting, artificial recharge or water banking; use of brackish and saline waters for agriculture; desalination; noncultivated watershed and vegetative management; and others.

The relative potential or importance of each local water supply technology varies from state-to-state and a regional prioritization of these methods for additional R&D funding is not practical. As a general measure of additional cost for expanded R&D for Strategy Three technologies, the current annual funding level could be increased by three to five percent annually until 1990 (in real terms) and the relative progress and potential for each technology reevaluated at that time. Current levels of agricultural research in High Plains Study states (all sources) of about $20-$25 million annually would thus 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.

Environmental Effects*

Alternative Strategy Three--Some methods similar to those in Strategies One and Two. Effects on fish and wildlife resources vary by method. Level of effects, both positive and negative, intensified in Strategy Three due to emphasis on structural and manipulative measures.

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* Excerpted from U.S. Fish & Wildlife Service Report, November 1981, pp. v, vi and vii, Executive Summary.

- ° Weather Modification--Could benefit fish and wildlife resources in areas of enhanced precipitation. Any net decreases in precipitation experienced in other localities could be detrimental, however.

- °Snowpack Management--Introduction of increased amounts of water to streams and wetlands in northern portion of study area could be beneficial to fish and wildlife resource. However, if coupled with water harvesting and upland wetland modification, detrimental effects would occur.

- ° Water Harvesting/Water Banking--Adverse effects would be expected due to reductions in native prairie, shrub-grassland communities, and riparian zones. Some off-setting benefits could result from creation of aquatic habitat.

- ° Natural Recharge--Depending upon specific techniques used, wetland and/or aquatic habitat could be created with attendant benefits. Loss of native prairie and shrub-grassland habitats could be detrimental.

- ° Land Treatment and Modification (Noncultivated areas)--Pitting and chiseling of selected rangeland sites could be beneficial in increasing water infiltration and enhancement of vegetative growth. Water catchment installation also could benefit wildlife resources in providing water sources and diversifying habitats. Brush control, when properly planned and implemented, also can be beneficial; however, wholesale brush eradication eliminates habitat for most upland species. Upland wetland (such as playa lakes) modifications, if applied on a wide scale, could result in drastic reductions in the value of this habitat to both migratory and resident species.

- ° Land Treatment and Modification (Cultivated Areas)--Deep plowing/clay pan controls likely would have little effect on fish and wildlife resources. Terracing/benching/leveling/diversions could provide indirect benefits through decreasing soil erosion and increasing infiltration. Basin tillage would provide similar benefits. Runoff recovery systems except for upland wetland modification, would provide additional aquatic habitat.

- Noxious, Deep-Rooted Vegetation (Brush) Control--Brush control when properly planned, and implemented, can benefit some segments of the wildlife resource. Wholesale brush eradication however, usually is detrimental.

- Phreatophyte Treatment, Management or Control--Nearly always very harmful to terrestrial wildlife resources due to elimination of riparian habitat values. Stream aquatic habitat may be benefited in localized instances although effectiveness of phreatophyte control in augmenting flows has been questioned.

- Reestablishment of Native Grassland--Possibly most beneficial to wildlife resources of any of the Strategy methods or techniques being evaluated. Would increase and improve habitat for numerous upland species. Care should be exercised, however, in application in shrub-grassland communities.

- Application of Antitranspirants & Evaposuppressants--Effects on fish and wildlife resources largely unknown. Could negatively affect individual animals contacting chemicals. Some aquatic habitats could be rendered unavailable if covered by plastics or similar materials.

- Conjunctive Water Uses--Wetlands and aquatic habitat values of upland wetlands would be reduced to an extreme degree with extensive modification.

- Natural Runoff and Agricultural Tailwaters--Increased modification of upland wetlands likely would occur with effects similar to those resulting from <u>conjunctive water uses</u>.

- Wastewater Reclamation/Reuse--Effects, again, could be localized and dependent upon specific application.

- Use of Brackish/Saline Water, Desalination--Localized effects expected again. Drainage of alkaline or saline upland wetlands could be detrimental, while desalination and use of alkaline or saline ground water could indirectly benefit tailwater habitats.

° Artificial Recharge of Surface Waters--Could result in dewatering of upland and lowland wetlands and streams which would significantly impact important fish and wildlife resources. Degree of impact dependent upon extent of application.

Institutional Implications

Any legal/institutional changes necessary to implement Strategy Three in the six states, would depend upon the local water supply augmentation programs to be undertaken. Several of the possibilities suggested in this report could be undertaken by the individual farmer; for some, incentives such as technical and financial assistance may be necessary to induce early and widespread adoption. Some state agencies and local districts already have the necessary powers to carry out certain augmentation activities requiring community action, if adequately funded and staffed.

Certain large-scale potential augmentation programs, such as desalting of brackish and saline waters, water harvesting and water banking if found possible, would require legislative action to establish requisite policies, authorities (state and local agencies) and funding, possibly with federal financial assistance.

Programs of the U.S. Department of Agriculture involving technical and financial assistance to farmers and local agencies for water conservation, would need to be broadened and additionally funded to include additional water supply augmentation programs such as artificial recharge.

A policy would be needed in each state requiring farmers and local agencies to implement all economicaly feasible measures and programs to augment local water supplies in the High Plains Region, and providing the necessary powers and funding for implementation by state and local agencies.

MANAGEMENT STRATEGY FOUR

In Chapter Three, the underlying assumption identifying intrastate interbasin transfers to be evaluated for their potential to augment local water supply in Strategy Four was defined as those diversions and transfer for which "all decisions and actions required to implement the water transfer are within the power and authority (existing or amended) of the individual state and would not require interstate agreements". Each of the six states examined existing and ongoing state planning results to determine whether surface waters were available in state for diversion to the High Plains Region.

Nebraska and Oklahoma have developed plans for such intrastate diversions and transfers, and therefore included analyses of Strategy Four as an alternative to be considered in meeting long-term water supply needs in their respective states. A diversion of about 200,000 acre-feet per year from the South Platte River for use in the High Plains Region of northeastern Colorado, the Trans-County Project, has been considered and is undergoing further study by Colorado agencies but was not included by the state in its research for this Study. Texas had included in its state plan of 1969 an importation to the High Plains of water diverted from the river basins in northeast Texas supplemented by diversion from the Mississippi River in Louisiana. However, based on subsequent studies, Texas researchers determined that current projections of long-term demands for the water in the eastern basins for inbasin uses and for municipal and industrial purposes in the nearby river basins of Central Texas do not leave sufficient remaining surpluses available for diversion to the High Plains Region. As a result of studies for the Kansas State Water Plan, the State of Kansas had previously determined that there was no surplus surface water available in eastern and central Kansas for transfer to western Kansas. There is very little, if any, water available in New Mexico that might be transferred to the High Plains of eastern New Mexico.

Management Strategy Four - State Plans

Nebraska

Three conceptual schemes for intrastate interbasin diversion and transfers of surplus water from the Niobrara and/or Loup River basins to the Platte, Republican, and Big and Little Blue River basins were developed and evaluated by the Nebraska Natural Resources Commission. These were modifications of schemes originally set forth in the Report on the Nebraska Framework Study, May 1971. Each scheme contains a feature that would transfer water from Lake McConaughy on the North Platte River to the upper part of the Republican River basin. Water diverted from Lake McConaughy would be replaced by water transferred southerly from the Niobrara or Loup River basins.

The physical elements of these three single purpose schemes, together with areas that would be served with irrigation water are shown conceptually on Figures VI-1, VI-2 and VI-3.

Estimated construction and operation and maintenance costs developed by the Nebraska Natural Resources Commission, in terms of 1980 dollars, are presented in Table VI-44*, together with the estimated amounts of water to be delivered based on projected depleted flows in source streams as of 2020 using development in source basins projected under Strategy Two. Annual costs, indexed to year 2000, the projected completion date, are also shown in Table VI-44*. The costs are based on financing under the current criteria and loan rates of the Nebraska Resources Development Fund which are lower than the current federal rate.

The values of surface water used in irrigation by subregion as estimated by the Commission in terms of 1977 dollars are presented in Table VI-45. These estimates equal the differences in net returns to agriculture under irrigated versus dryland conditions.

Comparisons of the water values in Table VI-45 with water costs in Table VI-44 show that costs would be about two to seven times the values. Because of this wide disparity between costs incurred and values received, the Commission concluded that major changes in Nebraska state policies would be necessary before large-scale, intrastate interbasin transfers should be considered further. No additional analyses have been made.

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* Tables in this section. Tables VI-1 through VI-43 are presented in Appendix B.