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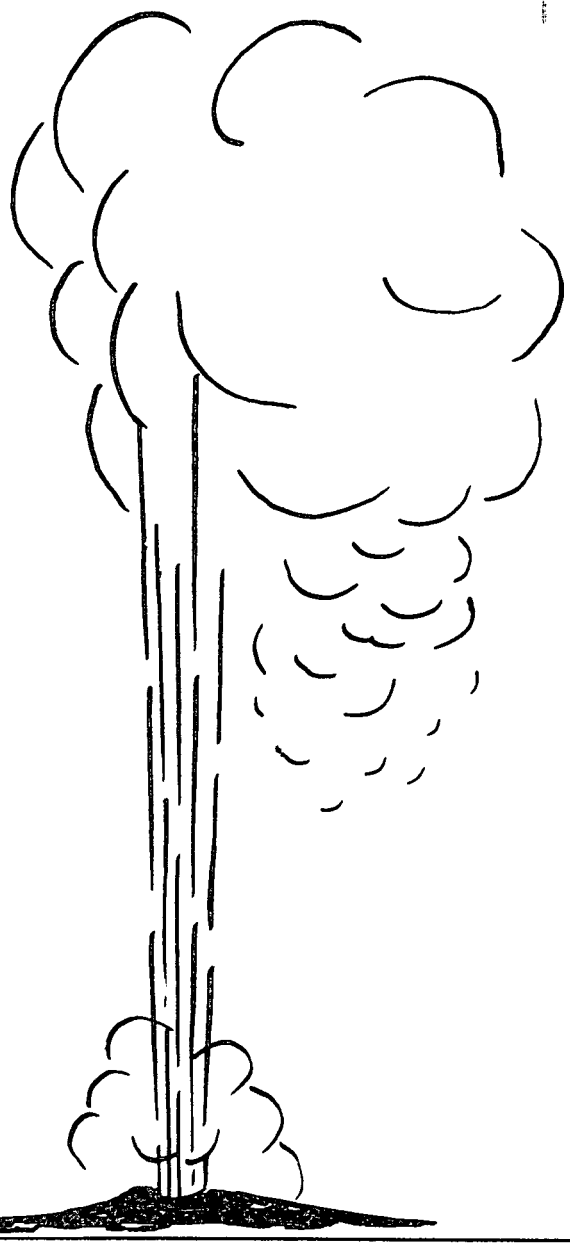
**GEOPRESSURED—GEOTHERMAL ENERGY
DEVELOPMENT: SOCIAL AND ECONOMIC ISSUES**

Geopressed—Geothermal Technical Paper No. 3

July 1979

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The General Land Office of Texas
RPC, Inc.
Austin, Texas



**U. S. DEPARTMENT OF ENERGY
Geothermal Energy**

DEPARTMENT OF ENERGY

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SOCIAL AND ECONOMIC ISSUES

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The General Land Office of Texas
Bob Armstrong, Commissioner

RPC, Inc.
Austin, Texas

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ABSTRACT

This paper presents information relevant to rule-making for geopressured-geothermal development on state-owned lands. The analysis is focused on those potential social and economic effects of resource development, if any, which may require special attention during the leasing and permitting process.

For the most part, many of the expected socioeconomic impacts are not unique to geothermal development, but are already being felt by residents of the fairways because of ongoing developmental activities. The social and economic impacts likely to result from resource development depend upon characteristics specific to the site and surrounding social and economic systems. Specific impacts and their probability, magnitude, and duration can only be determined through a case-by-case analysis.

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This technical paper is one of a series of four papers in which the legal, financial, socioeconomic, and ecological aspects of geopressed-geothermal resource development on Public Free School Lands are discussed.

Many individuals contributed to the production of this paper. The project manager was Ann Orzech. Principal investigators were Leah Pagan and Barbara Haefeli. The technical editor was Nancy Grona; production assistance was provided by Kyle Pierce and Lori Snyder. The cover was designed by Kyle Pierce.

Ronald T. Luke
President
RPC, Inc.

1. INTRODUCTION

The purpose of the social and economic analysis was to identify the types of socioeconomic impacts likely to result from geopressured-geothermal energy development. Specifically, since the objective of this study is to produce information relevant to rule-making for geopressured-geothermal development on state-owned land, the focus of the analysis was on determining those potential social and economic effects of resource development, if any, which are sufficiently different from the effects of other types of development such as to potentially require special attention during the leasing and permitting process.

The analysis was based on production levels postulated for each of the fairways of the Frio Formation containing substantial portions of Public Free School Lands. These fairways are the Brazoria, Matagorda, and Corpus Christi Fairways. The scenarios were derived from work performed at the Center for Energy Studies (Zinn, 1977). To ensure that all types of socioeconomic effects associated with geothermal development were identified, the scenarios were chosen to represent the maximum projected development that might occur based on the potential productivity of the brine-holding sand reservoirs that underlie the fairways.

Recent conversations with staff of both the Center for Energy Studies (CES) and Bureau of Economic Geology (BEG), both at the University of Texas at Austin, suggest that sufficient resources to sustain the postulated maximum production levels probably do not exist on the three selected fairways, especially on the state-owned portions. The areas that appear to best meet criteria established by CES/BEG for commercial geopressured-geothermal production are the upland (not state-owned) portions of the Brazoria Fairway.

During the analysis, it became obvious that many of the anticipated geopressured-geothermal resource development activities are similar to other energy development activities already occurring along the Texas coast. The drilling procedures and equipment used in the exploitation of this resource, for example, are expected to be identical or very similar to those employed in oil and gas production. Table 1 lists the yearly number of oil and gas wells drilled between 1970 and 1977 in the counties encompassing the three fairways. For Brazoria and Corpus Christi Fairways, the numbers of wells postulated for a single power plant facility equal 5 percent and 10 percent, respectively, of the numbers drilled in 1977; the percentage for Matagorda Fairway is 47 percent.

For the most part, many of the expected socioeconomic impacts are not unique to geothermal development but rather are those already being felt by residents of the fairways due to ongoing developmental activities.

Table 1

TOTAL OIL AND GAS WELLS DRILLED
IN COUNTIES ENCOMPASSING FAIRWAYS
1970-1977

Year ^a	Fairway		
	Brazoria (Brazoria, Galveston Counties)	Matagorda (Matagorda County)	Corpus Christi (Aransas, San Patricio, Nueces Counties)
1970	103	71	198
1971	100	46	195
1972	103	57	210
1973	107	57	166
1974	121	58	222
1975	138	50	209
1976	145	63	208
1977	194	57	263
8-Year Average	126	57	209
Postulated Wells Per Single Geothermal Facility Number ^b	9	27	27
Percent of Wells Drilled in 1977	5%	47%	10%

^aTexas Mid-Continent Oil and Gas Association, personal communication, February, 1979.

^bZinn, 1977

Chapter 2 summarizes the findings of the social and economic analysis. Chapter 3 describes the potential social and economic impacts of geopressured-geothermal development, focusing particular attention on those effects which may require special consideration, at least during the initial phases of development.

Of necessity, the analysis includes only a generalized description of impacts. As more information concerning the resource becomes available and as specific development projects are proposed, site-specific social and economic effects assessments may be undertaken; such a site-specific assessment would provide the basis for the leasing and permitting of each proposed resource development program. Appendix A discusses methodologies and models which could be employed in such a case-by-case effects assessment.

2. SUMMARY OF FINDINGS

Three major benefits resulting from geopressed-geothermal energy development on Public Free School Lands (PFSL) were identified:

1. Geothermal development would make available an alternative energy source for residential and industrial consumption.
2. Leasing of PFSL for development would provide additional funds for the Texas public education system.
3. Natural gas occupation tax revenue accruing to the State Treasury would increase as a result of application of the tax to the value of methane contained within the geothermal brine.

Effects of potential resource development on many factors are not unique to geothermal development but rather are those likely to be associated with any development activity. These factors are:

1. Employment
2. Regional output
3. Personal income
4. Local government finance
5. Municipal infrastructure
6. Transportation
7. Recreation
8. Historical/archeological resources

Based on the ecological analysis and on geothermal development in other areas, the social and economic effects of certain aspects of geopressed-geothermal energy development were identified as potentially requiring special consideration, at least during the initial phases of development:

1. Water consumption during plant operation
2. Air emissions during production and plant operation
3. Noise, especially during field exploration and development
4. Surface water contamination due to accidental brine discharges and sub-surface contamination of water reservoirs
5. Subsidence/fault activation during well drilling and field production
6. Land use implications of all phases of geothermal development
7. Personal safety hazards related to blowouts during well drilling and production
8. Sociocultural impacts associated with development of a new type of energy

These aspects were the subject of more detailed analysis in the study. Of these, the analysis indicated that subsidence/fault activation has the greatest potential for serious socioeconomic effect.

The social and economic impacts likely to result from resource development depend upon characteristics of the development site and surrounding social and economic systems. While the analysis indicated the general kinds of impacts likely to result from resource development, specific impacts and their probability, magnitude, and duration can only be determined through a case-by-case analysis.

3. DISCUSSION OF IMPACTS

This chapter describes the potential social and economic effects of geopressed-geothermal resource development. First, major benefits resulting from development on PFSL are presented; second, those impacts which are similar in type and magnitude to the impacts of other energy development activities (particularly oil and gas development), and which thus will probably not require special attention during the leasing and permitting process, are outlined; finally, those effects which may demand special consideration, at least during the initial phases of development, are discussed.

BENEFITS RESULTING FROM RESOURCE DEVELOPMENT ON PFSL

The availability of an alternate energy source for residential and industrial consumption is a major benefit of geopressed-geothermal resource development and is one with potentially significant economic implications for both the regional economies and the nation. The importance of this benefit was confirmed by an attitudinal survey of citizens in Brazoria County: 42 percent of the sample listed geothermal energy as a much-needed resource to help alleviate energy shortages (Lopreato and Blisset, 1977).

In addition, the state government should realize an increase in revenue from two sources. First, leasing of PFSL for geopressed-geothermal resource development would provide additional funds for the Permanent Free School Fund. Assuming the optimistic production scenarios, a thirty-year production period, and a royalty rate of 12.5 percent, lease bonus payments and royalty revenues from production of brine and methane from the wells associated with a single power plant facility could approximate \$138 million for the Brazoria Fairway, and \$39 million for the Matagorda and Corpus Christi Fairways. Second, methane recovered from geothermal brine will probably be subject to the natural gas occupation tax; the tax rate presently equals 7.5 percent of gross receipts. Again, assuming optimistic production scenarios, a thirty-year production period, and an initial price of methane of \$2 per MCF, occupation tax revenues from wells associated with a single facility could total \$59 million for the Brazoria Fairway, and \$15 million for the Matagorda and Corpus Christi Fairways.

GENERAL SOCIAL AND ECONOMIC EFFECTS

Many potential social and economic impacts of geopressed-geothermal resource development are expected to be similar in type and magnitude to effects of

other energy development activities occurring in the coastal area. These should not require special attention during the leasing and permitting process.

Economic Impacts

Major impacts on the regional economies expected as a result of geopressured-geothermal development are beneficial increases in total economic activity (output), personal income, and employment. While total output, income, and employment should increase, the values of specific sectors displaced by geothermal development, if any, may fall. Agricultural output and income would decrease as a result of resource development, for instance, to the extent agricultural land is taken from production. These effects are the same type that would be expected to result from any change in economic activity in an area.

The magnitude and incidence of the impacts on the local and regional economies will vary according to the residence choices of new resident-workers, and during construction, according to the location of the contracting firm. As an example, in the case of the Corpus Christi Fairway, a drilling firm located in Corpus Christi (a "local" firm) can be expected to spend a greater percentage of its expenditures within the Corpus Christi area than would a firm from Beaumont. And, while the local firm's labor force would be drawn almost entirely from the local labor pool, the non-local firm would tend to bring into the area skilled operators while hiring unskilled workers locally.

Direct employment associated with geothermal development was estimated in order to determine if employment build-up, especially during construction, might cause any special problems. The estimates are presented in Appendix B and are based on the postulated production scenarios. Neither the magnitude nor phasing-in of manpower requirements for a geopressured-geothermal project would seem to create any special difficulties.

Local governments should experience increased tax revenue and infrastructural costs as a result of geopressured-geothermal development. Again, these effects would be associated with any type of economic activity. The former will occur due to the employment and income generated by development activities, and the latter as a consequence of expanded demand for public services by the new-resident population. The net effect on a given unit of local government will depend on the extent to which expenditures are made and new-resident employees and their families locate in the community.

The specific community response to increased service demands will also vary among jurisdictions according to the degree to which facilities and services are currently used, the community's ability to finance capital improvements and expanded service levels and the desires of the electorate. Certain communities may choose to meet increases in public service demands with existing facilities and personnel; any strain on public facilities and services would then be reflected in a decrease in the level or quality of services provided rather than in increased expenditure levels.

Social Impacts

An influx of new-resident workers and their families to within commuting range of the geothermal well and plant sites will increase demands on the infrastructure of the communities in which the new residents locate, as indicated in Figure 1. The types of facilities and services for which demand is likely to increase include:

1. Housing
2. Education
3. Law enforcement services
4. Fire protection
5. Health care facilities and personnel
6. Municipal water supply
7. Wastewater treatment and disposal
8. Solid waste disposal

The infrastructural impacts are the same as for any development activity with associated population change due to new-resident workers and their families moving into a community.

Maximum geothermal-related population increases as a percentage of projected population for those counties encompassing the fairways are estimated in Table 2. Percentage changes are estimated for the maximum population increases associated both with a single power plant and related facilities, and with development of PFSL as postulated in the production scenarios. As discussed in Appendix B, it is assumed that 85 percent of project-related employees will be new-resident workers. For all fairways, the percentage changes in regional population are insignificant.

While regional population changes are expected to be minor, the change for a given community may be significant. The communities close to or in the three fairways are listed in Table 3; these jurisdictions will most likely experience the population changes and thus feel the infrastructural impacts of geopressured-geothermal development. The magnitude of the impacts on any one community will depend in part upon present community size and current utilization and capacity levels of the infrastructure. That is, a small town far from any large population centers would tend to be more greatly affected than a large city; and a community with facilities which are already overburdened will be more greatly affected than one in which the facilities are underutilized.

An increase in automobile and truck traffic can be expected on the road segments leading to the well and plant sites. Road damage due to materials delivery, especially during the construction phase, is a potential project impact.

The Texas Geothermal Act precludes the School Land Board from leasing for geopressured-geothermal resource development PFSL that include wildlife refuges or recreational areas. And, according to the Antiquities Code of Texas, the Antiquities Committee is the legal custodian of all cultural resources, historic and prehistoric, within the public domain of the state of Texas; the committee thus has the responsibility of protecting these resources on PFSL. Consequently, neither recreation areas

Figure 1
DERIVATION OF IMPACTS ON MUNICIPAL
INFRASTRUCTURE

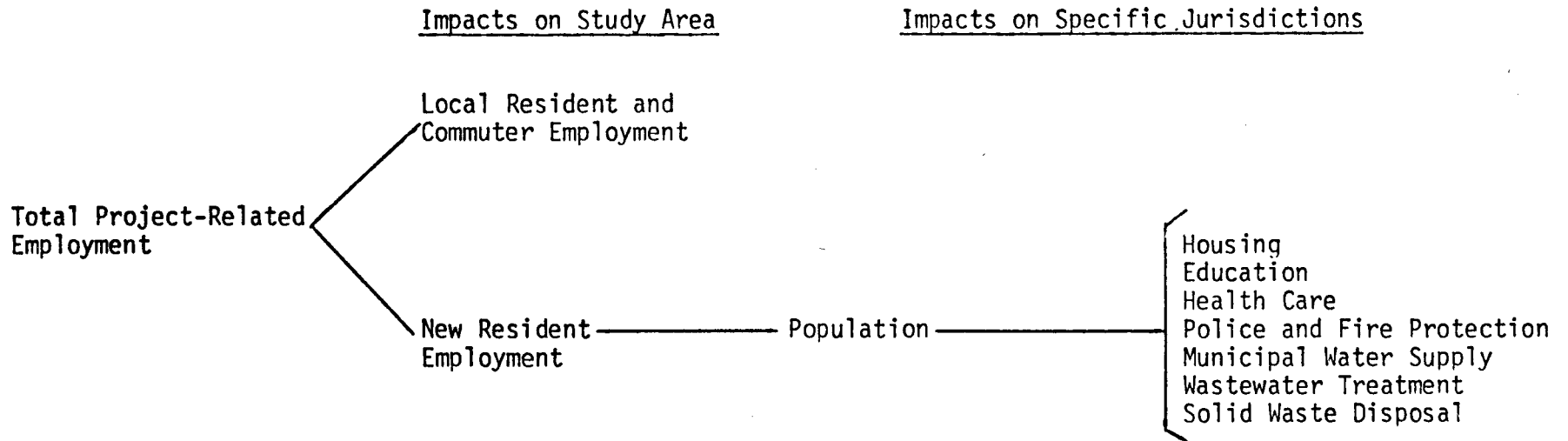


Table 2

COMPARISON OF PROJECT-RELATED NEW POPULATION
WITH ESTIMATED POPULATION
OF COUNTIES ENCOMPASSING FAIRWAYS

	Fairway		
	Brazoria (Brazoria, Galveston Counties)	Matagorda (Matagorda County)	Corpus Christi (Aransas, San Patricio, Nueces Counties)
Projected Population ^a			
1980	337,800	30,700	341,900
1990	405,800	33,400	389,500
2000	451,200	36,300	444,900
Projected Peak Change in Population Due to Geo- thermal Development ^b			
Single facility	518	518	518
Total PFSL Development in Fairway	995	803	1,320
Population Change As Percent of Projected Population ^c			
Single Facility	0.15%	1.69%	0.15%
Total PFSL Development in Fairway	0.22%	2.40%	0.34%

^aTexas Water Development Board. Population Projections. Austin, Texas: Texas Water Development Board, November 1976.

^bAssumes 85 percent of direct employment will be new-resident workers. See Appendix B for a discussion of employment requirements for each fairway. New population is the product of new-resident employment and the July 1978 ratio of state population to employment.

^cPercentage for single facility is for the year 1980 for all Fairways. Total PFSL development percentage for Brazoria Fairway is for the year 2000; Matagorda and Corpus Christi Fairways, 1990. These years approximate the year of peak employment for each fairway.

Table 3

COMMUNITIES LIKELY TO BE MOST IMPACTED
BY GEOPRESSURED-GEOTHERMAL DEVELOPMENT
ON PUBLIC FREE SCHOOL LANDS

<u>Fairway</u>	<u>County</u>	<u>City</u>
Brazoria	Galveston	Galveston Texas City
	Brazoria	Angleton Brazosport*
Matagorda	Brazoria	Brazosport*
	Matagorda	Bay City Matagorda Palacios
Corpus Christi	Refugio	Rockport Fulton
	San Patricio	Aransas Pass Port Aransas Ingleside Portland Taft Gregory
	Nueces	Corpus Christi

*Brazosport is a name given to these closely associated municipalities: Jones Creek, Lake Jackson, Clute, Freeport, Richwood, Brazoria, Quintana, Surfside and Oyster Creek.

nor historic/archeological resources should be directly impacted by geothermal development on PFSL. Recreation may be indirectly affected, however, in two ways: first, an expanded population may increase demands for regional and local recreational facilities; second changes in land use of adjacent private lands due to geothermal-related development may decrease the opportunities for certain types of recreational activities (for example, hiking or hunting).

SPECIAL ISSUES

The social and economic effects of certain aspects of resource development were identified as being sufficiently different in magnitude or type from other developmental activities so as to potentially warrant special consideration, at least during the initial phases of development. These aspects are:

1. Noise, especially during field exploration and development
2. Air emissions during production and plant operation
3. Water consumption during plant operation
4. Potential surface water contamination due to accidental brine discharges, and subsurface contamination of water reservoirs
5. Potential subsidence/fault activation during well drilling and field production
6. Land use implications of all phases of geothermal development
7. Personal safety hazards related to potential blowouts during well drilling and production
8. Sociocultural impacts associated with development of a new source of energy

These issues were identified based on the ecological analysis and on an examination of geothermal development in other areas. (See Geopressured-Geothermal Technical Paper No. 4 for more information concerning the potential ecological impacts of resource development.) Of these, subsidence/fault activation has the greatest potential for serious socioeconomic effect.

Air Emissions

During the exploration phase of geopressured-geothermal resource development, the major sources of air emissions are the gases and vapors released during the drilling and testing of wells. During the operational phase, hydrogen sulfide (H_2S) is carried along with the steam when flashing occurs. Emission controls should be quite effective for condensable and some reactive gases and vapors. In nonflashing systems, such as a binary fluid system, the sulfide may not escape from the water and could be reinjected.

It is assumed that present air quality and emissions standards must be met for development to occur. Studies to date indicate that it is unlikely that H₂S emission will cause significant ecological or health effects, but its odor presents a major nuisance that is unacceptable to the public (USDOE, 1978).

The major potential social and economic effect of air emissions associated with resource development concerns aesthetics. Determining specific impacts of changes in air quality on aesthetics is highly subjective, especially given the range and variety of development activities in the scenario areas. Residents in truly pristine rural areas, for example, may view any associated air quality changes as negatively impacting aesthetics. The release of odorous compounds, such as H₂S, and visible compounds, such as carbon dioxide (CO₂), tends to be more noticeable in rural areas than release of these compounds in urban areas where industrial and vehicular activity is already impacting air quality.

However, rural residents may be willing to bear aesthetic changes in their environment in order to reap economic benefits. In the fairway areas, where oil and gas production is commonplace, the impact of geothermal development on air quality may prove indistinguishable from emissions from other types of development activity. The only means of determining the aesthetic impact of air quality changes is discussion of potential changes in a public forum with impacted residents present.

Noise

Noise will be generated by a wide variety of activities and operations during all phases of large-scale geothermal development projects. Depending on the development activity and distance from noise source, persons in the vicinity of a site may be exposed to noise at levels varying from 40 to 120 decibels. The noisiest activities are drilling and construction. Ambient noise levels for an operational geopressured-geothermal field has been estimated at 40 decibels (USEPA, 1977). In comparison, ambient levels for undeveloped land (for example, marsh, beach) and agriculture have been estimated at 35 and 40 decibels, respectively (Fabos and Caswell, 1977).

The potential noise levels associated with certain developmental activities may significantly impact nearby residents, especially in rural areas. Noise is a pervasive impact directly affecting the quality of individuals' lives, and one that many individuals find objectionable, especially if the source is located near homes. The character of the surrounding area, the informed opinion of the public, and the level and duration of noise involved in a development project, should be carefully considered during site-specific impact assessments.

Water Consumption

Water will be required by the power plants for cooling purposes. The amount of water required depends largely on plant design. For example, a binary cycle plant would require twice as much cooling water as other types of plants.

Cooling water can be provided to a geothermal site in three ways:

1. A "once through" cooling system, in which external water, frequently from a river or lake, is used once for cooling and then discharged to its source (direct transfer of heat to a body of water)
2. An evaporative cooling tower, in which the external water is evaporated to the atmosphere
3. A dry cooling tower, in which the fluid is cooled by air and continually circulated in a closed system (direct transfer of heat to the atmosphere)

The water requirements for these systems vary widely. Once-through systems and wet cooling towers require substantial amounts of water. Dry cooling towers require very little water.

Water consumption is a potential problem associated with geothermal development. Depending on the cooling technique, water requirements for a 50 Megawatt (MW) plant may range from 38 acre-feet-MW-year to 113 acre-feet-MW-year (Underhill et al., 1976).

The availability of suitable water is a matter of concern in many areas of the Texas coastal region. For instance, projections of water supply and demand by the Texas Water Development Board (1977) indicate that by 2000 shortages of water for irrigation are expected for the coastal region between the Nueces and San Jacinto rivers. This area includes all of the Brazoria and Matagorda Fairways, and most of the Corpus Christi Fairway. Depending on the availability of water near a specific site, it will be necessary to consider water consumption in the design of the plant in order not to harm future business and industrial activity in the area. If substantial quantities of fresh water are required by the power plant, potential social and economic impacts of geothermal development include the exclusion of other types of development with heavy water requirements.

Subsurface and Surface Water Contamination

Geopressured-geothermal resource development may affect both subsurface and surface water quality. Subsurface brine discharges and resulting contamination of groundwater reservoirs may be brought about by drilling pipe or casing leaks and leaks through uncased intervals in improperly plugged wells. Corrosion, blowout damage below ground, and movement along intersected faults are the most likely causes of leaks. The risk of subsurface brine discharges in conjunction with geothermal resource development is particularly great because of the large volume of brine involved and its toxicity and high pressure. Such contamination, however, can be prevented almost entirely through proper use of current technology.

State and federal regulations currently exist which control the surface discharge and reinjection of brine. Nevertheless, surface land and water may be contaminated as a result of the accidental surface discharge of geothermal brines due to well blowouts, pipeline leaks or breaks, failure of storage facilities, and through accidents in the gas separation and power generation facilities. Of the types of accidents just mentioned, well blowouts during the early stages of development drilling are the most unpredictable and are potentially of the greatest magnitude. Postulated well flow rates range from 40,000 to 128,000 barrels of brine per day. As discussed in Technical Paper No. 4, a blowout from a well may remain out of control for months, and could release 4 to 16 acre-feet of brine per day.

Decline in water quality of surface water or groundwater can have both short-term and long-term social and economic consequences. First, contamination of water may, depending on the degree, threaten the health and safety of individuals. Second, brine-related accidents, particularly well blowouts, could impact aesthetics through destruction of vegetation or could have an economic impact on nearby landowners, particularly if the land affected is used for agricultural cultivation or grazing.

Subsidence/Fault Activation

Subsidence is potentially a serious consequence of geothermal resource development along the Texas coast. The probability that subsidence will occur, the areal extent, the magnitude, and the rate of subsidence depend on a number of factors, including the size and geologic properties of the geothermal reservoir and the geologic properties of strata surrounding and underlying the reservoir. Subsidence could occur over an area equal to that of the portion of the reservoir from which fluids are withdrawn. Over the long projected production life of a geothermal production reservoir, some elevation loss could be expected over the entire reservoir. The amount of subsidence, though, would normally tend to decrease laterally from the well.

Fault activation is another potential ecological effect of resource development. The activation process is identical to production-related subsidence, and the rate and cumulative extent of fault movement at a given location is closely related to local subsidence. While there is no clear indication that geothermal resource development along the Texas coast would either result in or be seriously affected by fault activation, such activation on the Texas Coastal Plain is very often the result of groundwater withdrawal and is less often associated with oil and gas production.

Subsidence in particular has the potential for serious social and economic effect on both current and future development in the affected area. First, subsidence increases the potential for flooding of existing development, posing hazards to life and property, especially given hurricane activity within the scenario areas. Second, fault activation and subsidence may affect the structural foundation of existing structures and constrain new development due to shifting and flooding. The economic consequences of these impacts include loss of property, decline in property value, and revenue losses to both individuals and communities. Depending upon the severity and magnitude, these impacts may threaten personal safety and contribute to a decline in the quality of individuals' lives.

The areas most likely to be affected by subsidence in the Matagorda Fairways and the middle to western portions of the Brazoria Fairway are primarily rural agricultural areas. Subsidence in these portions would thus be likely to affect isolated industrial, residential, and agricultural structures, roads, and pipelines. The Corpus Christi Fairway and eastern portion of the Brazoria Fairway are more heavily developed. Subsidence in these areas could potentially affect significant population and industrial centers, causing major property damage.

Land Use

The amount of land required for any one geothermal facility, including associated well and pipeline rights-of-way is small: 178 acres for the Brazoria Fairway, and 515 acres for the Matagorda and Corpus Christi Fairways (Underhill et al., 1976; Texas General Land Office, 1978a). Estimates of the total acreage potentially devoted to geothermal energy extraction, assuming extensive development of the resource, are presented in Table 4.

Most of the PFSL potentially affected by geothermal development are wetlands or bay waters. Development of the resource on PFSL is expected to have a minimal direct impact on land uses of state lands. Development may, however, indirectly affect adjacent private lands.

Current land uses of adjacent lands vary greatly, as indicated by regional land use maps (GLO, 1975). These include residential, industrial, and commercial development, cropland, rangeland, woodland, and marshland. The potential environmental impacts associated with development of the resource, including subsidence, fault activation, and brine accidents could render adjacent or nearby land unsuitable for certain types of uses.

Since much of the potentially affected PFSL and adjacent lands are used for farming and ranching, resource development may have the greatest impact on farming and ranching activities. As noted by Letlow et al. (1976), farmers and ranchers, while unlikely to oppose development as a group, nevertheless tend to view geothermal development as simply one of many more activities which are, in their totality, reducing agricultural land availability. Development of all types has slowly eroded the amount of land in Texas available for farming and ranching during the last century, with both social and economic consequences, since farming and ranching represents a lifestyle as well as a major income source to many individuals.

A word of caution is in order. Available land use maps represent generalized information which should be used only as a regional overview of resources and not for on-site decision-making. While general effects are noted above, specific land use impacts of geothermal development can only be determined with a survey of the site and adjoining land.

Table 4

ESTIMATED ACREAGE REQUIRED FOR PLANTS,
WELL SITES, AND PIPELINE RIGHT-OF-WAY*

<u>Fairway</u>	<u>Plants Serviced By Wells In or Adjacent to PFSL and Associated Facilities</u>	<u>Total Fairway Development</u>
Brazoria	1,068	2,848
Matagorda	2,060	3,090
Corpus Christi	4,120	4,120

*Based on Texas General Land Office, 1978a; Underhill et al., 1976; Zinn, 1977. Acreage requirements represent optimistic development scenarios.

Personal Safety

As discussed above, there is a danger of well blowouts during well drilling and production. Such blowouts potentially threaten the safety and health of individuals. The safety hazards associated with wells drilled on PFSL, however, should normally affect only geothermal workers.

Sociocultural Effects

The sociocultural impacts of geothermal development or any development activity refer to project-related effects on interactions among and perceptions of individuals or groups. Substantial portions of the study area, especially the Matagorda Fairway, are primarily rural and thus more susceptible to sociocultural impacts.

Two distinct levels of sociocultural impacts exist: the individual, familial level, and the group or community level. Obviously, there is a great deal of interaction between these two levels. For example, the reaction of individuals to projects they define as aesthetically unappealing may have political repercussions within a community. These individuals' common interest may draw them together and encourage them to participate more actively in local government. Or, a development project may fill a small community's streets with strangers. The long-time residents may feel disenfranchised and withdraw from political life in the community. A new political hierarchy may form consisting of distinctly different individuals. Or, both could occur simultaneously. (See, for instance, Finsterbusch and Wolf, 1977, and Fitzsimmons et al., 1975, for a discussion of sociocultural impact assessment.)

A project's potential sociocultural effects thus depend to a large degree on the attitudes and perceptions of individuals and groups. The attitudinal work performed to date indicates that the public may have misconceptions as to the benefits and costs of a geopressured-geothermal project. For example, these researchers found that 15 percent of the sample believed that it is a cheaper energy source which might decrease utility bills or consumer price (Lopreato and Blisset, 1977). In fact, this has not been shown to be true. The investigators also found that residents along the Texas coast now are generally receptive to geothermal development.

Those attitudes may be somewhat contingent upon environmental effects since many of the respondents simply did not know what such effects might be . . . it is safe to assume that for the most part local citizens will continue to be amenable to resource development if they feel that the environmental concerns are being taken care of. And, they are most likely to feel that way if they are well informed and involved in the planning process (p. 39). (Emphasis added.)

In short, there may be sociocultural impacts associated with geothermal development, particularly if those potentially affected are misinformed concerning a project's benefits and costs. The exact nature of such impacts, however, can be determined only on a case-by-case basis with the aid of an appropriately trained social scientist.

The need for such a social scientist to assist in a sociocultural impact assessment should be emphasized. For instance, even the indicators generally accepted and used for sociocultural effects assessments (quality of life, family stability, community cohesion) are difficult to apply. The major obstacles are the general lack of adequate baseline data, the cost of acquiring such data, and the individualized nature of these impacts. The applicable set of indicators for a specific assessment can be determined only on a case-by-case basis by a competent investigator.

APPENDIX A

A Discussion of Methodologies for Site-Specific Social and Economic Impact Assessment

INTRODUCTION

The social and economic factors normally included in a socioeconomic impact assessment are listed in Table A1. For convenience, these can be grouped into three categories: economic, social/infrastructural, and sociocultural. In addition, the social and economic consequences of identified environmental effects should be examined; in the case of geopressured-geothermal development, the environmental effects likely to have socioeconomic impacts include air emissions, water quality, and subsidence/fault activation.

Prior to any assessment, the impact area must be defined. Depending on the nature of the impact factor and of the project, impact may be appropriately assessed for multi-county areas, cities, school districts, or other subcounty areas. For the social/infrastructural factors especially, impacts on each factor should be projected where feasible for the units of government with responsibility for provision of that service.

The appropriate time framework for analysis must also be determined. For projects expected to have long-term effects, a projection of conditions in the study area without the project ("without-project future") should be made in order to provide a meaningful basis for comparison of project impacts.

In this appendix, methodologies for the assessment of the economic and social/infrastructural factors are suggested. Methodologies for a sociocultural analysis, however, are not discussed. Rather it is recommended that a sociocultural analysis be undertaken only under the auspices of an appropriately trained social scientist and include the collection of adequate data on the attitudes and lives of impacted residents.

Much has been published on socioeconomic impact assessment in recent years; Table A2 presents some of the more widely known assessment models. Because of the number of available models and methodologies, all cannot possibly be examined in this report. The reader is referred to the literature for more detailed information concerning specific models.

One model, the social and economic component of the activity assessment routine (SEC), is discussed in some detail. This model was developed under the Texas Coastal Management Program for use by the Texas General Land Office during the permitting process in determining the socioeconomic impacts of developmental activities in the Texas coastal region.

Table A1

SOCIAL AND ECONOMIC FACTORS NORMALLY
CONSIDERED IN AN IMPACT ASSESSMENT

I. Economic

1. Personal Income
2. Employment
3. Output
4. Industrial Water Use
5. Fiscal Impacts

II. Social/Infrastructural

1. Population
2. Housing
3. Education
4. Health Care
5. Police and Fire Protection
6. Municipal Water Supply
7. Wastewater Treatment and Disposal
8. Solid Waste Disposal
9. Transportation
10. Recreation
11. Visual Aesthetics
12. Historical/Archaeological Resources
13. Land Use
14. Noise
15. Safety

III. Social/Cultural

1. Quality of Life
2. Community Cohesion
3. Attitudes

Table A2

SOCIOECONOMIC IMPACT ASSESSMENT MODELS

<u>Name</u>	<u>Reference</u>
1. ATOM 3	Beckhelm et al., 1975
2. BOOM 1	Ford, 1976 <u>a</u> and 1976 <u>b</u>
3. BREAM	Mountain West Research, 1978
4. CLIPS	Monts and Bareiss, 1979
5. CPEIO	Monarch and Taylor, 1977
6. HARC	Cluett et al., 1977
7. MULTIREGION	Olsen et al., 1977
8. NAVAHO	Reeve et al., 1976
9. NEW MEXICO	Brown and Zink, 1977
10. RED-II	Hertsgaard et al., 1978; Leistritz, et al., 1978
11. SEAM	Stenehjem, 1978
12. SEC	Texas General Land Office, 1978 <u>b</u>
13. WEST	Denver Research Institute, 1979

METHODOLOGIES FOR ECONOMIC FACTORS

There are three major economic frameworks or classes of models that have been used for economic impact assessment. They are export-base models, input/output (I/O) models, and regional econometric models. While these classes of models are not necessarily unrelated, they do have certain unique characteristics which should be identified and evaluated for use in a given assessment.

Multipliers can be derived through use of the export-base and input/output analyses. These multipliers are then used to estimate total changes in regional income, output, and employment as a result of a project. The input/output framework has also been used to derive water-use and tax revenue multipliers, thus permitting an estimate of total tax revenue and water use resulting directly and indirectly from a given development activity. Regional econometric models are most often used to simulate the behavior of the regional economy under a variety of assumptions about the values of the exogeneous variables. In this manner, statements are made about the impacts of certain changes on the regional economy.

Each of the models listed in Table A2 uses either export-base or input/output analyses. The SEC, for example, employs regional input/output models; use of the models permits the determination of project impacts on the five economic factors listed in Table A1. (For more information, see Texas General Land Office 1978b, 1978c, and 1978d.)

The SEC can be used to calculate the fiscal impacts for the state government and, in aggregate, for all local governments within the I/O region. A number of approaches that may be used to determine fiscal impacts on individual communities are fully described in Burchell and Listokin (1978). In addition, the industrial impact model, prepared by Dr. Ronnie Jones, Texas A&M University, can be used to determine the benefits and costs of operation of an industrial plant to three sectors of a community's economy.

METHODOLOGIES FOR SOCIAL/INFRASTRUCTURAL FACTORS

POPULATION-RELATED FACTORS

Project impacts on certain of the social/infrastructural factors listed in Table A1 are population-related in the sense that new demands on a community's infrastructure as a result of a project depend directly on the number of new residents the community must provide services to.

Those "population-driven" factors are:

1. Population
2. Housing
3. Education
4. Health care
5. Police and fire protection
6. Municipal water supply
7. Wastewater treatment and disposal
8. Solid waste disposal

The underlying process and assumptions used in many assessment models to determine impacts on these factors is shown graphically in Figure A1. First, total project-related employment is estimated. Then the number of workers who are likely to be new residents to the study area is estimated. In the third step, the new-resident employment is allocated to specific cities in the study area through a gravity model or some other means, and the expected change in population is derived. Finally, project-induced service demands are projected, the new levels of demand are compared with current or "without-project future" service levels, and the capability of the impact area to absorb impacts is determined.

Any of the models listed in Table A2 may be used to determine impacts on some or all of the population-related factors. The SEC, for instance, provides a standard routinized way to assess major infrastructural impacts (Texas General Land Office, 1978b and 1978e). The SEC is based on the assumption that the project under consideration will be built or operated as soon as possible, and that current conditions are the "without-project" conditions. If the operation phase of a project is not scheduled to begin for a number of years, projections of infrastructural services should be used as a baseline rather than current conditions.

TRANSPORTATION

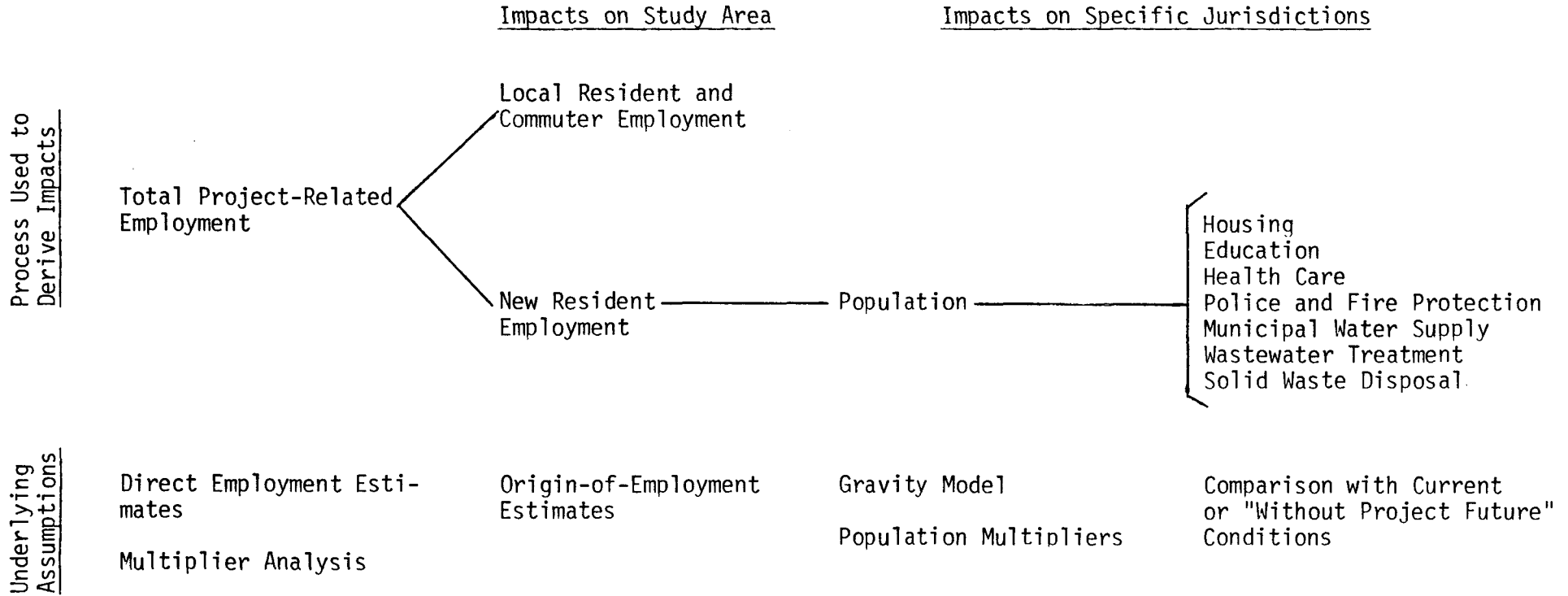
Damage to roads due to increased truck and automobile traffic is a potentially serious project impact, especially during the construction phase. The effects of a project on transportation systems, especially on roads and highways, are thus commonly ascertained. The SEC is an example of a methodology whereby increases in highway traffic count and potential road damage can be estimated.

RECREATION

The Texas Parks and Wildlife Department has published Outdoor Recreation on the Texas Gulf Coast as part of its Texas Outdoor Recreation Plan (TORP). By county,

Figure A1

DERIVATION OF IMPACTS ON CERTAIN SOCIAL/INFRASTRUCTURAL FACTORS



the volume looks at: recreation lands, public and private facilities, recreational opportunities, total current and projected participation, and combined resource requirements. The Texas Parks and Wildlife Department, Comprehensive Planning Branch, has also almost completed the Texas Outdoor Recreation Inventory System (TORIS) which is a computer system containing recreational information for Texas locations of any size. In addition, the Comprehensive Branch has appropriate assessment techniques catalogued for use in determining impacts on recreation in regions of all sizes.

VISUAL AESTHETICS

In attempting to determine a project's effects on visual aesthetics, two sometimes conflicting criteria can be applied. Under the first standard, the effect is determined by the number of people exposed visually to the facility; it is assumed that the fewer who can see a plant (either because of low population or because of a constricted view of the area), the better. Under the second criterion, the impact is determined by the quality of the present environment. The two criteria may be in conflict because a smaller viewing population may be indicative of a natural, pristine area that should be left undeveloped.

Needless to say, the determination of project impacts on visual aesthetics tends to be quite subjective. Two sources in which methodologies are discussed are the Maryland Major Facilities Study (1977) and Battelle Pacific Northwest Labs (1974).

HISTORICAL/ARCHEOLOGICAL RESOURCES

Historic sites are important man-made aspects of a people's history and culture and are indicated by one or more historic structures, districts, or areas. Archeological resources are all objects and modifications which give evidence of past human occupation of an area. The determination of impacts on these resources is best performed by an appropriately trained scientist. Such an assessment will most likely include a survey of the site.

LAND USE

In order to ascertain changes in land use, present land uses must be recorded, and the amount and location of land required for the geopressed-geothermal wells and facilities, and for related changes such as new roads, must be known. Information on present uses may often be obtained from an agency such as the local planning

authority or the Council of Governments, or from a survey of the site. Information on proposed uses may be discerned by considering project plans. Special problems, such as the effect of subsidence, must also be considered.

Changes in land use often have economic, social, or environmental consequences. For example, a change in use from agricultural to industrial (as in the case of a power plant in a rural area) may cause a decline in agricultural production and farm income. As a result, the effects of a project on land use are often discussed in impact assessments within the context of other factors.

NOISE

The SEC provides a method of measuring the impact of a project on noise. First, the noise level in decibels of both the existing and the proposed activities is estimated. Then, the impact of the project on noise in the immediate project area is determined by an estimation of the distance from the site needed to reduce noise to the preproject level.

PERSONAL SAFETY

A detailed assessment of the impact of geopressured-geothermal resource development on personal safety should include an identification of possible threats to safety due to accidents at the work site or natural catastrophe, an evaluation of the likelihood of their occurrence, and a discussion of precautionary measures. The Texas Coastal and Marine Council has done extensive research in the area of natural catastrophes in the Texas coastal region.

Appendix B

POSTULATED EMPLOYMENT REQUIREMENTS
FOR RESOURCE DEVELOPMENT

INTRODUCTION

The on-site direct employment associated with geopressured-geothermal development for each of the three fairways was postulated based on knowledge of personnel requirements for associated activities and on conversations with industry representatives. Total employment schedules were estimated for the construction and operation of a single power facility; these schedules were then applied to the postulated production scenarios to give estimated employment through time for each of the fairways.

EMPLOYMENT ASSOCIATED WITH SINGLE POWER FACILITY

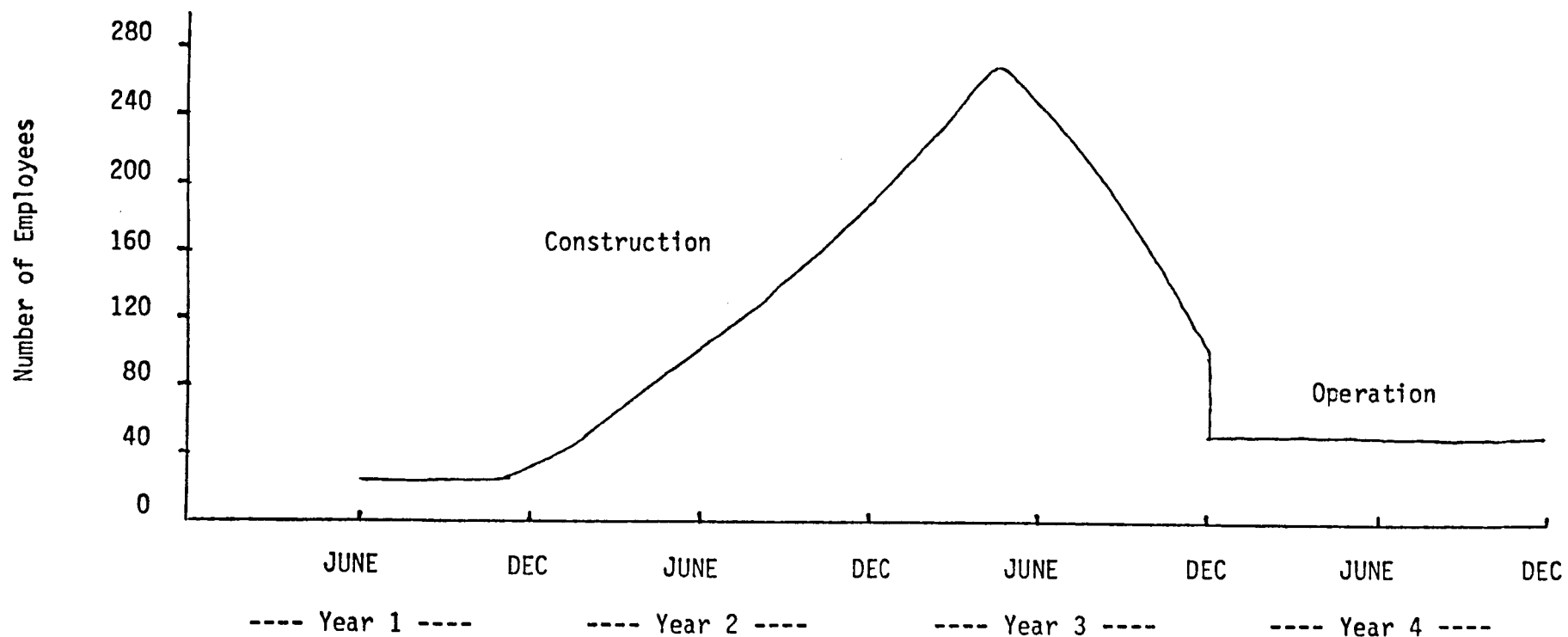
The time required to drill producing and disposal wells and to construct the utility fuel plants and related facilities is estimated to be three years (Zinn, 1977). Postulated on-site total employment associated with the construction activities is shown in Figures B1 (Brazoria Fairway) and B2 (Matagorda and Corpus Christi Fairways). Employment varies among fairways because of different assumptions concerning number of wells and power plant size.

Employment during the construction phase is expected to gradually increase to a maximum of about 270 employees; and then decline. The peak is projected to occur during the second quarter of the third year. About 50 employees will be required for operation.

The number of employees who will be hired locally (from within commuting distance) will depend on such factors as the hiring practices of contractors, the availability of skilled labor in the region, the area's unemployment rate, and the location of the contractor. If the contracting firms used in developing the Brazoria Fairway are based in Houston, for example, most of the workers are likely to commute to the project site from Brazoria, Harris, or Galveston Counties; very few are likely to move into the project vicinity for the project duration.

Discussion with industry representatives revealed that only unskilled workers (10 to 20 percent of the total construction and operation workforce) would be hired locally in the maximum impact case. The remaining 80 to 90 percent would be new-resident employees who would move to within reasonable commuting distance of the project site. Thus, assuming maximum impact conditions, peak new-resident construction employment would be about 230; new-resident employment during operations would number about 40.

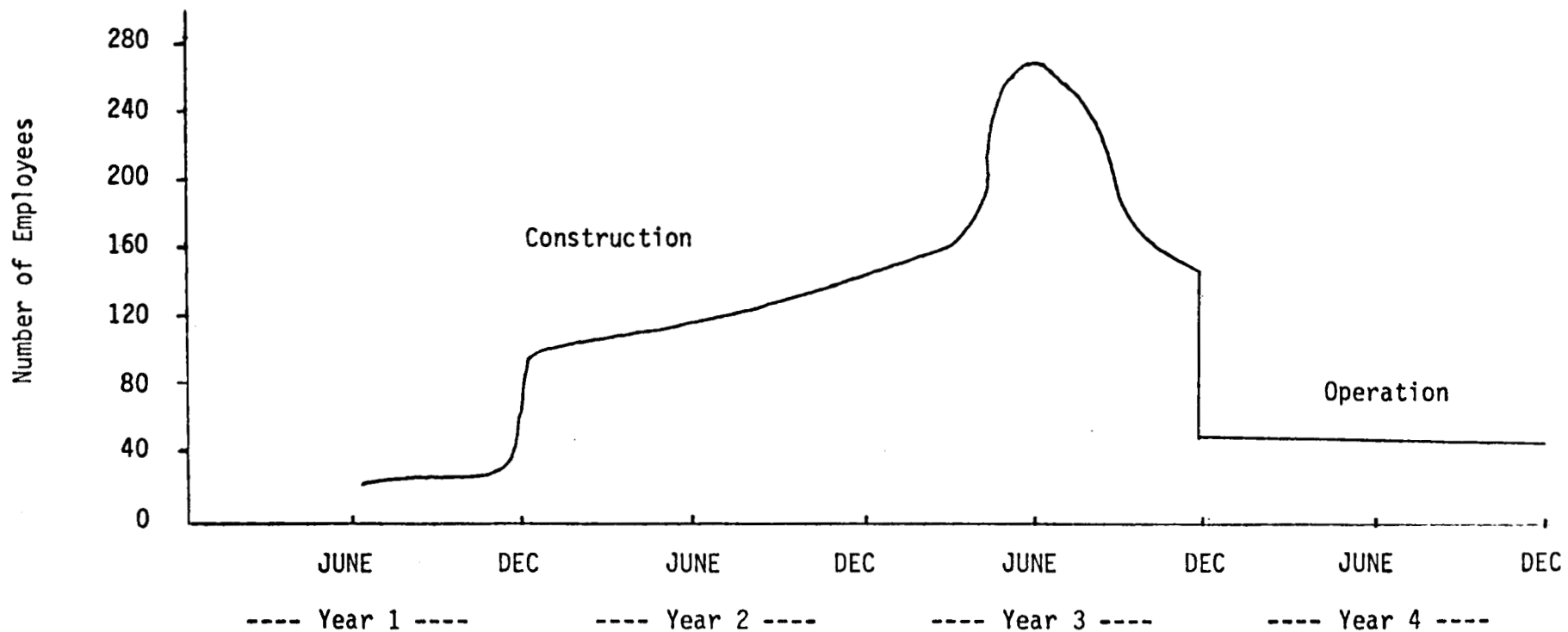
Figure B1

PROJECTED EMPLOYMENT FOR SINGLE POWER PLANT
AND RELATED FACILITIES - BRAZORIA FAIRWAY

Sources: Zinn, 1977; personal communications with industry representatives.

Figure B2

PROJECTED EMPLOYMENT FOR SINGLE POWER PLANT
AND RELATED FACILITIES - MATAGORDA AND CORPUS CHRISTI FAIRWAYS



EMPLOYMENT THROUGH TIME

The employment schedules associated with a single power facility were applied to the projection scenarios postulated for each fairway to provide an estimate of total employment through time. The results are shown in Figures B3 (Brazoria Fairway), B4 (Matagorda Fairway), and B5 (Corpus Christi Fairway).

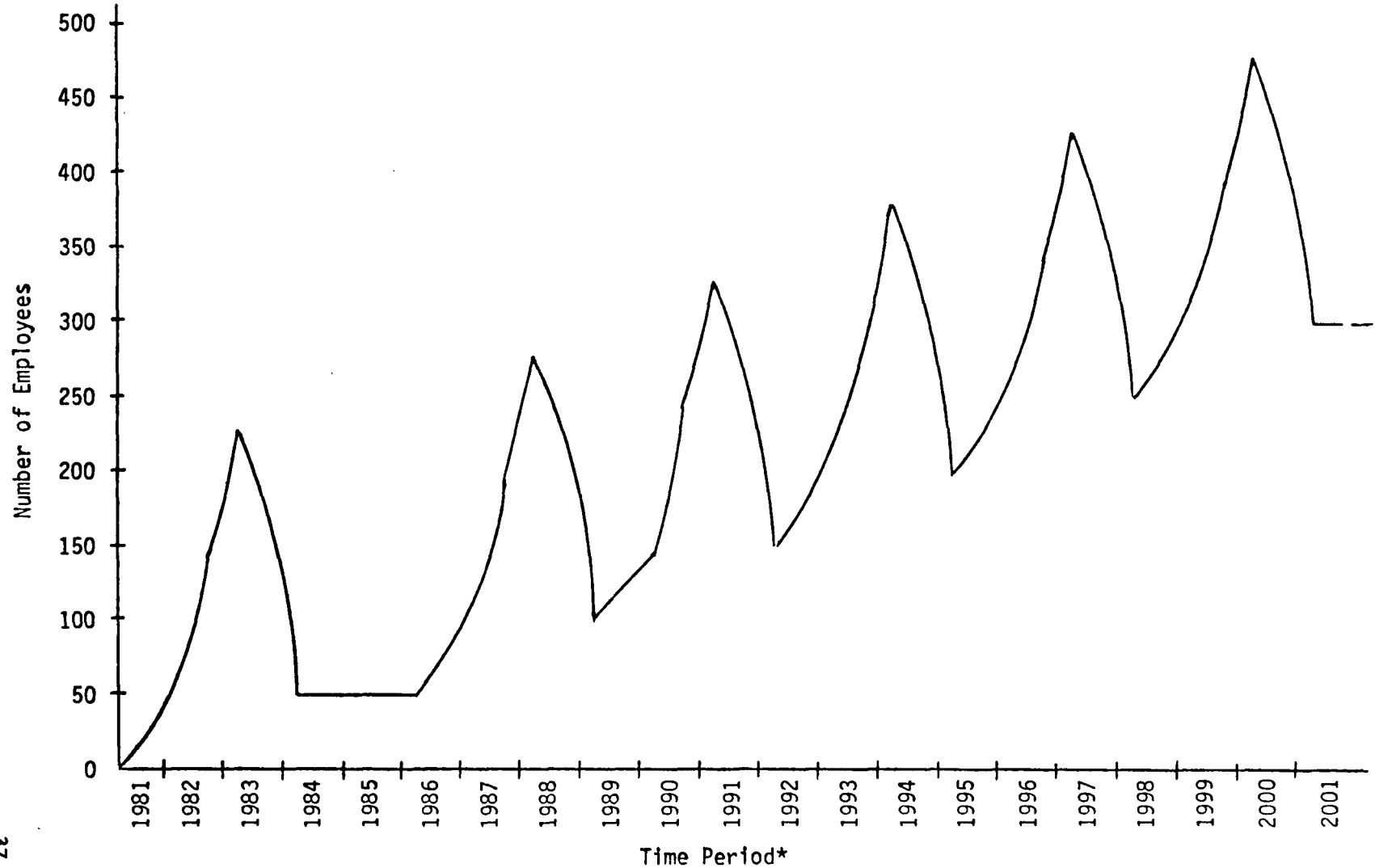
Peak employment would be reached in 2000 in Brazoria Fairway, during construction of the last plant. Peak construction employment of 270 would be added to employment associated with operation of the five plants on-line to give total employment during the second quarter of that year of approximately 520. From 2001 on, employment would be stabilized at the number required to operate the six plants (300).

In the Matagorda Fairway, a total of four power facilities are assumed to be built which will be fed by wells on or adjacent to Public Free School Lands (PFSL). A new plant is assumed to come on-line every two years from 1986 to 1992. Peak employment of about 420 will be reached in 1991; of these 270 would be construction workers, and 150 would be employees associated with the operation of the three on-line facilities. Beginning in 1992, operations employment is estimated to approximate 200.

In the Corpus Christi Fairway, it is postulated that eight power plants and related facilities will be built which will be fed by wells on or adjacent to the PFSL. Construction of the first plant is estimated to begin in 1983. The first and second plants are projected to come on-line in 1986 and 1988, respectively. The remaining six plants will be phased into production from 1990 to 1995 at a rate of one a year. Employment will peak in 1993 at about 690, during which time two plants and related facilities will be under construction, and six will be in operation. Beginning in 1995, total operation employment for the eight plants is estimated to equal 400.

Figure B3

TOTAL EMPLOYMENT ASSOCIATED WITH PLANTS FED BY WELLS
ON OR ADJACENT TO PFSL: BRAZORIA FAIRWAY

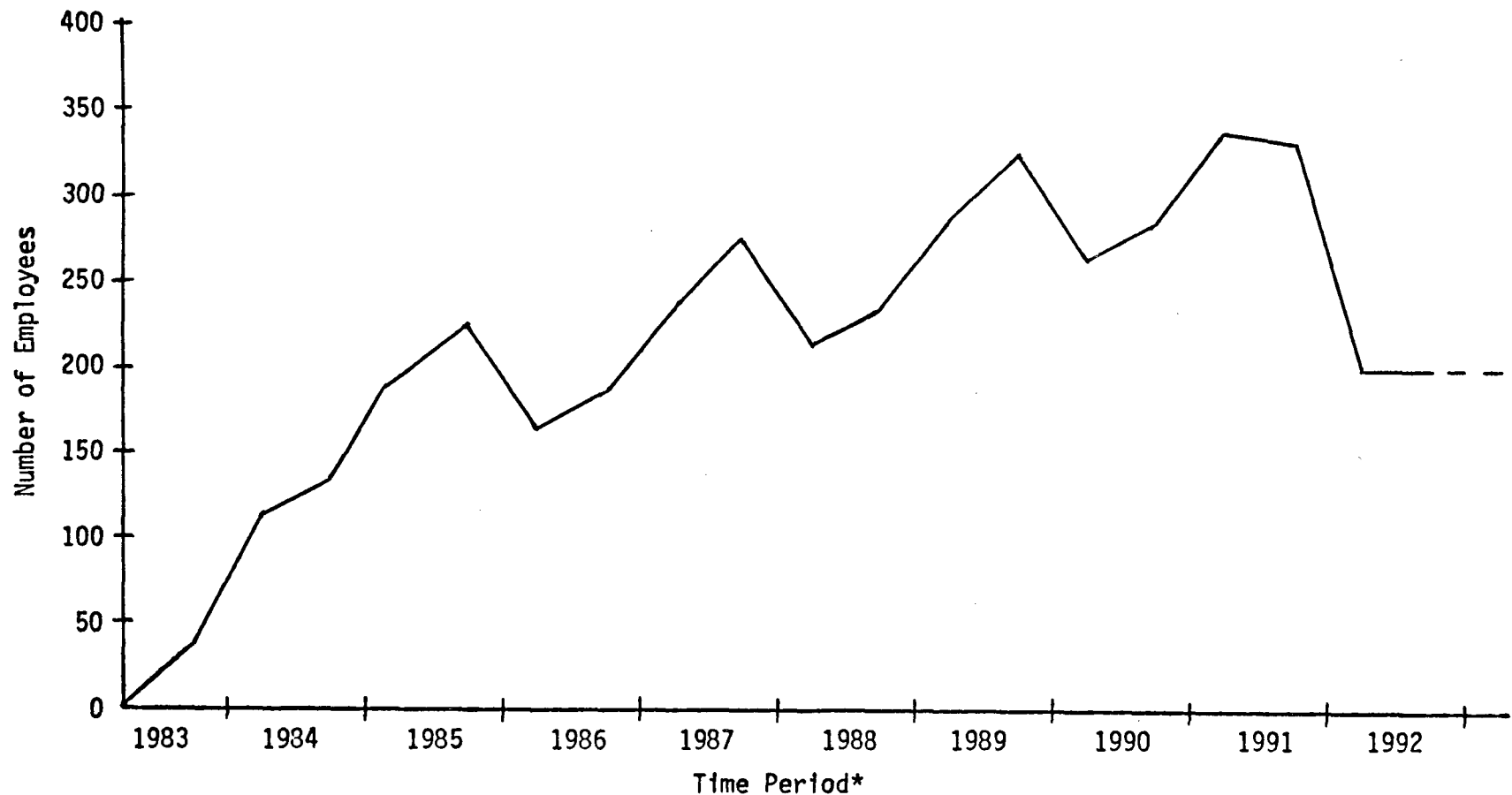


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*Each year shows six-month averages for the number of employees for the periods of January-June and July-December. Assumes commercial development of resource begins in 1981. In the year 2001 all plants are in operation. Peak number of employees is 515 in April and May of 2000.

Sources: Zinn, 1977; Figure B1; production scenarios postulated as part of this study.

Figure B4

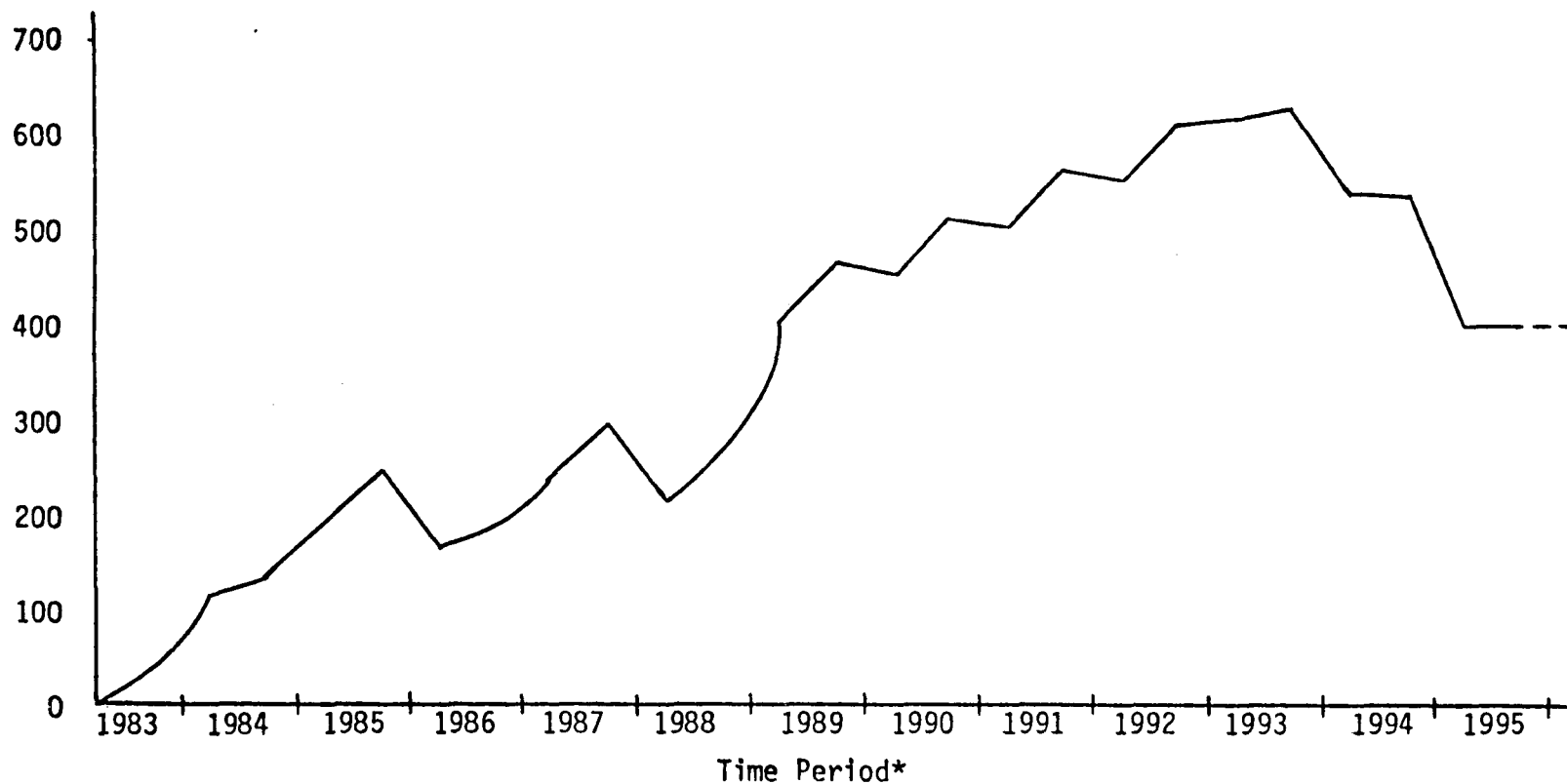
TOTAL EMPLOYMENT ASSOCIATED WITH PLANTS FED BY WELLS
ON OR ADJACENT TO PFSL: MATAGORDA FAIRWAY

*Each year shows six-month averages for the number of employees for the periods of January-June and July-December. Assumes commercial development of resources begins in 1983. In the year 1992 all plants are in operation. Peak number of employees is 418 in June 1991.

Sources: Zinn, 1977; Figure B2; production scenarios postulated as part of this study.

Figure B5

TOTAL EMPLOYMENT ASSOCIATED WITH PLANTS FED BY WELLS
ON OR ADJACENT TO PFSL: CORPUS CHRISTI FAIRWAY



*Each year shows six-month averages for the number of employees for the periods of January-June and July-December. Assumes commercial development of recourse begins in 1983. In the year 1995 all plants are in operation. Peak number of employees is 691 in June 1993.

Sources: Zinn, 1977; Figure B2; production scenarios postulated as part of this study.

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