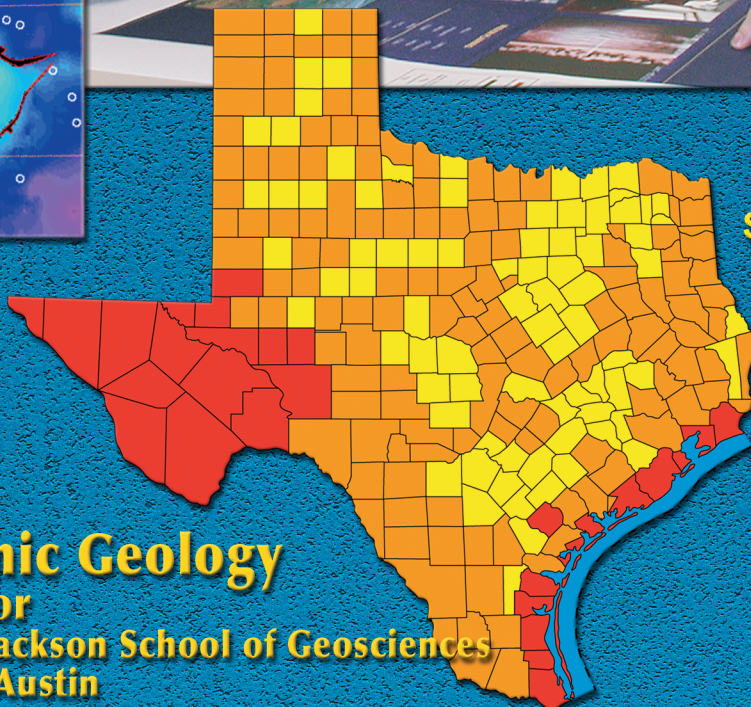# PROJECT STARR

STATE OF TEXAS ADVANCED OIL AND GAS RESOURCE RECOVERY

PROGRESS REPORT

Researchers
Robert G. Loucks, Ramon H. Treviño, Randy L. Remington,
L. Frank Brown, Jr., Shinichi Sakurai, Jeff Kane, Luciano Correa Vivar,
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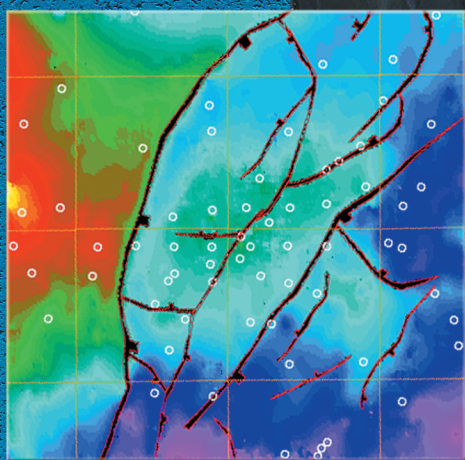
TEXAS
STATE LANDS

August
2002

PROJECT STARR

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Executive Summary

In light of the declining oil and gas production and reserves on State of Texas-owned submerged lands and the dominance of independent operators searching for these reserves, strong measures need to be taken to reverse this decline. The Bureau of Economic Geology (BEG) proposes an initiative directed toward developing an organized public inventory of potential new exploration fairways on Texas submerged lands. The proposed strategy for this initiative involves the systematic application of state-of-the-art technology and methods to evaluate and document tracts of Texas submerged lands that have potential for successful prospecting by the private sector.

The results of the proposed initiative will stimulate exploration and development on submerged lands by guiding investments of the independent operators to areas most favorable for economic results. The small independent operators need this support because they do not have the technological resources of the major oil companies that originally developed the area.

The investigation will provide an up-to-date comprehensive summary of exploration potential on State-owned submerged lands and will provide the basis for promoting further prospecting by the private sector. The final report will define geologic petroleum plays and geographic fairways and will be accompanied by supporting maps, cross sections, wireline logs, select seismic profiles, and other documents.

The proposed initial 2-year study of Texas-owned submerged lands will require funding in the amount of $2.8 million. This is the amount necessary for an experienced, fully integrated geoscience/engineering team to accomplish a state-of-the-art fairway study on the Middle Texas submerged lands area. The BEG will make every effort to leverage investments with matching State and/or Federal dollars.

The BEG believes that $2.8 million is a fair investment to uncover the multibillion dollar resource that still remains under Texas submerged lands, assuming only a 10 percent addition to current reserves, the potential value of this resource to Texas oil and gas operators and citizens is significant. This value can be calculated in a variety of ways. For example, the wellhead value alone of this resource amounts to over $3 billion assuming $25/bbl and $3/Mcf. Total economic value assuming the 2.91 multiplier used by the Texas Comptroller's Input-Output model yields close to $9 billion. Approximately $324 million royalty revenues would be deposited in the Texas Permanent School Fund (PSF).

Background

During the past 20 years, the availability and applicability of new technology and improved petroleum exploration and exploitation concepts have revolutionized the petroleum industry worldwide. The use of three-dimensional (3-D) seismic data has increased the recognition and accurate delineation of subsurface structures that previously were inadequately resolved with 2-D seismic data. Major international petroleum companies were the first to utilize this and other related technological advancements, especially beneath continental shelves and slopes. The digital computing revolution likewise made it possible to manipulate, integrate, and extract information beyond any prior technology. The increasing power of workstation and PC technology made it possible for independents and small operators to utilize the same data previously available only to major companies. Geophysical well logging, which has been a tool for decades, was similarly revolutionized by the growing digital capability to extract critical and very accurate information about reservoir properties.

At the same time that the geophysical sciences were at the forefront of the application of rapidly evolving digital and computing technologies, petroleum geology was undergoing significant conceptual advances in stratigraphic, structural, petrologic, and sedimentary methods and approaches to exploration and exploitation. Fundamental scientific advances in each of these important geoscience specialties in the last 20 years were quickly integrated with products from the computer revolution to provide an enormous volume of new data for petroleum interpretation. The major companies immediately utilized these advances, but their use by independents has lagged.

Large volumes of oil and gas have been produced from State of Texas-owned submerged lands since early in the 20th century. The benefits of extracting oil and gas from State Lands are well understood by most Texans. Financing of public education and other services for Texans continues to depend heavily on maintaining robust oil and gas production rates.

Ensuring continued supplies of oil and gas for the growing Texas markets is ultimately the responsibility of private industry but is also vitally important to Texas government. Petroleum production on State Lands has resulted from the venturing of highly speculative private investments using the best geologic and geophysical science available during past decades. Such scientific applications are behind the many fields producing on State Lands. Many fields discovered by major companies have been sold to smaller operators, and most major

companies have terminated active exploration both onshore and offshore (State Waters) Texas. Opportunities in Texas for locating new reserves rest largely with smaller companies owned by Texas operators.

Texas State Submerged Lands Historical Production and Forecast

Historically, the Texas State submerged lands have produced a significant amount of oil and gas. In 31 years from 1970 through 2001, 219 million bbl of oil (Figure 1) and 8.4 Tcf of gas (Figure 2) have been produced. However, production from Texas State submerged lands has been in decline with 2001 annual production at approximately 3.4 million bbl of oil (Figure 3) and 121 Bcf of gas (Figure 4). The number of oil and gas wells producing has also followed production decline from 25,066 wells in 1970 to 6,879 wells in 2001 (Figure 5).

Although the area is largely a gas province, historically the shallow sections have been targets of oil exploration and development. Deeper sections could provide incremental oil and gas reserves to stabilize the rapid production decline. For example, only 5 percent of all wells drilled on the offshore (Federal waters) continental shelf have penetrated sediments below 15,000 feet subsea (Minerals Management Service, 2001). Yet, the Minerals Management Service (MMS) estimates there could be 5 to 20 Tcf, with the most likely value of 10.5 Tcf of deep gas recoverable resources below this depth. New discoveries of deep gas offer the best opportunity for achieving the large reserve additions and necessary high flow rates to offset declining Texas State submerged lands' production.

To estimate oil and gas resources that might be recoverable from the deeper sections of Texas State submerged lands, historical oil and gas production data was utilized (Figures 1 to 4). Since no publicly available data exists that separates this area's production, production records were separately analyzed and aggregated using the following methodology. Oil and gas production records from 17 Texas coastal counties were extracted from Lasser's Texas Production Database and the Texas Railroad Commission's Oil and Gas Annual Reports. Based on lease names, abstract, section, and block identifiers, as well as Texas State submerged lands' fields designated by the Energy Information Administration's Field Code Master List (FCML), 424 fields were determined to have oil and gas production from Texas State leases. Oil and gas production records from these fields were aggregated to provide historical production on Texas
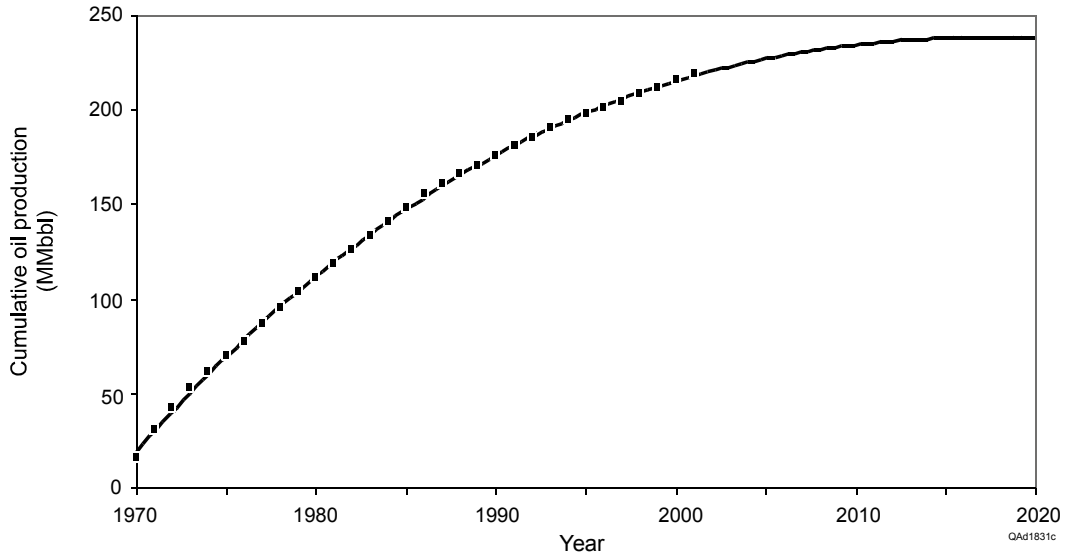
Figure 1. Cumulative oil production on Texas submerged lands since 1970.
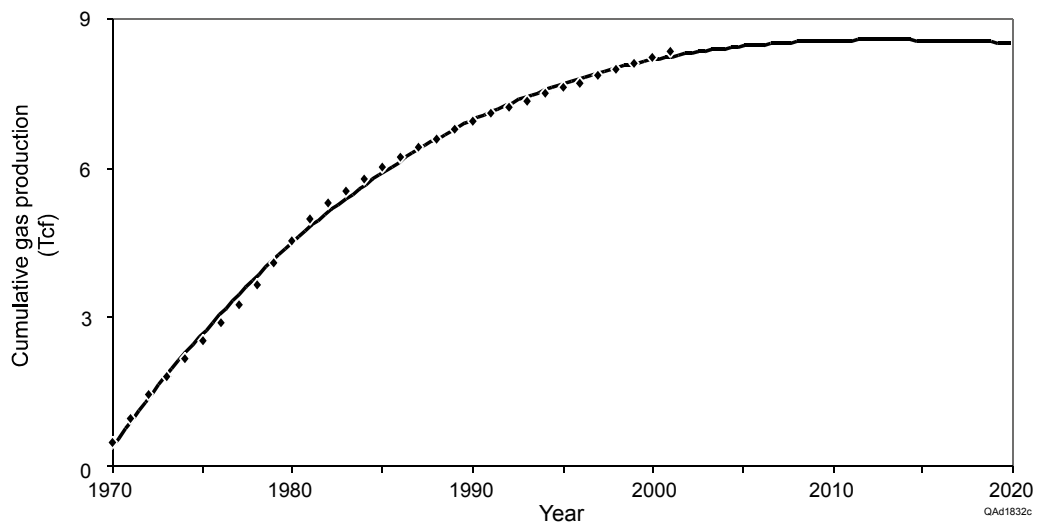
Figure 2. Cumulative gas production on Texas submerged lands since 1970.

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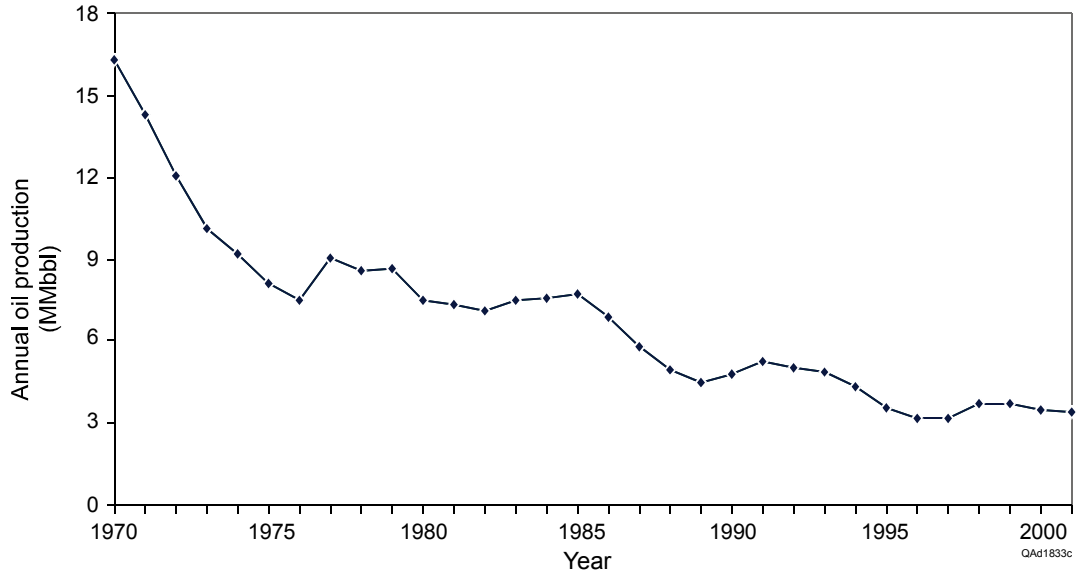
Figure 3. Oil production on Texas submerged lands by year since 1970.
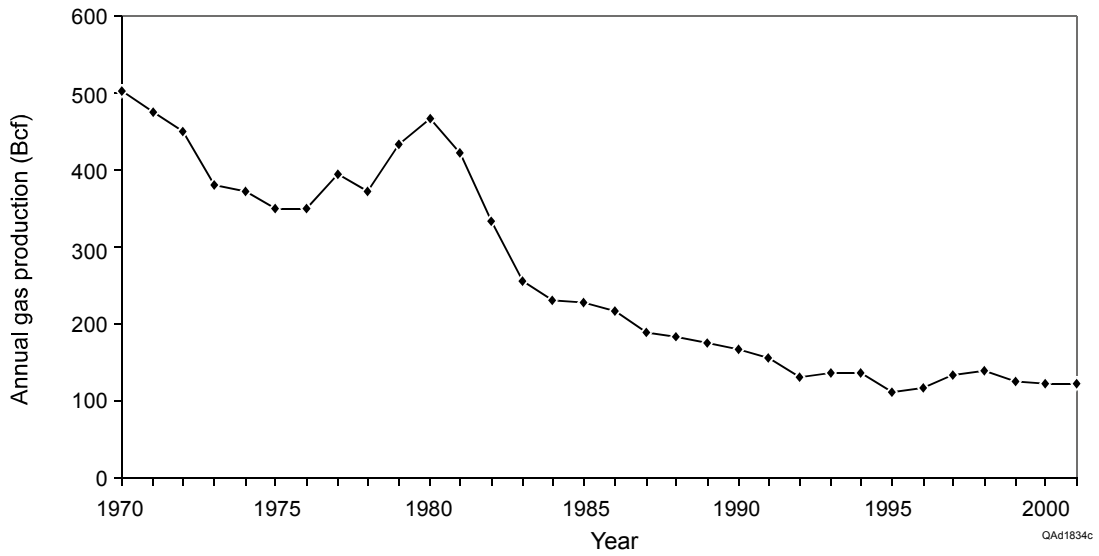
Figure 4. Gas production on Texas submerged lands by year since 1970.
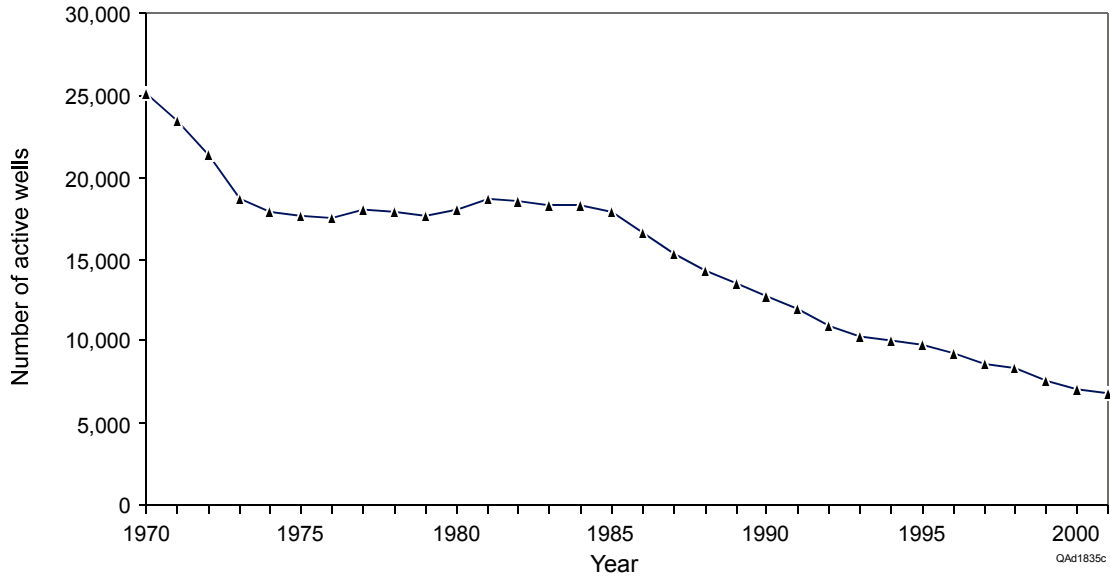
Figure 5. Oil and gas wells on Texas submerged lands by year.

State submerged lands. Annual production records were compiled from year 1970 to 2001, as well as cumulative production during the 31-year time frame.

As seen in annual and cumulative production plots (Figures 1 to 4), Texas State submerged lands is a very mature province with declining oil and gas production. A shifting of the curve or changing the slope could be achieved through exploration and development of the deeper sections not previously targeted. Using the cumulative production data as a reference, if only 10 percent of additional reserves are recoverable, approximately 22 million bbl of oil and 837 Bcf of gas could be expected (Table 1). This is a conservative estimate based on historical production of a limited time frame from the shallow sections.

However, in terms of the potential value of this resource to Texas oil and gas operators and citizens, the amount is not trivial. The value of this resource has been calculated in various terms (Table 1). For example, the wellhead value only of this resource amounts to over $3 billion assuming $25/bbl and $3/Mcf. Total economic value assuming the 2.91 multiplier used by the Texas Comptroller's Input-Output model yields close to $9 billion with the approximately $324 million royalty revenues that would be deposited in the Texas Permanent School Fund (PSF).

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Table 1. Potential value of the State of Texas submerged lands regional study.

	Cumulative production since 1970 (bbl, Mcf)	10% Incremental cumulative production (bbl, Mcf)	Wellhead value ($25/bbl, $3/Mcf)	Severance taxes (4.6% oil, 7.5% gas)	Ad valorem taxes (3.95%)	Jobs created (19.1 jobs per $1MM wellhead value)	Economic value (wellhead value × 2.91)	Indirect taxes (0.18% franchise)	Indirect taxes (2% sales)	Royalty revenue (12.5%)
Oil	219,151,195	21,915,120	$547,877,988	$25,202,387	$21,641,181	10,464	$1,594,324,944	$2,869,785	$31,886,499	$68,484,748
Gas	8,368,287,134	836,828,713	$2,510,486,140	$188,286,461	$99,164,203	47,950	$7,305,514,668	$13,149,926	$146,110,293	$313,810,768
Total			$3,058,364,128	$213,488,848	$120,805,383	58,415	$8,899,839,612	$16,019,711	$177,996,792	$382,295,516

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General Proposal

Independent operators do not have the scientific resources of the major oil companies. As a result, the smaller companies, which now dominate production from State submerged lands, are unable to fully utilize new technological and conceptual advances. A two-fold initiative (1) to help improve the productivity of existing fields and (2) to increase the potential for the discovery of new reserves is critical. The former initiative is covered under "Project STARR" (State of Texas Advanced Resource Recovery Program), which has run successfully for the past 8 years. The latter initiative is now proposed to stimulate the independent private sector to successfully explore for oil and gas.

The Bureau of Economic Geology is responsible for the first initiative (Project STARR) as an on-going, State-funded project facilitating the addition of reserves in fields located on Texas State Lands. Continuing cooperative projects between local operators and research scientists at the Bureau of Economic Geology have successfully increased reserves in several fields, benefiting future Texas Permanent School Fund and State of Texas revenues, while also increasing the future income of private investors.

The Bureau of Economic Geology proposes a second initiative directed toward developing an organized public inventory of potential new exploration fairways under Texas submerged lands (Figure 6). An initial 2-year study of the Middle Texas submerged lands area (Figure 6) designed to provide publicly available results would permit evaluation to decide if the program should be extended (Figure 7). A successful program could continue until detailed regional exploration recommendations exist for all Texas submerged lands.

Percentage of State Lands

< 0.1

0.1 to 10

> 10

100 (Texas-owned submerged lands)

N

0   200 mi

0   300 km

Upper

Middle

Lower

Texas-owned submerged lands

SYSTEM		SERIES		FORMATION
Quaternary		Holocene		Undifferentiated
		Plio-Pleistocene		Undifferentiated
Tertiary	Upper	Miocene		Goliad
				Lagarto
				Oakville
	Lower	Oligocene		Anahuac
				Frio
				Vicksburg

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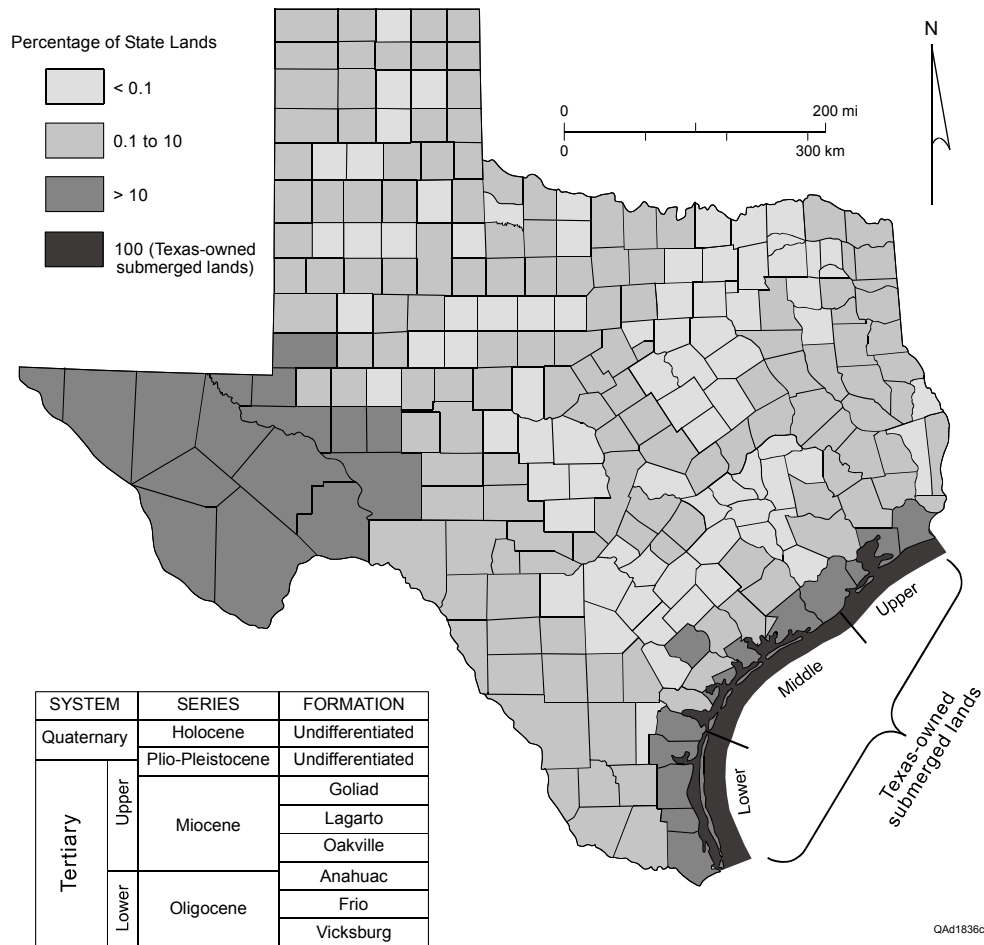
Figure 6. Location of Texas State Lands and State submerged lands and general stratigraphic section. Onshore counties are shaded according to the percentage of area that is State Lands. Modified from Holtz and Garrett (1997).
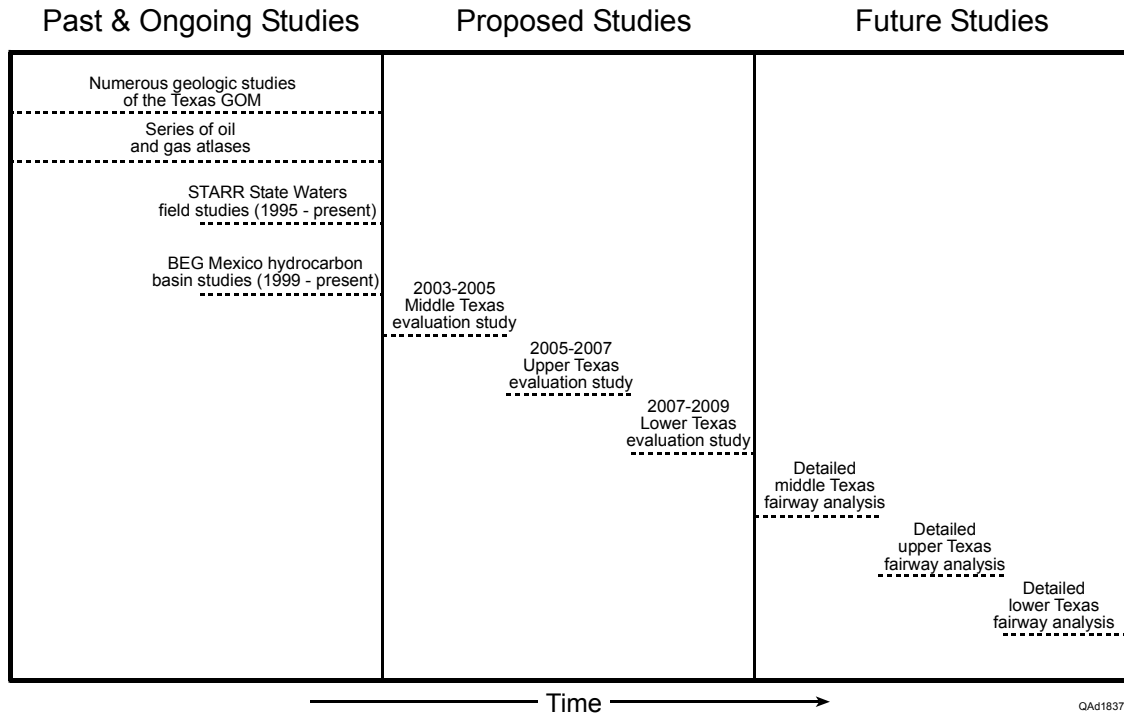
Figure 7. Chart displaying relationship of past studies by the Bureau of Economic Geology to the proposed studies and future potential studies on Texas-owned submerged lands.

Previous Related Programs

The Bureau of Economic Geology (BEG) has for more than 90 years provided the results of basic and applied research for the benefit of the State of Texas. Results of these research efforts are documented in hundreds of publications, maps, and other publicly available products. Many of these BEG publications are referenced worldwide. Contributions include, among others,

- mineral resource investigations,
- petroleum studies,
- lignite resources,
- environmental evaluations,
- hydrologic resources,
- basic bedrock, land resource, and hazard maps,
- shoreline change studies,
- coastal environmental geology atlases,
- submerged Texas lands atlases,
- oil and gas atlases,
- oil and gas field studies,
- myriad basic and applied earth science documents, and
- geologic maps

Of specific relationship to this proposed State Lands regional exploration program are the following already completed programs and products (see Figure 7):

- studies to enhance productivity on State Lands
- oil and gas atlases of
    - Texas onshore
    - Northern Gulf of Mexico (Miocene, older)
    - Northern Gulf of Mexico (Plio-Pleistocene)
    - Central eastern Gulf Coast
    - U.S. Mid-continent
- petroleum field studies in northern Gulf of Mexico
- studies of onshore and offshore Mexico petroleum basins
- Venezuela petroleum basin studies
- many studies of petroleum-bearing formations

Research Scientists and Facilities

Scientists to be assigned to this program include Ph.D. and M.S. graduates, many having lengthy experience with major international oil and gas companies. All have significant project and publication experience. All are involved in leading-edge research and present their research results regularly to peers at meetings of national and international geological and geophysical associations. Graduate-student research assistants from The University of Texas at Austin aid these researchers. Projects such as that proposed here are valuable on-the-job training opportunities for graduate students.

The Bureau of Economic Geology operates in its facilities on the J. J. Pickle Research Campus, The University of Texas at Austin. State-of-the-art technological equipment is available including computer workstations, software, PC's, printers, 3-D visualization room, large-format color plotters, and other necessary laboratory facilities. The BEG is the designated State repository for cores and samples, and it serves as the Railroad Commission's designated repository for all Texas wireline logs.

Geologic Petroleum Plays and Geographic Fairways

The geologic formations that have produced oil and gas on Texas submerged lands (bays, estuaries, lagoons, and offshore to approximately 10 miles) include the following in order of importance from highest to lowest: lower/upper Oligocene Frio and Anahuac Formations, Miocene Goliad and Lagarto Formations, unnamed Plio-Pleistocene formations, and lowermost Oligocene Vicksburg Formation (Figure 6 see inset).

By far the most productive reservoirs occurring on State-owned submerged lands occur within the Frio Formation. Early exploration focused on shallow-water, shelfal sandstone reservoirs and domal structures. Fault and rollover anticlinal structures with shelf-edge deltaic reservoirs have become the principal targets in the past several decades. Deeper slope and basinal reservoirs are now becoming targets. The younger, shallower Miocene exhibits similar structures and reservoirs, but fields are smaller and mostly gas charged. Plio-Pleistocene and older Oligocene Vicksburg reservoirs contain similar but fewer targets.

Independent operators have informed the BEG that a comprehensive modern summary of exploration potential in these units would help them direct their efforts more effectively. It is recommended that *geologic petroleum plays* (prospects having common types of reservoir, trap, seal, source, and migration routes) be defined along with their associated *geographic fairways* (area where a play is prospective) under State submerged lands within each of the three study areas: Upper, Middle, and Lower Texas. Each proposed study is 2 years in length (Figure 7). This approach focuses on prospective geologic criteria in an area of manageable size. Each play will represent a grouping of similar opportunities, making it convenient for operators to assess exploration risk necessary to capitalize on the play's potential. The fairways and component plays define areas that can be mapped. All potential reservoirs and trap styles in each geographic area will be investigated. Geological studies, to be effective, will extend beyond State leases to some extent because the distribution of plays will not follow State submerged lands boundaries.

Products

A report, along with maps, cross sections, wireline logs, seismic profiles, and other documents will compose the final products of this project. The report will be in CD format and/or published format and sold essentially at cost. The report will provide the basis for further prospecting by the private sector. It will resemble the documents produced in the

research/technology divisions of major petroleum companies, but it will have no proprietary constraints.

Data generated and organized during the course of the project will be provided on CD's as part of the final product or independent of the report. Such data sets will include information for each well analyzed during the project in a user-friendly matrix or chart format. Many illustrations will be included on CD's. Maps and cross sections will be digital and transportable, so that users can add or modify them to their specifications and interpretations.

The final products (report, illustrations, digital documents, and data sets) will be designed to be user friendly. They will be carefully focused on the data and knowledge required by geologists and geophysicists to continue toward mature prospecting, financial evaluation, bidding, and lease acquisition. Where possible, fields from similar plays will be spotlighted so that operators can better evaluate their potential interest. BEG scientists involved in the projects will be available for discussions with and knowledge transfer to operator geophysicists and geologists.

Project Design

Our goal is to delineate the major hydrocarbon play opportunities under Texas-owned submerged lands and show the value of these reserves to stimulate private-sector investment in exploration and development. Our approach will involve analysis of the total drilled stratigraphic section along the entire Texas Gulf Coast. The Texas submerged lands will be divided into three geographical areas (Lower, Middle, and Upper Texas) for study (Figure 6). Each area will take approximately 24 months to analyze. Areas will be studied in order of relative importance of known production—the Middle Texas area first, followed by Upper Texas and finally Lower Texas.

Geologic petroleum-play types and geologic fairways of known production intervals will be defined. Results will be used to assess geologic fairways that may have been underdeveloped or unrecognized because of lack of key information. Deeper targets will have obvious future potential because there are fewer well penetrations and therefore less understanding. Many deeper targets may be slope fans or basin-floor fans that are only now being recognized and delineated by experienced interpreters using high-quality 3-D seismic data. These deeper deposited sandstone reservoirs have previously been considered to have low reservoir quality,

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but this may be a poor assumption for several reasons. Worldwide, basin-floor and slope fans commonly comprise good-quality reservoir sands because rivers transported coarser-grained sediment to shelf edges during episodes of lowered sea level. In addition, many deeper, low-quality sand reservoirs can now be stimulated for economical production by modern fracing techniques.

An integrated, interdisciplinary exploration/reservoir-characterization team of geoscientists, petrophysicists, and engineers will analyze each geographic area. Details of the major activities to complete the project are presented in Appendix 1. Described below is an overview of the design of the project.

Phase I consists of database assembly. This work includes preparing base maps and selecting, preparing, and loading wireline logs and seismic data.

Phase II comprises the construction of site-specific, sequence stratigraphic section benchmark logs (S^5-benchmark logs) for each study area defined by major depositional centers related to major growth faults. An S^5-benchmark log is a composite log that displays the total drilled stratigraphic section of a specific area (Figure 8). The log commonly causes significant revision of local "conventional wisdom" and therefore is a key exploration tool that has recently been developed by Project STARR at the BEG. It is divided vertically into sequence-stratigraphic packages that allow reliable correlations within and between different fault blocks. Available fossil ages of bounding stratal surfaces, correspondent strata, and pay zones are exhibited on S^5-benchmark logs. These logs permit time correlations throughout the submerged lands area. Time correlations are critical because rock correlations are commonly not traceable over broad areas.

Phase III includes construction of dip-oriented, cross sections at approximately 10-mile intervals, and several strike lines connecting the dip lines. Cross sections will display the distribution of sand reservoirs and associated seals within a properly correlated framework. The sections permit the construction of generalized distribution maps of prospective sand reservoirs. Data from selected reflection seismic lines will help researchers construct the cross sections, especially to define faults and to verify key geometric relationships.
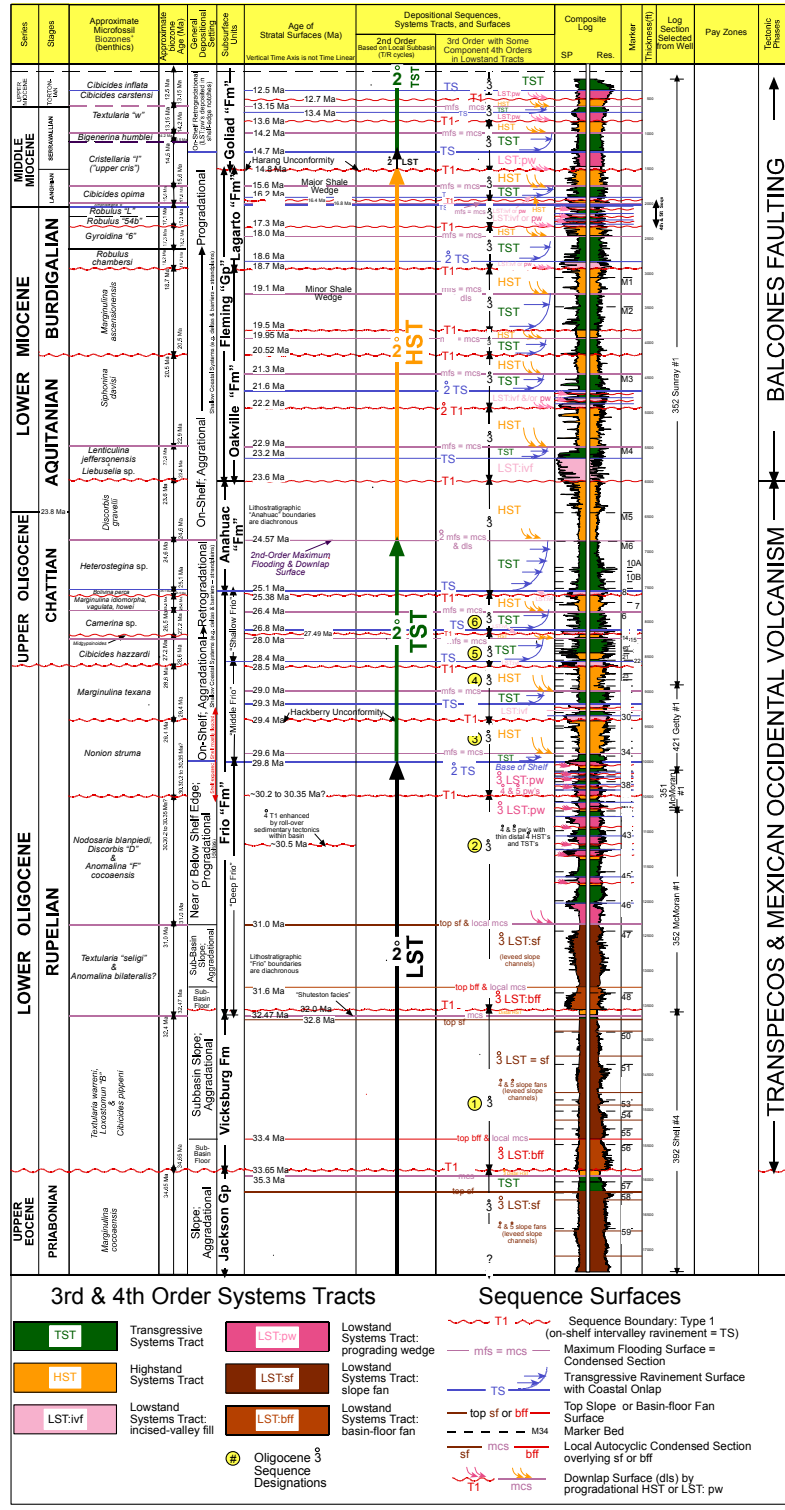
Figure 8. Example of an S^5-benchmark log displaying a composite log, sequence stratigraphic analysis, and corresponding stratigraphic data. These logs improve correlation of regional fairway trends and enhance understanding of stratigraphic architecture.

Phase IV will investigate mineralogy, texture, and burial history of reservoir quality sand. The economic basement of potentially viable reservoirs will be established. Reservoir-quality economic basement is the deepest burial depth where there remains sufficient porosity to store economic amounts of hydrocarbon and adequate permeability to produce economic amounts of hydrocarbons.

Phase V selects fields representative of different fairways. The field analogs will be analyzed to characterize productive sands (stratigraphic sequence position and reservoir quality), seal, and trap configuration. The analog fields support definition of play types.

Phase VI delineates play types and fairways. Major play trend maps will be generated from cross sections, field analogs, and reservoir-quality economic basement analyses. New concepts that revise or expand plays will be employed.

Phase VII is an economic (metrics) and engineering analysis of plays and fairways. Recently improved stimulation and recovery techniques to enhance the value of a geologic fairway will be reviewed. The project will emphasize the economic viability of geologic fairways to help operators evaluate the potential value for investment of capital resources in exploring the fairways.

Phase VIII consists of technology transfer to operators. Results of the study will be presented to interested operators in workshops, meetings, lectures, and publications. Effective communication to the operators of the results of our analysis is a critical activity. We expect to describe how new concepts define new plays and expand known plays. Arrangements can be made for potential users to visit and observe the methods, processes, and other aspects of data preparation and interpretation. This opportunity can pass along new ideas and techniques so that operator's staff members can learn to carry out similar studies. Transfer of the results and onsite training could enrich the capabilities of professionals who have had limited time to advance their capabilities but desire continuing education and updating about latest research advancements.

Phase IX will involve implementation. Helping operators apply results is obviously critical to meeting the objectives of the project: to increase hydrocarbon reserves and production under Texas-owned submerged lands and add the value of these reserves to the Texas Permanent School Fund and the Texas economy. Project STARR at the Bureau of Economic Geology is an important vehicle to help implement the results of this study as demonstrated by Project STARR during the past 8 years.

Budget Justification

We propose that this initial 2-year study of Texas-owned submerged lands will require funding in the amount of $2,803,988 (Table 2). A staff of geoscience and engineering professionals having extensive experience supported by state-of-the-art hardware and software are the major requirements for a successful project. Most of the budget will support the salaries of highly qualified staff. Acquisition of well and production data and advanced technologies will compose the other major expenses. The BEG has a successful record of leveraging investments with private, State, and Federal dollars and will make every effort to do so in this project.

Conclusions

State-owned submerged lands along the Texas Gulf Coast contribute significantly to the Texas Permanent School Fund as well as to the Texas economy (Table 1). Much oil and gas has been produced from this important State-owned resource, but much more can be recovered by applying new technology and concepts using the abundant geologic, geophysical, and engineering data available. Untapped and bypassed resources on State Lands fully justify exploration and prospecting for the large remaining resources. Using the cumulative production data as a reference, if only 10 percent of additional reserves are recovered in the deeper sections of the Texas submerged lands, approximately 22 million bbl of oil and 837 Bcf of gas could be expected. The wellhead value alone of this resource amounts to over $3 billion, and total economic value to Texas, assuming the 2.91 multiplier used by the Texas Comptroller's Input-Output model, is close to $9 billion. Small operators commonly do not have the technical resources to assess concepts of expensive deeper, new exploration targets or geologic fairways. These small, typically Texas-based companies now compose most of the industry interested in submerged lands along the Texas Gulf Coast. This proposed study by the Bureau of Economic Geology is designed to aid these operators in exploring and developing new reserves. Without further studies to define new regional opportunities for exploration, production will continue to decline rapidly on the State-owned submerged lands, as will the concomitant revenues. The Bureau of Economic Geology welcomes this opportunity to work with companies interested in future exploration programs on the Texas-owned submerged lands. If this study increases production by only a few percentage points, the incremental amount of increased production would be significant, both to the operators and to the State.

Table 2. Budget.

			Year 1	Year 2	TOTAL
Salaries and Wages	Effort (months)				
B. Loucks Principal Investigator	12.00	12.00	101,069	105,112	206,181
S. Tinker Director	0.50	0.50	6,640	6,906	13,546
E. Potter Associate Director, Energy	1.00	1.00	8,925	9,282	18,207
D. Ratcliff Associate Director, Administration	1.50	1.50	15,882	16,517	32,399
F. Brown Sequence Stratigrapher Geologist	6.00	6.00	55,435	57,652	113,087
Unnamed Geologists (2)	24.00	24.00	163,012	169,532	332,544
M. DeAngelo Geophysicist	12.00	12.00	55,558	57,780	113,338
S. Sakurai Petrophysicist	6.00	6.00	47,669	49,575	97,244
M. Holtz Petroleum Engineer	6.00	6.00	35,762	37,192	72,954
D. Dunlap IT Support	3.00	3.00	13,416	13,953	27,369
Unnamed GRAs (3)	18.00	18.00	58,032	60,353	118,385
Digitizer Data Entry	3.00	3.00	9,347	9,721	19,068
Graphics Illustrator	3.00	3.00	9,347	9,721	19,068
Editor	2.00	2.00	6,153	6,399	12,552
Subtotal Salaries and Wages			586,247	609,695	1,195,942
Fringe Benefits, VSL			187,599	195,102	382,701

Table 2. Budget.

	Year 1	Year 2	TOTAL
Materials and Services			
Expendable supplies	6,000	6,000	12,000
Base maps	6,000	0	6,000
Raster wireline logs	10,000	2,000	12,000
Paleo data	5,000	0	5,000
Core-related data	3,000	3,000	6,000
Thin sections 300	3,000	3,000	6,000
Cap pressure 25	0	10,000	10,000
A2D Raster software training	7,000	5,000	12,000
Report preparation materials	0	5,000	5,000
Plots and reproductions	8,000	8,000	16,000
Workshop materials	0	3,000	3,000
Subtotal Materials and Services	48,000	45,000	93,000
Computer			
PC Usage	29,400	29,400	58,800
Unix Usage	54,000	54,000	108,000
Subtotal Computer	83,400	83,400	166,800
Travel			
Airfare @ $300/ea.	3,600	3,600	7,200
Vehicle mileage @ $.345/mile	2,341	2,341	4,682
50 days per diem @ $110/day	5,500	5,500	11,000
Professional meeting registrations	4,000	4,000	8,000
Subtotal Travel	15,441	15,441	30,882
Total Direct Costs	920,687	948,638	**$1,869,325**
Total Indirect Costs	460,344	474,319	**$934,663**
Total Project Costs	1,381,031	1,422,957	**$2,803,988**

Reference

Holtz, M. H., and Garrett, C. M., Jr., 1997, Play analysis and resource assessment of Texas State Lands, *in* Major, R. P., ed., Oil and gas on Texas State Lands: an assessment of the resource and characterization of type reservoirs: The University of Texas at Austin, Bureau of Economic Geology Report of Investigations No. 241, p. 1–30.

Appendix 1. Outline of Major Activities

Phase I: Assemble Data and Construct Databases

Activity 1: Well-Log Selection and Retrieval

Select 300 to 400 well logs for Middle Texas submerged lands that best represent the area of interest. Logs are selected on the basis of location, depth of penetration, and production. A2D Technologies correlation-software programs and their SmartRaster (A2D) log database will be used to construct the cross sections. Previously rasterized logs will allow rapid construction of well files and use of the well files in computerized work programs. A2D Technologies has thousands of well logs from the Texas Gulf Coast submerged lands rasterized and available for purchase. A2D Technologies workstation programs facilitate the construction of log cross sections using rasterized logs.

Activity 2: Base Map Construction

Construct base map of selected wells showing depth of penetration, deepest formation penetrated, and production status. Field outlines and geologic age of each field will be shown.

Phase II: Construct S^5-Benchmark Logs

Activity 1: Select Areas to Construct S5-Benchmark Logs

The rocks under Texas-owned submerged lands were deposited in large growth-fault compartments or subbasins. Transgressive and highstand sea-level systems tracts deposited on the ancient continental shelf correlate among compartments. Lowstand sea-level systems tracts were, however, deposited in specific compartments and are highly restricted in their geographic distribution. It is, therefore, important to define the major growth-fault compartments (subbasins) in order to understand the stratigraphic variations of hydrocarbon potential in submerged State lands. Published and in-house maps of growth-fault systems identify the growth-faulted subbasins where S^5-benchmark logs will be constructed.

Activity 2: Construct S5-Benchmark Logs (Site-Specific Sequence-Stratigraphic Section Benchmark Logs)

Approximately 20 S[5]-benchmark logs will be constructed for Middle Texas submerged lands, depending on the number of major deposition centers related to major growth-fault subbasins. S[5]-benchmark logs are composite geophysical wireline logs (composed of several wells) that exhibit the total drilled stratigraphic section of a specific area. Composite geophysical wireline logs are the basis for identifying systems tracts from log signatures and vertical variations. Paleontologic ages of sequence stratal surfaces, "formation" names, and pay zones are included, among other criteria.

Phase III: Construction of Cross Sections and Regional Sand Maps

Activity 1: Select Cross-Section Lines

For Middle Texas submerged lands, approximately 20 cross sections will be constructed on the basis of density and distribution of wells. Wireline geophysical log cross sections will traverse all major fields, and they will conform to the S[5]-benchmark logs and will include the deepest wells available. Major faults will be displayed. Cross sections normal to the ancient coastlines will be spaced approximately 10 miles apart.

Activity 2: Analyze Selected Seismic Lines

Selected seismic reflection files (approximately 30 to 40), where available, will be used in the construction of the cross sections. Synthetic seismic profiles will be generated to correlate wireline logs into the seismic sections. Seismic lines delineate faults and shale ridges, verify correlations via time-parallel reflections, and provide insight about the sequence stratigraphy. The Texas General Land Office (GLO) has the rights to view seismic data from State Lands, and this task would be done in cooperation with the GLO.

Activity 3: Correlate Cross Sections

Using A2D correlation software, key stratigraphic surfaces (time-parallel) will be correlated on the basis of the S^5-benchmark logs and seismic reflection analyses. Major faults identified from seismic data will be plotted.

Activity 4: Incorporate Production Data

Wireline-log cross sections will be annotated with petroleum-production data to display stratigraphic and structural constraints on hydrocarbon production. Data will be retrieved from several commercial databases as well as from the Texas Railroad Commission and the General Land Office.

Activity 5: Construction of Regional Sand Maps

Generalized sand isopach (thickness) maps of selected systems tracts comprising potentially productive sequences will be contoured from wireline-log data to delineate the regional distribution of reservoir-sand bodies within depositional systems. The maps will display general fault trends and sand thickness-trends comprising the complex structure and stratigraphy beneath State-owned submerged lands. Detailed mapping is beyond the scope and resources of this present study and is best done at the detailed prospect level.

Phase IV: Delineate Reservoir-Quality Economic Basement

Activity 1: Whole-Core and Side-Wall Porosity and Permeability Data

Results of core analyses will be collected from companies that have operated wells on Texas submerged lands. The data will be entered into digital databases and analyzed for regional and depth trends. Other than flow tests, these are the only data that provide permeability values. These values permit identification of the reservoir-quality of different systems tract facies.

Activity 2: Petrographic Analysis of Sand Quality

Select core samples will be analyzed for petrographic parameters. Mineralogy, texture, consolidation history, and pore types are necessary factors to understand reservoir quality relative to regional geographic and depth-of-burial trends.

Activity 3: Petrophysical Analysis of Wireline-Log

Selected geophysical wireline-logs will be modeled and analyzed for porosity and fluid content. Special attention will be focused on deep wells having comprehensive geophysical wireline-log suites. Pressure and thermal data from the wireline logs will be collected and filed in a database to plot overpressured zones and geothermal gradients. These data define reservoir-quality economic basement.

Activity 4: Delineate Reservoir-Quality Economic Basement

Results of above Phase IV activities will be integrated to delineate reservoir-quality economic basement for genetically different geographical and petrophysical sand classes (mineralogy, texture, and/or systems tract facies). Maps will be produced that show depth to reservoir-quality economic basement.

Activity 5: Completion and Stimulation Techniques That May Deepen Reservoir-Quality Economic Basement

New well completion and stimulation techniques such as fracing of low-permeability reservoirs could extend the depth of economic basement. Summaries of potentially viable techniques to deepen reservoir-quality economic basement will be prepared.

Phase V: Develop Petroleum-Play Catalog of Selected Geologic Analogs

Activity 1: Collect Data on Selected Fields/Reservoirs

Selected fields/reservoirs (approximately 10) will be reviewed for geology and engineering attributes to develop geologic petroleum-play analogs. Selection will be based on sequence and

systems tract stratigraphy, trap configuration, and depth of burial. Information from public and private sources will be used, and a special effort will be made to have operators contribute in-house studies to the geologic petroleum-play analog database.

Activity 2: Characterize Geologic Petroleum-Play Analogs

Geologic petroleum-play analog fields and reservoirs will be analyzed to define stratigraphic sequence position and reservoir quality, seal, trap configuration, drive mechanism, and production history for productive sands.

Phase VI: Delineate Geologic Fairways

Activity 1: Define Geologic Fairways with Cross Sections and Maps

Geophysical wireline-log cross sections and maps display geologic fairways (play trends) based on sandstone-quality parameters, stratigraphic architecture, petroleum-play analogs, and reservoir-quality basement.

Activity 2: Summarize Characteristics of Geologic Fairways

Each geologic fairway will be characterized. Summary geological data will include "formation," sequence-stratigraphic systems tracts, trap configurations, and reservoir quality, among others. Engineering data will include fluid types, drive mechanisms, etc.

Phase VII: Economic Analysis of Geologic Fairways

Activity 1: Perform Economic Analysis

Economic metrics will be generated for each geologic fairway. Volume of reserves will be estimated, and value will be applied to these reserves.

Phase VIII: Technology Transfer

Results of this investigation will be widely disseminated to ensure that interested operators have maximum access to technical results. Technology transfer of results will be through public workshops, technical presentations, technical reports, consultations with individual operators, and professional society publications. The project will work in close association with the Texas Petroleum Technology Transfer Council for maximum interaction with independents.

Activity 1: Public Workshops

At the end of each of the three stages of the project, we propose to hold a series of public technology transfer workshops to present results to interested operators. The Bureau of Economic Geology has many years of experience leading such workshops, and we have historically developed cooperative relationships with local geological and engineering societies to ensure broad participation.

Activity 2: Professional Presentations

We propose public presentations to local, regional, and national professional organizations such as the American Association of Petroleum Geologists, Society of Petroleum Engineers, and Gulf Coast Association of Geological Societies. These organizations are the principal professional forums for nonproprietary exchange of ideas in the petroleum geoscience industry.

Activity 3: Final Reports

Comprehensive reports (one for each of the three areas) will be published by the Bureau of Economic Geology. The BEG's publications are available approximately at cost and are widely distributed among independent operators, major company and public libraries, and geoscientists. We propose a CD-ROM format so that large geophysical log cross sections, maps, and large databases can be widely distributed. Atlases of geologic fairway maps and S^5-benchmark logs may also be published in hardcopy editions.

Activity 4: Direct Operator Consultation and Support

Technology transfer requires numerous contacts with interested operators. Initial contacts during data-gathering stages will be followed by public presentation of project results. Some operators may request extended discussions to assess the value of our results on their exploration properties. Texas oil and gas operators have historically turned to the Bureau of Economic Geology for technical information.

Phase IX: Implementation of Results

Activity 1: Short-Term Interaction with Operators

We can provide short-term interaction with operators and other interested parties to help make the most appropriate use of project results.

Activity 2: Long-Term Interaction with Operators

Project STARR (State of Texas Advanced Resource Recovery) provides an ideal forum to help interested operators assess their State submerged land leases over the long-term course of their development. Furthermore, STARR is designed to help them define field extensions and deeper drilling targets. Project STARR has cooperated with 17 operators during the past 8 years, enhancing reserves and production on State Land leases. Project STARR can incorporate the results obtained form the State of Texas Submerged Lands Regional Study and work with operators to apply these results.