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SALTON SEA SCIENTIFIC DRILLING PROGRAM

Report of the Third Quarter

FY 1985

September 1985

U.S. DEPARTMENT OF ENERGY

Office of Renewable Energy Technologies
Geothermal Technology Division

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EXECUTIVE SUMMARY

Since the signing of the contract between DOE and Bechtel, the Salton Sea Scientific Drilling Program has undergone a reduction in scope due to funding limitations. Engineering research aspects of the program have been given a somewhat lower priority in favor of collecting as much data as possible and enhancing the scientific research program.

By the end of the third quarter of FY-1985, program activities had progressed to the point of preparation for drilling operations. On-site operational assignments had been made and a preliminary science plan had been formulated to coordinate the many down-hole tests, measurements and experiments during drilling.

The present plan for drilling and scientific evaluation reflects the rescoping of the project that began in March. An estimate of costs for a reduced version of the SSSDP was made by Bechtel ($6.2 million), after which minor clarification showed other areas where cost savings could occur. Based upon this estimate, a total project cost ceiling of $6.1 million was established.

During this reporting period, the important issues of coring and fluid sampling technology were addressed. In an effort to improve scientific return, the option of wireline core retrieval vs using conventional coring methods was evaluated. Subsequently, conventional coring methods were recommended for use in the SSSDP, but development of wireline retrieval technology was recommended for future use in the Continental Scientific Drilling Program. Concern about the present limited fluid sampling plan remains an important issue, which will be continuously evaluated until an optimum balance can be achieved between the need for increasing the number and duration of flow tests, and the need to reduce cost, while maintaining a comprehensive data collection program.

As the program proceeds, a higher degree of cooperation and coordination has been established among the many participants. The roles and responsibilties

among the concerned parties are being confirmed. As the spud-in date draws near, the many individual efforts are becoming focused on the primary program objective - the scientific study of the deep hydrothermal system beneath the Salton Sea Geothermal Field.

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INTRODUCTION

The Salton Sea Scientific Drilling Program (SSSDP) is a scientific research effort of the U.S. Department of Energy (DOE), the U.S. Geological Survey (USGS), and the National Science Foundation (NSF) to study the roots of the Salton Sea hydrothermal system in southern California's Imperial Valley. The program had its beginning as a university-industry proposed well-of-opportunity within the Continental Scientific Drilling Program and is the first major project of its type to specifically address issues related to thermal regimes beneath continental spreading zones and the genesis of ore forming minerals.

PROGRAM PLAN

Background

Since the initial concept of a deep drilling program within the Salton Sea Geothermal Field (SSGF) was proposed to NSF and DOE in early 1983, a number of funding-related events occurred which necessitated alteration of the approach to the original proposed project. Major events that helped shape the program to the beginning of this reporting period were:

- September 1983: After NSF and DOE received unsolicited proposals in early 1983 by U.C. Riverside (UCR) and Republic Geothermal, Inc. (RGI) to deepen an existing well in the SSGF from 12,000 to 18,000 feet, and after subsequent presentations by RGI and UCR, Congress authorized DOE's Geothermal Technology Division (GTD) to investigate the deep thermal regime in the SSGF and appropriated $5.9 million of FY-1984 funds.

- March 1984: Government procurement policy dictated a competitively awarded contract. Therefore, DOE's San Francisco Operations office (DOE/SAN) issued an RFP soliciting industry participation in the Drilling and Engineering phase of a proposed program. The RFP outlined a program to spud a new well or deepen an existing well to a depth of 6000 feet below the level of the 300°C isotherm, to a maximum depth of 18,000 feet.

- June 1984: Bechtel National, Inc. was selected by DOE for contract negotiation and was awarded a contract for $5.3 million in cooperation with Kennecott Corporation to manage drilling and testing of a research well. Bechtel became the prime contractor and began preliminary procurement and project organization.

- November 1984: In response to an informational meeting held in August 1984 to inform the science community of the management plan for the project and procedures for submitting scientific proposals, 57 proposals were received by the Science Coordinating Committee (SCC) and evaluated by the Scientific Experiments Committee (SEC). The proposals were then ranked by a joint DOE Office of Basic Energy Science (OBES)-NSF Peer Review Panel.

- January 1985: DOE/SAN issued a "stop work" order to Bechtel after new cost projections indicated a high likelihood of large overruns.

- March 1985: An SSSDP Reformulation Task Force was created to investigate drilling and engineering "trade-offs," reduction of project costs, and preservation of the scientific integrity of the program. Several "trade-offs" for cost reduction were initially identified and the estimated total cost of the program was reduced to $6.4 million. Other savings were subsequently identified within the well casing design and the coring program to further reduce the estimated total cost to about $5.9 million.

By the end of the second quarter (March 31) of FY 1985 the SSSDP had undergone significant rescoping in order to maintain the value of the scientific return of the program while staying within the program budget. Major elements of the rescoped program are summarized in Table 1.

PROJECT ACTIVITY	DESCRIPTION
• Scientific Well Drilling:	Estimated total depth = 10,000 feet; 8.5 inch bottom hole diameter; total estimated drilling time-approximately 7 months.
• Brine Disposal:	1.1 million gallon brine holding pond; treatment limited to simple wellhead facilities.
• Production Testing:	One 24-hour flow test below 6000 feet.
• Data Collecting:	Amount of coring to be limited to a budget of $1 million; will obtain a complete suite of geophysical logs, production logs and well cuttings.
• Abandonment:	Plugging of scientific well; restoration of the site; and reclamation of the brine pond.

TABLE 1: Description of Major SSSDP Program Elements

Current Program

In April, Bechtel National, Inc. produced a revised cost estimate that reflected the latest project rescoping. Key elements of this estimate are shown in Table 2.

The estimated total did not represent an approved contract. The final ceiling was to be negotiated. A "change order" issued by DOE/SAN allowed Bechtel to proceed with site preparation and development of subcontract packages

Task		Estimated Cost ($ Million)
Preliminary Plans; Project Rescoping		0.8
1. Initial Site Preparation		0.3
2. Final Site Preparation; Final Drilling/Science Plan		0.5
3. Drilling and Engineering		
• Drilling and Casing	1.9	
• Coring and Geophysical Logging	1.2	
• Site Support/Administration	0.4	
Subtotal Drilling and Engineering		3.5
4. Flow Test		0.3
5. Standby		0.2
6. Site Abandonment		
• Plug and Abandon	0.1	
• Decontaminate and Restore Site	0.4	
• Final Report/Closeout	0.1	
Subtotal Site Abandonment		0.6
Estimated Total		$6.2

Table 2: Budget Forecast by Bechtel

while the contract was being renegotiated to fall within an established $6.1 million cost ceiling.

As part of the rescoping effort, particular attention was given to evaluating the reasonableness of drilling costs by using data from other Imperial Valley wells. Heber field cost information was obtained from Chevron Resources Company and Niland field data from the Republic Geothermal drilling experience near the SSSDP site. Data from these two fields are quite different, reflecting differences in subsurface conditions, and commercial and scientific drilling programs.

General well costs obtained from Chevron's drilling at Heber indicated that production wells could be drilled for $1 million to $1.5 million, each. Characteristics of the Heber drilling program were as follows:

- Twenty-eight production wells drilled on a "time and materials basis" with limited coring.
- Average drilling time - 30 to 35 days.
- Depths drilled ranged from 7,000 ft to 10,500 ft.
- Average temperature - 182°C.

The wells were drilled with a commercial approach to field development, where one simple, repetitive design was used, and where drilling operations were streamlined to the maximum extent possible. Drilling contracts were awarded for multiple wells.

Data provided by Republic Geothermal from three wells drilled near the SSSDP site indicated that the average cost for a commercial well was about $2.2 million. The drilling program is summarized as follows:

- Three production wells drilled, without coring.
- Average drilling time - 65 to 70 days.
- Depths drilled ranged from 9,700 ft. to 11,600 ft.
- Average temperature - 297°C.

Bechtel estimated the cost of the SSSDP well to be $2.236 million, if the well were to be drilled as a commercial producer, and completed within a period of 62 days. A breakdown of the Bechtel estimate is:

Well design (Berkeley Group/Bechtel)	$94,000
Mobilize rig, drill and case to 3,000 ft	$699,000
Drill and case to 6,000 ft	$466,000
Drill to 10,000 ft, install liner and wellhead, and demobilize	$423,000
Fishing budget	$300,000
Drilling engineer	$77,000
Site facilities	$48,000
Site management	$129,000
TOTAL	$2,236,000

The cost differences between the Chevron and Republic estimates, or a hypothetical commercial SSSDP well, relate to the higher bottom-hole temperatures (379°C is expected in the SSSDP well). Also, the SSSDP well is a first-of-a-kind well, where costs shown in the itemized list above correlate to two of the items shown in Table 2, namely, Drilling and Casing, and Site Support/Administration.

Subcontracting activities were begun and a total of 45 packages were prepared in anticipation of release for bid. By the end of the reporting period, the status of subcontracting activities was as follows:

Number of Subcontracts	Status
3	Work completed
7	Subcontracts awarded
2	Pending DOE consent to award
7	Out for bid, or bids under evaluation
13	Technical specs in preparation
13	Future specifications

Highest priorities were assigned to activities requiring long lead-times, complex procurement, or were critical to the schedule.

Drilling and Engineering

The drilling and engineering plan has continued to be examined and reshaped. Vital elements of the plan must be in place early so that the science plan can be effectively carried out. Reduction of the flow testing activities has been necessary in order to reduce project costs. However, much concern has been expressed over the diminished opportunities to collect the pristine fluid samples required for many of the scientific studies. In addition, the wisdom of using conventional coring methods has been weighed against the possibility of obtaining continuous cores from the drilled interval using wireline retrieval techniques.

The fluid sampling program at present is considered to be the weakest part of the program. The present fluid sampling plan includes a single 24-hour flow test from a producing horizon below a depth of 6000 feet and deployment of a downhole fluid sampler. The limitation on flow testing is imposed by the 1.1 million gallon capacity of the brine holding pond.

Los Alamos National Laboratory (LANL) has been enlisted to develop two high-temperature downhole fluid samplers. The 3.5 inch diameter sampling device to be lowered by wire-line will be attached to an electronic tool under development by Sandia National Laboratories (SNL). The tool will provide power and timing for opening and closing the sampler's valves.

Three other downhole measuring devices are also under development by SNL. These devices will be used to measure temperature, pressure and flow, and are being acquired from the Kuster Company. All of them are dewared to allow them to function at extremely high temperature in corrosive fluid. The tools for measurement of temperature and pressure will utilize a standard commercial design. The flow measuring tool will require more of a development effort.

The three mechanical tools will be packaged as 3-inch diameter units, each approximately eight feet in length. The units will be enclosed in heat shields

to allow at least 12 hours of operation at temperatures of 400°C. The tools mechanically record measurements as a function of time and are read at the surface after removal from the well. When coupled with instrumentation for recording depth as a function of time, the tools can be used for standard logging.

Studies were performed by Bechtel's consultant and Sandia National Laboratories to evaluate the feasibility of using continuous wireline coring methods in the SSSDP well. The studies were the result of the need to obtain maximum core recovery within the established coring budget. It was hoped that, if large diameter (6+ inches), continuous wireline coring was feasible, coring could be attempted across the entire 4000 ft interval below 6000 ft. The constraints that were identified during the study were:

1) limitations imposed by a fixed budget and the desire not to delay the project further for development of an innovative coring technique; and

2) potential safety and material performance risks of an unproven methodology in a hot, corrosive, saline environment.

The decision was reached that continuous wireline coring would not be attempted in the SSSDP, but should be pursued for future use in scientific drilling into hot, hostile subsurface environments that are characteristic of many thermal regimes. The continuous wireline coring option was investigated because it appeared to offer better core recovery at less cost to the project. This option was not recommended for the SSSDP mainly because the method required excessive time for development, was unproven in large (6+ inch) diameter boreholes drilled into hot corrosive environments, and was estimated to be more costly than conventional methods. In addition, use of the method to drill a smaller diameter borehole would have violated the original Kennecott/Bechtel agreement regarding the use of Kennecott's leaseholds which required the drilling of a well "suitable for commercial use."

The present coring program consists of an established $1 million coring budget to be expended on coring attempts at various depths in the 10,000' well. The following points summarize the coring program:

- Maximum estimated amount of core using 30 ft core barrels is 1200 ft.
- Core recovery using 60 ft barrels has been conservatively estimated at 1600 ft. If the longer barrels can be used successfully, it is thought that as much as 2400 ft of core can be attempted within the existing $1 million budget.
- About 400 ft of core will be attempted above a depth of 6000 ft.
- Under "worst case" conditions, it is estimated that the 800 ft of coring projected below 6000 ft will require about 70% (or 45 days) of the total drilling time for that interval.

During drilling operations, the coring budget will be used by the scientists to pay for all hardware (core barrels, bits, etc.) and the daily cost, based upon an hourly rate, for all equipment and site support necessary to maintain operations. If fishing is required during coring activities, contingency funds will be used until they are expended, at which time the scientists assume responsibility for the additional costs. Application of the daily cost-rate to the coring budget will be as follows: (1) between bit changes at the time the driller begins preparation for tripping out and ending when the conventional bit returns to bottom; and (2) at bit changes at the time the core bit is attached to the drill collar, and ending at the time the conventional drill bit is reattached to the drill collar. Early estimates from existing cost data indicate that the daily cost rate will be approximately $11,000 per day.

DOE/SAN advertised on May 15, a Request for Invitation to Bid in the Commerce Business Daily for "high-temperature, high-corrosion resistant, armored logging cable." The prospective contractor was requested to supply a 15,000 foot, continuous length cable to meet the following conditions and specifications:

- General

  Nominal Diameter: 7/16 inch
  Number of Conductors: 7 (6 around 1) center conductor designed for maximum stretch.

- Conductors

  Size: 20 guage equivalent
  Insulation: Teflon TFE
  Temperature Rating; 315°C (600°F) minimum
  Coating: 27% nickel by cross section
  Resistance/1000 ft: 14 OHMS/1000-ft maximum per conductor
  Capacitance/ft: 40 PF/ft.

- Armor

  Material: MP35N
  Breaking Strength: 18,000 pounds minimum
  Inner Wrap, Right Hand Lay: 18 wire .042-in. diameter
  Outer Wrap, Left Hand Lay: 18 wire .059-in. diameter

- Spooling

  Cable is to be spooled on U.S. Geological Survey, WRD Borehole Geophysics Research Project Truck by contractor or his designated agent.

Delivery of the cable will be critical to the program because drilling is scheduled to begin before the receipt of the cable. The cable must be on-site and ready for use when drilling has reached the depth of the second logging run (about 6000 ft). The cable purchase is a joint procurement by the USGS and DOE where both agencies cost-shared the purchase. The USGS will also provide research geophysical well logging.

Scientific Experiments

The scientific experiments program has been organized around the concept of "exploring the roots of the Salton Sea geothermal system by drilling, sampling and studying the deepest, hottest borehole possible." To this end, a scientific experiments package comprised of 31 activities has been selected by the Science Coordinating Committee (SCC) for funding from more than 60 proposals submitted to DOE, USGS, and NSF. Table 3 shows the 6 categories of activities that were selected for funding at a level of about $2.2 million, including both scientific

experiments and hardware development. The total package of funded proposals is shown in Table 4. In addition to the funded proposals, requests for non-funded access to SSSDP samples are continuing to be processed.

	FUNDING AGENCY				
CATEGORY	NSF	OBES	USGS	GTD	TOTAL
Geochemistry	168	103	165	-	436
Petrology	280	150	-	-	430
Geophysics (Lab)	-	135	80	-	215
Geophysics (Site)	-	175	175	-	350
Bio-Organic	-	-	70	-	70
Hardware	-	-	120	547	667
Total Funding	448	563	610	547	2,168
Total Activities	6	9	11	5	31

Table 3: A Summary of Funding by Category and Agency for Scientific Research Associated with the SSSDP (values shown in dollars X 1000).

A "science planning" document is currently in preparation by the Scientific Experiments Committee (SEC). The document will be used as a basis for organizing activities related to the overall scientific program. The plan will be subdivided into seven sections as follows:

- Logging and Downhole Experiments
- Fluid Sampling
- Coring Strategy
- On-site Post Drilling Activities
- Curation and Laboratory Investigations
- Organization and Communications
- Contingencies

The science plan attempts to optimize the science program within the restrictions imposed by the projected program schedule, budget and scientific

Table 4: Salton Sea Scientific Drilling Program: Scientific Experiments Package - Funded Projects

PI/INSTITUTION	TITLE	FUNDED BY	K$/MONTHS
GEOCHEMISTRY			
REYNOLDS/UC-BERKELEY	"Noble Gases at the Deep Well of the SSSDP"	NSF/EAR	6/12
VALETTE-SILVER/CARNEGIE-DTM	"Study of the Salton Sea Geothermal System Using Be10 Isotope and Trace Element Geochemistry"	DOE/BES	43/12
GOFF, WHITE/LANL, LBL	"In-Situ Fluid Sampling of Salton Sea Scientific Drilling Program Well"	DOE/BES	60/12
WILLIAMS/UC-RIVERSIDE	"Oxygen Isotope Exchange in Minerals During Hydrothermal Metamorphism: Salton Trough Sediments"	NSF/EAR	64/12
EDMOND/MIT	"SSSDP-Chemistry of Hydrothermal Waters"	NSF/EAR	98/12
BETHKE/USGS	"Small-Volume In-Situ Fluid Sampling Using Synthetic Fluid Inclusions"	USGS	15/12
COPLEN/USGS	"The Application of C136 to Geochemical Problems of the Salton Sea Geothermal System"	USGS	10/9
COPLEN/USGS	"Environmental Isotope Hydrology and Geochemistry of the Salton Sea Geothermal System"	USGS	30/21
FOURNIER, TRUSDELL/USGS	"Liquid and Gas Sampling and Analyses"	USGS	70/12
ROEDDER/USGS	"Fluid Inclusions in Salton Sea Core"	USGS	40/12
ELDERS ET AL./UC-RIVERSIDE	"A Study of Trace Element Mobility in Brines Within the Salton Sea Geothermal Field"	-	0/12
HIGGINS/MCMASTER	"SSSDP Samples: Boron Studies"	-	0/12
PETROLOGY			
PAPIKE/SDSM&T	"Cores from the SSSDP: Metamorphic Reaction Progress as a Function of Chemical and Thermal Environment"	DOE/BES	50/12
ELDERS, COHEN/UC-RIVERSIDE	"Igneous Rocks in the Magma-Hydrothermal Systems of the Salton Trough"	NSF/EAR	100/24
PEACOR/MICHIGAN	"Mineral Transitions in Salton Sea Argillaceous Sediments"	NSF/EAR	50/12
LIOU, BIRD/STANFORD	"Salton Sea Drill Hole: A National Laboratory for Investigation of the Greenschist-Amphibolite Transition"	NSF/EAR	130/24
MCKIBBEN/UC-RIVERSIDE	"A Study of Sulfide-Oxide-Silicate Phase Equilibria and Associated Fluid Inclusion Properties in the Salton Sea Geothermal System"	DOE/BES	50/12
MCDOWELL/MICHIGAN TECH	"Geothermal Alteration of Sediments in the Salton Sea Scientific Drill Hole"	DOE/BES	50/12
HAYASHI/KYUSHU	"Thermal History by the Analysis of Fission-Track Length Distribution"	-	0/12
JEDWAB/BRUXELLE	"Small Particulate Minerals Suspended in SSSDP Fluids"	-	0/12

Table 4 (continued)

PI/INSTITUTION	TITLE	FUNDED BY	K$/MONTHS
GEOPHYSICS (LAB)			
KING ET AL./LBL	"Geomechanics Laboratory Studies"	DOE/BES	60/12
DAILY, LIN/LLNL	"Physical and Chemical Laboratory Studies of Cores from the SSSDP"	DOE/BES	75/12
OLSON, MORIN/USGS	"Transport Properties of SSSDP Cores: Laboratory Measuremments and Interpretation"	USGS	80/30
GEOPHYSICS (SITE)			
MAJER, MCEVILLY/LBL	"Reflection Profiling at the Salton Sea Deep Hole Site"	DOE/BES	100/12
MORIN, PAILLET/USGS	"SSSDP-Geothermal Logging, Analysis, and Interpretation"	USGS	75/12
OLHOEFT/USGS	"NCLR and Pt-RTD Borehole Logging"	USGS	100/15
PAILLET/USGS	"Acoustic Characterization of Fractures and Hydrothermal Alteration in the Salton Sea Geothermal Reservoir"	DOE/GTD	40/12
KASAMEYER, HEARST/LLNL	"Constraints from Borehole Gravity on Geothermal Models and Resource Definition in the Salton Sea Geothermal Field"	DOE/BES	75/12
BIO-ORGANIC			
BARKER, PRICE/USGS	"Kerogen Thermal Metamorphism in open and closed Geochemical Systems: Salton Trough, California"	USGS	25/12
KHARAKA/USGS	"Nature, Distribution and Inorganic Interactions of Organic Species Dissolved in Geothermal Waters, Imperial Valley, California"	USGS	40/12
FOURNIER, BARGER/USGS	"Thermophilic Microorganisms in Fluid Inclusions: SSSDP"	USGS	5/12
DAHM, BAROSS/NM, WASH.	"SSSDP Samples: Thermophilic Micro-Organisms"	-	0/12
HARDWARE			
LANL	"Two LANL 2-Liter capacity fluid samplers; support of field activities and fabrication of 2 high-temperature cable heads"	DOE/GTD	60
SANDIA	"Downhole power source for LANL fluid sampler"	DOE/GTD	90
SANDIA	"For mechanical T-P flow tool"	DOE/GTD	147
DOE/SAN	"Ship geopressured cable to Imperial Valley GTF"	DOE/GTD	2
DOE/SAN	"New High-Temperature Cable"	DOE/GTD & USGS	368

priorities.

A preliminary schedule for logging and downhole experimentation has been developed by the On-site Science Manager and the Chief Scientist based upon "best case" and "worst case" scenarios for the length of time required for drilling (Table 5). The "best case" assumes a 20 week drilling period (most rig-time available for experiments), while a "worst case" assumes a 40 week drilling period (least rig-time available for experiments).

BEST CASE (20-Week Drilling Period)		WORST CASE (40-Week Drilling Period)	
ACTIVITIES DURING DRILLING	HOURS	ACTIVITIES DURING DRILLING	HOURS
Bottom Hole Temperatures	50	Bottom Hole Temperatures	50
Down-Hole Fluid Samples	50	Down-Hole Fluid Samples	25
Geophysical Logs	450	Geophysical Logs	175
Vertical Seismic Profiling	50		
Down-Hole Gravity	50		
POST-DRILLING ACTIVITIES		POST-DRILLING ACTIVITIES	
Small Volume Sampling	25	Small Volume Sampling	25
Down-Hole Sampling	25	Down-Hole Sampling	25
Temperature Measurements	120	Temperature Measurements	120
		Vertical Seismic Profiling	50
		Down-Hole Gravity	50
TOTAL	820	TOTAL	520

Table 5: Estimates of Time Required for Down-Hole Scientific Experiments

Project Schedule

The project schedule has been modified over the past several months in response to better management control. The current project schedule is illustrated in Figure 1. Of significance is the projected spud-date for the well and the estimate of time required for drilling and coring. The spud-date is projected for mid September with expected completion by late February.

Post-drilling standby time will necessarily be at least the equivalent of one drilling period, as this is considered to be a firm requirement of the scientific program. The post-drilling period will be managed in such a way as to expand the standby period to allow maximum access to the well for scientific experimentation at minimum cost to the program.

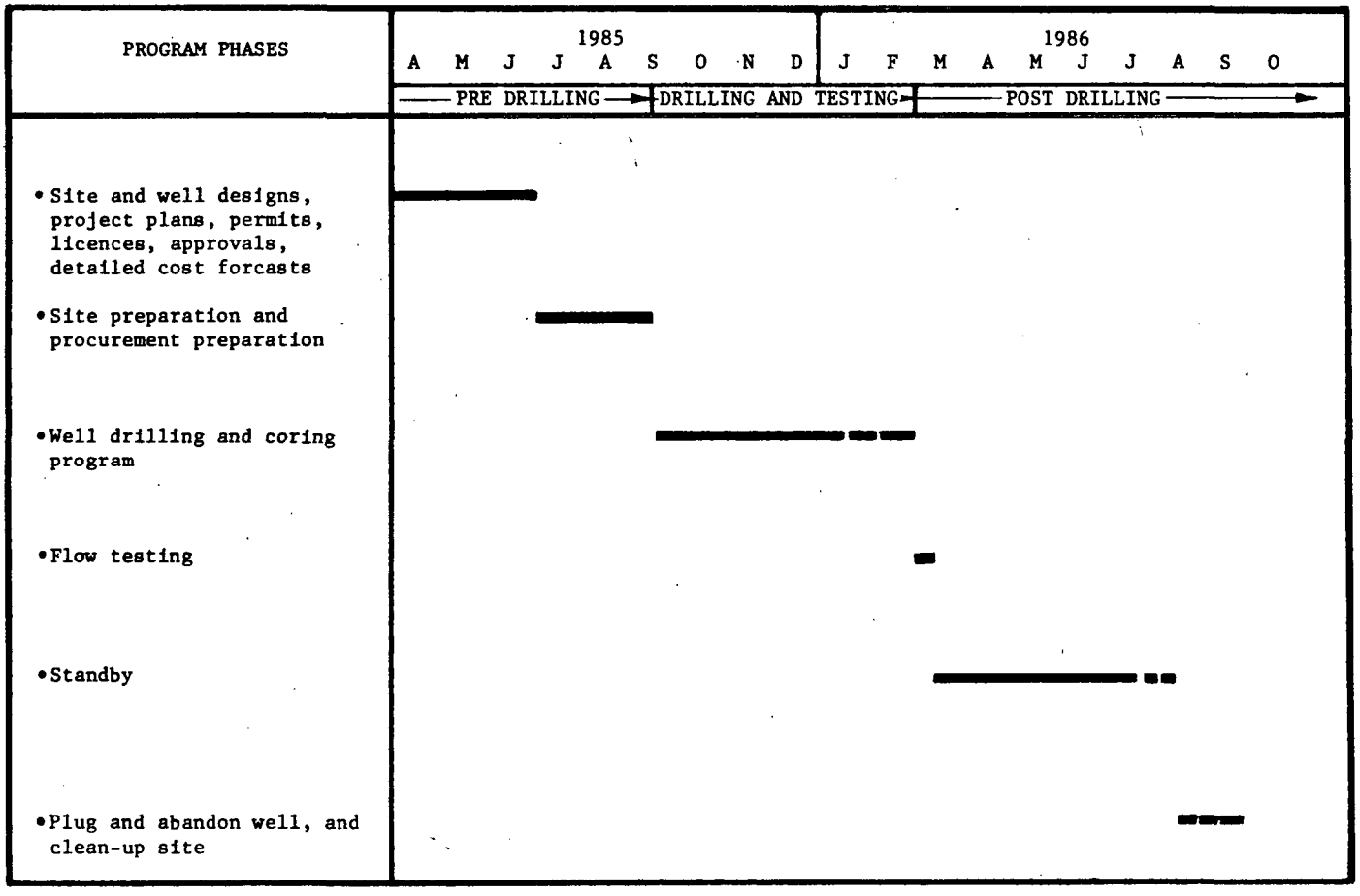

Figure 1: Salton Sea Scientific Drilling Program Schedule

SIGNIFICANT MEETINGS

SEC/SCC Meeting; April 25, 1985

A joint meeting of the Scientific Experiments Committee (SEC) and the Science Coordinating Committee (SCC) was held at the offices of the U.S. Geological Survey in Menlo Park, California. The main issues discussed at the meeting included: (1) the fluid sampling plan and the likelihood of obtaining representative samples from the SSSDP well; (2) the amount of time that will be required for geophysical logging; and (3) new coring technologies, procedures, and their possible uses in the SSSDP Well.

Sandia Briefing; May 23,1985

A briefing was held at the U.S. Department of Energy, San Francisco Operations Office (DOE/SAN) concerning strategies for obtaining core from the SSSDP well. Representatives from Sandia National Laboratories (SNL) presented results of their preliminary assessment of coring options and made recommendations to personnel from DOE/SAN, Bechtel, and the SSSDP Chief Scientist. New perspectives on coring options were discussed in relation to: (1) goals of the program; (2) budgetary constraints and the need for an early start-date; and (3) the expected drilling environment. Options for data recovery discussed were: (1) the drilling of multiple wells to obtain all of the necessary data; and (2) continuous wireline coring to the projected total depth of 10,000 feet.