

UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

Salton Sea Scientific Drilling Project
On-Site Science Management

by

J. H. Sass, S. S. Priest, L. C. Robison, and J. D. Hendricks

Open File Report 86-397

This report is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards. Any use of trade names and trademarks is for descriptive purposes only and does not constitute endorsement by the U. S. Geological Survey.

Flagstaff, Arizona
1986

TABLE OF CONTENTS

	<u>page</u>
Abstract	3
Introduction	4
Acknowledgements	6
Administrative Structure, Phase II	7
Cores and Cuttings	11
Geophysical Logging.	14
Flow Tests and Downhole Experiments.	18
Temperature Logging.	22
Summary and Concluding Remarks	23
 Figures:	
Figure 1. Salton Sea Scientific Drilling Program management plan. . .	5
Figure 2. SSSDP on-site operations organization	8
Figure 3. Depth drilled as a function of time, SSSDP.	10
Figure 4. Well configuration, SSSDP	17
 Tables:	
Table 1. Summary of SSSDP Costs (from Harper and Rabb, 1986).	6
Table 2. History of coring attempts and recovery, SSSDP	12
Table 3. Dates, intervals, and types of Schlumberger logs, SSSDP. . .	15
Table 4. History of USGS geophysical logs, SSSDP.	16
Table 5. Downhole experiments, SSSDP.	19

ABSTRACT

In response to a request from the Science Coordinating Committee of the Salton Sea Scientific Drilling Program (SSSDP) a four-member on-site science management team from the U. S. Geological Survey, Flagstaff, Arizona, was assembled in the autumn of 1984. This team participated in all planning phases of the scientific project together with the Chief Scientist, Scientific Experiments Committee, Department of Energy, and the prime contractor (Bechtel National Inc.).

The well was spudded on October 23, 1985, and reached total depth of 10,564 ft (3.2 km) on March 17, 1986. From the standpoint of science management, the project was a success. A spirit of mutual trust, respect and cooperation developed very early among on-site personnel, both scientific and non-scientific, with the result that scientific goals of the program were integrated smoothly with engineering and technological objectives. The ideal of "science driving the drill" was achieved in large measure.

INTRODUCTION

The U. S. Geological Survey (USGS) was involved in many aspects of the Salton Sea Scientific Drilling Program (SSSDP). Under the interagency agreement governing continental scientific drilling, USGS personnel were active in the Executive Steering Committee, the Science Coordinating Committee, and the Scientific Experiments Committee (fig. 1). Many USGS scientists participated as principal investigators for scientific work on samples and for in-hole experiments. The purpose of this report is to describe and explain the Geological Survey's role in on-site science management of the project.

In July of 1984, John Sass was asked by Ben Morgan, U. S. Geological Survey's Assistant Chief Geologist for Programs, to serve as On-site Science Manager for the SSSDP. Shortly thereafter, a team comprising John Sass, John Hendricks, Sue Priest, and Lori Robison was assembled, and a project description and FY 1985 budget request in the amount of K\$138 was forwarded to USGS' Geologic Division in anticipation of a February or March 1985 spud date. The projected duration of the active phase was 4 to 6 months. Thus, we initially anticipated completion of this phase during FY 85 with only minor funding (for post-drilling science and tying up of loose ends) required in FY 86.

It became apparent, however, that because of the need for competitive procurement and a change in project scope, part of the active phase was going to carry over into FY 86. As problems and consequent delays mounted, it seemed most probable that the spud date would be early in FY 86, which is what eventually transpired. The unanticipated delays required reprogramming of FY 85 funds and redirection of the efforts of the management team. They also resulted in a FY 86 budget comparable to the original one (K\$140+).

The SSSDP well was spudded on October 23, 1985 and was completed on March 17, 1986. An additional 14 days of flow testing, logging, and downhole experiments followed. Following the running of initial temperature logs, the well was shut in for a six-month idle period during which a time series of temperature logs was scheduled to be run. The project was divided into three phases as illustrated in Table 1.

Phase I was frustrating to the Chief Scientist, the On-site Science Manager, and the Scientific Experiments Committee because of their inability to participate to a significant extent in the initial planning and "scoping" of the project. The management plan as originally conceived (fig. 1) worked satisfactorily down to the second level in Phase I, but suffered from an absence of stronger linkages and joint planning from the SAN OPERATIONS - SCIENCE SERVICES level downward. The original policy of DOE SAN was to solicit input from the Scientific Experiments Committee, then independently to design a drilling/engineering program for later review by the scientists. This approach left each group on a separate track as implied by the parallel programs shown in figure 1. Eventually, management changes were made both at DOE and Bechtel National Inc. A joint working group was then formed to reconcile differences in priority and to bring the entire project within budgetary constraints. From this point onward, planning went smoothly with strong linkages being forged among DOE's management, the Chief Scientist,

SALTON SEA SCIENTIFIC DRILLING PROGRAM MANAGEMENT PLAN

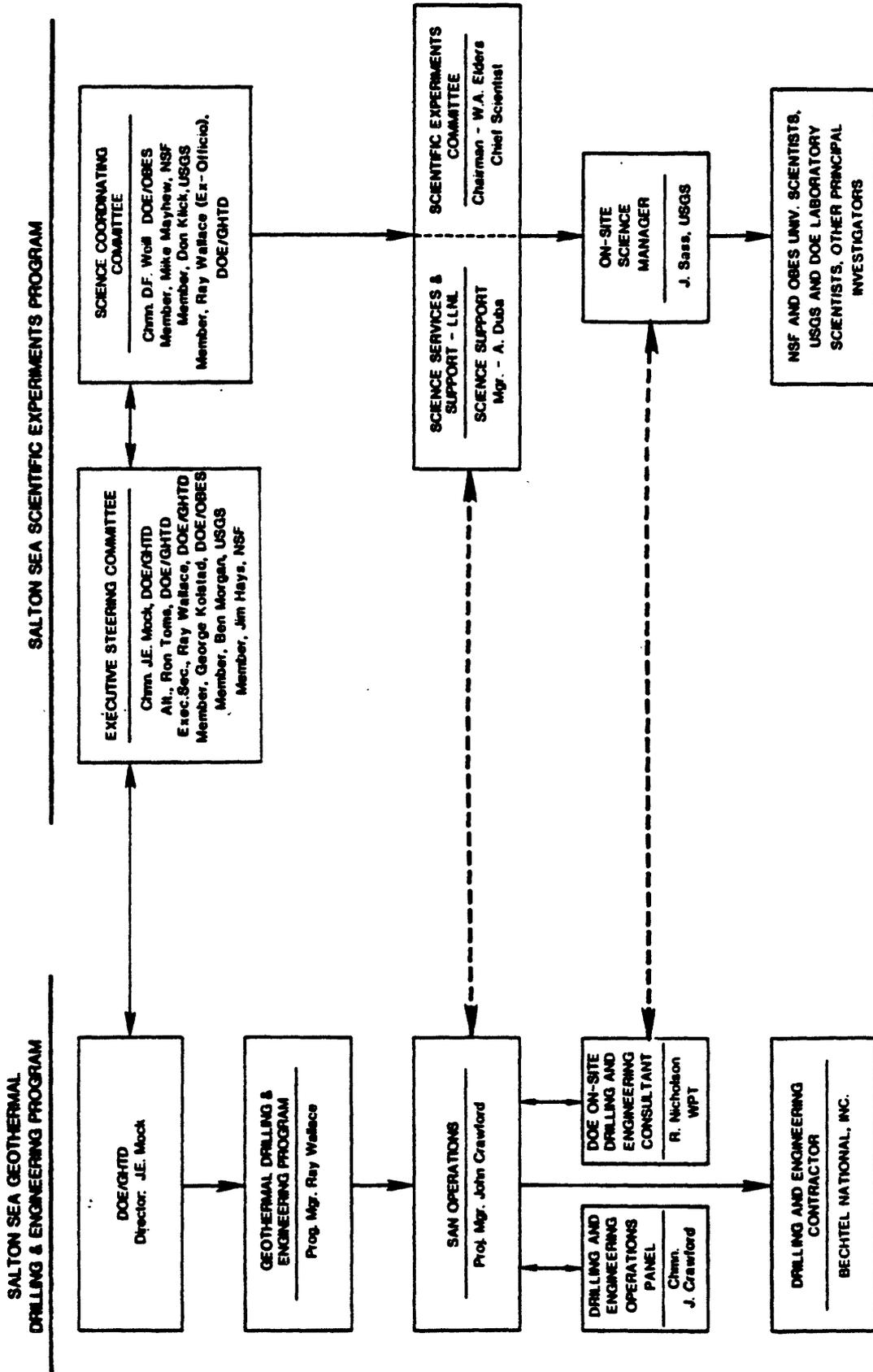


Figure 1. Salton Sea Scientific Drilling Program management plan.

Table 1. Summary of SSSDP Costs (from Harper and Rabb, 1986).

Phase	Activity	Period of Performance	Estimated Cost (\$1000s)
I	Presbud	Sept. 1984 through Oct. 1985	1,720
II	Drilling and Completion	Oct. 1985 through Mar. 1986	2,975
	Coring and Logging	Oct. 1985 through Mar. 1986	930
	Flow Test Facility and Two Flow Tests	Dec. 1985 and Mar. 1986	680
III	Standby and Restoration	Apr. 1986 through Nov. 1986	400
	Total Budget		\$6,705

Science Support Manager, On-site Science Manager, and the prime contractor's personnel. These linkages carried on into the active phase of the project, resulting in a smoothly running day-to-day operation.

In what follows, we shall look at the on-site science management structure during Phase II in some detail. We provide this information, not as a blueprint for future projects, but as a narrative account of the evolution of an operation which proved effective and responsive to the needs of this particular project.

ACKNOWLEDGEMENTS

Al Duba, Wilfred Elders, Charles Harper, Don Klick, and Ray Wallace provided constructive comments on an early draft of this report. We thank Ben Morgan for his continuing support, both fiscal and moral, during the entire program.

ADMINISTRATIVE STRUCTURE, PHASE II

The on-site operations as originally envisaged in the on-site procedures manual (fig. 2) shows the site manager at the center of a web with strong linkages to all drilling and auxiliary personnel, weak (dashed line) interactions with DOE's on site representative and the science community and no crossovers (other than through the site manager) between the two groups. Fortunately, this organization plan was never implemented in detail. The focus of on-site planning and activity was the site coordination committee consisting of the site manager (chairman), DOE on-site representative, drilling supervisor, On-site Science Manager, and drilling contractor's toolpusher. Bechtel's Project Manager (Charles Harper) and the Chief Scientist (Wilfred Elders) were also part of this committee when on site. This group could also include the mud logger, flow test consultant, coring engineer, mud engineer, or others as deemed appropriate. The committee met daily (usually at 7 AM) and began with a report from the drilling supervisor summarizing the previous days activities. This report was reviewed and the current day's planned activities were discussed. The committee also discussed medium and longer term goals (days-weeks) and attempted to anticipate possible problems and to formulate solutions to the problems.

From the beginning, the site coordination committee operated on the principles of mutual respect and forbearance, and adhered to the principle that this was a scientific endeavor, so that scientific goals should be paramount where safe and workable. We were impressed with the knowledge and experience of our drilling and engineering colleagues and with their willingness to try unusual procedures to accomplish scientific objectives. They and the Bechtel staff demonstrated a continuing sensitivity to the scientific goals and needs of the project. In this atmosphere the project was able to achieve most of its scientific objectives and exceed them in some instances.

When W. A. Elders, the Chief Scientist, was on site, his participation was quite straightforward. In the more usual situation in which he was in Riverside, Ca., the standard procedure was for one of the On-site Science Manager's staff (whoever attended the daily meeting) to telephone Elders immediately following the meeting. The results of the meeting were reviewed, Elders' input was received, and followup calls were made as necessary.

Implementation of decisions by the site coordination committee generally was accomplished along the lines indicated in figure 2. On-site operations were directed by the drilling supervisor and requests for modifications or changes in the overall plan were sent from the site manager through Bechtel's project manager to DOE's program manager. One important deviation from this structure involved the delegation, by the site manager and drilling supervisor, of many contacts between scientists and operational personnel to the USGS management team. This enabled us to interact creatively and productively with drilling personnel, mud loggers, coring specialists, and others without the burden of intermediaries. These informal arrangements were a direct result of the atmosphere of mutual respect and trust, among key individuals, that arose from contacts during the Planning Phase (I) and continued into the Active Phase (II) (Table 1).

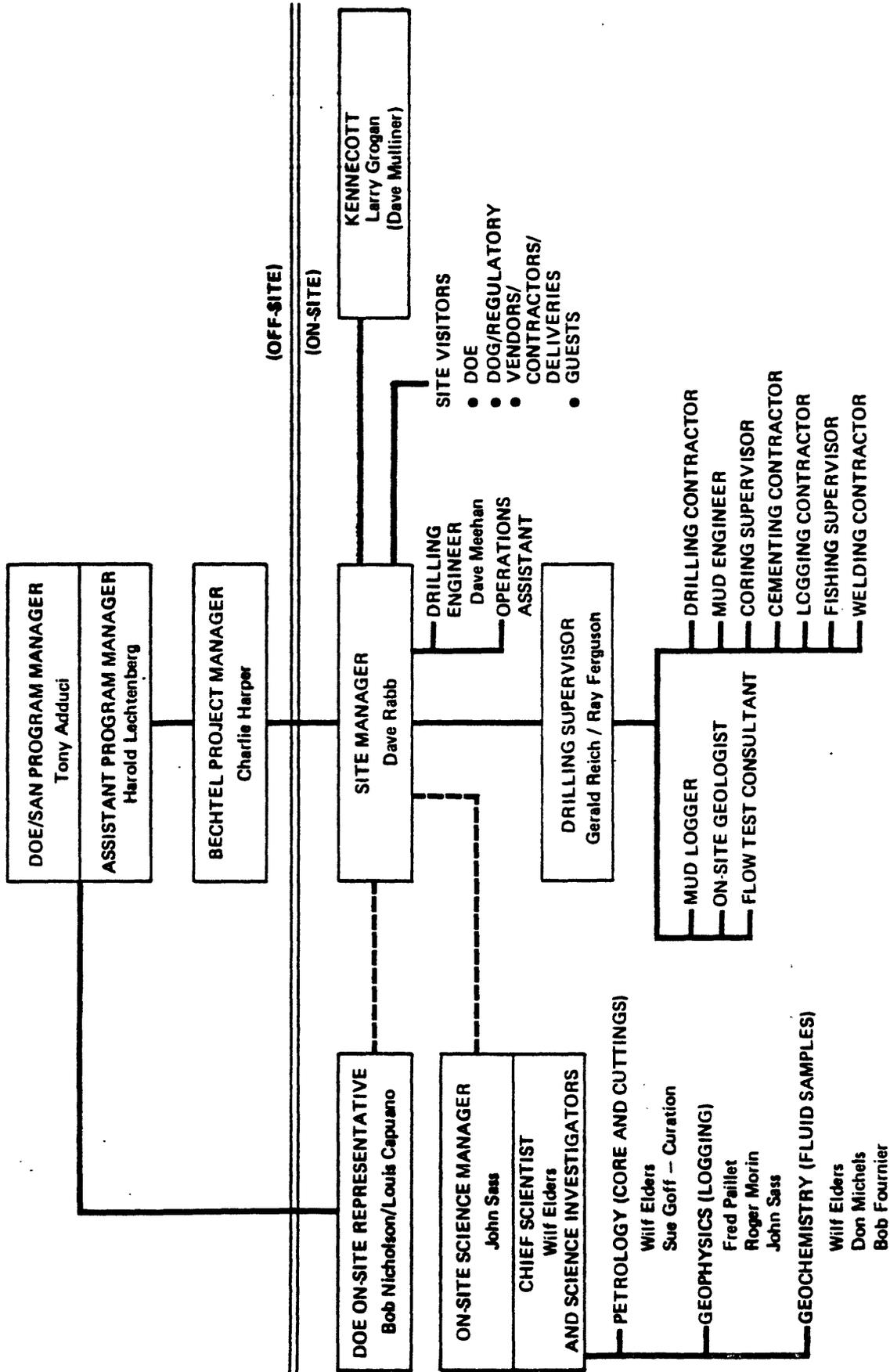


Figure 2. SSSDP on-site operations organization.

We originally planned to provide 24-hour coverage of drilling operations. The plan called for rotating teams of two people on a weekly basis, each person covering a 12-hour shift. This plan was appropriate for much of the active phase, but there were periods such as when we were called upon to provide temperature logs, or when the frequency of coring increased, when both people were on-site for several hours and off-site for some part of the day. A representative overlapping shift might be Sass, 0500-1800, Robison, 1100 - 2400. When both members of a team were off-site, at least one of them was on call at the management team's apartment to respond to any unanticipated events at the drillsite. During flow testing and other periods of intense scientific activity, the entire 4-person management team was present, with two people covering each 12-hour shift.

Figure 3 illustrates the progress of the well as a function of time. In the sections that follow, we shall address, in turn, the coring, logging, flow tests, and downhole experiments from the perspective of on-site managers.

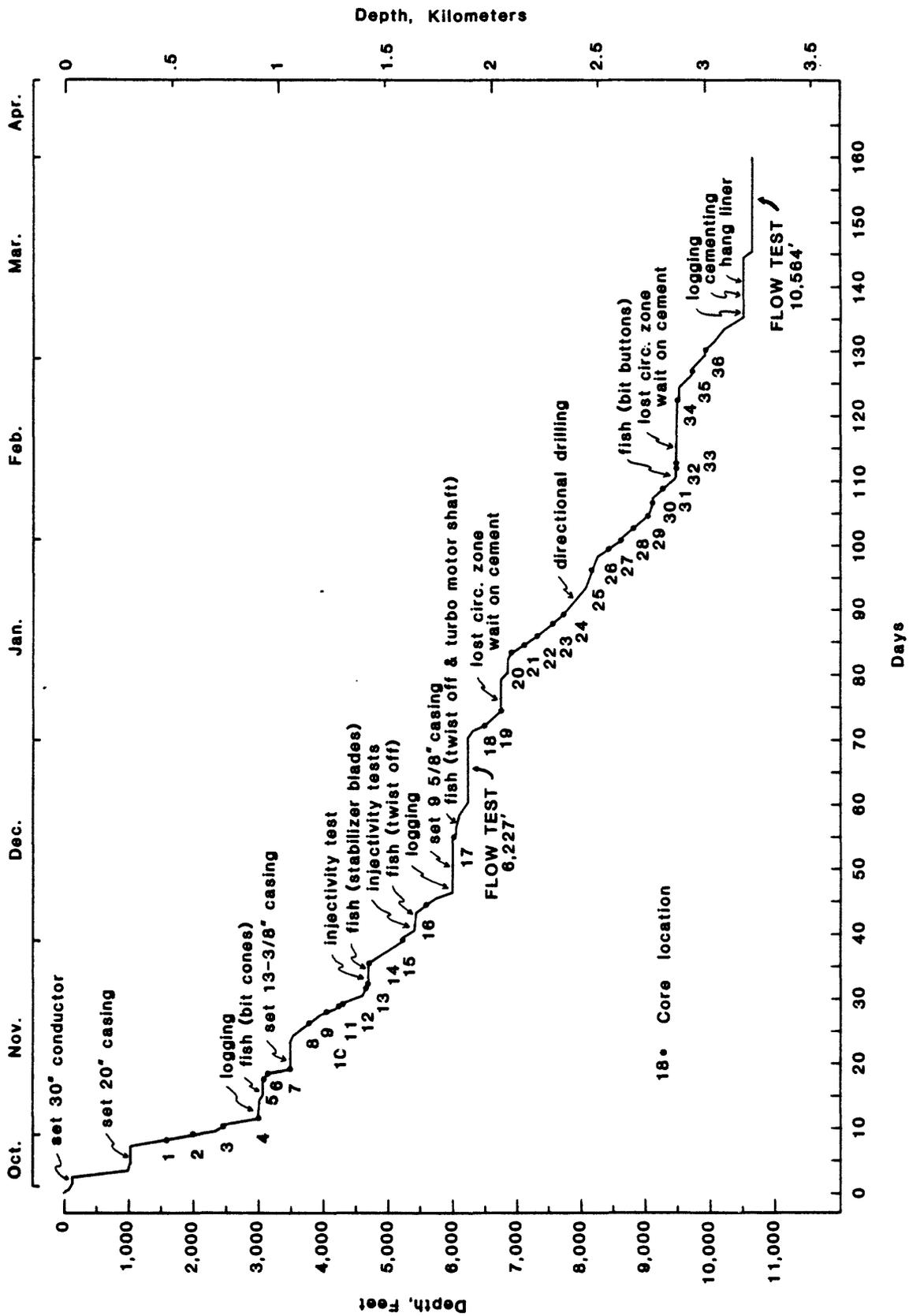


Figure 3. Depth drilled as a function of time, SSSDP.

CORES AND CUTTINGS

Results of the coring program are summarized in Table 2. The coring plan developed before drilling envisaged 43 coring attempts between 1,700 and 10,000 ft (518 and 3,048 m) with an average interval of 200 ft between cores in the depth range 3,000 to 10,000 ft. We hoped to recover 1,200 to 1,500 ft (366 to 460 m) of core, depending on the number of 30 ft core runs as opposed to 60 ft runs. A total of 36 cores were attempted, of which two (marked N/A in the footage/recovery columns of Table 2) were obtained in junk baskets or junk subs during fishing operations. Percentage recovery was reasonable over the entire depth, but the core-drilled footage declined precipitously below 5,000 ft (1,500 m). This was due, primarily, to fracturing of the rock, either in situ by the release of stress by the core bit or by thermal stresses caused by cooling the bit-face. As a result, the core barrel jammed frequently, often after only a few feet had been cored. Jamming also resulted when lost circulation material built up in the annulus between inner and outer core-barrels, causing the inner barrel to rotate. In addition, some cores were drilled "blind" (no circulation) which made coring even more difficult.

Even though there were problems, we are satisfied with the total recovery of about 730 ft (222 m) in terms of its utility in characterizing the stratigraphy of the well and in satisfying the requirements of the principal investigators interested in physical properties, petrology, and geochemistry of solid rock samples. In view of the difficulties experienced using the best in off-the-shelf technology and experienced coring personnel, it would seem that coring in ultra-deep and/or ultra-hot wells will require considerable research and redesign of some conventional coring hardware, and development of new technology.

Our role in the coring operation was, in the absence of the chief scientist, to make the decision when to core and to pass this request through the proper on site channels. Elders was consulted before each coring attempt. Either he, Jim Mehegan (core curator), or an assistant from University of California at Riverside (UCR), was present on-site for most core recovery operations unless the cored interval was small. One or both members of the On-site Science Management (OSSM) team were present on the rig floor for handling the core during extraction, and also participated in washing and marking the core.

Cores were to be taken at scheduled intervals unless key minerals, mineral assemblages, or rock types were noted in the cuttings. Cuttings were monitored continually by EXLOG/Smith's (the mud logging contractor) personnel. We maintained close communication with the mud loggers and examined the cuttings to familiarize ourselves with the lithologies and to recognize significant changes. As the drill approached the scheduled coring depth, we watched the cuttings closely for changes in mineralogy or lithology that would influence the exact coring point. If significant changes occurred before the scheduled depth, a request was made for drilling to stop until the cuttings from depth were circulated to the surface (a bottoms-up sample). If the changes were still present in the bottoms-up sample, an immediate core was requested. Otherwise, drilling continued to the regularly scheduled core depth.

Table 2. History of coring attempts and recovery, SSSDP

Date	Core	Ft. drilled	Marked core interval	% recovery
10/31/85	1	25	1553-1577.6	98.4
11/01/85	2	30	1983-2012.2	97.3
11/02/85	3	30	2448-2478.0	100.0
11/04/85	4	60	2970-3028.4	97.3
11/08-09/85	5	N/A	3083-3087.0	N/A
11/11/85	6	60	3107-3161.7	91.2
11/12/85	7	35	3470-3504.0	97.1
11/19/85	8	60	3790-3846.6	94.3
11/20/85	9	60	4007-4069.9	100.0
11/21/85	10	40	4241-4300.4	99.0
11/22/85	11	33	4301-4338.6	100.0
11/25/85	12	33	4643-4680.5	100.0
11/26/85	13	5	4681-4683.0	40.0
11/27-28/85	14	N/A	4718-4718.5	N/A
12/02/85	15	30	5188-5219.2	100.0
12/07/85	16	17.5	5574-5591.5	100.0
12/19/85	17	18	6026-6040.8	82.2
01/03/86	18	11	6506-6517.0	100.0
01/06/86	19	13	6758-6766.0	61.5
01/14/86	20	9	6880-6883.6	40.0
01/16/86	21	9	7100-7107.0	77.7
01/18/86	22	13	7300-7311.5	88.5
01/19/86	23	30	7547-7574.5	91.6
01/20/86	24	30	7708-7738.0	100.0
01/28/86	25	29	8133-8161.0	96.5
01/31/86	26	6	8395-8400.0	83.3
02/01/86	27	19	8585-8597.0	63.2
02/03/86	28	7	8800-8804.5	64.3
02/05/86	29	23	9004-9009.5	23.9
02/07/86	30	3	9095-9098.0	100.0
02/10/86	31	6	9248-9251.5	58.3
02/13/86	32	5	9453-9455.3	46.0
02/14/86	33	15	9458-9463.0	33.3
02/23/86	34	4	9473-9475.0	50.0
02/28/86	35	4	9694-9697.5	87.5
03/02/86	36	5	9907-9908.0	20.0

To initiate coring operations, we first submitted a coring request to the site manager. We then consulted with the drilling supervisor for any hazardous drilling conditions which would prohibit coring a particular interval. After receiving the drilling supervisor's approval, either he or the OSSM would inform the tool pusher and driller of plans to core at a specified depth. A coring engineer was present throughout the operation to supervise the assembly of the core barrel, cutting and extraction of core, and disassembly of the core barrel.

Once cutting of the core was completed, an estimate of the interval drilled was obtained from the coring engineer or mud logger. While the drill-crew was pulling drill pipe out of the hole, the appropriate number of single-tray, three-foot core boxes and metal inserts were carried up to the rig floor. These boxes were used specifically for transporting core from the rig floor to the core recovery and processing ramada and were reused for subsequent core runs. Metal inserts were crimped at one end which indicated the downhole side for core orientation.

Core extraction operated smoothly with three people on the rig floor (in addition to the coring engineer, driller, and rig hands). The lowermost section of core was extracted first. One person was required to catch and monitor the orientation of each piece as it came out of the core barrel. A second person helped arrange the pieces of core to fill the length of the metal tray and then slid the tray over to the core boxes. The third person placed the tray into the core box, replaced the lid, and prepared the next box in the sequence. In many instances, the lowermost foot or so of core was taken off the rig floor immediately and washed by the Chief Scientist or one of his assistants to determine whether or not an immediate second core run was advisable. For safety reasons, the rig hands, instead of the science crew, carried the core boxes down from the rig floor to a pickup truck parked near the stairwell.

The core was transported to the ramada (a three sided building with tables, shelves, and sinks) to be washed and labeled starting with the stratigraphically uppermost section of core. To facilitate washing, a screen was installed over the sink so the core could be easily rolled out of the boxes and placed under hoses with spray nozzles. Holding trays made from PVC pipe cut lengthwise were used to reassemble core pieces in place. Once the core was washed and dried either we or the UCR representative would mark the core (Mehegan and others, 1986). The core was placed in new boxes that were labeled both by core run number and depths. Many of the on-site personnel volunteered to help with core-washing and assembly of broken pieces.

Associated with coring was the routine collection of cuttings. Four 16-ounce containers of cuttings were collected by the mud logger at 10 or 20 foot intervals, depending on drill rate and variability of samples. These included one washed sample and three unwashed samples. The mud loggers collected and stored these samples for later transportation to U. C. Riverside along with the core.

GEOPHYSICAL LOGGING

Complementary and, in some cases, redundant sets of geophysical logs were run at 3,000 ft, the 3,515 ft casing point and the 6,000 ft casing point (Figure 4) by both Schlumberger and the USGS Water Resources Division's Research Logging Unit (Tables 3 and 4). The Schlumberger logs allowed a comparison and correlation with commercial logs from other wells in the Salton Sea field. The USGS logs provided both a comparison and confirmation of such things as depth registration (gamma-ray logs) and an extension of the commercial logs. Lawrence Livermore National Laboratory (LLNL) provided at the site, a system capable of reading and displaying digital data from both USGS and commercial logs, the Terra Station System. This proved useful for real time analysis and interpretation. A second commercial company (Dia-Log) carried out a casing caliper log on March 30, 1986 to assess the condition of the 9-5/8 in. casing (Figure 4). Several attempts were made by the USGS (Table 4) to obtain televiwer logs, particularly in loss zones and flow zones. At the 6,000 ft casing point (Figure 4), the televiwers encountered repeated mechanical and electrical problems. Below 6,000 ft, televiwer records were obtained, but because of deleterious effects of hole washouts, viscous mud, lost circulation material, and cement, a large percentage of the energy was absorbed, resulting in poor record quality. The same comment applies to the acoustic logs made by both Schlumberger and USGS, although useful data were obtained in both cases.

Because of financial constraints, the commercial loggers could only be brought in on specific occasions such as casing points. On the other hand, the USGS Water Resources Division committed its geothermal research logging truck for the duration of the period from 3,000 ft to total depth. This gave us the flexibility to run logs, particularly when drilling was suspended (eg. while waiting for fishing tools). This capability was enhanced by the fact that we were trained in running the logging unit and could do so literally on a moment's notice.

The USGS role in logging and downhole experiments was facilitated greatly by contributions from DOE's Geothermal Technology Division (GTD) and its technology development group at Sandia National Laboratory. GTD contributed the bulk of the funding for the 15,000 foot-long 7-conductor high-temperature (300°C) cable with a corrosion-resistant, non-ferrous (MP35N) armor deployed on the USGS logging truck. GTD also transferred a high-temperature MP35N-armored single-conductor cable from the Geopressured Program to the USGS on-site science management team for use in deploying fluid samplers and "slickline" (downhole recording) tools. The Sandia Group, under C. C. Carson, procured and supplied dewared slickline tools, both mechanically recording (Kuster) and digitally recording. Temperature and pressure data were successfully obtained using these tools in highly corrosive, high temperature (>350°C) brines.

Our role as managers differed considerably between commercial loggers and the USGS operation. In the first instance, we assisted the site manager and drilling supervisor in evaluating log quality as well as monitoring closely, the logging operation. With our USGS colleagues, we provided technical assistance, where necessary, in rigging up and down, and running logs. In addition, we kept track of time in relation to the total science budget, and

provided advice on priorities for logging techniques. We also read field tapes into the LLNL Terra Station System and organized the reproduction of analog field data for distribution to other on-site personnel.

Table 3. Dates, intervals, and types of Schlumberger logs, SSSDP

Date	Logged Interval (ft.)	Logs*
11/04/85	1,032 to 3,008	1,2,3,4,5,6
11/13/85	2,900 to 3,525	1,2,3,4,5,6
11/17/85	30-3,523	7
12/09/85	3,520 to 5,988	1,2,3,4,5,6
12/18/85	50-5,670	8
12/18/85	190-5,696	7
03/10/86	6,020-8,813	9

- *
 1) Dual Induction
 2) Compensated Neutron-Formation Density
 3) Borehole Compensated Sonic
 4) Sonic Waveforms
 5) Gamma Ray
 6) 4-arm Caliper
 7) Cement bond
 8) Temperature
 9) Deep induction

Table 4. History of USGS geophysical logs, SSSDP

Date	Log	Interval (ft.)	Comments/Results
11/05/85	Temp	100-2,998	Before circulation.
11/05/85	Nat Gamma	9-3,000	Two second time constant.
11/06/85	Temp/Caliper	100-2,998	After circulation.
11/06/85	Televiewer	N/A	No useful logs due to mud density & problems with tools.
11/06/85	Temp	100-3,000	Many stationary readings.
11/06/85	Caliper	943-2,950	
11/06/85	Acoustic DT	1,000-2,950	2 and 3 ft. spacing.
11/07/85	Waveform		2 microsecond sampling.
11/07/85	Temp	2,500-3,000	Stationary readings temperature vs. time.
11/07/85	Nat Gamma	1,000-2,980	
11/07/85	Gamma Spec	1,000-2,980	
11/07/85	Temp	2,500-2,998	Stationary readings at bottom.
12/04/85	Temp		Stationary readings at bottom.
12/09/85	Temp	2,700-5,984	Build up, stationary readings on bottom.
12/10/85	Temp/Caliper	3,375-6,000	
12/10/85	Televiewer		Both televiewers failed.
12/11/85	Nat Gamma	3,400-6,000	Tool did not work.
12/11/85	Gamma Spec		Analyzer failed after one spectrum. Tool burned up.
12/11/85	Single Point Resistivity		
12/11/85	Acoustic DT		Data marginal due to mud density.
12/11/85	Acoustic Full Wave		Total waveforms.
12/11/85	Temp/Caliper	3,400-5,120	Tool hung up.
12/12/85	Caliper	3,500-6,000	
12/12/85	Neutron	2,900-5,980	
12/23-24/85	Temp	3,500-6,230	
12/28/85	Temp	300-6,240	
02/15/86	Temp	6,000-10,400	
03/08/86	Temp	0-10,500	Pre-flow test.
03/12/86	Temp	0-10,500	Pre-flow test.
03/12/86	Televiewer	6,000-6,500	Log through first flow zone, marginal pictures.
03/13/86	Sonic	6,000-8,000	Several passes.
03/27/86	Temp	0-10,220	After 1st phase of reinjection.
03/29-30/86	Gamma Ray	5,690-10,000	
03/29-30/86	Neutron	5,770-10,000	
03/31-04/1	Temp	0-10,200	
04/07/86	Temp	0-9,660	Insulation resistance declining, Run terminated.

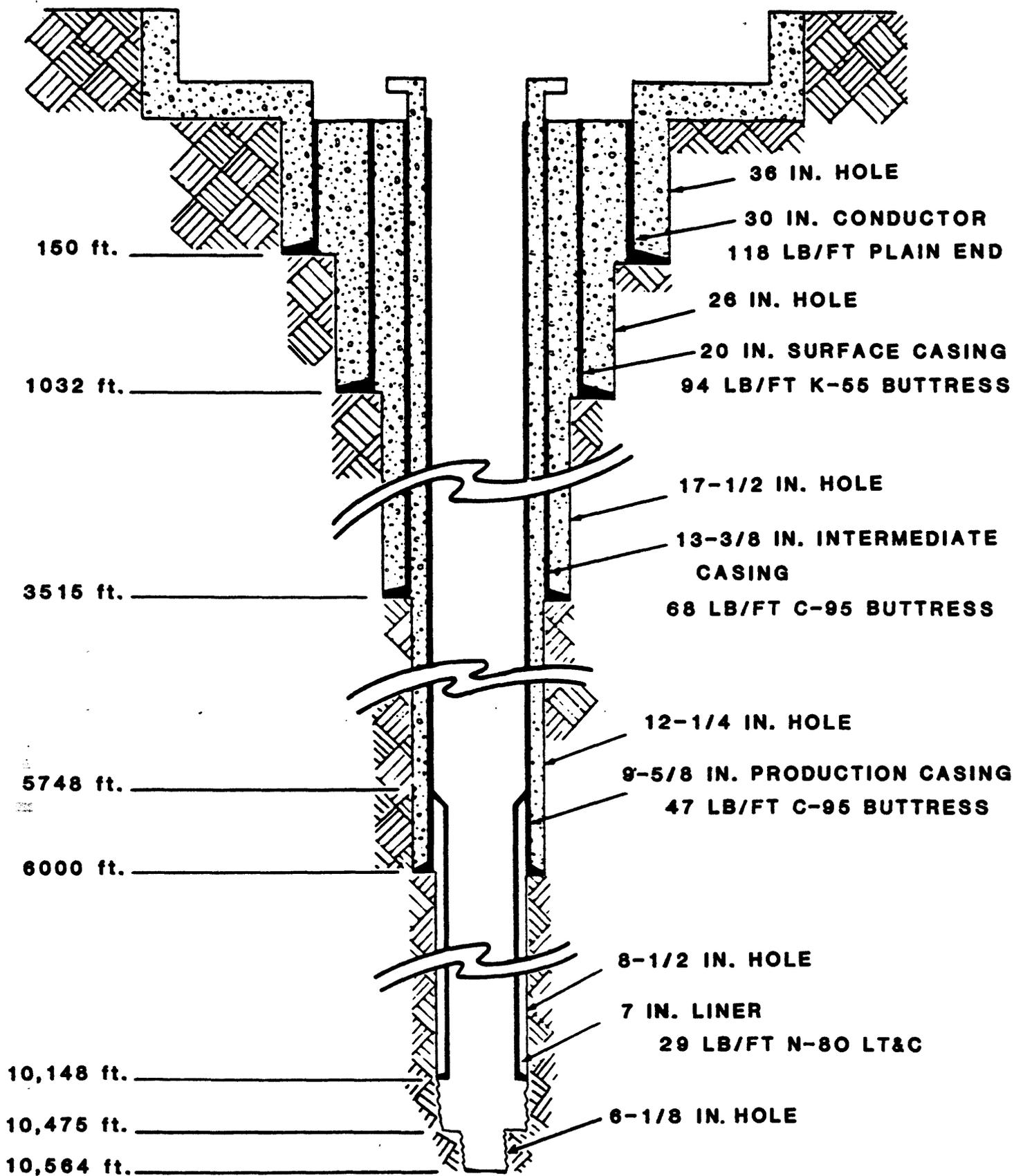


Figure 4. Well configuration, SSSDP.

FLOW TESTS AND DOWNHOLE EXPERIMENTS

The project's active phase included two flow tests; the first at a depth of 6,227 feet and the second at 10,564 feet, total depth (figures 3 and 4). Our role in this phase of the project was fourfold: 1) planning and coordinating experiments with the associated scientists and support groups, before, during, and after the flow tests, 2) orienting and assisting the scientific investigators on site during these events, 3) conducting downhole temperature, pressure, and flow experiments and 4) assisting in downhole fluid sampling. We also monitored temperature and pressure gauges along the flow line during the first flow test. We had two two-person teams working 12-hour shifts to provide 24-hour coverage and assistance. This arrangement allowed us to participate in meetings, work on logistics, help operate equipment and provide necessary on-site assistance.

The On-site Science Manager was a permanent member of the flow-test committee. As such, we were directly involved in the committee's decision on when to flow the well. Once this decision was made, we designed a preliminary schedule for the related science experiments and contacted the investigators for these activities. This schedule provided a time frame for the mobilization of people and equipment, and gave each group an estimate of time allotted for their particular experiment. Planning and coordinating downhole experiments was one of our most important and time consuming jobs. We needed to optimize the interaction of people and equipment to allow maximum efficiency and minimum time on-site by Principal Investigators. Schedules changed constantly in response to unanticipated events. If tools failed, we had to decide when to cancel field repairs. We acted as intermediaries between scientists and support groups. Investigators were placed on call well in advance of their scheduled times, therefore, we needed to know their location in order to contact them at a moment's notice.

During both flow tests, a large number of people who were unfamiliar with this project's drilling operations would arrive at the drill site. We would show them around the site, discuss safety rules and regulations, and help organize space for experiments. Several people from the flow-test committee were assigned specific responsibilities during the flow test. Problems or questions that we could not answer were directed to those in charge.

For the first flow test, we read a series of temperature and pressure gauges placed along the flow line and recorded other measurements and events which would influence the interpretation of these readings. The flow-test line was continually monitored to get a thorough coverage of changes in readings and related events. We found that this responsibility was time consuming and adversely affected our performance as on-site science managers. Therefore, during the second flow test U. C. Riverside personnel were assigned the task of recording these measurements. Our duties during the second flow test were supervision and coordination of the logging of temperature, pressure, and flow using Kuster wireline tools. We also worked with the USGS Water Resources Division personnel.

Downhole experiments performed during and after the flow tests are summarized in Table 5. USGS, DOE National Lab, and University personnel were

Table 5. Downhole Experiments, SSSDP

Date	Depth (ft)	Experiment	Comments/Results
a) <u>1st Flow Test - 6,220 ft.</u>			
12/30/85	6200	Kuster T/P	Log during flow and buildup after shutin. Well bottom hole temp. (BHT) 305 \pm 5°C.
12/31/85	6200	LANL/Sandia downhole fluid sampler	Two attempts: 1st failed due to brine flashing upon entry into sample bottle and clogging port. 2nd failed due to malfunction of battery system.
(b) <u>2nd Flow Test - 10,564 ft.</u>			
03/21/86	0-5,000	Kuster spinner/pressure	Spinner failed at 5,000 ft.
03/21/86	0-10,000	Kuster T/P	Baseline error on temp chart.
03/22/86	0-10,400	Kuster T/P	BHT 350 \pm 10°C.
03/22-23/86	10,400	1st LANL downhole fluid sampler	No sample due to seal failure causing motor to flood and short out.
03/23/86	10,400	2nd LANL	No sample due to seal failure.
03/23/86	10,400	1st Leutert downhole fluid sampler	Failure due to LCM clogging bullnose.
03/23/86	10,200	2nd Leutert	Clock stopped so canister did not close.
03/23/86	10,200	3rd Leutert	O-rings on sampler bottle failed.
03/23-24/86		USGS Bethke fluid inclusion	Wireline broke leaving tool in bottom of hole. One fishing attempt with no recovery.
03/25/86	10,200	3rd LANL	Sample bottle returned empty.
03/25/86	10,200	4th LANL	Recovered 1.5 liters liquid and .5 liter gas sample.
03/25/86	10,200	5th LANL	Bottle did not open.

Table 5. Downhole Experiments, SSSDP (continued)

Date	Depth (ft)	Experiment	Comments/Results
03/25/86	10,200	LBL fluid sampler	Recovered 1 liter unpressurized fluid.
03/27-29/86	50-5,650	LBL- Vertical Seismic Profile	Two good data sets with vibrators on drill pad and 1/2 mile off pad. 3rd data set with tool in liner produced too much noise. 4th run tool shorted out.
03/30-31/86	6,000	LLNL downhole gravity	Recovered good data with gravimeter ascending hole from 6000'.
<u>(c) Shut in Period, April-September, 1986</u>			
04/08/86	10,080	Digital T/P	Calibration off on temp tool.
04/22/86	10,080	Kuster T	Stops at 2,016, 4,032, 6,048, 8,064, 10,080.
04/22/86	10,080	Digital T/P	Same stops as above.

*T, temperature; P, pressure

very active in collection and preliminary analysis of liquid and gas samples at surface sampling ports during both flow tests. Details of these activities will be the subject of reports by W. A. Elders and the flow test consultant D. E. Michels. The bulk of the effort in this phase was dedicated to obtaining temperature and pressure measurements during flow, as well as post-flow temperature-pressure buildups, and to obtaining downhole fluid and gas samples. Because of the failure to achieve this latter goal with LANL's sampler during the first test, we decided to try a variety of available devices during the second flow test. The results are summarized in Table 5, but we append here a few additional remarks.

Los Alamos Sampler: Chuck Grigsby, Fraser Goff, and associates collected fluid samples on the surface during the flow test. After the flow test, several attempts were made to obtain downhole fluid samples, one of which was successful. The first run failed because of a seal malfunction which caused the motor to flood. The same seal failed on the second run causing the wiring to short out. This seal was effectively bypassed before the next run by welding the two affected segments of the sampler together. The third run failed because of an ailing motor. The fourth time was a charm, however, and an approximate 1.5 liter fluid sample and nearly 0.5 liter of gas were recovered. A fifth and final run failed because of electrical problems.

Leutert Sampler: Deployment of this sampler was initially suggested by Marvin Henderson of OTIS Engineering's slickline services. It is a flow-through sampler that can be closed electrically or mechanically using either a clock similar to that employed in Kuster's downhole instruments or by a "jar-head" latch tripped by working the wireline. The tool is much simpler in concept than the Los Alamos or LBL sampler, but was not designed for operation at the high temperatures encountered in this well. Because of the temperature limitations, this tool was unsuccessful in obtaining samples. If the basic design can be adapted to higher temperature by upgrading of the seals, however, we feel that this type of instrument (flow-through with mechanical tripping of the latch) holds great promise as a reliable downhole sampler.

Lawrence Berkeley Sampler: Art White, Ray Solbau and Don Lippert successfully deployed the Berkeley flow-through sampler on the USGS/DOE single-conductor wireline. The USGS hoist was fresh out of the shop from major modifications, and we had some spooling problems coming out of the well, thereby cooking the sampler for longer than was desirable. This may have contributed to loss of the gas fraction at the surface; however, about a liter of murky, unpressured liquid was recovered.

The remaining experiments involved an attempt to anneal fractured quartz crystals by leaving them near the bottom of the well for 24 hours, a Vertical Seismic Profiling (VSP) experiment by Lawrence Berkeley National Laboratory and a downhole gravity survey by Lawrence Livermore National Laboratory. The quartz annealing experiment was unsuccessful owing to the failure of the slickline because of corrosion. The VSP experiment obtained excellent data. Useful data were also obtained with the downhole gravimeter, but measurements were curtailed when electrical noise became excessive.

TEMPERATURE LOGGING

Objectives for temperature logging were twofold: 1) scientific in the context of heat-flow experiments, and 2) operational, in providing a service to assist in analyzing problems encountered while drilling. We were trained to operate two logging units located on site; the USGS Water Resources Division (WRD) geothermal research logging truck and USGS Geologic Division's single conductor wireline winch. Two team members were needed to carry out logging operations. Assistance was also required from the drilling subcontractor's personnel to help rig up the cable and to open and close the master valve to allow the tool to pass through.

Scientific temperature logging was originally scheduled to take place at each 1,000 foot interval starting at 3,000 feet, during and after flow tests, and intermittently during the post drilling shut-in period. Because of negative tradeoffs between data quality and rig time required, this schedule was later modified to include only the logging associated with the flow tests and shut-in period. We used Kuster tools to measure temperatures at given depths and to measure buildups while shutting in the well. The Kuster tools were run on the USGS Geologic Division's wireline unit.

Operational logs were carried out at the request of the site-manager or drilling supervisor. These logs were used to help define zones of fluid loss and gain. We also ran logs before and after cement jobs to determine whether loss zones were effectively plugged. Since our schedules were flexible, this service could be called upon at a moment's notice, and the only cost to the project was rig time. The WRD logging unit provided temperature logs in both digital and analog formats.

SUMMARY AND CONCLUDING REMARKS

The request for on-site science management services carried with it no explicit guidelines as to what constituted these services. We thus had the challenge and the opportunity of defining the scope of our activities and in effect, designing our job. From the outset, it was apparent that this was a complex drilling project that would test the limits of existing technology, particularly as regards coring, downhole fluid sampling, and logging. None of us had direct experience in drilling, coring, or logging of deep wells in such a hostile environment. Therefore, we could not presume to provide leadership in the technical aspects of these activities. Our combined expertise in science management, conventional drilling operations, economic geology, geophysics, well-logging, thermal problems, and sedimentary petrology and stratigraphy did, however, allow us to coordinate the activities of experts in the field, to communicate effectively with our technical and management colleagues on-site, and to provide willing and trained (or trainable) hands for the downhole deployment of instruments and experiments designed and built by others.

Apart from interacting with colleagues on-site, coordinating and facilitating on-site scientific activities, and helping in the deployment of downhole instruments and experiments, our most important function was to communicate information to those off-site who needed it. This became particularly important, as noted above, as the dates for flow tests approached and a relatively large number of busy people had to be kept informed of schedules and changes therein. We have also mentioned the daily communications with the Chief Scientist, whose other duties kept him away from the site during most of the drilling period. Other important scientific communications that we maintained on a regular basis included frequent telephone calls to DOE's program manager Ray Wallace (figure 1), and to Don Klick, who served as a link to both the Science Coordinating Committee and the USGS Chief Geologist's office.

In summary, we feel that our success on this project was the result of our adapting individual and collective skills to the demands of the project, learning as much as possible as quickly as possible about the specific activities with which we were dealing, and working with our on-site colleagues in a constructive and complementary manner. We emphasize that our experience should not be viewed as a detailed blueprint on how to provide on-site science management for other Continental Scientific Drilling projects. We do feel strongly, however, that an on-site management presence of about the level of that provided for the SSSDP is essential for a balanced, successful scientific program, particularly for the larger and more complex projects.

REFERENCES CITED

Harper, C. A., and Rabb, D. T., 1986, The Salton Sea Scientific Drilling Project: drilling program summary: Transactions of the Geothermal Resources Council, in press.

Mehegan, J. M., Herzig, C. T., and Sullivan, R. M. eds. , 1986, Salton Sea Scientific Drilling Project California State 2-14 Well-visual core descriptions: University of California, Riverside publication UCR/IGPP-86/1, volume 1.