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**REPRESENTATIVE WELL MODELS
FOR EIGHT GEOTHERMAL-RESOURCE AREAS**

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ABSTRACT

Representative well models have been constructed for eight major geothermal-resource areas. The models define representative times and costs associated with the individual operations that can be expected during drilling and completion of geothermal wells. The models were made for and have been used to evaluate the impacts of potential new technologies. The nature, construction, and validation of the models are presented.

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CONTENTS

<u>Section</u>	<u>Page</u>
1 INTRODUCTION	9
2 FRAMEWORK FOR THE WELL MODELS	11
2.1 Introduction	11
2.2 Well Model Design	11
2.3 Well Model Construction	16
2.4 Validation of the Well Models	22
2.5 Limitations of the Well Models	27
3 SUMMARIES OF THE MODELS	29
3.1 The Geysers Model	29
3.2 Imperial Valley Models	31
3.3 Baca Model	45
3.4 Roosevelt Hot Springs Model	56
4 DETAILED OPERATIONS SEQUENCES	65
4.1 The Geysers Model	65
4.2 Imperial Valley Models	75
4.3 Baca Model	103
4.4 Roosevelt Hot Springs Model	113
REFERENCES	121
APPENDIX - Drilling Cost and Time Categories	123

ILLUSTRATIONS

<u>Figure</u>		
1	Geothermal Well Cost Pattern by Region	24
2	Total Time--Imperial Valley Wells	25
3	Total Time--The Geysers Wells	26
4	Map of the Geysers Area	32

ILLUSTRATIONS (Continued)

<u>Figure</u>		<u>Page</u>
5	Casing Program for The Geysers Representative Well Model	33
6	The Geysers Drilling Time Versus Cost and Depth	35
7	Map of the Imperial Valley, California	36
8	Casing Program for the East Mesa Representative Well Model	39
9	The East Mesa Drilling Time Versus Cost and Depth	41
10	Casing Program for the Heber Representative Well Model	42
11	The Heber Drilling Time Versus Cost and Depth	44
12	Casing Program for the Brawley Representative Well Model	46
13	The Brawley Drilling Time Versus Cost and Depth	48
14	Casing Program for the Salton Sea Representative Well Model	49
15	The Salton Sea Drilling Time Versus Cost and Depth	51
16	Casing Program for the Westmorland Representative Well Model	52
17	The Westmorland Drilling Time Versus Cost and Depth	54
18	Baca Ranch, Valles Caldera, New Mexico	55
19	Casing Program for the Baca Representative Well Model	57
20	The Baca Drilling Time Versus Cost and Depth	59
21	Location of Roosevelt Hot Springs Area Relative to Other Utah KGRAs	60
22	Casing Program for the Roosevelt Hot Springs Representative Well Model	62
23	The Roosevelt Hot Springs Drilling Time Versus Cost and Depth	64

TABLES

<u>Table</u>		
1	KGRAs Modeled	11
2	Summary of Generic Well Models	23

TABLES

<u>Table</u>		<u>Page</u>
3	Summary of the Geothermal Resources for the Modeled Areas	30
4	Drilling Cost and Time by Category: The Geysers Well Model	34
5	Drilling Cost and Time by Category: East Mesa Well Model	40
6	Drilling Cost and Time by Category: Heber Well Model	43
7	Drilling Cost and Time by Category: Brawley Well Model	47
8	Drilling Cost and Time by Category: Salton Sea Well Model	50
9	Drilling Cost and Time by Category: Westmorland Well Model	53
10	Drilling Cost and Time by Category: Baca Well Model	58
11	Drilling Cost and Time by Category: Roosevelt Hot Springs Well Model	63
12	Drilling Operation Sequence for the Representative Geysers Well Model	66
13	Drilling Operation Sequence for the Representative East Mesa Well Model	76
14	Drilling Operation Sequence for the Representative Heber Well Model	82
15	Drilling Operation Sequence for the Representative Brawley Well Model	88
16	Drilling Operation Sequence for the Representative Salton Sea Well Model	93
17	Drilling Operation Sequence for the Representative Westmorland Well Model	98
18	Drilling Operation Sequence for the Representative Baca Well Model	104
19	Drilling Operation Sequence for the Representative Roosevelt Hot Springs Well Model	114

SECTION 1

INTRODUCTION

Sandia National Laboratories manages the U.S. Department of Energy's Geothermal Drilling and Completion Technology Development Program. The purpose of this program is to develop technologies that reduce the costs of and alleviate problems associated with drilling and completing geothermal wells. In order to evaluate new technologies, it is essential to understand current drilling and completion practices and to characterize their costs and problems. One aspect of the continuing work in this area has been the construction of representative well descriptions, that is, well models, that provide a baseline for the evaluation of new technologies. These models comprise detailed descriptions of the times and costs associated with the sequences of operations required in the drilling and completion of typical geothermal wells.

Individual models are presented here for eight known geothermal resource areas (KGRAs) selected according to past and expected future drilling activity. For each area, one or more well models was built to represent actual drilling practices. Each model presents a scenario that describes the activities from the time a pad is first cleared for drilling until the drilling rig is released.

Several steps are involved in the construction of a representative model. A survey of the drilling and completion history for an area provides data for designing an initial casing program. Then, a schedule of drilling and completion operations is compiled from well records and conversations with producers, operators, and service companies active in the region. This schedule is then completed with specific times and costs for each portion of each operation. These

data are compiled from several sources, including manufacturers' price lists, actual quotes and bills, bit records, drilling records, conversations with operators, etc. Finally, when this process is complete, the entire well plan with detailed, subtotaled, and totaled costs and times is verified by discussion with producers and operators. The result of these efforts is a well model.

The well models presented represent drilling that is free of major problems. Analysis of common drilling problems that arise in different areas has been discussed elsewhere.¹ However, the trouble-free models presented here have, by themselves, had a significant impact on the technology development program. They provide an understanding of the relative contributions of different operations to total well cost, allow analysis of the sensitivity of well costs to changes in various parameters, and make possible the analysis of the potential well-cost reductions available through new technologies.

SECTION 2

FRAMEWORK FOR THE WELL MODELS

2.1 INTRODUCTION

The generic geothermal well models define representative times and costs associated with typical "trouble free" but non-optimal well drilling operations. In effect, they define a baseline for the time and cost associated with the normal sequence of operations required in the drilling of representative geothermal wells. Models have been constructed for the eight known geothermal resource areas (KGRAs) listed in Table 1.

Table 1

KGRAs Modeled

The Geysers, California
Baca Ranch, New Mexico
Roosevelt Hot Springs, Utah
Imperial Valley, California:
 East Mesa
 Heber
 Brawley
 Salton Sea
 Westmorland

2.2 WELL MODEL DESIGN

A representative well model reflects the drilling practices currently (mid 1981) used in a specific region. No attempt is made to change casing programs or other design factors from those actually used. In KGRAs where there is more than one operator, the model reflects the most common practices. The model is built around the casing program, drilling fluid practice, bit selection, and the use or lack of use of directional drilling for the area under consideration.

Casing Programs

The Geysers -- The casing program for The Geysers is illustrated in Section 3. The surface conductor is usually 30-inch, 94-pound, H40 welded casing set to approximately 50 feet. The first structural casing point is at 350 feet to which a 20-inch casing is run in a 26-inch hole. This string eliminates the majority of surface water problems. Below the 20-inch casing, a 17-1/2-inch bit is drilled to about 1,900 feet at which point 13-3/8-inch casing is run, generally all the way to the surface. This casing string establishes well control. A 12-1/4-inch hole is drilled from 1,900 feet to roughly 5,500 feet, and the first 2,000 feet of this section is used for directional drilling to build the desired angle in the hole. Because the mountainous terrain of the region limits the number of possible drilling sites, this directional drilling is often necessary in order for the well to reach its desired target. The directional drilling uses two to five bit runs to establish the kickoff (direction change) and to build the desired angle. Once the desired angle is achieved, the hole is drilled as straight as possible. The liner that is run in this section is 9-5/8-inch casing, normally with about a 200-foot overlap with the previous 13-3/8-inch pipe. It is cemented in place. Because of the fractured, underpressured nature of the deeper formations, the hole below 5,500 feet is air drilled. Since the deeper formations are competent, the bottom of the hole is completed barefoot (no casing) in order to maximize production. Drilling is stopped when sufficient steam flow is encountered. At this time, a "tieback" casing string, either 9-5/8 inches or 10-3/4 inches, is run from the surface to the top of the liner at 1,700 feet and cemented in place. This serves to avoid problems from potential casing damage that might have been caused by drilling through the 13-3/8-inch casing.

Imperial Valley -- The casing programs for the five Imperial Valley wells are shown in Section 3. Four of them are generally similar--the exception being the Salton Sea well. For the four other areas, the casing program begins with 100 feet of 20-inch casing at the surface to protect against rubble. Beneath this casing, a 17-1/2-inch hole is drilled to between 1,300 and 2,000 feet, depending on the

KGRA. A 13-3/8-inch casing is cemented in this hole, and it seals off groundwaters, satisfying legal and institutional requirements. Beneath this 13-3/8-inch casing, a 12-1/4-inch hole is drilled to about 2,000 feet above the anticipated top of the production zone. A 9-5/8-inch liner is hung in this interval (from the 13-3/8-inch casing above it) and is cemented in place. This liner can later be tied back to the surface to protect against casing failure, just as at The Geysers; but this precaution is not included in the Imperial Valley models. The final casing string through the producing zone is either a liner that is cemented in place and then explosively perforated or a noncemented slotted liner. In the models, a 7-inch slotted liner is used in an 8-1/2- or 8-3/4-inch hole. It is suspended by a casing hanger from the 9-5/8-inch casing and extends to the bottom of the production area.

In the Salton Sea area, which is hotter at shallower depths than the other Imperial Valley areas, an additional string of pipe is used in order to establish earlier control of the formation and formation waters. A 30-inch conductor is first run to 70 feet and the 20-inch casing is extended to 600 feet. This requires starting with a larger diameter hole at the surface.

Baca -- The Baca casing program is illustrated in Section 3. The casing string normally starts with 30 to 70 feet of 30-inch conductor to protect against hole collapse. This conductor is run in a 42-inch-diameter hole, which is initially drilled with a 36-inch bit and then opened by reaming. A 200- to 300-foot-long 20-inch casing string is then set in a 26-inch hole to preclude surface water influx. Beneath this string, a 17-1/2-inch hole is drilled to approximately 1,500 feet, and a 13-3/8-inch casing string is cemented back to the surface. Following this, 9-5/8-inch liner is cemented in a 12-1/4-inch hole from the 1,500-foot level to the top of the production zone, at 3,000 to 4,000 feet. Drilling through the producing zone is done with an 8-3/4-inch bit. Then a 7-inch slotted liner is suspended in the production zone and not cemented. Finally, a 9-5/8-inch tieback string is used to connect the 9-5/8-inch liner to the surface in order to protect against casing failure.

Roosevelt Hot Springs -- The Roosevelt Hot Springs casing program is similar to that at the Baca site and is illustrated in Section 3. A 30-inch conductor pipe is run 30 to 50 feet from the surface for rubble protection; and this is followed by 200-foot section of 20-inch casing. The 13-3/8-inch casing is set shallower, at 800 feet, in an attempt to close off shallow lost circulation zones. Beneath the 13-3/8-inch casing, a 12-1/4-inch hole is drilled to the top of the production zone, and a 9-5/8-inch casing string is cemented completely back to the surface. This is not done with a liner and tieback string as in the Baca, because the 800-foot depth of the 13-3/8-inch casing is too shallow to ensure positive well control. Therefore, control is established with the complete 9-5/8-inch casing string. The production zone is completed with a 7-inch slotted liner extending from 3,200 feet to the bottom of the well.

Drilling Fluid Practices

The common drilling fluid practices for the model areas are not as well defined as the casing programs. Fluid practices evolve through drilling experience to a much larger degree; and so, as fields mature or products improve, the practices change. In addition, the mud program for a particular well responds to the problems and situations encountered in drilling that well. Some of these situations can be anticipated. For example, the primary difficulty in the upper portion of wells in The Geysers area is generally to maintain the wellbore in the face of formation sloughing, whereas in the Baca area, it is to maintain circulation. Though the degree to which these problems will arise in a particular well cannot be predicted, the representative well models are built around drilling fluids practices that account for the general tendencies.

Mud Drilling -- Imperial Valley drilling fluids are essentially standard oil field muds with temperature compensation provided by the addition of lignosulfonates. Control of water loss into the formation is accomplished either by viscosity additives or by using Cypan or another water loss agent. Muds are used for the entire well.

Mud programs for the upper portions of The Geysers wells use conventional oil-field techniques for shale protection to keep the serpentine and the graywacke from falling into the hole. The lower part of the hole is air drilled.

The mud programs at the Baca and Roosevelt Hot Springs areas are designed to combat both lost circulation and corrosion. These problems are avoided using standard oil-field muds and additives for the entire Roosevelt well and for the upper portions of the Baca well. The bottom portion of the Baca well is drilled with aerated mud.

Aerated Mud Drilling -- Aerated mud is used in order to combat lost circulation in the 8-3/4-inch section of the Baca well. The mud is a continuous-water-phase aerated mud--basically there is air in the mud, as opposed to mud in the air, which would be the case in mist drilling. This lessens the hydrostatic loads on the exposed formations and thus helps avoid lost circulation. However, the addition of air to the mud means that high-oxygen-content, high-temperature, corrosive fluids surround the drill pipe and casing. This can cause extreme corrosion problems and generally forces the addition of large quantities of expensive corrosion inhibitors to the mud.

Air Drilling -- The 8-3/4-inch portion of The Geysers well is drilled with air as the drilling fluid. This portion of the hole is into the potential production zone, and air drilling helps avoid lost circulation. It also reduces the chances of damage to the formation and allows sensing and gauging steam production. Just as with aerated mud drilling, air drilling can cause corrosion and erosion of the drill pipe and casing, but these are less critical than the lost circulation problems that are avoided and are dealt with separately.

Bit Selection

The selection of the bits for well models was made by examining bit records and discussing with bit salesmen, bit manufacturers, operators, field engineers, and contractors the appropriate bits to be used in the various sections of the holes. The lives and the rates of

penetration for the selected bits are estimated using historic bit records to build performance curves that reflect actual drilling experience.

Directional Drilling

Well site location difficulties at The Geysers, due to rough terrain, dictate the drilling of multiple wells from the same pad and, thus, directional drilling. As noted above, this directional drilling is done in the top of the 12-1/4-inch portion of the hole. Normal deviations are between 15° and 22°, and they are accomplished by approximately five turbine runs using a roller cone bit.

Directional drilling requirements have not yet been encountered in the Imperial Valley, Baca, and Roosevelt Hot Springs areas. However, they are expected to become more common in the Imperial Valley as production concepts mature. A power plant requires a central steam delivery point, and this, combined with the heavy agricultural use of the surface above the reservoirs, will make a single location with multiple wells on it nearly as desirable in the Imperial Valley as it is at The Geysers. At Baca and Roosevelt, directional drilling is currently used primarily as an exploration tool in order to establish better communication with reservoir fractures. It is likely that if the Baca field is heavily developed, the mountainous terrain will force multiple wells from the same pad, just as at The Geysers.

2.3 WELL MODEL CONSTRUCTION

Approach

The construction of a representative well model is based on the casing design, drilling fluids practices, bit selection, and directional drilling (if any) appropriate for a specific area. These elements provide a rough outline for the drilling of the well, but they lack essential information detailing the required operations, their times and costs, and the costs for required services and equipment.

These details are included in the models by estimating the time necessary for each individual operation in drilling the well, by determining the appropriate equipment and service costs, and by calculating time-related drilling costs. This approach leads to an operation-by-operation description and a reasonable time and cost accounting for the drilling of a representative geothermal well. The costs for the well models are calculated based on estimates for the third quarter of 1979, and the costs are accumulated in the 18 categories discussed in the Appendix.

Time Sequence

Different techniques were used to estimate the times required to perform the various operations.

Drilling -- The time required for drilling refers to the time that is spent with the drill bit rotating on the bottom of the hole. There are two special cases. The time spent reaming the hole is included--reaming either with a reamer or hole opener, for example, to expand a 36-inch hole to a 42-inch hole at the Baca, or in trying to get a new bit to enter an undersized hole left by a worn bit. The time spent drilling cement out of the casing after a cement job is included in the cementing time, not in drilling time. Bit life and rate-of-penetration are the critical parameters that determine the time spent drilling. These are estimated based on drilling histories for the area of interest. Distribution curves are drawn for each and are used to introduce variability around a realistic average performance.

Tripping -- Tripping time is the time spent extracting or inserting the drill string out of or into the hole. Tripping is generally done to change bits or other parts of the bottomhole assembly (BHA) or to prepare for an operation such as casing or logging. Tripping rates for the geothermal regions are similar to those in the oil industry. The nominal rate selected for tripping is 7 hours per round trip for a 10,000-foot well. This 1,429 ft/h rate, a 1-hour bit changeover, and a 2-hour bottomhole assembly changeover were used in the models to

estimate tripping times. A rate of 1,000 ft/h was used in cases where tripping was encumbered by either rig size or the heat of the production steam.

Logging -- Logging time includes all of the time required to make measurements in the hole. In addition to the time actually spent logging, a 2-hour setup time is included along with a 1-hour rig-down time after logging. Logging times are estimated based on the running speeds of the tools and the number of tools to be run. Actual logging is usually done on the trip out of the hole and so rapid running speeds into the well are possible. Logging speeds on the logging run depend on the tool being used.^{2,3} For each operation, a combined calculation is made that includes the fast trip into the well, the restricted speed during the logging period, and fast speed out of the hole above the logged zone. The total time is rounded off to the nearest 1/2 hour, and then 1 hour is added for contingencies.

Prior to logging before running casing, a quick trip to clean mud from the borehole wall is sometimes made; in addition, there often is a period of time devoted to circulating clean fluid to clean the hole for the logging operation. Appropriate time estimates are included for these operations.

Casing -- Two hours were allocated to rig up for casing and 1 hour to rig down. The tools and setup of the drill rig must be modified as its function changes from running drill pipe into the hole to running casing. These 3 hours account for the two required changeovers, and they are added to the time actually required for putting the casing in the hole (running casing). Realistic casing running rates were determined by interviews with field operators and drilling contractors for all casing strings from 20 inches down through 7 inches. For those cases in which a partial liner was hung beneath casing, the liner hanger was assumed to be run on the end of drill pipe using the same rate as for putting casing in the hole. Also, there was a time of 3 to 4 hours allocated for the setting the hanger at the bottom of the casing.

Cementing -- The time allocated to cementing includes a rig-up period, a cement pumping period, and a rig-down period. Following these are a wait-on-cement period, which is generally 4 to 6 hours and the time required to drill cement from the casing. The time required to pump the cement is determined from the pumping rate and the cement volume required to fill the annular space that is to be cemented plus the volume capacity of the cemented casing. The volume of cement is usually exaggerated in this way to ensure a sufficient fill of the annular space. One hour for closing and opening valves and for contingencies is added, and the total is rounded off to the nearest 1/2 hour.

Wellhead Equipment -- When the casing size at the surface changes, it is necessary to change the wellhead equipment. The time to remove a blowout preventer, to install a new valve or wellhead, and to install a different blowout preventer stack is estimated by allocating a time for each unit to be replaced. This estimate is based on experience in the various fields. The total time for changing wellhead equipment ranges from 6 to 20 hours.

Equipment and Service Costs

Equipment and service costs were estimated from a variety of sources. The costs were adjusted to the third quarter of 1979 using appropriate inflation rates for the type of equipment or service under consideration. The inflation rates for different equipment were established using actual price lists from different dates.

Bits -- Bit costs were obtained from an industry price sheet for the third quarter of 1979.⁴ (Bit prices from the major bit manufacturers are nearly identical.) Costs for nozzles were added where appropriate. Bit and nozzle costs are added to well cost at the time the bit enters the hole.

Logging -- Logging costs were estimated from References 2 and 3.

Casing Costs -- Pipe costs were estimated based on a U.S. Steel price sheet for the third quarter 1979 that gave the cost of the

casing at its point of origin.⁵ Required transportation costs for shipping the casing to the appropriate geothermal field were added. Reference 2, information from U.S. Steel, and information from trucking companies were used to estimate freight rates.

The costs for cementing equipment that must be attached to casing as it goes into the hole, were estimated from Reference 2 and from catalogs.⁶ In the case of slotted liners, an additional 50% surcharge is added to pipe costs to account for shop costs for slotting the liner. This charge was verified by bills from shops performing this service.

Cementing Costs -- Material costs for cement were estimated using Reference 2. Two types of cement were considered--a low-temperature cement, for those sections of hole where temperature is less than 300°F and density of cement is not a problem, and a high-temperature cement with a considerable amount of perlite, silica flour, and other components for use where temperatures exceed 300°F. Costs for cementing services were determined from catalog prices⁶. These included pumping costs, mileage costs, handling costs, and transportation.

Wellheads -- Wellhead costs were estimated based on Reference 2 and catalog prices.

Time-Related Cost Factors

Time-related or variable cost factors are determined for each operation and are accumulated separately in the models to facilitate evaluation of new technologies. They can be computed at the end of any sequence of activities and combined with equipment and service costs to give a picture of the total cost of that sequence.

Rig -- The 1979 rig charging rates were determined by interviews with four different rig contractors. Rates were determined for different rig sizes appropriate for the various areas. It was necessary to use judgment in setting rig rates since the different contractors included different services in their rig charges.

Fuel -- Fuel costs are treated separately from rig costs so that their variability can be adequately handled in cost analyses. Fuel usage was determined in two different ways. Each contractor was asked to estimate fuel usage rate per day for rigs of a particular size and makeup. In addition, usage was estimated to be 0.06 gallons per horsepower hour times the total installed horsepower on the rig multiplied by a 35% utilization factor. These two approaches generally resulted in usage rates that agreed within 5%.

Mud -- Total mud cost for a well has four components--three of which are the cost of mud maintenance, the cost of mud to replace volume losses (such as those due to seepage into the formation), and the cost of new mud added due to the volume of the new hole that has been drilled. The fourth component is a mud logger, who is assumed to be brought on site when the hole passes 3,000 feet in depth or 300°F in formation temperature to monitor chemicals entering the wellbore and to control mud composition. Mud maintenance cost was estimated to be \$500/day when temperatures are under 300°F, and \$750/day for temperatures above 300°F. The costs due to volume losses and volume added are calculated based on the material costs for mud and estimates of mud loss. Material costs were estimated based on conversations with mud service company personnel and estimates from contractors operating in the four geothermal areas.

Transportation -- Transportation costs are those charges associated with deliveries to the rig.

Miscellaneous -- This category includes all items not specifically included in the other categories. Items in this category normally total \$50,000 to \$70,000 for a 25- to 30-day drilling operation. For lack of a better definition, they are included in the representative wells as a continuing, time-related cost.

Rentals -- Rental costs include charges for rental items that are not expensive enough to be treated individually. Examples are surveying collars, various blowout preventer units, rotating heads for

high-temperature drilling, small compressors, and generators. These costs were estimated based on rental charges for historical wells.

Supervision -- The amount of supervision by operating company personnel was estimated for the four geothermal areas. The daily cost of this was set at either \$500 or \$700, depending on whether the well required one or one and one-half individuals per day.

2.4 VALIDATION OF THE WELL MODELS

Many historical cost and time data have been collected from actual geothermal wells and used both to build and to assess the realism of the well models.

Drilling Cost

Historical well costs were collected to aid in building the well models and to verify their accuracy. It would be convenient if these historical costs themselves could be used, rather than representative models, for evaluation of new technologies. Unfortunately, historical data are insufficient for evaluation of new or proposed technologies for four reasons:

1. The historical well costs that are collected are seldom detailed enough to allow consideration of the costs of individual operations. The accounting normally is done in categories, such as those discussed in the Appendix, and costs and times for the individual operations are not available.
2. Historical well costs are tied to specific drilling practices and technologies. They have little applicability to evaluation of new technologies.
3. Historical costs are frequently inaccurate. Total cost figures obtained for the same well have been found to differ by as much as 20%. Discrepancies in the details of cost breakdowns have been significantly larger.
4. Often, well cost data are protected and are unavailable. The data used here come mostly from wells in which the U.S. government has had a financial interest.

In spite of their lack of applicability to the evaluation of new technologies, the cost data do display interesting trends. Furthermore, the data have been valuable in establishing the validity of the generic well models.

Figure 1 indicates results from the compilation of well costs. Costs for approximately 50 geothermal wells were collected and define the cost envelopes shown.⁷ The dependence of well cost on depth is apparent, but there is wide variation among costs within a geothermal region. The total costs for the representative well models are shown and they fall well within the cost envelopes for their respective geothermal regions. They do tend to fall at the low side of the envelopes, indicating that they represent "trouble-free" wells.

Table 2 presents the total well costs and drilling time from generic well models.

Table 2
Summary of Generic Well Models

Well	Depth (feet)	Drilling Costs* (\$ x 103)	Drilling Time (Days)
The Geysers	8,000	1,153	48
East Mesa	7,600	724	28
Heber	8,000	776	31
Brawley	6,000	616	23
Salton Sea	4,500	630	21
Westmorland	11,000	1,025	41
Baca	6,000	1,075	40
Roosevelt Hot Springs	7,500	1,130	53

* All costs in 3rd Quarter 1979 dollars

Drilling Time

Drilling time data are much more available than cost data, and these data can also be used to verify the realism of the well models.

Figure 1. Geothermal Well Cost Pattern by Region

Figures 2 and 3 summarize historical drilling time data for the Imperial Valley and The Geysers areas in California and compare them to the representative wells.⁷ These data were collected from well information on record at the Petroleum Information Company⁸ and the Division of Oil and Gas, State of California. The spread among the data points in these figures is perhaps their most impressive feature. There could be several factors contributing to this spread, but unplanned drilling troubles comprise one of the most important. More clearly than the comparisons with cost data, these figures indicate that the well models represent nonoptimal, but trouble-free, drilling. Some of the actual wells were drilled and completed faster than the models, the great majority took longer, and a few took nearly 10 times as long.

2.5 LIMITATIONS OF THE WELL MODELS

The representative well models are meant to comprise detailed time and cost breakdowns that reflect current operating practices in geothermal fields. They represent nonoptimal, trouble-free wells. This means that extreme lost circulation, drill pipe failures, rig failures, rig repair, and other problems are not accounted for. Similarly, extremely high rates of penetration or long bit lifetimes are not used. The models display the sequence of activities required for drilling a well and are designed to allow evaluation of the impacts on cost and time of new technologies. They should not be construed as a cost estimating tool for future wells. Their weakness in this regard is that they provide no way to account for contingencies and problems. In effect, they estimate a reasonable lower bound on expected well costs.

A second weakness of the well models is that they are tied to current practices. Analysis of deeper or larger diameter wells or different casing plans, like evaluation of radically different technologies, would require modification or reworking of the representative models.

A final problem is that the representative well costs cannot be used in estimating the costs of developing and maintaining a geothermal field. The cost of the well itself may be only a subordinate part of the cost of maintaining a field and generating electricity. Different wells will produce different amounts of geothermal fluids. Furthermore, the model costs include only initial costs for a well and ignore subsequent operational and workover costs. Much more analysis is necessary to extend the well costs to energy costs.

SECTION 3

SUMMARIES OF THE WELL MODELS

This section summarizes the representative well models. The detailed times and costs required for each operation are presented in the next section.

The first representative well discussed is for The Geysers area, located approximately 80 miles north of San Francisco, California. Descriptions of wells for the Imperial Valley geothermal areas, located in Imperial County in extreme southern California, follow. The third area considered is the Baca area in the Valles Caldera located in north-central New Mexico. The last well model is for the Roosevelt Hot Springs area in southwestern Utah. Table 3, summarized from USGS Circular 790,⁹ gives the locations, temperature ranges, and resource discussions for the geothermal areas described in this report.

3.1 THE GEYSERS MODEL

The Geysers geothermal area is located 40 to 50 miles northeast of Santa Rosa, California. The geothermal development in this area is the largest in the world and has progressed rapidly--primarily because it is the only known developable area in the United States that produces dry steam. The area history and geology and an overview of present and proposed power generation can be found in References 8 and 10. The Mayacmos mountains are underlain by the Jarassic-Cretaceous Franciscan formation, which is a eugeosynclinal sequence of graywacke, shale, basalt, and serpentine. In some cases, elevations vary from 1,600 to over 3,000 feet above sea level in less than a mile. Because of the difficulty in locating drill sites, many wells are directionally drilled from central pads, which are located either on ridges or

Table 3

Summary of the Geothermal Resources for the Modeled Areas^a

Name of Area	Mean Reservoir Temperature, °C	Estimated Electrical Energy MW _e /30 yr	Comments
The Geysers	237±8	1,610	Area may range from 60 to 120 km ² . Boundaries of the reservoir have not been exactly delimited, although unsuccessful step-out wells have been drilled at the northwest and southeast edges of the presently developed field. Reservoir probably extends deeper than 9,800 feet. More than 200 wells have been drilled. Generating capacity in early 1979 will be 663 MW _e ; facilities to generate an additional 320 MW _e are under construction and planned to be operational by mid-1980.
East Mesa	182±7	360	No surface discharge. Twenty or more wells drilled. Maximum reported temperature is 204°C at 7,500 feet in brine. A 10-MW _e binary cycle plant designed for a working temperature of about 180°C is under construction; additional facilities to produce 48 MW _e are planned.
Heber	175±5	650	No surface discharge. Eleven wells drilled. Average bottom hole temperature is 180°C; maximum field temperature is about 190°C. Plans to develop a 50-MW _e plant have been announced.
Brawley	253±10	640	No surface discharge. Eight wells drilled. Maximum reported temperature is 262°C at 7,900 feet in brine. May consist of two separate systems.
Salton Sea Area	323±8	3,400	More than 20 wells drilled with maximum reported temperature of 360°C at 6,900 feet. Produced fluids are hypersaline brines. A geothermal loop experimental facility is currently being tested.
Westmorland	217±7	1,710	No surface discharge. Six geothermal test wells drilled. Temperatures at 6,000 feet average between 190° and 250°C. May be extension of the Salton Sea system.
Baca	233±8	2,700	One group of acid-sulfate springs, extensive hydrothermal alteration and associated gas seeps, and 17 wells in southwest quadrant of Pleistocene caldera. Maximum measured temperature is about 330°C. A vapor-dominated reservoir locally overlies the hot-water reservoir. A 50-MW _e generating plant is planned.
Roosevelt Hot Springs	265±8	970	Seven wells in a 6-km ² area are capable of producing over 4.5 x 10 ⁵ kg/h total mass flow at 260°C. A 55-MW _e plant is planned. Springs are inactive; extensive sinter deposits along a 4.8-km trend.

^aInformation based on Geological Survey Circular 790, Assessment of Geothermal Resources of the United States - 1978, U.S. Department of Interior, 1979.

on valley floors in order to avoid unstable locations on steep hillsides. Directional drilling also aids the intersection of the vertical or near-vertical steam-bearing fractures of the reservoir.

The major drilling problems encountered in The Geysers are (1) vibration- and abrasion-related drill pipe failures and resulting fishing, (2) borehole instability through rubblized rock, (3) lost circulation, (4) directional control difficulties, and (5) casing wear by the drill pipe.

Over 300 wells have been drilled in The Geysers area mostly by Union Geothermal. (See Figure 4.¹⁰) The field is located over 300 miles from petroleum industry service centers at Ventura and Bakersfield, but because of the magnitude of operations, several specialty shops stock supplies at Santa Rosa. A service center at The Geysers (almost exclusively for the use of Halliburton cementing services) has also been established under an agreement with Union.

Figure 5 shows the casing program for the representative Geysers well. The detailed drilling operation sequences and costs are presented in Section 4. Table 4 shows the breakdown of times and costs for The Geysers generic well. Such breakdowns, by drilling and completion operations, are especially important for evaluation of technologies. Figure 6 summarizes depth and cost accumulation from the well model.

3.2 IMPERIAL VALLEY MODELS

The Imperial Valley is a great structural basin extending from Coachella Valley of California south to the Mexicali basin in Mexico. The known geothermal resource areas in this basin include East Mesa, Heber, Brawley, Salton Sea, and Westmorland (as well as several others). (See Figure 7.¹⁰) The Cerro Prieto field in Mexico is also in this basin, and the basin, in general, is likely to be the next U.S. geothermal area to experience rapid growth and heavy drilling activity.

Figure 4. Map of The Geysers Area

Figure 5. Casing Program for The Geysers Representative Well Model

Table 4

Drilling Cost and Time by Category: The Geysers Well Model

Cost/Time Categories	(1) Direct Cost (\$x10 ³)	(2) Variable Cost ^a by Source (\$x10 ³)	(3) Variable Cost ^a by Activity (\$x10 ³)	(4) Total Cost by Activity (\$x10 ³)	(5) Percent of Cost	(6) Time Used (h)	(7) Percent of Time
1. Site Preparation	42.5			42.5	3.7		
2. Initiation	12.5			12.5	1.1		
3. Move In, Rig Up/ Rig Down	38.5			38.5	3.3		
4. Rig Rental		312.9					
4.1 Drilling			297.7	297.7	25.8	602.2	52.1
4.2 Tripping			100.3	100.3	8.7	203.0	17.6
4.3 Reaming			18.9	18.9	1.6	35.0	3.0
5. Fuel		60.6					
6. Mud				6.7	0.6	4.5	0.4
6.1 Mud Origination	4.4						
6.2 Drilling Mud		26.7	2.3				
6.3 Corrosion Chemicals		2.8					
7. Casing	187.4		22.1	209.5	18.2	47.8	4.1
8. Cementing	79.0		30.6	109.6	9.5	66.1	5.7
9. Drill String	25.5		6.8	32.3	2.8	15.0	1.3
9.1 Drill Pipe		21.3					
10. Directional	13.2		18.5	31.7	2.8	38.0	3.3
11. Logging							
12. Bits	90.8			90.8	7.9		
13. Water and Waste Disposal	21.0			21.0	1.8		
14. Special				71.2	6.2	53.0	4.6
14.1 Air Compressor		23.5	0.9				
14.2 BOP/Wellhead	46.7		23.6				
15. Transportation/ Miscellaneous		72.1					
16. Rental							
16.1 Tools		17.3					
17. Supervision		24.1					
18. Completion	29.9		39.6	69.5	6.0	91.0	7.9
Total	591.4	561.3	561.3	1152.7	100	1155.3	100

^aVariable costs are broken out in two ways, first by the source of the costs and then by activity. As illustrated in the Drilling Operation Sequence Tables, Nos. 12 through 19, variable costs are time-related costs accrued from several sources, such as rig, fuel, mud, etc., charges. The "Variable Cost by Source" figures (column 2) total these charges for the different sources. The "Variable Cost by Activity" figures (column 3) total these charges for each of the activities that require time. The "Total Cost by Activity" figures (column 4) are the sum of the "Variable Cost by Activity" figures (column 3) and the "Direct Cost" figures (column 1).

Figure 6. The Geysers Drilling Time Versus Costs and Depth

Figure 7. Map of the Imperial Valley, California

The Imperial Valley is a flat sedimentary basin, irrigated by the Imperial Valley canal system from the Colorado River and used principally for agriculture. The 8,000 to 17,000 feet of sediments in the Imperial Valley basin are primarily sandstones, shales, claystone, and conglomerates that were deposited by the ancestral Colorado River as it formed its delta. Impermeable shales form the caprock for the underlying hot water. Below the caprock are thick sections of sand deposited by ancient rivers. The field overlies the San Andreas, San Jacinto, and Elsinor fault zones, which have caused frequent earthquake and volcanic activities over geologic time.

The reservoirs and the brines can be quite different in different parts of the valley, but drilling practices at the various areas are similar. The superheated water contains up to 300,000 ppm total dissolved solids at Salton Sea and only 2,000 ppm at East Mesa. Elsewhere in the valley, solids content varies within these extremes, e.g., 14,000 ppm at Heber and 80,000 ppm at Brawley. The problems of brine chemistry may be the most serious technical problem in the Valley. The brine can cause scale buildup in production wells due to flashing, cooling, or pressure loss. Similar problems can also affect an injection system. Potentially, the most serious obstacle to full development of the geothermal resources under the Imperial Valley may be developing sufficient safeguards for the agricultural usage. Even localized subsidence of a few inches would seriously disturb irrigation and drainage patterns, and so operators are likely to face requirements to reinject all or a great portion of their spent brine.

There do not appear to be any major drilling problems associated with current operations in the Imperial Valley though they may arise in the future. At Cerro Prieto, Mexico, a similar, more mature field, there has been a historical tendency to drill deeper. The deeper formations tend to be fracture-dominated rather than matrix-dominated, and severe lost circulation problems can be encountered. Since this trend is also expected in the Imperial Valley, lost circulation may become a frequent problem.

East Mesa Model

The East Mesa KGRA is located 30 miles east of El Centro, California, on the eastern edge of the Imperial Valley sedimentary basin. This area is located in uninhabited desert land and is near to, but at a higher elevation than, a major irrigation canal bordering the eastern edge of the area of extensive cultivation.

A major portion of the KGRA is leased to Republic Geothermal, Inc., which has proposed a 64-MW power plant. The other active operator is Magma Power, which is operating a 10-MW demonstration plant in the southern portion of the KGRA. The U.S. Bureau of Reclamation established an East Mesa test site for geothermal and desalination studies that is now managed by the Department of Energy. Of the more than 24 wells that have been completed in the area, 5 were drilled by the U.S. government in the 1971-1974 period, 10 were completed by RGI, and 8 were completed by Magma.

Figure 8 shows the casing plan for the representative East Mesa well. The results of the drilling costs and times are summarized in Table 5. A plot of time versus depth and cost is shown in Figure 9.

Heber Model

The Heber KGRA is located 5 miles north of the United States-Mexico border. Chevron USA, Inc. is planning geothermal brine production facilities to supply a 50-MW plant to be constructed by Southern California Edison. Other operators of interest are Union Oil of California and the New Albion Resource Company affiliated with San Diego Gas & Electric. Fifteen test wells have been drilled since 1972. Depth to the top of the producing formation is about 2,000 feet with the bottom limit at approximately 8,000 feet.

Figure 10 shows the casing plan for a representative Heber well. The drilling costs and times from the model well are summarized in Table 6. A plot of time versus depth and cost is shown in Figure 11.

Figure 8. Casing Program for the East Mesa Representative Well Model

Table 5

Drilling Cost and Time by Category: East Mesa Well Model

Cost/Time Categories	(1) Direct Cost (\$x10 ³)	(2) Variable Cost ^a by Source (\$x10 ³)	(3) Variable Cost ^a by Activity (\$x10 ³)	(4) Total Cost by Activity (\$x10 ³)	(5) Percent of Cost	(6) Time Used (h)	(7) Percent of Time
1. Site Preparation	16.2			16.2	2.2		
2. Initiation	10.2			10.2	1.4		
3. Move In, Rig Up/ Rig Down	35.9			35.9	5.0		
4. Rig Rental		156.0					
4.1 Drilling			140.9	140.9	19.5	302.8	45.6
4.2 Tripping			22.7	22.7	3.1	46.4	7.0
5. Fuel		27.3					
6. Mud				6.0	0.8	6.0	0.9
6.1 Mud Origination	3.3						
6.2 Drilling Mud		32.6	2.7				
7. Casing	186.1		34.6	220.7	30.5	89.6	13.5
8. Cementing	63.5		15.7	79.2	10.9	32.8	4.9
9. Drill String	2.5		9.7	12.2	1.7	26.9	4.1
10. Directional	2.0		2.0	4.0	0.6	4.0	0.6
11. Logging	34.7		19.3	54.0	7.5	41.2	6.2
12. Bits	14.7			14.7	2.0		
13. Water and Waste Disposal	21.0			21.0	2.9		
14. Special							
14.2 BOP/Wellhead	15.1		12.8	27.9	3.9	31.0	4.7
15. Transportation/ Miscellaneous		41.4					
16. Rental							
16.1 Tools		9.9					
16.2 Mud Logger		10.5					
17. Supervision		13.8					
18. Completion	27.0		31.1	58.1	8.0	83.0	12.5
Total	432.2	291.5	291.5	723.7	100	663.7	100

^a Variable costs are broken out in two ways, first by the source of the costs and then by activity. As illustrated in the Drilling Operation Sequence Tables, Nos. 12 through 19, variable costs are time-related costs accrued from several sources, such as rig, fuel, mud, etc., charges. The "Variable Cost by Source" figures (column 2) total these charges for the different sources. The "Variable Cost by Activity" figures (column 3) total these charges for each of the activities that require time. The "Total Cost by Activity" figures (column 4) are the sum of the "Variable Cost by Activity" figures (column 3) and the "Direct Cost" figures (column 1).

Figure 9. The East Mesa Drilling Time Versus Cost and Depth

Figure 10. Casing Program for the Heber Representative Well Model

Table 6

Drilling Cost and Time by Category: Heber Well Model

Cost/Time Categories	(1) Direct Cost (\$x10 ³)	(2) Variable Cost ^a by Source (\$x10 ³)	(3) Variable Cost ^a by Activity (\$x10 ³)	(4) Total Cost by Activity (\$x10 ³)	(5) Percent of Cost	(6) Time Used (h)	(7) Percent of Time
1. Site Preparation	16.2			16.2	2.1		
2. Initiation	10.0			10.0	1.3		
3. Move In, Rig Up/ Rig Down	36.0			36.0	4.6		
4. Rig Rental		174.9					
4.1 Drilling			164.5	164.5	21.2	354.1	47.5
4.2 Tripping			30.2	30.2	3.9	65.3	8.7
5. Fuel		30.8					
6. Mud			2.7	6.0	0.8	6.0	0.8
6.1 Mud Origination	3.3						
6.2 Drilling Mud		36.8					
7. Casing	194.1		37.8	231.9	29.9	94.0	12.6
8. Cementing	60.5		14.6	75.1	9.7	34.8	4.7
9. Drill String	2.5		11.1	13.6	1.7	27.3	3.7
10. Directional	2.0		3.4	5.4	0.7	7.0	0.9
11. Logging	35.2		20.0	55.2	7.1	43.2	5.8
12. Bits	21.0			21.0	2.7		
13. Water and Waste Disposal	21.0			21.0	2.7		
14. Special							
14.2 BOP/Wellhead	19.1		12.8	31.9	4.1	31.0	4.2
15. Transportation/ Miscellaneous		46.6					
16. Rental							
16.1 Tools		11.2					
16.2 Mud Logger		12.4					
17. Supervision		15.5					
18. Completion	<u>27.0</u>	<u> </u>	<u>31.1</u>	<u>58.1</u>	<u>7.5</u>	<u>83.0</u>	<u>11.1</u>
Total	447.9	328.2	328.2	776.1	100	745.5	100

^aVariable costs are broken out in two ways, first by the source of the costs and then by activity. As illustrated in the Drilling Operation Sequence Tables, Nos. 12 through 19, variable costs are time-related costs accrued from several sources, such as rig, fuel, mud, etc., charges. The "Variable Cost by Source" figures (column 2) total these charges for the different sources. The "Variable Cost by Activity" figures (column 3) total these charges for each of the activities that require time. The "Total Cost by Activity" figures (column 4) are the sum of the "Variable Cost by Activity" figures (column 3) and the "Direct Cost" figures (column 1).

Figure 11. The Heber Drilling Time Versus Cost and Depth

Brawley Model

Development of the Brawley geothermal field began in 1975. Union Oil has drilled 10 producing wells in this field, 4 of which have been supplying hot brine to the initial 10-MW plant operated by Southern California Edison. Chevron has drilled two wells west of the plant.

Figure 12 shows the casing plan for a representative Brawley well. The resulting drilling costs and times are summarized in Table 7. A plot of time versus depth and cost is shown in Figure 13.

Salton Sea Model

The Salton Sea Geothermal Field, located near the southeastern tip of the Salton Sea, is a designated portion of the larger Salton Sea KGRA. It is the highest-temperature resource in the Imperial Valley. The schematic in Figure 14 is a representative casing program. Many existing wells were drilled in the mid-1960s for mineral extraction, and completions for them and for exploratory wells have been at greatly varying depths.

The drilling costs and time by category derived from the representative well model are presented in Table 8. A plot of time versus depth and cost is shown in Figure 15.

Westmorland Model

Westmorland is located a few miles south of the Salton Sea field. Westmorland Geothermal Association has drilled at least four wells in the area. The depth of the wells is more than 10,000 feet.

Figure 16 shows the casing plan for a representative Westmorland well. The resulting drilling costs and times are summarized in Table 9. A plot of time versus depth and cost is shown in Figure 17.

3.3 BACA MODEL

The Baca KGRA is located in the Jemez mountains 55 miles north of Albuquerque, New Mexico. Surface elevation of the wells is about

Figure 12. Casing Program for the Brawley Representative Well Model

Table 7

Drilling Cost and Time by Category: Brawley Well Model

Cost/Time Categories	(1) Direct Cost (\$x10 ³)	(2) Variable Cost ^a by Source (\$x10 ³)	(3) Variable Cost ^a by Activity (\$x10 ³)	(4) Total Cost by Activity (\$x10 ³)	(5) Percent of Cost	(6) Time Used (h)	(7) Percent of Time
1. Site Preparation	16.2			16.2	2.6		
2. Initiation	10.0			10.0	1.6		
3. Move In, Rig Up/ Rig Down	36.0			36.0	5.8		
4. Rig Rental		130.7					
4.1 Drilling			110.8	110.8	18.0	235.8	43.1
4.2 Tripping			12.5	12.5	2.0	27.3	5.0
5. Fuel		22.6					
6. Mud			1.3	4.6	0.8	3.0	0.5
6.1 Mud Origination	3.3						
6.2 Drilling Mud		24.1					
7. Casing	157.4		28.7	186.1	30.2	71.2	13.0
8. Cementing	50.7		12.5	63.2	10.3	29.5	5.4
9. Drill String	0.8		9.4	10.2	1.7	22.5	4.1
10. Directional	1.8		2.8	4.6	0.8	6.0	1.1
11. Logging	24.4		17.1	41.5	6.7	37.6	6.9
12. Bits	12.5			12.5	2.0		
13. Water and Waste Disposal	21.0			21.0	3.4		
14. Special							
14.2 BOP/Wellhead	15.8		12.8	28.6	4.6	31.0	5.7
15. Transportation/ Miscellaneous		34.2					
16. Rental							
16.1 Tools		8.2					
16.2 Mud Logger		7.9					
17. Supervision		11.4					
18. Completion	<u>27.0</u>	<u> </u>	<u>31.2</u>	<u>58.2</u>	<u>9.5</u>	<u>83.0</u>	<u>15.2</u>
Total	376.9	239.1	239.1	616.0	100	546.9	100

^aVariable costs are broken out in two ways, first by the source of the costs and then by activity. As illustrated in the Drilling Operation Sequence Tables, Nos. 12 through 19, variable costs are time-related costs accrued from several sources, such as rig, fuel, mud, etc., charges. The "Variable Cost by Source" figures (column 2) total these charges for the different sources. The "Variable Cost by Activity" figures (column 3) total these charges for each of the activities that require time. The "Total Cost by Activity" figures (column 4) are the sum of the "Variable Cost by Activity" figures (column 3) and the "Direct Cost" figures (column 1).

Figure 13. The Brawley Drilling Time Versus Cost and Depth

Figure 14. Casing Program for the Salton Sea Representative Well Model

Table 8

Drilling Cost and Time by Category: Salton Sea Well Model

Cost/Time Categories	(1) Direct Cost (\$x10 ³)	(2) Variable Cost ^a by Source (\$x10 ³)	(3) Variable Cost ^a by Activity (\$x10 ³)	(4) Total Cost by Activity (\$x10 ³)	(5) Percent of Cost	(6) Time Used (h)	(7) Percent of Time
1. Site Preparation	16.2			16.2	2.6		
2. Initiation	10.0			10.0	1.6		
3. Move In, Rig Up/ Rig Down	36.0			36.0	5.7		
4. Rig Rental		115.9					
4.1 Drilling			83.5	83.5	13.3	185.3	37.5
4.2 Tripping			13.7	13.7	2.2	31.7	6.4
5. Fuel		20.3					
6. Mud				5.8	0.9	6.0	1.2
6.1 Mud Origination	3.3						
6.2 Drilling Mud		21.1	2.5				
7. Casing	156.5		30.4	186.9	29.7	69.4	14.0
8. Cementing	59.8		14.0	73.8	11.7	35.1	7.1
9. Drill String	2.9		4.0	6.9	1.1	9.5	1.9
10. Directional			1.7	1.7	0.3	4.8	1.0
11. Logging	28.0		14.9	42.9	6.8	32.3	6.6
12. Bits	11.3			11.3	1.8		
13. Water and Waste Disposal	21.0			21.0	3.3		
14. Special							
14.2 BOP/Wellhead	46.1		15.7	61.8	9.8	37.0	7.5
15. Transportation/ Miscellaneous		30.8					
16. Rental							
16.1 Tools		7.4					
16.2 Mud Logger		5.7					
17. Supervision		10.3					
18. Completion	<u>27.0</u>	<u> </u>	<u>31.1</u>	<u>58.1</u>	<u>9.2</u>	<u>83.0</u>	<u>16.8</u>
Total	418.1	211.5	211.5	629.6	100	494.1	100

^aVariable costs are broken out in two ways, first by the source of the costs and then by activity. As illustrated in the Drilling Operation Sequence Tables, Nos. 12 through 19, variable costs are time-related costs accrued from several sources, such as rig, fuel, mud, etc., charges. The "Variable Cost by Source" figures (column 2) total these charges for the different sources. The "Variable Cost by Activity" figures (column 3) total these charges for each of the activities that require time. The "Total Cost by Activity" figures (column 4) are the sum of the "Variable Cost by Activity" figures (column 3) and the "Direct Cost" figures (column 1).

Figure 15. The Salton Sea Drilling Time Versus Cost and Depth

Figure 16. Casing Program for the Westmorland Representative Well Model

Table 9

Drilling Cost and Time by Category: Westmorland Well Model

Cost/Time Categories	(1) Direct Cost (\$x10 ³)	(2) Variable Cost ^a by Source (\$x10 ³)	(3) Variable Cost ^a by Activity (\$x10 ³)	(4) Total Cost by Activity (\$x10 ³)	(5) Percent of Cost	(6) Time Used (h)	(7) Percent of Time
1. Site Preparation	16.2			16.2	1.6		
2. Initiation	10.0			10.0	1.0		
3. Move In, Rig Up/ Rig Down	37.8			37.8	3.7		
4. Rig Rental		256.0					
4.1 Drilling			252.6	252.6	24.6	518.5	53.3
4.2 Tripping			41.8	41.8	4.1	86.0	8.9
5. Fuel		47.4					
6. Mud			2.7	6.0	0.6	6.0	0.6
6.1 Mud Origination	3.3						
6.2 Drilling Mud		42.2					
7. Casing	273.9		44.6	318.5	31.1	101.2	10.4
8. Cementing	69.5		16.7	86.2	8.4	37.2	3.8
9. Drill String	7.6		9.0	16.6	1.6	20.8	2.1
10. Directional	2.0		7.0	9.0	0.9	13.5	1.4
11. Logging	46.5		23.9	70.4	6.9	51.8	5.3
12. Bits	24.5			24.5	2.4		
13. Water and Waste Disposal	21.0			21.0	2.0		
14. Special							
14.2 BOP/Wellhead	28.5		13.9	42.4	4.1	31.0	3.2
15. Transportation/ Miscellaneous		60.8					
16. Rental							
16.1 Tools		14.6					
16.2 Mud Logger		15.7					
17. Supervision		20.3					
18. Completion	27.0		44.8	71.8	7.0	107.0	11.0
Total	567.8	457.0	457.0	1024.8	100	973.0	100

^aVariable costs are broken out in two ways, first by the source of the costs and then by activity. As illustrated in the Drilling Operation Sequence Tables, Nos. 12 through 19, variable costs are time-related costs accrued from several sources, such as rig, fuel, mud, etc., charges. The "Variable Cost by Source" figures (column 2) total these charges for the different sources. The "Variable Cost by Activity" figures (column 3) total these charges for each of the activities that require time. The "Total Cost by Activity" figures (column 4) are the sum of the "Variable Cost by Activity" figures (column 3) and the "Direct Cost" figures (column 1).

Figure 17. The Westmorland Drilling Time Versus Cost and Depth

9,000 feet above sea level. Union Oil of California joined the Public Service Company of New Mexico and the Department of Energy (DOE) in an effort to develop a 50-MW power plant to be used for demonstration and evaluation of a variety of technical problems. This joint project has been abandoned and development of the Baca resources by Union will proceed more slowly.

Figure 18 shows the general features of the Baca field. The geothermal resource presently being developed in the Valles Caldera is in the Redondo Creek area. It has been selected for initial development because of its very thick section of Bandelier Tuff, which can be porous and highly fractured. A large magma chamber is believed to exist beneath the Caldera.

Figure 18. Baca Ranch, Valles Caldera, New Mexico
(Courtesy Union Oil of California)

Above the Bandelier Tuff is the Redondo Creek rhyolite and caldera fill. These sections have a tendency to slough. They are mud-drilled and must be cased to prevent the hole from falling in, causing stuck drill pipe and loss of the hole. The upper portion of the Bandelier Tuff is a densely welded tuff with low porosity and negligible fractures. This upper Bandelier Tuff together with the sections above it form the caprock for the reservoir. The lower portion of the Bandelier Tuff is more pumicey, porous, and consistently contains permeable fractures. Below the Bandelier Tuff, the upper part of the underlying Paliza Canyon Andesite and Tertiary sands are potential production zones. Present production strategy calls for completions in the lower part of the Bandelier Tuff and upper part of the Paliza Canyon Andesite. This procedure allows fluids from the rest of the reservoir to drain or flow into these formations along fractures.

Drilling wells in the Baca field has presented numerous problems. The reservoir formation is underpressured, compared to hydrostatic pressure, by 600 to 900 psi. Using mud as the drilling fluid in the reservoir often causes severe lost circulation due to the large pressure differential between the wellbore and the formation. Drilling with air increases corrosion of drill pipe and tubulars and allows sloughing of the formations, resulting in a high risk of losing the hole. As of this date, 23 wells have been drilled in the Baca field. Drilling problems have included lost circulation, sloughing, stuck pipe, drill pipe twist off, lost logging tools, plugged bits, and others.

Figure 19 shows the casing plan for a representative Baca well. The drilling costs and times from the model well are summarized in Table 10. A plot of time versus depth and cost is shown in Figure 20.

3.4 ROOSEVELT HOT SPRINGS MODEL

The Roosevelt Hot Springs KGRA is located on the western flank of the Mineral Mountains in the Basin and Range geologic province of the Western United States (see Figure 21). Hot water (500°F and 7,500 to

Figure 19. Casing Program for the Baca Representative Well Model

Table 10

Drilling Cost and Time by Category: Baca Well Model

Cost/Time Categories	(1) Direct Cost (\$x10 ³)	(2) Variable Cost ^a by Source (\$x10 ³)	(3) Variable Cost ^a by Activity (\$x10 ³)	(4) Total Cost by Activity (\$x10 ³)	(5) Percent of Cost	(6) Time Used (h)	(7) Percent of Time
1. Site Preparation	47.5			47.5	4.4		
2. Initiation	12.5			12.5	1.2		
3. Move In, Rig Up/ Rig Down	37.8			37.8	3.5		
4. Rig Rental		249.7					
4.1 Drilling			235.5	235.5	21.9	457.1	47.6
4.2 Tripping			63.7	63.7	5.9	122.9	12.8
4.3 Reaming			19.7	19.7	1.8	36.0	3.7
5. Fuel		46.6					
6. Mud				9.5	0.9	12.0	1.3
6.1 Mud Origination	3.3						
6.2 Drilling Mud		25.8	6.2				
6.3 Corrosion Chemicals		18.2					
7. Casing	204.2		32.1	236.3	22.0	69.9	7.3
8. Cementing	86.0		22.3	108.3	10.1	53.3	5.6
9. Drill String	20.2		4.9	25.1	2.3	12.0	1.3
10. Directional	2.0		20.9	22.9	2.1	35.0	3.6
11. Logging	27.2		15.4	42.6	4.0	34.4	3.6
12. Bits	64.6			64.6	6.0		
13. Water and Waste Disposal	22.0			22.0	2.1		
14. Special							
14.1 Air Compressor		32.3					
14.2 BOP/Wellhead	32.1		14.2	46.3	4.3	33.0	3.4
15. Transportation/ Miscellaneous		59.9					
16. Rental							
16.1 Tools		14.4					
16.2 Mud Logger		7.7					
17. Supervision		20.0					
18. Completion	40.8		39.7	80.5	7.5	94.0	9.8
Total	600.2	474.6	474.6	1074.8	100	959.6	100

^aVariable costs are broken out in two ways, first by the source of the costs and then by activity. As illustrated in the Drilling Operation Sequence Tables, Nos. 12 through 19, variable costs are time-related costs accrued from several sources, such as rig, fuel, mud, etc., charges. The "Variable Cost by Source" figures (column 2) total these charges for the different sources. The "Variable Cost by Activity" figures (column 3) total these charges for each of the activities that require time. The "Total Cost by Activity" figures (column 4) are the sum of the "Variable Cost by Activity" figures (column 3) and the "Direct Cost" figures (column 1).

Figure 20. The Baca Drilling Time Versus Cost and Depth

KGRA ●

KGRA	NO. OF ACRES
COVE FORT-SULPHURDALE	24,074
CRATER SPRINGS	17,321
LUND	3,840
MEADOW-HUTTON	1,927
MONROE-JOSEPH	16,364
NAVAJO LAKE	2,522
NEWCASTLE	2,636
ROOSEVELT HOT SPRINGS	29,791
THERMO HOT SPRINGS	26,019
	<hr/>
	124,594

Figure 21. Location of Roosevelt Hot Springs Area Relative to Other Utah KGRAs

8,000 ppm total dissolved solids) is found in interconnected-fracture granite or hard metamorphosed sediments as shallow as 1,600 feet. Beneath a thin alluvium cover, a silica-filled caprock extends to depths of from 2,000 feet or less, in the present area of activity, to several thousand feet elsewhere. Shallow hot water flows are very near the surface in faulted zones. Considerable geologic data are available as a result of federal, state, and University of Utah studies. However, very little well drilling and completion data have been published.

Well depths within the primary area of interest range from 2,800 to 7,500 feet, though a 13,000-foot-deep test well was drilled nearby. Well configurations are simple, much like those in other areas. Casing is cemented in a mud-drilled hole to the top of fractures, and the reservoir is tapped with a long string of slotted liner. However, drilling in the reservoir is not done by air due to strong water in flows. Reservoir pressure is nearly hydrostatic, but fluid returns are not guaranteed. One operator claims to drill ahead with clear water with or without returns. Bit drops (indicating small caverns or openings) and lost circulation are common.

The casing plan for a representative well is shown in Figure 22. Wells at Roosevelt Hot Springs have not been directionally drilled because surface pads are easily located in this noncultivated, non-populated area. The closest oil and gas service centers are Vernal, Utah, or Farmington, New Mexico, each about 250 miles from Milford.

Phillips Petroleum Company operates the Roosevelt Hot Springs Unit, which encompasses leased and privately-owned (fee) properties of several other organizations including Union, Getty, the Amax-Thermal Power-O'Brien group, Geothermal Power Company, and the Roosevelt Hot Springs Corporation. Reportedly, a 20-MW plant will be installed first by Phillips, followed by two 50-MW installations.

Table 11 presents the drilling cost and time as predicted from the representative Roosevelt Hot Springs well model. A summary of drilling time versus depth and cost is shown in Figure 23.

Figure 22. Casing Program for the Roosevelt Hot Springs Representative Well Model

Table 11

Drilling Cost and Time by Category: Roosevelt Hot Springs Well Model

Cost/Time Categories	(1) Direct Cost (\$x10 ³)	(2) Variable Cost ^a by Source (\$x10 ³)	(3) Variable Cost ^a by Activity (\$x10 ³)	(4) Total Cost by Activity (\$x10 ³)	(5) Percent of Cost	(6) Time Used (h)	(7) Percent of Time
1. Site Preparation	47.5			47.5	4.2		
2. Initiation	12.5			12.5	1.1		
3. Move In, Rig Up/ Rig Down	36.0			36.0	3.2		
4. Rig Rental		300.6					
4.1 Drilling			342.1	342.1	30.3	783.7	61.2
4.2 Tripping			45.8	45.8	4.1	106.9	8.3
4.3 Reaming			24.2	24.2	2.1	55.0	4.3
5. Fuel		52.7					
6. Mud			0.8	4.1	0.4	2.0	0.2
6.1 Mud Origination	3.3						
6.2 Drilling Mud		49.4					
7. Casing	219.3		30.4	249.7	22.1	78.6	6.1
8. Cementing	55.4		17.1	72.5	6.4	42.0	3.3
9. Drill String	16.3		5.6	21.9	1.9	15.0	1.2
10. Directional	4.9		16.3	21.2	1.9	37.0	2.9
11. Logging	29.3		11.9	41.2	3.6	29.4	2.3
12. Bits	69.3			69.3	6.1		
13. Water and Waste Disposal	21.0			21.0	1.9		
14. Special							
14.2 BOP/Wellhead	45.5		16.6	62.1	5.5	42.0	3.3
15. Transportation/ Miscellaneous		79.8					
16. Rental							
16.1 Tools		19.2					
16.2 Mud Logger		15.4					
17. Supervision		26.7					
18. Completion	<u>25.4</u>	<u> </u>	<u>33.0</u>	<u>58.4</u>	<u>5.2</u>	<u>88.0</u>	<u>6.9</u>
Total	585.7	543.8	543.8	1129.5	100	1279.6	100

^aVariable costs are broken out in two ways, first by the source of the costs and then by activity. As illustrated in the Drilling Operation Sequence Tables, Nos. 12 through 19, variable costs are time-related costs accrued from several sources, such as rig, fuel, mud, etc., charges. The "Variable Cost by Source" figures (column 2) total these charges for the different sources. The "Variable Cost by Activity" figures (column 3) total these charges for each of the activities that require time. The "Total Cost by Activity" figures (column 4) are the sum of the "Variable Cost by Activity" figures (column 3) and the "Direct Cost" figures (column 1).

Figure 23. The Roosevelt Hot Springs Drilling Time Versus Cost and Depth

SECTION 4

DETAILED OPERATIONS SEQUENCES

4.1 THE GEYSERS MODEL

The drilling operation sequence for The Geysers well model is given in Table 12. This table gives the depth, time, variable costs, time categories, direct costs, direct cost category, cumulative time, and cumulative costs by activity and the variable cost rates for the various groupings of activities.

Table 12

Drilling Operation Sequence for the Representative Geysers Well Model

Activity/Equipment/Service in Order of Occurrence	Depth (ft)	Time Used (h)	Variable Cost (\$x10 ³)	Time Category ^a	Direct Cost ₃ (\$x10 ³)	Direct Cost Category ^a	Cumulative	
							Time (h)	Cost ₃ (\$x10 ³)
Site Preparation	0	240.0			42.50	1.0		42.5
Initiation								
Drill 42 in./Set 30 in. Conductor	50	72.0			12.50	2.0		55.0
Pipe/Cement/Tools/ Equipment					7.50	7.1		62.5
Move In/Rig Up	50	144.0			38.50	3.0		101.0
Originate Mud	50	4.0			4.40	6.0		105.4
Spud	50						0	105.4
Trip In (17-1/2 in. Bit, 1-1-1) ^c	50	0.5	0.23	4.2	1.55	12.1	0.5	107.18
Drill Cement	50	2.5	1.15	8.1			3.0	108.33
Drill 17-1/2 in. Hole	350	10.0	4.61	4.1			13.0	112.94
Trip Out/In (26 in. Bit, 1-3-1) ^c	350	0.5	0.23	4.2	2.50	12.1	13.5	115.67
Change BHA ^d		1.0	0.46	9.0			14.5	116.13
Open Hole to 26 in.	350	10.0	4.61	4.1			24.5	120.74
Circulate Mud	350	0.5	0.23	6.0			25.0	120.97
Trip Out	350	1.0	0.46	4.2			26.0	121.43
Rig Up Casing Tools	350	2.0	0.92	7.2			28.0	122.35
Run 20 in. Casing	350	1.5	0.69	7.2			29.5	123.04
Casing					14.99	7.2.1		138.03
Tools/Service					1.64	7.2.2		139.67
Cement Equipment					3.56	8.2.2		143.23
Rig Down Casing Tools	350	1.0	0.46	7.2			30.5	143.69
Rig Up Cementing Tools		2.0	0.92	8.2			32.5	144.61
Cementing	350	1.5	0.69	8.2			34.0	145.30
Cement					4.21	8.2.1		149.51
Service					1.84	8.2.3		151.35
Rig Down Cementing Tools	350	1.0	0.46	8.2			35.0	151.81
Wait on Cement	350	4.0	1.84	8.2			39.0	153.65

^aTime and direct cost categories are identified in Appendix A.

^bThese pre-spud times are not included in the cumulative time.

^cDesignates bit diameter and API Standard RP 7G bit classification, e.g., 17-1/2 in. diameter, series 1- type 1- features 1.

^dBHA = bottomhole assembly

Table 12 (Continued)

Drilling Operation Sequence for the Representative Geysers Well Model

Activity/Equipment/Service in Order of Occurrence	Depth (ft)	Time Used (h)	Variable Cost (\$x10 ³)	Time Category ^a	Direct Cost (\$x10 ³)	Direct Cost Category ^a	Cumulative	
							Time (h)	Cost (\$x10 ³)
Install Wellhead/BOP ^e /Test	350	15.0	6.91	14.2	31.65	14.2	54.0	192.21
Trip In (Rerun 17-1/2 in.)	350	0.5	0.23	4.2			54.5	192.44
Drill Cement	350	2.5	1.15	8.2			57.0	193.59
Test Shoe	350	2.0	0.92	8.2			59.0	194.51
Trip Out	350	0.5	0.23	4.2			59.5	194.74
Variable Cost Rates Used in Above Variable Cost Calculations (\$/h)								
Rig	270.85							
Fuel	52.50							
Transportation/Misc.	62.50							
Rental	15.00							
Supervision	20.85							
Mud	39.04							
Combined	460.74							
Change BHA ^d (Stabilizers) ^f	350	4.0	1.91	9.0	1.92	9.0	63.5	198.57
Trip In (17-1/2 in. Bit, 5-2-5) ^c	350	0.4	0.19	4.2	9.63	12.1	63.9	208.39
Drill 17-1/2 in. Hole	1400	70.0	33.40	4.1			133.9	241.79
Survey	1400	1.0	0.48	10.0			134.9	242.27
Trip Out/In (17-1/2 in. Bit, 5-3-5) ^c	1400	1.4	0.67	4.2	9.63	12.1	136.3	252.57
Change BHA ^d (Stabilizers) ^f	1400	2.0	0.95	4.2	0.96	9.4	138.3	254.48
Drill 17-1/2 in. Hole	1900	56.0	26.72	4.1			194.3	281.20
Circulate	1900	2.0	0.95	10.0			196.3	282.15
Survey	1900	1.0	0.48	10.0			197.3	282.63
Trip Out	1900	2.0	0.95	4.2			199.3	283.58
Wiper Trip	1900	1.0	0.48	7.3			200.3	284.06
Rig Up Casing Tools	1900	2.0	0.95	7.3			202.3	285.01
Run 13-3/8 in. Casing	1900	7.6	3.63	7.3			209.9	288.64
Casing					46.48	7.3.1		335.12
Tools/Service					5.38	7.3.2		340.50
Cement Equipment					2.90	8.3.2		343.40

^a Time and direct cost categories are identified in Appendix A.

^c Designates bit diameter and API Standard RP 7G bit classification, e.g., 17-1/2 in. diameter, series 1- type 1- features 1.

^d BHA = bottomhole assembly

^e BOP = blowout preventer

^f A parenthetical note after "Change BHA" denotes item(s) associated with direct costs or item(s) requiring special attention.

Table 12 (Continued)

Drilling Operation Sequence for the Representative Geysers Well Model

Activity/Equipment/Service in Order of Occurrence	Depth (ft)	Time Used (h)	Variable Cost ₃ (\$x10 ³)	Time Category ^a	Direct Cost ₃ (\$x10 ³)	Direct Cost Category ^a	Cumulative	
							Time (h)	Cost ₃ (\$x10 ³)
Rig Down Casing Tools	1900	1.0	0.48	8.3			210.9	343.88
Rig Up Cementing Tools	1900	2.0	0.95	8.3			212.9	344.83
Cementing		2.9	1.38	8.3			215.8	346.21
Cement					12.13	8.3.1		346.21
Service					4.77	8.3.2		363.11
Rig Down Cementing Tools	1900	1.0	0.48	8.3			216.8	363.59
Wait on Cement	1900	4.0	1.91	8.3			220.8	365.50
Nipple Down BOP ^e	1900	5.0	2.39	14.2			225.8	367.89
Install Wellhead	1900	6.0	2.86	14.3	15.07	14.3	231.8	385.82
Nipple Up BOP ^e /Test	1900	10.0	4.77	14.2			241.8	390.59
Trip In (Rerun Bit)	1900	2.9	1.38	4.2			244.7	391.97
Drill Cement	1900	2.5	1.19	8.3			247.2	393.16
Test Shoe	1900	3.0	1.43	8.3			250.2	394.59
Trip Out/In (12-1/4 in. Bit, 5-2-5) ^c	1900	1.9	0.91	4.2	4.62	12.1	252.1	400.12
BHA ^d (Stabilizers) ^f	1900	2.0	0.95	4.2	1.69	9.4	254.1	402.76
Drill 12-1/4 in. Hole	2810	65.0	31.01	4.1			319.1	433.77
Trip Out/In (12-1/4 in. Bit, 5-3-5) ^c	2810	2.8	1.34	4.2	4.62	12.1	321.9	439.73
Change BHA ^d (Turbo) ^f	2810	5.0	2.39	4.2			326.9	442.12
Orientation	2810	4.0	1.91	10.0	2.20	10.2	330.9	446.23
Drill 12-1/4 in. (Turbo)	2891	9.0	4.29	4.1	1.44	9.0	339.9	451.96
Survey	2891	1.0	0.48	10.0			340.9	452.44
Trip Out/In (12-1/4 in. Bit, 5-3-5) ^c	2891	2.8	1.34	4.2	4.62	12.1	343.7	458.40
Change BHA ^d (Turbo) ^f		5.0	2.39	4.2			348.7	460.79
Orientation	2891	4.0	1.90	10.0	2.20	10.2	352.7	464.89
Drill 12-1/4 in. (Turbo)	2955	8.0	3.82	4.1	1.28	9.0	360.7	469.99
Survey	2955	1.0	.48	10.0			361.7	470.47

^aTime and direct cost categories are identified in Appendix A.

^cDesignates bit diameter and API Standard RP 7G bit classification, e.g., 17-1/2 in. diameter, series 1- type 1- features 1.

^dBHA = bottomhole assembly

^eBOP = blowout preventer

^fA parenthetical note after "Change BHA" denotes item(s) associated with direct costs or item(s) requiring special attention.

Table 12 (Continued)

Drilling Operation Sequence for the Representative Geysers Well Model

Activity/Equipment/Service in Order of Occurrence	Depth (ft)	Time Used (h)	Variable Cost ³ (\$x10 ³)	Time Category ^a	Direct Cost (\$x10 ³)	Direct Cost Category ^a	Cumulative	
							Time (h)	Cost ³ (\$x10 ³)
Trip Out/In (12-1/4 in. Bit, 5-3-5) ^c	2955	2.9	1.38	4.2	4.62	12.1	364.6	476.47
Change BHA ^d (Stabilizers) ^f	2955	5.0	2.39	4.2	2.53	9.4	369.6	481.39
Variable Cost Rates Used in Above Variable Cost Calculations (\$/h)								
Rig	270.85							
Fuel	52.50							
Transportation/Misc.	62.50							
Rental	15.00							
Supervision	20.85							
Drill Pipe (air)	20.85							
Mud	34.57							
Combined	477.12							
Drill 12-1/4 in. Hole	3675	60.0	29.10	4.1			429.6	510.49
Survey	3675	1.0	0.49	10.0			430.6	510.98
Trip Out/In (12-1/4 in. Bit, 5-3-5) ^c	3675	3.7	1.79	4.2	4.62	12.1	434.3	517.39
Change BHA ^d (Turbo) ^f		5.0	2.43	4.2			439.3	519.82
Orientation	3675	4.0	1.94	10.0	2.20	10.2	443.3	523.96
Drill 12-1/4 in. (Turbo)	3739	8.0	3.88	4.1	1.28	9.0	451.3	529.12
Trip Out/In (12-1/4 in. Bit, 6-1-5) ^c	3739	3.7	1.79	4.2	4.62	12.1	455.0	535.53
Change BHA ^d (Turbo) ^f	3739	5.0	2.43	4.2			460.0	537.96
Orientation	3739	4.0	1.94	10.0	2.20	10.2	464.0	542.10
Drill 12-1/4 in. (Turbo)	3803	8.0	3.88	4.1	1.28	9.0	472.0	547.26
Survey	3803	1.0	0.49	10.0			473.0	547.75
Trip Out/In (12-1/4 in. Bit, 5-3-5) ^c	3803	3.8	1.84	4.2	4.62	12.1	476.8	554.21
Change BHA ^d (Stabilizers) ^f		5.0	2.43	4.2	1.69	9.4	481.8	558.33
Drill 12-1/4 in. Hole	4583	65.0	31.53	4.1			546.8	589.86
Trip Out/In (12-1/4 in. Bit, 6-1-5) ^c	4583	4.5	2.18	4.2	4.62	12.1	551.3	596.66
Change BHA ^d (Turbo) ^f		5.0	2.43	4.2			556.3	599.09

^aTime and direct cost categories are identified in Appendix A.

^cDesignates bit diameter and API Standard RP 7G bit classification, e.g., 17-1/2 in. diameter, series 1- type 1- features 1.

^dBHA = bottomhole assembly

^fA parenthetical note after "Change BHA" denotes item(s) associated with direct costs or item(s) requiring special attention.

Table 12 (Continued)

Drilling Operation Sequence for the Representative Geysers Well Model

Activity/Equipment/Service in Order of Occurrence	Depth (ft)	Time Used (h)	Variable Cost ₃ (\$x10 ³)	Time Category ^a	Direct Cost ₃ (\$x10 ³)	Direct Cost Category ^a	Cumulative	
							Time (h)	Cost ₃ (\$x10 ³)
Orientation	4583	4.0	1.94	10.0	2.20	10.2	560.3	603.23
Drill 12-1/4 in. (Turbo)	4655	8.0	3.88	4.1	1.28	9.0	568.3	608.39
Survey	4655	1.0	0.49	10.0			569.3	608.88
Trip Out/In (12-1/4 in. Bit, 6-1-5) ^c	4655	4.6	2.23	4.2	4.62	12.1	573.9	615.73
Change BHA ^d (Turbo) ^f		5.0	2.43	4.2			578.9	618.16
Orientation	4655	4.0	1.94	10.0	2.20	10.2	582.9	622.30
Drill 12-1/4 in. (Turbo)	4719	8.0	3.88	4.1	1.28	9.0	590.9	627.46
Survey	4719	1.0	0.49	10.0			591.9	627.95
Trip Out/In (12-1/4 in. Bit, 5-3-5) ^c	4719	4.7	2.28	4.2	4.62	12.1	596.6	634.85
Change BHA ^d (Stabilizers) ^f		4.0	1.94	4.2	2.53	9.4	600.6	639.32
Drill 12-1/4 in. Hole	5379	60.0	29.10	4.1			660.6	668.42
Survey	5379	1.0	0.49	10.0			661.6	668.91
Trip Out/In (12-1/4 in. Bit, 6-1-5) ^c	5379	5.4	2.62	4.2	4.62	12.1	667.0	676.15
Change BHA ^d (Stabilizers) ^f		4.0	1.94	4.2	1.69	9.4	671.0	679.78
Drill 12-1/4 in. Hole	5500	12.1	5.87	4.1			683.1	685.65
Wiper Trip	5500	4.0	1.94	7.4			687.1	687.59
Trip Out	5500	4.8	2.33	4.2			691.9	689.92
Variable Cost Rates Used in Above Variable Cost Calculations (\$/h)								
Rig	270.85							
Fuel	52.50							
Transportation/Misc.	62.50							
Rental	15.00							
Supervision	20.85							
Drill Pipe (air)	20.85							
Mud	42.53							
Combined	485.08							
Rig Up Casing Tools	5500	2.0	0.89	7.4			693.9	690.81

^aTime and direct cost categories are identified in Appendix A.

^cDesignates bit diameter and API Standard RP 7G bit classification, e.g., 17-1/2 in. diameter, series 1- type 1- features 1.

^dBHA = bottomhole assembly

^fA parenthetical note after "Change BHA" denotes item(s) associated with direct costs or item(s) requiring special attention.

Table 12 (Continued)

Drilling Operation Sequence for the Representative Geysers Well Model

Activity/Equipment/Service in Order of Occurrence	Depth (ft)	Time Used (h)	Variable Cost ₃ (\$x10 ³)	Time Category ^a	Direct Cost ₃ (\$x10 ³)	Direct Cost Category ^a	Cumulative	
							Time (h)	Cost ₃ (\$x10 ³)
Run 9-5/8 in. Casing	5500	11.0	4.87	7.4			704.9	695.68
Casing					63.47	7.4.1		759.15
Tools/Service					9.09	7.4.2		768.24
Cement Equipment					4.67	8.4.2		772.91
Hanger		3.0	1.33	7.4	18.60	7.4.2	707.9	792.84
Rig Down Casing Tools	5500	1.0	0.44	7.4			708.9	793.28
Rig Up Cementing Tools	5500	2.0	0.89	8.4			710.9	794.17
Cementing	5500	3.5	1.55	8.4			714.4	795.72
Cement					14.68	8.4.1		810.40
Service					5.46	8.4.3		815.86
Wait on Cement	5500	4.0	1.77	8.4			718.4	817.63
Rig Down Cementing Tools/ Nipple Down BOP ^e /Nipple Up BOP ^e /Test	5500	15.0	6.64	14.2			733.4	824.27
Trip In	5500	3.7	1.64	4.2			737.1	825.91
Drill Cement	5500	2.5	1.11	8.4			739.6	827.02
Test Shoe	5500	3.0	1.33	8.4			742.6	828.35
Trip Out	5500	3.0	1.33	4.2			745.6	829.68
Rig to Air Drill	5500	2.0	0.89	14.1			747.6	830.57
(Air Compressor Added)								
Variable Cost Rates Used in Above Variable Cost Calculations (\$/h)								
Rig	270.85							
Fuel	52.50							
Transportation/Misc.	62.50							
Rental	15.00							
Supervision	20.85							
Drill Pipe	20.85							
Combined	442.55							
Trip In (8-3/4 in. Bit, 6-1-3) ^c	5500	2.7	1.40	4.2	2.08	12.1	750.3	834.05
Change BHA ^d (Stabilizers) ^f		3.0	1.56	4.2	1.26	9.4	753.3	836.87
Displace Mud	5500	4.0	2.08	6.0			757.3	838.95
Drill 8-3/4 in. Hole	6000	20.0	10.78	4.1			777.3	849.73

^aTime and direct cost categories are identified in Appendix A.^cDesignates bit diameter and API Standard RP 7G bit classification, e.g., 17-1/2 in. diameter, series 1- type 1- features 1.^dBHA = bottomhole assembly^eBOP = blowout preventer^fA parenthetical note after "Change BHA" denotes item(s) associated with direct costs or item(s) requiring special attention.

Table 12 (Continued)

Drilling Operation Sequence for the Representative Geysers Well Model

Activity/Equipment/Service in Order of Occurrence	Depth (ft)	Time Used (h)	Variable Cost ₃ (\$x10 ³)	Time Category ^a	Direct Cost ₃ (\$x10 ³)	Direct Cost Category ^a	Cumulative	
							Time (h)	Cost ₃ (\$x10 ³)
Survey	6000	1.0	0.52	10.0			778.3	850.25
Trip Out/In (8-3/4 in. Bit, 6-3-5) ^c	6000	6.0	3.12	4.2	2.08	12.1	784.3	855.45
Change BHA ^d (Stabilizer) ^f		2.0	1.04	4.2	0.42	9.4	786.3	856.91
Ream (100 ft/6 h)	6000	6.0	3.23	4.3			792.3	860.14
Drill 8-3/4 in. Hole	6340	20.0	10.78	4.1			812.3	870.92
Survey	6340	1.0	0.52	10.0			813.3	871.44
Trip Out/In (8-3/4 in. Bit, 7-2-3) ^c	6340	6.3	3.28	4.2	2.08	12.1	819.6	876.80
Change BHA ^d (Stabilizer) ^f		3.0	1.56	4.2	0.42	9.4	822.6	878.78
Ream (60 ft/5 h)	6340	5.0	2.70	4.3			827.6	881.48
Drill 8-3/4 in. Hole	6660	20.0	10.78	4.1			847.6	892.26
Survey		1.0	0.52	10.0			848.6	892.78
Trip Out/In (8-3/4 in. Bit, 7-2-3) ^c	6660	6.6	3.43	4.2	2.08	12.1	855.2	898.29
Change BHA ^d (Stabilizer) ^f		3.0	1.56	4.2	0.42	9.4	858.2	900.27
Ream (60 ft/5 h)	6660	5.0	2.70	4.3			863.2	902.97
Drill 8-3/4 in. Hole	6930	18.0	9.70	4.1			881.2	912.67
(Surveys cease)								
Trip Out/In (8-3/4 in. Bit, 7-2-3) ^c	6930	6.9	3.59	4.2	2.08	12.1	888.1	918.34
Change BHA ^d (Stabilizer) ^f		4.0	2.08	4.2	0.42	9.4	892.1	920.84
Ream (60 ft/4 h)	6930	4.0	2.16	4.3			896.1	923.00
Drill 8-3/4 in. Hole	7200	18.0	9.70	4.1			914.1	932.70
Trip Out/In (8-3/4 in. Bit, 7-2-1) ^c	7200	7.2	3.75	4.2	2.08	12.1	921.3	938.53
Change BHA ^d (Stabilizer) ^f		4.0	2.08	4.2	0.42	9.4	925.3	941.03
Ream (60 ft/4 h)	7200	4.0	2.16	4.3			929.3	943.19
Drill 8-3/4 in. Hole	7470	15.0	8.09	4.1			944.3	951.28

^aTime and direct cost categories are identified in Appendix A.

^cDesignates bit diameter and API Standard RP 7G bit classification, e.g., 17-1/2 in. diameter, series 1- type 1- features 1.

^dBHA = bottomhole assembly

^fA parenthetical note after "Change BHA" denotes item(s) associated with direct costs or item(s) requiring special attention.

Table 12 (Continued)

Drilling Operation Sequence for the Representative Geysers Well Model

Activity/Equipment/Service in Order of Occurrence	Depth (ft)	Time Used (h)	Variable Cost ₃ (\$x10 ³)	Time Category ^a	Direct Cost ₃ (\$x10 ³)	Direct Cost Category ^a	Cumulative	
							Time (h)	Cost ₃ (\$x10 ³)
Trip Out/In (8-3/4 in. Bit, 7-2-1) ^c	7470	7.5	3.90	4.2	2.08	12.1	951.8	957.26
Change BHA ^d (Stabilizers) ^f		4.0	2.08	4.2	0.84	9.4	955.8	960.18
Ream (50 ft/5 h)	7470	5.0	2.70	4.3			960.8	962.88
Drill 8-3/4 in. Hole	7700	15.0	8.09	4.1			975.8	970.97
Trip Out/In (8-3/4 in. Bit, 6-3-5) ^c	7700	7.7	4.01	4.2	2.08	12.1	983.5	977.06
Change BHA ^d (Stabilizer) ^f		4.0	2.08	4.2	0.42	9.4	987.5	979.56
Ream (60 ft/6 h)	7700	6.0	3.23	4.3			993.5	982.79
Drill 8-3/4 in. Hole	8000	19.0	10.24	4.1			1012.5	993.03
Trip Out	8000	6.0	3.12	4.2			1018.5	996.15
Variable Cost Rates Used in Above Variable Cost Calculations (\$/h)								
Rig	270.85							
Fuel	52.50							
Transportation/Misc.	62.50							
Rental	15.00							
Supervision	20.85							
Drill Pipe	20.85							
Corrosion Chemicals	10.00							
Compressor:								
When Drilling	86.45							
(Other Times)	(67.71)							
Combined	539.00							
(When Drilling)	(520.26)							
Rig Up Casing Tools	8000	2.0	0.94	7.5			1020.5	997.09
Run 1700 ft., 10-3/4 in. Tieback	8000	8.7	4.09	7.5			1029.2	1001.18
Casing					33.71	7.5.1		1034.89
Tools/Service					5.14	7.5.2		1040.03
Cement Equipment					1.52	8.5.2		1041.55
Rig Down Casing Tools	8000	1.0	0.47	7.5			1030.2	1042.02
Rig Up Cementing Tools	8000	2.0	0.94	8.5			1032.2	1042.96

^aTime and direct cost categories are identified in Appendix A.^cDesignates bit diameter and API Standard RP 7G bit classification, e.g., 17-1/2 in. diameter, series 1- type 1- features 1.^dBHA = bottomhole assembly^fA parenthetical note after "Change BHA" denotes item(s) associated with direct costs or item(s) requiring special attention.

Table 12 (Continued)

Drilling Operation Sequence for the Representative Geysers Well Model

Activity/Equipment/Service in Order of Occurrence	Depth (ft)	Time Used (h)	Variable Cost (\$x10 ³)	Time Category ^a	Direct Cost ₃ (\$x10 ³)	Direct Cost Category ^a	Cumulative	
							Time (h)	Cost ₃ (\$x10 ³)
Cementing	8000	10.6	4.98	8.5			1042.8	1047.94
Cement					3.00	8.5.1		1050.94
Services					1.67	8.5.3		1052.61
Wait on Cement	8000	4.0	1.88	8.5			1046.8	1054.49
Rig Down Cementing Tools/ Nipple Down BOP /Nipple Up Wellhead	8000	13.0	6.11	18.0	29.92	18.0	1059.8	1090.52
Trip in 8-1/2 in. Rerun Bit	8000	1.8	0.85	4.2			1061.6	1091.37
Drill Cement	8000	2.5	1.17	8.5			1064.1	1092.54
<div><div>Variable Cost Rates Used in Above Variable Cost Calculations (\$/h)</div><div><div>Rig270.85</div><div>Fuel52.50</div><div>Transportation/Misc.62.50</div><div>Rental15.00</div><div>Supervision20.85</div><div>Drill Pipe20.85</div><div>Compressor27.08</div><div>Combined469.63</div></div><div><div>Variable Cost Rates Used Below in Final Variable Cost Calculations (\$/h)</div><div><div>Rig270.85</div><div>Fuel52.50</div><div>Transportation/Misc.62.50</div><div>Rental15.00</div><div>Supervision20.85</div><div>Drill Pipe20.85</div><div>Compressor27.08</div><div>Combined469.63</div></div></div></div>								
Trip In	8000	3.2	1.50	4.2			1067.3	1094.04
Circulate	8000	2.0	.94	18.0			1069.3	1094.98
Displace Drill Fluid	8000	4.0	1.88	18.0			1073.3	1096.86
Lay Down Drill Pipe/Collar	8000	10.0	4.43	9.0			1083.3	1101.29
Completion (Estimate)	8000	72.0	30.36	18.0			1155.3	1131.65
Miscellaneous								
Water					9.0	13.0		1140.65
Waste					12.0	13.0		1152.65
CUMULATIVE TOTALS							1155.3	1152.65
							(48 Days)	

^aTime and direct cost categories are identified in Appendix A.^eBOP = blowout preventer

4.2 IMPERIAL VALLEY MODELS

The drilling operation sequence for the East Mesa, Heber, Brawley, Salton Sea, and Westmorland well models are given in Tables 13, 14, 15, 16, and 17, respectively. These tables give the depth, time, variable costs, time categories, direct costs, direct cost category, cumulative time, and cumulative costs by activity and the the variable cost rates for the various groupings of activities.

Table 13

Drilling Operation Sequence for the Representative East Mesa Well Model

Activity/Equipment/Service in Order of Occurrence	Depth (ft)	Time Used (h)	Variable Cost ₃ (\$x10 ³)	Time Category ^a	Direct Cost ₃ (\$x10 ³)	Direct Cost Category ^a	Cumulative	
							Time (h)	Cost ₃ (\$x10 ³)
Site Preparation	0	120.0			16.20	1.0		16.20
Initiation								
Drill 26 in./Set 20 in.	100	96.0			10.00	2.0		26.20
20 in. Conductor					4.01	7.1.1		30.21
Tools/Service					1.61	7.1.2		31.82
Cement Equipment					3.56	8.1.2		35.38
Cement					0.96	8.1.1		36.34
Move In/Rig Up	100	72.0			35.95	3.0		72.29
Originate Mud	100	2.0			3.30	6.0		75.59
Spud	100						0	75.59
Trip In (17-1/2 in. bit, 1-1-1) ^c	100	0.5	0.24	4.2	3.23	12.1	0.5	79.06
Drill Cement	100	2.0	0.96	8.1			2.5	80.02
Condition Mud	100	1.0	0.48	6.0			3.5	80.50
Trip Out/In	100	0.5	0.24	4.2			4.0	80.74
Drill 17-1/2 in. Hole	1700	25.8	12.37	4.1			29.8	93.11
Circulate	1700	2.0	0.96	11.0			31.8	94.07
Trip Out	1700	0.8	0.38	11.0			32.6	94.45
Rig Up Logging Tools	1700	2.5	1.20	11.0			35.1	95.65
Log	1700	1.0	0.48	11.1	2.07	11.1	36.1	98.20
Rig Down Logging Tools	1700	1.0	0.48	11.0			37.1	98.68
Variable Cost Rates Used in Above Variable Cost Calculations (\$/h)								
Rig	235.40							
Fuel	41.25							
Transportation/Misc.	62.50							
Rental	15.00							
Supervision	20.85							
Mud	104.45							
Combined	479.45							
Wiper Trip	1700	3.4	1.35	7.2			40.5	100.03
Rig Up Casing Tools	1700	2.0	0.79	7.2			42.5	100.82

^aTime and direct cost categories are identified in Appendix A.

^bThese pre-spud times are not included in the cumulative time.

^cDesignates bit diameter and API Standard RP 7G bit classification, e.g., 17-1/2 in. diameter, series 1- type 1- features 1.

Table 13 (Continued)

Drilling Operation Sequence for the Representative East Mesa Well Model

Activity/Equipment/Service in Order of Occurrence	Depth (ft)	Time Used (h)	Variable Cost ₃ (\$x10 ³)	Time Category ^a	Direct Cost ₃ (\$x10 ³)	Direct Cost Category ^a	Cumulative	
							Time (h)	Cost ₃ (\$x10 ³)
Run 13-3/8 in. Casing	1700	8.5	3.36	7.2			51.0	104.18
Casing					41.65	7.2.1		145.83
Tools/Service					4.85	7.2.2		150.68
Cement Equipment					3.13	8.2.2		153.81
Rig Down Casing Tools	1700	1.0	0.40	7.2			52.0	154.21
Rig Up Cementing Tools	1700	2.0	0.79	8.2			54.0	155.00
Cementing	1700	2.8	1.11	8.2			56.8	156.11
Cement					12.99	8.2.1		169.10
Service					3.73	8.2.3		172.83
Rig Down Cementing Tools	1700	1.0	0.40	8.2			57.8	173.23
Wait On Cement	1700	4.0	1.58	8.2			61.8	174.81
Install Wellhead/BOP ^e	1700	12.0	4.75	14.2	15.07	14.2	73.8	194.63
Test Wellhead/BOP ^e	1700	4.0	1.58	14.2			77.8	196.21
Trip In (12-1/4 in. Bit, 1-1-1) ^c	1700	1.8	0.71	4.2	1.17	12.1	79.6	198.09
Stabilizers					1.69	9.0		199.78
Drill Cement	1700	2.5	0.99	8.2			83.1	200.77
Condition Mud	1700	1.0	0.40	6.0			83.1	201.17
Test Shoe		3.0	1.19	8.2			86.1	202.36
Variable Cost Rates Used in Above Variable Cost Calculations (\$/h)								
Rig	235.40	}						
Fuel	41.25							
Transportation/Misc.	62.50							
Rental	15.00							
Supervision	20.85							
Mud	20.85							
Combined	395.85							
Condition Mud	1700	2.0	0.94	6.0			88.1	203.30
Drill 12-1/4 in. Hole	3140	32.0	15.00	4.1			120.1	218.30

^aTime and direct cost categories are identified in Appendix A.^cDesignates bit diameter and API Standard RP 7G bit classification, e.g., 17-1/2 in. diameter, series 1- type 1- features 1.^eBOP = blowout preventer

Table 13 (Continued)

Drilling Operation Sequence for the Representative East Mesa Well Model

Activity/Equipment/Service in Order of Occurrence	Depth (ft)	Time Used (h)	Variable Cost, (\$x10 ³)	Time Category ^a	Direct Cost, (\$x10 ³)	Direct Cost Category ^a	Cumulative	
							Time (h)	Cost, (\$x10 ³)
Trip Out/In (12-1/4 in. Bit, 1-1-1) ^c	3140	4.2	1.97	4.2	1.17	12.1	124.3	221.44
Variable Cost Rates Used in Above Variable Cost Calculations (\$/h)								
Rig	235.40							
Fuel	41.25							
Transportation/Misc.	62.50							
Rental	15.00							
Supervision	20.85							
Mud	93.61							
Combined	468.61							
(Start Mud Logger)								
Drill 12-1/4 in. Hole	4204	28.0	13.87	4.1			152.3	235.31
Survey	4204	1.0	0.50	10.0			153.3	235.81
Trip Out/In (12-1/4 in. Bit, 1-2-1) ^c	4204	6.2	3.07	4.2	1.59	12.1	159.5	240.47
Drill 12-1/4 in. Hole	5500	37.0	18.32	4.1			196.5	258.79
Circulate	5500	3.0	1.49	11.0			199.5	260.28
Survey (Multi-Shot)	5500	3.0	1.49	10.0	2.00	10.2	202.5	263.77
Trip Out	5500	3.8	1.88	4.2			206.3	265.65
Variable Cost Rates Used in Above Variable Cost Calculations (\$/h)								
Rig	235.40							
Fuel	41.25							
Transportation/Misc.	62.50							
Rental	15.00							
Supervision	20.85							
Mud	93.61							
Mud Log	26.60							
Combined	495.21							
Rig Up Logging Tools	5500	2.0	1.02	11.0			208.3	266.67
Test/Calibrate	5500	3.5	1.79	11.0			211.8	268.46
Log (1700 ft to 5500 ft)	5500	8.4	4.30	11.1	15.13	11.1	220.2	287.89

^aTime and direct cost categories are identified in Appendix A.^cDesignates bit diameter and API Standard RP 7G bit classification, e.g., 17-1/2 in. diameter, series 1- type 1- features 1.

Table 13 (Continued)

Drilling Operation Sequence for the Representative East Mesa Well Model

Activity/Equipment/Service in Order of Occurrence	Depth (ft)	Time Used (h)	Variable Cost ³ (\$x10 ³)	Time Category ^a	Direct Cost ³ (\$x10 ³)	Direct Cost Category ^a	Cumulative	
							Time (h)	Cost ³ (\$x10 ³)
Rig Down Logging Tools	5500	1.0	0.51	11.0			221.2	288.40
Variable Cost Rates Used in Above Variable Cost Calculations (\$/h)								
Rig	235.40							
Fuel	41.25							
Transportation/Misc.	62.50							
Rental	15.00							
Supervision	20.85							
Mud	109.80							
Mud Log	26.60							
Combined	511.40							
Wiper Trip	5500	14.0	6.06	7.3			235.2	294.46
Rig Up Casing Tools	5500	2.0	0.87	7.3			237.2	295.33
Run 9-5/8 in. Liner	5500	18.3	7.92	7.3			255.5	303.25
Casing					69.83	7.3.1		373.08
Tools/Service					9.52	7.3.2		382.60
Cement Equipment					4.55	8.3.2		387.15
Hanger		3.0	1.30	7.3	12.40	8.3.2	258.5	400.85
Rig Down Casing Tools	5500	1.0	0.43	7.3			259.5	401.28
Rig Up Cementing Tools	5500	2.0	0.87	8.3			261.5	402.15
Cementing	5500	3.0	1.30	8.3			264.5	403.45
Cement					10.86	8.3.1		414.31
Service					4.53	8.3.3		418.84
Rig Down Cementing Tools	5500	1.0	0.43	8.3			265.5	419.27
Wait On Cement	5500	6.0	2.60	8.3			271.5	421.87
Install BOP ^e /Test	5500	15.0	6.49	14.2			286.5	428.36
Lay Down 4-1/4 in. Drill Pipe/8 in. Drill Collar	5500	7.5	3.25	9.0			294.0	431.61
Pick up 3-1/2 in. Drill Pipe/6 in. Drill Collar								
Change BHA ^d	5500	4.0	1.73	9.0			298.0	433.34

^a Time and direct cost categories are identified in Appendix A.

^c Designates bit diameter and API Standard RP 7G bit classification, e.g., 17-1/2 in. diameter, series 1- type 1- features 1.

^d BHA = bottomhole assembly

^e BOP = blowout preventer

Table 13 (Continued)

Drilling Operation Sequence for the Representative East Mesa Well Model

Activity/Equipment/Service in Order of Occurrence	Depth (ft)	Time Used (h)	Variable Cost (\$x10 ³)	Time Category ^a	Direct Cost (\$x10 ³)	Direct Cost Category ^a	Cumulative	
							Time (h)	Cost (\$x10 ³)
Trip In (8-1/2 in. Bit, 1-2-1) ^c	5500	2.8	1.21	4.2	0.69	12.1	300.8	435.24
Stabilizers					0.84	9.0		436.08
Drill Cement	5500	2.5	1.08	8.3			303.3	437.16
Test Shoe	5500	3.0	1.30	8.3			306.3	438.46
Variable Cost Rates Used in Above Variable Cost Calculations (\$/h)								
Rig	235.40							
Fuel	41.25							
Transportation/Misc.	62.50							
Rental	15.00							
Supervision	20.85							
Mud	31.25							
Mud Log	26.60							
Combined	432.85							
Condition Mud	5500	2.0	0.91	6.0			308.3	439.37
Drill 8-1/2 in.	5758	22.0	10.00	4.1			330.3	449.37
Trip Out/In (8-1/2 in. Bit, 1-1-2) ^c	5758	7.7	3.50	4.2	0.86	12.1	338.0	453.73
Drill 8-1/2 in. Hole	6178	35.0	15.91	4.1			373.0	469.64
Trip Out/In (8-1/2 in. Bit, 5-1-7) ^c	6178	8.1	3.68	4.2	3.02	12.1	381.1	476.34
Drill 8-1/2 in. Hole	6893	65.0	29.55	4.1			446.1	505.89
Trip Out/In (8-1/2 in. Bit, 5-1-7) ^c	6893	8.8	4.00	4.2	3.02	12.1	454.9	512.91
Drill 8-1/2 in. Hole	7600	57.0	25.91	4.1			511.9	538.82
Circulate	7600	3.0	1.36	11.0			514.9	540.18
Trip Out	7600	4.8	2.18	4.2			519.7	542.36
(Release Mud Logger)								
Variable Cost Rates Used in Above Variable Cost Calculations (\$/h)								
Rig	235.40							
Fuel	41.25							
Transportation/Misc.	62.50							
Rental	15.00							
Supervision	20.85							
Mud	53.03							
Mud Log	26.60							
Combined	454.63							

^aTime and direct cost categories are identified in Appendix A.^cDesignates bit diameter and API Standard RP 7G bit classification, e.g., 17-1/2 in. diameter, series 1- type 1- features 1.

Table 13 (Continued)

Drilling Operation Sequence for the Representative East Mesa Well Model

Activity/Equipment/Service in Order of Occurrence	Depth (ft)	Time Used (h)	Variable Cost (\$x10 ³)	Time Category ^a	Direct Cost (\$x10 ³)	Direct Cost Category ^a	Cumulative	
							Time (h)	Cost (\$x10 ³)
Rig Up Logging Tools	7600	2.0	0.81	11.0			521.7	543.17
Test/Calibrate	7600	3.5	1.42	11.0			525.2	544.59
Log (5500 ft to 7600 ft)	7600	6.5	2.64	11.1	17.51	11.1	531.7	564.74
Rig Down Logging Tools	7600	1.0	0.41	11.0			532.7	565.15
Variable Cost Rates Used in Above Variable Cost Calculations (\$/h)								
Rig	235.40							
Fuel	41.25							
Transportation/Misc.	62.50							
Rental	15.00							
Supervision	20.85							
Mud	31.25							
Combined	406.25							
Wiper Trip	7600	7.6	2.85	7.5			540.3	568.00
Rig Up Casing Tools	7600	2.0	0.75	7.5			542.3	568.75
Run 7 in. Slotted Liner	7600	21.8	8.18	7.5			564.1	576.93
Casing					49.15	7.5.1		626.08
Tools/Service					5.50	7.5.2		631.58
Equipment					0.71	8.5.2		632.29
Hanger		3.0	1.13	8.5	6.07	7.5.2	567.1	639.49
Rig Down Casing Tools	7600	1.0	0.38	7.5			568.1	639.87
Nipple Down BOP ^e /Install Wellhead	7600	11.0	4.13	18.0	27.00	18.0	579.1	671.00
Completion (Estimate)	7600	72.0	27.00	18.0			651.1	698.00
Lay Down Drill Pipe/ Drill Collar	7600	12.6	4.73	9.0			663.7	702.73
Variable Cost Rates Used in Above Variable Cost Calculations (\$/h)								
Rig	235.40							
Fuel	41.25							
Transportation/Misc.	62.50							
Rental	15.00							
Supervision	20.85							
Combined	375.00							
Miscellaneous								
Waste Disposal					12.00	13.2		714.73
Water					9.00	13.1		723.73
CUMULATIVE TOTALS							663.7 (28 Days)	723.73

^a Time and direct cost categories are identified in Appendix A.^e BOP = blowout preventer

Table 14

Drilling Operation Sequence for the Representative Heber Well Model

Activity/Equipment/Service in Order of Occurrence	Depth (ft)	Time Used (h)	Variable Cost ₃ (\$x10 ³)	Time Category ^a	Direct Cost ₃ (\$x10 ³)	Direct Cost Category ^a	Cumulative	
							Time (h)	Cost ₃ (\$x10 ³)
Site Preparation	0	120.0			16.20	1.0		16.20
Initiation								
Drill 26 in./Set 20 in.	100	96.0			10.00	2.0		26.20
Conductor					4.01	7.1.1		30.21
Tools/Service					1.61	7.1.2		31.82
Cement Equipment					3.56	8.1.2		35.38
Cement					0.96	8.1.1		36.34
Move In/Rig Up	100	72.0			35.95	3.0		72.29
Originate Mud	100	2.0			3.30	6.0		75.59
Spud	100						0	75.59
Trip In (17-1/2 in. Bit, 1-1-1) ^c	100	0.5	0.24	4.2			0.5	75.83
Drill Cement		2.0	0.96	8.1			2.5	76.79
Condition Mud		1.0	0.48	6.0			3.5	77.27
Trip Out/In (17-1/2 in. Bit, 1-1-1) ^c	100	0.5	0.24	4.2	3.23	12.1	4.0	80.74
Drill 17-1/2 in. Hole	1700	25.8	12.37	4.1			29.8	93.11
Circulate	1700	2.0	0.96	11.0			31.8	94.07
Trip Out	1700	0.8	0.38	11.0			32.6	94.45
Rig Up and Test Logging Tools	1700	2.5	1.20	11.0			35.1	95.65
Log	1700	1.0	0.48	11.1	2.07	11.1	36.1	98.20
Rig Down Logging Tools		1.0	0.48	11.0			37.1	98.68
Variable Cost Rates Used in Above Variable Cost Calculations (\$/h)								
Rig	235.40							
Fuel	41.25							
Transportation/Misc.	62.50							
Rental	15.00							
Supervision	20.85							
Mud	104.44							
Combined	479.44							

^aTime and direct cost categories are identified in Appendix A.

^bThese pre-spud times are not included in the cumulative time.

^cDesignates bit diameter and API Standard RP 7G bit classification, e.g., 17-1/2 in. diameter, series 1- type 1- features 1.

Table 14 (Continued)

Drilling Operation Sequence for the Representative Heber Well Model

Activity/Equipment/Service in Order of Occurrence	Depth (ft)	Time Used (h)	Variable Cost ₃ (\$x10 ³)	Time Category ^a	Direct Cost ₃ (\$x10 ³)	Direct Cost Category ^a	Cumulative	
							Time (h)	Cost ₃ (\$x10 ³)
Wiper Trip	1700	3.4	1.35	7.2			40.5	100.03
Rig Up Casing Tools	1700	2.0	0.79	7.2			42.5	100.82
Run 13-3/8 in. Casing	1700	8.5	3.36	7.2			51.0	104.18
Casing					41.66	7.2.1		145.84
Tools/Service					4.85	7.2.2		150.69
Cement Equipment					3.13	8.2.2		153.82
Rig Down Casing Tools	1700	1.0	0.40	7.2			52.0	154.22
Rig Up Cementing Tools	1700	2.0	0.79	8.2			54.0	155.01
Cementing	1700	2.8	1.11	8.2			56.8	156.12
Cement					12.99	8.2.1		169.11
Service					3.73	8.2.3		172.84
Rig Down Cementing Tools	1700	1.0	0.40	8.2			57.8	173.24
Wait On Cement	1700	4.0	1.58	8.2			61.8	174.82
Install Wellhead/BOP ^e	1700	12.0	4.75	14.2	15.07	14.2	73.8	194.64
Test Wellhead/BOP ^e		4.0	1.58	14.2			77.8	196.22
Trip In (12-1/4 in. Bit, 1-1-1) ^c		1.8	0.71	4.2	1.17	12.1	79.6	198.10
Stabilizers					1.69	9.4		199.79
Drill Cement		2.5	0.99	8.2			82.1	200.78
Condition Mud		1.0	0.40	6.0			83.1	201.18
Test Shoe		3.0	1.19	8.2			86.1	202.37
<div> <div>Variable Cost Rates Used in Above Variable Cost Calculations (\$/h)</div> <div> <div>Rig235.40</div> <div>Fuel41.25</div> <div>Transportation/Misc.62.50</div> <div>Rental15.00</div> <div>Supervision20.85</div> <div>Mud20.85</div> <div>Combined395.85</div> </div> </div>								
Condition Mud	1700	2.0	0.94	6.0			88.1	203.31
Drill 12-1/4 in. Hole	3140	32.0	14.98	4.1			120.1	218.29

^aTime and direct cost categories are identified in Appendix A.

^cDesignates bit diameter and API Standard RP 7G bit classification, e.g., 17-1/2 in. diameter, series 1- type 1- features 1.

^eBOP = blowout preventer

Table 14 (Continued)

Drilling Operation Sequence for the Representative Heber Well Model

Activity/Equipment/Service in Order of Occurrence	Depth (ft)	Time Used (h)	Variable Cost ₃ (\$x10 ³)	Time Category ^a	Direct Cost ₃ (\$x10 ³)	Direct Cost Category ^a	Cumulative	
							Time (h)	Cost ₃ (\$x10 ³)
Trip Out/In (12-1/4 in. Bit, 1-1-1) ^c (Mud Logger & Cooler Added)	3140	4.2	1.97	4.2	1.17	12.1	124.3	221.43
Drill 12-1/4 in. Hole	4204	28.0	13.85	4.1			152.3	235.28
Survey		1.0	0.49	10.3			153.3	235.77
Trip Out/In (12-1/4 in. Bit, 1-2-1) ^c	4204	6.2	3.07	4.2	1.60	12.1	159.5	240.44
Drill 12-1/4 in. Hole	5500	37.0	18.30	4.1			196.5	258.74
Circulate		3.0	1.48	11.0			199.5	260.22
Survey (Multi-Shot)	5500	3.0	1.48	10.3	2.00	10.2	202.5	263.70
Trip Out		3.8	1.88	4.2			206.3	265.58
Variable Cost Rates Used in Above Variable Cost Calculations (\$/h)								
Rig	235.40							
Fuel	41.25							
Transportation/Misc.	62.50							
Rental	15.00							
Supervision	20.85							
Mud Log (below 3140 ft)	26.60							
Mud	93.00							
Combined	494.60							
Rig Up Logging Tools	5500	2.0	1.02	11.0			208.3	266.60
Test/Calibrate		3.5	1.79	11.0			211.8	268.39
Log (1700 ft to 5500 ft)	5500	8.4	4.30	11.1	15.10	11.1	220.2	287.79
Rig Down Logging Tools	5500	1.0	0.51	11.0			221.2	288.30
Variable Cost Rates Used in Above Variable Cost Calculations (\$/h)								
Rig	235.40							
Fuel	41.25							
Transportation/Misc.	62.50							
Rental	15.00							
Supervision	20.85							
Mud Log	26.60							
Mud	109.80							
Combined	511.40							

^a Time and direct cost categories are identified in Appendix A.^c Designates bit diameter and API Standard RP 7G bit classification, e.g., 17-1/2 in. diameter, series 1- type 1- features 1.

Table 14 (Continued)

Drilling Operation Sequence for the Representative Heber Well Model

Activity/Equipment/Service in Order of Occurrence	Depth (ft)	Time Used (h)	Variable Cost ³ (\$x10 ³)	Time Category ^a	Direct Cost ³ (\$x10 ³)	Direct Cost Category ^a	Cumulative	
							Time (h)	Cost ³ (\$x10 ³)
Wiper Trip	5500	14.0	6.06	7.3			235.2	294.36
Rig Up Casing Tools	5500	2.0	0.87	7.3			237.2	295.23
Run 9-5/8 in. Liner		18.3	7.92	7.3			255.5	303.15
Casing					62.59	7.3.1		366.74
Tools/Service					10.46	7.3.2		376.20
Cement Equipment					4.56	8.3.2		380.76
Hanger		3.0	1.30	7.3	12.40	7.3.2	258.5	394.46
Rig Down Casing Tools	5500	1.0	0.43	7.3			259.5	394.89
Rig Up Cementing Tools	5500	2.0	0.87	8.3			261.5	395.76
Cementing		3.0	1.30	8.3			264.5	397.06
Cement					9.97	8.3.1		407.03
Service					2.48	8.3.3		409.51
Rig Down Cementing Tools	5500	1.0	0.43	8.3			265.5	409.94
Wait On Cement	5500	6.0	2.60	8.3			271.5	412.54
Install Wellhead/BOP ^e / Test	5500	15.0	6.49	14.2	4.00	14.3	286.5	423.03
Lay Down 4-1/2 in. Drill Pipe + 8 in. Drill Collar/Pick up 3-1/2 in. Drill Pipe + 6 in. Drill Collar	5500	7.5	3.25	9.0			294.0	426.28
Change BHA ^d /Trip In (8-1/2 in. Bit, 1-2-1) ^c		6.8	2.94	9.0	0.87	12.1	300.8	430.09
Stabilizers					0.84	9.4		430.93
Drill Cement	5500	2.5	1.08	8.3			303.3	432.01
Test Shoe	5500	3.0	1.30	8.3			306.3	433.31

Variable Cost Rates Used in Above
Variable Cost Calculations (\$/h)

Rig	235.40
Fuel	41.25
Transportation/Misc.	62.50
Rental	15.00
Supervision	20.85
Mud Log	26.60
Mud	31.25
Combined	432.85

^aTime and direct cost categories are identified in Appendix A.

^cDesignates bit diameter and API Standard RP 7G bit classification, e.g., 17-1/2 in. diameter, series 1- type 1- features 1.

^dBHA = bottomhole assembly

^eBOP = blowout preventer

Table 14 (Continued)

Drilling Operation Sequence for the Representative Heber Well Model

Activity/Equipment/Service in Order of Occurrence	Depth (ft)	Time Used (h)	Variable Cost ₃ (\$x10 ³)	Time Category ^a	Direct Cost ₃ (\$x10 ³)	Direct Cost Category ^a	Cumulative	
							Time (h)	Cost ₃ (\$x10 ³)
Condition Mud	5500	2.0	0.91	6.0			308.3	434.22
Drill 8-1/2 in. Hole	5860	30.0	13.70	4.1			338.3	447.92
Survey		1.0	0.46	10.3			339.3	448.38
Trip Out/In (8-1/2 in. Bit, 1-2-1) ^c	5860	7.9	3.61	4.2	0.82	12.1	347.2	452.81
Drill 8-1/2 in. Hole	6110	25.0	11.42	4.1			372.2	464.23
Trip Out/In (8-1/2 in. Bit, 5-1-7) ^c	6110	8.1	3.70	4.2	3.02	12.1	380.3	470.95
Drill 8-1/2 in. Hole	6782	56.0	25.57	4.1			436.3	496.52
Survey		1.0	0.46	10.3			437.3	496.98
Trip Out/In (8-1/2 in. Bit, 5-1-7) ^c	6782	8.7	3.97	4.2	3.02	12.1	446.0	503.97
Drill 8-1/2 in. Hole	7142	36.0	16.44	4.1			482.0	520.41
Survey		1.0	0.46	10.3			483.0	520.87
Trip Out/In (8-1/2 in. Bit, 5-1-7) ^c	7142	9.1	4.16	4.2	3.02	12.1	492.1	528.05
Drill 8-1/2 in. Hole	7692	50.0	22.83	4.1			542.1	550.88
Trip Out/In (8-1/2 in. Bit, 5-1-7) ^c	7692	9.6	4.38	4.2	3.02	12.1	551.7	558.28
Drill 8-1/2 in. Hole	8000	34.2	15.62	4.1			585.9	573.90
Circulate		4.0	1.83	11.0			589.9	575.73
Trip Out (Release Mud Logger)		5.0	2.28	4.2			594.9	578.01
Variable Cost Rates Used in Above Variable Cost Calculations (\$/h)								
Rig	235.40							
Fuel	41.25							
Transportation/Misc.	62.50							
Rental	15.00							
Supervision	20.85							
Mud Log	26.60							
Mud	55.09							
Combined	456.69							
Rig Up Logging Tools	8000	2.0	0.81	11.0			596.9	578.82
Test and Calibrate	8000	3.5	1.42	11.0			600.4	580.24
Log (5500 ft to 8000 ft)	8000	7.3	2.97	11.1	18.32	11.1	607.7	601.53

^aTime and direct cost categories are identified in Appendix A.

^cDesignates bit diameter and API Standard RP 7G bit classification, e.g., 17-1/2 in. diameter, series 1- type 1- features 1.

Table 14 (Continued)

Drilling Operation Sequence for the Representative Heber Well Model

Activity/Equipment/Service in Order of Occurrence	Depth (ft)	Time Used (h)	Variable Cost (\$x10 ³)	Time Category ^a	Direct Cost (\$x10 ³)	Direct Cost Category ^a	Cumulative	
							Time (h)	Cost (\$x10 ³)
Rig Down Logging Tools	8000	1.0	0.41	11.0			608.7	601.94
Wiper Trip	8000	8.0	3.25	7.5			616.7	605.19
Rig Up Casing Tools	8000	2.0	0.81	7.5			618.7	606.00
Run Liner	8000	26.8	10.89	7.5			645.5	616.89
Casing (7 in. Slotted Liner)					57.70	7.5.1		674.59
Test and Service					5.93	7.5.2		680.52
Equipment					.85	8.5.2		681.37
Hanger		3.0	1.22	7.5	6.07	7.5.2	648.5	688.66
Rig Down Casing Tools	8000	1.0	0.41	7.5			649.5	689.07
Nipple Down BOP ^e /Wellhead	8000	11.0	4.47	18.0	27.00	18.0	660.5	720.54
Completion (Estimate)	8000	72.0	29.25	18.0			732.5	749.79
Lay Down Drill Pipe	8000	13.0	5.28	9.0			745.5	755.07
Variable Cost Rates Used in Above Variable Cost Calculations (\$/h)								
Rig	235.40							
Fuel	41.25							
Transportation/Misc.	62.50							
Rental	15.00							
Supervision	20.85							
Mud	31.25							
Combined	406.25							
Miscellaneous								
Waste Disposal					12.0	13.2		767.07
Water					9.00	13.1		776.07
CUMULATIVE TOTALS							745.5	776.07
							(31 Days)	

^aTime and direct cost categories are identified in Appendix A.^eBOP = blowout preventer

Table 15

Drilling Operation Sequence for the Representative Brawley Well Model

Activity/Equipment/Service in Order of Occurrence	Depth (ft)	Time Used (h)	Variable Cost (\$x10 ³)	Time Category ^a	Direct Cost ³ (\$x10 ³)	Direct Cost Category ^a	Cumulative	
							Time (h)	Cost ³ (\$x10 ³)
Site Preparation		120.0			16.20	1.0		16.20
Initiation								
Drill 26 in. and Set 20 in. Pipe	100	96.0			10.00	2.0		26.20
Conductor					4.01	7.1.1		30.21
Tools/Service					1.61	7.1.2		31.82
Cement Equipment					3.56	8.1.2		35.38
Cement					0.96	8.1.1		36.34
Move In/Rig Up	100	72.0			35.95	3.0		72.29
Originate Mud	100	2.0			3.30	6.0		75.59
Spud							0	75.59
Trip In (17-1/2 in. Bit, 1-1-1) ^c	100	0.5	0.24	4.2			0.5	75.83
Drill Cement		2.0	0.96	8.1			2.5	76.79
Condition Mud		1.0	0.48	6.0			3.5	77.27
Trip Out/In (17-1/2 in. Bit, 1-1-1) ^c		0.5	0.24	4.2	3.23	12.1	4.0	80.74
Drill 17-1/2 in. Hole	1400	21.6	10.36	4.1			25.6	91.10
Circulate	1400	2.0	0.96	11.0			27.6	92.06
Trip Out	1400	0.7	0.34	11.0			28.3	92.40
Rig Up Logging Tools	1400	2.5	1.20	11.0			30.8	93.60
Log	1400	1.0	0.48	11.1	2.11	11.1	31.8	96.19
Rig Down Logging Tools	1400	1.0	0.48	11.0			32.8	96.67
Variable Cost Rates Used in Above Variable Cost Calculations (\$/h)								
Rig	235.40							
Fuel	41.25							
Transportation/Misc.	62.50							
Rental	15.00							
Supervision	20.85							
Mud	104.44							
Combined	479.44							
Wiper Trip	1400	2.8	1.11	7.2			35.6	97.78
Rig Up Casing Tools	1400	2.0	0.79	7.2			37.6	98.57

^aTime and direct cost categories are identified in Appendix A.

^bThese pre-spud times are not included in the cumulative time.

^cDesignates bit diameter and API Standard RP 7G bit classification, e.g., 17-1/2 in. diameter, series 1- type 1- features 1.

Table 15 (Continued)

Drilling Operation Sequence for the Representative Brawley Well Model

Activity/Equipment/Service in Order of Occurrence	Depth (ft)	Time Used (h)	Variable Cost (\$x10 ³)	Time Category ^a	Direct Cost (\$x10 ³)	Direct Cost Category ^a	Cumulative	
							Time (h)	Cost ³ (\$x10 ³)
Run 13-3/8 in. Casing	1400	7.0	2.77	7.2			44.6	101.34
Casing					34.30	7.2.1		135.64
Tools/Service					4.08	7.2.2		139.72
Cement Equipment					2.88	8.2.2		142.60
Rig Down Casing Tools	1400	1.0	0.40	7.2			45.6	143.00
Rig Up Cementing Tools	1400	2.0	0.79	8.2			47.6	143.79
Cementing	1400	2.5	0.99	8.2			50.1	144.78
Cement					10.69	8.2.1		155.47
Service					2.05	8.2.3		157.52
Rig Down Cementing Tools	1400	1.0	0.40	8.2			51.1	157.92
Wait On Cement	1400	4.0	1.58	8.2			55.1	159.50
Install Wellhead/BOP ^e	1400	12.0	4.75	14.2	15.07	14.2	67.1	179.32
Test Wellhead/BOP ^e		4.0	1.58	14.2			71.1	180.90
Trip In (12-1/4 in. Bit, 1-1-1) ^c		1.7	0.67	4.2	1.17	12.1	72.8	182.74
Stabilizers					1.69	9.4	72.8	184.43
Drill Cement	1400	2.5	0.99	8.2			75.3	185.42
Test Shoe	1400	2.0	0.79	8.2			77.3	186.21
Condition Mud	1400	1.0	0.40	6.0			78.3	186.61
<div>Variable Cost Rates Used in Above Variable Cost Calculations (\$/h)</div> <div><div><div>Rig235.40</div><div>Fuel41.25</div><div>Transportation/Misc.62.50</div><div>Rental15.00</div><div>Supervision20.85</div><div>Mud20.85</div><div>Combined395.85</div></div><div>}</div></div>								
Condition Mud	1400	1.0	0.49	6.0			79.3	187.10
Drill 12-1/4 in. Hole	2840	32.0	15.69	4.1			111.3	202.79
Trip Out/In (12-1/4 in. Bit, 1-1-1) ^c	2840	3.8	1.86	4.2	1.17	12.1	115.1	205.82
(Mud Logger Added)								

^aTime and direct cost categories are identified in Appendix A.^cDesignates bit diameter and API Standard RP 7G bit classification, e.g., 17-1/2 in. diameter, series 1- type 1- features 1.^eBOP = blowout preventer

Table 15 (Continued)

Drilling Operation Sequence for the Representative Brawley Well Model

Activity/Equipment/Service in Order of Occurrence	Depth (ft)	Time Used (h)	Variable Cost ₃ (\$x10 ³)	Time Category ^a	Direct Cost ₃ (\$x10 ³)	Direct Cost Category ^a	Cumulative	
							Time (h)	Cost ₃ (\$x10 ³)
Drill 12-1/4 in. Hole	4000	30.5	14.95	4.1			145.6	220.77
Circulate		2.5	1.23	11.0			148.1	222.00
Survey (Multi-Shot)	4000	3.0	1.47	10.3	1.75	10.3	151.1	225.22
Trip Out	4000	3.0	1.47	4.2			154.1	226.69
Variable Cost Rates Used in Above Variable Cost Calculations (\$/h)								
Rig	235.40							
Fuel	41.25							
Transportation/Misc.	62.50							
Rental	15.00							
Supervision	20.85							
Mud Log	26.60							
Mud	88.64							
Combined	490.24							
Rig Up Logging Tools	4000	2.0	0.97	11.0			156.1	227.66
Test/Calibrate	4000	3.5	1.70	11.0			159.6	229.36
Log (1400 ft to 4000 ft)	4000	6.0	2.92	11.1	12.38	11.1	165.6	244.66
Rig Down Logging Tools	4000	1.0	0.49	11.0			166.6	245.15
Variable Cost Rates Used in Above Variable Cost Calculations (\$/h)								
Rig	235.40							
Fuel	41.25							
Transportation/Misc.	62.50							
Rental	15.00							
Supervision	20.85							
Mud Log	26.60							
Mud	84.96							
Combined	486.56							
Wiper Trip	4000	11.0	4.76	7.3			177.6	249.91
Rig Up Casing Tools	4000	2.0	0.87	7.3			179.6	250.78
Run 9-5/8 in. Liner	4000	13.3	5.76	7.3			192.9	256.54
Casing					48.88	7.3.1	305.42	
Tools/Service					7.28	7.3.2	312.70	
Cement Equipment					3.97	8.3.2	316.67	
Hanger		3.0	1.30	7.3	12.40	7.3.2	195.9	330.37
Rig Down Casing Tools	4000	1.0	0.43	7.3			196.9	330.80
Rig Up Cementing Tools	4000	2.0	0.87	8.3			198.9	331.67

^aTime and direct cost categories are identified in Appendix A.

Table 15 (Continued)

Drilling Operation Sequence for the Representative Brawley Well Model

Activity/Equipment/Service in Order of Occurrence	Depth (ft)	Time Used (h)	Variable Cost ³ (\$x10 ³)	Time Category ^a	Direct Cost ³ (\$x10 ³)	Direct Cost Category ^a	Cumulative	
							Time (h)	Cost ³ (\$x10 ³)
Cementing	4000	2.5	1.08	8.3			201.4	332.75
Cement					7.62	8.3.1		340.37
Services					3.43	8.3.3		343.80
Rig Down Cementing Tools	4000	1.0	0.43	8.3			202.4	344.23
Wait On Cement	4000	4.0	1.73	8.3			206.4	345.96
Install BOP ^e /Test	4000	15.0	6.49	14.2			221.4	352.45
Variable Cost Rates Used in Above Variable Cost Calculations (\$/h)								
Rig	235.40							
Fuel	41.25							
Transportation/Misc.	62.50							
Rental	15.00							
Supervision	20.85							
Mud Log	26.60							
Mud	31.25							
Combined	432.85							
Lay Down 4-1/2 in. Drill Pipe + 8 in. Drill Collar/Pick up 3-1/2 in. Drill Pipe + 6 in. Drill Collar	4000	5.5	2.50	9.0			226.9	354.95
Change BHA ^d /Trip In (8-1/2 in. Bit, 1-2-1) ^c	4000	6.0	2.73	9.0	0.87	12.1	232.9	358.55
Drill Cement	4000	2.5	1.14	8.3			235.4	359.69
Test Shoe	4000	3.0	1.36	8.3			238.4	361.05
Drill 8-1/2 in. Hole	4450	30.0	13.63	4.1			268.4	374.68
Stabilizer					0.84	9.0	268.4	375.52
Survey		1.0	0.45	10.3			269.4	375.97
Trip Out/In (8-1/2 in. Bit, 5-1-7) ^c	4450	6.5	2.95	4.2	3.02	12.1	275.9	381.94
Drill 8-1/2 in. Hole	5290	60.0	27.26	4.1			335.9	409.20
Survey	5290	1.0	0.45	10.3			336.9	409.65
Trip Out/In (8-1/2 in. Bit, 5-1-7) ^c	5290	7.3	3.32	4.2	3.02	12.1	344.2	415.99
Drill 8-1/2 in. Hole	6000	59.2	26.90	4.1			403.4	442.89
Survey	6000	1.0	0.45	10.3			404.4	443.34

^a Time and direct cost categories are identified in Appendix A.

^c Designates bit diameter and API Standard RP 7G bit classification, e.g., 17-1/2 in. diameter, series 1- type 1- features 1.

^d BHA = bottomhole assembly

^e BOP = blowout preventer

Table 15 (Continued)

Drilling Operation Sequence for the Representative Brawley Well Model

Activity/Equipment/Service in Order of Occurrence	Depth (ft)	Time Used (h)	Variable Cost (\$x10 ³)	Time Category ^a	Direct Cost ₃ (\$x10 ³)	Direct Cost Category ^a	Cumulative	
							Time (h)	Cost (\$x10 ³)
Circulate	6000	3.0	1.36	11.0			407.4	444.70
Trip Out	6000	4.0	1.82	4.2			411.4	446.52
(Release Mud Logger)								
Variable Cost Rates Used in Above Variable Cost Calculations (\$/h)								
Rig	235.40							
Fuel	41.25							
Transportation/Misc.	62.50							
Rental	15.00							
Supervision	20.85							
Mud Log	26.60							
Mud	52.79							
Combined	454.39							
Rig Up Logging Tools	6000	2.0	0.81	11.0			413.4	447.33
Test and Calibrate	6000	3.5	1.42	11.0			416.9	448.75
Log (4000 ft to 6000 ft)	6000	5.9	2.40	11.1	8.96	11.1	422.8	460.11
Rig Down Logging Tools	6000	1.0	0.41	11.0			423.8	460.52
Rig Up Casing Tools	6000	2.0	0.81	7.5			425.8	461.33
Wiper Trip	6000	6.0	2.44	7.5			431.8	463.77
Run 7 in. Slotted Liner	6000	17.1	6.95	7.5			448.9	470.72
Casing					44.88	7.5.1		515.60
Tools/Service					6.51	7.5.2		522.11
Hanger		3.0	1.22	7.5	6.07	7.5.2	451.9	529.40
Rig Down Casing Tools	6000	1.0	0.41	7.5			452.9	529.81
Nipple Down Wellhead/BOP ^e	6000	11.0	4.47	18.0	27.00	18.0	463.9	561.28
Completion (Estimated)	6000	72.0	29.25	18.0			535.9	590.53
Lay Down Drill Pipe	6000	11.0	4.47	9.0			546.9	595.00
Variable Cost Rates Used in Above Variable Cost Calculations (\$/h)								
Rig	235.40							
Fuel	41.25							
Transportation/Misc.	62.50							
Rental	15.00							
Supervision	20.85							
Mud	31.25							
Combined	406.25							
Waste Disposal					12.00	13.2		607.00
Water					9.00	13.1		616.00
CUMULATIVE TOTALS							546.9	616.00
							(23 Days)	

^aTime and direct cost categories are identified in Appendix A.^eBOP = blowout preventer

Table 16

Drilling Operation Sequence for the Representative Salton Sea Well Model

Activity/Equipment/Service in Order of Occurrence	Depth (ft)	Time Used (h)	Variable Cost ₃ (\$x10 ³)	Time Category ^a	Direct Cost ₃ (\$x10 ³)	Direct Cost Category ^a	Cumulative	
							Time (h)	Cost ₃ (\$x10 ³)
Site Preparation	0	120.0			16.20	1.0		16.20
Initiation								
Drill 42 in./Set 30 in. Pipe	70	96.0			10.00	2.0		26.20
Conductor/Tools/Service/ Cement	70				8.50	7.1.1		34.70
Move In/Rig Up	70	72.0			35.95	3.0		70.65
Originate Mud	70	2.0			3.30	6.0		73.95
Spud	70						0	73.95
Trip in 26 in. Bit, (1-1-1) ^c	70	0.5	0.20	4.2			0.5	74.15
Bottom Hole Assembly		1.0	0.40	9.0			1.5	74.55
Drill Cement	70	2.0	0.79	8.1			3.5	75.34
Condition Mud		1.0	0.40	6.0			4.5	75.74
Trip Out/In (26 in. Bit, 1-1-1) ^c	70	1.0	0.40	4.2			5.5	76.14
Drill 26 in. Hole	600	11.5	4.55	4.1	1.99	12.1	17.0	82.68
Circulate	600	0.5	0.20	7.2			17.5	82.88
Variable Cost Rates Used in Above Variable Cost Calculations (\$/h)								
Rig	235.40							
Fuel	41.25							
Transportation/Misc.	62.50							
Rental	15.00							
Supervision	20.85							
Mud	20.85							
Combined	395.85							
Rig Up Casing Tools	600	2.0	0.92	7.2			19.5	83.80
Run 20 in. Casing	600	3.0	1.38	7.2			22.5	85.18
Casing	600				28.48	7.2.1		113.66
Tools/Service	600				2.35	7.2.2		116.01
Cement Equipment	600				3.45	8.2.2		119.46
Rig Down Casing Tools	600	1.0	0.46	7.2			23.5	119.92
Rig Up Cementing Tools	600	2.0	0.92	8.2			25.5	120.84
Cementing		2.2	1.01	8.2			27.7	121.85
Cement					7.97	8.2.1		129.82
Services					2.36	8.2.3		132.18
Rig Down Cementing Tools	600	1.0	0.46	8.2			28.7	132.64
Nipple Up 20 in. BOP ^e /Test	600	16.0	7.37	14.2	31.02	14.2	44.7	171.03

^aTime and direct cost categories are identified in Appendix A.^bThese pre-spud times are not included in the cumulative time.^cDesignates bit diameter and API Standard RP 7G bit classification, e.g., 17-1/2 in. diameter, series 1- type 1- features 1.^eBOP = blowout preventer

Table 16 (Continued)

Drilling Operation Sequence for the Representative Salton Sea Well Model

Activity/Equipment/Service in Order of Occurrence	Depth (ft)	Time Used (h)	Variable Cost ₃ (\$x10 ³)	Time Category ^a	Direct Cost ₃ (\$x10 ³)	Direct Cost Category ^a	Cumulative	
							Time (h)	Cost ₃ (\$x10 ³)
Trip In (17-1/2 in. Bit, 1-1-1, Rerun) ^c	600	2.3	1.06	4.2			47.0	172.09
Drill Cement	600	2.5	1.15	8.2			49.5	173.24
Test Shoe	600	3.0	1.38	8.2			52.5	174.62
Condition Mud	600	1.0	0.46	6.0			53.5	175.08
Trip Out/In (17-1/2 in. Bit, 1-1-1) ^c	600	1.6	0.74	4.2	3.10	12.1	55.1	178.92
Variable Cost Rates Used in Above Variable Cost Calculations (\$/h)								
Rig	235.40	}		↑				
Fuel	41.25							
Transportation/Misc.	62.50							
Rental	15.00							
Supervision	20.85							
Mud	85.32							
Combined	460.32							
Drill 17-1/2 in. Hole	1300	14.0	6.22	4.1			69.1	185.14
Circulate	1300	2.0	0.89	11.0			71.1	186.03
Survey	1300	0.8	0.36	10.0			71.9	186.39
Trip Out	1300	1.7	0.76	4.2			73.6	187.15
Rig Up Logging Tools	1300	2.0	0.89	11.0			75.6	188.04
Log	1300	1.0	0.44	11.0	2.07	11.1	76.6	190.55
Rig Down Logging Tools	1300	1.0	0.44	11.0			77.6	190.99
Wiper Trip	1300	2.6	1.16	7.3			80.2	192.15
Rig Up Casing Tools		2.0	0.89	7.3			82.2	193.04
Run 13-3/8 in. Casing	1300	6.5	2.89	7.3			88.7	195.93
Casing					31.85	7.3.1		227.78
Tools/Service					3.76	7.3.2		231.54
Cement Equipment					2.54	8.3.2		234.08
Rig Down Casing Tools		1.0	0.44	7.3			89.7	234.52
Variable Cost Rates Used in Above Variable Cost Calculations (\$/h)								
Rig	235.40	}		↑				
Fuel	41.25							
Transportation/Misc.	62.50							
Rental	15.00							
Supervision	20.85							
Mud	69.28							
Combined	444.28							

^aTime and direct cost categories are identified in Appendix A.^cDesignates bit diameter and API Standard RP 7G bit classification, e.g., 17-1/2 in. diameter, series 1- type 1- features 1.

Table 16 (Continued)

Drilling Operation Sequence for the Representative Salton Sea Well Model

Activity/Equipment/Service in Order of Occurrence	Depth (ft)	Time Used (h)	Variable Cost ₃ (\$x10 ³)	Time Category ^a	Direct Cost ₃ (\$x10 ³)	Direct Cost Category ^a	Cumulative															
							Time (h)	Cost (\$x10 ³)														
Rig Up Cementing Tools	1300	2.0	0.79	8.3			91.7	235.31														
Cementing	1300	2.4	0.95	8.3			94.1	236.26														
Cement					9.93	8.3.1		246.19														
Service					3.03	8.3.3		249.22														
Wait on Cement	1300	4.0	1.58	8.3			98.1	250.80														
Rig Down Cementing Tools	1300	1.0	0.40	8.3			99.1	251.20														
Nipple Down/Install																						
Wellhead/Nipple Up	1300	17.0	6.73	14.2	15.07	14.2	116.1	273.00														
Test Wellhead BOP ^e	1300	4.0	1.58	14.2			120.1	274.58														
Trip In (12-1/4 in. Bit, 1-2-1) ^c	1300	2.6	1.03	4.2	1.55	12.1	122.7	277.16														
Stabilizers					1.69	9.4		278.85														
Drill Cement	1300	2.5	0.99	8.3			125.2	279.84														
Test Shoe	1300	3.0	1.19	8.3			128.2	281.03														
Condition Mud	1300	2.0	0.79	6.0			130.2	281.82														
<div style="display: flex; align-items: center;"><div style="margin-right: 20px;"><u>Variable Cost Rates Used in Above Variable Cost Calculations (\$/h)</u><table><tr><td>Rig</td><td>235.40</td></tr><tr><td>Fuel</td><td>41.25</td></tr><tr><td>Transportation/Misc.</td><td>62.50</td></tr><tr><td>Rental</td><td>15.00</td></tr><tr><td>Supervision</td><td>20.85</td></tr><tr><td>Mud</td><td>20.85</td></tr><tr><td>Combined</td><td>395.85</td></tr></table></div><div style="border-left: 1px solid black; padding-left: 10px; margin-left: 10px;"><p>↑</p></div></div>									Rig	235.40	Fuel	41.25	Transportation/Misc.	62.50	Rental	15.00	Supervision	20.85	Mud	20.85	Combined	395.85
Rig	235.40																					
Fuel	41.25																					
Transportation/Misc.	62.50																					
Rental	15.00																					
Supervision	20.85																					
Mud	20.85																					
Combined	395.85																					
Drill 12-1/4 in. Hole	1750	10.0	4.49	4.1			140.2	286.31														
(Mud Log added)																						
Drill 12-1/4 in. Hole	3000	27.8	13.21	4.1			168.0	299.52														
Circulate	3000	2.0	0.95	11.0			170.0	300.47														
Survey	3000	1.0	0.48	10.0			171.0	300.95														
Trip Out	3000	2.5	1.19	4.2			173.5	302.14														
Rig Up Logging Tools	3000	2.0	0.95	11.0			175.5	303.09														
Test and Calibrate	3000	3.5	1.66	11.0			179.0	304.75														
Log	3000	4.0	1.90	11.1	12.29	11.1	183.0	318.94														
Rig Down Logging Tools	3000	1.0	0.48	11.0			184.0	319.42														
Wiper Trip	3000	8.0	3.80	7.4			192.0	323.22														
Rig Up Casing Tools	3000	2.0	0.95	7.4			194.0	324.17														
Run 9-5/8 in. Liner	3000	10.0	4.75	7.4			204.0	328.92														
Casing					33.16	7.3.1		362.08														
Tools/Service					6.34	7.3.2		368.42														
Cement Equipment					3.89	8.3.2		372.31														
Hanger					12.40	8.3.2		384.71														

^aTime and direct cost categories are identified in Appendix A.^cDesignates bit diameter and API Standard RP 7G bit classification, e.g., 17-1/2 in. diameter, series 1- type 1- features 1.^eBOP = blowout preventer

Table 16 (Continued)

Drilling Operation Sequence for the Representative Salton Sea Well Model

Activity/Equipment/Service in Order of Occurrence	Depth (ft)	Time Used (h)	Variable Cost (\$x10 ³)	Time Category ^a	Direct Cost ³ (\$x10 ³)	Direct Cost Category ^a	Cumulative	
							Time (h)	Cost ³ (\$x10 ³)
Rig Down Casing Tools	3000	1.0	0.48	7.4			205.0	385.19
Variable Cost Rates Used in Above Variable Cost Calculations (\$/h)								
Rig	235.40							
Fuel	41.25							
Transportation/Misc.	62.50							
Rental	15.00							
Supervision	20.85							
Mud	73.62							
Mud Logger (Below 3000 ft)	26.60							
Combined	475.22							
Rig Up Cementing Tools	3000	2.0	0.90	8.4			207.0	386.09
Cementing	3000	2.0	0.90	8.4			209.0	386.99
Cement					4.68	8.4.1		391.67
Services					2.47	8.3.3		394.14
Rig Down Cementing Tools	3000	1.0	0.45	8.4			210.0	394.59
Trip In (8-1/2 in. Bit, 1-2-1) ^c	3000	2.5	1.13	4.2	0.84	12.1	212.5	396.56
Stabilizers					0.84	9.4		397.40
Drill Cement	3000	2.5	1.13	8.4			215.0	398.53
Condition Mud	3000	2.0	0.90	6.0			217.0	399.43
Drill 8-1/2 in. Hole	3481	37.0	16.67	4.1			254.0	416.10
Survey		1.0	0.45	10.0			255.0	416.55
Trip Out/In (8-1/2 in. Bit, 5-2-7) ^c	3481	5.4	2.43	4.2	2.99	12.1	260.4	421.97
Stabilizer					0.42	9.4		422.39
Drill 8-1/2 in. Hole	4356	70.0	31.54	4.1			330.4	453.93
Survey		1.0	0.45	10.0			331.4	454.38
Trip Out/In (8-1/2 in. Bit, 1-2-1) ^c	4356	6.3	2.84	4.2	0.84	12.1	337.7	458.06
Drill 8-1/2 in. Hole	4500	15.0	6.76	4.1			352.7	464.82
Variable Cost Rates Used in Above Variable Cost Calculations (\$/h)								
Rig	235.40							
Fuel	41.25							
Transportation/Misc.	62.50							
Rental	15.00							
Supervision	20.85							
Mud	48.96							
Mud Logger	26.60							
Combined	450.56							

^aTime and direct cost categories are identified in Appendix A.^cDesignates bit diameter and API Standard RP 7G bit classification, e.g., 17-1/2 in. diameter, series 1- type 1- features 1.

Table 16 (Continued)

Drilling Operation Sequence for the Representative Salton Sea Well Model

Activity/Equipment/Service in Order of Occurrence	Depth (ft)	Time Used (h)	Variable Cost (\$ $\times 10^3$)	Time Category ^a	Direct Cost (\$ $\times 10^3$)	Direct Cost Category ^a	Cumulative	
							Time (h)	Cost ^j (\$ $\times 10^3$)
Circulate	4500	3.0	1.36	11.0			355.7	466.18
Survey		1.0	0.45	10.0			356.7	466.63
Trip Out	4500	4.3	1.95	4.2			361.0	468.58
Rig Up Logging Tools	4500	2.0	0.91	11.0			363.0	469.49
Log/Test/Calibration/Tool Change	4500	7.8	3.54	11.1	13.67	11.1	370.8	486.70
Rig Down Logging Tools	4500	1.0	0.45	11.0			371.0	487.15
Wiper Trip/Displacement (Release Mud Logger) (Mud System Stop)	4500	11.0	5.00	7.4			382.8	492.15
Rig Up Casing Tools	4500	2.0	0.75	7.4			384.8	492.90
Run 7 in. Slotted Liner	4500	12.8	4.80	7.4			397.6	497.70
Casing					36.33	7.5.1		534.03
Tools/Service					4.78	7.5.2		538.81
Equipment					.57	8.5.2		539.38
Hanger		3.0	1.13	7.5	6.06	7.5.2	400.6	546.57
Rig Down Casing Tools		1.0	0.38	7.5			401.6	546.95
Nipple Down BOP ^e /Install Well Head		11.0	4.13	18.0	27.00	18.0	412.6	578.08
Completion (Estimate)		72.0	27.00	18.0			484.6	605.08
Lay Down Drill Pipe	4500	9.5	3.56	9.0			494.1	608.64
Variable Cost Rates Used in Above Variable Cost Calculations (\$/h)								
Rig	235.40							
Fuel	41.25							
Transportation/Misc.	62.50							
Rental	15.00							
Supervision	20.85							
Mud (Until Stopped)	52.67							
Mud Logger (Until Released)	26.60							
Combined	454.27							
Miscellaneous								
Waste Disposal					12.00	13.1		620.64
Water					9.00	13.1		629.64
CUMULATIVE TOTALS							494.1 (20 Days)	629.64

^aTime and direct cost categories are identified in Appendix A.^eBOP = blowout preventer

Table 17

Drilling Operation Sequence for the Representative Westmorland Well Model

Activity/Equipment/Service in Order of Occurrence	Depth (ft)	Time Used (h)	Variable Cost ₃ (\$x10 ³)	Time Category ^a	Direct Cost ₃ (\$x10 ³)	Direct Cost Category ^a	Cumulative	
							Time (h)	Cost ₃ (\$x10 ³)
Site Preparation		120.0			16.20	1.0		16.20
Initiation								
Drill 26 in./Set 20 in. Pipe	100	96.0			10.00	2.0		26.20
Conductor					4.00	7.1.1		30.20
Transportation/Service					1.60	7.1.2		31.80
Cement Equipment					3.60	8.1.2		35.40
Cement					1.00	8.1.1		36.40
Move In/Rig Up	100	72.0			37.80	3.0		74.20
Originate Mud	100	2.0			3.30	6.0		77.50
Spud	100						0	77.50
Trip In (Rerun Bit)		0.5	0.26	4.2			0.5	77.76
Drill Cement	100	2.0	1.02	8.1			2.5	78.78
Condition Mud	100	1.0	0.51	6.0			3.5	79.29
Trip Out/In (17-1/2 in. Bit, 1-1-1) ^c	100	0.5	0.26	4.2	3.10	12.1	4.0	82.65
Drill 17-1/2 in. Hole	2000	34.5	17.66	4.1			38.5	100.31
Circulate	2000	2.0	1.02	11.0			40.5	101.33
Trip Out	2000	2.0	1.02	11.0			42.5	102.35
Rig Up Logging Tools	2000	2.5	1.28	11.0			45.0	103.63
Log	2000	1.0	0.51	11.1	2.07	11.1	46.0	106.21
Variable Cost Rates Used in Above Variable Cost Calculations (\$/h)								
Rig	260.85							
Fuel	48.75							
Transportation/Misc.	62.50							
Rental	15.00							
Supervision	20.85							
Mud	103.98							
Combined	511.93							
Rig Down Logging Tools	2000	1.0	0.43	11.0			47.0	106.64
Wiper Trip	2000	3.0	1.29	7.2			50.0	107.93
Rig Up Casing Tools	2000	2.0	0.86	7.2			52.0	108.79
Run 13-3/8 in. Casing	2000	8.0	3.43	7.2			60.0	112.22
Casing					49.01	7.2.1		161.23
Tools/Service					5.13	7.2.2		166.36
Cement Equipment					3.36	8.2.2		169.72
Rig Down Casing Tools	2000	1.0	0.43	7.2			61.0	170.15
Rig Up Cementing Tools	2000	2.0	0.86	8.2			63.0	171.01
Cement	2000	3.2	1.37	8.2			66.2	172.38
Cement					15.35	8.2.1		187.73
Service/Tools/Cement					4.21	8.2.3		191.94

^a Time and direct cost categories are identified in Appendix A.^b These pre-spud times are not included in the cumulative time.^c Designates bit diameter and API Standard RP 7G bit classification, e.g., 17-1/2 in. diameter, series 1- type 1- features 1.

Table 17 (Continued)

Drilling Operation Sequence for the Representative Westmorland Well Model

Activity/Equipment/Service in Order of Occurrence	Depth (ft)	Time Used (h)	Variable Cost ₃ (\$x10 ³)	Time Category ^a	Direct Cost ₃ (\$x10 ³)	Direct Cost Category ^a	Cumulative	
							Time (h)	Cost ₃ (\$x10 ³)
Rig Down Cementing Tools	2000	1.0	0.43	8.2			67.2	192.37
Wait on Cement	2000	4.0	1.72	8.2			71.2	194.09
Install Wellhead/BOP ^e	2000	12.0	5.15	14.2	15.07	14.2	83.2	214.31
Test Wellhead/BOP ^e	2000	4.0	1.72	14.2			87.2	216.03
Trip In (12-1/4 in. Bit, 1-1-1) ^c	2000	2.0	0.86	4.2	1.12	12.1	89.2	218.01
Stabilizers					1.69	9.4		219.70
Drill Cement	2000	2.5	1.07	8.2			91.7	220.77
Condition Mud	2000	1.0	0.43	6.0			92.7	221.20
Test Shoe	2000	3.0	1.29	8.2			95.7	222.49
Variable Cost Rates Used in Above Variable Cost Calculations (\$/h)								
Rig	260.85
Fuel	48.75							
Transportation/Misc.	62.50							
Rental	15.00							
Supervision	20.85							
Mud	20.85							
Combined	428.80							
Condition Mud	2000	2.0	1.08	6.0			97.7	223.57
Drill 12-1/4 in. Hole	3280	32.0	17.28	4.1			129.7	240.85
(Mud Logger Added)								
Trip Out/In (12-1/4 in. Bit, 1-3-1) ^c	3280	5.2	2.95	4.2	1.12	12.1	134.9	244.92
Stabilizers					.84	9.4		245.76
Drill 12-1/4 in. Hole	4344	28.0	15.86	4.1			162.9	261.62
Survey	4344	1.0	0.57	10.3			163.9	262.19
Trip Out/In (12-1/4 in. Bit, 1-2-1) ^c	4344	6.3	3.57	4.2	1.55	12.1	170.2	267.31
Stabilizers					0.84	9.4		268.15
Drill 12-1/4 in. Hole	5919	45.0	25.49	4.1			215.2	293.64
Survey	5919	1.0	0.57	10.3			216.2	294.21
Trip Out/In (12-1/4 in. Bit, 1-2-1) ^c	5919	7.9	4.48	4.2	1.55	12.1	224.1	300.24
Stabilizers					0.84	9.4		301.08
Drill 12-1/4 in. Hole	7119	40.0	22.66	4.1			264.1	323.74
Survey Wireline (6500 ft)	7119	2.0	1.13	10.3			266.1	324.87
Go Devil	7119	1.0	0.57	10.3			267.1	325.44
Trip Out/In (12-1/4 in. Bit, 1-2-1) ^c	7119	9.1	5.16	4.2	1.12	12.1	276.2	331.72
Stabilizers					0.84	9.4		332.56

^a Time and direct cost categories are identified in Appendix A.^c Designates bit diameter and API Standard RP 7G bit classification, e.g., 17-1/2 in. diameter, series 1- type 1- features 1.^e BOP = blowout preventer

Table 17 (Continued)

Drilling Operation Sequence for the Representative Westmorland Well Model

Activity/Equipment/Service in Order of Occurrence	Depth (ft)	Time Used (h)	Variable Cost ₃ (\$x10 ³)	Time Category ^a	Direct Cost ₃ (\$x10 ³)	Direct Cost Category ^a	Cumulative	
							Time (h)	Cost ₃ (\$x10 ³)
Drill 12-1/4 in. Hole	8000	30.0	17.00	4.1			306.2	349.56
Circulate	8000	3.0	1.70	11.0			309.2	351.26
Survey (Multi-Shot)	8000	3.0	1.70	10.3	2.00	10.2	312.2	354.96
Trip Out	8000	5.0	2.83	4.2			317.2	357.79
Variable Cost Rates Used in Above Variable Cost Calculations (\$/h)								
Rig	260.85							
Fuel	48.75							
Transportation/Misc.	62.50							
Rental	15.00							
Supervision	20.85							
Mud	131.99							
Mud Logger (Below 3000 ft)	26.60							
Combined	566.54							
Rig Up Logging Tools	8000	2.0	0.93	11.0			319.2	358.72
Test and Calibrate	8000	3.5	1.63	11.0			322.7	360.35
Log	8000	13.0	6.06	11.1	19.91	11.1	335.7	386.32
Rig Down Logging Tools	8000	1.0	0.47	11.0			336.7	387.79
Wiper Trip	8000	19.0	8.85	7.3			355.7	395.64
Rig Up Casing Tools	8000	2.0	0.93	7.3			357.7	396.57
Run 9-5/8 in. Liner	8000	22.8	10.62	7.3			380.5	407.19
Casing					139.65	7.3.1		546.84
Tools/Service					14.79	7.3.2		561.63
Cement Equipment					4.99	8.3.2		566.62
Rig Down Casing Tools	8000	1.0	0.47	7.3			381.5	567.09
Rig Up Cementing Tools	8000	2.0	0.93	8.3			383.5	568.02
Cementing	8000	5.0	2.33	8.3			388.5	570.35
Cement					21.72	8.3.1		592.07
Service					8.16	8.3.3		600.23
Rig Down Cementing Tools	8000	1.0	0.47	8.3			389.5	600.70
Wait on Cement	8000	6.0	2.79	8.3			395.5	603.49
Install Wellhead/BOP ^e & Test	8000	15.0	6.99	14.2	13.41	14.3	410.5	623.89
Variable Cost Rates Used in Above Variable Cost Calculations (\$/h)								
Rig	260.85							
Fuel	48.75							
Transportation/Misc.	62.50							
Rental	15.00							
Supervision	20.85							
Mud	31.25							
Mud Logger	26.60							
Combined	465.80							

^a Time and direct cost categories are identified in Appendix A.^e BOP = blowout preventer

Table 17 (Continued)

Drilling Operation Sequence for the Representative Westmorland Well Model

Activity/Equipment/Service in Order of Occurrence	Depth (ft)	Time Used (h)	Variable Cost (\$x10 ³)	Time Category ^a	Direct Cost (\$x10 ³)	Direct Cost Category ^a	Cumulative	
							Time (h)	Cost ₃ (\$x10 ³)
Lay Down 8 in. Drill Collar, Pick Up 6 in. Drill Collar	8000	4.0	1.78	9.0			414.5	625.67
Trip In (8-1/2 in. Bit, 5-2-7) ^c								
Change BHA ^d	8000	8.0	3.57	9.0	2.99	12.1	422.5	632.23
Stabilizers					0.84	9.4		633.07
Drill Cement	8000	2.5	1.11	8.3			425.0	634.18
Test Shoe	8000	3.0	1.34	8.3			428.0	635.52
Condition Mud	8000	2.0	0.89	6.0			430.0	636.41
(Begin Changeover to Water)								
Drill 8-1/2 in. Hole	8600	60.0	26.76	4.1			490.0	663.17
Survey		1.0	0.45	10.3			491.0	663.62
Trip Out/In (8-1/2 in. Bit, 5-2-7) ^c	8600	9.6	4.28	4.2	2.99	12.1	500.6	670.89
Stabilizer					0.42	9.4		671.34
Drill 8-1/2 in. Hole	9230	70.0	31.22	4.1			570.6	702.53
Survey		1.0	0.45	10.3			571.6	702.98
Trip Out/In (8-1/2 in. Bit, 5-2-7) ^c	9230	10.2	4.55	4.2	2.99	12.1	581.8	710.52
Stabilizer					0.42	9.4		710.94
Drill 8-1/2 in. Hole	9780	50.0	22.30	4.1			631.8	733.24
Survey		1.0	0.45	10.3			632.8	733.69
Trip Out/In (8-1/2 in. Bit, 6-1-7) ^c	9780	10.8	4.82	4.2	2.99	12.1	643.6	741.50
Stabilizer					0.42	9.4		741.92
Drill 8-1/2 in. Hole	10430	65.0	28.99	4.1			708.6	770.91
Survey		1.5	0.67	10.3			710.1	771.58
Trip Out/In (8-1/2 in. Bit, 6-1-7) ^c	10430	11.4	5.08	4.2	2.99	12.1	721.5	779.65
Stabilizer					0.42	9.4		780.07
Drill 8-1/2 in. Hole	11000	64.0	28.54	4.1			785.5	808.61
Survey		1.0	0.45	10.3			786.5	809.06
Cleaning Trip/Circulate	11000	6.0	2.68	11.0			792.5	811.74

^a Time and direct cost categories are identified in Appendix A.

^c Designates bit diameter and API Standard RP 7G bit classification, e.g., 17-1/2 in. diameter, series 1- type 1- features 1.

^d BHA = bottomhole assembly

Table 17 (Continued)

Drilling Operation Sequence for the Representative Westmorland Well Model

Activity/Equipment/Service in Order of Occurrence	Depth (ft)	Time Used (h)	Variable Cost ₃ (\$x10 ³)	Time Category ^a	Direct Cost ₃ (\$x10 ³)	Direct Cost Category ^a	Cumulative	
							Time (h)	Cost ₃ (\$x10 ³)
Trip Out (Release Mud Logger)	11000	7.5	3.34	4.2			800.0	815.08
Variable Cost Rates Used in Above Variable Cost Calculations (\$/h)								
Rig	260.85							
Fuel	48.75							
Transportation/Misc.	62.50							
Rental	15.00							
Supervision	20.85							
Mud	11.40							
Mud Logger	26.60							
Combined	445.95							
Rig Up Logging Tools	11000	2.0	0.84	11.0			802.0	815.92
Change Tools/Calibrate	11000	3.5	1.46	11.0			805.5	817.38
Log 8000 ft to 11000 ft	11000	9.3	3.89	11.1	23.52	11.1	814.8	844.79
Rig Down Logging Tools	11000	1.0	0.42	11.0			815.8	845.21
Wiper Trip		11.0	4.60	7.5			826.8	849.81
Rig Up Casing Tools	11000	2.0	0.84	7.5			828.8	850.65
Run 7 In. Slotted Liner	11000	24.4	10.21	7.5			853.2	860.86
Casing					51.86	7.5.1		912.72
Tools/Service					6.85	7.5.2		919.57
Equipment					1.08	8.5.3		920.65
Hanger	11000	3.0	1.26	7.5	6.06	7.5.3	856.2	927.97
Rig Down Casing Tools	11000	1.0	0.42	7.5			857.2	928.39
Lay Down Drill Pipe/ Collar	11000	8.8	3.68	9.0			866.0	932.07
Nipple Down BOP ^e /Install Remainder of Wellhead	11000	11.0	4.60	18.0	27.0	18.0	877.0	963.67
Completion (Estimate)	11000	96.0	40.16	18.0			973.0	1003.83
Variable Cost Rates Used in Above Variable Cost Calculations (\$/h)								
Rig	260.85							
Fuel	48.75							
Transportation/Misc.	62.50							
Rental	15.00							
Supervision	20.85							
Mud	10.40							
Combined	418.35							
Miscellaneous								
Waste Disposal					12.0	13.2		1015.83
Water					9.00	13.1		1024.83
CUMULATIVE TOTALS							973.0 (41 Days)	1024.83

^aTime and direct cost categories are identified in Appendix A.^eBOP = blowout preventer

4.3 BACA MODEL

The drilling operation sequence for the Baca well model is given in Table 18. This table gives the depth, time, variable costs, time categories, direct costs, direct cost category, cumulative time, and cumulative costs by activity and the variable cost rates for the various groupings of activities.

Table 18

Drilling Operation Sequence for the Representative Baca Well Model

Activity/Equipment/Service in Order of Occurrence	Depth (ft)	Time Used (h)	Variable Cost ₃ (\$x10 ³)	Time Category ^a	Direct Cost ₃ (\$x10 ³)	Direct Cost Category ^a	Cumulative	
							Time (h)	Cost ₃ (\$x10 ³)
Site Preparation	0	240.0			47.50	1.0		47.50
Initiation	50	72.0			12.50	2.0		60.00
30 in. Surface Conductor	50				2.90	7.1		62.90
Cement/Services	50				2.00	8.1		64.90
Move In/Rig Up/Rig Down	50	72.0			37.78	3.0		102.68
Originate Mud		2.0			3.30	6.0		105.98
Spud	50						0	105.98
Trip In (17-1/2 in. Bit, 2-1-4) ^c	50	0.5	0.22	4.2	0.75	12.1	0.5	106.95
Change BHA ^d		1.0	0.44	4.2			1.5	107.39
Drill Cement	50	1.0	0.44	8.1			2.5	107.83
Condition Mud	50	1.0	0.44	6.0			3.5	108.27
Trip In (17-1/2 in. Bit, 5-1-5) ^c	50	1.0	0.44	4.2	2.41	12.1	4.5	111.12
Drill 17-1/2 in. Hole	200	11.5	5.01	4.1			16.0	116.13
Trip Out/In (Hole Opener)	200	1.2	0.52	4.2	2.50	12.3	16.2	119.15
26 in. Hole Opener	200	2.0	0.87	4.1			19.2	120.02
Drill 26 in. Hole	200	15.0	6.54	4.1			34.2	126.56
Condition Mud	200	1.0	0.44	6.0			35.2	127.00
Variable Cost Rates Used in Above Variable Cost Calculations (\$/h)								
Rig	260.85							
Fuel	48.75							
Transportation/Misc.	62.50							
Rental	15.00							
Supervision	20.85							
Mud	27.80							
Combined	435.75							
Wiper Trip	200	2.0	0.86	7.1			37.2	127.86
Rig Up Casing Tools	200	2.0	0.86	7.1			39.2	128.72
Run 20 in. Casing	200	2.0	0.86	7.1			41.2	129.58
Casing					9.45	7.1.1		139.03
Tools/Service					1.66	7.1.2		140.69
Cement Equipment					3.55	8.1.2		144.24
Rig Down Casing Tools	200	1.0	0.43	7.1			42.2	144.67
Rig Up Cementing Tools	200	2.0	0.86	8.1			44.2	145.53
Cementing	200	1.5	0.64	8.1			45.7	146.17
Cement					2.42	8.1.1		148.59
Service					3.52	8.1.2		152.11

^aTime and direct cost categories are identified in Appendix A.^bThese pre-spud times are not included in the cumulative time.^cDesignates bit diameter and API Standard RP 7G bit classification, e.g., 17-1/2 in. diameter, series 1- type 1- features 1.^dBHA = bottomhole assembly

Table 18 (Continued)

Drilling Operation Sequence for the Representative Baca Well Model

Activity/Equipment/Service in Order of Occurrence	Depth (ft)	Time Used (h)	Variable Cost ₃ (\$x10 ³)	Time Category ^a	Direct Cost ₃ (\$x10 ³)	Direct Cost Category ^a	Cumulative	
							Time (h)	Cost ₃ (\$x10 ³)
Rig Down Cementing Tools	200	1.0	0.43	8.1			46.7	152.54
Wait on Cement	200	4.0	1.72	8.1			50.7	154.26
Install Wellhead	200	6.0	2.57	14.2	17.00	14.0	56.7	173.83
Test Wellhead	200	4.0	1.72	14.2			60.7	175.55
Variable Cost Rates Used in Above Variable Cost Calculations (\$/h)								
Rig	260.85							
Fuel	48.75							
Transportation/Misc.	62.50							
Rental	15.00							
Supervision	20.85							
Mud	20.85							
Combined	428.80							
Trip In (17-1/2 in. Bit, 5-2-5) ^c	200	1.0	0.45	4.2	9.69	12.1	61.7	185.69
BHA ^d (Stabilizers) ^f		2.0	0.90	4.2	1.92	9.4	63.7	188.51
Drill Cement	200	2.5	1.12	8.1			66.2	189.63
Condition Mud	200	1.0	0.45	6.0			67.2	190.08
Test Cement	200	2.0	0.90	8.1			69.2	190.98
Drill 17-1/2 in. Hole	1320	80.0	35.80	4.1			149.2	226.78
Survey	1320	1.0	0.45	10.3			150.2	227.23
Trip Out/In (17-1/2 in. Bit, 5-2-5) ^c	1320	1.3	0.58	4.2	4.85	12.1	151.5	232.66
BHA ^d (Stabilizers) ^f		3.0	1.34	4.2	1.92	9.4	154.5	235.92
Drill 17-1/2 in. Hole	1500	16.4	7.34	4.1			170.9	243.26
Circulate	1500	3.0	1.34	11.0			173.9	244.60
Variable Cost Rates Used in Above Variable Cost Calculations (\$/h)								
Rig	260.85							
Fuel	48.75							
Transportation/Misc.	62.50							
Rental	15.00							
Supervision	20.85							
Mud	39.61							
Combined	447.56							

^aTime and direct cost categories are identified in Appendix A.

^cDesignates bit diameter and API Standard RP 7G bit classification, e.g., 17-1/2 in. diameter, series 1- type 1- features 1.

^dBHA = bottomhole assembly

^fA parenthetical note after "Change BHA" denotes item(s) associated with direct costs or item(s) requiring special attention.

Table 18 (Continued)

Drilling Operation Sequence for the Representative Baca Well Model

Activity/Equipment/Service in Order of Occurrence	Depth (ft)	Time Used (h)	Variable Cost (\$x10 ³)	Time Category ^a	Direct Cost ₃ (\$x10 ³)	Direct Cost Category ^a	Cumulative	
							Time (h)	Cost ₃ (\$x10 ³)
Trip Out	1500	1.8	0.77	4.2			175.7	245.37
Rig Up Logging Tools	1500	2.0	0.86	11.0			177.7	246.23
Log	1500	1.0	0.43	11.1	2.07	11.1	178.7	248.73
Rig Down Logging Tools	1500	1.0	0.43	11.0			179.7	249.16
Wiper Trip	1500	3.0	1.29	7.2			182.7	250.45
Rig Up Casing Tools	1500	2.0	0.86	7.2			184.7	251.31
Run 13-3/8 in. Casing	1500	6.0	2.57	7.2			190.7	253.88
Casing					36.55	7.2.1		290.43
Tools/Service					3.91	7.2.2		294.35
Cement Equipment					2.66	8.2.2		297.00
Rig Down Casing Tools	1500	1.0	0.43	7.2			191.7	297.43
Rig Up Cementing Tools	1500	2.0	0.86	8.2			193.7	298.29
Cementing	1500	2.6	1.11	8.2			196.3	299.40
Cement					8.35	8.2.1		307.75
Service					9.52	8.2.3		317.27
Rig Down Cementing Tools	1500	1.0	0.43	8.2			197.3	317.70
Wait-on-Cement	1500	4.0	1.72	8.2			201.3	319.42
Nipple Up BOP ^e /Wellhead	1500	12.0	5.15	14.0	15.07	14.0	213.3	339.64
<div> <div>Variable Cost Rates Used in Above Variable Cost Calculations (\$/h)</div> <div> <div>Rig</div> <div>Fuel</div> <div>Transportation/Misc.</div> <div>Rental</div> <div>Supervision</div> <div>Mud</div> <div>Combined</div> <div>260.85</div> <div>48.75</div> <div>62.50</div> <div>15.00</div> <div>20.85</div> <div>20.85</div> <div>428.80</div> </div> </div>								
Trip In (12-1/4 in. Bit, 5-2-5) ^c	1500	0.8	0.35	4.2	1.00	12.1	214.1	340.99
BHA ^d	1500	2.0	0.87	4.2			216.1	341.86
Drill Cement	1500	2.5	1.09	8.2			218.6	342.95
Trip Out/In (12-1/4 in. Bit, 5-2-5) ^c	1500	2.5	1.09	4.2	4.65	12.1	221.1	348.69
BHA ^d (Stabilizers) ^f	1500	2.0	0.87	4.2	1.92	9.4	223.1	351.48
Drill 12-1/4 in. Hole	1800	30.0	13.03	4.1			253.1	364.51
Survey	1800	2.0	0.87	10.3			255.1	365.38
Trip Out/In (12-1/4 in. Bit, 5-3-5) ^c	1800	2.8	1.22	4.2	4.65	12.1	257.9	371.25
BHA ^d (Stabilizers) ^f	1800	2.0	0.87	4.2	1.92	9.4	259.9	374.04
Ream	1800	4.0	1.74	4.3			263.9	375.78
Drill 12-1/4 in. Hole	2134	36.0	15.64	4.1			299.9	391.42
Survey	2134	2.0	0.87	10.3			301.9	392.29

^aTime and direct cost categories are identified in Appendix A.^cDesignates bit diameter and API Standard RP 7G bit classification, e.g., 17-1/2 in. diameter, series 1- type 1- features 1.^dBHA = bottomhole assembly^eBOP = blowout preventer^fA parenthetical note after "Change BHA" denotes item(s) associated with direct costs or item(s) requiring special attention.

Table 18 (Continued)

Drilling Operation Sequence for the Representative Baca Well Model

Activity/Equipment/Service in Order of Occurrence	Depth (ft)	Time Used (h)	Variable Cost ₃ (\$x10 ³)	Time Category ^a	Direct Cost ₃ (\$x10 ³)	Direct Cost Category ^a	Cumulative	
							Time (h)	Cost ₃ (\$x10 ³)
Trip Out/In (12-1/4 in. Bit, 6-2-5) ^c	2134	3.1	1.35	4.2	4.65	12.1	305.0	398.29
BHA ^d (Stabilizers) ^f	2134	2.0	0.87	4.2	1.92	9.4	307.0	401.08
Ream	2134	4.0	1.74	4.3			311.0	402.82
Drill 12-1/4 in. Hole	2390	22.0	9.56	4.1			333.0	412.38
Survey	2398	2.0	0.87	10.3			335.0	413.25
Trip Out/In (12-1/4 in. Bit, 6-1-5) ^c	2398	3.4	1.48	4.2	4.65	12.1	338.4	419.38
BHA ^d (Stabilizers) ^f	2398	2.0	0.87	4.2	1.92	9.4	340.4	422.17
Ream	2398	4.0	1.74	4.3			344.4	423.91
Drill 12-1/4 in. Hole	2708	31.0	13.47	4.1			375.4	437.38
Survey	2708	2.0	0.87	10.3			377.4	438.25
Trip Out/In (12-1/4 in. Bit, 6-2-5) ^c	2708	3.7	1.61	4.2	4.65	12.1	381.1	444.51
BHA ^d (Stabilizers) ^f	2708	2.0	0.87	4.2	1.92	9.4	383.1	447.30
Ream	2708	3.0	1.30	4.3			386.1	448.60
Drill 12-1/4 in. Hole	3000	26.5	11.51	4.1			412.6	460.11
Circulate	3000	4.0	1.74	11.0			416.6	461.85
Survey (Multi-Shot)	3000	6.0	2.61	10.3	1.0	10.3	422.6	465.46
Trip Out	3000	2.5	1.09	4.2			425.1	466.55
Variable Cost Rates Used in Above Variable Cost Calculations (\$/h)								
Rig	260.85							
Fuel	48.75							
Transportation/Misc.	62.50							
Rental	15.00							
Supervision	20.85							
Mud	26.50							
Combined	434.45							
Rig Up Logging Tools	3000	2.0	0.86	11.0			427.1	467.41
Log	3000	7.8	3.34	11.1	8.42	11.1	434.9	479.17
Rig Down Logging Tools	3000	1.0	0.43	11.0			435.9	479.60
Rig Up Casing Tools	3000	2.0	0.86	11.0			437.9	480.46
Run 9-5/8 in. Casing	3000	8.6	3.69	7.3			446.5	484.15
Casing					29.51	7.3.1		513.66
Tools/Service					5.84	7.3.2		519.50
Cement Equipment					2.97	8.3.2		522.47
Hanger		3.0	1.29	7.3	18.60	7.3.2	449.5	542.36
Rig Down Casing Tools	3000	1.0	0.43	7.3			450.5	542.79
Rig Up Cementing Tools	3000	2.0	0.86	8.3			452.5	543.65

^a Time and direct cost categories are identified in Appendix A.

^c Designates bit diameter and API Standard RP 7G bit classification, e.g., 17-1/2 in. diameter, series 1- type 1- features 1.

^d BHA = bottomhole assembly

^f A parenthetical note after "Change BHA" denotes item(s) associated with direct costs or item(s) requiring special attention.

Table 18 (Continued)

Drilling Operation Sequence for the Representative Baca Well Model

Activity/Equipment/Service in Order of Occurrence	Depth (ft)	Time Used (h)	Variable Cost ₃ (\$x10 ³)	Time Category ^a	Direct Cost ₃ (\$x10 ³)	Direct Cost Category ^a	Cumulative	
							Time (h)	Cost ₃ (\$x10 ³)
Cementing	3000	1.9	0.81	8.3			454.4	544.46
Cement					4.25	8.3.1		548.71
Service					5.68	8.3.3		554.39
Rig Down Cementing Tools	3000	1.0	0.43	8.3			455.4	554.82
Wait-on-Cement	3000	6.0	2.57	8.3			461.4	557.39
Nipple Down/Wellhead BOP ^e	3000	11.0	4.72	14.1			472.4	562.11
Trip In (8-3/4 in. Bit, 6-1-5) ^c	3000	1.5	0.64	4.2			473.9	562.75
BHA	3000	3.0	1.29	4.2			476.9	564.04
Drill Cement	3000	2.5	1.07	8.2			479.4	565.11
Trip Out/In (8-3/4 in. Bit, 6-1-5) ^c	3000	4.0	1.72	4.2	2.45	12.1	483.4	569.28
BHA ^d (Stabilizers) ^f	3000	2.0	0.86	4.2	0.84	9.4	485.4	570.98
Variable Cost Rates Used in Above Variable Cost Calculations (\$/h)								
Rig	260.85							
Fuel	48.75							
Transportation/Misc.	62.50							
Rental	15.00							
Supervision	20.85							
Mud	20.85							
Combined	428.80							
Drill 8-3/4 in. Hole	3486	27.0	16.88	4.1			512.4	587.86
Survey	3486	2.0	1.25	10.3			514.4	589.11
Trip Out/In (8-3/4 in. Bit, 5-1-5) ^c	3486	4.4	2.75	4.2	2.46	12.1	518.8	594.32
BHA ^d (Stabilizers) ^f	3486	2.0	1.25	4.2	0.84	9.4	520.8	596.41
Ream	3486	3.0	1.88	4.3			523.8	598.29
Drill 8-3/4 in. Hole	3810	27.0	16.88	4.1			550.8	615.17
Survey	3810	2.0	1.25	10.3			552.8	616.42
Trip Out/In (8-3/4 in. Bit, 6-2-1) ^c	3810	4.8	3.00	4.2	2.46	12.1	557.6	621.88
BHA ^d (Stabilizers) ^f	3810	2.0	1.25	4.2	0.84	9.4	559.6	623.97
Ream	3810	3.0	1.88	4.3			562.6	625.85
Drill 8-3/4 in. Hole	4062	21.0	13.13	4.1			583.6	638.98
Survey	4062	2.0	1.25	10.3			585.6	640.23
Trip Out/In (8-3/4 in. Bit, 5-1-5) ^c	4062	5.0	3.13	4.2	2.46	12.1	590.6	645.82
BHA ^d (Stabilizers) ^f	4062	2.0	1.25	4.2	0.84	9.4	592.6	647.91

^aTime and direct cost categories are identified in Appendix A.^cDesignates bit diameter and API Standard RP 7G bit classification, e.g., 17-1/2 in. diameter, series 1- type 1- features 1.^dBHA = bottomhole assembly^eBOP = blowout preventer^fA parenthetical note after "Change BHA" denotes item(s) associated with direct costs or item(s) requiring special attention.

Table 18 (Continued)

Drilling Operation Sequence for the Representative Baca Well Model

Activity/Equipment/Service in Order of Occurrence	Depth (ft)	Time Used (h)	Variable Cost ₃ (\$x10 ³)	Time Category ^a	Direct Cost ₃ (\$x10 ³)	Direct Cost Category ^a	Cumulative	
							Time (h)	Cost ₃ (\$x10 ³)
Ream	4062	3.0	1.88	4.3			595.6	649.79
Drill 8-3/4 in. Hole	4440	21.0	13.13	4.1			616.6	662.92
Survey	4440	2.0	1.25	10.3			618.6	664.17
Trip Out/In (8-3/4 in. Bit, 5-1-5) ^c	4440	5.4	3.38	4.2	2.46	12.1	624.0	670.01
BHA ^d (Stabilizers) ^f	4440	2.0	1.25	4.2	0.84	9.4	626.0	672.10
Ream	4440	3.0	1.88	4.3			629.0	673.98
Drill 8-3/4 in. Hole	4968	33.0	20.63	4.1			662.0	694.61
Survey	4968	2.0	1.25	10.3			664.0	695.86
Trip Out/In (8-3/4 in. Bit, 7-2-5) ^c	4968	6.0	3.75	4.2	2.46	12.1	670.0	702.07
BHA ^d (Stabilizers) ^f	4968	2.0	1.25	4.2	0.84	9.4	672.0	704.16
Ream	4968	3.0	1.88	4.3			675.0	706.04
Drill 8-3/4 in. Hole	5388	21.0	13.13	4.1			696.0	719.17
Survey	5388	2.0	1.25	10.3			698.0	720.42
Trip Out/In (8-3/4 in. Bit, 6-1-5) ^c	5388	6.4	4.00	4.2	2.46	12.1	704.4	726.88
BHA ^d (Stabilizers) ^f	5388	2.0	1.25	4.2	0.84	9.4	706.4	728.97
Ream	5388	3.0	1.88	4.3			709.4	730.85
Drill 8-3/4 in. Hole	5802	23.0	14.38	4.1			732.4	745.23
Survey	5802	2.0	1.25	10.3			734.4	746.48
Trip Out/In (8-3/4 in. Bit, 7-2-5) ^c	5802	6.8	4.25	4.2	2.46	12.1	741.2	753.19
BHA ^d (Stabilizers) ^f	5802	2.0	1.25	4.2	0.84	9.4	743.2	755.28
Ream	5802	3.0	1.88	4.3			746.2	757.16
Drill 8-3/4 in. Hole	6000	13.7	8.56	4.1			759.9	765.72
Circulate	6000	5.0	3.13	11.0			764.9	768.85
Survey (Multi-shot)	6000	6.0	3.75	10.3	1.00	10.3	770.9	773.60
Trip Out	6000	5.0	3.13	4.2			775.9	776.73

Variable Cost Rates Used in Above
Variable Cost Calculations (\$/h)

Rig	260.85
Fuel	48.75
Transportation/Misc.	62.50
Rental	15.00
Supervision	20.85
Air Compressor	89.80
Mud Logger	26.60
Mud	38.26
Corrosion Chemical	62.50
Combined	625.11

^a Time and direct cost categories are identified in Appendix A.

^c Designates bit diameter and API Standard RP 7G bit classification, e.g., 17-1/2 in. diameter, series 1- type 1- features 1.

^d BHA = bottomhole assembly

^f A parenthetical note after "Change BHA" denotes item(s) associated with direct costs or item(s) requiring special attention.

Table 18 (Continued)

Drilling Operation Sequence for the Representative Baca Well Model

Activity/Equipment/Service in Order of Occurrence	Depth (ft)	Time Used (h)	Variable Cost ₃ (\$x10 ³)	Time Category ^a	Direct Cost ₃ (\$x10 ³)	Direct Cost Category ^a	Cumulative	
							Time (h)	Cost ₃ (\$x10 ³)
(Air Compressor to Stand by)								
(Release Mud Logger/ Corrosion Chemical)								
Rig Up Logging Tools	6000	2.0	1.00	11.0			777.9	777.73
Log	6000	11.6	5.82	11.1	16.72	11.1	789.5	800.27
Rig Down Logging Tools		1.0	0.50	11.0			790.5	800.77
Rig Up Casing Tools	6000	2.0	1.00	7.4			792.5	801.77
Run 7 in. Liner	6000	13.3	6.67	7.4			805.8	808.44
Casing					51.67	7.4.1		859.11
Tools/Service					6.23	7.4.2		866.34
Cement Equipment					1.09	8.4.2		867.43
Hanger		3.0	1.51	7.4	6.07	7.4.2	808.8	875.01
Variable Cost Rates Used in Above Variable Cost Calculations (\$/h)								
Rig	260.85	}		↑				
Fuel	48.75							
Transportation/Misc.	62.50							
Rental	15.00							
Supervision	20.85							
Air Compressor	62.50							
Mud	31.25							
Combined	501.70							
Run 9-5/8 in. Bridge Plug	6000	6.0	2.82	7.5	1.50	7.5	814.8	879.33
Rig to Run Tieback		2.0	0.94	7.5			816.8	880.27
Run 9-5/8 in. Casing	6000	11.0	5.17	7.5			827.8	885.44
Casing					48.61	7.5.1		934.05
Tools/Service					6.32	7.5.2		940.37
Cement Equipment					2.02	8.5.2		942.39
Rig Down Casing Tools	6000	1.0	0.47	7.5			828.8	942.86
Rig Up Cementing Tools	6000	2.0	0.94	8.5			830.8	943.80
Cementing	6000	2.3	1.08	8.5			833.1	944.88
Cement					6.01	8.5.1		950.89
Service					7.33	8.5.3		958.22
Wait on Cement	6000	6.0	2.82	8.5			839.1	961.04
Rig Down Cementing Tools	6000	1.0	0.47	8.5			840.1	961.51

^aTime and direct cost categories are identified in Appendix A.

Table 18 (Continued)

Drilling Operation Sequence for the Representative Baca Well Model

Activity/Equipment/Service in Order of Occurrence	Depth (ft)	Time Used (h)	Variable Cost ₃ (\$x10 ³)	Time Category ^a	Direct Cost ₃ (\$x10 ³)	Direct Cost Category ^a	Cumulative	
							Time (h)	Cost ₃ (\$x10 ³)
Trip In (Rerun Bit)	6000	3.5	1.65	4.2	0.50	12.1	843.6	963.66
Drill Cement	6000	2.5	1.18	8.5			846.1	964.84
Trip Out/In	6000	5.0	2.35	4.2			851.1	967.19
Mill Plug	6000	6.0	2.82	18.0	2.00	18.0	857.1	972.01
Trip Out	6000	2.5	1.18	4.2			859.6	973.19
Nipple Down BOP ^e /Nipple Up Wellhead	6000	16.0	7.53	18.0	38.81	18.0	875.6	1019.53
(Compressor Change Ceased)								
Lay Down Drill Pipe/Collar	6000	12.0	4.90	9.0			887.6	1024.43
Completion (Estimate)	6000	72.0	29.37	18.0			959.6	1053.80
<div>Variable Cost Rates Used in Above Variable Cost Calculations (\$/h)</div> <div><div><div>Rig260.85</div><div>Fuel48.75</div><div>Transportation/Misc.62.50</div><div>Rental15.00</div><div>Supervision20.85</div><div>Air Compressor62.50</div><div>Combined470.45</div></div><div></div></div>								
Miscellaneous								
Waste Disposal					12.0	13.2		1065.80
Water					9.00	13.1		1074.80
CUMULATIVE TOTALS							959.6 (40 Days)	1074.80

^aTime and direct cost categories are identified in Appendix A.^eBOP = blowout preventer

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4.4 ROOSEVELT HOT SPRINGS MODEL

The drilling operation sequence for the Roosevelt Hot Springs well model is given in Table 19. This table gives the depth, time, variable costs, time categories, direct costs, direct cost category, cumulative time, and cumulative costs by activity and the variable cost rates for the various groupings of activities.

Table 19

Drilling Operation Sequence for the Representative Roosevelt Hot Springs Well Model

Activity/Equipment/Service in Order of Occurrence	Depth (ft)	Time Used (h)	Variable Cost (\$x10 ³)	Time Category ^a	Direct Cost ₃ (\$x10 ³)	Direct Cost Category ^a	Cumulative	
							Time (h)	Cost ₃ (\$x10 ³)
Site Preparation	0	240.0	b		47.50	1.0		47.50
Initiation	30	72.0			12.50	2.0		60.00
30 in. Line Pipe					1.50	7.1.1		61.50
Tools/Service					0.40	7.1.2		61.90
Cement Equipment					5.60	8.1.2		67.50
Cement/Service					0.50	8.1.1		68.00
Move In/Rig Up	30	72.0			35.95	3.0		103.95
Originate Mud	30	2.0			3.30	6.0		107.25
Spud	30						0	107.25
Trip In (17-1/2 in. Bit, 1-1-1) ^c	30	0.5	0.20	4.2	0.75	12.1	0.5	108.20
BHA ^d		1.0	0.40	4.2			1.5	108.60
Drill Cement	30	1.0	0.40	8.1			2.5	109.00
Condition Mud		1.0	0.40	6.0			3.5	109.40
Trip In (17-1/2 in. Bit, 1-3-1) ^c	30	1.0	0.40	4.2	3.20	12.1	4.5	113.00
Drill 17-1/2 in. Hole	200	11.5	4.55	4.1			16.0	117.55
Trip Out	200	0.5	0.20	4.2			16.5	117.75
Change to Hole Opener	200	2.5	0.99	4.2	2.50	12.2	19.0	121.24
Trip In		0.5	0.20	4.2			19.5	121.44
Drill 26 in. Hole	200	17.0	6.73	4.3			36.5	128.17
Wiper Trip	200	2.0	0.79	7.2			38.5	128.96
Rig Up Casing Tools	200	2.0	0.79	7.2			40.5	129.75
Run 20 in. Surface Casing	200	15.0	5.94	7.2			55.5	135.69
Casing					7.82	7.2.1		143.51
Tools/Service					2.20	7.2.2		145.71
Cement Equipment					3.55	8.2.2		149.26
Rig Down Casing Tools	200	1.0	0.40	7.2			56.5	149.66
Rig Up Cementing Tools	200	2.0	0.79	8.2			58.5	150.45
Cementing	200	1.5	0.59	8.2			60.0	151.04
Cement					2.52	8.2.1		153.56
Service					3.51	8.2.3		157.07
Rig Down Cementing Tools	200	1.0	0.40	8.2			61.0	157.47
Wait on Cement	200	4.0	1.58	8.2			65.0	159.05
Install Wellhead/BOP ^e	200	6.0	2.38	14.2	17.00	14.0	71.0	178.43

^aTime and direct cost categories are identified in Appendix A.^bThese pre-spud times are not included in the cumulative time.^cDesignates bit diameter and API Standard RP 7G bit classification, e.g., 17-1/2 in. diameter, series 1- type 1- features 1.^dBHA = bottomhole assembly^eBOP = blowout preventer

Table 19 (Continued)

Drilling Operation Sequence for the Representative Roosevelt Hot Springs Well Model

Activity/Equipment/Service in Order of Occurrence	Depth (ft)	Time Used (h)	Variable Cost ₃ (\$x10 ³)	Time Category ^a	Direct Cost ₃ (\$x10 ³)	Direct Cost Category ^a	Cumulative	
							Time (h)	Cost ₃ (\$x10 ³)
Test Wellhead/BOP ^e	200	4.0	1.58	14.2			75.0	180.01
Variable Cost Rates Used in Above Variable Cost Calculations (\$/h)								
Rig	235.40							
Fuel	41.25							
Transportation/Misc.	62.50							
Rental	15.00							
Supervision	20.85							
Mud	20.85							
Combined	395.85							
Trip In (17-1/2 in. Bit, 5-2-5) ^c	200	1.0	0.42	4.2	9.73	12.1	76.0	190.16
BHA ^d (Stabilizers) ^f	200	1.0	0.42	4.2	1.94	9.4	77.0	192.52
Drill Cement	200	2.5	1.04	8.2			79.5	193.56
Condition Mud		1.0	0.42	6.0			80.5	193.98
Test Cement	800	2.0	0.83	8.2			82.5	194.81
Drill 17-1/2 in. Hole	800	43.0	17.88	4.1			125.5	212.69
Survey	800	1.0	.42	10.3			126.5	213.11
Circulate	800	3.0	1.25	8.2			129.5	214.36
Variable Cost Rates Used in Above Variable Cost Calculations (\$/h)								
Rig	235.40							
Fuel	41.25							
Transportation/Misc.	62.50							
Rental	15.00							
Supervision	20.85							
Mud	40.79							
Combined	415.79							
Trip Out	800	1.4	0.55	4.2			130.9	214.91
Rig Up Casing Tools	800	2.0	0.79	7.3			132.9	215.70
Run 13-3/8 in. Casing	800	4.0	1.58	7.3			136.9	217.28
Casing					19.05	7.3.1		236.33
Tools/Service					2.43	7.3.2		238.76
Cement Equipment					2.24	8.3.2		241.00
Rig Down Casing Tools	800	1.0	0.40	7.3			137.9	241.40

^a Time and direct cost categories are identified in Appendix A.

^c Designates bit diameter and API Standard RP 7G bit classification, e.g., 17-1/2 in. diameter, series 1- type 1- features 1.

^d BHA = bottomhole assembly

^e BOP = blowout preventer

^f A parenthetical note after "Change BHA" denotes item(s) associated with direct costs or item(s) requiring special attention.

Table 19 (Continued)

Drilling Operation Sequence for the Representative Roosevelt Hot Springs Well Model

Activity/Equipment/Service in Order of Occurrence	Depth (ft)	Time Used (h)	Variable Cost ₃ (\$x10 ³)	Time Category ^a	Direct Cost ₃ (\$x10 ³)	Direct Cost Category ^a	Cumulative	
							Time (h)	Cost ₃ (\$x10 ³)
Rig Up Cementing Tools	800	2.0	0.79	8.3			139.9	242.19
Cementing	800	2.0	0.79	8.3			141.9	242.98
Cement					4.65	8.3.1		247.63
Service					5.60	8.3.2		253.23
Rig Down Cementing Tools	800	1.0	0.40	8.3			142.9	253.63
Wait-on-Cement	800	4.0	1.58	8.3			146.9	255.21
Nipple Up BOP ^e /Wellhead	800	12.0	4.75	14.2	15.07	14.2	158.9	275.03
Variable Cost Rates Used in Above Variable Cost Calculations (\$/h)								
Rig	235.40							
Fuel	41.25							
Transportation/Misc.	62.50							
Rental	15.00							
Supervision	20.85							
Mud	20.85							
Combined	395.85							
Trip Out/In (12-1/4 in. Bit, 5-2-7) ^c	800	0.4	0.18	4.2	5.80	12.1	159.3	281.01
BHA ^d (Stabilizers) ^f	800	2.0	0.92	4.2	1.92	9.4	161.3	283.85
Drill Cement	800	2.5	1.15	8.3			163.8	285.00
Drill 12-1/4 in. Hole	1570	70.0	32.32	4.1			233.8	317.32
Survey	1570	1.0	0.46	10.3			234.8	317.78
Trip Out/In (12-1/4 in. Bit, 5-2-7) ^c	1570	2.5	1.15	4.2	5.80	12.1	237.3	324.73
BHA ^d (Stabilizers) ^f	1570	2.0	0.92	4.2	1.92	9.4	239.3	327.57
Ream (100 ft/5 h)	1570	5.0	2.31	4.3			244.3	329.88
Drill 12-1/4 in. Hole	2190	60.0	27.70	4.1			304.3	357.58
Survey (2 Wirelines)	2190	4.0	1.85	10.3	1.80	10.0	308.3	361.23
Go Devil	2190	1.0	0.46	10.3			309.4	361.69
Trip Out/In (12-1/4 in. Bit, 6-1-7) ^c	2190	3.2	1.48	4.2	5.80	12.1	312.5	368.97
BHA ^d (Stabilizers) ^f	2190	2.0	0.92	4.2	0.96	9.4	314.5	370.39

^aTime and direct cost categories are identified in Appendix A.

^cDesignates bit diameter and API Standard RP 7G bit classification, e.g., 17-1/2 in. diameter, series 1- type 1- features 1.

^dBHA = bottomhole assembly

^eBOP = blowout preventer

^fA parenthetical note after "Change BHA" denotes item(s) associated with direct costs or item(s) requiring special attention.

Table 19 (Continued)

Drilling Operation Sequence for the Representative Roosevelt Hot Springs Well Model

Activity/Equipment/Service in Order of Occurrence	Depth (ft)	Time Used (h)	Variable Cost ₃ (\$x10 ³)	Time Category ^a	Direct Cost (\$x10 ³)	Direct Cost Category ^a	Cumulative	
							Time (h)	Cost ₃ (\$x10 ³)
Ream (100 ft/5 h)	2190	5.0	2.31	4.3			319.5	372.70
Drill 12-1/4 in. Hole	2676	54.0	24.93	4.1			373.5	397.63
Survey (Wireline)	2676	2.0	0.92	10.3			375.5	398.55
Go Devil	2676	1.0	0.46	10.3			376.5	399.01
Trip Out/In (12-1/4 in. Bit, 6-1-7) ^c	2676	3.7	1.71	4.2	5.80	12.1	380.2	406.52
BHA ^d (Stabilizers) ^f	2676	2.0	0.92	4.2	1.92	9.4	382.2	409.36
Ream (100 ft/5 h)	2676	5.0	2.31	4.3			387.2	411.67
Drill 12-1/4 in. Hole	3180	63.0	29.08	4.1			450.2	440.75
Survey (Wireline)	3180	2.0	0.92	10.3			452.2	441.67
Go Devil	3180	1.0	0.46	10.3			453.2	442.13
Trip Out/In (12-1/4 in. Bit, 6-1-7) ^c	3180	4.2	1.94	4.2	5.80	12.1	457.4	449.87
BHA ^d (Stabilizers) ^f	3180	2.0	0.92	4.2	0.96	9.4	459.4	451.75
Ream (100 ft/5 h)	3180	5	2.31	4.3			464.4	454.06
Drill 12-1/4 in. Hole	3400	17.0	7.85	4.1			481.4	461.91
Circulate	3400	3.0	1.38	11.0			484.4	463.29
Survey	3400	1.0	0.46	10.3			485.4	463.75
Trip Out	3400	3.7	1.71	4.2			489.1	465.46
Variable Cost Rates Used in Above Variable Cost Calculations (\$/h)								
Rig	235.40							
Fuel	41.25							
Transportation/Misc.	62.50							
Rental	15.00							
Supervision	20.85							
Mud	86.65							
Combined	461.65							
Rig Up Logging Tools	3400	2.0	0.79	11.0			491.1	466.25
Calibrate		2.0	0.79	11.0			493.1	467.04
Log	3400	5.9	2.34	11.1	9.91	11.1	499.0	479.29
Rig Down Logging Tools	3400	1.0	0.40	11.0			500.0	479.69
Wiper Trip	3400	6.8	2.69	7.4			506.8	482.38
Rig Up Casing Tools	3400	2.0	0.79	7.4			508.0	483.17
Run 9-5/8 in. Casing	3400	9.7	3.84	7.4			518.5	487.01
Casing					57.65	7.4.1		544.66
Tools/Service					6.83	7.4.2		551.49
Cement Equipment					3.32	8.4.2		554.81

^aTime and direct cost categories are identified in Appendix A.

^cDesignates bit diameter and API Standard RP 7G bit classification, e.g., 17-1/2 in. diameter, series 1- type 1- features 1.

^dBHA = bottomhole assembly

^fA parenthetical note after "Change BHA" denotes item(s) associated with direct costs or item(s) requiring special attention.

Table 19 (Continued)

Drilling Operation Sequence for the Representative Roosevelt Hot Springs Well Model

Activity/Equipment/Service in Order of Occurrence	Depth (ft)	Time Used (h)	Variable Cost ₃ (\$x10 ³)	Time Category ^a	Direct Cost ₃ (\$x10 ³)	Direct Cost Category ^a	Cumulative	
							Time (h)	Cost ₃ (\$x10 ³)
Rig Down Casing Tools	3400	1.0	0.40	7.4			519.5	555.21
Rig Up Cementing Tools	3400	2.0	0.79	8.4			521.5	556.00
Cementing	3400	3.0	1.19	8.4			524.5	557.19
Cement					8.47	8.4.1		565.66
Services					9.36	8.4.3		575.02
Rig Down Cementing Tools	3400	1.0	0.40	8.4			525.5	575.42
Wait-on-Cement	3400	4.0	1.58	8.4			529.5	577.00
Nipple Down BOP ^e /Install	3400	20.0	7.92	14.2	13.40	14.3	549.5	598.32
Wellhead/Nipple Up/Test								
Variable Cost Rates Used in Above Variable Cost Calculations (\$/h)								
Rig	235.40							
Fuel	41.25							
Transportation/Misc.	62.50							
Rental	15.00							
Supervision	20.85							
Mud	20.85							
Combined	395.85							
Trip In (8-1/2 in. Bit, 6-1-7) ^c	3400	1.7	0.73	4.2	3.01	12.1	551.2	602.06
BHA ^d (Stabilizers) ^f		2.0	0.85	4.2	0.84	9.4	553.2	603.75
Drill Cement	3400	2.5	1.07	8.4			555.7	604.82
Test Shoe	3400	3.0	1.28	8.4			558.7	606.10
Drill 8-1/2 in. Hole	3940	60.0	25.64	4.1			618.7	631.74
Survey (Wireline)	3940	2.0	0.85	10.3			620.7	632.59
Go Devil	3940	1.0	0.43	10.3			621.7	633.02
Trip Out/In (8-1/2 in. Bit, 6-3-7) ^c	3940	4.9	2.09	4.2	3.01	12.1	626.6	638.12
BHA ^d (Stabilizers) ^f	3940	2.0	0.85	4.2	0.84	9.4	628.6	639.81
Ream (100 ft/5 h)	3940	5.0	2.14	4.3			633.6	641.95
Drill 8-1/2 in. Hole	4342	57.0	24.36	4.1			690.6	666.31
Survey (Wireline)	4342	2.0	0.85	10.3			692.6	666.16
Go Devil	4342	1.0	0.43	10.3			693.6	667.59
Trip Out/In (8-1/2 in. Bit, 6-3-7) ^c	4342	5.4	2.31	4.2	3.01	12.1	699.0	672.91
BHA ^d (Stabilizers) ^f	4342	2.0	0.85	4.2	0.84	9.4	701.0	674.60
Ream (100 ft/5 h)	4342	5.0	2.14	4.3			706.0	676.74
Drill 8-1/2 in. Hole	4812	52.0	22.22	4.1			758.0	698.96

^a Time and direct cost categories are identified in Appendix A.^c Designates bit diameter and API Standard RP 7G bit classification, e.g., 17-1/2 in. diameter, series 1- type 1- features 1.^d BHA = bottomhole assembly^e BOP = blowout preventer^f A parenthetical note after "Change BHA" denotes item(s) associated with direct costs or item(s) requiring special attention.

Table 19 (Continued)

Drilling Operation Sequence for the Representative Roosevelt Hot Springs Well Model

Activity/Equipment/Service in Order of Occurrence	Depth (ft)	Time Used (h)	Variable Cost ₃ (\$x10 ³)	Time Category ^a	Direct Cost ₃ (\$x10 ³)	Direct Cost Category ^a	Cumulative	
							Time (h)	Cost ₃ (\$x10 ³)
Survey (Wireline)	4812	2.0	0.85	10.3			760.0	699.81
Go Devil	4812	1.0	0.43	10.3			761.0	700.24
Trip Out/In (8-1/2 in. Bit, 7-3-7) ^c	4812	5.7	2.44	4.2	3.01	12.1	766.7	705.69
BHA ^d (Stabilizers) ^f	4812	2.0	0.85	4.2	0.84	9.4	768.7	707.38
Ream (100 ft/5 h)	4812	5.0	2.14	4.3			773.7	709.52
Drill 8-1/2 in. Hole	5442	63.0	26.92	4.1			836.7	736.44
Survey (Wireline)	5442	2.0	0.85	10.3			838.7	737.29
Go Devil	5442	1.0	0.43	10.3			839.7	737.72
Trip Out/In (8-1/2 in. Bit, 6-3-7) ^c	5442	6.4	2.73	4.2	3.01	12.1	846.1	743.46
BHA ^d (Stabilizers) ^f	5442	2.0	0.85	4.2	0.84	9.4	848.1	745.15
Ream (100 ft/5 h)	5442	5.0	2.14	4.3			853.1	747.29
Drill 8-1/2 in. Hole	5834	49.0	20.94	4.1			902.1	768.23
Survey	5834	1.0	0.43	10.3			903.1	768.66
Trip Out/In (8-1/2 in. Bit, 7-3-7) ^c	5834	6.8	2.91	4.2	3.01	12.1	909.9	774.58
BHA ^d (Stabilizers) ^f	5834	2.0	0.85	4.2	0.84	9.4	911.9	776.27
Ream (100 ft/5 h)	5834	5.0	2.14	4.3			916.9	778.41
Drill 8-1/2 in. Hole	6549	65.0	27.78	4.1			981.9	806.19
Survey (Wireline)	6549	2.0	0.85	10.3			983.9	807.04
Go Devil	6549	1.0	0.43	10.3			984.9	807.47
Trip Out/In (8-1/2 in. Bit, 6-3-7) ^c	6549	7.6	3.25	4.2	3.01	12.1	992.5	813.73
BHA ^d (Stabilizers) ^f	6549	2.0	0.85	4.2	0.84	9.4	994.5	815.42
Ream (100 ft/5 h)	6549	5.0	2.14	4.3			999.5	817.56
Drill 8-1/2 in. Hole	7143	66.0	28.20	4.1			1065.5	845.76
Survey (Wireline)	7143	2.0	0.85	10.3			1067.5	846.61
Go Devil	7143	1.0	0.43	10.3			1068.5	847.04
Trip Out/In (8-1/2 in. Bit, 6-2-7) ^c	7143	8.3	3.55	4.2	3.01	12.1	1076.8	853.60
BHA ^d (Stabilizers) ^f	7143	2.0	0.85	4.2	0.84	9.4	1078.8	855.29
Ream (100 ft/5 h)	7143	5.0	2.14	4.3			1083.8	857.43
Drill 8-1/2 in. Hole	7500	35.7	15.26	4.1			1119.5	872.69
Survey (Multi-shot)	7500	4.0	1.71	10.3	2.20	10.3	1123.5	876.60

^a Time and direct cost categories are identified in Appendix A.

^c Designates bit diameter and API Standard RP 7G bit classification, e.g., 17-1/2 in. diameter, series 1- type 1- features 1.

^d BHA = bottomhole assembly

^f A parenthetical note after "Change BHA" denotes item(s) associated with direct costs or item(s) requiring special attention.

Table 19 (Continued)

Drilling Operation Sequence for the Representative Roosevelt Hot Springs Well Model

Activity/Equipment/Service in Order of Occurrence	Depth (ft)	Time Used (h)	Variable Cost ₃ (\$x10 ³)	Time Category ^a	Direct Cost ₃ (\$x10 ³)	Direct Cost Category ^a	Cumulative		
							Time (h)	Cost ₃ (\$x10 ³)	
Trip Out	7500	5.8	2.48	4.2			1129.3	879.08	
Variable Cost Rates Used in Above Variable Cost Calculations (\$/h)									
Rig	235.40	}	↑						
Fuel	41.25								
Transportation/Misc.	62.50								
Rental	15.00								
Supervision	20.85								
Mud	25.73								
Mud Log	26.60								
Combined	427.33								
(Release Mud Logger)									
Rig Up Logging Tools	7500	2.0	0.79	11.0			1131.3	879.87	
Test Tool	7500	2.0	0.79	11.0			1133.3	880.66	
Log	7500	10.5	4.16	11.1	19.36	11.1	1143.8	904.18	
Rig Down Logging Tools	7500	1.0	0.40	11.0			1144.8	904.58	
(Stop Mud System)									
Wiper Trip	7500	10.0	3.75	7.5			1154.8	908.33	
Rig Up Casing Tools	7500	2.0	0.79	7.5			1156.8	909.12	
Run 7 in. Liner	7500	19.0	7.09	7.5			1175.8	916.21	
Casing					113.14	7.5.1		1029.35	
Tools/Service					8.69	7.5.2		1038.04	
Hanger					6.06	7.5.2		1044.10	
Rig Down Casing Tools	7500	1.0	0.38	7.5			1176.8	1044.48	
Nipple Down/Install Wellhead	7500	16.0	6.00	18.0			1192.8	1050.48	
Completion (Estimate)	7500	72.0	27.00	18.0	25.40	18.0	1264.8	1102.88	
Lay Down Drill Pipe/ Collars	7500	15.0	5.63	9.0			1279.8	1108.51	
Variable Cost Rates Used in Above Variable Cost Calculations (\$/h)									
Rig	235.40	}	↑						
Fuel	41.25								
Transportation/Misc.	62.50								
Rental	15.00								
Supervision	20.85								
Mud	20.85								
Combined	395.85								
Miscellaneous									
Waste Disposal					13.2	13.2		1120.51	
Water					9.00	13.1		1129.51	
CUMULATIVE TOTALS							1279.6 (53 Days)	1129.51	

^aTime and direct cost categories are identified in Appendix A.

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APPENDIX

Drilling Cost and Time Categories

A.1 DISCUSSION OF COST AND TIME ACCOUNTING CATEGORIES

The costs and times included in the well models can be combined and analyzed in numerous ways. Accounting for them in the following 18 categories is consistent with standard oil field drilling cost breakdowns. Costs included in each category are explained in the following paragraphs.

Road Location and Site Preparation

Included in this category are costs incurred in road and drilling pad preparation and in digging and lining the reserve mud pit. These costs vary widely among the geothermal areas. For example, difficulty in locating the production drilling pads at The Geysers area has resulted in the use of pads of sufficient size for two to five wells, and the cost associated with such a pad must be divided among the wells. The cost estimates for site preparation were arrived at by discussions with operators and contractors. The decision was made to divide these costs between two wells at The Geysers but to allocate them to one well at each of the other areas.

Initiation

Initiation is a separate activity from drilling. A smaller rig than is used for drilling the well is required to drill the large, shallow hole for the surface conductor, to set the conductor, and to drill small holes (mouse hole and rat hole) on the drill site. This could be done with the large rig, but it is done more efficiently with a smaller one. Small rig operators usually work on a fixed price based on the hardness and expected difficulty of drilling the surface rock.

Move In, Rig Up, and Rig Down

Move in, rig up, and rig down costs for an actual well are based on a bid price from the contractor to the operator that includes the expense of moving the rig from another drilling site, of preparing the rig for drilling, and of dismantling the rig after drilling. The way bids are currently made, the contractor's profit is sometimes included in this category so that a lower daily rental rate can be quoted to the operator. Thus, the cost quoted for move in, rig up, and rig down may not reflect the actual expense to the contractor for these activities. For consistency with other costs, the estimate used is five times the daily rig rate. No additional personnel or equipment charges are made, and all these costs are charged at the initiation, or the beginning, of the well rather than charging some at the outset and some afterward.

Rig Rental

Rig rental costs include all charges that are made by the contractor that are accrued based on time and that are not third-party, pass-through costs. Pass-through costs are accounted for in other cost categories. For all areas but The Geysers, the rental costs include charges for the basic rig, for the required equipment and tools, such as drill collars and drill pipe, and for personnel; but they do not include fuel costs. The difference in The Geysers area is that the rig costs do not include the costs of drill pipe and drill collars. The normal approach for rig rental costs is a day rate contract under which the rig is rented for a specific rate.

Fuel

Fuel costs include those costs to supply the rig with diesel fuel at the usage rate discussed in Section 2.

Drilling Mud

Drilling mud costs include all nonrental expenses that would be incurred in supplying and maintaining the drilling fluid. These costs include the cost of water and additives for the original mud supply,

the daily maintenance expenses, and costs of additional mud required due to losses in the wellbore and to the increased volume needed by additional hole volume. They do not include the charges for the mud logger, when required, as this is a pass-through, rental expense. Costs in the representative models do not reflect costs for the lost circulation materials that are necessary in many geothermal areas. Lost circulation is a problem that is not included in these models of trouble-free wells.

Casing

Casing costs include only those hardware and equipment charges required with the casing. The items that are attached to the casing but used primarily in the cementing process are included as cementing expenses. Thus, the casing costs include the cost of the pipe and its transportation to the rig and the cost of casing or liner hangers. In addition, casing costs include tools and services required for inspection of the pipe; casing tools, such as elevators, slips, tongs, etc.; and the casing crew itself. These rental items are estimated to require four men at \$27.50/hour each plus \$150.00/hour for the casing equipment.

Cementing

Cementing costs include the cost of the cement; the cost of services required to deliver and pump the cement; the cost of waiting for the cement to set and then drilling it out of the casing; and the cost of those items affixed to the casing, as it is inserted into the hole, to aid the cementing process. The services include mileage charges for equipment, a handling charge based on cement volume, a transportation charge from the station to the well site, and pumping charges for placing the cement into the well.

Drill String

Drill string charges are included for The Geysers, where the rig is rented without drill pipe. This is the practice due to the severe erosion/corrosion suffered by the drill pipe. In the other areas, the

rig operator supplies and includes a charge for the drill pipe and accepts the risk of damage.

Directional

Directional costs are those special charges related to the directional equipment and services required for the directional program for a well. The Geysers well is the only representative model which utilizes directional drilling, although surveying is performed in several. Costs include the cost of surveying, orientation runs, and turbine runs.

Logging

Logging costs reflect all logging service company charges, including travel costs to the site, set-up cost at the site, costs for logging the hole, temperature penalties, etc., as well as the time-related charges for the logging operation.

Bits and Hole Openers

For the bits, catalog prices are used for the cost of each individual bit. The charges for hole openers are estimated from catalogs, and when appropriate, stabilizer charges are also included.

Water and Waste Disposal

Water and waste disposal are treated as a fixed charge at the end of drilling and completion activity. Water for cement is reflected in the cement cost, and water for mud in the mud cost. Included in this category are excess water to supply the rig and waste disposal throughout rig activity.

Special

Included in the "special" category are costs of air compressors, which are used in The Geysers area and in the Baca region. These costs were determined by interview with a supplier of the equipment. Specialized wellhead, muffler, and flow line expenses are also included in this category.

Transportation and Miscellaneous

Transportation charges are an estimate of truck transportation costs for supplies--both normal, daily supplies and special transportation for maintenance of 24-hour rig activity.

In the "miscellaneous" category are charges for miscellaneous services and equipment used during the entire rig operation.

Rentals

Rental costs include charges for special, rented tools and equipment. In many cases, rental charges are third-party costs that the contractor "passes through" to the operator.

Supervision

Supervision costs are company (not contractor) overhead costs for part-time supervision required on the rig. This activity can also include costs for a company geologist. This charge varies from area to area and is based on difficulty of drilling and whether drilling is an exploration or a production operation.

Completion

Completion costs include the costs associated with special well-head or downhole equipment. In addition, 2- or 3-day period at the end of the operation is charged to completion.

A.2 LIST OF DRILLING COST AND TIME CATEGORIES

Table A-1 shows the various cost and time categories and their subcategories used in the operations sequences presented in Section 4.

Table A-1

Generic Wells Time and Cost Categories

- 1.0 Road, location & cellar
- 2.0 Initiation
- 3.0 Move, rig up and rig down
- 4.0 Rig rental
 - 4.1 Drilling
 - 4.2 Tripping
 - 4.3 Reaming
- 5.0 Fuel
- 6.0 Drilling mud
- 7.0 Casing
 - 7.1 Surface conductor
 - 7.1.1 Casing
 - 7.1.2 Tools and service
 - 7.1.3 Other equipment
 - 7.2 Surface casing
 - 7.2.1 Casing
 - 7.2.2 Tools and service
 - 7.2.3 Other equipment
 - 7.3 Intermediate casing
 - 7.3.1 Casing
 - 7.3.2 Tools and service
 - 7.3.3 Other equipment
 - 7.4 Second intermediate casing
 - 7.4.1 Casing
 - 7.4.2 Tools and service
 - 7.4.3 Other equipment
 - 7.5 Final casing string
 - 7.5.1 Casing
 - 7.5.2 Tools and service
 - 7.5.3 Other equipment
 - 7.6 Other casing/liners
 - 7.6.1 Casing
 - 7.6.2 Tools and service
 - 7.6.3 Other equipment
- 8.0 Cement
 - 8.1 Surface conductor
 - 8.1.1 Cement
 - 8.1.2 Cement equipment
 - 8.1.3 Cement service
 - 8.2 Surface casing
 - 8.2.1 Cement
 - 8.2.2 Cement equipment
 - 8.2.3 Cement service

Table A-1 (Continued)

Generic Wells Time and Cost Categories

- 8.3 Intermediate casing
 - 8.3.1 Cement
 - 8.3.2 Cement equipment
 - 8.3.3 Cement service
- 8.4 Second intermediate casing
 - 8.4.1 Cement
 - 8.4.2 Cement equipment
 - 8.4.3 Cement service
- 8.5 Final casing string
 - 8.5.1 Cement
 - 8.5.2 Cement equipment
 - 8.5.3 Cement service
- 8.6 Other casing/liners
 - 8.6.1 Cement
 - 8.6.2 Cement equipment
 - 8.6.3 Cement service
- 9.0 Drill String
 - 9.1 Drill pipe and special cost
 - 9.2 Collars and special cost
 - 9.3 Inspection
 - 9.4 Stabilizers
- 10.0 Directional
 - 10.1 Monel
 - 10.2 Directional service
 - 10.3 Survey
- 11.0 Logging - General
 - 11.1 Logging Operation
- 12.0 Bits and hole openers
 - 12.1 Bits
 - 12.2 Hole openers
 - 12.3 Reamers
- 13.0 Water and waste disposal
 - 13.1 Water
 - 13.2 Waste disposal
 - 13.3 Environmental
- 14.0 Special
 - 14.1 Air compressor
 - 14.2 BOP stack
 - 14.3 Well head, muffler and flow line
- 15.0 Transportation/Miscellaneous

Table A-1 (Continued)

Generic Wells Time and Cost Categories

- 16.0 Rental
 - 16.1 Miscellaneous equipments
 - 16.2 Mud log and mud cooling tower
- 17.0 Supervision and overhead
 - 17.1 Supervision
 - 17.2 General administration
- 18.0 Completion and equipment

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