REPORT BY THE U.S.

General Accounting Office

More Assurance Is Needed That Strategic Petroleum Reserve Oil Can Be Withdrawn As Designed

The Department of Energy (DOE) has designed the Strategic Petroleum Reserve so that large quantities of oil can be withdrawn over a sustained time period if oil imports are disrupted. DOE has tested its ability to withdraw oil through actual drawdown exercises and computer model simulations, and has determined that when all necessary equipment and piping modifications are made, it can meet the designed withdrawal rates.

GAO examined the basis for DOE's determination and found that:

--The oil withdrawal tests met their objectives but required more pumping equipment than DOE planned and may not have been long enough to demonstrate whether the oil withdrawal can be sustained over a long period of time.

--DOE relied on computer simulation models to assess its overall drawdown capability but used assumptions of equipment performance that may not occur during actual withdrawal operations.

--Past construction deficiencies that could affect the adequacy of current oil withdrawal systems have not all been fully resolved.

DOE is planning to conduct further tests and bring all systems up to design performance levels. During this effort, GAO recommends that the Secretary of Energy correct other identified problems and ensure that the withdrawal tests are of sufficient size and duration to fully test system capabilities.

GAO/RCED-85-104
SEPTEMBER 27, 1985

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UNITED STATES GENERAL ACCOUNTING OFFICE
WASHINGTON, D.C. 20548

RESOURCES, COMMUNITY,
AND ECONOMIC DEVELOPMENT
DIVISION

B-208196

The Honorable James A. McClure
Chairman, Committee on Energy and
Natural Resources
United States Senate

The Honorable J. Bennett Johnston
Ranking Minority Member, Committee
on Energy and Natural Resources
United States Senate

This report presents the results of our review of the Department of Energy's ability to withdraw oil from the Strategic Petroleum Reserve at design rates. The review was undertaken as part of a comprehensive effort to evaluate the administration's performance in developing, filling, and maintaining the Strategic Petroleum Reserve. As requested on March 8, 1984, we are providing you with the results of our review.

Copies of the report are being sent to the Chairman, Subcommittee on Environment, Energy, and Natural Resources, House Committee on Government Operations; the Secretary of Energy; the Director, Office of Management and Budget; and other interested parties.

J. Dexter Peach
Director

The Strategic Petroleum Reserve (SPR), the cornerstone of the nation's energy emergency preparedness program, is designed to protect the economy in the event of an oil import disruption. Since authorizing the program in 1975, the Congress has appropriated $17.8 billion for the SPR. Given the program's importance and size, GAO assessed whether the Department of Energy (DOE) will be able to withdraw SPR oil at the design rate and sustain this rate over time.

BACKGROUND

DOE has been implementing a three-phase plan to develop a 750-million-barrel SPR at six storage sites in Louisiana and Texas. Phase II of this plan--designed to bring the storage capacity to 550 million barrels--is due to be completed in 1987. As of July 31, 1985, DOE had 483.5 million barrels of oil in storage at five SPR sites. DOE is continuing to develop additional storage capacity at three of these sites and at a sixth site using a process known as leaching. This involves pumping water into the salt deposits and replacing the resulting brine (salt-saturated water) with oil.

During an emergency DOE would withdraw, or "draw down," SPR oil from underground storage caverns by pumping in water to force the oil out, and would then transport the oil by pipeline to one of three SPR marine terminals for distribution to refineries to replace lost imports. While the SPR was designed so oil could be withdrawn at any time during its development, DOE has established specific withdrawal rates to be achieved at the completion of each of the three phases. The withdrawal rate at the end of phase II is 3.5 million barrels per day for 107 days. (See pp. 1 to 8.)

RESULTS IN BRIEF

DOE asserts that the SPR phase II drawdown rate can be achieved and sustained on the basis of (1) a computer model that simulates drawdown operations, (2) drawdown tests conducted at three sites, and (3) pumping equipment performance during its cavern-leaching program that DOE believes is analagous to the drawdown process. However, operational and technical problems have

been identified in oil and water systems at SPR storage sites that in GAO's view, may affect DOE's ability to withdraw oil from the SPR at phase II design rate. GAO therefore questions the assumptions used by DOE to support its view that the drawdown rate can be met and believes that uncertainties will continue to exist until corrective actions are completed and the systems are fully tested for compliance with performance specifications.

PRINCIPAL FINDINGS

Operational and Technical Problems

GAO found that operational and technical problems exist in pipelines, on-site piping, and pumping equipment that may affect DOE's ability to achieve the design drawdown rate. Marine growth and debris in water systems, for example, have reduced the amount of water available to force oil out of the storage caverns; however, DOE has not yet fully determined the impact of this factor on drawdown rates. According to DOE contractor reports, a high degree of corrosion in one major oil pipeline and uncertainty about the quality of some of the buried on-site piping raises further questions about the system's ability to hold up under the pressures required during drawdown. In addition to pipeline and piping problems, relatively new oil withdrawal pumps at one site have experienced operational problems that are requiring extensive inspection and repairs. Further, maintenance, support, and control systems problems have been identified by others as well.

DOE has been aware of these problems for varying periods of time, going back to 1980, but has been slow initiating corrective actions. Some problems have yet to be addressed. (See pp. 19 to 29.)

Computer Model

DOE used a computer model to simulate SPR capabilities for an extended drawdown under completed phase II conditions. The model's key assumptions are that (1) all currently needed modifications to on-site systems are made, (2) all equipment operates at design performance levels for the duration of the drawdown, and (3) distribution enhancements at one site are made to allow withdrawal of two types of oil. Based on

these assumptions, the model simulation shows that the SPR can be drawn down at the phase II design rate for 107 days.

Because of the SPR operational and technical problems identified above and DOE's delay in initiating corrective action on long-standing problems, GAO believes that DOE's reliance on a computer simulation model, which assumes ideal operating conditions, is questionable. (See pp. 11 to 13, and 25 and 26.)

Drawdown Tests

DOE limited SPR oil withdrawal tests to three of the five sites for 1 day because site development and oil fill were not fully completed at the time. In conducting these tests, DOE used its backup (or spare) pumps to achieve oil withdrawal objectives because of certain system deficiencies at two sites. (See pp. 13 to 15.)

Although these tests showed that oil can be withdrawn from the three sites, the tests provided only limited confidence that the SPR drawdown goals can be achieved. First, the tests used emergency measures--the backup pumps--to achieve basic withdrawal rates. Secondly, the test duration was not long enough to adequately assess equipment reliability. Engineers familiar with SPR or similar equipment told GAO that a 5- to 7-day test would be a more reasonable demonstration of the SPR's capability to sustain an extended drawdown. (See pp. 15 and 16.)

Leaching Experience

Since the cavern-leaching program uses the same equipment as that needed for the drawdown, DOE has based its confidence in achieving the SPR's drawdown rate, in part, on the leaching equipment performance. During the period December 1983 through November 1984, for example, the large pumps used in the leaching process had an availability factor of over 95 percent. GAO noted, however, that the pumps at the two largest sites generally have not been required to operate consistently at full capacity as would be required under drawdown conditions. In addition, two backup pumps have generally been available during the leaching process while only one will be available during drawdown. Because of these increased operating requirements, there is some

question whether the high pump availability experienced during leaching can be achieved under drawdown conditions. (See pp. 13 and 14.)

RECOMMENDATIONS

GAO recommends that the Secretary of Energy implement certain specific actions designed to resolve SPR's operational and technical problems. GAO also recommends that the Secretary of Energy direct that SPR officials conduct further tests of the SPR that allow an assessment of its capability to meet design drawdown goals while recognizing the trade-off between cost and the level of assurance gained. GAO's prior analyses of various test scenarios can provide some guidance in determining the appropriate duration and type of test to be conducted. (See p. 32.)

AGENCY COMMENTS

DOE disagreed with the thrust of GAO's draft report, which expressed concern about SPR drawdown capability. In supporting its position, DOE provided GAO the results of an updated computer simulation and more recent analyses of equipment performance during leaching. DOE believes that this information, along with the history of successful leaching, provides sufficient evidence to refute GAO's concern and to support its capability to meet or exceed drawdown rates. (See app. I.)

GAO has revised its report to reflect the information provided as well as to add more detailed technical information. GAO agrees that the activities cited by DOE provide some assurance that the phase II drawdown rate can be achieved. GAO, however, is not as confident as DOE is about planned actions to correct noted problems and achieve phase II design performance levels. This stems from GAO's observations of the history of problems at the SPR sites and the lack of attention to some of the technical problems noted in the report. Thus, GAO believes that until the corrections are actually made and the system is fully tested at design levels, uncertainty will remain in DOE's ability to achieve and sustain the phase II drawdown rate. (See pp. 32 and 33.)

Contents

ILLUSTRATIONS

ABBREVIATIONS

API	American Petroleum Institute
DCAS	Defense Contract Administration Services
DOE	Department of Energy
FEA	Federal Energy Administration
GAO	General Accounting Office
ILS	Integrated logistics support
JDE	Jacobs D'Appolonia Engineers
SPR	Strategic Petroleum Reserve

CHAPTER 1

INTRODUCTION

Following the 1973-74 Arab oil embargo, the Congress passed the Energy Policy and Conservation Act (Public Law 94-163, Dec. 22, 1975). The act authorized the development of a 1-billion-barrel Strategic Petroleum Reserve (SPR) as a means of reducing the anticipated adverse economic effects of another oil supply disruption. The Department of Energy (DOE) is developing underground storage facilities for the SPR at six sites in Louisiana and Texas.

As the cornerstone of the nation's energy emergency preparedness program, the SPR is designed to provide oil supplies to the economy in the event of a severe energy supply disruption. In this situation, the President could authorize the Secretary of Energy to withdraw (draw down) the oil from the SPR storage sites and pump it to marine terminals or other distribution points for transfer to purchasers' control. Drawdown may also be authorized to fullfill an obligation of the United States under the international energy program.[1]

The ability to withdraw oil from the SPR at a high daily rate is important because it provides the option of quickly replacing all or a large part of the oil supply disrupted during an emergency. This action can dampen, or slow, the rate of initial price increases during disruptions, thereby mitigating some of the adverse economic impacts of a disruption. The ability to sustain a drawdown over a reasonable length of time is important because it provides assurance to the public and industry that oil supplies will be available on a continuous basis, thus diminishing the tendency to hoard crude oil and/or petroleum products.

SPR DEVELOPMENT AND CURRENT STATUS

On the basis of 1974-75 oil import levels, the Federal Energy Administration (FEA), one of DOE's predecessor agencies, initially proposed a plan for a 500-million-barrel SPR. DOE subsequently amended the FEA plan and increased the size of the SPR to its current planned level of 750 million barrels.

DOE has been implementing a three-phase program to develop and maintain sites for storing the planned 750 million barrels of crude oil. Phase I storage capacity was acquired and developed during the period 1977-83. Phase II development started in 1979, and DOE planned to complete oil fill in 1987. Phase III began in 1982, with a planned completion date of 1990.

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[1]The SPR's size and use are linked to the country's commitment as a member of the International Energy Agency.

The locations of the storage sites and the projected storage capacities that DOE had planned under the three development phases are shown in table 1.1.

Table 1.1

SPR Storage Capacity

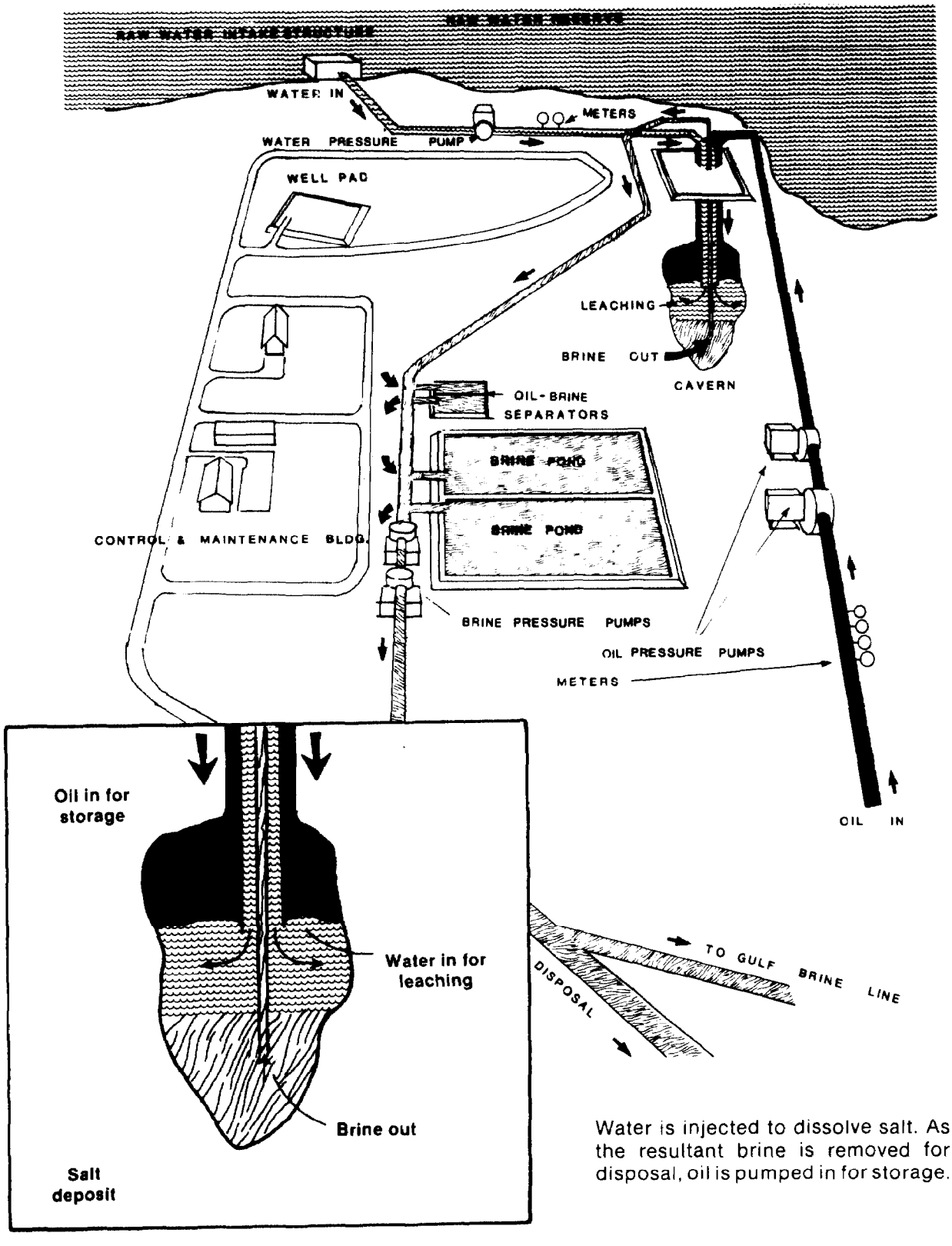
Site[a]	Phase I	Phase II	Phase III	Total
	(millions of barrels)			
Bayou Choctaw, La.	47	10	10	67
Weeks Island, La.	73	-	-	73
West Hackberry, La.	49	160	10	219
Sulphur Mines, La.	26	-	-	26
Big Hill, Tex.	-	-	140	140
Bryan Mound, Tex.	65	120	40	225
Total	260	290	200	750

[a]Each site is connected by pipeline to one of three marine terminals that receive oil deliveries for storage in the SPR. DOE owns and operates the marine terminal at St. James, Louisiana, and has multiyear contracts to use two commercial terminals at Nederland and Freeport, Texas. These terminals and the sites connected to them are referred to, respectively, as the Capline, Texoma, and Seaway distribution groups because at the time of selection, they were connected to those interstate crude oil pipelines.

The development of storage capacity has differed to some extent under each of the phases. During phase I, for example, DOE purchased five sites with existing storage space in underground salt domes and converted them into SPR facilities. Phase II, however, involves creating new storage capacity at three of these sites. To do so, wells are drilled into the salt domes; and caverns are created by continually pumping fresh water into the wells to dissolve, or leach, the salt and pumping out the resultant brine (salt-saturated water) solution. As storage space is created by removing the brine, oil is injected into the top of the cavern. This simultaneous process of creating storage space and injecting oil is referred to as the leach/fill process. (Figure 1.1 shows how the leach/fill process is carried out.) The leach/fill process continues until the caverns can each store about 10 million barrels of crude oil. Phase III involves creating additional storage at three sites and at a new site at Big Hill, Texas. However, DOE planned to develop the storage capacity at Big Hill using a leach then fill process. With this process, DOE would leach the entire volume of each cavern before injecting the oil to replace the brine.

Figure 1.1

Fluid Flow During the Leach/Fill Process



Water is injected to dissolve salt. As the resultant brine is removed for disposal, oil is pumped in for storage.

With one exception, the drawdown process is the same at each site. The oil stored in SPR sites, other than Weeks Island, can be withdrawn by pumping water into the bottom of the caverns and forcing the oil out into the on-site pipeline system. The oil is then pumped to one of the three marine terminals for distribution to refineries. (Figure 1.2 shows the oil withdrawal process.) At Weeks Island, the oil is stored in a mechanically mined salt cavern and must be pumped out of the storage space. Eleven submersible oil pumps have been installed underground in the mine area for this purpose. Although all of the equipment necessary to accomplish drawdown through phase II development was in place at each of the sites at the time of our review, DOE officials stated that some pump and cavern modifications are needed before phase II can be considered complete.

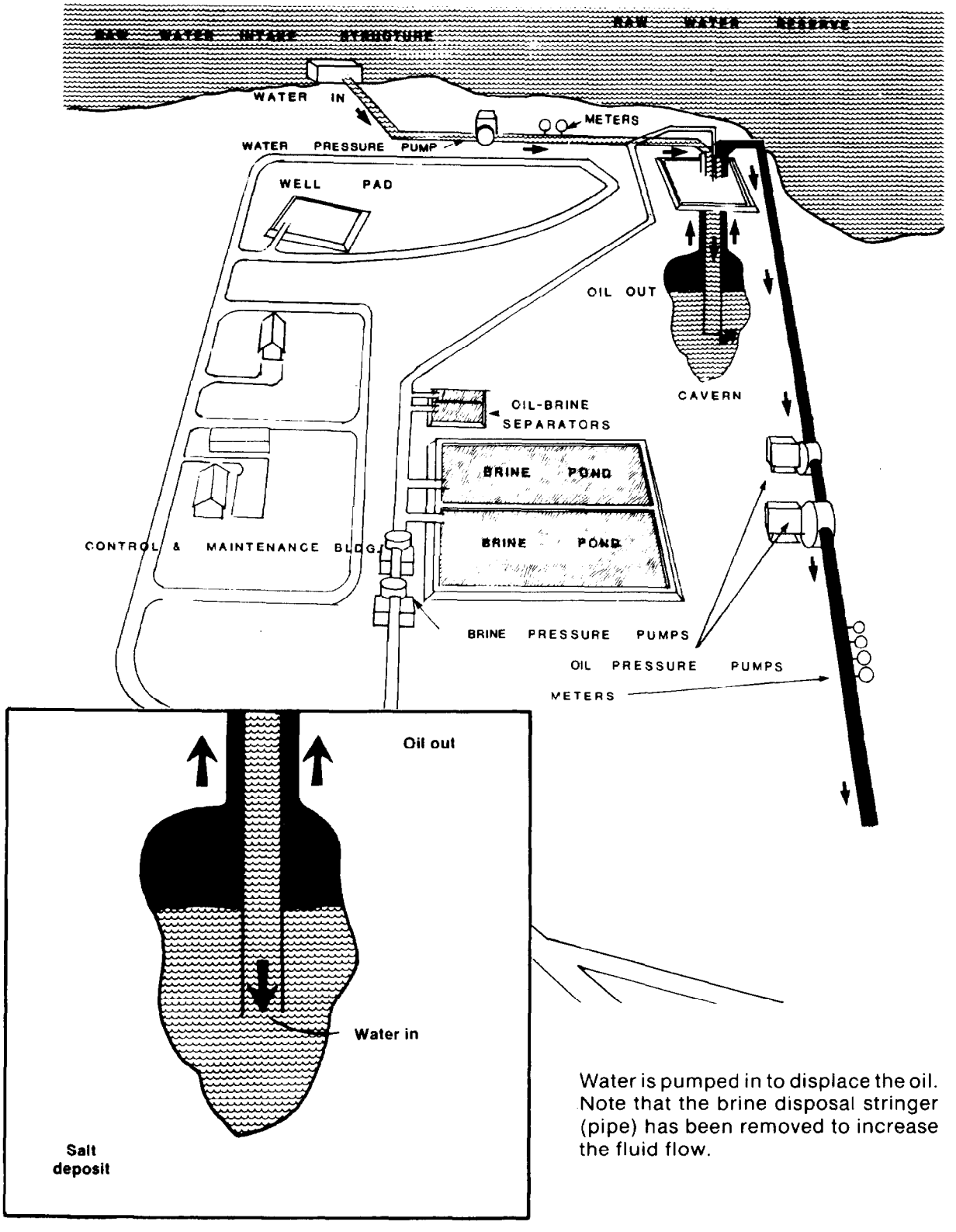
At the end of fiscal year 1984, the Congress had appropriated nearly $2.7 billion for planning, construction, and operation of the SPR sites and about $15.1 billion for crude oil. By the end of fiscal year 1985, phase II SPR facilities costing about $709 million will virtually be fully funded. DOE estimates that it would need an additional $8 billion to complete development and fill the SPR to its planned 750-million-barrel capacity by 1990.

However, the administration's fiscal year 1986 budget proposed an indefinite moratorium on developing and filling the SPR. Under the proposal, DOE would stop filling the SPR at the end of fiscal year 1985, when it contains 489 million barrels of oil. The administration would reassess its position on the moratorium as conditions changed. The administration also deferred funds that would have been used in fiscal year 1985 to continue the development of the SPR's storage capacity. Under the moratorium, the completion date of a 750-million-barrel reserve would be delayed beyond 1990.

In the 1985 Supplemental Appropriations Act (Public Law 98-88), the Congress disapproved the deferral of SPR construction funds and partially disapproved the deferral of SPR oil acquisition funds. Thus, these funds were made available for the continued development of the SPR and for oil purchases to bring the SPR inventory level up to 500 million barrels in 1986.

Figure 1.2

Fluid Flow During Drawdown



Water is pumped in to displace the oil. Note that the brine disposal stringer (pipe) has been removed to increase the fluid flow.

As of July 31, 1985, the SPR contained about 483.5 million barrels of various types of crude oil. The amounts, types, and locations of the oil are shown in table 1.2.

Table 1.2

SPR Inventory Summary,
July 31, 1985

Distribution group	Site	Type of oil			
		Sweet[a]	Sour[b]	Other	Total
		---(millions of barrels)---			
Capline	Bayou Choctaw	17.5	27.9	-	45.4
	Weeks Island	-	-	73.0[c]	73.0
Texoma	West Hackberry	104.5	44.7	-	149.2
	Sulphur Mines	-	26.1	-	26.1
	Big Hill	-	-	-	-
Seaway	Bryan Mound	64.3	111.0	11.2[d]	186.5
Total		186.3	209.7	84.2	480.2
Tanks and pipelines					3.3
Total					483.5

[a]Low-sulfur content crude with an American Petroleum Institute (API) gravity range of 30 to 45 degrees.

[b]High-sulfur content crude with an API gravity range of 30 to 36 degrees.

[c]Weeks Island blend, which is composed of Alaskan North Slope, Mexican Maya-Isthmus blend, and other sour crude oils.

[d]Maya oil, which is a lower quality crude with maximum sulfur content of 3.5 percent and a minimum API gravity of 22 degrees.

The different types of oil stored at a site can affect the drawdown rate. Because of their physical characteristics and associated values, the different oil types are moved and stored separately. Since in general, a single pipeline runs from the site to the marine terminal, oil would be withdrawn by type either in batches, alternating between types, or until the inventory of a particular type is exhausted. DOE officials told us that to achieve the required drawdown pressure levels, oil is withdrawn from several caverns simultaneously; if adequate volumes of the type being withdrawn are not available, less pressure and, consequently, a lower drawdown rate would result.

SPR SIZE AND DESIGN DRAWDOWN CRITERIA HAVE VARIED

The original SPR plan proposed by FEA called for a 500-million-barrel reserve that could be drawn down in 150 days. The reserve size was determined in accordance with the legislative requirement that at a minimum, the reserve should be large enough to offset the highest amount of oil imported during a consecutive 3-month period in 1974-75. Subsequent amendments by DOE to the original plan increased the SPR size to 750 million barrels and specified storage capacities at the sites for each phase of development as shown in table 1.1. Each of the three phases also had a specified design drawdown rate as shown below:

--1.7 million barrels per day at the end of phase I,

--3.5 million barrels per day at the end of phase II, and

--4.5 million barrels per day at the end of phase III.

Each of the three end-of-phase drawdown rates for the SPR is composed of the drawdown rates applicable to each individual site. The cavern size and configuration, the piping size and specifications, and the pumping equipment were designed so that each site could achieve its specified drawdown rate. Table 1.3 shows DOE's projected drawdown rates for each phase of development.

Table 1.3

Design Drawdown Rate Capability by Phase of Development

Site	Drawdown rate		
	Phase I	Phase II	Phase III
	----(millions of barrels per day)-----		
Bayou Choctaw	0.240	0.480	0.480
Weeks Island	.590	.590	.590
West Hackberry	.402	1.402	1.402
Sulphur Mines	.100	[a]	[a]
Big Hill	-	-	.935
Bryan Mound	.387	1.054	1.054
Total	1.719	3.526	4.461

[a]The West Hackberry and Sulphur Mines sites share a common pipeline to the marine terminal. The combined drawdown rate of the two sites is 1.402 million barrels per day; Sulphur Mines contributes 100,000 barrels per day.

DOE's ability to meet the design drawdown criteria is dependent on the progress made in developing each site. Since it is already completed, phase I should provide at least 1.7 million barrels of oil per day, if necessary. The additional amount available from phase II caverns, however, is currently dependent on such things as (1) the oil inventory and mix of oil types now stored at each site, (2) whether the piping configurations in the caverns have been converted from leaching to drawdown mode, and (3) the condition of the operating equipment.

As a result of changes in the types and/or volumes of oil stored at the Bryan Mound, West Hackberry, and Bayou Choctaw sites, DOE dropped the criterion called for in the original SPR plan that the sites should be capable of sustaining a drawdown for a 150-day period. The DOE program office has changed this criterion to the length of time required to draw down 90 percent of each site's inventory. The average daily drawdown rates, however, remain the same as initially conceived. Under the new criterion, the phase II drawdown rate would be sustained for about 107 days before dropping below the 3.5-million-barrels-per-day level.

ORGANIZATIONAL RESPONSIBILITY FOR THE SPR

FEA was responsible for the SPR's initial planning and development. When DOE was created on October 1, 1977, it assumed responsibility for the SPR. Within DOE, responsibility for the continued development of the SPR was assigned to the SPR Program Office in Washington, D.C. In early 1978 DOE established a Project Management Office in New Orleans to improve the overall management of SPR activities. Responsibility was divided between the program and project offices. The Deputy Assistant Secretary for the SPR headed the program office and had oversight of program management, planning, and budgeting activities. The project office, headed by a project manager, was responsible for day-to-day activities and reported to the Deputy Assistant Secretary. The project office responsibilities included developing and filling the storage facilities, operating and maintaining the sites, testing drawdown capabilities, and preparing the sites for standby status after oil-fill activities were completed. In June 1983 management of the project office was transferred from the program office to DOE's Oak Ridge Operations Office in Oak Ridge, Tennessee. The project office retained day-to-day responsibility for SPR activities and now reports to the operations office. The program office retained responsibility for overall program management and planning.

OBJECTIVES, SCOPE, AND METHODOLOGY

Because of concerns raised during prior audit work about the condition of equipment and piping at SPR storage sites, we

conducted this review to determine whether DOE will be able to withdraw SPR oil at the design rates and sustain the rate over time. Since DOE considers the SPR to be a major system, we examined its adherence to generally recognized project management practices during the engineering, design, construction, and operations phases of SPR project development. Our examination covered past and present DOE management practices and the current and projected capability and status of the SPR sites in relation to what was initially conceived, funded, designed, and constructed. The report is being sent to the Chairman and Ranking Minority Member of the Senate Committee on Energy and Natural Resources pursuant to a March 8, 1984, request that we report the results of our review to them.

Our audit work was performed at the New Orleans, Louisiana, offices of DOE and SPR contractors and at four of the five SPR storage sites--Bryan Mound, Texas; and West Hackberry, Weeks Island, and Sulphur Mines, Louisiana. Three of these sites were selected because they will have the largest storage capacities at the end of phase II and are connected to separate distribution terminals that are expected to be integral parts of any oil drawdown effort. Sulphur Mines was included because it is a completed site. We did not visit the Bayou Choctaw site, but we reviewed the site report prepared by DOE's Office of Inspector General. We also interviewed DOE program and operations office officials in Washington, D.C., and Oak Ridge, Tennessee.

We limited our review to assessing DOE's ability to withdraw the oil from the storage caverns and deliver it to terminals or other transfer points where it would be picked up by purchasers. Further, although DOE's plan for the SPR includes the completion of phase III caverns, for a total oil inventory of 750 million barrels, we limited our assessment of the drawdown capability to phase II sites and equipment. Phase III facilities are not sufficiently advanced to provide a basis for any meaningful assessment.

At the project office, we interviewed DOE officials, including the project manager, assistant project managers for operations and engineering and construction, and personnel responsible for technical activities, to discuss drawdown requirements and the status of the SPR systems. We obtained records and documents from DOE officials relating to the design, engineering, construction, operations, and maintenance of the SPR facilities. These included design data books; architectural drawings for planned construction and for facilities as they were actually built; and DOE and contractor studies on the reliability, maintainability, and operations of the SPR. We used these records and documents to determine the performance capabilities of the SPR and to identify how closely project management practices had been followed in developing the SPR. We discussed the information developed from this work with

project office officials and contractors hired to provide design and engineering capability, perform technical studies, or operate and maintain the SPR system.

At the storage sites, we interviewed DOE's site representatives and the operations and maintenance contractor's site manager and other contract personnel to assess site status, operations and maintenance problems, and activities under way to improve site conditions. We obtained and reviewed operations and maintenance records on the actual performance of hardware components such as pumps and motors that are directly associated with and critical to drawdown. For example, we compared pump performance during leaching with pump performance requirements during drawdown. Our work at the Bryan Mound and the West Hackberry sites also included observations of 1-day oil movement exercises.

In mid-1983 the Oak Ridge Operations Office conducted a comprehensive review of the SPR to determine its status and assess the need for corrective actions. In October 1983 Oak Ridge issued its Baseline Assessment of the SPR Project Management Office. We reviewed the report and discussed its findings and recommendations, as they affect SPR mission performance, with appropriate DOE and contractor personnel.

In performing our review we were assisted by a certified professional mechanical engineer, Heinz A. Gorges, Ph.D. Dr. Gorges is a member of the American Society of Mechanical Engineers and the New York Academy of Sciences.

Our audit work was conducted from October 1983 through February 1985 and except for the following was in accordance with generally accepted government auditing standards. The data relating to DOE's projections of SPR drawdown capability were generated by a computerized mathematical model, and we did not attempt to validate the model or assess the reliability of the related computer programs.

DOE was provided a copy of our draft report for comment. On July 29, 1985, we met with SPR staff officials from the DOE headquarters Program Office, the Oak Ridge Operations Office, and the New Orleans Project Office. At that meeting, DOE officials provided us with written and oral technical and editorial comments on certain aspects of the draft report. DOE subsequently provided formal written comments with its views on the general thrust of our report. (See app. I.)

CHAPTER 2

DOE'S DRAWDOWN CAPABILITIES ARE UNCERTAIN AND NEED FURTHER TESTING

DOE has not conducted a full-scale test to assess its ability to successfully withdraw oil from all five SPR storage sites. Instead, it has relied on several other activities to determine that design drawdown criteria will be met at successive stages of site completion. These activities include (1) computer model simulations of site-specific drawdown capabilities, (2) cavern-leaching operations at the phase II sites, and (3) selected test oil withdrawal exercises.

We reviewed these three activities to see how well they supported DOE's assessment that the SPR would be able to meet its phase II design criteria. We noted that while these activities provide DOE some assurance, each activity has its limitations.

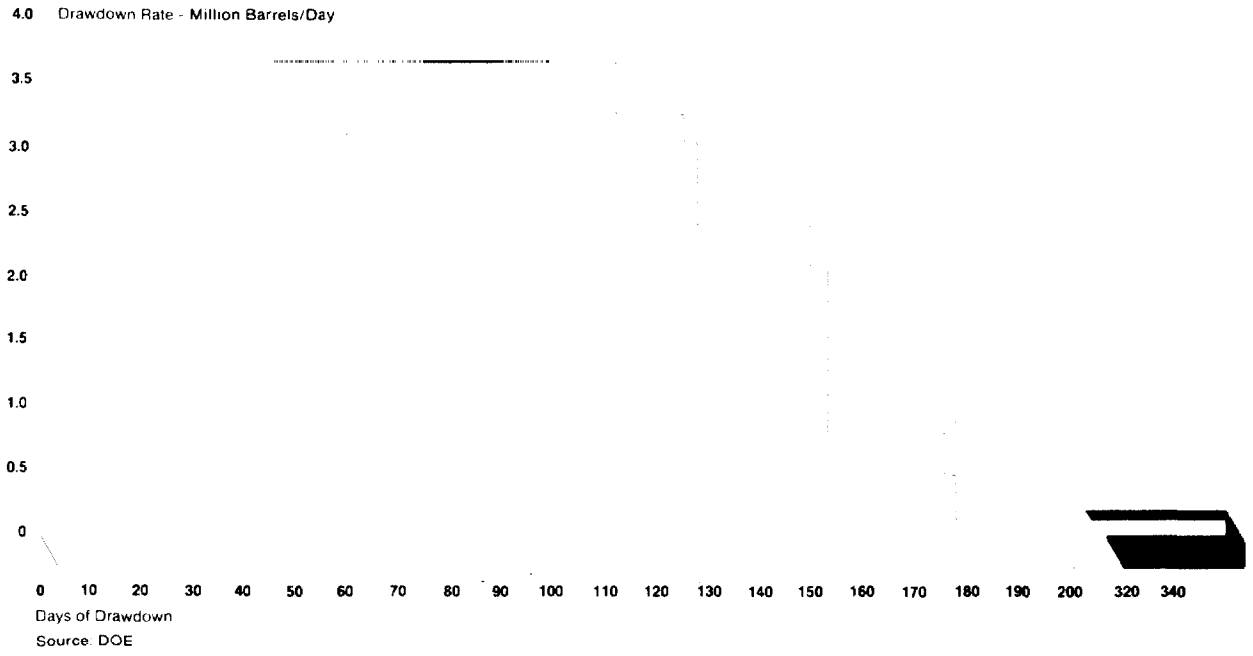
DOE officials plan to minimize or remove these limitations by making modifications/repairs to the drawdown system components at each storage site so that they will operate at design performance levels when phase II is completed. We agree that these actions are needed, but believe they should be accompanied by rigorous tests of the system and components to the extent practicable under conditions comparable to actual drawdown.

COMPUTER SIMULATION SHOWING THAT THE DRAWDOWN RATE COULD BE SUSTAINED REQUIRES OPTIMISTIC ASSUMPTIONS

DOE developed a computerized site operations planning model that simulates SPR site operations during oil fill or drawdown under varying assumptions about site conditions such as equipment availability, oil inventory levels, piping configurations, and oil withdrawal rates. DOE has used the model to simulate the drawdown rate that would be sustained when phase II is completed in 1987, and all of the equipment is operating according to design specifications.

The results of this simulation show that when the individual rates projected for each site are combined, the SPR meets the design drawdown rate of 3.5 million barrels per day for 107 days. During the 107-day period, about 384 million barrels, or about 70 percent of the oil in storage, would be withdrawn. After 107 days, the drawdown rate starts to decline rapidly as the inventory at various sites is depleted. (See fig. 2.1.)

Figure 2.1: SPR Phase II Drawdown Capability



Source: DOE

The model used to project the phase II drawdown rates assumes that currently needed modifications to equipment and facilities have been completed. Among these are pump and piping modifications at the storage sites; converting cavern piping to drawdown configuration; and distribution system enhancements at Bryan Mound which, in addition to replacing and upgrading distribution capability, allow simultaneous withdrawal of two types of crude oil.

The model also assumes that all equipment operates at designed performance levels. DOE is planning to make changes to meet these conditions. We believe, however, that the assumption reflects an ideal situation, which may be difficult to achieve and/or sustain under actual operating conditions and may produce a higher level of confidence than is warranted. Chapter 3 discusses a number of technical problems facing DOE in assuring that the drawdown systems operate as designed. For example, DOE has had continuing problems with the submersible pumps at the Weeks Island site that have affected their capability to operate at design levels even though they have had only a few hundred hours of operating time. In addition, we noted that silt buildup around the raw water intake structure at Bryan Mound has been a continuing problem affecting pump performance. While DOE has taken steps to resolve this problem, it is possible that silt buildup may recur when the larger volumes of water needed for drawdown flow through the intake system causing an unanticipated strain on the pumps. Further, we pointed out that DOE has not

resolved the question raised by its architect/engineer contractor concerning the integrity of on-site piping and has no current plans for further action.

Extensive effort will be required by DOE to identify and correct the system deficiencies that could prevent the SPR from operating at design levels. While we believe this can be done, periodic tests that stress the capability of the system and its components need to be a part of the effort to achieve and maintain a high degree of confidence in the SPR.

LEACHING EXPERIENCE PROVIDES SOME EVIDENCE OF DRAWDOWN SUSTAINABILITY

With the exception of the Weeks Island SPR storage site--which uses submersible pumps to lift the oil out of the mine area--the withdrawal of oil from the cavern storage areas is dependent on a sustained flow of water at rates generally equivalent to the oil drawdown rate. DOE officials have stated that equipment performance during the cavern-leaching process (see fig. 1.1, p. 3) shows that a drawdown at design rates can be sustained. Their position is that the high reliability levels of the equipment used to supply the raw water for leaching, which is the same as that used for drawdown, have allowed the equipment to be available for use more than 95 percent of the time (at least during the period December 1983 through November 1984) indicating the SPR's ability to sustain design drawdown rates.

We examined the cavern-leaching program at the two largest SPR sites--Bryan Mound and West Hackberry--during the period April 1982 through December 1984 to ascertain the validity of DOE's assessment. Our analysis did not attempt to verify a 95-percent or greater equipment availability record, but did show that with few exceptions, DOE has maintained a reasonably consistent leaching operation at the two sites during the 33-month period covered.

Our analysis also showed, however, that the high levels of equipment availability during leaching do not fully indicate that the same availability levels will be sustained during actual drawdown operations. The lesser quantities of water needed for leaching provided (1) a greater redundancy of equipment and (2) less load on the pumps than is likely to occur when withdrawing the oil. For example, the West Hackberry site has four water intake pumps, each with a rated performance capacity of about 500,000 barrels of water per day. During the period reviewed, water requirements for leaching averaged 900,000 barrels per day or less. At this level of operation, the output of two of the four pumps should have been more than adequate for leaching requirements at any time. This leaves two pumps as spares and provides a high level of pump availability. During drawdown, however, DOE will need nearly 1.5 million barrels of water per day at West Hackberry to achieve the site design drawdown rate of 1.4 million barrels of oil per day. This requires the full output of three pumps on a sustained basis, leaving only one spare pump.

In addition to equipment redundancy, the pumps are not necessarily run at capacity levels during leaching. While the water quantities needed at Bryan Mound for leaching were about the same as at West Hackberry (900,000 barrels per day or less), the lower output level of the pumps (about 390,000 barrels per day) required the use of three of the four pumps about half of the time during the 33-month review period--usually at 75 percent or less of their full output capacity. A drawdown at design rates for Bryan Mound will require the sustained performance of three pumps at nearly full capacity to reach the required 1.1 million barrels of water per day with the fourth pump left in reserve.

DRAWDOWN TESTS DEMONSTRATED THAT OIL CAN BE WITHDRAWN BUT WERE LIMITED IN SCOPE

DOE has conducted a number of 1-day tests to show that oil can be withdrawn from the SPR. These tests have helped to make DOE confident that the SPR will be able to meet the phase II drawdown rate. While the tests met their objectives, DOE had to use more equipment than anticipated in two of the tests to achieve these objectives. Additionally, although the appropriate duration of a test that would stress the system has not been defined, engineers familiar with the SPR or comparable oil industry equipment have indicated that a 5- to 7-day test would appear to be reasonable. Consequently, although the 1-day tests showed that oil can be withdrawn from the SPR, they provide limited confidence that the SPR will be able to achieve its design drawdown goals.

DOE conducted its first oil withdrawal test at the West Hackberry site on February 27-28, 1980. The test was conducted at the request of the Secretary of Energy to demonstrate the readiness and capability to withdraw oil from storage at the phase I drawdown rate of 402,000 barrels per day. Although the test was not run for a full 24-hour period, DOE reported that the oil was withdrawn at a 448,000-barrels-per-day rate.

A second test was conducted 2 months later, on April 22-23, 1980. This test, Operation Quick Draw I, was planned to demonstrate SPR capabilities to withdraw and move crude oil simultaneously from three sites--Bayou Choctaw, Bryan Mound, and West Hackberry--at phase I rates. During Operation Quick Draw I, 1.273 million barrels of oil were withdrawn from storage during a 1-day period. This exceeded the combined phase I rates of the three sites by 244,000 million barrels.

The Sulphur Mines and Weeks Island sites were excluded from Operation Quick Draw I because they did not contain oil at the time. Although both sites have been filled with oil since 1983, neither has been comprehensively tested, i.e., operated at design rates for a specified time period under controlled conditions. The Sulphur Mines site has not been tested because DOE does not consider the site suitable for more than a single drawdown. Each time oil is withdrawn from a cavern, the water that is injected to

replace the oil dissolves salt from the cavern walls and enlarges the cavern. Most SPR caverns are designed to be drawn down up to five times. At Sulphur Mines, however, because of the proximity of the caverns to each other and to the edge of the salt dome, DOE is concerned that the caverns may grow together or break through the salt dome if oil is withdrawn more than once. Weeks Island has not been comprehensively tested because DOE has relied on the periodic withdrawal of oil from the site while exercising the equipment and cleaning the Weeks Island-St. James terminal pipeline.

DOE noted in its technical comments on our draft report that it believes a comprehensive drawdown test is necessary and that it is planning such a test demonstration at the Weeks Island and other SPR sites during fiscal year 1986.

In July 1983 DOE conducted another oil withdrawal test at Bayou Choctaw in response to a request from DOE's Inspector General. The Inspector General wanted to assess whether there were any technical reasons why the site's mechanical systems would not perform reliably during a withdrawal of oil. The objective of the 1983 test at Bayou Choctaw was also the phase I rate of 240,000 barrels per day. During the test 259,000 barrels of sour oil were withdrawn and moved to the St. James terminal. The DOE Inspector General's report on the exercise, Drawdown Reliability of the Bayou Choctaw Site on the Strategic Petroleum Reserve, dated September 28, 1983, stated that the pumps, valves, and piping were adequately designed to support the phase I drawdown rate but that DOE might have problems reaching the phase II rate of 480,000 barrels of oil per day. The report cited a need for piping modifications, additional pumps, well modifications, and additional cavern capacity. The report also pointed out that the single pipeline to the St. James terminal limits the drawdown to one type of oil at a time. The SPR project manager told us that work plans are being prepared for the changes noted in the Inspector General's report and that DOE expects to achieve the phase II capability of withdrawing 480,000 barrels per day of either type of oil from Bayou Choctaw when phase II is completed.

DOE continued testing the SPR oil withdrawal capability by conducting separate 1-day tests using phase II caverns and equipment at the Bryan Mound site in November 1983 and at West Hackberry in February 1984. DOE did not, however, attempt to meet individual phase II drawdown objectives at the sites. According to DOE, although the mechanical equipment needed to meet phase II drawdown levels was in place at the sites, cavern piping and pump configurations precluded attempts to achieve design rates even for the short duration of the tests. At both Bryan Mound and West Hackberry, the cavern piping was set up for leach/fill operations. As illustrated in figure 1.1, this reduces the space in the piping through which the oil can flow out of the caverns. After leaching is completed and the caverns are filled with oil,

the pipes in the caverns will be changed to allow a less restricted oil flow so that the rate at which oil can be withdrawn will increase.

Withdrawal rates were further restricted by site-specific conditions at West Hackberry. Shifting from the leach/fill mode to the drawdown mode at the site requires changing certain pump parts to increase the flow of water into the caverns and converting part of the brine disposal system used in leach/fill operations to carry oil. If these components were used in a test, complete cleaning of pumps and piping after running oil through them would be required to preclude contaminating the brine that is sent to the Gulf of Mexico for disposal once the leach/fill operations resume. DOE decided not to make the conversions for the 1-day oil withdrawal test. DOE also had to limit oil withdrawal for the West Hackberry test to selected phase II caverns because the piping in the phase I cavern with the same type of oil was not designed to withstand the higher pressure required to move the oil out of the phase II caverns while they are in the leach/fill mode. Table 2.1 provides data on the three oil movement exercises.

Table 2.1

Results of Oil Movement Exercises From Bayou Choctaw, Bryan Mound, and West Hackberry

Site	Test date	Drawdown rate objective	Drawdown rate achieved	Drawdown objective achieved
		(millions of barrels)		(percent)
Bayou Choctaw	July 11-12, 1983	0.240	0.259	107.9
Bryan Mound	Nov. 3-4, 1983	.900	1.007	111.9
West Hackberry	Feb. 28-29, 1984	1.000	1.053	105.3

As discussed in more detail in chapter 3, during the tests at both Bryan Mound and West Hackberry, DOE had to use more equipment than originally expected to meet the test objectives. During both tests an additional raw water pump had to be used to achieve the test results; at Bryan Mound, this involved using the inplace spare pump.

As a result of its tests of oil withdrawal capability, DOE has shown the ability to draw down about 2.3 million barrels of oil per day during separate 1-day exercises. As additional caverns are completed, filled, and prepared for drawdown, DOE expects to increase this amount. However, how much additional oil can be obtained from these sites, as well as the amounts that can be withdrawn from the untested sites, still remains to be demonstrated.

DOE COULD CONDUCT TESTS AT THE PHASE II DRAWDOWN RATES

The withdrawal tests conducted at three of the SPR sites were designed to demonstrate that site equipment could withdraw oil. They were not intended to demonstrate that the three sites can achieve the drawdown rates that would be required for a phase II drawdown or to show that drawdown rates could be sustained.

Project office officials told us that the tests were conducted at the rates discussed above and for 1 day because oil inventories were not adequate at the time of the tests to achieve higher rates and ongoing leaching activities would be disrupted if the test exceeded 1 day. DOE now is in a better position to test the SPR at the phase II drawdown rate because the oil inventory at all sites, except Bayou Choctaw, is adequate to test the design rate; and phase II leaching activities are completed or nearly complete at all sites except West Hackberry. (West Hackberry, however, has enough oil in storage to enable the phase II drawdown rate to be tested.) While DOE should be able to test each site (except Bayou Choctaw) at its design rate, the duration of such tests would be limited by DOE's ability to store or sell the oil withdrawn. During an actual drawdown, the rates at which oil can be withdrawn from storage will depend primarily on three factors: (1) the ability to physically remove the oil from storage facilities, (2) the rate at which oil can be moved through distribution facilities (marine terminals and pipelines), and (3) the rate at which buyers will accept the oil.

We discussed the costs, limitations, and expected benefits of various SPR testing scenarios in a May 1985 report.[1] We pointed out that to provide maximum confidence in the reliability of the total SPR system, it should be tested at either design capacity or the maximum capacity permitted by the conditions existing at the time the test is conducted (i.e., the capacity allowed by the oil inventory and ongoing leaching activities). Although there is no defined time period that the SPR should be operated to test system reliability, engineers familiar with the SPR or with equipment comparable to that used by the SPR have indicated that a 5- to 7-day test appears reasonable. We reported that a test at current drawdown/distribution rates could be run for that time period. We noted that tests that include oil sales would be more costly than tests that move oil from the SPR sites to temporary storage facilities and return it to the sites at the conclusion of the tests. We also noted that test costs increase in direct proportion to the quantity of oil withdrawn. While storage-oriented tests and those involving small volumes of oil are less costly, they do not provide the same opportunities to assess the SPR system as tests that involve oil sales and higher oil volumes.

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[1] Analysis of Oil Withdrawal and Distribution Tests for the Strategic Petroleum Reserve (GAO/RCED-85-115, May 8, 1985).

We noted that even though the SPR distribution facilities currently are limited to a through-put capacity of 2.3 million barrels per day, a test could be designed that would stress the SPR drawdown capacity. Such a test would involve storing some of the oil in tanks at the SPR marine terminals while the remaining volume withdrawn is loaded onto ships or barges or distributed by pipelines. We noted that a test that uses a combination of sales and storage and the maximum volumes of oil that can be withdrawn and distributed could minimize the limitations of a storage-only test, reduce the costs associated with a sales-only test, and stress the drawdown capabilities of the SPR equipment.

LEGISLATIVE ACTIONS AFFECT SPR TESTING

The Energy Policy and Conservation Amendments Act of 1985 (Public Law 99-58) extended the SPR authorization until 1989 and also provided for a SPR drawdown and distribution test. The legislation provides for a test through the sale or exchange of about 1.1 million barrels of crude oil from SPR storage within 180 days after passage of the act. Although the intent of the drawdown excercise is to test the bidding and purchasing process for the oil, we continue to believe that in order to test the total reliability of the SPR system, it should be tested at either design capacity or the maximum capacity permitted by conditions existing when the test is conducted.

Because the requirement for an SPR test was contained in legislation recently enacted, funds for its execution were not included in the fiscal year 1986 budget submitted to the Congress. As a result, DOE submitted to the cognizant congressional committees on September 17, 1985, a request to reprogram about $500,000 of appropriated funds for this purpose. Pending approval of the reprogramming action, DOE officials are proceeding with preparations for a test sale of oil as required in the Energy Policy and Conservation Amendments Act.

CHAPTER 3

SPR DRAWDOWN CAPABILITY UNCERTAIN BECAUSE OF PIPING AND EQUIPMENT PROBLEMS

Technical and operational problems in key SPR components and systems raise uncertainties about DOE's ability to sustain a drawdown at the design rate. These problems occurred because of poor project management procedures during the early years of the SPR development. They persisted because, until recently, DOE concentrated its efforts on developing storage capacity and filling the SPR instead of correcting these problems. We found that

--some drawdown-critical piping is restricted by marine growth or has been damaged by corrosion,

--the integrity of the piping at the SPR sites and its ability to withstand drawdown pressures is questionable because poor project management procedures existed at the time the piping was installed,

--pump failures at the Weeks Island site raise questions about their reliability, and

--potential drawdown-related problems exist because DOE did not devote adequate attention to maintenance and had problems in developing and implementing logistics support and automated control systems.

During 1984 DOE focused its attention on resolving problems such as those listed above that could affect the SPR drawdown capability and initiated corrective actions in a number of areas. However, until these problems are resolved, DOE's ability to successfully sustain a drawdown at the phase II design rate will remain uncertain.

PIPELINE RESTRICTIONS AND CORROSION MAY AFFECT DRAWDOWN CAPABILITY

Restrictions and/or corrosion in certain drawdown-critical pipelines may affect DOE's ability to sustain a drawdown at the design level. These pipelines are used to move raw water from its source to the sites to flush oil from the caverns and to move the oil from the sites to the distribution terminals. We found that marine growth and debris in the raw water pipelines at Bryan Mound and West Hackberry restrict the flow of water needed for drawdown. We also found that corrosion was occurring in some of the raw water pipelines and in the Bayou Choctaw-St. James oil pipeline. Although DOE was aware that these problems existed, it took up to 2 years to initiate actions to determine the extent of

the problems. Additionally, DOE did not try to determine whether similar problems exist in other SPR pipelines until late 1984.

Debris and marine growth restrict water flow at Bryan Mound

The Bryan Mound raw water intake structure, which is located on the Brazos River, has four pumps, each with separate intake bays. A 36-inch-diameter raw water pipeline extends about 1/2 mile from the intake structure to another set of pumps located on-site. River water is drawn through a series of screens that prevents large pieces of debris and marine life from reaching the intake pumps.

According to the SPR Project Manager, the primary problems with the raw water pipeline are marine growth (small shellfish) and the presence of loose shells, sticks, and other debris that accumulate at the water intake screens and within the pipeline. He said that the marine growth and debris restrict the water flow and adversely affect pressure levels in the pipelines. This reduces the quantity of oil that can be drawn down. The Project Manager also stated that silting conditions near the intake bays place a heavy burden on the screens and require frequent back-flushing operations. To alleviate the silting and debris problem, DOE has instituted a program to periodically clean the intake bays and plans an engineering change to modify the approach channel leading to the intake structure.

The engineering change, however, would not eliminate marine growth and sedimentation in the raw water pipeline. Mechanical cleaning of the pipeline to remove the marine growth is required; but this involves extensive piping modifications to install the mechanisms needed to allow the cleaning tool to be inserted and removed from the pipeline. Such modifications have not been made and currently are not planned. Chemical inhibitors to limit this growth are not used on the raw water pipelines because of environmental concerns. DOE flushed the pipeline in June 1983 but flooding of the area adjacent to the pipeline limited the effectiveness of this procedure. DOE plans to make piping changes that will provide a permanent capability to flush this line into the site brine pond when cleaning is needed. This will eliminate the flooding problem and allow the pumps to run longer so that more of the debris can be flushed from the line. Although operating records confirmed that the flushing operation results in improved pressure readings and water flow, it does not remove the marine growth. However, in the July 29, 1985, meeting, DOE officials said that the marine growth will not adversely affect the water flow and the changes made or proposed will allow the site to meet its oil drawdown design rates.

The importance of correcting the water problem was highlighted by conditions noted during the October 1983 test drawdown exercise and our subsequent analysis. During the test,

DOE started with three raw water pumps as the site design calls for, but within a few hours the fourth pump, which was designed to be reserved as an inplace spare, had to be started to maintain adequate pressure and water flow into the caverns to sustain the test objectives. (See table 2.2.) According to DOE, the extra pump was needed because the water level at the intake structure was low during the test period and because silt accumulation in the raw water intake channel restricted the water flow.

Our analysis of subsequent water flow at the Bryan Mound site indicated a continuing water flow problem. We analyzed the pump performance data for the October through December 1983 time period and noted that DOE needed three or four pumps for much of the period to meet the water requirements for leaching--which, on the average, uses less than the rated capacity of three pumps. DOE officials told us that the fourth pump was frequently needed because of low water levels and silt problems that limited the pump output.

DOE provided data in its technical comments on our draft report that indicated its efforts to resolve the silt problem have improved the water flow. During the first 12 days in June 1985, only two pumps were used to provide an average of 731,000 barrels of water per day for leaching. The data did not substantiate the sustainability of this rate, however, since three pumps were used for the remainder of June and July 1985 even though lesser quantities of water were actually pumped. We noted that this action effectively reduced the output of each pump to about 55 percent of its design performance level. The Bryan Mound site operations chief told us that the third raw water pump was needed during that particular period to increase the pressure of the water going into the caverns rather than to increase the volume of water being pumped.

DOE's efforts to alleviate the silting problems have resulted in some improvement in water flow, and the planned changes to the water intake channel appear to offer additional improvement. The silting problem may also have been alleviated to some extent because the quantities of water pumped for leaching since DOE began its silt-containment effort in 1984 have been generally lower than the quantities pumped during 1983. Also, leaching has required only about two-thirds of the quantity that will be pumped during drawdown. The effectiveness of DOE's efforts to resolve the silt problem will, therefore, remain uncertain until all of the planned improvements are completed, the raw water pumps are run at the higher drawdown rates, and the amount of silt buildup at higher water flow volumes is determined.

The West Hackberry water flow is affected by restrictions and corrosion

Raw water and corrosion problems exist at the West Hackberry site. The West Hackberry 42-inch-diameter raw water pipeline extends 4.5 miles from the intake structure on the intracoastal waterway to the site. As with Bryan Mound, the water is filtered

through screens into four intake pumps, one of which is also designated as a spare. Although this system empties into on-site ponds--which allows for a continuous flushing action--this pipeline also experiences marine growth and sediment collection and requires occasional mechanical cleaning to be capable of flowing the volume of raw water required to support drawdown. However, temporary equipment must be installed each time to allow the mechanical cleaning tool to be inserted into the pipeline. The pipeline was last cleaned in September 1982 when some silt and scale were removed during a site shutdown. DOE is constructing a permanent mechanism that will facilitate its cleaning capability and expects this work to be completed by September 1985.

In April 1983 a chemical company independently performed an internal corrosion survey on the West Hackberry raw water pipeline. This survey indicated that severe internal corrosion was occurring. The company's analysis of intake and discharge water showed that iron concentrations of up to 1,800 pounds were being lost to corrosion each day. The company estimated that the life expectancy of the raw water pipeline was less than 10 years and that the replacement cost of a 5-mile, 42-inch-diameter pipeline was about $8 million.

DOE project office officials disagreed with the study's conclusions about the rate of corrosion, believing that with such a high corrosion rate, the pipeline would have already failed. They also noted that the chemical corrosion inhibition program suggested in the study would cost about $1 million a year. However, DOE did not base its assessment on a separate study or analysis.

As it did at Bryan Mound, DOE's test drawdown exercise at West Hackberry pointed out the seriousness of the raw water supply problem. When the West Hackberry site was tested in February 1984, we noted that although two of the four raw water pumps should have been capable of supplying enough water to meet the test objective of 1 million barrels of oil per day and that the plans for the exercise called for the use of two pumps, a third pump was turned on 35 minutes into the test and ran throughout the 24-hour exercise. Measurements taken by DOE's contractor of the raw water reservoir[1] showed that the water level declined to nearly one-half of the starting level. This indicates that even three raw water pumps could not move enough water from the intracoastal waterway into the reservoir to sustain a 1-million-barrel drawdown rate for very long. According to DOE, silt and marine growth in the raw water pipeline caused the reduced water flow, and they expect that when the permanent cleaning mechanism is installed, the site will be capable of withdrawing oil at its design rate. In their technical comments, DOE also stated that larger impellers will be installed in the raw

[1]At West Hackberry, water is pumped from its source into a reservoir on the site and then pumped into the caverns.

water pumps and this will increase water flow to the required levels with three pumps.

Corrosion exists in the Bayou Choctaw-St. James oil pipeline

In November 1983 a DOE contractor conducted a corrosion analysis of the 37-mile, 36-inch-diameter crude oil pipeline between the Bayou Choctaw site and the St. James terminal. An electronic corrosion detection tool sent through the pipeline revealed some degree of corrosion in about 20 percent of the 5,000 joints in the pipeline. Specifically, the inspection detected 790 joints of pipe with corrosion penetration between 15 and 30 percent of the pipe wall thickness, 146 joints with penetrations between 30 and 50 percent, and 17 joints with penetrations exceeding 50 percent. According to the report, oil that was left stagnant in the pipeline for about 2 years was the main suspected cause of the corrosion. Although the inspection indicated that the corrosion has stopped, the contractor concluded that the high degree of corrosion found could cause failure under drawdown pressures in the sections with more than 50 percent corrosion. To confirm the integrity of this pipeline, DOE has decided to pressure test the pipeline by the end of fiscal year 1985 and to replace sections that fail.

Results of DOE's corrosion-testing program are mixed

At the time of our audit work in mid-1984, DOE had not determined the condition or rate of corrosion occurring in the raw water pipelines or the rate of corrosion in on-site piping at any of the sites. The raw water pipelines and on-site piping have been in place for varying periods of time going back to 1977, when construction of the SPR began. In September 1984, DOE initiated a program to install corrosion-monitoring coupons (strips of metal similar to the pipe material) in all pipelines to determine the rate of corrosion. On July 26, 1985, DOE provided us with preliminary data from the corrosion-monitoring program.

The corrosion rate data, interpreted in accordance with National Association of Corrosion Engineers standards, indicate that the raw water intake and on-site raw water piping at Bayou Choctaw are experiencing only low to moderate rates of corrosion. No data on the on-site crude oil piping were available. The raw water intake piping to the caverns at Sulphur Mines appears to be experiencing an increasing rate of corrosion, as indicated by the coupons. The data show corrosion in the severe range (5-10 millimeters) of the standards. The raw water intake piping to the Sulphur Mines fire water tank also appears to have had severe corrosion readings. To illustrate severe corrosion, the raw water piping to the fire water tank at Sulphur Mines has a wall thickness of 280 mills. The latest coupon data for this line show

annual corrosion between 8 and 12 mills per year. Corrosion at this rate would reduce the wall thickness by one-half of the original size within 14 years.

The raw water intake piping at both Bryan Mound and West Hackberry are, according to the coupon data, experiencing severe to very severe corrosion. Data for on-site, raw water piping at Bryan Mound show very severe corrosion on piping to one cavern. This corrosion rate, about 19 mills per year, would completely corrode the pipe in about 20 years. The corrosion tests at the West Hackberry raw water line tend to support the corrosion survey results discussed earlier. Coupons in the segment of the line nearest to the raw water intake pumps show an average corrosion rate of 25 millimeters/year, based on 10 individual readings taken over a several-months period.

DOE has not yet determined the full significance of the coupon data nor the full extent of any prior corrosion. SPR engineers plan to continue the coupon-testing program, since less than 1 year of data is available, before any piping systems are replaced.

In its technical comments, DOE disagreed with our concerns about the pipeline intregrity and its ability to withstand drawdown pressures. DOE stated that all pipelines were built to industry standards and were adequately protected against corrosion. Further, DOE stated it has an on-going corrosion-inhibiting program.

We agree that DOE currently has a corrosion-inhibiting program for its pipelines which is protecting the pipelines from further corrosion. We found, however, that the contractors that constructed the pipelines did not always implement the required corrosion protection measures as soon as the pipelines were completed, and the potential effects of this deficiency precipitated our concerns.

INTEGRITY OF SPR PIPING REMAINS QUESTIONABLE

In addition to the concerns raised by the piping restriction and pipeline corrosion problems, there are other uncertainties about piping integrity that stem from poor project management practices during the early days of SPR development.

At that time, pressure came from the administration and the Congress to store oil in the SPR as quickly as possible. Oil imports were still increasing, and a high level of concern was expressed over the potential adverse economic impact of an oil supply disruption. To expedite oil storage, DOE decided to accelerate the design and construction of the SPR and put the program on a "fast track" basis. Although a fast track approach can be an acceptable project management technique when necessary, its use should be accompanied by an increased level of management

attention to the project and a sound quality assurance program to ensure that equipment and systems are installed and will operate as they are designed. However, during the time when a majority of the SPR equipment and piping was purchased and installed, the quality assurance program was not being effectively implemented.

The Defense Contract Administration Services (DCAS) was responsible for monitoring contractor activities for quality assurance purposes under a 1977 interagency agreement. However, according to the project office quality assurance director, DCAS was not authorized to direct the contractors to correct deficiencies that were found. DCAS could only report the deficiencies to DOE for corrective action. At the time, DOE did not have a quality assurance staff and consequently did not follow up on the DCAS efforts to ensure that quality work was being performed by the contractors.

Because the quality assurance program was not effective when on-site piping was installed, questions remain about their capability to withstand a drawdown. Concerns about the integrity of piping welds and fittings raised by two DOE contractors illustrate the uncertainties that still exist.

The integrity of some welds is uncertain

In 1979 Aerospace Corporation, DOE's system engineer, reported on quality assurance activities at West Hackberry, Bryan Mound, and Weeks Island. Aerospace identified a number of quality assurance problems with the phase I work at these sites. It reported that work had not been properly inspected, inspection and testing documentation was missing, and compliance with established procedures had been waived by contractor and DOE officials. Aerospace also concluded that the integrity of pipe welds was questionable because inspection and testing documentation was inadequate or missing. The report also concluded that inspection procedures caused some of these problems and needed to be improved. The report noted that x-rays of the welds were defective or missing, welds with known defects had been approved, and evidence that defective welds had been corrected was insufficient. Many of the welds are on buried piping, which makes after-the-fact determinations of piping integrity difficult. We could find no evidence that DOE took action on the Aerospace report.

Subsequently, in a March 1984 report, DOE's Inspector General reviewed documentation for pipe welds at Bryan Mound. The Inspector General reported that the quality of documentation made during early construction by former contractors ranged from poor to good and that some documentation could not be interpreted. In addition, the Inspector General reported that welds made in 1982 and 1983 by the operations and maintenance contractor were unsatisfactory and recommended that a more complete review be

performed. In August 1984, at DOE's direction, the operations and maintenance contractor initiated the necessary corrective action (primarily, replacement of on-site piping with defective welds) on the 1982 and 1983 welds that the Inspector General identified. However, DOE's instructions did not include work done by other contractors, and additional actions were not taken to review the welds made by other contractors prior to 1982.

The adequacy of certain pipe fittings has been questioned

In 1980 DOE's architect/engineering firm, Jacobs D'Appolonia Engineers (JDE), reported that a review of design specifications indicated that pipes and fittings with differing wall thicknesses may have been used in parts of the piping systems at four SPR sites and that the fittings with thinner walls might not be strong enough to hold up over the life of the SPR program under the pressures that they would experience. In 1981 Aerospace Corporation, another DOE contractor, conducted an independent review of the adequacy of piping at the West Hackberry site. Aerospace also reported that the adequacy of pipe fittings was questionable.

DOE subsequently authorized its operations and maintenance contractor to measure the wall thicknesses of fittings at West Hackberry. After examining selected above-ground fittings, the contractor concluded that they generally adhered to the design specifications and that it was not necessary to examine the fittings on buried piping. In April 1984 DOE requested additional information from JDE on the piping situation. JDE maintained its position that the adequacy of the fittings was still questionable because buried fittings had not been examined. JDE stated that there was no way of determining the adequacy of these fittings without further examination or testing. This matter still had not been resolved when our field work ended.

DRAWDOWN RELIABILITY OF WEEKS ISLAND PUMPS IS QUESTIONABLE

The Weeks Island site was designed to sustain a drawdown rate of 590,000 barrels per day, but its ability to accomplish this is uncertain. The Weeks Island site is in sharp contrast to the rest of the SPR. It is the only mechanically excavated storage area in the SPR and is the only site where the oil is withdrawn by submersible pumps rather than injected water. The submersible pumps lift the oil from the mine storage area to the surface, where it is transferred to the St. James terminal by pipeline. However, some of the submersible pumps have failed after relatively few operating hours. DOE has initiated a comprehensive inspection/repair program for all pumps, but the pump failures raise questions about the site's reliability to sustain oil delivery at design drawdown rates.

At the other SPR sites, DOE has had an opportunity to gain experience with and develop some understanding of the equipment reliability. At Weeks Island, however, the 11 submersible pumps were installed after the mine area was filled with oil. The operations and maintenance contractor reported in a quarterly Reliability Report that because the pumps were held in storage before they were installed and proper start-up and break-in procedures were not followed after the pumps were installed, a number of pump problems had occurred. Additionally, the report indicated that these pumps were out of warranty when start-up testing began, so limited assistance was provided by the manufacturer.

Since the site fill activities were completed, the pumps have received little use. They have been run for a few hours each month to recycle oil out of and back into the mine, and for longer periods several times each year, when oil is pumped from the site to the St. James terminal during pipeline-cleaning exercises. We noted, however, that even though the pumps have had limited use, the site maintenance records showed that the pumps have had a number of problems such as excessive bearing wear, bent pump shafts, misalignment of pump impellers with the pump casing, and parts failures. Submersible pumps are not commonly used in oil industry operations, so spare parts replacement has been a problem. The operations and maintenance contractor's Associate Director of Maintenance pointed out that pump repair and overhaul time had averaged 6 months in the past because of the spare parts problem. The contractor, however, now has one spare pump and motor on hand.

One example of the problems experienced with these pumps involves the failure of the adapter plug on two of the pumps. The adapter plug failed on one pump as it was being removed from the cavern for repair and on another pump while it was being tested after other repairs. The two failures indicated a weakness in the design. In June 1984 DOE decided to increase the size and material strength of the adapter plug for all of the pumps. In addition, the operations and maintenance contractor plans to have the remaining nine pumps inspected and repaired as necessary--one pump/motor combination at a time. However, the pumps' location in the mine chamber also makes it difficult to remove them for repair. Mechanical problems with the overhead crane that is essential in pulling the pumps out of the mine chamber area have delayed the repair process. The crane repair was completed in March 1985, and the first pump was pulled out of the mine and sent to the repair contractor in early June 1985.

The Associate Director also stated that limited head room in the mine chamber requires that the pump and motor be disassembled before removal and reassembled in the mine after repairs are completed. This can take several days. According to the contractor official, this procedure adds to the time a pump is out of service and increases the probability of continuing problems because of errors made during reassembly.

The contractor estimates the cost of repairing all nine pumps at $200,000, if other problems are not found during teardown and inspection. DOE expects to establish a 60-day repair cycle for the remaining nine pumps. Under this schedule, the pump repairs are expected to be completed by late 1986.

MAINTENANCE AND SYSTEMS DEVELOPMENT PROBLEMS AFFECTED DRAWDOWN READINESS

Because of the emphasis that was placed on filling the SPR and the management problems that existed during the early years of the SPR's development, equipment maintenance has not been adequate. The development and installation of logistics support and automated control systems, which are needed to facilitate DOE's readiness for and ability to carry out a drawdown, have also been delayed.

Site maintenance still needs improvement

The October 1983 Oak Ridge baseline assessment report pointed out that serious maintenance problems existed at the SPR sites and concluded that without an increased emphasis on maintenance, some loss of drawdown capability could be anticipated. In response to the report's recommendations, the project office has taken actions to improve site maintenance and to reduce the backlog of maintenance work needed at the sites. However, when our field work ended, the project office had not achieved its goal of reducing the backlog of corrective maintenance work to less than 30 days (±10 days) at each of the sites.

In its technical comments, DOE agreed that its goals had not been achieved. DOE stated, however, that it could accomplish all essential drawdown-related maintenance work within 30 days and thus the maintenance backlog would not affect its drawdown capability.

Development of logistics support and control systems has been slow

DOE has had problems in completing an integrated logistics support (ILS) system for the SPR. An ILS system should be developed during the initial design of a project so that maintenance and spare parts requirements can be established and decisions can be made as to potential trade-offs between operational and support requirements. We reported in April 1984[2] that DOE did not initiate work on an ILS system until 1980 and that because of deficiencies in its controls over the

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[2]Additional Improvements Needed in Logistics Support for the Strategic Petroleum Reserve (GAO/RCED-84-12, Apr. 13, 1984).

responsible contractor, the system still had not been completed. During 1984 DOE continued to work on the ILS system, but said during September 1984 hearings[3] that the system's data base would not be sufficient to accurately determine spare parts requirements for about 1-1/2 years. Nevertheless, during the past year, spare parts have been acquired for the SPR, which DOE officials believe provide adequate support for drawdown-related operations. In our July 29, 1985, meeting, these officials acknowledge that as additional operating experience is gained, adjustments to the spare parts inventory will probably be necessary.

DOE's historical management problems also resulted in problems in completing an automated instrumentation and control system, which was designed to operate and protect critical field equipment such as pumps, motors, and valves from a central control room at each site. The combination of control room computers and sensory devices on the field equipment was to be used not only to start and stop pumps and open and close valves but also to detect equipment malfunctions and initiate corrective action before serious damage occurred. We discussed cost increases and other difficulties associated with installing the instrumentation and control systems for the Bryan Mound and West hackberry sites at congressional oversight hearings in May 1983.[4] (The instrumentation and control systems at the other three sites were complete or nearly complete at the time.)

DOE continued to experience difficulties in completing the system at the Bryan Mound and West Hackberry sites in 1983 and 1984. At Bryan Mound the field instrumentation was reported to be 97 percent operational as of December 10, 1984. However, the instrumentation still needs to be integrated with the control room equipment. A contract for integration of the control room was scheduled to be awarded in January 1985, with an estimated completion date of April 1986. In mid-January, however, a bid protest was filed, and award of this contract was delayed until May 1985. Contract completion is now scheduled for June 1986.

At West Hackberry, the field instrumentation was reported to be 98-percent operational as of December 10, 1984. The control room work has been completed, and check-out/verification of the automated system was completed in early June 1985. However, planned modifications to the raw water intake system controls extended completion of the system. The work on this last part of the instrumentation and control system is expected to be completed in January 1986.

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[3]Subcommittee on Oversight and Investigations, House Committee on Energy and Commerce, hearings on the SPR (Sept. 24, 1984).

[4]Subcommittee on Environment, Energy, and Natural Resources, House Committee on Government Operations, hearings on financial irregularities at the SPR (May 24, 1983).

CHAPTER 4

CONCLUSIONS AND RECOMMENDATIONS

The Congress authorized the SPR to develop a reliable reserve of crude oil that could be made available to the oil industry in the event of a severe energy supply disruption. DOE designed the SPR to meet specified goals at the end of each of the three development phases. DOE is nearing the completion of phase II, which has a drawdown-rate goal of 3.5 million barrels per day.

CONCLUSIONS

DOE officials are confident that the SPR will be able to meet the design goal, on the basis of the results of a computer model that simulates oil withdrawals, equipment performance during cavern-leaching activities, and selected oil withdrawal exercises. While these efforts provide DOE a certain level of assurance that the SPR will operate as designed, limitations in each effort tend to make them less than fully convincing. For example, DOE's computer-simulated drawdown shows that the phase II drawdown rate of 3.5 million barrels of oil can be achieved. But the simulation's reliability requires that all currently needed pump and piping modifications be completed and all equipment operate at designed performance levels for the duration of the drawdown--conditions that may be difficult to achieve and sustain under actual operating conditions.

DOE's leaching experience has provided a measure of equipment availability and useful input into its modeling efforts for assessing site drawdown capability. We believe, however, that the equipment availability levels achieved during the leaching process may not be fully reflected in a drawdown situation because of the different operating conditions for each activity.

Comprehensive oil withdrawal tests have been limited to three of the five sites, and the drawdown rate objectives have reflected site configurations existing at the time of the tests. Although they met their test objectives, more pumping equipment was used than the test design called for, and the tests were conducted for only 1 day--probably not long enough to adequately test the drawdown systems.

Further, during the early years of the SPR program, DOE did not ensure that equipment specifications and performance criteria were met. As a result, DOE's ability to successfully draw down the SPR at its phase II design level criteria of 3.5 million barrels per day until 90 percent of the oil inventory is depleted is now contingent on DOE's ability to remedy a number of technical and operational problems that exist at the various SPR storage sites. The primary problems relate to the (1) raw

water supply systems at the Bryan Mound and West Hackberry sites, (2) Weeks Island pumps, and (3) uncertainty of piping integrity at the sites.

While DOE stated that it was constrained from achieving the design drawdown rates during its tests at the three sites because site development and oil fill were not fully completed, we believe that raw water supply problems at Bryan Mound and West Hackberry were also major factors in limiting the amount of oil withdrawn. DOE has initiated action at Bryan Mound to clear the silt buildup from the raw water intake channel and plans to make other changes to restrict the silt inflow. Until these changes are made and their effectiveness evaluated, it is uncertain whether the problem has been resolved and that it will not recur.

Because the submersible pumps at Weeks Island have had operating problems and no comprehensive drawdown test has been done at the site, we also believe that DOE's ability to withdraw oil at Weeks Island remains questionable. To assess the reliability of the submersible pumps in the mine storage area and the pumps needed to move the oil to the St. James terminal, the site should be tested for drawdown to the maximum extent possible.

In our view, DOE did not respond adequately to the concerns raised by its engineering contractors about pipeline and piping integrity problems associated with corrosion and the adequacy of welds and pipe fittings. We believe that DOE's actions so far on these problems have not provided a basis for a high degree of confidence that the system can accommodate operating pressures on a sustained basis or that the system will meet its design life expectancy without major repairs or replacements.

As construction of the storage sites progressed, DOE contracted for the development of a logistics support system that would ensure adequate supplies of spare parts necessary for a sustained drawdown period. DOE also began developing--and has nearly completed--automated instrumentation and control systems at each site so that starting and stopping pumps and opening and closing valves in the proper sequence could be computerized. The systems were set up so that protective sensory devices on the field equipment could be monitored and the equipment controlled from a central location. DOE has experienced numerous delays in completing these systems, and they are still not fully operational at all sites. Although these systems are not essential for operating the SPR, their completion will provide a greater degree of confidence that an SPR drawdown can be sustained in a safe manner. Consequently, we believe that DOE should ensure that these systems are completed as soon as possible.

Although storage site maintenance was also neglected under DOE's fast track development methods, progress has been made in reducing the backlog of maintenance activities. We believe, however, that continued management attention will be required to keep the sites in "drawdown-ready" condition.

RECOMMENDATIONS

To ensure that the SPR system has the capability to provide a readily available supply of oil, we recommend that the Secretary of Energy direct the Manager, Oak Ridge Operations Office, to take the following actions:

--Conduct further tests of the SPR that allow an assessment of its capability to meet design drawdown goals while recognizing the trade-off between cost and the level of assurance gained. GAO's prior analyses of various test scenarios can provide some guidance in determining the appropriate duration and type of test to be conducted. (See p. 17.)

--Ensure that measures are taken at all sites to (1) assess the ability of pipelines/piping to withstand drawdown-related pressure levels and (2) protect the pipelines/piping systems from future restrictions and/or corrosion. This should include resolving the concerns raised by the SPR's contractor about corrosion and the adequacy of welds and pipe fittings.

--After making the planned modifications to the Bryan Mound and West Hackberry raw water lines and the intake channel at Byran Mound, test the raw water systems to ensure that drawdown is not limited by inadequate water supplies.

--Ensure that ongoing work on the logistics support and automated control systems is satisfactorily completed and that the systems function as designed.

AGENCY COMMENTS

In addition to the formal comments on a draft of this report as a whole, included in appendix I, DOE provided us additional editorial and technical comments, most of which were discussed with DOE officials at a meeting in New Orleans, La., at the SPR Project Management Office on July 29, 1985. These comments provided updated information, which has been incorporated into the final report where appropriate and resulted in some tempering of our initial concerns about DOE's ability to sustain a design drawdown rate.

In its formal comments, DOE did not agree with the thrust of the draft report, believing that substantial evidence supports a conclusion that SPR design drawdown rates can be achieved and sustained over an extended period. This evidence

is based on (1) computer model simulations of future drawdown capabilities and (2) analyses of site system availabilities. DOE also believes that its leaching experience is a good indicator of the SPR's ability to sustain design drawdown rates but took exception to our use of the cavern-leaching water flow rates as an indication of expected drawdown flow rate capabilities. Further, DOE does not believe that the operational and technical problems discussed would prevent DOE from achieving drawdown requirements.

We agree that DOE's model simulation and system availabilities provide some assurance that drawdown rates can be achieved. However, we noted that the model simulation results require assumptions about future site operations and performance levels that may be difficult to meet and sustain under drawdown conditions. On the basis of the history of problems at SPR sites and the seeming lack of responsiveness by DOE, we are less confident than DOE about its ability to make all the necessary changes and we are less confident that the systems will operate as designed throughout an extended drawdown period as indicated by the model. We also noted that the system availabilities referred to were developed under leaching conditions that were somewhat less rigorous than a full drawdown will impose on the system.

Much of the uncertainty we noted about meeting drawdown requirements focused on the availability of raw water supplies and the performance of the raw water pumps and piping. We recognize that DOE is planning changes to this system, but until the changes are completed and tests are made to ensure that adequate supplies of water will be available on a sustained basis, the uncertainty will remain. We agree with DOE that leach flow rates, as discussed in the draft of this report, are not directly comparable to drawdown flow rates and we have modified this final report accordingly.

Our report does not state that certain operational and technical problems about which we expressed concern will prevent DOE from meeting drawdown requirements but rather that these problems add a degree of uncertainty. We continue to believe that DOE needs to identify all of the potential problem areas, complete corrective action, and test the system to eliminate as many of the uncertainties as possible.

Department of Energy
Washington, D.C. 20585

AUG 12 1985

Mr. J. Dexter Peach
Director, Resources, Community
and Economic Development Division
U.S. General Accounting Office
Washington, DC 20548

Dear Mr. Peach:

The Department of Energy (DOE) appreciates the opportunity to review and comment on the General Accounting Office (GAO) draft report entitled "Strategic Petroleum Reserve Oil Can Be Withdrawn But Site Improvements Are Needed."

DOE does not agree with the thrust of the draft report. The report expresses concerns that the Strategic Petroleum Reserve (SPR) cannot achieve the Phase II design drawdown rate and sustain it over an extended drawdown period. DOE believes that there is substantial evidence to support a conclusion that SPR design drawdown rates can be achieved and sustained over an extended period. Since Phase II of the SPR project, which includes reconfiguration of site equipment and caverns for drawdown operations, has not been completed, the ability to demonstrate Phase II design drawdown rates by way of operational tests is currently limited. However, results of computer simulations of SPR operations based on final site system configurations, combined with analyses of site system availabilities, provide substantial analytic evidence of the capability of SPR sites to meet or exceed drawdown performance criteria.

More than five years of successful leaching and fill operations at SPR sites have provided a good indicator of system reliability and availability, and thus an indicator of the SPR's ability to sustain design drawdown rates since much of the same equipment is used in both modes of operation. However, the GAO's use of the leach flow rates as an indicator of expected drawdown flow rate capabilities is not appropriate since there are significant differences in the modes of operation associated with leaching and drawdown.

DOE believes that the operational and technical problems reported by the GAO will not prevent the achievement of SPR drawdown performance requirements. Based on operational histories of SPR sites, site system availabilities of greater than 95 percent exist, providing a high level of confidence in the SPR's ability to sustain drawdown operations. In addition, availability

APPENDIX I

analyses of SPR sites indicate a high degree of system design redundancy which would mitigate many of the uncertainties expressed by GAO. While some pipe marine growth and corrosion have developed, corrective measures have been initiated.

Additional technical comments and supporting data were discussed with GAO staff at a meeting at the SPR Project Management Office on July 29, 1985. A summary of these technical comments is being forwarded separately. DOE hopes these comments will be helpful to GAO and considered in the preparation of the final report.

Sincerely,

Martha Hesse Dolan
Assistant Secretary
Management and Administration

(001743)

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